ABC Cleaners 002
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Revision 1

REMEDIAL INVESTIGATION

ABC ONE-HOUR CLEANERS
OPERABLE UNIT 2
JACKSONVILLE, NORTH CAROLINA

Work Assignment No. 03-4L9E

MAY 1994

REGION IV

U.S. EPA CONTRACT NO. 68-W9-0057

Roy F. Weston, Inc.
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Norcross, Georgia 30071
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10098568

WESTON W.O. No. 04400-003-022-0005-12

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REMEDIAL INVESTIGATION REPORT

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MAY 1994

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EXECUTIVE SUMMARY

A Remedial Investigation (RI) of the ABC One-Hour Cleaners (ABC) site was conducted for the U.S. Environmental Protection Agency, Region IV by Roy F. Weston, Inc. (WESTON®). WESTON has prepared this report under Work Assignment No. 03-4L-9E of the Alternative Remedial Contracting Strategy (ARCS) Contract (No. 68-W9-0075) in accordance with the Remedial Investigation Work Plan dated June 28, 1990, and the addendum to the Work Plan prepared by WESTON, dated April 9, 1993.

WESTON conducted the initial phase of the RI known as Operable Unit 1 (OU1) in mid-1992 for characterization of the nature and extent of groundwater contamination at the ABC site. This supplemental phase (OU2) of the RI (Fall 1993) examined the source of contaminants and the nature and extent of contamination in soils. The OU2 RI also addressed data gaps identified in the OU1 study.

Data collected during the OU2 study were used to develop a Risk Assessment that addresses the public health risks associated with soil contamination detected at the site. The results of the RI (and the Risk Assessment contained within the RI) will be used in the development of a Feasibility Study (FS) that will examine potential remedial alternatives to eliminate or reduce the risk posed by the site to acceptable levels. Field activities commenced in September 1993 and were completed in November 1993. Major field activities conducted as a part of the field investigation included:

- Collecting and analyzing 65 surface and subsurface soil samples within and adjacent to the ABC facility to characterize the vertical and horizontal extent of volatile organic compounds (VOCs).

- Conducting a test of a soil vapor extraction (SVE) system and sampling the effluent from the treatment system to evaluate the viability of this technology at the ABC site.

- Collecting and analyzing a sample of the septic tank contents at ABC to support data collected from previous investigations and to further characterize the suspected source area.

- Installing one surficial aquifer monitor well to evaluate the upgradient position of the previously identified (OU1) groundwater plume and provide a permanent groundwater monitoring location.

- Installing three Castle Hayne aquifer monitor wells to assist in evaluating the groundwater plume within the Castle Hayne and to provide permanent groundwater monitoring locations.

- Collecting and analyzing 19 monitor well samples to evaluate groundwater quality and plume migration.

- Conducting a monitor well elevation survey and collecting water level measurements to establish groundwater flow directions and gradients.

- Performing aquifer testing of the surficial and Castle Hayne aquifers to evaluate site specific hydrogeologic parameters for use in the Remedial Design.

The following conclusions are based upon site characterization and the public health risk assessments.

Soil Characterization

- Based on the results of the OU1 and OU2 field investigations, the ABC site, specifically the former septic tank system, is a primary source for VOCs, including tetrachloroethene (PCE), trichloroethene (TCE), and 1,2-dichloroethene (1,2-DCE), detected in soil and groundwater samples.

- Soil samples collected from soil borings installed beneath the ABC building indicate contaminant concentrations (PCE, TCE, 1,2-DCE) exist within the unsaturated soil profile (from 0 to 15 feet below ground surface). The highest levels of VOC contamination were detected in the 0- to 2-foot interval.

- VOCs in the unsaturated soil profile underneath the ABC building have persisted because biological, chemical, and physical processes that act to degrade or transport contaminants have been limited by the presence of the building's concrete floor.

- Soil samples collected from soil borings exterior to the ABC building indicate that VOC concentrations decrease markedly when compared to samples from beneath the building, except in the areas where asphalt driveways exist.

- The full horizontal extent of the VOCs in soils is not yet established.

- A septic tank sample indicated that the concentration of PCE was estimated to be approximately 240,000,000 μg/kg, representing a significant contaminant source.

Groundwater Characterization

- Groundwater samples from the surficial and the Castle Hayne aquifer monitor wells collected during the OU2 investigation indicated PCE, TCE, 1,2-DCE, vinyl chloride, and chloroform concentrations in excess of the ROD groundwater goals, EPA Maximum Contaminant Levels (MCLs), and North Carolina Groundwater Quality Standards (NCGWQSs).

- Aquifer testing conducted through surficial aquifer monitor well S2 for 72 hours at a rate of 13.1 gallons per minute (gpm) indicated a capture zone radius of over 960 feet in the surficial aquifer and over 870 feet in the Castle Hayne aquifer.

- An unidentified upgradient source of chlorinated and aromatic VOCs appears to be contributing to surficial aquifer groundwater contamination.

Risk Assessment

- No current use scenarios were calculated to exceed the guidelines of 10^{-4} carcinogenic risk or a hazard index of 1.0. Under future potential scenarios, the future on-site resident scenario exceeded a hazard index of 1.0 (3.0 for child) and a carcinogenic risk level of 10^{-4} (2×10^{-4} for lifetime exposure). No other future use scenarios exceeded these benchmarks. The potential risk for a future construction worker was calculated to be 6×10^{-7}, while the potential risk for current on-site workers was 2×10^{-5}. The principal contaminant causing risk to exceed guidelines was PCE.

SECTION 1

INTRODUCTION

Roy F. Weston, Inc., (WESTON®) has prepared this report for the U.S. Environmental Protection Agency (EPA), Region IV, documenting the Operable Unit 2 (OU2) Remedial Investigation (RI) conducted at ABC One-Hour Cleaners, Inc., (ABC) site in Jacksonville, North Carolina. WESTON has prepared the RI report under Work Assignment No. 03-4L-9E of Contract No. (68-W9-0057) with EPA and in accordance with the Remedial Investigation Work Plan, prepared by WESTON, dated June 28, 1990, and amended April 9, 1993. The RI was conducted in accordance with the requirements of the National Contingency Plan (NCP) as amended by the Superfund Amendment and Reauthorization Act of 1986 (SARA) and "EPA Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final" (October 1988).

The ABC site is a fund lead site. WESTON, under the U.S. EPA Region IV Alternative Remedial Contracting Strategy (ARCS), was assigned the responsibility of conducting a Remedial Investigation/Feasibility Study (RI/FS) to define the source and areal extent of migration of contaminants emanating from the ABC facility. The site consists of two operable units:

- *Operable Unit No. 1*, the groundwater contaminant plume, consisting of the groundwater which has become contaminated by the release of VOCs.
- *Operable Unit No. 2*, the source, consisting of the septic tank, the tank's contents, and surrounding and underlying unsaturated soils having VOC contamination as well as data gaps remaining from the OU1 RI.

This report focuses on Operable Unit No. 2 and presents the results of WESTON's RI activities conducted for the ABC site.

1.1 PURPOSE OF REPORT

The purpose of this RI report is to present and evaluate data gathered during the field investigation. The main focus of this RI was to evaluate the source area and the extent of soil contamination. In addition, field investigation duties focused on groundwater plume data gaps identified from the OU1 RI. Field data collected included chemical analyses of soil, groundwater, and septic tank samples. The risk posed by soil contamination is evaluated in a Risk Assessment and will be used to support EPA's selection of a remedial action alternative that will eliminate or sufficiently reduce the risk posed by the ABC site to public health and to the environment.

1.2 REPORT ORGANIZATION

This RI report contains seven major sections:

- Section 1 - Introduction
- Section 2 - Site Information - Site History and Previous Investigations
- Section 3 - Study Area Investigation (addresses septic tank, hydrogeologic, geotechnical, soil, and groundwater investigations)
- Section 4 - Physical Characteristics of Study Area (addresses surface features, meteorology, surface water hydrology, geology, soils, hydrogeology, demography and land use, and ecology)

- Section 5 - Nature and Extent of Contamination (addresses sources and groundwater)

- Section 6 - Contaminant Fate and Transport (addresses potential routes of migration, contaminant persistence, and contaminant migration)

- Section 7 - Baseline Risk Assessment (includes two types of assessments: evaluation of risk to public health, including exposure and toxicity assessments and a risk characterization; and environmental assessment)

- Section 8 - Summary and Conclusions (addresses nature and extent of contamination, fate and transport, risk assessment, and recommended remedial action objectives)

SECTION 2

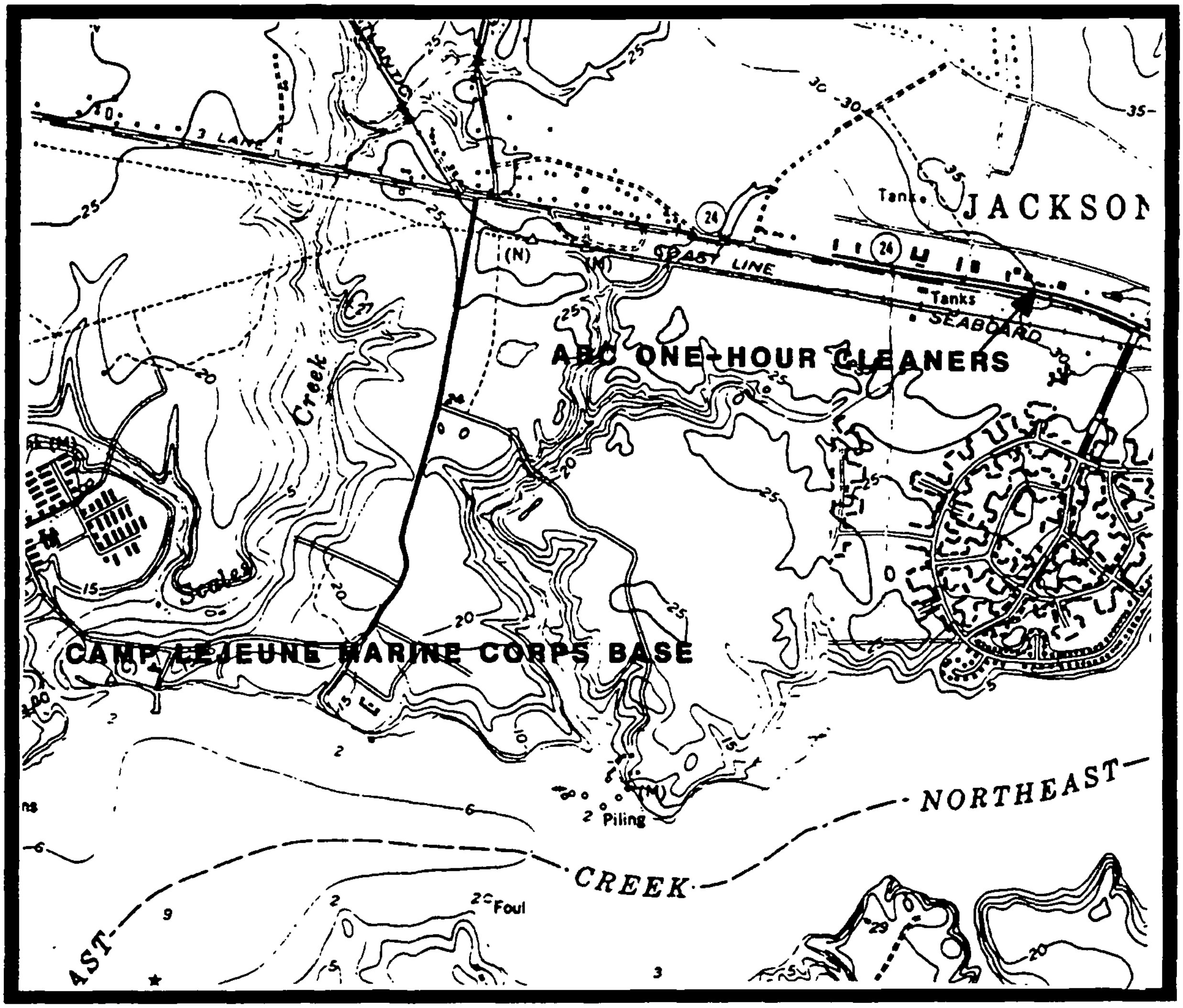
SITE INFORMATION

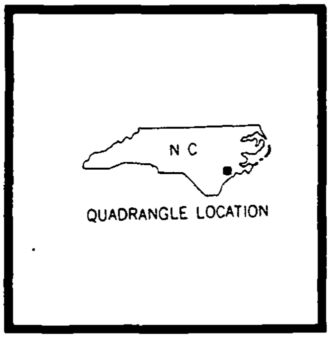
This section provides information regarding the operational history of the site and investigation conducted prior to the RI.

2.1 SITE HISTORY

The ABC facility is located at 2127 Lejeune Boulevard, Jacksonville, Onslow County, North Carolina (Figure 2-1). The dry cleaning facility encompasses an area of approximately 1 acre. The dry cleaning establishment, consisting of three buildings joined to form one complex, is located on the southern portion of the property. A small parking lot fronts Lejeune Boulevard and driveways exist on the east and west of the complex. Across Lejeune Boulevard to the south are woodlands and the Tarawa Terrace Housing Development. The Tarawa Terrace complex serves as housing for non-commissioned officers of the Camp Lejeune Marine Corps Base (Base), and their families (Figure 2-2).

ABC is a North Carolina corporation registered with the Secretary of State as of March 4, 1958. Martha Melts and Milton Melts purchased the property on which the ABC facility is located on September 16, 1964. Prior to purchasing, the Melts' leased the property from Carolina Eastern Realty Company, Inc. (lease entered into on May 2, 1955). According to the lease document, the building was previously used as a model/hobby shop (Detwiler, 1988). Currently, Mr. Melts serves as the owner and President of ABC; Victor Melts is the Vice President, Secretary, and Treasurer. Victor Melts and Milton Melts are the sole directors and shareholders of ABC (Dunn, 1989b).





SOURCE: USGS 7.5 MINUTE QUADRANGLES
JACKSONVILLE SOUTH, N.C. (PHOTOINSPECTED 1978)
AND CAMP LEJEUNE, N.C. (PHOTO REVISED 1971)

0 2000 4000
1"=2000'
SCALE FEET

ABC ONE HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

SITE LOCATION MAP

FIGURE 2-1

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN D.O.	DATE 5-11-94	DES. ENG.	DATE	W. O. NO. 04400-003
CHECKED	DATE	APPROVED	DATE	DWG. NO. TEMPBORD

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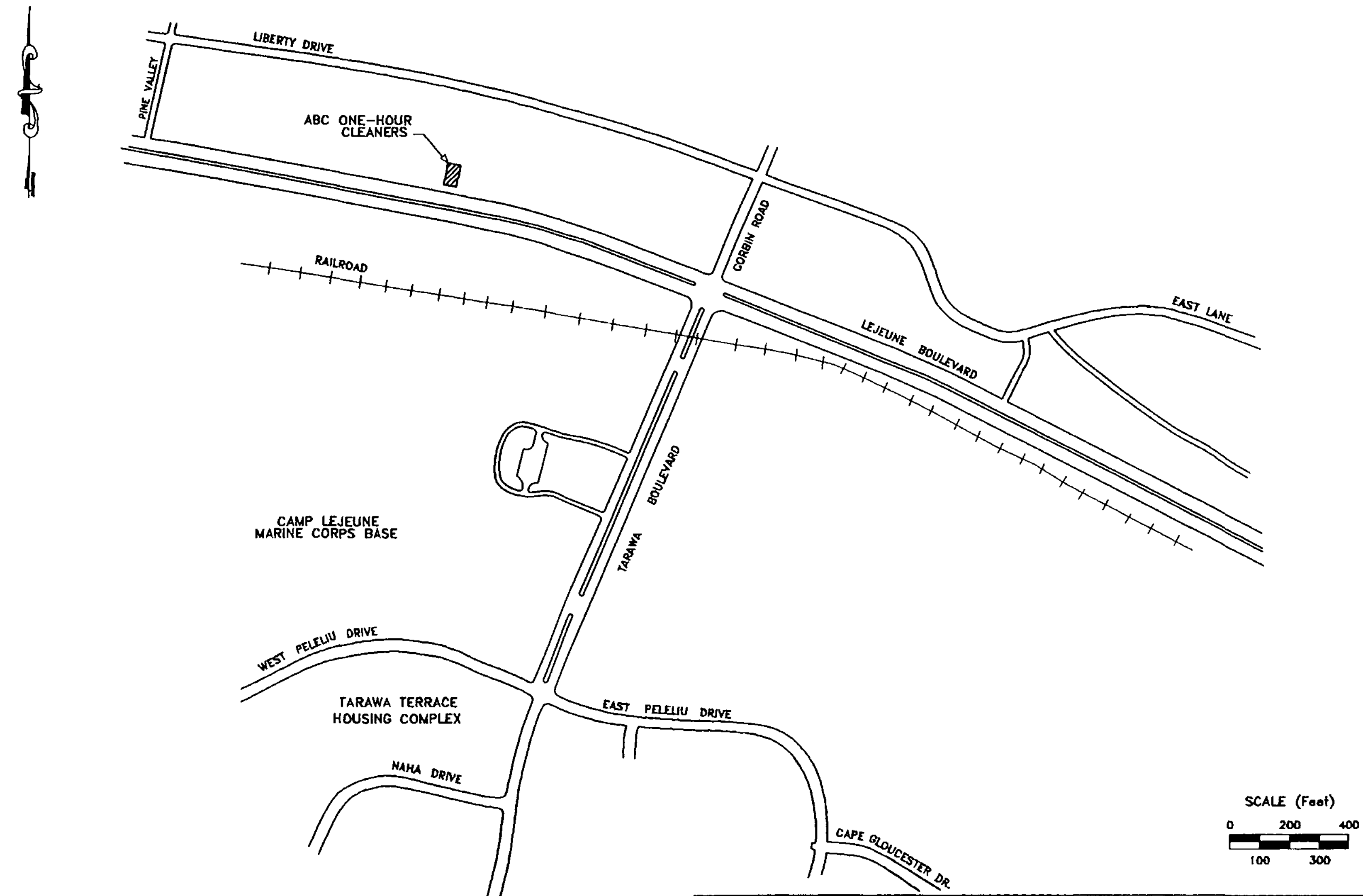

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FILE NO. ABCNMAP

OPERABLE UNIT 2
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

SITE VICINITY MAP

FIGURE 2-2

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN WRS	DATE 10/28/93	DES. ENG.	DATE	W. O. NO 04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO. ABCNMAP

Typical of the dry cleaning industry, ABC uses tetrachloroethene (PCE) as a dry cleaning solvent. At ABC, the solvent was stored in a 250-gallon aboveground storage tank located along the west side of the building. Spent PCE was reclaimed through a filtration-distillation process contained within the main building. The system used filter aids made of hyflo-diatomaceous earth and Darco-brand activated carbon. The filter was mounted above a still. Three times a week, solvent and powder were dropped via direct piping into the still for purification via distillation (Dunn, 1989b). Following completion of the distillation process, the still bottoms, consisting of powder residues, were placed in the dirt drive west of the building as a "pothole" filler. It is estimated that approximately 1 ton of still bottoms was placed on the driveway over a 30-year operating period (Dunn, 1989a). Since 1985, ABC has used the services of Safety-Kleen, Inc. to recover and recycle its dry cleaning fluid.

Under the Resource Conservation and Recovery Act (RCRA), still bottoms are considered to be a hazardous waste (RCRA Waste No. F002). ABC is classified as a small quantity generator under RCRA (No. NCD981751126) and generates less than 1,000 kilograms per month of hazardous waste (ABC, 1986).

A septic tank soil absorption system is located in the rear of the building complex. The septic system consists of an underground concrete tank with a concrete lid and a pipe of unknown length that discharges into the subsurface soil. The septic system is located within 4 feet of the PCE storage tank (Shiver, 1985). The age of the septic system reportedly dates back to the original construction of the building in the 1940's (Dunn, 1989b). ABC began occupying the building in 1955.

In the 1960s, ABC installed a floor drain to the septic tank and tied its wastewater discharge, except for its lavatories, into the Weyerhaeuser Properties' water and sewer system. The lavatories remained tied into the septic system until approximately 1985, at which time they were also tied into the Weyerhaeuser Properties' system (Dunn, 1989b).

In July 1984, as part of a routine water quality evaluation, the Department of the Navy collected groundwater samples from 40 of the 100 community water supply wells located on the Base. The Navy determined that dichloroethene (DCE), trichloroethene (TCE), and tetrachloroethene (PCE) were present in 10 of the wells sampled. Of the 10 wells in which groundwater contamination was noted, 8 of the wells had been directly impacted by sources located on the Base. The remaining two wells were located within the Tarawa Terrace well field (TT-23 and TT-26) in the vicinity of two off-base commercial dry cleaning operations, ABC and Glam-O-Rama, Inc.

In February 1985, the two affected wells plus a third community well (TT-25) were disconnected from the Base's drinking water supply system. In June 1985, an emergency water line from the Base's Holcomb Boulevard system was installed to provide the Tarawa Terrace development with drinking water (Shiver, 1985).

During the same time period (April 1985), the Wilmington Regional Office (WiRO) of the Division of Environmental Management, North Carolina Department of Natural Resources and Community Development (NRCD) was notified by the United States Marine Corps, that two deep water wells in the Tarawa Terrace housing area at the Base were contaminated by what appeared to be off-site sources. From April through September 1985, WiRO staff conducted a groundwater pollution study to define the source of PCE in wells within the Tarawa Terrace well field (Shiver, 1985). Results of this study are detailed in Section 2.2. The study concluded that the most likely source of groundwater contamination was ABC One-Hour Cleaners.

On January 24, 1986, WiRO (NRCD, 1986) notified Mr. Milton Melts, owner of ABC, that he was in violation of the following North Carolina General Statutes:

1) G.S. 143-215.1(a)(5) for changing the nature of waste discharged through a disposal system by disposing of dry cleaning solvents in the septic tank systems

2) G.S. 143-215.1(a)(6) for discharging dry cleaning solvents in the septic tank nitrification field resulting in the violation of standards for underground waters

Subsequent to the receipt of the Notice of Violation issued by NRCD, ABC contracted the services of Law Engineering and Testing, Inc., to conduct preliminary investigations of the septic tank soil absorption system and surrounding soils. The results of two preliminary investigations conducted on April 8, 1986 (Law, 1986a), and September 10-11, 1986 (Law, 1986b), confirmed the presence of PCE and its derivatives in soils immediately surrounding the septic tank and adjacent to the existing floor drain, thereby confirming the source of groundwater contamination.

On October 30, 1986, ABC submitted a proposal for a remedial action plan involving partial removal and/or treatment of contaminated soils. The plan, according to NRCD, failed to address problems associated with the groundwater contaminant plume emanating from beneath ABC (NRCD, 1987). The NRCD rejected the proposed plan and proceeded with application of the Hazard Ranking System (HRS) and nomination of the site for inclusion on the Superfund National Priorities List (NPL) of uncontrolled hazardous waste sites.

Based upon observed releases of PCE and existing groundwater contamination, as well as other factors considered in the application of the HRS, the ABC site was scored at 29.11 (NCDHR, 1987). Sites with scores of 28.5 or greater are listed on the NPL. Accordingly, the site was proposed for NPL listing in June 1988, and placed on the final list in March 1989.

Under contract to the U.S. EPA through the ARCS program, WESTON was assigned the responsibility of conducting a Remedial Investigation/Feasibility Study (RI/FS) to define the source and areal extent of migration of contaminants emanating from the ABC facility. The site consisted of two operable units. Operable Unit 1 (OU1) was considered the groundwater contaminant plume consisting of groundwater that had become contaminated by the release of VOCs. Operable Unit 2 (OU2) was to consider the source consisting of the septic tank, the tank's contents, and surrounding and underlying unsaturated soils containing VOCs. OU2 investigations also included field work to address data gaps identified during the review of the OU1 RI.

A Project Operations Plan was issued by WESTON in late 1990 with field investigation activities for OU1 taking place from mid-1991 to early 1992. Analytical laboratory data was collected on samples of soil, groundwater, and sludge from the septic tank, which indicated that extensive soil and surficial aquifer contamination existed and was related to leakage of VOCs from the septic tank. Groundwater samples from a deeper aquifer, the Castle Hayne Formation, were also found to be contaminated by VOCs.

An addendum to 1990 Project Operations Plan was issued by WESTON for OU2 in February 1993. The field portion of OU2 was conducted from early September 1993 to early November 1993 consisting of an in-depth investigation into the source of the contamination as well as filling in data gaps identified in the OU1 RI.

2.2 PREVIOUS INVESTIGATIONS

To date, five investigations, including the field investigation for OU1, have been conducted at ABC:

- Water Quality Investigation, Department of the Navy, July 1984.
- Groundwater Pollution Study, North Carolina Department of Natural Resources, April 1985.
- Septic Tank and Surrounding Soils Investigation, Law Engineering and Testing Corporation, April 1986.
- Additional Soil Sampling, Law Engineering and Testing Corporation, September 1986.
- Remedial Investigation Report, Operable Unit 1, Roy F. Weston, Inc., November 1992.

This section summarizes the results and major conclusions of these investigations.

2.2.1 Water Quality Investigation - July 1984

In July 1984, the Department of the Navy collected groundwater samples as part of routine water quality evaluation from 40 of the more than 100 community supply wells servicing the Base. Analytical results for 10 of the 40 samples collected indicated the presence of volatile organic compounds (VOCs), principally organic solvents, including tetrachloroethene (PCE), trichloroethene (TCE), and dichloroethene (DCE). Eight of the 10 contaminated wells were determined to have been directly impacted by sources located on the Base. Contamination in the other two wells (TT-26 and TT-23) was believed to be unrelated to Base activities and possibly related to two off-base commercial dry cleaning facilities, ABC One-Hour Cleaners and Glam-O-Rama.

According to documentation provided to WiRO by the Base (USMC, 1988), the contaminated wells were resampled on January 16, 1985; February 12, 1985; and February 19, 1985, by Base personnel. The duplicate series samples collected on February 19, 1985, were forwarded to the North Carolina Department of Human Resources Occupational Health Laboratory for analyses. A summary of the analytical data is provided in Table 2-1.

Based upon the discovery of volatile organic contamination during the Navy's initial investigation and subsequent samplings by Camp Lejeune, the Base discontinued use of the two wells (TT-26 and TT-23), as well as a third well, (TT-25) located hydraulically downgradient of the contaminated wells in February 1985.

Table 2-1

Tarawa Terrace Water System
Summary of Water Quality Data
(Results in parts per billion [ppb])

LOCATION	PARAMETER	JANUARY 16	FEBRUARY 12	FEBRUARY 19	FEBRUARY 19*
TT-26	Tetrachloroethene	1,580	--	64	55
	Trichloroethene	57	--	--	--
	Dichloroethene	92	--	--	--
	Vinyl Chloride	27	--	--	--
	Benzene	--	--	--	--
TT-23	Tetrachloroethene	132	37	--	26
	Trichloroethene	--	--	--	53
	Dichloroethene	11	--	13	--
	Vinyl Chloride	--	--	--	--
	Benzene	--	--	--	--

-- = Not detected above laboratory analytical detection limit.
* State of North Carolina, Occupational Health Laboratory Detection Limit - 10 ppb.

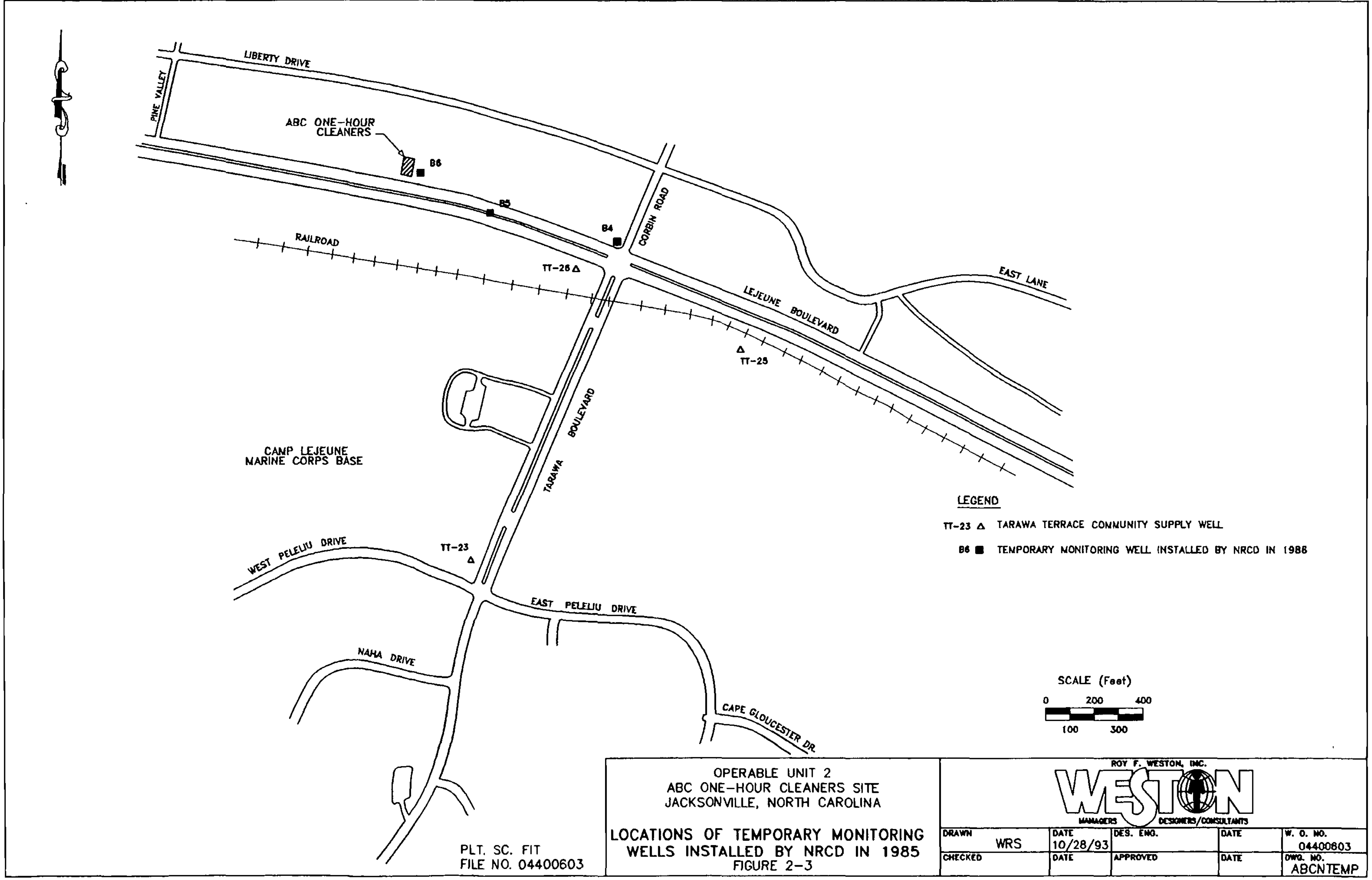
2.2.2 Groundwater Pollution Study - April 1985 (Shiver, 1985)

At the request of the Base and the Department of the Navy, the North Carolina Department of Natural Resources and Community Development conducted a groundwater pollution study to define the source of PCE and its derivatives in the Tarawa Terrace well field. This investigation, conducted by the WiRO from April through September 1985, included the sampling of the three closed Tarawa Terrace community wells [designated as TT-23, TT-25, and TT-26 (renamed b1, b2, and b3, respectively, in the WiRO Study)]. The study also involved the installation and sampling of three off-base monitor wells (b4, b5, and b6) at locations shown in Figure 2-3.

WiRO staff collected groundwater samples from the six wells on April 9, and September 25, 1985. A summary of the analytical data is provided in Table 2-2.

As part of this investigation, WiRO also inspected the Glam-O-Rama and ABC facilities with respect to storage, use, and recycling of PCE. Based upon the WiRO inspection, WiRO determined that the Glam-O-Rama facility was not the likely source of PCE contamination. This conclusion was based upon the following findings:

- There was no obvious source at Glam-O-Rama as the facility has always been connected to a central water and sewer system (i.e., no septic system).
- Inspections of the area where PCE was stored, used, and recycled indicated no obvious pathways for release of PCE to enter the subsurface.
- Until August 1985, Glam-O-Rama disposed of its still bottoms into an on-site dumpster for disposal into the county landfill.



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OPERABLE UNIT 2
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

LOCATIONS OF TEMPORARY MONITORING WELLS INSTALLED BY NRCD IN 1985
FIGURE 2-3

DRAWN	WRS	DATE	10/28/93	DES. ENG.	DATE	W. O. NO.	04400603
CHECKED		DATE		APPROVED	DATE	DWG. NO.	ABCNTEMP

Table 2-2

Tarawa Terrace Groundwater Investigation Samples Collected and Analyzed by WiRO Summary of Water Quality Data (Results in parts per billion [ppb])

WELL DESIGNATION	TETRACHLOROETHENE		TRICHLOROETHENE		DICHLOROETHENE	
	4/9/85	9/25/85	4/9/85	9/25/85	4/9/85	9/25/85
b1 (TT-26)	630	1,100	18	--	1.4	--
b2 (TT-23)	--	4.0	--	--	--	--
b3 (TT-25)	--	0.43	--	--	--	--
b4	--	2.2	--	--	--	--
b5	--	4.9	--	0.98	--	--
b6	--	12,000	--	2.7	--	--

-- = Not detected above laboratory detection limit.

Visual observations and information gathered by the WiRO staff during their investigation of the ABC facility suggested that the PCE plume appeared to originate from the septic tank soil absorption system. The reasons for identifying the septic tank soil absorption system at the ABC facility as the principal source were as follows:[1]

- ABC has always used PCE to dry clean clothes.
- ABC has used the septic tank soil absorption system for disposal of its wastewater.
- Inspection of the area where PCE was stored, used, and recycled indicated that PCE releases can and have entered the septic tank via spillage to a floor drain.
- The soils obtained from a depth of 0 to 15 feet while drilling well b6 (located adjacent to ABC) had an obvious chemical odor which infers a PCE release to the subsurface.
- Interpretation of the water elevation data indicated a direction of flow within the water table aquifer to be from ABC to wells b1, b2, and b3.
- While there was a disparity in depths between wells b1 through b3 and b4 through b6, and considering that PCE is about 60% more dense than natural groundwater, the data closely indicated a source of PCE at ABC and groundwater contamination leading to the impacted wells.
- Until August 1985, ABC disposed of still bottoms by filling potholes in the dirt driveway south and west of the building constituting a potential secondary source of PCE contamination at ABC.

---

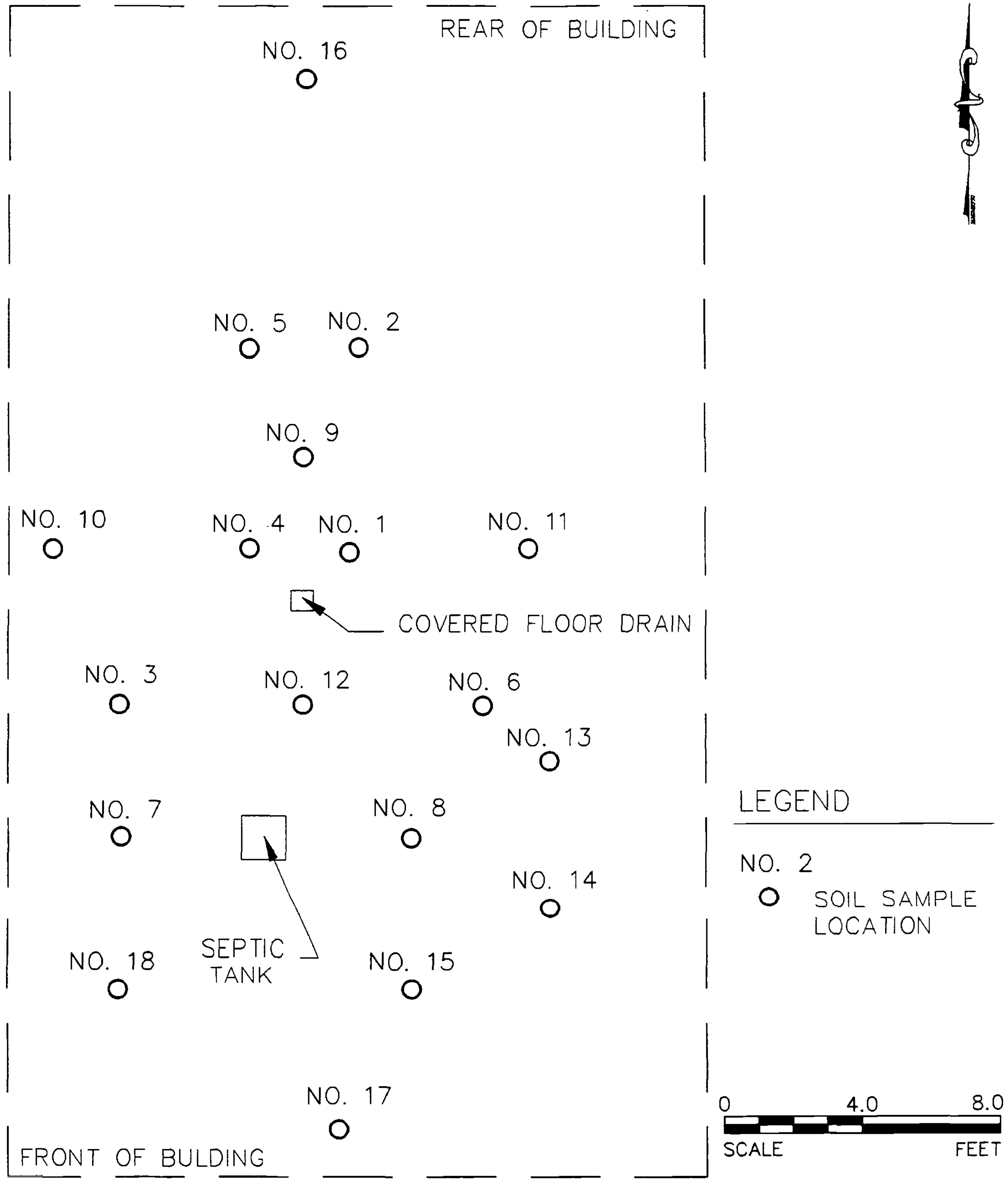
[1] Reference Shiver, Rick, 1985 Draft Summary Report Investigation to Define the Source(s) of Tetrachloroethylene that have contaminated three community water supply wells at Tarawa Terrace North Carolina Department of Environmental Management 1985

On January 24, 1986, WiRO issued a Notice of Violation (NRCD, 1986) to ABC for discharging dry cleaning solvents into the septic tank system resulting in the contamination of groundwater in the area. The notice called for ABC to immediately stop the discharge of all dry cleaning fluids to the septic tank system; implement a sampling and analysis plan to determine the extent of soil and groundwater contamination; and propose a remedial action plan to excavate soil as well as restore groundwaters to acceptable levels as determined by the State.

2.2.3 Septic Tank and Surrounding Soils Investigation - April 1986 (Law, 1986a)

In response to the Notice of Violation, ABC hired Law Engineering and Testing Corporation (Law) to conduct an investigation of the ABC septic tank and surrounding soils. Samples were collected from the septic tank fluids as well as the septic sludge. The purpose of the sampling was to determine the extent to which the septic tank system could be serving as a source for the contaminants in the groundwater. Results of the investigation indicated PCE concentrations of 1,402 milligrams per liter (mg/l) present in a sludge sample collected from the septic tank.

Analytical results of soil samples collected from the area surrounding the septic tank and adjacent floor drain from a depth of 4 feet below ground surface (bgs) indicated PCE concentrations as high as 404 milligrams per kilogram (mg/kg). This investigation confirmed the presence of PCE contamination within the septic tank system and surrounding soils at ABC. It did not assess the full extent of horizontal and vertical migration of PCE. Sample locations and analytical results of the Law investigation are presented in Figure 2-4 and Table 2-3, respectively.



MODIFIED FROM LAW ENGINEERING TESTING COMPANY

ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

LOCATION OF SOIL SAMPLES
FROM LAW ENGINEERING
1986 STUDY
FIGURE 2-4

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN WRS	DATE 12/20/93	DES. ENG.	DATE	W. O. NO. 04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO. 04400603

PLT. SC. FIT FILE NO. ABCNLOC

Table 2-3

Results of Septic Soil Sample Analyses(1)
ABC One-Hour Cleaners, Inc.
Jacksonville, North Carolina

Sample ID(2)	Unit	1,1-Dichloroethene	1,2-Dichloroethene	Trichloroethene	Tetrachloroethene
ABC Septic Top (water)	mg/L(3)	<0.1	<0.1	22	1.04
ABC Septic Bottom (septage)	mg/L	24	15	9.5	1,402
ABC No. 1	mg/kg(4)	<0.1	11.3	4.0	85
ABC No. 2	mg/kg	<0.1	0.4	0.1	1.4
ABC No. 3	mg/kg	<0.1	0.9	0.5	2.3
ABC No. 4	mg/kg	<0.1	7.3	2.3	18.4
ABC No. 5	mg/kg	<0.1	2.3	0.4	2.0
ABC No. 6	mg/kg	<0.1	0.5	0.5	1.4
ABC No. 7	mg/kg	<0.1	0.9	1.2	<0.1
ABC No. 8	mg/kg	<0.1	8.1	14	404
ABC No. 9	mg/kg	<0.1	3.9	0.4	<0.1

(1) Samples were collected on April 8, 1986; samples were analyzed by Law Engineering and Testing Corporation.

(2) ABC top and bottom samples were collected from the septic tank. ABC No. 1 through No. 9 were collected from 4 feet below ground surface (bgs).

(3) mg/L indicates milligrams per liter.

(4) mg/kg indicates milligrams per kilogram.

Laboratory detection limits were not reported.

Reference: Law Engineering and Testing Company Corporation, 1986a. On-Site Sampling-Septic Tank and Outlying Area, ABC One-Hour Cleaners, Inc., Jacksonville, NC.

2.2.4 Additional Soil Sampling - September 1986 (Law, 1986b)

In September 1986, Law conducted an additional soils investigation at ABC to evaluate vertical and horizontal extent of contamination. The investigation involved the collection of soil samples at depths ranging from 4 to 16 feet bgs in the area of the septic tank (Figure 2-4). Results of the laboratory analyses, presented in Table 2-4, indicated elevated concentrations of PCE and TCE present beneath the ABC building.

Based on the analytical results from this investigation, Law concluded that the level of PCE and its derivatives in soils immediately adjacent to the septic tank constituted a source of groundwater contamination; however, the extent of contamination could not be determined.

On December 3, 1987, following a review of the data with ABC, Law recommended a restoration program which incorporated the following elements:

- A remedial study to focus on the extent of groundwater contamination and hydrogeologic characteristics of the aquifer system.
- Removal of the source of contamination via excavation and disposal of contaminated soils.
- Restoration of groundwater quality through extraction, treatment, and re-infiltration of the treated water.
- Follow-up site monitoring and evaluation as to the effectiveness of the remedial action.

Concurrent with the proposed restoration program, the State of North Carolina applied the Hazard Ranking System to the site and nominated the site for inclusion on the Superfund

Table 2-4

Results of Soil Sample Analyses[1]
September, 1986
ABC One-Hour Cleaners, Inc.
Jacksonville, North Carolina

Boring No.	Depth (ft bgs)[2]	1,1-Dichloroethene (mg/kg)[3]	1,2-Dichloroethene (mg/kg)	Trichloroethene (mg/kg)	Tetrachloroethene (mg/kg)
3	8	<0.1	<0.1	1.1	5.9
9	4	<0.1	<0.1	1.5	106
9	8	<0.1	<0.1	8.6	450
9	12	<0.1	<0.1	1.7	22
9	16	<0.1	<0.1	1.1	12
10	4	<0.1	<0.1	0.55	1.3
10	8	<0.1	<0.1	0.50	0.11
11	4	<0.1	<0.1	16	450
11	8	<0.1	<0.1	3.8	170
12	4	<0.1	<0.1	24	720
12	8	<0.1	<0.1	4.2	860
12	10	<0.1	<0.1	15	820
13	4	<0.1	<0.1	22	630
13	8	<0.1	<0.1	4.1	260
14	4	<0.1	<0.1	6.3	24
14	8	<0.1	<0.1	7.6	280
15	4	<0.1	<0.1	0.90	12
15	8	<0.01	<0.01	1.0	18
17	4	<0.1	<0.1	1.9	5.6

Table 2-4 (Continued)

Results of Soil Sample Analyses(1)
September, 1986
ABC One-Hour Cleaners, Inc.
Jacksonville, North Carolina

Boring No.	Depth (ft bgs)(2)	1,1-Dichloroethene (mg/kg)(3)	1,2-Dichloroethene (mg/kg)	Trichloroethene (mg/kg)	Tetrachloroethene (mg/kg)
17	8	<0.1	<0.1	1.6	5.8
18	4	<0.1	<0.1	0.30	17
18	8	<0.1	<0.1	0.13	6.0

(1) Samples were collected on September 10-11, 1986; samples were analyzed by Law Engineering and Testing Corporation.

(2) ft bgs indicates feet below ground surface.

(3) mg/kg indicates milligrams per kilogram.

Laboratory detection limits were not reported.

Reference: Law Engineering and Testing Corporation, 1986b. On-Site Sampling ABC One-Hour Cleaners, Inc. Jacksonville, NC.

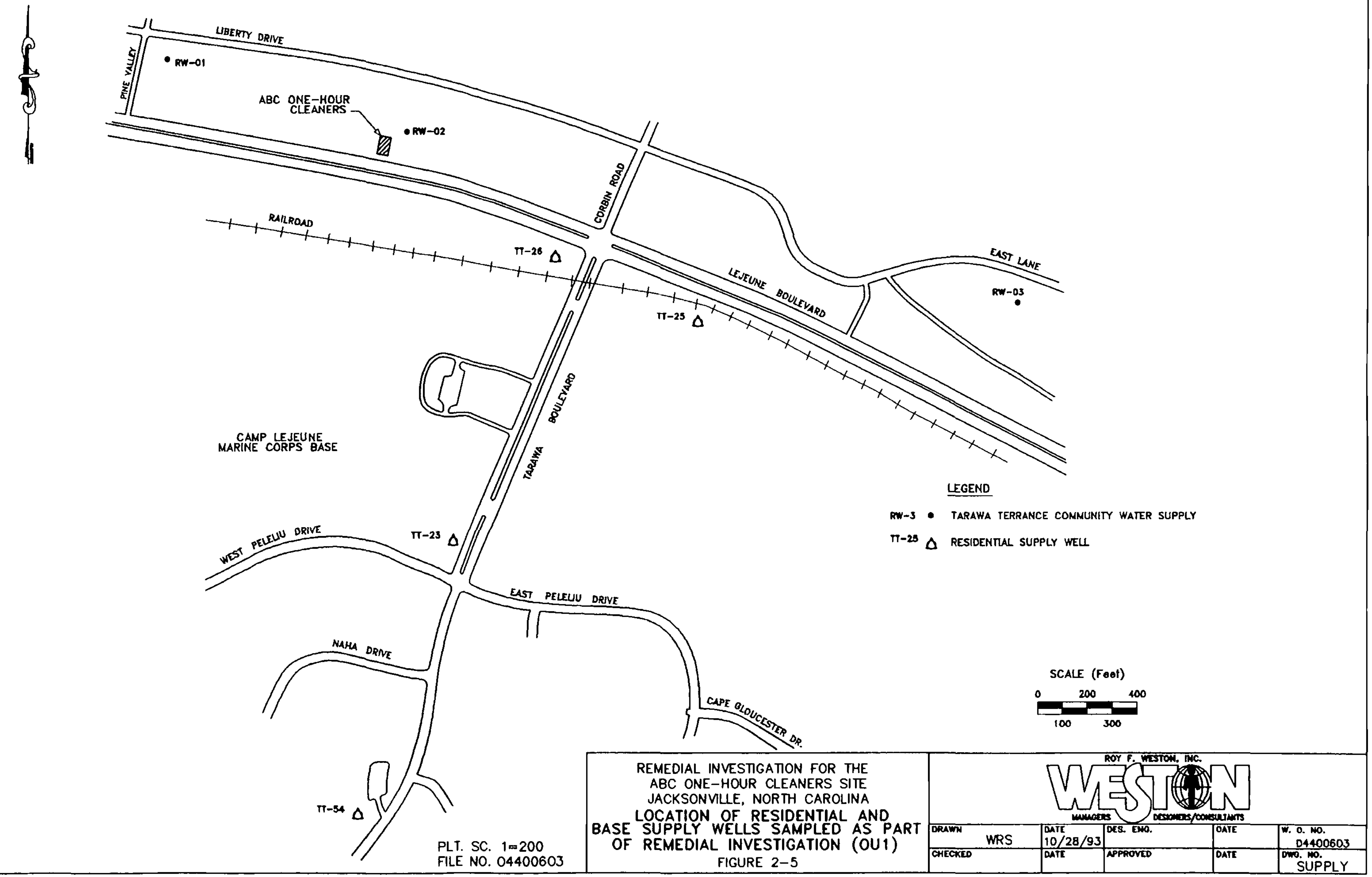
National Priorities List (NPL) of uncontrolled hazardous waste sites. Based upon a score of 29.11, which exceeds the score of 28.5 or greater necessary for listing, the ABC One-Hour Cleaners, Inc., site was proposed for the NPL in June 1988, and placed on the final list in March 1989.

2.2.5 Remedial Investigation Report (OU1) - November 1992 (WESTON, 1992)

Under the U.S. EPA Region IV ARCS contract, WESTON conducted a remedial investigation to characterize the nature and extent of contamination in groundwater at the ABC site. Field activities commenced in June 1991, and continued through June 1992. Major field activities conducted as part of the field investigation included: (1) identifying and sampling existing Base and residential wells; (2) collecting and analyzing septic tank contents; (3) sampling groundwater from temporary hydrocone locations installed during the Direct Push Technology (DPT) program; (4) installing surficial and Castle Hayne aquifer monitor wells; (5) collecting and analyzing monitor well samples; (6) collecting water level measurements and establishing monitor well elevations; and (7) performing aquifer testing of surficial and Castle Hayne aquifers.

The locations of the residential and Base water supply wells located and sampled during the OU1 investigation are indicated in Figure 2-5. The locations used for sampling during the DPT program are indicated in Figure 2-6. The surficial and Castle Hayne aquifer monitor well locations are indicated in Figure 2-7.

