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REMEDIAL INVESTIGATION/RCRA FACILITIES INVESTIGATION FOR SITE/SOLID WASTE  
MANAGEMENT UNIT 45 (SWMU 45) FORMER MWR DRY CLEANING FACILITY VOLUME 1  
OF 2 TEXT MCRD PARRIS ISLAND SC (DRAFT ACTING AS FINAL)

11/01/2004

TETRA TECH NUS INC

**Remedial Investigation/  
RCRA Facilities Investigation  
for  
Site/SWMU 45 - Former MWR Dry  
Cleaning Facility**

**Marine Corps Recruit Depot  
Parris Island, South Carolina**

Volume I - Text



**Southern Division  
Naval Facilities Engineering Command  
Contract Number N62467-94-D-0888  
Contract Task Order 0127**

November 2004

**REMEDIAL INVESTIGATION/  
RCRA FACILITIES INVESTIGATION  
FOR  
SITE/SWMU 45  
FORMER MWR DRY CLEANING FACILITY**

**FOR**

**MARINE CORPS RECRUIT DEPOT  
PARRIS ISLAND, SOUTH CAROLINA**

**COMPREHENSIVE LONG-TERM  
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT**

**Submitted to:  
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**CERTIFICATION PAGE**

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CERTIFICATION**

By affixing my seal to this report, I certify that the geologic data and interpretations stated in this *Remedial Investigation / RCRA Facility Investigation for Site/SWMU 45 – MWR Dry Cleaning Facility* at the Recruit Training Facility, Marine Corp Recruit Depot, Parris Island, South Carolina, are true and accurate to the best of my knowledge. I further certify that I am registered to practice geology in the State of South Carolina and that it is within my professional expertise to verify the correctness of this information.



  
\_\_\_\_\_  
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\_\_\_\_\_  
Date

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## ACRONYM LIST

ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
B&R	Brown and Root Environmental
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
bgs	Below Ground Surface
BOD	Biological Oxygen Demand
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLEAN	Comprehensive Long-Term Environmental Action Navy
CMS	Corrective Measures Study
COC	Chemical of Concern
COD	Chemical Oxygen Demand
COPC	Chemical of Potential Concern
CSF	Cancer Slope Factor
CTO	Contract Task Order
DCE	Dichloroethene
DNAPL	Dense Non-Aqueous Phase Liquid
DO	Dissolved Oxygen
DPT	Direct-Push Technology
DQO	Data Quality Objective
EE/WP	Engineering Evaluation and Interim Removal Remedial Work Plan
ET	Exposure time
FEMA	Federal Emergency Management Agency
FID	Flame Ionization Detector
FS	Feasibility Study
GC	Gas Chromatograph
gpm	Gallons per Minute
HEAST	Health Effects Assessment Summary Tables
HI	Hazard Index
HQ	Hazard Quotient
IAS	Initial Assessment Study
ICR	Incremental Cancer Risk
ID	Inner Diameter
IDW	Investigation-Derived Waste
ILCR	Incremental Lifetime Cancer Risk

IR	Installation Restoration
IRIS	Integrated Risk Information System
K	Hydraulic Conductivity
LOAEL	Lowest-Observed-Adverse-Effect Level
MCL	Maximum Contaminant Level
MCRD	Marine Corps Recruit Depot
MCL	Maximum Contaminant Level
µg/kg	Micrograms Per Kilogram
µg/L	Micrograms Per liter
MIP	Membrane Interface Probe
MS/MSD	Matrix Spike/Matrix Spike Duplicate
msl	Mean Sea Level
MW	Monitoring Well
MWR	Morale, Welfare and Recreation
NACIP	Naval Assessment and Control of Installation Pollutants
NAD 83	North American Datum 1983
NAPL	Non-Aqueous-Phase Liquids
NAVFAC	Naval Facilities Engineering Command
Navy	Department of the Navy
NEESA	Naval Energy and Environmental Support Activity
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No-Observed-Adverse-Effect Level
NTU	Nephelometric Turbidity Unit
ORP	Oxidation-Reduction Potential
PAH	Polynuclear Aromatic Hydrocarbon
PAI	Parris Island
PARCC	Precision, Accuracy, Representativeness, Completeness, and Comparability
PCB	Polychlorinated Biphenyl
PCE	Tetrachloroethene
PEF	Particulate Emissions Factor
PID	Photoionization Detector
PRG	Preliminary Remediation Goal
PSI	Per Square Inch
QA	Quality Assurance
QAP	Quality Assurance Plan
QA/QC	Quality Assurance/Quality Control
RAGS	Risk Assessment Guidance for Superfund

RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facilities Assessment
RfC	Reference Concentration
RfD	Reference Dose
RFI	RCRA Facility Investigation
RGO	Remedial Goal Options
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
ROD	Record of Decision
RPD	Relative Percent Difference
SARA	Superfund Amendments and Reauthorization Act
SCDHEC	South Carolina Department of Health and Environmental Control
SCDNR	South Carolina Department of Natural Resources
SOUTHDIV	Southern Division
SP	Poorly Graded Sand
SP/SM	Poorly Graded Sand to Silt Sand
SSL	Soil Screening Level
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit
TAL	Target Analyte List
TCE	Trichloroethene
TCL	Target Compound List
TEF	Toxicity Equivalence Factor
TOC	Total Organic Carbon
TtNUS	Tetra Tech NUS, Inc.
UCL	Upper Confidence Limit
USCS	Unified Soil Classification System
U.S. EPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
UV	Ultraviolet
VC	Vinyl Chloride
VF	Volatilization Factor
VOCs	Volatile Organic Compound

## EXECUTIVE SUMMARY

Tetra Tech NUS, Inc. (TtNUS) prepared this remedial investigation (RI)/Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) report to summarize field activities conducted at the former Morale, Welfare and Recreation (MWR) Dry Cleaning Facility [Site 45/Solid Waste Management Unit (SWMU) 45], located at the Marine Corps Recruit Depot (MCRD) Parris Island, South Carolina.

Prior to 2001, Site 45 – MWR Dry Cleaning Facility was in a building located in the Main Post area of MCRD Parris Island. Four above-ground storage tanks were situated along the northern side of the building. These tanks were first put into place in 1988, following the removal of an underground storage system where hydrocarbon cleaning solvents were previously stored.

It was reported that, on March 11, 1994, one of the tanks was overfilled with PCE. An unknown amount of the contaminant flowed into the concrete catch basin. The PCE overflow was not collected at that time, and heavy rainfall subsequently washed the contaminant onto the surrounding soil. Contaminated soils were excavated, and an interim remedial action was initiated.

In early 2001, the main dry cleaning building, solvent tanks, and other related structures were demolished and removed from the site. Currently, the site is mostly a vacant lot covered with mowed grass. Some isolated shrubs and trees are also present.

The field investigation for SWMU 45 (Site 45) was performed from March through December 2001. The activities consisted of surface and subsurface soil sampling; installation of shallow, intermediate, and deep temporary groundwater monitoring wells; installation of permanent deep monitoring wells; groundwater sampling from these temporary and permanently installed wells and existing wells. A short-term pumping test and slug tests of all the existing and new wells were also conducted. These field activities supported the collection of data to meet the following objectives:

- To characterize the nature and extent of contaminant migration from past PCE releases at Site 45 – MWR Dry Cleaning Facility. The media of concern are soil and groundwater located in the vicinity of Site 45.
- To assess the human health risks associated with potential direct contact with contaminants. Human health risks to construction workers, site employees (maintenance and other), adolescent trespassers, and future residents are assessed and ecological receptors were identified.

A summary of the field investigation activities and the rationale for these activities are presented in this report. Information collected during the investigation was used to supplement existing geologic and hydrogeologic information at Site 45. The work plan for this investigation was conducted over several stages. The results from one phase were to define and optimize the activities for the next phase.

Because of potential concerns with the quality of the deep groundwater at the site (greater than 20 feet bgs), a work plan for the installation of five deep permanent monitoring wells was prepared in September 2001 and amended in October 2001 (Appendix B of the Work Plan). These monitoring wells were installed in October and November 2001.

The work plan for conducting pump tests was prepared in October 2001 (Appendix C of the Work Plan). Except as noted in Section 3.1, these tests were conducted in October and November 2001.

The work plan for a monitored natural attenuation (MNA) study was prepared in September 2001 (Appendix D of the Work Plan). The fieldwork for these activities was conducted in October 2001. If the Navy pursues an MNA or partial MNA remedy at this site, analyses will be done as part of the Feasibility Study/Proposed Plan/Record of Decision or possibly in a Treatability Study.

Subsurface soil samples were collected from each of 13 soil borings, PAI-45-SB-01 through PAI-45-SB-13. The on-site samples were analyzed for TCL VOCs, TCL SVOCs, DNAPL screening, and total organic carbon (TOC); the off-site samples were analyzed for TOC, pH, grain size, and vertical hydraulic conductivity.

A total of 72 temporary wells were installed at 35 locations as a part of this investigation; 29 temporary monitoring wells were installed in the upper surficial aquifer, 29 temporary monitoring wells were installed in the lower surficial aquifer, and 14 temporary monitoring wells were installed in the deep monitored interval.

Five permanent monitoring wells (PAI-45-MW04D, PAI-45-05D, PAI-45-MW09D, PAI-45-MW10D, and PAI-45-MW11D) and three piezometers (PZ09S through PZ11S) were installed at Site 45 as part of this investigation. The five permanent monitoring wells (deep wells) were installed below the peat layer at the site. The depths of the five deep wells ranged from 41 to 43 feet bgs. The three piezometers were installed to provide observation well information during the short-term pumping test.

The conclusions and recommendations developed during the Site/SWMU 45 RI/RFI are summarized as follows.

- PCE and other chlorinated VOC breakdown products, TCE, DCE, and VC, were detected in surface and subsurface site soils at concentrations that can continue to impact site groundwater through leaching and result in groundwater concentrations greater than drinking water standards (MCLs).
- PCE was detected at a maximum concentration of 8000 mg/kg in one soil sample, near the area of the documented PCE spill in 1994. Field screening tests of site soils for pure solvent found some evidence of trace quantities of non-aqueous phase product. However, no free product was found and no further conclusions were developed.
- Chlorinated VOCs, arsenic, and PAHs were also detected in soils at concentrations greater than background and soil screening concentrations (U.S. EPA Region 9 PRGs) for direct contact exposure under a residential use scenario. The highest concentrations of VOCs and PAHs were found at the water table. The maximum arsenic concentration (2.1 mg/kg) was only slightly greater than the facility background concentration (1.44 mg/kg). The human health risk assessment concluded that site soils do not pose unacceptable risks to current maintenance workers, commercial workers, adult visitors, or potential future residents.
- The human health risk assessment indicated that surficial groundwater consumption resulted in unacceptable excess risk for the on-site child resident, the on-site adult resident, and the on-site lifeline resident based on vinyl chloride, TCE, and PCE contamination. The HI for surficial groundwater for the child resident (248) and the adult resident (224) exceeded the acceptable level of 1.0.
- Chlorinated VOCs were found in site groundwater at concentrations up to 2,000 times greater than drinking water standards (MCLs). Based on groundwater temporary well data, two sources areas of the groundwater contamination are likely, one near the former above-ground storage tanks and one from within the footprint of Building 193, the Former MWR Dry Cleaners Building. Even though site groundwater is not used as a potable water source, the site would result in unacceptable risks to human health if used as such.
- The horizontal and vertical extents of chlorinated VOC-contaminated groundwater are adequately defined. The plume is approximately 240 feet long and up to 140 feet wide (less than 1 acre). The plume extends from approximately the northwestern corner of the former dry cleaner building to near the temporary lodging. The contaminant plume is consistent with groundwater flow that is to the south-southeast. Based on approximately 5 years of data, significant plume migration is not apparent.

- The vertical extent of the groundwater contaminant plume extends from the water table (approximately 4 to 5 feet bgs) to a low permeable layer located at a depth of approximately 12 to 22 feet bgs. Chlorinated VOCs were detected in the groundwater below this low permeable layer but not at concentrations that exceed drinking water standards.
- Fuel-type hydrocarbon VOCs were detected infrequently in site groundwater. With the exception of benzene, concentrations of these chemicals did not exceed drinking water standards. Benzene (15 µg/L) was detected at one location from a temporary well at depth of 32 feet bgs. The downgradient extent of this contamination has been defined by testing of a permanent monitoring well.
- A natural attenuation evaluation for degradation of chlorinated VOCs was conducted. This evaluation concluded that the VOCs were naturally degrading at the site. Modeling efforts conducted with this evaluation indicated that contaminant migration could have a maximum range 500 feet to more than 1,000 feet beyond the source area. Associated migration time estimates range from approximately 30 years to greater than 100 years. Without source area control, more than 260 years may be required before the Site 45 VOC groundwater contaminants dissipate to below measurable levels.
- Preliminary basic groundwater modeling results indicate that the plume is effectively captured within the containment system. Further model refinement is necessary if model performance is to be developed for the FS/CMS.
- There is sufficient information available to proceed to an FS/CMS to evaluate remedial options.

## **1.0 INTRODUCTION**

### **1.1 PURPOSE OF REPORT**

Tetra Tech NUS, Inc. (TtNUS) prepared this remedial investigation (RI)/Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) report to summarize field activities conducted at the former Morale, Welfare and Recreation (MWR) Drying Cleaning Facility [Site 45/Solid Waste Management Unit (SWMU) 45], located at the Marine Corps Recruit Depot (MCRD) Parris Island, South Carolina. This report was prepared for the United States Navy (Navy) Southern Division (SOUTHDIV) Naval Facilities Engineering Command (NAVFAC) under Contract Task Order (CTO) 0127, for the Comprehensive Long-Term Environmental Action Navy (CLEAN) III Contract Number N62467-94-D-0888.

### **1.2 REGULATORY SETTING**

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act of 1986 (SARA) established a program for the cleanup of hazardous waste disposal and spill sites nationwide. This program contains provisions for the cleanup of contamination from past hazardous waste operations and past hazardous material spills and is the framework for Installation Restoration (IR) programs at Navy and Marine Corps installations. RCRA, as amended, also establishes a cleanup program that provides for current and future hazardous waste management practices, as well as cleanup of past disposal sites at permitted or interim status Navy/Marine Corps installations. SOUTHNAVFACENCOM has the responsibility for implementing the Navy's IR Program at MCRD Parris Island.

Because of the past hazardous waste activities conducted at the MCRD Parris Island, South Carolina, the MCRD meets criteria for conducting IR activities under the CERCLA regulatory framework. To date, the MCRD has completed steps equivalent to the preliminary assessment/site inspection phases of the CERCLA remedial action process at Site/SWMU 45. The MCRD also meets the criteria for conducting IR activities under the authority of RCRA because, in the late 1980s, the MCRD submitted a RCRA Part A application. In accordance with RCRA, this action required the MCRD to conduct corrective action for the release of hazardous waste or hazardous constituents from SWMUs. As part of this requirement, an Interim RCRA Facility Assessment (RFA) was conducted in 1990 in which both the incinerator landfill and the former incinerator were addressed as SWMUs. Since this time, the MCRD has withdrawn its Part A application.

Because of the circumstances surrounding the MCRD's IR program history, discussions have been held among representatives from the U.S. Marine Corps, U.S. Navy, South Carolina Department of Health and Environmental Control (SCDHEC), and the U.S. Environmental Protection Agency (U.S. EPA), Region 4 to determine the appropriate regulatory framework for conducting IR activities at the MCRD. From these discussions, it has been decided that this report will encompass both CERCLA and RCRA requirements and the title, RI/RFI, reflects this decision. For ease of reading and clarity, the former MWR Dry Cleaning Facility (Site/SWMU 45) will be referred to as Site 45 for the remainder of this document.

In 1996, the partnering team for MCRD Parris Island was established. The original members of the team consisted of the Navy, Marine Corps – MCRD Parris Island, U.S. EPA, and SCDHEC. In 1997, representatives of the National Oceanic and Atmospheric Administration (NOAA), the South Carolina Department of Natural Resources (SCDNR), and U.S. Fish and Wildlife Service (USFWS) joined the team as natural resource trustees. The partnering team was developed to facilitate the development, review, and approval of work plans, RI/RFI reports, Feasibility Study/Corrective Measures Study (FS/CMS) Report, and decision documents [Proposed Plans and Records of Decision (ROD)].

### **1.3 SCOPE OF RI/RFI**

The RI/RFI field investigation was conducted from March 2001 to December 2001. The objectives of this investigation are to characterize the nature and extent of contaminant migration from past PCE releases at Site 45. The media of concern that will be investigated are soil and groundwater located in the vicinity of Site 45.

Data collected from this investigation will be used to assess the human health risks associated with potential direct contact with contaminants. Human health risks to construction workers, site employees (maintenance and other), adolescent trespassers, and future residents will be assessed. Due to the location of the site in the center of the commercial district of the depot, it is unlikely to have significant impacts to ecological receptors. Based on this information, decisions for remedial action will be evaluated and determined.

Data collected during the investigation have been entered into a database. The database was used in this report to support the risk assessments, including the comparison of analytical results to state and federal standards and to background levels. Data evaluation and recommendations for Site 45 are included herein. The full data validation was performed on approximately 10 percent of the data packages received from a laboratory. All analytes were covered by at least one full data validation. A data review was performed on the remaining data packages for the purposes of identifying false positive and negative results.

## **1.4 HISTORICAL INFORMATION**

### **1.4.1 Facility Background**

MCRD Parris Island is located along the southern coast of South Carolina, approximately 1 mile south of the city of Port Royal and 3 miles south of the city of Beaufort within Beaufort County. MCRD Parris Island covers approximately 8,047 acres that consist of dry land, salt marshes, saltwater creeks, and ponds, as shown in Figure 1-1. MCRD Parris Island is the reception and recruit training facility for the Marine Corps for enlisted men from states east of the Mississippi River and for enlisted women nationwide.

### **1.4.2 Site 45 Background and History**

Prior to 2001, Site 45 – MWR Dry Cleaning Facility was in a building located in the Main Post area of MCRD Parris Island, between Panama Street to the north, Kyushu Street to the south, and Samoa Street to the east (Figure 1-2). West of the facility are other commercial establishments, including a cobbler, a tailor, a coin-operated laundry facility, and a new dry cleaning facility. Four above-ground storage tanks were situated along the northern side of the building. These tanks were first put into place in 1988, following the removal of an underground storage system where hydrocarbon cleaning solvents were previously stored. The new storage tanks are positioned within a concrete catch basin used to contain any overflow during tank filling.

It was reported that, on March 11, 1994, one of the tanks was overfilled with PCE. An unknown amount of the contaminant flowed into the concrete catch basin. The PCE overflow was not collected at that time, and heavy rainfall subsequently washed the contaminant onto the surrounding soil. Contaminated soils were excavated, and an interim remedial action was initiated.

In early 2001, the main dry cleaning building, solvent tanks, and other related structures were demolished and removed from the site. Currently, the site is mostly a vacant lot covered with mowed grass. Some isolated shrubs and trees are also present. Physical features remaining at the site consist of three above-ground extraction well housing units (approximately 2 feet by 2 feet by 3 feet) and one groundwater treatment system shed (approximately 10 feet by 20 feet).

### **1.4.3 Previous Site 45 Investigations**

#### **Initial Assessment and Soil Remediation**

Three days after the reported PCE spill in 1994, Parris Island personnel took one sample from the water in the concrete catch basin and another from the soil near the discharge pipe of the basin. The soil

sample had a PCE concentration of 3,000,000 µg/kg, and the water sample had 2,000,00 µg/L. After these results were received, 17 other soil samples were collected in the vicinity of the tanks and along Panama Street. The results of these samples showed a range of soil contamination from nondetections to 250,000 µg/kg. After evaluation of the results, Parris Island personnel excavated seven 55-gallon drums of contaminated soils for disposal at an off-site incineration facility.

#### **Contamination Assessment and Conceptual Corrective Action Plan (S&ME, 1994)**

After the soil removal, the MWR contracted S&ME, Inc. to perform a PCE Contamination Assessment and Corrective Action Plan. In April 1994, S&ME initiated the study by installing piezometers to study groundwater flow and direction. In addition, groundwater samples from various intervals to a maximum depth of 12 feet bgs, three hand-auger-collected soil samples, and one catch basin water sample were collected.

Sixteen of the 32 groundwater samples that underwent field gas chromatograph (GC) analysis exhibited detectable amounts of PCE, with concentrations ranging from 14 to 5,147 µg/L. Six groundwater samples were also sent to a fixed-based laboratory for analysis. PCE was detected in three of these six samples at concentrations ranging from 1.3 to 370 µg/L, and trichloroethene (TCE) was detected in three of the six groundwater samples at concentrations ranging between 7.3 and 840 µg/L. Also, cis-1,2-dichloroethene (DCE) was detected in five of the six samples at concentrations ranging between 2.7 and 9,250 µg/L.

The two piezometer groundwater samples (PZ-4 and PZ-5) were also analyzed for petroleum-based contaminants. No contaminants were found in the groundwater at PZ-4. However, PZ-5 was shown to have nine other contaminants, in addition to chlorinated hydrocarbons. The contaminants were ethylbenzene (5.6 µg/L), 1-ethyl-2-methylbenzene (31 µg/L), 1-ethyl-3-methylbenzene (39 µg/L), 2-ethyl-1,4-dimethylbenzene (21 µg/L), naphthalene (18 µg/L), toluene (24 µg/L), 1,2,4-trimethylbenzene (223 µg/L), 1,3,5-trimethylbenzene (31 µg/L), and xylene (25 µg/L).

Of the three soil samples, PCE was detected in only one (PZ-5s), at a concentration of 44.1 µg/kg. This sample also contained decane (7,700 µg/kg), 2-methylnonane (1,100 µg/kg), 2-piperidinone (2,300 µg/kg), 2,3,4-trimethylheptane (1,000 µg/kg), 2,3,6-trimethyloctane (1,000 µg/kg), 2,3,7-trimethyloctane (1,000 µg/kg), and 2,5,6-trimethyldecane (1,300 µg/kg).

S&ME's final conclusion was that the soils surrounding the site contained elevated levels of PCE, which had begun to migrate into the surficial aquifer. A pump and treat system was proposed to remove PCE-contaminated water from the aquifer.

## **Technical Memorandum for Groundwater Evaluation and Air Sparging Pilot Study at Building 193 (Bechtel, 1997a)**

In the summer of 1996, Bechtel Environmental conducted a soil and groundwater investigation to establish baseline soil and groundwater contamination levels and determine the stratigraphy of Site 45.

Initially, groundwater samples were collected with direct-push technology (DPT) and analyzed with a field GC. Analytical results indicated that a plume of PCE, TCE, 1,2-DCE, and vinyl chloride existed at concentrations exceeding regulatory limits. Based on these results, 16 permanent monitoring wells were installed at Site 45. The wells were established at eight locations surrounding the site using direct-push technology. The monitoring wells were installed in pairs, with one completed at approximately 7.5 feet bgs and the other at 15.5 feet bgs. All groundwater samples were analyzed for volatile organic compounds (VOCs), chloride, nitrates, and sulfates.

The results of the analysis confirmed VOC migration to groundwater. PCE concentrations ranged from nondetect at 193-1MW-S to 32,000 µg/L at 193-8MW-S in the shallow wells and nondetect at 193-1MW-D to 60,000 µg/L at 193-7MW-D in the deep wells. Additionally, TCE was detected in five shallow wells (193-4MW-S, 5MW-S, 6MW-S, 7MW-S, and 8MW-S), at concentrations ranging from 2.9 to 4,900 µg/L, and was also found in five deep wells (193-2MW-D, 5MW-D, 6MW-D, 7MW-D, and 8MW-D), at concentrations of 0.64, 77, 2,800, 15,000, and 1,400 µg/L, respectively. In five shallow monitoring wells (193-3MW-S, 5MW-S, 6MW-S, 7MW-S, and 8MW-S), cis-1,2-DCE was found at concentrations ranging from 2.3 µg/L to 1,100 µg/L. This VOC was also detected in the adjacent deep monitoring wells. The concentrations of cis 1,2-DCE in these wells ranged from 3.8 µg/L at 193-5MW-D to 3,800 µg/L at 193-7MW-D. Two VOCs, trans-1,2-DCE and vinyl chloride, were found only at one location (193-6MW-S), with concentrations of 8.3 µg/L and 170 µg/L, respectively.

Note that, during the preparation of this 2002 RI, these historic monitoring well location identifications were modified to be consistent with basewide labels:

- Building Number "193" was changed to Parris Island Site 45 "PAI-45"
- Monitoring well "#MW" was changed to "MW-#" and
- Well depths "S" and "D" were changed to surficial upper "SU" and surficial lower "SL", respectively.

During the drilling of monitoring wells 193-6MW-D, 7MW-D, and 8MW-D, soil samples were collected at the 1- to 3-foot bgs interval and the 5- to 7-foot bgs interval. These six samples were then analyzed for VOCs. PCE was detected at the 5- to 7-foot interval of 193-8MW-D at an estimated concentration of 1,100 µg/kg. PCE was detected in four other samples at levels ranging from 1 to 32 µg/kg. TCE was

detected in five samples at concentrations ranging from 0.8 to 80 µg/kg, and cis-1,2-DCE was detected in four samples at concentrations ranging from 0.9 to 22 µg/kg.

### **Summary Report For Air Sparging Pilot Test (Bechtel, 1997b)**

In December 1996, Bechtel, Inc. conducted an air sparging pilot study at Site 45 to determine whether air sparging was a viable remedial option for site contaminants. The objectives of the pilot study included determining the radius of influence of the one air sparging well installed for the study and the optimum air injection rate and pressure at the air sparging well.

One air sparging well was constructed for the pilot study (193-1-MW-D) north of the dry cleaning building in a clean area. This well was installed 14 feet bgs. Five observation wells were also installed to monitor the pilot study. 193-1-MW-S was installed 7 ft bgs 2 feet south of 193-1-MW-D. Two temporary well clusters of two wells each were installed 10 and 20 feet from the air sparging well. Each well cluster had a shallow and deep well installed to a depth of 7 and 14 ft bgs respectively. The pilot test concluded that air sparging was effective through the layer of finer material at the 7-foot level. The study recommended a radius of influence of 15 feet and a design capacity of 5 standard cubic feet per minute per well.

### **Engineering Evaluation and Interim Removal Remedial Work Plan (Bechtel, 1997c)**

The Engineering Evaluation and Interim Removal Remedial Work Plan (EE/WP) prepared by Bechtel evaluated the results of the air sparging study and of other technologies for interim remedial action at Site 45. The results of the engineering evaluation recommended a pump and treat system to prevent the migration of groundwater contaminants until a comprehensive RI could take place.

The groundwater pump and treat system start-up occurred in April, 1998. The system operated through early 2000, with increasing downtime for maintenance activity. Some of the maintenance problems that were encountered included recurring electrical control issues and silt packing up manifolds and pumps. Finally, following removal from operation sometime in early 2000 for maintenance, the system was simply not restarted. The total volume of water that was removed by this system was 1,056,410 gallons, based on the final operation and maintenance logsheet. Four submersible pumps operated at 2 to 5 gpm each through variable speed controls linked to water level sensors installed in the sump of each well. Groundwater was pumped from the wells to a multi-tray air stripping unit rated at 6 to 15 gpm. The system operated in fully automatic mode, and featured remote monitoring and control.

This pump and treat system is not currently in operation. The system consists of three electric recovery pumps, groundwater discharge piping, fittings, flow counters, limit switches, and accessories. Additionally, the system includes a low-profile air stripper for removing VOCs from the groundwater and a

pumping system for discharging the treated groundwater to an adjacent sewer manhole for ultimate discharge to the Depot's wastewater treatment facility. Continued system operation is on hold pending evaluation of an in-situ dechlorination technology (CLEANOX).

## **1.5 REPORT ORGANIZATION**

This report is divided into seven sections. Section 1.0, Introduction, provides historic information about MCRD Parris Island and Site 45 in particular. Section 2.0, Environmental Setting, provides geological and geographical information about MCRD Parris Island and the surrounding areas. Section 3.0, Investigation Summary, summarizes the sampling program and presents the Site 45 geology and hydrogeology based on the field results. Section 4.0, Nature and Extent of Contamination, addresses the nature and extent of site contamination for all investigated media. Section 5.0, Contaminant Fate and Transport, is a reference-like section describing the chemical and physical properties of the analytes positively detected at Site 45. Section 6.0, Human Health Risk Assessment presents the methodology and results of the human health risk assessments. Section 7.0, Conclusions and Recommendations, focuses on the magnitude of site-related risks and remedies, if any, to address those risks. Appendices A through F provide support documentation for the field investigation and supplemental information for the evaluation of results.

ACAD: 0502CM14.dwg 02/15/02 HJB



SOURCE: PARRIS ISLAND 1998 AERIAL PHOTOGRAPH

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HJB	2/15/02

CHECKED BY	DATE

COST/SCHED-AREA

SCALE
NOT TO SCALE



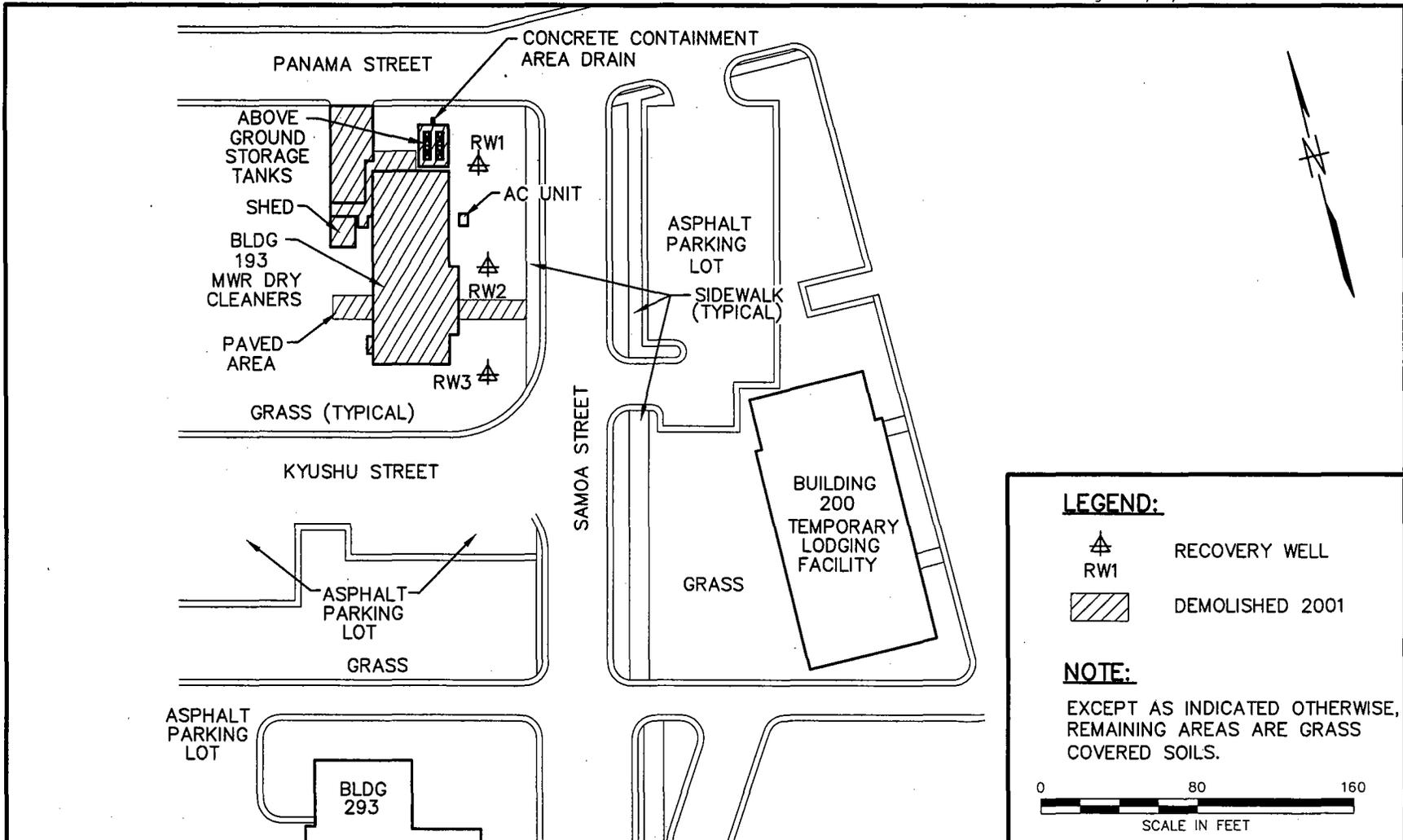
**SITE 45 - MWR DRY CLEANING FACILITY**  
**MCRD PARRIS ISLAND**  
**PARRIS ISLAND, SOUTH CAROLINA**

CONTRACT NO.
0502

APPROVED BY	DATE

APPROVED BY	DATE

DRAWING NO.	REV.
FIGURE 1-1	0



**LEGEND:**

-  RECOVERY WELL
- RW1
-  DEMOLISHED 2001

**NOTE:**

EXCEPT AS INDICATED OTHERWISE, REMAINING AREAS ARE GRASS COVERED SOILS.

0 80 160  
SCALE IN FEET

DRAWN BY HJB	DATE 2/15/02
CHECKED BY	DATE
COST/SCHED--AREA	
SCALE AS NOTED	



**SITE LAYOUT**  
**SITE 45 - MWR DRY CLEANING FACILITY**  
**MCRD PARRIS ISLAND**  
**PARRIS ISLAND, SOUTH CAROLINA**

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 1-2	REV. 0

## **2.0 ENVIRONMENTAL SETTING**

This section contains general information about the environmental setting common to all the sites currently under investigation at MCRD Parris Island. A comprehensive discussion of the environmental setting at the MCRD can be found in the Master Work Plan (B&R Environmental 1998a) or the Initial Assessment Study (IAS) (NEESA, 1986).

### **2.1 CLIMATE**

MCRD Parris Island is in the southernmost region of South Carolina, where the climate is milder than elsewhere in the state. This low-lying coastal area has numerous islands, inlets, streams, and marshes and a temperature regime that clearly reflects the influences of its maritime and southern location. The climate is subtropical, with long and hot summers followed by short and mild winters. Precipitation is abundant, averaging about 49 inches per year and remaining within the range of 40 to 58 inches during most years. Precipitation in the amount of 0.1 inch or more falls on an average of about 77 days per year. The annual distribution shows a major monthly maximum of about 7 inches in July and a major monthly minimum of about 2 inches in November. The period from April through October, which includes the growing season for most crops in this area, receives an average of about 34 inches of rain, about 70 percent of the annual total.

### **2.2 TOPOGRAPHY**

MCRD Parris Island lies in the Lower Coastal Plain physiographic province. Elevations range from sea level to 22 feet above mean sea level (msl); the elevation at Site 45 ranges from approximately 6 to 9 feet above msl. The Depot consists of Parris Island (the largest and most developed island), seven smaller, named islands, many small unnamed islands, salt marshes, and related tidal creeks. Because of the low elevation, most of the Depot is within the 100-year flood plain. The majority of the area of Parris Island north of Ballast Creek, the east-central area of Page Field, and the central part of Horse Island are the only surfaces above the 100-year flood plain (NEESA, 1986).

The Depot covers 8,047 acres: 1,502 acres are devoted to forest management; 744 acres are grass and facilities; 4,344 acres are saltwater marsh; and the remainder consists of creeks, ponds, and causeways. Dry land makes up 3,274 acres (NEESA, 1986).

### **2.3 SURFACE WATER DRAINAGE**

Drainage off the land surface is to the nearest surface water body. Three generally east-west trending creeks drain much of the Depot. Archers Creek, at the northern boundary of the Depot, connects Battery

Creek to the north with the Broad River to the west of Parris Island (see Figure 1-1). Ribbon Creek drains the area between Horse and Parris Islands and flows westward into the Broad River. Ballast Creek drains the middle of Parris Island and flows eastward into the Beaufort River. Surface water at Site 45 drains into base storm sewers and then into Ballast Creek. Smaller unnamed creeks drain the areas west and east of Page Field.

The Beaufort and Broad Rivers meet at the southern end of Parris Island to form Port Royal Sound, which extends about 4 miles southeastward to the Atlantic Ocean.

## **2.4 SOILS**

Soils at MCRD Parris Island have been mapped by the U.S. Soil Conservation Service as both individual soils and groupings of soils (units). The Depot has been mapped as having 15 individual soil types, but only eight types are present beneath sites currently under investigation. Three soil units have been mapped for the Depot (the Wando-Seabrook-Seewee, Coosaw-Williman-Ridgeland, Bohicket-Capers-Handsboro Soil Unit). A further discussion of the soils and soil units identified at the MCRD can be found in the Master Work Plan for MCRD Parris Island (B&R Environmental, 1998a) or the IAS (NEESA, 1986).

## **2.5 GEOLOGY**

Four geological units are present in the Beaufort-Jasper County Area. These units from the oldest (Eocene age) to the youngest (Pleistocene age) are the Santee Limestone, Cooper Marl, Hawthorn Formation, and Pleistocene sands and clays. A further discussion of the descriptive and structural geology of the Beaufort-Jasper County area can be found in the Master Work Plan for MCRD Parris Island (B&R Environmental, 1998a) or the IAS (NEESA, 1986). The geology of Site 45 is further discussed in Section 3.3.

## **2.6 HYDROGEOLOGY**

Two primary aquifers are present within the Beaufort-Jasper County Area: the surficial aquifer and the Floridan Aquifer. These aquifers are generally separated by the Hawthorn Formation and Cooper Marl, which act as confining units to the underlying Floridan Aquifer.

In the MCRD Parris Island area, the shallow, unconfined aquifer generally consists of permeable, fine to medium, Pleistocene age sands. Surface relief is relatively low. The area is drained by fresh and brackish-water streams inland and by tidal streams along the coast. The water table in the MCRD Parris Island area usually ranges from 0 to 10 feet bgs and is most commonly found at a depth of 3 feet bgs. Water-table fluctuations are a function of recharge, evaporation, and transpiration and have been

observed to be as great as 6.5 feet at some locations (Glowacz, et al., 1980). The direction of groundwater flow in the upper portion of the shallow surficial aquifer is generally toward the nearest surface water body, such as a pond, river, tidal creek, or the ocean.

In the Beaufort-Jasper County Area, the Floridan Aquifer system occurs near land surface, and confining beds vary from essentially 0 to more than 150 feet in thickness. Groundwater in the Floridan Aquifer occurs in solutionally enlarged openings or cavities in the limestone. In general, groundwater occurs in a series of broadly defined water-bearing (permeable) zones that serve as aquifers and are separated by less permeable bedrock. Two hydrogeologic zones within the Floridan Aquifer lie beneath the MCRD Parris Island area. These two hydrogeologic units consist of a 200-foot-thick Upper Hydrogeologic Unit that contains an upper permeable zone and an 800-foot-thick Lower Hydrogeologic Unit that has a somewhat lower permeability compared to the Upper Unit.

A further discussion of the hydrogeological characteristics of the Beaufort-Jasper County area can be found in the Master Work Plan for MCRD Parris Island (B&R Environmental, 1998a). The hydrogeology of Site 45 is detailed in Section 3.4.

## **2.7 ECOLOGY**

General discussions on the ecosystems present and threatened and endangered plants and animals that occur or potentially occur on MCRD Parris Island can be found in the Master Work Plan for MCRD Parris Island (B&R Environmental, 1998a) or the IAS (NEESA, 1986).

Specific ecology information about Site 45 includes that it is located in a highly developed portion of MCRD Parris Island. The site consists of a small area (40 feet by 120 feet) of turf grass. Paved streets border the site on three sides, and a building borders the site on the fourth side (Figure 1-2). Parking lots, streets, buildings, and construction areas are located in the immediate area surrounding the site. Five cabbage palms (*Sabal palmetto*), one slash pine (*Pinus elliottii*), and eight small ornamental shrubs occur as roadside plants immediately beyond the periphery of the site. Thus, Site 45 and the adjacent areas provide only limited terrestrial habitat of poor quality in a developed (urban-type) setting. Ecological receptors that occur at Site 45 consist of those typically found in urban areas, such as terrestrial invertebrates and lizards. Various songbirds occasionally forage on the site. Mammals at the site are probably limited to exotic rodents such as the black rat and house mouse. No signs of moles (*Talpidae*) were observed in several visits by TtNUS biologists.

No surface water is present at or near the site. The terrain is flat, and surface water runoff in the vicinity is collected by the storm sewer system. There are no surface water bodies or wetlands near the site.

The nearest surface water body is a shallow tidal marsh approximately 900 feet south-southeast of the site.

The marsh is dominated by cordgrass (*Spartina alterniflora*). Black needlerush (*Juncus roemerianus*) is also present in the marsh, and seashore saltgrass (*Distichlis spicata*) and glasswort (*Salicornia virginica*) occur in portions of the marsh/upland boundary. A narrow wooded area occurs immediately upslope of the marsh. The wooded area is dominated by slash pine and loblolly pine (*Pinus taeda*), with an understory of various shrubby species. The marsh provides habitat for a variety of fauna, such as fish and crustaceans, as well as several species of animals that prey upon the fish and crustaceans. Various shorebirds and wintering waterfowl forage in the marsh.

Groundwater flow at Site 45 is primarily to the south-southeast in the general direction of the marsh. The leading edge of the Site 45 groundwater plume is approximately 800 feet from the marsh in the direction of groundwater flow. Based on 5 years of monitoring data from 1996 through 2001, there was no obvious migration of groundwater contamination. However, sampling at one location in early 2003 did indicate that some downgradient migration had occurred. The Navy has since provided funding for additional field activities that will update the plume maps in a future report. The site contaminants are limited to VOCs which are being monitored. For these reasons, the groundwater exposure route is negligible for ecological receptors at this time.

In summary, Site 45 provides only 0.1 acre of terrestrial habitat in an industrial setting. Terrestrial habitat consists of mowed turf grass and receptors consist of species acclimated to urban and industrial conditions. A complete exposure pathway has three components: a source of contaminants that can be released to the environment; a route of contaminant transport through an environmental medium; and an exposure or contact point for an ecological receptor. The poor habitat, the urban/industrial nature of the area, and the small size of Site 45 result in an exposure pathway that is essentially incomplete. Therefore, with the possible exception of receptors such as soil invertebrates, the potential for ecological impacts from site-related contaminants does not exist, and the terrestrial exposure pathway was not evaluated further. Potential effects to soil invertebrates (if any) would be limited to an extremely small area and would not be ecologically significant. Groundwater migration will be monitored in the future; contaminants were to migrate as far as the marsh, then potential ecological impacts would need to be re-evaluated.

### 3.0 INVESTIGATION SUMMARY

The field investigation for SWMU 45 (Site 45) was performed from March through December 2001. The activities consisted of surface and subsurface soil sampling; installation of shallow, intermediate, and deep temporary groundwater monitoring wells; installation of permanent deep monitoring wells; groundwater sampling from these temporary and permanently installed wells and existing wells. A short-term pumping test and slug tests of all the existing and new wells were also conducted. These field activities supported the collection of data to meet the following objectives:

- To characterize the nature and extent of contaminant migration from past PCE releases at Site 45 – MWR Dry Cleaning Facility. The media of concern are soil and groundwater located in the vicinity of Site 45.
- To assess the human health risks associated with potential direct contact with contaminants. Human health risks to construction workers, site employees (maintenance and other), adolescent trespassers, and future residents are assessed and ecological receptors were identified.

A summary of the field investigation activities and the rationale for these activities are presented in Table 3-1. Information collected during the investigation was used to supplement existing geologic and hydrogeologic information at Site 45. The following sections discuss deviations from the work plan, the field activities conducted, and the site-specific geologic and hydrogeologic setting at Site 45. A summary of the 2001 RFI/RI soil and groundwater sampling activities is provided in Tables 3-2 and 3-3. The layout of Site 45 is shown in Figure 1-2.

The work plan for this investigation was conducted over several stages. The results from one phase were to define and optimize the activities for the next phase. The primary work plan, finalized in February 2001, identified soil testing and an initial groundwater evaluation using temporary monitoring wells. The initial fieldwork was conducted in March and April 2001. Based on a review of these results, an addendum was issued in May 2001 to conduct additional groundwater testing in temporary monitoring wells and some select permanent monitoring wells (Appendix B of the Work Plan). The work was conducted in May and June 2001. Except as noted in Section 3.1, these data were used to confirm the horizontal and vertical extent of the groundwater plume.

Because of potential concerns with the quality of the deep groundwater at the site (greater than 20 feet bgs), a work plan for the installation of five deep permanent monitoring wells was prepared in September 2001 and amended in October 2001 (Appendix B of the Work Plan). These monitoring wells were installed in October and November 2001.

The work plan for conducting pump tests was prepared in October 2001 (Appendix C of the Work Plan). Except as noted in Section 3.1, these tests were conducted in October and November 2001. A long-duration pump test has not been conducted to date because the controls for the currently-inactive system still will not allow automatic system operation, which is necessary for the test. If the system is returned to operability and a long-duration pump test is necessary for pumping remedy evaluation, the test will be conducted and documented in the Feasibility Study.

The work plan for a monitored natural attenuation study was prepared in September 2001 (Appendix D of the Work Plan). The fieldwork for these activities was conducted in October 2001.

### **3.1 DEVIATIONS FROM THE WORK PLAN**

Work plan deviations are presented as follows.

- The work plan for the site anticipated an air sparging/soil vapor extraction pilot study. The work plan addendum discussing the study was to be presented in Appendix E of the work plan. However, during the field investigation conducted between March and June 2001, a thin silty clay unit was observed near the water table in the area of the most contaminated groundwater. It was originally anticipated that an air sparging/soil vapor extraction system would be most effective in this area, but this clay unit would interfere with the injection of air and complete capture of contaminated soil gas. As a result, the pilot study was not attempted.
- Benzene was detected in one deep temporary monitoring well sample in the March/April 2001 field event. The work plan addendum prepared in May 2001 (Appendix B) identified four additional temporary monitoring wells to be installed in June 2001 to confirm the presence and extent of this single benzene detection. One planned boring (PAI-45-TW29) was not installed because of the presence of utilities throughout the proposed well location. Based on subsequent deep permanent monitoring well data collected in October and November 2001, this location was determined to be side-gradient of the temporary well point of concern, and groundwater quality data at this point were not required.
- As presented in the work plan addendum (Appendix C), a two-phase pumping test for Site 45 was planned. The first phase, which involved pumping a single groundwater extraction well over several days, was conducted as planned. This test required round-the-clock operator attention to monitor the pump test and operate the treatment system. However, the second phase, which involved pumping all three groundwater wells over a 1 week period, was not conducted because of equipment problems. A water transfer pump within the treatment unit did not operate reliably during the first

phase of the test and required manual operation during the entire test. Manual operation for a week-long test was not practical.

## **3.2 FIELD INVESTIGATION**

The following sections discuss the field activities conducted at Site 45. The specific field activities conducted during the 2001 RI/RFI investigation are then discussed, including monitoring well installation; subsurface soil, surface soil, and groundwater sampling; the performance of slug testing and a short-term pump test; and investigation-derived waste (IDW) management. Lastly, a discussion of quality assurance/quality control samples and sample analysis is presented.

### **3.2.1 Surface Soil Sampling**

During the 2001 RI/RF, surface soil samples (Figure 3-1) were collected from eight soil borings (PAI-45-SB-01 through PAI-45-SB-08) using dedicated disposable trowels. The boring/sample locations are biased toward areas of potential contamination. These locations were selected while Building 193 and related equipment were still in place. The surface soils were analyzed for target compound list (TCL) VOCs, TCL semivolatile organic compounds (SVOC), target analyte list (TAL) metals, and tin. All surface samples were screened in the field using a photoionization detector (PID). The results of the sampling are presented in Appendix C. Copies of the soil samples log sheets are provided in Appendix A. A summary of the surface soil samples collected is presented in Table 3-2.

### **3.2.2 Subsurface Soil Sampling**

Subsurface soil samples (Figures 3-1 and 3-2) were collected from each of the 13 soil borings, PAI-45-SB-01 through PAI-45-SB-13. The on-site samples were analyzed for TCL VOCs, TCL SVOCs, DNAPL screening, and total organic carbon (TOC); the off-site samples were analyzed for TOC, pH, grain size, and vertical hydraulic conductivity. The results of the subsurface soil sampling are presented in Appendix C-4. The soil borings were drilled using 4.25-inch inside-diameter hollow-stem augers and 2-inch-diameter split-spoons. As noted on Table 3-2, soil samples were collected for chemical analysis and/or geotechnical parameters. Upon retrieval, the entire soil sample was screened for the presence of volatile organics with a PID and visually classified for lithology, soil moisture, and other pertinent observations, and the samples were divided for field screening and potential fixed-base laboratory analysis. For the on-site samples, the portion of the core with the greatest PID detection or staining based upon visual observation was separated into two aliquots to allow for field screening in accordance with the following procedures:

1. Ultraviolet (UV) fluorescence test: This field screening procedure was performed on samples collected from select soil borings (Table 3-2). UV fluorescence has been shown to be an effective tool in screening soil samples for the presence of non-aqueous-phase liquids (NAPL) such as TCE and PCE (Cohen and Mercer, 1993). Soil samples containing a significant amount of NAPL illuminated a fluorescent (frequently milky-white) color. The results of the UV fluorescence were noted on the soil sample log sheets and/or boring logsheets. There was evidence of trace NAPL levels, but no substantial zones were identified.
2. Fixed-base laboratory analysis: Based upon the PID results, UV testing, and visual observation, samples were collected according to the work plan for fixed-base laboratory analysis.

Samples collected for chemical analysis were immediately sealed in appropriate containers so that minimal head space existed. The actual sample depths were based on FID screening and visual observations for contaminants. See Table 3-2 or Appendix C for the sample depths. Boring logs are provided in Appendix A. Copies of the soil samples log sheets are provided in Appendix A. A summary of the collected subsurface soil samples is presented in Table 3-2.

### **3.2.3 Temporary Monitoring Well Installation**

This section discusses the installation and construction details of the newly installed temporary monitoring wells. All monitoring wells were installed in accordance with the state of South Carolina well requirements. Temporary monitoring well locations are shown on Figure 3-3.

A total of 72 temporary wells were installed at 35 locations as a part of this investigation; 29 temporary monitoring wells were installed in the upper surficial aquifer, 29 temporary monitoring wells were installed in the lower surficial aquifer, and 14 temporary monitoring wells were installed in the deep monitored interval. Table 3-3 summarizes the temporary well drilling/sampling program for the 2001 RI/RFI investigation.

The upper surficial temporary wells were installed with 3- to 4-foot-long screens that straddle the water-table surface. The screened section was placed approximately 1 foot above and 2 to 3 feet below the static water level, as determined during drilling by the field geologist. All these wells were screened within 6 to 10 feet bgs. The lower surficial monitoring wells were installed immediately above the top of the highly organic clay confining layer (peat) with an approximately 3- to 4-foot well screen ranging from 14 to 21 feet bgs. The deep monitoring wells were installed immediately under the bottom of the highly organic clay layer, with an approximately 2- to 4-foot well screen ranging from 30 to 40 feet bgs. The basis for screen placement was to maximize the monitoring of the designated aquifer. The temporary monitoring wells were installed using DPT methods.

All 72 temporary monitoring wells were constructed of 1-inch (ID) stainless-steel drive rods and ¾-inch Geoprobe® screen point samplers. Each section of drive rod and screen was properly decontaminated before installing. The well screens had a slot size of 0.0057 inch and were supplied with a flush-joint drive point. When the drive rod and Geoprobe® screen point samplers were set at the required depths, sampling began. Note that temporary wells are not subject to hydraulic development. Boring logs for the temporary wells are provided in Appendix A-2.

### **3.2.4 Permanent Monitoring Well Installation**

Five permanent monitoring wells (PAI-45-MW04D, PAI-45-05D, PAI-45-MW09D, PAI-45-MW10D, and PAI-45-MW11D) and three piezometers (PZ09S through PZ11S) were installed at Site 45 as part of this investigation. The five permanent monitoring wells (deep wells) were installed below the peat layer at the site. The depths of the five deep wells ranged from 41 to 43 feet bgs. The three piezometers were installed to provide observation well information during the short-term pumping test. The locations of the permanent wells and piezometers are shown on Figure 3-3. Table 3-4a summarizes the monitoring well construction information for these wells, along with key construction details for pre-existing monitoring wells at the site. Table 3-4b shows the water volumes that were noted during well development. Boring logs, well construction diagrams, and well permit records are provided in Appendix A.

Before the deep wells were installed, a 6-inch diameter steel casing was set and grouted into the peat layer with either large-diameter hollow-stem augers or mud rotary methods as described in the field notes in the appendices. After the grout had set for a minimum of 24 hours, drilling proceeded through the 6-inch-diameter casing with the mud rotary method, using a 5-7/8-inch-diameter rotary bit to the final depth of the well. Split-spoon samples were collected for lithology, screened with a PID, and recorded on the boring logs. When the final depth was reached, the monitoring wells were installed through the open borehole. The wells were installed in accordance with SCDHEC regulations. See the well logs for additional information.

The three piezometers were installed using 4.25-inch ID hollow-stem augers. Split-spoon samples were taken in only one of the three (PZ-11S) borings. Soil cuttings were logged in the other two piezometers. These piezometers served as observation wells for the short-term pump test and were not sampled.

A licensed South Carolina driller employed by Richard Simmons Drilling, Inc. installed the monitoring wells. All monitoring wells and piezometers were developed after construction using surging and pumping methods. Well development logs were completed during development and are provided in Appendix A.

The groundwater monitoring wells were developed using a surge block and electric pump with discharge tubing. The surge block was used to sweep the screen interval (and filter pack) several times throughout the development process. The well water was pumped into 55-gallon drums and labeled as IDW. Water was collected for monitoring in a stainless-steel beaker, and a Horiba U-10 was used to measure field parameters consisting of temperature, specific conductance, pH, salinity, dissolved oxygen, and turbidity. At least three times the calculated well volume of water was removed during development. Potable water was used to fill the augers during drilling to prevent sand from flowing into the augers or to remove a sand bridge during installation of the sand pack. Readings were collected until the field parameters stabilized in accordance with the approved work plan.

A target turbidity of 10 NTUs was used in an attempt to reduce the turbidity as much as possible during the development phase. Time pumped, volume of water pumped, and the turbidity of the water were used to determine whether development was complete when stabilization had been achieved.

### **3.2.5 Groundwater Sampling**

Groundwater sampling was performed in both the temporary wells and the select permanent monitoring wells. The 72 temporary monitoring wells (at 35 locations) and six pre-existing permanent monitoring wells were sampled in the spring and summer of 2001. The five permanent deep wells and selected pre-existing monitoring wells were sampled during the winter of 2001. This section describes the sampling equipment and techniques used for groundwater sample collection during both events.

#### **3.2.5.1 Temporary Monitoring Well Sampling**

A total of 72 groundwater samples at 35 locations were collected from the temporary wells. Groundwater sampling was performed using a peristaltic pump and pre-cleaned disposable tubing. The tubing was lowered in the temporary well to approximately the midpoint of the well screen. The wells were then purged in accordance with the low-flow sampling techniques specified in the approved work plan (Tetra Tech NUS, Inc., 2001). Water-level data and water-quality parameters, such as temperature, pH, specific conductance, turbidity, dissolved oxygen, and salinity, were collected during purging of the monitoring wells and recorded on Low-Flow Purge Data Sheets and Groundwater Sample Log Sheets (included in Appendix A). The groundwater sample from each well was collected by reducing the flow to minimize volatilization of the sample and collecting the sample in the appropriate containers directly from the tubing after it passed through the peristaltic pump. All the temporary wells were sampled for quick-turnaround VOCs. A summary of the temporary monitoring well sampling is provided on Table 3-3. Sample log sheets and analytical results are provided in Appendix C.

### **3.2.5.2 Permanent Monitoring Well Sampling**

A total of six groundwater samples were collected from pre-existing monitoring wells during June 2001 and analyzed for TCL VOCs. During the winter of 2001, the five newly installed deep wells and five pre-existing wells were sampled. Natural attenuation sampling was also performed in the field on the five pre-existing monitoring wells (PAI-45-MW-01SU, PAI-45-MW-04SU, PAI-45-MW-05SL, PAI-45-MW-06SU, and PAI-45-MW-08SU).

The groundwater samples collected in June 2001 (PAI-45-MW-06SU/SL through PAI-45-MW-08SU/SL) and the deep wells (PAI-45-MW-04D, PAI-45-MW-05D, PAI-45-MW-09D, PAI-45-MW-10D, and PAI-45-MW-11D) sampled in October and December 2001 were analyzed for TCL VOCs. The five pre-existing monitoring wells (PAI-45-MW-01SU, PAI-45-MW-04SU, PAI-45-MW-05SL, PAI-45-MW-06SU, and PAI-45-MW-08SU) sampled in October 2001 were analyzed for low-concentration VOCs, methane, ethane, and ethene, TOC, COD, BOD, alkalinity, various anions, and metals.

Groundwater sampling for the permanent wells was similar to that of the temporary wells. Peristaltic pumps with pre-cleaned disposable tubing were used to purge the monitoring wells. Prior to purging, the intake of the sampling tube was placed approximately between the midpoint of the screen and the bottom of the hole. Purging was performed using the low-flow technique described in the work plan (Tetra Tech NUS, Inc., 2001).

The groundwater analytical parameters for the permanent wells are summarized in Table 3-3. General water-quality parameters (including dissolved oxygen, salinity, temperature, pH, and turbidity) were also collected and are included on the sample log sheets provided in Appendix A. The groundwater sample locations are shown on Figure 3-3.

These wells were purged in an effort to reduce the turbidity to less than the benchmark of 5 NTUs.

### **3.2.6 Water-Level Measurements**

Five rounds of groundwater-level measurements were collected during the Site 45 field investigation to determine groundwater flow directions. Four rounds, collected on October 29, October 30, November 3, and November 12, 2001, included all the surficial aquifer permanent monitoring wells. The fifth round, collected on December 10, 2001, included only the deep monitoring wells at the site. The water levels and associated groundwater elevations are presented in Table 3-4. In addition to these rounds of water levels, additional water-level measurements were taken during well development, sampling, and hydraulic testing activities.

### **3.2.7 Slug Tests**

Slug tests were performed on 24 monitoring wells, which included all the pre-existing monitoring wells (16 wells), all the newly installed deep wells (five wells), and all three of the piezometers. Rising-head slug tests were performed at each of the monitoring wells versus falling head tests based on their better accuracy in saturated zones and the fact that some well screens straddled the water table. The procedure for performing the rising-head slug test consisted of injecting a slug of known volume below the water level within the well. After the water level re-stabilized, the slug was suddenly removed to create a drop of water level within the well. A 20 pounds per square inch (psi) pressure transducer and a data logger were used to record the rate of water-level recovery. The data were analyzed using the Hvorslev Method (Hvorslev, 1951). Slug test calculations are provided in Appendix B and showed high variability across the site. Slug test results are discussed in Section 3.4.3.1.

### **3.2.8 Pumping Test**

A short-term pumping test (47-hour duration) was performed at Site 45 using existing extraction well RW-3 as the pumping well. The results from the pumping test were used to determine the overall hydraulic characteristics of the shallow aquifer at the site and to finalize the approach for the long-term pumping test of the entire extraction well system that is anticipated to be performed in 2002.

Prior to start-up of the pumping test, two comprehensive rounds of water levels were collected from all Site 45 wells, one round the day before and one round just before the beginning of the test (see Table 3-4). Data loggers (in-situ mini trolls) were used to collect water-level data in 11 observation wells: MW04SL, which was used for trend measurements, and MW03SU/SL, MW06SU/SL, MW07SU/SL, MW08SU/SL, PZ10S, and PZ11S. Hand measurements of water levels were also taken in wells RW1, RW2, PZ09S, MW01SU/SL, MW04SU/D, and MW05SU/SL/D. Hand measurements of the mini-troll monitored wells were also collected periodically to verify the transducer data (see pumping test data sheets in Appendix B).

The pumping test was begun at 1:00 pm on October 30, 2001 and was stopped at 12:00 pm on November 1, 2001 (47-hour test duration), when it was determined that steady-state drawdown conditions had been reached. A constant pumping rate of 1.3 gallons per minute (gpm) was used throughout the pumping test. A slight increase to 1.4 gpm was noted approximately 1,000 minutes into the test.

Distances from the pumping well to each of the observation wells were field measured and recorded on each pumping test data sheet. All water generated during the pumping test was discharged through the groundwater treatment system. The flow rate was calculated by reading the flow meter inside the extraction well pump house.

Transducer (mini-trolls) data were periodically downloaded during the test, and the observation well drawdowns were plotted using a laptop computer. These data were then electronically mailed to the Pittsburgh office. At the conclusion of the active pumping phase of the test, recovery measurements were taken in all transducer-monitored observation wells and in other selected wells. Recovery measurements were taken for 24 hours after the conclusion of the pumping test.

Drawdown data obtained from the wells monitored during the pumping tests, along with the pumping rate data, were evaluated to determine aquifer transmissivity and storativity. The data evaluation procedures and the results are presented in Section 3.4.3.2. Test data, drawdown plots, and pumping test evaluation information is provided in Appendix B.

### **3.2.9 Surveying**

All monitoring well and soil boring sample locations at Site 45 were surveyed for horizontal and vertical control by Palmetto Land Surveying, Inc., of Charleston, South Carolina (South Carolina licensed), in accordance with the RFI/RI work plan (Tetra Tech NUS, Inc., 2001). The northing and easting coordinates are tied into the South Carolina State Plane Coordinate System, North American Datum 1983 (NAD83). Survey results are presented in Appendix A.

### **3.2.10 Investigation-Derived Waste (IDW)**

During the investigation, decontamination, development, and purge waters were transferred to a bulk tank. After testing, these waters were discharged to the base sewage treatment plant. Soil cuttings were placed in a roll-off box located at Site 45. These soils were tested, found to be nonhazardous, and sent off-site for disposal in a nonhazardous landfill. All IDW was handled in accordance with the Master Work Plan (Tetra Tech NUS, Inc. 2001) and the Work Plan for Site 45 (Tetra Tech NUS, Inc., 2001).

### **3.2.11 Quality Assurance/Quality Control (QA/QC) Samples**

Quality assurance (QA) objectives are evaluated by assessing the parameters defined in the Master Quality Assurance Plan (QAP). These parameters are precision, accuracy, representativeness, comparability, and completeness. QA/QC samples were collected to provide information pertaining to these key quality characteristics. The QA/QC sample results from this investigation are summarized in the following subsections.

The following QA/QC samples were collected during the investigation of Site 45: four soil field duplicates, two groundwater field duplicates, four trip blanks, and two matrix spike/matrix spike duplicate sets. The

data validation was limited in scope, and the evaluation of analytical data was conducted in such a manner that only false positives were assessed. The data validation memoranda were formulated to address only gross noncompliances resulting in the qualification of analytical data as rejected "R" or unusable.

QA/QC sample log sheets are provided in Appendix A. Appendix D contains the data validation summaries and a detailed PARCC discussion. The sample chain-of-custody forms can be found in Appendix A.

### **Precision**

Precision is a measure of the degree to which two or more measurements are in agreement. Field sampling precision was assessed through the collection and analysis of field duplicate samples. The precision of the laboratory's analytical program was assessed through the calculation of relative percent difference (RPD) for the matrix spike/matrix spike duplicate (MS/MSD) samples. According to the QAP, field duplicate results are considered to be precise if the RPD is less than 50 percent for solid samples and less than 30 percent for aqueous samples. Laboratory duplicates for solid and aqueous matrices are considered to be precise if the RPD is less than 35 percent and 20 percent, respectively.

No results were qualified based on laboratory precision noncompliance.

For the Site 45 surface/subsurface soil field duplicates, several RPDs exceeded the 50 percent quality control limit for the volatile and semivolatile analyses. As a result, positive and nondetected results for dibenzo(a,h)anthracene, 2-methylnaphthalene, benzo(a)pyrene, benzo(b)fluoranthene, carbazole, chrysene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene and phenanthrene were qualified as estimated "J" and "UJ," respectively. Positive results for cis-1,2-DCE, PCE, TCE, benzo(a)anthracene, dibenzofuran, fluoranthene, and pyrene were qualified as estimated "J," and nondetected results for butyl benzyl phthalate, acenaphthene, acenaphthylene, anthracene, benzo(g,h,i)perylene, and benzo(k)fluoranthene were qualified as estimated "UJ." The qualification of analytical data was limited to the associated field duplicate pair.

For the Site 45 groundwater samples, the Relative Percent Difference for TOC results exceeded the 30 percent quality control limit. As a result, positive results for TOC were qualified as "J" estimated.

### **Accuracy**

Accuracy is the degree of agreement between an observed value and an accepted reference value. Accuracy in the field is assessed through the use of field equipment rinsate blanks, trip blanks, and

source water blanks and also through adherence to sample handling, preservation, and holding times. Laboratory accuracy is assessed through the analysis of matrix spike, standard reference materials, and the determination of percent recoveries. Spike recoveries (e.g., blank, surrogate, and matrix spikes) are compared to acceptance limits statistically derived by the laboratory in accordance with established practices identified in the analytical method followed and further defined in the laboratory QAP.

### **Percent Recovery**

For the Site 45 surface/subsurface soil samples, initial and continuing calibration recovery noncompliances were noted for several VOCs during data validation; however, data quality was not compromised and no qualifiers were assigned based on these noncompliances. In contrast, poor instrument response was noted for the initial and continuing calibration of the semivolatle compound 3,3'-dichlorobenzidine. As a result, the nondetected results for 3,3'-dichlorobenzidine were qualified as unusable "R" in all the surface/subsurface soil samples.