During the DPT investigation, soil and groundwater data were generated and used to help place monitor wells in the most efficient locations. The monitor well locations shown in Figure 2-7



PLT. SC. 1=200
FILE NO. 04400603

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

LOCATION OF RESIDENTIAL AND BASE SUPPLY WELLS SAMPLED AS PART OF REMEDIAL INVESTIGATION (OU1)

FIGURE 2-5

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

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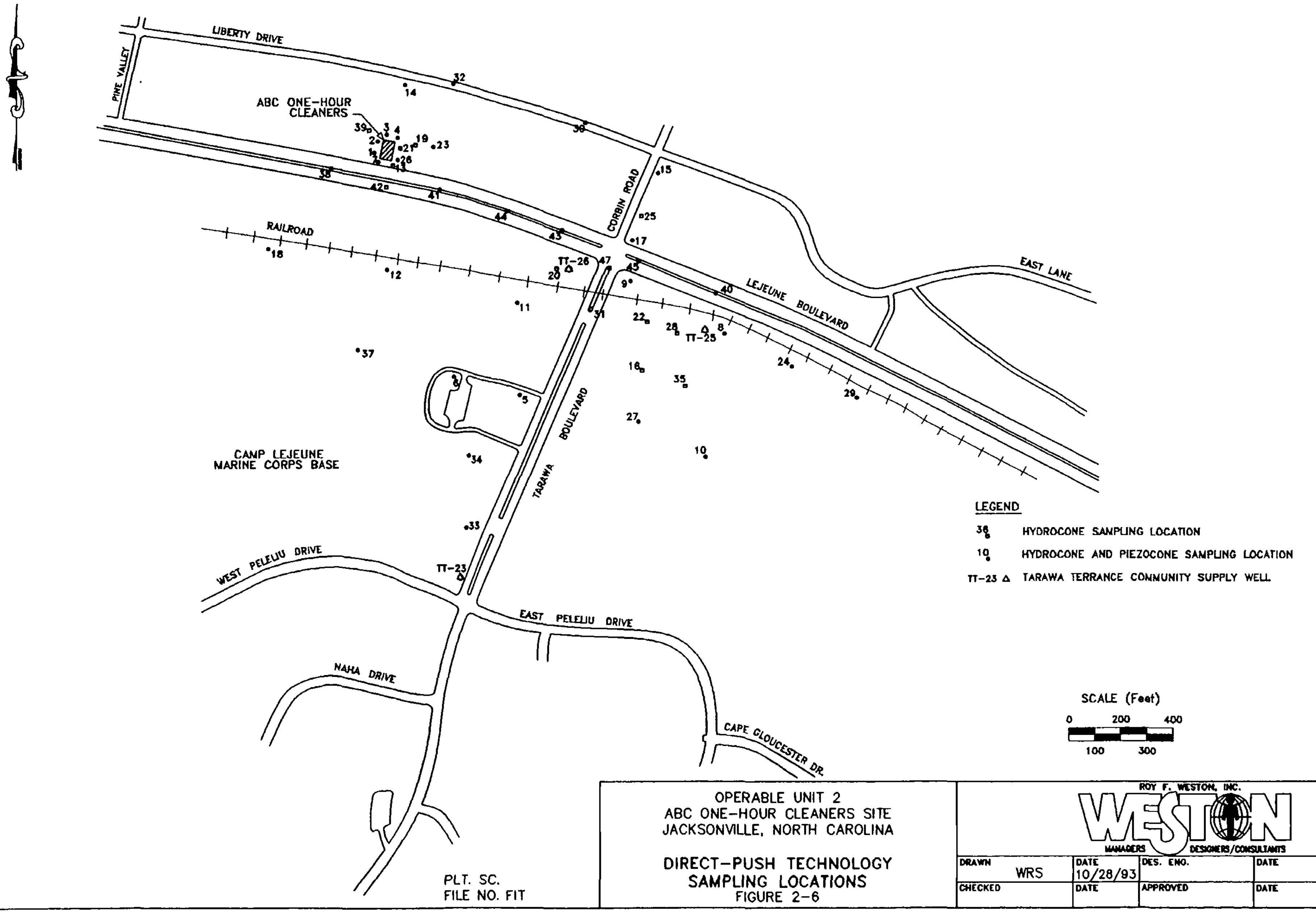


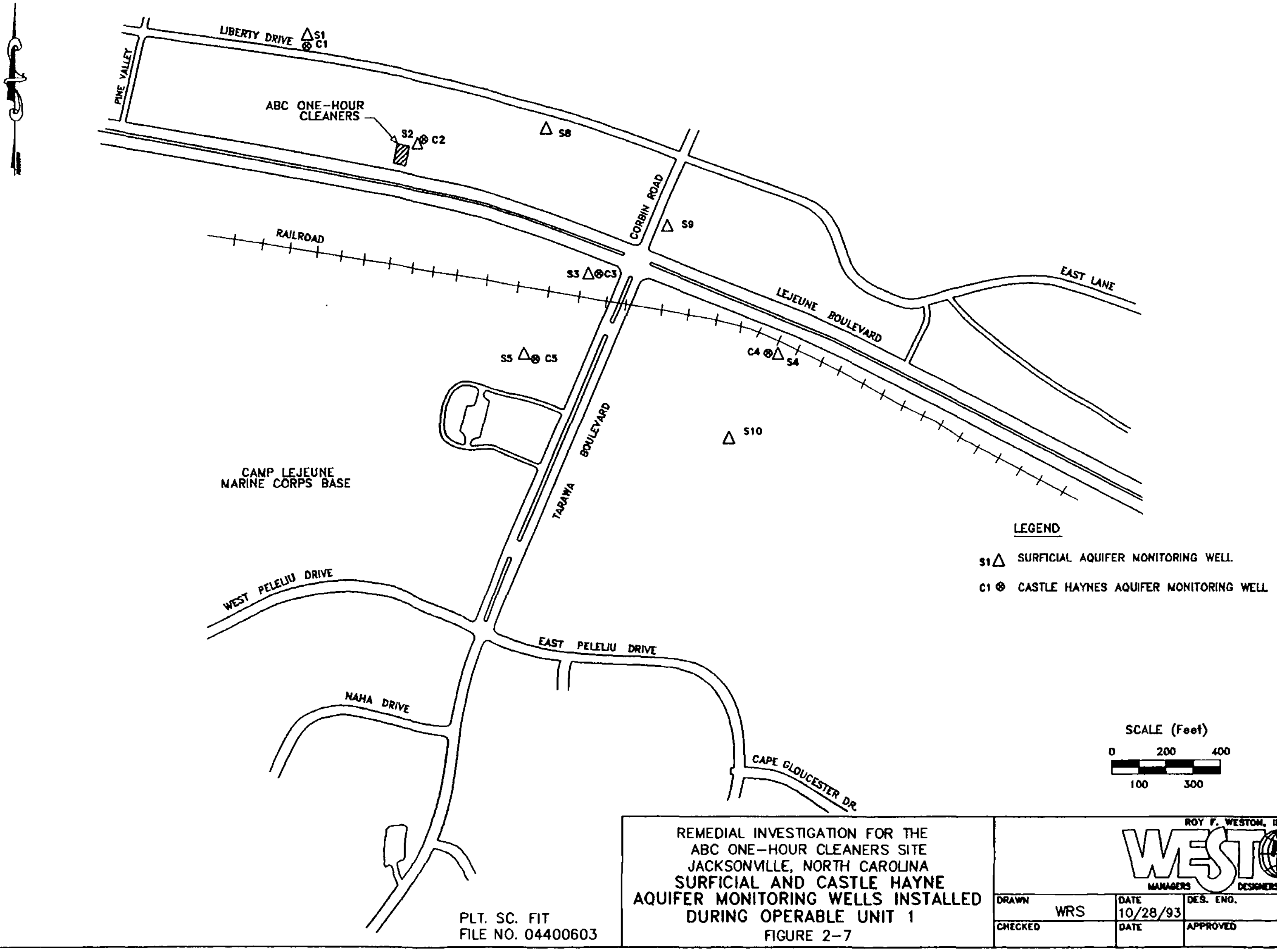
OPERABLE UNIT 2
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

DIRECT-PUSH TECHNOLOGY
SAMPLING LOCATIONS
FIGURE 2-6

PLT. SC.
FILE NO. FIT

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN WRS	DATE 10/28/93	DES. ENG.	DATE	W. O. NO. 04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO. ABCPUSH



PLT. SC. FIT
FILE NO. 04400603

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
SURFICIAL AND CASTLE HAYNE
AQUIFER MONITORING WELLS INSTALLED
DURING OPERABLE UNIT 1
FIGURE 2-7

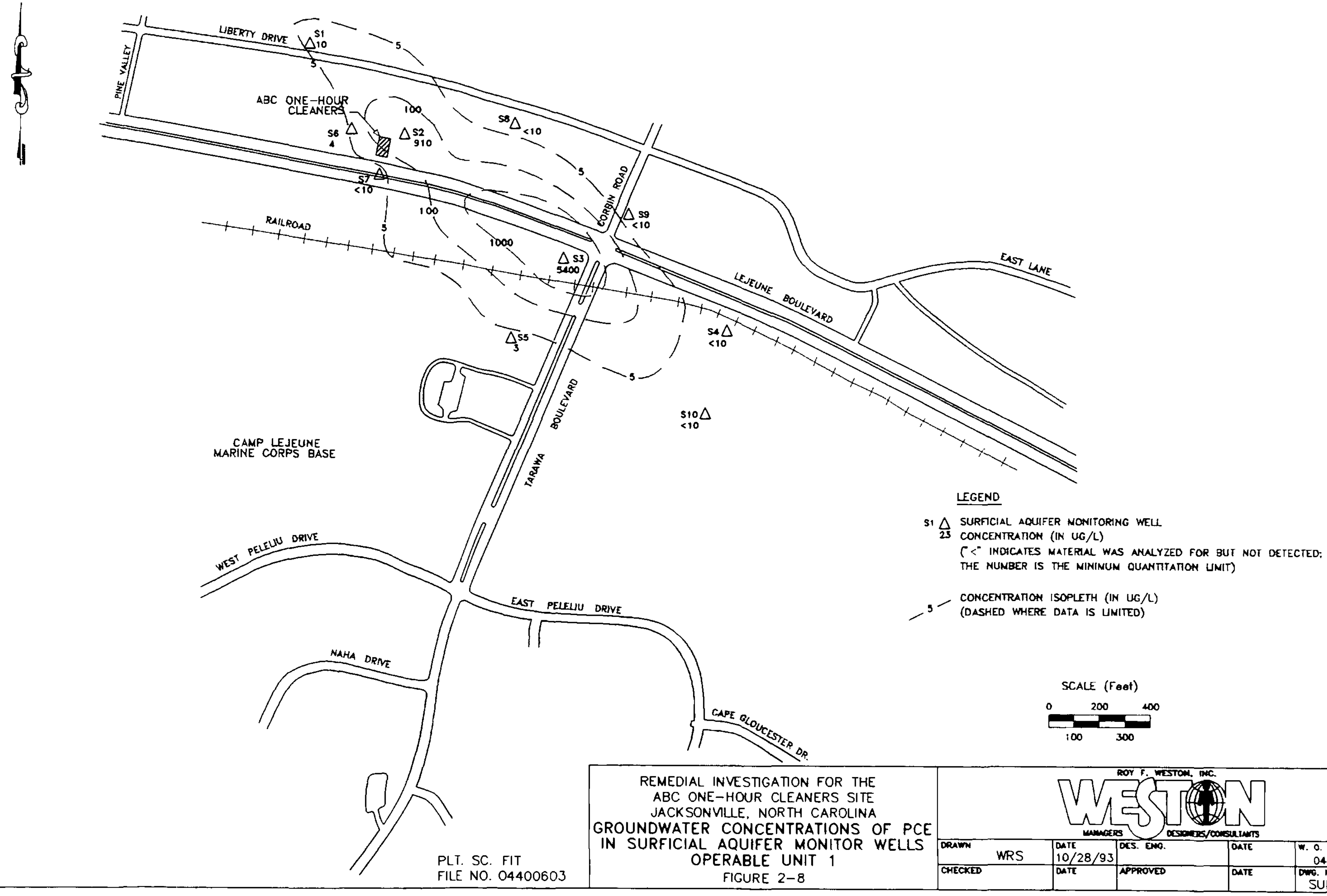
ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN WRS	DATE 10/28/93	DES. ENG.	DATE	W. O. NO. 04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO. CAS-AQU

were sampled, and the results plotted for the surficial and Castle Hayne aquifers. These plots are provided in Figures 2-8 through 2-14. The principal directions of contaminant migration from the ABC site appeared to be to the north, northeast, east, and southeast within the surficial aquifer and to the east and southeast within the Castle Hayne aquifer.

Results of the investigation concluded that the former septic tank system at the ABC site was the primary source for VOCs, including tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2 dichloroethene (cis-1,2-DCE), and vinyl chloride, as detected in soil and groundwater samples. In addition, water quality data from surficial and Castle Hayne aquifer sampling points showed PCE, TCE, 1,2 DCE (total) and vinyl chloride concentrations to be in excess of Maximum Contaminant Levels (MCLs) and North Carolina Groundwater Quality Standards.

Data collected during the study and used to construct a Risk Assessment indicated that contaminants posing most of the total estimated carcinogenic risk for the surficial aquifer included PCE (51%), vinyl chloride (39%), and arsenic (8%). Arsenic was not considered to be a contaminant released by ABC. The source of arsenic has not been investigated during this study. The contaminants posing most of the total estimated carcinogenic risk for the Castle Hayne aquifer were also found to be contaminants not released by ABC.



PLT. SC. FIT
FILE NO. 04400603

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
GROUNDWATER CONCENTRATIONS OF PCE
IN SURFICIAL AQUIFER MONITOR WELLS
OPERABLE UNIT 1
FIGURE 2-8

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

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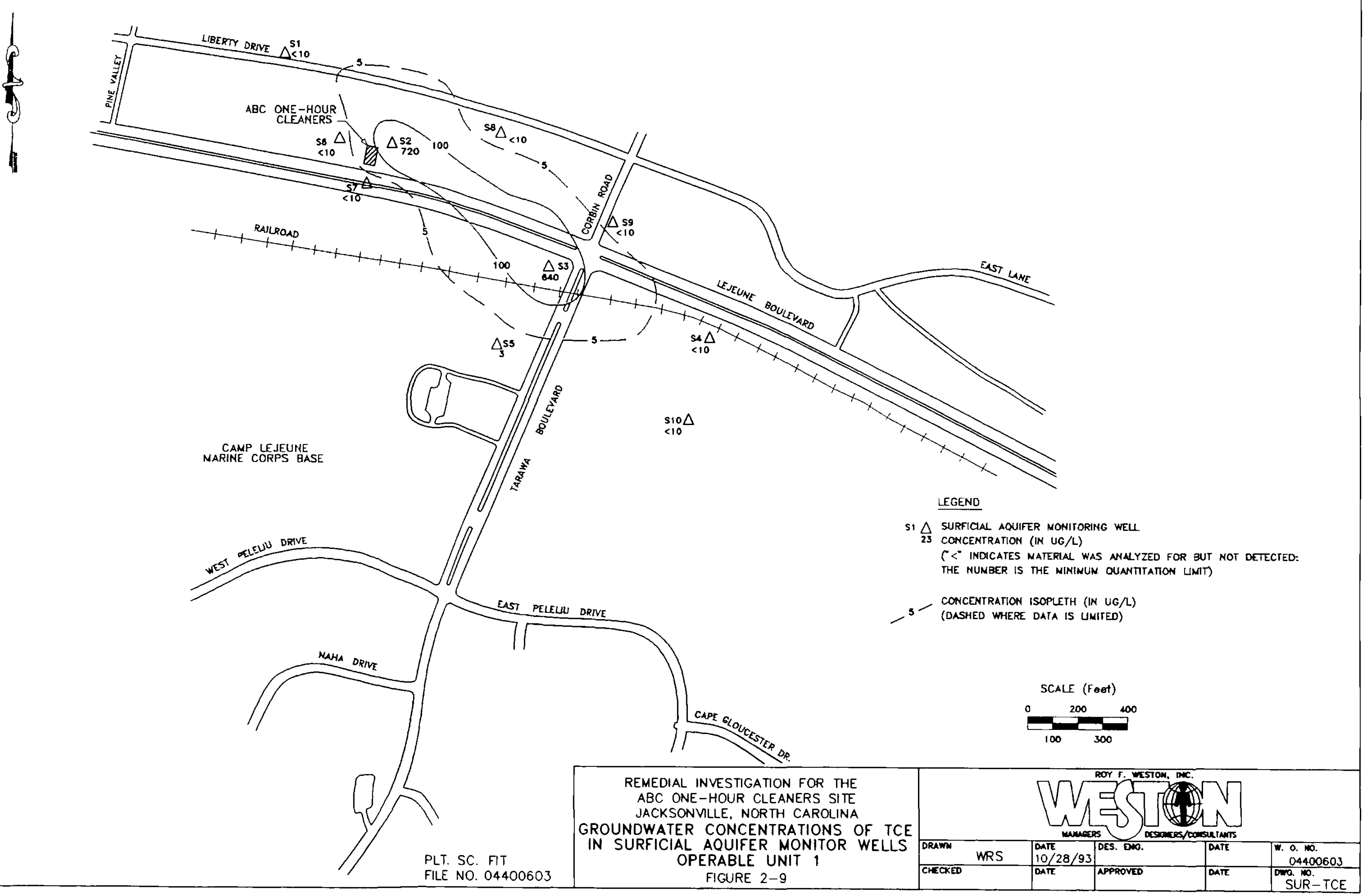
WRS	10/28/93			04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO.
				SUR-PCE



LEGEND

S1 △ 23 SURFICIAL AQUIFER MONITORING WELL CONCENTRATION (IN UG/L)
("<" INDICATES MATERIAL WAS ANALYZED FOR BUT NOT DETECTED: THE NUMBER IS THE MINIMUM QUANTITATION LIMIT)

5 CONCENTRATION ISOPLETH (IN UG/L)
(DASHED WHERE DATA IS LIMITED)

SCALE (Feet)
0 100 200 300 400

PLT. SC. FIT
FILE NO. 04400603

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
GROUNDWATER CONCENTRATIONS OF TCE
IN SURFICIAL AQUIFER MONITOR WELLS
OPERABLE UNIT 1
FIGURE 2-9

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN	WRS	DATE 10/28/93	DES. ENG.	DATE	W. O. NO. 04400603
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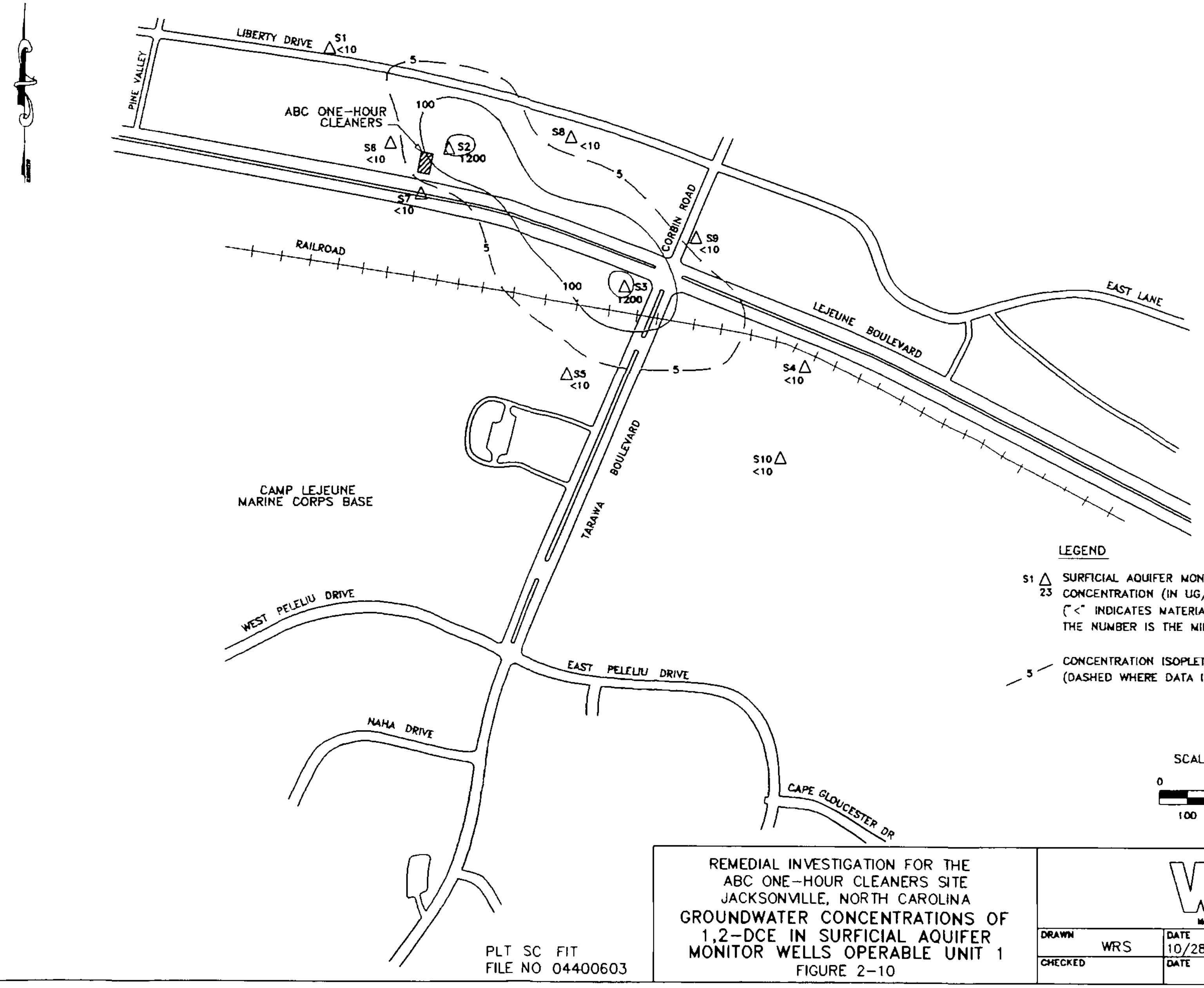

LEGEND

S1 △ 23 SURFICIAL AQUIFER MONITORING WELL CONCENTRATION (IN UG/L)
("<" INDICATES MATERIAL WAS ANALYZED FOR BUT NOT DETECTED. THE NUMBER IS THE MINIMUM QUANTITATION LIMIT)

— 5 — CONCENTRATION ISOPLETH (IN UG/L)
(DASHED WHERE DATA IS LIMITED)

SCALE (Feet)
0 100 200 300 400

PLT SC FIT
FILE NO 04400603

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
GROUNDWATER CONCENTRATIONS OF
1,2-DCE IN SURFICIAL AQUIFER
MONITOR WELLS OPERABLE UNIT 1
FIGURE 2-10

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

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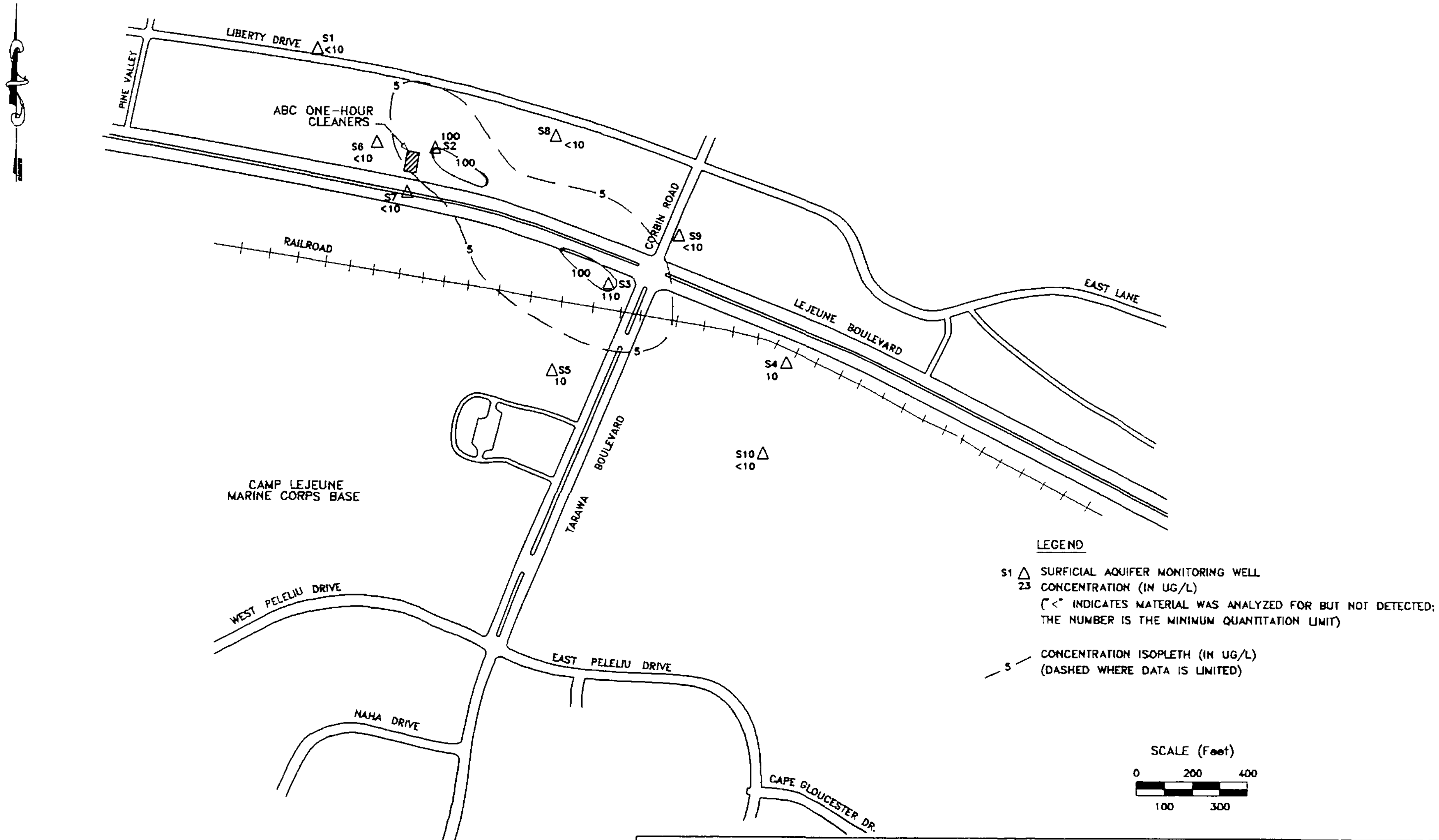
WRS	10/28/93			04400603
CHECKED	DATE	APPROVED	DATE	DWG NO
				SUR-DCE

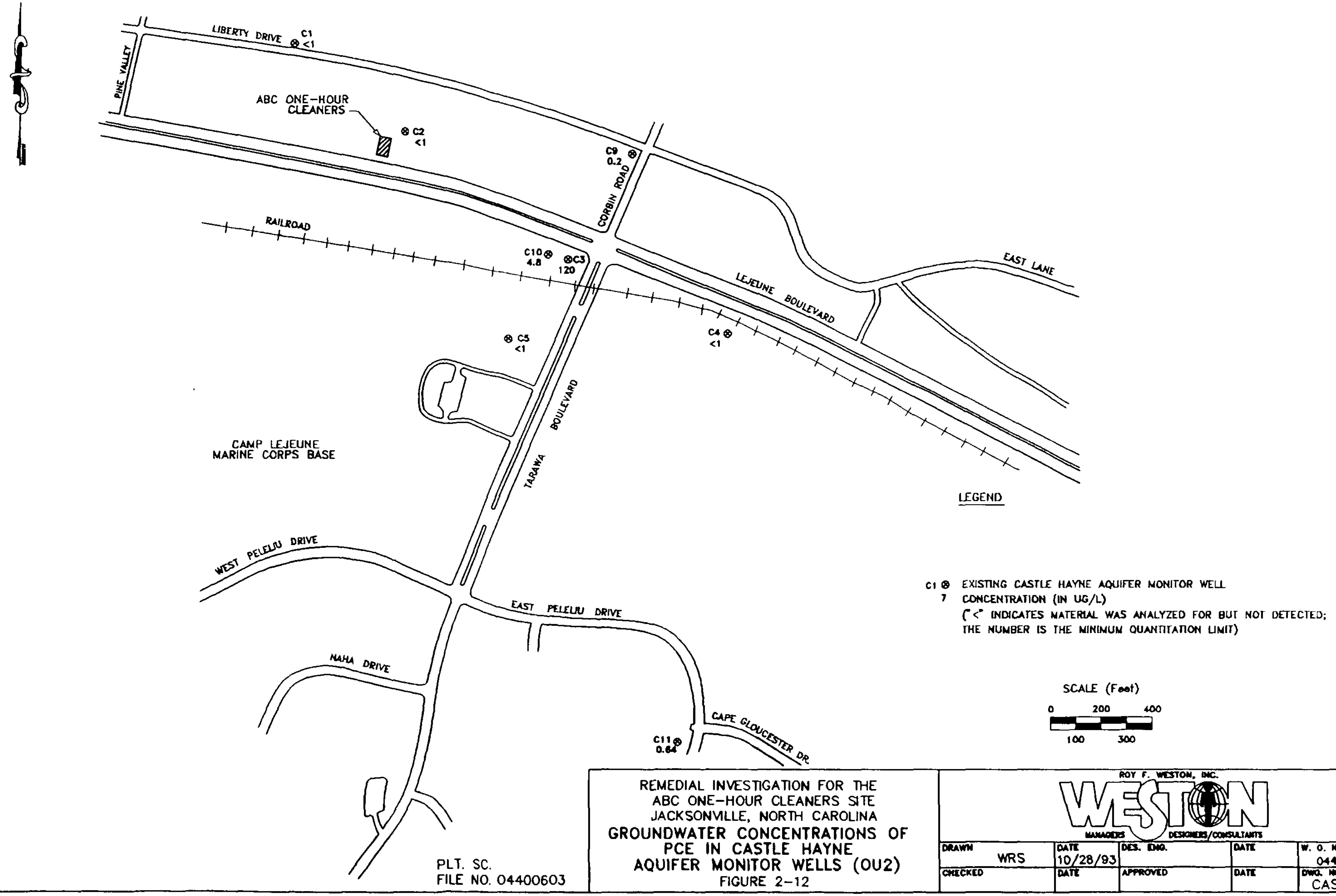


PLT SC. FIT
FILE NO. 04400603

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
GROUNDWATER CONCENTRATIONS OF
VINYL CHLORIDE IN SURFICIAL
AQUIFER MONITOR WELLS (OU1)
FIGURE 2-11

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN	DATE	DES. ENG.	DATE	W. O. NO.
WRS	10/28/93			04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO.
				VINYL



LEGEND

C1 ⊗ EXISTING CASTLE HAYNE AQUIFER MONITOR WELL
7 CONCENTRATION (IN UG/L)
("<" INDICATES MATERIAL WAS ANALYZED FOR BUT NOT DETECTED;
THE NUMBER IS THE MINIMUM QUANTITATION LIMIT)

PLT. SC.
FILE NO. 04400603

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
**GROUNDWATER CONCENTRATIONS OF
PCE IN CASTLE HAYNE
AQUIFER MONITOR WELLS (OU2)**
FIGURE 2-12

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

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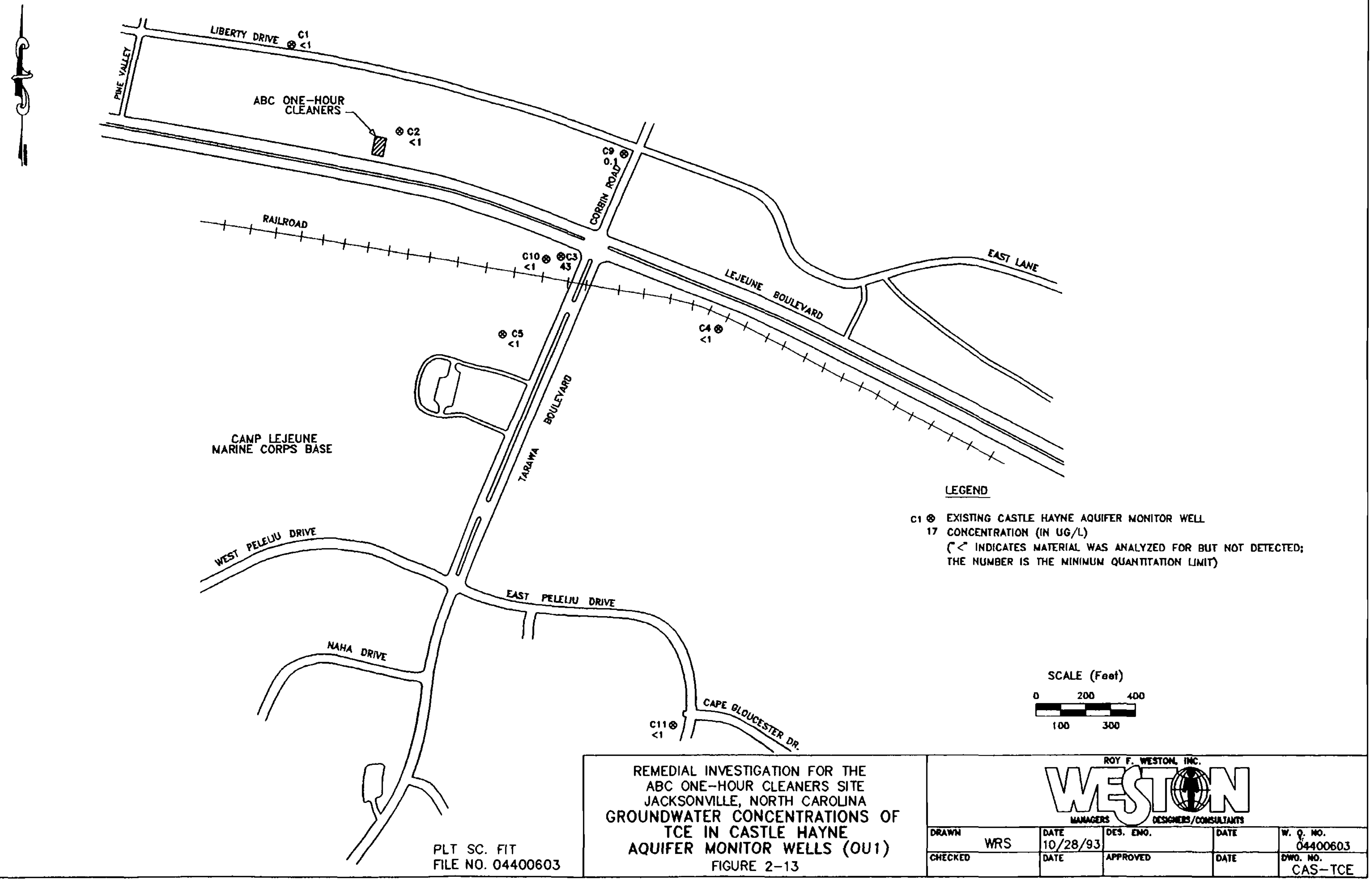
CHECKED	DATE	APPROVED	DATE	DWG. NO. CAS-PCE

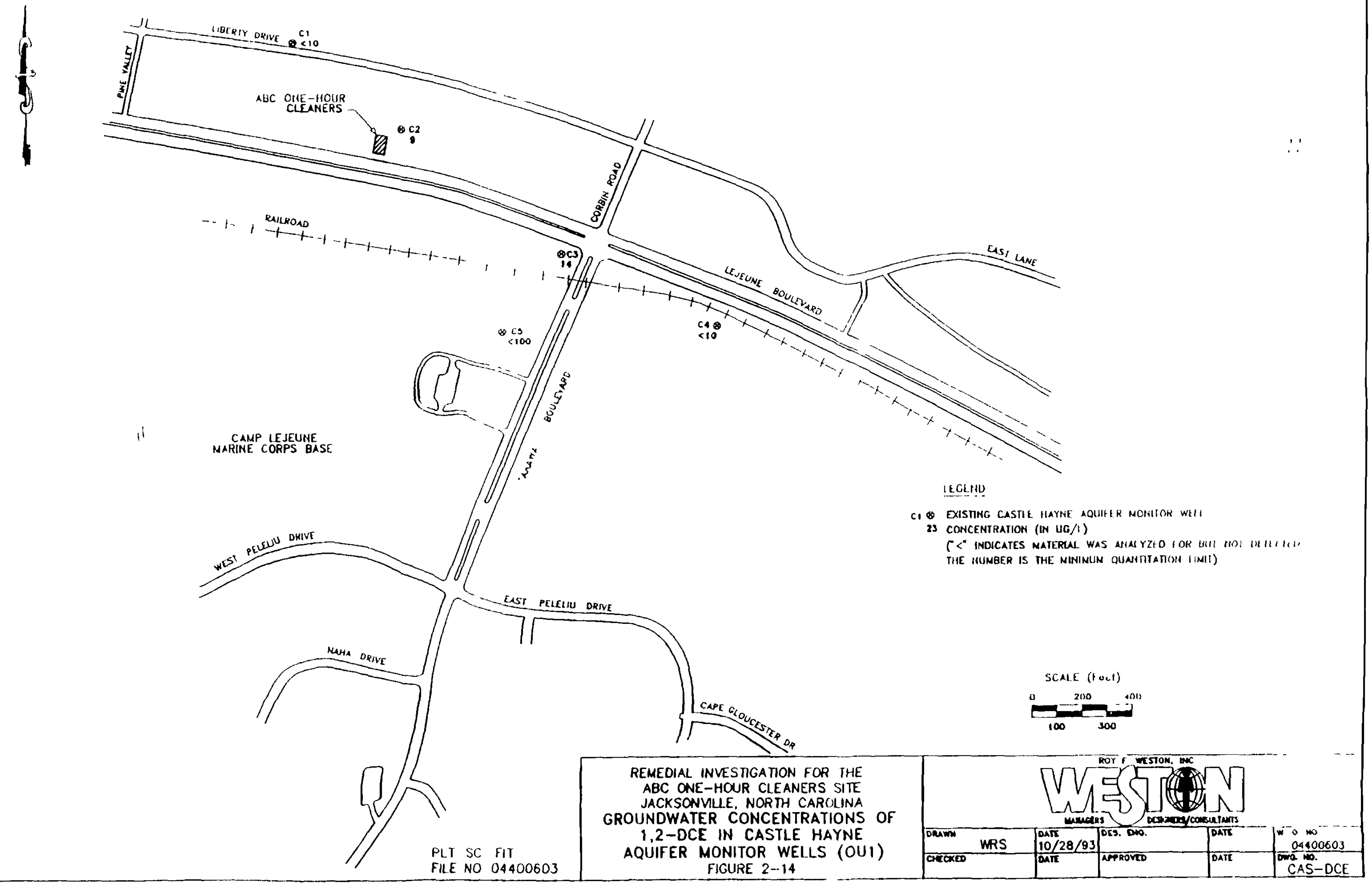


PLT SC. FIT
FILE NO. 04400603

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
GROUNDWATER CONCENTRATIONS OF
TCE IN CASTLE HAYNE
AQUIFER MONITOR WELLS (OU1)
FIGURE 2-13

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN	DATE	DES. ENG.	DATE	W. O. NO.
WRS	10/28/93			04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO.
				CAS-TCE



LEGEND

C1 ⊗ EXISTING CASTLE HAYNE AQUIFER MONITOR WELL
23 CONCENTRATION (IN UG/L)
("<" INDICATES MATERIAL WAS ANALYZED FOR BUT NOT DETECTED
THE NUMBER IS THE MINIMUM QUANTITATION LIMIT)

PLT SC FIT
FILE NO 04400603

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
GROUNDWATER CONCENTRATIONS OF
1,2-DCE IN CASTLE HAYNE
AQUIFER MONITOR WELLS (OU1)
FIGURE 2-14

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN	WRS	DATE	10/28/93	DES. ENG.		DATE		W.O. NO. 04400603
CHECKED		DATE		APPROVED		DATE		DWG. NO. CAS-DCE

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SECTION 3

FIELD INVESTIGATION

This section provides a general overview of field activities and details specific field activities conducted as part of the OU2 RI.

3.1 OVERVIEW OF FIELD ACTIVITIES

The objectives of the OU2 RI conducted at the ABC One-Hour Cleaners site were to delineate the source and extent of VOC contamination, evaluate the pathways of possible migration or releases to the environment, and define the extent of potential pathways of human exposure to contamination. To meet these objectives, a multi-task field program was designed to supplement data obtained from previous investigations, and provide new data to support development of a risk assessment and feasibility study. The tasks included the following:

- Collect and analyze surface and subsurface soil samples at the site.
- Install shallow soil borings for a Soil Vapor Extraction (SVE) field treatability study of VOC contamination in soils.
- Install SVE equipment into the soil borings and conduct the SVE field treatability study.
- Collect and analyze a sludge sample from the septic tank.
- Install and survey monitor wells and piezometers in shallow and deep aquifers underlying the site.
- Collect and analyze groundwater samples and obtain water level measurements from the shallow and deep monitor wells and piezometers.

- Conduct aquifer testing.

Table 3-1 provides a purpose summary of the purpose of each task. A detailed discussion of each task is presented in the following subsections.

3.2 SOIL BORINGS

This section describes the installation and collection of soil samples from soil borings in the vicinity of the ABC facility. The samples were collected to provide data on the horizontal and vertical extent of contamination, provide data to support a risk assessment, and provide information allowing for the geological assessment of the unsaturated soils.

3.2.1 Soil Boring Locations

From September 9, 1993, through September 21, 1993, WESTON completed 19 soil borings on the interior and exterior of the ABC facility in order to collect surface and subsurface soil samples. A total of 58 soil samples were collected from these borings. Also, two borings were completed outside of the ABC facility in order to collect Shelby tube samples for the SVE Treatability Study. The geotechnical boring program is described in Section 3.4. Figure 3-1 presents the locations for soil borings.

A total of 11 soil borings were completed within the ABC facility (Figure 3-1). Soil boring locations selected for the interior of the building were used for two different purposes. Foremost, the boring locations were used to assess the horizontal extent of soil contamination (primarily in the north-south direction) and to provide an assessment of the vertical magnitude

Table 3-1

Summary of Site Investigation Activities
ABC One-Hour Cleaners
Operable Unit 2

TASK	DESCRIPTION	PURPOSE
Surface and Subsurface Soil Sampling	Determine contaminant extent in soils surrounding ABC facility.	Provide data on geology surrounding the ABC facility and horizontal and vertical extent of VOC contamination in soil underlying the site.
Septic Tank Sampling	Collect and analyze a single sludge sample from the septic tank within the ABC facility.	Obtain chemical data on the type and concentration of VOCs of the suspected contaminant source.
Monitor Well Installation - Surficial and Castle Hayne Aquifers	Install monitoring wells within both aquifers to provide additional monitoring points.	Provide a means for collecting additional groundwater quality data to assist in definition of horizontal and vertical extent of plume; provide hydrogeologic data on aquifers.
Monitor Well Sampling and Analysis	Collect samples from monitor wells for VOC content analysis.	Provide groundwater quality data to evaluate horizontal and vertical extent of contamination to support risk assessment and evaluation of remedial action alternatives.
Monitor Well Survey and Water Level Measurements	Collect measuring points for water level elevations.	Collect data points to prepare water table and potentiometric surface maps to determine groundwater flow directions, gradients, and recharge/discharge areas.
Soil Vapor Extraction (SVE) Borings	Install shallow soil borings within ABC facility for SVE system; obtain geotechnical samples exterior to the ABC facility.	Characterize geology of subsurface soils where SVE system was installed. Obtain soil samples for chemical analysis of soil quality. Install borings to certain depths and widths in preparation for SVE piping. Obtain data from geotechnical samples related to physical parameters of the soil profile underlying the ABC site.

Table 3-1 (Continued)

Summary of Site Investigation Activities
ABC One-Hour Cleaners
Operable Unit 2

TASK	DESCRIPTION	PURPOSE
SVE System and Treatability Study	Install SVE equipment and conduct an operational test of system.	Provide data on whether an SVE type system would be able to remove VOC contamination from the soils underlying ABC and whether it would be cost effective.
Aquifer Testing - Surficial and Castle Hayne Aquifers	Conduct two-step drawdown tests and one 72-hour aquifer test.	Used with water level data and effective porosity to calculate groundwater flow velocities. Data used as input for groundwater flow modeling in Remedial Design.
Septic Tank Contents Removal	Remove wastes and VOC contaminants from septic tank within ABC facility.	Elimination of source material and determine if septic tank system is still being used by ABC operation.

of soil contamination in the unsaturated soil profile. Secondly, the borings were used as part of the SVE Treatability Study, as described in Section 3.5.

Eight of the 19 soil borings were located outside of the ABC building (Figure 3-1). The locations of these borings were selected in an attempt to further define the horizontal and vertical extent of contamination. Data generated from these soil samples were combined with data from the OU1 investigation to refine the interpretation of the horizontal extent of contamination, as described in Section 5.1.2.

3.2.2 Drilling and Sampling Procedures

Soil borings installed during the OU2 investigation were either completed by hand auger techniques or through the use of a drill rig. All soil borings were extended to a depth of 15 feet bgs. At each borehole location surface and/or subsurface soil samples were collected on 5-foot intervals beginning at the surface, as follows: 0 to 2 feet bgs, 3 to 5 feet bgs, 8 to 10 feet bgs, and 13 to 15 feet bgs. Locations within the ABC facility and to the west of the building had concrete and/or asphalt covers and were cored with a concrete coring machine prior to the initiation of the boring and sample collection.

All soil sample numbers are identified as in the following example: ABC-SS-017-01-02. Each letter or number set is representative of information pertaining to the particular sample involved. The "ABC" portion denotes the site area while "SS" identifies the sample as being a soil sample. The following number sequences "017-01-02" represent the soil boring number, the order of the sample (i.e., in this case it being the first sample), and the sampling interval depth. Installation and sampling methods are discussed below.

3.2.2.1 Borehole Installation-Hand Auger

Sixteen soil borings were completed using hand auger techniques (5 exterior and 11 interior to the ABC facility). This method was preferred over other techniques because of building and equipment restrictions of the ABC facility. The hand auger was comprised of a stainless steel bucket with 3-foot extensions attached to the bucket.

Each boring began with a decontaminated hand auger. Decontamination of the hand auger equipment was performed according to protocols described in Section 3.3.5. Typically, the first 2 feet of soil below the ground surface was sampled. Once the sample was collected, the boring was continued downward. As the boring was continued, the hand auger bucket would become full of soil cuttings, causing it to be removed from the borehole. Soils in the bucket were carefully removed and placed onto visqueen sheeting where it was characterized and logged by a WESTON field representative. The boring was continued in this manner until the top of the next sampling zone was reached. When the auger bucket with the soil designated for sampling was brought to the surface, the soil was carefully removed and placed onto a clean portion of visqueen sheeting. Once all the soil was removed from the bucket, portions of the soil were collected by hand and placed directly into pre-labelled, unpreserved 4-ounce sampling jars. Upon reaching this point, the hand auger equipment was pulled from the borehole, the bucket was removed and a decontaminated auger bucket was put into place. The equipment was returned to the borehole and the interval was sampled. This process was continued until collection of the last sample (13 to 15 feet bgs).

For sampling of individual intervals, portions of the soil were collected and placed into pre-labeled, unpreserved 4-ounce sampling jars capped with teflon septum-sealed screw-on lids. The sample jar was placed into a ziploc-type bag and then into an ice-cooled container prior to transport to an analytical laboratory. Table 3-2 indicates exterior borehole numbers and the samples collected from each borehole using the hand auger technique. Table 3-3 indicates the borehole number and the samples collected from each borehole, using the hand auger technique on the interior of the building.

Samples identified as SPM (Subsurface Pressure Monitor boring) or V (vent boring) were hand augered to collect soil samples and geologically log the borings in support of the soil vapor extraction system. Two soil samples were collected from each sampling interval of each soil vapor extraction system boring. One sample was used to determine if VOC contamination existed in the unsaturated soil profile through laboratory analysis. The other was used as part of the Soil Vapor Extraction System/Treatability Study, as described in Section 3.4.

Once a hand augered boring was completed all equipment was removed from the boring for decontamination, as described in Section 3.3.5. Soil cuttings were removed from the boring locations and transported to roll-off bins in the secured area behind the ABC facility, as described in Section 3.3.7. All borings that were not used as part of the Soil Vapor Extraction System were grouted to the surface with a cement and bentonite slurry. Remaining borings were reamed with 6-inch outer diameter augers attached to a hydraulically-driven power auger, prior to installation of Soil Vapor Extraction equipment (refer to Section 3.5). The power augers were decontaminated between boring locations.

Table 3-2

Soil Borings and Samples Collected From Each Hand-Augered Boring Outside of ABC Building During Soil Sampling Program
ABC One-Hour Cleaners
Operable Unit 2

SOIL BORING NUMBER	SOIL SAMPLE IDENTIFICATION
SB-17	ABC-SS-017-01-02
	ABC-SS-017-02-05
	ABC-SS-017-03-10
	ABC-SS-017-04-15
SB-18	ABC-SS-018-01-02
	ABC-SS-018-02-05
SB-20	ABC-SS-020-01-00
SB-21	ABC-SS-021-01-00
SB-24	ABC-SS-024-01-00
	ABC-SS-024-02-05
	ABC-SS-024-03-10
	ABC-SS-024-04-15

NOTE: ABC-SS-017-01-02 is nomenclature denoting ABC site; soil sample; soil boring number; first sample; and sampling interval depth.

Table 3-3

Soil Borings and Samples Collected From Each Hand-Augered Boring Within ABC Building During Soil Sampling Program
ABC One-Hour Cleaners
Operable Unit 2

SOIL BORING NUMBER	SOIL SAMPLE IDENTIFICATION
SB-16	ABC-SS-016-01-02
	ABC-SS-016-02-05
	ABC-SS-016-03-10
	ABC-SS-016-04-15
SB-SPM5	ABC-SS-SPM5-01-00
	ABC-SS-SPM5-02-05
	ABC-SS-SPM5-03-10
	ABC-SS-SPM5-04-15
SB-19	ABC-SS-019-01-02
	ABC-SS-019-02-05
	ABC-SS-019-03-09
	ABC-SS-019-04-15
SB-SPM2	ABC-SS-SPM2-01-00
	ABC-SS-SPM2-02-05
	ABC-SS-SPM2-03-10
	ABC-SS-SPM2-04-15

NOTE: ABC-SS-016-01-02 is nomenclature denoting ABC site; soil sample; soil boring number; first sample; and sampling interval depth.

Table 3-3 (Continued)

Soil Borings and Samples Collected From Each Hand-Augered Boring Within ABC Building During Soil Sampling Program
ABC One-Hour Cleaners
Operable Unit 2

SOIL BORING NUMBER	SOIL SAMPLE IDENTIFICATION
SB-V2	ABC-SS-V2-01-02
	ABC-SS-V2-02-05
	ABC-SS-V2-03-10
	ABC-SS-V2-04-14
SB-22	ABC-SS-022-01-02
	ABC-SS-022-02-05
	ABC-SS-022-03-10
	ABC-SS-022-04-15
SB-V1	ABC-SS-V1-01-10
	ABC-SS-V1-02-14
SB-SPM1	ABC-SS-SPM1-01-00
	ABC-SS-SPM1-02-05
	ABC-SS-SPM1-03-10
	ABC-SS-SPM1-04-14
SB-23	ABC-SS-023-01-02
	ABC-SS-023-02-05
	ABC-SS-023-03-10
	ABC-SS-023-04-15

NOTE: ABC-SS-016-01-02 is nomenclature denoting ABC site; soil sample; soil boring number; first sample; and sampling interval depth.

3.2.2.2 Borehole Installation-Drill Rig

Three soil borings (SB-13, -14, and -15) were advanced to the west of the ABC facility (Figure 3-1) using a Mobile B-57 drill rig. Soil sampling intervals for these borings were identical to those used during the hand-augered borings. Table 3-4 indicates the borehole number and the samples collected from each using the drill rig techniques.

Under the direct supervision of WESTON, McCall Brothers, Inc., sampled the first zone (0 to 2 feet bgs) using a decontaminated split-spoon sampler. The sampler, lined with four decontaminated 6-inch by 2-inch diameter brass tubes, was attached to a sampling rod and driven into the undisturbed soil below the lead auger following the Standard Penetration Test (SPT) - American Society of Testing Materials (ASTM) Method D-1586. The number of blows required to drive the split-spoon through four continuous 6-inch intervals (24 inches total) was recorded by the WESTON field representative.

Once the split-spoon sampling had been completed for that zone, the split-spoon was removed from the boring and detached from the sampling rod. The split-spoon was then opened and the four brass tubes were removed, labeled, and placed into ziploc-type bags for transport and analysis.

The boring was advanced to the next sampling interval through the use of 8.5-inch outer diameter, 4.5-inch inner diameter, hollow-stem augers. Once the top of the zone had been reached, a decontaminated split-spoon sampler was used to sample the zone as previously described. The sampling process continued until sampling of the last identified interval was complete. All drilling equipment was then removed from the borehole.

Table 3-4

Soil Boring Number and Soil Samples Collected by Drill Rig Techniques During the Soil Sampling Program ABC One-Hour Cleaners Operable Unit 2

SOIL BORING NUMBER	SOIL SAMPLE IDENTIFICATION
SB-13	ABC-SS-013-01-00
	ABC-SS-013-02-05
	ABC-SS-013-03-10
	ABC-SS-013-04-15
SB-14	ABC-SS-014-01-00
	ABC-SS-014-02-05
	ABC-SS-014-03-10
	ABC-SS-014-04-15
SB-15	ABC-SS-015-01-00
	ABC-SS-015-02-04
	ABC-SS-015-03-10
	ABC-SS-015-04-14

NOTE: ABC-SS-013-01-00 is nomenclature denoting ABC site; soil sample; soil boring number; sample number; and sampling interval depth.

Each boring was grouted up to the surface using a cement and bentonite slurry. All soil cuttings were placed in a drum which was transported to a roll-off bin where the contents of the drum were emptied into the bin, as described in Section 3.3.7. All drilling and sampling equipment was then decontaminated as described in Section 3.3.5.

3.3 MONITOR WELL AND PIEZOMETER INSTALLATION, SAMPLING, AND DEVELOPMENT

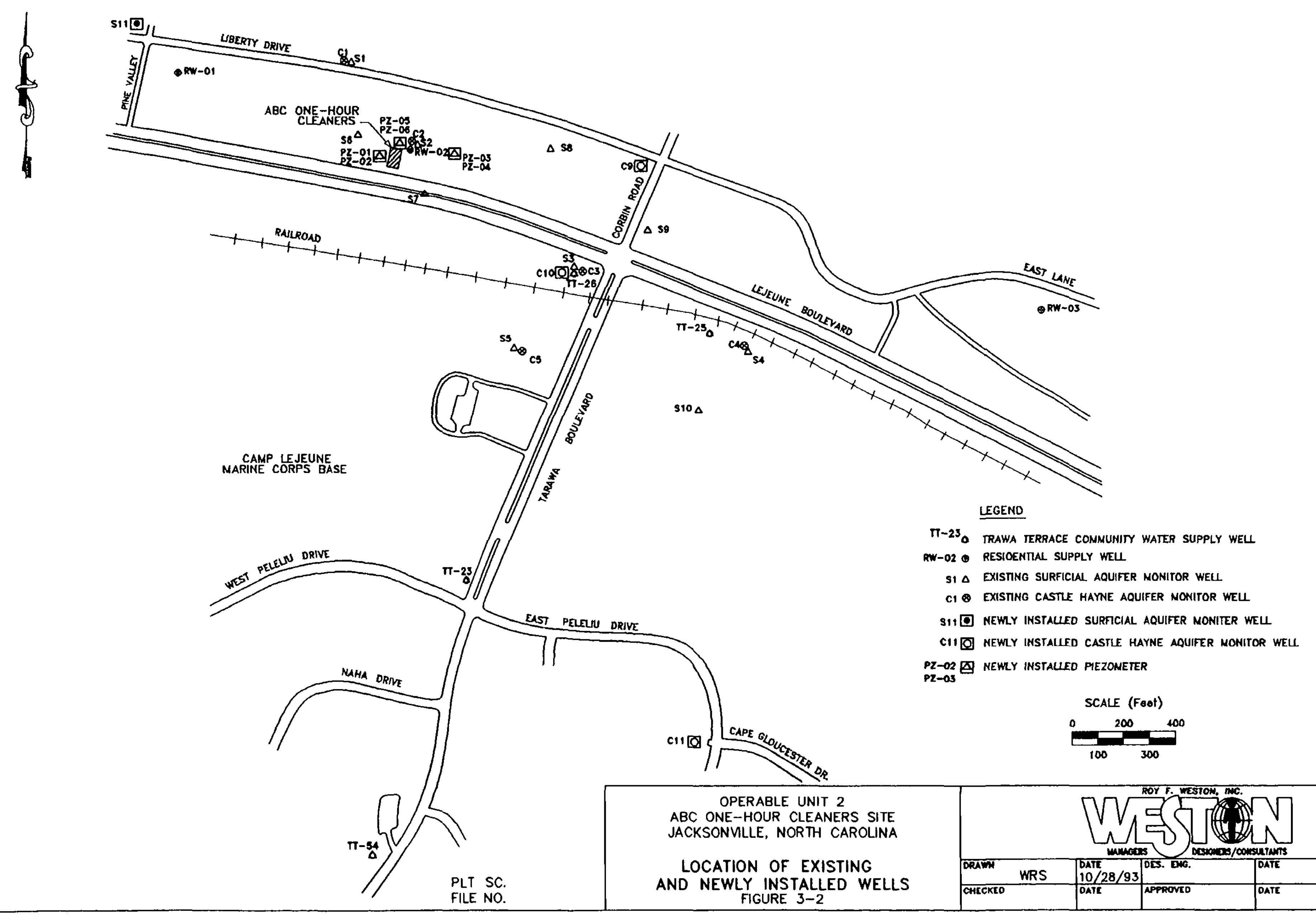
Four monitor wells (one surficial and three Castle Hayne aquifer wells) and six piezometers (three each within the surficial and Castle Hayne aquifers) were installed during the OU2 RI field investigation. A discussion of the methods used for well installation is presented in the following subsections.

3.3.1 Surficial Aquifer Well

One surficial aquifer monitor well was installed during OU2 activities. The well was completed by McCall Brothers, Inc., under the direct supervision of WESTON. A Mobile Drill B-57 was used for well installation; 6-inch outer diameter augers were used during the lithologic sampling phase of the well installation; and 10¼-inch outer diameter augers were used during well construction.

3.3.1.1 Surficial Aquifer Well Location

During analysis of groundwater samples from the OU1 monitor well sampling phase PCE was detected in the sample from the upgradient well (S1); therefore, additional data were required to determine groundwater quality further upgradient in an attempt to define the extent of plume migration. WESTON selected the location of surficial aquifer monitor well (S11) to provide a monitoring point upgradient of the existing upgradient monitor well S1 (Figure 3-2).



PLT SC.
FILE NO.