### **Holding Times**

For the Site 45 groundwater samples, the holding time exceeded the 28-day quality control limit for chloride analysis. As a result, the positive result for chloride was qualified as estimated "J" in one environmental sample. The effect of this noncompliance was limited to one groundwater sample.

### **Laboratory and Field Blanks**

For surface/subsurface soil sample analysis, acetone, methylene chloride, methyl acetate, PCE, and toluene were detected in laboratory method blanks and/or trip blanks at concentrations ranging from 3 to 8 µg/kg. Inorganics were detected in the laboratory method blanks/preparation blanks at concentrations ranging from 0.059 µg/kg to 4.29 µg/kg. Positive sample results less than five times the maximum blank concentration (or 10 times for typical laboratory contaminants) were qualified as nondetected "U," due to blank contamination. All surface/subsurface soil samples were affected by one or more of the aforementioned blank contaminants. Sixty-nine of 2,000 (approximately 3.4 percent) data points were qualified as nondetected "U," as a result of blank contamination in the surface/subsurface soil samples.

For groundwater sample analyses, methylene chloride and 1,2,4-trichlorobenzene were detected in laboratory method blanks and/or trip blanks at concentrations ranging from 0.5 µg/L to 3 µg/L. Calcium and sodium were detected in laboratory method blanks and preparation blanks at concentrations ranging from 14 µg/L to 39 µg/L. One of eight groundwater samples was affected by blank contamination, and less than one percent (i.e., one of 438 data points) of the data was qualified as nondetected "U," due to blank contamination for groundwater samples at Site 45. Details are presented in Appendix D.

## **Representativeness**

Representativeness was qualified through the field sampling procedures and evaluation of laboratory analytical data. The site data accurately and precisely depict the actual characteristics of the environmental conditions that exist at Site 45. U.S. EPA-approved work plans and standardized sampling, handling, analytical, and reported procedures were followed to ensure that the final data accurately represent actual site conditions. Validated results support this finding.

## **Comparability**

Comparability, the confidence of comparing one data set to another, was satisfied by comparing results obtained from the analysis of eight groundwater samples by two independent laboratories (Test America Inc. and Katahdin Analytical Services). The evaluation indicates that values for most detected chemicals (except cis-1,2-DCE) were in agreement by approximately 45 percent to 55 percent. In cases where positive results for a specific chemical were reported by only one laboratory, it was found that the reported values were typically at or near sample reporting limits. Slight variance in instrument sensitivity and laboratory reporting protocol may account for the reporting discrepancies for these chemicals.

## **Completeness**

Completeness is the percentage of analyses with valid results compared to the total number of analyses for each analytical method in a given matrix. For this project, 90 percent completeness is acceptable for meeting the data completeness objective. For Site 45, no data points were rejected for VOC, dissolved gases, inorganic, or geotechnical analyses. However, nondetected results for the semivolatile compound 3,3'-dichlorobenzidine were qualified as unusable "R" or rejected. The amount of rejected data was approximately 1.5 percent for SVOC analyses. Therefore, the amount of usable and valid data available was 100 percent for all analytical fractions except SVOCs, which was 98.5 percent. These values meet the project objective for completeness. Appendix D presents the details of the validation reports.

## **Detection Limits**

Due to the presence of VOCs at elevated concentrations, several surface and subsurface soil samples were analyzed at dilution factors ranging from 24 to 120,000. This accounts for the elevated detection limits for samples in this medium. Soil samples were reported on a dry-weight basis.

### 3.2.12 Sample Analysis

Environmental samples were analyzed at two laboratories. Groundwater from the temporary monitoring wells was analyzed by Test America in Nashville, Tennessee (quick-turnaround VOC analysis), and the soil and the balance of the groundwater samples were analyzed by Katahdin in West Brook Maine. Analytical methods are summarized as follows.

Parameter	Soil	Groundwater
Volatile Organic Compounds	SW-846 8260B	SW-846 8260B (Test America) SW-846 8260B (Katahdin)
Semivolatile Organic Compounds	SW-846 8270C	
Metals	SW 846 6010B SW 848 7471A (mercury)	
Methane/Ethane/Ethene		Modified RSK 175
Total Organic Carbon	SW 846 9060 Lloyd Kahn	EPA 415.1
Alkalinity		EPA 310.1
Biochemical Oxygen Demand		EPA 405.1
Chemical Oxygen Demand		EPA 410.4
Nitrate		EPA 353.2
Orthophosphate		EPA 365.2
PH		EPA 150.1
Specific Conductance		EPA 120.1
Chloride/Nitrite/Sulfate		EPA 300.0

Geotechnics of Pittsburgh, Pennsylvania performed the geotechnical analysis. Results are presented in Appendix A and are discussed in Sections 3.3 and 3.4.

### 3.3 SITE-SPECIFIC GEOLOGY

Geologic conditions at Site 45 were characterized as part of the 2001 field investigation. Subsurface materials at Site 45 were visually classified based on split-spoon samples collected during the drilling of test borings and the temporary and permanent monitoring wells and from existing well data. Three geologic cross-sections were drawn through Site 45 as shown on Figure 3-3, based on the data collected during the field investigation.

The shallow subsurface lithology of Site 45 to a depth of approximately 17 feet consists of a heterogeneous mixture of Pliocene to Holocene age sediments of the Pamplico and Waccamaw Formations (Bechtel Environmental Inc., 1997), consisting primarily of fine sand and silty sand. Laboratory sieve analysis of samples from these deposits (Table 3-5) indicates that the Unified Soil Classification System (USCS) description of these sediments is SP (poorly graded sand) to SP/SM

(poorly graded sand to silty sand). Thin, discontinuous lenses of finer-grained silty clay and clayey sand were also encountered within the predominantly sandy sediments. Please see the appendices for the infrequent exceptions to this general description.

A thin (less than 1 to 3 feet) layer of peat was encountered below the shallow sandy sediments at depths ranging from 17 to 21 feet below ground. The peat was directly underlain by a 3- to 6-foot-thick clay unit, encountered at depths ranging from approximately 18 to 27 feet bgs. Beneath this potential confining layer formed by the peat and clay, the five newly installed deep well borings encountered unconsolidated deposits consisting primarily of sand, clayey sand, and silty fine sand. Total depths of the deep well borings ranged from 41.5 to 45 feet bgs.

The Miocene age Hawthorn Formation, a regional confining unit that separates the surficial deposits from the underlying Floridan aquifer, reportedly underlies MCRD Parris Island at an average elevation of 30 feet below msl. The Hawthorn Formation is reportedly approximately 25 to 40 feet thick in the area, except where it has been eroded away by tidal scour and stream erosion (Bechtel Environmental Inc., 1997). The deep borings at Site 45 did not confirm the presence of this unit locally.

Figures 3-4, 3-5, and 3-6 show cross-sectional transects A-A', B-B', and C-C', which were developed from soil boring data collected during the current investigation. The locations of these cross-sections are shown on Figure 3-3. Based on the cross sections, the individual geologic units at Site 45 appear to be essentially flat lying across the site.

Background samples were originally collected to support the Site/SWMU 3 RI/RFI. For each background sample area, sample locations were visually located in the field to confirm the absence of waste management activities and to represent a range of undisturbed soil and sediment types. Fine sand and silty sand identified at Site/SWMU 45 correlated well with the fine/medium grain sand and silty fine sand soil types at Site/SWMU 3. See Appendix H for a Summary of Detected Background Concentrations and Background Sample Description, Locations, and Supporting Collection Data.

### **3.4 SITE-SPECIFIC HYDROGEOLOGY**

The hydrogeologic conditions at Site 45 were interpreted from data obtained during the subsurface investigation activities at the site, including drilling and well installation, groundwater sampling, groundwater-level measurements, and a pumping test and slug tests performed during the 2001 investigation.

### **3.4.1 Hydrogeologic Framework**

The uppermost aquifer (surficial aquifer) underlying Site 45 consists of the sandy Pliocene to Holocene sediments present beneath the site to an average depth of approximately 18 feet. In general, the water table encountered within these heterogeneous sediments is shallow and is typically encountered at a depth of 3 to 4 feet bgs at the site. Groundwater is expected to preferentially migrate through the higher permeability sandy sediments within the surficial aquifer. Due to their limited areal extents, the localized silty/clayey lenses found within the surficial aquifer are not expected to function as significant confining units. Recharge to the surficial aquifer is likely to occur primarily through infiltration of precipitation.

The peat layer found underlying the surficial aquifer sediments throughout the site at depths ranging from 17 to 27 feet bgs is expected to function locally as a confining unit to groundwater flow. Based on the results of laboratory hydraulic conductivity testing of six samples from this unit (see Table 3-5), the geometric mean vertical hydraulic conductivity for this confining unit is 0.00166 feet per day ( $5.8 \times 10^{-7}$  cm/sec). This, in combination with an average thickness of 5 to 6 feet, indicates that the unit significantly restricts vertical groundwater flow.

The silty sand deposits that were encountered beneath the peat/clay layer form a deeper aquifer within the Pliocene/Holocene sediments beneath the site. The thickness of this deeper unit is unknown because the Hawthorn Formation, a regional confining unit expected to directly underlie these deposits, was not identified in the deep borings drilled at the site.

Site 45 is located within the 100-year flood plain, according to the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (1986).

### **3.4.2 Groundwater Flow Directions**

Groundwater flow directions were established based on several rounds of water-level measurements collected in November and December 2001 (Table 3-4). Groundwater flow directions in the upper portion of the surficial aquifer were evaluated using water-level data from –SU monitoring wells; water level data from the –SL wells were used to evaluate groundwater flow directions in the lower portion of the surficial aquifer; and water levels from the –D wells were used to evaluate groundwater flow directions in the upper portion of the deeper aquifer at the site. The November 3 and November 12 rounds of water levels were evaluated to identify surficial aquifer flow patterns, and the December 10 round of water levels was used to evaluate the deeper groundwater flow pattern. All groundwater level measurements discussed herein were taken under non-pumping conditions. Since the system control is impaired, as previously discussed, stable measurements under pumping conditions were not available.

For the upper portion of the surficial aquifer, the groundwater flow direction is to the southeast, as shown on Figure 3-7 (November 3, 2001 round of water levels) and Figure 3-9 (November 12, 2001 round of water levels). Localized groundwater mounding in the immediate vicinity of well PA-45-MW06-SU is evident during both time periods. For the November 3 round of water levels, an overall groundwater flow gradient of 0.0029 across the site was calculated; for the November 12 round of water levels, the gradient was slightly lower at 0.0024. The overall gradients are generally consistent across the study area for both sets of water levels.

For the lower portion of the surficial aquifer, the groundwater flow direction is also to the southeast, as shown on Figure 3-8 (November 3, 2001 round of water levels) and Figure 3-10 (November 12, 2001 round of water levels). The localized groundwater mounding observed in the immediate vicinity of well PA-45-MW06-SU, however, is not evident for the deeper portion of the surficial aquifer. For the November 3 round of water levels, an overall groundwater flow gradient was calculated for the lower portion of the surficial aquifer of 0.0029 across the site; for the November 12 round of water levels, the gradient was slightly lower at 0.0023. The overall gradients are generally consistent across the study area for both sets of water levels. In general, the water levels and the flow patterns for the upper and lower portions of the surficial aquifer match up closely, indicating a strong hydraulic connection.

With few exceptions, vertical gradients at upper/lower surficial aquifer well clusters were minimal, with typical differences in water levels of less than 0.1 feet. A notable exception to this was at well cluster 6SU/SL, where the shallow well had a water level approximately 0.2 foot higher than the water level in the deeper surficial aquifer well. There was also no apparent overall pattern to the vertical head differentials in terms of shallow versus deep; some clusters had consistent upward or downward gradients, and others varied from round to round.

The overall groundwater flow direction in the deeper aquifer is to the south-southwest, as shown on Figure 3-11 (December 10, 2001 round of water levels). In general, the flow patterns for the surficial aquifer and the deeper aquifer indicate that there is a limited hydraulic connection between the two flow systems. For the December 10 round of water levels, an overall groundwater flow gradient for the deeper aquifer of 0.0021 across the site was calculated, although in the vicinity of well clusters 4 and 5 there is a downward vertical gradient between the surficial and deep aquifers.

#### **3.4.3 In-Situ Hydraulic Testing of the Surficial Aquifer**

In-situ hydraulic testing was performed at Site 45 to determine the hydraulic characteristics of the surficial aquifer. The results of the hydraulic testing were used to evaluate groundwater flow and contamination migration rates and will be used in the FS evaluation of remedial options for groundwater.

#### 3.4.3.1 Slug Tests

Rising-head slug tests were performed at all newly installed monitoring wells, piezometers, and the existing wells at Site 45 to generate estimates of the hydraulic conductivities of the aquifer sediments in the immediate vicinities of the well screens. The results of the test evaluations are presented in Table 3-6. The geometric mean hydraulic conductivity (K) for all 19 shallow surficial aquifer wells was calculated to be approximately four feet per day ( $1.4 \times 10^{-3}$  cm/sec), which is within the typical range for clayey, silty sands (Fetter, 1980). Subdividing these wells into upper and lower surficial aquifer wells, the geometric mean K for the upper surficial aquifer wells (eight feet/day) is somewhat higher than that of the lower surficial aquifer wells (2 feet/day). The geometric mean K for the five deep aquifer wells was calculated to be approximately 1 foot per day ( $2.1 \times 10^{-4}$  cm/sec), which is within the typical range for well-sorted sands to silty sands and fine sands (Fetter, 1980). Water-level recovery plots and calculations based on the slug tests are included in Appendix B.

#### 3.4.3.2 Pumping Test

A short-term pumping test (47-hour duration) was performed from October 30 through November 1, 2001, using existing extraction well RW-3 as the pumping well. Water-level data were collected from 11 observation wells prior to, during, and immediately after the test. A target pumping rate of 1.3 gpm was used for the pumping test, except for a slight increase to 1.4 gpm noted approximately 1,000 minutes into the test. Details regarding the testing process are presented in Section 3.2.8. Drawdown data obtained from the wells monitored during the pumping tests, along with the pumping rate data, were evaluated to determine aquifer transmissivity and storativity. The data were plotted on both semi-log and log-log graph paper and analyzed using the appropriate data analysis methods.

Time-drawdown data for the observation wells were downloaded directly from the transducers and data loggers and plotted on time versus drawdown graphs (included in Appendix B). Responses to the pumping of RW3 were noted almost immediately (within a few minutes or less) in the nearby observation wells. A relatively quick response time (approximately 30 minutes) was also observed in wells MW08SU and MW08SL, located approximately 125 feet from RW3. The observance of pumping-related drawdowns within this short time interval, considering the low pumping rate used (1.3 gpm), suggests that the aquifer response to pumping is more indicative of a leaky confined aquifer than an unconfined aquifer.

Well MW04SL, located approximately 195 feet from RW3, was monitored during the test for background water-level fluctuations. Based on the down-gradient and cross-gradient location of this well with respect to RW3 it was anticipated that this well would provide a good indication of background conditions. The water-level data, presented graphically in Appendix B, clearly show cyclical tidal effects ranging in magnitude up to approximately 0.2 foot. In addition, the water level declined in this well over the time

period that active pumping occurred, indicating that the well was within the cone of influence of the pumping test. After pumping was terminated, approximately 2,820 minutes after the test was started, the water levels in MW04SL and in the closer observation wells steadily rose to within a few hundredths of a foot of the pre-pumping water levels. In addition, there was no precipitation during the time period over which the test was performed. As a result, no trend corrections to the time-drawdown data were considered necessary prior to data analysis. Best-fit drawdown curves were used to negate the cyclical effects of tidal fluctuations.

### Pumping Test Results

Time-drawdown data from wells MW03SL, MW06SL, MW07SU, MW07SL, MW08SU, MW08SL, PZ10S, and PZ11S were analyzed individually to generate estimates of aquifer transmissivity, hydraulic conductivity, and storativity. Both a semilog time-drawdown method for confined aquifers (Cooper-Jacob, 1946) and a log-log time-drawdown pumping test analysis method for leaky confined aquifers (Hantush-Jacob, 1955) were used. In addition, a distance-drawdown method (Cooper-Jacob, 1946) was used, incorporating data from all the observation wells, to support the time-drawdown analyses. Although these methods are generally for confined aquifers and boring log data indicate that the surficial aquifer is unconfined, the drawdown patterns that were observed in response to the pumping of RW3 more closely match a typical confined or leaky-confined aquifer response. This may be a result of the presence of relatively finer-grained sediments (silty sand) within the upper portion of the shallow aquifer in comparison to the deeper sediments (fine sand).

The time-drawdown field data were imported into Waterloo Hydrogeologic's AquiferTest computer program (v. 3.0) for data analysis. The program can be used to automatically obtain best-fit matches between type curves and test data (log-log analyses) or best-fit straight line matches with test data (semilog analyses). The test data can also be manipulated by the user to obtain a custom fit, as would typically be performed by manual evaluation methods. Transmissivity and storativity are automatically calculated based on the selected matches between field data and type curves, for log-log analyses, or by the slope and intercepts of the straight lines generated from semilog analyses of the data. Log-log and semilog time-drawdown analyses were performed for each individual observation well. In addition, a semilog distance-drawdown analysis was performed using data from all the observation wells. In general, the best-fit matches selected by the computer program were manually adjusted to fine-tune the analyses, based on professional judgment. Appendix G provides the log-log and semilog plots, along with the final type curve or straight line matches that were selected for each test.

Table 3-7 summarizes the results of the pumping test analyses. Based on the evaluation of the pumping test data, an average transmissivity of approximately 230 feet<sup>2</sup> per day is estimated for the shallow aquifer. Assuming an average aquifer thickness of 15 feet, the overall average hydraulic conductivity of

the shallow aquifer sediments is 15.3 feet per day. Storativity averages about 0.0025. The pumping-test-derived average hydraulic conductivity is somewhat higher than the average hydraulic conductivity calculated from the slug test data (4.04 feet per day). Pumping tests are generally considered to be more reliable and accurate methods to determine aquifer characteristics than slug tests.

Little or no response to pumping was observed in shallow surficial aquifer wells MW06SU and MW03SU, located within 50 feet or less of RW3. The corresponding deeper surficial aquifer observation wells MW06SL and MW03SL had maximum observed drawdowns of over 0.8 foot and 0.4 foot, respectively. Conversely, the drawdowns in the upper and lower wells were almost identical at the other upper/lower surficial aquifer well cluster locations (MW08SU/SL; MW07SU/SL). The lack of drawdowns in MW06SU and MW03SU in comparison to the responses noted in the companion deeper wells indicates that there is a localized low-permeability unit that isolates the upper few feet of the surficial aquifer from the deeper portion of the surficial aquifer in the vicinity of RW3 and these observation wells and that RW3 preferentially draws water from the deeper portion of the surficial aquifer.

#### **3.4.4 Extraction System Capture Zone Delineation**

Groundwater flow and particle track modeling was performed for Site 45 in order to delineate the groundwater extraction system capture zone under various pumping scenarios. The modeling focused on the uppermost aquifer at the site and was approached as more of a generalized modeling effort adequate for approximation purposes rather than a detailed, rigorous, in-depth modeling effort. A steady-state, two-dimensional groundwater flow and particle tracking model was created using Visual MODFLOW (Waterloo Hydrogeologic, 1996), an integrated modeling environment for the MODFLOW and MODPATH groundwater models developed by the United States Geological Survey (USGS). Initially, the groundwater flow model was set on a grid with a modeled area of 1,700 feet by 1,600 feet. Key hydrogeologic parameters used to create the model include

- Hydraulic conductivity -  $K_x = 15.3$  ft/day;  $K_y = 15.3$  ft/day;  $K_z = 3$  ft/day
- Effective porosity - 0.12
- Total porosity - 0.24
- Specific yield - 0.0015
- Specific storage - 0.0015
- Groundwater flow gradient - 0.0026, to the south-southeast
- Aquifer thickness - 15 feet

The model was set up to first replicate the groundwater flow pattern observed under non-pumping conditions (Run No. 1, Appendix B-3Figure 1). Constant head cells were added to the upgradient and

downgradient edges of the model to generate the background groundwater flow field. It was initially assumed that the surficial aquifer was isolated from the deep aquifer. When a reasonable match was obtained between the Run No. 1 results and the groundwater flow maps that were developed from field measurements (presented in Section 3.4.2), additional model runs were performed with various combinations of pumping rates for the three extraction wells that currently exist at the site. Forward-tracking particles were added to the groundwater flow field near the upgradient edge of the model and at selected points within the interior of the model, and backward-tracking particles were added in the area around the extraction wells. The migration paths of these particles were used to delineate groundwater flow patterns and the capture zones of both the individual extraction wells and the overall extraction system. Three different combinations of pumping rates were simulated for capture zone prediction purposes:

Run No.	Pumping Rate, ft <sup>3</sup> /day (gpm)		
	RW1	RW2	RW3
2	192.51 (1)	385 (2)	577.5 (3)
3	58 (0.3)	96 (0.5)	289 (1.5)
4	385 (2)	577.5 (3)	770 (4)

The pumping rates used for Run No. 2 are rates that historic extraction system pumping information indicates are readily sustainable when the wells are functioning properly. The Run No. 3 rates were set slightly below the long-term average rates at which the wells actually operated from January through July 2001. The pumping rates used for Run No. 4 are 50 percent above the Run No. 2 rates and probably represent the upper limit of what could be expected from the wells.

Under the Run No. 2 pumping scenario (6 gpm total), the capture zone of the extraction system extends approximately 400 feet south-southeastward (downgradient) of the source area (Building 193), as shown in Appendix G, Figure 2. For Run No. 3 (2.3 gpm) and Run No. 4 (9 gpm), the downgradient capture zones extend approximately 160 and 600 feet downgradient from Building 193, as shown in Appendix B-3 Figures 3 and 4. Under all three pumping scenarios, the source area for the Site 45 groundwater contamination is completely contained within the extraction system capture zone. As the extraction system pumping rate increases, more of the downgradient portion of the contaminant plume is captured.

Based on the capture zone simulations, the extraction wells appear to be well situated to capture the source area portion of the contaminant plume associated with Site 45. The determination of the optimum long-term pumping rates for the wells should be made based on a combination of factors, including the long-term sustainable yields of the wells, treatment system constraints, and the downgradient extent of desired capture.

TABLE 3-1

SITE-SPECIFIC INVESTIGATION SUMMARY AND RATIONALE  
 SITE 45 – MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA  
 PAGE 1 OF 2

Medium	Data Gap/Need	Investigation Activity	Number of Samples	Analysis
Soil	<ul style="list-style-type: none"> <li>Nature and extent</li> </ul>	<ul style="list-style-type: none"> <li>Collect surface soil samples.</li> </ul>	8	TCL VOCs TCL SVOCs TAL Metals (Total) and Tin
	<ul style="list-style-type: none"> <li>Nature and extent</li> </ul>	<ul style="list-style-type: none"> <li>Collect subsurface soil samples in vadose zone.</li> </ul>	8	TCL VOCs TCL SVOCs TOC
	<ul style="list-style-type: none"> <li>Determine if DNAPL is present</li> </ul>	<ul style="list-style-type: none"> <li>Field screening.</li> </ul>	31	Fluorescent light screening
	<ul style="list-style-type: none"> <li>Soil Classification/ Loggings</li> </ul>	<ul style="list-style-type: none"> <li>Document soil characteristics during soil boring and monitoring well installation (temporary and permanent).</li> </ul>	Continuous	Field characterization
	<ul style="list-style-type: none"> <li>Groundwater modeling parameters</li> </ul>	<ul style="list-style-type: none"> <li>Collect saturated subsurface soil.</li> </ul>	3 on site 3 off site	TOC, pH, grain-size analysis
		<ul style="list-style-type: none"> <li>Collect shelly tube sample from the Hawthorn Formation.</li> </ul>	3 on site 3 off site	Vertical hydraulic conductivity
	<ul style="list-style-type: none"> <li>Natural attenuation testing (laboratory analysis)</li> </ul>	<ul style="list-style-type: none"> <li>Collect one upgradient saturated subsurface soil sample.</li> </ul>	1	Fraction organic carbon
Groundwater	<ul style="list-style-type: none"> <li>Profiling wells</li> </ul>	<ul style="list-style-type: none"> <li>Collect shallow and deep groundwater samples (temporary wells).</li> </ul>	35	VOCs – 48 hour turn-around time
	<ul style="list-style-type: none"> <li>Nature and extent wells</li> </ul>	<ul style="list-style-type: none"> <li>Collect four shallow, and one intermediate well.</li> </ul>	5	TCL VOCs

**TABLE 3-1**

**SITE-SPECIFIC INVESTIGATION SUMMARY AND RATIONALE  
 SITE 45 – MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA  
 PAGE 2 OF 2**

<b>Medium</b>	<b>Data Gap/Need</b>	<b>Investigation Activity</b>	<b>Number of Samples</b>	<b>Analysis</b>
Groundwater (continued)	<ul style="list-style-type: none"> <li>Water-quality parameters (collected in field)</li> </ul>	<ul style="list-style-type: none"> <li>Measure from groundwater sample.</li> </ul>	All groundwater samples	Dissolved oxygen, salinity, pH, specific conductivity, turbidity, temperature
	<ul style="list-style-type: none"> <li>Hydraulic conductivity</li> </ul>	<ul style="list-style-type: none"> <li>Perform slug tests (new monitoring wells).</li> </ul>	21	Evaluation of hydraulic conductivity
	<ul style="list-style-type: none"> <li>Groundwater extraction system evaluation</li> </ul>	<ul style="list-style-type: none"> <li>Measure hydrogeological characteristics.</li> </ul>	1	Water-level and pumping rate measurements
	<ul style="list-style-type: none"> <li>Natural attenuation testing and water-quality parameters (laboratory analysis)</li> </ul>	<ul style="list-style-type: none"> <li>Collect one upgradient, one downgradient, one source area, and two samples within the plume.</li> </ul>	5	TCL VOCs, alkalinity, chloride, ethane, ethene, methane, nitrate, nitrite, phosphate, sulfate, and TOC, hardness, total dissolved solids, total suspended solids, and fluoride
	<ul style="list-style-type: none"> <li>Natural attenuation testing (field analysis)</li> </ul>	<ul style="list-style-type: none"> <li>Collect one upgradient, one downgradient, one source area, and two samples within the plume.</li> </ul>	5	Dissolved carbon dioxide, iron, manganese, dissolved oxygen, sulfide, specific conductance, oxidation reduction potential, pH, temperature, and turbidity

**Notes:**

1. Does not include QA/QC samples.

TABLE 3-2

SUMMARY OF SOIL SAMPLING  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA  
 PAGE 1 OF 2

Sample Location	Sample Designation	Sample Depth	Sample Analysis						
			TCL VOCs	TCL SVOCs	TAL Metals (Total) and Tin	DNAPL Screening	TOC	pH and Grain Size	Average Permeability
PAI-45-SS-01	PAI-45-SS-01-01	0-1	●	●	●				
PAI-45-SS-02	PAI-45-SS-02-01	0-1	●	●	●				
PAI-45-SS-03	PAI-45-SS-03-01	0-1	●	●	●				
PAI-45-SS-04	PAI-45-SS-04-01	0-1	●	●	●				
PAI-45-SS-05	PAI-45-SS-05-01	0-1	●	●	●				
PAI-45-SS-06	PAI-45-SS-06-01	0-1	●	●	●				
PAI-45-SS-07	PAI-45-SS-07-01	0-1	●	●	●				
PAI-45-SS-08	PAI-45-SS-08-01	0-1	●	●	●				
PAI-45-SB-01	PAI-45-SB-01-05	4-5	●	●			●		
	PAI-45-SB-01-14	12-14					●	●	
	PAI-45-SB-01-07	7				●			
	PAI-45-SB-01-23	20-22.5							●
PAI-45-SB-02	PAI-45-SB-02-04	3-4	●	●			●		
	PAI-45-SB-02-06	6				●			
PAI-45-SB-03	PAI-45-SB-03-04	2-4	●	●			●		
	PAI-45-SB-03-03	3				●			
PAI-45-SB-04	PAI-45-SB-04-04	3-4	●	●			●		
	PAI-45-SB-04-06	6				●			
	PAI-45-SB-04-08	8				●			
PAI-45-SB-05	PAI-45-SB-05-04	2-4	●	●			●		
	PAI-45-SB-05-06	6				●			
PAI-45-SB-06	PAI-45-SB-06-04	2-4	●	●			●		
	PAI-45-SB-06-06	6				●			
PAI-45-SB-07	PAI-45-SB-07-04	3-4	●	●			●		
	PAI-45-SB-07-05	5				●			
PAI-45-SB-08	PAI-45-SB-08-04	3-4	●	●			●		
	PAI-45-SB-08-06	6				●			
PAI-45-SB-09	PAI-45-SB-09-14	12-14					●	●	
	PAI-45-SB-09-23	20-22.5							●
PAI-45-SB-10	PAI-45-SB-10-13	11-13					●	●	
	PAI-45-SB-10-23	20-22.5							●
PAI-45-SB-11	PAI-45-SB-11-10	8-10					●	●	
	PAI-45-SB-11-23	20-23							●

**TABLE 3-2**

**SUMMARY OF SOIL SAMPLING  
SITE 45 - MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA  
PAGE 2 OF 2**

PAI-45-SB-12	PAI-45-SB-12-10	8 -10					•	•	
	PAI-45-SB-12-21	18 -21							•
PAI-45-SB-13	PAI-45-SB-13-10	8 -10					•	•	
	PAI-45-SB-13-21	18 -21							•

**Notes:**

Surface soil samples were collected from the shallow, most native soils.  
Surface soil samples were collected at the same location as the soil borings.  
For example: PAI-45-SS-01 was collected at location PAI-45-SB-01

TABLE 3-3

SUMMARY OF GROUNDWATER SAMPLING  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA  
 PAGE 1 OF 3

Sample Location	Sample Designation	Screen Length (ft)	Sample Depth (ft bgs)	Sample Analysis				Low Conc VOC's	Methane, Ehtane, Ethene	TOC COD	BOD, Alk. Anions <sup>(4)</sup>	Metals
				QT VOCs	Soil Logging <sup>(1)</sup>	MIPs <sup>(2)</sup>	Soil Cond <sup>(3)</sup>					
PAI-45-TW01	PAI-45-TW-01-10	4	10	●	●							
	PAI-45-TW-01-15	4	15	●	●							
PAI-45-TW02	PAI-45-TW-02-10	4	10	●	●							
	PAI-45-TW-02-16	4	16	●	●							
PAI-45-TW03	PAI-45-TW-03-08	4	8	●	●							
	PAI-45-TW-03-17	4	17	●	●							
PAI-45-TW04	PAI-45-TW-04-06	4	6	●	●							
	PAI-45-TW-04-14	4	14	●	●							
PAI-45-TW05	PAI-45-TW-05-07	4	7	●	●							
	PAI-45-TW-05-20	4	20	●	●							
	PAI-45-TW-05-34	4	27	●	●							
PAI-45-TW06	PAI-45-TW-06-06	4	6	●	●							
	PAI-45-TW-06-18	4	18	●	●							
PAI-45-TW07	PAI-45-TW-07-08	4	8	●	●							
	PAI-45-TW-07-16	4	16	●	●							
PAI-45-TW08	PAI-45-TW-08-08	4	8	●	●							
	PAI-45-TW-08-19	4	19	●	●							
	PAI-45-TW-08-32	4	32	●	●							
PAI-45-TW09	PAI-45-TW-09-07	4	7	●	●							
	PAI-45-TW-09-15	4	15	●	●							
PAI-45-TW10	PAI-45-TW-10-07	4	7	●	●							
	PAI-45-TW-10-16	4	16	●	●							
	PAI-45-TW-10-32	4	32	●	●							
PAI-45-TW11	PAI-45-TW-11-10	3	10	●	●							
	PAI-45-TW-11-20	3	20	●	●							
	PAI-45-TW-11-32	3	32	●	●							
PAI-45-TW12	PAI-45-TW-12-07	4	7	●	●							
	PAI-45-TW-12-16	4	16	●	●							
PAI-45-TW13	PAI-45-TW-13-06	4	6	●	●							
	PAI-45-TW-13-18	4	18	●	●							

TABLE 3-3

**SUMMARY OF GROUNDWATER SAMPLING  
SITE 45 - MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA  
PAGE 2 OF 3**

Sample Location	Sample Designation	Screen Length (ft)	Sample Depth (ft bgs)	Sample Analysis				Low Conc VOC's	Methane, Ehtane, Ethene	TOC COD	BOD, Alk. Anions <sup>(4)</sup>	Metals
				QT VOCs	Soil Logging <sup>(1)</sup>	MIPs <sup>(2)</sup>	Soil Cond <sup>(3)</sup>					
PAI-45-TW14	PAI-45-TW-14-07	3	7	●	●							
	PAI-45-TW-14-17	3	17	●	●							
	PAI-45-TW-14-30	3	30	●	●							
PAI-45-TW15	PAI-45-TW-15-10	4	10	●	●							
	PAI-45-TW-15-18	4	18	●	●							
PAI-45-TW16	PAI-45-TW-16-06	4	6	●	●							
	PAI-45-TW-16-19	4	19	●	●							
PAI-45-TW17	PAI-45-TW-17-06	4	6	●	●							
	PAI-45-TW-17-21	4	21	●	●							
PAI-45-TW18	PAI-45-TW-18-07	4	7	●	●							
	PAI-45-TW-18-17	4	17	●	●							
PAI-45-TW19	PAI-45-TW-19-07	4	7	●	●							
	PAI-45-TW-19-18	4	18	●	●							
	PAI-45-TW-19-32	4	32	●	●							
	PAI-45-TW-19A-32	4	32	●	●							
	PAI-45-TW-19A-40	4	40	●	●							
PAI-45-TW20	PAI-45-TW-20-07	4	7	●	●							
	PAI-45-TW-20-19	4	19	●	●							
PAI-45-TW21	PAI-45-TW-21-07	4	7	●	●							
	PAI-45-TW-21-19	4	19	●	●							
PAI-45-TW22	PAI-45-TW-22-06	4	6	●	●							
	PAI-45-TW-22-32	4	32	●	●							
PAI-45-TW23	PAI-45-TW-23-09	4	9	●	●							
	PAI-45-TW-23-19	4	19	●	●							
	PAI-45-TW-24-06	4	6	●	●							
	PAI-45-TW-24-18	4	18	●	●							
PAI-45-TW24	PAI-45-TW-25-06	4	6	●	●							
	PAI-45-TW-25-18	4	18	●	●							
PAI-45-TW26	PAI-45-TW-26-07	4	7	●	●							
	PAI-45-TW-26-17	4	17	●	●							

TABLE 3-3

SUMMARY OF GROUNDWATER SAMPLING  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA  
 PAGE 3 OF 3

Sample Location	Sample Designation	Screen Length (ft)	Sample Depth (ft bgs)	Sample Analysis				Low Conc VOC's	Methane, Ehtane, Ethene	TOC COD	BOD, Alk. Anions <sup>(4)</sup>	Metals
				QT VOCs	Soil Logging <sup>(1)</sup>	MIPs <sup>(2)</sup>	Soil Cond <sup>(3)</sup>					
PAI-45-TW27	PAI-45-TW-27-08	4	8	●	●							
	PAI-45-TW-27-18	4	18	●	●							
PAI-45-TW28	PAI-45-TW-28-32	4	32	●	●							
	PAI-45-TW-28-40	4	40	●	●							
PAI-45-TW30	PAI-45-TW-30-08	4	8	●	●							
	PAI-45-TW-30-16	2	16	●	●							
	PAI-45-TW-30-32	4	32	●	●							
PAI-45-TW31	PAI-45-TW-31-12	4	12	●	●	●	●					
PAI-45-TW32	PAI-45-TW-32-16	4	16	●	●	●	●					
PAI-45-TW33	PAI-45-TW-33-15	4	15	●	●	●	●					
PAI-45-TW34	PAI-45-TW-34-14	4	14	●	●	●	●					
PAI-45-TW35	PAI-45-TW-35-32	4	32	●	●	●	●					
PAI-45-MW-01SU	PAI-45-GW-01SU-01	4	7		●			●	●	●	●	
PAI-45-MW-04SU	PAI-45-GW-04SU-01	4	7		●			●	●	●	●	
PAI-45-MW-04D	PAI-45-GW-04D-01	10	41	●	●							
PAI-45-MW-05SL	PAI-45-GW-05SL-01	5	7		●			●	●	●	●	
PAI-45-MW-05D	PAI-45-GW-05D-01	10	43	●	●							
PAI-45-MW-06SU	PAI-45-GW-06SU-01	4	7	●	●			●	●	●	●	
PAI-45-MW-06SL	PAI-45-GW-06SL-01	5	14	●	●							
PAI-45-MW-07SU	PAI-45-GW-07SU-01	4	7	●	●							
PAI-45-MW-07SL	PAI-45-GW-07SL-01	5	14	●	●							
PAI-45-MW-08SU	PAI-45-GW-08SU-01	4	7	●	●			●	●	●	●	
PAI-45-MW-08SL	PAI-45-GW-08SL-01	5	14	●	●							
PAI-45-MW-09D	PAI-45-GW-09D-01	10	41	●	●							
PAI-45-MW-10D	PAI-45-GW-10D-01	10	41	●	●							
PAI-45-MW-11D	PAI-45-GW-11D-01	10	41	●	●							

Notes

1. DNAPL screening was conducted if significant PID readings were obtained (greater than 50 ppm) or if visual observations warranted further investigation.
2. Groundwater in the temporary wells was collected at the depth corresponding to the highest VOC detection.
3. Measured using MIP (Membrane Interface Probe).
4. Anions include chloride, sulfate, nitrate, nitrite and orthophosphate (see sample log sheets for details).

QTCOCs = Quick-turn volatile organic compounds.

TABLE 3-4

WELL CONSTRUCTION DETAILS, WATER-LEVEL MEASUREMENTS  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND,, SOUTH CAROLINA

Well	TOC Elevation (ft)	Well Diameter (inches)	Screened Interval (ft below ground)	10/29/01		10/30/01		11/03/01		11/12/01		12/10/01	
				DTW (ft from TOC)	Elevation (ft)								
MW01SU	7.60	2	3-7	3.30	4.30	3.29	4.31	3.36	4.24	3.51	4.09		
MW01SL	7.57	2	11.6-14	3.30	4.27	3.29	4.28	3.32	4.25	3.55	4.02		
MW02SU	7.11	2	3-7	2.99	4.12	2.99	4.12	3.06	4.05	3.29	3.82		
MW02SL	7.23	2	9-14	3.08	4.15	3.07	4.16	3.09	4.14	3.31	3.92		
MW03SU	7.60	2	3-7	3.55	4.05	3.56	4.04	3.70	3.90	3.91	3.69		
MW03SL	7.57	2	9-14	3.66	3.91	3.54	4.03	3.67	3.90	3.84	3.73		
MW04SU	6.98	2	3-7	3.38	3.60	3.25	3.73	3.40	3.58	3.52	3.46		
MW04SL	6.93	2	9-14	3.34	3.59	3.18	3.75	3.35	3.58	3.47	3.46		
MW04D*	6.75	2	31-41	3.88	2.87	3.82	2.93	4.06	2.69	4.20	2.55	4.25	2.50
MW05SU	8.60	2	3-7	5.16	3.44	4.81	3.79	5.18	3.42	5.21	3.39		
MW05SL	8.26	2	9-14	4.75	3.51	4.46	3.80	4.80	3.46	4.83	3.43		
MW05D*	8.64	2	34-44	5.63	3.01	5.64	3.00	5.76	2.88	5.91	2.73	6.04	2.60
MW06SU	7.61	2	3-7	3.53	4.08	3.43	4.18	3.54	4.07	3.62	3.99		
MW06SL	7.52	2	9-14	3.63	3.89	3.56	3.96	3.65	3.87	3.80	3.72		
MW07SU	7.68	2	3-7	3.75	3.93	3.70	3.98	3.77	3.91	3.95	3.73		
MW07SL	7.72	2	9-14	3.76	3.96	3.72	4.00	3.78	3.94	3.99	3.73		
MW08SU	7.60	2	3-7	3.58	4.02	3.53	4.07	3.57	4.03	3.80	3.80		
MW08SL	7.53	2	9-14	3.50	4.03	3.47	4.06	3.51	4.02	3.71	3.82		
MW09D*	7.24	2	31-41									4.69	2.55
MW10D*	7.25	2	31-41	4.20	3.05	4.18	3.07	4.30	2.95	4.42	2.83	4.50	2.75
MW11D*	6.43	2	31-41									4.13	2.30
PZ09S*	7.47	2	5-15	3.51	3.96	3.47	4.00	3.52	3.95	3.70	3.77		
PZ10S*	7.58	2	5-15	3.67	3.91	3.63	3.95	3.68	3.90	3.88	3.70		
PZ11S*	7.39	2	5-15	3.51	3.88	3.44	3.95	3.52	3.87	3.69	3.70		
RW1**	9.81	6	4-16	-	-	-	-	5.88	3.93	6.06	3.75		
RW2**	9.63	6	4-16	-	-	-	-	5.72	3.91	5.90	3.73		
RW3**	9.35	6	4-16	-	-	-	-	5.50	3.85	5.65	3.70		

\* 1/24/02 survey data (NGVD 88) for these wells were adjusted by +0.88 ft to match with pre-existing survey data (NGVD 29), based on a resurvey of selected previously surveyed wells.

\*\* Recovery well elevation data were obtained from well casing tags, not surveyed with monitoring wells.  
 Screened interval data obtained from typical construction drawing.

TOC - Top of well casing.

DTW - Depth to water.

TABLE 3-4a

**WELL CONSTRUCTION DETAILS, WATER-LEVEL MEASUREMENTS  
SITE 45 - MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND,, SOUTH CAROLINA**

Well	TOC Elevation (ft)	Well Diameter (inches)	Screened Interval (ft below ground)	10/29/01		10/30/01		11/03/01		11/12/01		12/10/01	
				DTW (ft from TOC)	Elevation (ft)	DTW (ft from TOC)	Elevation (ft)						
MW01SU	7.60	2	3-7	3.30	4.30	3.29	4.31	3.36	4.24	3.51	4.09		
MW01SL	7.57	2	11.6-14	3.30	4.27	3.29	4.28	3.32	4.25	3.55	4.02		
MW02SU	7.11	2	3-7	2.99	4.12	2.99	4.12	3.06	4.05	3.29	3.82		
MW02SL	7.23	2	9-14	3.08	4.15	3.07	4.16	3.09	4.14	3.31	3.92		
MW03SU	7.60	2	3-7	3.55	4.05	3.56	4.04	3.70	3.90	3.91	3.69		
MW03SL	7.57	2	9-14	3.66	3.91	3.54	4.03	3.67	3.90	3.84	3.73		
MW04SU	6.98	2	3-7	3.38	3.60	3.25	3.73	3.40	3.58	3.52	3.46		
MW04SL	6.93	2	9-14	3.34	3.59	3.18	3.75	3.35	3.58	3.47	3.46		
MW04D*	6.75	2	31-41	3.88	2.87	3.82	2.93	4.06	2.69	4.20	2.55	4.25	2.50
MW05SU	8.60	2	3-7	5.16	3.44	4.81	3.79	5.18	3.42	5.21	3.39		
MW05SL	8.26	2	9-14	4.75	3.51	4.46	3.80	4.80	3.46	4.83	3.43		
MW05D*	8.64	2	34-44	5.63	3.01	5.64	3.00	5.76	2.88	5.91	2.73	6.04	2.60
MW06SU	7.61	2	3-7	3.53	4.08	3.43	4.18	3.54	4.07	3.62	3.99		
MW06SL	7.52	2	9-14	3.63	3.89	3.56	3.96	3.65	3.87	3.80	3.72		
MW07SU	7.68	2	3-7	3.75	3.93	3.70	3.98	3.77	3.91	3.95	3.73		
MW07SL	7.72	2	9-14	3.76	3.96	3.72	4.00	3.78	3.94	3.99	3.73		
MW08SU	7.60	2	3-7	3.58	4.02	3.53	4.07	3.57	4.03	3.80	3.80		
MW08SL	7.53	2	9-14	3.50	4.03	3.47	4.06	3.51	4.02	3.71	3.82		
MW09D*	7.24	2	31-41									4.69	2.55
MW10D*	7.25	2	31-41	4.20	3.05	4.18	3.07	4.30	2.95	4.42	2.83	4.50	2.75
MW11D*	6.43	2	31-41									4.13	2.30
PZ09S*	7.47	2	5-15	3.51	3.96	3.47	4.00	3.52	3.95	3.70	3.77		
PZ10S*	7.58	2	5-15	3.67	3.91	3.63	3.95	3.68	3.90	3.88	3.70		
PZ11S*	7.39	2	5-15	3.51	3.88	3.44	3.95	3.52	3.87	3.69	3.70		
RW1**	9.81	6	4-16	-	-	-	-	5.88	3.93	6.06	3.75		
RW2**	9.63	6	4-16	-	-	-	-	5.72	3.91	5.90	3.73		
RW3**	9.35	6	4-16	-	-	-	-	5.50	3.85	5.65	3.70		

\* 1/24/02 survey data (NGVD 88) for these wells were adjusted by +0.88 ft to match with pre-existing survey data (NGVD 29), based on a resurvey of selected previously surveyed wells.

\*\* Recovery well elevation data were obtained from well casing tags, not surveyed with monitoring wells.  
Screened interval data obtained from typical construction drawing.

TOC - Top of well casing.

DTW - Depth to water.

TABLE 3-4b  
WELL DEVELOPMENT WATER VOLUMES  
SITE 45 - MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA

Well	WL	TD	Water Column	Well Vol	Sand Pack Vol.	Total Vol.	5 Vols.	Amount Removed	Comments
PZ-09S	3.35	15.30	11.95	1.95	4.70	6.64	33.22	45	Clear Water. Removed enough vol.
PZ-10S	3.88	15.24	11.36	1.85	4.73	6.58	32.89	45	Turb > 10. Removed enough vol.
PZ-11S	3.2	15.12	11.92	1.94	4.70	6.64	33.21	60	Turb > 10. Removed enough vol.
PAI-45-MW04D	4.15	41.8	37.65	6.14	3.88	10.02	50.09	105	Stable Parameters. Removed enough vol.
PAI-45-MW05D	4.59	43.85	39.26	6.40	3.80	10.20	51.00	140	Stable Parameters. Removed enough vol.
PAI-45-MW09D	3.65	40.65	37.00	6.03	3.91	9.94	49.72	105	Turb > 10. Removed enough vol.
PAI-45-MW10D	3.62	41.6	37.98	6.19	3.86	10.05	50.27	120	Stable Parameters. Removed enough vol.
PAI-45-MW11D	12.4	41.77	29.37	4.79	4.29	9.07	45.36	5.5	Went dry twice. Pumped 5.5 gal in 2 hours

Water Column = TD - WL

Well Volume = Water Column x 0.163 x r<sup>2</sup> (radius equals 1 for 2" well)

Sand Pack Volume = ((0.163 x Length of Sand Pack x r<sup>2</sup>) - Well Vol.) x 30%

Length of Sand Pack obtained from Well constructions

radius equals 3 for 6" borehole below casing (actually 5 7/8")

assume 30% porosity

Total Volume = Well Vol. + Sand Pack Vol.

TABLE 3-5

SUMMARY OF GEOTECHNICAL PARAMETERS  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA

Sample Location	Sample Designation	Sample Depth	pH	Geotechnical Analysis	
				Sample Description <sup>1</sup>	Vertical Hydraulic Conductivity <sup>2</sup> (ft/day)
PAI-45-SB-01	PAI-45-SB-01-05				
	PAI-45-SB-01-14	12 -14	5.5	Silty Sand (SM)	
	PAI-45-SB-01-07	7			
	PAI-45-SB-01-23	20 -22.5			0.0014
PAI-45-SB-09	PAI-45-SB-09-14	12 -14	5.2	Sand with Silt (SP/SM)	
	PAI-45-SB-09-23	20 -22.5			0.00062
PAI-45-SB-10	PAI-45-SB-10-13	11 -13	7.3	Sand (SP)	
	PAI-45-SB-10-23	20 -22.5			0.011
PAI-45-SB-11	PAI-45-SB-11-10	8 -10	7.8	Sand (SP)	
	PAI-45-SB-11-23	20 -23			0.016
PAI-45-SB-12	PAI-45-SB-12-10	8 -10	6.4	Sand with Silt (SP/SM)	
	PAI-45-SB-12-21	18 -21			0.00085
PAI-45-SB-13	PAI-45-SB-13-10	8 -10	6.4	Sand with Silt (SP/SM)	
	PAI-45-SB-13-21	18 -21			0.00016
Geometric mean hydraulic conductivity					0.00166

1. Sample description and USCS symbol based on lab sieve analysis. See Appendix A5 for details.
2. Vertical hydraulic conductivity based on Flexible Wall Permeability Test. See Appendix A5 for details.

Sample depth is approximate feet below ground surface.

**TABLE 3-6**

**SLUG TEST RESULTS  
SITE 45 - MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA**

Well Number	K Value (ft/day)	Well Diameter (inches)	Screened Interval (ft below ground)
<b>Surficial Aquifer Wells</b>			
MW01SL	0.8	2	11.6 - 14
MW01SU	2	2	3-7
MW02SL	2	2	9-14
MW02SU	2	2	3-7
MW03SL	3	2	9-14
MW03SU	8	2	3-7
MW04SL	4	2	9-14
MW04SU	12	2	3-7
MW05SL	0.4	2	9-14
MW05SU	43	2	3-7
MW06SL	3	2	9-14
MW06SU	11	2	3-7
MW07SL	4	2	9-14
MW07SU	12.5	2	3-7
MW08SL	4	2	9-14
MW08SU	5	2	3-7
PZ09S	10	2	5-15
PZ10S	4	2	5-15
PZ11S	2	2	5-15
Geometric mean K, SU+SL wells =			4 ft/day
Geometric mean K, SU wells =			8 ft/day
Geometric mean K, SL wells =			2 ft/day
Geometric mean K, piezometers =			4 ft/day
<b>Deep Aquifer Wells</b>			
MW04D	0.8	2	31-41
MW05D	5	2	34-44
MW09D	1	2	31-41
MW10D	2	2	31-41
MW11D	0.01	2	31-41
Geometric mean K, deep wells =			1 ft/day

K - Hydraulic conductivity.

SU - Upper surficial aquifer wells.

SL - Lower surficial aquifer wells.

D - Deep aquifer wells.

PZ - Surficial aquifer piezometers (screened across both upper and lower surficial aquifer zones).

TABLE 3-7

RW3 PUMPING TEST RESULTS SUMMARY  
SITE 45, MCRD PARRIS ISLAND

Well	r, ft	T, ft <sup>2</sup> /day		S	
		Log-log analysis	Semi-log analysis	Log-log analysis	Semi-log analysis
MW06SL	14	63	163	0.0031	0.002
PZ11S	28	100	200	0.0018	0.0012
PZ10S	47.5	213	240	0.0016	0.0011
MW03SL	58	241	256	0.0011	0.001
MW07SU	63	214	233	0.0021	0.0015
MW07SL	66	228	259	0.0015	0.00097
MW08SU	125	235	214	0.0025	0.0063
MW08SL	129	251	206	0.0024	0.0062

r = Radial distance from pumping well RW3.

T = Transmissivity.

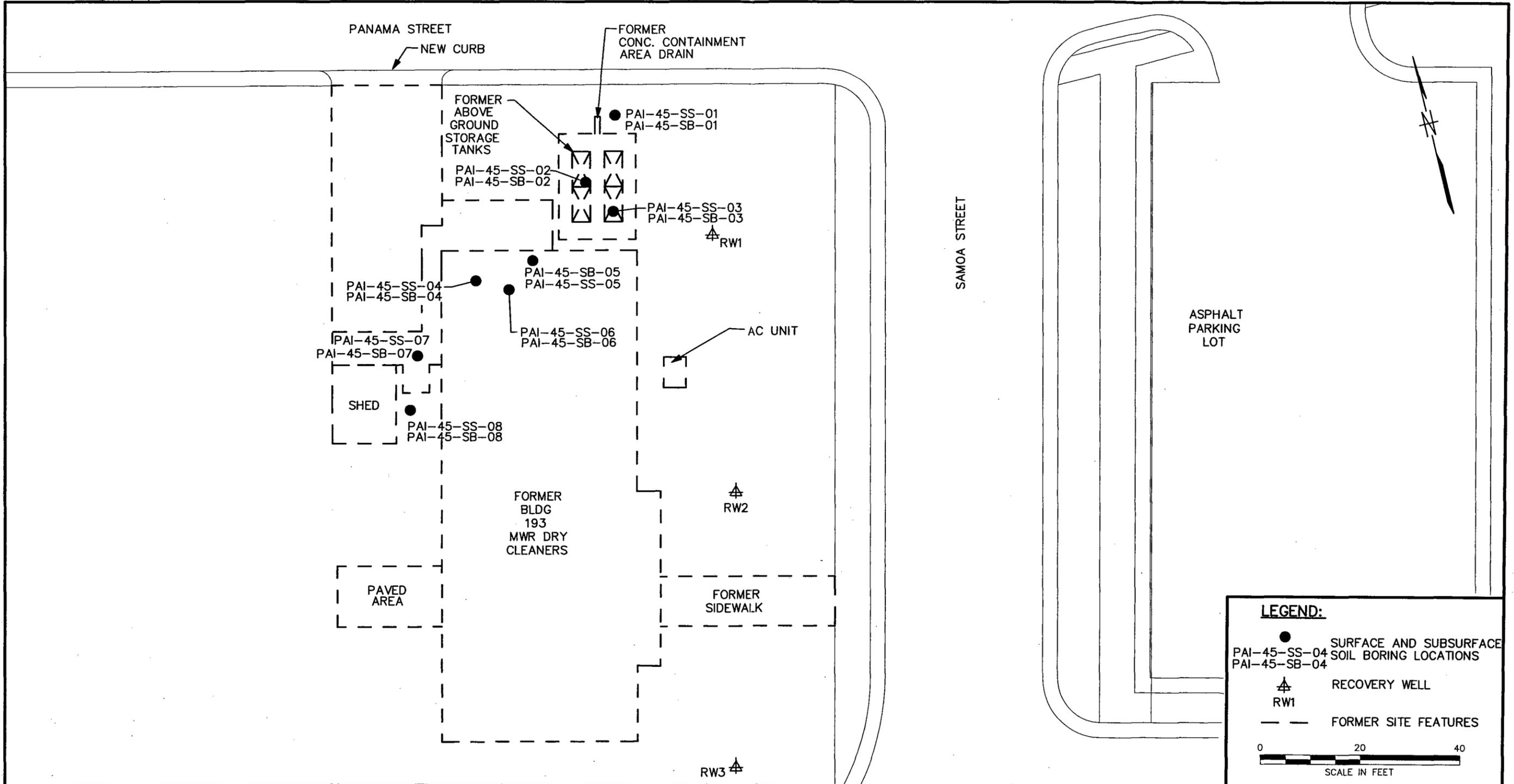
S = Storativity (dimensionless).

Pumping rate = 1.3 gpm = 250 ft<sup>3</sup>/day.

Semilog distance/drawdown transmissivity and storativity.

$$T = 166 \text{ ft}^2/\text{day}$$

$$S = 0.0037$$



**LEGEND:**

- SURFACE AND SUBSURFACE SOIL BORING LOCATIONS  
PAI-45-SS-04  
PAI-45-SB-04
- ▲ RECOVERY WELL  
RW1
- - - FORMER SITE FEATURES

0 20 40  
SCALE IN FEET

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

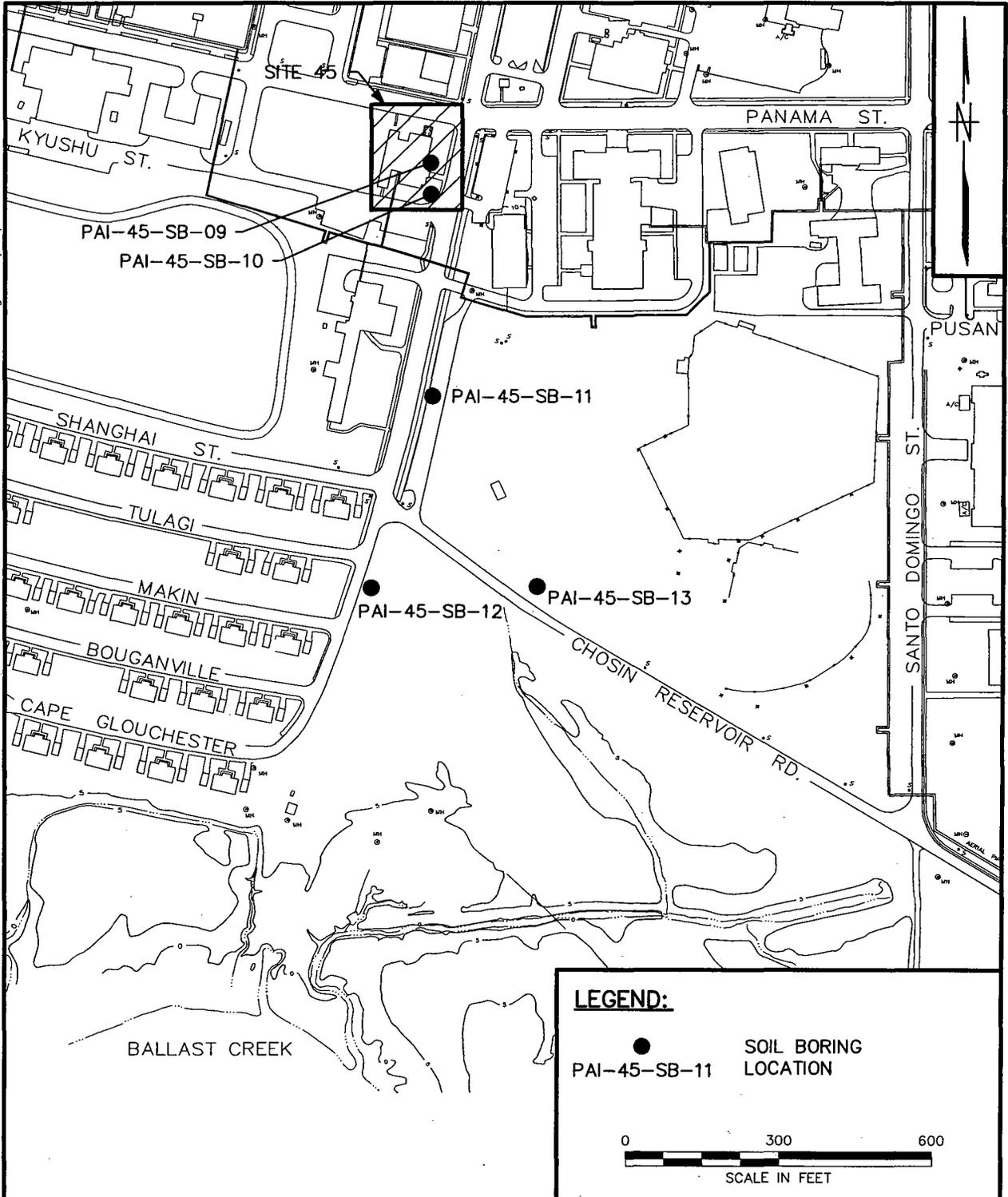
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 CHECKED BY DATE  
 COST/SCHED-AREA  
 SCALE AS NOTED



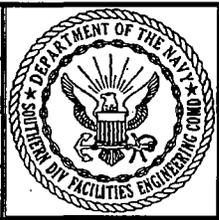
**SURFACE AND SUBSURFACE SOIL BORING LOCATIONS**  
**SITE 45 - MWR DRY CLEANING FACILITY**  
**MCRD PARRIS ISLAND**  
**PARRIS ISLAND, SOUTH CAROLINA**

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 3-1	REV. 0

ACAD:0502CMI13.dwg 02/15/02 HJB

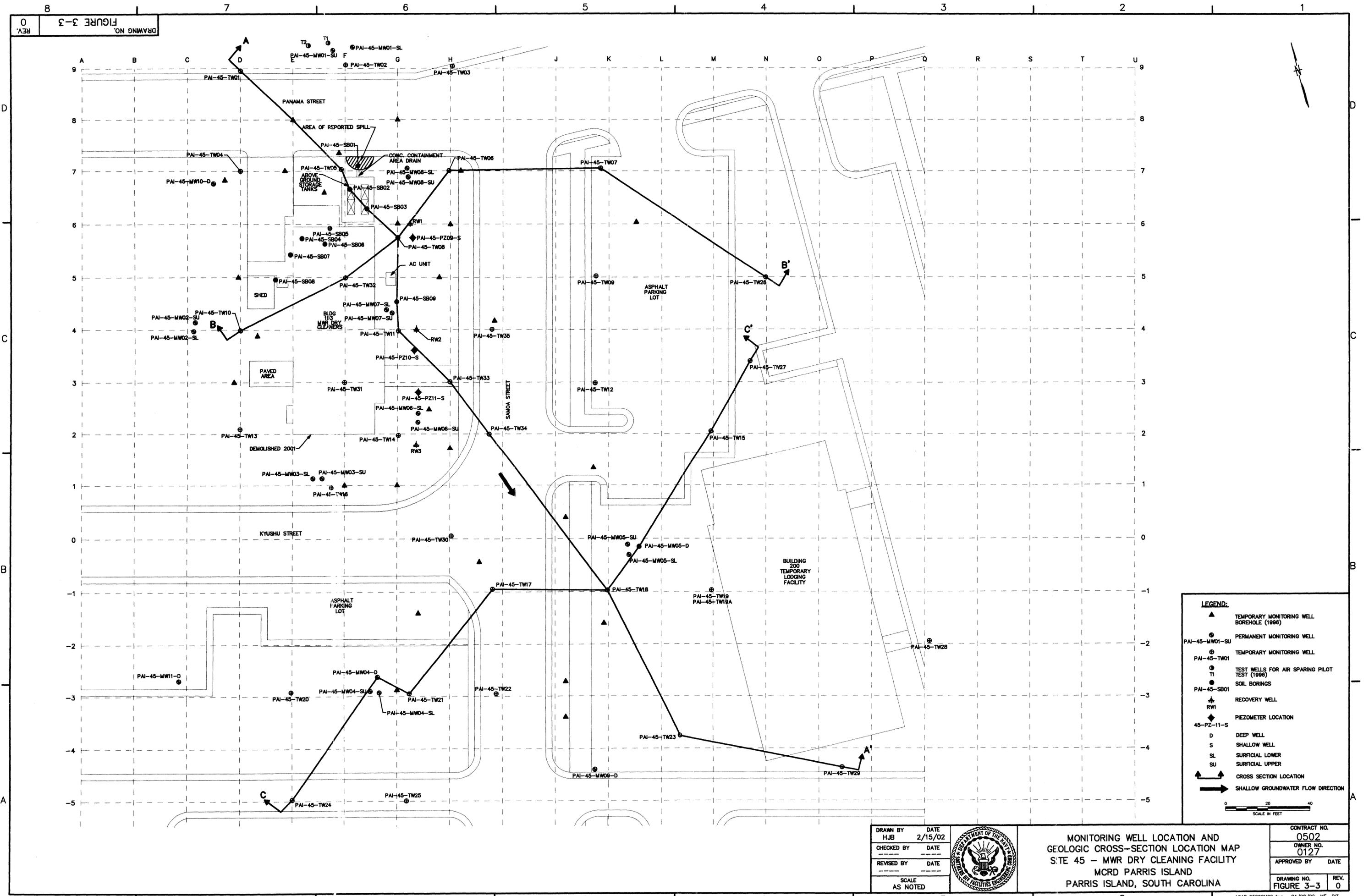


DRAWN BY HJB	DATE 2/15/02
CHECKED BY	DATE
COST/SCHED-AREA	
SCALE AS NOTED	



**SOIL BORING LOCATIONS SOUTH OF  
SITE 45  
SITE 45 - MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND  
PARRIS ISLAND, SOUTH CAROLINA**

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 3-2	REV. 0

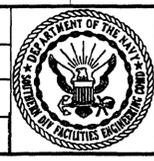


**LEGEND:**

- ▲ TEMPORARY MONITORING WELL BOREHOLE (1996)
- PAI-45-MW01-SU PERMANENT MONITORING WELL
- ⊙ PAI-45-TW01 TEMPORARY MONITORING WELL
- ⊙ TEST WELLS FOR AIR SPARING PILOT TEST (1996)
- ⊙ T1
- PAI-45-SB01 SOIL BORINGS
- ▲ RW1 RECOVERY WELL
- ◆ 45-PZ-11-S PIEZOMETER LOCATION
- D DEEP WELL
- S SHALLOW WELL
- SL SURFICIAL LOWER
- SU SURFICIAL UPPER
- ↔ CROSS SECTION LOCATION
- ➔ SHALLOW GROUNDWATER FLOW DIRECTION

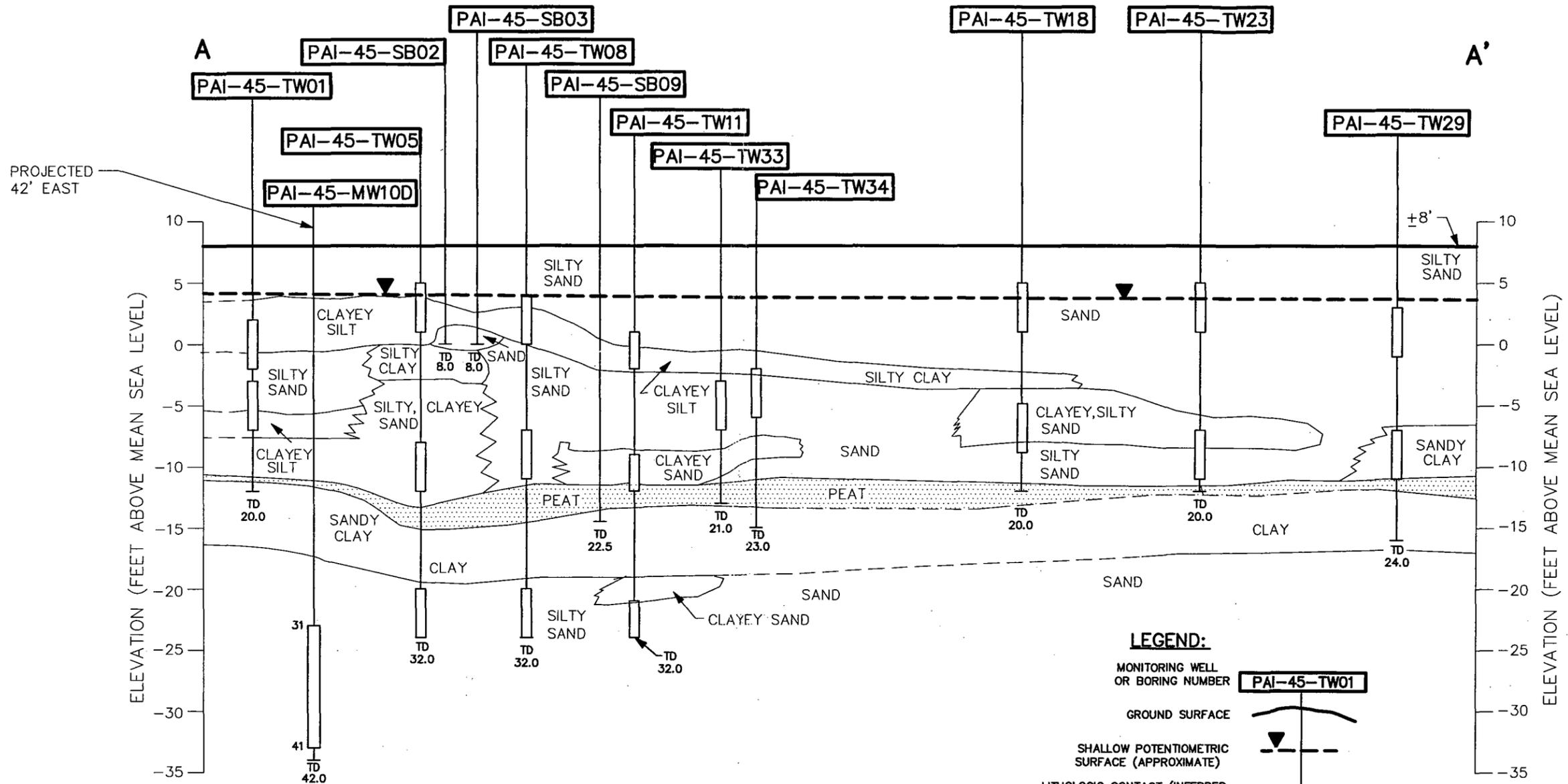
0 20 40  
SCALE IN FEET

DRAWN BY HJB	DATE 2/15/02
CHECKED BY	DATE
REVISED BY	DATE
SCALE AS NOTED	



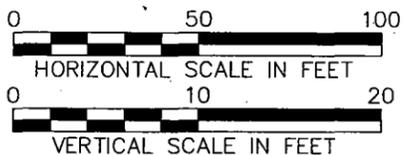
MONITORING WELL LOCATION AND  
 GEOLOGIC CROSS-SECTION LOCATION MAP  
 S:TE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
OWNER NO. 0127	
APPROVED BY	DATE
DRAWING NO. FIGURE 3-3	REV. 0



**LEGEND:**

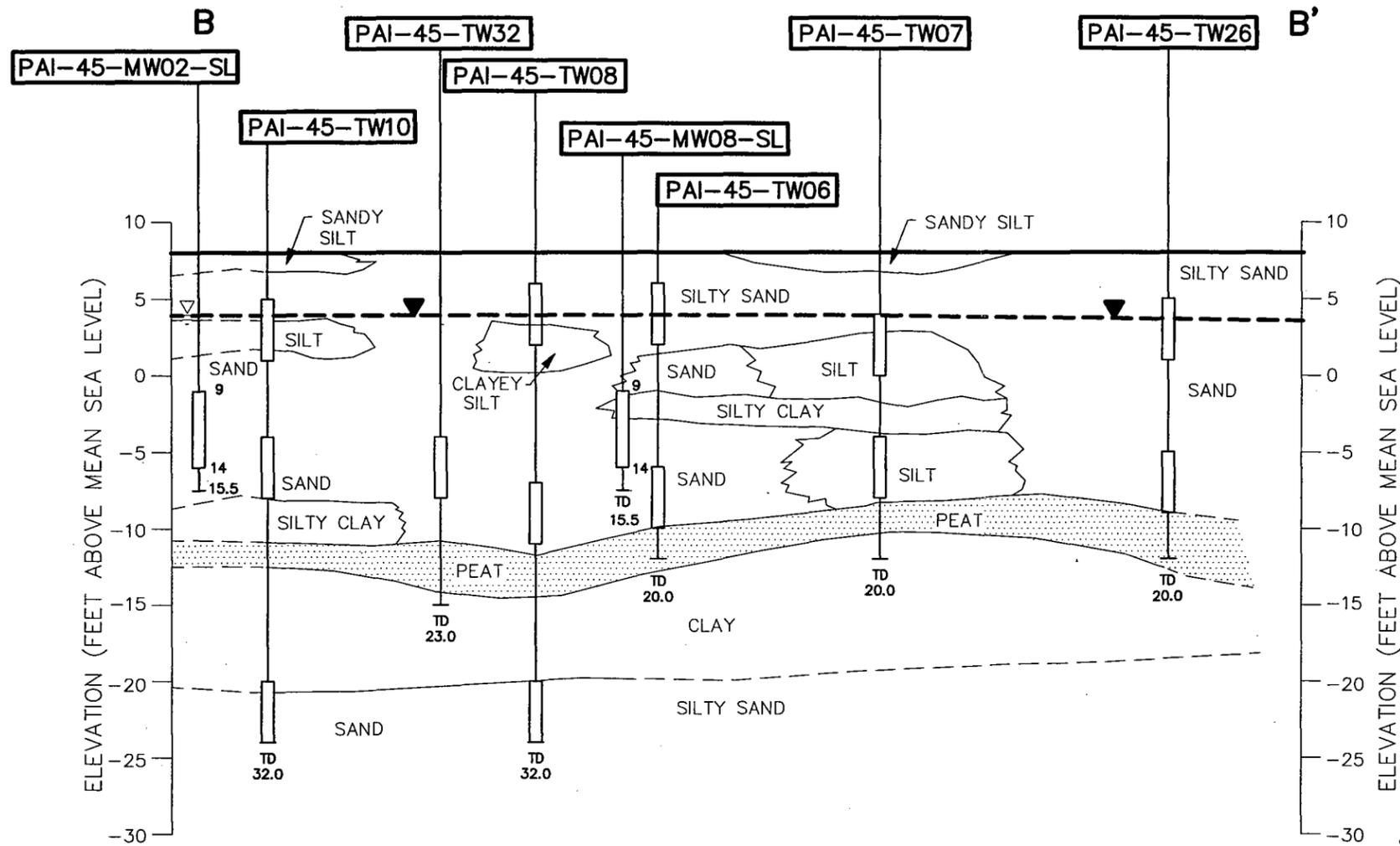
- MONITORING WELL OR BORING NUMBER: PAI-45-TW01
- GROUND SURFACE: [Symbol]
- SHALLOW POTENTIOMETRIC SURFACE (APPROXIMATE): [Symbol]
- LITHOLOGIC CONTACT (INFERRED BETWEEN BORINGS AND WHEN DASHED): [Symbol]
- SCREENED INTERVAL: [Symbol]
- TOTAL DEPTH OF WELL OR BORING (FT BGS): TD 20.0



**NOTES**

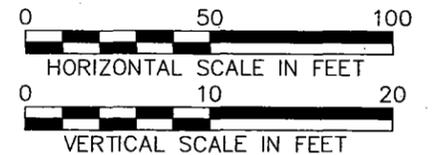
PAI-45-TW33 & PAI-45-TW34 LITHOLOGY WAS INTERPRETED USING MIPs (MEMBRANE INTERFACE TECHNOLOGY) IN CONJUNCTION WITH GEOLOGIST'S BORING LOGS.