OPERABLE UNIT 2
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

LOCATION OF EXISTING AND NEWLY INSTALLED WELLS

FIGURE 3-2

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN	DATE	DES. ENG.	DATE	W. O. NO.
WRS	10/28/93			04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO. ABCNEW-A

3.3.1.2 Drilling and Well Installation

A drill rig equipped with hollow-stem augers was used to install surficial aquifer well S11. Two different sized augers were used in the well construction. The first auger size used (6-inch outer diameter) was for lithologic sampling purposes. Once the target sampling depth of approximately 15 feet below the water table was reached, the hole was reamed with larger size augers to facilitate setting of the well materials.

During advancement of the small diameter augers, lithologic samples were collected continuously using decontaminated, unlined split-spoon samplers. When the split-spoon was brought to the surface and opened, the sample was field screened for organic vapor content using a photoionization detector (PID). The WESTON representative would then scan the sample for geologic characteristics, which were recorded on the WESTON Geolis Logging system. Appendix A contains the boring logs for this well.

The continuous split-spoon sampling was carried out to a depth of approximately 30-feet bgs. At that point, formation materials composed of saturated, fine-grained, clean sands were encountered. The sands began to flow into the hollow inner annulus of the auger forcing the drilling and the collection of split-spoon samples to halt. Although lithologic logging continued, it was based on cuttings taken during drilling of the borehole with a bentonite slurry.

Potable water was added to the inner annulus of the augers in an attempt to wash out the sand that had flowed into the augers as well as to maintain a water level above that of the formation. However, this process did not keep the sands from flowing back into the augers. Small diameter augers were removed from the boring and larger diameter (10¼-inch outer diameter) augers were used to ream the borehole. As the depth neared where the flowing sands were encountered, a thick bentonite slurry was mixed and pumped into the inner annulus of the augers in an attempt to provide a positive hydraulic head relative to the formation, thereby preventing the sands from once again flowing into the borehole. The bentonite slurry was circulated from the boring back into a large "mud tub" and then repumped into the augers.

The target depth of 15 feet below the first saturated soil encountered (or approximately 35 feet bgs) was eventually reached with minimal sand flowing into the borehole. Upon reaching this point, the surficial aquifer monitor well was constructed inside the augers using 4-inch diameter flush threaded stainless steel casing and screen. The bottom of the screen was sealed with a stainless steel cap. The slot size of the screen was 0.01 inches. This well was screened across the water table using 20 feet of screen.

A washed, graded sand was then tremied (using potable water) around the outer annulus of the screen. As the level of the filter pack rose, the augers were gradually removed. Eventually the sand was brought up to a level of 3 feet above the top of the screen. During the time that sand was being added to the borehole, the bentonite slurry was being displaced into the "mud tub." The slurry was also displaced as the bentonite cap and the grout seal were added to the well. The slurry was removed from the tub and placed into 55-gallon drums for subsequent disposal.

When the sand pack had reached a level of 3 feet above the top of the screen, a swabbing unit was installed into the casing to help remove fines and increase the tightness of the filter pack. The swabbing action was carried out for approximately 30 minutes, after which the unit was removed from the casing and the depth to the top of the sand pack was determined. In this case, the level of the sand had dropped 6 inches and additional sand was added to return the height of the filter pack to 3 feet above the top of the screen.

With the filter pack in place, bentonite pellets were poured directly onto the sand to a thickness of approximately 4 feet. Potable water, present in the borehole from the placement of the sand, was allowed to hydrate the pellets overnight.

The following day, a cement and bentonite slurry used for the grout seal was poured on top of the bentonite seal and brought up to a level of 1 foot below ground surface. After an 8-hour drying period, a flush mounted manhole was placed over the top of the well casing and grouted into place. A lockable cap was placed on top of the well casing and secured with a padlock.

3.3.2 Castle Hayne Aquifer Wells

Three Castle Hayne aquifer monitor wells were completed during this investigation (Figure 3-2). Two of the monitor wells (C9 and C11) were completed to the top of the Castle Hayne formation. Well C9 was drilled and completed to a depth of 76 feet bgs. Well C11 was drilled and completed to a depth 108 feet bgs. The third Castle Hayne aquifer well (C10) was drilled and completed to a total depth of 175 feet bgs. Both C10 and C11 were installed using mud rotary drilling techniques, whereas C9 was installed using a combination of hollow-stem auger and mud rotary drilling techniques.

3.3.2.1 Castle Hayne Aquifer Well Locations

Monitor well C9 was installed to provide monitoring capabilities of the Castle Hayne aquifer in an area presumed to be on the northern edge of the groundwater plume and for which no Castle Hayne monitor data existed. The proposed location of monitor well C9 was immediately adjacent to monitor well S9; however, due to the presence of underground utilities in the area, the location was relocated approximately 200 feet to the northwest (at the corner of Liberty Drive and Corbin Road) (Figure 3-2).

The location of monitor well C10 was chosen to evaluate whether groundwater contamination detected in well C3 extends to greater depths than currently monitored. Monitor well C11 was located south-southeast of Base supply well TT-23 to monitor a possible plume that may have migrated in the direction of the estimated gradient as a result of groundwater withdrawal at well TT-23.

3.3.2.2 Drilling and Well Installation

Monitor wells C9 and C11 were to be drilled to approximately 90 feet bgs so as to monitor the top of the Castle Hayne aquifer; however, conditions encountered in the field caused variations from these projections. During the drilling of C9, the top of the Castle Hayne was encountered (based on returning drill cuttings) at approximately 66 feet bgs. The Castle Hayne aquifer was not encountered until 97 feet bgs during the drilling of well C11. Both wells utilized 10 feet of screen within the top 15 feet of the Castle Hayne aquifer.

Monitor well C10 was the only well during this investigation to have dual casings installed. Dual casings were necessary to seal off the surficial aquifer from the underlying Castle Hayne so that potential contaminants in either aquifer would not be able to migrate upward or downward directly through the borehole. The first casing was composed of 10-inch inner diameter carbon steel and was installed to a depth of 90 feet bgs. The second, inner casing was 4-inch stainless steel set from the ground surface to 175 feet bgs. Appendix A presents the boring logs and well construction logs for all Castle Hayne wells installed during Operable Unit 2.

For monitor well C9, a standard auger rig was used to hollow-stem auger the borehole to the maximum depth feasible to collect split-spoon samples. As described in this section, flow of formation sands into the hollow-stem of the auger flight prevented split-spoon sampling below a depth of approximately 35 feet bgs. Once split-sampling had been completed to this depth, the hollow-stem auger rig was demobilized and the mud rotary rig was set up on the borehole. Using a 8-¾ inch tricone roller bit, the boring was advanced using mud rotary drilling techniques to the predesignated borehole termination depth.

For monitor wells C10 and C11, mud rotary techniques were used to advance the boring from the ground surface to termination depth (175 and 108 feet bgs, respectively). Well C11 was originally to have been started using hollow-stem auger techniques. However, due to project delays and to the concern of reducing project expenses, the mud rotary rig was used instead to complete the boring as well as collect borehole cuttings for lithologic examination.

Drilling mud was mixed fresh for each mud rotary drilling site. The mud was composed of a bentonite powder and potable water mixture. The drill rig operator controlled the viscosity of drilling mud. Potable water was provided from the source used to supply potable water for equipment decontamination, which was from the City of Jacksonville Public Water Supply.

During the drilling of well C10, a layer of high hydraulic conductivity was encountered at approximately 95 feet bgs, resulting in significant flow of drilling fluids into the formation and subsequent loss of circulation. A re-formulation of mud was mixed consisting of a drilling fluid polymer and bentonite. This mixture served to increase viscosity and help form a "cake" along the walls of the borehole and over the high hydraulic conductivity layer.

Drilling recommenced at this point; however, after a short period of time, circulation was lost again. The installation continued without the use of drilling mud on the assumption that the Castle Hayne Formation would not collapse on the borehole once the drill stem was removed. After completing the boring to target depth and removing the drilling materials, the well materials were placed into the borehole and the borehole proved to be intact.

Upon reaching the borehole termination depth for all Castle Hayne OU2 wells, the drilling tools were removed. Well construction then occurred within the open borehole. A 10-foot long, 4-inch inner diameter, 0.020-inch slot size stainless steel well screen with a stainless steel cap at the bottom was screwed into 4-inch inner diameter, flush threaded stainless steel riser pipe and lowered into the borehole. Additional riser pipe was added to the casing string until the screen section had reached the bottom of the borehole.

With screen and casing in place, a filter pack composed of washed, graded sand was tremied into place from the bottom of the borehole to at least 3 feet above the top of the screen. A swabbing unit was then lowered into the well casing by the drill rig and used to increase the tautness of the filter pack as well as remove fine grained material from it. After a period of approximately 30 to 45 minutes, the swabbing unit was removed and additional sand was tremied onto the filter pack as necessary. A seal comprised of bentonite chips was poured into place for well C9 only and tremied into place for wells C10 and C11, and extending from the top of the filter pack to at least 4 feet above the filter pack. The remaining annular space outside the well was then tremie grouted with a cement and bentonite slurry to a depth of approximately one foot below ground surface. The grout was allowed to set for at least ten hours prior to completion of the well with a flush mounted manhole. The manhole was placed over the top of the well casing and cemented into position.

All drilling mud and cuttings were contained on-site. Initially, drilling residuals were placed in drums and transported to the storage area where they were divided between liquid and solid storage. Section 3.3.7 provides a more detailed description of residuals handling procedures. All drilling equipment and accessories were returned to the decontamination area for cleaning prior to the initiation of continued drilling activity.

3.3.3 Piezometers

Six piezometers were installed to aid in the definition of hydrogeologic properties of the surficial and Castle Hayne aquifers as defined from aquifer testing (Section 3.11). In addition, depth to water measurements collected from the piezometers were used to define the hydraulic gradient and to allow for more detailed potentiometric maps.

The piezometers were installed as pairs in a radial pattern from the C2/S2 location (Figure 3-2). Two piezometers were installed in each borehole. Each pair consisted of one piezometer that was screened within the surficial aquifer and a second piezometer screened within the Castle Hayne aquifer. All surficial aquifer piezometers were drilled to 35 feet bgs and all Castle Hayne aquifer piezometers were drilled to 80 feet bgs.

3.3.3.1 Piezometer Locations

The locations of the piezometer pairs were chosen specifically for the purpose of groundwater level monitor stations for the aquifer testing (see Section 3.11) at the C2/S2 well pair location. The pairs were spaced roughly 120° apart and radiated out from the C2 location. Due to building locations and underground and overhead utilities, the piezometers were placed at radial distances of 40 feet, 60 feet, and 110 feet relative to well C2 (Figure 3-2).

3.3.3.2 Drilling and Installation

For piezometer pairs PZ-01/PZ-02 and PZ-05/PZ-06 located 110 and 60 feet from well C2, respectively, the boreholes were initially advanced using hollow-stem auger techniques to facilitate the collection of soil samples for lithologic analysis. Samples were collected on a continuous basis until flowing sands were encountered at approximately 32 feet bgs. At that point the hollow-stem auger rig was removed from the borehole and replaced with a mud rotary rig.

For piezometer pair PZ-03/PZ-04, the entire borehole was drilled using mud rotary techniques with lithologic analysis based on drill cuttings.

Drilling mud was freshly mixed for each piezometer location. This mud was composed of bentonite powder and potable water. The drill rig operator was responsible for maintaining the correct viscosity of the fluid. Potable water was supplied from the same source used to supply water for equipment decontamination (City of Jacksonville Public Water Supply).

As each piezometer borehole was drilled, the drilling mud was circulated through the drill stem and up the sides of the borehole to aid in removal of the cuttings and to form a "cake" along the borehole wall to prevent collapsing. This process continued until the target depth of 80 feet bgs was reached for each piezometer borehole.

While drilling the PZ-05/PZ-06 location, circulation of the drilling fluid was lost at approximately 67 feet bgs due to the presence of a layer of a high hydraulic conductivity. A reformulated drilling mud consisting of potable water, bentonite, and a drilling fluid polymer was utilized to increase viscosity and binding strength. This mud allowed the drillers to complete the borehole to the target depth.

With the borehole advanced to depth, the drilling tools were removed from the borehole and well materials were inserted. A 5-foot long, 2-inch diameter, 0.010-inch slotted, schedule 40 PVC screen with a 6-inch long cap at the bottom was attached to schedule 40 PVC threaded riser pipe. As the pipe was lowered into the borehole and through the drilling fluid, it became extremely buoyant. Potable water was added to the inside of the pipe to help lower it to the bottom of the borehole. Upon reaching this point, washed, graded sand was tremied from the bottom of the borehole to 3 feet above the top of the screen. The tremie pipe was then removed from the borehole.

Coarse bentonite chips were then poured into the borehole to form a seal from the top of the filter pack to a depth of 35 feet bgs. A second 5-foot screen (attached to a separate riser pipe composed of 2-inch diameter, schedule 40 PVC) was then placed into the borehole. Washed, graded sand was then tremied into position from the bottom of the screen to 3 feet above the top of the screen. Bentonite pellets were then placed on top of the filter pack to form a 4-foot thick seal. This seal was allowed to hydrate for approximately 30 minutes.

A cement and bentonite slurry was mixed and tremied into the remaining borehole annulus forming a grout seal from 23 feet bgs to 1 foot bgs. After a period of at least 12 hours, the piezometers were completed at the surface in the same manner as the monitor wells.

As materials were added to the borehole, the drilling fluid was displaced and collected within a mud tub. From there it was stored in drums for later transport and storage within larger containers. Refer to Section 3.3.7 for further description of residuals handling procedures.

3.3.4 Monitor Well and Piezometer Development

All monitor wells and piezometers were developed after 24 hours from the time the grout seal was placed. Monitor wells were developed in a two stage process involving bailing and pumping. Due to the fact that drilling fluids were used to complete the piezometer boreholes, each piezometer was developed by bailing methods only.

The first step in developing the monitor wells was to use a bottom-opening suction bailer to remove any solids that may have entered the well during the construction process. The bailing action continued until all fine-grained sediment had been removed from the well casing and the water removed from the well appeared clear.

The next step in monitor well development was to mobilize a drill rig over the well and insert a pump attached to either decontaminated galvanized pipe or polyethylene tubing. The pump was initially set at the bottom of the well. Once pumping started, the pump was slowly raised and lowered several times over the length of the screen to act as a swabbing unit. During this pumping phase, the WESTON representative noted the discharge rate of the water and whether the well could sustain the pumping rate. If during pumping, the rate of discharge were to decrease rapidly, the discharge rate was throttled back using a gate valve to allow pumping of the well to continue.

The development process continued until: 1) a minimum of five standing well borehole volumes were removed/computed at an estimated 30% porosity for the annular volume occupied by the saturated filter pack plus the full standing water volume inside the well casing; 2) the effluent was free of visible suspended solids as was practical; and 3) pH, temperature, and specific conductance parameters had stabilized. Parameters were considered stable when three successive readings agreed to within 0.1 standard pH units, 0.5 degrees Centigrade, and within 5% microohms conductivity, with at least 5% of a single development volume passing between each successive measurement.

Piezometer pairs were also developed; however, the task was completed using only a bottom-opening suction bailer. The bailer was used to remove fines that may have entered the well during the construction process. The bailing action continued within a piezometer until five

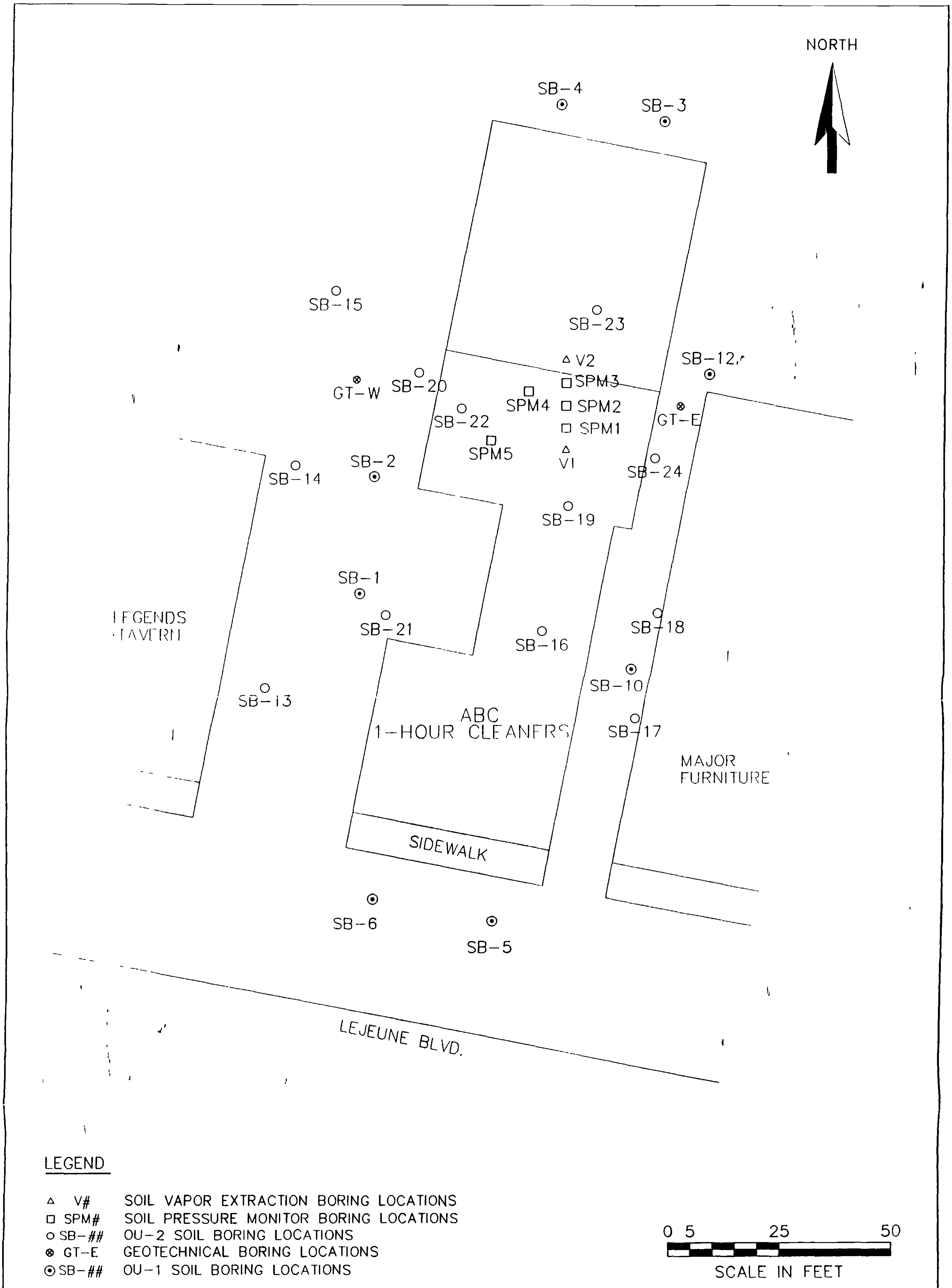


FIGURE 3-1
DATE 10/25/93
REVISION 0
DRAWN BY J.C., W.M.
FILE 04400-01.DWG

SOIL BORING LOCATIONS
REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

standing borehole volumes of water had been removed and the water was free of sediment and appeared to be relatively clear.

All effluent from the development process was stored in either 55-gallon drums or a trailer-mounted holding tank before transport and storage to larger holding tanks. Section 3.3.7 describes the procedures employed for residuals handling.

3.3.5 Equipment and Materials Decontamination

During the monitor well and piezometer installation program, all down-hole drilling equipment (including augers, bits, drill pipe, rods, split-spoons, etc.) and PVC/stainless steel well casings, well screens, end caps, and tremie pipes were decontaminated using the following procedure:

(1) Thoroughly rinse with potable water as soon as possible following use.

(2) Wash and scrub with a solution of potable water and Alconox.

(3) Rinse with a high pressure, hot water sprayer delivering potable water.

(4) Thoroughly rinse with organic-free water.

(5) Rinse with reagent grade isopropanol and allow to air-dry. If the equipment was to be used immediately after decontamination or if atmospheric conditions did not permit air-drying, the equipment was thoroughly rinsed a second time with organic-free water.

(6) Depending upon size, the equipment was wrapped in aluminum foil, placed inside a plastic bag, or wrapped in clear plastic sheeting.

Organic-free water was produced from potable water from the City of Jacksonville Public Water Supply which was processed through an on-site water organic filtering unit. The water produced from this unit was continuously sampled throughout the field project as it was used for field, equipment, rinse, and trip blanks. The analyses of the water consisted of TCL-VOC.

All pumps, hoses, tubing, well sounders, and other measuring instruments were also decontaminated using the described procedure. All residuals from the decontamination process, including water and sediment, were containerized on-site, and disposed of as described in Section 3.3.7.

3.3.6 Well Construction Materials Sampling

During construction of monitor well C10, a sample of the bentonite/potable water drilling fluid was collected. The fluid sample was collected soon after the mud had been mixed and before the circulation process through the well borehole started. The sample was extracted from the mud tub by directly dipping two 8-ounce, unpreserved, wide-mouth glass jars in the fluid. A meniscate surface of the fluid was maintained at the very top of the jar as the teflon-lined, septum sealed screw caps were placed onto the jar. The sample was submitted for TCL-VOC.

An equipment rinse blank was also collected during the well construction process. The blank was collected from the 6-inch augers after they had been decontaminated by the process described previously. This sample was also submitted for TCL-VOC analysis. Refer to Section 3.10 for list and description of all blanks collected during the field investigation.

3.3.7 Residuals Handling

At the conclusion of monitor well and piezometer completion, all drilling fluid and cuttings were removed from the mud tub and placed into 55-gallon drums. Also, all cuttings that had fallen onto the ground were shoveled and placed into the drums. These drums were sealed with lids and transported to a secured residuals storage area located behind the ABC facility. Due to the fact that the drilling fluid and cuttings were intermixed, the contents of the drums were allowed to settle for approximately 24 hours while the water and sediment separated. At the end of the 24-hour period, the water was pumped into holding tanks and the solids removed from the drum and placed into lined roll-off bins. These drums were reused throughout the field investigation. All water produced from the well drilling was stored in three 5,800-gallon polyethylene tanks. All drill cuttings were dumped into plastic-lined, 30-cubic-yard, roll-off bins. These bins were designed to hold 30 cubic yards, but the soil and other solid waste transport reduced this capacity to approximately 11 cubic yards.

During the first stage of well development, water and sediment were contained in 55-gallon drums, which were later sealed and transported to the secured storage area. The water and sediment were disposed of in the manner described above for drilling fluid. During the pumping phase of well development, the water was contained in a trailer-mounted tank, which was later transported to the secured storage area and pumped into one of the holding tanks.

Water and sediment produced from piezometer development were stored in 55-gallon drums and disposed of in the same manner as previously described.

All water produced during decontamination was placed into 55-gallon drums and eventually pumped into the holding tanks. The sediment from the decontamination process was removed from the decontamination pad and dumped into the roll-off bins.

After one of the 5,800 gallon holding tanks became full, the water was pumped out of the tank through a carbon treatment system (comprised of three 55-gallon CARBTROL® carbon canisters connected in series) and into a receiving 5,800-gallon holding tank. Once the tank of treated water became full, a sample was collected and analyzed for TCL-VOC on a 24-hour turnaround basis by a local laboratory. If the sample was determined to be free of site-related contaminants (i.e., PCE, TCE), the treated water was released to the local sanitary sewer with permission from the City of Jacksonville. The results of this analysis and chain-of-custody sheets are found in Appendix B.

The contents of the roll-off bins were also sampled prior to transport and disposal. The results of this sampling may also be found in Appendix B. The contents and total weight of contents disposed of are provided in Table 3-5.

3.4 GEOTECHNICAL BORINGS AND SAMPLING

Two geotechnical borings were conducted to the east and west of the septic tank on the exterior of the ABC building in order to collect Shelby tube soil samples that were used to determine the in-situ properties and characteristics of the site soils. The geotechnical analysis of the undisturbed site soils was conducted in accordance with ASTM approved methods, as summarized in Table 3-6.

Table 3-5

Material and Final Quantity of Contents Disposed of From Roll-Off Bins
ABC One-Hour Cleaners
Operable Unit 2

BIN NO.	CONTENTS	WEIGHT (TONS)	FINAL DESTINATION
546553	Soil (drill cuttings), tyvek, visqueen	11.37	Piedmont Landfill and Recycling Center Kernersville, NC
46683	Soil (drill cuttings), visqueen, kiln dust (for solidification)	8.96	
49426	Soil, kiln dust (to solidify soil), PPE	10.02	
50895	Soil (drill cuttings), PPE, visqueen, kiln dust	11.14	

Table 3-6

Geotechnical Testing Program
ABC One-Hour Cleaners
Operable Unit 2

PARAMETER	ASTM METHOD[1]	DATA OBTAINED FROM: (1) Shelby Tube Sample (2) Laboratory Study Soil Sample
Moisture and Organic Content	D2974	1,2
Particle Size Distribution	D421/D422	1,2
Liquid and Plastic Limits	D4318	1,2
Specific Gravity	D854	1,2
Bulk Density	D2937	1
Total Porosity	Calculation	1,2
Air-Filled Porosity	Calculation	1,2
pH	D4972	1
Hydraulic Permeability	D5084	1

[1] All analytical methods derived from the Annual Book of ASTM Standards, Section 4, Volume 4.08, Soil and Rock; Building Stones; Geotextiles: American Society of Testing Materials, Philadelphia, PA, 1991.

Each geotechnical boring was performed using the hollow-stem auger method and 6-inch diameter augers. The procedure required initial testing of soil consistency using a split-spoon sampler according to ASTM Method D1586 as the augers proceeded downward. If the sum of the second and third blow counts was less than 10, the soil was considered suitable for sampling with a Shelby tube. Prior to sampling, the borehole was "cleaned" by rotating the augers to 6 inches below the depth of the last split-spoon. A 3-inch diameter Shelby tube was then advanced 2 feet beyond the end of the lead auger without rotation in a single motion. After 5 minutes, the drill rods and tubes were rotated to break off the sample in-situ. After an additional 5 minutes, the sample tube was carefully retrieved. A list of the locations and depths of all geotechnical samples is presented in Table 3-7. Figure 3-1 presents the locations of the geotechnical soil boring locations (labelled as GT-E and GT-W).

Upon retrieval, the sample was sealed in the Shelby tube with melted wax to prevent leakage and disturbance of the sample during handling. The ends of the tube were then closed with a tight fitting plastic cap, and the seam between the cap and the tube was wrapped with tape. Finally, the ends of the tube were marked for top and bottom orientation prior to shipping. The analytical results of the Shelby tube samples are provided in Appendix C. Chain-of-Custody Records for the Shelby tubes are found in Appendix B.

Additional geotechnical samples were also collected during the SVE boring installation program. A total of 18 different samples were collected from various depths and used in a bench-scale treatability study (Table 3-7). A majority of the samples were packed within a single column using standard compaction methods to meet site conditions of soil density and porosity. These parameters were obtained from the geotechnical/Shelby tube sample analysis. The soil column is representative of the physical/soil conditions in which the SVE system would operate. The

Table 3-7

Geotechnical Samples for Soil Treatability Study
ABC One-Hour Cleaners
Operable Unit 2

SAMPLE LOCATION *	SAMPLE NUMBER	SAMPLE DEPTH (FT BGS)	SAMPLE TYPE
GT-E	GT-E-01-03	3 - 5.5	Shelby Tube
	GT-E-02-08	8 - 10.5	Shelby Tube
	GT-E-03-13	13 - 15.5	Shelby Tube
GT-W	GT-W-01-04	4 - 6.5	Shelby Tube
	GT-W-02-10	10 - 12.5	Shelby Tube
	GT-W-03-13	12.5 - 15	Shelby Tube
V1	SS-V1-01-10	10	Soil Boring Sample
	SS-V1-02-14	14	Soil Boring Sample
SPM1	SS-SPM1-01-00	0 - 2	Soil Boring Sample
	SS-SPM1-02-05	5	Soil Boring Sample
	SS-SPM1-03-10	10	Soil Boring Sample
	SS-SPM1-04-14	14	Soil Boring Sample
SPM2	SS-SPM2-01-00	0 - 2	Soil Boring Sample
	SS-SPM2-02-05	5	Soil Boring Sample
	SS-SPM2-03-10	10	Soil Boring Sample
	SS-SPM2-04-15	15	Soil Boring Sample

Table 3-7 (Continued)

Geotechnical Samples for Soil Treatability Study
ABC One-Hour Cleaners
Operable Unit 2

SAMPLE LOCATION *	SAMPLE NUMBER	SAMPLE DEPTH (FT BGS)	SAMPLE TYPE
V2	SS-V2-01-02	0 - 2	Soil Boring Sample
	SS-V2-02-05	5	Soil Boring Sample
	SS-V2-03-10	10	Soil Boring Sample
	SS-V2-04-14	14	Soil Boring Sample

* = For sample locations, refer to Figure 3-1.
ft bgs = feet below ground surface.

NOTE: GT-E-01-03 is nomenclature denoting geotechnical boring; eastern or western side of ABC building; sampling interval; sampling interval depth, respectively.

remaining samples were analyzed for grain size and VOC content. Analysis of the VOC content was completed to obtain a measure of concentrations at sampling. The results of the bench-scale testing program are provided in the Treatability Study report for the SVE system.

3.5 SOIL VAPOR EXTRACTION EQUIPMENT INSTALLATION

Soil vapor extraction (SVE) is an in-situ soil treatment technology that offers an alternative to the conventional excavation, treatment, and disposal approach to soil remediation. The technology offers the advantage of in-place soil treatment without excavation, minimal interruption in facility operations, and, once installed, low operational and maintenance requirements. An SVE system removes VOCs from the soil by mechanically drawing air through the soil pore spaces. At the ABC site, the installation of the SVE system was part of a pilot-scale study that involved soil borings, soil sampling, equipment installation into the borings, and connection of a mobile SVE testing unit. This section will only discuss the installation of soil borings and SVE equipment into the borings. A more detailed description of the process and results may be found within the SVE Treatability Study for the Report (WESTON, May 1994)

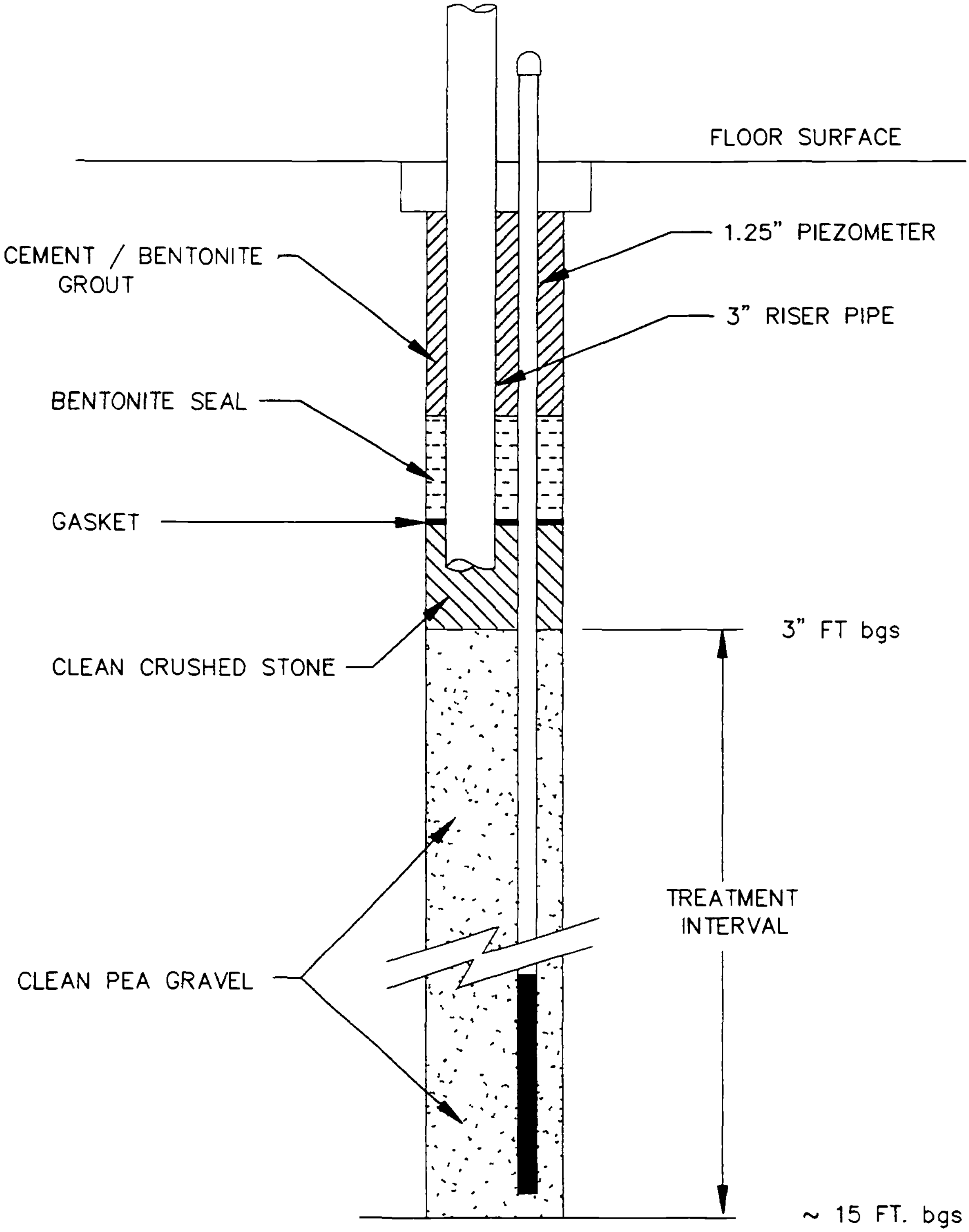
3.5.1 Equipment and Construction

As part of the pilot-scale study, WESTON installed seven soil borings during the Soil Boring Installation Program to serve as borings for the SVE system equipment. These borings were installed in various positions surrounding the septic tank location (Figure 3-1).

Two borings on the eastern side of the septic tank had extraction vents installed within them. The two extraction vents (V1 and V2) are located 20 feet apart and arranged to provide coverage and treatment of soils in the septic tank area showing the highest VOC concentrations as detected by previous studies. Subsurface pressure monitor (SPM) probes were installed within five soil borings (labeled SPM1 through SPM5) at various distances away from the extraction vents (Figure 3-1). The purpose of the probes was to provide monitoring points of subsurface pressure when the SVE equipment was activated and began to pull vapor through the soil under a vacuum effect. These SPM probes (SPM1 through SPM5) were installed at distances of 5, 10, 15, and 25 feet from each extraction vent (Figure 3-1). One SPM probe (SPM5) was installed on the western side of the septic tank to monitor the effect of the septic tank on subsurface air flow.

All soil borings intended for the SVE system were completed to a depth of approximately 15 feet bgs, which was approximately 1 foot above the top of the groundwater table. Each extraction vent borehole was 6 inches in diameter. A 1¼-inch outer diameter PVC piezometer with a 5-foot section of 0.01-inch slotted PVC screen was installed in each vent borehole. The remaining annular space in the boreholes was filled with clean "pea gravel" to approximately 11 feet bgs. A 1-foot thick layer of clean crushed stone with an average diameter of 1 to 2 inches was then placed on top of the pea gravel. Before the entire layer of crushed stone was emplaced, a section of 4-inch Schedule 40 PVC riser pipe was centered within the crushed stone layer. The remaining crushed stone was added to the outer annulus of the 4-inch PVC pipe bringing the pea gravel and crushed stone interval to a depth of approximately 3 feet bgs (Figure 3-3).

A gasket composed of 6-millimeter thick plastic sheeting was placed on top of the crushed stone layer around the PVC riser pipe. A 1-foot thick layer of bentonite slurry was placed on top of



NOT TO SCALE

ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

SVE EXTRACTION VENT
SCHEMATIC

3-3

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

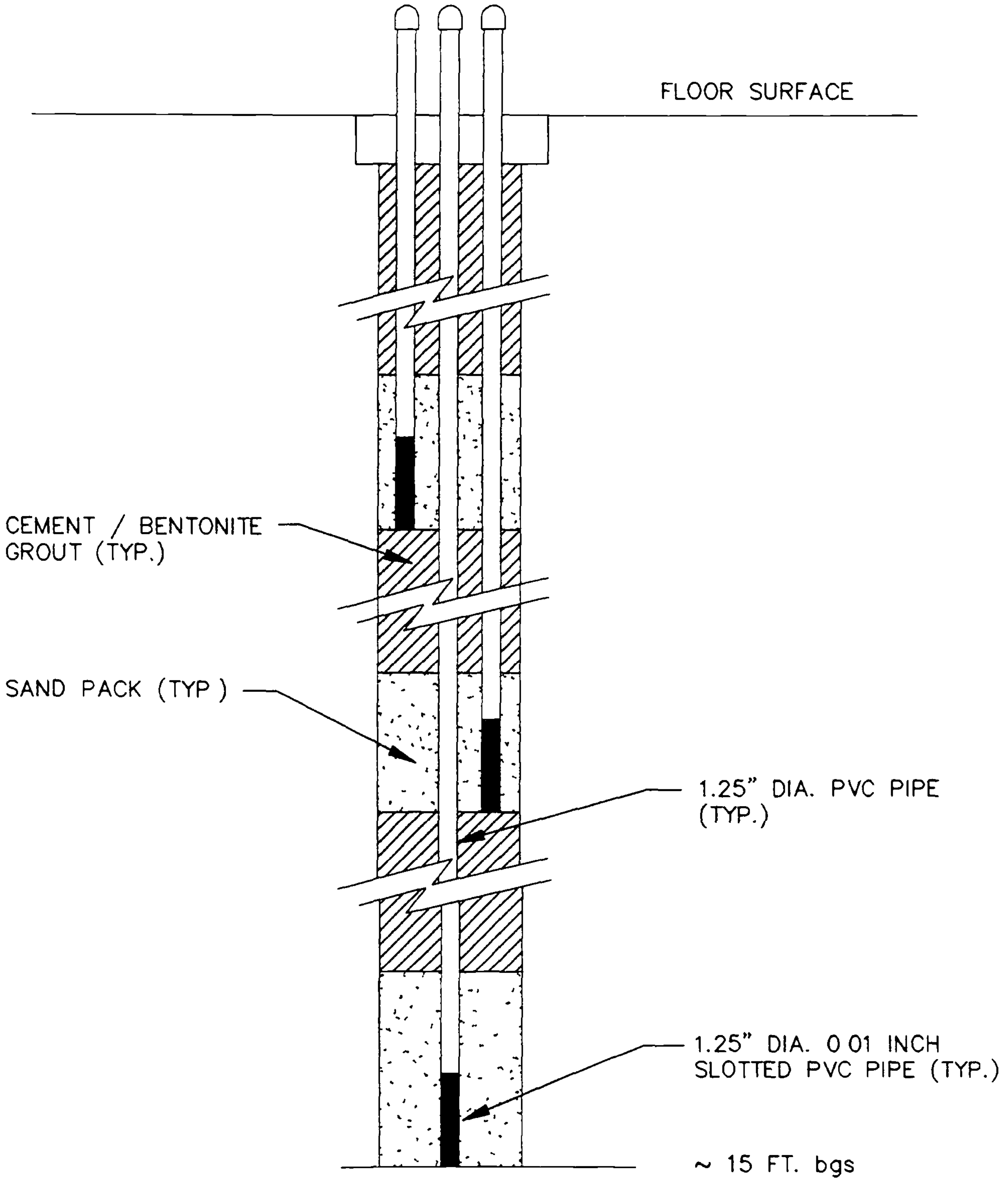
DRAWN WRS	DATE 12/13/93	DES. ENG.	DATE	W. O. NO. 04400-003
CHECKED	DATE	APPROVED	DATE	DWG NO ABCW3

PLT. SC. FIT FILE NO ABCW3

the gasket. The gasket acted to prevent the bentonite seal from flowing into the crushed stone. The bentonite layer also provided an air-tight seal to prevent atmospheric air from entering the annular space and entering the riser pipe. A grout seal consisting of a cement and bentonite slurry was placed on top of the bentonite seal and brought to the ground surface.

SPM probe locations consisted of either a cluster of three SPM probes (Figure 3-4) at varying depths or a single SPM probe (Figure 3-5) at approximately 1 foot above the water table. These probes were used to evaluate the change of subsurface pressure related to depth. Each individual SPM probe consisted of a 1 foot long section of 0.010-inch slotted Schedule 40 PVC screen and 1.25-inch outer diameter Schedule 40 PVC riser pipe. The top of the probe was covered with an airtight cap having a port for attaching a pressure monitor gauge. For single SPM probe locations, the bottom 3 feet of the boring was filled with cleaned, graded sand to act as a sand pack. The 1-foot long slotted PVC screen was situated within the sand pack. A 2-foot thick bentonite seal was placed on top of the sand pack. A cement and bentonite slurry was then placed on top of the bentonite seal and brought to the ground surface. For clustered SPM probes, a 3-foot thick layer of sand pack was placed around each of the PVC screen sections for each SPM probe. A layer of bentonite seal was placed between each sand pack layer and the borehole was completed as previously described.

The vapor extraction vents (V1 and V2) were connected to a vapor extraction manifold, which was an aboveground system of 4-inch diameter lateral PVC pipes (laterals). Laterals from each extraction vent were equipped with a 4-inch diameter butterfly valve used to regulate the air flow in each vent. The laterals from each extraction vent were also equipped with sampling ports for sample collection and physical parameter measurement. The two separate lateral pipes were joined to a 4-inch diameter PVC manifold pipe. The manifold pipes were run along the ceiling



NOT TO SCALE

ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

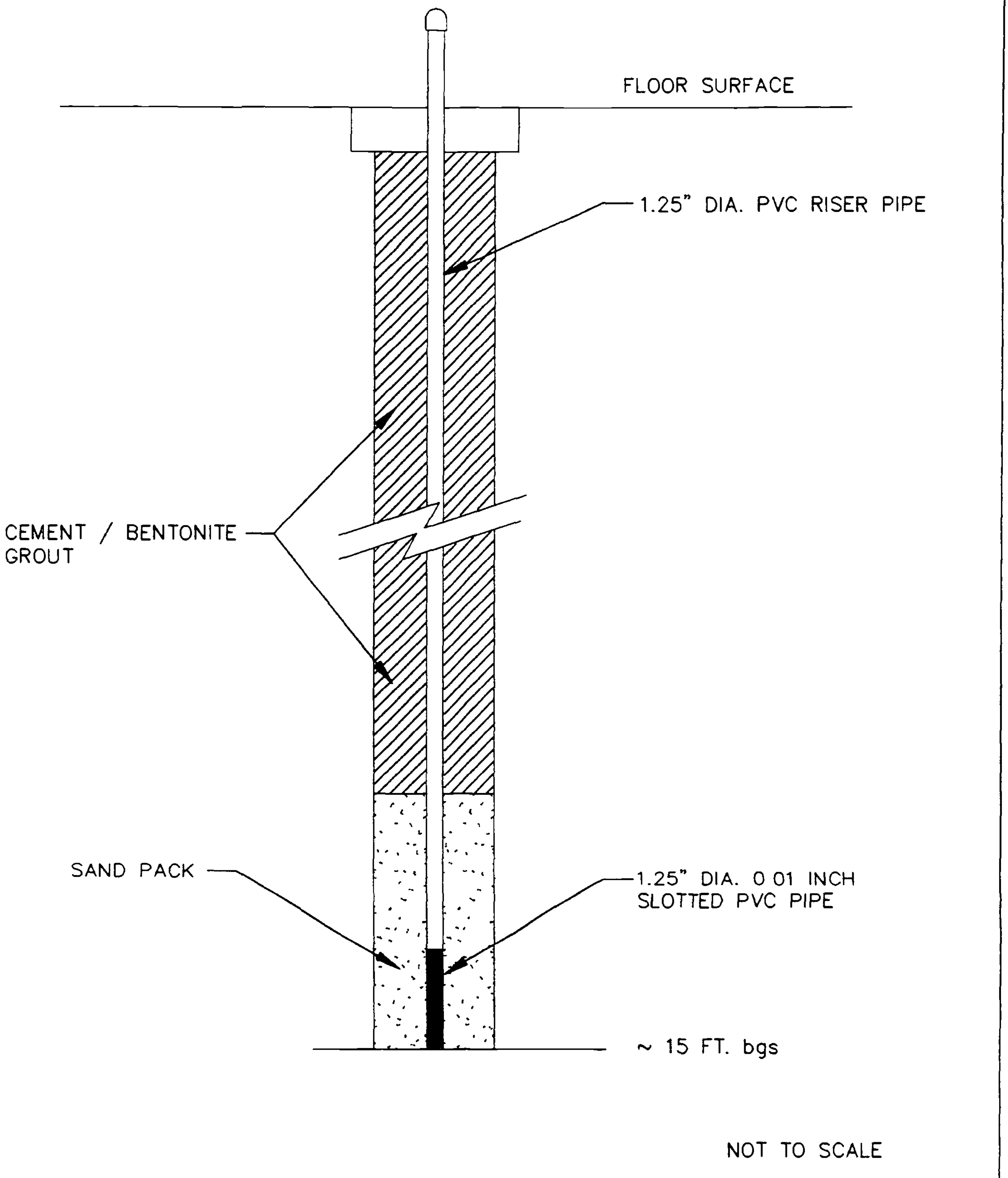
CLUSTERED SPM PROBE SCHEMATIC

3-4

ROY F WESTON, INC
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN	DATE	DES ENG	DATE	W O NO
WRS	12/13/93			04400-003
CHECKED	DATE	APPROVED	DATE	DWG NO ABCW1

PLT SC FIT FILE NO. ABCW1



ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

SINGLE SPM PROBE SCHEMATIC

3-5

ROY F. WESTON, INC.
MANAGERS DESIGNERS/CONSULTANTS

DRAWN WRS	DATE 12/13/93	DES ENG	DATE	W O NO 04400-003
CHECKED	DATE	APPROVED	DATE	DWG NO ABCW2

PLT. SC. FIT FILE NO. ABCW2

of the ABC building toward the rear of the building, where the equipment trailer and mobile SVE unit were located.

Upon arrival at the site and prior to the commencement of the pilot-scale study, WESTON personnel connected the piping manifold to the equipment trailer inlet. The trailer outlet was connected to 3 vapor-phase carbon canisters connected in series for capture of contaminants prior to discharge to ambient air.

Results from the pilot-scale study of the SVE system are provided within the separate SVE Treatability Study Report. The Treatability Study Report will further discuss the processes involved in the SVE system study, as well as a laboratory bench-scale study of the system.

3.6 SEPTIC TANK SAMPLING

As a result of an error in sampling protocol in obtaining a septic tank sample during the OU1 study, WESTON collected an additional septic tank sample. Consequently, on September 22, 1993, a sample of the sludge and liquid contents of the septic tank within the ABC building was collected to obtain information relative to the concentration of VOCs contained in the septic tank.

The method used to sample the septic tank involved attaching a sample bottle directly to a decontaminated steel rod and lowering the rod to the bottom of the tank. The rod was moved up and down several times within the sludge at the bottom of the tank in order to fill the bottle as much as possible. After a short period, the bottle was retrieved and capped with a teflon lined, septum sealed lid. This process was repeated for a second sample container.

Once the sampling was complete, all equipment was taken to the decontamination pad for cleaning according to methods previously described in Section 3.3.5. Sample bottles were tagged, sealed, and placed in an ice-cooled container for subsequent forwarding to the designated analytical laboratory.

3.7 SEPTIC TANK CONTENTS REMOVAL

During the course of the ABC OU2 field investigation, WESTON (with EPA concurrence) determined that the contents of the septic tank should be removed in order to: (1) facilitate elimination of the source area; (2) determine if the septic tank was continuing to be used by the ABC operation; and (3) aid in identification of the location of the septic tank drain line and drain field.

The equipment necessary for the septic tank contents removal included 55-gallon drums, an air compressor (capable of producing 100 cubic feet per inch), and a vacuum drum pump with extension hose. The hose from the vacuum drum pump was connected to a 7-foot long, 2-inch diameter PVC pipe, which was inserted into the tank. Health and safety air monitoring equipment used during this operation included an organic vapor analyzer (OVA) and a combustible gas/O_2 level indicator. At first, Level C personal protective equipment was used; however, after obtaining high OVA readings (from 50 to over 1,000 units) and evaluating the potential for breakthrough of Level C canisters a decision was made that Level B would be necessary for continued operation.

Once in Level B, the vacuuming process began with the connection of a hose from the air compressor unit onto the vacuum drum pump. This pump was attached to a large disk approximately the same size of a 55-gallon drum lid. The entire pump unit was placed on top of an empty drum. When a valve on the drum pump was opened the force of the air moving across the drum pump created a vacuum within the drum. This vacuum extended to the end of the hose that was connected to PVC pipe allowing the contents of the septic tank to be removed.

WESTON personnel moved the PVC pipe through the contents of the tank allowing the contents of the tank to be discharged to a 55-gallon drum. Once a drum was filled, the drum pump was placed on top of another empty drum and the vacuuming process continued.

After removing a large portion of the liquid and sludge contents from the tank, other items became visible. These items included glass bottles, large cement fragments, clay pipe fragments, fragments of wooden boards, broken bricks, and other small unidentifiable items. This debris could not be removed from the tank with the available equipment and was left in the tank. When all liquid was removed from the tank additional potable water was added to help partially clean out any remaining sludge content. Rinse waters were vacuumed to the drums as well.

Septic tank construction appeared to consist of a concrete floor (approximately 5 feet long and 3 feet wide) with concrete walls (approximately 6 feet high) and brick finishing at the top. There was also a 6-inch thick, 2-foot long, and 2-foot wide concrete cap over the manhole (Figure 3-6). Within the top ten inches of the tank two clay inlet pipes were present. The pipes were approximately 5 inches in inner diameter and in a position of one on top of the other (Figure 3-7). At the opposite end of the tank, a single line, reportedly leading from the tank to the drain field, was observed.

Figure 3-6

Photograph of opening to septic tank oriented to the east. Concrete cap of septic tank is outlined by yellow lines. Note two inlet pipes to the south just below opening. Standard 3-inch wide by 8-inch long bricks for scale.

Figure 3-7

View into septic tank. View oriented to the east. Debris at bottom consists of broken clay pipe ends, fragments of wooden board, concrete pieces, fragments of brick and paper. Color difference at halfway point along eastern and southern walls is resultant from the majority of the sludge being at the bottom of the tank. Note two inlet pipes at south end of tank. Pipe outlined in yellow is upper pipe, while pipe outlined in red is lower pipe. Blue line marks northern edge of upper end of the tank structure. Scale varies depending upon depth.

3.7.1 Septic Tank Residuals Handling

During the vacuuming process, as a drum became full, the equipment was removed from the top of the drum, and a fastenable lid was used to cap the drum. After each tank cleaning session, the drums were transported to the secured area behind ABC for storage. During April 1994, the septic wastes were transported via a licensed waste hauler to the Rollins Environmental incineration facility of New Jersey for final disposal. As of the date of this report, a Certificate of Destruction had not been received.

Equipment used during the vacuuming operation was decontaminated as previously described in Section 3.3. This equipment included vacuum hose, drum pump, PVC pipe, personal protective gear, and small tools. Several pieces of personal protective equipment, including tyvek and saranex coveralls, rubber gloves, and booties were disposed of in the soil cuttings roll-off bins for disposal.

3.8 SEPTIC TANK DRAIN LINE TRACING

As originally proposed in the February 1993 Addendum to the Project Operations Plan for OU2, the leach field and possible leaks in the drain line were to be traced using either smoke testing or closed-circuit television. These activities were to be used to determine: 1) the location of the leach field; 2) location of other possible sources of contaminant release to soil along the drain line; and 3) if VOCs in the septic tank were being displaced from the septic tank by incoming wastewater.

However, during field operations for OU2 (on October 6, 1993), Mr. Victor Melts, operator of the ABC facility, met with WESTON field representatives to discuss the location of the former drain field. According to Mr. Melts, the location of the drain field was approximately 20 feet to the north of the present septic tank location. Figures 3-8 and 3-9 display the location of the drain field, as described by Mr. Melts within the ABC facility. Mr. Melts stated that the drain was filled with cement when it was abandoned in the mid-1980s. He stated that this was approximately at the same time that the septic tank was taken out of service and facility sewage lines connected to the City of Jacksonville sewer system.

Based on this conversation with Mr. Melts and removal of the contents of the septic tank (Section 3.7), the septic tank drain line tracing was not performed.

3.9 MONITOR WELL ELEVATION SURVEY AND WATER LEVEL MEASUREMENTS

On October 14, 1993, Charles Rawls and Associates, Inc., (a North Carolina registered land surveyor) under the supervision of WESTON, performed a monitor well elevation survey at the site. Tops of casings and ground surface elevations were surveyed for the four newly installed monitor wells and the six piezometers. In addition, the elevations for soil borings SB-13, -14, -15, -17, -18, and -23 and the elevation for geotechnical boring GT-W were surveyed. The elevations were based on North American Vertical Datum (NAVD) 29. The benchmark of origin was Station Terrace as described by the North Carolina Geodetic Survey. Table 3-8 presents the survey data results.

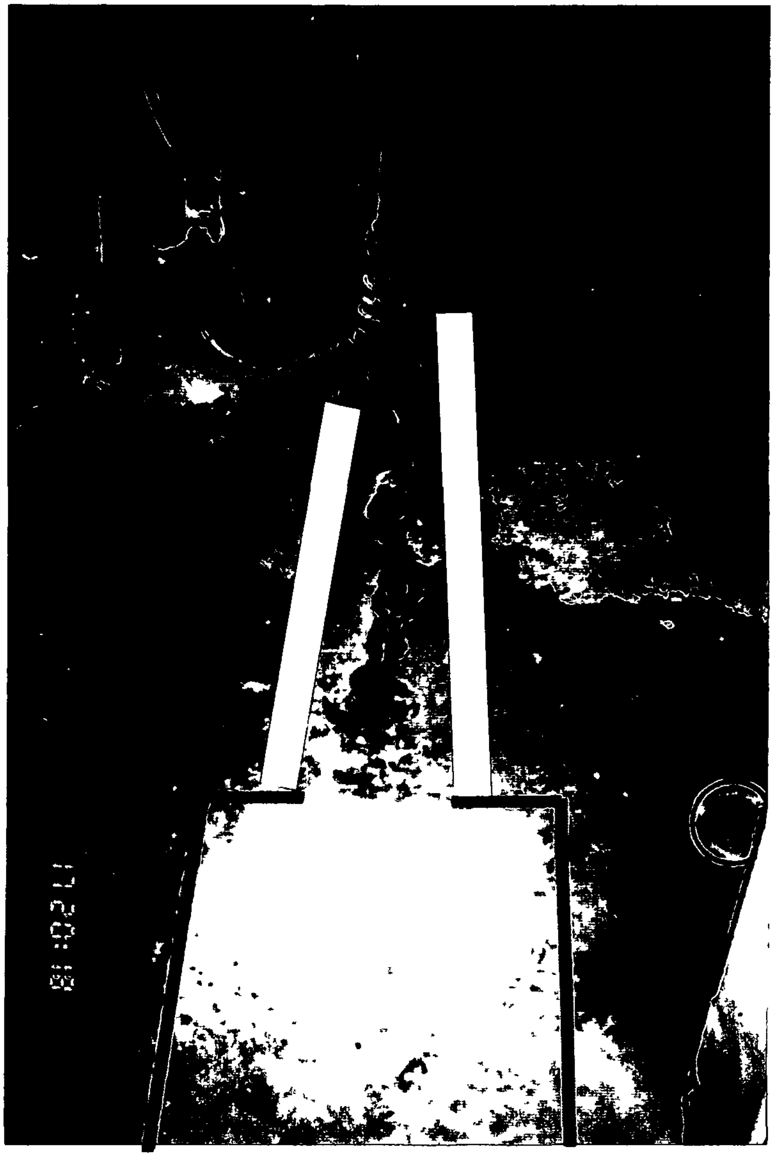


Figure 3-8

Photograph of a view across a portion of the former drain field area and the line leading from the septic tank. View is oriented to the south. Septic tank is located behind aqua-colored dry cleaning machine. Thick yellow lines mark perimeter of line from the septic tank. Blue lines mark perimeter of drain field. Scale is 6 inch-wide cap to the right (circled in black).