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES	DRAWN BY	DATE		CROSS SECTION A-A' SITE 45 MCRD PARRIS ISLAND PARRIS ISLAND, SOUTH CAROLINA	CONTRACT NO. 0502	
							DM	2/18/02			APPROVED BY	DATE
											APPROVED BY	DATE
											DRAWING NO. 3-4	REV. 0



**LEGEND:**

- MONITORING WELL OR BORING NUMBER
- GROUND SURFACE
- SHALLOW POTENTIOMETRIC SURFACE (APPROXIMATE)
- LITHOLOGIC CONTACT (INFERRED BETWEEN BORINGS AND WHEN DASHED)
- SCREENED INTERVAL
- TOTAL DEPTH OF WELL OR BORING (FT BGS)



**NOTE:**

PAI-45-TW32'S LITHOLOGY WAS INTERPRETED USING MIPs (MEMBRANE INTERFACE PROBE) TECHNOLOGY

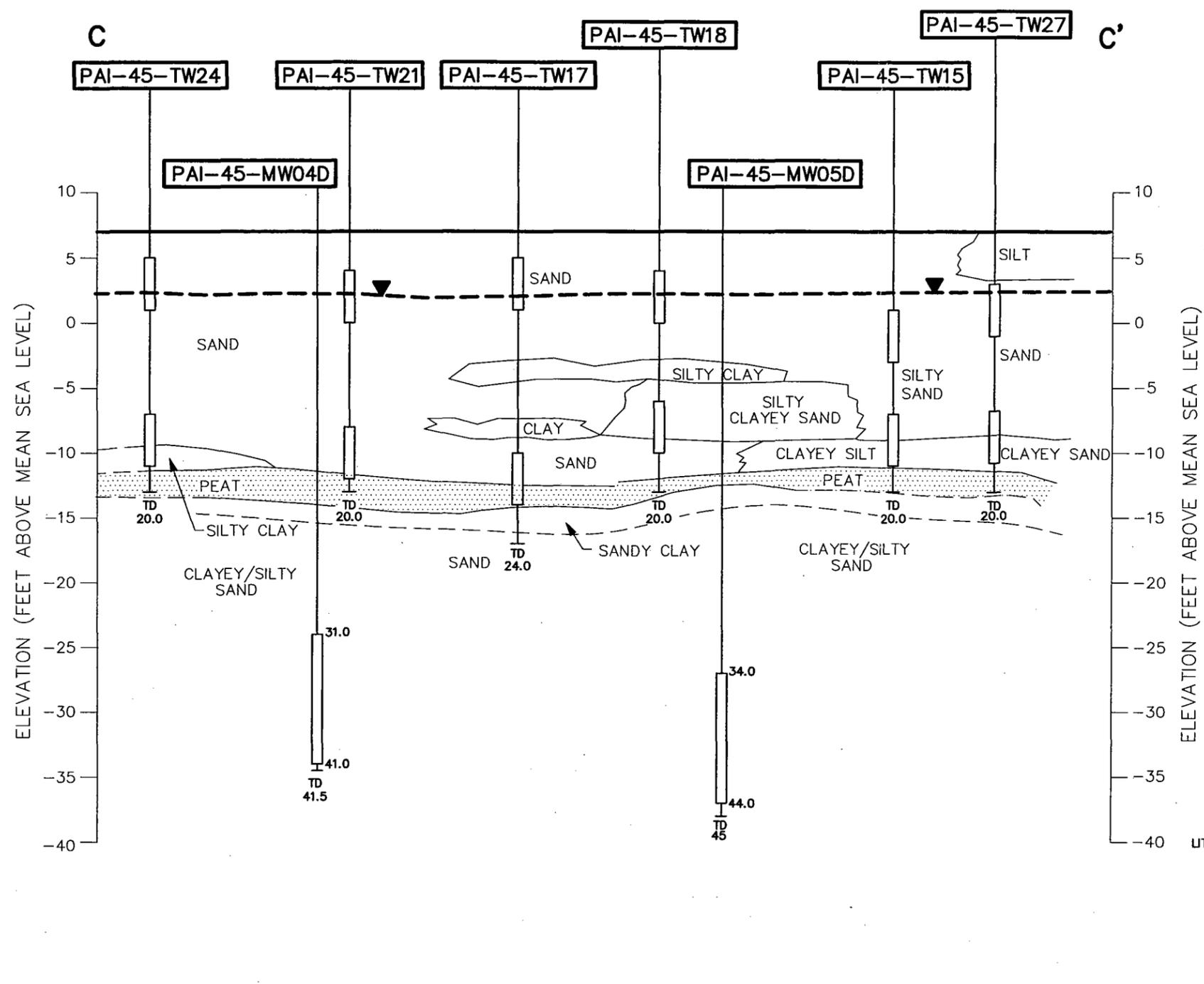
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY	DATE
DM	2/18/02
CHECKED BY	DATE
COST/SCHED-AREA	
SCALE	
AS NOTED	



**CROSS SECTION B-B'**  
**SITE 45**  
**MCRD PARRIS ISLAND**  
**PARRIS ISLAND, SOUTH CAROLINA**

CONTRACT NO.	
0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO.	REV.
FIGURE 3-5	0



**LEGEND:**

MONITORING WELL OR BORING NUMBER

PAI-45-TW24

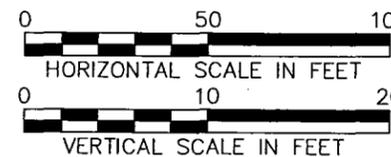
GROUND SURFACE

SHALLOW POTENTIOMETRIC SURFACE (APPROXIMATE)

LITHOLOGIC CONTACT (INFERRED BETWEEN BORINGS AND WHEN DASHED)

SCREENED INTERVAL

TOTAL DEPTH OF WELL OR BORING (FT BGS)



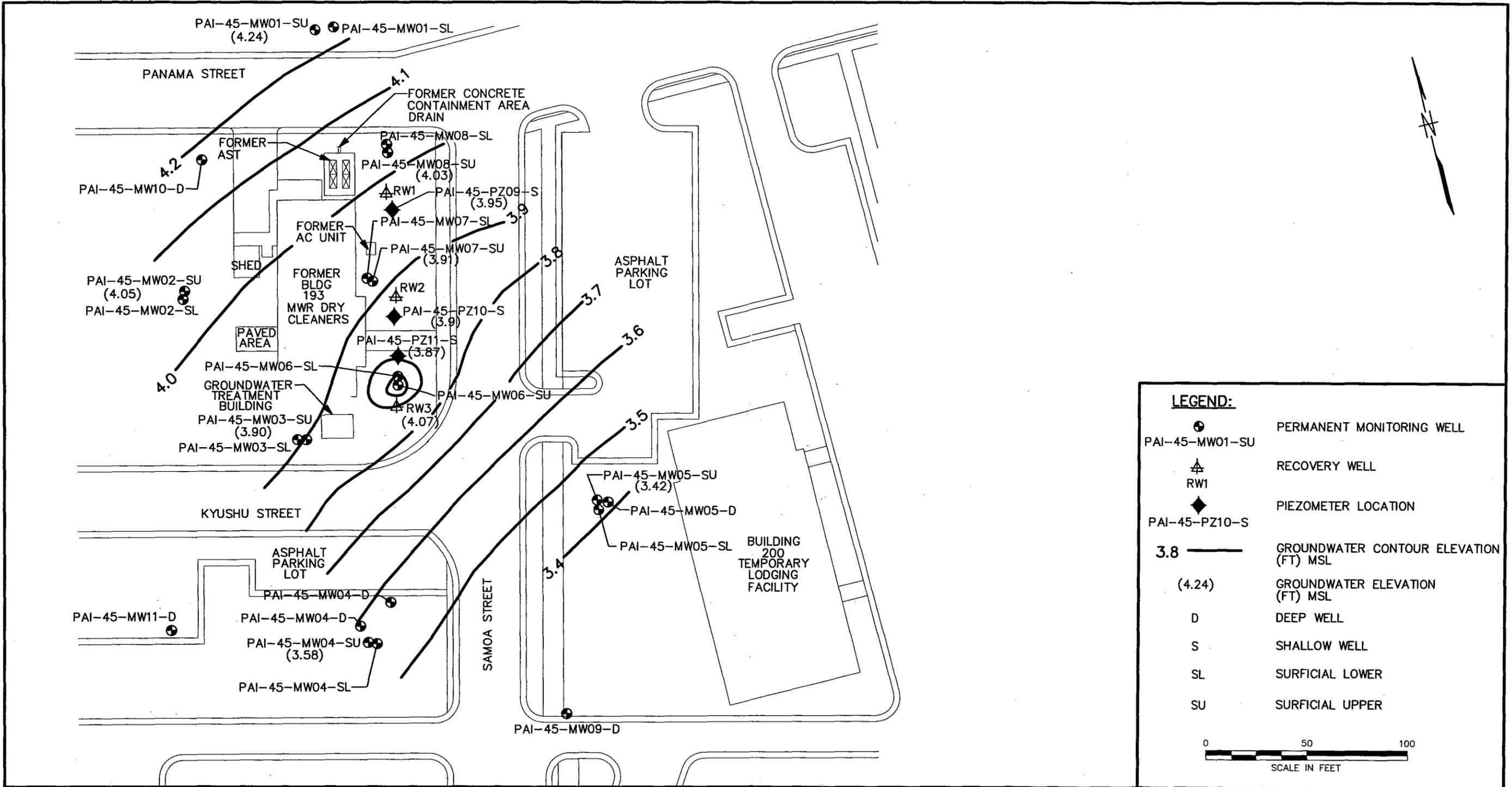
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY DM DATE 2/18/02  
 CHECKED BY DATE  
 COST/SCHED-AREA  
 SCALE AS NOTED



CROSS SECTION C-C'  
 SITE 45  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 3-6	REV. 0



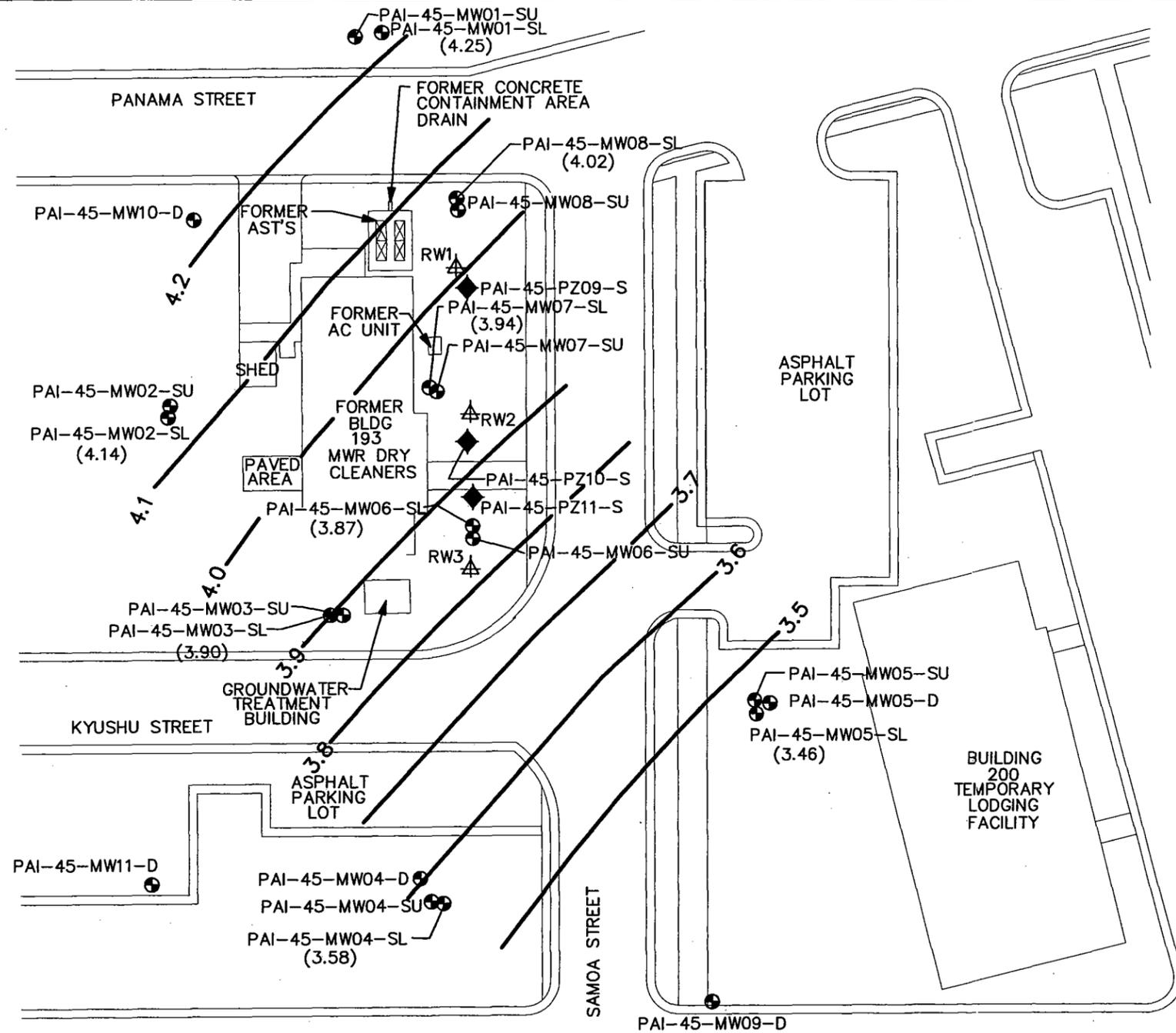
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DRAWN BY HJB DATE 2/1/5/02  
 CHECKED BY DATE  
 COST/SCHED-AREA  
 SCALE AS NOTED



UPPER SURFICIAL AQUIFER  
 GROUNDWATER FLOW MAP  
 NOVEMBER 3, 2001  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 3-7	REV. 0



**LEGEND:**

- PERMANENT MONITORING WELL
- PAI-45-MW01-SL
- RECOVERY WELL
- RW1
- PIEZOMETER LOCATION
- PAI-45-PZ10-S
- GROUNDWATER CONTOUR ELEVATION (FT) MSL
- GROUNDWATER ELEVATION (FT) MSL
- DEEP WELL
- SHALLOW WELL
- SURFICIAL LOWER
- SURFICIAL UPPER

0 50 100  
SCALE IN FEET

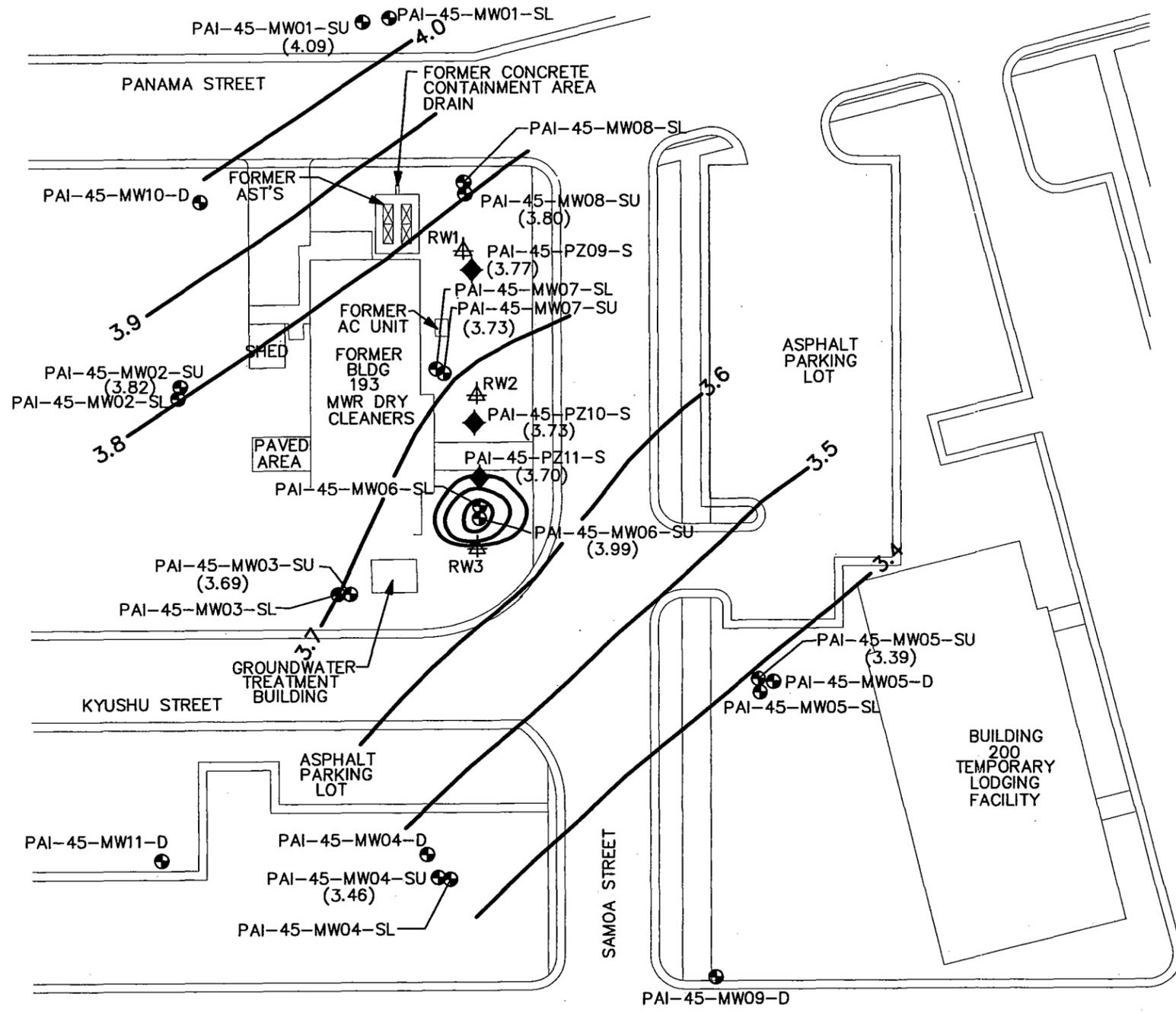
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY	DATE
HJB	2/15/02
CHECKED BY	DATE
COST/SCHED-AREA	
SCALE	
AS NOTED	



LOWER SURFICIAL AQUIFER  
GROUNDWATER FLOW MAP  
NOVEMBER 3, 2001  
SITE 45 - MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND  
PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 3-8	REV. 0



**LEGEND:**

- PERMANENT MONITORING WELL
- PAI-45-MW01-SU
- RECOVERY WELL
- RW1
- PIEZOMETER LOCATION
- PAI-45-PZ10-S
- 3.4 GROUNDWATER CONTOUR ELEVATION (FT) MSL
- (4.09) GROUNDWATER ELEVATION (FT) MSL
- D DEEP WELL
- S SHALLOW WELL
- SL SURFICIAL LOWER
- SU SURFICIAL UPPER

0 50 100  
SCALE IN FEET

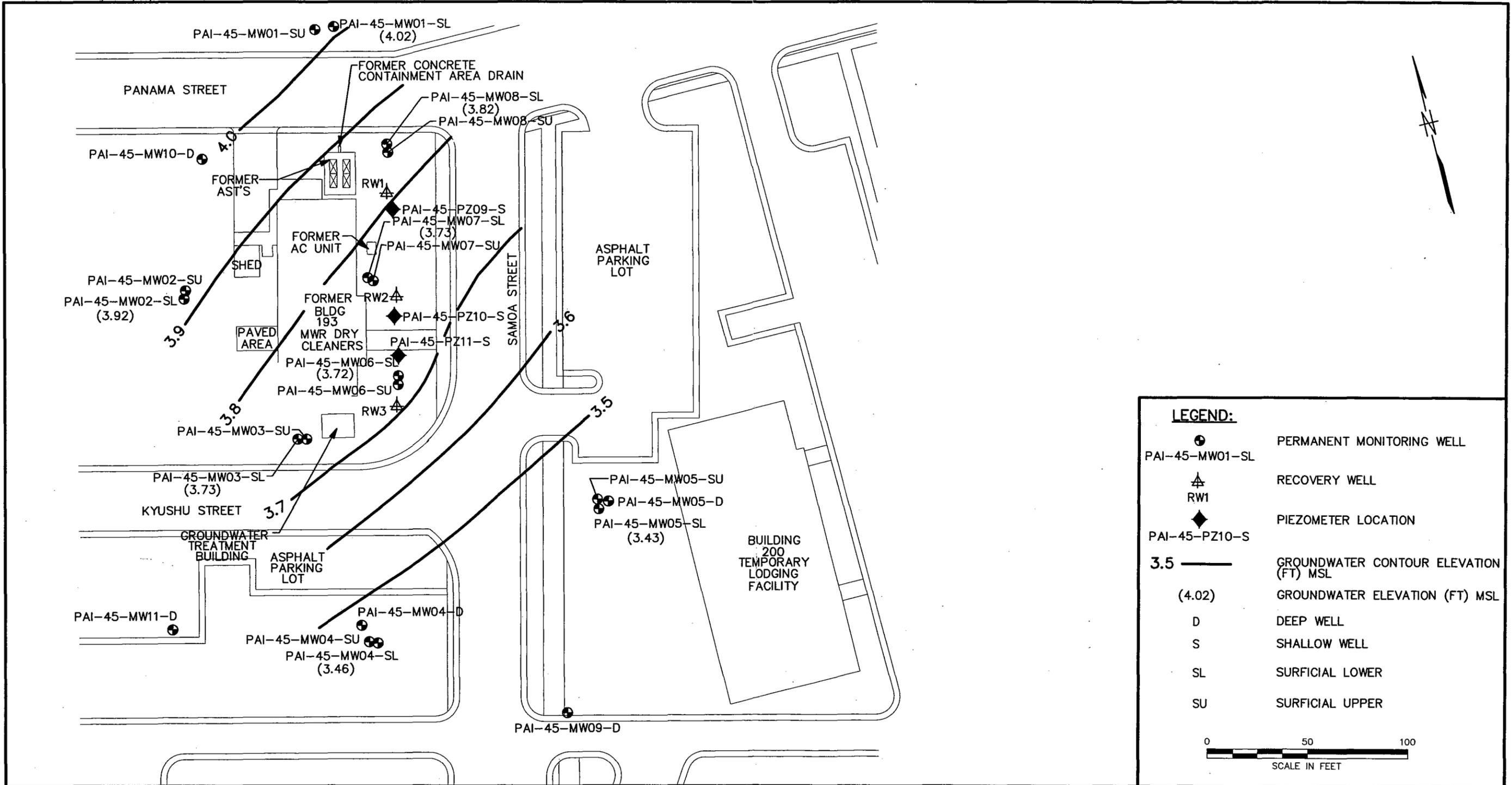
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJB DATE 2/18/02  
 CHECKED BY DATE  
 COST/SCHED-AREA  
 SCALE AS NOTED



UPPER SURFICIAL AQUIFER  
 GROUNDWATER FLOW MAP  
 NOVEMBER 12, 2001  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 3-9	REV. 0



**LEGEND:**

- PERMANENT MONITORING WELL
- RECOVERY WELL
- PIEZOMETER LOCATION
- 3.5 ——— GROUNDWATER CONTOUR ELEVATION (FT) MSL
- (4.02) GROUNDWATER ELEVATION (FT) MSL
- D DEEP WELL
- S SHALLOW WELL
- SL SURFICIAL LOWER
- SU SURFICIAL UPPER

0 50 100  
SCALE IN FEET

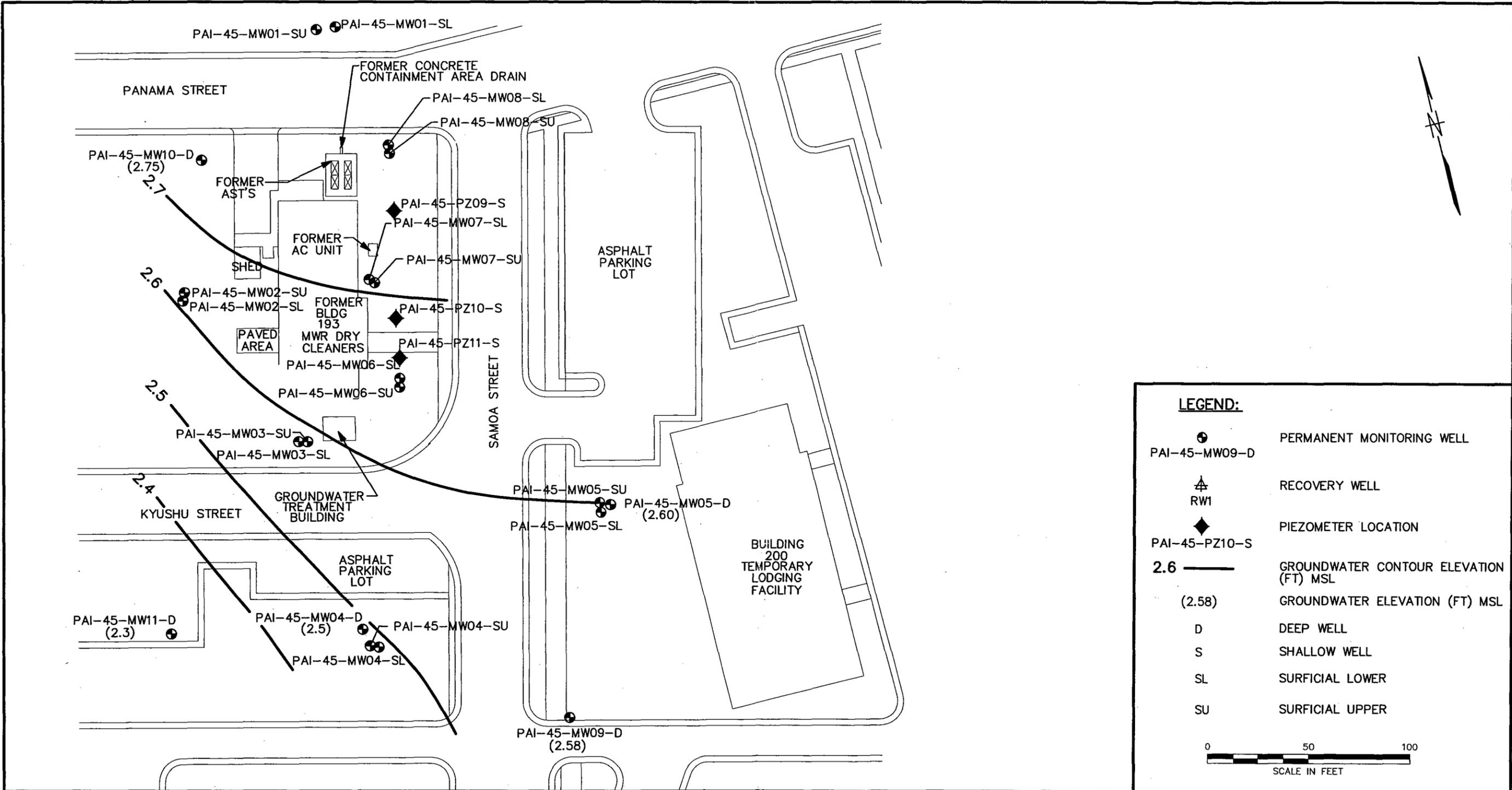
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJB DATE 2/18/02  
 CHECKED BY DATE  
 COST/SCHED-AREA  
 SCALE AS NOTED



LOWER SURFICIAL AQUIFER  
 GROUNDWATER FLOW MAP  
 NOVEMBER 12, 2001  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 3-10	REV. 0



NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJB DATE 2/18/02  
 CHECKED BY DATE  
 COST/SCHED-AREA  
 SCALE AS NOTED



DEEP AQUIFER  
 GROUNDWATER FLOW MAP  
 DECEMBER 10, 2001  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 3-11	REV. 0

## 4.0 NATURE AND EXTENT OF CONTAMINATION

This section presents the results of sampling and laboratory analysis of surface, subsurface, and groundwater samples collected as part of the 2001 field investigation at Site/SWMU 45.

Based on the site history, three locations were identified as possible sources of solvent contamination in the soils and groundwater. One location is the secondary containment drain for the raw PCE aboveground storage tanks (located north of the tanks). A documented spill of PCE and an interim soil cleanup occurred at this location in 1994. The second location is in the rear (west end) of the building. Waste solvents may have been handled or accumulated in this area. No documented leaks or spills occurred in this location. The third location is within the northwestern corner of the former building (No. 193), where the dry cleaning process was conducted. A concrete floor that would serve as secondary containment was noted in this area prior to building demolition. No documented leaks or spills occurred in this area.

In March through December 2001, surface soil, subsurface soil, and groundwater samples were collected as part of the Site 45 field investigation. The samples were analyzed for site-related contamination VOCs, SVOCs, metals, and geotechnical parameters. Sample locations and VOC, SVOC, and metal results are discussed below. Geotechnical parameters are discussed in Section 3.0.

The tables at the end of this section present the frequency of detection, the range of detection, the range of nondetects, the location of maximum concentration, the average of positive results, and the average of all results (using one-half the detection limit for nondetected results) for each chemical detected in soils and groundwater. In addition, since surface soil samples were analyzed for metals, the site-specific background metals concentrations are also presented.

Analytical results are presented graphically in a series of figures. For clarity, the tag maps for soils present only those chemicals and results that exceed a screening criterion, including EPA Region 9 Preliminary Remediation Goals (PRGs) (residential), EPA soil screening levels for soil to air, and EPA soil screening levels for soil to groundwater. This step does represent a screening of soil data to be evaluated in the human health risk assessment (Section 6.0).

The tag map for groundwater presents all positive detections of VOCs. The groundwater results are also illustrated in a series of figures that present chemical isoconcentration contours in plan and cross-section views for the four primary site contaminants (PCE, TCE, DCE, and vinyl chloride).

A complete analytical database for the surface soil, subsurface soil, and groundwater sample results are provided in Appendix C.

#### 4.1 SURFACE SOIL

Eight surface soil samples were collected and analyzed for VOCs, SVOCs, and metals (see Figure 4-1). Three samples were collected in the vicinity of the former PCE storage tanks (PAI-45-SS-01, 02, 03). Two samples were collected west of the building, where waste solvents were accumulated (PAI-45-SS-07, 08). Three samples were collected in the northwestern corner of former Building 193 (MWR Dry Cleaners) in an area where dry cleaning units were located (PAI-45-SS-04, 05, 06). These data were validated (see Appendix D) and used in the human health risk assessment for Site 45 (see Section 6.0).

Seven chlorinated VOCs (1,1,1-trichloroethane, 1,2-dichlorobenzene, dichlorodifluoromethane, PCE, trans-1,2-DCE, TCE and cis-DCE) were detected in the surface soil samples at concentrations ranging from 2 µg/kg (1,2-DCE, 1,2-dichlorobenzene, and dichlorodifluoromethane) to 7,500 µg/kg (PCE) (see Table 4-1 and Figure 4-1).

PCE and TCE were detected the most frequently (eight of eight samples and seven of eight samples, respectively). Maximum detected PCE and TCE concentrations were 7,500 µg/kg and 320 µg/kg, respectively. Trans-1,2-DCE was detected in two out of eight surface soil samples at a maximum concentration of 50 µg/kg. The stereoisomer cis-DCE was detected in five of eight samples at a maximum concentration of 730 µg/kg. 1,1,1-Trichloroethane, 1,2-dichlorobenzene, and dichlorodifluoromethane were detected at a frequency of one of eight samples, at concentrations of 4 µg/kg, 2 µg/kg, and 4 µg/kg, respectively.

Eighteen SVOCs were detected in the surface soils at Site 45. The carcinogenic polynuclear aromatic hydrocarbons (PAHs) benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, benzo(k)fluoranthene, chrysene, and indeno(1,2,3-cd)pyrene were detected at concentrations ranging from 20 µg/kg [dibenzo(a,h)anthracene] to 180 µg/kg [benzo(b)fluoranthene]. Of the detected carcinogenic PAHs, benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, and chrysene were detected most frequently (seven of eight samples); however, only benzo(a)pyrene (maximum concentration of 130 µg/kg) was found to exceed the 62 µg/kg screening level for the protection of human health.

The non-carcinogenic PAHs acenaphthene (one of eight samples), anthracene (three of eight samples), benzo(g,h,i)perylene (six of eight samples), fluorene (one of eight samples), fluoranthene (seven of eight samples), naphthalene (one of eight samples), phenanthrene (seven of eight samples) and pyrene (seven

of eight samples) were detected at concentrations ranging from 18 µg/kg (fluorene) to 300 µg/kg (fluoranthene). None of these compounds were found to exceed any of the applicable screening criteria.

Butyl benzyl phthalate (five of eight samples) and diethyl phthalate (one of eight samples) were detected at maximum concentrations of 900 µg/kg and 19 µg/kg, respectively. In addition, carbazole was detected in three of eight samples at a maximum concentration of 44 µg/kg.

Seventeen inorganics were identified in the surface soil samples. Except for cobalt, all 17 of the inorganic analytes were detected in all eight of the surface soil samples. Cobalt was detected in five of eight samples at a maximum concentration of 0.8 mg/kg.

The following inorganics (and maximum concentrations) were detected in the surface soil samples at concentrations that exceed site background: aluminum (9,840 mg/kg), barium (28.6 mg/kg), chromium (9.1 mg/kg), calcium (3,720 mg/kg), cobalt (0.8 mg/kg), copper (48.1 mg/kg), potassium (315 mg/kg), nickel (3.2 mg/kg), lead (50.2 mg/kg), and zinc (338 mg/kg). As detailed in Section 6.0, these compounds were not found to exceed any of the applicable screening criteria.

Iron, magnesium, manganese, mercury, sodium, and vanadium were also detected in the surface soil samples but at concentrations that do not exceed background values. None of the above-mentioned inorganics exceed the applicable screening criteria.

Arsenic was the only inorganic constituent found to exceed a screening criterion (EPA Region 9 residential PRG of 0.39 mg/kg). Arsenic was detected above the screening criteria at all sample locations at concentrations ranging from 0.94 mg/kg to of 2.1 mg/kg. The maximum concentration of arsenic (2.1 mg/kg) at sample location PAI-45-SS-01 only marginally exceeds its background value of 1.44 mg/kg.

## **4.2 SUBSURFACE SOIL**

Eight subsurface soil samples and two field duplicates were collected from eight soil boring locations at the site (see Figure 4-2). These locations correspond to the surface soil sample locations, discussed in Section 4.1. The samples were collected at depths ranging from 2 to 5 feet bgs and were biased toward depths in which there was evidence of contamination (i.e., staining and elevated PID readings). The samples were analyzed for VOCs and SVOCs. The samples were not analyzed for metals, pesticides, or PCBs. As described in the Site 45 Work Plan, the soil sampling approach was designed based on knowledge of the site operations and history. The site was only investigated because of the historic dry cleaning operations and reported/suspected historic spills. As such, site contaminants are limited to solvents and potentially semi-volatile organic compounds that may have been absorbed during the

solvent cleaning process. Metals, pesticides, and PCBs would not be present as site-related contamination and therefore were not evaluated. The sample results were validated (see Appendix D) and used in the human health risk assessment for Site 45 (see Section 6.0).

The subsurface soil samples from the boring, as well as all the borings installed within the area of the site, were evaluated in the field for the possible presence of pure solvent using an ultraviolet light technique. This field evaluation indicated the possible presence of trace amounts of non-aqueous phase product in isolated areas. However, the presence was not positively identified and no further conclusions were developed (see Appendix A).

The analysis of subsurface soil samples for site related contamination detected a total of 17 VOCs (see Table 4-2 and Figure 4-2). Twelve VOCs were halogenated hydrocarbons (1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,1-dichloroethene, 1,2-dichlorobenzene, bromomethane, cis-1,2-DCE, PCE, trans-1,2-DCE, TCE, and vinyl chloride) ranging in concentration from of 20 µg/kg (trans-1,2-DCE) to 8,000,000 µg/kg (PCE). Four aromatic hydrocarbons [ethylbenzene, isopropylbenzene, toluene and total xylenes (consisting of the ortho-, meta- and para-substituted isomers)] were present at concentrations ranging from 22 µg/kg (isopropylbenzene) to 1,500 µg/kg (ethylbenzene). One aliphatic hydrocarbon (methyl ethyl ketone) was detected in one sample at a concentration of 140 µg/kg.

The most frequently detected VOCs were PCE (seven of eight samples) and two of its degradation products, TCE (seven of eight samples) and cis-1,2-DCE (seven of eight samples). These chemicals accounted for the most significant contamination in the surface and subsurface soils at Site 45. As shown in Table 4-2 and Figure 4-2, subsurface PCE concentrations range from 1,900 µg/kg to 8,000,000 µg/kg. The maximum detection of PCE occurred in the area of the 1994 solvent spill. Subsurface TCE concentrations ranged from 65 µg/kg to 120,000 µg/kg. Subsurface cis-1,2-DCE concentrations ranged from 470 µg/kg to 40,000 µg/kg. Trans-1,2-DCE (also a degradation product of PCE) was identified at slightly fewer sample locations (six of eight samples) at concentrations ranging from 20 µg/kg to 810 µg/kg.

1,1,1-Trichloroethane (210 µg/kg), 1,1-dichloroethene (43 µg/kg), 1,2-dichlorobenzene (260 µg/kg), 1,1,2-trichloroethane (210 µg/kg), chlorobenzene (2,000 µg/kg), vinyl chloride (30 µg/kg), 1,1-dichloroethane (34 µg/kg), and bromomethane (90 µg/kg) were detected in one to three of the eight samples. The four aromatic hydrocarbons (ethylbenzene, isopropyl benzene, toluene, and total xylenes) were detected in four of eight samples at concentrations ranging from 22 µg/kg to 1500 µg/kg.

Twenty-one SVOCs were detected in the subsurface soils at Site 45. Eight carcinogenic PAHs [benzo(a)anthracene (three of eight samples), benzo(a)pyrene (two of eight samples),

benzo(b)fluoranthene (three of eight samples), benzo(k)fluoranthene (two of eight samples), carbazole (one of eight samples), chrysene (two of eight samples), dibenzo(a,h)anthracene (one of eight samples) and indeno(1,2,3,-cd)pyrene (two of eight samples)] were detected at concentrations ranging from 17 µg/kg to 7,200 µg/kg [benzo(a)anthracene]. Benzo(a)anthracene (7,200 µg/kg) and benzo(a)pyrene (5,800 µg/kg) were present at concentrations that exceed Region 9 residential PRGs and (SSLs). In addition, benzo(b)fluoranthene (7,100 µg/kg), dibenzo(a,h)anthracene (780 µg/kg), and indeno(1,2,3-cd)pyrene (3,700 µg/kg) were found in sample PAI-45-SB-07-04-D at concentrations that exceed Region 9 PRGs.

Nine noncarcinogenic PAHs [acenaphthene (one of eight samples), acenaphthylene (one of eight samples), anthracene (one of eight samples), benzo(g,h,i)perylene (two of eight samples), fluoranthene (three of eight samples), fluorene, (two of eight samples), naphthalene (three of eight samples), phenanthrene (two of eight samples) and pyrene (two of eight samples)] were detected at concentrations ranging from 14 µg/kg to 16,000 µg/kg (fluoranthene). However, these concentrations were not found to exceed any of the applicable screening criteria.

Dibenzofuran (360 µg/kg), di-N-octyl phthalate (290 µg/kg), and bis(2-ethylhexyl)phthalate (5,500 µg/kg) were detected once but at concentrations below applicable screening criteria. 2-Methylnaphthalene was detected in three of eight samples at a maximum concentration of 820 µg/kg but does not exceed any of the applicable screening criteria.

As presented in Figure 4-2, these SVOC exceedances of the human health screening criteria were found at only one subsurface soil boring location (PAI-45-SB-07) at Site 45. This is the location where waste solvents may have been handled.

### **4.3 GROUNDWATER**

As detailed in Section 3.4, the water table surface of the surficial aquifer is located at approximately 4 to 5 feet bgs and extends to a depth of approximately 18 to 22 feet bgs. Surficial groundwater flow is to the southeast. The deep aquifer starts at approximately 27 feet bgs and extends to at least 45 feet bgs. Deep groundwater flow is to the south-southwest. A peat/silty clay layer is located between these two aquifers and functions locally as a confining unit. This lithologic information is presented as background to the isoconcentration contour maps presented in this section.

The groundwater investigation consisted of two phases. The first phase was conducted to delineate the extent of VOC-contaminated groundwater and included collecting and analyzing approximately 83 samples. This phase used temporary monitoring well sample collection techniques and select testing of existing permanent monitoring wells coupled with quick-turn-around analysis. These screening data

were not validated. The second phase of the groundwater investigation was conducted to document the findings of the first phase. This phase consisted of testing surficial and deep groundwater from permanent monitoring wells. The second-phase data were validated and used in the human health risk assessment (Section 6.0).

In phase I, PCE, TCE, cis-1,2-DCE, and vinyl chloride were all detected at concentrations greater than 1,000 µg/l. These chemicals are presented graphically on isoconcentration contour maps in plan and cross-section on Figures 4-3 through 4-22. Note that in subsequent October 2001 sampling to support the natural attenuation sampling, elevated concentrations of some VOCs were detected downgradient of the "non-detect" contour depicting the RI/RFI sampling results. All VOCs detected in Phase I are presented in Figure 4-23. The location of cross-sections A-A', B-B', and C-C' are presented on Figure 3-3. Cross section A-A' runs from the source area to the southeast, approximately the centerline of the groundwater contaminant plume. Cross sections B-B' and C-C' run perpendicular to groundwater flow, near the source area and the downgradient edge of the plume, respectively.

In Phase I, and as illustrated on Figures 4-3 through 4-23, the highest concentrations of VOCs were detected in the surficial aquifer near the former above-ground storage tanks and within the northern portion of the former Building No. 193 (MWR Dry Cleaning Facility). Maximum detected concentrations in temporary wells were PCE at 9,600 µg/l, TCE at 13,000 µg/l, DCE at 14,000 µg/l, and vinyl chloride at 3,100 µg/l. For comparison, U.S. EPA maximum contaminant levels (MCLs) are 5, 5, 70, and 2 µg/l, respectively.

Phase I determined that the horizontal extents of PCE, TCE, cis-1,2-DCE, and vinyl chloride contamination are approximately limited to the north by Panama Street, to the south by Kyusnu Street, to the west by the former location of Building No. 193, and to the east by Building 200 (Temporary Lodging Facility). The individual contaminants follow a similar distribution in the surficial aquifer; the highest concentrations were detected near suspected source areas and then generally decreased radially outward, following the groundwater flow. The groundwater plots indicate that there may be two source areas for the VOC contamination - the former aboveground storage tanks area, and from within the footprint of Building 193, the Former MWR Dry Cleaners Building, see Figure 3-1.

In Phase I, in addition to these four chlorinated solvents, 1,1-dichloroethane (26 µg/l), 1,1-DCE (4 µg/l), trans-1,2-DCE (140 µg/l), chlorodibromomethane (4 µg/l), ethylbenzene (33 µg/l), acetone (2 µg/l), 2-hexanone (18 µg/l), isopropylbenzene (20 µg/l), toluene (60 µg/l), and total xylenes (250 µg/l) were detected in the surficial aquifer.

In Phase I, the vertical extent of the chlorinated VOC contamination was found to be limited to approximately 19 feet bgs, where a clay unit confines the surficial from the underlying deep. The clay unit is described as a confining unit based on noted physical properties and the observation that contaminant concentrations decrease by several orders of magnitude over a short distance of only a few feet. In general, confining units restrict but do not prevent all migration. Therefore, the detection of some chemicals in the lower aquifer is not unexpected. Although several detections of chlorinated VOCs were noted in the deep aquifer, none of the detected concentrations exceed U.S. EPA MCLs. Benzene (15 µg/L) was detected in the deep groundwater at one temporary well location (PAI-45-TW-19) at a concentration that exceeds the MCL of 5 µg/L. Benzene was not detected at any other well location at Site 45.

Phase II analytical data for groundwater samples collected from five surficial and five deep permanent groundwater monitoring wells are presented in Tables 4-3 and 4-4, respectively. In the surficial permanent wells, TCE, PCE, and cis-1,2-DCE were each detected in four of five samples at maximum concentrations of 10,000, 10,000, and 3,400 µg/L, respectively. The chemical concentrations and distributions were similar to that observed in the temporary monitoring well program. Note that in the natural attenuation investigations, elevated concentrations of some VOCs were detected downgradient of the "non-detect" contour depicting the current results.

In the deep permanent monitoring wells, three VOCs were detected in the deep groundwater. PCE was detected in three of five deep well samples at concentrations ranging from 1 µg/L to 5 µg/L. TCE and chloroform were both detected in two out of five samples at concentrations ranging from 0.5 µg/L (chloroform) to 2 µg/L (TCE).

Benzene was not detected in the groundwater samples collected from deep permanent monitoring well installations, including one installed approximately 100 feet downgradient of the benzene detections in the temporary monitoring well program.

A comparison of groundwater VOC data was conducted between permanent monitoring wells analyzed using a quick turn-around-time (TAT), and groundwater samples collected from permanent wells using a standard TAT. In addition, temporary wells were also compared if co-located within a reasonable distance to the associated permanent monitoring well cluster. This comparison was conducted to determine whether any bias existed between analytical results of samples with different TAT, and between samples collected from permanent wells versus temporary wells. Each set of samples were grouped together to compare their respective PCE and biodegradation products (TCE; cis-1,2-DCE; trans-1,2-DCE; VC) (see Table 4-5). Comparing the analytical data between the two TATs proved to be questionable. Because the samples were collected 4 to 7 months apart, it is difficult to discern any trends

or biases in the data as being attributed to sample quality dictated by TAT, from biodegradation or contaminant migration during that time interval. Comparing analytical results between permanent wells and temporary wells sampled during the same event and screening within similar intervals could be evaluated with more confidence. However, this scenario was not apparent in most cases.

A comparison of the Membrane Interface Probe (MIP) data logs to the groundwater analytical was also conducted. MIP data logs were conducted for TW31 through TW35 measuring Photoionization Detector (PID), Flame Ionization Detector (FID), and Electronic Capture Detector (ECD) readings in situ during boring installation. Based on the MIPS data logs, depth intervals with elevated detections were selected for sampling. The groundwater analytical data and the data logs correlate such that samples selected for analysis based on the MIP data logs indicated elevated concentrations of VOCs above USEPA MCLs, particularly PCE and TCE. One exception was TW35 where an elevated FID reading was observed at 19 and 21 feet below ground surface. Groundwater at this boring was sampled below this interval at the FID reading corresponding with a clay layer. The results of the groundwater sample from TW35 indicated no elevated VOC concentrations. See Table 4-6 for a summary of the MIP data compared to the groundwater analytical results.

See Section 5.4 for information detailing the Site 45 natural attenuation study.

At Site 45, MW08SU and MW07SU are considered source area wells, while MW06SU, MW05SL, and MW04SU are located progressively further downgradient from the source area. PCE and TCE concentrations drop off significantly from MW08SU to MW06SU while DCE and VC concentrations remain similar. Further downgradient at wells MW05SL and MW04SU, the dropoff of DCE and VC concentrations is greater than that of PCE and TCE.

PCE concentrations, as well as its degradation products (TCE, cis-1,2-DCE, and VC), are most evident within the upper surficial aquifer (0'-10') with the highest detected concentrations around the areas of MW08SU, and MW07SU and TW11. These plumes appear to be separate and are well defined by the surrounding temporary wells. Concentrations decrease with downgradient groundwater flow. Similar conditions are observed within the lower portion of the surficial aquifer (11'-20').

#### **4.4 SUMMARY**

PCE and its degradation products (TCE, cis-1,2-DCE, and 1,2-DCE and VC) were detected in surface and subsurface soils and groundwater above screening levels in all three identified potential source areas. PAHs were detected in the soil sample locations across Site 45 but at relatively low concentrations compared to human health screening criteria.

Rather subjective analysis by ultraviolet light for non-aqueous phase product was conducted for soils. The evaluation indicated possible trace amounts in isolated areas. However, the presence of pure product was not positively identified and no further conclusions were developed.

Results of the field sampling and analytical program suggest that the inorganic constituents detected in surface soils were similar to background conditions at MCRD Parris Island or at levels below human health screening criteria.

Temporary and permanent monitoring well data indicate chlorinated VOC contamination in the surface and subsurface soil at Site 45 has impacted the groundwater (i.e., groundwater contaminant concentrations above screening levels) to depths ranging from the upper boundaries of the unconfined aquifer to approximately 19 feet bgs. Furthermore, investigations of the underlying deep aquifer found only limited VOC contamination, suggesting that the contaminant plume may be contained within the surficial aquifer. In other investigations (natural attenuation), elevated concentrations of some VOCs were detected downgradient of the "non-detect" contour depicting the current results.

TABLE 4-1

**SUMMARY STATISTICS-SURFACE SOIL  
SITE 45 - MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA**

CAS	Parameter	Frequency of Detection	Range of Positive Detects	Range of Nondetects	Location of Maximum Concentration	Average of Positive Results	Average of All Results	Background Values	Exceeds Background (yes/no)
<b>Volatile Organics (ug/kg)</b>									
71-55-6	1,1,1-Trichloroethane	1/8	4	5 - 160	PAI-45-SS-05	4	16	NA	NA
95-50-1	1,2-Dichlorobenzene	1/8	2	5 - 160	PAI-45-SS-05	2	16	NA	NA
75-71-8	Dichlorodifluoromethane	1/8	2	5 - 160	PAI-45-SS-02	2	16	NA	NA
127-18-4	Tetrachloroethene	8/8	14 - 7500	0	PAI-45-SS-05	2274	2274	NA	NA
156-60-5	Trans-1,2-dichloroethene	2/8	2 - 50	5 - 160	PAI-45-SS-04	22	21	NA	NA
79-01-6	Trichloroethene	7/8	3 - 320	6	PAI-45-SS-05	69	60	NA	NA
156-59-2	cis-1,2-dichloroethene	5/8	2 - 730	6 - 140	PAI-45-SS-06	134	93	NA	NA
<b>Semivolatile Organics (ug/kg)</b>									
83-32-9	Acenaphthene	1/8	25	360 - 430	PAI-45-SS-03	25	175	NA	NA
120-12-7	Anthracene	3/8	21 - 290	360 - 430	PAI-45-SS-06	112	164	NA	NA
56-55-3	Benzo(a)anthracene	7/8	44 - 150	360	PAI-45-SS-03	92	103	NA	NA
50-32-8	Benzo(a)pyrene	7/8	26 - 130	360	PAI-45-SS-02	77	90	NA	NA
50-32-8	Benzo(a)pyrene	7/8	26 - 130	360	PAI-45-SS-03	77	90	NA	NA
205-99-2	Benzo(b)fluoranthene	7/8	42 - 180	360	PAI-45-SS-03	109	118	NA	NA
191-24-2	Benzo(g,h,i)perylene	6/8	36 - 110	360 - 400	PAI-45-SS-02	71	101	NA	NA
207-08-9	Benzo(k)fluoranthene	5/8	32 - 64	360 - 400	PAI-45-SS-03	50	104	NA	NA
85-68-7	Butyl Benzyl Phthalate	5/8	25 - 900	360 - 430	PAI-45-SS-03	237	223	NA	NA
86-74-8	Carbazole	3/8	22 - 44	360 - 430	PAI-45-SS-03	36	135	NA	NA
218-01-9	Chrysene	7/8	45 - 170	360	PAI-45-SS-03	97	107	NA	NA
53-70-3	Dibenzo(a,h)anthracene	4/8	20 - 29	360 - 430	PAI-45-SS-02	26	112	NA	NA
53-70-3	Dibenzo(a,h)anthracene	4/8	20 - 29	360 - 430	PAI-45-SS-05	26	112	NA	NA
84-66-2	Diethyl Phthalate	1/8	19	360 - 430	PAI-45-SS-05	19	174	NA	NA
206-44-0	Fluoranthene	7/8	42 - 300	360	PAI-45-SS-03	129	135	NA	NA
86-73-7	Fluorene	1/8	18	360 - 430	PAI-45-SS-03	18	174	NA	NA
193-39-5	Indeno(1,2,3-cd)pyrene	6/8	34 - 120	360 - 400	PAI-45-SS-02	73	103	NA	NA
91-20-3	Naphthalene	1/8	22	360 - 430	PAI-45-SS-03	22	175	NA	NA
85-01-8	Phenanthrene	7/8	22 - 230	360	PAI-45-SS-03	81	93	NA	NA
129-00-0	Pyrene	7/8	52 - 280	360	PAI-45-SS-03	138	143	NA	NA
<b>Inorganics (mg/kg)</b>									
7429-90-5	Aluminum	8/8	4300 - 9480	0	PAI-45-SS-04	6289	6289	7270	no
7440-38-2	Arsenic	8/8	0.94 - 2.1	0	PAI-45-SS-01	1.45	1.45	1.44	yes
7440-39-3	Barium	8/8	14.2 - 28.6	0	PAI-45-SS-04	20	20	24	no
7440-70-2	Calcium	8/8	724 - 3720	0	PAI-45-SS-03	1612	1612	766	yes
7440-47-3	Chromium	8/8	7 - 9.1	0	PAI-45-SS-03	7.7	7.7	6.23	yes
7440-48-4	Cobalt	5/8	0.57 - 0.8	0.46 - 0.58	PAI-45-SS-08	0.652	0.503	0.363	yes
7440-50-8	Copper	8/8	5 - 48.1	0	PAI-45-SS-01	12	12	1.5	yes
7439-89-6	Iron	8/8	2330 - 3650	0	PAI-45-SS-08	3047	3047	3920	no
7439-92-1	Lead	8/8	6.5 - 50.2	0	PAI-45-SS-05	32	32	13	yes
7439-95-4	Magnesium	8/8	267 - 437	0	PAI-45-SS-04	346	346	515	no
7439-96-5	Manganese	8/8	23.1 - 53.7	0	PAI-45-SS-06	36	36	129	no
7439-97-6	Mercury	8/8	0.03 - 0.06	0	PAI-45-SS-04, PAI-45-SS-08	0.043	0.043	0.11	no
7440-02-0	Nickel	8/8	2 - 3.2	0	PAI-45-SS-08	2.4	2.4	1.8	yes
7440-09-7	Potassium	8/8	165 - 315	0	PAI-45-SS-04	243	243	313	no
7440-23-5	Sodium	8/8	26 - 75.5	0	PAI-45-SS-04	46	46	241	no
7440-62-2	Vanadium	8/8	5.5 - 8.6	0	PAI-45-SS-04	6.8	6.8	10	no
7440-66-6	Zinc	8/8	21.8 - 338	0	PAI-45-SS-01	90	90	10	yes

Sample and duplicate are counted as one.  
Associated Samples:

NA = Not applicable.

PAI-45-SS-01-01	PAI-45-SS-05-01
PAI-45-SS-02-01	PAI-45-SS-06-01
PAI-45-SS-03-01	PAI-45-SS-07-01
PAI-45-SS-04-01	PAI-45-SS-08-01
PAI-45-SS-04-01-D	PAI-45-SS-08-01-D

TABLE 4-2

**SUMMARY STATISTICS-SUBSURFACE SOIL  
SITE 45 - MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA**

CAS	Parameter	Frequency of Detection	Range of Positive Detects	Range of Nondetects	Location of Maximum Concentration	Average of Positive Results	Average of All Results
<b>Volatile Organics (ug/kg)</b>							
71-55-6	1,1,1-Trichloroethane	1/8	210	100 - 240	PAI-45-SB-01-05	210	86
79-00-5	1,1,2-Trichloroethane	1/8	69	100 - 240	PAI-45-SB-07-04	69	69
75-34-3	1,1-Dichloroethane	2/8	28 - 34	100 - 240	PAI-45-SB-05-04	31	60
75-35-4	1,1-Dichloroethene	1/8	43	100 - 240	PAI-45-SB-05-04	43	65
95-50-1	1,2-Dichlorobenzene	1/8	260	100 - 240	PAI-45-SB-03-04	260	93
78-93-3	2-Butanone	1/8	140	100 - 240	PAI-45-SB-03-04	140	78
74-83-9	Bromomethane	2/8	42 - 90	100 - 240	PAI-45-SB-01-05	66	69
108-90-7	Chlorobenzene	3/8	76 - 2000	100 - 240	PAI-45-SB-03-04	718	314
100-41-4	Ethylbenzene	4/8	23 - 1500	100 - 240	PAI-45-SB-03-04	491	282
98-82-8	Isopropylbenzene	4/8	22 - 850	100 - 240	PAI-45-SB-03-04	403	238
127-18-4	Tetrachloroethene	7/8	1900 - 8000000	100	PAI-45-SB-01-05	1150000	1006000
108-88-3	Toluene	1/8	62	100 - 530	PAI-45-SB-05-04	62	113
1330-20-7	Total Xylenes	3/8	100 - 1000	100 - 240	PAI-45-SB-03-04	533	245
156-60-5	Trans-1,2-dichloroethene	6/8	20 - 810	100 - 240	PAI-45-SB-03-04	395	318
79-01-6	Trichloroethene	7/8	65 - 120000	240	PAI-45-SB-05-04	19552	17123
75-01-4	Vinyl Chloride	1/8	30	100 - 240	PAI-45-SB-03-04	30	64
156-59-2	cis-1,2-dichloroethene	7/8	470 - 40000	240	PAI-45-SB-05-04	14941	13089
<b>Semivolatile Organics (ug/kg)</b>							
91-57-6	2-Methylnaphthalene	3/8	94 - 820	400	PAI-45-SB-03-04	345	254
83-32-9	Acenaphthene	1/8	520	400	PAI-45-SB-07-04	360	220
208-96-8	Acenaphthylene	1/8	36	400	PAI-45-SB-07-04	36	180
120-12-7	Anthracene	1/8	2900	400	PAI-45-SB-07-04	1550	369
56-55-3	Benzo(a)anthracene	3/8	17 - 7200	400	PAI-45-SB-07-04	1233	587
50-32-8	Benzo(a)pyrene	2/8	58 - 5800	400	PAI-45-SB-07-04	1529	532
205-99-2	Benzo(b)fluoranthene	3/8	20 - 7100	400	PAI-45-SB-07-04	1254	595
191-24-2	Benzo(g,h,i)perylene	2/8	69 - 3200	400	PAI-45-SB-07-04	885	371
207-08-9	Benzo(k)fluoranthene	2/8	29 - 2200	400	PAI-45-SB-07-04	615	304
117-81-7	Bis(2-Ethylhexyl)phthalate	1/8	5500	400 - 760	PAI-45-SB-03-04	5500	874
86-74-8	Carbazole	1/8	360	400	PAI-45-SB-07-04	360	220
218-01-9	Chrysene	2/8	70 - 6200	400	PAI-45-SB-07-04	1635	559
117-84-0	Di-n-octyl phthalate	1/8	290	400 - 760	PAI-45-SB-03-04	290	223
53-70-3	Dibenzo(a,h)anthracene	1/8	780	400	PAI-45-SB-07-04	490	236
132-64-9	Dibenzofuran	1/8	360	400	PAI-45-SB-07-04	280	210
206-44-0	Fluoranthene	3/8	14 - 16000	400	PAI-45-SB-07-04	2708	1140
86-73-7	Fluorene	2/8	16 - 930	400	PAI-45-SB-07-04	291	223
193-39-5	Indeno(1,2,3-cd)pyrene	2/8	75 - 3700	400	PAI-45-SB-07-04	1013	403
91-20-3	Naphthalene	3/8	55 - 4500	400	PAI-45-SB-03-04	1725	772
85-01-8	Phenanthrene	2/8	64 - 9700	400	PAI-45-SB-07-04	2507	777
129-00-0	Pyrene	2/8	120 - 12000	400	PAI-45-SB-07-04	3110	928
<b>Miscellaneous Parameters (mg/kg)</b>							
TTNUS003	Total Organic Carbon	9/14	3493 - 21700	2500 - 4600	PAI-45-SB-04-04	8890	6322

Sample and duplicate are counted as one.