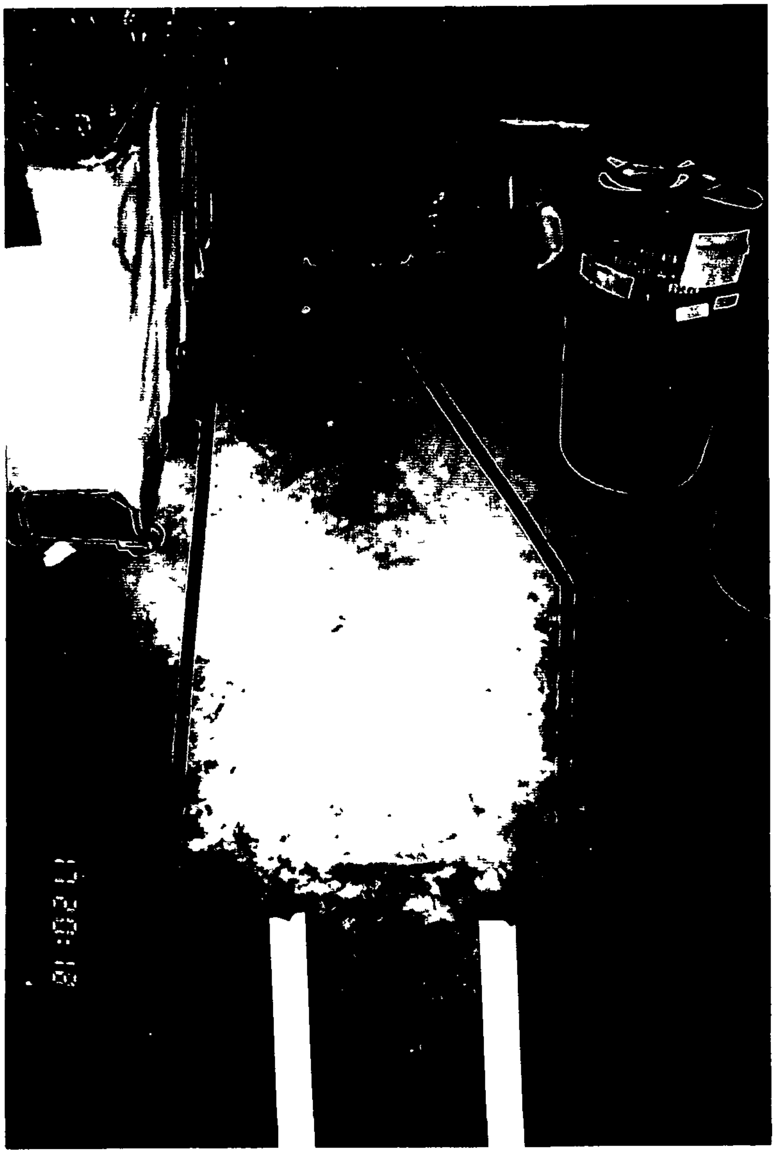


Figure 3-9

Photograph of drain field area as outlined by thin blue lines. View is oriented to the north. Thick yellow lines mark perimeter of drain line originating from the septic tank. Scale is 3-foot tall black drum.

Table 3-8

Surveyed Elevations of Monitor Wells, Piezometers, and Borings
ABC One-Hour Cleaners
Operable Unit 2

WELL NUMBER	ELEVATION OF TOP OF CASING (FT ABOVE MSL*)	ELEVATION OF NEARBY GROUND SURFACE (FT ABOVE MSL)
S1	30.28	30.58
S2	32.44	32.46
S3	35.91	32.95
S4	34.63	32.21
S5	34.37	31.89
S6	30.92	31.12
S7	31.43	31.30
S8	30.59	30.80
S9	32.46	32.74
S10	31.19	31.55
S11	30.37	30.79
C1	30.36	30.60
C2	31.83	32.02
C3	36.30	33.40
C4	34.62	32.18
C5	34.77	32.03
C9	31.74	32.14
C10	32.17	32.50
C11	30.84	31.01

Table 3-8 (Continued)

Surveyed Elevations of Monitoring Wells, Piezometers, and Borings
ABC One-Hour Cleaners
Operable Unit 2

WELL NUMBER	ELEVATION OF TOP OF CASING (FT ABOVE MSL*)	ELEVATION OF NEARBY GROUND SURFACE (FT ABOVE MSL)
PZ-01	31.33	31.94
PZ-02	31.34	31.94
PZ-03	32.17	32.53
PZ-04	32.16	32.53
PZ-05	31.22	31.96
PZ-06	31.16	31.96
SB-13	32.10	
SB-14	31.99	
SB-15	31.87	
SB-17	33.24	
SB-18	33.42	
SB-23	33.23	
GT-W	31.96	

* ft above msl = feet above mean sea level.

WESTON collected water level measurements referenced to the top of the well and piezometer casing from each well prior to sampling or, in the case of the piezometers, prior to aquifer testing. Levels were obtained using a Solinst Model 100 Water Level Probe. For each measurement two consecutive readings were collected and recorded along with the time of day at which the measurement was taken. Depth to water measurements were collected until two readings were within 0.01-foot range of each other. The total depth of the well was also recorded.

The water level probe and tape were decontaminated prior to each measurement. The decontamination procedures were the same as those described in Section 3.3.

A series of water level measurements was collected prior to aquifer testing of well S2 on October 1, 1993. A second series of water level measurements was collected on November 18, 1993, during disposal of the roll-off bins. Water levels were collected as described above using the Solinst Model 100. Section 4.6 contains potentiometric maps constructed from the water level data.

3.10 MONITOR WELL SAMPLING

WESTON collected groundwater samples from each of the existing (10) and newly installed (4) wells at the ABC site. Prior to sampling newly installed wells, a minimum of ten days was allowed to elapse following well development.

3.10.1 Well Purging

Each well cap was unlocked, removed, and all vapors allowed to vent from the casing. After a short period, the depth to water relative to the top of the casing and total depth of the well were measured. The depth to water value was subtracted from the total depth value producing the total amount of water column (in feet). The known diameter of the well casing was then multiplied by the total footage of the water column, equalizing the standing casing water volume. This volume was multiplied by 3 and 5 to obtain minimum and maximum purge volumes, respectively. All measurements and well volume calculations were recorded on the WESTON Geolis Logging System for monitor well sampling.

Well purging consisted of lowering a 4-inch, decontaminated, stainless-steel Grundfos electric submersible pump (rated for 12 to 20 gallons per minute) into the well. Pump intakes were set within the middle of the water column so that the entire water column was affected during the purge. If necessary, the height of the pump in the well or the pump flow rate was adjusted to avoid drawing the water level below the level of the pump's intake. For surficial aquifer wells, the high pumping capacity removed water with such efficiency that in many cases, even with the pump at the bottom of the well, the pump was turned off momentarily so that the water level did not drop below the pump intake. Even though the pump did not have to be turned off for any of the Castle Hayne wells, the pump was lowered in several cases. Using the start time, initial flow rate, and, if applicable, the adjusted flow rate(s) and time of adjustment(s), volumes removed during pumping were measured and compared to the calculated minimum and maximum purge volumes. All times, flow rates, and adjustments were recorded on the appropriate Geolis forms. All wells, with the exception of S5, S9, and S10 were purged in this manner.

Due to the fact that wells S5, S9, and S10 had low purge volume requirements, the purge was completed using a teflon bailer. Using new monofilament line, the bailer was repeatedly lowered into the water column and retrieved. Bailer contents were discharged into a 5-gallon bucket, allowing the quantity of water removed from the well to be measured. The bailing process was repeated until purging was completed, as described below. The remainder of the purging procedure was as previously described in this section.

During the purge procedure, the water quality parameters of pH, specific conductance, and temperature were recorded after each well volume was removed. Notes were also made describing the turbidity or clarity of the water and the amount of water (in gallons) removed from the well.

All effluents from the purge process were directed into a mobile tank. When filled to load capacity, the tank was transported to the staging area and its contents pumped into the large holding tanks present on-site. As the capacity of the mobile tank exceeded the required purge volumes for all wells, interruption of purging at a given well location was never required.

The purge was considered complete when a maximum of five well volumes of water had been removed from the well and/or three pH readings were within 0.1 units, three temperature readings were within 0.5 degrees Centigrade, and three specific conductance readings were within 5 percent.

3.10.2 Well Sampling

After all purging equipment was removed from the well area a decontaminated teflon bailer with new monofilament line was lowered into the well and completely submerged into the water column and retrieved. The contents of the bailer were slowly poured down the side of a pre-labeled, unpreserved, 40-milliliter glass sample bottle. This bottle was capped with a septum-sealed lid so that no air remained entrapped, placed in a ziplock bag, and stored in an iced cooled container prior to shipment to the analytical laboratory for TCL-VOC analysis. Appendix B contains Chain-of-Custody records for the collected samples.

Pumps, electrical lines, water level probes, bailers, and any other items submerged into the well for purging and sampling were decontaminated prior to first use and between use following procedures outlined in Section 3.3.

In addition to collection of monitor well groundwater samples, 28 field Quality Assurance/Quality Control (QA/QC) samples were collected, including field, rinsate, and trip blanks as well as duplicate groundwater samples. Table 3-9 describes the sample collection date and locations. Field blanks were collected in various locations using organic-free water provided by the on-site organic-free water system. Rinsate blanks were collected by pouring organic-free water over or into a decontaminated piece of equipment. Trip blanks were collected directly from the polyethylene discharge hose of the organic-free water system. All QA/QC samples were submitted for TCL-VOC analysis. Chain-of-Custody Records for all samples can be found in Appendix B. Section 5 contains a discussion of the analytical results of the QA/QC samples.

Table 3-9

Quality Assurance/Quality Control Water Samples
ABC One-Hour Cleaners
Operable Unit 2

DATE	SAMPLE NUMBER	SAMPLE TYPE	SAMPLING LOCATION
9/14/93	ABC-PZ-RBL-01	Rinse Blank	Sample collected from PVC pipe use as piezometer material after being decontaminated.
9/17/93	ABC-RBL-02	Rinse Blank	Sample collected from 6-inch augers after decontamination.
9/17/93	ABC-RBL-03	Rinse Blank	Sample collected from hand auger buckets used to collect soil samples after decontamination.
9/17/93	ABC-RBL-04	Rinse Blank	Sample collected from teflon bailer after decontamination.
9/30/93	ABC-RBL-05	Rinse Blank	Sample collected from teflon bailer after decontamination.
9/17/93	ABC-FBL-01	Field Blank	Decontamination Pad.
9/17/93	ABC-FBL-02	Field Blank	Rear building of ABC after operating hours of 9/17/93.
9/17/93	ABC-FBL-03	Field Blank	Pressing room (septic tank area) of ABC building after operating hours of 9/17/93.
9/22/93	ABC-FBL-04	Field Blank	Pressing room of ABC building during operating hours of 9/22/93.
9/22/93	ABC-FBL-05	Field Blank	Washing room (septic tank room) of ABC building during operating hours of 9/22/93.
9/22/93	ABC-FBL-06	Field Blank	Rear room (storage area) of ABC during operating hours of 9/22/93.
9/22/93	ABC-FBL-07	Field Blank	Decontamination pad.
9/29/93	ABC-FBL-08	Field Blank	Decontamination pad.

Table 3-9 (Continued)

Quality Assurance/Quality Control Water Samples
ABC One-Hour Cleaners
Operable Unit 2

DATE	SAMPLE NUMBER	SAMPLE TYPE	SAMPLING LOCATION
9/22/93	ABC-TBL-02	Trip Blank	Organic-free water system.
9/23/93	ABC-TBL-03	Trip Blank	Organic-free water system.
9/29/93	ABC-TBL-04	Trip Blank	Organic-free water system.
9/29/93	ABC-TBL-05	Trip Blank	Organic-free water system.
10/2/93	ABC-TBL-05	Trip Blank	Organic-free water system.
10/14/93	ABC-TBL-06	Trip Blank	Organic-free water system.
10/2/93	ABC-MW-C2-02	Duplicate	Monitor well C2 groundwater sample duplicate.
10/2/93	ABC-MW-S2-02	Duplicate	Monitor well S2 groundwater sample duplicate.
9/22/93	ABC-MW-C5-MS	Matrix Spike	Monitor well C5 groundwater sample duplicate, intended as matrix spike for laboratory.
9/13/93	ABC-W-BLK-01	EPA Blank	*Issued by EPA/ESD
9/13/93	ABC-W-SPK-01	EPA Spike	Issued by EPA/ESD
9/20/93	ABC-W-BLK-02	EPA Blank	Issued by EPA/ESD
9/20/93	ABC-W-SPK-02	EPA Spike	Issued by EPA/ESD
9/24/93	ABC-W-BLK-03	EPA Blank	Issued by EPA/ESD
9/24/93	ABC-W-SPK-03	EPA Spike	Issued by EPA/ESD

* Blank and spike water samples were issued to WESTON from the Environmental Services Division of EPA Region IV.

The sample number ABC-TBL-05 was inadvertently used twice during the field investigation.

In addition to the collection of field QA/QC samples by WESTON, the Environmental Services Division of EPA in Athens, Georgia, issued additional soil and water spikes and blanks for QA/QC of the EPA CLP laboratories. The sample numbers are found in the Chain-of-Custody Records in Appendix B labelled as P.E. (Performance Evaluation) samples under Column K.

3.11 AQUIFER TESTING

The four aquifer tests conducted as part of the OU2 RI are listed in Table 3-10 and are discussed below in detail.

3.11.1 Step-Drawdown Test and Extended Development

An 8-hour, step-drawdown test and a 4-hour, extended well development were performed in wells C2 and S2, respectively, at the ABC One-Hour Cleaners site. These tests were performed to estimate a maximum pumping rate for the screened zone of the surficial aquifer (S2) and Castle Hayne aquifer (C2). Also, these tests allowed WESTON to evaluate the cone of depression created while pumping and to evaluate the transmissivity and storativity of the two aquifers.

3.11.1.1 Test Design

For the step-drawdown and extended development tests, a measure of the depth to water in each well located within 500 feet of the pumping well (either C2 or S2) was recorded. Pressure transducers were lowered into each well to be monitored during the test. Each transducer, which detected pressure changes in the well as the test progressed, was connected to a central

Table 3-10

Aquifer Testing Conducted as Part of OU2 RI
ABC One-Hour Cleaners
Operable Unit 2

TEST DESCRIPTION	LOCATION	DURATION	PURPOSE
Step Drawdown	C2	8 hour pumping phase; 4.8 hour recovery phase	To estimate maximum pumping rate and other hydrogeologic parameters for Castle Hayne aquifer.
Extended Well Development	S2	4 hour pumping phase; 3.4 hour recovery phase	To determine pump rate to be used in 72-hour aquifer test; to provide crude estimates of other hydrogeologic parameters in surficial aquifer.
Background Test	All 72-hour test observation (and pumping) wells	22 hours	To monitor outside influences on wells prior to pumping.
Aquifer Test	S2	72 hours	To estimate hydrogeologic parameters in surficial and Castle Hayne aquifers.

data logger. The data logger converted the pressure readings into water levels and matched it with a particular point of time, measured from the beginning of the test. These raw data were stored in the data logger memory for computer retrieval.

After securing all transducers and loading preliminary transducer data into the data logger, a 4-inch diameter pump was lowered into the well. This pump was connected electrically to local power. The discharge tubing from the top of the pump was connected to a flowmeter reading discharge in gallons per minute (gpm).

Monitor wells used during the tests as observation wells included: C2, S2, and PZ-03, -04, -05, and -06. The step-drawdown and extended development tests were conducted in six steps (Tables 3-11 and 3-12). For the step-drawdown test, the first four steps were pumping phases that lasted approximately one hour. The fifth step, also a pumping phase, lasted four hours (Table 3-11). For the extended development test, the first five steps were pumping phases, although the length of time varied (Table 3-12). Each step represented an increase in the discharge rate.

The sixth and final step for both tests was the recovery phase (Tables 3-11 and Table 3-12). At the beginning of the recovery phase the pump was turned off, the gate valve closed, and the data logger activated to record recovering water level data. Typically, the recovery phase lasted until the water levels in the monitored wells returned to approximate pre-test levels. Upon successful completion of a test, the pump and transducers were left in their respective positions in anticipation of the S2 72-hour aquifer test.

Table 3-11

Dimensions of Step-Drawdown Test on Well C2
Test Date: October 1, 1993
ABC One-Hour Cleaners OU2

STEP NO.	LENGTH OF TIME (Min.)	DISCHARGE RATE (gpm)	PHASE TYPE
0	60	5.3	Pumping
1	62	8.1	Pumping
2	61	10.2	Pumping
3	61	12.6	Pumping
4	240	14.7	Pumping
5	288	--	Recovery

min = minute
gpm = gallons per minute

Table 3-12

Dimensions of Extended Development on Well S2
Test Date: October 2, 1993
ABC One-Hour Cleaners OU2

STEP NO.	LENGTH OF TIME (Min.)	DISCHARGE RATE (gpm)	PHASE TYPE
0	62	4.6	Pumping
1	63	6.3	Pumping
2	30	8.6	Pumping
3	30	12.2	Pumping
4	59	15.8	Pumping
5	201	--	Recovery

min = minute
gpm = gallons per minute

All water generated from the pumping well during the test was contained in on-site tanks. The discharged water was later transferred into a carbon treatment system; afterward it was stored in tanks prior to sampling and final disposal into the City of Jacksonville sanitary sewer system. Sample results of the treated water may be found in Appendix B.

After the step-drawdown and extended development test data had been collected, the information was downloaded into a computer from the data logger and entered into the computer program, AQTESOLV (Geraghty and Miller, 1991), for determination of transmissivity. (See Section 3.11.4)

3.11.2 Background Test

After the step-drawdown and extended development tests were completed and all data were transferred to a computer for storage, two additional transducers from piezometers PZ-01 and PZ-02 were connected to the central data logger at the C2/S2 well pair location.

The two newly installed transducers and the original six transducers were used to evaluate the background water levels in the monitored wells during the 72-hour test. Influences may include tidal effects, pumping domestic wells, industrial supply wells and changes in barometric pressure. A data logger with two additional transducers was also used near the well pair C3/S3 to monitor for background influences. These two wells were also monitored during the 72-hour test.

All data from the background test were downloaded onto a computer for subsequent interpretation. Section 4.6 presents the discussion of the significance of the data from the background test. Raw test data are found in Appendix F.

3.11.3 72-Hour Aquifer Test

A 72-hour test of the surficial aquifer was conducted through well S2. The discharge rate of this test was determined by the test results of the S2 extended development. Eleven surficial aquifer monitor wells and seven Castle Hayne aquifer monitor wells were used as observation points during the test. Drawdown data from this test from observation wells located only in the surficial aquifer were interpreted using the methods described in Section 3.11.4. This test was conducted to estimate transmissivity and storativity values from the surficial aquifer for use in modeling in the Remedial Design.

3.11.3.1 Test Design

At the end of the 24-hour background test, the data was once again downloaded into a computer for later interpretation. Once downloading was completed, the transducers were reconnected to their respective data loggers and the preparations began for the 72-hour test.

The design for the 72-hour test followed the same procedures as the previously conducted OU2 aquifer tests. In this case, however, S2 was the pumping well and wells C2, S3, C3 and piezometers PZ-01 through PZ-06 were used as observation wells through the use of transducers. Monitor wells C1, S1, C2, S2, S6, and S7, and piezometers PZ-01 through PZ-06 were monitored for water level changes by manual measurements throughout the test on a routine basis (Appendix D). These measurements were collected by an electric water level recorder.

In addition, water levels in wells C3, S3, S8, C9, S9, and S10 were measured at different periods during the test.

Based on the results of the extended development test, a discharge rate of 13.1 gallons per minute was established as the rate at which the aquifer could sustain a 72-hour test. The same gate valve and flowmeter system used during the step-drawdown and extended development tests to control the discharge rate were used during the 72-hour test.

After the 72-hour pumping phase expired, the recovery phase began. At the start of this phase, the pump was turned off, the gate valve closed, and the data logger activated to record recovering water level data. This recovery phase lasted for approximately 23 hours due to the fact that all water levels had recovered to within 5 percent of the pre-test level. During the latter part of this period, a rainfall event of 0.75 inches (according to the National Weather Service at the Onslow County Airport) occurred over the greater Jacksonville area. According to the raw data (Appendix F), this event did not have an effect on the rate of water level recovery within observation monitor wells and piezometers because the levels had returned to within approximately 7 percent of pretest levels before the event occurred. A discussion of the results of the analysis for transmissivity and storativity from the pumping and recovery phases is provided in Section 4. Graphs of the drawdown versus time data are provided in Appendix C. Raw data from the tests are found in Appendix F.

All water discharged from the aquifer was stored and treated in the same manner as described in Section 3.11.2.1. Sampling results of the treated water can be found in Appendix B.

All pumps, hoses, electrical lines, electric water level tapes, transducers, and transducer lines were decontaminated before and after use following the procedures outlined in Section 3.3.5.

3.11.4 DATA ANALYSIS

3.11.4.1 Step Test Data

All Castle Hayne and surficial aquifer observation well data obtained during the step-drawdown and extended development tests were analyzed to estimate the specific capacity of monitor wells C2 and S2 which, subsequently, can provide an estimate of aquifer transmissivity. For the surficial aquifer, transmissivity was estimated using the following equation provided by Driscoll (1986) for unconfined aquifers:

$$\frac{Q}{s} = \frac{T}{1500}$$

Where: Q = discharge rate (gpm)
s = drawdown in pumped well (ft)
T = transmissivity (gallons per day per foot)
$\frac{Q}{s}$ = specific capacity (gpm/ft)

This equation assumes a well efficiency of 100 percent and, therefore, provides a theoretical estimate of transmissivity.

For the Castle Hayne aquifer, the data was analyzed to provide estimates of specific capacity and transmissivity using the following equation provided by Driscoll (1986) for confined aquifers:

$$\frac{Q}{s}=\frac{T}{2000}$$

Where: Q = discharge rate (gpm)

s = drawdown in pumped well (ft)

T = transmissivity (gallons per day per foot)

$\frac{Q}{s}$ = specific capacity (gpm/ft)

As was the case for the surficial aquifer, this method assumes the well is 100 percent efficient.

3.11.4.2 S2 72-Hour Aquifer Test

To analyze the data obtained from the drawdown phase of the aquifer test, WESTON used the Theis (1935) and the Neuman (1975) methods to obtain transmissivity and storativity values after concluding that aquifer and test parameters met several assumptions of this method. The Theis method is commonly used for interpretation of confined aquifer data under the following assumptions:

- The aquifer is bounded above and below the aquicludes.
- All layers are horizontal and extend infinitely in the radial direction.
- The initial piezometric surface (before pumping begins) is horizontal and extends infinitely in the radial direction.
- The aquifer is homogenous and isotropic.
- Groundwater density and viscosity are constant.
- Groundwater flow can be described by Darcy's Law.
- Groundwater flow is horizontal and is directed radially toward the well.
- The pumping and observation wells are screened over the entire aquifer thickness.
- The pumping rate is constant.
- Head losses through the well screen and pump intake are negligible.
- The pumping well has an infinitesimal diameter.
- The aquifer is compressible and completely elastic.

(Dawson and Istok, 1991)

However, according to Kruseman and DeRidder (1983), "in an unconfined aquifer in which no effects of delayed yield are apparent, the flow pattern to a pumped well is identical with the flow pattern to a pumped well in a confined aquifer." The method, therefore, may be used for analysis of pumping test data if the Theis method assumptions are satisfied and:

a. the aquifer is unconfined;

b. the flow to the well is in unsteady state;

c. the water removed from storage is discharged instantaneously with decline of head; and

d. the well diameter is extremely small.

The aquifer and test parameters of all aquifer tests conducted satisfied these assumptions.

Transmissivity refers to the product of the average hydraulic conductivity and the thickness of the aquifer. Thus, it is the rate of flow under a hydraulic gradient equal to unity through a cross-section of unit width over the whole thickness of the aquifer (Kruseman and DeRidder, 1983). Transmissivity is measured in units of length squared over time. The storativity or storage coefficient is defined as the volume of water released or stored per unit surface area of the aquifer per unit change in the component of head normal to that surface (Kruseman and DeRidder, 1983). Storativity is a dimensionless value.

The transmissivity (T) was determined for the aquifer from the time versus drawdown data by the Theis (1935) equation:

$$T = \frac{Q}{4\pi s} W(\mu)$$

where: Q = the discharge rate, cubic feet per day

s = the drawdown in feet measured in a piezometer or well at a distance r in feet from the pumping well

$W(\mu)$ = Theis well function

Storativity (S) was determined for the aquifer from the time versus drawdown data by the Theis (1935) equation:

$$S = 4T(t/r^2)\mu$$

where: T = transmissivity, square feet per minute

t = the time in minutes since pumping started

r = the linear distance from the piezometer or well to the pumped well

and:

$$\mu = \frac{r^2 S}{4Tt}$$

Typically, the value for μ is achieved through curve matching of a plot of s versus t or s versus 1/t overlaying a type curve $W(\mu)$ versus $1/\mu$ or $W(\mu)$ versus μ, respectively.

In order to account for possible delayed yield effects that may have occurred during the 72-hour test, WESTON applied the Neuman (1975) method to estimate the transmissivity and storativity of the surficial aquifer. The assumptions for this method are as follows:

- This aquifer has an infinite areal extent.
- The aquifer is homogeneous and has uniform thickness.
- The potentiometric surface in the aquifer is initially horizontal.
- The pumping rate is constant.
- Flow to a well is unsteady.
- The diameter of the pumping well is very small so that storage in the well can be neglected.

The reader is referred to the original article by Neuman for review of the equations and parameters used in the estimation of transmissivity and storativity.

Analysis of the recovery phase of the 72-hour aquifer test also allows for the estimation of transmissivity. The analysis of the recovery data "has the advantage that the rate of recharge, Q, is constant and equal to the near rate of discharge, Q, during pumping" (Kruseman and DeRidder, 1983). Drawdown variations that may occur during the pumping phase as a result of changes in discharge rate typically do not occur during recovery.

All recovery data from an observation well installed in either aquifer were analyzed according to the Theis (1935) recovery method. Theis (1935) refers to the recovery of the well as the residual drawdown, s, which is "the difference between the original water level prior to pumping and the actual water level measured at a certain moment, t', since pumping stopped" (Kruseman and DeRidder, 1983). The residual drawdown is given by:

$$s' = \frac{Q}{4\pi T}\left(ln\frac{4Tt'}{r^2S} - ln\frac{4Tt'}{r^2S'}\right)$$

where: s' = residual drawdown, feet

r = distance in feet from pumping well to observation well or if data is from pumping well, then $r = r_w$ = effective radius of the pumped well

S = coefficient of storage during pumping, dimensionless

S' = coefficient of storage during recovery, dimensionless

t = time since pumping started, minutes

t' = time since cessation of pumping, minutes

T = transmissivity, ft^2/day

Q = rate of recharge - rate of discharge, gpm or ft^3/min

The procedure for interpretation is also by graphical means where s is plotted versus t/t' on single logarithmic paper (see Kruseman and DeRidder, 1983, for more information).

A discussion of the results of analysis of the tests for transmissivity and storativity values is in Section 4. Graphs of the drawdown versus time data are in Appendix C. Raw data from the tests are found in Appendix F.

The variation in transmissivities determined by aquifer testing at the ABC site maybe a result of the aquifer(s) not being homogenous and isotropic. Homogeneity in an aquifer implies that the physical properties are the same in all locations. According to Fetter (1988), "it is a very unusual geologic formation that is perfectly homogeneous. Geologic processes operate at varying rates and over uneven terrain, resulting in heterogeneity." Isotropism in an aquifer occurs when the intrinsic permeability is the same in all directions. According to Bouwer (1978), hydraulic conductivity in the vertical direction is usually one-fifth to one-tenth that of the hydraulic conductivity in the horizontal direction for alluvial deposits (e.g., the geologic material underlying the ABC site). Nevertheless, the assumption of isotropism is used in most aquifer interpretation methods.

Aquifer interpretation methods are based on mathematical theory that assume idealistic conditions exist within the aquifer, even when this is not a probable situation. The heterogeneity of an aquifer has not been considered in aquifer interpretation methods until recently (Hantush and Marino, 1994). Until such time as these methods become accepted with the hydrogeologic community and are proven to be accurate relative to field conditions, the more established methods which assume homogeneity and isotropism will continue to be used.

3.12 REFERENCES

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SECTION 4

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section describes the regional and site-specific characteristics of the study area, including the following:

- Surface Features
- Meteorology
- Surface Water Hydrology
- Geology
- Soils
- Hydrogeology
- Demography and Land Use
- Ecology

4.1 SURFACE FEATURES

4.1.1 Regional

Onslow County and the Jacksonville area, including the ABC site, lie within the Coastal Plain physiographic province. The land surface is a plain that slopes gently eastward toward the Atlantic Ocean. The topography is typified by broad, relatively flat interstream areas, interrupted by low escarpments that are present adjacent to stream valleys. The elevation ranges from sea level to slightly above 50 feet (Jurney, 1923).

4.1.2 Site-Specific

ABC is situated at an elevation of about 30 feet above mean sea level (msl). The facility is located approximately 4,000 feet northwest of Northeast Creek, which is situated at an elevation of approximately 5 feet above msl and is influenced by tidal changes. Elevations decline gradually to the south and southeast toward Northeast Creek.

ABC is bounded to the south by North Carolina State Highway 24 (also known as Lejeune Boulevard in the vicinity of the site), to the west by Legends Tavern, to the north by Liberty Drive, and to the east by Major Furniture. The site is paved on the southern portion between the storefront and Highway 24 and has a gravel drive along its western border extending from Highway 24 northward to Liberty Drive. A paved drive owned by Major Furniture lies between the east side of the cleaners and the west side of Major Furniture. The northernmost one-third of the site is a grassy field.

The Base housing facility, Tarawa Terrace I, is located south and southeast of Highway 24. In the vicinity of the cleaners a grammar school and a Base maintenance shop are present, as is a group of Base athletic fields for use by the residents of the community. Most of the Base residential housing is located south of the study area. The landscaping of the housing community is composed predominantly of lawn grass interspersed with pine trees. A stand of pine trees runs along the northern border of the housing community, extending up to a shallow (approximately 400 feet long) drainage ditch which runs adjacent to Highway 24. The eastern and southeastern borders of the housing community are adjacent to Northeast Creek.

4.2 METEOROLOGY

4.2.1 Regional

Meteorological information for Onslow County is based on data collected at the Hoffman Forest weather station in the northeast section of Onslow County. Meteorological data for the station is published in an annual summary by the National Oceanic and Atmospheric Administration. Figure 4-1 provides temperature and precipitation information for Onslow County.

Total precipitation at the Hoffman Weather Station was 36.61 inches in 1990 (the most recent annual survey available). The largest amount of precipitation fell in March of 1990 while the driest month in 1990 was September. Total precipitation since 1985 has been between 45 and 67 inches per year.

The average temperature in Onslow County in 1990 was 67.6 degrees Fahrenheit (°F). The average monthly temperatures ranged from 53.9°F in January to 84°F in July. The coldest temperature in 1990 was 22°F in February, and the hottest temperature in 1990 was 104°F in June. Since 1985, the average temperature per year has been between 62°F and 68°F.

According to data collected at the weather station office at the Wilmington Airport (located approximately 50 miles southwest of the site), the mean number of days per year with precipitation greater than 0.01 inches is 117, and a mean of 34 days with more than 0.05 inches of precipitation. The mean number of days with snowfall greater than 0.1 inches is 1 day per year, and the mean number of days with fog per year is 175. The mean number of days per year that temperatures fall between 70 and 90°F is 236, and 43 days per year with temperatures

FIGURE 4-1

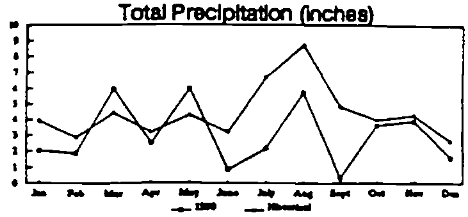
ONSLOW COUNTY

TEMPERATURE AND PRECIPITATION

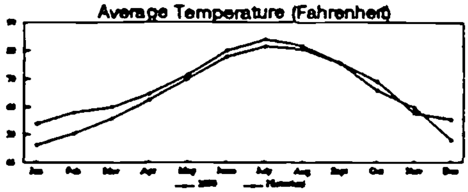
	Average Temperature		Total Precipitation	
Month	**1990**	**Historical***	**1990**	**Historical***
Jan	53.9	46.2	2.07	3.93
Feb	58.1	50.4	1.86	2.89
Mar	60.0	55.8	5.96	4.44
Apr	64.5	62.5	2.50	3.20
May	71.4	70.1	5.95	4.29
June	80.0	78.0	0.86	3.21
July	84.0	81.6	2.21	6.70
Aug	81.8	80.4	5.72	8.74
Sept	75.8	75.7	0.33	4.83
Oct	69.1	65.8	3.64	3.99
Nov	57.7	59.7	3.91	4.28
Dec	55.4	47.8	1.60	2.65
Annual	67.6	64.5	36.61	53.13

* Based on data from 1985 to 1990.

Total Precipitation (inches)



Average Temperature (Fahrenheit)



TEMPERATURE AND PRECIPITATION EXTREMES						
	1985	**1986**	**1987**	**1988**	**1989**	**1990**
Wettest Month	October 9.35 in.	August 12.25 in.	August 8.57 in.	August 7.38 in.	August 10.63 in.	March 5.97 in.
Dryest Month	December 1.28 in.	April 0.55 in.	October 0.65 in.	December 0.4 in.	November 2.07 in.	September 0.33 in.
Highest Temp.	100 June	96 July	97 July	100 August	102 July	104 June
Lowest Temp.	2 January	12 January	15 January	18 ' February	−2 December	22 February

less than 32°F. The mean number of days with thunderstorms is 47 days per year. At the Wilmington airport prevailing wind speed is 8 knots to the north, with maximum gusts reaching 68 knots. These data are based on data from 1948 to 1989.

4.2.2 Site-Specific

The site can be expected to experience similar meteorological conditions to those previously described. There are no site-specific meteorological data available.

4.3 SURFACE WATER HYDROLOGY

4.3.1 Regional

Onslow County is drained largely by the New River and its tributaries. The New River is at a higher elevation in the extreme northwestern part of the county and flows southward to the Atlantic Ocean. The New River is short, with a course of approximately 50 miles in the central Coastal Plain of the state. The White Oak River and its tributaries drain the eastern part of the county, and Black, Ninemile, Sandy Run, Shelter, and Juniper Swamps drain the western part. Small streams which empty directly into the sound carry the drainage in the extreme southern and southeastern portions of Onslow County (Jurney, et al., 1923).

4.3.2 Site-Specific

Surface runoff from the ABC site flows overland into ditches and culverts that are directed across Highway 24 onto Base property and, along with runoff originating on the Base, into

Northeast Creek. Northeast Creek is the nearest surface water to the site and is approximately 4,000 feet southeast of the site. It flows in a southwesterly direction to the New River which drains into the Atlantic Ocean. Within three miles of the site, swimming, water skiing, boating, and fishing (recreational and commercial) occur on both Northeast Creek and the New River.

4.4 GEOLOGY

4.4.1 Regional

According to 1985 Geologic Map of North Carolina, the ABC site is directly underlain by the Oligocene Age River Bend Formation. This formation is described as being composed of limestone (calcarenite) overlain by and interrelated with indurated, sandy, molluscan mold limestone. The River Bend unconformably overlies the Castle Hayne Formation.

Although there is some disagreement as to the exact age of the Castle Hayne, this formation, according to Ward and others (1978), is composed of two members - the New Hanover and Comfort. The New Hanover is a basal conglomeratic unit that is thin and discontinuous. Ward and others (1978) described the unit as consisting of "cobble to pebble size, sandy, calcareous dusts, usually subrounded to well-rounded and usually coated with phosphate and glavcanite. Occasional quartz pebbles and flat clay chips are also present along with very fine sand, glavcanite, and phosphate in a cream-colored micrite matrix."

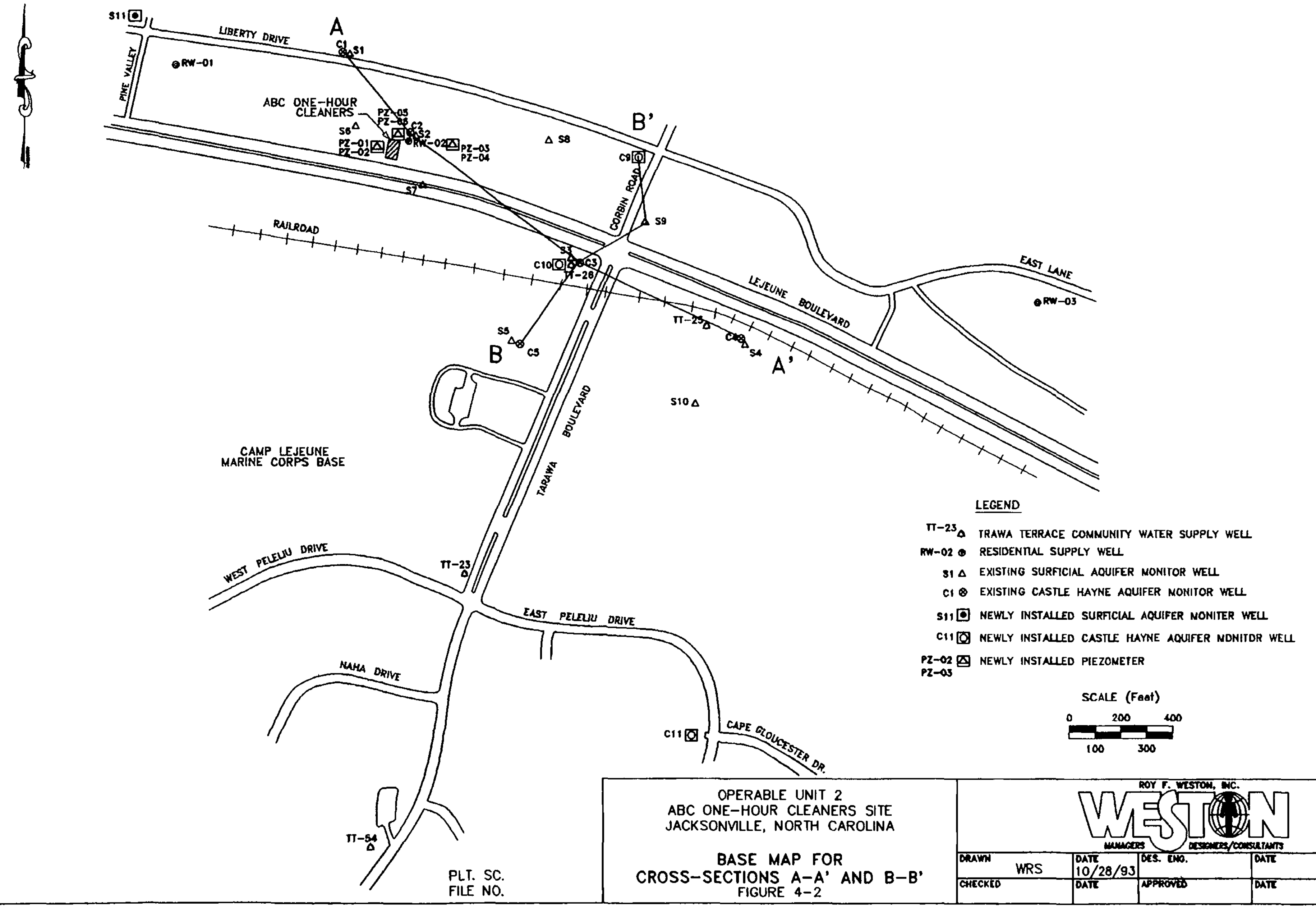
The Comfort Member comprises the bulk of the Castle Hayne. Ward and others (1978) described the Comfort Member as consisting of "gray to cream colored, bryzoan-enhinoid calcirudite, grading to a fine calcarenite, containing small mixtures of fine quartz, detrital and authigenic glavconite, and some detrital phosphate." The thickness of the Comfort Member varies from a thin eastern area to over three hundred feet in the western Cape Lookout area.

4.4.2 Site-Specific

Data on the geology underlying the ABC site were generated from soil borings and the piezometer and monitor well installations. Figure 4-2 shows the location of cross-sectional views of the site, and Figures 4-3A and 4-3B show the cross-sections of the site. Lithologic and well construction logs are found in Appendix A. Geologic data from the soil borings extend to the maximum depth of the upper unsaturated soils (typically encountered at approximately 18 feet bgs). Data generated during OU2 sampling extend to a depth of 175 feet bgs. OU1 information was provided from the C-4 boring to a maximum depth of 200 feet bgs. Geologic data generated from split-spoon samples extend to a depth of approximately 30 feet bgs. Additional data was based on examination of mud rotary drill cuttings.

During OU1, five distinct lithologic layers were found underlying the ABC study area (WESTON, 1992). OU2 data, from advancement of monitor well borings, confirm that five different layers are found underlying the study area (Figure 4-3). The first (uppermost) zone encountered extends from ground surface to approximately 25 feet bgs. The unconsolidated sediments comprising this zone are typically inter-bedded sands, silts, and clays. The percentage of clay is highest within the first 12 feet bgs. Quartz-rich sand is very fine to fine grained until approximately 20 feet bgs where coarse grained sand becomes prevalent.

The second zone extends on average from approximately 25 feet bgs to 65 feet bgs. The unit is described as a saturated sand with variable amounts of clay, silt, or gravel (silt and gravel



PLT. SC.
FILE NO.

OPERABLE UNIT 2
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

BASE MAP FOR
CROSS-SECTIONS A-A' AND B-B'
FIGURE 4-2

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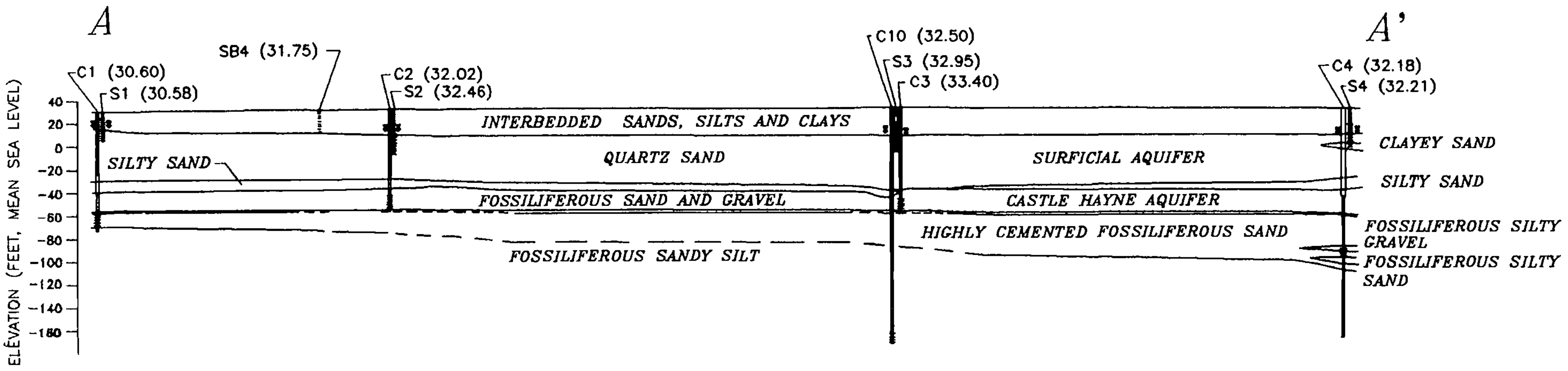
DRAWN WRS	DATE 10/28/93	DES. ENG.	DATE	W. O. NO. 04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO. ABCNEW-X



LEGEND

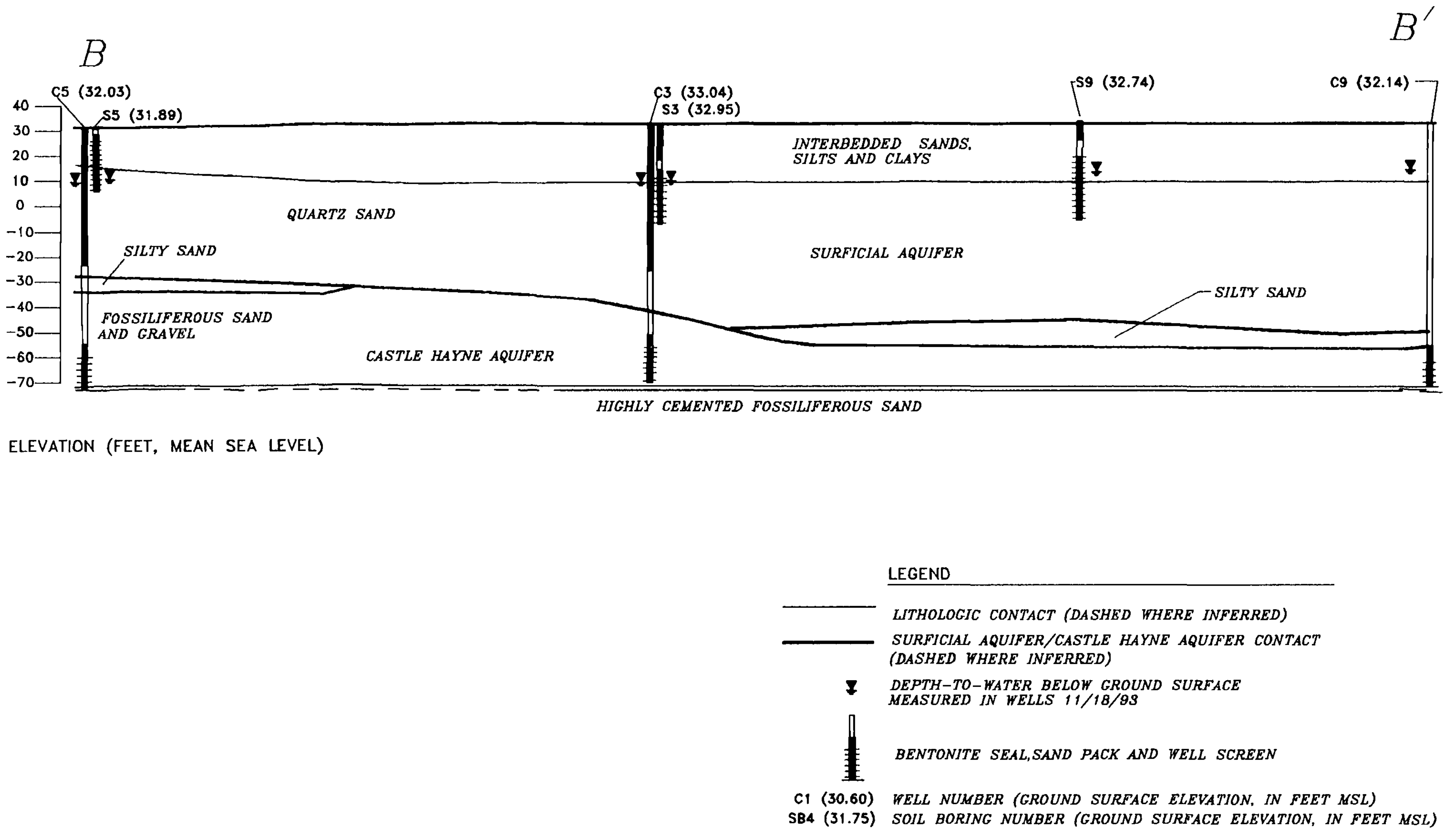
──	*LITHOLOGIC CONTACT (DASHED WHERE INFERRED)*
━━	*SURFICIAL AQUIFER/CASTLE HAYNE AQUIFER CONTACT (DASHED WHERE INFERRED)*
▼	*DEPTH-TO-WATER BELOW GROUND SURFACE MEASURED IN WELLS 11/18/93*
▮	*BENTONITE SEAL,SAND PACK AND WELL SCREEN*
C1 (30.60)	*WELL NUMBER (GROUND SURFACE ELEVATION, IN FEET MSL)*
SB4 (31.75)	*SOIL BORING NUMBER (GROUND SURFACE ELEVATION, IN FEET MSL)*

0' 200 400

HORIZONTAL SCALE

VERTICAL EXAGGERATION = 5X

FIGURE	4-3A	CROSS-SECTION A-A'
DATE	9/2/92	ABC ONE-HOUR CLEANERS SITE OPERABLE UNIT 2 JACKSONVILLE, NORTH CAROLINA
REVISION	0	
DRAWN BY	J.C.,W.M.	
FILE	ABCROSS2	



0' 75' 150'

HORIZONTAL SCALE

VERTICAL EXAGGERATION = 5X

WESTON
MANAGERS DESIGNERS/CONSULTANTS

FIGURE	4-3B
DATE	9/2/92
REVISION	0
DRAWN BY	J.C.,W.M.
FILE	ABCROSS

CROSS-SECTION B-B'

ABC ONE-HOUR CLEANERS SITE
OPERABLE UNIT 2
JACKSONVILLE, NORTH CAROLINA

content estimated at less than 15% by volume). The sands appeared to be predominantly composed of quartz and is of fine to coarse texture. At two piezometer locations (PZ-01 and -02, and PZ-05 and 06), the bottom 10 feet of this zone were predominantly composed of fine grained sand. The third layer is a silty, clayey sand that was observed underlying the clean sands. Where observed, this layer was typically about 10 feet thick and first observed at about 60 feet bgs, with the exception of C10 where the layer was about 15 feet thick and first encountered at about 52 feet bgs. This silty clayey sand layer is composed of approximately 15% silt, 40% clay, and 45% sand and is made up of very fine grained quartz grains.

The fourth layer encountered, thought to represent the Castle Hayne Formation, was typically encountered at 70 feet bgs, although at well C10 it was first observed at approximately 85 feet bgs. The formation has been described by the appearance of fossils including shark teeth, sea urchin spines, and/or various other small shells and shell fragments (WESTON, 1992). The matrix is predominately calcareous sands to quartz sands.

The fifth layer is found within the Castle Hayne. During OU1 and OU2, a highly cemented layer of fossiliferous sands was encountered at about 90 feet bgs. Below this layer, the fossiliferous sands and gravels became increasingly silty. This siltier material comprises an almost distinct layer. With depth, the layer appears to consist of approximately equal volumes of silt and sand.

4.5 SOILS

4.5.1 Regional

Upon the basis of similarity in color, texture, structure, and drainage conditions, the soils of Onslow County have been grouped into soils series, shown in Table 4-1. A wide variation of soil types exist within Onslow County, which is principally due to the diverse formation of the soils within the Lower Coastal Plain physiographic province. This province is dominated by several dynamic environments including the ocean, estuaries, swamps, creeks, and wide, undissected interstream areas. As a result of these environments and their inherent rich plant life, fine grained sand, organic matter, clay, and marine shell fragments are common components of the soils, creating complex soil horizons. The subsurface stratigraphy underlying this region reflects this complex of environments and resultant soil materials.

4.5.2 Site-Specific

The soils in the site area have been classified in the Baymeade-Urban land complex series (USDA, 1992). Fifty percent of this soil type is well drained Baymeade; 30% is covered by building, streets, etc.; the rest includes soil that has been disturbed during urban development. Surface layers are dominated by gray fine sand. Subsurface layers from 0 to 2 inches bgs are dominated by gray fine sand. Subsurface layers from 2 to 30 inches bgs are composed of fine sand that is light gray, light yellow brown, and white in color. Subsoils (from 30 to 80 inches bgs) are dominated by brownish yellow, yellowish brown fine sandy loam.

Table 4-1

Onslow County Soil Types
ABC One-Hour Cleaners
Operable Unit 2

SERIES	MORPHOLOGY
Alpin	Gray to light brown to white in color. Consists of excessively drained soils on uplands. Formed in course textured sediments. Dominantly fine sand. Range from very strongly acid to medium acidity.
Autryville	Typically brown, grayish brown, pale brown, yellowish brown, and light gray. Composed of loamy fine sand, fine sandy loam, and sandy clay loam. Typically friable. Ranges from very strongly acid to strongly acidic.
Baymeade	Gray, light gray, white, yellowish brown, fine sand that is very friable and can be in a subangular blocky structure. Consists of well drained soils or uplands. Formed in coarse textured sediments. Strongly acid to medium acid.
Bohicket	Dark gray to gray silty clay loam to loamy sand that is very friable. Consists of very poorly drained soils in tidal marshes that are less than 3 feet above sea level. Formed in silty and clayey sediments that were washed from drainage areas of freshwater streams. Typically slightly acid to moderately alkaline.
Carteret	Very dark gray, gray, greenish gray fine sand to sandy loam with slightly decomposed litter and roots. Consists of very poorly drained soils in tidal marshes along Intercoastal Waterway. Formed in sandy marine sediments. Medium acidity to moderately alkaline.
Corolla	Pale brown to grayish brown. Fine sand with 5 percent shells and small shell fragments. Consists of moderately well drained and somewhat poorly drained soils on the Outer Banks. Formed in coarse textured sediments. Medium acid to mildy alkaline.
Craven	Grayish brown, brownish yellow, red mottles, and gray sandy and clay loam to clay. Blocky structure common. Consists of moderately well drained soils on uplands. Formed in fine textured marine sediments. Very strongly acid to strongly acid.

Table 4-1 (Continued)

Onslow County
Soil Types

SERIES	MORPHOLOGY
Croatan	Black muck to dark reddish brown muck, sandy loam to dark grayish brown sandy clay loam to light brownish gray sandy loam. Very friable organic matter. Ranges from 16 to 51 inches in thickness. Consists of very poorly drained, organic soils on uplands. Formed in herbaceous plant residue over loamy material. Usually extremely acid.
Dorovan	Very dark grayish brown muck, dark reddish brown muck, and very dark grayish brown sandy loam. Consists of very poorly drained, organic soils on flood plains. Formed in plant residue over sandy sediments. Very strongly acid to strongly acid, decomposed organic layers.
Duckston	Dark grayish brown, light brownish gray, gray fine sand with fine shell fragments. Consists of poorly drained soils that formed in sandy windblown material deposited in shallow depressions or on flats between sand ridges and marshes. Sulfur odor common. Ranges from medium acid to moderately alkaline.
Foreston	Dark gray loamy fine sand, light yellowish brown fine sandy loam, brownish yellow fine sandy loam, light gray fine sandy loam. Medium granular structure, very friable, and very strongly acid. Consists of moderately well drained soils on uplands. Formed in moderately coarse textured sediments.
Goldsboro	Dark grayish brown, yellowish brown, pale brown, to gray sandy clay and fine sandy loam. Very friable subangular blocky structure. Very strongly acid to strongly acid. Consists of moderately well drained soils on uplands. Formed in moderately fine textured sediments.
Grifton	Light gray, gray, greenish gray, light brownish gray, and very dark grayish brown, fine sandy loam and sandy clay loam. Weak fine subangular blocky structure. Sticky and plastic. Acidity varies according to depth. Consist of poorly drained soils on uplands. Formed in moderately fine textured sediments with soft marl. Poorly drained soils on uplands.
Kureb	Gray, light gray, brownish yellow, mottled pale brown, fine sand. Concretions common. Very friable. Very strongly acid to neutral. Consists of excessively drained soils on uplands. Formed in coarse textured sediments.

Table 4-1 (Continued)

Onslow County
Soil Types

SERIES	MORPHOLOGY
Lafitte	Dark brown, very dark brown, black muck. Fibrous, rooty. Some mineral grains and silt and sand content. Decomposed organic material that ranges from 51 to more than 99 inches in thickness. Ranges from extremely acid to mildly alkaline. Consists of very poorly drained soils on flood plains at elevations of less than 5 feet. Formed in plant residue over sandy sediments.
Lenoir	Dark gray, brown, brownish yellow, grayish brown loam, fine sandy loam, clay, sandy clay loam. Very friable. Sticky and plastic. Mottling common. Always strongly acid. Consists of somewhat poorly drained soils or uplands. Formed in fine textured marine sediments.
Muckalee	Gray to grayish brown, loam and sandy loam. Massive; loose; friable; mottles. Organic matter common. Acidity varies with depth. Consists of poorly drained soils on low flood plains. Formed in moderately coarse textured recent sediments.
Murville	Fine sand that is black, dark reddish brown, and grayish brown in color. Always very friable. Extremely acid to strongly acid. Formed in coarse textured sediments in very poorly drained soils on uplands.
Newhan	Light gray fine sand. Marine shells, very fine fragments. Loose. Neutral pH. Soil is at least 72 inches thick. Calcareous shell fragments make up as much as 25 percent of the soils. Consists of excessively drained soils that formed in coastal sandy sediments deposited by wind.
Norfolk	Brown, pale brown, yellowish brown, brownish yellow, light gray, mottled gray loamy fine sand, and sandy clay loam. Mottling common. Very friable. Slightly sticky and plastic. Very strongly acid. Consists of well drained soils on uplands. Formed in moderately fine textured sediments.
Onslow	Very dark gray, gray, pale brown, brownish yellow, yellowish brown, light gray, and white sandy clay loam, fine sandy loam, loamy fine sand, and sandy loam. Concretions common. Subangular blocky structure to medium granular structure. Very friable. Slightly sticky and slightly plastic. Consists of moderately well drained and somewhat poorly drained soils on uplands. Formed in moderately fine textured sediments.

Table 4-1 (Continued)

Onslow County
Soil Types

SERIES	MORPHOLOGY
Pactolus	Fine sand, gray, grayish brown, light yellowish brown, pale brown, and light gray in color. Some mottling and some concretions. Few fine roots common. Soils range from very strongly acid to medium acid. Consists of moderately well drained and somewhat poorly drained soils on uplands and stream terraces. Formed in coarse textured sediments.
Pantego	Black mucky loam, grayish brown fine sandy loam, grayish brown sandy clay loam, gray sandy clay loam. Slightly sticky and sticky plastic. Weak medium granular structure to weak fine subangular blocky structure. Friable. Few coarse roots. Consists of very poorly drained soils and uplands. Formed in moderately fine textured sediments.
Rains	Fine sandy loam to sandy clay loam to sandy loam. Gray to grayish brown. Mottling very common. Moderately fine to weak fine subangular blocky structure. Slightly sticky and slightly plastic. Root channels common. Very strongly acid to strongly acid. Consists of poorly drained soils on uplands. Formed in moderately fine textured sediments.
Stallings	Dark gray, pale brown, very pale brown, light yellowish brown, light gray, mottled yellow brown, red, gray sandy clay loam, fine sandy loam and loamy fine sand. Weak medium granular structure to fine subangular blocky structure. Very friable. Extremely acid to strongly acid. Consists of somewhat poorly drained soils on uplands. Formed in moderately coarse textured sediments.
Torhunta	Black, very dark gray, dark gray, and grayish brown fine sandy loam. Light gray loamy fine sand. Light greenish, gray sandy loam. Weak medium granular structure to weak fine subangular blocky structure. Very friable. Wavy boundary. Extremely acid to very strongly acid. Very poorly drained soils on uplands. Formed in moderately coarse textured sediments.
Wando	Fine sand that is grayish brown, yellowish brown, dark brown, very pale brown, and yellow. Loose. Wavy boundary. Medium acidity. Few weakly cemented concretions. Formed in coarse textured sediments on excessively drained soils on uplands.

Table 4-1 (Continued)

Onslow County
Soil Types

SERIES	MORPHOLOGY
Woodington	Loamy fine sand, fine sandy loam, and sandy loam. Very dark gray, grayish brown, light brownish gray, gray. Mottling very common. Weak fine subangular blocky structure. Fine roots common. Consists of poorly drained soils. Formed in moderately coarse textured sediments.
Yaupon	Fine sandy loam to clay to sandy clay dark gray, light yellowish brown, greenish gray, very dark gray. Very friable. Weak medium granular structure. Shrinkage cracks or desiccation cracks occur commonly. Fragments of shells common. Commonly ranges from 20 to 80 inches thick. Formed in fine textured material deposited by dredging operations. Consists of somewhat poorly drained and moderately well drained soils near the edges of the Intercoastal Waterway.

Reference: United States Department of Agriculture, Soil Conservation Service, 1992. Soil Survey of Onslow County, North Carolina. Publ. of Nat'l. Cooperative Soil Survey. 139p., illust.

Soil data collected from boreholes b-4, b-5, and b-6 during drilling operations in 1985 indicated that the surficial sediments beneath and within the immediate vicinity of the ABC site consist of "mud" and fine sand to a depth of approximately 60-feet bgs (NRCD unpublished lithologic logs, 1985).

From soil samples collected as part of the OU2 RI, the shallow soils (from ground surface to approximately 25 feet bgs) consist of finely interbedded sands, silts, and clays. Clay is the dominant component within the first 12 feet of the soil profile. Sand in this zone is quartz rich and very fine to fine grained. Increasing with depth, the percentage of sand becomes higher and more coarsely grained.

4.5.2.1 Shelby Tube Geotechnical Analysis Results

Of the Shelby tubes submitted for geotechnical laboratory analyses during the ABC OU2 RI, two tubes were extracted and their contents analyzed for several geotechnical and hydrogeologic properties. The data gained from this testing were used in the design of the bench-scale treatability study as part of the SVE system study, as well as in the calculation of soil cleanup goals as part of the Summers Model (Section 6.7). All samples were analyzed by the Environmental Technology Laboratory of WESTON in Lionville, PA, using the ASTM method D5084 with a flexi-wall permeameter with back pressure. Raw sample results can be found in Appendix B. Figure 3-1 (Section 3) shows the location of Shelby tube sampling locations (labelled GT-E and GT-W).

From the data obtained in the geotechnical study, the soils can be described as light brown to light gray, silty, and clayey sand. The two samples varied in their amount of silt and clay. One sample (ABC-GT-W-01-4) contained 49 percent clay whereas the other (ABC-GT-W-02-10) contained 38 percent silt. The samples were collected from depths of 4 and 10 feet bgs, respectively, based on the number of split-spoon blows, as described in Section 3.4. Natural moisture in these samples varied from 18.3 to 22 percent.

The pH of the samples was measured to be 7.95 standard pH units in the 4-foot bgs sample and 4.71 standard pH units in the 10-foot bgs sample.

Important hydrogeologic parameters were also obtained in the sample analysis. Sample GT-W-01-4 had a void ratio of 0.49 and a porosity of 32.9 percent. Hydraulic conductivity within the sample was found to be $2.44\text{x}10^{-7}$ centimeters per second (cm/sec), while the intrinsic permeability was determined to be $2.53\text{x}10^{-4}$ darcys. Sample GT-W-02-10 contained a void ratio of 0.58 with a porosity of 36.5 percent. Hydraulic conductivity in the sample was $1.39\text{x}10^{6}$ cm/sec, and the intrinsic permeability was found to be $1.44\text{x}10^{-3}$ darcys.

Appendix B presents laboratory analysis results for the Shelby tube samples.

4.6 HYDROGEOLOGY

4.6.1 Regional

The sediments of the Coastal Plain include 10 aquifers listed below (Harned, et. al, 1989):

- Surficial
- Pungo River
- Beaufort
- Yorktown
- Castle Hayne
- Peedee

- Black Creek
- Lower Cretaceous
- Upper Cape Fear
- Lower Cape Fear

All aquifers, other than the surficial aquifer, have confining or semi-confining units (less permeable clay and silt beds) that serve to impede the flow of groundwater between the aquifers.

The surficial aquifer comprised of sand and clay, extends to a depth of approximately 50- to 100-feet bgs. Underlying the surficial aquifer are beds of sand and limestone that comprise the Castle Hayne aquifer, which is the principal source of fresh water in Onslow County. The top of the Castle Hayne aquifer generally occurs at about 40 feet below msl. The upper half of the aquifer is reportedly composed of unconsolidated sand, and the lower half is composed of consolidated to partly consolidated sand and limestone. Clay layers are present throughout the Castle Hayne aquifer, which has a thickness of about 300 feet in the vicinity of the ABC site. The clay layers are generally discontinuous and vary in thickness from about 5 to 20 feet (Harned et al., 1989).

The Beaufort and Peedee aquifers underlie the Castle Hayne aquifer, and are composed predominantly of sand with interbedded clay. Underlying these aquifers are the Black Creek, and upper and lower Cape Fear aquifers. In the vicinity of the Base these aquifers contain salt water and are not used for potable water supply (Harned et al., 1989).

4.6.2 Site-Specific

Efforts to characterize the hydrogeology at the site included lithologic sampling during the soil boring and monitor well installation programs, collection of water level data from monitor wells, and aquifer testing of two monitor wells (wells C2 and S2). The surficial and shallow portions of the Castle Hayne aquifers were included in the OU1 and OU2 investigations, with eleven wells installed into the surficial aquifer and eight wells installed into the Castle Hayne aquifer. Figure 4-2 illustrates the location of the cross-sections generated for the site and Figure 4-3 presents the cross-sections. Appendix A presents the lithologic and well construction logs for the soil borings and monitor wells installed at the site. Appendix C presents data collected during aquifer testing.

4.6.2.1 Hydrostratigraphy

The surficial aquifer is comprised primarily of saturated quartz sand which extends to a depth of approximately 70 feet bgs across most of the site. Overlying this saturated sand aquifer is a zone of interbedded sands, silts, and clays extending from ground surface downward to the top of the saturated sands at approximately 25 feet bgs. The lower portion of this interbedded zone is saturated. From a comparison of the depth to first saturated soil (as observed during the lithologic samples collected during well installation) to the depth to water below ground surface (from water level data collected after well development, adjusted from top-of-casing reference to ground surface reference), the static water levels in the wells are typically higher than the first occurrence of saturated soil (Figure 4-3). This suggests that the interbedded zone acts to partially confine the surficial aquifer.

Most of the surficial wells were screened such that the top of the 20-foot long screen extends about two feet above first saturation, resulting in the top of the screen being approximately equal to the top of the water column. Three wells (S2, S3, and S6) were screened lower (from about 40 feet bgs to about 20 feet bgs).

The Castle Hayne aquifer underlies the surficial aquifer at the site. The Castle Hayne aquifer is comprised primarily of saturated fossiliferous sands and gravels with variable silt content. The uppermost portions of the aquifer (typically from about 70 feet bgs to about 100 to 120 feet bgs) contain less than about 15% silt by volume. Below this depth the formation appears to be comprised of approximately equal volumes of saturated fossiliferous silts and sands. At location C1, the silt content increased to about 50% at a depth of 104 feet bgs. At location C4, the silt content was at approximately 50% from about 140 feet bgs to about 200 feet bgs.

A highly cemented layer of fossiliferous sand was encountered at a depth of approximately 90 feet bgs. At three of the Castle Hayne monitor well locations (C2, C3, and C5) drilling refusal was encountered at this layer, and the wells were screened upward 10 feet from this layer. At locations C1, C4, and C10, the layer was penetrated and the screens were set below the layer (Figures 4-2 and 4-3). All of the Castle Hayne monitor wells were screened above the lower, siltier portion of the Castle Hayne except locations C4 and C10. At monitor well C4, the upper half of the 10-foot long screen intercepted a lens of fossiliferous silty sand (estimated at 5 feet thick).

No definitive confining unit was observed separating the surficial aquifer from the Castle Hayne aquifer; although lithologic sampling below 35 feet bgs relied on the less accurate method of mud rotary cuttings, significant changes in lithology were observed. At all locations except monitor C3, a 3- to 20-foot thick silty sand (silt content estimated at approximately 45% or less) was observed at the base of the surficial aquifer which may act as a confining unit for the Castle Hayne aquifer.

4.6.2.2 Groundwater Elevations

WESTON collected two rounds of water levels (on October 1 and November 18, 1993) from the surficial and Castle Hayne aquifer monitor wells and piezometers. The depth-to-water data were converted to water level elevations, and potentiometric maps were prepared. Table 4-2 presents the groundwater elevations for all wells for each measurement date referenced to the elevation above mean sea level (MSL). Figures 4-4 and 4-5 present surficial aquifer potentiometric maps for the above dates, respectively. Figures 4-6 and 4-7 present potentiometric maps for the Castle Hayne aquifer for the above dates, respectively.

The surficial aquifer potentiometric maps (Figures 4-4 and 4-5) reveal a fairly consistent groundwater surface, with slight variations due to seasonal effects. The highest elevations are observed in the northwestern corner of the site at monitor well S11 and in the northern portion of the site at monitor well S8. Without the benefit of well S11, the OU1 study recorded the highest elevations in the northwestern corner of the site at monitor well S1. The high elevation recorded at S8 during the OU2 study is most likely due to infiltration into the groundwater table from a nearby (less than 50 feet) malfunctioning drainage ditch that has resulted in the formation of a small pond. The lowest surficial aquifer groundwater elevations during the OU2 study were recorded at wells S4 and S10 (Figures 4-4 and 4-5).

According to the potentiometric maps, groundwater in the surficial aquifer appears to be generally flowing from the northwest to the southeast toward Northeast Creek.

Table 4-2

Water Level Elevations in Monitor Wells for the Two Water Level Collecting Dates ABC One-Hour Cleaners Operable Unit 2

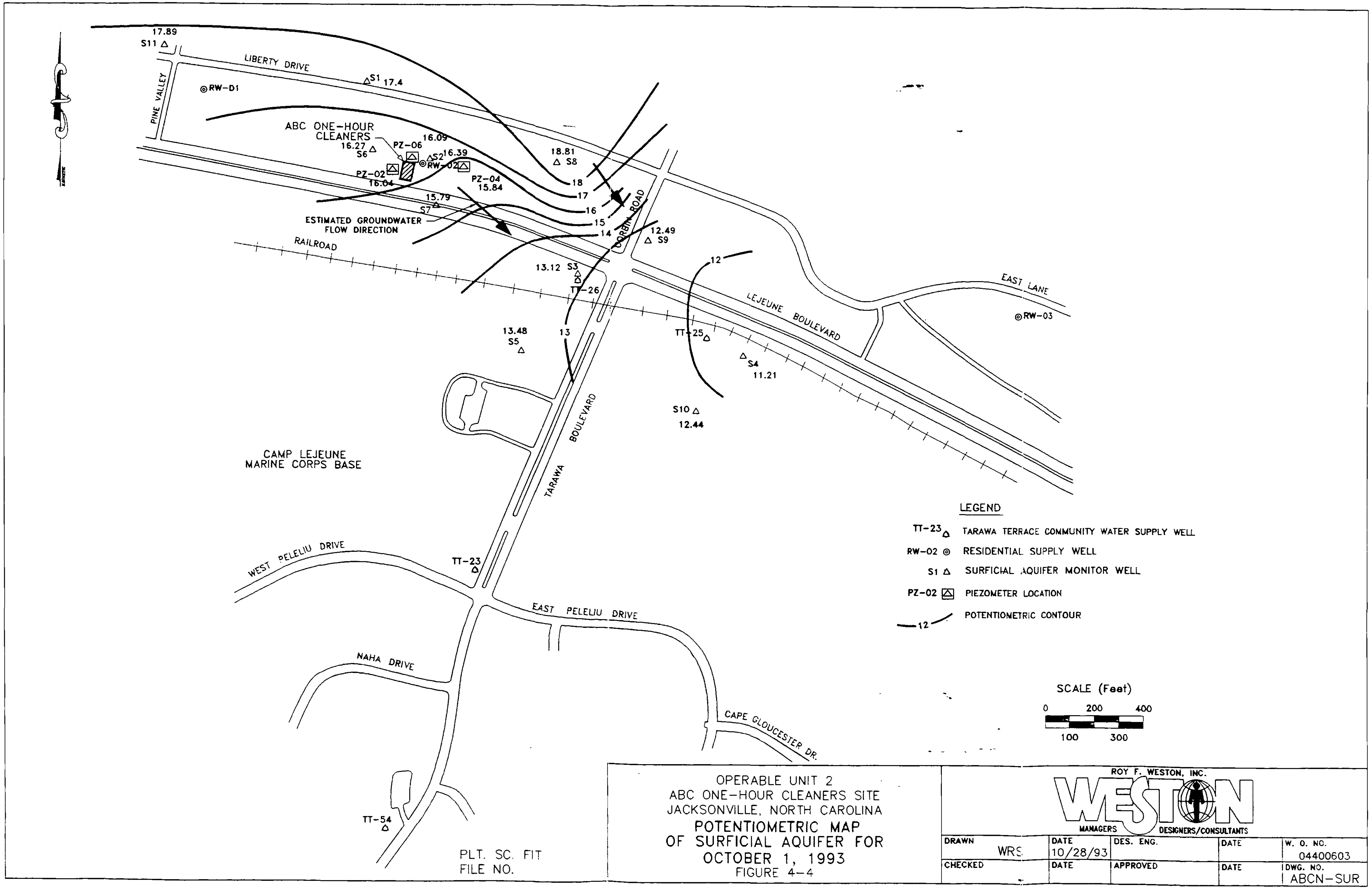
WELL/ PIEZOMETER NUMBER	WATER LEVEL ELEVATIONS ON 10/1/93	WATER LEVEL ELEVATIONS ON 11/18/93
S1	17.40	18.33
S2	16.39	16.62
S3	13.12	13.55
S4	11.21	13.51
S5	13.48	13.71
S6	16.27	17.11
S7	15.79	16.63
S8	18.81	18.96
S9	12.49	12.99
S10	12.44	12.73
S11	17.89	19.02
C1	16.80	17.75
C2	15.67	16.47
C3	12.94	13.42
C4	9.67	10.28
C5	13.31	13.57
C9	12.42	13.04
C10	--	12.64
C11	6.27	6.29

Table 4-2 (Continued)

Water Level Elevations in Monitor Wells for the Two Water-Level Collecting Dates ABC One-Hour Cleaners Operable Unit 2

WELL/ PIEZOMETER NUMBER	WATER LEVEL ELEVATIONS ON 10/1/93	WATER LEVEL ELEVATIONS ON 11/18/93
PZ-01	15.89	16.69
PZ-02	16.04	16.67
PZ-03	15.65	16.63
PZ-04	15.84	16.42
PZ-05	15.67	16.71
PZ-06	16.09	--

NOTE: All elevations are in feet MSL
-- = Not recorded



PLT. SC. FIT
FILE NO.

OPERABLE UNIT 2
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
POTENTIOMETRIC MAP
OF SURFICIAL AQUIFER FOR
OCTOBER 1, 1993
FIGURE 4-4

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DRAWN WRS	DATE 10/28/93	DES. ENG.	DATE	W. O. NO. 04400603
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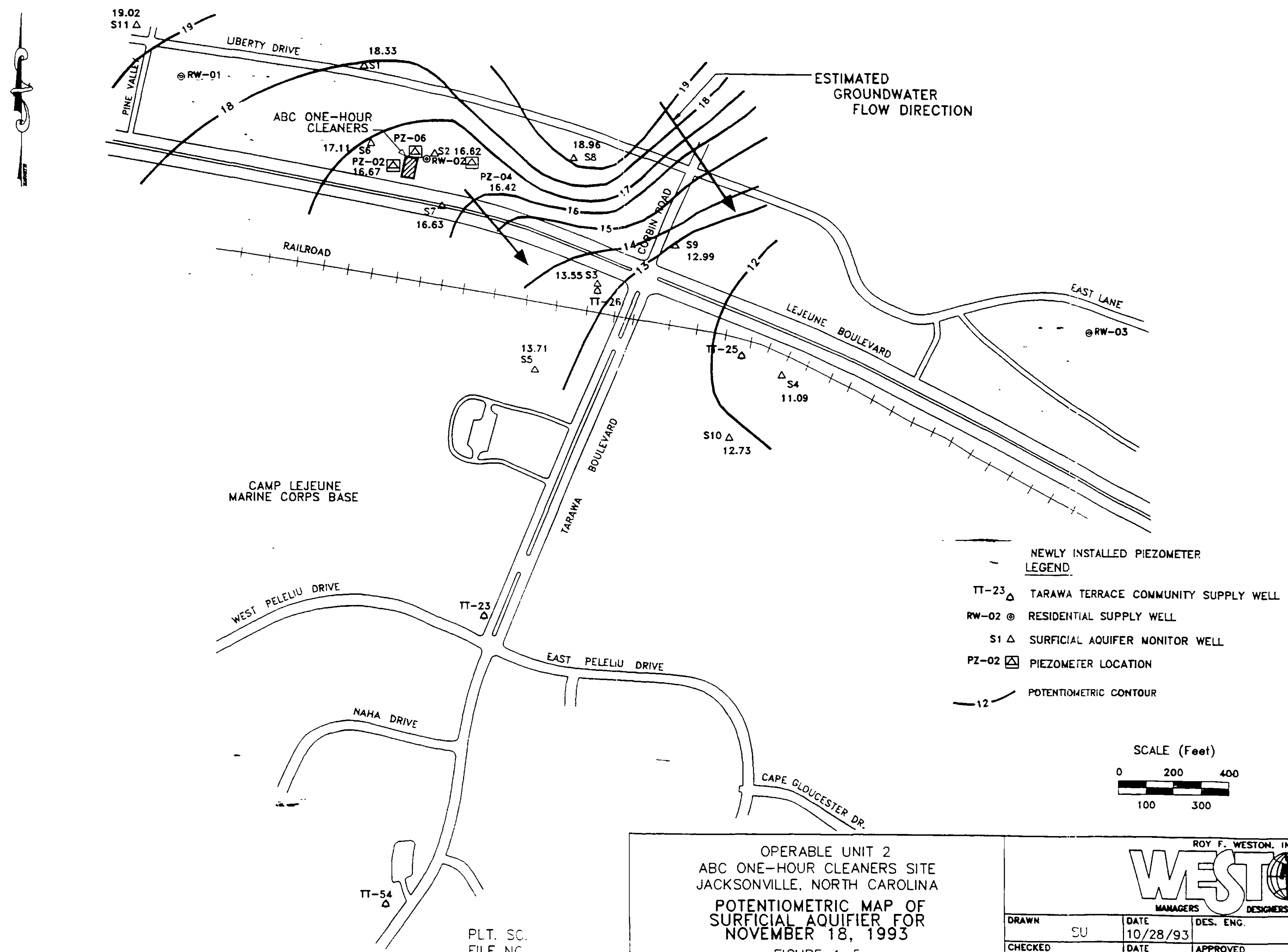

NEWLY INSTALLED PIEZOMETER

LEGEND

- TT-23 △ TARAWA TERRACE COMMUNITY SUPPLY WELL
- RW-02 ◎ RESIDENTIAL SUPPLY WELL
- S1 △ SURFICIAL AQUIFER MONITOR WELL
- PZ-02 ⊠ PIEZOMETER LOCATION
- 12 POTENTIOMETRIC CONTOUR

PLT. SC.
FILE NC

OPERABLE UNIT 2
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

POTENTIOMETRIC MAP OF SURFICIAL AQUIFER FOR NOVEMBER 18, 1993

FIGURE 4-5

ROY F. WESTON, INC.
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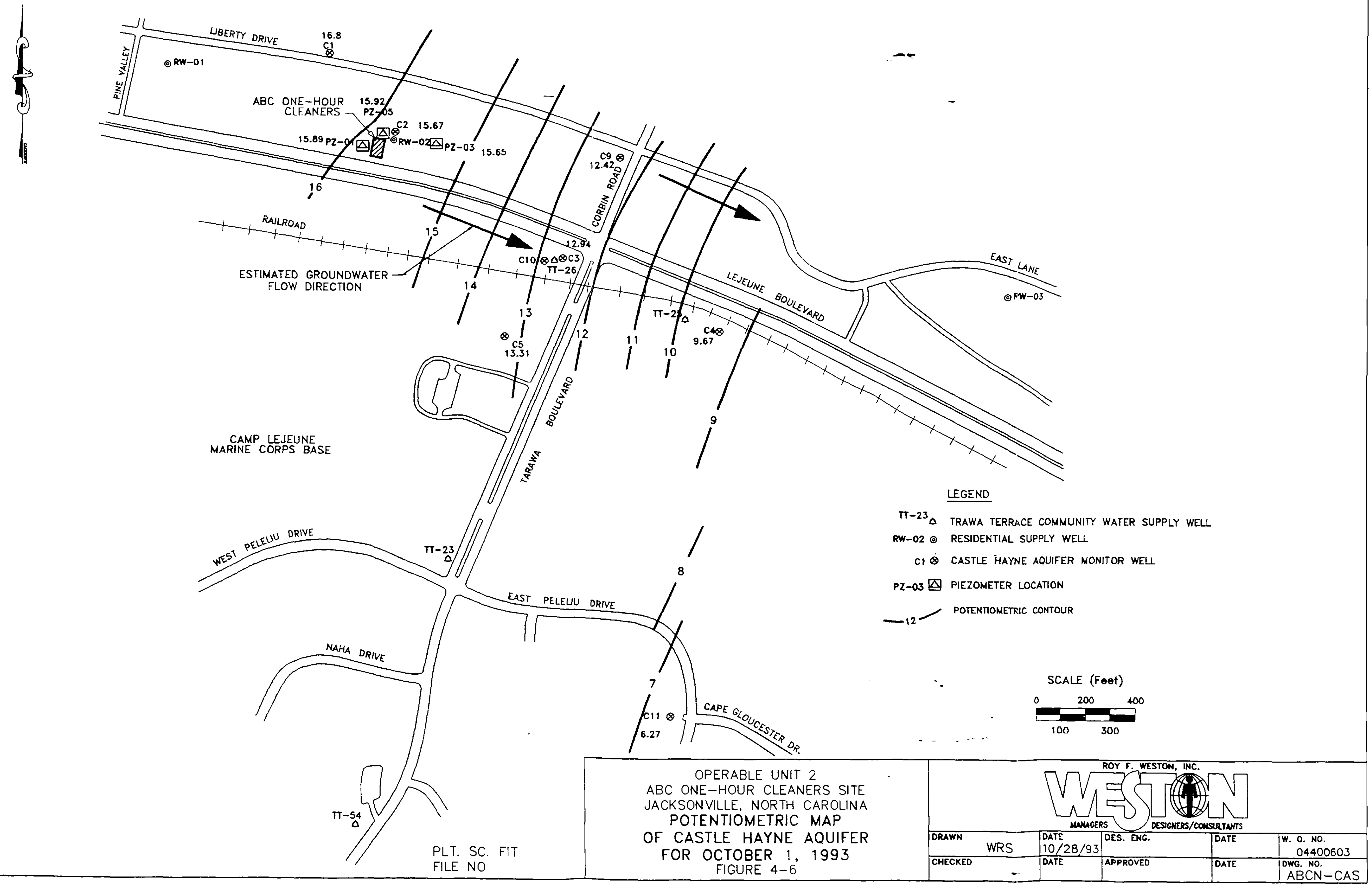
DRAWN	SU	DATE 10/28/93	DES. ENG.	DATE	W. O. NO. 04400603
CHECKED		DATE	APPROVED	DATE	DWG. NO. ABCNEW-B

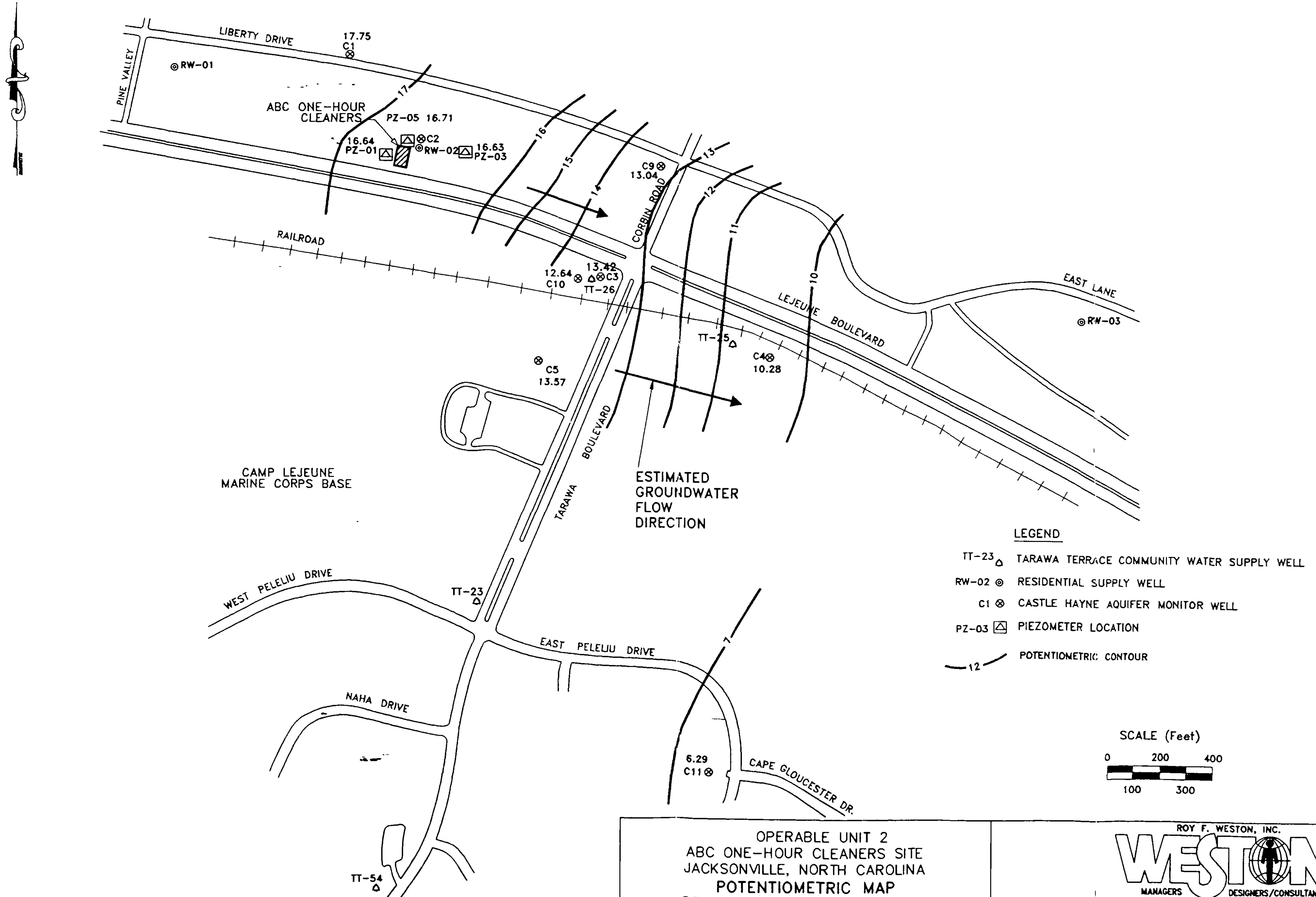


PLT. SC. FIT
FILE NO

OPERABLE UNIT 2
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
POTENTIOMETRIC MAP
OF CASTLE HAYNE AQUIFER
FOR OCTOBER 1, 1993
FIGURE 4-6

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN	DATE	DES. ENG.	DATE	W. O. NO.
WRS	10/28/93			04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO.
				ABCN-CAS



PLT. SC.
FILE NO.

OPERABLE UNIT 2
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
POTENTIOMETRIC MAP
OF CASTLE HAYNE AQUIFER
NOVEMBER 18, 1993
FIGURE 4-7

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN WRS	DATE 10/28/93	DES. ENG.	DATE	W. O. NO. 04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO. ABCNEW-C

The potentiometric maps of the surficial aquifer groundwater have been used to estimate the magnitude of the hydraulic gradient in the surficial aquifer. For the October 1, 1993 potentiometric maps, a line formed between piezometer PZ-04 and well S10 is nearly parallel to the estimated direction of groundwater flow. The gradient magnitude is then estimated as the elevation difference between the two monitor wells, (15.84 feet above MSL at PZ-04 minus 12.44 feet above MSL at S10) divided by the distance between the two locations (estimated at 1388 feet), yielding 0.0024. The gradient magnitude for the November 18, 1993 date, estimated using the same locations, was determined to be 0.0027. The average of the two gradient magnitudes was 0.0025.

The potentiometric maps for the Castle Hayne aquifer also reveal a consistency in the groundwater surface for the two dates water level measurements were recorded. The highest groundwater elevation in the Castle Hayne aquifer was observed at monitor well C1 in the northwest corner of the site. Groundwater elevations decrease to the southeast, reaching a minimum at monitor well C11. Consequently, groundwater in the Castle Hayne aquifer appears to flow to the east-southeast with a stronger eastern component than was estimated for the surficial aquifer. The groundwater flow direction in the Castle Hayne aquifer during the OU1 study was also to the east-southeast.

The magnitude of the hydraulic gradient in the Castle Hayne was calculated in the same manner as that for the surficial aquifer. For both water level collection dates the line from piezometer PZ-01 to monitor well C3 was used because it is nearly parallel to the predicted direction of groundwater flow. The distance between these two locations is estimated at 920 feet.

For October 1, 1993, the groundwater elevations (in feet MSL) for PZ-01 and C4 were 15.89 and 12.94, respectively, representing a gradient magnitude 0.0033.

For November 18, 1993, the groundwater elevations (in feet MSL) for PZ-01 and C4 were 16.69 and 13.42, respectively, representing a gradient magnitude 0.0036. The average of the two gradient magnitudes is 0.0035. Therefore, the gradient in the Castle Hayne is approximately 30% greater than the gradient in the surficial aquifer.

During the OU1 study a measurable difference was found in groundwater levels between the Castle Hayne and surficial aquifers, suggesting a vertical hydraulic gradient exists between the two aquifers. The difference in water level elevations was at a maximum of 2 feet in the C1/S1 well pair, and a minimum of 0.1 feet in the C3/S3 well pair. During the OU2 study, using data from both monitor well and piezometer pairs, a measurable difference was once again observed in groundwater levels between the Castle Hayne and surficial aquifers (Table 4-3). For the two measuring dates, the maximum difference was found to be 3.23 feet higher in the surficial aquifer at the well pair C4/S4, and the minimum was found to be 0.13 feet in well pair C3/S3. During the November 18, 1993 readings, the Castle Hayne piezometers PZ-01 and PZ-03 were found to have higher groundwater elevations than the surficial aquifer piezometers. This difference is probably attributable to drainage of surface water from inside the well housing into the piezometer casing during opening before readings were collected.

Wherever there is an occurrence that groundwater elevations in two possibly distinct aquifers within the same area are different, the presence of an aquitard is usually suspected. At the ABC site, groundwater elevation differences in piezometer and well pairs, although variable, do exist

Table 4-3

Comparison of Water Level Elevations in Monitor Well/Piezometer Pairs ABC One-Hour Cleaners Operable Unit 2

WELL/ PIEZOMETER PAIR	WATER LEVEL ELEVATIONS FOR 10/1/93	DIFFERENCE IN WATER LEVEL ELEVATIONS FOR 10/1/93	WATER LEVEL ELEVATIONS FOR 11/18/93	DIFFERENCE IN WATER LEVEL ELEVATIONS FOR 11/18/93
C1/S1	16.80/17.40	0.6	17.75/18.33	0.58
C2/S2	15.67/16.39	0.72	16.47/16.62	0.15
C3/S3	12.94/13.12	0.18	13.42/13.55	0.13
C4/S4	9.67/11.21	1.54	10.28/13.51	3.23
C5/S5	13.31/13.48	0.17	13.57/13.71	0.14
PZ-01/PZ-02	15.89/16.04	0.15	16.69/16.67	-0.02
PZ-03/PZ-04	15.65/15.84	0.19	16.63/16.42	-0.21
PZ-05/PZ-06	15.67/16.09	0.42	--	--

NOTE: All elevations are in feet above MSL.
Difference computed by subtraction of Castle Hayne data from surficial data.
Odd numbered piezometers are screened in Castle Hayne.

-- = Data not recorded for PZ-06

across the site. No single geologic structure was identified during the OU1 or OU2 studies that is capable of acting alone as an aquitard between the surficial and Castle Hayne aquifers. The discontinuous silty sand (approximately 45% or less silt content) layer observed at the base of the surficial aquifer may act as an aquitard more effectively in some areas. For example, at the C4/S4 location, this layer is approximately 10 feet thick and groundwater elevation differences were at a maximum at this location; whereas at the C3/S3 and C5/S5 locations (where the silty sand was not observed or was approximately 3-feet thick) the elevation differences are the lowest of all well pairs. This comparison suggests that the silty sand layer is partially responsible for the differences in water level elevation observed at the well pairs.

It is possible that some of the variation in groundwater elevations is due to a number of different layers, especially clay-rich or silt-rich sand layers, acting as a cumulative aquitard. Several layers were observed during drilling of monitor wells that would restrict the downward movement of groundwater. For example, the thin (approximately 0.5 feet thick) highly cemented layer of fossiliferous sands observed within the Castle Hayne aquifer could create a difference in groundwater elevations. Other evidence that points to a cumulative aquitard effect is the difference in groundwater elevations within the Castle Hayne aquifer. For example, at the 60 feet deep C3 location the water level elevation is 13.42 feet above MSL, whereas at the 176 feet deep C10 location the water level is 12.64 feet above MSL, a difference of 0.78 feet. These two locations are only ten horizontal feet apart, which indicates that there are most likely confining layers present between the 60-feet deep horizon and the 176-feet deep horizon. A cumulative aquitard effect by individual layers will typically produce differences in groundwater elevations in water levels across the site and may affect contaminant migration.

4.6.3 Aquifer Testing

The following sections present the results from the aquifer testing performed during the OU2 field investigation as defined within Section 3.11. These results were collected from:

- C2 Step Drawdown Test
- S2 Extended Development Test
- 24-Hour Background Test
- S2 72-Hour Aquifer Test

These results included analysis of discharge rates of the C2 and S2 tests, transmissivity and storativity values for the surficial and Castle Hayne aquifers, and the cone of depression from the center of each pumping well.

The C2 Step Drawdown Test and the S2 Extended Development Test are known as step discharge tests. Although step-drawdown tests involve four or five pumping periods with increasing discharge rates, they also involve similar procedures used for extended period testing, and therefore, produce reasonable estimates of aquifer properties. The transmissivity values generated from the data can be considered reliable estimates of aquifer properties.

4.6.3.1 Results From C2 Step Drawdown Test

Estimation of Maximum Discharge Rates

One of the main purposes for conducting an aquifer step test is to estimate the maximum discharge rate that an aquifer (at the particular well location) is able to sustain over a given period of time without dewatering the pumping well. This is accomplished by pumping water from a well and determining if the water level stabilizes during the given time period. For the C2 Step test, this method was used in order to estimate a possible maximum sustainable rate for wells installed in the Castle Hayne aquifer. Table 3-10 provides the discharge rate and length of pumping for each rate used during the C2 Step test.

The discharge rate and the resultant drawdown of water levels with respect to the static water level (in feet bgs) for well C2 during the C2 Step test are provided below.

Step No.	Discharge Rate (gpm)	Water level (ft bgs) *	Drawdown (ft)
0	5.3	21.61	5.45
1	8.1	26.94	10.78
2	10.2	30.65	14.49
3	12.6	35.25	19.09
4	14.7	38.71	22.55

* Static water level in well C2 before the test began was 16.16 feet bgs.

The static water level for the 90-foot deep C2 well was 16.16 feet bgs before the step test was initiated. During the final step of the test the water level dropped to 38.71 feet bgs, leaving a water column of 51.29 feet remaining in the well. This indicates that the aquifer was not sufficiently stressed during the test to determine a possible maximum discharge rate for the Castle Hayne aquifer at this location. This is principally due to mechanical limitations of the pump. A rate of more than 15 gallons per minute can obviously be sustained in this portion of the Castle Hayne aquifer.

Cone of Depression

Monitor wells and piezometers that were used as observation wells during the C2 Step test included three from the surficial aquifer (S2, PZ-04, and PZ-06) and two from the Castle Hayne aquifer (PZ-03 and PZ-05). The maximum distance of an observation point from the C2 location was 61 feet at piezometer PZ-05 and -06. Of those wells and piezometers used as observation points during the test, all showed evidence of drawdown of water levels in varying amounts, as a response to pumping of monitor well C2.

The cone of depression is the area around the pumping well where the hydraulic head in the aquifer has been lowered by the pumping. The table below displays the amount of drawdown that occurred in each observation well at the end of the final pumping step of the C2 step test relative to the static water table (as measured by the pressure transducers present in the observation wells).

Observation Well No.	Aquifer Screened	Distance from Pumping Well (feet)	Drawdown (feet)
S2	surficial	5	0.301
PZ-03	Castle Hayne	40	1.778
PZ-04	surficial	40	0.365
PZ-05	Castle Hayne	61	1.134
PZ-06	surficial	61	0.336

For the Castle Hayne aquifer, the cone of depression was most likely a much greater distance than 61 feet in radius, as evidenced by the high amount of drawdown in PZ-05. Within the surficial aquifer the cone of depression appears to have been a shallow yet extensive area as evidenced by the even drawdown values for the surficial aquifer observation points. This may reflect changes in thickness or lithology of the confining unit separating the two aquifers, and, therefore, reflects changes in the degree of hydraulic communication between the two aquifers.

The fact that drawdown occurred in both aquifers indicates that the surficial and Castle Hayne are interconnected and are in hydraulic communication with one another; however, unequal drawdown of water levels occurring within the aquifers indicates that the Castle Hayne is under semi-confined conditions. Further, depending upon the extent of interconnection between the aquifers, contaminants may migrate from the surficial into the Castle Hayne.

Hydrogeologic Aquifer Parameter Calculations

Transmissivity values for the Castle Hayne aquifer were estimated from the C2 Step Drawdown test data using methods described in Section 3.11. Arithmetic average values of transmissivity for the Castle Hayne aquifer for each step of the test, as described by the observation points, are given in Table 4-4.

Table 4-4

Transmissivity Values as Determined by Specific Capacity for Each Step of C2 Step Drawdown Test for Castle Hayne Observation Points

Step No.	Length of Step (min)	Specific Capacity (gpm/ft)	Transmissivity (gpd/ft)	T (ft^2/day)
0	60	0.97	1,940	259
1	62	0.75	1,500	200
2	61	0.70	1,400	187
3	61	0.66	1,320	176
4	240	0.65	1,300	174
Recovery	288		254	34

As can be seen in Table 4-4, average transmissivity values tend to decrease with each step. As seen below, results from the analyses of recovery data give an average transmissivity of approximately 230 ft^2/day.

WELL NO.	AQUIFER	PHASE	SOLUTION METHOD	TRANSMISSIVITY (ft^2/day)
C2	Castle Hayne	RECOVERY	THEIS RECOVERY	34
PZ-03	Castle Hayne	RECOVERY	THEIS RECOVERY	427

NOTE: PZ-05 recovery data was not included on table because of mechanical failure of pressure transducer producing erroneous results.

4.6.3.2 Results from S2 Extended Development Test

The results of the S2 Extended Development include a discussion of the possible maximum discharge rate that was used during the 72-hour aquifer test, a discussion of the extent of the cone of depression, and a presentation of transmissivity and storativity values obtained from the drawdown data. A limited discussion (because of the 72-hour testing of the same well (S2) and the same observation wells) is provided of the transmissivity values.

Aquifer Test Parameter Results

As with the C2 Step Test, an estimated maximum discharge rate that the surficial aquifer (at the S2 well location) is able to sustain over a given period of time was calculated using the S2 Extended Development Test (S2 Test) results. The S2 Test data was used to determine a possible rate for other wells installed within the surficial aquifer; however, geologic conditions, which will influence discharge rates, often vary across the aquifer. Table 3-11 provides the discharge rates and the length of pumping for each rate used during the S2 Test.

The discharge rate and the resultant drawdown of water levels with respect to the static water level (in feet bgs) for well S2 during the S2 Test are provided below.

Step No.	Discharge Rate (gpm)	Water level (ft bgs)	Drawdown (ft)
0	4.6	19.92	3.87
1	6.3	21.45	5.40
2	8.6	23.26	7.21
3	12.2	26.21	10.16
4	15.8	29.21	13.16

Note: Static water level in pre-test S2 well was 16.05 feet bgs.

The static water level for the approximately 40-foot deep S2 well was 16.05 feet bgs before the test commenced. During the test, as discharge rates were increased, the drawdown of water level in well S2 continuously increased, until the water column in the S2 well was less than 11 feet. The water column height was even smaller (7.8 feet) between the location of the pump intake (approximately 37 feet bgs) and the top of the water level. More importantly, as the raw drawdown data from the last step of this test (Appendix F) suggest, the water level was continuing to drop and had not equilibrated as may occur after an aquifer has responded to an increased discharge rate.

Since water levels in the S2 well were continuing to drop over the length of the last pumping step, the data suggest that the discharge rate of 15.8 gallons per minute (gpm) used during the last pumping step of the S2 Test is beyond the surficial aquifer's (at the S2 location) ability to sustain. A rate of less than 15.8 gpm would have to be used in order to not draw the water column down past the pump intake. This rationale was used in establishing a discharge rate for the S2 72-hour aquifer test, as explained below.

Since the maximum discharge rate used during the S2 Test could not be used in the 72-hour aquifer test without drawing the water level beyond the level of the pump intake (approximately 37 feet bgs), a new maximum sustainable discharge rate would have to be defined. The following guide was used to define a possible new rate.

Step No.	Discharge Rate (gpm)	Change in Rate (gpm)	Cumulative Change (gpm)	Drawdown (ft)	Change in Drawdown (ft)	Cumulative Change (ft)	Water Level Above Pump (ft)
0	4.6			3.8			17.2
1	6.3	1.7	1.7	5.4	1.6	1.6	15.6
2	8.6	2.3	4	7.2	1.8	3.4	13.8
3	12.2	3.6	7.6	10.1	2.9	6.3	10.9
4	15.8	3.6	11.2	13.1	3.0	9.3	7.9

The guide helps to define a new maximum sustainable discharge rate by allowing comparison of discharge rate columns to drawdown columns. The discharge rate is also compared to the water level above the pump. The main focus is to estimate which discharge rate the aquifer can sustain and still allow a buffer zone between pump location and top of water level above the pump. The changes in discharge will produce changes in drawdown, which are examined to note how much change in drawdown actually occurred. If an increased discharge rate is too large for an aquifer to sustain, the resultant drawdown will show larger increases. A limitation of the guide is that it does not show whether the water level above the pump equilibrated in response to the discharge rate or not; however, along with the raw data (Appendix F), a determination can be made as to which rate the aquifer may sustain.

As can be seen from this guide, as the discharge rate from S2 increased, drawdown inside well S2 increased, as expected. However, the larger increase in drawdown between Steps 3 and 4, as a result of a slight increase in discharge, was unexpected. Therefore, as a result of the large increase in drawdown and the raw data (Appendix F) suggesting that the water level was not equilibrating, a discharge rate of less than 15.8 gpm and more than 12.5 was thought to be the most appropriate. Based on this guide, a value of 13.0 to 13.1 gpm was estimated as an adequate discharge rate that the surficial aquifer at well S2 would be able to sustain.

Cone of Depression

The monitor wells and piezometers used as observation wells during the S2 Test included three from the Castle Hayne aquifer (C2, PZ-03, and PZ-05) and two from the surficial aquifer (PZ-04 and PZ-06). The maximum distance of an observation point from the S2 location was 61 feet at piezometer PZ-05 and -06. All wells and piezometers used during the test as observation points showed evidence of drawdown in water levels to some degree.

The following table displays the amount of drawdown that occurred in each observation well at the end of the final pumping step of the S2 Test relative to the static water table (as measured by the pressure transducers present in the observation well).

Observation Well No.	Aquifer Screened	Distance from Pumping Well (feet)	Drawdown (ft bgs)
C2	Castle Hayne	5	0.397
PZ-03	Castle Hayne	40	0.412
PZ-04	Surficial	40	2.4
PZ-05	Castle Hayne	61	0.381
PZ-06	Surficial	61	1.411

The data within the table indicate that the cone of depression created by discharge at well S2 exceeds a 61-foot radius for both aquifers. For the surficial aquifer, the cone of depression was most likely much larger by the amount of drawdown observed in PZ-06. The cone of depression in the Castle Hayne is not as areally extensive as evidenced by decreased drawdown values in all three Castle Hayne observation points.

Drawdown occurred in both aquifers while pumping from only one aquifer during the S2 Test. This same reaction was produced during the C2 Step test. The S2 data reconfirms that the aquifers are interconnected to some degree.

Hydrogeologic Aquifer Parameter Calculations

The aquifer parameter of transmissivity for the surficial aquifer was calculated from the S2 Extended Development Test data using methods described above in Section 3.11. Table 4-5 presents the results for each step and each corresponding well or piezometer.

Average values of the transmissivity and storativity from each step of the S2 Test for the surficial aquifer are provided in Table 4-5. As stated in Section 3.11, these values of transmissivity are theoretical and assume 100 percent well efficiency. They can be compared to transmissivity values calculated from the 72-hour aquifer test to determine well efficiency. Recovery data (shown below) provided an average of 321 ft^2/day for transmissivity of the surficial aquifer. The overall average transmissivity for the pumping phases for the surficial aquifer was 239 ft^2/day, which equals a hydraulic conductivity of approximately 5 ft/day. According to Morris and Johnson (1967), this corresponds to an aquifer composed of medium to coarse sand, which is similar to the material composing the surficial aquifer.

WELL NO.	AQUIFER	PHASE	SOLUTION METHOD	TRANSMISSIVITY (ft^2/day)
PZ-06	Surficial	PUMPING	THEIS	1770
S2	Surficial	RECOVERY	THEIS RECOVERY	79
PZ-04	Surficial	RECOVERY	THEIS RECOVERY	397
PZ-06	Surficial	RECOVERY	THEIS RECOVERY	488

Table 4-5

Transmissivity Value as Determined by Specific Capacity for Each Step of S2 Extended Development Test for Surficial Aquifer Observation Points

Step No.	Length of Step (min)	Specific Capacity (gpm/ft)	Transmissivity (gpd/ft)	T (ft^2/day
0	62	1.19	1,785	239
1	63	1.17	1,755	235
2	30	1.19	1,785	239
3	30	1.20	1,800	240
4	59	1.20	1,800	240
Recovery				321

4.6.3.3 Results of the 24-Hour Background Test

All wells or piezometers acting as observation points during the 72-hour aquifer test through the use of pressure transducers were monitored for 24 hours prior to the start of the aquifer test to determine if there were any external influences on the static water levels in the wells. The influences include changes as a result of tides, discharge from other wells, etc. The results of the test are discussed below. Graphs of the resultant data from the test are found in Appendix F.

Examination of the background test data reveals that there does appear to be a slight tidal influence on the water table across the entire site. The graphs of these data show that during the 24-hour period, on average, water levels dropped 0.06 feet and rose as much as 0.08 feet. The overall trend was cyclic as the water levels appeared to have dropped during the first three hours of monitoring, rose during the next six hours, and then dropped during the next six-hour period (see plots for C3, PZ-02, and PZ-05). This periodic rise and fall of water levels is indicative of tidal cycles.

However, because the water level rise or fall in each cycle was less than 0.1 feet over the entire 24-hour test, the tidal influence on water levels during the 72-hour test was not considered significant. The small change in water levels due to tides would not significantly affect the influence of discharge from well S2 on observation wells within the cone of depression, except possibly for those on the fringe.

4.6.3.4 Results From S2 72-Hour Aquifer Test

The 72-hour aquifer test was conducted using the surficial aquifer well S2 as the pumping well and twelve other wells as observation points. The surficial aquifer wells and piezometers used as observation points included S1, S3, S6, S7, PZ-02, -04, and -06. Castle Hayne aquifer observation points included C1, C2, C3, PZ-01, -03, and -05. All of the drawdown data collected from these wells and piezometers were used in the calculation of hydraulic properties of the surficial aquifer and determining the effects that pumping in the surficial aquifer has on the water levels of the Castle Hayne aquifer monitor wells. In addition, wells S8, S9, and C9 were used as observation points for determination of cone of depression extent.

The following discussion of data focuses on: (1) the cone of depression created during the S2 aquifer test; and (2) the aquifer properties calculated from the data.

Cone of Depression

The pumping of well S2 at approximately 13.1 gpm over a 72-hour period produced a wide cone of depression within both aquifers. Aquifer response to the discharge at well S2 is indicative of properties conducive to contaminant retention and/or cleanup.

The table below displays the amount of drawdown that occurred in each observation well at the end of the pumping phase relative to the static water table (as measured by pressure transducers and manually).