Associated Samples:

PAI-45-SB-01-05  
PAI-45-SB-01-14  
PAI-45-SB-02-04  
PAI-45-SB-03-04  
PAI-45-SB-04-04  
PAI-45-SB-05-04  
PAI-45-SB-06-04  
PAI-45-SB-07-04-D

PAI-45-SB-08-04  
PAI-45-SB-08-04-D  
PAI-45-SB-09-14  
PAI-45-SB-10-13  
PAI-45-SB-11-10  
PAI-45-SB-12-10  
PAI-45-SB-13-10

TABLE 4-3

**SUMMARY STATISTICS - SURFICIAL AQUIFER  
PERMANENT MONITORING WELL DATA  
SITE 45 - MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA**

CAS	Parameter	Frequency of Detection	Range of Positive Detects	Range of Nondetects	Location of Maximum Concentration	Average of Positive Results	Average of All Results
<b>Volatile Organics (ug/L)</b>							
75-35-4	1,1-Dichloroethene	2/5	1 - 4	5	PAI-45-MW08SU	3	3
67-64-1	Acetone	1/5	2	5	PAI-45-MW08SU	2	2
124-48-1	Chlorodibromomethane	1/5	4	5	PAI-45-MW08SU	4	3
74-85-1	Ethene	5-Jan	19	10	PAI-45-MW08SU	19	8
74-82-8	Methane	5/5	97 - 3000	0	PAI-45-MW05SL	906	906
127-18-4	Tetrachloroethene	4/5	6 - 10000	5	PAI-45-MW08SU	2554	2044
108-88-3	Toluene	1/5	5	5	PAI-45-MW08SU	5	3
156-60-5	Trans-1,2-dichloroethene	2/5	22 - 140	5	PAI-45-MW08SU	81	34
79-01-6	Trichloroethene	4/5	9 - 10000	5	PAI-45-MW08SU	2536	2030
75-01-4	Vinyl Chloride	3/5	1 - 710	5	PAI-45-MW08SU	452	272
156-59-2	cis-1,2-dichloroethene	4/5	1 - 3400	5	PAI-45-MW08SU	1201	961
<b>Inorganics (ug/L)</b>							
7440-70-2	Calcium	5/5	3930 - 145000	0	PAI-45-MW06SU	53706	53706
7439-89-6	Iron	5/5	426 - 19500	0	PAI-45-MW05SL	9623	9623
7439-95-4	Magnesium	5/5	4250 - 142000	0	PAI-45-MW06SU	34330	34330
7439-96-5	Manganese	5/5	14 - 308	0	PAI-45-MW05SL	88	88
7440-09-7	Potassium	5/5	770 - 41500	0	PAI-45-MW06SU	10556	10556
7440-23-5	Sodium	5/5	20700 - 1170000	0	PAI-45-MW06SU	284340	284340
<b>Miscellaneous Parameters (ug/L)</b>							
TTNUS008	Alkalinity	4/5	30000 - 220000	20000	PAI-45-MW06SU	128750	105000
TTNUS017	Chemical Oxygen Demand	4/5	20000 - 50000	15000	PAI-45-MW06SU, PAI-45-MW08SU	36250	30500
16887-00-6	Chloride	5/5	9000 - 2000000	0	PAI-45-MW06SU, PAI-45-MW06SU	487800	487800
14797-55-8	Nitrate	1/5	80	50	PAI-45-MW05SL	80	36
TTNUS032	Orthophosphate	3/5	90 - 960	50	PAI-45-MW05SL	380	238
TTNUS002	pH (s.u.)	5/5	5.4 - 7.8	0	PAI-45-MW04SU	7	7
TTNUS038	Specific Conductance (umhos)	5/5	380 - 6300	0	PAI-45-MW06SU	1710	1710
14808-79-8	Sulfate	5/5	7300 - 460000	0	PAI-45-MW06SU	110260	110260
TTNUS003	Total Organic Carbon	5/5	1000 - 51000	0	PAI-45-MW08SU	20680	20680

Associated Samples:

Sample and duplicate are counted as one.

PAI-45-GW01SU-01  
PAI-45-GW04SU-01  
PAI-45-GW05SL-01  
PAI-45-GW06SU-01  
PAI-45-GW06SU-01-D  
PAI-45-GW08SU-01

TABLE 4-4

SUMMARY STATISTICS - DEEP AQUIFER  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA

CAS	Parameter	Frequency of Detection	Range of Positive Detects	Range of Nondetects	Location of Sample Maximum	Average of Positive Results	Average of All Results
<b>Volatile Organics (ug/L)</b>							
67-66-3	Chloroform	2/5	0.5 - 1	5	PAI-45-MW05D	0.8	1.8
127-18-4	Tetrachloroethene	3/5	1 - 5	5	PAI-45-MW04D	2.8	2.7
79-01-6	Trichloroethene	2/5	0.6 - 2	5	PAI-45-MW04D	1.4	2.0

Associated Samples:

Sample and duplicate are counted as one.

- PAI-45-GW09D-01
- PAI-45-GW11D-01
- PAI-45-GW04D-01
- PAI-45-GW05D-01
- PAI-45-GW10D-01
- PAI-45-GW10D-01-D

TABLE 4-5

GROUNDWATER COMPARISON SUMMARY  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA  
 PAGE 1 OF 5

Location	PAI45MW04SU	PAI45TW21	PAI45TW21
Sample	PAI-45-GW04SU-01	PAI-45-TW-21-07	PAI-45-TW-21-19
Depth of Range (ft)	(3-7)	(3-7)	(15-19)
Sample Date	10/17/2001	4/9/2001	4/9/2001
Matrix	Groundwater	Groundwater	Groundwater
Units	UG/L	UG/L	UG/L
Well Type	Permanent	Temporary	Temporary
Analysis Turn Around Time	Standard	Quick Turn	Quick Turn
<b>Volatile Organic Compounds</b>			
TETRACHLOROETHENE	6		U
TRICHLOROETHENE	11		2
CIS-1,2-DICHLOROETHENE	2	J	U
TRANS-1,2-DICHLOROETHENE		U	U
VINYL CHLORIDE	1		U

TABLE 4-5

GROUNDWATER COMPARISON SUMMARY  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA  
 PAGE 2 OF 5

Location	PAI45MW05SL	PAI45TW18	PAI45TW18
Sample	PAI-45-GW05SL-01	PAI-45-TW-18-07	PAI-45-TW-18-17
Depth of Range (ft)	(2-7)	(3-7)	(13-17)
Sample Date	10/17/2001	4/5/2001	4/5/2001
Matrix	Groundwater	Groundwater	Groundwater
Units	UG/L	UG/L	UG/L
Well Type	Permanent	Temporary	Temporary
Analysis Turn Around Time	Standard	Quick Turn	Quick Turn
<b>Volatile Organic Compounds</b>			
TETRACHLOROETHENE	9		U
TRICHLOROETHENE	9		U
CIS-1,2-DICHLOROETHENE	1 J	5	U
TRANS-1,2-DICHLOROETHENE		U	U
VINYL CHLORIDE		U	U

TABLE 4-5

GROUNDWATER COMPARISON SUMMARY  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA  
 PAGE 3 OF 5

Location	PAI45MW06SU	PAI45MW06SU	PAI45MW06SL	PAI45TW14	PAI45TW14
Sample	PAI-45-GW06SU-01	PAI-45-MW06S-0601	PAI-45-MW06D-0601	PAI-45-TW-14-7	PAI-45-TW-14-17
Depth of Range (ft)	(3-7)	(3-7)	(9-14)	(4-7)	(14-17)
Sample Date	10/17/2001	6/5/2001	6/5/2001	3/12/2001	3/12/2001
Matrix	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Units	UG/L	UG/L	UG/L	UG/L	UG/L
Well Type	Permanent	Permanent	Permanent	Temporary	Temporary
Analysis Turn Around Time	Standard	Quick Turn	Quick Turn	Quick Turn	Quick Turn
Volatile Organic Compounds					
TETRACHLOROETHENE	200	230	5.1	21	48
TRICHLOROETHENE	120	159	184	197	129
CIS-1,2-DICHLOROETHENE	1400	1280	160	124	47
TRANS-1,2-DICHLOROETHENE	U	14.9	U	U	U
VINYL CHLORIDE	630	190	U	16	16

TABLE 4-5

GROUNDWATER COMPARISON SUMMARY  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA  
 PAGE 4 OF 5

Location	PAI45MW07SU	PAI45MW07SL	PAI45TW11	PAI45TW11
Sample	PAI-45-MW07S-0601	PAI-45-MW07D-0601	PAI-45-TW-11-10	PAI-45-TW-11-20
Depth of Range (ft)	(3-7)	(9-14)	(7-10)	(17-20)
Sample Date	6/11/2001	6/11/2001	3/12/2001	3/12/2001
Matrix	Groundwater	Groundwater	Groundwater	Groundwater
Units	UG/L	UG/L	UG/L	UG/L
Well Type	Permanent	Permanent	Temporary	Temporary
Analysis Turn Around Time	Quick Turn	Quick Turn	Quick Turn	Quick Turn
<b>Volatile Organic Compounds</b>				
TETRACHLOROETHENE	13.6	8460	9600	21
TRICHLOROETHENE	62.2	6630	12800	13
CIS-1,2-DICHLOROETHENE	138	1430	14000	13
TRANS-1,2-DICHLOROETHENE	4.5	91.3	565	U
VINYL CHLORIDE	17.1	46	3110	U

TABLE 4-5

GROUNDWATER COMPARISON SUMMARY  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA  
 PAGE 5 OF 5

Location	PAI45MW08SU	PAI45MW08SU	PAI45MW08SL
Sample	PAI-45-GW08SU-01	PAI-45-MW08S-0601	PAI-45-MW08D-0601
Depth of Range (ft)	(3-7)	(3-7)	(9-14)
Sample Date	10/18/2001	6/11/2001	6/11/2001
Matrix	Groundwater	Groundwater	Groundwater
Units	UG/L	UG/L	UG/L
Well Type	Permanent	Permanent	Permanent
Analysis Turn Around Time	Standard	Quick Turn	Quick Turn
<b>Volatile Organic Compounds</b>			
TETRACHLOROETHENE	10000	7540	2920
TRICHLOROETHENE	10000	13000	1520
CIS-1,2-DICHLOROETHENE	3400	2900	740
TRANS-1,2-DICHLOROETHENE		U 111	26.4
VINYL CHLORIDE	710	490	69.8

Notes:

J = Estimate

U = Non-detect

TABLE 4-6

**MIPS COMPARISON SUMMARY  
SITE 45 - MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA**

Location	PAI45TW31	PAI45TW32	PAI45TW33	PAI45TW34	PAI45TW35
Sample	PAI-45-TW-31-12	PAI-45-TW-32-16	PAI-45-TW-33-15	PAI-45-TW-34-14	PAI-45-TW-35-32
Depth of Range (ft)	(8-12)	(12-16)	(11-15)	(10-14)	(28-32)
Sample Date	6/6/2001	6/6/2001	6/6/2001	6/7/2001	6/7/2001
Matrix	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
Units	UG/L	UG/L	UG/L	UG/L	UG/L
MIPS Interval Range Detection (ft)	10-12	12-17	12-16	13-15	19-21
MIPS Detector Type	ECD	PID and ECD	PID and ECD	PID and ECD	FID
<b>Volatile Organic Compounds</b>					
TETRACHLOROETHENE	713	3240	585	1290	U
TRICHLOROETHENE	252	2480	3760	1660	U
CIS-1,2-DICHLOROETHENE	163	109	390	678	U
TRANS-1,2-DICHLOROETHENE	2.4	3.5	25.3	34.1	U
VINYL CHLORIDE	U	U	3.8	8.8	U

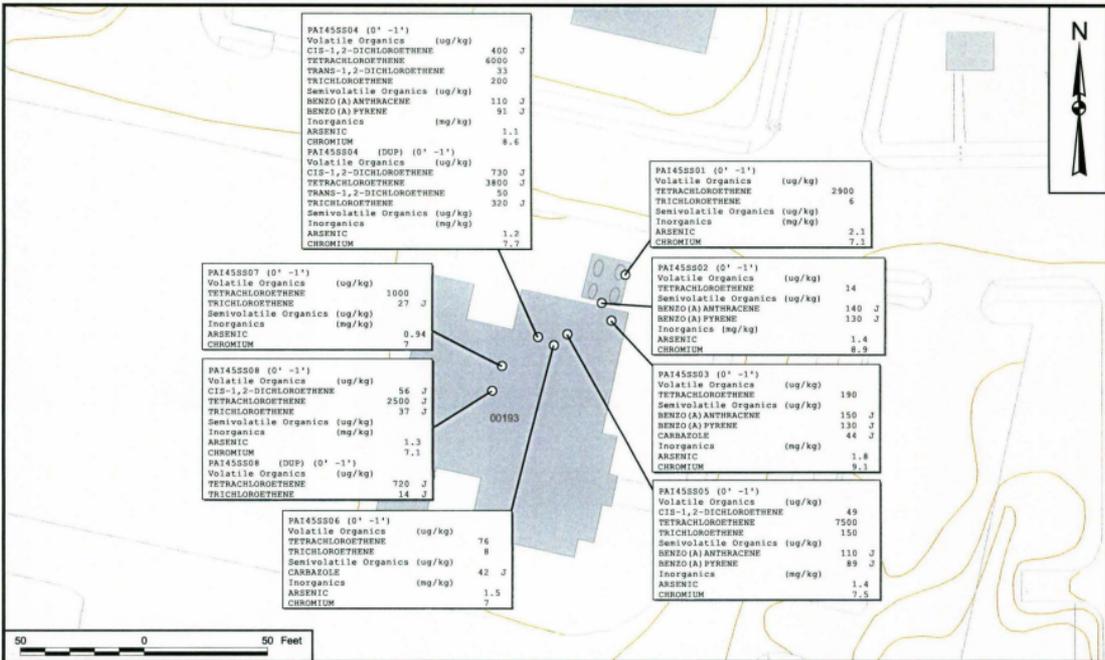
## Notes:

PID = Photoionization Detector

FID = Flame Ionization Detector

ECD = Electronic Capture Detector

U = Not detect



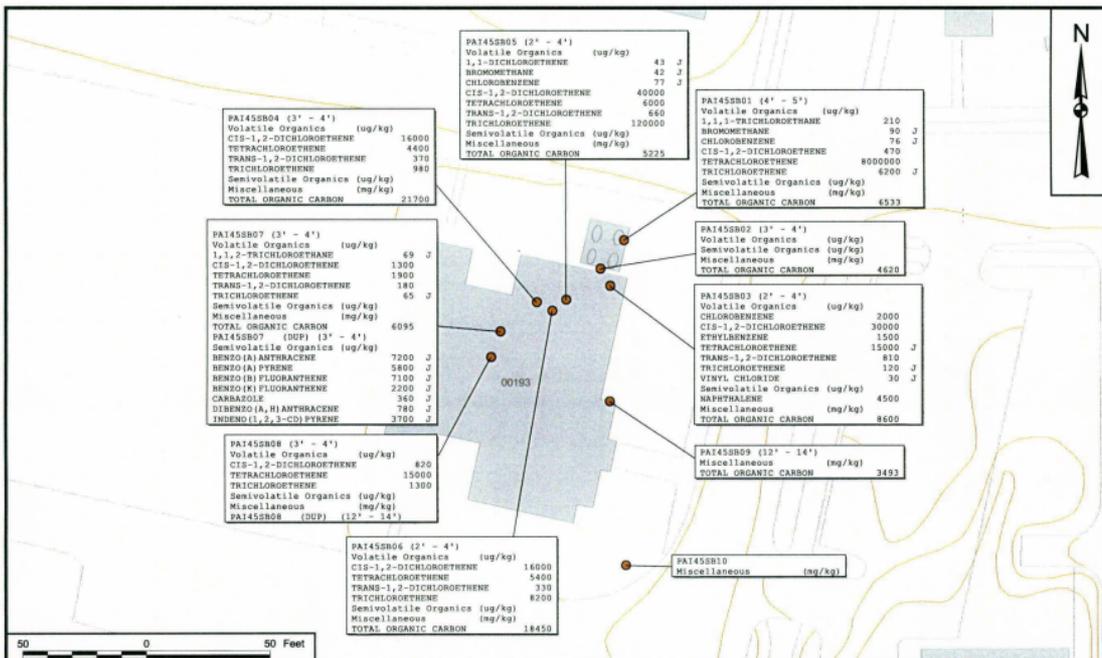
DRAWN BY	DATE
A. JANCOCHA	9/21/04
CHECKED BY	DATE
M. SLADIC	10/28/04
COST/SCHEDULE AREA	
SCALE AS NOTED	



SCREENING CRITERIA EXCEEDANCES IN SURFACE SOIL  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NUMBER CTO 127	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO.	REV 0

FIGURE 4-1



PA145SB04 (3' - 4')

Volatile Organics (ug/kg)	
CIS-1,2-DICHLOROETHENE	16000
TETRACHLOROETHENE	4400
TRANS-1,2-DICHLOROETHENE	370
TRICHLOROETHENE	980
SemiVolatile Organics (ug/kg)	
Miscellaneous (mg/kg)	
TOTAL ORGANIC CARBON	21700

PA145SB05 (2' - 4')

Volatile Organics (ug/kg)	
1,1-DICHLOROETHENE	43 J
BROMOMETHANE	42 J
CHLOROETHENE	77 J
CIS-1,2-DICHLOROETHENE	40000
TETRACHLOROETHENE	6000
TRANS-1,2-DICHLOROETHENE	660
TRICHLOROETHENE	120000
SemiVolatile Organics (ug/kg)	
Miscellaneous (mg/kg)	
TOTAL ORGANIC CARBON	5225

PA145SB01 (4' - 5')

Volatile Organics (ug/kg)	
1,1,1-TRICHLOROETHANE	210
BROMOMETHANE	30 J
CHLOROETHENE	76
CIS-1,2-DICHLOROETHENE	470
TETRACHLOROETHENE	800000
TRICHLOROETHENE	6200 J
SemiVolatile Organics (ug/kg)	
Miscellaneous (mg/kg)	
TOTAL ORGANIC CARBON	6533

PA145SB07 (3' - 4')

Volatile Organics (ug/kg)	
1,1,2-TRICHLOROETHANE	69 J
CIS-1,2-DICHLOROETHENE	1300
TETRACHLOROETHENE	1900
TRANS-1,2-DICHLOROETHENE	180
TRICHLOROETHENE	65 J
SemiVolatile Organics (ug/kg)	
Miscellaneous (mg/kg)	
TOTAL ORGANIC CARBON	4095

00193

PA145SB02 (3' - 4')

Volatile Organics (ug/kg)	
SemiVolatile Organics (ug/kg)	
Miscellaneous (mg/kg)	
TOTAL ORGANIC CARBON	4620

PA145SB03 (2' - 4')

Volatile Organics (ug/kg)	
CHLOROBENZENE	2000
CIS-1,2-DICHLOROETHENE	30000
ETHYLENE	1500
TETRACHLOROETHENE	15000 J
TRANS-1,2-DICHLOROETHENE	810
TRICHLOROETHENE	120 J
VINYL CHLORIDE	30 J
SemiVolatile Organics (ug/kg)	
NAPHTHALENE	4500
Miscellaneous (mg/kg)	
TOTAL ORGANIC CARBON	8600

PA145SB08 (3' - 4')

Volatile Organics (ug/kg)	
CIS-1,2-DICHLOROETHENE	820
TETRACHLOROETHENE	15000
TRICHLOROETHENE	1300
SemiVolatile Organics (ug/kg)	
Miscellaneous (mg/kg)	
PA145SB06 (DDP) (12' - 14')	

PA145SB09 (12' - 14')

Miscellaneous (mg/kg)	
TOTAL ORGANIC CARBON	3493

PA145SB06 (2' - 4')

Volatile Organics (ug/kg)	
CIS-1,2-DICHLOROETHENE	16000
TETRACHLOROETHENE	5400
TRANS-1,2-DICHLOROETHENE	330
TRICHLOROETHENE	8200
SemiVolatile Organics (ug/kg)	
Miscellaneous (mg/kg)	
TOTAL ORGANIC CARBON	18450

PA145SB10

Miscellaneous (mg/kg)	
-----------------------	--

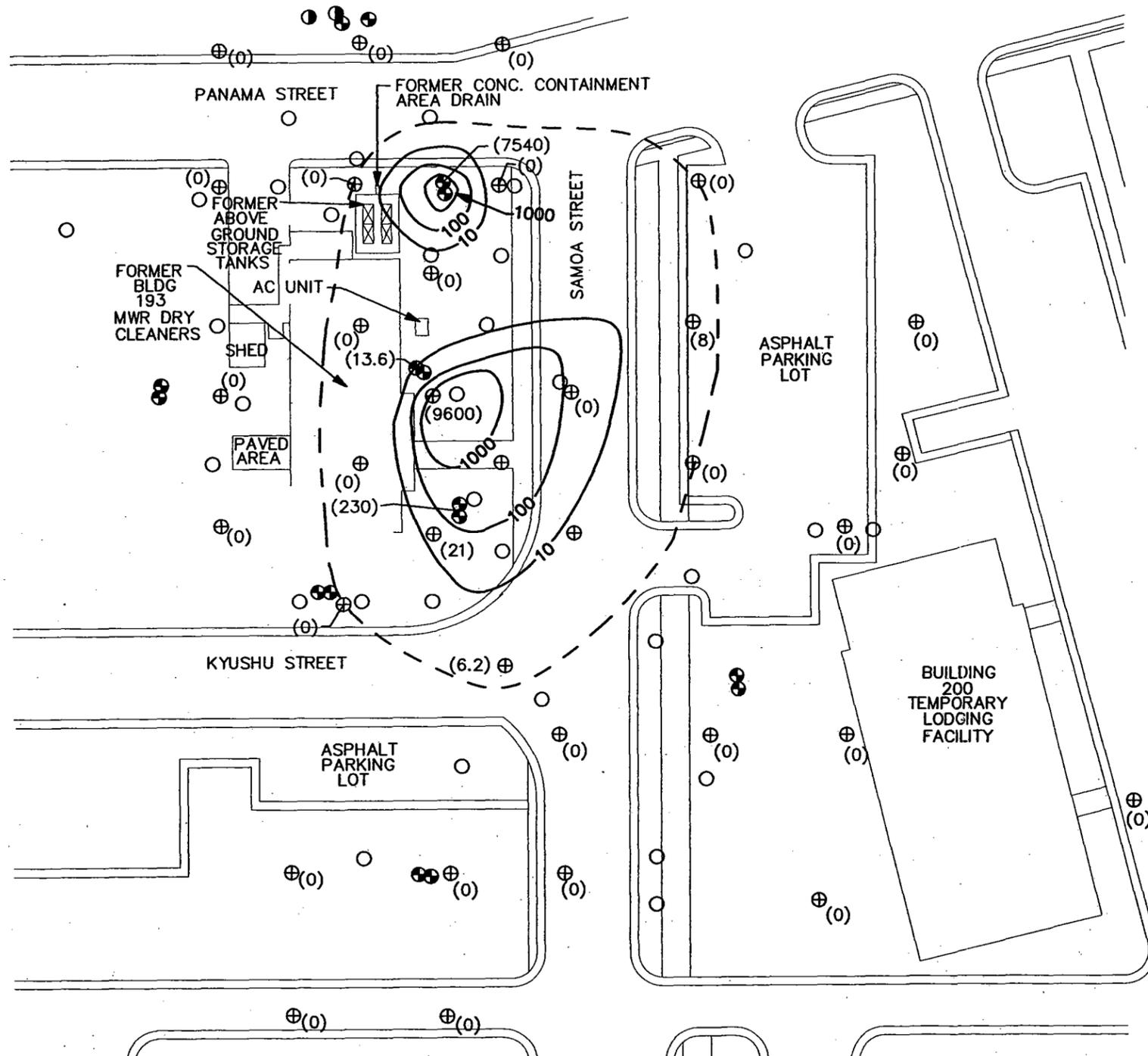
50 0 50 Feet	
DRAWN BY	DATE
A. JANICHA	9/21/04
CHECKED BY	DATE
M. SLADIC	10/28/04
COST/SCHEDULE AREA	
SCALE	
AS NOTED	



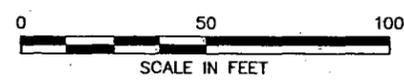
SCREENING CRITERIA EXCEEDANCES IN  
SUBSURFACE SOIL  
SITE 45 - MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND  
PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NUMBER	
CTO 127	
APPROVED BY	DATE
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APPROVED BY	DATE
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DRAWING NO.	REV
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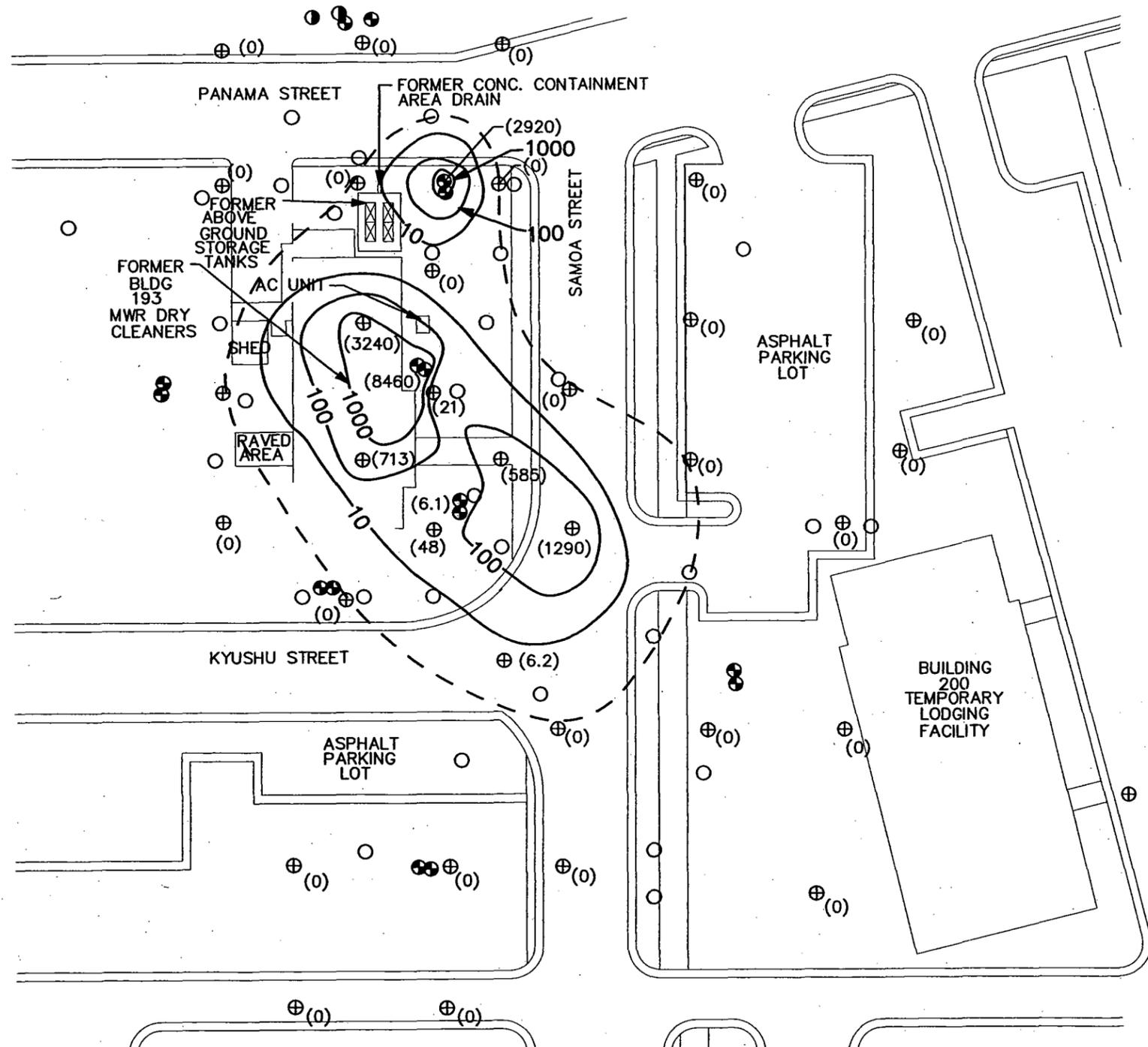
FIGURE 4-2



- LEGEND:**
- TEMPORARY MONITORING WELL (1996)
  - ⊕ PERMANENT MONITORING WELL PAI-45-MW01-SU
  - ⊕ TEMPORARY MONITORING WELL (2001) PAI-45-TW01
  - TEST WELLS FOR AIR SPARING PILOT TEST (1996) T1
  - 10 ——— ISOCOCONCENTRATION CONTOUR
  - (0) CHEMICAL NOT DETECTED
  - (1290) CONCENTRATION USED FOR CONTOURING
  - - - NON DETECT LINE
  - SL SURFICIAL LOWER
  - SU SURFICIAL UPPER
  - UG/L MICROGRAMS PER LITER
  - ➔ GROUNDWATER FLOW DIRECTION



NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES	DRAWN BY	DATE		PCE GROUNDWATER RESULTS (0-10 FEET) UG/L SITE 45 - MWR DRY CLEANING FACILITY MCRD PARRIS ISLAND PARRIS ISLAND, SOUTH CAROLINA	CONTRACT NO. 0502	
							HJB	12/7/01			APPROVED BY	DATE
											APPROVED BY	DATE
											DRAWING NO. FIGURE 4-3	REV. 0



- LEGEND:**
- TEMPORARY MONITORING WELL (1996)
  - ⊕ PERMANENT MONITORING WELL PAI-45-MW01-SU
  - ⊕ TEMPORARY MONITORING WELL (2001) PAI-45-TW01
  - T1 TEST WELLS FOR AIR SPARING PILOT TEST (1996)
  - 10 ——— ISOCOCONTRATION CONTOUR
  - (0) CHEMICAL NOT DETECTED
  - (1290) CONCENTRATION USED FOR CONTOURING
  - - - NON DETECT LINE
  - SL SURFICIAL LOWER
  - SU SURFICIAL UPPER
  - UG/L MICROGRAMS PER LITER
  - ➔ GROUNDWATER FLOW DIRECTION

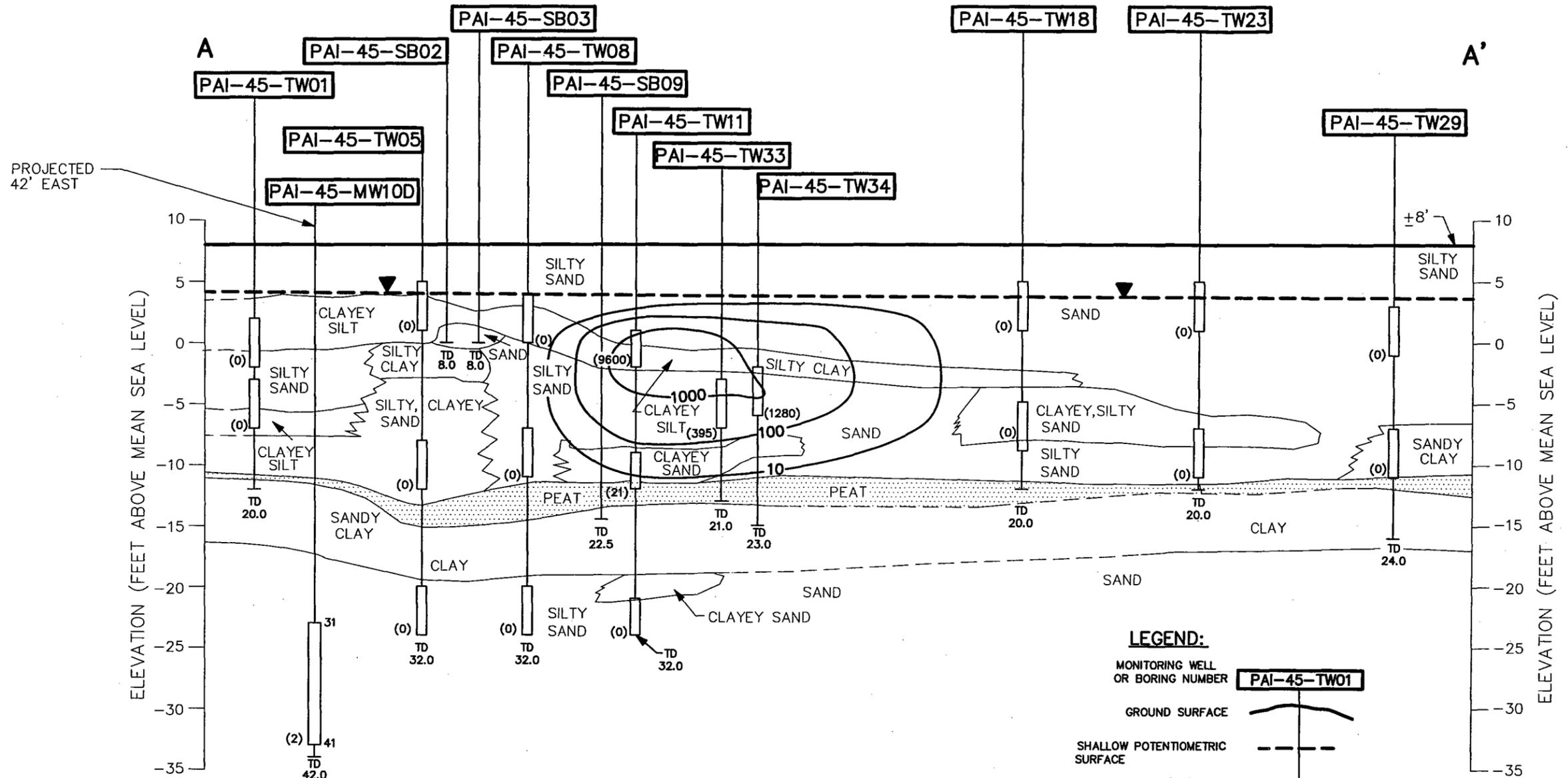
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJB DATE 12/7/01  
 CHECKED BY DATE  
 COST/SCHED-AREA  
 SCALE AS NOTED



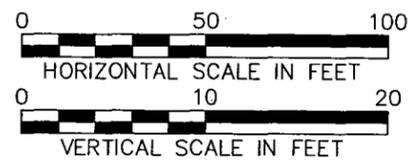
PCE GROUNDWATER RESULTS (11-20 FEET) UG/L  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 4-4	REV. 0



**LEGEND:**

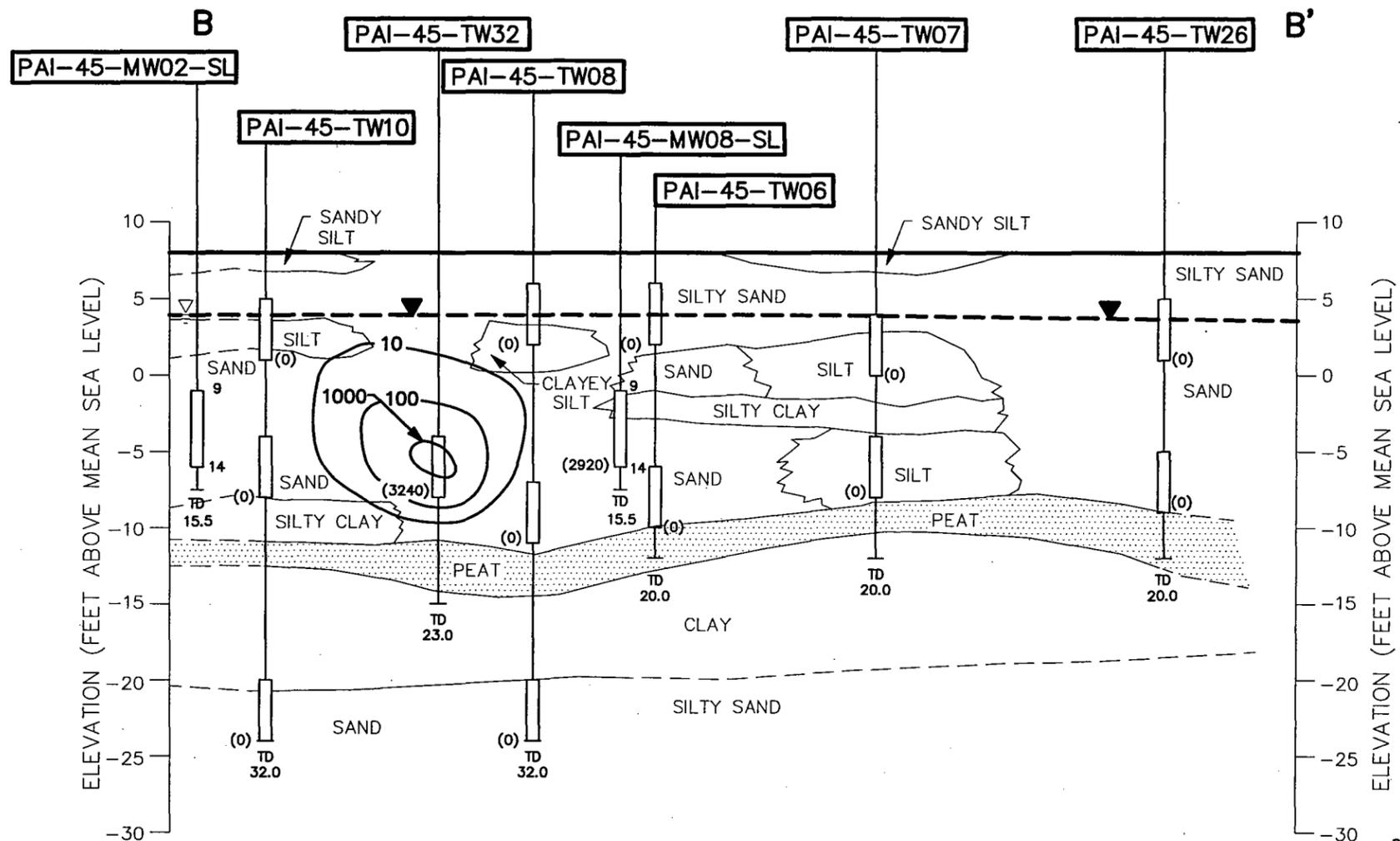
- MONITORING WELL OR BORING NUMBER: PAI-45-TW01
- GROUND SURFACE: [Symbol]
- SHALLOW POTENTIOMETRIC SURFACE: [Symbol]
- LITHOLOGIC CONTACT (INFERRED BETWEEN BORINGS AND WHEN DASHED): [Symbol]
- ISOCONCENTRATION CONTOUR: [Symbol]
- SCREENED INTERVAL AND CONTAMINANT CONCENTRATION: [Symbol]
- TOTAL DEPTH OF WELL OR BORING (FT BGS): [Symbol]



**NOTES:**

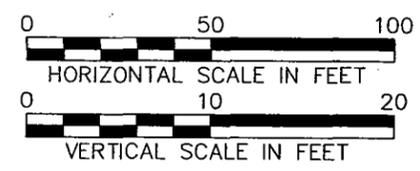
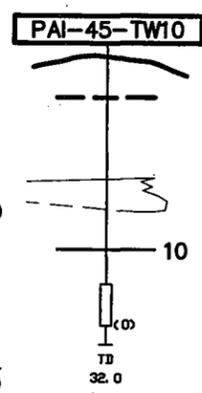
PAI-45-TW33 & PAI-45-TW34 LITHOLOGY WAS INTERPRETED USING MIPs (MEMBRANE INTERFACE TECHNOLOGY) IN CONJUNCTION WITH GEOLOGIST'S BORING LOGS.

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES	DRAWN BY	DATE		PCE ISOCONCENTRATION CONTOUR MAP		CONTRACT NO. 0502	
							HJB	3/6/02		CROSS SECTION A-A'		APPROVED BY	DATE
										SITE 45		APPROVED BY	DATE
										MCRD PARRIS ISLAND			
									PARRIS ISLAND, SOUTH CAROLINA		DRAWING NO.	REV.	
											FIGURE 4-5	0	



**LEGEND:**

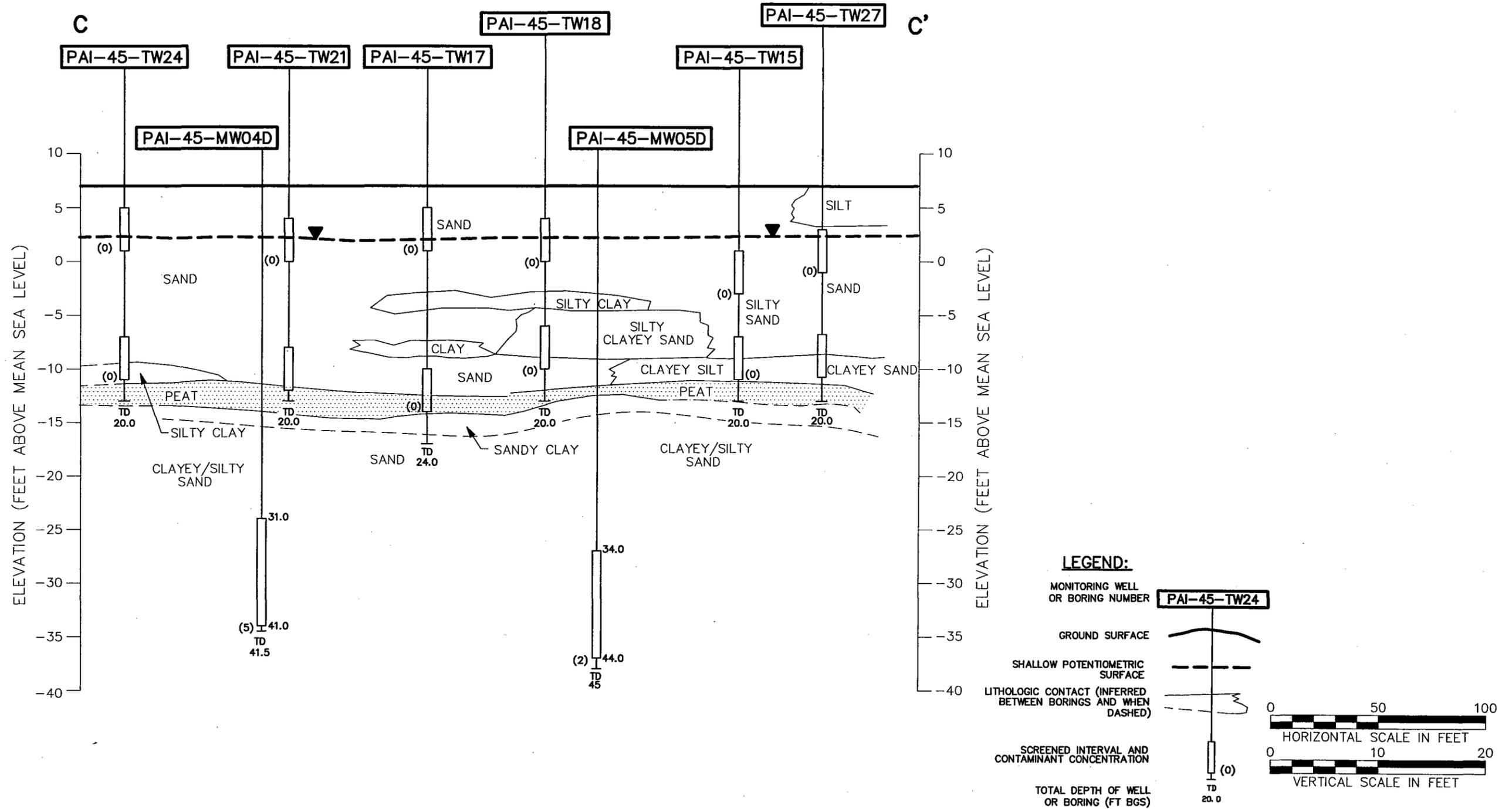
- MONITORING WELL OR BORING NUMBER
- GROUND SURFACE
- SHALLOW POTENTIOMETRIC SURFACE
- LITHOLOGIC CONTACT (INFERRED BETWEEN BORINGS AND WHEN DASHED)
- ISOCONCENTRATION CONTOUR
- SCREENED INTERVAL AND CONTAMINANT CONCENTRATION
- TOTAL DEPTH OF WELL OR BORING (FT BGS)



**NOTE:**

PAI-45-TW32'S LITHOLOGY WAS INTERPRETED USING MIPs (MEMBRANE INTERFACE PROBE) TECHNOLOGY

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES	DRAWN BY	DATE		PCE ISOCONCENTRATION CONTOUR MAP CROSS SECTION B-B' SITE 45 MCRD PARRIS ISLAND PARRIS ISLAND, SOUTH CAROLINA		CONTRACT NO. 0502	
							HJB	3/6/02		APPROVED BY	DATE	APPROVED BY	DATE
										APPROVED BY	DATE	APPROVED BY	DATE
										DRAWING NO.	REV.	DRAWING NO.	REV.
									SCALE		FIGURE 4-6	0	



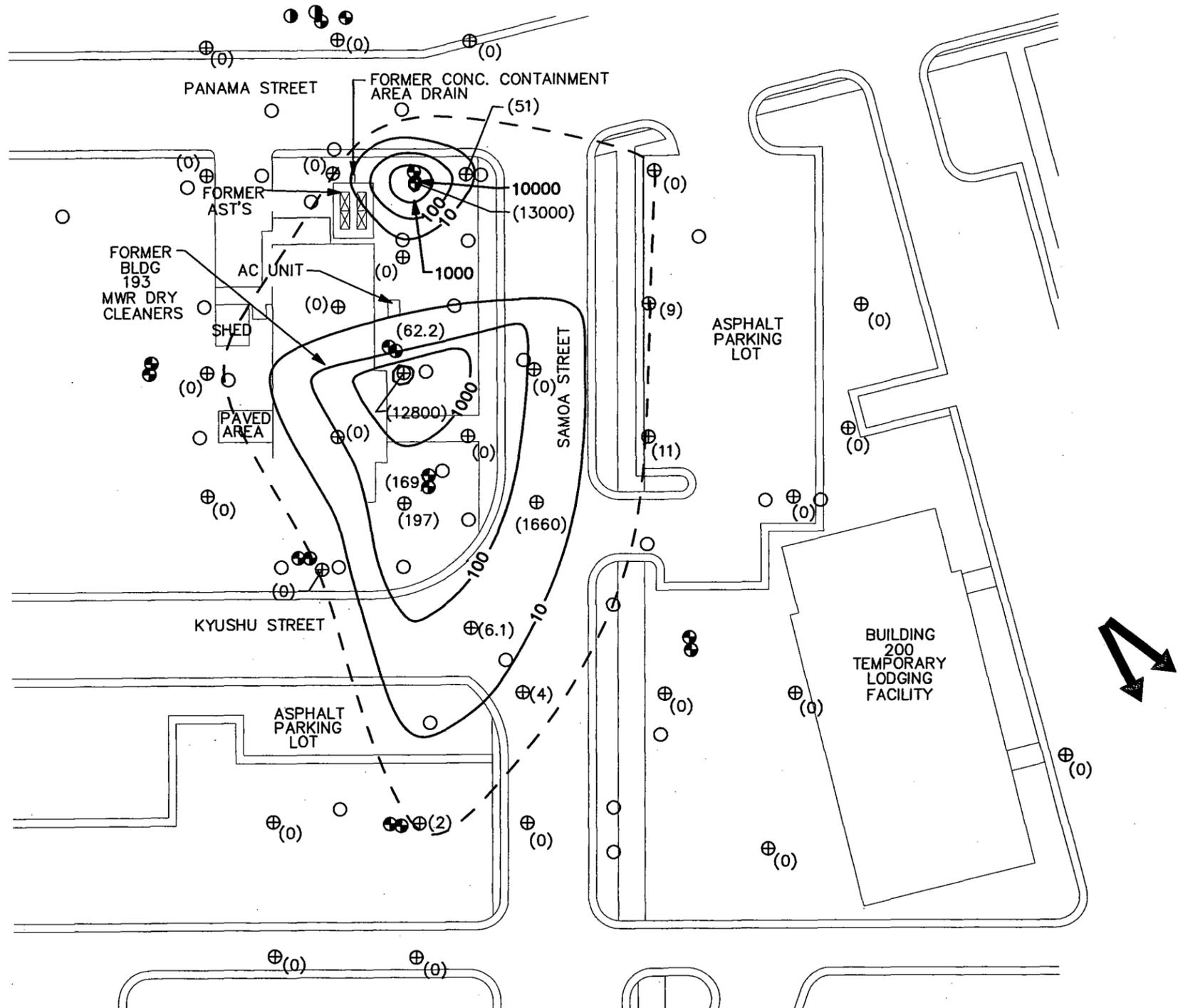
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY	DATE
HJB	3/6/02
CHECKED BY	DATE
COST/SCHED-AREA	
SCALE	
AS NOTED	



PCE ISOCONCENTRATION CONTOUR MAP  
 CROSS SECTION C-C'  
 SITE 45  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 4-7	REV. 0



**LEGEND:**

- TEMPORARY MONITORING WELL (1996)
- ⊕ PERMANENT MONITORING WELL PAI-45-MW01-SU
- ⊕ TEMPORARY MONITORING WELL (2001) PAI-45-TW01
- T1 TEST WELLS FOR AIR SPARING PILOT TEST (1996)
- 10 ——— ISOCONCENTRATION CONTOUR
- (0) CHEMICAL NOT DETECTED
- (197) CONCENTRATION USED FOR CONTOURING
- - - NON DETECT LINE
- SL SURFICIAL LOWER
- SU SURFICIAL UPPER
- UG/L MICROGRAMS PER LITER
- ➔ GROUNDWATER FLOW DIRECTION

0 50 100  
SCALE IN FEET

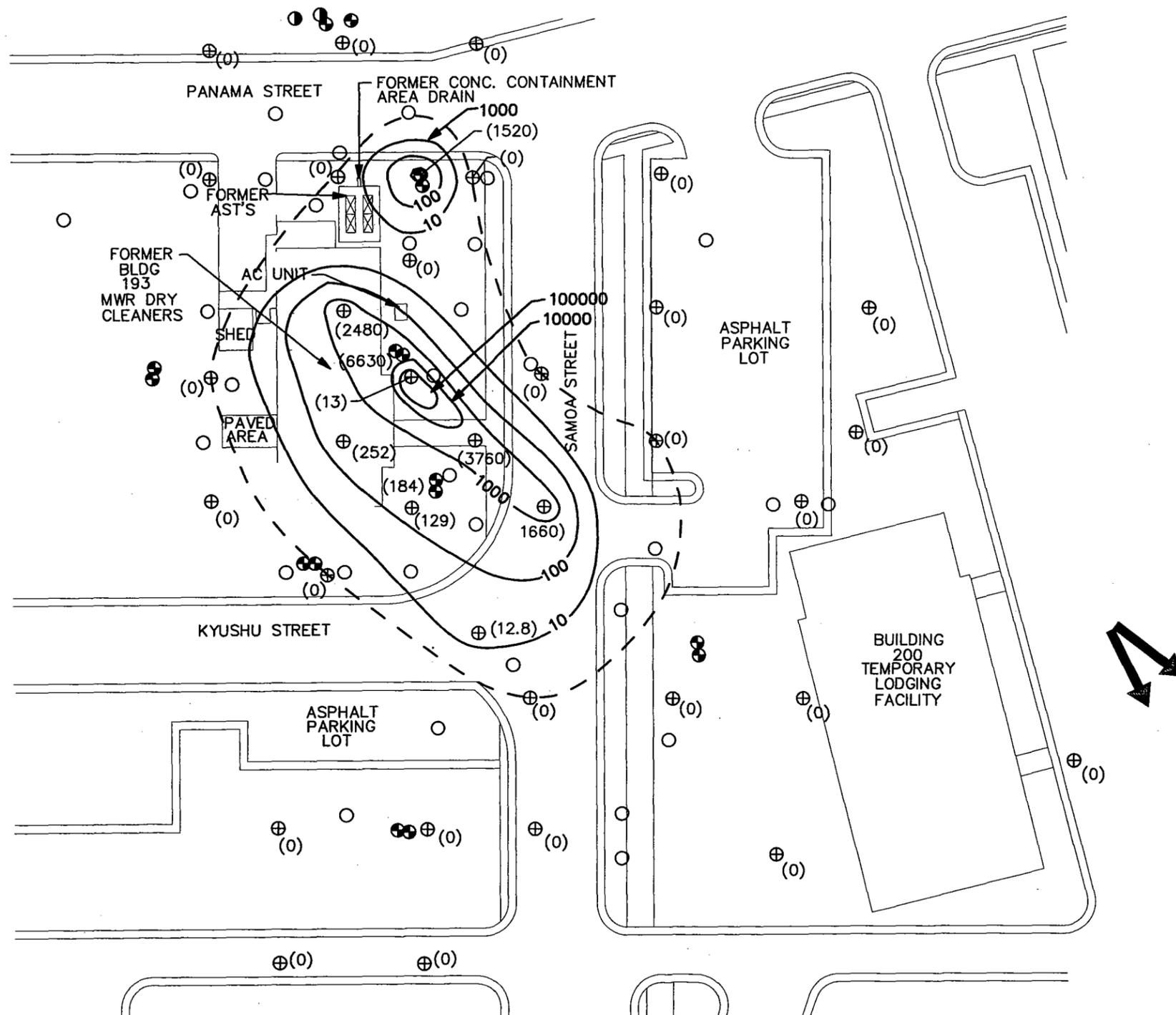
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJB DATE 3/6/02  
 CHECKED BY DATE  
 COST/SCHED-AREA  
 SCALE AS NOTED



TCE GROUNDWATER RESULTS (0-10 FEET) UG/L  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 4-8	REV. 0



**LEGEND:**

- TEMPORARY MONITORING WELL (1996)
- ⊕ PERMANENT MONITORING WELL PAI-45-MW01-SU
- ⊕ TEMPORARY MONITORING WELL (2001) PAI-45-TW01
- TEST WELLS FOR AIR SPARING PILOT TEST (1996) T1
- 10 ——— ISOCONCENTRATION CONTOUR
- (0) CHEMICAL NOT DETECTED
- (129) CONCENTRATION USED FOR CONTOURING
- - - NON DETECT LINE
- SL SURFICIAL LOWER
- SU SURFICIAL UPPER
- UG/L MICROGRAMS PER LITER
- ➔ GROUNDWATER FLOW DIRECTION

0 50 100  
SCALE IN FEET

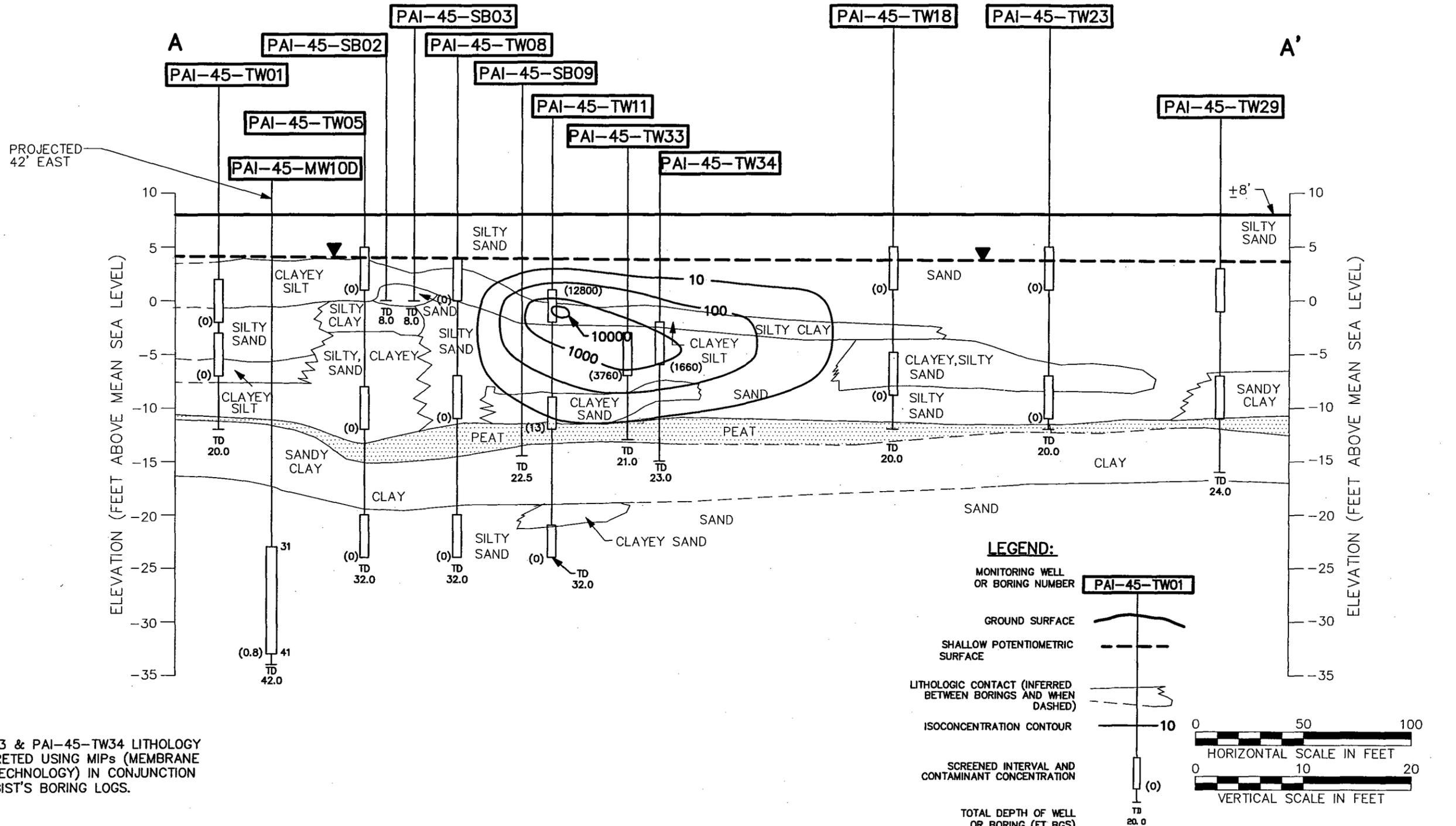
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJB DATE 12/10/01  
 CHECKED BY DATE  
 COST/SCHED-AREA  
 SCALE AS NOTED



TCE GROUNDWATER RESULTS (11-20 FEET) UG/L  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 4-9	REV. 0



**NOTES:**

PAI-45-TW33 & PAI-45-TW34 LITHOLOGY WAS INTERPRETED USING MIPs (MEMBRANE INTERFACE TECHNOLOGY) IN CONJUNCTION WITH GEOLOGIST'S BORING LOGS.