Well No.	Aquifer Screened	Distance from Pumping Well (ft)	Observed Maximum Drawdown (ft)
C1	Castle Hayne	427	0.52*
S1	Surficial	425	0.72*
C2	Castle Hayne	5	0.922
C3	Castle Hayne	801	0.047
S3	Surficial	798	0.339
PZ-02	Surficial	110	1.29
PZ-03	Castle Hayne	40	0.936
PZ-04	Surficial	40	2.814
PZ-05	Castle Hayne	60	0.638
PZ-06	Surficial	60	1.168
S6	Surficial	240	0.95*
S7	Surficial	200	0.83*
S8	Surficial	520	0.26*
S9	Surficial	960	0.32*
C9	Castle Hayne	870	0.31*

* Indicates data on drawdown from manual measurements.

For the surficial aquifer, the data within the table indicates that the extreme edge of the cone of depression was beyond well S9, which, at 960 feet, was the most distant observation location from S2. Therefore, the cone of depression may have been over 1,920 feet in diameter, assuming homogeneity exists in the aquifer. For the Castle Hayne, the data within the table indicates that the capture zone was beyond the C9 location, which is the farthest Castle Hayne observation point from S2 (approximately 870 feet). Therefore, the entire cone of depression within the Castle Hayne may have been over 1,740 feet in diameter.

A review of the table above also reveals that, as expected, the drawdown of water levels was greater within surficial aquifer observation points. Also, drawdown was more pronounced on surficial and Castle Hayne aquifer wells and piezometers that are within 200 feet of well S2. These data suggest that potential contaminant removal by pumping of the surficial aquifer, depending upon the pumping rate, will extract a majority of the groundwater from the aquifer in which the pump resides and thereby reducing contaminant levels more significantly within that aquifer; however, the fact that water levels in both aquifers displayed a response to pumping from one aquifer indicates that the aquifers are interconnected to some degree.

Hydrogeologic Aquifer Parameter

Transmissivity and storativity were calculated from the drawdown data of the surficial aquifer observation wells (where pertinent) from the S2 72-Hour Aquifer Test using methods described above in Section 3.11. Table 4-6 presents the results for the pumping and recovery phases for each corresponding well or piezometer. The average of all the calculated transmissivity and storativity values for the pumping and recovery phases for each aquifer are also presented in the table.

All pertinent drawdown data from surficial aquifer observation points were analyzed by the Theis (1935) and Neuman (1975) method. The surficial aquifer observation point data were used to calculate an average transmissivity value of 1,469 ft^2/day. The average storativity for the surficial aquifer observation points is 1.731×10^{-3}. Hydraulic conductivity calculated from the average transmissivity of 1,469 ft^2/day for the surficial aquifer equals 29 ft/day, which,

Table 4-6

Aquifer Parameter Estimates From S2 72-Hour Aquifer Test
October 1993
ABC One-Hour Cleaners
Operable Unit 2

WELL NO.	PHASE	AQUIFER	SOLUTION METHOD	TRANSMISSIVITY (ft^2/day)	STORATIVITY
S1	PUMPING	Surficial	THEIS	2,180	*
S3	PUMPING	Surficial	NEUMAN	257	0.001731
PZ-02	PUMPING	Surficial	THEIS	1,374	0.0003326
PZ-02	PUMPING	Surficial	NEUMAN	1,356	0.0005278
PZ-04	PUMPING	Surficial	THEIS	1,127	*
PZ-04	PUMPING	Surficial	NEUMAN	431	*
PZ-06	PUMPING	Surficial	THEIS	2,530	0.002111
PZ-06	PUMPING	Surficial	NEUMAN	2,422	0.003954
S6	PUMPING	Surficial	THEIS	1,308	*
S7	PUMPING	Surficial	THEIS	1,701	*
Surficial Aquifer Average:				1,469	0.001731

Table 4-6 (Continued)

Aquifer Parameter Estimates From S2 72-Hour Aquifer Test
October 1993
ABC One-Hour Cleaners
Operable Unit 2

WELL NO.	PHASE	AQUIFER	SOLUTION METHOD	TRANSMISSIVITY (ft^2/day)	STORATIVITY
S2	RECOVERY	S	THEIS RECOVERY	65	NA
PZ-02	RECOVERY	S	THEIS RECOVERY	980	NA
PZ-04	RECOVERY	S	THEIS RECOVERY	395	NA
PZ-06	RECOVERY	S	THEIS RECOVERY	595	NA
Surficial Aquifer Average:				509	NA

* Storativity values for these wells were not used in computation of the average.
NA = Not applicable

according to Morris and Johnson (1967), corresponds to an aquifer made of fine to medium grained sand. As a result, this value is considered to be the more accurate of the three calculated for the surficial aquifer.

The recovery phase data from the S2 aquifer test were also used to produce average transmissivity values for the surficial aquifer. For the surficial aquifer, the average transmissivity for the S2 aquifer test data is 509 ft^2/day. This value is considerably lower than earlier calculated values and probably represents the endpoint of the low range of transmissivity values. This surficial aquifer transmissivity value provides a hydraulic conductivity value of 10 ft^2/day.

4.6.3.5 Summary of Estimated Hydrogeologic Parameters

The most intensive pumping test for each aquifer (the S2 aquifer test in the surficial aquifer, and the C2 Step test in the Castle Hayne aquifer) will be used to estimate the aquifer parameters for future groundwater modeling. These values are provided below.

Test Type	Aquifer	Transmissivity (ft^2/day)	Storativity	Cone of Depression/Pumping (radius-ft)	Hydraulic Conductivity (ft/day)
C2 Step Drawdown	Castle Hayne	1,690	--	> 61 @ 14.7 gpm	--
S2 72-Hour Aquifer Test	Castle Hayne	--	--	> 870 @ 13.1 gpm --	-- --
	Surficial	1,452 (P) 509 (R)	--	> 960 @ 13.1 gpm --	29 10

-- = Value not obtainable.
P = Pumping phase
R = Recovery phase

4.7 DEMOGRAPHY AND LAND USE

4.7.1 Regional

According to the 1990 U.S. Census, Onslow County is ranked 9th in population among 100 North Carolina counties, with a population of 149,838. Onslow County covers 763 square miles. Approximately 45% of the county's population resides in the City of Jacksonville or on the Base. The Base covers a land area of 19.59 square miles with a population of 36,716, ranking it as the 18th most populated area in North Carolina. The City of Jacksonville covers a land area of 12.99 square miles with a population of 30,013, ranking it as the 20th most populated area in the state. Both areas are densely populated with a population density of approximately 1,874 persons per square mile within the Base and a population density of approximately 2,310 persons per square mile in the City of Jacksonville.

Based on a telephone conversation with the City of Jacksonville Planning office, approximately 75% of the City of Jacksonville is developed.

4.7.2 Site-Specific

The ABC site is located within the Jacksonville city limits. The population within a 1-mile radius of the site is approximately 2,800 and includes approximately 726 houses (McMorris, 1987).

Properties in the areas to the east and west of the ABC site are presently used for general business purposes. These include both commercial and retail establishments. To the north of the site are residential areas, including Pinewood Downs, a multi-family residential development. Land located to the south of the site is partially wooded and is a Base housing community (Tarawa Terrace I).

4.8 ECOLOGY

4.8.1 Regional

The U.S. Department of the Interior, Fish and Wildlife Service lists three threatened species in Onslow County. These include the American alligator, the green sea turtle, and the loggerhead sea turtle. In addition, it lists six endangered species in Onslow County. These include the red-cockaded woodpecker, the rough-leaved loose strife, Cooley's meadowrus, the Eastern cougar, the leatherback sea turtle, and the Kemp's Ridley sea turtle.

The *Initial Assessment Study of Marine Corps Base, Camp Lejeune, North Carolina*, April 1983, lists additional threatened species at the Base, located south of the dry cleaning facility. These include the Venus Flytrap, Yellow, Sweet, Hooded, and Venus Flytrap Pitcher Plants. The study also lists the Brown Pelican as an endangered species.

4.8.2 Site-Specific

There are no habitat areas in the immediate vicinity of the site. The site includes several commercial and residential buildings, paved roads and paved parking areas, and areas of mowed grassy fields and small stands of pine trees. This configuration inhibits the formation of habitat areas, as it is completely developed. Given the nature of the ABC site, it is unlikely that any of the threatened or endangered species described in Section 4.8.1 would be present at the site or directly impacted from contaminants present at the site.

Groundwater flow is generally from the higher elevations in the northwest corner of the site to the lower elevations in the southeast corner of the site, where it discharges into Northeast Creek. Due to the absence of streams or wetlands on the site, the immediate area appears to represent a zone of recharge to the surficial aquifer.

4.9 REFERENCES

Morris, D.A. and Johnson, A.I., 1967. Summary of Hydrologic and Physical Properties of Rock and Soil Materials, as Analyzed by the Hydrologic Laboratory of the U.S. Geologic Survey, 1948-60. U.S. Geological Survey Water-Supply Paper 1839-D, 42 p.

Neuman, S.P., 1975. Analysis of pumping test data from anisotropic unconfined aquifers considered delayed gravity response. Water Resources Research, V. 10, p. 303-312.

Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage. Transactions of the Amer. Geoph. Union, V. 16, p. 519-524.

United States Department of Agriculture, Soil Conservation Service, 1992. *Soil Survey of Onslow County, North Carolina*. Publ. of Nat'l. Cooperative Soil Survey. 139p., illust.

SECTION 5

NATURE AND EXTENT OF CONTAMINATION

This section discusses analytical results for all samples collected as a part of OU2. Where appropriate, analytical results of OU1 have been included for discussion and/or comparative purposes. Specifically, soil boring data collected during the OU1 field investigation which were not reported in the OU1 Remedial Investigation Report have been included.

During the course of the OU2 field investigation program, three media were sampled (septic tank sludge, soil, and groundwater) to evaluate the nature and extent of contamination at the ABC site. Septic tank sampling efforts involved collecting a grab sample of the septic tank sludge. According to historical information, the septic tank was taken off-line in 1985. Soil sampling efforts focused on surficial and subsurface soils directly beneath and immediately adjacent to the ABC facility. Groundwater sampling efforts focused on resampling of existing wells (installed during OU1), and installation of new monitoring wells to define cited OU1 data gaps.

Based upon the analytical results from OU1, in which PCE and its derivatives (TCE, DCE, and vinyl chloride) were determined to be the primary contaminants of concern, OU2 matrix samples were analyzed for TCL-VOCs only. Primary samples, QA/QC samples, inclusive of field duplicates, rinse blanks, trip blanks, and matrix spikes, were submitted through the EPA Contract Laboratory Program (CLP) or directly to EPA's Environmental Services Division for analysis. Analytical data sheets for OU2 and OU1 soil boring samples, OU2 groundwater samples, and the OU2 septic sludge sample are presented in Appendix B of this report.

5.1 SOURCE AREA

The septic tank and areas surrounding the ABC facility where still bottoms were utilized to fill "potholes" have been identified as potential source areas.

As determined from previous investigations (Law, 1986a; Law 1986b; WESTON, 1992), and confirmed through this investigation, the presence of VOCs in unsaturated soils underlying and surrounding ABC supports the conclusion that the septic tank serves as the principal source for contamination to both groundwater and soils of the area. The secondary source of contamination involved the historical practice of placing still bottoms, consisting of powder residues, in the dirt drive located west of the ABC building as a "pothole" filler. Over the 30-year operational period of the dry cleaning facility, it is estimated that over 1 ton of still bottoms were disposed of in such a manner.

The following subsections present the results of Remedial Investigation sampling efforts regarding septic tank contents and probable extent of VOC contamination present in surficial and subsurface soils of the ABC site.

5.1.1 Septic Tank Sample

Due to an error in sampling protocol, the OU1 septic tank sludge sample was suspect. Therefore, as part of OU2 field operations, WESTON collected one grab sample (ABC-ST-02) from the septic tank. Visual observations at the time of tank opening indicated the presence of a liquid phase (approximately 1 to 1.5 feet deep) overlying 5 feet of septic sludge. Similar observations were apparent during OU1 when discrete samples were collected of both the liquid and sludge phases.

Analytical results of septic samples are presented in Table 5-1. Of note is the "estimated" PCE concentration of 230,000 µg/kg reported for the OU1 septic sludge (SS-011-02). This concentration is approximately 1,000 times less than the 240,000,000 µg/kg range reported for the sample collected for OU2. However, the OU2 result was qualified with a footnote ("U") indicating that the compound was analyzed for but not detected. According to conversations with a representative at EPA's Environmental Services Division (EPA, 1993), complications arose when trying to quantify the concentrated sample:

> "Although the septic tank sample and an accompanying laboratory blank were analyzed by the CLP laboratory, the concentrations were such that the sample required dilution. Upon dilution and re-analysis, the results indicated concentrations of 10 times less than that of the laboratory blank (non-detectable according to established CLP protocols). Based upon these results, a review of the initial analysis of the sample was performed and PCE concentrations in the range of 240,000,000 µg/kg were estimated."

Analytical results for all other TCL-VOC parameters could not be determined; but are reported as 160,000,000 µg/kg with a "U" data qualifier (Appendix B).

Table 5-1

Results of Analyses of Septic Tank Samples For Volatile Organic Compounds ABC One-Hour Cleaners Operable Units 1 and 2

Parameter	SS-011-01 6/29/91	SS-011-02 6/29/91	ST-02 9/22/93
Vinyl Chloride	4,000	7,900 J	< 16,000,000
Cis-1,2-Dichloroethene	6,700	63,000	< 16,000,000
Chloroform	< 2,000	< 10,000	< 16,000,000
Trichloroethene	840 J	3,400 J	< 16,000,000
Bromodichloromethane	< 2,000	< 10,000	< 16,000,000
Tetrachloroethene	6,800	230,000	< 250,000,000
Dibromomethane	< 2,000	< 10,000	< 16,000,000

Notes: SS-011-01 and SS-011-02 units are micrograms per liter (μg/l).
ST-02 units are micrograms per kilogram (μg/kg).
SS-011-01 was sampled from liquid phase.
SS-011-02 was sampled from sludge phase.
< indicates that a material was analyzed for but not detected. The reported value is the minimum quantitation limit.
J indicates an estimated value.

These results further suggest that the septic tank system represents a historical source for chlorinated VOCs observed for both area soils and groundwater.

5.1.2 Soils

Soil sampling was conducted during both operable units of the RI to evaluate the horizontal and vertical extent of contamination. Sample locations included standard soil borings as well as soil borings for the soil vapor extraction (SVE) system vents and monitoring probes. Similar methods were employed for each of the soil boring tasks as described in Section 3.

5.1.2.1 Soil Borings

A total of 65 soil samples were submitted for TCL-VOC analysis during the soil boring installation program for OU2. As discussed in Section 3.2, the samples were collected on five-foot centers beginning with a sample from the ground surface and concluding at borehole termination. Figure 5-1 presents the locations of Remedial Investigation soil borings.

A total of nine soil borings, involving the collection of 21 discrete samples, were installed during field activities associated with OU1. The analytical results of samples collected during OU1 (June 1991) were not presented in the OU1 RI report based upon a decision by EPA that an additional soil investigation (OU2) would be required to further define the extent of contamination beneath the ABC facility. TCL-VOC sample analytical data from OU1, coupled with the results of OU2, allows for the estimation of the horizontal and vertical extent of VOC contamination within the unsaturated soil profile underlying and adjacent to the ABC building and immediate vicinity.

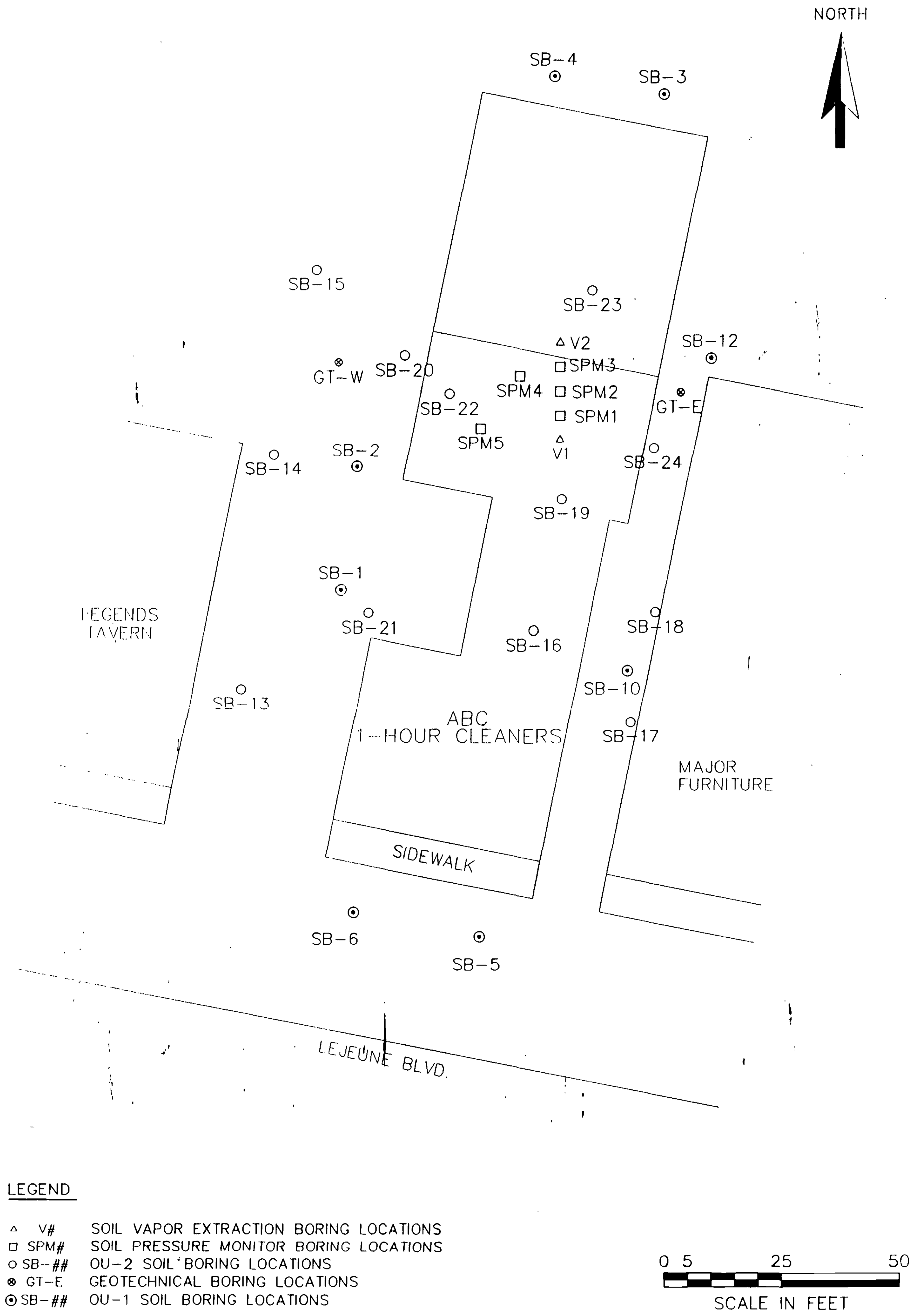


FIGURE	5-1
DATE	10/25/93
REVISION	0
DRAWN BY	J.C., W.M.
FILE	04400-01.DWG

SOIL BORING
LOCATIONS
REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

Volatile Organic Compounds

Table 5-2 presents the VOC analysis data for soil samples collected during the field investigations within and around the ABC building. Of the VOCs analyzed for, seven compounds generally associated with the dry cleaning industry were detected above the laboratory analytical detection limit: PCE; TCE; 1,2-dichloroethene (total) (1,2-DCE); vinyl chloride; chloroform; 1,1-dichloroethene (1,1-DCE); and toluene. In general, three compounds (PCE, TCE, and 1,2-DCE) were detected at consistently higher concentrations, both interior and exterior to the ABC building.

Since vinyl chloride, chloroform, 1,1-DCE, and toluene were detected in a lesser number of samples, these compounds are discussed as a group. Specifics regarding the vertical and horizontal extent of contamination for these compounds are discussed within this section.

PCE

Figure 5-2 presents soil sample locations and concentrations of PCE detected at various depths. PCE was by far the most prominent contaminant in all soil samples. Moreover, PCE was observed to have the highest concentrations for all VOCs detected. In general, concentrations of PCE tended to be the highest in samples from the 0 to 2 feet bgs interval. PCE contamination appeared to be heavily concentrated in soils underlying the building in the immediate area of the septic tank.

Within the immediate area of the septic tank, some degree of PCE contamination was observed in borings V1, V2, SPM-1, -2, and -5, SB-19, -22, and -23. The concentrations of PCE within

Table 5-2

Soil Sample Analysis Results Summary
ABC One-Hour Cleaners
Operable Unit 1 (June 1991) and
Operable Unit 2 (September 1993)

	Contaminant Concentrations [1]						
Sample Identification [2]	**Tetrachloro-ethene**	**Tri-chloroethene**	**1,2,-Dichloroethene (total)**	**Vinyl Chloride**	**Chloro-form**	**1,1-Dichloroethene**	**Toluene**
SS-001-01-06*	640	96	95	<57	<29	<29	<29
SS-001-01-10*	37	2J	<6	<11	<6	<6	<6
SS-001-01-14*	440	16J	<28	<56	<28	<28	<28
SS-002-01-02*	10	2J	<5	<11	<5	<5	2J
SS-002-01-06*	19	72	200	42	<8	<8	<8
SS-002-01-10*	27J	110	730	55J	<30	<30	14J
SS-002-01-14*	<740	<740	1,800	<1,500	<740	<740	<740

[1] concentration reported in μg/kg - micrograms per kilogram

[2] indicates depth of sample bgs

* - OU1 samples collected June 1991. KEY: SS-001-01-06 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth.
SS-016-01-015 is nomenclature for soil sample; soil boring number; sampling interval; and sample collection depth.

J - estimated value

< - not detected above identified quantitation limit

Table 5-2 (Continued)

Soil Sample Analysis Results Summary
ABC One-Hour Cleaners
Operable Unit 1 (June 1991) and
Operable Unit 2 (September 1993)

	Contaminant Concentrations [1]						
Sample Identification [2]	**Tetrachloro-ethene**	**Tri-chloroethene**	**1,2,-Dichloroethene (total)**	**Vinyl Chloride**	**Chloro-form**	**1,1-Dichloroethene**	**Toluene**
SS-003-01-06*	<6	<6	<6	<12	<6	<6	<6
SS-003-01-10*	<6	<6	<6	<12	<6	<6	2J
SS-003-01-14*	<29	<29	<29	<58	<29	<29	<29
SS-004-01-12*	<6	<6	<6	<12	<6	<6	<6
SS-004-01-16*	<6	<6	<6	<12	<6	<6	2J
SS-005-01-06*	3J	<6	<6	<13	<6	<6	9

[1] concentration reported in μg/kg - micrograms per kilogram

[2] indicates depth of sample bgs

* - OU1 samples collected June 1991. KEY: SS-001-01-06 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth.
SS-016-01-015 is nomenclature for soil sample; soil boring number; sampling interval; and sample collection depth.

J - estimated value

< - not detected above identified quantitation limit

Table 5-2 (Continued)

Soil Sample Analysis Results Summary
ABC One-Hour Cleaners
Operable Unit 1 (June 1991) and
Operable Unit 2 (September 1993)

	Contaminant Concentrations [1]						
Sample Identification [2]	**Tetrachloro-ethene**	**Tri-chloroethene**	**1,2,-Dichloroethene (total)**	**Vinyl Chloride**	**Chloro-form**	**1,1-Dichloroethene**	**Toluene**
SS-005-01-12*	<6	<6	<6	<13	<6	<6	2J
SS-006-01-12*	<6	<6	<6	<12	<6	<6	7
SS-006-01-14*	<7	<7	<7	<13	<7	<7	22
SS-007-01A-10*	<6	<6	<6	<11	<6	<6	<6
SS-007-01B-10*	<6	<6	<6	<12	<6	<6	10
SS-007-01-14*	<6	<6	<13	<6	<6	<6	5J

[1] concentration reported in $\mu g/kg$ - micrograms per kilogram

[2] indicates depth of sample bgs

* - OU1 samples collected June 1991. KEY: SS-001-01-06 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth. SS-016-01-015 is nomenclature for soil sample; soil boring number; sampling interval; and sample collection depth.

J - estimated value

< - not detected above identified quantitation limit

Table 5-2 (Continued)

Soil Sample Analysis Results Summary
ABC One-Hour Cleaners
Operable Unit 1 (June 1991) and
Operable Unit 2 (September 1993)

	Contaminant Concentrations [1]						
Sample Identification [2]	**Tetrachloro-ethene**	**Tri-chloroethene**	**1,2,-Dichloroethene (total)**	**Vinyl Chloride**	**Chloro-form**	**1,1-Dichloroethene**	**Toluene**
SS-009-01-06*	<46	<46	<46	<46	<46	<46	<46
SS-009-01-12*	<42	<42	<42	<42	<42	<42	<42
SS-010-01-04*	2100J	<10,000	<10,000	<10,000	<10,000	<10,000	<10,000
SS-010-01-10*	210J	<1,600	<1,600	<1,600	<1,600	<1,600	<1,600
SS-010-01-14*	90J	<170	<170	<170	<170	<170	<170
SS-012-01-04*	<38	<38	<38	<38	<38	<38	12J

[1] concentration reported in μg/kg - micrograms per kilogram

[2] indicates depth of sample bgs

* - OU1 samples collected June 1991. KEY: SS-001-01-06 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth. SS-016-01-015 is nomenclature for soil sample; soil boring number; sampling interval; and sample collection depth.

J - estimated value

< - not detected above identified quantitation limit

Table 5-2 (Continued)

Soil Sample Analysis Results Summary
ABC One-Hour Cleaners
Operable Unit 1 (June 1991) and
Operable Unit 2 (September 1993)

	Contaminant Concentrations [1]						
Sample Identification [2]	**Tetrachloro-ethene**	**Tri-chloroethene**	**1,2,-Dichloroethene (total)**	**Vinyl Chloride**	**Chloro-form**	**1,1-Dichloroethene**	**Toluene**
SS-012-01A-08*	<46	<46	<46	<46	<46	<46	<46
SS-012-01B-08*	<36	<36	<36	<36	<36	<36	11J
SS-012-01-12*	<50	<50	<50	<50	<50	<50	<50
SS-012-01-16*	<33	<33	<33	<33	<33	<33	<33
SS-013-01-00	<11	<11	<11	<11	<11	<11	<5
SS-013-02-05	<11	<11	<11	<11	<11	<11	<5

[1] concentration reported in µg/kg - micrograms per kilogram

[2] indicates depth of sample bgs

* - OU1 samples collected June 1991. KEY: SS-001-01-06 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth. SS-016-01-015 is nomenclature for soil sample; soil boring number; sampling interval; and sample collection depth.

J - estimated value

< - not detected above identified quantitation limit

Table 5-2 (Continued)

Soil Sample Analysis Results Summary
ABC One-Hour Cleaners
Operable Unit 1 (June 1991) and
Operable Unit 2 (September 1993)

	Contaminant Concentrations [1]						
Sample Identification [2]	Tetrachloro-ethene	Tri-chloroethene	1,2,-Dichloroethene (total)	Vinyl Chloride	Chloro-form	1,1-Dichloroethene	Toluene
SS-015-01-00	20	<11	<11	<11	<11	<11	<5
SS-015-02-04	<13	<13	17	<13	<13	<13	<5
SS-015-03-10	<12	<12	<12	<12	<12	<12	<5
SS-015-04-14	<12	<12	<12	<12	<12	<12	<5
SS-016-01-2	49000	2500J	400J	<12	17	<12	<5
SS-016-02-5	27000	920J	150	<12	10J	<12	<5

[1] concentration reported in μg/kg - micrograms per kilogram
[2] indicates depth of sample bgs
* - OU1 samples collected June 1991. KEY: SS-001-01-06 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth. SS-016-01-015 is nomenclature for soil sample; soil boring number; sampling interval; and sample collection depth.
J - estimated value
< - not detected above identified quantitation limit

Table 5-2 (Continued)

Soil Sample Analysis Results Summary
ABC One-Hour Cleaners
Operable Unit 1 (June 1991) and
Operable Unit 2 (September 1993)

	Contaminant Concentrations [1]						
Sample Identification [2]	Tetrachloro-ethene	Tri-chloroethene	1,2,-Dichloroethene (total)	Vinyl Chloride	Chloro-form	1,1-Dichloroethene	Toluene
SS-016-03-10	200	20	50	<12	<12	<12	<5
SS-016-04-15	390	28	22	<11	<11	<11	<5
SS-017-01-2	14	<11	<11	<11	<11	<11	<5
SS-017-02-5	1400J	200	290J	<12	<12	<12	<5
SS-017-03-10	650	130	330	<54	<54	<54	<5
SS-017-04-15	1400J	110	210	<62	<62	<62	<5

[1] concentration reported in μg/kg - micrograms per kilogram

[2] indicates depth of sample bgs

* - OU1 samples collected June 1991. KEY: SS-001-01-06 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth.
SS-016-01-015 is nomenclature for soil sample; soil boring number; sampling interval; and sample collection depth.

J - estimated value

< - not detected above identified quantitation limit

Table 5-2 (Continued)

Soil Sample Analysis Results Summary
ABC One-Hour Cleaners
Operable Unit 1 (June 1991) and
Operable Unit 2 (September 1993)

	Contaminant Concentrations [1]						
Sample Identification [2]	**Tetrachloro-ethene**	**Tri-chloroethene**	**1,2,-Dichloroethene (total)**	**Vinyl Chloride**	**Chloro-form**	**1,1-Dichloroethene**	**Toluene**
SS-018-01-02	830000	<43,000	<43,000	<43,000	<43,000	<43,000	<5
SS-018-01-02A	2100000	33000	<31,000	<31,000	<31,000	<31,000	<5
SS-018-02-05	110000	260000	110000	<16,000	<16,000	<16,000	<5
SS-019-01-02	12000	11000	4300	<1,300	<1,300	<1,300	<5
SS-019-01-02A	300000	120000	<47,000	<47,000	<47,000	<47,000	<5
SS-019-02-05	4900	1400	3100	190	<12	<12	<5

[1] concentration reported in μg/kg - micrograms per kilogram

[2] indicates depth of sample bgs

* - OU1 samples collected June 1991. KEY: SS-001-01-06 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth.
SS-016-01-015 is nomenclature for soil sample; soil boring number; sampling interval; and sample collection depth.

J - estimated value

< - not detected above identified quantitation limit

Table 5-2 (Continued)

Soil Sample Analysis Results Summary
ABC One-Hour Cleaners
Operable Unit 1 (June 1991) and
Operable Unit 2 (September 1993)

	Contaminant Concentrations [1]						
Sample Identification [2]	**Tetrachloro-ethene**	**Tri-chloroethene**	**1,2,-Dichloroethene (total)**	**Vinyl Chloride**	**Chloro-form**	**1,1-Dichloroethene**	**Toluene**
SS-019-03-09	16	<12	<12	<12	<12	<12	<5
SS-019-04-15	5100	<1,400	840J	<1,400	<1,400	<1,400	<5
SS-020-01-00	56	<11	<11	<11	<11	<11	<5
SS-021-01-00	170	14	<11	<11	<11	<11	<5
SS-021-01-00A	94	14	<11	<11	<11	<11	<5
SS-022-01-02	580000	15000	720	<7,000	<7,000	<7,000	<5

[1] concentration reported in $\mu g/kg$ - micrograms per kilogram

[2] indicates depth of sample bgs

* - OU1 samples collected June 1991. KEY: SS-001-01-06 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth. SS-016-01-015 is nomenclature for soil sample; soil boring number; sampling interval; and sample collection depth.

J - estimated value

< - not detected above identified quantitation limit

Table 5-2 (Continued)

Soil Sample Analysis Results Summary
ABC One-Hour Cleaners
Operable Unit 1 (June 1991) and
Operable Unit 2 (September 1993)

	Contaminant Concentrations [1]						
Sample Identification [2]	**Tetrachloro-ethene**	**Tri-chloroethene**	**1,2,-Dichloroethene (total)**	**Vinyl Chloride**	**Chloro-form**	**1,1-Dichloroethene**	**Toluene**
SS-022-01-02A	790000	<130,000	<130,000	<130,000	<130,000	<130,000	<5
SS-022-02-05	21000	1000J	2400	<1,500	<1,500	<1,500	<5
SS-022-03-10	26000	1700	3700	<1,500	<1,500	<1,500	<5
SS-022-04-15	2900	<1,400	670J	<1,400	<1,400	<1,400	<5
SS-023-01-02	41000J	3600J	85J	<14	<14	<14	<5
SS-023-02-05	120	22	12J	<12	<12	<12	<5

[1] concentration reported in $\mu g/kg$ - micrograms per kilogram

[2] indicates depth of sample bgs

* - OU1 samples collected June 1991. KEY: SS-001-01-06 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth. SS-016-01-015 is nomenclature for soil sample; soil boring number; sampling interval; and sample collection depth.

J - estimated value

< - not detected above identified quantitation limit

Table 5-2 (Continued)

Soil Sample Analysis Results Summary
ABC One-Hour Cleaners
Operable Unit 1 (June 1991) and
Operable Unit 2 (September 1993)

	Contaminant Concentrations [1]						
Sample Identification [2]	**Tetrachloro-ethene**	**Tri-chloroethene**	**1,2,-Dichloroethene (total)**	**Vinyl Chloride**	**Chloro-form**	**1,1-Dichloroethene**	**Toluene**
SS-023-03-10	20	14	37	<13	<13	<13	<5
SS-023-04-15	44	85	180	<12	<12	<12	<5
SS-024-01-00	<5,400	440J	<1,400	<1,400	<1,400	<1,400	<5
SS-024-02-05	<1,400	<1,400	<1,400	<1,400	<1,400	<1,400	<5
SS-024-03-10	<1,900	190J	<1,400	<1,400	<1,400	<1,400	<5
SS-024-04-15	<3,000	270J	460J	<1,400	<1,400	<1,400	<5

[1] concentration reported in μg/kg - micrograms per kilogram

[2] indicates depth of sample bgs

* - OU1 samples collected June 1991. KEY: SS-001-01-06 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth.
SS-016-01-015 is nomenclature for soil sample; soil boring number; sampling interval; and sample collection depth.

J - estimated value

< - not detected above identified quantitation limit

Table 5-2 (Continued)

Soil Sample Analysis Results Summary
ABC One-Hour Cleaners
Operable Unit 1 (June 1991) and
Operable Unit 2 (September 1993)

	Contaminant Concentrations [1]						
Sample Identification [2]	**Tetrachloro-ethene**	**Tri-chloroethene**	**1,2,-Dichloroethene *(total)***	**Vinyl Chloride**	**Chloro-form**	**1,1-Dichloroethene**	**Toluene**
SS-SPM1-01-00	49000	1000J	940J	< 1,400	< 1,400	< 1,400	<5
SS-SPM1-02-05	7500	790J	1500	< 1,400	< 1,400	< 1,400	<5
SS-SPM1-03-10	7100	530J	1200J	< 1,400	< 1,400	< 1,400	<5
SS-SPM1-04-14	8900	780J	1800	< 1,400	< 1,400	< 1,400	<5
SS-SPM2-01-00	4400	730J	900J	< 1,300	< 1,300	< 1,300	<5
SS-SPM2-02-05	11000	1600	2300	< 1,400	< 1,400	< 1,400	<5

[1] concentration reported in $\mu g/kg$ - micrograms per kilogram

[2] indicates depth of sample bgs

* - OU1 samples collected June 1991. KEY: SS-001-01-06 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth.
SS-016-01-015 is nomenclature for soil sample; soil boring number; sampling interval; and sample collection depth.

J - estimated value

< - not detected above identified quantitation limit

Table 5-2 (Continued)

Soil Sample Analysis Results Summary
ABC One-Hour Cleaners
Operable Unit 1 (June 1991) and
Operable Unit 2 (September 1993)

	Contaminant Concentrations [1]						
Sample Identification [2]	**Tetrachloro-ethene**	**Tri-chloroethene**	**1,2,-Dichloroethene (total)**	**Vinyl Chloride**	**Chloro-form**	**1,1-Dichloroethene**	**Toluene**
SS-SPM2-02-05A	14000	2200	3100	<1,500	<1,500	<1,500	<5
SS-SPM2-03-10	15000	1500	2000	<27	<27	<27	<5
SS-SPM2-04-15	6000	<1,400	<1,400	<1,400	<1,400	<1,400	<5
SS-SPM5-01-00	43000	<2,500	<2,500	<2,500	<2,500	<2,500	<5
SS-SPM5-02-05	11000	<12	5100	79	<12	<12	<5
SS-SPM5-03-10	3000	<1,400	<1,400	<1,400	<1,400	<1,400	<5

[1] concentration reported in μg/kg - micrograms per kilogram

[2] indicates depth of sample bgs

* - OU1 samples collected June 1991. KEY: SS-001-01-06 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth.
SS-016-01-015 is nomenclature for soil sample; soil boring number; sampling interval; and sample collection depth.

J - estimated value

< - not detected above identified quantitation limit

Table 5-2 (Continued)

Soil Sample Analysis Results Summary
ABC One-Hour Cleaners
Operable Unit 1 (June 1991) and
Operable Unit 2 (September 1993)

	Contaminant Concentrations [1]						
Sample Identification [2]	**Tetrachloro-ethene**	**Tri-chloroethene**	**1,2,-Dichloroethene (total)**	**Vinyl Chloride**	**Chloro-form**	**1,1-Dichloroethene**	**Toluene**
SS-SPM5-04-15	13000	<1,300	990J	<1,300	<1,300	<1,300	<5
SS-V1-01-10	33000	810J	1200J	<1,400	<1,400	<1,400	<5
SS-V1-02-14	47000	1700	3000	<1,400	<1,400	<1,400	<5
SS-V1-02-14A	180000	1100J	<1,400	<1,400	<1,400	<1,400	<5
SS-V2-01-02	180000J	36000J	20000J	<20	<20	29J	<5
SS-V2-02-05	5400J	510	370	<39	<39	<39	<5

[1] concentration reported in $\mu g/kg$ - micrograms per kilogram

[2] indicates depth of sample bgs

* - OU1 samples collected June 1991. KEY: SS-001-01-06 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth. SS-016-01-015 is nomenclature for soil sample; soil boring number; sampling interval; and sample collection depth.

J - estimated value

< - not detected above identified quantitation limit

Table 5-2 (Continued)

Soil Sample Analysis Results Summary
ABC One-Hour Cleaners
Operable Unit 1 (June 1991) and
Operable Unit 2 (September 1993)

	Contaminant Concentrations [1]						
Sample Identification [2]	Tetrachloro-ethene	Tri-chloroethene	1,2,-Dichloroethene (total)	Vinyl Chloride	Chloro-form	1,1-Dichloroethene	Toluene
SS-V2-03-10	580	91	83	<12	<12	<12	<5
SS-V2-03-10A	2300	110	95	<12	<12	<12	<5
SS-V2-04-14	800	120	100	<12	<12	<12	<5

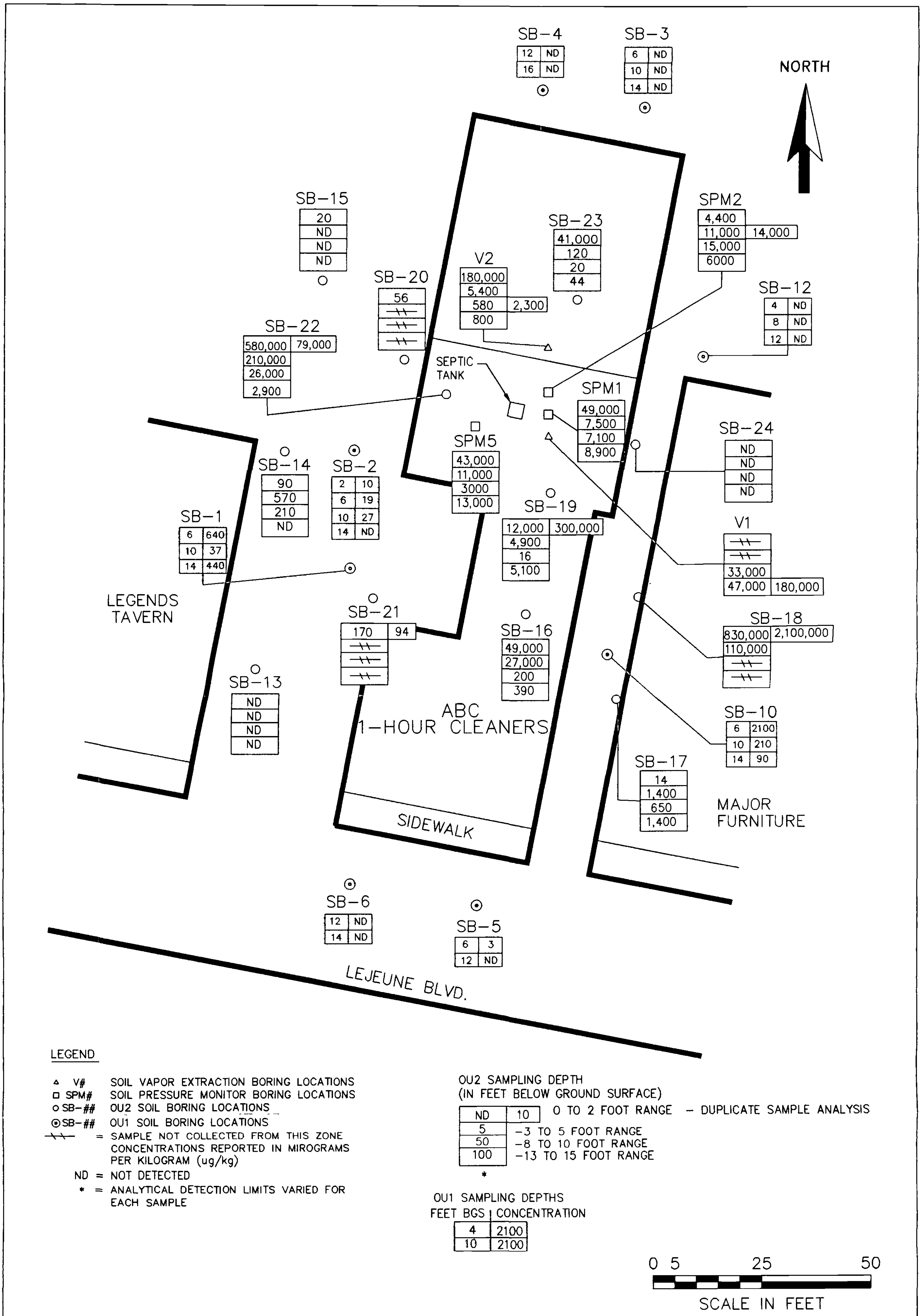
[1] concentration reported in µg/kg - micrograms per kilogram

[2] indicates depth of sample bgs

* - OU1 samples collected June 1991. KEY: SS-001-01-06 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth. SS-016-01-015 is nomenclature for soil sample; soil boring number; sampling interval; and sample collection depth.

J - estimated value

< - not detected above identified quantitation limit



WESTON MANAGERS DESIGNERS/CONSULTANTS	FIGURE 5-2	TETRACHLOROETHENE (PCE) CONTENT WITHIN SOIL SAMPLES FROM ABC SITE
	DATE 10/25/93	
	REVISION 0	REMEDIAL INVESTIGATION FOR THE ABC ONE-HOUR CLEANERS SITE JACKSONVILLE, NORTH CAROLINA
	DRAWN BY J.C., W.M.	
	FILE 04400-1B.DWG	

samples collected from these borings ranged from 580,000 μg/kg (SB-22-01-02) to 16 μg/kg (SB-19-03-09). The average concentrations of PCE in the 0-2 ft interval is 129,914 μg/kg. The average concentrations of PCE in the 3-5 ft, 8-10 ft, and 13-15 ft intervals are 35,917 μg/kg, 10,697 μg/kg, and 18,781 μg/kg, respectively. When considering the variations observed in the 8-10 ft interval to that of the 13-15 ft interval it is apparent that the extremely high concentrations reported for location V1 are skewing the average. Without the duplicate from V1 (100,000 μg/kg), the revised average concentration of PCE at 13-15 ft is 10,468 μg/kg. These findings suggest that soils within the immediate area of the septic tank are highly contaminated with PCE and may serve as a primary source for PCE contamination to area groundwaters.

PCE concentrations were also observed exterior to the building, most notably at Soil Boring 18, located adjacent to the Major Furniture building. The concentration of PCE within the 0-2 feet interval of this sample was the highest concentration (830,000 μg/kg) observed in all samples. A duplicate of this sample contained 2,100,000 μg/kg of PCE. The average concentration of PCE for samples detected at the 0-2 ft interval from borings exterior to the ABC building (SB-3, -6, -12, -15, -17, -18, -20, -21, and -24) was 244,219 μg/kg. However, this value is skewed by the extremely high concentration within sample 018-01-02A. Excluding samples 018-01-02 and 018-01-02A, the average concentration of PCE in samples exterior to the building was 62 μg/kg. The average concentration for PCE detected in the 3-5 ft interval is 27,993 μg/kg. Excluding SB-18, the average concentration becomes 658 μg/kg. The average concentration of PCE at the 8-10 ft interval is 430 μg/kg. At the 13-15 ft interval, PCE was detected at 1,400 μg/kg at SB-17 only.

Figures 5-3 and 5-4 present a color-coded three-dimensional illustration of PCE contamination in the unsaturated soil profile. With the exception of soil borings SB-17 and SB-18, these views reinforce the idea that the majority of PCE contamination within the soil profile lies within the 0- to 2-foot interval underlying the ABC building. Overall, the concentration of PCE in soils tends to decrease with increasing depth. For example, PCE in samples collected from soil boring SB-22 decreases from 580,000 μg/kg in the 0- to 2-foot interval to 2,900 μg/kg within the 13- to 15-foot zone. This trend is prominent in sample locations where the boring is covered, whether from asphalt (SB-18 location) or a building floor (V2 location). Asphalt and building floors are thought to serve as a barrier to infiltration, hence contaminants are not subject to downward migration (Refer to Section 6, Fate and Transport). In areas where there is no cover or the cover is broken or fragmented in some manner, the majority of samples were observed to have significantly lower (SB-14) or non-detectable concentrations (SB-24).

Interestingly, only aromatic hydrocarbons (e.g., toluene) were observed in soil samples to the north of the ABC building, whereas chlorinated hydrocarbons (e.g., PCE) were observed in borings of all other directions. These results potentially indicate the presence of another contaminant source influencing soils located to the north of the ABC site.

Field investigation analytical data can be used to evaluate the horizontal and vertical extent of PCE contamination within the unsaturated soils. Figure 5-5 presents the horizontal extent of PCE in soils at the ABC site. As indicated, the northern, northeastern, and southwestern quadrants of the horizontal extent are truly definable to the extent that non-detectable concentrations of chlorinated hydrocarbons were observed. The northwestern, western, southwestern, and southern quadrants are close to being defined; however, some PCE contamination (10-20 μg/kg) is still prevalent within the soils at SB-14 and SB-15, respectively.

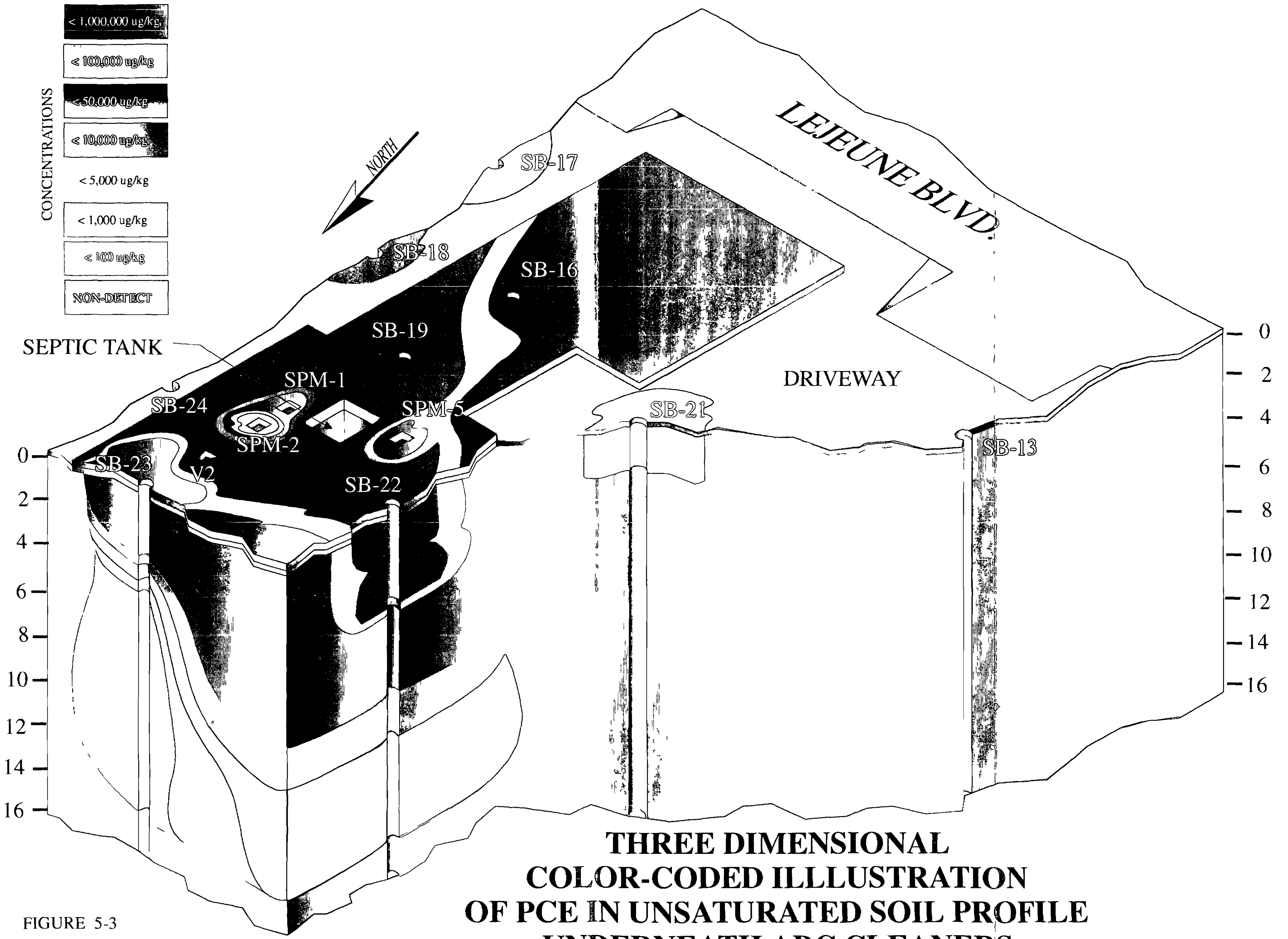


FIGURE 5-3

THREE DIMENSIONAL COLOR-CODED ILLLUSTRATION OF PCE IN UNSATURATED SOIL PROFILE UNDERNEATH ABC CLEANERS

FILE 3DABC CDR

FILE: ABCISO.CDR

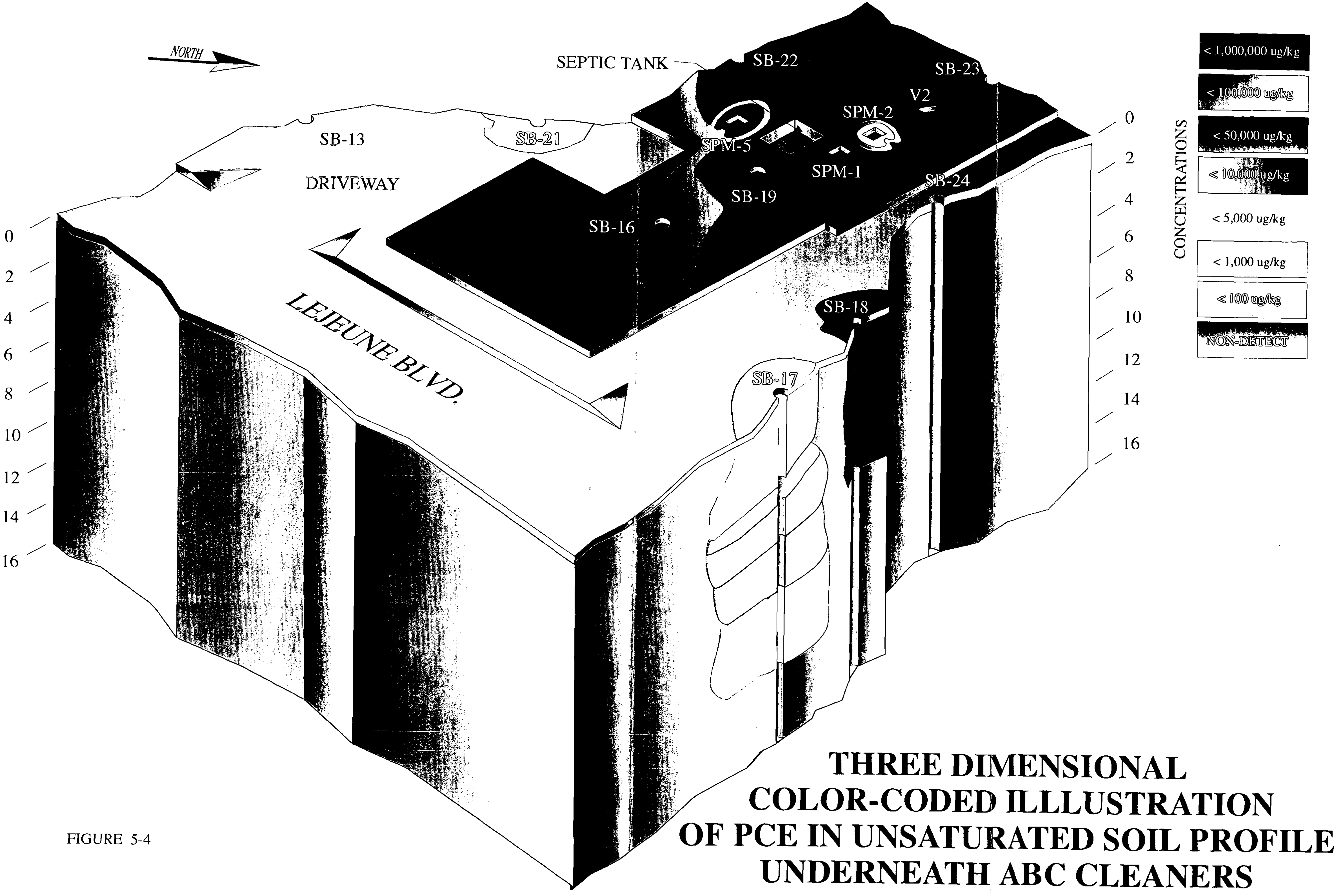
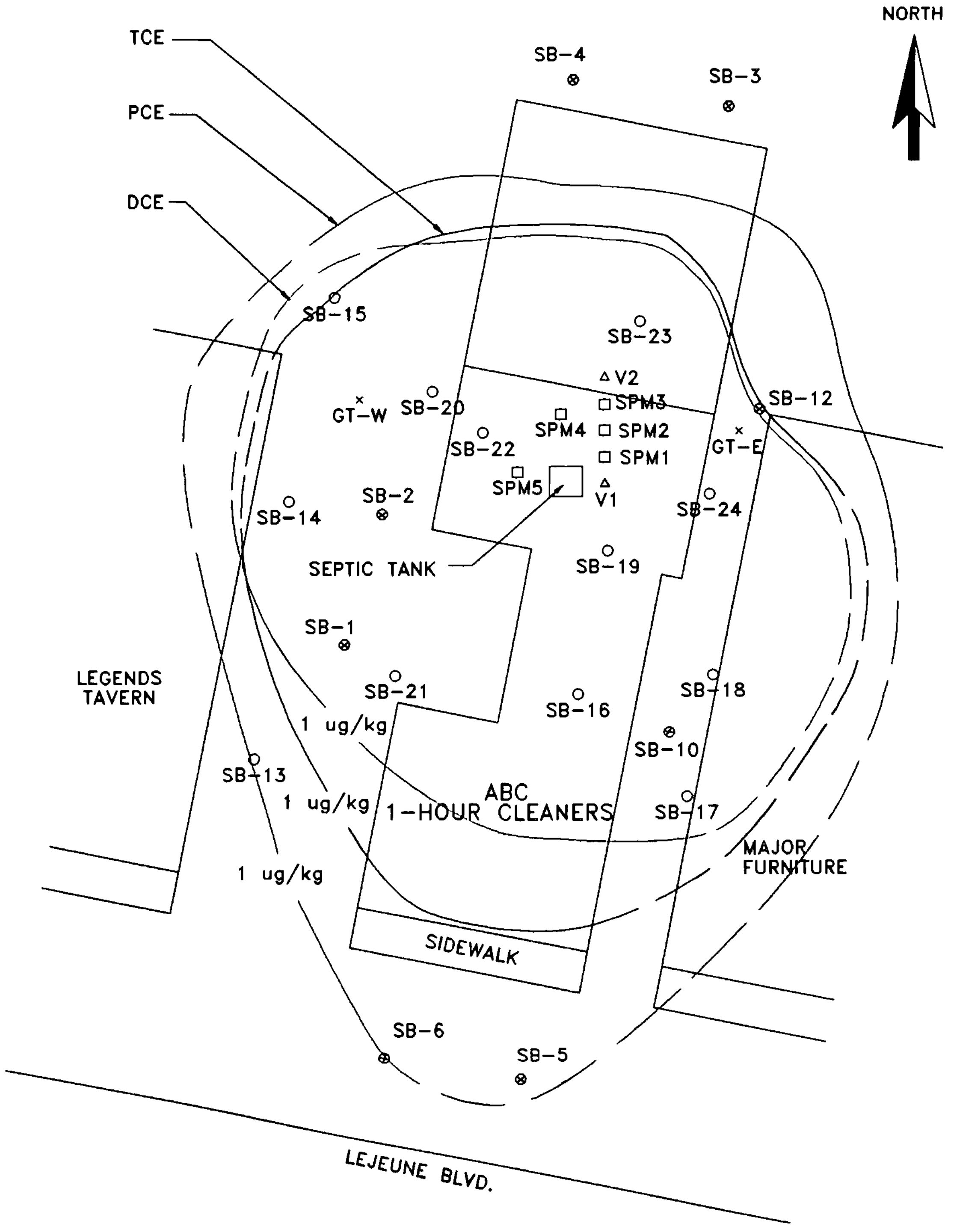


FIGURE 5-4

THREE DIMENSIONAL
COLOR-CODED ILLLUSTRATION
OF PCE IN UNSATURATED SOIL PROFILE
UNDERNEATH ABC CLEANERS



LEGEND

▵ V#	SOIL VAPOR EXTRACTION BORING LOCATIONS
□ SPM#	SOIL PRESSURE MONITOR BORING LOCATIONS
○ SB-##	SOIL BORING LOCATIONS
× GT-E	GEOTECHNICAL BORING LOCATIONS
⊗ SB-##	OU1 SOIL BORING LOCATIONS
— — —	PROBABLE EXTENT
———	DEFINITE EXTENT

0 5 25 50

SCALE IN FEET

WESTON
MANAGERS DESIGNERS/CONSULTANTS

FIGURE	5-5
DATE	10/25/93
REVISION	0
DRAWN BY	J.C., W.M.
FILE	04400-AA.DWG

APPROXIMATE HORIZONTAL EXTENT OF PCE,TCE, AND 1,2-DCE IN UNSATURATED SOIL HORIZON (0 TO 15 FEET bgs)

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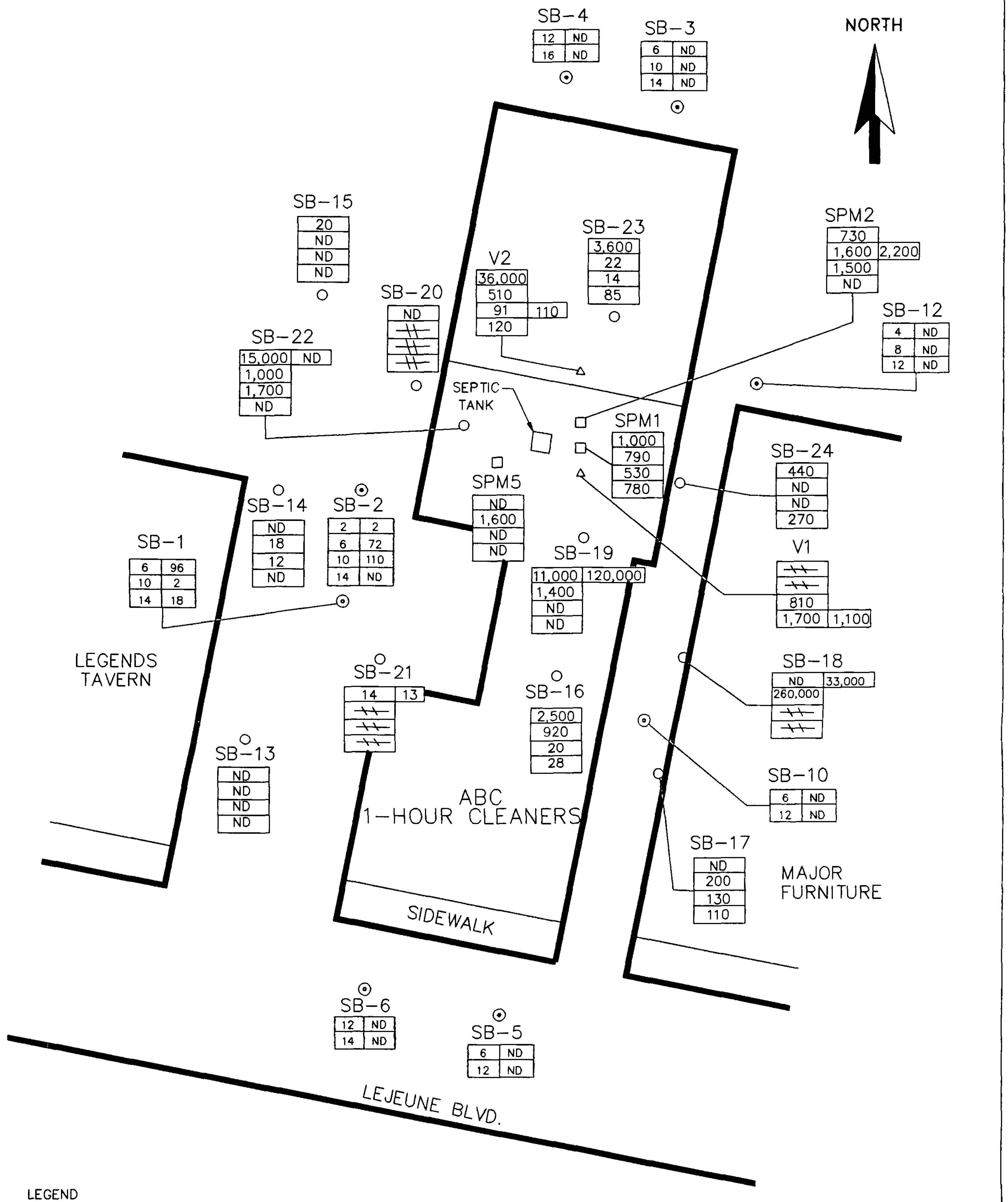
The eastern extent of horizontal PCE contamination remains to be defined as it appears that contamination has migrated to soils underlying the adjacent Major Furniture building (SB-10, SB-17, SB-18).

The vertical extent of PCE contamination within the unsaturated soil profile is more easily defined. Many of the samples collected from 13- to 15-foot bgs interval contained PCE. Since the water table occurs at a depth approximately 15.5 feet bgs, it appears that PCE contamination exists from the ground surface to the top of the water table for soils immediately underlying and directly east of the ABC building. Indeed, these locations corresponded to the highest concentrations of PCE observed in soil samples collected from the surface to 15 feet bgs.

TCE

Figure 5-6 presents soil sample locations and concentrations of TCE detected at various depths. TCE was detected in most of the samples in which PCE was detected. In general, wherever elevated PCE concentrations were observed, elevated TCE levels were also noted. TCE concentrations were typically lower than PCE concentrations. This relationship is to be expected, in that the initial breakdown product of PCE is TCE (refer to Section 6, Fate and Transport).

In general, TCE concentrations were highest in samples collected from soils underlying the ABC building. Concentrations of TCE ranged from 120,000 μg/kg (SB-19 duplicate sample) to 14 μg/kg (SB-23). The average concentration for borings near the septic tank interior to the ABC building at the 0-2 ft interval was 20,305 μg/kg. The duplicate sample at SB-19 is skewing the average. Excluding the SB-19 duplicate result, the average becomes 11,222 μg/kg. As with



LEGEND

- △ V# SOIL VAPOR EXTRACTION BORING LOCATIONS
- □ SPM# SOIL PRESSURE MONITOR BORING LOCATIONS
- ○ SB-## OU2 SOIL BORING LOCATIONS
- ⊙ SB-## OU1 SOIL BORING LOCATIONS
- -/ /- = SAMPLE NOT COLLECTED FROM THIS ZONE

CONCENTRATIONS REPORTED IN MIROGRAMS PER KILOGRAM (ug/kg)

ND = NOT DETECTED

* = ANALYTICAL DETECTION LIMITS VARIED FOR EACH SAMPLE

OU2 SAMPLING DEPTHS
(IN FEET BELOW GROUND SURFACE)

5	10	-0 TO 2 FOOT RANGE - DUPLICATE SAMPLE ANALYSIS
ND		-3 TO 5 FOOT RANGE
50		-8 TO 10 FOOT RANGE
100		-13 TO 15 FOOT RANGE
*		

OU1 SAMPLING DEPTHS

FEET BGS	CONCENTRATION
6	2
12	72

0 5 25 50
SCALE IN FEET

WESTON
MANAGERS DESIGNERS/CONSULTANTS

FIGURE	5-6
DATE	10/25/93
REVISION	0
DRAWN BY	J.C., W.M.
FILE	04400-1A.DWG

TRICHLORETHENE(TCE) CONTENT
WITHIN SOIL SAMPLES FROM ABC SITE

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

PCE, the higher TCE contaminant levels were observed in samples collected within the 0- to 2-foot interval, and tended to decrease with depth. The average detected concentration for TCE at the 3-5 ft, 8-10 ft, and 13-15 ft intervals were 1,032 μg/kg, 776 μg/kg, and 596 μg/kg respectively. However, unlike PCE, TCE was not reported for every sample collected from beneath the ABC building. Deeper samples from borings SB-19, SB-22, SPM-2, and SPM-5 contained non-detectable concentrations of TCE , whereas PCE concentrations were relatively high (range of 200 μg/kg to 13,000 μg/kg) within these samples.

In samples from borings exterior to the ABC building, TCE concentrations were generally one order of magnitude less than interior borings. On the western side of the ABC building, concentrations of TCE, when detected, were less than 96 μg/kg. In contrast, samples from borings on the eastern side of ABC contained significantly higher levels of TCE. The sample collected from the 3- to 5-foot interval of boring SB-18 contained the highest level of TCE observed in all samples (260,000 μg/kg). This boring also exhibited the highest of PCE concentration detected. In other borings east of the ABC building (SB-17, SB-24) concentrations of TCE, when detected, ranged from 110 μg/kg to 440 μg/kg. TCE was not detected in the sample from boring SB-10, which exhibited PCE contamination.

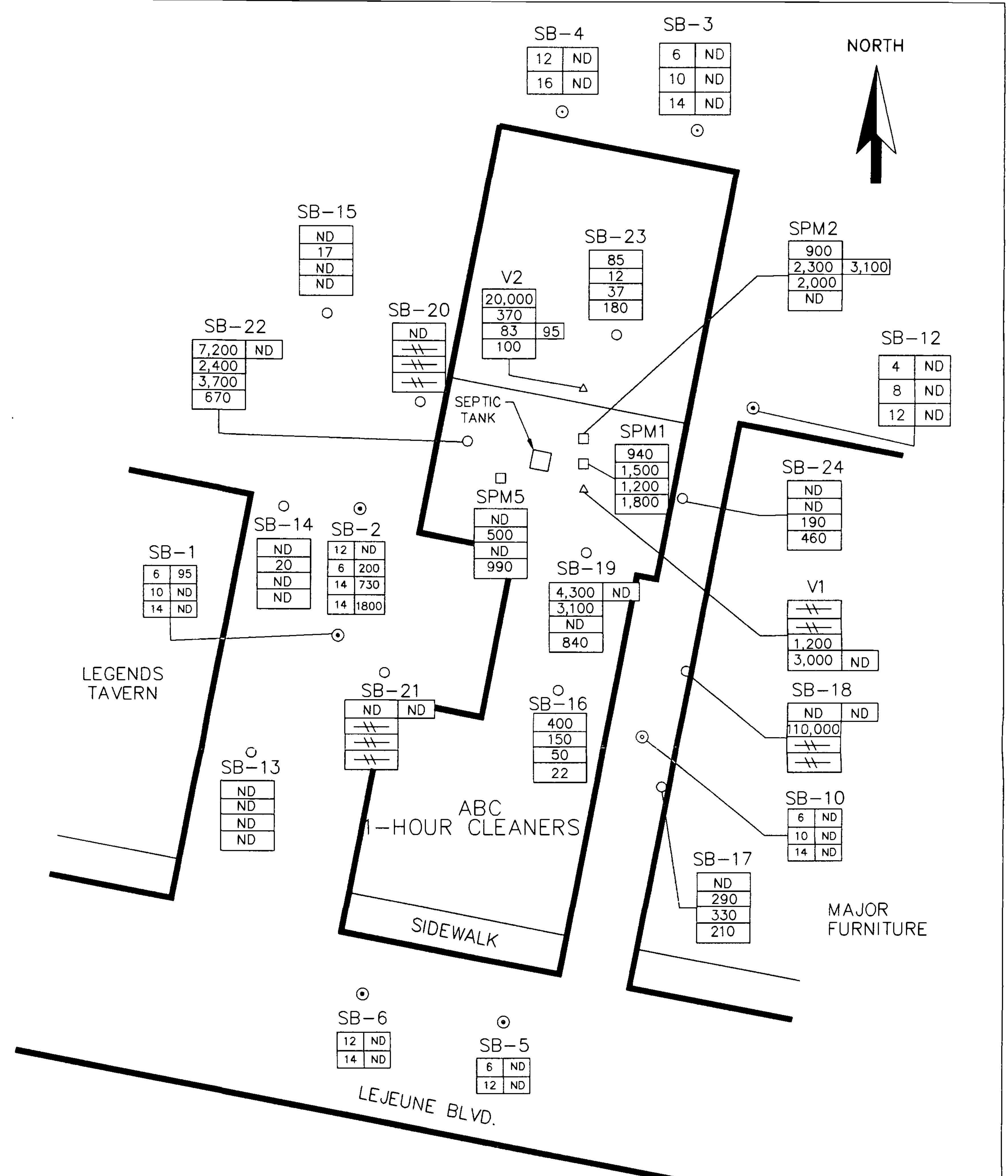
Comparing the TCE data to Figures 5-3 and 5-4, it is apparent that TCE and PCE contamination can be found at the same locations, and that concentrations of both contaminants tend to be higher within the 0- to 2-foot zone. The southeasterly view of Figure 5-3 displays the vertical extent of PCE contamination underlying the ABC building and the proximity of contamination to the water table. According to the southeasterly view, contamination extends to the water table at soil boring locations in proximity to the septic tank and along the eastern edge of the ABC property. It is suspected that TCE contamination (similar to PCE) extends easterly to soils which lie beneath the Major Furniture building.

The horizontal extent of TCE within the soil surrounding the ABC building is very similar to that of PCE contamination. As shown in Figure 5-5, the probable horizontal extent of TCE as described by OU1 and OU2 analytical data appears to be slightly less extensive than the PCE contaminated soils. The presence of TCE in soil borings located east of the ABC building indicates that TCE may have migrated easterly to soils below the Major Furniture building.

1,2-DCE

Figure 5-7 presents the sample locations and concentrations of 1,2-DCE detected. Sample locations containing 1,2-DCE are very similar to those observed for both PCE and TCE, with the highest concentrations of 1,2-DCE observed in samples collected beneath the ABC building. The highest detected value beneath the ABC building near the septic tank was 20,000 μg/kg in boring V2 at 0-2 ft bgs; the lowest was 12 μg/kg in SB-23. The average 1,2-DCE value for samples collected from beneath the ABC building at 0-2 ft interval was 5,570 μg/kg. The average concentration decreased at each increasing sample depth: 1,764 μg/kg at 3-5 ft interval, 1,372 μg/kg at the 8-10 ft interval, and 1,083 μg/kg at the 13-15 ft interval.

Exterior to the ABC building, soil borings on the western side revealed four descrete samples of detectable concentrations of 1,2-DCE. In SB-1, 95 μg/kg was detected at 6 feet bgs. In SB-2, 1,2-DCE was detected at depths up to 14 ft bgs. In SB-15, the 3- to 5-foot bgs interval contained 17 μg/kg. In SB-14, the 3- to 5-foot bgs contained 20 μg/kg. As with PCE and TCE,



LEGEND

- △ V# SOIL VAPOR EXTRACTION BORING LOCATIONS
- □ SPM# SOIL PRESSURE MONITOR BORING LOCATIONS
- ○ SB-## OU2 SOIL BORING LOCATIONS
- ⊙ SB-## OU1 SOIL BORING LOCATIONS
- -\\- = SAMPLE NOT COLLECTED FROM THIS ZONE

CONCENTRATIONS REPORTED IN MIROGRAMS PER KILOGRAM (ug/kg)

ND = NOT DETECTED

* = ANALYTICAL DETECTION LIMITS VARIED FOR EACH SAMPLE

OU2 SAMPLING DEPTH
(IN FEET BELOW GROUND SURFACE)

ND | 10 -0 TO 2 FOOT RANGE - DUPLICATE SAMPLE ANALYSIS
5 -3 TO 5 FOOT RANGE
50 -8 TO 10 FOOT RANGE
100 -13 TO 15 FOOT RANGE
*

OU1 SAMPLING DEPTHS

FEET BGS	CONCENTRATION
6	ND
12	ND

0 5 25 50
SCALE IN FEET

WESTON
MANAGERS DESIGNERS/CONSULTANTS

FIGURE	5-7
DATE	10/25/93
REVISION	0
DRAWN BY	J.C., W.M.
FILE	04400-1D.DWG

1,2-DICHLORETHENE(TOTAL) CONTENT WITHIN SOIL SAMPLES FROM ABC SITE

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

concentrations of 1,2-DCE along the eastern side of the ABC property were higher than those along the western side. In soil boring SB-24, the 8- to 10-foot and 13- to 15-foot bgs intervals contained 190 μg/kg and 460 μg/kg, respectively. In SB-17, concentrations ranged from 290 μg/kg in the 3- to 5-foot interval, 330 μg/kg in the 8- to 10-foot interval, and 210 μg/kg in the 13- to 15-foot bgs interval. The only sample from SB-18 that contained 1,2-DCE was the 3- to 5-foot bgs sample (110,000 μg/kg), the highest concentration of 1,2-DCE in all samples analyzed. Similarly, this soil boring also contained the highest PCE and TCE concentrations.

The horizontal extent of 1,2-DCE contamination in the soil can be traced along similar lines as that of PCE and TCE contamination (Figure 5-5). The north, southwest, south, southeast, and northeast portions of the contamination are readily definable. The northwest and western portions are close to being defined. The eastern extent of 1,2-DCE contamination most likely extends beneath the Major Furniture building.

Samples collected from soils underlying the ABC building indicate that the vertical extent of 1,2-DCE contamination extends throughout the unsaturated zone, from the surface to approximately 15 feet bgs. Outside the ABC building, the vertical extent of 1,2-DCE varies with location. At SB-14 and SB-15, the contamination is present in the 3- to 5-foot intervals. At SB-2, contamination extends from 6 to 14 feet. SB-1 contained contamination at the 6-foot zone. On the eastern side of the building, contamination, as described by SB-17, -18, and -24 soil boring locations, extends from approximately 3- to 5-foot bgs interval to the 13- to 15-foot bgs interval. Samples from borings in the northern and southern areas outside of the ABC building did not indicate the presence of 1,2-DCE contamination, as defined by SB-3 through SB-6.

Chloroform, 1,1-DCE, Vinyl Chloride and Toluene

Chloroform, 1,1-DCE, vinyl chloride, and toluene were infrequently detected in soil samples from the OU1 and OU2 studies (Table 5-2). In all cases the detected concentrations were relatively low. Unlike PCE, TCE, and 1,2-DCE, sample locations having reportable concentrations indicated no clear trends as to their occurrences.

Chloroform was detected in two samples only, both of which were from the OU2 SB-16 location. In the 0- to 2-foot bgs interval, 17 μg/kg was reported, whereas the 3- to 5-foot bgs interval contained 10 μg/kg. 1,1-DCE was detected at 29 μg/kg in one sample from OU2 boring V2 at a depth of 0 to 2 feet. Vinyl chloride was detected within the 3- to 5-foot bgs interval of SB-19 at 190 μg/kg, in the 3- to 5-foot bgs interval of SPM-5 at 79 μg/kg, and in SB-2 at levels of 42 μg/kg and 55 μg/kg in samples collected from 6-foot and 10-foot depths.

Of the lesser detected compounds presented in Table 5-2, toluene was detected in the greatest number of samples. The range of values reported for toluene were 22 μg/kg in the 14-foot bgs sample from soil boring SB-6 to 2 μg/kg in samples collected from three separate locations. All of the detected toluene levels are within samples located in soil borings within the immediate vicinity of the ABC building, except SB-7 which is 200 feet to the north. As toluene is not a normal component of the dry cleaning business, the source for the toluene contamination remains unknown at this time.

5.1.2.2 OU1 Soil Sampling (Other Compounds)

In addition to the analytical results for the compounds described in Section 5.1.2.1, a variety of other compounds were detected within soil samples collected during OU1. These compounds include acetone, bromomethane, methylene chloride, and xylene (total). Table 5-3 presents these compounds and associated analytical results.

The source of the acetone and methylene chloride is unknown at this time. Neither compound is used in the dry cleaning process and neither compound was used during any portion of the field decontamination procedures. Bromomethane is most likely a dehalogenation product of PCE. The xylenes (total) detection may be related to the source of the toluene.

5.2 GROUNDWATER

All wells installed during the OU2 RI were intended to provide groundwater quality information to address data gaps established from the OU1 RI review. As part of OU2, WESTON sampled groundwater from all newly installed and existing surficial and Castle Hayne aquifer monitor wells. Analytical data for OU2 groundwater sampling efforts and a comparison to OU1 data are discussed in the following section.

5.2.1 OU1 VOC Analytical Results

Analysis of groundwater wells installed during OU1 resulted in the detection of twelve VOCs in five surficial aquifer monitor wells (Table 5-4). The primary VOCS detected in elevated

Table 5-3

Various VOC Compounds Detected in OU1 Soil Samples
ABC One-Hour Cleaners
June 1991

Compound	Sample Number					
	SS-001-01-14	SS-002-01-02	SS-002-01-06	SS-002-01-10	SS-003-01-06	SS-003-01-14
Acetone	1,400 J	230 J	330 J	510	230 J	< 100
Bromomethane	< 56	< 11	< 15	< 60	< 12	8 J
Methylene Chloride	< 28	< 7	< 8	< 40	< 6	< 200
Xylene (total)	< 28	< 5	< 8	< 30	< 6	< 29

Compound	Sample Number					
	SS-005-01-06	SS-005-01-12	SS-006-01-12	SS-006-01-14	SS-006-01-14	SS-012-01-04
Acetone	340 J	14,000 J	< 60	2,600 J	2,600 J	270 J
Bromomethane	< 13	< 13	< 12	< 13	< 13	< 38
Methylene Chloride	< 10	7,100 J	< 10	< 20	< 20	< 120
Xylene (total)	< 6	< 6	4 J	< 7	< 7	< 38

NOTE: Units are micrograms per kilogram (μg/kg).
< indicates not detected above the method detection limit.
J indicates presumptive evidence of material.

KEY: SS-001-01-14 is nomenclature for soil sample; soil boring number; Operable Unit 1; sample collection depth.

Table 5-4

Groundwater Sample Analysis Data from Surficial Aquifer Wells
Operable Unit 2
ABC One-Hour Cleaners
September 1993

Sample Designation	Parameter	Results (µg/L)
MW-S1	Trichloroethene	0.6J
	Tetrachloroethene	27
	cis-1,2,Dichloroethene	0.2J
MW-S2	Vinyl Chloride	70
	1,1 Dichloroethene	1
	Trichloroethene	280
	Benzene	0.4J
	Tetrachloroethene	490
	cis-1,2-dichloroethene	460
	trans-1,2-dichloroethene	6
	Toluene	2
	Chlorobenzene	0.6J
	Ethylbenzene	0.4J
	Xylenes (total)	3
	Ethyldimethylbenzene (2 isomers)	5JN
	Tetramethylbenzene (2 isomers)	6JN
	Methylindan	3JN
	Ethylmethylbenzene	4JN

< indicates not detected above the method detection limit.
µg/l indicates micrograms per liter.
A indicates duplicate sample.
J indicates estimated value.
N indicates presumptive evidence of presence of material.

Table 5-4 (Continued)

Summary of
Groundwater Sample Analysis Data from Surficial Aquifer Wells
Operable Unit 2
ABC One-Hour Cleaners
September 1993

Sample Designation	Parameter	Results (µg/L)
MW-S3	Vinyl Chloride	10
	1,1-Dichloroethene	0.3J
	Trichloroethene	24
	Tetrachloroethene	380
	cis-1,2-Dichloroethene	45
	trans-1,2-Dichloroethene	0.5J
MW-S4	ND	<1
MW-S5	Tetrachloroethene	0.8J
MW-S6	Trichloroethene	0.1J
	Benzene	0.4J
	Tetrachloroethene	0.5J
	Toluene	0.2J
	Ethylbenzene	2
	Dihydromethylindene	5JN
	Methylindan	6JN
	Ethyldimethylbenzene	4JN
	Methylcyclohexane	30JN
	Dimethylcyclopentane	10JN

< indicates not detected above the method detection limit.
µg/l indicates micrograms per liter.
A indicates duplicate sample.
J indicates estimated value.
N indicates presumptive evidence of presence of material.

Table 5-4 (Continued)

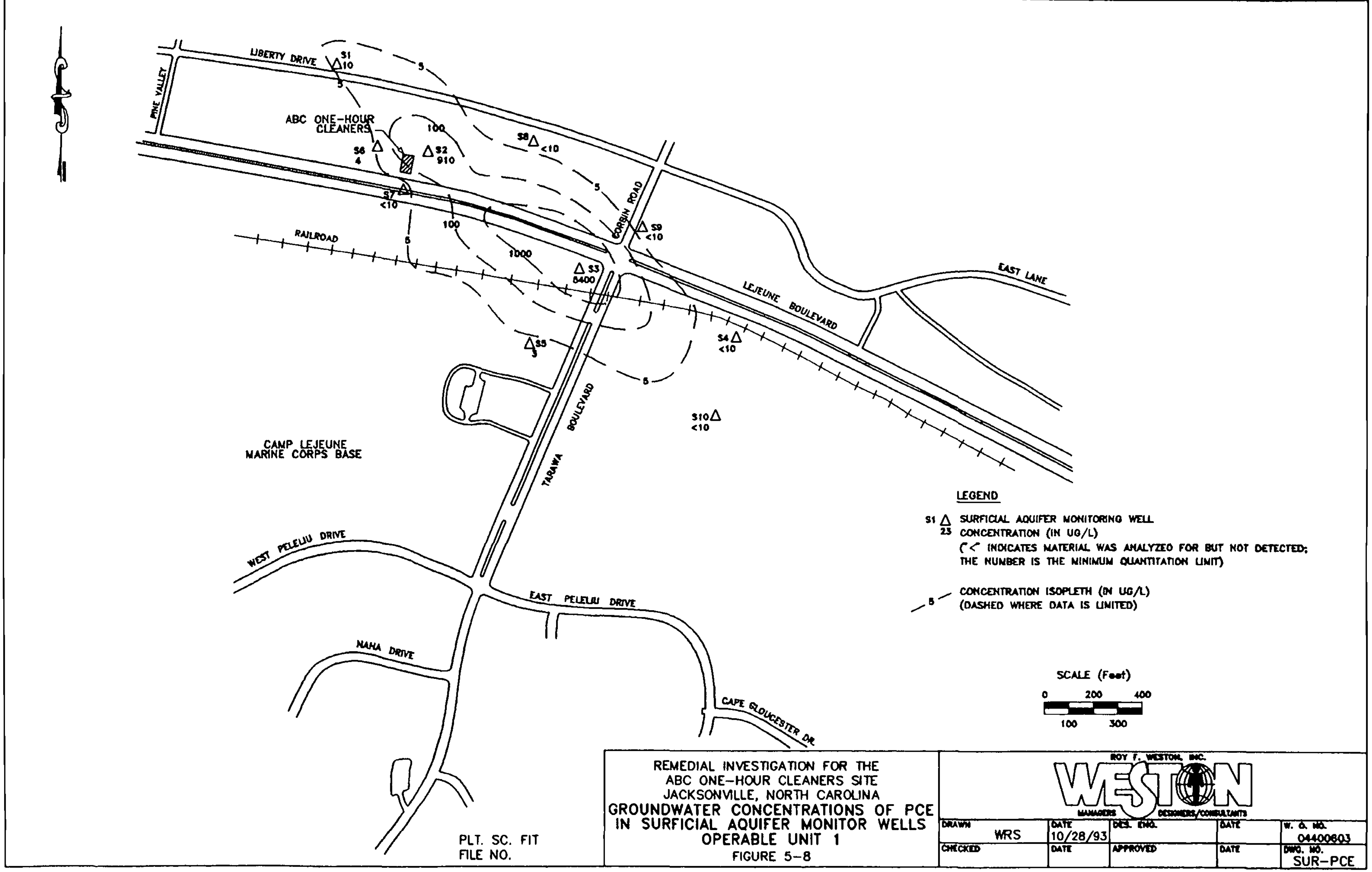
Summary of
Groundwater Sample Analysis Data from Surficial Aquifer Wells
Operable Unit 2
ABC One-Hour Cleaners
September 1993

Sample Designation	Parameter	Results (μg/L)
MW-S6 (Continued)	Methylcyclopentane	20JN
	Ethyldimethylpentane	20JN
	Dimethylbutane	20JN
MW-S7	Tetrachloroethene	0.2J
	Toluene	0.1J
MW-S7A	Tetrachloroethene	0.1J
	Toluene	0.1J
MW-S8	ND	<1
MW-S9	ND	<1
MW-S10	ND	<1
MW-S11	Chloroform	3J
	1,1,1-Trichloroethane	0.6J
	Bromodichloromethane	2
	Trichloroethene	46
	Dibromochloromethane	2
	Bromoform	0.7J
	Tetrachloroethene	0.3J
	Toluene	0.1J

< indicates not detected above the method detection limit.
μg/l indicates micrograms per liter.
A indicates duplicate sample.
J indicates estimated value.
N indicates presumptive evidence of presence of material.

concentrations (relative to the analytical detection limit) were PCE, TCE, 1,2,DCE, and vinyl chloride. For wells in which the aforementioned contaminants were detected, concentrations observed exceeded established EPA Maximum Contaminant Levels (MCLs) and North Carolina Groundwater Quality Standards (NCGWQSs). The areal extent of these contaminants as defined by groundwater concentration isopleth maps is presented in Figures 5-8 through 5-11. The surficial aquifer analytical data indicate that VOCs originating in the vicinity of ABC (well S2) extend downgradient to well S3. VOC concentrations were observed at levels below detection limits of 10 micrograms per liter (μg/L) at downgradient wells S4 and S10. The southern boundary of the respective contaminant plumes were indicated by wells S5 and S7. Except for the PCE concentration detected in well S1, all chlorinated VOC concentrations in upgradient wells S1 and S6 were below detection limits of 10 μg/L. Such results serve to delineate the northern edge of the groundwater plume associated with the ABC site.

Groundwater samples were also collected and analyzed for VOCs from five Castle Hayne aquifer monitor wells. Sample analyses indicated that three of the wells (C2, C3, and C5) contained VOCs, including PCE, TCE, 1,2-DCE, chloroform, acetone, benzene, and toluene (Table 5-4). The origin of acetone within these samples is unknown and considered anamolous. As discussed later, acetone was also observed in the analysis of QA/QC samples. Acetone was not used during the field portion of decontamination. The concentrations of PCE, TCE, and 1,2-DCE as defined by groundwater concentration isopleth maps are presented in Figures 5-12 through 5-14. Since the highest chlorinated VOC concentrations in the OU1 samples were observed in wells C2 and C3, local supply wells RW-2 and TT-26 were suspected of being possible conduits for downward migration of chlorinated VOCs into the Castle Hayne aquifer. The origin of benzene and toluene was unknown. PCE, TCE, and chloroform concentrations were found to be above the MCLs and NCGWQSs for wells C2, C3, and C5.



PLT. SC. FIT
FILE NO.

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
GROUNDWATER CONCENTRATIONS OF PCE
IN SURFICIAL AQUIFER MONITOR WELLS
OPERABLE UNIT 1
FIGURE 5-8

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

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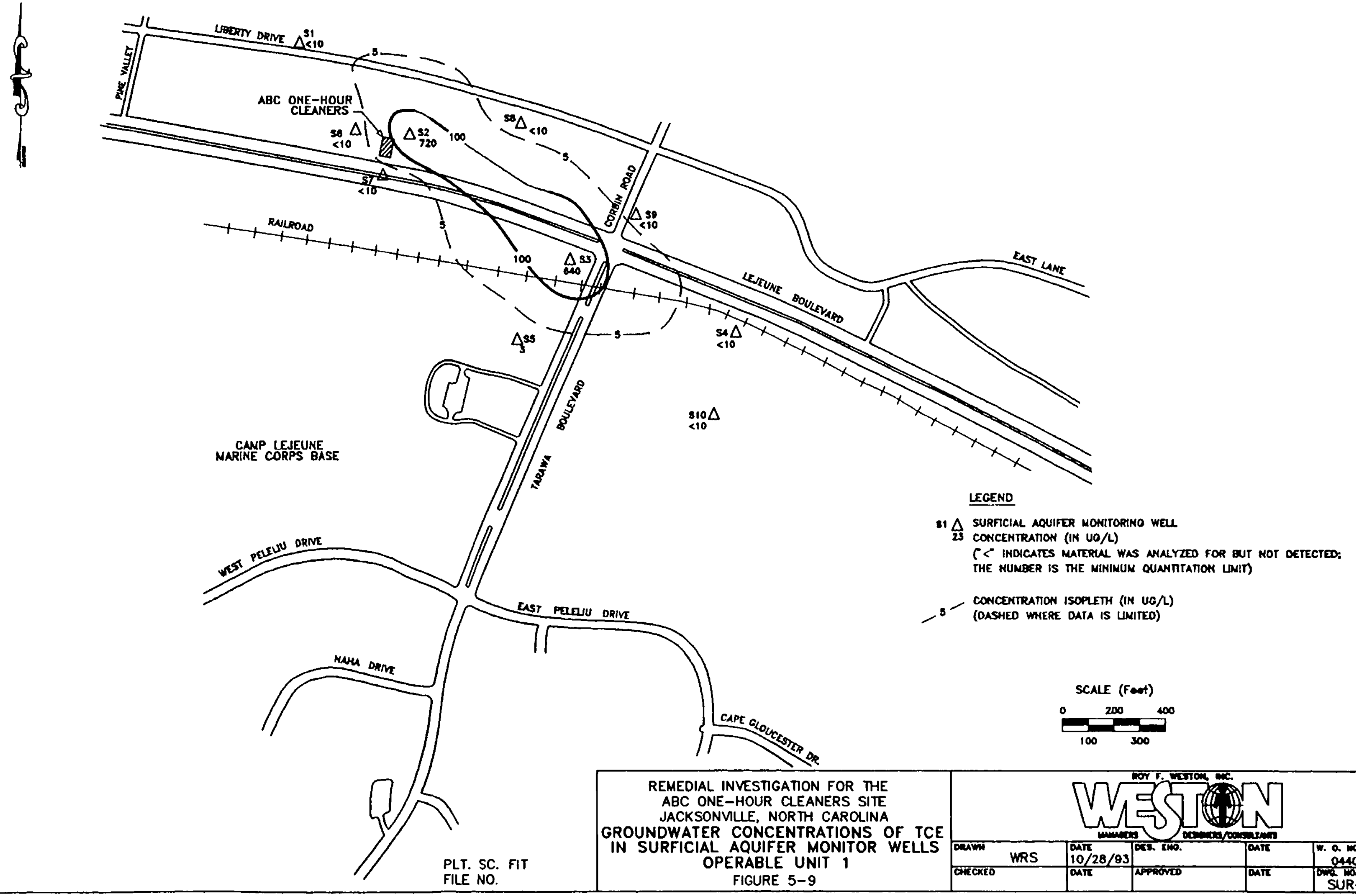
CHECKED	DATE	APPROVED	DATE	DWG. NO. SUR-PCE



PLT. SC. FIT
FILE NO.

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

GROUNDWATER CONCENTRATIONS OF TCE
IN SURFICIAL AQUIFER MONITOR WELLS
OPERABLE UNIT 1

FIGURE 5-9

ROY F. WESTON, INC.
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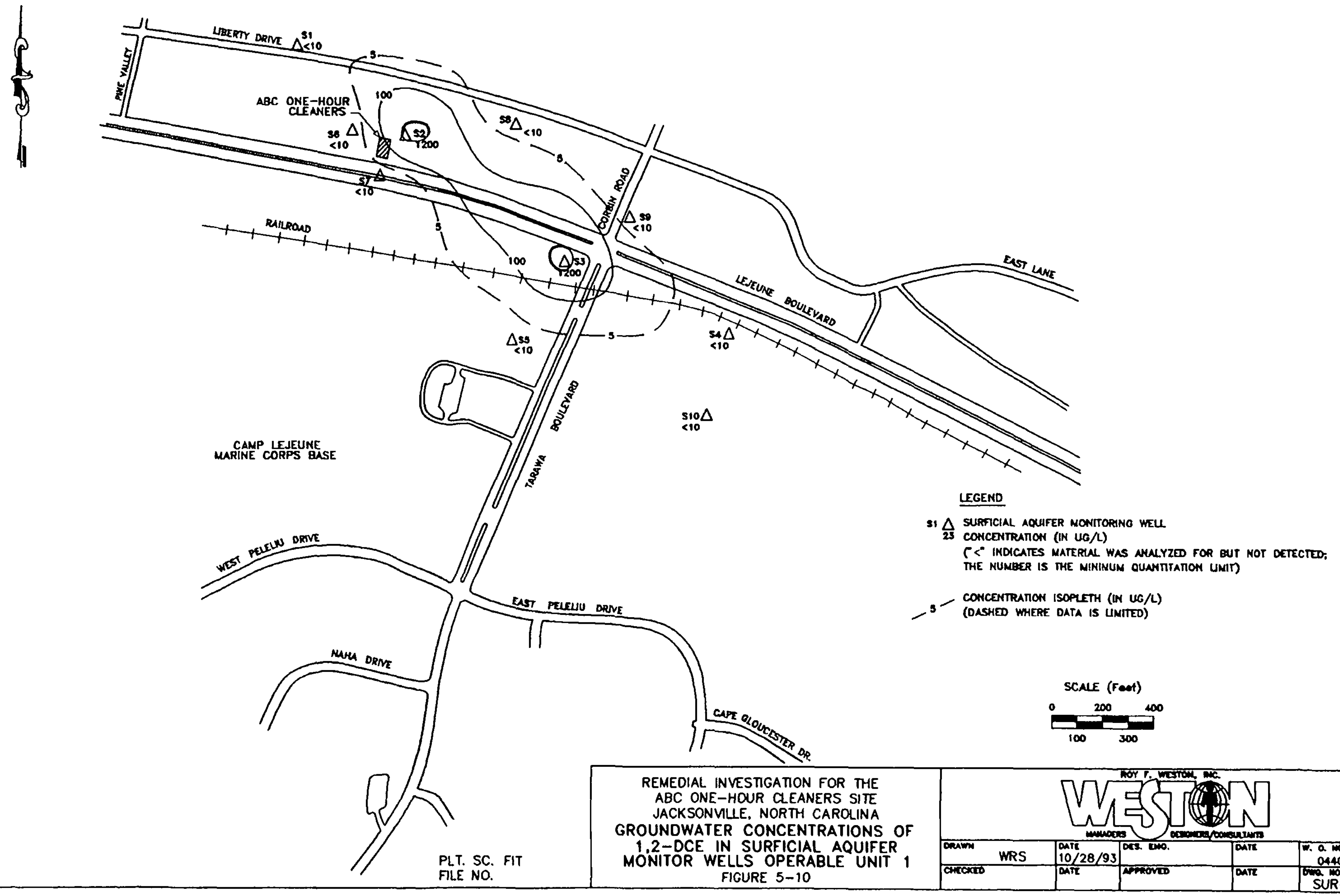
WRS	10/28/93			04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO.
				SUR-TCE

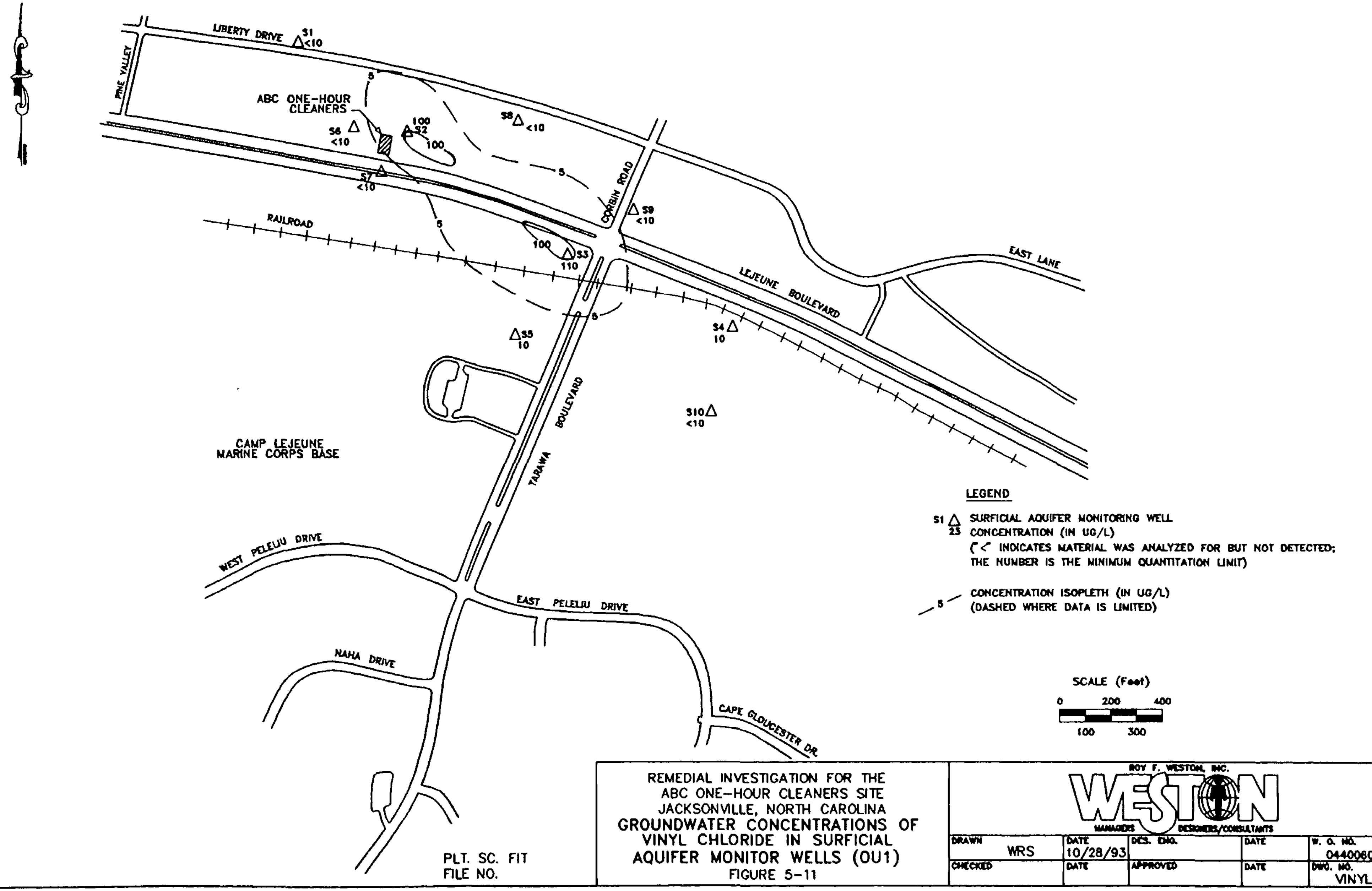


PLT. SC. FIT
FILE NO.

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
GROUNDWATER CONCENTRATIONS OF
1,2-DCE IN SURFICIAL AQUIFER
MONITOR WELLS OPERABLE UNIT 1
FIGURE 5-10

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN WRS	DATE 10/28/93	DES. ENG.	DATE	W. O. NO. 04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO. SUR-DCE



PLT. SC. FIT
FILE NO.

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
GROUNDWATER CONCENTRATIONS OF
VINYL CHLORIDE IN SURFICIAL
AQUIFER MONITOR WELLS (OU1)
FIGURE 5-11

ROY F. WESTON, INC.
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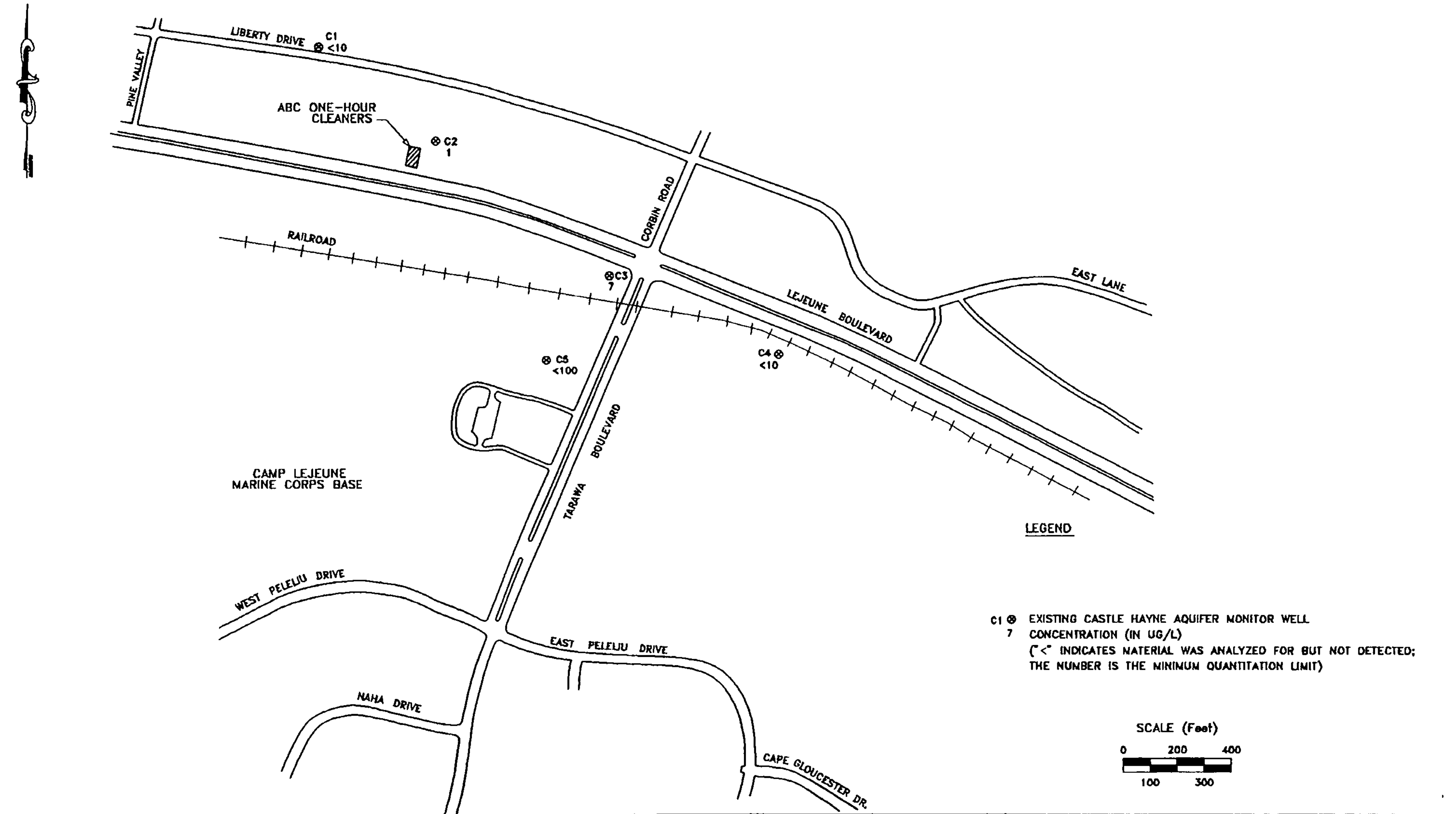
DRAWN WRS	DATE 10/28/93	DES. ENG.	DATE	W. O. NO. 04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO. VINYL



LEGEND

C1 ⊗ 7 EXISTING CASTLE HAYNE AQUIFER MONITOR WELL CONCENTRATION (IN UG/L)
("<" INDICATES MATERIAL WAS ANALYZED FOR BUT NOT DETECTED; THE NUMBER IS THE MINIMUM QUANTITATION LIMIT)

SCALE (Feet)
0 100 200 300 400

PLT. SC. 1=200
FILE NO.

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
GROUNDWATER CONCENTRATIONS OF
PCE IN CASTLE HAYNE
AQUIFER MONITOR WELLS (OU1)
FIGURE 5-12

ROY F. WESTON, INC.
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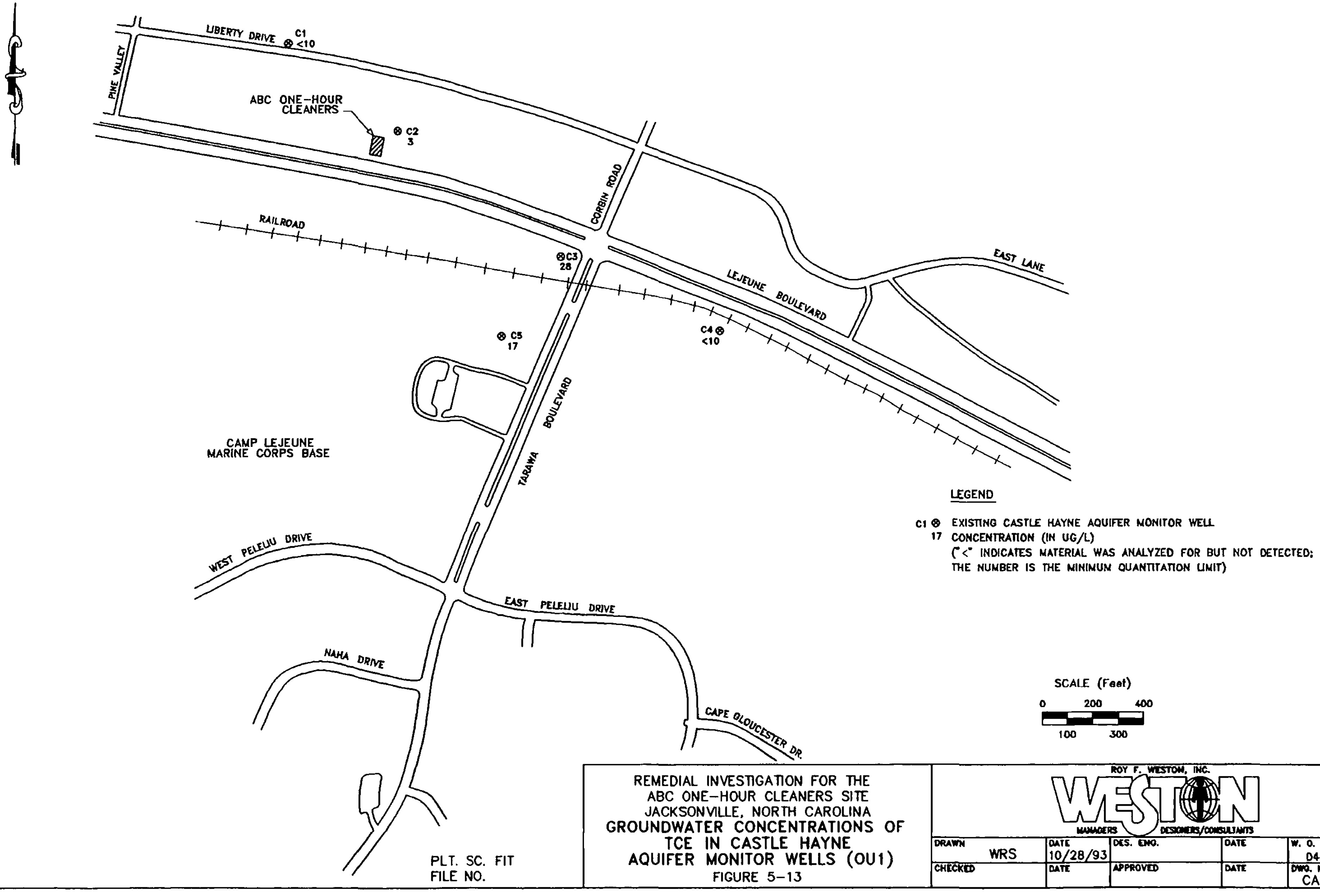
DRAWN WRS	DATE 10/28/93	DES. ENG.	DATE	W. O. NO. 04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO. CAS-PCE

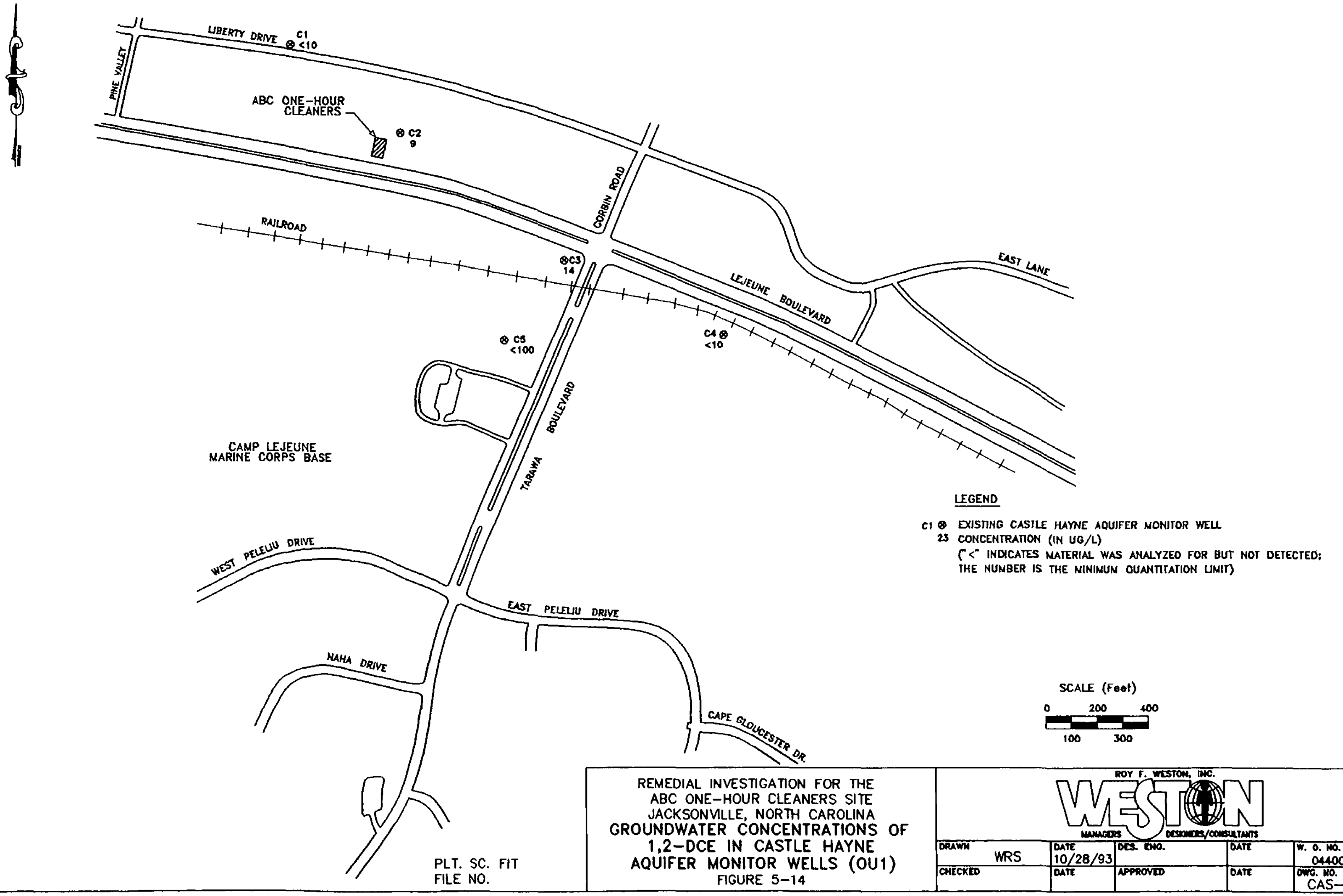


PLT. SC. FIT
FILE NO.