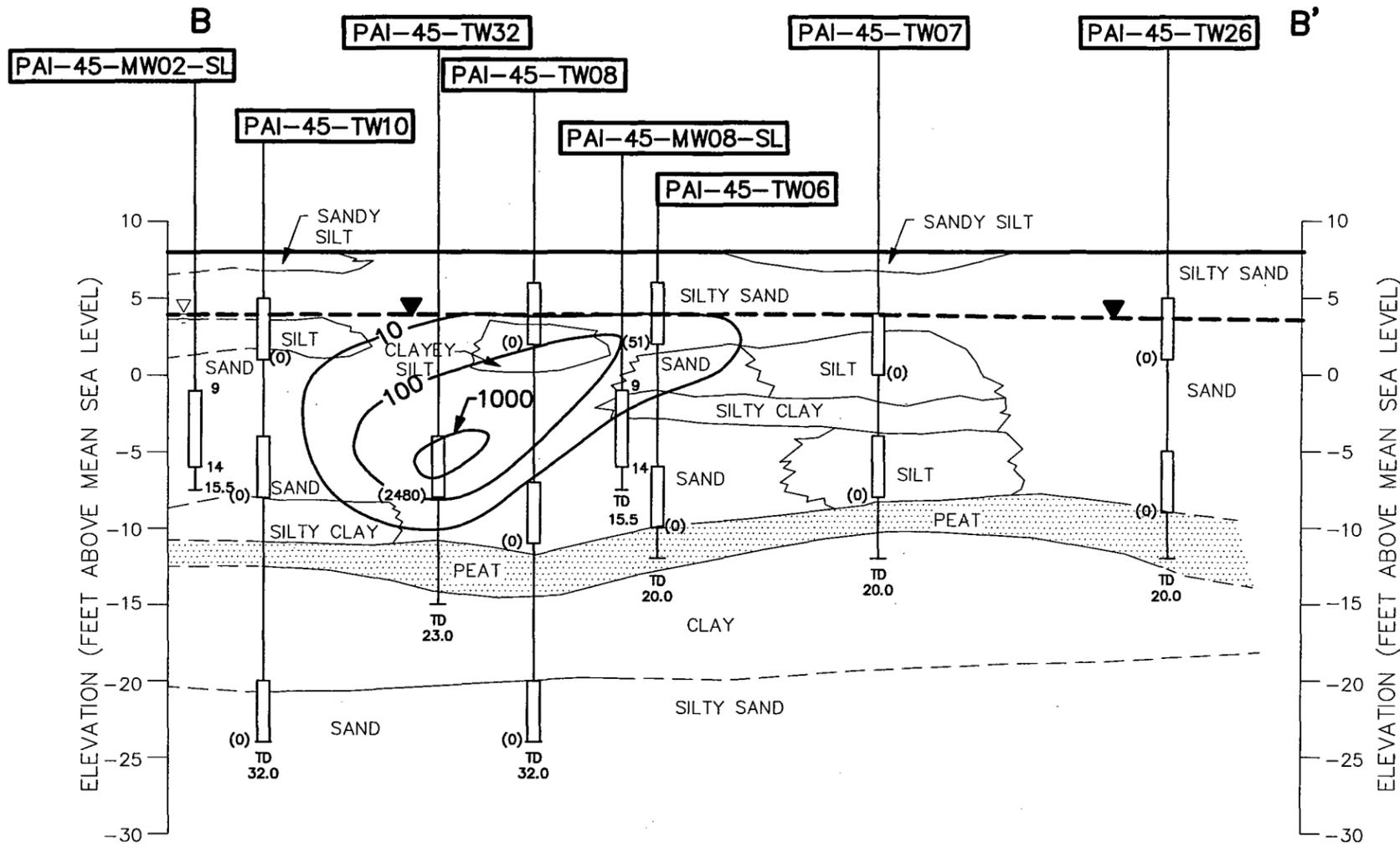
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJB DATE 3/6/02  
 CHECKED BY DATE  
 COST/SCHED-AREA  
 SCALE AS NOTED



**TRICHLOROETHENE ISOCONCENTRATION CONTOUR**  
**CROSS SECTION A-A'**  
 SITE 45  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

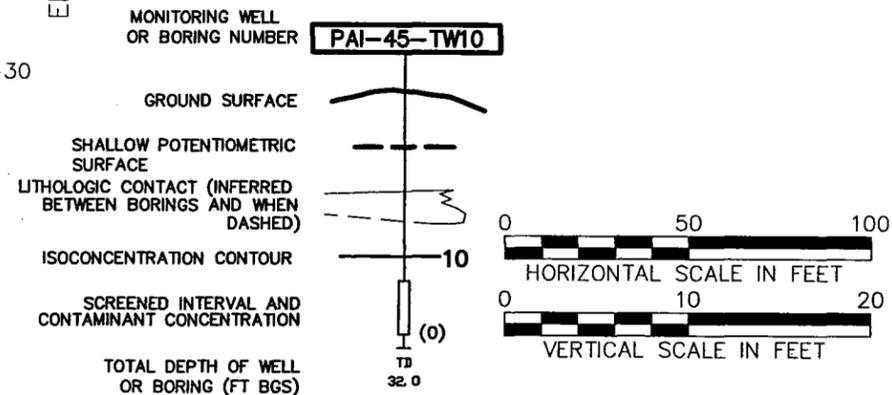
CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 4-10	REV. 0



**NOTE:**

PAI-45-TW32'S LITHOLOGY WAS INTERPRETED USING MIPs (MEMBRANE INTERFACE PROBE) TECHNOLOGY

**LEGEND:**



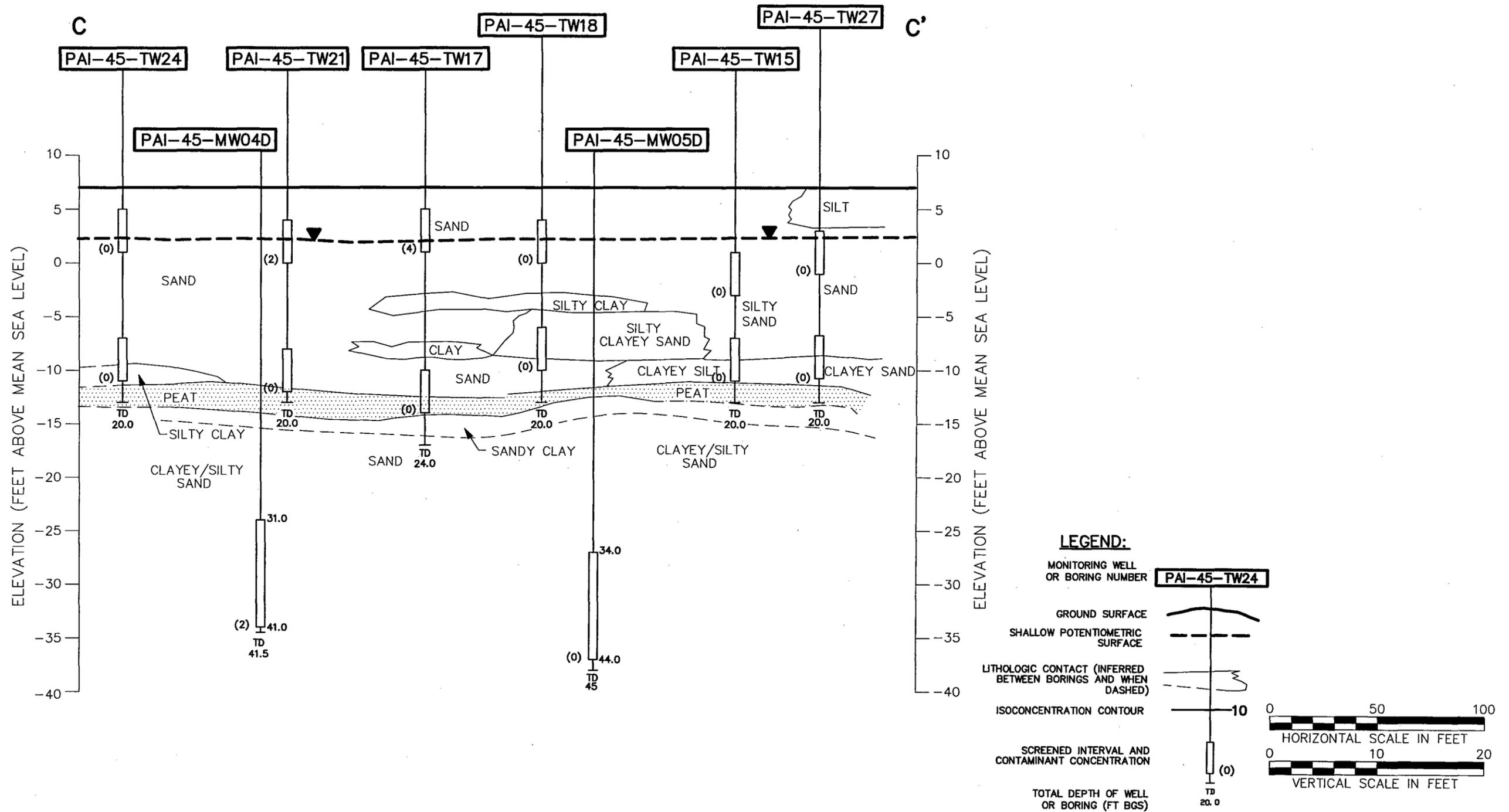
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJB DATE 3/6/02  
 CHECKED BY DATE  
 COST/SCHED-AREA  
 SCALE AS NOTED



TRICHLOROETHENE ISOCONCENTRATION  
 CONTOUR MAP  
 CROSS SECTION B-B'  
 SITE 45  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 4-11	REV. 0



**LEGEND:**

- MONITORING WELL OR BORING NUMBER: PAI-45-TW24
  - GROUND SURFACE: [Symbol]
  - SHALLOW POTENTIOMETRIC SURFACE: [Symbol]
  - LITHOLOGIC CONTACT (INFERRED BETWEEN BORINGS AND WHEN DASHED): [Symbol]
  - ISOCONCENTRATION CONTOUR: [Symbol]
  - SCREENED INTERVAL AND CONTAMINANT CONCENTRATION: [Symbol]
  - TOTAL DEPTH OF WELL OR BORING (FT BGS): [Symbol]
- 0 50 100  
HORIZONTAL SCALE IN FEET
- 0 10 20  
VERTICAL SCALE IN FEET

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

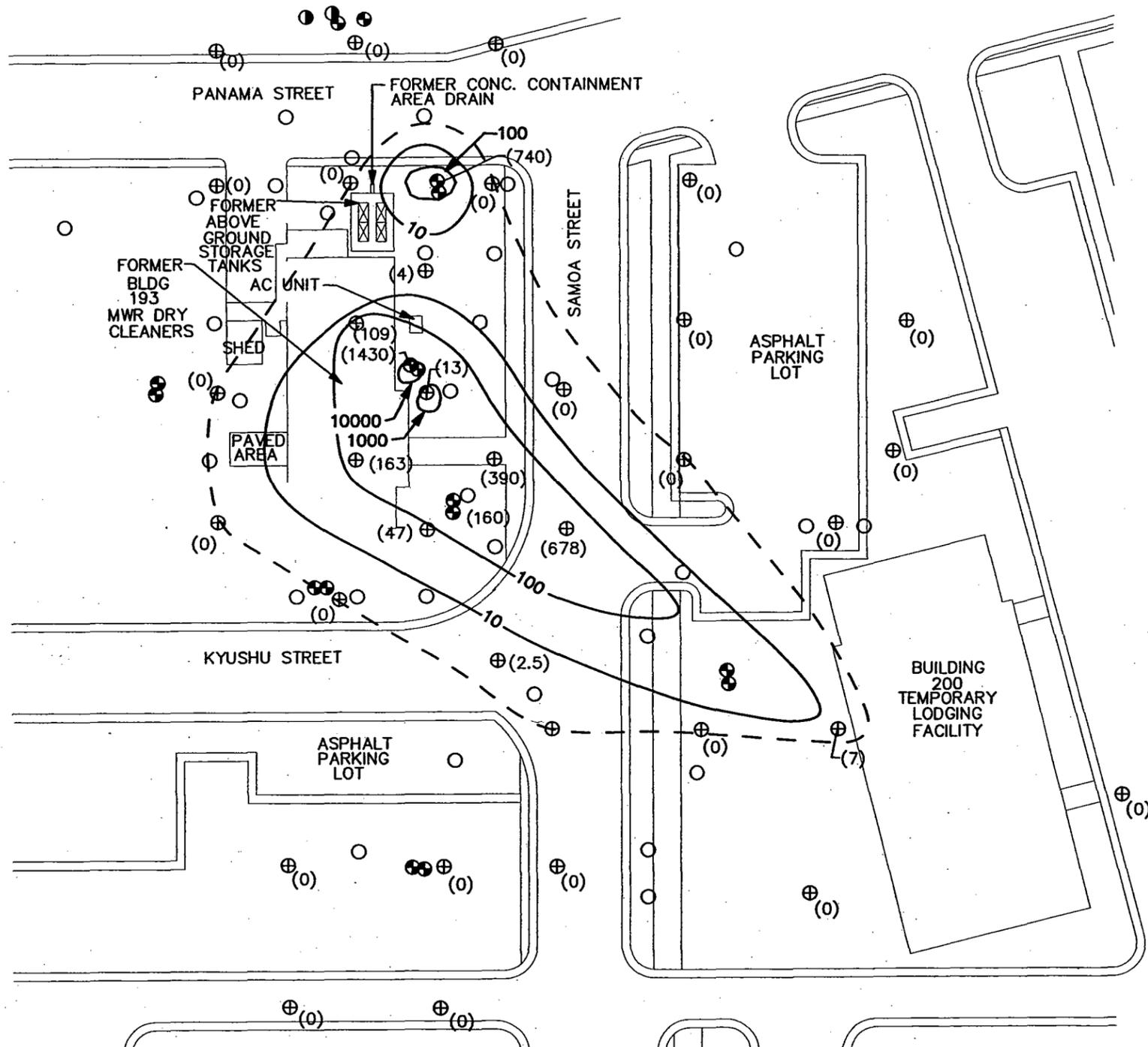
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 CHECKED BY: DATE:   
 COST/SCHED-AREA:   
 SCALE: AS NOTED



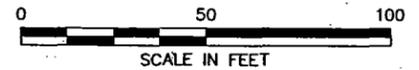
**TRICHLOROETHENE ISOCONCENTRATION  
 CONTOUR MAP  
 CROSS SECTION C-C'  
 SITE 45  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA**

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 4-12	REV. 0





- LEGEND:**
- TEMPORARY MONITORING WELL (1996)
  - ⊕ PERMANENT MONITORING WELL PAI-45-MW01-SU
  - ⊕ TEMPORARY MONITORING WELL (2001) PAI-45-TW01
  - TEST WELLS FOR AIR SPARING PILOT TEST (1996) T1
  - 10 ——— ISOCONCENTRATION CONTOUR
  - (0) CHEMICAL NOT DETECTED
  - (47) CONCENTRATION USED FOR CONTOURING
  - - - NON DETECT LINE
  - SL SURFICIAL LOWER
  - SU SURFICIAL UPPER
  - UG/L MICROGRAMS PER LITER
  - ➔ GROUNDWATER FLOW DIRECTION



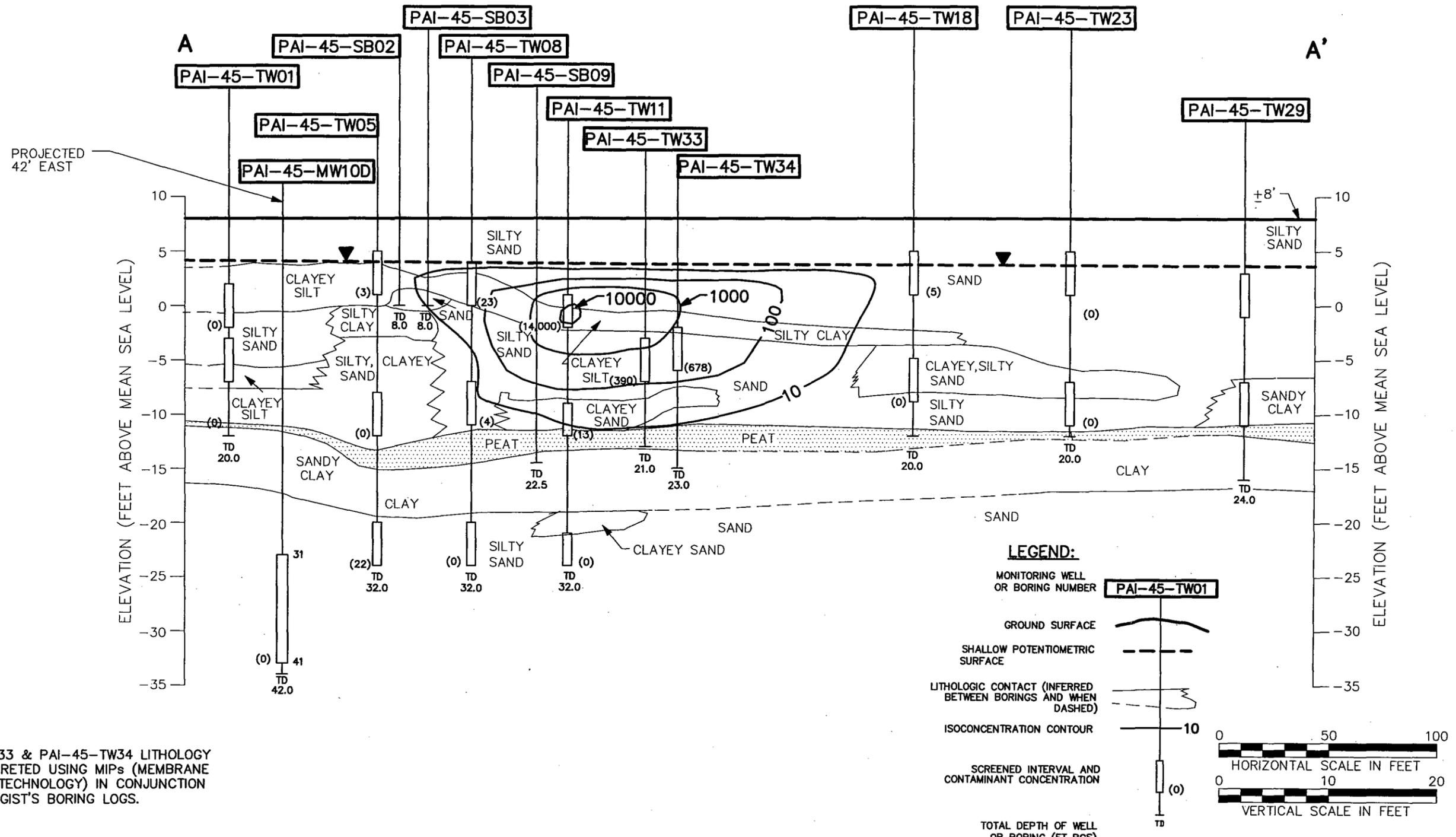
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJB	DATE 3/6/02
CHECKED BY	DATE
COST/SCHED-AREA	
SCALE AS NOTED	



CIS-1,2 DCE GROUNDWATER RESULTS  
(11-20 FEET) UG/L  
SITE 45 - MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND  
PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 4-14	REV. 0



**NOTES:**  
 PAI-45-TW33 & PAI-45-TW34 LITHOLOGY WAS INTERPRETED USING MIPs (MEMBRANE INTERFACE TECHNOLOGY) IN CONJUNCTION WITH GEOLOGIST'S BORING LOGS.

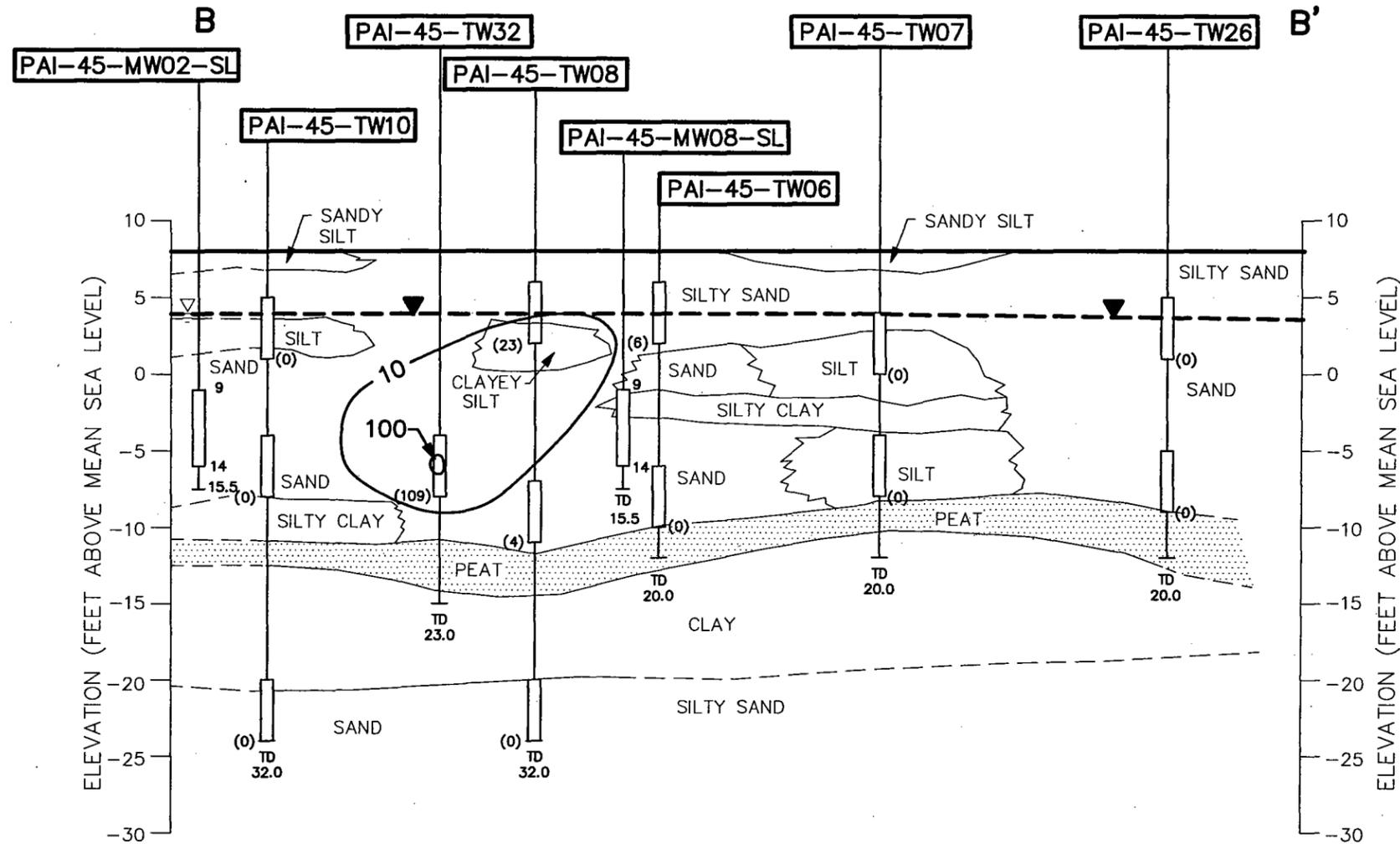
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DRAWN BY HJB 3/7/02  
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 COST/SCHED-AREA  
 SCALE AS NOTED

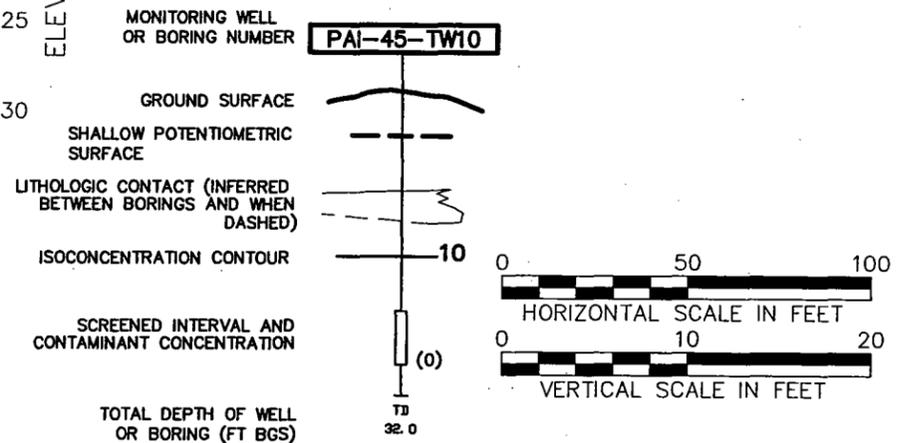


CIS-1,2-DICHLOROETHENE  
 ISOCONCENTRATION CONTOUR MAP  
 CROSS SECTION A-A'  
 SITE 45  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 4-15	REV. 0



**LEGEND:**



**NOTE:**

PAI-45-TW32'S LITHOLOGY WAS INTERPRETED USING MIPs (MEMBRANE INTERFACE PROBE) TECHNOLOGY

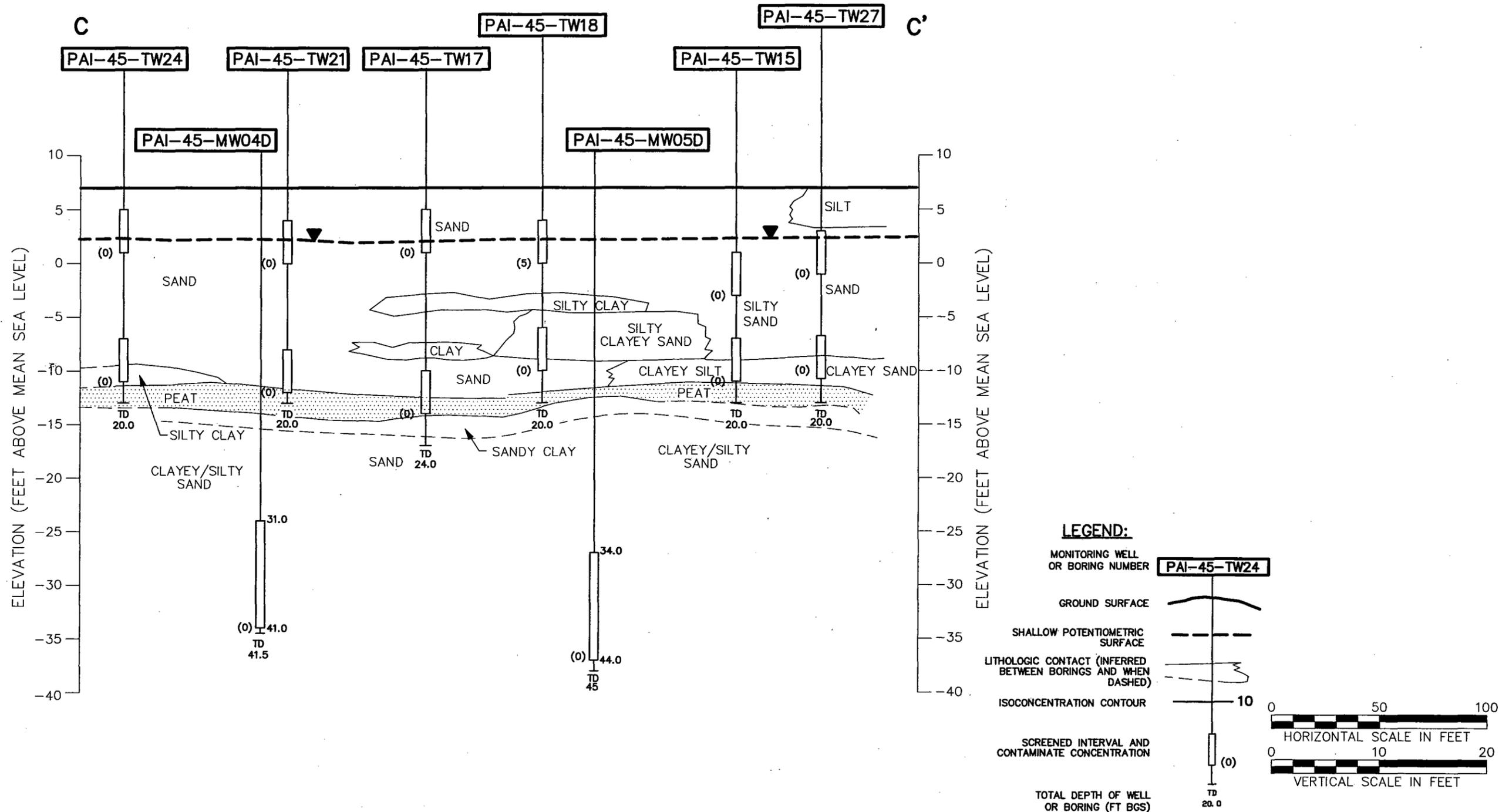
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJB DATE 3/7/02  
 CHECKED BY DATE  
 COST/SCHED-AREA  
 SCALE AS NOTED



CIS-1,2-DICHLOROETHENE  
 ISOCONCENTRATION CONTOUR MAP  
 CROSS SECTION B-B'  
 SITE 45  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 4-16	REV. 0



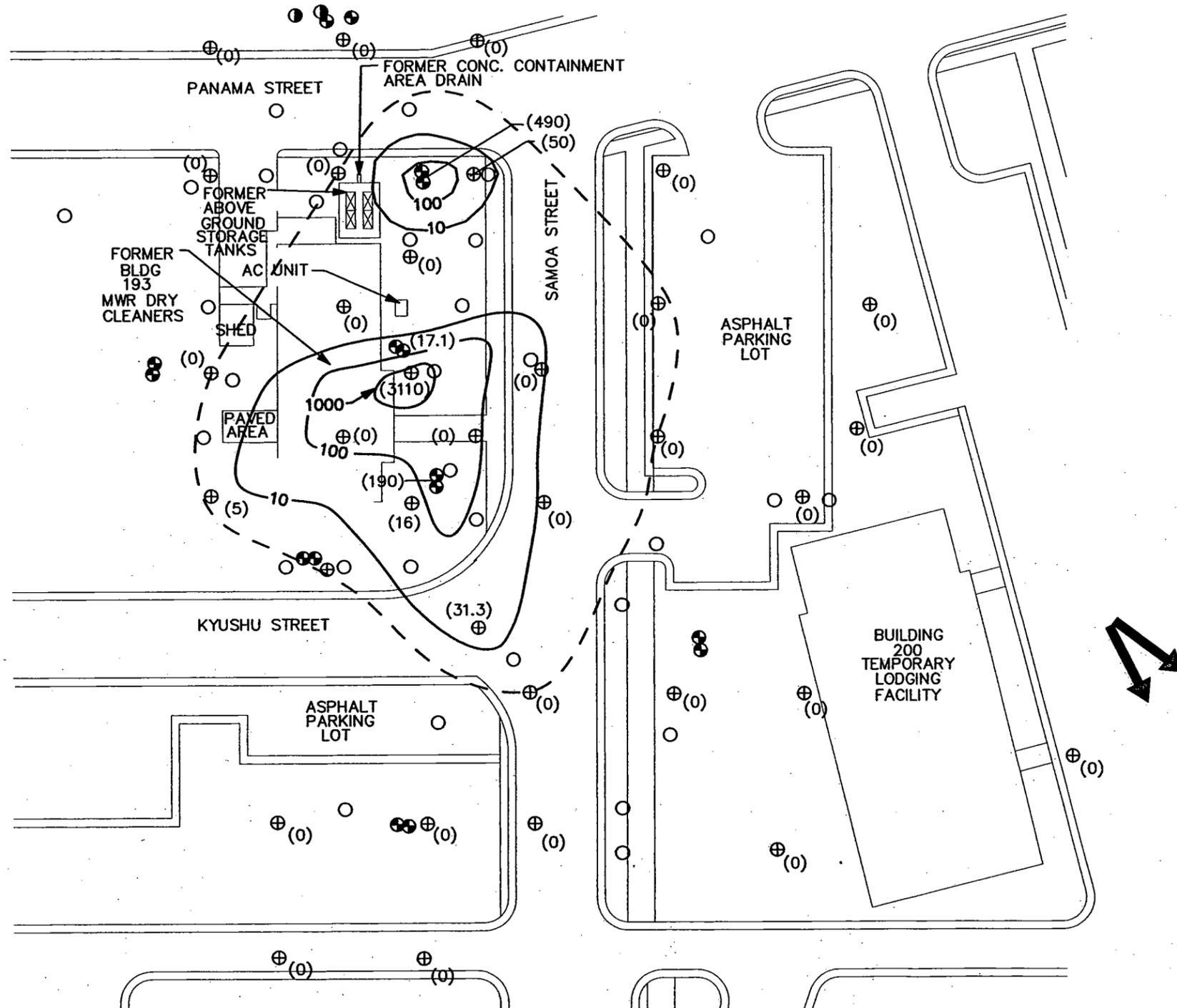
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY	DATE
HJB	3/7/02
CHECKED BY	DATE
COST/SCHED-AREA	
SCALE	
AS NOTED	

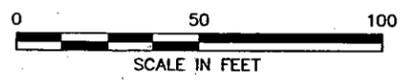


CIS-1,2-DICHLOROETHENE  
 ISOCONCENTRATION CONTOUR MAP  
 CROSS SECTION C-C'  
 SITE 45  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO.	
0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO.	REV.
FIGURE 4-17	0



- LEGEND:**
- TEMPORARY MONITORING WELL (1996)
  - ⊕ PERMANENT MONITORING WELL PAI-45-MW01-SU
  - ⊕ TEMPORARY MONITORING WELL (2001) PAI-45-TW01
  - ⊙ T1 TEST WELLS FOR AIR SPARING PILOT TEST (1996)
  - 10 ——— ISOCONCENTRATION CONTOUR
  - (0) CHEMICAL NOT DETECTED
  - (47) CONCENTRATION USED FOR CONTOURING
  - - - NON DETECT LINE
  - SL SURFICIAL LOWER
  - SU SURFICIAL UPPER
  - UG/L MICROGRAMS PER LITER
  - ➔ GROUNDWATER FLOW DIRECTION



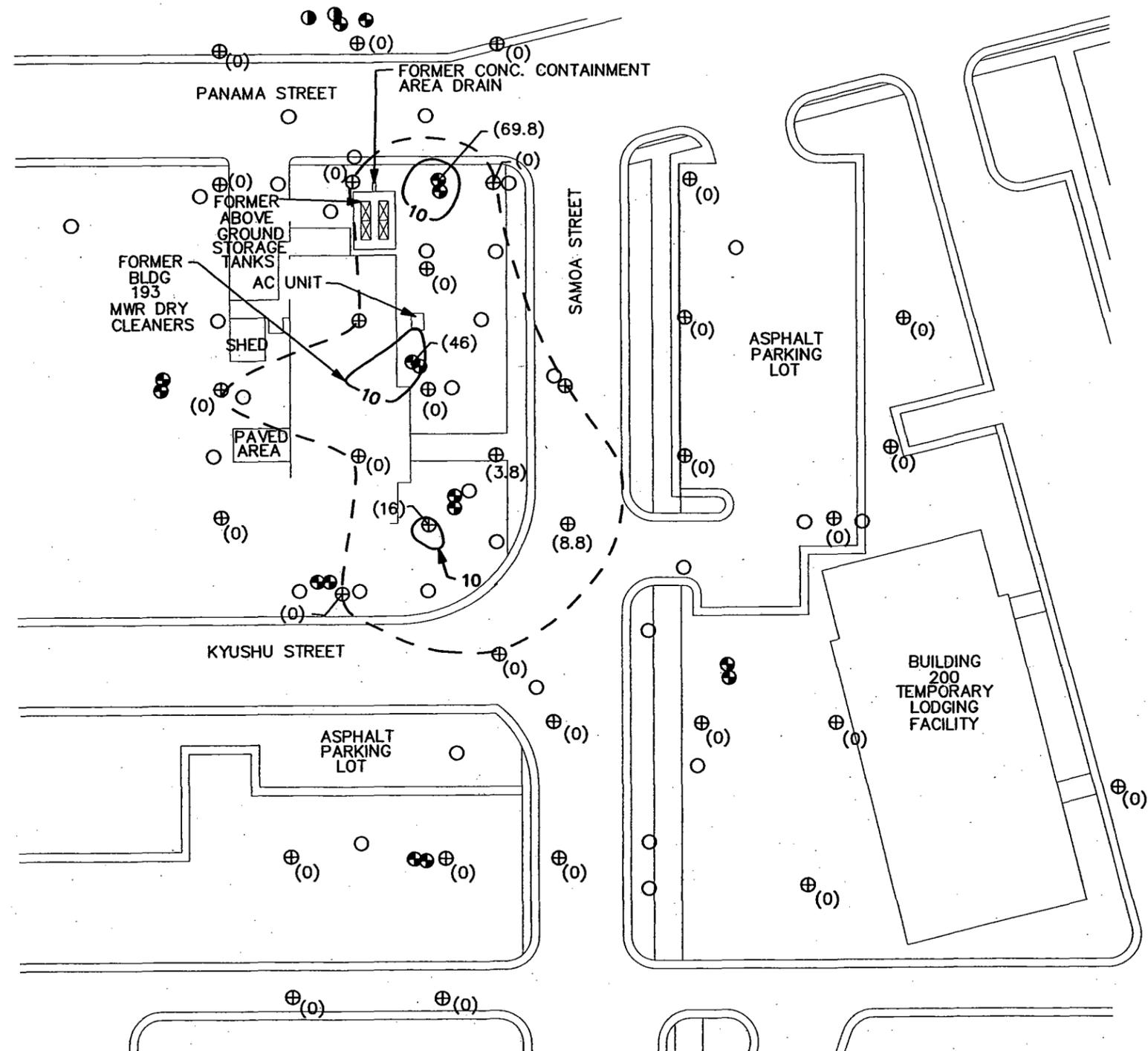
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJB DATE 3/6/02  
 CHECKED BY \_\_\_\_\_ DATE \_\_\_\_\_  
 COST/SCHED-AREA \_\_\_\_\_  
 SCALE AS NOTED

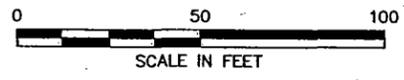


**VINYL CHLORIDE GROUNDWATER RESULTS**  
 (0-10 FEET) UG/L  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 4-18	REV. 0



- LEGEND:**
- TEMPORARY MONITORING WELL (1996)
  - PERMANENT MONITORING WELL PAI-45-MW01-SU
  - ⊕ TEMPORARY MONITORING WELL (2001) PAI-45-TW01
  - T1 TEST WELLS FOR AIR SPARING PILOT TEST (1996)
  - 10 ——— ISOCONCENTRATION CONTOUR
  - (0) CHEMICAL NOT DETECTED
  - (8.8) CONCENTRATION USED FOR CONTOURING
  - - - NON DETECT LINE
  - SL SURFICIAL LOWER
  - SU SURFICIAL UPPER
  - UG/L MICROGRAMS PER LITER
  - ➔ GROUNDWATER FLOW DIRECTION



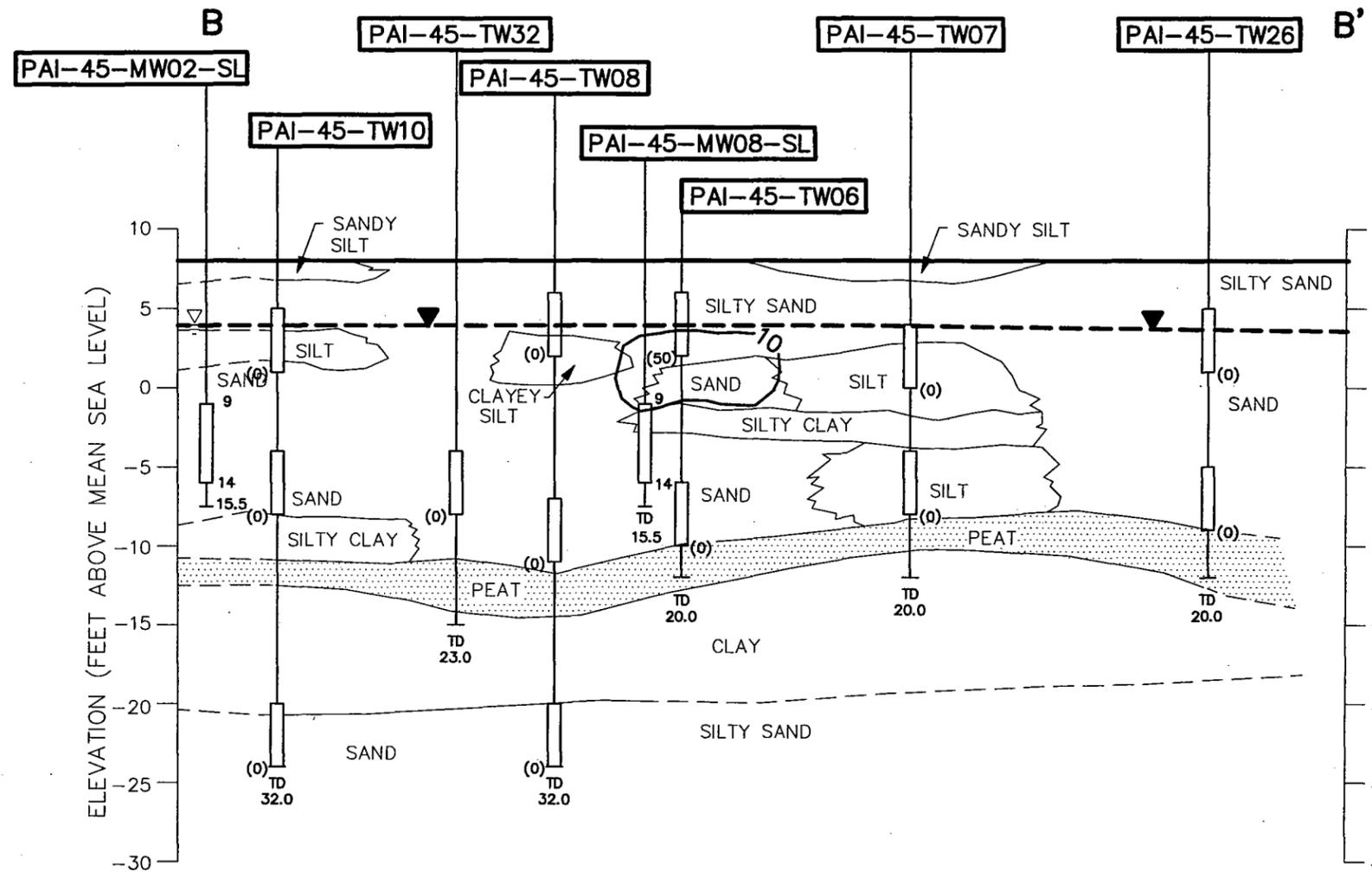
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJB DATE 3/6/02  
 CHECKED BY DATE  
 COST/SCHED-AREA  
 SCALE AS NOTED

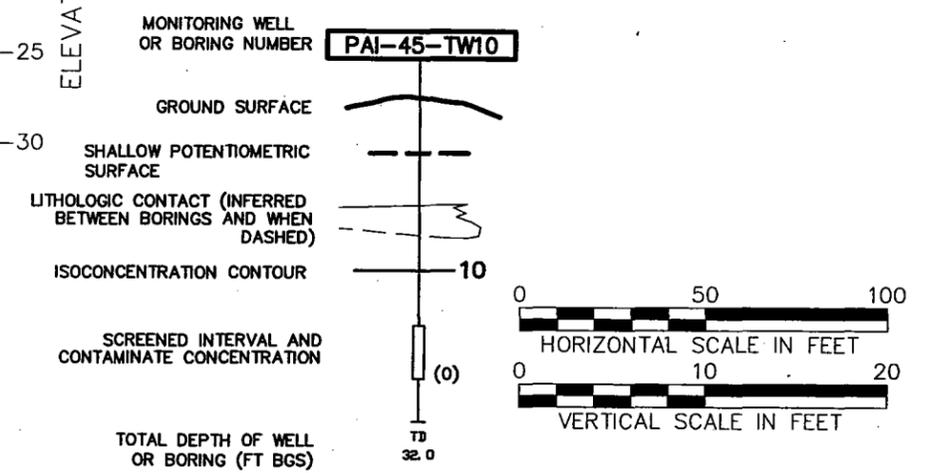
VINYL CHLORIDE GROUNDWATER RESULTS  
 (11-20 FEET) UG/L  
 SITE 45 - MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 4-19	REV. 0





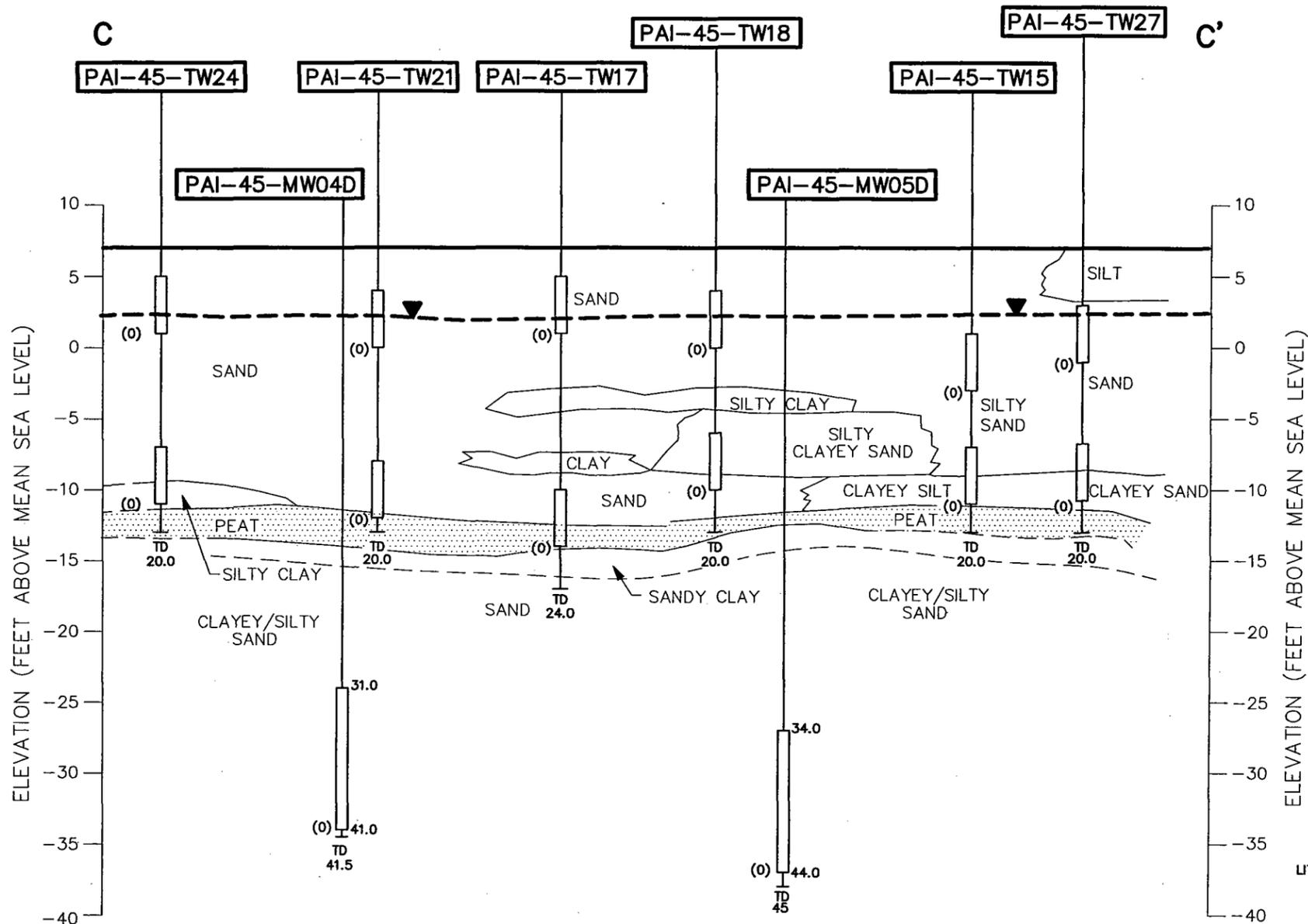
**LEGEND:**



**NOTE:**

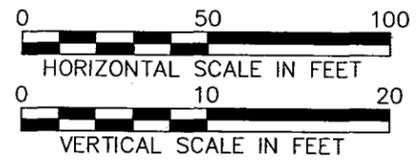
PAI-45-TW32'S LITHOLOGY WAS INTERPRETED USING MIPs (MEMBRANE INTERFACE PROBE) TECHNOLOGY

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES	DRAWN BY HJB	DATE 3/7/02		VINYL CHLORIDE ISOCONCENTRATION CONTOUR MAP CROSS SECTION B-B' SITE 45 MCRD PARRIS ISLAND PARRIS ISLAND, SOUTH CAROLINA		CONTRACT NO. 0502	
							CHECKED BY	DATE		APPROVED BY	DATE	APPROVED BY	DATE
							COST/SCHED-AREA					DRAWING NO. FIGURE 4-21	REV. 0
							SCALE AS NOTED						



**LEGEND:**

- MONITORING WELL OR BORING NUMBER **PAI-45-TW24**
- GROUND SURFACE
- SHALLOW POTENTIOMETRIC SURFACE
- LITHOLOGIC CONTACT (INFERRED BETWEEN BORINGS AND WHEN DASHED)
- ISOCONCENTRATION CONTOUR 10
- SCREENED INTERVAL AND CONTAMINATE CONCENTRATION
- TOTAL DEPTH OF WELL OR BORING (FT BGS) TD 20.0



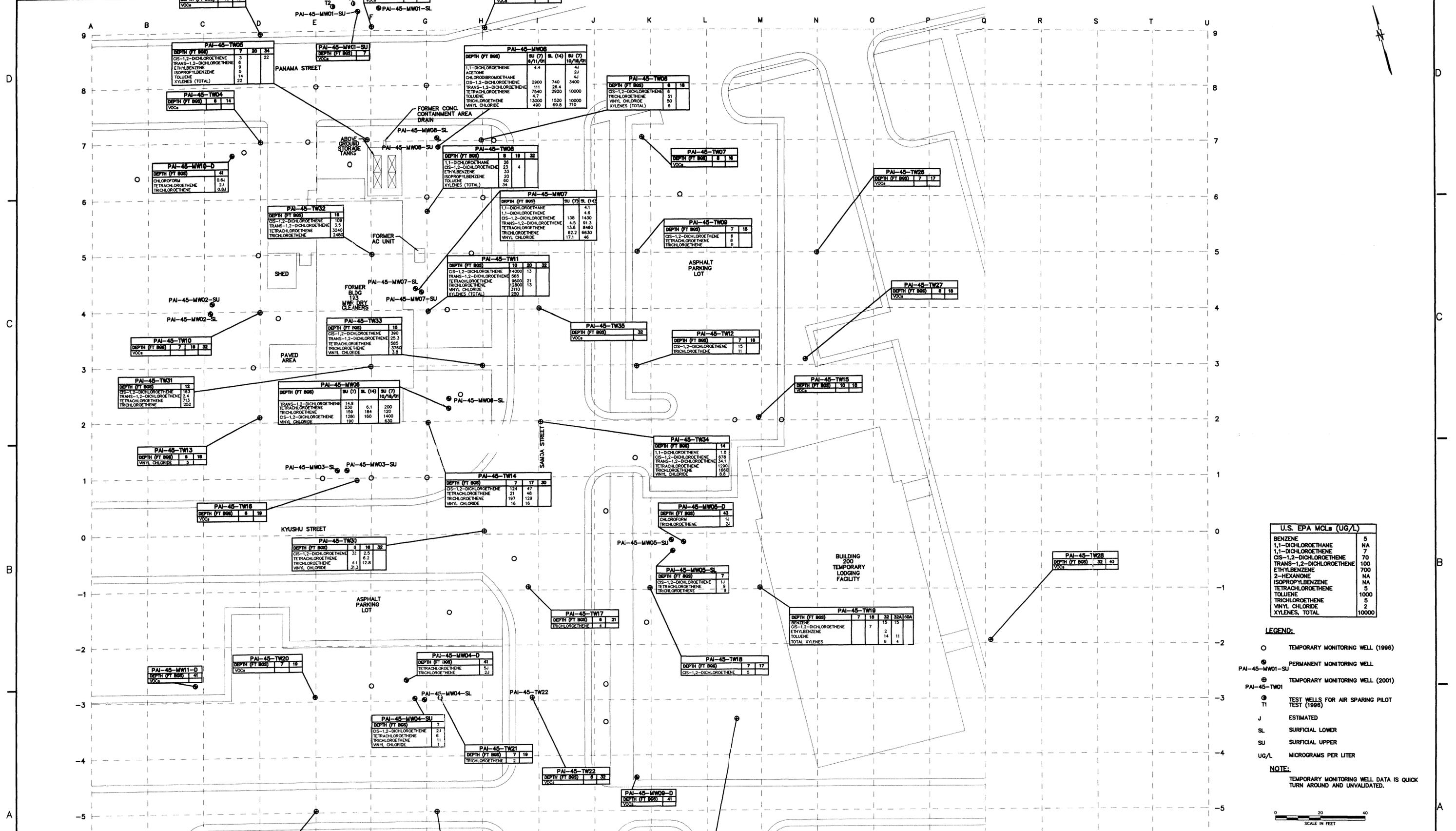
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJB DATE 3/7/02  
 CHECKED BY DATE  
 COST/SCHED-AREA  
 SCALE AS NOTED



VINYL CHLORIDE ISOCONCENTRATION  
 CONTOUR MAP  
 CROSS SECTION C-C'  
 SITE 45  
 MCRD PARRIS ISLAND  
 PARRIS ISLAND, SOUTH CAROLINA

CONTRACT NO. 0502	
APPROVED BY	DATE
APPROVED BY	DATE
DRAWING NO. FIGURE 4-22	REV. 0



**U.S. EPA MCLs (UG/L)**

BENZENE	5
1,1-DICHLOROETHANE	NA
1,1-DICHLOROETHENE	7
CIS-1,2-DICHLOROETHENE	100
TRANS-1,2-DICHLOROETHENE	700
ETHYLBENZENE	NA
2-HEXANONE	NA
ISOPROPYLBENZENE	5
TETRACHLOROETHENE	1000
TOLUENE	5
TRICHLOROETHENE	2
VINYL CHLORIDE	5
XYLENES, TOTAL	10000

- LEGEND:**
- TEMPORARY MONITORING WELL (1996)
  - PERMANENT MONITORING WELL
  - PAI-45-MW01-SU
  - ⊕ TEMPORARY MONITORING WELL (2001)
  - PAI-45-TW01
  - ⊙ TEST WELLS FOR AIR SPARING PILOT TEST (1996)
  - T1
  - J ESTIMATED
  - SL SURFICIAL LOWER
  - SU SURFICIAL UPPER
  - UG/L MICROGRAMS PER LITER

**NOTE:**  
TEMPORARY MONITORING WELL DATA IS QUICK TURN AROUND AND UNVALIDATED.



DRAWN BY HJP CHECKED BY REVISED BY SCALE AS NOTED	DATE 6/25/01 DATE DATE		CONTRACT NO. OWNER NO. APPROVED BY DATE
GROUNDWATER RESULTS TEMPORARY AND PERMANENT MONITORING WELLS SITE 45 - MWR DRY CLEANING FACILITY MCRD PARRIS ISLAND PARRIS ISLAND, SOUTH CAROLINA			DRAWING NO. FIGURE 4-23 REV. 0

## 5.0 CHEMICAL FATE AND TRANSPORT ANALYSIS

This section contains information on contaminant fate and transport and the chemical properties affecting contaminant migration at Site 45. Section 5.1 discusses the chemical and physical properties of the detected analytes. Section 5.2 presents brief discussions of contaminant persistence. Section 5.3 presents a summary of contaminant migration. Section 5.4 presents a natural attenuation evaluation using site-specific data.

### 5.1 CHEMICAL AND PHYSICAL PROPERTIES

Chemical and physical properties are used to estimate the environmental behavior of site chemicals. Table 5-1 presents the chemical and physical properties of the organics detected Site 45. Table 5-2 presents the chemical and physical properties of the detected inorganics. Empirically determined literature values of the water solubility, octanol/water partition coefficient, organic carbon partition coefficient, vapor pressure, Henry's Law constant, bioconcentration factor, and specific gravity are presented on these tables, when available. Calculated values, which were obtained using approximation methods, are presented when literature values are not available.

### 5.2 CHEMICAL PERSISTENCE

The persistence of various classes of chemicals is discussed in this section. Several transformation mechanisms affect chemical persistence, such as hydrolysis, biodegradation, photolysis, and oxidation/reduction reactions. The following general classes of compounds are discussed:

- Ketones
- Monocyclic aromatics
- Halogenated aliphatics
- PAHs
- Phthalate esters
- Metals

#### 5.2.1 Ketones

Ketones are highly volatile and soluble, and these two characteristics dominate the fate of these compounds in the environment. Hydrolysis is generally not a significant fate process for this class of chemicals nor is bioconcentration significant, based on the low  $K_{ow}$ s (Howard, 1990).

2-Butanone (methyl ethyl ketone) may be removed from soil by direct photolysis, volatilization, or aerobic biodegradation. It is also susceptible to leaching and may be found in groundwater. If released to surface water, it has a estimated atmospheric half-life of about 14 days and is also subject to direct photolysis. 2-Butanone does not significantly bioconcentrate or adsorb to soil and is expected to biodegrade under aerobic and anaerobic conditions (TOXNET, online, 2001).

### **5.2.2 Monocyclic Aromatics**

Monocyclic aromatic compounds such as chlorobenzene and ethylbenzene are not considered to be persistent in the environment, particularly in comparison to chemicals such as PCBs and pesticides. Monocyclic aromatics are subject to degradation via the action of both soil and aquatic microorganisms. The biodegradation of these compounds in the soil matrix is dependent on the abundance of microflora, macronutrient availability, soil reaction (pH), temperature, etc.

Although these compounds are amenable to microbial degradation, it is not anticipated that degradation will occur at an appreciable rate, although macronutrient availability is not known. In the event that these compounds discharge to surface water bodies, volatilization and biodegradation may occur relatively rapidly.

However, chlorinated monocyclic aromatics such as chlorobenzene are not expected to be highly susceptible to microbial degradation. For example, a reported first-order biodegradation rate constant for chlorobenzene is  $0.0045 \text{ day}^{-1}$  in aquatic systems, which corresponds to an aquatic half-life of approximately 150 days.

Additional environmental degradation processes, such as hydrolysis and photolysis, are considered to be insignificant fate mechanisms for monocyclic aromatics in aquatic systems. However, some monocyclic aromatics such as benzene and toluene have been shown to undergo clay-, mineral-, and soil-catalyzed oxidation.

### **5.2.3 Halogenated Aliphatics**

In general, halogenated aliphatic hydrocarbons are subject to abiotic dehydrohalogenation. This process is an elimination reaction that results in the formation of an ethene from a saturated halogenated compound. Research indicates that microbial degradation of highly chlorinated ethanes is a relatively slow process. Hydrolysis, photolysis, and oxidation are generally not considered to be significant fate processes for the chlorinated ethanes.

Under certain conditions, volatilization is a significant fate process for these compounds. Volatilization is only significant at the air-soil or air-water interface. Compounds such as chloroform and methylene

chloride volatilize rapidly to the atmosphere from soil or surface water due to low soil adsorption. Adsorption should not be considered as an important fate for these types of compounds when compared to more hydrophobic compounds. Bioconcentration factors indicate that these compounds should not bioaccumulate.

Photolysis is not considered to be a relevant degradation mechanism for this class of compounds. Limited hydrolysis of saturated aliphatics (i.e., alkanes) may occur, but it does not appear to be a significant degradation mechanism for unsaturated species (i.e., alkenes).

#### 5.2.4 PAHs

PAHs have very low solubilities, vapor pressures, and Henry's Law constants and high  $K_{oc}$ s and  $K_{ow}$ s. The lower-molecular-weight PAHs (e.g., acenaphthene, anthracene, fluorene, and phenanthrene) are more environmentally mobile than the higher molecular weight PAHs and are more likely to leach to groundwater. The high-molecular-weight PAHs [e.g., benzo(a)pyrene, benz(a)anthracene, chrysene, etc.] are less mobile and tend to adhere to soil particles. Therefore, PAHs in soil are much more likely to bind to soil and be transported via mass transport mechanisms than to go into solution. PAHs are subject to degradation via aerobic bacteria but may be relatively persistent in the absence of microbial population or macronutrients such as phosphorus and nitrogen.

Bioconcentration of PAHs in aquatic organisms is greater for the higher-molecular-weight compounds than the lower-molecular-weight compounds. PAHs can be bioaccumulated from water, sediments, or lower organisms in the food chain.

Landspreading applications have indicated that PAHs are highly amenable to microbial degradation in soil. The rate of degradation is influenced by temperature, pH, oxygen concentrations, initial chemical concentrations, and moisture. Photolysis, hydrolysis, and oxidation are not important fate processes for the degradation of PAHs in soil.

The most important fates of PAHs in water are photo-oxidation, chemical oxidation, and biodegradation. PAHs do not contain functional groups that are susceptible to hydrolytic action, and hydrolysis is considered to be an insignificant degradation mechanism. The rate of photodegradation is influenced by water depth, turbidity, and temperature. Benzo(a)pyrene and chrysene are reported to be resistant to photodegradation. PAHs may also be oxidized by chlorination and ozonation and may be metabolized by microbes under oxygenated conditions.

### **5.2.5 Phthalate Esters**

Phthalate esters are considered to be relatively persistent chemicals in the environment. Although numerous studies have demonstrated that phthalate esters undergo biodegradation, it appears that this is a slow process in both soils and surface waters. Certain microorganisms have been shown to excrete products that increase the solubility of phthalate esters and enhance their biodegradation.

Biodegradation of bis(2-ethylhexyl) phthalate and di-n-butyl phthalate in water is an important fate mechanism. However, hydrolysis of bis(2-ethylhexyl) phthalate is very slow, with a calculated half-life of 2,000 years (U.S. EPA, December 1979). In soil, microorganisms appear to be capable of degrading di-n-butyl phthalate rapidly. Bioaccumulation is also a significant fate process. Photolysis and volatilization are considered to be insignificant degradation mechanisms.

### **5.2.6 Metals**

Metals are highly persistent environmental contaminants. They do not biodegrade, photolyze, hydrolyze, etc. The major fate mechanisms for metals are adsorption to the soil matrix (as compared to being part of the soil structure) and bioaccumulation.

The mobility of metals is influenced primarily by their physical and chemical properties, in combination with the physical and chemical characteristics of the soil matrix. Factors that assist in predicting the mobility of inorganic species are the soil/pore water pH, soil/pore water Eh, and cation exchange capacity. The mobility of metals generally increases with decreasing soil pH and cation exchange capacity (Table 5-2).

## **5.3 CHEMICAL MIGRATION**

This section presents a brief overview of contaminant fate and transport issues for volatile organics, PAHs, and metals.

### **5.3.1 Volatile Organics**

Volatile organic chemicals are typically considered to be fairly soluble and have a low capacity for retention by soil organic carbon; therefore, volatiles are the organic compounds most frequently detected in groundwater. Volatile organics may migrate through the soil column after they are released by a spill event or by subsurface waste burial as infiltrating precipitation solubilizes them. Some fraction of these chemicals is retained by the soil, but most will continue migrating downward to the water table. At that time, migration occurs primarily laterally with the hydraulic gradient. Again, some portion of the chemical may be retained by the saturated soil.

Several of these compounds have specific gravities less than that of water (e.g., ethylbenzene, toluene, and xylenes). These compounds are typically found in fuel, and if a large enough fuel spill occurs, these compounds may move through the soil column as a bulk liquid until they reach the water table. There, instead of going into solution, the majority of the release may remain as a discrete fuel layer on the water table surface, with some of the material going into solution at the water/fuel interface.

Similarly, compounds with specific gravities greater than that of water (e.g., PCE) are often used in various industrial applications such as dry cleaning facilities. If a large enough spill of these solvents occurs, these chemicals may also migrate as a bulk liquid but will not stop at the water table (i.e., these chemicals will mix and sink into the aquifer).

### **5.3.2 Polycyclic Aromatic Hydrocarbons**

PAHs are generally considered to be fairly immobile chemicals in the environment. They are large molecules with high organic carbon partition coefficients and low solubilities when compared to the volatile organics. These compounds, when found in the soil, generally do not migrate vertically to a great extent. Instead, they are more likely to adhere to soil particles and to be removed from the site via surface runoff and erosional processes.

### **5.3.3 Metals**

Because metals are frequently incorporated into the soil matrix and remain bound to particulate matter, they also migrate from the source areas via bulk movement processes (erosion). The larger particles (greater than 0.45 micron, which are removed via the filtration step prior to water analysis) are not generally considered to be mobile in groundwater. The metals detected in unfiltered groundwater samples are often representative of suspended soil material in the samples.

There are some instances, however, where these metals are found at such concentrations or in such form as to be able to migrate in solution. It is possible that industrial activities could saturate all available exchange sites in soil and hence a metal may be mobilized. Metals are also more mobile under acidic conditions, which may exist in areas where plating-type activities have occurred. Finally, a metal solution may be utilized in some industrial applications. In these cases, it is possible for metals to migrate vertically through the soil column and reach the groundwater.

## 5.4 NATURAL ATTENUATION EVALUATION

A primary focus of the Site 45 RI/RFI field investigation was to determine whether natural attenuation processes are active at the site and, if so, to identify the extent of impacts of natural attenuation on contaminant concentrations (chlorinated ethenes) in groundwater. The fieldwork performed in support of this evaluation included groundwater sampling and analysis, along with general aquifer characterization activities (pumping test, slug tests, water-level measurements and flow mapping). Preceding sections of this RI Report describe the field program in detail and present a detailed discussion of the results of the aquifer characterization activities. This section provides a summary discussion of the natural attenuation evaluation; Appendix E provides a detailed presentation and evaluation of the natural-attenuation-related data that were collected. Table 5-3 provides a summary of the natural-attenuation-related data.

Guidance documents for evaluating natural attenuation processes at a site (U.S. EPA, 1997; U.S. EPA, 1998) suggest that a weight-of-evidence approach be taken to evaluate the impacts of natural attenuation processes on contaminant concentration changes in groundwater. Lines of evidence that can be used to support the natural attenuation evaluation include

- Historical groundwater and/or soil chemistry data that demonstrate a clear and meaningful trend of declining contaminant mass and/or concentration over time.
- Hydrogeologic and geochemical data that can be used to demonstrate indirectly the type(s) of natural attenuation processes active at the site and the rate at which such processes will reduce contaminant concentrations to required levels.
- Data from field or microcosm studies that directly demonstrate the occurrence of a particular natural attenuation process at the site and its ability to degrade the contaminants of concern.

Of the three lines of evidence above, the first two are preferred approaches to evaluating natural attenuation processes, and the third is a supplementary approach that can be implemented if site conditions or other constraints preclude adequate evaluation using the two preferred approaches. For the groundwater investigation at Site 45, data were collected to support a natural attenuation evaluation using the two primary approaches described above.

### 5.4.1 Direct Evidence of Biodegradation

For chlorinated ethenes, the biodegradation process is characterized primarily by the sequential loss of chlorines (dechlorination) through both anaerobic and aerobic processes. In the dechlorination process, the primary degradation path for chlorinated ethenes involves the breakdown of PCE to TCE, which

degrades to 1,2-DCE (primarily cis-1,2-DCE), which breaks down to vinyl chloride (VC), which is then degraded to carbon dioxide or ethene. Reductive (anaerobic) dechlorination is the most effective biodegradation process for PCE and TCE, and DCE and VC can be biodegraded both anaerobically through reductive dechlorination and aerobically through direct metabolism and cometabolism (TCE can also degrade aerobically through cometabolism). Under anaerobic conditions, the rate of biodegradation decreases as the degree of chlorination decreases (PCE and TCE will degrade more readily and quickly than DCE and VC); the opposite is generally true for aerobic biodegradation processes.

At Site 45, PCE is the only chlorinated solvent reported to have been used; therefore, the observed presence of TCE, DCE, and VC in groundwater is a strong indicator that biodegradation processes are active at the site. The October 2001 concentrations of PCE, TCE, DCE, and VC detected in selected wells at the site are presented in Table 5-3. Well MW08SU is the source area well, and MW06SU, MW05SL, and MW04SU are located progressively farther downgradient from the source area. Based on historic information, monitoring well MW05SL was observed to contain greater concentrations of VOCs than MW05SU. This data suggests that MW05SL is a more appropriate downgradient monitoring well than MW05SU. PCE and TCE concentrations drop off significantly from MW08SU to MW06SU, and DCE and VC concentrations remain similar. This pattern indicates that PCE and TCE are actively undergoing reductive dechlorination to DCE and VC, and DCE and VC levels are relatively persistent (the rate of production of DCE/VC through biodegradation is approximately equal to the loss of DCE and VC through dispersion, dilution, and biodegradation). An alternative interpretation of the observed pattern may be that little degradation is taking place, and the observed changes in concentration are attributable to physical processes of dispersion and dilution, possibly influenced by past operation of the groundwater pumping system. Further downgradient at wells MW05SL and MW04SU, the dropoff of DCE and VC concentrations is greater than that of PCE and TCE, suggesting that aerobic degradation processes (co-metabolism and/or use of DCE and VC as primary growth substrate) become more active in the downgradient area.

This observed parent-daughter pattern of chlorinated ethenes concentration is the strongest and most conclusive evidence available that biodegradation processes are active in groundwater at Site 45. Overall, the pattern of contamination suggests mixed behavior of the chlorinated solvent plume, with anaerobic biodegradation in the source area and oxidation of vinyl chloride in the downgradient area, either aerobically or through iron reduction (U.S. EPA, 1998). This is considered the most favorable overall pattern for chlorinated solvent degradation, because both the more highly chlorinated and the less-chlorinated ethenes are degraded.

Table 5-4 is a comparison of 1996 to 2001 sampling results for wells MW08SU, MW06SU, MW05SL, and MW04SU. The relative proportions of PCE, TCE, DCE, and VC to the total amount of chlorinated

ethenes were calculated for each well for each sampling round, then were compared to see whether the proportions changed over time. For the source area well (MW08SU), the relative amount of PCE decreased in 2001 in comparison to 1996 (dropped from 84 percent of the total chlorinated ethenes to 41 percent), and the relative proportions of TCE, DCE, and VC increased. In well MW06SU, the relative proportions of PCE and TCE dropped in 2001, and the proportions of DCE and VC increased. In MW05SL, the relative proportions of the chlorinated ethenes did not materially change over time, and in MW04SU the relative proportion of PCE dropped and TCE and DCE proportions increased. These results show a definite pattern of dechlorination over time that is indicative of biodegradation activities.

Evaluating the ratio of cis-1,2-DCE to trans-1,2-DCE is another way of determining whether the biodegradation of TCE is occurring. Typically the biodegradation of TCE will result in higher concentrations of cis-1,2-DCE when compared to concentrations of trans-1,2-DCE. When evaluating groundwater data collected during the RI, samples with positive detects indicate a higher ratio of cis-1,2-DCE to trans-1,2-DCE. Samples collected from temporary wells TW01 through TW25 during March and April 2001, indicated a cis-/trans- ratio ranging from 4:1 to 124:1. The highest ratios were observed at TW14 (124:1 and 47:1), which is located approximately 50 feet downgradient of a source area (MW07).

Samples collected from temporary wells TW24 through TW35 and monitoring wells MW06SU/SL through MW08SU/SL during June 2001, indicated cis-/trans- ratios ranging from 5:1 to 160:1. The highest ratios were observed at MW06SU/SL (85:1 and 160:1, respectively) and TW31 (68:1). These locations are also located downgradient of a source area (MW07).

Samples collected from monitoring wells MW01SU, MW04SU, MW05SL, MW06SU, and MW08SU during October 2001, indicated cis-/trans- ratios ranging from 24:1 to 64:1. The highest ratios were observed at MW06SU (64:1) and MW08 (24:1). MW06 is located downgradient of the plume observed at MW07, and MW08 is located in the smaller plume to the north around the former AST area.

Given the ratios of cis-1,2-DCE to trans-1,2-DCE observed in the groundwater samples, it is reasonable to assume that TCE biodegradation is occurring, particularly within the source areas and downgradient of the source areas.

#### **5.4.2 Geochemical Indicators of Biodegradation**

Table 5-3 lists the results of both field and fixed-base lab geochemical analyses performed in support of the natural attenuation evaluation. Methane, an indicator of biological activity, is elevated in the source area and downgradient relative to the upgradient (MW01SU) concentration. It should be noted that upgradient well MW01SU is as close to a background well as feasible at the facility. Utilities, roadways,

and buildings restrict placing background wells in more strategic locations, (i.e. 30 to 50 feet to the west). Since there are no known unique sources of contamination hydraulically upgradient of the MW01 well cluster or the site, the plume is relatively wide (100 feet across) and groundwater from this cluster flows onto parts of the site, and the MW01 cluster wells do not contain detectable concentrations of site contaminants, this well cluster was selected as the upgradient well for the site. Chloride, which is produced when chlorine atoms are replaced by hydrogen during dechlorination processes, is elevated in the downgradient wells in comparison to the upgradient well. Carbon dioxide, an indicator of biologic respiration, is elevated in the source area and downgradient in comparison to the upgradient level. Total organic carbon, which is a measurement of the substrate available for biological activity, is elevated in the source area. Ferrous (reduced) iron, which is an indicator of moderately reducing conditions in groundwater, is elevated within the source area and immediately downgradient in comparison to the upgradient concentration (as groundwater becomes more reducing, oxygen, then nitrate, iron, sulfate, and finally carbonate are used by bio-organisms as electron acceptors and are thus reduced). Sulfate, which is reduced during anaerobic biological activity when the available ferric iron is reduced to ferrous iron, does not show a trend of decreasing concentration nor does the reduced form (sulfide) show an increase in concentration. This suggest that the reducing conditions in the aquifer have not progressed to the sulfate reduction level.

Dissolved oxygen (DO) levels of less than 0.5 mg/L and oxidation-reduction potential (ORP) measurements of less than 50 millivolts are generally considered indicative of a reducing environment. Contrary to what was expected based on other geochemical indicators, the DO levels measured in October 2001 are indicative of an aerobic environment. A review of historic sampling data, however, reveals a wide variation in DO levels, which may indicate that the groundwater environment changes seasonally or with discrete precipitation events, as discussed further in Appendix E. ORP readings on the other hand are in the reducing range in four of the five wells sampled in 2001. Historically, ORP readings in these wells have also varied (see Appendix E) but, with the exception of well MW04SU, have been predominantly within the reducing (less than 50 mV) range.

Chemical oxygen demand (COD) results for the 2001 round of sampling are elevated in the source area and near-downgradient wells (MW08SU and MW06SU) in comparison to the upgradient well and the further downgradient wells. COD levels indicate the amount of organics present in the water and are therefore an indicator of the degree of contamination.

#### **5.4.3 Biodegradation Screening**

As a supplement to the specific evaluations presented above, the EPA Worksheet for Screening for Anaerobic Biodegradation of Chlorinated Solvents was used to obtain an overall perspective regarding the likelihood that biodegradation processes are active at Site 45. Wells MW08SU, MW06SU, MW05SL,

and MW04SU were scored using the procedure developed by U.S. EPA and presented in their document Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water (U.S. EPA, 1998). Based on the scoring (see Appendix E, Attachment A), there is strong evidence of anaerobic biodegradation at well MW08SU (adequate evidence of anaerobic biodegradation at wells MW06SU and MW05SL and limited evidence of anaerobic biodegradation at well MW04SU). These results are consistent with the patterns of contamination and geochemistry observed at the site, where the data generally suggest anaerobic biodegradation in the source area and near downgradient area and groundwater conditions become more aerobic in the farther downgradient area.

#### **5.4.4 Contaminant Trends Over Time**

Sampling results for the Site 45 monitoring wells since 1996 were graphed to look for trends in contaminant concentrations over time. The time/concentration graphs in Appendix E, Attachment B generally show no strong trends in contaminant concentration changes over time in source area wells (MW08SU, MW08SL, MW07SU, MW07SL). Well MW06SU, located near the downgradient edge of the source area, has no apparent trend in overall chlorinated ethene concentrations; however, PCE and TCE levels have generally declined while DCE and VC levels have increased. A decline in overall contaminant levels over time is apparent in the adjacent deeper well MW06SL. For downgradient wells MW05SL and MW04SU, the chlorinated ethene concentrations dropped significantly over the 5-year time period, which is most likely due to the operation of the groundwater extraction system since source area concentrations appear to be remaining more or less consistent. Documentation indicates that the system operated for approximately 2 years, which is a reasonable amount of time to attribute it to the observed drop in concentrations.

#### **5.4.5 Natural Attenuation Modeling**

Analytical screening-level models were also used to obtain rough estimates regarding how contaminant levels in groundwater may be expected to change over time in the future. Model simulations (Appendix E, Attachment C) were run using two public-domain screening models, BIOSCREEN and BIOCHLOR. Both models are designed to be used as tools to aid in evaluating natural attenuation.

BIOSCREEN (Newell, et al., 1996) simulates the fate and transport of a chemical under three scenarios: contaminant transport with no biodegradation, transport with biodegradation modeled as a first-order decay process, and transport with biodegradation modeled as an instantaneous biodegradation reaction. For a multi-chemical plume, separate contaminant characteristics cannot be input for multiple chemicals; input parameters must be used that best approximate the overall plume. BIOSCREEN also allows for a decaying source over time; that is, the original source term depletes in mass over time.

BIOCHLOR (Aziz and Newell, 2000) specifically simulates the fate and transport of chlorinated ethenes (PCE, TCE, DCE, and VC). Chemical degradation (sequential dechlorination) is modeled as a first-order decay process, with contaminant-specific half-lives used to project concentrations over time for each contaminant. One significant limitation of the BIOCHLOR model is that it only simulates a constant (nondepleting) source; therefore the source term is infinite and the model cannot be used to evaluate the time required for a plume to cleanup to target concentrations.

To the extent possible, site-specific data were used for model inputs. Where site-specific data were not available or not appropriate, typical values for input parameters were used, based on information and guidance provided in the models' user's manuals.

Based on the BIOSCREEN model runs, the maximum downgradient distance that the Site 45 contaminant plume will migrate at concentrations of 1 µg/L or more is approximately 500 to 600 feet, and the time of maximum downgradient impacts is approximately 30 years from the assumed release time of 1988. The model-predicted time for contaminant levels to decline to 1 µg/L or less throughout the plume is approximately 260 years (assuming a residual source mass of 100 kg), with contaminant levels persisting in the source area for the longest time. The duration will increase or decrease with an increase or decrease, respectively, in the source mass term. The BIOSCREEN model results may be biased low because a finite source mass of 100 kg was assumed and utilized in the model.

Based on the BIOCHLOR model runs, the projected maximum downgradient distance that the Site 45 contaminant plume will migrate at concentrations of 1 µg/L or more is approximately 900 feet (low-end half-lives) to more than 1,000 feet (mid-range half-lives). The projected time required to reach the steady-state maximum plume extent is approximately 80 years (low-end half-lives) to more than 100 years (mid-range half-lives, concentrations increased for 100 years, did not run out further) from the assumed release time of 1988. For BIOCHLOR, once the maximum predicted plume configuration is reached as predicted by biotransformation (biodegradation) constraints, the plume remains in this configuration for an infinite time since the source is assumed to be constant and ongoing. As a result, the BIOCHLOR model cannot be used to predict the length of time required for the contaminant plume to be naturally remediated to a target concentration.

It should be emphasized that both BIOSCREEN and BIOCHLOR are screening-level models, and as such the modeling results should be regarded as rough approximations at best. The most significant data limitation for both models is a lack of site data that can be used to define trends in contaminant concentrations over distance and/or time, and thus be used to assist in model calibration. Another limitation of the modeling is that there are likely at least two sources of contamination at the site (neither of which has been characterized in detail), which makes both source definition and distance-

concentration trend determinations problematic. Additional groundwater monitoring over time may allow for more rigorous future model calibration and increase the accuracy of model predictions.

TABLE 5-1

**FATE AND TRANSPORT CHEMICAL AND PHYSICAL CHARACTERISTICS FOR ORGANICS**  
**SITE 45 – FORMER MWR DRY CLEANING FACILITY**  
**MCRD PARRIS ISLAND, SOUTH CAROLINA**  
**PAGE 1 OF 2**

Chemical	Specific Gravity (@ 20/4°C) <sup>(1,6,7)</sup>	Vapor Pressure (mm Hg @ 20°C) <sup>(1,6,7)</sup>	Solubility (mg/L @ 20°C) <sup>(1,6,7)</sup>	Octanol/ Water Partition Coefficient <sup>(1,6,7)</sup>	Organic Carbon Partition Coefficient <sup>(2,6,7)</sup>	Henry's Law Constant (atm-m <sup>3</sup> /mole) <sup>(1,6,7)</sup>	Bioconcentration Factor (mg/L/mg/kg) <sup>(2,6,7)</sup>
<b>KETONES</b>							
2-Butanone	0.8054	1.0E+02 (25°C)	2.75E+05	1.82E+00	4.44E+0 <sup>(5)</sup>	4.66E-05 (25°C)	9.3E-01 <sup>(4)</sup>
Acetone	0.7899	2.66E+02 (25°C)	Miscible	5.75E-01	7.8E+03 <sup>(3)</sup>	4.276E-05 (25°C)	3.81E-01 <sup>(4)</sup>
<b>MONOCYCLIC AROMATIC</b>							
1,2-Dichlorobenzene	1.3059	1.36E+00	1.56E+02	2.40E+03	6.17E+02	1.50E-03	2.30E+02
Chlorobenzene	1.11	1.18E+01	4.72E+02(3)	7.24E+02(3)	2.24E+02(3)	2.43E-03(3)	7.9E+01(5)
Ethylbenzene	0.867	1E+1 (25.9°C)	1.52E+02	1.41E+03	3.63E+02 <sup>(3)</sup>	8.043E-3 (25°C)	4.70E+02
Toluene	0.8669	2.8E+01 (25°C)	5.15E+02	4.90E+02	1.82E+02 <sup>(3)</sup>	5.92E-03 (25°C)	1.48E+02
Xylenes (Total)	0.86104 - 0.8801	1E+01 (27.3 - 32.1°C)	1.6E+02 - 1.75E+02 <sup>(7)</sup>	5.89E+02 - 1.58E+03	3.63E+02 - 4.07E+02 <sup>(3)</sup>	4.184E-03 - 6.662E-03 (25°C)	7.5E+01 - 1.59E+02 <sup>(4)</sup>
<b>HALOGENATED ALIPHATICS</b>							
1,1,1-Trichloroethane	1.339	1.00E+02	4.40E+03	2.95E+02	1.10E+02 (10)	4.08E-3 (25°C)	8.10E+01
1,1,2-Trichloroethane	1.4397	2.50E+01	4.42E+02	1.12E+02	5.01E+01	9.13E-04	1.90E+01
1,1-Dichloroethene	1.218	5.91E+2 (25°C)	2.1E+2 (25°C)	3.02E+01	5.89E+01 (10)	2.286E-2 (25°C)	5.30E+01
Bromomethane	1.73 (0/0°C)	1.824E+3 (25°C)	9.00E+02	1.10E+00	2.10E+00	6.24E-03	4.70E+00
Chloroform	1.5	1.51E+02	8.2E+03	9.33E+02	31	2.87E-03	3.75
Cis-1,2-dichloroethene	1.2837	2.02E+2 (25°C)	8.00E+02	1.58E+02	3.55E+01 (10)	4.08E-3 (24.8°C)	1.4E+1(3)
Tetrachloroethene	1.626	1.4E+01	150	2512	1.55E+02	1.8E-02	226
Trans-1,2-dichloroethene	1.2565	3.31E+02	6.30E+03	1.17E+22	5.25E+01	9.38E-03	4.80E+01
Trichloroethene	1.46	69	1,100	2.63E+02	1.0E+02	1.03E-02	9.7E+01
Vinyl Chloride	0.9106	2.58E+03	1.1E+3 (25°C)	3.98E+00	1.86E+01 (10)	2.78E-2 (25°C)	5.70E+00
<b>MISCELLANEOUS VOLATILE ORGANIC COMPOUNDS</b>							
Isopropylbenzene	0.862	4.50E+00	6.13E+01	3.16E+03	2.29E+03	1.15E-02	2.70E+02
<b>SEMIVOLATILE ORGANIC COMPOUNDS</b>							
2-Methylnaphthalene	1.0058	1E+1 (105°C)	2.6E+1 (25°C)	7.24E+03	7.27E+2 (9)	4.99E-4 (25°C)	5.1E+2 (6)
Acenaphthene	1.0242(90/4°C)	1E+01 (131°C)	3.42E+0 (25°C)	8.32E+03	7.08E+03 <sup>(3)</sup>	2.41E-04 (25°C)	1.80E+03
Acenaphthylene	0.899	NA	3.93	NA	NA	NA	NA
Anthracene	1.283 (25/4°C)	1.95E-04 (25°C)	1.29E+0 (25°C)	2.82E+04	2.95E+04 <sup>(3)</sup>	8.6E-05 (25°C)	4.70E+03
Benzo(a)anthracene	1.274	5.00E-09	1.0E-02 (24°C)	4.07E+05	3.98E+05 <sup>(3)</sup>	6.60E-07	5.30E+04
Benzo(b)fluoranthene	NA	5.00E-07	1.2E-03 (25°C)	3.72E+06	1.23E+06 <sup>(3)</sup>	1.20E-05	1.40E+05
Benzo(k)fluoranthene	NA	9.59E-11	5.5E-04 (25°C)	6.92E+06	1.23E+06 <sup>(3)</sup>	1.04E-03	1.40E+05

TABLE 5-1

**FATE AND TRANSPORT CHEMICAL AND PHYSICAL CHARACTERISTICS FOR ORGANICS**  
**SITE 45 – FORMER MWR DRY CLEANING FACILITY**  
**MCRD PARRIS ISLAND, SOUTH CAROLINA**  
**PAGE 2 OF 2**

Chemical	Specific Gravity (@ 20/4°C) <sup>(1, 6,7)</sup>	Vapor Pressure (mm Hg @ 20°C) <sup>(1,6,7)</sup>	Solubility (mg/L @ 20°C) <sup>(1,6,7)</sup>	Octanol/ Water Partition Coefficient <sup>(1,6,7)</sup>	Organic Carbon Partition Coefficient <sup>(2,6,7)</sup>	Henry's Law Constant (atm-m <sup>3</sup> /mole) <sup>(1,6,7)</sup>	Bioconcentration Factor (mg/L/mg/kg) <sup>(2,6,7)</sup>
Benzo(g,h,i)perylene	NA	1.00E-10	2.6E-04 (25°C)	1.70E+07	1.60E+06	1.4E-07 (25°C)	3.50E+05
Benzo(a)pyrene	1.351	5.00E-09	3.8E-03 (25°C)	9.55E+05	1.02E+06 <sup>(3)</sup>	4.9E-07 (25°C)	1.40E+05
Carbazole	1.1 (18/4°C)	4.0E+02 (323°C)	NA	1.95E+03	3.39E+03	NA	1.86E+02
Chrysene	1.274 (20°C)	6.3E-09 (25°C)	6E-03 (25°C)	4.07E+05	3.98E+05 <sup>(3)</sup>	1.05E-06 (25°C)	5.30E+04
Dibenzo(a,h)anthracene	1.282	1.00E-10	5E-04 (25°C)	9.33E+05	3.80E+06 <sup>(3)</sup>	7.3E-08 (25°C)	6.90E+05
Dibenzofuran	1.0886(99/4°C)	NA	1.00E+01	1.32E+04	1.23E+3	NA	7.97E+02
Fluoranthene	1.252	5.0E-06 (25°C)	2.65E-01 (25°C)	2.14E+05	1.07E+05 <sup>(3)</sup>	6.5E-06 (25°C)	1.20E+04
Fluorene	1.202	1E+01 (146°C)	1.9E+0 (25°C)	1.51E+04	1.38E+04 <sup>(3)</sup>	1.17E-04 (25°C)	3.80E+03
Indeno(1,2,3-cd)pyrene	NA	1E-010 (25°C)	6.20E-02	4.57E+07	3.47E+06 <sup>(3)</sup>	6.95E-08 (25°C)	3.50E+05
2-Methylnaphthalene	1.0058	1E+01 (105°C)	2.6E+01 (25°C)	7.24E+03	7.27E+02 <sup>(5)</sup>	4.99E-04 (25°C)	5.1E+02 <sup>(4)</sup>
Naphthalene	1.162	8.2E-02 (25°C)	3E+01 (25°C)	2.34E+03	2.00E+03 <sup>(3)</sup>	4.83E-04 (25°C)	4.20E+02
Pentachlorophenol	1.978 (22/4°C)	1.10E-04	1.40E+01	1.02E+05	5.92E+02 <sup>(3)</sup>	2.80E-06	1.6E-04
Phenanthrene	0.980 (4°C)	1E+0 (118.2°C)	8.16E-01 (21°C)	2.88E+04	1.40E+04	3.93E-05 (25°C)	4.70E+03
Pyrene	1.271 (23/4°C)	2.5E+0 (200°C)	1.6E-01 (26°C)	1.51E+05	1.05E+05 <sup>(3)</sup>	5.1E-06 (25°C)	1.20E+04
<b>PHTHALATE ESTERS</b>							
Bis(2-ethylhexyl) phthalate	0.99 (20/20°C)	1.2E+0 (200°C)	4.0E-01 (25°C)	2.00E+05	1.51E+07 <sup>(3)</sup>	3.00E-07	2.30E+08
Butylbenzyl phthalate	NA	8.6E-06	2.69	8.123E+04	68-350	1.3E-06	663
Diethyl phthalate	1.12	1.65E-03	1,080	2.95E+02	142	4.8E-06	117
Di-n-octyl phthalate	6.978	6.45E-06	0.3	1.3E+05	10,000-100,000	1.1E-05	100-10,000

- 1 U.S. EPA, September 1992, Handbook of RCRA Groundwater Monitoring Constituents: Chemical and Physical Properties.
- 2 U.S. EPA, December 1982, Aquatic Fate Process Data for Organic Priority Pollutants.
- 3 U.S. EPA, July 1996, Soil Screening Guidance.
- 4 Lyman et al., 1990, Equation 5-2.
- 5 Lyman et al., 1990; Equation 4-5.
- 6 Howard, 1989, Handbook of Environmental Fate and Exposure Data for Organic Chemicals, Volumes I, II, and III.
- 7 Verschueren, 1983, Handbook of Environmental Data of Organic Chemicals.

NA - Not available.

TABLE 5-2

FATE AND TRANSPORT CHEMICAL AND PHYSICAL CONSTANTS FOR INORGANICS  
 SITE 45 – FORMER MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA

Chemical	Molecular Weight (g/mol) <sup>(1)</sup>	Specific Gravity (20/4 C) <sup>(1)</sup>	Vapor Pressure (25 C) (mm Hg) <sup>(1)</sup>	Solubility (25 C) (mg/L) <sup>(1)</sup>	Henry's Law Constant (25 C) (atm·m <sup>3</sup> /mol) <sup>(1)</sup>	Bioconcentration Factor (L/kg) <sup>(2)</sup>
<b>Inorganics</b>						
Aluminum	26.98 <sup>(3)</sup>	2.708 (20 C) <sup>(3)</sup>	NA	NA	NA	NA
Arsenic	74.9216	5.727 (14 C)	1 (372 C)	insoluble	NA	NA
Barium	137.33	3.51 (20 C)	10 (1049 C)	hydrolyzes	NA	NA
Chromium	51.996	7.2 (28 C)	1 (1616 C)	insoluble	NA	NA
Cobalt	58.9332	8.9 (UT)	30 (2375 C)	insoluble	NA	NA
Copper	63.546	8.92 (UT)	1 (1628 C)	insoluble	NA	NA
Lead	207.2	11.2960 (16 C)	1 (970 C)	insoluble	NA	NA
Manganese	54.938 <sup>(4)</sup>	7.2 <sup>(4)</sup>	NA	NA	NA	NA
Mercury	200.59	13.5939	100 (260 C)	0.056	1.14E-02 (UT)	3133 <sup>(5)</sup>
Nickel	58.69	8.9 (UT)	1 (1800 C)	insoluble	NA	NA
Vanadium	50.9415	5.96 (UT)	NA	insoluble	NA	NA
Zinc	65.38	7.14 (UT)	1 (487 C)	insoluble	NA	NA

- 1 Handbook of RCRA Ground-Water Monitoring Constituents: Chemical and Physical Properties, September 1992. Solubility of metals in water is dependent on other parameters, such as pH and temperature.
- 2 Aquatic Fate Process Data for Organic Priority Pollutants, December 1982.
- 3 The Condensed Chemical Dictionary, Van Nostrand Reinhold Company, New York, 1971.
- 4 Chemical, Physical, and Biological Properties of Compounds Present at Hazardous Waste Sites, Clement Associates, September 1985.
- 5 Lyman, W., Reehl, W., and Rosenblatt, D., 1990. Handbook of Chemical Property Estimation Methods.

TABLE 5-3

**SUMMARY OF NATURAL ATTENUATION DATA COLLECTED OCTOBER 2001  
SITE 45 - MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA**

Natural Attenuation Analysis	Units	Well Number				
		MW01SU	MW04SU	MW05SL	MW06SU	MW08SU
<b>Field Analyses</b>						
pH	SU	5.18	4.56	5.1	5.9	5
Specific Conductance	mS/cm	0.36	0.452	1.19	7.22	0.43
Temperature	°C	22.3	23	24.2	23.3	21.4
Turbidity	NTU	3.5	4.5	4.09	1.64	2.06
Dissolved Oxygen, meter	mg/L	4.18	5.98	5.82	4.88	5.26
Dissolved Oxygen, test kit	mg/L	2-3	2-3	2-3	4-5	3-4
Oxidation-Reduction Potential	mV	-10	138	-35	-53	27
Carbon Dioxide	mg/L	25	48	45	30	150
Sulfide	mg/L	0	0	0.02	0	0
<b>Fixed-Base Lab Analyses- Miscellaneous Parameters</b>						
Alkalinity	mg/L	160	<20	30	220	110
Total Organic Carbon	mg/L	22	8.4	10	23	51
Chloride	mg/L	9	100	300	2000	30
Nitrite	mg/L	<0.05	<0.1	<0.05	<0.05	<0.05
Nitrate	mg/L	<0.05	<0.05	0.08	<0.05	<0.05
Sulfate	mg/L	30	27	7.3	460	57
Phosphate	mg/L	0.09	<0.05	0.96	0.09	<0.05
Manganese	mg/L	0.023	0.014	0.308	0.081	0.014
Ferrous Iron	mg/L	2.49	0.43	19.5	11.4	14.5
Biochemical Oxygen Demand	mg/L	<24	<6	<6	<6	<24
Chemical Oxygen Demand	mg/L	30	<15	20	50	50
Methane	mg/L	0.097	0.12	3	0.43	0.9
Ethane	mg/L	ND	ND	ND	ND	0.019
Ethene	mg/L	ND	ND	ND	ND	ND
Calcium	mg/L	48	3.93	38.2	145	36.9
Magnesium	mg/L	8.78	4.25	13.9	142	4.72
Sodium	mg/L	20.7	69.8	149	1100	42.2
Potassium	mg/L	3.37	4.42	2.87	41.5	0.77
<b>Fixed-Base Lab Analyses - Chlorinated Ethenes</b>						
Tetrachloroethene	ug/L	ND	6	9	200	10000
Trichloroethene	ug/L	ND	11	9	120	10000
cis-1,2-Dichloroethene	ug/L	ND	2	1	1400	3400
Vinyl Chloride	ug/L	ND	1	ND	630	710
<b>Well Location</b>						
		Upgradient	Far Downgradient	Far Downgradient	Near Downgradient	Source Area

TABLE 5-4

PCE/TCE/CIS-1,2-DCE/VINYL CHLORIDE TRENDS (ug/L)  
 SITE 45-MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND,  
 SOUTH CAROLINA

Well	Date	PCE	TCE	1,2-DCE	VC	Sum (PCE/ TCE/DCE/VC)	PCE/Sum	TCE/Sum	DCE/Sum	VC/Sum
MW08SU	1996	32000	4900	1100	0	38000	0.84	0.13	0.03	0.00
	2001	10000	10000	3400	710	24110	0.41	0.41	0.14	0.03
MW06SU	1996	360	130	610	170	1270	0.28	0.10	0.48	0.13
	2001	200	120	1400	630	2350	0.09	0.05	0.60	0.27
MW05SL	1996	66	77	3.8	0	146.8	0.45	0.52	0.03	0.00
	2001	9	9	0	0	18	0.50	0.50	0.00	0.00
MW04SU	1996	180	2.9	0	0	182.9	0.98	0.02	0.00	0.00
	2001	6	11	2	0	19	0.32	0.58	0.11	0.00

## 6.0 BASELINE HUMAN HEALTH RISK ASSESSMENT

The baseline human health risk assessment contained in this section was performed to characterize and quantify potential health risks at Site 45 in the absence of remedial action. The results of the baseline risk assessment are also used to focus the evaluation of remedial action alternatives, if action is required. The baseline risk assessment consists of six major components:

- Data evaluation
- Exposure assessment
- Toxicity assessment
- Risk characterization
- Uncertainty analysis
- Remedial goal options

Methods for selection of the chemicals of potential concern (COPCs) that will be evaluated quantitatively in the baseline human health risk assessment, as well as those chemicals identified as COPCs for Site 45, are described in Section 6.1, Data Evaluation. The data evaluation section is primarily concerned with the selection of COPCs that are representative of the type and magnitude of potential human health effects. The COPC screening process involves the comparison of maximum site concentrations to risk-based screening levels and other health-based standards. Recent and historical data available for the site are considered during the selection process. A brief discussion of data usability is also provided.

Section 6.2, Exposure Assessment, identifies potential receptor populations and exposure pathways by which receptors may come in contact with contaminants at the site. Potential exposure routes under current and future land uses are developed from information on source area, chemical concentrations, chemical release mechanisms, patterns of human activity, and other pertinent information. A concise conceptual site model illustrates the potential receptors and exposure pathways evaluated in the baseline risk assessment. The exposure assessment also includes the calculation of quantitative estimates of chemical intake for each identified receptor, pathway, and route of exposure under the reasonable maximum exposure (RME) scenario. Equations and relevant exposure input parameters used in estimating chemical intakes are provided.

Section 6.3, Toxicity Assessment, presents the chemical-specific toxicity criteria for the identified COPCs that are used in the quantification of potential human health risks. These toxicity criteria, when integrated with the estimated chemical intakes developed in the exposure assessment, provide the basis for quantifying potential human health risks.

Methods used for characterizing risks associated with noncarcinogenic and carcinogenic effects for exposure to COPCs are provided in Section 6.4, Risk Characterization. Actual numerical results of the baseline human health risk assessment for Site 45 are summarized in Table 6-19.

Because the quantitative risk estimates developed in the risk characterization are based on a number of assumptions (concerning exposure, land use, toxicity, etc.), various uncertainties are associated with the risk assessment process. A brief discussion of the uncertainties associated with the risk evaluation for Site 45 is contained in Section 6.5, Uncertainty Analysis.

Remedial goal options are developed in Section 6.6 for those media with estimated lifetime cancer risks greater than  $1 \times 10^{-4}$  and total Hazard Index (HIs) greater than 1.0.

To assess potential public health risks, four major aspects of chemical contamination and exposure must be considered: contaminants with toxic characteristics must be found in environmental media, the contaminants must be released by either natural processes or by human action, potential exposure points must exist, and human receptors must be present at the point of exposure. Risk is a function of both toxicity and exposure; without one of the factors listed above, there is no risk.

An illustration of the baseline human health risk assessment process is provided in Figure 6-1.

The baseline human health risk assessment for Site 45 was conducted using the most recent guidance from the U.S. EPA, including regional supplemental guidance (U.S. EPA Region 4, 1995). To maintain consistency among risk assessments performed at various sites at the Base, methodologies presented in the Master Work Plan for MCRD Parris Island (B&R Environmental, 1998b) were also used to develop the baseline risk assessment for this site.

Due to the location of the site in the center of the commercial district or the depot, it is unlikely to have significant impacts to ecological receptors. Therefore, a Screening Level Ecological Risk Assessment (sERA) was not performed at this site.

## **6.1 DATA EVALUATION**

Data evaluation is a site-specific task that uses a variety of information to determine which of the detected chemicals at a site are most likely to present a risk to potential human receptors. The end result of this qualitative selection process is a list of COPCs for each environmental medium under consideration. Section 6.1.1 provides a brief summary of data usability, as it pertains to the baseline human health risk assessment. The selection of COPCs for Site 45 is contained in Section 6.1.2.

### **6.1.1 Data Usability**

This section addresses the usability of data collected as part of the 2000 RI/RFI field investigation. The use of approved work plans for the Site 45 RI/RFI promotes quality by identifying appropriate sample locations, analytical parameters, analytical methods, and data quality objectives (DQOs). Appendix D summarizes the results of measures (field and laboratory quality control, data validation, etc.) taken to ensure the quality of data collected during the RI/RFI field investigation.

Only validated sample data collected for Site 45 were used to assess potential human health risks. The qualification of data during the formal data validation process is not expected to compromise the results of the baseline human health risk assessment. Analytical data qualified as estimated were utilized, even though the reported positive concentrations or sample-specific quantitation limits may be somewhat imprecise. The use of estimated data adds to the uncertainty associated with the risk assessment; however, the associated uncertainty is expected to be negligible compared to the other uncertainties inherent in the risk evaluation process (i.e., uncertainties with land uses, exposure scenarios, toxicological criteria, etc.).

### **6.1.2 Selection of COPCs**

The overall goal of the baseline human health risk assessment is to quantify risks associated with those chemicals that represent a potentially significant human health hazard on the basis of toxicity, environmental concentration, and mobility. U.S. EPA guidance recommends focusing the baseline risk assessment by quantifying risk only for a select list of COPCs at a site. These chemicals, which are a subset of all detected chemicals in a given medium, are defined as those chemicals likely to dominate the overall potential risks for a site.

For the purposes of this baseline risk assessment, COPCs for a particular medium are limited to those chemicals that exceed a selection criterion. The maximum concentration of a chemical detected in soil and groundwater was compared to the screening criteria for that chemical. Screening criteria have been determined for cancer risk levels of  $1 \times 10^{-6}$  and noncancer (Hazard Quotient) levels of 1.0 and are presented in the most recent version of the U.S. EPA Region 9 PRG Table (U.S. EPA, 2000). The values in the PRG table were divided by 10 for noncarcinogens to screen to the more conservative Hazard Quotient of 0.1. The maximum concentrations of chemicals detected in soil were compared to U.S. EPA Region 9 residential PRGs for soil ingestion. U.S. EPA soil screening levels for the transfer to air or groundwater were used to evaluate the inhalation pathway and the potential for chemicals to migrate from soil to groundwater (U.S. EPA, 1996a). Chemicals detected in groundwater were compared to the U.S. EPA Region 9 PRG for tap water and the U.S. EPA Drinking Water Regulations and Health Advisories

MCLs. Chemicals with maximum detected concentrations exceeding the PRGs, SSLs, or MCLs were retained as COPCs.

Inorganic COPCs were also selected based on a comparison of site-specific chemical concentrations to background chemical concentrations in accordance with U.S. EPA Region 4 guidance. Comparisons were made between the maximum concentration of the site-specific chemical and twice the mean of the background chemical concentration. If the maximum detected concentration of a chemical in surface soil exceeded the applicable screening criteria but was less than the background chemical concentrations, then that chemical was not retained as a COPC.

Screening levels for essential nutrients were derived using recommended daily allowances advocated by the Food and Nutrition Board. The development of the screening levels for essential nutrients is presented in Appendix F.

Maximum detected chemical concentrations (in a single sample) in each sample medium for Site 45 were compared to the risk-based and health-based screening criteria. If the maximum concentration exceeded any of the screening criteria, that chemical was retained as a COPC for all significant exposures involving that medium. For example, if arsenic was retained for soil, this chemical was evaluated as a COPC for both ingestion and dermal exposure routes. If none of the chemicals detected in a medium exceeded criteria, that medium was dropped from further consideration and the potential risks associated with exposure to that medium were regarded as relatively insignificant.

Table 6-1 summarizes the screening criteria used in the selection of COPCs. Complete RAGS Part D tables for COPC selection are included in Appendix F. A medium-specific discussion of the specific criteria used for COPC selection and the results for the selection process are provided in the remainder of this section.

#### **6.1.2.1 Surface Soil**

Seven VOCs, 18 SVOCs, and 11 metals were detected in eight surface soil samples collected as part of the 2001 field investigation conducted at Site 45. A comparison of the maximum detected surface soil concentrations to U.S. EPA Region 9 PRGs for residential exposures and U.S. EPA soil screening levels for the transfer to air or groundwater is presented in Table 6-2.

The following chemicals were detected at maximum concentrations in surface soil that exceeded the risk-based screening levels for direct contact exposures and were retained as COPCs for surface soil at Site 45:

- VOCs - PCE
- SVOCs - benzo(a)pyrene
- Inorganics - aluminum and arsenic

In accordance with U.S. EPA Region 4 guidance, all carcinogenic PAHs were retained as COPCs for surface soil since the maximum concentration of at least one carcinogenic PAH exceeded the screening criteria. Therefore, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene were also selected as COPCs.

A comparison of the maximum detected surface soil concentrations to U.S. EPA SSLs<sub>air</sub> for soil to air is presented in Table 6-2. Concentrations of all chemicals detected in surface soil were less than the U.S. EPA SSLs for soil to air; therefore, exposures through inhalation of fugitive dust at Site 45 were not evaluated in the risk assessment.

Also shown in Table 6-2 is a comparison of the maximum detected surface soil concentrations to U.S. EPA SSLs for soil to groundwater migration. PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, benzo(a)anthracene, carbazole, arsenic, and chromium concentrations exceeded the SSLs for soil to groundwater migration, indicating the potential for these chemicals to migrate to groundwater. Chemicals identified at concentrations in excess of EPA SSLs were retained as COPCs.

#### 6.1.2.2 Subsurface Soil

Eight subsurface soil samples were collected and analyzed for VOCs and SVOCs as part of the Site 45 field investigation. Seven VOCs and seven SVOCs were detected in the samples. In Table 6-3, the maximum detected concentrations were compared to U.S. EPA Region 9 PRGs for residential exposures and U.S. EPA SSLs for the transfer to air and groundwater.

The following chemicals were detected at maximum concentrations in subsurface soil that exceeded the risk-based screening levels for direct contact exposures and were retained as COPCs at Site 45:

- VOCs - PCE, TCE, and cis-1,2-DCE.
- SVOCs - benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a, h)anthracene, and indeno(1,2,3-cd)pyrene.

In accordance with U.S. EPA Region 4 guidance, all carcinogenic PAHs were retained as COPCs for subsurface soil since the maximum concentration of at least one carcinogenic PAH exceeded the screening criteria. Therefore, benzo(k)fluoranthene and chrysene were also selected as COPCs in subsurface soil.

A comparison of the maximum detected surface soil concentrations to U.S. EPA for soil to air (SSLs<sub>air</sub>) is presented in Table 6-3. Concentrations of PCE and TCE in subsurface soil exceeded the U.S. EPA SSLs for soil to air; therefore, exposures through inhalation of fugitive dust at Site 45 were evaluated in the risk assessment.

Also shown in Table 6-3 is a comparison of the maximum detected subsurface soil concentrations to U.S. EPA SSLs for soil to groundwater migration. PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, vinyl chloride, chlorobenzene, 1,1,2-trichloroethane, 1,1,1-trichloroethane, 1,1-DCE, bromomethane, ethylbenzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, carbazole, dibenzo(a,h)anthracene, indeno(1,2,3,de)pyrene, and naphthalene concentrations exceeded the SSLs for soil to groundwater migration, indicating the potential for these chemicals to migrate to groundwater. Chemicals identified at concentrations in excess of EPA SSLs were retained as COPCs.

### 6.1.2.3 Groundwater

In 1999/2000, a total of 10 groundwater samples (five surficial well and five deep well) were collected during the Site 45 groundwater investigation and analyzed for VOCs. Maximum detected chemical concentrations in the surficial and deep groundwater were compared to U.S. EPA Region 9 PRGs and U.S. EPA MCLs in Tables 6-4 and 6-5, respectively.

#### Surficial Groundwater

The following chemicals were detected in the surficial groundwater at maximum concentrations that exceeded one or both of the risk-based screening criteria:

- VOCs - PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, chlorodibromomethane, and vinyl chloride

#### Deep Groundwater

The following chemicals were detected in the deep groundwater at maximum concentrations that exceeded only their respective U.S. EPA Region 9 PRGs:

- VOCs - PCE, TCE, and chloroform

Table 6-6 lists the chemicals retained as COPCs for soil and groundwater at Site 45.

## 6.2 EXPOSURE ASSESSMENT

The exposure assessment defines and evaluates the exposures experienced by likely receptor populations at a site. In order to have an exposure, several factors must be present: a source and mechanism of release, a route of contaminant transport through an environmental medium, a contact point for a human receptor, and an exposure route at the point of contact. All four components must be present for the exposure to occur.

The exposure assessment presented in this section of the report consists of several subsections that characterize the physical site setting and the potential receptors of concern, identify the potential contaminant migration and exposure pathways, define the contaminant concentrations at the point of exposure, and present the equations used to quantify exposure in terms of contaminant intake (dose). Appendix F of this report contains sample calculations for the quantification of contaminant intakes, as well as the chemical-specific intakes for Site 45.

### 6.2.1 Exposure Setting

Prior to 2001, Site 45 – MWR Dry Cleaning Facility was in a building located in the Main Post Area of MCRD Parris Island, between Panama Street to the north, Kyushu Street to the south, and Samoa Street to the east. West of the facility are other commercial establishments, including a cobbler, a tailor, a coin-operated laundry facility, and a new dry cleaning facility. Four above-ground storage tanks were situated along the northern side of the building. These tanks were first put into place in 1998, following the removal of an underground storage system where hydrocarbon cleaning solvents were previously stored.

In early 2001, the main dry cleaning facility, the solvent tanks, and other related structures were demolished and removed from the site. Currently, the site is mostly a vacant lot, covered with mowed grass. Some isolated trees and shrubs are also present.

### 6.2.2 Conceptual Site Model

This section discusses the conceptual site model for Site 45. A conceptual site model facilitates consistent and comprehensive evaluation of the potential risks to human health by creating a framework for identifying the pathways by which human receptors may come in contact with contaminated media resulting from the source area. A conceptual site model depicts the relationships among the following elements, which are necessary for defining complete exposure pathways:

- Site sources of contamination
- COPCs in environmental media

- Contaminant release mechanisms
- Contaminant transport pathways
- Exposure mechanisms and exposure routes
- Potential receptors

The conceptual site model for Site 45 is provided in Figure 6-2. The potential sources of contamination at Site 45 are the existing VOC plumes in the soil and groundwater. Contaminants may be released from Site 45 by mechanisms such as leaching of COPCs from surface soil via infiltrating water to subsurface soil and subsequent migration through the subsurface soil to the water table. Migration via surface water runoff is not expected to occur at Site 45 because the surface elevation of Site 45 is lower than the surrounding areas; consequently, surface water will pool at Site 45 as opposed to flowing off the site.

Chemicals adsorbed to surface soil at Site 45 may also be released from a site via wind erosion of loose soil material. These particulates are carried downwind and potentially off site if the grain size is small enough and the wind velocity is great enough. Additionally, chemicals may also be released from soil at Site 45 via volatilization.

Once released from the source, contaminants are transported in media such as soil, groundwater, or air. Potential receptors may be exposed either directly or indirectly to contaminants in these media by a variety of exposure mechanisms, such as direct contact and immersion. Typically, several exposure routes (ingestion, dermal contact, inhalation, etc.) are associated with a particular exposure mechanism.

The conceptual site model presented in Figure 6-2 also indicates those exposure routes that are carried through the quantitative risk assessment for each potential receptor. One objective of the development of the conceptual site model, as well as the baseline human health risk assessment, is to focus attention on those pathways that contribute the most to the potential impacts on human health and the environment and to provide the rationale for eliminating other exposure pathways that are considered to be minor components of the overall risk.

### **6.2.3 Potential Exposure Pathways**

Potential receptors can come into contact with contaminants in a variety of ways, which are generally the result of interactions between a receptor's behavior or lifestyle and an exposure medium. This assessment defines an exposure route as a stylized description of the behavior that brings a receptor into contact with a contaminated medium.

### **6.2.3.1 Air**

This pathway is based on the scenario that a receptor is immersed in air that contains suspended particulates and/or volatile organic vapors originating from the source area. Subsequent exposure of the receptor occurs upon inhalation of the ambient air.

A qualitative comparison of maximum detected concentrations in surface and subsurface soil at Site 45 to U.S. EPA SSLs, based on intermedium transfer (from soil to air), was performed to determine if additional quantitative analysis of this potential exposure pathway was warranted. The SSLs are based on residential land use and lifetime exposure scenarios and are, therefore, conservative values for potential receptors under current and future land use conditions. This screening is summarized in Tables 6-2 and 6-3. Based on the qualitative screening, maximum detected concentrations of PCE and TCE in subsurface soil exceeded the soil to air SSLs; therefore, exposure via the inhalation pathway was evaluated in the risk assessment.

### **6.2.3.2 Direct Contact with Soil**

Potential receptors may come into direct contact with soil, which may be affected by the release of chemicals from the source area. During the receptor's period of contact, the individual may be exposed via incidental ingestion of soil or via dermal absorption of contaminants from soil.

Dermal contact with chemicals detected in the site soil may or may not result in a significant exposure. In general, for chemicals to be percutaneously absorbed, they must first desorb from soil and diffuse through the skin. Various factors affect the rate of dermal absorption, including the amount of soil on the skin surface, soil characteristics (moisture, pH, organic carbon content, etc.), skin characteristics (thickness, temperature, hydration, etc.), volatilization losses, and chemical-specific properties. Dermal exposures to chemicals in soil are evaluated quantitatively in the baseline risk assessment.

### **6.2.3.3 Direct Contact with Groundwater**

Human receptors using groundwater as a potable water supply may be exposed to groundwater via ingestion, dermal contact, and inhalation. Groundwater is not currently used as a potable water supply at Site 45; however, a residential land use scenario may consider the groundwater as a potable water supply. Although it is unlikely that groundwater would be used for potable purposes, ingestion of groundwater will be considered as an exposure pathway. Construction workers may have dermal contact with groundwater if excavation below the water table occurs.

#### 6.2.4 Potential Receptors

Potential receptors were identified for both current and future land use conditions. The receptors were identified by analyzing the interaction of current land use practices and the identified sources of contamination. Future site use is expected to remain the same as the current site use, which is industrial. Receptors are as follows:

- **Construction workers** may contact surface and subsurface soil during future excavation and construction activities. Dermal exposure to shallow groundwater may also be possible for this receptor. Since the site is small in size (approximately 1/4-acre), it will be assumed that the construction worker is exposed to surface soil for 3 months over a 1-year period and would be engaged in activities where he could be exposed to groundwater 1 month out of the year.
- **Maintenance workers** may be exposed to site media while performing maintenance activities (e.g., mowing, landscaping), site inspections, or daily duties. The maintenance worker is assumed to be a long-term employee at the site. The maintenance worker will be evaluated for exposure to surface soil only. Exposure to groundwater will not be evaluated for this receptor because shallow groundwater at Site 45 is not used as a potable water supply under current conditions. It will be assumed that the maintenance worker is engaged in activities at the site where he can be exposed to surface soil 1 day a week.
- **Commercial Workers** are individuals who would work at the site if it were developed for commercial use in the future. Commercial workers are assumed to be exposed to surface soil on a daily basis.
- **Adult Visitors** are individuals who may cross the site on their way to other places at the base. The adult visitor receptor is similar to the trespasser receptor. The adult visitor is being evaluated instead of an adult trespasser because access to the site is not restricted and the site is located in an area that is readily accessible by the public. The adult visitor is assumed to be exposed to surface soil 1 day a week.
- **Hypothetical Future On-Site Residents** are evaluated as potential receptors. Future on-site residents (child and adult) are assumed to be exposed to soil and groundwater on a daily basis. Future child and adult residents are not receptors under current or expected future land use and are included only to provide an indication of potential risks if the base were to close and then be developed for residential use. Although military personnel reside at the base under current conditions, the residential scenario is not applicable for these receptors since they do not reside in the areas of investigation and they are assigned to the base for a relatively short period of time (e.g., 3 to 6 years).

Military personnel, industrial workers, and recreational users are not considered to be potential receptor groups because the site is too small to support the activities engaged in by these receptors. In addition, the area around the site is currently commercial and is not expected to change in the future. A summary of the rationale used for the selection or elimination of a potential receptor group is provided in Table 6-7.

### 6.2.5 Exposure Point Concentrations

According to U.S. EPA guidance risk assessments are conducted using a representative exposure point concentration for each COPC. The exposure point concentration is typically defined as the upper 95 percent confidence limit (UCL), which is based on the distribution of a data set. However, when small data sets (i.e., fewer than 11 samples) are available for a site and/or medium, the 95 percent UCL is not considered to be a good estimate of the sample mean; in those cases, the maximum detected concentration is used as the exposure point concentration. It should be noted that a sample and its duplicate sample were averaged prior to the determination of the exposure point concentration.

For normally distributed data, the calculation of the exposure point concentration (UCL) is a two-step process. First, the standard deviation of the sample set must be determined, as follows:

$$S = \left[ \frac{\sum(X_i - \bar{X})^2}{(n-1)} \right]^{1/2}$$

where: S = standard deviation  
 $X_i$  = individual sample value  
 n = number of samples  
 $\bar{X}$  = mean sample value

The one-sided UCL on the mean is then calculated as follows:

$$UCL = \bar{X} + t \left( \frac{S}{n^{1/2}} \right)$$

where: UCL = 95% upper confidence limit of the mean  
 $\bar{X}$  = arithmetic average  
 t = one-sided t distribution factor ( $t_{0.95}$ )

S = standard deviation  
n = number of samples

For lognormally distributed data sets, the exposure concentration is calculated using the following equation:

$$UCL = \exp\left(\bar{X} + 0.5S^2 + \frac{HS}{(n-1)^{1/2}}\right)$$

where: UCL = 95% upper confidence limit of the mean  
exp = constant (base of the natural log, e)  
 $\bar{X}$  = mean of the transformed data  
S = standard deviation of the transformed data  
H = H-statistic (from Gilbert, 1987;  $H_{0.95}$ )  
n = number of samples

This equation uses individual sample results that have been transformed using the natural logarithm function. If the data set has an undefined distribution, then the maximum detected concentration was used as the exposure point concentration.

U.S. EPA Region 4 has adopted a Toxicity Equivalence Factor (TEF) approach to evaluate potentially carcinogenic PAHs. These TEFs are based on the relative potency of each compound relative to that of benzo(a)pyrene. TEFs for the individual carcinogenic PAHs are as follows:

<u>Compound</u>	<u>TEF</u>
Benzo(a)pyrene	1.0
Benz(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.01
Chrysene	0.001
Dibenz(a,h)anthracene	1.0
Indeno(1,2,3-cd)pyrene	0.1

The TEFs are used to convert each individual carcinogenic PAH concentration into an equivalent concentration of benzo(a)pyrene. Using individual benzo(a)pyrene equivalent concentrations, an exposure point concentration for carcinogenic PAHs is derived.

Exposure point concentrations for COPCs for surface soil, surface/subsurface soil, and groundwater are summarized in Table 6-8.

## 6.2.6 Quantification of Exposure

Estimates of exposure are based on the contaminant concentrations at the exposure points and on scenario-specific assumptions and intake parameters. The models and equations used to quantify intakes are described in this section and have been obtained from a variety of U.S. EPA guidance documents, which are cited in the specific intake estimation sections that follow.

Exposure model parameters for all receptors are presented in Table 6-9. The parameters are based on those presented in the Master Work Plan for MCRD Parris Island (B&R Environmental, 1998) and standard U.S. EPA Region 4 default values. Rationale is provided below for those parameters that are non-standard values or values other than those presented in the Master Work Plan. The parameters are used in the equations presented in this section, along with the exposure point concentrations previously defined to estimate contaminant intakes, which will be used to determine potential risks. Individual chemical intakes for each receptor/exposure route combination are presented in Appendix F.

### 6.2.6.1 Incidental Ingestion of Soil

Direct physical contact with soil may result in the incidental ingestion of chemicals by construction workers, maintenance workers, commercial workers, adult visitors, and on-site residents. Exposure associated with the oral route is estimated in the following manner (U.S. EPA, 1989):

$$\text{Intake}_{\text{si}} = \frac{(C_{\text{si}})(\text{IR}_{\text{s}})(\text{FI})(\text{EF})(\text{ED})(\text{CF})}{(\text{BW})(\text{AT})}$$

where: Intake<sub>i</sub> = intake of contaminant "i" from soil (mg/kg/day)  
C<sub>si</sub> = concentration of contaminant "i" in soil (mg/kg)  
IR = incidental ingestion rate (mg/day)  
FI = fraction ingested from contaminated source (decimal fraction)  
EF = exposure frequency (days/year)  
ED = exposure duration (years)  
CF = conversion factor (10<sup>-6</sup> kg/mg)  
BW = body weight (kg)

AT = averaging time (days);  
 for noncarcinogens, AT = ED x 365 days/year;  
 for carcinogens, AT = 70 years x 365 days/year

Since Site 45 is relatively small in size, it was assumed that a construction worker would be engaged in construction-related activities 90 days a year ( $EF_{\text{soil}}$ ) over a 1-year period (ED). Maintenance workers and adult visitors were assumed to be at the site one day a week for 50 days a year. All other exposure parameters for incidental ingestion of soil are standard U.S. EPA default values.

### 6.2.6.2 Dermal Contact with Soil

During direct contact, construction workers, maintenance workers, commercial workers, adult visitors, and on-site residents may contact contaminated soil with their skin. Dermal absorption from potentially contaminated soil is calculated using the following equation:

$$\text{Intake}_{\text{si}} = \frac{(C_{\text{si}})(SA)(AF)(ABS)(CF)(EF)(ED)}{(BW)(AT)}$$

where:  $\text{Intake}_{\text{si}}$  = amount of chemical "i" absorbed during contact with soil (mg/kg/day)  
 $C_{\text{si}}$  = concentration of chemical "i" in soil (mg/kg)  
 SA = skin surface area available for contact ( $\text{cm}^2/\text{day}$ )  
 AF = skin adherence factor ( $\text{mg}/\text{cm}^2$ )  
 ABS = absorption factor (decimal fraction)  
 CF = conversion factor ( $10^{-6}$  kg/mg)  
 EF = exposure frequency (days/year)  
 ED = exposure duration (years)  
 BW = body weight (kg)  
 AT = averaging time (days);  
 for noncarcinogens, AT = ED x 365 days/year;  
 for carcinogens, AT = 70 years x 365 days/year

The same exposure frequencies and durations used in the estimation of incidental ingestion intakes of soil are used to estimate exposure via dermal contact. Current guidance is used to develop the following default assumptions concerning the amount of skin surface area available for contact for a receptor: For construction workers, maintenance workers, commercial workers, and the adult visitor, the exposed skin surface area was assumed to be  $3,300 \text{ cm}^2$ . This value represents the hands, forearms, and head being exposed to soil. For child residents, the exposed skin surface area was assume to be  $2,800 \text{ cm}^2$ , which represents the head, hands, forearms, lower legs, and feet. For adult residents, the exposed skin surface

area was assumed to 5,700 cm<sup>2</sup>, which represents the head, hands, forearms, and lower legs. Appendix E presents information on how the exposed skin surface areas were derived. Soil skin adherence factors used in the risk assessment were 0.3 mg/cm<sup>2</sup> for the construction worker; 0.2 mg/cm<sup>2</sup> for the maintenance worker, commercial worker, and child resident; and 0.07 for the adult visitor and adult resident. Absorption factors of 0.13 and 0.03 were used to assess dermal exposure to benzo(a)pyrene and arsenic, respectively. Region 4 default values of 0.01 for organics and 0.001 for inorganics were used for those chemicals for which chemical-specific absorption factors were not available (U.S. EPA Region 4, 1995).

### 6.2.6.3 Inhalation of Air and Fugitive Dust/Volatile Emissions

The amount of a chemical a receptor takes in as a result of breathing is determined using the concentration of the contaminant in air. Intakes of both particulates and vapors/gases are calculated using the same equation, as follows:

$$\text{Intake}_{\text{ai}} = \frac{(C_{\text{ai}})(\text{IR}_{\text{a}})(\text{ET})(\text{EF})(\text{ED})}{(\text{BW})(\text{AT})}$$

where:

Intake <sub>ai</sub>	=	intake of chemical "i" from air via inhalation (mg/kg/day)
C <sub>ai</sub>	=	concentration of chemical "i" in air (mg/m <sup>3</sup> )
IR <sub>a</sub>	=	inhalation rate (m <sup>3</sup> /hr)
ET	=	exposure time (hours/day)
EF	=	exposure frequency (days/yr)
ED	=	exposure duration (yr)
BW	=	body weight (kg)
AT	=	averaging time (days);
		for noncarcinogens, AT = ED x 365 days/yr;
		for carcinogens, AT = 70 yr x 365 days/yr

The same exposure frequencies and durations used in the estimation of incidental ingestion intakes of soil are used to estimate exposure via inhalation of air and fugitive dust or volatile emissions. U.S. EPA Region 4 default inhalation rates were used for all receptors.

The concentrations of chemicals in air resulting from emissions from soil were developed following procedures presented in U.S. EPA Soil Screening Guidance. The chemical concentration in air is calculated from:

$$C_a = C_s \times \left[ \frac{1}{PEF} + \frac{1}{VF} \right]$$

where:  $C_a$  = chemical concentration in air, mg/m<sup>3</sup>  
 $C_s$  = chemical concentration in soil, mg/kg  
PEF = Particulate emission factor, m<sup>3</sup>/kg  
VF = volatilization factor, m<sup>3</sup>/kg

The particulate emissions factor (PEF) relates the concentration of the chemical in soil with the concentration of dust particles in air. A site-specific PEF of  $2.91 \times 10^{+10}$  m<sup>3</sup>/kg was calculated using the following equation from U.S. EPA's Soil Screening Guidance:

$$PEF = Q/C \times \frac{3600 \text{ sec/hour}}{0.036 \times (1 - V) \times (U_m / U_t)^3 \times F(x)}$$

where:  $Q/C$  = Inverse of mean concentration at center of source, g/m<sup>2</sup>-s per kg/m<sup>3</sup>  
 $V$  = fraction of vegetative cover, unitless  
 $U_m$  = mean annual wind speed, m/s  
 $U_t$  = equivalent threshold value of wind speed at 7 m, m/s  
 $F(x)$  = function dependent on  $U_m/U_t$  derived using Cowherd et al (1985), unitless.

Ambient air concentrations resulting from the volatilization of COPCs from soil are chemical dependent and were calculated using the following equation from U.S. EPA's Soil Screening Guidance:

$$VF = \frac{Q/C \cdot (3.14 \cdot D_a \cdot T)^{0.5} \cdot 10^{-4} \text{ (m}^2 / \text{cm}^2 \text{)}}{(2 \cdot \rho_b \cdot D_a)}$$

and

$$D_a = \frac{[(\theta_a^{10/3} \cdot D_i \cdot H' + \theta_w^{10/3} \cdot D_w) / n^2]}{\rho_b \cdot K_d + \theta_w + \theta_a \cdot H'}$$

where: VF = volatilization factor (m<sup>3</sup>-air/kg-soil)  
 $Q/C$  = inverse of the mean concentration at the center of source (gm/m<sup>2</sup>-sec per kg/m<sup>3</sup>)  
 $D_a$  = apparent diffusivity, chemical specific (cm<sup>2</sup>/sec)  
 $T$  = exposure interval, exposure specific (sec)  
 $\rho_b$  = dry bulk soil particle density (g/cm<sup>3</sup>)

$\theta_a$	=	air-filled soil porosity ( $L_{air}/L_{soil}$ )
$D_i$	=	diffusivity in air, chemical specific ( $cm^2/sec$ )
$n$	=	total soil porosity ( $L_{pore}/L_{soil}$ )
$\theta_w$	=	water-filled soil porosity ( $L_{air}/L_{soil}$ )
$D_w$	=	diffusivity in water, chemical specific ( $cm^2/sec$ )
$K_d$	=	soil-water partition coefficient, chemical specific
$H'$	=	dimensionless Henry's law constant, chemical specific

A limitation to the equation for volatilization factor (VF) is the soil saturation limit. The soil saturation limit is the chemical concentration at which soil pore air and pore water are saturated with the chemical and the adsorptive limits of the soil particles are reached. Above this concentration, the chemical may be present in the free phase. The soil saturation limit represents an upper limit to the applicability of the SSL VF model because Henry's Law does not apply when chemicals are in the free phase. Therefore, if the concentration of the chemical is greater than the soil saturation limit, the soil saturation limit is used to calculate the chemical concentration in air. The soil saturation limit is calculated from:

$$C_{sat} = \frac{S}{\rho_b} \cdot (K_d \cdot \rho_b + \theta_w + H' \cdot \theta_a)$$

where: $C_{sat}$	=	soil saturation concentration (mg/kg)
$S$	=	solubility limit (mg/L)
$\rho_b$	=	dry soil bulk density (kg/L)
$K_d$	=	soil-water partition coefficient (L/kg)
	=	$K_{oc} \times f_{oc}$
$K_{oc}$	=	soil organic carbon partition coefficient (L/kg)
$f_{oc}$	=	fraction organic carbon in soil (g/g)
$\theta_w$	=	air-filled soil porosity ( $L_{air}/L_{soil}$ )
$H'$	=	dimensionless Henry's Law Constant
$\theta_a$	=	air-filled soil porosity ( $L_{air}/L_{soil}$ )
	=	$n - \theta_w$
$n$	=	total soil porosity ( $L_{pore}/L_{soil}$ )
	=	$1 - (\rho_b/\rho_s)$
$\rho_s$	=	soil particle density (kg/L)

Input assumptions for the calculation of PEF and the volatilization from soil to outdoor air model are presented in Table 6-10. Chemical properties were obtained from EPA's Soil Screening Guidance: User's Guide and are presented in Table 6-12.

#### 6.2.6.4 Ingestion of Groundwater

Future child and adult residents may use groundwater as a potable water supply. Intakes associated with ingestion of water are evaluated using the following equations:

$$\text{Intake}_{wi} = \frac{(C_w)(IR_w)(EF)(ED)}{(BW)(AT)} \text{ for Groundwater}$$

where:  $\text{Intake}_{wi}$  = intake of chemical "i" from water (mg/kg/day)  
 $C_w$  = concentration of chemical "i" in water (mg/L)  
 $IR_w$  = ingestion rate for groundwater (L/day)  
 $ET$  = exposure time for surface water (hours/day)  
 $EF$  = exposure frequency (days/year)  
 $ED$  = exposure duration (years)  
 $BW$  = body weight (kg)  
 $AT$  = averaging time (days);  
for noncarcinogens,  $AT = ED \times 365$  days/year;  
for carcinogens,  $AT = 70$  years  $\times$  365 days/year

For potable use of groundwater, it was assumed that a child would ingest 1 liter per day, 350 days a year for 6 years and an adult would ingest 2 liters per day, 350 days a year for 24 years.

#### 6.2.6.5 Dermal Contact with Groundwater

Construction workers may contact groundwater during construction activities if excavation occurs below the water table. Future child and adult residents may use groundwater as a potable water supply. The following equation is used to assess exposures resulting from dermal contact with water:

$$\text{DAD}_{wi} = \frac{(DA_{\text{event}})(EV)(ED)(EF)(A)}{(BW)(AT)}$$

where:  $\text{DAD}_{wi}$  = dermally absorbed dose of chemical "i" from water (mg/kg/day)  
 $DA_{\text{event}}$  = absorbed dose per event (mg/cm<sup>2</sup>/event)  
 $EV$  = event frequency (events/day)  
 $ED$  = exposure duration (years)  
 $EF$  = exposure frequency (days/year)  
 $A$  = skin surface area available for contact (cm<sup>2</sup>)  
 $BW$  = body weight (kg)

AT = averaging time (days);  
 for noncarcinogens, AT = ED x 365 days/year;  
 for carcinogens, AT = 70 years x 365 days/year

The absorbed dose per event ( $DA_{event}$ ) is estimated using a non-steady-state approach for organic compounds and a more traditional steady-state approach for inorganics. For organics, the following equations apply:

$$\text{If } t_{event} < t^*, \text{ then: } DA_{event} = (2 K_p) (FA) (C_w) (CF) \left( \sqrt{\frac{6 \tau t_{event}}{\pi}} \right)$$

$$\text{If } t_{event} > t^*, \text{ then: } DA_{event} = (K_p) (FA) (C_w) (CF) \left( \frac{t_{event}}{1+B} + 2 \tau \left( \frac{1+3B+3B^2}{(1+B)^2} \right) \right)$$

where:  $t_{event}$  = duration of event (hour/event)  
 $t^*$  = time it takes to reach steady-state conditions (hours)  
 $K_p$  = permeability coefficient from water through skin (cm/hour)  
 $C_w$  = concentration of chemical "i" in water (mg/L)  
 $\tau$  = lag time (hour)  
 $\pi$  = constant (unitless; equal to 3.141592654)  
 $CF$  = conversion factor ( $10^{-3}$  L/cm<sup>3</sup>)  
 $B$  = partitioning constant derived by Bunge Model (dimensionless)  
 $FA$  = fraction absorbed (dimensionless)

Values for the chemical-specific parameters ( $K_p$ ,  $\tau$ ,  $t^*$ , and  $B$ ) were obtained from the current dermal guidance and are presented in Table 6-12.

Current guidance is used to develop the following default assumptions concerning the amount of skin surface area available for contact. The exposed skin surface area for construction workers was assumed to be 2,490 cm<sup>2</sup>. This value represents the hands and forearms being exposed to groundwater. The exposure time (ET) for construction workers is 8 hours per day, the length of a typical workday. It was assumed that the entire body would be available for exposure for a child (6,600 cm<sup>2</sup>) and adult (18,000 cm<sup>2</sup>). It was assumed that a child would be exposed to groundwater while bathing 20 minutes per day, 350 days per year for 6 years and an adult would be exposed 15 minutes per day, 350 days per year for 24 years.

### 6.2.6.5 Inhalation of Volatiles in Groundwater

Groundwater exposure may also result in inhalation of volatiles, typically for adult residential receptors, who may be exposed while showering, bathing, washing dishes, etc., or for the construction worker who may contact shallow groundwater. Future adult residents exposure through inhalation while showering was evaluated following U.S. EPA Region 4 guidance. U.S. EPA Region 4 Human Health Risk Assessment Guidance stipulates that intakes as a result of inhalation of volatile COPCs while showering are equivalent to the intake from ingestion of 2 liters of contaminated water per day. In order to calculate total risk from groundwater in accordance with U.S. EPA Region 4 guidance, the risk from ingestion of groundwater for volatile COPCs was doubled to factor in the risk from inhalation of contaminants in groundwater.

Exposures for construction workers associated with the inhalation route is estimated in the following manner:

$$\text{Intake}_{\text{ai}} = \frac{(C_{\text{ai}})(IR_{\text{a}})(ET)(EF)(ED)}{(BW)(AT)}$$

where:  $\text{Intake}_{\text{ai}}$  = intake of chemical "i" from air via inhalation (mg/kg/day)

$C_{\text{ai}}$  = concentration of chemical "i" in air (mg/m<sup>3</sup>)

$IR_{\text{a}}$  = inhalation rate (m<sup>3</sup>/hr)

ET = exposure time (hours/day)

EF = exposure frequency (days/yr)

ED = exposure duration (yr)

BW = body weight (kg)

AT = averaging time (days);

for noncarcinogens, AT = ED x 365 days/yr;

for carcinogens, AT = 70 yr x 365 days/yr

Construction workers may be exposed to COPCs that have volatilized from groundwater when excavation exposes the shallow water table. Ambient air concentrations resulting from the volatilization of COPCs from groundwater to outdoor air were calculated by using the following equation from American Society for Testing and Materials Standard Guide for Risk-Based Corrective Action. The air concentration was calculated from

$$C_{\text{air}} = VF_{\text{gw,amb}} \cdot C_{\text{gw}}$$

where:  $C_{air}$  = chemical concentration in indoor air, mg/m<sup>3</sup>  
 $VF_{gw,amb}$  = volatilization factor from groundwater to indoor air, L/m<sup>3</sup>  
 $C_{gw}$  = chemical concentration in groundwater, mg/L

The volatilization factor,  $VF_{gw,amb}$ , was calculated from

$$VF_{gw,amb} = \frac{1}{\left[ \frac{DF_{amb} \cdot L_{GW}}{D_{ws}^{eff}} \right] \cdot \frac{1}{H'}} \cdot 10^3 \cdot \frac{L}{m^3}$$

and

$$DF_{amb} = \frac{U_{air} \cdot W \cdot d_{air}}{A}$$

where:  $VF_{gw,amb}$  = volatilization factor for groundwater (L/m<sup>3</sup>)  
 $H'$  = Henry's law constant, chemical specific (cm<sup>3</sup>-H<sub>2</sub>O)/(cm<sup>3</sup>-air)  
 $L_{GW}$  = depth to groundwater (cm)  
=  $h_v + h_{cap}$   
 $h_v$  = thickness of vadose zone (cm)  
 $h_{cap}$  = thickness of capillary fringe (cm)  
 $D_{ws}^{eff}$  = effective diffusion coefficient between groundwater and surface soil, chemical specific (cm<sup>2</sup>/sec)  
 $DF_{amb}$  = dispersion factor for outdoor air (cm/sec)  
 $U_{air}$  = wind speed above ground surface in mixing zone (cm/sec)  
 $d_{air}$  = ambient air mixing zone (cm)  
 $W$  = width of source parallel to groundwater flow direction (cm)  
 $A$  = source-zone area (cm<sup>2</sup>)

Because exposure to constituents that have volatilized from groundwater is a result of direct exposure, the depth to groundwater is simply ( $L_{gw}$ ) defined as the thickness of the capillary fringe ( $h_{cap}$ ).

The effective diffusion coefficient between groundwater and surface soil,  $D_{ws}^{eff}$  is calculated from

$$D_{ws}^{eff} = \frac{L_{gw}}{(h_v / D_s^{eff}) + (h_{cap} / D_{cap}^{eff})}$$

Where  $D_{cap}^{eff}$  = effective diffusion through capillary fringe, chemical specific,  $cm^2/sec$   
 $D_s^{eff}$  = effective diffusion in soil based on vapor-phase concentration, chemical specific,  $cm^2/sec$

It was assumed that excavation would occur to the water table; therefore, the thickness of the vadose zone was set equal to 0 and the thickness of the capillary fringe was set equal to 0.1 cm. Because  $h_v$  is equal to zero, this equation reduces to show that the effective diffusion between groundwater and surface soil ( $D_{ws}^{eff}$ ) is equal to the effective diffusion through the capillary fringe ( $D_{cap}^{eff}$ ).

The effective diffusion through the capillary fringe,  $D_{cap}^{eff}$ , is calculated from

$$D_{cap}^{eff} = D^{air} \cdot \frac{\theta_{acap}^{3.33}}{\theta_T^2} + D^{wat} \cdot \frac{1}{H} \cdot \frac{\theta_{wcap}^{3.33}}{\theta_T^2}$$

where:  $D^{air}$  = diffusion coefficient in air, chemical specific,  $cm^2/sec$   
 $D^{wat}$  = diffusion coefficient in water, chemical specific,  $cm^2/sec$   
 $\theta_{acap}$  = volumetric air content in capillary fringe soils,  $0.038 \text{ cm}^3\text{-air}/\text{cm}^3\text{-soil}$   
 $\theta_{wcap}$  = volumetric water content in capillary fringe soils,  $0.342 \text{ cm}^3\text{-H}_2\text{O}/\text{cm}^3\text{-soil}$   
 $\theta_T$  = total soil porosity,  $0.38 \text{ cm}^3/\text{cm}^3\text{-soil}$

Input assumptions for the volatilization from groundwater to outdoor air model are presented in Table 6-13. Site-specific values are used whenever possible. Model default values are used when they are believed to be representative of site conditions. Chemical properties were obtained from the Soil Screening Guidance: User's Guide and are presented in Table 6-14.

### 6.3 TOXICITY ASSESSMENT

The toxicity assessment examines information concerning the potential human health effects associated with exposure to COPCs. The goal of the toxicity assessment is to provide, for each COPC, a quantitative estimate of the relationship between the magnitude and type of exposure and the severity or probability of human health effects. The toxicity values presented in this section are integrated with the outputs of the exposure assessment to characterize the potential for the occurrence of adverse health effects.

The toxicological evaluation involves a critical review and interpretation of toxicity data from epidemiological, clinical, animal, and in vitro studies. This review of the data ideally determines both the nature of the health effects associated with a particular chemical and the probability that a given quantity

of a chemical could result in the referenced effect. This analysis defines the relationship between the dose received and the incidence of an adverse effect for the COPC.

The entire toxicological database is used to guide the derivation of cancer slope factors (CSFs) for carcinogenic effects and reference doses (RfDs) for noncarcinogenic effects. These data may include epidemiological studies, long-term animal bioassays, short-term tests, and comparisons of molecular structure. Data from these sources are reviewed to determine if a chemical is likely to be toxic to humans. Because of the lack of available human studies, however, the majority of toxicity data used to derive CSFs and RfDs comes from animal studies.

For noncarcinogenic effects, the most appropriate animal model (i.e., the species most biologically similar to the human) is identified. Pharmacokinetic data often enter into this determination. In the absence of sufficient data to identify the most appropriate animal model, the most sensitive species is chosen. The RfD is generally derived from the most comprehensive toxicology study that characterizes the dose response relationship for the critical effect of the chemical. Preference is given to studies using the exposure route of concern. In the absence of such data, however, an RfD for one route of exposure may be extrapolated from data from a study that used a different route of exposure. Such extrapolation must take into account pharmacokinetic and toxicological differences between the routes of exposure. Uncertainty factors are applied to the highest no-observed-adverse-effect-level (NOAEL) to adjust for inter- and intraspecies variation, deficiencies in the toxicological database, and use of subchronic rather than chronic animal studies. Additional uncertainty factors may be applied to estimate a NOAEL from a lowest-observed-adverse-effect-level (LOAEL) if the key study failed to determine a NOAEL.

CSFs for weights-of-evidence of Group A or B chemicals are generally derived from positive cancer studies that adequately identify the target organ in the test animal data and characterize the dose response relationship. CSFs are derived for Group C compounds for which the data are sufficient but are not derived for Group D or E chemicals. No consideration is given to similarity in the animal and human target organ(s) because a chemical capable of inducing cancer in any animal tissue is considered potentially carcinogenic to humans. Preference is given to studies using the route of exposure of concern, in which normal physiologic function was not impaired and in which exposure occurred during most of the animal's lifetime. Exposure and pharmacokinetic considerations are used to estimate equivalent human doses for computation of the CSF. When a number of studies of similar quality are available, the data may be combined in the derivation of the CSF.

Toxicological profiles for each of the COPCs are presented in Appendix F. These profiles present a summary of the available literature on carcinogenic and noncarcinogenic effects associated with human exposure to the chemical.

### 6.3.1 Carcinogenic Effects

The toxicity information considered in the assessment of potential carcinogenic risks includes a weight-of-evidence classification and a slope factor. The weight-of-evidence classification qualitatively describes the likelihood that a chemical is a human carcinogen and is based on an evaluation of the available data from human and animal studies. A chemical may be placed in one of three groups in U.S. EPA's classification system to denote its potential for carcinogenic effects:

- Group A - known human carcinogen
- Group B1 or B2 - probable human carcinogen
- Group C - possible human carcinogen

Chemicals that cannot be classified as a human carcinogen because of a lack of data are placed in Group D, and those for which there is evidence of noncarcinogenicity in humans are placed in Group E.

The CSF is the toxicity value used to quantitatively express the carcinogenic hazard of cancer-causing chemicals. It is defined as the upper-bound estimate of the probability of cancer incidence per unit dose averaged over a lifetime. Slope factors are derived from studies of carcinogenicity in humans and/or laboratory animals and are typically calculated for compounds in Groups A, B1, and B2, although some Group C carcinogens also have slope factors and some B2 carcinogens have none (e.g., lead). Slope factors are specific to a chemical and route of exposure and are expressed in units of  $(\text{mg/kg/day})^{-1}$  for both oral and inhalation routes. Inhalation cancer toxicity values are usually expressed as inhalation unit risks in units of reciprocal  $\mu\text{g}/\text{m}^3$  ( $1/\mu\text{g}/\text{m}^3$ ). Because cancer risk characterization requires an estimate of reciprocal dose in units of  $1/\text{mg}/\text{kg}/\text{day}$ , the inhalation unit risk must be converted to the mathematical equivalent of an inhalation cancer slope factor, or risk per unit dose ( $\text{mg}/\text{kg}/\text{day}$ ). This is done by assuming that humans weigh 70 kg and inhale  $20 \text{ m}^3$  of air per day [i.e., the inhalation unit risk ( $1/\mu\text{g}/\text{m}^3$ ) is divided by  $20 \text{ m}^3$ , multiplied by 70 kg, and multiplied by 1,000  $\mu\text{g}/\text{mg}$  to yield the mathematical equivalent of an inhalation slope factor ( $1/\text{mg}/\text{kg}/\text{day}$ )].

CSFs for COPCs at Site 45 are presented in Tables 6-17 and 6-18. The primary sources of information for these values are the U.S. EPA's Integrated Risk Information System (IRIS). U.S. EPA intends that IRIS supersede all other sources of toxicity information for risk assessment. If values are not available in IRIS, the annual Health Effects Assessment Summary Tables (HEAST) are consulted. The U.S. EPA Region 9 PRG Table is also used as a quick tabulated reference for available CSFs. If no CSF is available from any of these sources, carcinogenic risks are not quantified and potential exposures are addressed in Section 6.5, Uncertainty Analysis.

CSFs also exist for several (but not all) Class C compounds, which are identified as "possible" human carcinogens. These compounds typically exhibit inadequate evidence of carcinogenicity in humans and limited evidence in animals. In this human health risk assessment, Class C compounds are evaluated the same as Class A, B1, and B2 compounds. The uncertainty associated with this approach is discussed in Section 6.5.

Dermal CSFs are derived from the corresponding oral values. Regional guidance (U.S. EPA, Region 4, 1995a, 1996b) is used as a basis for determining the dermal CSFs. In the derivation of a dermal CSF, the oral CSF is divided by the gastrointestinal absorption efficiency to determine a CSF based on an absorbed dose rather than an administered dose, as follows:

$$CSF_{\text{dermal}} = (CSF_{\text{oral}}) / (ABS_{\text{GI}})$$

The oral CSF is divided by the absorption efficiency because CSFs are expressed as reciprocal doses. Dermal CSFs and the absorption efficiencies used in their determination are also included in Table 6-12.

### 6.3.2 Noncarcinogenic Effects

For noncarcinogens, it is assumed that there exists a dose below which no adverse health effects will be seen. Below this "threshold" dose, exposure to a chemical can be tolerated without adverse effects. For noncarcinogens, a range of exposure exists that can be tolerated. Toxic effects are manifested only when physiologic protective mechanisms are overcome by exposures to a chemical above its threshold level. Maternal and developmental endpoints are considered systemic toxicity.

The potential for noncarcinogenic health effects resulting from exposure to chemicals is assessed by comparing an exposure estimate (intake or dose) to an RfD. The RfD is expressed in units of mg/kg/day and represents a daily intake of contaminant per kilogram of body weight that is not sufficient to cause the threshold effect of concern. An RfD is specific to the chemical, the route of exposure, and the duration over which the exposure occurs. Separate RfDs are presented for ingestion and inhalation pathways. In particular, reference concentrations (RfCs) in units of mg/m<sup>3</sup> are typically presented for the inhalation pathway. Because characterization of noncarcinogenic effects requires an estimate of dose in units of mg/kg/day, the inhalation RfC must be converted to an inhalation RfD. This is done by assuming that humans weigh 70 kg and inhale 20 m<sup>3</sup> of air per day [i.e., the inhalation RfC (mg/m<sup>3</sup>) is multiplied by 20 m<sup>3</sup>/day and divided by 70 kg to yield an inhalation RfD (mg/kg/day)].

To derive an RfD, U.S. EPA reviews all relevant human and animal studies for each compound and selects the study (studies) pertinent to the derivation of the specific RfD. Each study is evaluated to determine the NOAEL or, if the data are inadequate for such a determination, the LOAEL. The NOAEL

corresponds to the dose (in mg/kg/day) that can be administered over a lifetime without inducing observable adverse effects. The LOAEL corresponds to the lowest daily dose that induces an observable adverse effect. The toxic effect characterized by the LOAEL is referred to as the "critical effect." To derive an RfD, the NOAEL (or LOAEL) is divided by uncertainty factors to ensure that the RfD will be protective of human health. Uncertainty factors are applied to account for extrapolation of data from laboratory animals to humans (interspecies extrapolation), variation in human sensitivity to the toxic effects of a compound (intraspecies differences), derivation of a chronic RfD based on a subchronic rather than a chronic study, and/or derivation of an RfD from the LOAEL rather than the NOAEL. In addition to these uncertainty factors, modifying factors between 1 and 10 may be applied to reflect additional qualitative considerations in evaluating the data. For most compounds, the modifying factor is 1.

A dermal RfD is developed from an oral RfD by multiplying by the gastrointestinal tract absorption factor, as follows:

$$RfD_{\text{dermal}} = (RfD_{\text{oral}})(ABS_{\text{GI}})$$

The resulting dermal RfD is, therefore, based on absorbed dose, which is what is calculated by the dermal exposure algorithms.

RfDs for the COPCs at Site 45 are presented in Tables 6-17 and 6-18. The primary source of these values is the IRIS database, followed by other U.S. EPA sources described for the carcinogens. Table 6-17 and 6-18 also includes the primary target organs affected by a particular chemical. This information may be used in the risk characterization section to segregate risks by target organ effects, unless the total HI is below unity. This ensures that "risks" are not overestimated when different compounds affect different target organs.

## **6.4 RISK CHARACTERIZATION**

This section provides a characterization of the potential human health risks associated with the potential exposure to COPCs at Site 45. Section 6.4.1 outlines the methods used to quantitatively estimate the type and magnitude of potential risks for human receptors. A summary of the risk characterization for Site 45 is provided in Section 6.4.2.

### **6.4.1 Methodology for Estimation of Quantitative Risks**

Potential human health risks resulting from exposure to COPCs are estimated using algorithms established by U.S. EPA. The methods described by U.S. EPA are protective of human health and are

likely to overestimate (rather than underestimate) risk. The methodology uses specific algorithms to calculate risk as a function of chemical concentration, human exposure parameters, and toxicity.

Risks from hazardous chemicals are calculated for either carcinogenic or noncarcinogenic effects. Some carcinogenic chemicals may also exhibit noncarcinogenic effects. Potential impacts are then characterized for both types of health effects.

#### 6.4.1.1 Carcinogenic Effects

Risks attributable to exposure to carcinogenic COPCs are estimated as the probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen. At low doses, the incremental lifetime cancer risk (ILCR) is determined as follows (U.S. EPA, 1989):

$$ILCR_i = (Intake_i)(CSF_i)$$

where:  $ILCR_i$  = incremental lifetime cancer risk for chemical "i", expressed as a unitless probability

$Intake_i$  = intake of chemical "i" (mg/kg/day)

$CSF_i$  = cancer slope factor of chemical "i" (kg/day/mg)

Estimated ILCRs are compared to the U.S. EPA target risk range,  $10^{-4}$  to  $10^{-6}$ . Risks below  $1 \times 10^{-6}$  (1/1,000,000, or a risk less than 1 in 1 million) are generally considered to be "acceptable" by the U.S. EPA, whereas risks greater than  $1 \times 10^{-4}$  (1 in 10,000) are generally considered to be "unacceptable" by the Agency. Depending on the risk management goals for the site, risks within  $10^{-4}$  to  $10^{-6}$  are also typically regarded as "acceptable."

When carcinogenic risks exceed  $1 \times 10^{-2}$  using the above methodology, the U.S. EPA (1989) specifies that the one-hit model be used, as follows:

$$ILCR_i = 1 - \exp(-Intake_i)(CSF_i)$$

Risks are estimated for all carcinogenic compounds regardless of the class designation (A, B, or C).

#### 6.4.1.2 Noncarcinogenic Effects

The hazards associated with the effects of noncarcinogenic COPCs are evaluated by comparing an exposure level or intake to an RfD. The ratio of the intake to the RfD is called the Hazard Quotient (HQ) and is defined as follows:

$$HQ_i = \frac{\text{Intake}}{\text{RfD}_i}$$

where:  $HQ_i$  = Hazard Quotient for chemical "i" (unitless)  
 $\text{Intake}_i$  = intake of chemical "i" (mg/kg/day)  
 $\text{RfD}_i$  = reference dose of chemical "i" (mg/kg/day)

A Hazard Index (HI) is generated by summing the individual HQs for all the COPCs. If the HI exceeds unity, there exists a potential for noncarcinogenic (toxic) effects to occur. When the HI exceeds unity, it is necessary to segregate the HQs by target organ effects since the HQs for all noncarcinogens are not considered to be truly additive unless similar target organs are affected.

The estimation of noncarcinogenic effects (i.e., the calculation of HQs/HIs) should not be construed as a probability in the manner of the ILCR but rather a numerical indicator of the extent to which a predicted intake exceeds, or is less than, an RfD.

#### **6.4.2 Results of the Risk Characterization**

This section contains a summary of the results of the risk characterization for Site 45. Potential cancer risks and HIs were calculated for construction workers, maintenance workers, commercial workers, adult visitors and on-site residents and are summarized in Table 6-19. Sample calculations are presented in Appendix F. Results of the risk assessment in RAGS Part D format are included in Appendix F.

##### **Construction Workers**

All estimated cancer risks for construction workers were within U.S. EPA's target risk range of  $10^{-4}$  to  $10^{-6}$ . The estimated cancer risk for construction workers was  $1.4 \times 10^{-5}$  for exposure to surface and subsurface soil and  $7.0 \times 10^{-6}$  for exposure to groundwater. The total cancer risk across all media was  $2.1 \times 10^{-5}$ .

The estimated HI for a construction worker exposed to surface and subsurface soil was 1.7, which exceeds the acceptable level of 1.0. PCE (HI = 1.7) was the main contributor to the HI for exposure to surface and subsurface soil. The estimated HI for a construction worker exposed to groundwater was 2.6, which also exceeds the acceptable level of 1.0. TCE (HI = 2.0) was the main contributor to the HI for exposure to groundwater. It should be noted that PCE and TCE were the only chemicals with an HI greater than 1.0 in all media. The cumulative HI across all media and exposure routes was 4.3.

### **Maintenance Workers**

The estimated cancer risk for maintenance workers exposed to surface soil was  $7.5 \times 10^{-7}$ , which is below the acceptable EPA risk threshold of  $1 \times 10^{-6}$ . The estimated HI for a maintenance worker exposed to surface soil was 0.004, which is less than the acceptable level of 1.0, indicating that no adverse health effects are anticipated under the defined conditions.

### **Commercial Workers**

The estimated cancer risk for commercial workers exposed to surface soil was  $2.9 \times 10^{-6}$ , which is within the U.S. EPA's target risk range of  $10^{-4}$  to  $10^{-6}$ .

The estimated HI for a commercial worker exposed to surface soil was 0.001, which is less than the acceptable level of 1.0, indicating that no adverse health effects are anticipated under the defined conditions.

### **Adult Visitors**

The estimated cancer risk for adult visitors exposed to surface soil was  $2.7 \times 10^{-7}$ , which is below the acceptable EPA risk threshold of  $1 \times 10^{-6}$ .

The estimated HI for adult visitors exposed to surface soil was 0.002, which is less than the acceptable level of 1.0, indicating that no adverse health effects are anticipated under the defined conditions.

### **On-Site Residents**

All estimated cancer risks for the on-site child resident were within the U.S. EPA's target risk range of  $10^{-4}$  to  $10^{-6}$ , with the exception of surficial groundwater. The estimated cancer risks for the on-site child were  $8.1 \times 10^{-6}$  for surface soil,  $1.2 \times 10^{-2}$  for surficial groundwater, and  $3.6 \times 10^{-6}$  for deep groundwater. Vinyl chloride (ICR =  $1.2 \times 10^{-2}$ ), TCE (ICR =  $1.6 \times 10^{-3}$ ), and PCE (ICR =  $6.6 \times 10^{-3}$ ) were the major contributors to the carcinogenic risk for exposure to surficial groundwater. The total cancer risk to the child resident across all exposure routes and all media was  $1.2 \times 10^{-2}$ .

All estimated cancer risks for the on-site adult resident were within U.S. EPA's target risk range of  $10^{-4}$  to  $10^{-6}$  with the exception of surficial groundwater. The estimated cancer risks for the on-site adult resident were  $4.0 \times 10^{-6}$  for exposure to surface soil,  $3.5 \times 10^{-2}$  for exposure surficial groundwater, and  $6.4 \times 10^{-6}$  for exposure to deep groundwater. Vinyl chloride (ICR =  $2.0 \times 10^{-2}$ ), PCE (ICR =  $1.2 \times 10^{-2}$ ), and TCE (ICR =  $2.8 \times 10^{-3}$ ) were the major contributors to the carcinogenic risk for exposure to surficial

groundwater. The total cancer risk to the on-site adult resident across all exposure routes and media was  $3.5 \times 10^{-2}$ .

All estimated cancer risks for the on-site lifelong resident were within U.S. EPA's target risk range of  $10^{-4}$  to  $10^{-6}$  with the exception of surficial groundwater. The estimated cancer risks for the on-site lifelong resident were  $1.1 \times 10^{-5}$  for exposure to surface soil,  $5.5 \times 10^{-2}$  for exposure to surficial groundwater, and  $9.2 \times 10^{-6}$  for exposure to deep groundwater. Vinyl chloride (ICR =  $3.2 \times 10^{-2}$ ), PCE (ICR =  $1.8 \times 10^{-2}$ ), and TCE (ICR =  $4.4 \times 10^{-3}$ ) were the major contributors to the carcinogenic risk for exposure to surficial groundwater. The total cancer risk to the on-site lifelong resident across all exposure routes and media was  $5.5 \times 10^{-2}$ .

The estimated HIs for the on-site child resident were 0.2 for exposure to surface soil and 0.1 for exposure to deep groundwater, which are less than the acceptable level of 1.0, indicating that no adverse health effects are anticipated for the on-site child resident exposed to surface soil and deep groundwater. The estimated HI for the on-site child resident for exposure to surficial groundwater was 248, exceeding the acceptable level of 1.0. TCE (HI = 281), PCE (HI = 149), cis-1,2-DCE (HI = 45), and vinyl chloride (HI = 31) were the major contributors to the HI. The cumulative HI across all exposure routes and media was 248.

The estimated HIs for the on-site adult resident were 0.03 for exposure to surface soil and 0.03 for exposure to deep groundwater, which are less than the acceptable level of 1.0, indicating that no adverse health effects are anticipated for the on-site adult resident exposed to surface soil and deep groundwater. The estimated HI for the on-site adult resident exposed to surficial groundwater was 224, exceeding the acceptable level of 1.0. TCE (HI = 126), PCE (HI = 66), cis-1,2-DCE (HI = 20), and vinyl chloride (HI = 13.2) were the major contributors to the HI. The cumulative HI across all exposure routes and media was 163.

## **6.5 UNCERTAINTY ANALYSIS**

There is uncertainty associated with all aspects of the baseline human health risk assessment presented in this section. A summary of the uncertainties, including a discussion of how they may affect the final risk numbers, is provided in this section.

Uncertainty in the selection of COPCs is related to the current status of the predictive databases, the grouping of samples, and the procedures used to include or exclude constituents as COPCs. Uncertainty associated with the exposure assessment includes the values used as input variables for a given intake route scenario, the assumptions made to determine exposure point concentrations, and the predictions regarding future land use and population characteristics. Uncertainty in the toxicity assessment includes

the quality of the existing toxicity data needed to support dose response relationships and the weight-of-evidence used to determine the carcinogenicity of COPCs. Uncertainty in risk characterization includes that associated with exposure to multiple chemicals and the cumulative uncertainty from combining conservative assumptions made in earlier activities.

Although there are various sources of uncertainty, as described above, the direction of uncertainty can be influenced by the assumptions made throughout the risk assessment, including selection of COPCs and selection of values for dose response relationships. Throughout the entire risk assessment, assumptions that consider safety factors are made so that the final calculated risks are overestimated.

Generally, risk assessments carry two types of uncertainty, measurement and informational. Measurement uncertainty refers to the usual variance that accompanies scientific measurements. For example, this type of uncertainty is associated with analytical data collected for each site. The risk assessment reflects the accumulated variances of the individual values used. Informational uncertainty stems from inadequate availability of information needed to complete the toxicity and exposure assessments. Often, this gap is significant, such as the absence of information on the effects of human exposure to low doses of a chemical, on the biological mechanism of action of a chemical, or on the behavior of a chemical in soil.

Once the risk assessment is complete, the results must be reviewed and evaluated to identify the type and magnitude of uncertainty involved. Reliance on results from a risk assessment without consideration to uncertainties, limitations, and assumptions inherent in the process can be misleading. For example, to account for uncertainties in the development of exposure assumptions, conservative estimates must be made to ensure that the particular assumptions that are made are protective of sensitive subpopulations or the maximum exposed individuals. If a number of conservative assumptions are combined in an exposure model, the resulting calculations can propagate the uncertainties associated with those assumptions, thereby producing a much larger uncertainty for the final results. This uncertainty is biased toward over predicting both carcinogenic and noncarcinogenic risks. Thus, both the results of the risk assessment and the uncertainties associated with those results must be considered when making risk management decisions.

This interpretation is especially relevant when the risks exceed the point of departure for defining "acceptable" risk. For example, when risks calculated using a high degree of uncertainty are below an acceptable risk level (i.e.,  $1 \times 10^{-6}$ ), the interpretation of no significant risk is typically straightforward. However, when risks calculated using a high degree of uncertainty are above an "acceptable" risk level (i.e.,  $1 \times 10^{-4}$ ), a conclusion can be difficult unless uncertainty is considered.

### **6.5.1 Uncertainty in Selection of COPCs**

There is a minor amount of uncertainty associated with the selection of COPCs that may impact the numerical risk estimates presented in Section 6.4, Risk Characterization. The most significant issues related to uncertainty in COPC selection for Site 45 are the screening levels used and the absence of screening levels for a few chemicals detected in the site media. A brief discussion of each of these issues is provided in the remainder of this section.

Another source of uncertainty may exist in the differences between the contaminants and concentrations detected by the QT and by the standard laboratory analyses (e.g. benzene in deep groundwater, TCE at a maximum concentration of 13,000 µg/L rather than 1,000 µg/L, and DCE at a maximum concentration of 14,000 µg/L rather than 4 µg/L). For this reason, the selected COPCs may not represent the entire range of contaminants, and the maximum concentrations used for risk assessment may underestimate the actual maximum concentrations.

#### **6.5.1.2 COPC Screening Levels**

The use of predetermined screening values based on conservative land use scenarios (i.e., residential land use for soil and ingestion and inhalation for groundwater), in combination with the use of risk-based screening values corresponding to an ILCR of  $1 \times 10^{-6}$  and an HI of 0.1, should ensure that the significant contributors to risk from a site are evaluated. The elimination of chemicals that are present at concentrations that correspond to an ILCR less than  $1 \times 10^{-6}$  and an HI less than 0.1 should not affect the final conclusions of the risk assessment since these chemicals are not expected to cause a potential health concern.

#### **6.5.1.3 Absence of COPC Screening Levels**

There are several chemicals [benzo(g,h,i)perylene and phenanthrene] for which there are no available health criteria and for which no risk-based COPC screening criterion could be developed. Therefore, as recommended by U.S. EPA Region 4 (1995), the screening criterion for pyrene was used as a surrogate for these chemicals since their chemical structures are similar to that of pyrene. Therefore, there is some uncertainty associated with screening these chemicals using the screening criteria for pyrene. The maximum detected concentrations of benzo(g,h,i)perylene and phenanthrene in surface and subsurface soil are approximately one or more orders of magnitude lower than the screening criteria for pyrene. Consequently, the absence of screening criteria for benzo(g,h,i)perylene and phenanthrene and the use of pyrene as a surrogate for these chemicals do not affect the conclusions of the risk assessment.

## **6.5.2 Uncertainty in the Exposure Assessment**

Uncertainty in the exposure assessment arises because of the methods used to calculate exposure point concentrations, the determination of land use conditions, the selection of receptors and scenarios, and the selection of exposure parameters. Each of these is discussed below.

### **6.5.2.1 Land Use**

Currently, the site is undeveloped, although land use patterns in the vicinity of the site are well established, thereby reducing the uncertainty associated with land use assumptions. Since the area around the site is currently used for commercial purposes, future land use at the site is expected to be limited in the future.

### **6.5.2.2 Exposure Point Concentrations**

For some chemicals in surface soil, surficial groundwater, and deep groundwater, the distribution of the chemical was not defined and the maximum detected concentration was used as the exposure point concentration. As a result, the estimations of risk, where the maximum concentrations were used as the exposure point concentrations, may be overstated because it is unlikely that potential receptors would be exposed to the maximum concentration over the entire exposure period. Conversely, in some areas where the maximum detected concentrations observed during the QP phase of the RI are significantly greater than those used during the risk assessment, the uncertainty over this representativeness may be overstated.

### **6.5.2.3 Exposure Routes and Receptor Identification**

The determination of various receptor groups and exposure routes of potential concern was based on current land use observed at the site. Therefore, the uncertainty associated with the selection of exposure routes and potential receptors is minimal because the possible future uses of the site are limited. Receptors quantitatively evaluated in the human health risk assessment for the site included construction workers, maintenance workers, commercial workers, adult visitors, and on-site residents. As previously discussed, the site is currently undeveloped and the only potential current receptors are maintenance workers and adult visitors. The site was the location of a dry cleaners in the past and it is possible that the site will be developed for commercial use in the future, making construction workers and commercial workers potential future receptors at the site. Land use in the vicinity of the site is currently commercial and is not expected to change in the future. Therefore, the evaluation of potential residential exposures that was performed in this baseline human health risk assessment was included primarily to aid in risk management decision making.

#### **6.5.2.4 Exposure Parameters**

Each exposure factor selected for use in the risk assessment has some associated uncertainty. Generally, exposure factors are based on surveys of physiological and lifestyle profiles across the United States. The attributes and activities studied in these surveys generally have a broad distribution. To avoid underestimation of exposure, the U.S. EPA guidelines on the RME receptor were used; these generally consist of the 95th percentile for most parameters. Therefore, the selected values for the RME receptor represent the upper bound of the observed or expected habits of the majority of the population.

Generally, the uncertainty can be assessed quantitatively for a number of assumptions made in determining factors for calculating exposures and intakes. Many of these parameters were determined from statistical analyses on human population characteristics. Often, the database used to summarize a particular exposure parameter (i.e., body weight) is quite large. Consequently, the values chosen for such variables in the RME scenario have low uncertainty. For many parameters for which limited information exists (i.e., dermal absorption of organic chemicals from soil), there is greater uncertainty. However, there are often sufficient data to estimate these parameters with low uncertainty.

Many of the quantities used to calculate exposures and risks in this report are selected from a distribution of possible values. For the RME scenario, the value representing the 95th percentile is generally selected for each parameter to ensure that the assessment bounds the actual risks from a postulated exposure. This risk number is used in risk management decisions but does not indicate what a more average or typical exposure might be or what risk range might be expected for individuals in the exposed population.

#### **6.5.3 Uncertainty in the Toxicological Evaluation**

Uncertainties associated with the toxicity assessment (determination of RfDs and CSFs and use of available criteria) are presented in this section.

##### **6.5.3.1 Derivation of Toxicity Criteria**

Uncertainty with the toxicity assessment is associated with hazard assessment and dose response evaluations for the COPCs. The hazard assessment deals with characterizing the nature and strength of the evidence of causation or the likelihood that a chemical that induces adverse effects in animals will also induce adverse effects in humans. Hazard assessment of carcinogenicity is evaluated as a weight-of-evidence determination, using the U.S. EPA methods. Positive animal cancer test data suggest that humans contain tissue(s) that may also manifest a carcinogenic response. However, the animal data cannot necessarily be used to predict the target tissue in humans. In the hazard assessment of

noncancer effects, however, positive animal data suggest the nature of the effects (i.e., the target tissues and type of effects) anticipated in humans.

Uncertainty in hazard assessment arises from the nature and quality of the animal and human data. Uncertainty is reduced when similar effects are observed across species, strain, sex, and exposure route; when the magnitude of the response is clearly dose related; when pharmacokinetic data indicate a similar fate in humans and animals; when postulated mechanisms of toxicity are similar for humans and animals; and when the chemical of concern is structurally similar to other chemicals for which the toxicity is more completely characterized.

Uncertainty in the dose response evaluation includes the determination of a CSF for the carcinogenic assessment and derivation of an RfD for the noncarcinogenic assessment. Uncertainty is introduced from interspecies (animal to human) extrapolation, which, in the absence of quantitative pharmacokinetic or mechanistic data, is usually based on consideration of interspecies differences in basal metabolic rate. Uncertainty also results from intraspecies variation. Most toxicity experiments are performed with animals that are very similar in age and genotype, so intragroup biological variation is minimal, but the human population of concern may reflect a great deal of heterogeneity, including unusual sensitivity or tolerance to the COPC. Even toxicity data from human occupational exposure reflect a bias, because only those individuals sufficiently healthy to attend work regularly (the "healthy worker effect") and those not unusually sensitive to the chemical are likely to be occupationally exposed. Finally, uncertainty arises from the quality of the key study from which the quantitative estimate is derived and the database. For cancer effects, the uncertainty associated with dose response factors is mitigated by assuming the 95 percent upper bound for the slope factor. Another source of uncertainty in carcinogenic assessment is the method by which data from high doses in animal studies are extrapolated to the dose range expected for environmentally exposed humans. The linearized multistage model, which is used in nearly all quantitative estimations of human risk from animal data, is based on a nonthreshold assumption of carcinogenesis. There is evidence to suggest, however, that epigenetic carcinogens, as well as many genotoxic carcinogens, have a threshold below which they are noncarcinogenic (Williams and Weisburger, 1991); therefore, the use of the linearized multistage model is conservative for chemicals that exhibit a threshold for carcinogenicity.

For noncancer effects, additional uncertainty factors may be applied in the derivation of the RfD to mitigate poor quality of the key study or gaps in the database. Additional uncertainty for noncancer effects arises from the use of an effect level in the estimation of an RfD, because this estimation is predicated on the assumption of a threshold below which adverse effects are not expected. Therefore, an uncertainty factor is usually applied to estimate a no-effect level. Additional uncertainty arises in estimation of an RfD for chronic exposure from less-than-chronic data. Unless empirical data indicate

that effects do not worsen with increasing duration of exposure, an additional uncertainty factor is applied to the no-effect level in the less-than-chronic study. Uncertainty in the derivation of RfDs is mitigated by the use of uncertainty and modifying factors that normally range between 3 and 10. The resulting combination of uncertainty and modifying factors may reach 1,000 or more.

#### **6.5.3.2 Use of PAH Toxicity Criteria**

Uncertainty also arises in the dose response assessment for values derived for several PAHs by using studies with limitations. These criteria are used to not only calculate risks for COPCs but are also used to determine risk-based COPC screening levels for PAHs. Potentially carcinogenic PAHs for which no toxicity data are available are evaluated using benzo(a)pyrene toxicity data with estimated orders of potential potency for the average and RME receptors. This may either underestimate or overestimate the carcinogenic risks associated with PAHs.

#### **6.5.4 Uncertainty in the Risk Characterization**

Uncertainty in risk characterization results primarily from assumptions made regarding additivity of effects from exposure to multiple COPCs from various exposure routes. High uncertainty exists when summing cancer risks for several substances across different exposure pathways. This assumes that each substance has a similar effect and/or mode of action. Often compounds affect different organs, have different mechanisms of action, and differ in their fate in the body, so additivity may not be an appropriate assumption. However, the assumption of additivity is made to provide a conservative estimate of risk.

Finally, the risk characterization does not consider antagonistic or synergistic effects. Little or no information is available to determine the potential for antagonism or synergism for the COPCs. Therefore, this uncertainty cannot be discussed for its impact on the risk assessment, since it may either underestimate or overestimate potential human health risk.

### **6.6 REMEDIAL GOAL OPTIONS**

In accordance with EPA Region 4 guidance, remedial goal options (RGOs) were developed for those media with estimated lifetime cancer risks greater than  $1 \times 10^{-4}$  and total HI greater than 1.0. As discussed in Sections 6.4 and 6.5, HIs for adult and child residents exposed to PCE, TCE, trans-1,2-DCE, cis-1,2-DCE, and vinyl chloride in surficial groundwater and HIs for construction workers exposed to PCE in surface and subsurface soil and TCE in surficial groundwater exceed the acceptable level of 1.0. ICRs for the lifelong, child and adult on-site residents exposed to PCE, TCE, and vinyl chloride in surficial groundwater exceeded EPA's target risk range; consequently, RGOs will be developed for these receptors.

RGOs for Site 45 were developed according to guidance provided in the Region 4 Human Health Risk Assessment Bulletins. The RGOs were calculated using the following equation:

$$\text{RGO}[\text{chemical } i] = \text{EPC}[\text{chemical } i] \times \text{Target Risk} / \text{Calculated Risk}[\text{chemical } i]$$

Where:

RGO[chemical i]	=	the chemical-specific remediation goal option.
EPC[chemical i]	=	the exposure point concentration for the chemical used in risk assessment calculations.
Target Risk	=	Target risk for carcinogens or the Target Hazard Quotients for noncarcinogens.
Calculated Risk[chemical i]	=	the total risk calculated for a specific chemical in the risk assessment.

In accordance to the Region 4 guidance, the target cancer risks to be used are  $1 \times 10^{-6}$ ,  $1 \times 10^{-5}$ , and  $1 \times 10^{-4}$  and the target HQs are 0.1, 1, and 3. The chemical-specific RGOs for child, adult, lifelong residents and construction workers are presented in Tables 6-20 and 6-21.

TABLE 6-1

**SCREENING CRITERIA USED IN SELECTION OF COPCS  
SITE 45 - FORMER MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA**

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CAS Number	Chemical	EPA Region 9 PRG (1) Residential (mg/kg)	EPA SSL (2) Soil to Air (mg/kg)	EPA SSL (2) Soil to Groundwater (mg/kg)	EPA Region 9 PRG (1) Tap Water (ug/L)	EPA MCL (3) (ug/L)
<b>Volatile Organics Compounds</b>						
71-55-6	1,1,1-Trichloroethane	630 N	1200 sat	0.1 MCLG	540 N	200
79-00-5	1,1,2-Trichloroethane	0.84 C	1 C	0.0009 MCLG	0.2 C	5
75-34-3	1,1-Dichloroethane	590 N	1300 N	1 N	810 N	NA
75-35-4	1,1-Dichloroethene	0.054 C	0.07 C	0.003 MCLG	0.046 C	7
95-50-1	1,2-Dichlorobenzene	370 sat	560 sat	0.9 MCLG	370 N	600
78-93-3	2-Butanone	7300 N	9000 N	4.4 N	1900 N	NA
67-64-1	Acetone	1600 N	100,000 sat	0.8 N	610 N	NA
74-83-9	Bromomethane	3.9 N	9.5 N	0.012 N	8.7 N	NA
71-43-2	Benzene	0.65 C	0.8 C	0.002 C	0.35 C	5
108-90-7	Chlorobenzene	150 N	130 N	0.07 MCLG	110 N	100
67-66-3	Chloroform	0.24 C	0.3 C	0.03 C	0.16 C	80
75-71-8	Dichlorodifluoromethane	94 N	250 N	28 N	390 N	NA
124-48-1	Dibromochloromethane	1.1 C	1300 sat	0.02 MCL	0.13 C	0.08
100-41-4	Ethylbenzene	230 sat	400 sat	0.7 MCLG	1300 N	700
98-82-8	Isopropylbenzene	160 N	850 sat	18 N	660 N	NA
127-18-4	Tetrachloroethene	5.7 C	11 C	0.003 MCL	1.1 C	5
108-88-3	Toluene	520 sat	650 sat	0.6 MCLG	720 N	1000
156-59-2	cis-1,2-dichloroethene	43 N	1200 sat	0.02 MCLG	61 N	70
156-60-5	Trans-1,2-dichloroethene	63 N	3100 sat	0.03 MCLG	120 N	100
79-01-6	Trichloroethene	2.8 C	5 C	0.003 MCL	1.6 C	5
75-01-4	Vinyl Chloride	0.15 C	0.03 C	0.0007 MCL	0.041 C	2
1330-20-7	Total Xylenes	210 sat	410 sat	9 MCLG	1400 N	10000
<b>Semivolatile Organics Compounds</b>						
91-57-6	2-Methylnaphthalene	56(4) N	NA	NA	6.2(4) N	NA
83-32-9	Acenaphthene	3700 N	NA	29 N	370 N	NA
208-96-8	Acenaphthylene	3700(5) N	NA	NA	370(5) N	NA
120-12-7	Anthracene	22000 N	NA	590 N	1800 N	NA
56-55-3	Benzo(a)anthracene	0.62 C	NA	0.08 C	0.092 C	NA
50-32-8	Benzo(a)pyrene	0.062 C	NA	0.4 C	0.0092 C	0.2
205-99-2	Benzo(b)fluoranthene	0.62 C	NA	0.2 C	0.092 C	NA
191-24-2	Benzo(g,h,i)perylene	2300(6) N	NA	NA	180(6) N	NA
207-08-9	Benzo(k)fluoranthene	6.2 C	NA	2 C	0.92 C	NA
117-81-7	Bis(2-Ethylhexyl)phthalate	35 C	31000 sat	180 MCL	4.8 C	6
85-68-7	Butyl Benzyl Phthalate	12000 N	930 sat	810 N	7300 N	NA
86-74-8	Carbazole	24 C	NA	0.03 C	3.4 C	NA
218-01-9	Chrysene	62 C	NA	8 C	9.2 C	NA
117-84-0	Di-n-octyl phthalate	1200 N	10000 sat	10000 sat	730 N	NA
53-70-3	Dibenzo(a,h)anthracene	0.062 C	NA	0.08 C	0.0092 C	NA
132-64-9	Dibenzofuran	290 N	210 sat	2.4 N	24 N	NA
84-66-2	Diethyl Phthalate	49000 N	2000 sat	23 N	29000 N	NA
206-44-0	Fluoranthene	2300 N	NA	210 N	1500 N	NA
86-73-7	Fluorene	2600 N	NA	28 N	240 N	NA
193-39-5	Indeno(1,2,3-cd)pyrene	0.62 C	NA	0.7 C	0.092 C	NA
91-20-3	Naphthalene	56 N	170 N	4 N	6.2 N	NA
85-01-8	Phenanthrene	2300(6) N	NA	NA	180(6) N	NA
129-00-0	Pyrene	2300 N	NA	210 N	180 N	NA
<b>Inorganics</b>						
7429-90-5	Aluminum	76000 N	NA	NA	36000 N	50 to 200(9)
7440-38-2	Arsenic	0.39 C	750 C	1 MCL	0.045 C	50
7440-39-3	Barium	5400 N	690000 N	82 MCLG	2600 N	2000
7440-70-2	Calcium	1000000(10) N	NA	NA	1055398(10) N	NA
7440-47-3	Chromium	30(7) C	270(7) C	2 C	110(7) N	100
7440-48-4	Cobalt	4700 N	NA	NA	2200 N	NA

TABLE 6-1

SCREENING CRITERIA USED IN SELECTION OF COPCS  
 SITE 45 - FORMER MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA

PAGE 2 OF 2

CAS Number	Chemical	EPA Region 9 PRG (1) Residential (mg/kg)	EPA SSL (2) Soil to Air (mg/kg)	EPA SSL (2) Soil to Groundwater (mg/kg)	EPA Region 9 PRG (1) Tap Water (ug/L)	EPA MCL (3) (ug/L)
7440-50-8	Copper	2900 N	NA	560 MCLG	1400 N	1300(8)
7439-89-6	Iron	23000 N	NA	NA	11000 N	300(9)
7439-92-1	Lead	400	NA	NA	NA	15(8)
7439-95-4	Magnesium	460468(10) N	NA	NA	118807(10) N	NA
7439-96-5	Manganese	1800 N	68600 N	110 N	880 N	50(9)
7439-97-6	Mercury	23 N	10 N	0.1 MCLG	11 N	2
7440-02-0	Nickel	1600 N	13000 C	7 N	730 N	NA
7440-09-7	Potassium	1000000(10) N	NA	NA	297016(10) N	NA
7440-23-5	Sodium	1000000(10) N	NA	NA	396022(10) N	NA
7440-62-2	Vanadium	550 N	NA	300 N	260 N	NA
7440-66-6	Zinc	23000 N	NA	620 N	11000 N	5000(9)

Notes:

- 1 U.S. EPA Region 9 Preliminary Remediation Goal Table, November 1, 2000.  
(Cancer benchmark value = 1E-06, HI = 1.0)
- 2 U.S. EPA Soil Screening Level Guidance: Technical Background Document. May 1996.  
U.S. EPA Soil Screening Calculations Web Site at [http://risk.lsd.ornl.gov/calc\\_start.htm](http://risk.lsd.ornl.gov/calc_start.htm)  
DAF = 1 for soil to groundwater SSLs.
- 3 U.S. EPA Drinking Water Regulations and Health Advisories, Summer 2000.
- 4 Value is for naphthalene.
- 5 Value is for acenaphthene.
- 6 Value is for pyrene.
- 7 Value is for hexavalent chromium.
- 8 Action Level.
- 9 Secondary MCL.
- 10 Derivation of screening value presented in Appendix F.

Definitions:

- N/A = Not applicable.
- C = Carcinogenic.
- N = Non-Carcinogenic.
- sat = saturation concentration.
- MCL = Maximum Contaminant Level.
- MCLG = Maximum Contaminant Level Goal.
- PRG = Preliminary Remediation Goal.
- SSL = Soil Screening Level.

TABLE 6-2

OCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN  
DIRECT CONTACT WITH SURFACE SOIL  
SITE 45 - FORMER MWR DRY CELANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA

CAS Number	Chemical	Minimum Concentration <sup>(1)</sup>	Minimum Qualifier	Maximum Concentration <sup>(1)</sup>	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Nondetects <sup>(2)</sup>	Concentration Used for Screening <sup>(2)</sup>	Background Value <sup>(4)</sup>	EPA Region 9 PRG-Residential <sup>(5)</sup>	EPA Soil Screening Levels- Inhalation <sup>(6)</sup>	EPA Soil Screening Levels-Soil to Groundwater <sup>(7)</sup>	COPC Flag	Rationale for Contaminant Deletion or Selection <sup>(8)</sup>
<b>Volatile Organic Compounds</b>																
71-55-6	1,1,1-Trichloroethane	4	J	4	J	ug/kg	PAI-45-SS-05-01	1/8	5 - 160	4	NA	63000 N	1200000 sat	100 MCLG	no	BSL
85-50-1	1,2-Dichlorobenzene	2	J	2	J	ug/kg	PAI-45-SS-05-01	1/8	5 - 160	2	NA	370000 sat	560000 sat	800 MCLG	no	BSL
75-71-8	Dichlorodifluoromethane	2	J	2	J	ug/kg	PAI-45-SS-02-01	1/8	5 - 160	2	NA	8400 N	25000 N	28000 N	no	BSL
127-18-4	Tetrachloroethane	14	J	7500	J	ug/kg	PAI-45-SS-05-01	8/8	NA	7500	NA	5700 C	11000 C	3 MCL	yes	ASL
156-60-5	Trans-1,2-dichloroethene	2	J	50	J	ug/kg	PAI-45-SS-04-01-D	2/8	5 - 160	50	NA	6300 N	3100000 sat	30 MCLG	yes	ASL
79-01-6	Trichloroethene	3	J	320	J	ug/kg	PAI-45-SS-04-01-D	7/8	6	320	NA	2800 C	5000 C	3 MCL	yes	ASL
156-59-2	cis-1,2-dichloroethene	2	J	730	J	ug/kg	PAI-45-SS-04-01-D	5/8	6 - 140	730	NA	4300 N	1200000 sat	20 MCLG	yes	ASL
<b>Semivolatile Organic Compounds</b>																
83-32-9	Acenaphthene	25	J	25	J	ug/kg	PAI-45-SS-03-01	1/8	360 - 430	25	NA	370000 N	NA	29000 N	no	BSL
120-12-7	Anthracene	21	J	290	J	ug/kg	PAI-45-SS-06-01	3/8	360 - 430	290	NA	2200000 N	NA	590000 N	no	BSL
56-55-3	Benzo(a)anthracene	44	J	150	J	ug/kg	PAI-45-SS-03-01	7/8	360	150	NA	620 C	NA	80 C	yes	cPAH
50-32-8	Benzo(a)pyrene	26	J	130	J	ug/kg	PAI-45-SS-02-01, PAI-45-SS-03-01	7/8	360	130	NA	62 C	NA	400 C	yes	ASL
205-99-2	Benzo(b)fluoranthene	42	J	180	J	ug/kg	PAI-45-SS-03-01	7/8	360	180	NA	620 C	NA	200 C	yes	cPAH
191-24-2	Benzo(g,h,i)perylene	36	J	110	J	ug/kg	PAI-45-SS-02-01	6/8	360 - 400	110	NA	230000 (9)N	NA	NA	no	BSL
207-08-9	Benzo(k)fluoranthene	32	J	64	J	ug/kg	PAI-45-SS-03-01	5/8	360 - 400	64	NA	6200 C	NA	2000 C	yes	cPAH
85-69-7	Butyl Benzyl Phthalate	25	J	900	J	ug/kg	PAI-45-SS-03-01	5/8	360 - 430	900	NA	1200000 N	930000 sat	810000 N	no	BSL
86-74-8	Carbazole	22	J	44	J	ug/kg	PAI-45-SS-03-01	3/8	360 - 430	44	NA	24000 C	NA	30 C	yes	ASL
218-01-9	Chrysene	45	J	170	J	ug/kg	PAI-45-SS-03-01	7/8	360	170	NA	62000 C	NA	8000 C	yes	cPAH
53-70-3	Dibenzo(a,h)anthracene	20	J	29	J	ug/kg	PAI-45-SS-02-01, PAI-45-SS-05-01	4/8	360 - 430	29	NA	62 C	NA	80 C	yes	cPAH
84-66-2	Diethyl Phthalate	19	J	19	J	ug/kg	PAI-45-SS-05-01	1/8	360 - 430	19	NA	4900000 N	2000000 sat	23000 N	no	BSL
206-44-0	Fluoranthene	42	J	300	J	ug/kg	PAI-45-SS-03-01	7/8	360	300	NA	230000 N	NA	210000 N	no	BSL
86-73-7	Fluorene	18	J	18	J	ug/kg	PAI-45-SS-03-01	1/8	360 - 430	18	NA	260000 N	NA	28000 N	no	BSL
193-39-5	Indeno(1,2,3-cd)pyrene	34	J	120	J	ug/kg	PAI-45-SS-02-01	6/8	360 - 400	120	NA	620 C	NA	700 C	yes	cPAH
91-20-3	Naphthalene	22	J	22	J	ug/kg	PAI-45-SS-03-01	1/8	360 - 430	22	NA	5600 N	17000 N	4000 N	no	BSL
85-01-8	Phenanthrene	22	J	230	J	ug/kg	PAI-45-SS-03-01	7/8	360	230	NA	230000 (9)N	NA	NA	no	BSL
129-00-0	Pyrene	52	J	280	J	ug/kg	PAI-45-SS-03-01	7/8	360	280	NA	230000 N	NA	210000 N	no	BSL
<b>Inorganics</b>																
7429-90-5	Aluminum	4300		9480		mg/kg	PAI-45-SS-04-01	8/8	NA	9480	7270	7600 N	NA	NA	yes	ASL
7440-39-2	Arsenic	0.94		2.1		mg/kg	PAI-45-SS-01-01	8/8	NA	2.1	1.44	0.39 C	750 C	1	yes	ASL
7440-39-3	Barium	14.2		28.6		mg/kg	PAI-45-SS-04-01	8/8	NA	28.6	23.6	540 N	69000 N	82 MCLG	no	BSL
7440-70-2	Calcium	724		3720		mg/kg	PAI-45-SS-03-01	8/8	NA	3720	766	1,000,000 N	NA	NA	no	NUT, BSL
7440-47-3	Chromium	7		6.1		mg/kg	PAI-45-SS-03-01	8/8	NA	9.1	6.23	30 (10)C	270 C	2 C	yes	ASL
7440-48-4	Cobalt	0.57		0.8		mg/kg	PAI-45-SS-08-01	5/8	0.46 - 0.58	0.8	0.363	470 N	NA	NA	no	BSL
7440-50-8	Copper	5		48.1		mg/kg	PAI-45-SS-01-01	8/8	NA	48.1	1.52	290 N	NA	560	no	BSL
7439-89-6	Iron	2330		3650		mg/kg	PAI-45-SS-08-01	8/8	NA	3650	3920	2300 N	NA	NA	no	BKG
7439-62-1	Lead	6.5		50.2		mg/kg	PAI-45-SS-05-01	8/8	NA	50.2	12.5	400	NA	NA	no	BSL
7439-95-4	Magnesium	267		437		mg/kg	PAI-45-SS-04-01	8/8	NA	437	515	460,468 N	NA	NA	no	NUT, BKG, BSL
7439-96-5	Manganese	23.1		53.7		mg/kg	PAI-45-SS-06-01	8/8	NA	53.7	129	180 N	6860 N	110 N	no	BSL, BKG
7439-97-6	Mercury	0.03		0.06		mg/kg	PAI-45-SS-04-01-D, PAI-45-SS-08-01	8/8	NA	0.06	0.11	2.3 N	1 N	0.1 MCLG	no	BSL, BKG
7440-02-0	Nickel	2		3.2		mg/kg	PAI-45-SS-08-01	8/8	NA	3.2	1.8	160 N	NA	7 N	no	BSL
7440-09-7	Potassium	165		315		mg/kg	PAI-45-SS-04-01	8/8	NA	315	313	1,000,000 N	NA	NA	no	NUT, BSL
7440-23-5	Sodium	26		75.5		mg/kg	PAI-45-SS-04-01	8/8	NA	75.5	241	1,000,000 N	NA	NA	no	NUT, BKG, BSL
7440-62-2	Vanadium	5.5		8.6		mg/kg	PAI-45-SS-04-01	8/8	NA	8.6	9.5	55 N	NA	300 N	no	BSL, BKG
7440-66-6	Zinc	21.8		338		mg/kg	PAI-45-SS-01-01	8/8	NA	338	9.7	2300 N	NA	620 N	no	BSL

Notes:

- Sample and duplicate are counted as two separate samples when determining the minimum and maximum detected concentrations.
- Values presented are sample-specific quantitation limits.
- The maximum detected concentration is used for screening purposes.
- Site specific background.
- U.S. EPA Region 9 Preliminary Remediation Goals Table, November 1, 2000. Residential criteria. (Cancer benchmark value = 1E-06, noncancer benchmark HI = 0.1)
- Soil Screening Levels for Inhalation U.S. EPA, May 1996. Soil Screening Guidance.
- U.S. EPA Soil Screening Level Guidance: Technical Background Document. May 1996. (Based on a DAF [Dilution Attenuation Factor] of 1).
- Rationale Codes:
 

Selection Reason:	Above Screening Levels (ASL).
	If one carcinogenic PAH (cPAH) is retained as a COPC then all carcinogenic PAHs are retained as COPCs.
Deletion Reason:	Essential Nutrient (NUT).
	Below Screening Level (BSL).
	Below Background Value (BKG).

9 - Value is for pyrene.

10 - Value is for hexavalent chromium.

Shading indicates that the maximum detected concentration exceeded the screening criteria; therefore, the chemical was retained as a COPC.

Associated Samples:

PAI-45-SS-01-01	PAI-45-SS-05-01
PAI-45-SS-02-01	PAI-45-SS-06-01
PAI-45-SS-03-01	PAI-45-SS-07-01
PAI-45-SS-04-01	PAI-45-SS-08-01
PAI-45-SS-04-01-AVG	PAI-45-SS-08-01-AVG
PAI-45-SS-04-01-D	PAI-45-SS-08-01-D

Definitions:

- NA = Not applicable.  
 SQL = Sample quantitation limit.  
 COPC = Chemical of potential concern.  
 ARAR/TBC = Applicable or Relevant and Appropriate Requirement/To Be Considered.  
 J = Estimated value.  
 C = Carcinogenic.  
 N = Noncarcinogenic.  
 sat = Soil saturation concentration.

TABLE 6-3

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN  
 DIRECT CONTACT WITH SUBSURFACE SOIL  
 SITE 45 - FORMER MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA

CAS Number	Chemical	Minimum Concentration <sup>(1)</sup>	Minimum Qualifier	Maximum Concentration <sup>(1)</sup>	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Nondetects <sup>(2)</sup>	Concentration Used for Screening <sup>(3)</sup>	Background Value	EPA Region 9 PRG Residential <sup>(4)</sup>	EPA Soil Screening Levels- Inhalation <sup>(5)</sup>	EPA Soil Screening Levels-Soil to Groundwater <sup>(6)</sup>	COPC Flag	Rationale for Contaminant Deletion or Selection <sup>(7)</sup>
<b>Volatile Organic Compounds</b>																
71-55-6	1,1,1-Trichloroethane	210		210		ug/kg	PAI-45-SB-01-05	1/8	100 - 240	210	NA	63000 N	1200000 sat	100 MCLG	yes	ASL
78-00-5	1,1,2-Trichloroethane	69	J	69	J	ug/kg	PAI-45-SB-07-04	1/8	100 - 240	69	NA	840 C	1000 C	0.9 MCLG	yes	ASL
75-34-3	1,1-Dichloroethane	28	J	34	J	ug/kg	PAI-45-SB-05-04	2/8	100 - 240	34	NA	58000 N	1300000 N	1000 N	no	BSL
75-35-4	1,1-Dichloroethane	43	J	43	J	ug/kg	PAI-45-SB-05-04	1/8	100 - 240	43	NA	54 C	70 C	3 MCLG	yes	ASL
95-50-1	1,2-Dichlorobenzene	260		260		ug/kg	PAI-45-SB-03-04	1/8	100 - 240	260	NA	370000 sat	560000 sat	900 MCLG	no	BSL
78-93-3	2-Butanone	140		140		ug/kg	PAI-45-SB-03-04	1/8	100 - 240	140	NA	730000 N	9000000 N	4400 N	no	BSL
74-83-9	Bromomethane	42	J	90	J	ug/kg	PAI-45-SB-01-05	2/8	100 - 240	90	NA	390 N	9500 N	12 N	yes	ASL
108-90-7	Chlorobenzene	78	J	2000	J	ug/kg	PAI-45-SB-03-04	3/8	100 - 240	2000	NA	15000 N	130000 N	70 MCLG	yes	ASL
100-41-4	Ethylbenzene	23	J	1500	J	ug/kg	PAI-45-SB-03-04	4/8	100 - 240	1500	NA	230000 sat	400000 sat	700 MCLG	yes	BSL
98-82-8	Isopropylbenzene	22	J	850	J	ug/kg	PAI-45-SB-03-04	4/8	100 - 240	850	NA	16000 N	850000 sat	18000 N	no	BSL
127-18-4	Tetrachloroethane	1900		8000000		ug/kg	PAI-45-SB-01-05	7/8	100	8000000	NA	5700 C	11000 C	3 MCL	yes	ASL
108-88-3	Toluene	62	J	62	J	ug/kg	PAI-45-SB-05-04	1/8	100 - 530	62	NA	520000 sat	650000 sat	900 MCLG	no	BSL
1330-20-7	Total Xylenes	100	J	1000	J	ug/kg	PAI-45-SB-03-04	3/8	100 - 240	1000	NA	210000 sat	410000 sat	6000 MCLG	no	BSL
156-80-5	Trans-1,2-dichloroethene	20	J	810	J	ug/kg	PAI-45-SB-03-04	6/8	100 - 240	810	NA	6300 N	3100000 sat	30 MCLG	yes	ASL
78-01-6	Trichloroethene	65	J	120000	J	ug/kg	PAI-45-SB-05-04	7/8	240	120000	NA	2800 C	5000 C	3 MCL	yes	ASL
75-01-4	Vinyl Chloride	30	J	30	J	ug/kg	PAI-45-SB-03-04	1/8	100 - 240	30	NA	150 C	30 C	0.7 MCL	yes	ASL
158-59-2	cis-1,2-dichloroethene	470		40000		ug/kg	PAI-45-SB-05-04	7/8	240	40000	NA	4300 N	1200000 sat	20 MCLG	yes	ASL
<b>Semivolatile Organic Compounds</b>																
91-57-5	2-Methylnaphthalene	84	J	820	J	ug/kg	PAI-45-SB-03-04	3/8	400	820	NA	5600 (8)N	NA	NA	no	BSL
83-32-9	Acenaphthene	520	J	520	J	ug/kg	PAI-45-SB-07-04-D	1/8	400	520	NA	370000 N	NA	29000 N	no	BSL
208-96-9	Acenaphthylene	36	J	36	J	ug/kg	PAI-45-SB-07-04-D	1/8	400	36	NA	370000 (8)N	NA	NA	no	BSL
120-12-7	Anthracene	2900	J	2900	J	ug/kg	PAI-45-SB-07-04-D	1/8	400	2900	NA	2200000 N	NA	590000 N	no	BSL
56-55-3	Benzo(a)anthracene	17	J	7200	J	ug/kg	PAI-45-SB-07-04-D	3/8	400	7200	NA	620 C	NA	80 C	yes	ASL
50-32-8	Benzo(a)pyrene	58	J	5800	J	ug/kg	PAI-45-SB-07-04-D	2/8	400	5800	NA	62 C	NA	400 C	yes	ASL
205-99-2	Benzo(b)fluoranthene	20	J	7100	J	ug/kg	PAI-45-SB-07-04-D	3/8	400	7100	NA	620 C	NA	200 C	yes	ASL
191-24-2	Benzo(g,h)perylene	69	J	3200	J	ug/kg	PAI-45-SB-07-04-D	2/8	400	3200	NA	230000 (10)N	NA	NA	no	BSL
207-08-9	Benzo(k)fluoranthene	29	J	2200	J	ug/kg	PAI-45-SB-07-04-D	2/8	400	2200	NA	6200 C	NA	2000 C	yes	cPAH
117-81-7	Bis(2-ethylhexyl)phthalate	5500		5500		ug/kg	PAI-45-SB-03-04	1/8	400 - 760	5500	NA	35000 C	31000000 sat	180000 MCL	no	BSL
86-74-8	Carbazole	360	J	360	J	ug/kg	PAI-45-SB-07-04-D	1/8	400	360	NA	24000 C	NA	30 C	yes	ASL
218-01-9	Chrysene	70	J	6200	J	ug/kg	PAI-45-SB-07-04-D	2/8	400	6200	NA	62000 C	NA	8000 C	yes	cPAH
117-84-0	Dibn-octyl phthalate	290	J	290	J	ug/kg	PAI-45-SB-03-04	1/8	400 - 760	290	NA	120000 N	10000000 sat	10000000 sat	no	BSL
53-70-3	Dibenz(a,h)anthracene	780	J	780	J	ug/kg	PAI-45-SB-07-04-D	1/8	400	780	NA	62 C	NA	80 C	yes	ASL
132-64-9	Dibenzofuran	360	J	360	J	ug/kg	PAI-45-SB-07-04-D	1/8	400	360	NA	29000 N	210000 sat	2400 N	no	BSL
206-44-0	Fluoranthene	14	J	16000	J	ug/kg	PAI-45-SB-07-04-D	3/8	400	16000	NA	230000 N	NA	210000 N	no	BSL
86-73-7	Fluorene	18	J	930	J	ug/kg	PAI-45-SB-07-04-D	2/8	400	930	NA	260000 N	NA	28000 N	no	BSL
193-39-5	Indeno(1,2,3-cd)pyrene	75	J	3700	J	ug/kg	PAI-45-SB-07-04-D	2/8	400	3700	NA	620 C	NA	700 C	yes	ASL
91-20-3	Naphthalene	55	J	4500	J	ug/kg	PAI-45-SB-03-04	3/8	400	4500	NA	5600 N	170000 N	4000 N	yes	ASL
85-01-8	Phenanthrene	64	J	9700	J	ug/kg	PAI-45-SB-07-04-D	2/8	400	9700	NA	230000 (10)N	NA	NA	no	BSL
129-00-0	Pyrene	120	J	12000	J	ug/kg	PAI-45-SB-07-04-D	2/8	400	12000	NA	230000 N	NA	210000 N	no	BSL

Notes:

- 1- Sample and duplicate are counted as two separate samples when determining the minimum and maximum detected concentrations.
- 2- Values presented are sample-specific quantitation limits.
- 3- The maximum detected concentration is used for screening purposes.
- 4- U.S. EPA Region 9 Preliminary Remediation Goals Table, November 1, 2000. Residential criteria. (Cancer benchmark value = 1E-06, noncancer benchmark HI = 0.1)
- 5- Soil Screening Levels for Inhalation U.S. EPA, May 1998. Soil Screening Guidance.
- 6- U.S. EPA Soil Screening Level Guidance: Technical Background Document, May 1996. (Based on a DAF [Dilution Attenuation Factor] of 1).
- 7- Rationale Codes:
  - Selection Reason:
    - Above Screening Levels (ASL).
    - If one carcinogenic PAH (cPAH) is retained as a COPC then all carcinogenic PAHs are retained as COPCs.
    - Essential Nutrient (NUT).
    - Below Screening Level (BSL).
  - Deletion Reason:

Definitions:

- NA = Not applicable.
- SOL = Sample quantitation limit.
- COPC = Chemical of potential concern.
- ARAR/TBC = Applicable or Relevant and Appropriate Requirement/To Be Considered.
- C = Carcinogenic.
- N = Noncarcinogenic.
- sat = Soil saturation concentration.

- 8 - Value is for naphthalene.
- 9 - Value is for acenaphthene.
- 10 - Value is for pyrene.

Shading indicates that the maximum detected concentration exceeded the screening criteria; therefore, the chemical was retained as a COPC.

Associated Samples:

PAI-45-SB-01-05	
PAI-45-SB-01-14	PAI-45-SB-08-04
PAI-45-SB-02-04	PAI-45-SB-08-04-AVG
PAI-45-SB-03-04	PAI-45-SB-08-04-D
PAI-45-SB-04-04	PAI-45-SB-09-14
PAI-45-SB-05-04	PAI-45-SB-10-13
PAI-45-SB-06-04	PAI-45-SB-11-10
PAI-45-SB-07-04	PAI-45-SB-12-10
PAI-45-SB-07-04-AVG	PAI-45-SB-13-10
PAI-45-SB-07-04-D	

TABLE 6-4

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN  
 DIRECT CONTACT WITH GROUNDWATER - SURFICIAL GROUNDWATER  
 SITE 45 - FORMER MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA

CAS Number	Chemical	Minimum Concentration <sup>(1)</sup>	Minimum Qualifier	Maximum Concentration <sup>(1)</sup>	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Nondetects <sup>(2)</sup>	Concentration Used for Screening <sup>(3)</sup>	Background Value	EPA Region 9 PRG for Tap Water <sup>(4)</sup>	Potential ARAR/TBC Value <sup>(5)</sup>	Potential ARAR/TBC Source	EPA Region 4 Salt Water/Surface Water Screening Values <sup>(6)</sup>	COPC Flag	Rationale for Contaminant Deletion or Selection <sup>(7)</sup>
<b>Volatile Organic Compounds</b>																	
75-35-4	1,1-Dichloroethene	1	J	4	J	ug/L	PAI-45-MW08SU	2/5	5	4	NA	0.046 C	7	MCL	8240	yes	ASL
67-64-1	Acetone	2	J	2	J	ug/L	PAI-45-MW08SU	1/5	5	2	NA	610 N	NA	NA	NA	no	BSL
124-48-1	Chlorodibromomethane	4	J	4	J	ug/L	PAI-45-MW08SU	1/5	5	4	NA	0.13 C	0.08	MCL	NA	yes	ASL
127-18-4	Tetrachloroethene	6	J	10000	J	ug/L	PAI-45-MW08SU	4/5	5	10000	NA	1.1 C	5	MCL	45	yes	ASL
108-88-3	Toluene	5	J	5	J	ug/L	PAI-45-MW08SU	1/5	5	5	NA	720 N	1000	MCL	37	no	BSL
156-60-5	Trans-1,2-dichloroethene	22	J	140	J	ug/L	PAI-45-MW08SU	2/5	5	140	NA	120 N	100	MCL	NA	yes	ASL
79-01-6	Trichloroethene	9	J	10000	J	ug/L	PAI-45-MW08SU	4/5	5	10000	NA	1.6 C	5	MCL	NA	yes	ASL
75-01-4	Vinyl Chloride	1	J	710	J	ug/L	PAI-45-MW08SU	3/5	5	710	NA	0.041 C	2	MCL	NA	yes	ASL
156-59-2	cis-1,2-dichloroethene	1	J	3400	J	ug/L	PAI-45-MW08SU	4/5	5	3400	NA	61 N	70	MCL	NA	yes	ASL

Notes:

- Sample and duplicate are counted as two separate samples when determining the minimum and maximum detected concentrations.
- Values presented are sample-specific quantitation limits.
- The maximum detected concentration is used for screening purposes.
- U.S. EPA Region 9 Preliminary Remediation Goal Table, November 1, 2000.
- U.S. EPA Drinking Water Regulations and Health Advisories, Summer 2000.
- U.S. EPA Region 4 Ecological Risk Assessment Bulletins - Supplement to RAGS, November, 2001.
- Rationale Codes:
  - Selection Reason: Above Screening Levels (ASL), No Toxicity Information (NTX), If one carcinogenic PAH (cPAH) is retained as a COPC then all carcinogenic PAHs are retained as COPCs.
  - Deletion Reason: Essential Nutrient (NUT), Below Screening Level (BSL), Below Background Value (BKG).

Definitions:

- NA = Not applicable.
- SCL = Sample quantitation limit.
- COPC = Chemical of potential concern.
- ARAR/TBC = Applicable or Relevant and Appropriate Requirement/To Be Considered.
- MCL = Maximum contaminant level.
- J = Estimated value.
- C = Carcinogenic.
- N = Noncarcinogenic.

Shading indicates that the maximum detected concentration exceeded the screening criteria; therefore, the chemical was retained as a COPC.

Associated Samples:

- PAI-45-GW01SU-01
- PAI-45-GW04SU-01
- PAI-45-GW05SL-01
- PAI-45-GW06SU-01
- PAI-45-GW06SU-01-D
- PAI-45-GW08SU-01

TABLE 6-5

**OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN  
DIRECT CONTACT WITH GROUNDWATER - DEEP GROUNDWATER  
SITE 45 - FORMER MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA**

CAS Number	Chemical	Minimum Concentration <sup>(1)</sup>	Minimum Qualifier	Maximum Concentration <sup>(1)</sup>	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Nondetects <sup>(2)</sup>	Concentration Used for Screening <sup>(3)</sup>	Background Value	EPA PRG for Tap Water <sup>(4)</sup>	Potential ARAR/TBC Value <sup>(5)</sup>	Potential ARAR/TBC Source	COPC Flag	Rationale for Contaminant Deletion or Selection (6)
<b>Volatile Organic Compounds</b>																
67-66-3	Chloroform	0.5	J	1	J	ug/L	PAI-45-GW05D-01	2/5	5	1	NA	0.16 C	80	MCL	yes	ASL
127-18-4	Tetrachloroethene	1	J	5	J	ug/L	PAI-45-GW04D-01	3/5	5	5	NA	1.1 C	5	MCL	yes	ASL
79-01-6	Trichloroethene	0.6	J	2	J	ug/L	PAI-45-GW04D-01	2/5	5	2	NA	1.6 C	5	MCL	yes	ASL

## Notes:

- 1 - Sample and duplicate are counted as two separate samples when determining the minimum and maximum detected concentrations.
- 2 - Values presented are sample-specific quantitation limits.
- 3 - The maximum detected concentration is used for screening purposes.
- 4 - U.S. EPA Region 9 Preliminary Remediation Goal Table, November 1, 2000.
- 5 - U.S. EPA Drinking Water Regulations and Health Advisories, Summer 2000.
- 6 - Rationale Codes:

Selection Reason: Above Screening Levels (ASL).  
No Toxicity Information (NTX).  
  
Essential Nutrient (NUT).  
Deletion Reason: Below Screening Level (BSL).  
Below Background Value (BKG).

## Definitions:

NA = Not applicable.  
SQL = Sample quantitation limit.  
COPC = Chemical of potential concern.  
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/To Be Considered.  
MCL = Maximum contaminant level.  
J = Estimated value.  
C = Carcinogenic.  
N = Noncarcinogenic.

Shading indicates that the maximum detected concentration exceeded the screening criteria therefore the chemical was retained as a COPC.

## Associated Samples:

PAI-45-GW09D-01  
PAI-45-GW11D-01  
PAI-45-GW04D-01  
PAI-45-GW05D-01  
PAI-45-GW10D-01  
PAI-45-GW10D-01-D

TABLE 6-6

**CHEMICALS RETAINED AS COPCs**  
**SITE 45 - FORMER MWR DRY CLEANING FACILITY**  
**MCRD PARRIS ISLAND, SOUTH CAROLINA**

Chemical	Surface Soil			Subsurface Soil			Groundwater	
	Direct Contact	Soil to Air	Soil to Groundwater	Direct Contact	Soil to Air	Soil to Groundwater	Surficial	Deep
<b>Volatile Organic Compounds</b>								
1,1,1-Trichloroethane						X		
1,1,2-Trichloroethane						X		
1,1-Dichloroethene						X	X	
Bromomethane						X		
Chlorobenzene						X		
Chlorodibromomethane							X	
Chloroform								X
cis-1,2-dichloroethene			X	X		X	X	
Ethylbenzene						X		
Tetrachloroethene	X		X	X	X	X	X	X
Trans-1,2-dichloroethene			X			X	X	
Trichloroethene			X	X	X	X	X	X
Vinyl Chloride						X	X	
<b>Semivolatile Organic Compounds</b>								
Benzo(a)anthracene	XC		X	X		X		
Benzo(a)pyrene	X			X		X		
Benzo(b)fluoranthene	XC			X		X		
Benzo(k)fluoranthene	XC			XC		X		
Carbazole			X			X		
Chrysene	XC			XC				
Dibenzo(a,h)anthracene	XC			X		X		
Indeno(1,2,3-cd)pyrene	XC			X		X		
Naphthalene						X		
<b>Inorganics</b>								
Aluminum	X							
Arsenic	X		X					
Chromium			X					

## Notes:

X - Indicates chemical was retained as a COPC.

XC - If one carcinogenic PAH is retained as a COPC, then all carcinogenic PAHs are retained as COPCs.

TABLE 6-7

SELECTION OF EXPOSURE PATHWAYS  
 SITE 45 - FORMER MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	On-Site/ Off-Site	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway		
Current/Future	Surface Soil	Surface Soil	Surface Soil	Maintenance Worker	Adult	Ingestion Dermal	On-Site On-Site	Quant Quant	Maintenance workers may contact surface soil during normal work activities.		
				Visitors	Adult	Ingestion Dermal	On-Site On-Site	Quant Quant	Visitors may be exposed to surface soil while at the site.		
		Air	Surface Soil	Maintenance Worker	Adult	Inhalation	On-site	None	No COPCs were identified for this pathway (1)		
				Visitors	Adult	Inhalation	On-site	None	No COPCs were identified for this pathway (1)		
	Subsurface Soil	Subsurface Soil	Subsurface Soil	Maintenance Worker	Adult	Ingestion Dermal	On-Site On-Site	None None	Maintenance workers are not exposed to subsurface soil.		
				Visitors	Adult	Ingestion Dermal	On-Site On-Site	None None	Visitors are not exposed to subsurface soil.		
		Air	Subsurface Soil	Maintenance Worker	Adult	Inhalation	On-site	None	Maintenance workers are not exposed to subsurface soil.		
				Visitors	Adult	Inhalation	On-site	None	Visitors are not exposed to subsurface soil.		
	Groundwater	Groundwater	Surficial Aquifer	Maintenance Workers	Adult	Ingestion Dermal	On-Site On-Site	None None	Maintenance workers are not exposed to groundwater.		
				Visitors	Adult	Ingestion Dermal	On-Site On-Site	None None	Visitors are not exposed to groundwater.		
		Air	Surficial Aquifer	Maintenance Workers	Adult	Inhalation	On-site	None	Maintenance workers are not exposed to groundwater.		
				Visitors	Adult	Inhalation	On-Site	None	Visitors are not exposed to groundwater.		
Future	Surface Soil	Surface Soil	Surface Soil	Construction Workers	Adult	Ingestion Dermal	On-Site On-Site	Quant Quant	Construction workers may have contact with surface soil during excavation activities.		
				Commercial Worker	Adult	Ingestion Dermal	On-Site On-Site	Quant Quant	Commercial workers may contact surface soil during normal work activities.		
				Residents	Child	Ingestion Dermal	On-Site On-Site	Quant Quant	Child residents may contact surface soil.		
					Adult	Ingestion Dermal	On-Site On-Site	Quant Quant	Adult residents may contact surface soil.		
		Air	Surface Soil	Construction Workers	Adult	Inhalation	On-site	None	No COPCs were identified for this pathway (1).		
				Commercial Worker	Adult	Inhalation	On-site	None	No COPCs were identified for this pathway (1).		
				Residents	Child	Inhalation	On-site	None	No COPCs were identified for this pathway (1).		
					Adult	Inhalation	On-site	None	No COPCs were identified for this pathway (1).		
		Subsurface Soil	Subsurface Soil	Subsurface Soil	Construction Workers	Adult	Ingestion Dermal	On-Site On-Site	Quant Quant	Construction workers may have contact with subsurface soil during excavation activities.	
					Commercial Worker	Adult	Ingestion Dermal	On-Site On-Site	None None	Commercial workers are not exposed to subsurface soil.	
					Residents	Child	Ingestion Dermal	On-Site On-Site	None None	Child residents are not exposed to subsurface soil.	
						Adult	Ingestion Dermal	On-Site On-Site	None None	Adult residents are not exposed to subsurface soil.	
	Air		Subsurface Soil	Construction Workers	Adult	Inhalation	On-site	Quant	Construction workers may be exposed to fugitive dust and volatile emissions during construction activities (2).		
				Commercial Worker	Adult	Inhalation	On-site	None	Commercial workers are not exposed to subsurface soil.		
				Residents	Child	Inhalation	On-site	Quant	Groundwater may be used as potable water if the site was developed for residential use.		
					Adult	Inhalation	On-site	Quant	Groundwater may be used as potable water if the site was developed for residential use.		
	Groundwater		Groundwater	Surficial Aquifer	Construction Workers	Adult	Ingestion Dermal	On-Site On-Site	None Quant	Groundwater is not used as a potable water supply at the site. Construction workers may contact groundwater during excavation activities.	
					Commercial Worker	Adult	Ingestion Dermal	On-Site On-Site	None None	Commercial workers are not exposed to groundwater.	
					Residents	Child	Ingestion Dermal	On-Site On-Site	Quant Quant	Groundwater may be used as potable water if the site was developed for residential use.	
						Adult	Ingestion Dermal	On-Site On-Site	Quant Quant	Groundwater may be used as potable water if the site was developed for residential use.	
		Air			Surficial Aquifer	Construction Workers	Adult	Inhalation	On-site	Quant	Construction workers may contact groundwater during excavation activities.
						Commercial Worker	Adult	Inhalation	On-site	None	Commercial workers are not exposed to groundwater.
		Air	Water Vapors at Shower Head	Residents	Child	Inhalation	On-site	Quant	Groundwater may be used as potable water if the site was developed for residential use.		
					Adult	Inhalation	On-Site	Quant	Groundwater may be used as potable water if the site was developed for residential use.		
			Deep Aquifer	Construction Workers	Adult	Ingestion Dermal	On-Site On-Site	None None	Groundwater is not used as a potable water supply at the site. Construction workers are not exposed to deep groundwater.		
				Commercial Worker	Adult	Ingestion Dermal	On-Site On-Site	None None	Commercial workers are not exposed to groundwater.		
				Residents	Child	Ingestion Dermal	On-Site On-Site	Quant Quant	Groundwater may be used as potable water if the site was developed for residential use.		
					Adult	Ingestion Dermal	On-Site On-Site	Quant Quant	Groundwater may be used as potable water if the site was developed for residential use.		
	Air	Deep Aquifer	Construction Workers	Adult	Inhalation	On-site	None	Construction workers are not exposed to deep groundwater.			
			Commercial Worker	Adult	Inhalation	On-site	None	Commercial workers are not exposed to groundwater.			
	Water Vapors at Shower Head	Residents	Child	Inhalation	On-site	Quant	Groundwater may be used as potable water if the site was developed for residential use.				
			Adult	Inhalation	On-Site	Quant	Groundwater may be used as potable water if the site was developed for residential use.				

Notes:

- Concentrations of all chemicals detected in surface soil were less than USEPA SSLs for soil to air, therefore, exposures through inhalation of fugitive dust were not retained for evaluation in the risk assessment.
- Exposures will be quantitatively evaluated for chemicals with maximum detected concentrations in subsurface soil which exceed USEPA SSLs for soil to air.

TABLE 6-8

EXPOSURE POINT CONCENTRATION  
 SITE 45 - FORMER MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA

Chemical	Surface Soil (mg/kg)	Surface/ Subsurface Soil (mg/kg)	Groundwater	
			Surficial (ug/L)	Deep (ug/L)
<b>Volatile Organic Compounds</b>				
1,1,2-Trichloroethane	NA	NA	NA	NA
1,1-Dichloroethene	NA	NA	4(1)	NA
Chlorobenzene	NA	NA	NA	NA
Chlorodibromomethane	NA	NA	4(1)	NA
Chloroform	NA	NA	NA	1(1)
cis-1,2-dichloroethene	NA	40(2)	3400(1)	NA
Tetrachloroethene	7.5(1)	8000(2)	10000(1)	5(1)
Trans-1,2-dichloroethene	NA	NA	140(1)	NA
Trichloroethene	NA	120(2)	10000(1)	2(1)
Vinyl Chloride	NA	NA	710(1)	NA
<b>Semivolatile Organic Compounds</b>				
Benzo(a)pyrene equivalents	0.20(1)	4.2(3)	NA	NA
<b>Inorganics</b>				
Aluminum	9480(1)	7130(4)	NA	NA
Arsenic	2(1)	1.75(2)	NA	NA

Notes:

RAGS Part D Tables for the exposure point concentrations are included in Appendix E.

1 - Insufficient number of samples to calculate an UCL; therefore, the maximum detected concentration is used as the exposure point concentration.

2 - 95% UCL for lognormal distribution.

3 - UCL is greater than maximum concentration; therefore, maximum concentration is used.

4 - 95% UCL for normal distribution.

NA - Chemical is not a COPC for this medium.

TABLE 6-9

**SUMMARY OF EXPOSURE INPUT PARAMETERS  
SITE 45 - FORMER MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA  
PAGE 1 OF 2**

Exposure Parameter	Construction Worker	Maintenance Worker	Commercial Worker	Adult Visitor	Child Resident	Adult Resident
<b>All Exposures</b>						
C <sub>soil</sub> (mg/kg)	Maximum or 95% UCL <sup>(1)</sup>					
C <sub>gw</sub> (mg/L)	Average <sup>(1)</sup>	NA	NA	NA	Average <sup>(1)</sup>	Average <sup>(1)</sup>
ED (years)	1 <sup>(2)</sup>	25 <sup>(4)</sup>	25 <sup>(4)</sup>	25 <sup>(4)</sup>	6 <sup>(4)</sup>	24 <sup>(4)</sup>
BW (kg)	70 <sup>(3)</sup>	70 <sup>(3)</sup>	70 <sup>(3)</sup>	70 <sup>(3)</sup>	15 <sup>(3)</sup>	70 <sup>(3)</sup>
AT <sub>n</sub> (days)	365 <sup>(3)</sup>	9,125 <sup>(3)</sup>	9,125 <sup>(3)</sup>	9,125 <sup>(3)</sup>	2,190 <sup>(3)</sup>	8,760 <sup>(3)</sup>
AT <sub>c</sub> (days)	25,550 <sup>(3)</sup>					
<b>Incidental Ingestion/Dermal Contact with Soil</b>						
IR (mg/day)	480 <sup>(4)</sup>	100 <sup>(4)</sup>	50 <sup>(4)</sup>	50 <sup>(4)</sup>	200 <sup>(4)</sup>	100 <sup>(4)</sup>
EF-Soil (days/year)	90 <sup>(2)</sup>	50 <sup>(13)</sup>	250 <sup>(4)</sup>	50 <sup>(13)</sup>	350 <sup>(4)</sup>	350 <sup>(4)</sup>
FI (unitless)	1 <sup>(4)</sup>					
SA (cm <sup>2</sup> /day)	3,300 <sup>(5,6)</sup>	3,300 <sup>(5,6)</sup>	3,300 <sup>(5,6)</sup>	3,300 <sup>(5,6)</sup>	2,800 <sup>(5,6)</sup>	5,700 <sup>(5,6)</sup>
AF (mg/cm <sup>2</sup> )	0.3 <sup>(5,6)</sup>	0.2 <sup>(5,6)</sup>	0.2 <sup>(5,6)</sup>	0.07 <sup>(5,6)</sup>	0.2 <sup>(5,6)</sup>	0.07 <sup>(5,6)</sup>
ABS (unitless)	chemical-specific <sup>(4,6)</sup>					
CF (kg/mg)	1E-06	1E-06	1E-06	1E-06	1E-06	1E-06
<b>Inhalation of Fugitive Dust and Volatile Emissions</b>						
C <sub>air</sub> (mg/m <sup>3</sup> )	calculated <sup>(7)</sup>	NA	NA	NA	NA	NA
InhR (m <sup>3</sup> /hour)	2.5 <sup>(4)</sup>	NA	NA	NA	NA	NA
ET (hours/day)	8 <sup>(4)</sup>	NA	NA	NA	NA	NA
PEF (m <sup>3</sup> /kg)	2.91E+10 <sup>(7,8)</sup>	NA	NA	NA	NA	NA
VF (m <sup>3</sup> /kg)	chemical-specific <sup>(7)</sup>	NA	NA	NA	NA	NA
Q/C (g/m <sup>2</sup> -s per kg/m <sup>3</sup> )	74.89 <sup>(7)</sup>	NA	NA	NA	NA	NA
Ut (m/sec)	11.32 <sup>(7)</sup>	NA	NA	NA	NA	NA
Um (m/sec)	3.6 <sup>(8,9)</sup>	NA	NA	NA	NA	NA
V (unitless)	0.5 <sup>(7)</sup>	NA	NA	NA	NA	NA
F(x) (unitless)	0.016 <sup>(8,9)</sup>	NA	NA	NA	NA	NA
<b>Ingestion/Dermal Contact with Groundwater</b>						
IR <sub>gw</sub> (L/day)	NA	NA	NA	NA	1 <sup>(4)</sup>	2 <sup>(4)</sup>
EF (days/year)	21 <sup>(10)</sup>	NA	NA	NA	350 <sup>(4)</sup>	350 <sup>(4)</sup>
ET (hours/day) and t <sub>event</sub> (hours/event)	8 <sup>(4)</sup>	NA	NA	NA	0.33 <sup>(6)</sup>	0.25 <sup>(6)</sup>
EV (events/day)	1 <sup>(10)</sup>	NA	NA	NA	1 <sup>(6)</sup>	1 <sup>(6)</sup>
A (cm <sup>2</sup> /day)	2,490 <sup>(11)</sup>	NA	NA	NA	6,600 <sup>(5,6)</sup>	18,000 <sup>(5,6)</sup>
K <sub>p</sub> (cm/hour)	chemical-specific <sup>(6)</sup>	NA	NA	NA	chemical-specific <sup>(6)</sup>	chemical-specific <sup>(6)</sup>
I* (hour/event), τ (hour), and B (unitless)	chemical-specific <sup>(6)</sup>	NA	NA	NA	chemical-specific <sup>(6)</sup>	chemical-specific <sup>(6)</sup>
CF (L/cm <sup>3</sup> )	1E-03	NA	NA	NA	1E-03	1E-03
<b>Inhalation of Volatile Emissions from Groundwater</b>						
C <sub>air</sub> (mg/m <sup>3</sup> )	calculated <sup>(12)</sup>	NA	NA	NA	NA <sup>(14)</sup>	NA <sup>(14)</sup>
InhR (m <sup>3</sup> /hour)	2.5 <sup>(4)</sup>	NA	NA	NA	NA <sup>(14)</sup>	NA <sup>(14)</sup>
ET (hours/day)	8 <sup>(4)</sup>	NA	NA	NA	NA <sup>(14)</sup>	NA <sup>(14)</sup>
VF (mg/m <sup>3</sup> )(mg/L)	chemical-specific <sup>(12)</sup>	NA	NA	NA	NA <sup>(14)</sup>	NA <sup>(14)</sup>

**Notes:**

- A Skin surface area available for contact.
- ABS Absorption factor.
- AF Soil-to-skin adherence factor.
- AT<sub>c</sub> Averaging time for carcinogenic effects.
- AT<sub>n</sub> Averaging time for noncarcinogenic effects.
- B Bunge Model partitioning coefficient.

TABLE 6-9

SUMMARY OF EXPOSURE INPUT PARAMETERS  
 SITE 45 - FORMER MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA  
 PAGE 2 OF 2

Exposure Parameter	Construction Worker	Maintenance Worker	Commercial Worker	Adult Visitor	Child Resident	Adult Resident
BW	Body weight.					
CF	Conversion factor.					
CR	Contact rate.					
C <sub>soil/gw</sub>	Exposure concentration for soil/groundwater.					
ED	Exposure duration.					
EF	Exposure frequency.					
ET	Exposure time.					
EV	Event frequency.					
FI	Fraction ingested from contaminated source.					
InhR	Inhalation rate.					
IR	Ingestion rate (soil or groundwater).					
K <sub>p</sub>	Permeability coefficient from water through skin.					
PEF	Particulate Emission Factor.					
Q/C	Inverse of mean concentration at the center of the source.					
SA	Skin surface area available for contact.					
τ	Lag time.					
t*	Time it takes to reach steady-state conditions.					
t <sub>event</sub>	Duration of event.					
Um	Mean annual wind speed.					
Ut	Equivalent threshold of wind velocity at 7 m.					
V	Fraction of vegetative cover.					

- 1 - U.S. EPA IV, 1995. 95% UCL is used if the data set is of sufficient size (i.e., 11 samples or more). For smaller data sets (i.e., less than 10 samples), the 95% UCL is not appropriate and the maximum concentration is used.
- 2 - Assumed that construction activities take place 90 days a year over a 1-year period.
- 3 - U.S. EPA, 1989: Risk Assessment Guidance for Superfund. Vol 1: Human Health Evaluation Manual, Part A.
- 4 - U.S. EPA, Region IV, November 1995: Supplement Guidance to RAGS: Region 4 Bulletins.
- 5 - U.S. EPA, 1997: Exposure Factors Handbook. EPA/600/8-95/002FA.
- 6 - U.S. EPA, 2001: Risk Assessment Guidance for Superfund (Part E, Supplemental Guidance for Dermal Risk Assessment Interim Guidance) EPA/540/R/99/005.
- 7 - U.S. EPA, 1996: Soil Screening Level Guidance.
- 8 - Site-specific.
- 9 - U.S. EPA, 1985: Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites. PB85-192219.
- 10 - Assumes that a construction worker is exposed to groundwater one working month.
- 11 - Assumes forearms and hands are exposed.
- 12 - ASTM, 1997: Standard Guide for Risk-Based Corrective Action, E50.04.
- 13 - Assumes 1-day a week or 50 days a year.
- 14 - Residential exposure to chemicals that have volatilized from groundwater is evaluated per EPA Region 4 guidance, which stipulates that intakes as a result of inhalation of volatile COPCs while showering is equivalent to the intake from ingestion of 2 liters of contaminated water per day. In order to calculate total risk from groundwater in accordance with U.S. EPA Region 4 guidance, the risk from ingestion of groundwater for volatile COPCs was doubled to factor in the risk from inhalation of contaminants in groundwater.

TABLE 6-10

**INPUT PARAMETERS FOR CALCULATION OF PEF AND THE  
VOLATILIZATION FROM SOIL TO OUTDOOR AIR MODEL  
SITE 45 - FORMER MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA**

Parameter	Value	Definition
Q/C	74.89 (Site-specific)	Inverse of mean concentration at center of source ( $\text{g}/\text{m}^2\text{-s}$ per $\text{kg}/\text{m}^3$ ).
V	0.5 (Default)	Fraction of vegetative cover (unitless).
$U_m$	3.6 (Site-specific)	Mean annual wind speed (m/s).
$U_t$	11.32 (default)	Equivalent threshold of wind velocity at 7 m (m/s)
F(x)	0.016 (Site-specific)	function dependent on $U_m/U_t$ derived using Cowherd et al (1985), (unitless).
T	3.2E+07 (Construction Worker)	Exposure interval (seconds).
pb	1.5 (default/professional judgement)	Dry soil bulk density ( $\text{g}/\text{cm}^3$ ).
ps	2.65 (default)	Soil particle density ( $\text{g}/\text{cm}^3$ ).
$\theta_w$	0.15 (default)	Water-filled soil porosity ( $L_{\text{pore}}/L_{\text{soil}}$ ).
n	0.434 (default)	Total soil porosity ( $L_{\text{pore}}/L_{\text{soil}}$ ).
$D_i$	Chemical specific	Diffusivity in air ( $\text{cm}^2/\text{sec}$ ).
$H'$	Chemical specific	Dimensionless Henry's Law Constant.
S	Chemical specific	Solubility limit (mg/L)
$D_w$	Chemical specific	Diffusivity in water ( $\text{cm}^2/\text{sec}$ ).
Koc	Chemical specific	Soil organic carbon partition coefficient ( $\text{cm}^3/\text{g}$ ).
foc	0.006 (default)	Fraction organic carbon in soil (g/g).
PEF	2.91E+10 (Site-specific)	Particulate emission factor ( $\text{m}^3/\text{kg}$ )

## Notes:

Chemical specific values are presented in Table 6-11.

Default values are representative of site conditions.

TABLE 6-11

CHEMICAL PROPERTIES FOR  
VOLATILIZATION FROM SOIL TO OUTDOOR AIR MODEL  
SITE 45 - FORMER MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA

Chemical	Chemical Properties				
	Organic Carbon Partition Coefficient Koc (cm <sup>3</sup> /g)	Diffusivity in Air Di (cm <sup>2</sup> /sec)	Diffusivity in Water Dw (cm <sup>2</sup> /sec)	Solubility Limit S (mg/L)	Henry Laws Constant H' (Dimensionless)
cis-1,2-dichloroethene	3.55E+01	7.36E-02	1.13E-05	3.50E+03	1.67E-01
Tetrachloroethene	1.55E+02	7.20E-02	8.20E-06	2.00E+02	7.54E-01
Trichloroethene	1.66E+02	7.90E-02	9.10E-06	1.10E+03	4.22E-01

Source: Soil Screening Guidance: User's Guide, U.S. EPA, July 1996.

TABLE 6-12

PARAMETERS FOR EVALUATION OF DERMAL CONTACT  
 WITH GROUNDWATER/SURFACE WATER  
 SITE 45 - FORMER MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA

Chemical	Estimated Kp (cm/hr)	$\tau$ (hr)	B	t* (hr)
<b>Volatile Organic Compounds</b>				
1,1-Dichloroethene	1.20E-02	3.7E-01	0	8.88E-01
Chlorodibromomethane	3.20E-03	1.6E+00	0	3.77E+00
Tetrachloroethene	3.30E-02	9.1E-01	0.2	2.18E+00
Trans-1,2-dichloroethene	7.70E-03	3.7E-01	0	8.88E-01
Trichloroethene	1.20E-02	5.8E-01	0.1	1.39E+00
Vinyl Chloride	5.60E-03	2.4E-01	0	5.76E-01
cis-1,2-dichloroethene	1.29E-02	3.7E-01	0.05	8.80E-01

Notes:

NA - Not applicable for inorganics.

Source: EPA, 2001: Risk Assessment Guidance for Superfund Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim. Exhibit B-3 EPA/540/R99/005.

TABLE 6-13

**INPUT PARAMETERS FOR  
VOLATILIZATION FROM GROUNDWATER TO OUTDOOR AIR MODEL  
SITE 45 - FORMER MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA**

Parameter	Value	Definition
Heff	Chemical specific	Henry's Law Constant ( $\text{cm}^3\text{-H}_2\text{O}/(\text{cm}^3\text{-air})$ )
Uair	360 (site-specific)	Wind speed above ground in mixing zone (cm/sec)
dair	200 (default)	Ambient air mixing zone height, (cm)
W	4500 (default)	Width of source parallel to groundwater flow direction (cm)
A	20250000 (default)	Source-zone area ( $\text{cm}^2$ )
hcap	0.1 (assumed)	Thickness of capillary fringe (cm)
hv	0 (assumed)	Thickness of vadose zone (cm)
Lgw	0.1 (assumed)	Depth to groundwater (cm)
Dws	Chemical specific	Effective diffusion coefficient between groundwater and soil ( $\text{cm}^2/\text{sec}$ )
Dcap	Chemical specific	Effective diffusion through capillary fringe ( $\text{cm}^2/\text{sec}$ )
Dair	Chemical specific	Diffusion coefficient in air, ( $\text{cm}^2/\text{sec}$ )
Dwater	Chemical specific	Diffusion coefficient in water ( $\text{cm}^2/\text{sec}$ )
n	0.38 (default)	Total soil porosity ( $\text{cm}^3/\text{cm}^3\text{-soil}$ )
$\theta_{\text{acap}}$	0.038 (default)	Volumetric air content in capillary fringe soils ( $\text{cm}^3\text{-air}/\text{cm}^3\text{-soil}$ )
$\theta_{\text{wcap}}$	0.342 (default)	Volumetric water content in capillary fringe soils ( $\text{cm}^3\text{-H}_2\text{O}/\text{cm}^3\text{-soil}$ )

## Notes:

Chemical-specific values are presented in Table 6-14.

Default values are representative of site conditions.

TABLE 6-14

**CHEMICAL PROPERTIES FOR  
VOLATILIZATION FROM GROUNDWATER TO OUTDOOR AIR MODEL  
SITE 45 - FORMER MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA**

<b>Chemical</b>	<b>Air Diffusivity (cm<sup>2</sup>/sec)</b>	<b>Water Diffusivity (cm<sup>2</sup>/sec)</b>	<b>Henry's Law Constant (Dimensionless)</b>
1,1-Dichloroethene	9.00E-02	1.04E-05	1.07E+00
Chlorodibromomethane	1.96E-02	1.05E-05	3.21E-02
Tetrachloroethene	7.20E-02	8.20E-06	7.54E-01
Trans-1,2-dichloroethene	7.07E-02	1.19E-05	3.85E-01
Trichloroethene	7.90E-02	9.10E-06	4.22E-01
Vinyl Chloride	1.06E-01	1.23E-05	1.11E+00
cis-1,2-dichloroethene	7.36E-02	1.13E-05	1.67E-01

Source: Soil Screening Guidance: User's Guide, U.S. EPA, July 1996.

TABLE 6-15

**NON-CANCER TOXICITY DATA - ORAL/DERMAL  
SITE 45 - FORMER MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA**

Chemical of Potential Concern	Chronic/ Subchronic	Oral RfD Value	Oral RfD Units	Oral to Dermal Adjustment Factor (1)	Adjusted Dermal RfD (2)	Units	Primary Target Organ	Combined Uncertainty/Modifying Factors	Sources of RfD: Target Organ	Dates of RfD: Target Organ (3) (MM/DD/YY)
<b>Volatile Organic Compounds</b>										
1,1-Dichloroethene	Chronic	9.0E-03	mg/kg/day	100%	9.0E-03	mg/kg/day	Liver	1000/1	IRIS	05/14/02
Cis-1,2-Dichloroethene	Chronic	1.0E-02	mg/kg/day	100%	1.0E-02	mg/kg/day	Blood	3000/1	HEAST	7/97
Chlorodibromomethane	Chronic	2.0E-02	mg/kg/day	60%	1.2E-02	mg/kg/day	Liver	1000/1	IRIS	05/14/02
Chloroform	Chronic	1.0E-02	mg/kg/day	20%	2.0E-03	mg/kg/day	Liver	100/1	IRIS	05/14/02
Tetrachloroethene	Chronic	1.0E-02	mg/kg/day	100%	1.0E-02	mg/kg/day	Liver	1000/1	IRIS	05/14/02
Trichloroethene	Chronic	6.0E-03	mg/kg/day	15%	9.0E-04	mg/kg/day	Liver	NA	EPA 9	11/01/00
<b>Semivolatile Organic Compounds</b>										
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
<b>Inorganics</b>										
Aluminum	Chronic	1.0E+00	mg/kg/day	10%	1.0E-01	mg/kg/day	Body Weight	NA	EPA 9	11/01/00
Arsenic	Chronic	3.0E-04	mg/kg/day	41%	1.2E-04	mg/kg/day	Skin, CVS	3/1	IRIS	05/14/02

## Notes:

- 1 - Oak Ridge National Laboratories.
- 2 -  $RfD_{dermal} = RfD_{oral} \times \text{Oral to Dermal Adjustment Factor}$ .
- 3 For IRIS values date that IRIS was searched.  
For HEAST values, the date of HEAST.  
FOR EPA 9, date of PRG Table.

## Definitions:

- CVS = Cardiovascular system.  
NA = Not applicable.  
IRIS = Integrated Risk Information System.  
HEAST = Health Effects Assessment Summary Tables.  
EPA 9 = USEPA Region 9 Preliminary Remediation Goals Table, November 1, 2000.

TABLE 6-16

**NON-CANCER TOXICITY DATA - INHALATION  
SITE 45 - FORMER MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA**

Chemical of Potential Concern	Chronic/ Subchronic	Value Inhalation RfC	Units	Adjusted Inhalation RfD (1)	Units	Primary Target Organ	Combined Uncertainty/Modifying Factors	Sources of RfC:RfD: Target Organ	Dates (2) (MM/DD/YY)
<b>Volatile Organic Compounds</b>									
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA
cis-1,2-Dichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlorodibromomethane	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloroform	Chronic	NA	NA	8.6E-05	mg/kg/day	Liver	NA	EPA 9	11/01/00
Tetrachloroethene	Chronic	NA	NA	1.1E-01	mg/kg-day	NA	NA	EPA 9	11/01/00
Trichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA
<b>Semivolatile Organic Compounds</b>									
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA	NA	NA	NA
<b>Inorganics</b>									
Aluminum	Chronic	NA	NA	1.4E-03	mg/kg-day	NA	NA	EPA 9	11/01/00
Arsenic	NA	NA	NA	NA	NA	NA	NA	NA	NA

## Notes:

- 1 Equation used for derivation provided in text.
- 2 For IRIS values, provide the date IRIS was searched.  
For HEAST values, provide the date of HEAST.  
For NCEA values, provide the date of the article provided by NCEA.

## Definitions:

N/A = Not applicable.  
 IRIS = Integrated Risk Information System.  
 HEAST = Health Effects Assessment Summary Tables.  
 EPA 9 = USEPA Region 9 Preliminary Remediation Goals Table, November 1, 2000.

TABLE 6-17

CANCER TOXICITY DATA - ORAL/DERMAL  
 SITE 45 - FORMER MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA

Chemical of Potential Concern	Oral Cancer Slope Factor	Oral to Dermal Adjustment Factor (1)	Adjusted Dermal Cancer Slope Factor (2)	Units	Weight of Evidence/ Cancer Guideline Description	Source	Date (3) (MM/DD/YY)
<b>Volatile Organic Compounds</b>							
1,1-Dichloroethene	6.0E-01	100%	6.0E-01	(mg/kg-day) <sup>-1</sup>	C	IRIS	05/14/02
cis-1,2-Dichloroethene	NA	NA	NA	NA	D	IRIS	05/14/02
Chlorodibromomethane	8.4E-02	60%	1.4E-01	(mg/kg-day) <sup>-1</sup>	C	IRIS	05/14/02
Chloroform	NA	NA	NA	NA	B2	IRIS	05/14/02
Tetrachloroethene	5.2E-02	100%	5.2E-02	(mg/kg-day) <sup>-1</sup>	NA	EPA 9	11/1/2000
Trichloroethene	1.1E-02	15%	7.3E-02	(mg/kg-day) <sup>-1</sup>	NA	EPA 9	11/1/2000
<b>Semivolatile Organic Compounds</b>							
Benzo(a)pyrene	7.3E+00	31%	2.4E+01	(mg/kg-day) <sup>-1</sup>	B2	IRIS	05/14/02
<b>Inorganics</b>							
Aluminum	NA	NA	NA	NA	NA	NA	NA
Arsenic	1.5E+00	41%	3.7E+00	(mg/kg-day) <sup>-1</sup>	A	IRIS	05/14/02

Notes:

- 1 - Oak Ridge National Laboratories.
- 2 - CSF<sub>dermal</sub> = CSF<sub>oral</sub>/Oral to Dermal Adjustment Factor.
- 3 - For IRIS values, the date IRIS was searched.  
 For HEAST values, the date of HEAST.

Definitions:

IRIS = Integrated Risk Information System.  
 HEAST = Health Effects Assessment Summary Tables.  
 EPA 9 = U.S. EPA Region 9 Preliminary Remediation Goals Table, November 1, 2000.  
 NA = Not available.

EPA Group:

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

TABLE 6-18

**CANCER TOXICITY DATA - INHALATION  
SITE 45 - FORMER MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA**

Chemical of Potential Concern	Unit Risk	Units	Adjustment	Inhalation Cancer Slope Factor	Units	Weight of Evidence/ Cancer Guideline Description	Source	Date (1) (MM/DD/YY)
<b>Volatile Organic Compounds</b>								
1,1-Dichloroethene	5.0E-02	(mg/m <sup>3</sup> ) <sup>-1</sup>	3.5	1.8E-01	(mg/kg-day) <sup>-1</sup>	C	IRIS	05/14/02
cis-1,2-Dichloroethene	NA	NA	NA	NA	NA	D	IRIS	05/14/02
Chlorodibromomethane	NA	NA	NA	NA	NA	C	IRIS	05/14/02
Chloroform	2.3E-02	(mg/m <sup>3</sup> ) <sup>-1</sup>	3.5	8.1E-02	(mg/kg-day) <sup>-1</sup>	B2	IRIS	05/14/02
Tetrachloroethene	NA	NA	NA	2.0E-03	(mg/kg-day) <sup>-1</sup>	NA	EPA 9	11/1/2000
Trichloroethene	NA	NA	NA	6.0E-03	(mg/kg-day) <sup>-1</sup>	NA	EPA 9	11/1/2000
<b>Semivolatile Organic Compounds</b>								
Benzo(a)pyrene	NA	NA	NA	3.1E+00	(mg/kg-day) <sup>-1</sup>	B2	EPA 4 / IRIS <sup>(2)</sup>	11/95 05/14/02
<b>Inorganics</b>								
Aluminum	NA	NA	NA	NA	NA	NA	NA	NA
Arsenic	4.3E+00	(mg/m <sup>3</sup> ) <sup>-1</sup>	3.5	1.5E+01	(mg/kg-day) <sup>-1</sup>	A	IRIS	05/14/02

## Notes:

1 For IRIS values, the date IRIS was searched.

For HEAST values, the date of HEAST.

2 - Inhalation CSF from EPA IV, Cancer Guideline Description from IRIS.

## Definitions:

IRIS = Integrated Risk Information System

HEAST= Health Effects Assessment Summary Tables

EPA 9 = USEPA Region 9 Preliminary Remediation Goals Table, November 1, 2000.

NA = Not Available

## EPA Group:

A - Human carcinogen.

B1 - Probable human carcinogen - indicates that limited human data are available.

B2 - Probable human carcinogen - indicates sufficient evidence in animals and inadequate or no evidence in humans.

C - Possible human carcinogen.

D - Not classifiable as a human carcinogen.

E - Evidence of noncarcinogenicity.

TABLE 6-19

SUMMARY OF CANCER RISKS AND HAZARD INDICES  
 SITE 45 - FORMER MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA

PAGE 1 OF 2

Receptor	Media	Exposure Route	Cancer Risk	Chemicals with Cancer Risks >10 <sup>-4</sup>	Chemicals with Cancer Risks >10 <sup>-5</sup> and < 10 <sup>-4</sup>	Chemicals with Cancer Risks >10 <sup>-6</sup> and < 10 <sup>-5</sup>	Hazard Index	Chemicals with HI > 1
Construction Worker	Surface/ Subsurface Soil	Ingestion	1.1E-05	--	Tetrachloroethene	--	1.4	Tetrachloroethene
		Dermal Contact	5.8E-07	--	--	--	0.02	--
		Inhalation	2.1E-06	--	--	Trichloroethene	0.3	--
		Total	1.4E-05	--	Tetrachloroethene	Benzo(a)pyrene equivalent, Trichloroethene	1.7	Trichloroethene
	Groundwater	Dermal Contact	6.8E-06	--	--	Tetrachloroethene, Trichloroethene, Vinyl Chloride	2.6	Trichloroethene
		Inhalation	1.3E-07	--	--	--	0.01	--
		Total	7.0E-06	--	--	Tetrachloroethene, Trichloroethene, Vinyl Chloride	2.6	Tetrachloroethene
		Total All Media	2.1E-05				4.3	
Maintenance Worker	Surface Soil	Ingestion	3.5E-07	--	--	--	0.003	--
		Dermal Contact	3.9E-07	--	--	--	0.0008	--
		Total	7.5E-07	--	--	--	0.004	--
Commercial Worker	Surface Soil	Ingestion	8.8E-07	--	--	--	0.008	--
		Dermal Contact	2.0E-06	--	--	Benzo(a)pyrene equivalent	0.004	--
		Total	2.9E-06	--	--	Benzo(a)pyrene equivalent, Arsenic	0.01	--
Adult Visitor	Surface Soil	Ingestion	1.8E-07	--	--	--	0.002	--
		Dermal Contact	9.1E-08	--	--	--	0.0005	--
		Total	2.7E-07	--	--	--	0.002	--
Child Resident	Surface Soil	Ingestion	5.5E-06	--	--	Benzo(a)pyrene equivalent, Arsenic	0.2	--
		Dermal Contact	2.6E-06	--	--	Benzo(a)pyrene equivalent	0.02	--
		Total	8.1E-06	--	--	Benzo(a)pyrene equivalent, Arsenic	0.2	--
	Groundwater Surficial Aquifer	Ingestion	5.9E-03	Tetrachloroethene, Trichloroethene, Vinyl Chloride	1,1,-Dichloroethene	Chlorodibromoethane	37	Tetrachloroethene, Trichloroethene, Vinyl Chloride, Cis-1,2- Dichloroethene
		Dermal Contact	1.7E-04	Tetrachloroethene, Trichloroethene, Vinyl Chloride	--	--	2	Tetrachloroethene, Trichloroethene, Cis-1,2- Dichloroethene
		Inhalation	5.9E-03	Tetrachloroethene, Trichloroethene, Vinyl Chloride	1,1,-Dichloroethene	Chlorodibromoethane	208	Tetrachloroethene, Trichloroethene, Vinyl Chloride, Cis-1,2- Dichloroethene
		Total	1.2E-02	Tetrachloroethene, Trichloroethene, Vinyl Chloride	1,1,-Dichloroethene	Chlorodibromoethane	248	Tetrachloroethene
	Groundwater Deep Aquifer	Ingestion	1.5E-06	--	--	Tetrachloroethene	0.06	--
		Dermal Contact	5.5E-07	--	--	--	0.03	--
		Inhalation	1.5E-06	--	--	Tetrachloroethene	0.06	--
		Total	3.6E-06	--	--	Tetrachloroethene	0.1	--
		Total All Media	1.2E-02				248	

TABLE 6-19

SUMMARY OF CANCER RISKS AND HAZARD INDICES  
SITE 45 - FORMER MWR DRY CLEANING FACILITY  
MCRD PARRIS ISLAND, SOUTH CAROLINA

PAGE 2 OF 2

Receptor	Media	Exposure Route	Cancer Risk	Chemicals with Cancer Risks >10 <sup>-4</sup>	Chemicals with Cancer Risks >10 <sup>-5</sup> and < 10 <sup>-4</sup>	Chemicals with Cancer Risks >10 <sup>-6</sup> and < 10 <sup>-5</sup>	Hazard Index	Chemicals with HI > 1
Adult Resident	Surface Soil	Ingestion	2.4E-06	--	--	Arsenic	0.02	--
		Dermal Contact	1.6E-06	--	--	Benzo(a)pyrene equivalent	0.003	--
		Total	4.0E-06	--	--	Benzo(a)pyrene equivalent, Arsenic	0.03	--
	Groundwater	Ingestion	1.6E-02	Tetrachloroethene, Trichloroethene, Vinyl Chloride	1,1-Dichloroethene	Chlorodibromomethane	89	Tetrachloroethene, Trichloroethene, Vinyl Chloride, Cis-1,2-Dichloroethene
		Dermal Contact	3.0E-03	Tetrachloroethene, Trichloroethene, Vinyl Chloride	--	1,1-Dichloroethene	46	Tetrachloroethene, Trichloroethene
	Surficial Aquifer	Inhalation	1.6E-02	Tetrachloroethene, Trichloroethene, Vinyl Chloride	1,1-Dichloroethene	Chlorodibromomethane	27	Tetrachloroethene
		Total	3.5E-02	Tetrachloroethene, Trichloroethene, Vinyl Chloride	1,1-Dichloroethene	Chlorodibromomethane	163	Tetrachloroethene, Trichloroethene, Vinyl Chloride, Cis-1,2-Dichloroethene
		Groundwater Deep Aquifer	Ingestion	2.6E-06	--	--	Tetrachloroethene	0.03
	Dermal Contact		1.1E-06	--	--	--	0.01	--
	Inhalation		2.6E-06	--	--	Tetrachloroethene	0.03	--
	Total		6.4E-06	--	--	Tetrachloroethene	0.06	--
	Total All Media		3.5E-02				163	
	Lifelong Resident	Surface Soil	Ingestion	7.2E-06	--	--	Benzo(a)pyrene equivalent, Arsenic	--
Dermal Contact			4.2E-06	--	--	Benzo(a)pyrene equivalent, Arsenic	--	--
Total			1.1E-05	--	Benzo(a)pyrene equivalent, Arsenic	Benzo(a)pyrene equivalent, Arsenic	--	--
Groundwater Surficial Aquifer		Ingestion	2.5E-02	Tetrachloroethene, Trichloroethene, Vinyl Chloride	1,1-Dichloroethene	Chlorodibromomethane	--	--
		Dermal Contact	4.5E-03	Tetrachloroethene, Trichloroethene, Vinyl Chloride	--	1,1-Dichloroethane	--	--
		Inhalation	2.5E-02	Tetrachloroethene, Trichloroethene, Vinyl Chloride	1,1-Dichloroethene	Chlorodibromomethane	--	--
		Total	5.5E-02	Tetrachloroethene, Trichloroethene, Vinyl Chloride	--	--	--	--
Groundwater Deep Aquifer		Ingestion	3.9E-06	--	--	Tetrachloroethene	--	--
		Dermal Contact	1.4E-06	--	--	Tetrachloroethene	--	--
		Inhalation	3.9E-06	--	--	Tetrachloroethene	--	--
		Total	9.2E-06	--	--	Tetrachloroethene	--	--
Total All Media		5.5E-02				--		

TABLE 6-20

REMEDIAL GOAL OPTIONS - SURFACE/SUBSURFACE SOIL  
 SITE 45 - FORMER MWR DRY CLEANING FACILITY  
 PARRIS ISLAND, SOUTH CAROLINA

CONSTRUCTION WORKERS						
Chemical	Target Cancer Risk Level			Target Hazard Index		
	10-6 (ug/kg)	10-5 (ug/kg)	10-4 (ug/kg)	0.1 (ug/kg)	1 (ug/kg)	3 (ug/kg)
Tetrachlorethene	189	235(1)	235(1)	70	235(1)	235(1)

Notes:

NA = Not applicable .

1 - Risk based level exceeds the soil saturation limit; therefore, the soil saturation limit is presented for the RGO.

TABLE 6-21

REMEDIAL GOAL OPTIONS - SURFICIAL GROUNDWATER  
 SITE 45 - FORMER MWR DRYCLEANING FACILITY  
 PARRIS ISLAND, SOUTH CAROLINA

ADULT RESIDENTS							
Chemical	EPA MCL (1) (ug/L)	Target Cancer Risk Level			Target Hazard Index		
		10-6 (ug/L)	10-5 (ug/L)	10-4 (ug/L)	0.1 (ug/L)	1 (ug/L)	3 (ug/L)
Cis-1,2-dichloroethene	70	NTX	NTX	NTX	17	170	510
Tetrachlorethene	5	0.8	8.3	83	15	152	455
Trichloroethene	5	3.6	36	357	8	79	238
Vinyl Chloride	2	0.04	0.4	3.6	5	54	161

CHILD RESIDENTS							
Chemical	EPA MCL (ug/L) (1)	Target Cancer Risk Level			Target Hazard Index		
		10-6 (ug/L)	10-5 (ug/L)	10-4 (ug/L)	0.1 (ug/L)	1 (ug/L)	3 (ug/L)
Cis-1,2-dichloroethene	70	NTX	NTX	NTX	8	76	227
Tetrachlorethene	5	1.5	15	152	7	67	201
Trichloroethene	5	6.3	63	625	4	36	107
Vinyl Chloride	2	0.06	0.6	5.9	2	23	69

LIFETIME RESIDENTS							
Chemical	EPA MCL (ug/L) (1)	Target Cancer Risk Level			Target Hazard Index		
		10-6 (ug/L)	10-5 (ug/L)	10-4 (ug/L)	0.1 (ug/L)	1 (ug/L)	3 (ug/L)
Tetrachlorethene	5	0.6	5.6	56	NA	NA	NA
Trichloroethene	5	2.3	23	227	NA	NA	NA
Vinyl Chloride	2	0.02	0.2	2.2	NA	NA	NA

CONSTRUCTION WORKERS							
Chemical	EPA MCL (ug/L) (1)	Target Cancer Risk Level			Target Hazard Index		
		10-6 (ug/L)	10-5 (ug/L)	10-4 (ug/L)	0.1 (ug/L)	1 (ug/L)	3 (ug/L)
Trichloroethene	5	5300	53000	530000	500	5000	15000

Notes:

1 - U.S. EPA Drinking Water Standards and Health Advisories, Summer 2000.

NA = Not applicable .

NTX = No Toxicity Criteria Available.

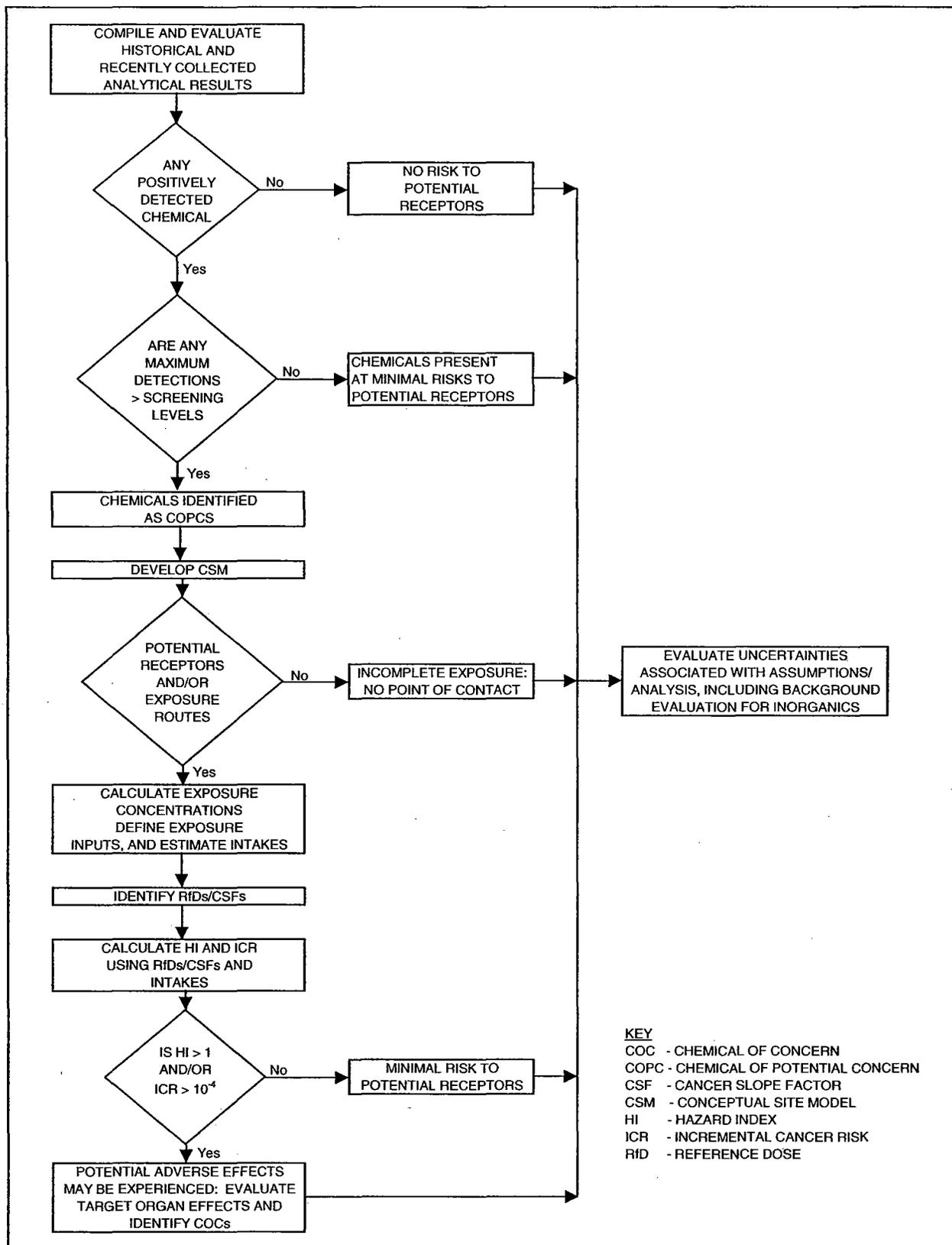


FIGURE 6-1

**SUMMARY OF HUMAN HEALTH RISK ASSESSMENT PROCESS  
 SITE 45 - FORMER MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA**

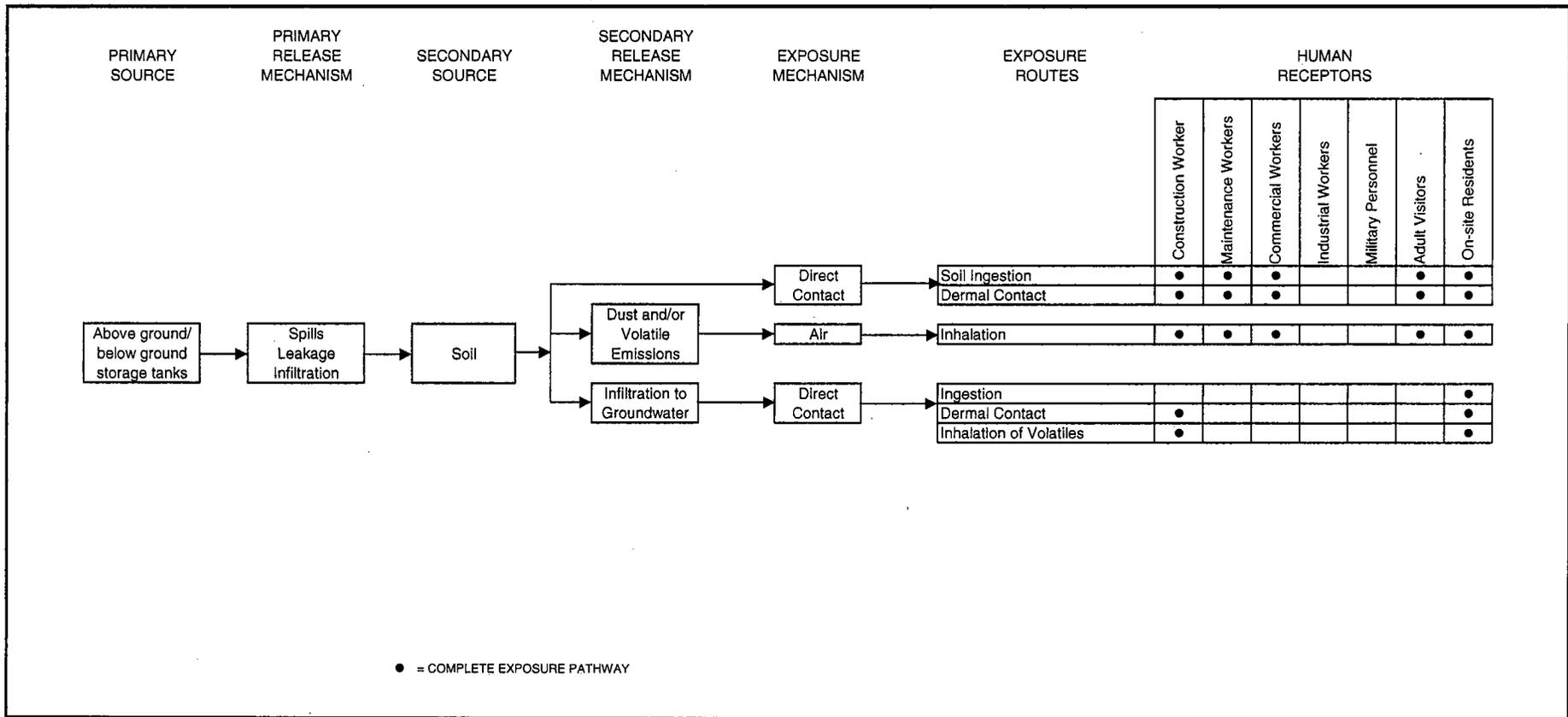


FIGURE 6-2

CONCEPTUAL SITE MODEL  
 SITE 45 - FORMER MWR DRY CLEANING FACILITY  
 MCRD PARRIS ISLAND, SOUTH CAROLINA

## 7.0 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations developed during the Site/SWMU 45 RI/RFI are summarized as follows.

- PCE and other chlorinated VOC breakdown products, TCE, DCE, and VC, were detected in surface and subsurface site soils at concentrations that can continue to impact site groundwater through leaching and result in groundwater concentrations greater than drinking water standards (MCLs).
- PCE was detected at a maximum concentration of 8000 mg/kg in one soil sample, near the area of the documented PCE spill in 1994. Field screening tests of site soils for pure solvent found some evidence of trace quantities of non-aqueous phase product. However, no free product was found and no further conclusions were developed.
- Chlorinated VOCs, arsenic, and PAHs were also detected in soils at concentrations greater than background and soil screening concentrations (U.S. EPA Region 9 PRGs) for direct contact exposure under a residential use scenario. The highest concentrations of VOCs and PAHs were found at the water table. The maximum arsenic concentration (2.1 mg/kg) was only slightly greater than the facility background concentration (1.44 mg/kg). The human health risk assessment concluded that site soils do not pose unacceptable risks to current maintenance workers, commercial workers, adult visitors, or potential future residents. HIs were less than 1.0, and ILC risks were within the range of  $10^{-4}$  to  $10^{-6}$  or less.
- The human health risk assessment indicated that surficial groundwater consumption resulted in unacceptable excess risk for the on-site child resident, the on-site adult resident, and the on-site lifelong resident based on vinyl chloride, TCE, and PCE contamination. The HI for surficial groundwater for the child resident (248) and the adult resident (224) exceeded the acceptable level of 1.0.
- Chlorinated VOCs were found in site groundwater at concentrations up to 2,000 times greater than drinking water standards (MCLs). Based on groundwater temporary well data, two sources areas of the groundwater contamination are likely, one near the former above-ground storage tanks and one from within the footprint of Building 193, the Former MWR Dry Cleaners Building. Even though site groundwater is not used as a potable water source, the site would result in unacceptable risks to human health if used as such. HIs were greater than 1.0, and ICL risks were greater than  $10^{-2}$ .

- The horizontal and vertical extents of chlorinated VOC-contaminated groundwater are adequately defined. The plume is approximately 240 feet long and up to 140 feet wide (less than 1 acre). The plume extends from approximately the northwestern corner of the former dry cleaner building to near the temporary lodging. The contaminant plume is consistent with groundwater flow that is to the south-southeast. Based on approximately 5 years of data, significant plume migration is not apparent.
- The vertical extent of the groundwater contaminant plume extends from the water table (approximately 4 to 5 feet bgs) to a low permeable layer located at a depth of approximately 12 to 22 feet bgs. Chlorinated VOCs were detected in the groundwater below this low permeable layer but not at concentrations that exceed drinking water standards.
- Fuel-type hydrocarbon VOCs were detected infrequently in site groundwater. With the exception of benzene, concentrations of these chemicals did not exceed drinking water standards. Benzene (15 µg/L) was detected at one location from a temporary well at depth of 32 feet bgs. The downgradient extent of this contamination has been defined by testing of a permanent monitoring well.
- A natural attenuation evaluation for degradation of chlorinated VOCs was conducted. This evaluation concluded that the VOCs were naturally degrading at the site. Modeling efforts conducted with this evaluation indicated that contaminant migration could have a maximum range 500 feet to more than 1,000 feet beyond the source area. Associated migration time estimates range from approximately 30 years to greater than 100 years. Without source area control, more than 260 years may be required before the Site 45 VOC groundwater contaminants dissipate to below measurable levels. If the Navy pursues a monitored natural attenuation (MNA) or partial MNA remedy at this site, analyses will be done as part of the Feasibility Study/Proposed Plan/Record of Decision or possibly in a Treatability Study.
- Preliminary basic groundwater modeling results indicate that the plume is effectively captured within the containment system. Further model refinement is necessary if model performance is to be developed for the FS/CMS.
- There is sufficient information available to proceed to an FS/CMS to evaluate remedial options.

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