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
GROUNDWATER CONCENTRATIONS OF
TCE IN CASTLE HAYNE
AQUIFER MONITOR WELLS (OU1)
FIGURE 5-13

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN WRS	DATE 10/28/93	DES. ENG.	DATE	W. O. NO. 04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO. CAS-TCE



PLT. SC. FIT
FILE NO.

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
GROUNDWATER CONCENTRATIONS OF
1,2-DCE IN CASTLE HAYNE
AQUIFER MONITOR WELLS (OU1)
FIGURE 5-14

ROY F. WESTON, INC.
WESTON
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CHECKED		DATE	APPROVED	DATE	DWG. NO. CAS-DCE

During the OU1 review of groundwater results, EPA identified several data gaps. These data gaps were related to estimations of the vertical and horizontal extent of contamination within the surficial and Castle Hayne aquifers. The following actions relative to OU2 field activities were completed in order to address the specific data gaps:

(1) Installation of a surficial aquifer monitor well upgradient of well S1 to further evaluate groundwater quality.

(2) Installation of two Castle Hayne aquifer monitor wells - one north of well C3 and the other south-southeast of well TT-23, to evaluate extent of contamination in these specific areas.

(3) Installation of a deep Castle Hayne aquifer monitor well near the C3/S3 location to evaluate the extent of contamination.

(4) Resampling of existing monitor wells to confirm groundwater sample data and further evaluate extent of groundwater contamination.

5.2.2 OU2 Groundwater Sampling Study

In an effort to address the aforementioned data gaps, WESTON installed the requested surficial (S11) and Castle Hayne aquifer monitor wells (wells C9, C10, and C11). Installation procedures and locations of these wells have been previously described in Section 3.3. Groundwater samples from the existing and newly installed surficial and Castle Hayne monitor wells were submitted through EPA's Contract Laboratory Program (CLP) for TCL-VOC analysis.

5.2.2.1 Surficial Aquifer Sample Analysis Results

Analysis of surficial aquifer groundwater samples indicated a total of 12 VOC analytes at or above respective detection limits. As listed below, nine of the VOCs are classified as chlorinated hydrocarbons; the remaining three are aromatic hydrocarbons frequently associated with petroleum products.

Chlorinated VOCs

- PCE
- TCE
- cis-1,2-DCE
- trans-1,2-DCE
- chloroform
- 1,1-dichloroethene
- vinyl chloride
- bromodichloromethane
- dibromochloromethane

Aromatic VOCs

- toluene
- ethylbenzene
- xylenes (total)

Various other compounds including bromoform, benzene, and chlorobenzene were reported at estimated concentrations below the laboratory detection limit of 1 μg/L. Table 5-4 summarizes the analytical results of the groundwater samples from the surficial aquifer.

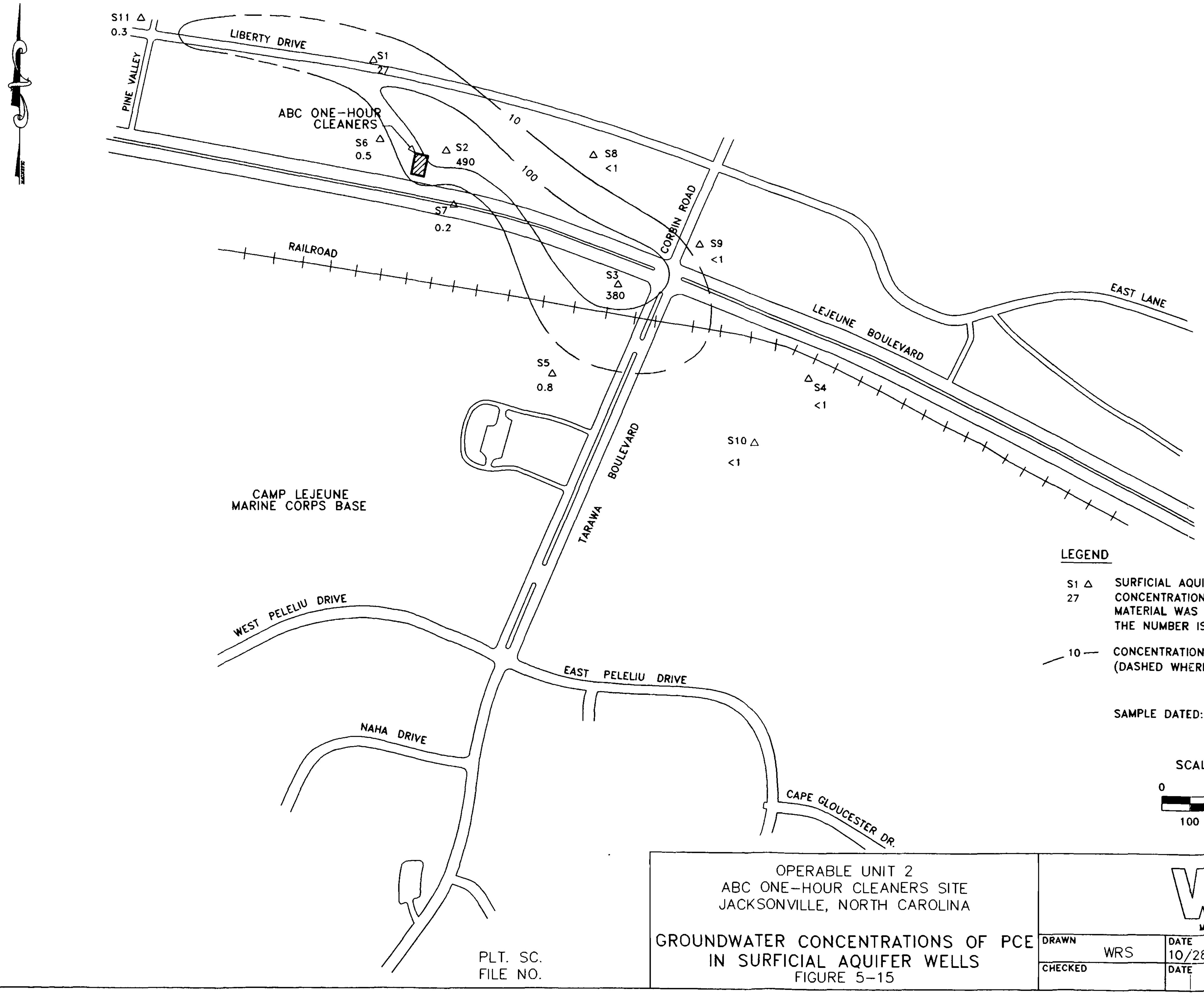
From a review of Table 5-4, wells S2 (located immediately downgredient of ABC and within 15 feet of supply well RW-2) and S3 (located downgradient of ABC and within approximately 20 feet of supply well TT-26) exhibited the highest concentrations (relative to other OU2 samples) of VOCs in surficial aquifer wells at the site. PCE was detected at concentrations of

490 and 280 μg/L, respectively. Other compounds reported in the S2 and S3 samples included 1,2-DCE (total), TCE, and vinyl chloride. Several other compounds were detected in these samples at estimated values. Other surficial aquifer samples typically contained these compounds along with other chlorinated aromatic VOCs at lower concentrations.

Surficial aquifer groundwater concentration isopleth maps have been generated for PCE, TCE, and 1,2-DCE (Figure 5-15, 5-16, and 5-17). The lowest concentration isopleths are estimates and are subject to some uncertainty as the areal extent of a particular contaminant is difficult to pinpoint. Additional uncertainty exists with respect to the location of the downgradient isopleths between wells S3, S4, and S10. Due to the distance between these wells and the lack of intermediate wells for additional resolution of VOC concentrations, the locating of isopleths for exact representation of the concentrations decreases in certainty.

A comparison of surficial aquifer isopleth maps for OU2 data confirms OU1 data that VOCs (particularly PCE and TCE) originate in the vicinity of ABC at well S2 and extend downgradient, southeast to well S3. According to OU2 data, VOC concentrations decrease to below detection limits of 1 μg/L at downgradient wells S4 and S10. The southern boundary of the VOC plumes are indicated by the concentrations within well S5 (0.8J μg/L) and S7 (0.2J μg/L).

Upgradient wells S1, S6, and S11 have concentrations that serve to delineate the plume north of the site. Well S1 contained 27 μg/L of PCE, while well S11 contained 46 μg/L of TCE and 2 μg/L of bromodichloromethane and dibromochloromethane. Other VOC compounds detected within these samples were estimated concentrations below established method detection limits



LEGEND

S1 △ 27	SURFICIAL AQUIFER MONITOR WELL CONCENTRATION (IN UG/L) ("<" INDICATES MATERIAL WAS ANALYZED FOR BUT NOT DETECTED; THE NUMBER IS THE MINIMUM QUANTITATION LIMIT)
10	CONCENTRATION ISOPLETH (IN UG/L) (DASHED WHERE DATA IS LIMITED)

SAMPLE DATED: SEPTEMBER, 1993

PLT. SC.
FILE NO.

OPERABLE UNIT 2
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

GROUNDWATER CONCENTRATIONS OF PCE IN SURFICIAL AQUIFER WELLS

FIGURE 5-15

ROY F. WESTON, INC.
WESTON
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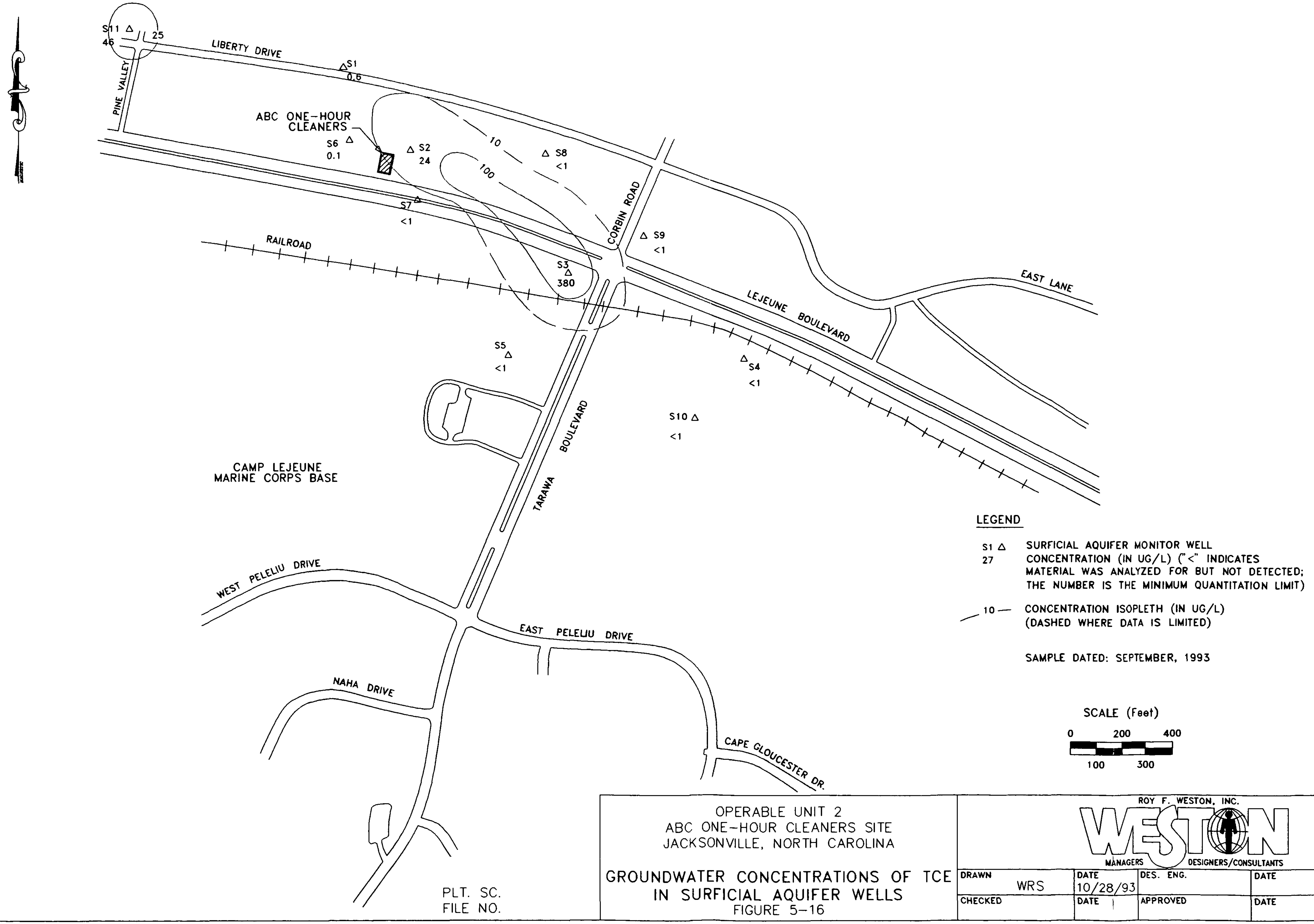
CHECKED		DATE	APPROVED	DATE	DWG. NO. ABC11



LEGEND

S1 △ 27	SURFICIAL AQUIFER MONITOR WELL CONCENTRATION (IN UG/L) ("<" INDICATES MATERIAL WAS ANALYZED FOR BUT NOT DETECTED; THE NUMBER IS THE MINIMUM QUANTITATION LIMIT)
—10—	CONCENTRATION ISOPLETH (IN UG/L) (DASHED WHERE DATA IS LIMITED)

SAMPLE DATED: SEPTEMBER, 1993

SCALE (Feet)

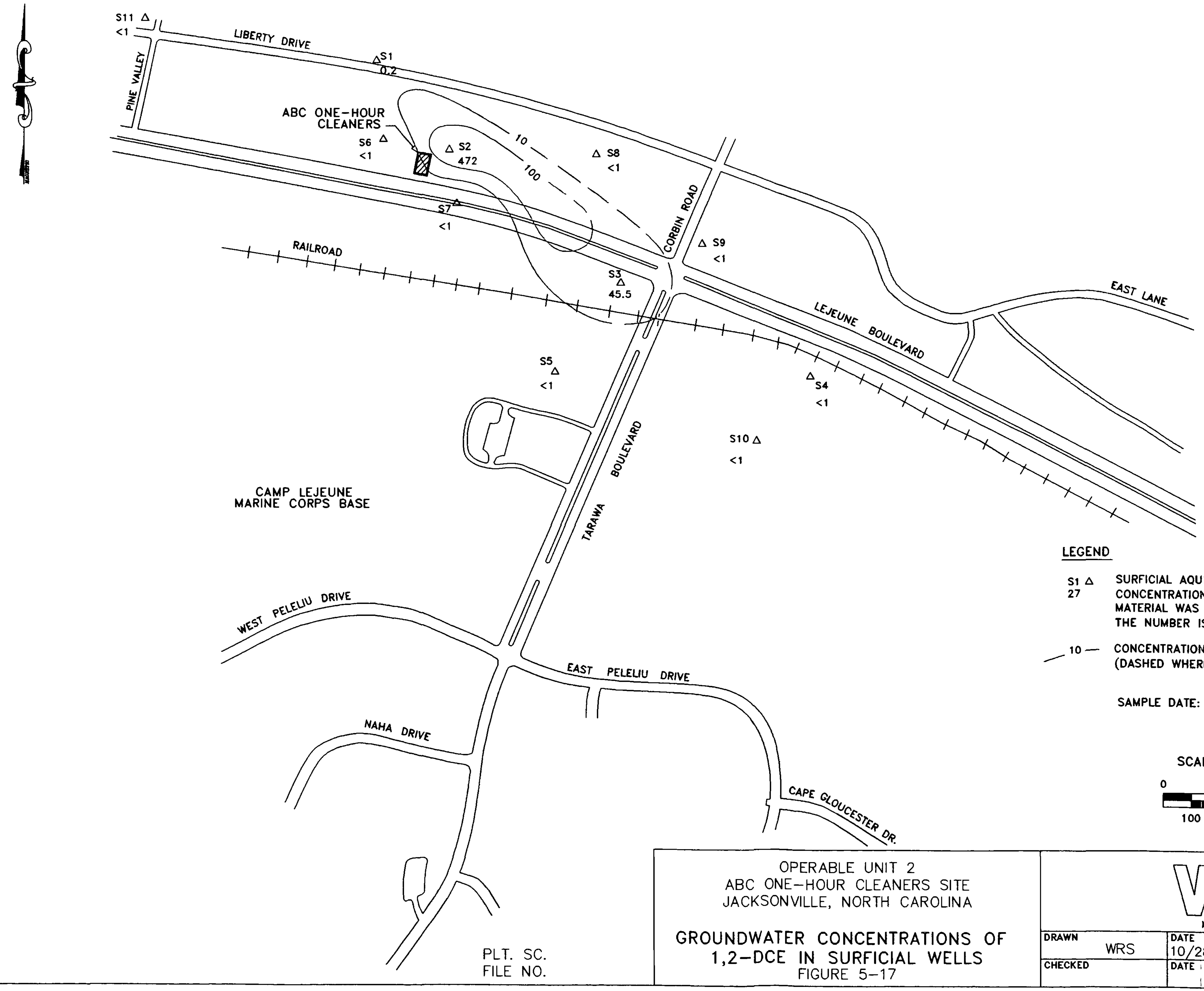
PLT. SC.
FILE NO.

OPERABLE UNIT 2
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

GROUNDWATER CONCENTRATIONS OF TCE
IN SURFICIAL AQUIFER WELLS
FIGURE 5-16

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN WRS	DATE 10/28/93	DES. ENG.	DATE	W. O. NO. 04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO. ABC33



LEGEND

S1 △ 27 — SURFICIAL AQUIFER MONITOR WELL CONCENTRATION (IN UG/L) ("<" INDICATES MATERIAL WAS ANALYZED FOR BUT NOT DETECTED; THE NUMBER IS THE MINIMUM QUANTITATION LIMIT)

10 — CONCENTRATION ISOPLETH (IN UG/L) (DASHED WHERE DATA IS LIMITED)

SAMPLE DATE: SEPTEMBER, 1993

SCALE (Feet)
0 100 200 300 400

PLT. SC.
FILE NO.

OPERABLE UNIT 2
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA

GROUNDWATER CONCENTRATIONS OF
1,2-DCE IN SURFICIAL WELLS
FIGURE 5-17

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN WRS	DATE 10/28/93	DES. ENG.	DATE	W. O. NO. 04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO. ABC22

as noted by the "J" data qualifier. The sample from well S6 also contained VOC concentrations; however, only the aromatic VOC ethylbenzene was observed above the method detection limit at 2 μg/L. All other VOC compounds detected in the S6 sample were estimated concentrations below detection limit. In the case of well S11, the isopleth map for PCE (Figure 5-15) shows a possible connection to the plumes surrounding ABC; however, the isopleth map for TCE (Figure 5-16) shows that the concentration is a separate entity indicating another source for VOC groundwater contamination within the surficial aquifer. Data from wells S1 and S6 indicate that the groundwater VOC plumes completely surround the ABC facility. Whether the VOC concentrations upgradient of the ABC facility are related to contamination detected in soils underneath ABC and the ultimate extent of this upgradient contamination will require further sampling of the existing wells and/or additional groundwater sampling at new locations.

Other compounds that were detected within surficial aquifer samples include aromatic volatiles that are commonly associated with petroleum products. These compounds, benzene, toluene, ethyl benzene, and xylene, were detected in samples from S7 and S11. During the OU1 study, aromatic volatiles were detected in samples collected from upgradient well S6, as well as the downgradient wells S2 and S5. For S2 and S5, the concentrations were only estimated values. Based on the fact that underground storage tanks are not present at ABC and that petroleum products are not used in the dry cleaning process, another source is likely. Immediately upgradient from the ABC location is an automobile repair shop, an automobile dealer, and a convenience store with gasoline pumps. No monitor wells were noticed in the automobile locations; however, the convenience store at 199 Pine Valley Road did have several monitoring wells surrounding the underground storage tank locations.

Clean-up Goals and Regulatory Limits

On January 26, 1993, EPA Region IV issued a Record of Decision (ROD) for the groundwater operable unit (OU1) at ABC One-Hour Cleaners. According to the ROD, the cleanup goals to be obtained for groundwater were stated for four primary contaminants. These contaminants and the associated clean-up goals were PCE (1.0 μg/L), TCE (2.8 μg/L), 1,2-DCE (70 μg/L), and vinyl chloride (1.0 μg/L).

EPA MCLs and NCGWQSs also exist for all VOCs detected in OU2 surficial aquifer groundwater samples, except for dibromochloromethane. Table 5-5 identifies these regulatory limits.

From a review of the OU2 analytical data presented in Table 5-4, with respect to ROD groundwater clean-up goals and other regulatory limits presented in Table 5-5, the following surficial aquifer wells contained contaminants in concentrations that exceed the established criteria.

Well	Contaminant
S1, S2, S3, S5	PCE
S2, S3, S11	TCE
S2, S3	Vinyl chloride
S2	1,2-DCE (total)
S11	Chloroform

Table 5-5

Summary of Regulatory Groundwater Quality Standards for Contaminants Detected in Surficial Aquifer Groundwater Samples ABC One-Hour Cleaners Operable Unit 2

Aromatic & Chlorinated VOCs	ABC ROD (μg/l)	NCGWQS (μg/l)	MCL (μg/l)
TCE	2.8	2.8	5
PCE	1.0	0.7	5
Vinyl chloride	1.0	0.015	2
cis-1,2-DCE	70	70	70
trans-1,2-DCE	70	70	100
1,1-DCE	--	7	7
Chloroform	--	0.19	100
Bromoform	--	1	100
Bromodichloromethane	--	--	100
Toluene	--	1,000	1,000
Ethylbenzene	--	29	700
Total Xylenes	--	400	10,000

μg/l = micrograms per liter.
-- indicates goal has not been issued.

The data in this table indicate that contaminants detected above regulatory limits in groundwater of the surficial aquifer are primarily in locations upgradient of the site (wells S1 and S11) and are concentrated around downgradient locations S2 and S3. However, PCE was also detected at levels exceeding regulatory limits in well S5.

Comparison of OU1 to OU2 Surficial Aquifer Groundwater Sampling Data

Comparison of groundwater sampling data from the OU2 monitor well sampling program to that of OU1 indicates that concentrations of four primary contaminants (PCE, TCE, 1,2-DCE, and vinyl chloride) have decreased over time. For example, OU1 samples collected from monitor wells S2 and S3 had much higher concentrations of these four contaminants than was detected in the OU2 samples. For one contaminant [1,2-DCE (total)], the levels have dropped by a factor of 25 from OU1 concentrations (MW-S3). Table 5-6 presents the summary of VOC analytical results for surficial aquifer groundwater samples from OU1 and OU2.

A similar trend is also apparent for other contaminants observed in OU2 sample results. For example, well S6 sample results indicated the presence of 28 μg/L of ethylbenzene. The OU2 sample for well S6 contained only 2 μg/L of ethylbenzene. The only contaminant for which concentrations increased from OU1 to OU2 sampling events was PCE in well S1, which increased from 10 to 27 μg/L. One possible explanation for the observed decreases in groundwater contaminant levels would be that contaminants may be undergoing biodegradation within the aquifer as the contaminants migrate through the aquifer. Another possible explination is that OU1 samples were collected in the month of April. The higher levels (relative to OU2 data) in these samples may reflect flushing and subsequent mobilization of contaminants from the soil into the surficial aquifer from winter and spring rainfall.

Table 5-6

Comparison of Analyses of Surficial Aquifer Groundwater Samples for 12 Primary Contaminants as Part of the OU1 (4/92) and OU2 (9/93) Remedial Investigations ABC One-Hour Cleaners

Parameter	Well #	S1		S2		S3		S4		S5	
	Sample Date	4-92	9-93	4-92	9-93	4-92	9-93	4-92	9-93	4-92	9-93
1,1-Dichloroethene		<10	<1	5J	1	6J	0.3J	<10	<1	<10	<1
1,2-Dichloroethene (total)		<10	0.2J	1,200	466	1,200	45.5	<10	<1	<10	<1
Chloroform		<10	<1	1J	<<1	<10	<1	<10	<1	<10	<1
Trichloroethene		<10	0.6J	690	280	640	24	<10	<1	3J	0.8J
1,1,2-Trichloroethane		<10	<1	<10	<1	2J	<1	<10	<1	<10	<1
Tetrachloroethene		10	27	880	490	5,400	380	<10	<1	3J	<1
Vinyl Chloride		<10	<1	100	70	110	10	<10	<1	2J	<1
Benzene		<10	<1	<10	0.4J	<10	<1	<10	<1	<10	<1

NOTES: $\mu g/l$ = micrograms per liter.
< indicates that material was not detected above the minimum quantitation limit.
J indicates an estimated value.

Table 5-6 (Continued)

Comparison of Analyses of Surficial Aquifer Groundwater Samples for 12 Primary Contaminants as Part of the OU1 (4/92) and OU2 (9/93) Remedial Investigations ABC One-Hour Cleaners

Parameter	Well #	S1		S2		S3		S4		S5	
	Sample Date	4-92	9-93	4-92	9-93	4-92	9-93	4-92	9-93	4-92	9-93
Toluene		< 10	< 1	< 10	2	< 10	< 1	< 10	< 1	4J	< 1
Ethylbenzene		< 10	< 1	< 10	0.4J	< 10	< 1	< 10	< 1	4J	< 1
Total Xylenes		< 10	< 1	< 10	3	< 10	< 1	< 10	< 1	5J	< 1
Chlorobenzene		< 10	< 1	< 10	0.6J	< 10	< 1	< 10	< 1	5J	< 1

NOTES: $\mu g/l$ = micrograms per liter.
< indicates that material was not detected above the minimum quantitation limit.
J indicates an estimated value.

Table 5-6 (Continued)

Comparison of Analyses of Surficial Aquifer Groundwater Samples for 12 Primary Contaminants as Part of the OU1 (4/92) and OU2 (9/93) Remedial Investigations ABC One-Hour Cleaners

Parameter	Well #	S6		S7		S8		S9		S10	
	Sample Date	4-92	9-93	4-92	9-93	4-92	9-93	4-92	9-93	4-92	9-93
1,1-Dichloroethene		< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1
1,2-Dichloroethene (total)		< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1
Chloroform		< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1
Trichloroethene		< 10	0.1J	< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1
1,1,2-Trichloroethane		< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1
Tetrachloroethene		4J	0.5J	< 10	0.2J	< 10	< 1	< 10	< 1	< 10	< 1
Vinyl Chloride		< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1
Benzene		2J	0.4J	< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1

NOTES: $\mu g/l$ = micrograms per liter.
< indicates that material was not detected above the minimum quantitation limit.
J indicates an estimated value.

Table 5-6 (Continued)

Comparison of Analyses of Surficial Aquifer Groundwater Samples for 12 Primary Contaminants as Part of the OU1 (4/92) and OU2 (9/93) Remedial Investigations ABC One-Hour Cleaners

Parameter	Well #	S6		S7		S8		S9		S10	
	Sample Date	4-92	9-93	4-92	9-93	4-92	9-93	4-92	9-93	4-92	9-93
Toluene		3J	0.2J	<10	0.1J	<10	<1	<10	<1	<10	<1
Ethylbenzene		28	2	<10	<1	<10	<1	<10	<1	<10	<1
Total Xylenes		<10	<1	<10	<1	<10	<1	<10	<1	<10	<1
Chlorobenzene		<10	<1	<10	<1	<10	<1	<10	<1	<10	<1

NOTES: µg/l = micrograms per liter.
< indicates that material was not detected above the minimum quantitation limit.
J indicates an estimated value.

Summary

Based on OU2 groundwater sample data for the surficial aquifer, the VOC contaminant plumes downgradient of the ABC site have not varied in overall area (Figures 5-15 through 5-17) since the OU1 sampling event (Figures 5-8 through 5-14). However, the concentrations from which isopleths are based have changed significantly. Upgradient of the site, the contaminant plume size and concentration isopleth has been revised, based on data from the installation and detection of PCE in monitor well S11, and the increase of PCE concentrations in well S1.

The OU2 groundwater sample data and the contaminant isopleth maps created from these data suggest that there are two sources for VOC contamination in the surficial aquifer. The OU2 data confirm the conclusion set forth in the OU1 study that VOCs in the surficial aquifer, downgradient of the ABC site, are attributable to the release of PCE from the septic tank system to subsurface soils and ultimately to area groundwater. However, the OU2 data also suggest that PCE and TCE concentrations upgradient of the site (specifically at wells S1 and S11) may be attributable to another source.

The primary contaminants in the surficial aquifer are PCE, TCE, vinyl chloride, 1,2-DCE (total), chloroform, and bromoform. These contaminants were primarily detected within samples collected from downgradient wells S2 and S3 and upgradient wells S1 and S11, although the upgradient well samples had lower concentrations. The monitor well S5 sample also contained a concentration of PCE in excess of regulatory guidelines.

5.2.2.2 Castle Hayne Aquifer Sample Analysis Results

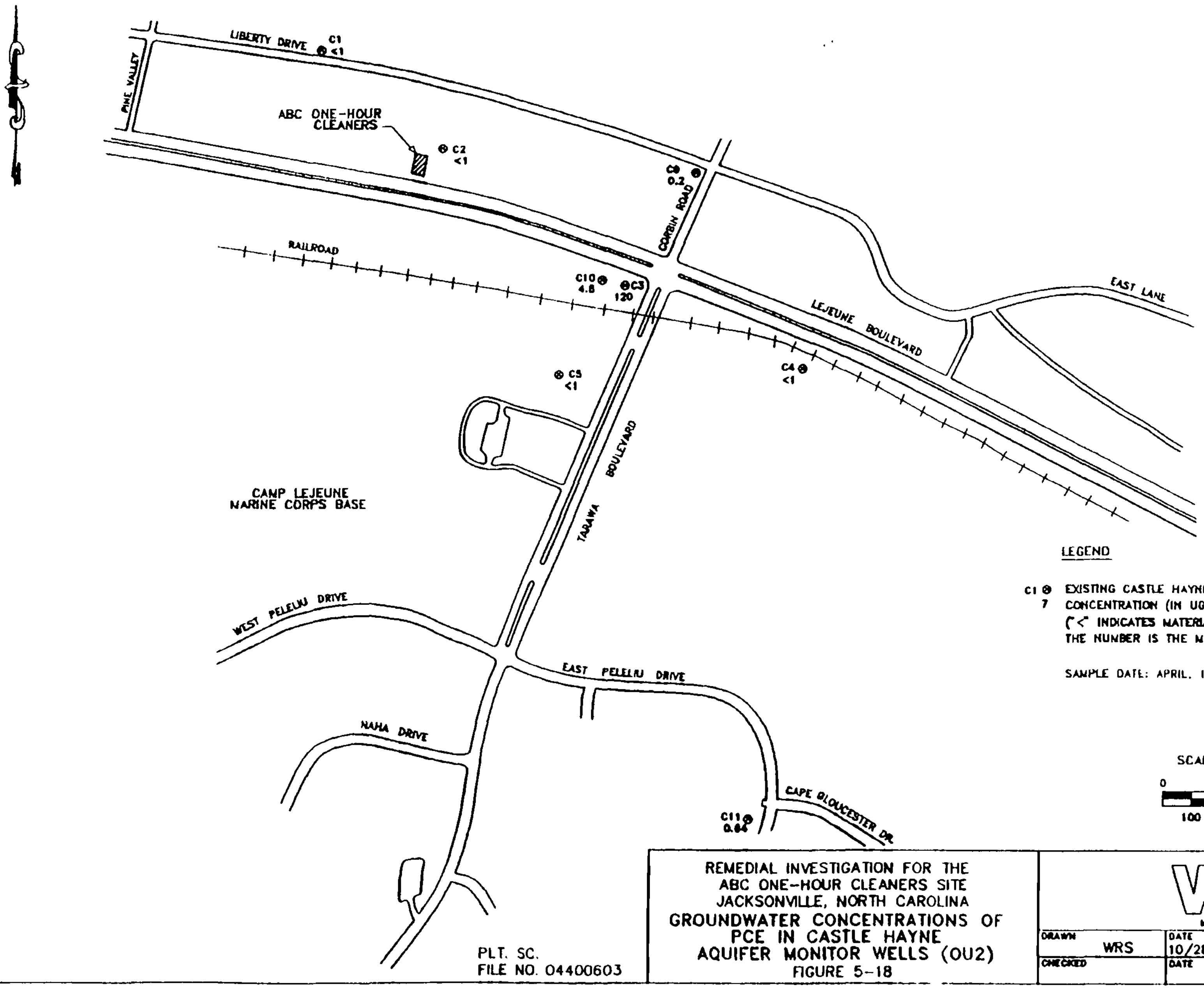
Analytical results of groundwater samples collected from the five existing and three newly installed Castle Hayne aquifer monitor wells indicates that a total of seven VOCs were detected above the laboratory detection limits. These seven VOCs are:

- PCE
- TCE
- cis-1,2-DCE
- methylpentanone
- dimethylpentanone
- isopropanol
- acetone

Various other compounds were also detected at estimated concentrations in Castle Hayne groundwater samples as summarized in Table 5-4. Not included in Table 5-4 was the detection of acetone in wells C2, C5, C9, and C11. Acetone, a compound not used in dry cleaning, was also observed in samples collected in wells C2, C5, C9, and C11. The origin of acetone within these samples is unknown and is considered anomalous. Acetone was not used during any portion of field decontamination procedures, but it is sometimes used during laboratory decontamination procedures.

PCE, TCE, and 1,2-DCE were the only contaminants detected in concentrations above the laboratory detection limit. The concentrations of these contaminants are presented in Figures 5-18 and 5-19. The highest concentration of PCE was detected within well C3 at 120 μg/L.

Of the original five Castle Hayne aquifer monitor wells installed during the OU1 field investigation, only the sample from well C3 revealed VOC concentrations above method



LEGEND

C1 ⊗ EXISTING CASTLE HAYNE AQUIFER MONITOR WELL
7 CONCENTRATION (IN UG/L)
("<" INDICATES MATERIAL WAS ANALYZED FOR BUT NOT DETECTED, THE NUMBER IS THE MINIMUM QUANTITATION LIMIT)

SAMPLE DATE: APRIL, 1992

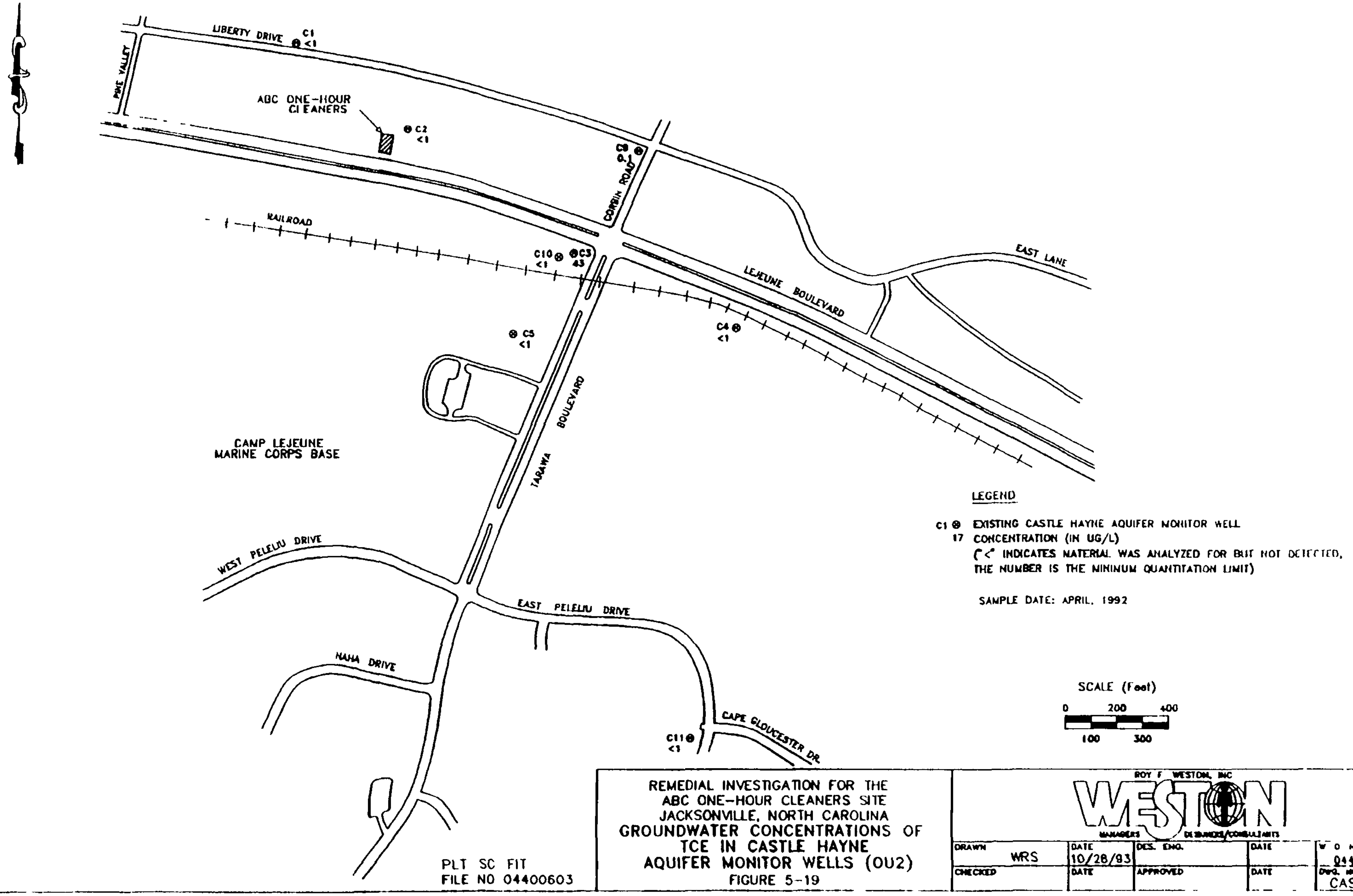
SCALE (Feet)
0 100 200 300 400

PLT. SC.
FILE NO. 04400603

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
GROUNDWATER CONCENTRATIONS OF
PCE IN CASTLE HAYNE
AQUIFER MONITOR WELLS (OU2)
FIGURE 5-18

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN	DATE	DES. ENG.	DATE	W. O. NO
WRS	10/28/93			04400603
CHECKED	DATE	APPROVED	DATE	DWG. NO.
				CAS-PCE



LEGEND

C1 ⊗ EXISTING CASTLE HAYNE AQUIFER MONITOR WELL
17 CONCENTRATION (IN UG/L)
("<" INDICATES MATERIAL WAS ANALYZED FOR BUT NOT DETECTED, THE NUMBER IS THE MINIMUM QUANTITATION LIMIT)

SAMPLE DATE: APRIL, 1992

PLT SC FIT
FILE NO 04400603

REMEDIAL INVESTIGATION FOR THE
ABC ONE-HOUR CLEANERS SITE
JACKSONVILLE, NORTH CAROLINA
GROUNDWATER CONCENTRATIONS OF
TCE IN CASTLE HAYNE
AQUIFER MONITOR WELLS (OU2)
FIGURE 5-19

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN	WRS	DATE 10/28/93	DES. ENG.	DATE	W. O. NO. 04400603
CHECKED		DATE	APPROVED	DATE	DWG. NO. CAS- TCE

detection limits. Well C1 contained contaminants (methylpentanone and dimethylpentatone); however, the presence of these compounds was estimated and considered presumptive. As reported in Table 5-4, the C3 sample contained 120 μg/L of PCE, 43 μg/L of TCE, and 21 μg/L of cis-1,2-DCE. By comparison, concentrations of VOCs in well C3 have increased since the OU1 sampling event (see Table 5-8 for OU1 VOC analytical results).

All samples collected from newly installed Castle Hayne aquifer wells (C9, C10, and C11) exhibited concentrations of various VOCs as detailed in Table 5-4. Monitor well C9, which contained estimated VOC concentrations for PCE and TCE, was installed to provide monitoring of the Castle Hayne aquifer in an area presumed to be on the northern edge of a groundwater plume within the aquifer. These results indicate the possibility of a VOC plume within this portion of the Castle Hayne aquifer and if the plume is oriented as depicted in Figure 5-18, the C9 location is on the edge of the southeast trending plume.

Monitor well C10, which was screened at a depth of 166 to 176 feet bgs, contained an estimated PCE concentration of 4.8 μg/L. This well was installed for the purpose of determining if groundwater contamination in well C3 extended to depths greater than 90 feet bgs. Monitor well C11 which was installed south-southeast of Base supply well TT-23 to monitor a possible plume that may have migrated in the direction of the estimated gradient following cessation of pumping, also contained an estimated concentration of 0.64 μg/L of PCE and 20 μ/gL of isopropanol. The presence of isopropanol is most likely the result of decontamination activities, specifically residues remaining within the pump used for purging.

The question of the origin of VOC contamination in the Castle Hayne aquifer was discussed within the OU1 RI. Arguments presented at that time included the possibility that contamination may reflect vertical movement of chlorinated VOCs naturally through the aquifer. Alternatively, the possibility of supply wells acting as vertical conduits for downward migration of contamination was also discussed. Historical groundwater samples collected from the supply wells have higher concentrations of VOCs than in corresponding Castle Hayne monitor wells. The possibility then exists that either: 1) groundwater from the VOC contaminated surficial aquifer was drawn into and intermixed with Castle Hayne aquifer water during use of the supply wells, thereby leading to Castle Hayne aquifer contamination: or 2) an improperly sealed supply well (RW-02 and TT-26, for example) screened in the Castle Hayne allowed groundwater from the surficial aquifer to leak into the well borehole and, under downward vertical gradient, move into the Castle Hayne aquifer. Contaminant migration into the Castle Hayne, according to this theory would be rather rapid with VOC concentrations emanating from these locations.

The distribution of contaminants exhibited by the monitor wells is not in conflict with the possibility of some general and variable leakage of groundwater from the surficial aquifer into the Castle Hayne aquifer. Given the nature (especially specific gravity when compared to water) of the contaminants (Table 5-7), it is highly possible that limited groundwater movement from the surficial aquifer into the Castle Hayne aquifer could produce the VOC concentrations observed in the Castle Hayne aquifer wells.

Regulatory Limits and/or Clean-up Goals - Castle Hayne Aquifer

ROD-based groundwater goals, EPA MCLs, and NCGWQSs were compared to VOCs detected in Castle Hayne groundwater samples. Only the concentrations of PCE and TCE within well C3 exceed the regulatory limits established in the ROD. All other contaminants were below established standards.

Table 5-7

Physical Properties of Selected Denser-than-Water Nonaqueous Phase Liquid (DNAPL) Chemicals (after Cohen and Mercer, 1993)

DNAPL Name	Specific Gravity	Viscosity (cp)	Solubility (mg/L)
Chlorobenzene	1.594	0.97	800
Chloroform	1.483	0.58	8,000
Methylene Chloride	1.327	0.43	20,000
Tetrachloroethene	1.623	0.89	150
1,1,1-Trichloroethane	1.339	0.83	1,360
Trichloroethene	1.464	0.57	1,100

cp = centipoise
mg/L = milligrams per Liter

Since the VOC concentrations detected in monitor well C3 were relatively high (when compared to other Castle Hayne samples), and because a hydraulic gradient is present eastwardly across the Castle Hayne, the contamination at C3 would be expected to migrate downgradient towards well C4. VOCs were not detected in well C4 groundwater samples for either OU1 or OU2 field sampling efforts. Thus, contaminants, may be either continuing to migrate toward well C4 or concentrating around well C3 and not moving at this time.

Comparison of OU1 to OU2 Castle Hayne Aquifer Groundwater Sampling Data

The OU1 monitor well sampling data for the Castle Hayne aquifer (wells C1 through C5) is presented in Table 5-8. The analytical data indicate that VOCs were detected in samples from wells C2, C3, and C5. Well C3 had the highest TCE and PCE concentrations, although the PCE value was estimated below the detection limit of 10 μg/L. Similarly, all of the C2 concentrations were estimated below the 10 μg/L detection limit. The C5 well sample contained an estimated value of TCE and estimated values for the aromatic compounds benzene and toluene. In comparison, the OU2 data shows that only well C3 had elevated levels of VOCs. In this sample, the concentrations of TCE increased 35%, PCE increased 94%, and 1,2-DCE (total) increased 33%. Wells C2 and C5 continued to have non-detectable concentrations for VOCs (OU1 and OU2).

Summary

Of the five monitor wells installed during the OU1 study, only wells C1 and C3 contained any VOCs; however, the presence of contaminants in C1 was considered estimated and presumptive. Only monitor well C3 contained contaminant concentrations that were not estimated. The

Table 5-8

Comparison of Analysis of Castle Hayne Aquifer Groundwater Samples For 6 Primary Contaminants As Part of the OU1 (4/92) and OU2 (9/93) Remedial Investigations

Parameter	Well #	C1		C2		C3		C4		C5	
	Sample Date	4-92	9-93	4-92	9-93	4-92	9-93	4-92	9-93	4-92	9-93
1,2-Dichloroethene (total)		< 10	< 1	9J	< 1	14	21	< 10	< 1	< 100	< 1
Chloroform		< 10	< 1	2J	< 1	< 10	< 1	< 10	< 1	< 100	< 1
Trichloroethene		< 10	< 1	3J	< 1	28	43	< 10	< 1	17J	< 1
Tetrachloroethene		< 10	< 1	1J	< 1	7J	120	< 10	< 1	< 100	< 1
Benzene		< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1	18J	< 1
Toluene		< 10	< 1	< 10	< 1	< 10	< 1	< 10	< 1	25J	< 1

NOTES: Units are micrograms per liter (μg/l).
< indicates that material was analyzed for but not detected above the minimum quantitation limit.
J indicates an estimated value.
N indicates presumptive evidence of presence of material.

concentrations PCE, TCE, and 1,2-DCE (total) within well C3 all increased from the time of the OU1 sampling to the OU2 sampling event. Groundwater samples from all newly installed Castle Hayne aquifer monitor wells contained VOCs; however, all the concentrations were considered estimated.

Only the concentrations of PCE and TCE in monitor well C3 were in excess of the ROD groundwater goals for the ABC site. Other detected contaminants in Castle Hayne wells were below established regulatory standards. Monitor well C10 contained 4.89 μg/L of PCE, which is above the ROD goal; however, this concentration was estimated.

There appear to be two prominent mechanisms by which contaminants may have entered into the Castle Hayne aquifer: 1)natural leakage under a hydraulic gradient from the surficial aquifer and; 2) leakage of contaminants from the surficial aquifer along boreholes of supply wells that are screened in the Castle Hayne aquifer.

The estimated extent of contamination is dependent on the relative contributions of the mechanisms by which contaminants enter the Castle Hayne aquifer whether it be from natural "leakage" of groundwater from the surficial aquifer into the Castle Hayne aquifer or from leakage along boreholes at supply wells RW-2 and TT-26. If contamination enters the Castle Hayne aquifer via the boreholes of supply wells, then contamination is expected to be limited to the near vicinity of these wells and to groundwater downgradient of the supply wells. If natural "leakage" of contaminated surficial aquifer groundwater is entering the Castle Hayne aquifer, the extent of contamination may be broader, with the area between the wells (corresponding to the area of highest contaminant concentrations observed in the surficial aquifer) being partially or totally included.

5.3 QUALITY ASSURANCE/QUALITY CONTROL SAMPLE ANALYSIS

Quality Assurance/Quality Control (QA/QC) samples during OU2 consisted of eight field blanks (FBL-01 through -08), five trip blanks (TBL-02 through -06), and five rinse blanks (RBL-01 through -05). Also included was one matrix spike (MW-C5-MS) and one well materials sample (MW-DF-01). All of the QA/QC samples were analyzed for TCL-VOCs. Results of the analysis are presented in Table 5-9. The locations for QA/QC sample collection were previously described in Table 3-9.

5.3.1 Field Blank Analysis

Five compounds were detected in four of the eight field (atmosphere) blanks collected during the OU2 field operations. The contaminants included PCE, methylethyl ketone (MEK), 1,1,1-trichloroethane (1,1,1-TCA), acetone, and methylene chloride. Samples FLB-04, -05, and -06 contained 17 μg/L, 15 μg/L, and 49 μg/L of PCE, respectively. These samples were collected during operating hours at ABC in three rooms that make up the rear three-quarters of the building (one sample per room). The other field blank sample that contained detectable contaminant concentrations was FBL-08, which contained 39 μg/L of MEK and an estimated amount of 0.4 μg/L of 1,1,1-TCA and 16 μg/L of acetone. This sample was collected within the decontamination pad area.

5.3.2 Rinse Blank Analysis

Of the five rinse blanks collected during ABC field operations, RBL-02 and RBL-05 exhibited VOC concentration of 81 μg/L of acetone and an estimated amount of 0.2 μg/L of 1,1,1-TCA, respectively (Table 5-9). This sample was collected from a teflon bailer after it had been decontaminated. The source of the 1,1,1-TCA is unknown at this time. The rinse blank analyses verify that decontamination procedures were performed correctly and adequately, and that cross-contamination was prevented.

5.3.3 Trip Blank Analysis

During field operations, all trip blanks were collected from the discharge side of the on-site organic-free water system located in the area of the decontamination pad. An individual trip blank was collected from the discharge hose prior to each sample shipment. Of the six trip blanks submitted for analysis, five contained a measurable quantity of VOCs above the laboratory detection limits. All of the concentrations of contaminants were reported in estimated values. The most prominent contaminant was 1,1,1-TCA, which was estimated within three samples. MEK had the highest concentration and was detected at an estimated value of 0.5 μg/L. Acetone was also detected at an estimated concentration of 6 μg/L.

The origin of the trip blank contaminants may be attributable to several sources. The PCE in TBL-03 is very likely due to contamination of the blank sample by vapors exhausted from the ABC building interior to the atmosphere. Other contaminants may be attributable to the laboratory analytical process and/or laboratory ambient atmospheres, or possibly decontamination activities.

Table 5-9

Quality Assurance/Quality Control Sample Analyses Results
ABC One-Hour Cleaners
Operable Unit 2

September 1993

Well Designation	Parameter	Results (μg/l)	MDL (μg/l)
FBL-01	ND	-	-
FBL-02	ND	-	-
FBL-03	ND	-	-
FBL-04	Tetrachloroethene	17	1
FBL-05	Tetrachloroethene	15	1
FBL-06	Tetrachloroethene	49	1
FBL-07	ND	-	-
FBL-08	Acetone	16J	5
	Methyl Ethyl Ketone	39	15
	1,1,1-Trichloroethane	0.4J	1
TBL-02	Methylene Chloride	0.3JN	1
	1,1,1-Trichloroethane	0.3JN	1
TBL-03	Tetrachloroethene	0.5JN	1

NOTES:
MDL indicates method detection limit.
ND indicates not detected above the MDL.
μg/l indicates micrograms per liter.
J indicates estimated value.
N indicates presumptive evidence of presence of material.
* During OU2 field operations, the sample number TBL-05 was inadvertently used twice.
FBL = Field (Atmosphere) Blank.
RBL = Rinse Blank.
TBL = Trip Blank.
MW - C5-MS = Matrix Spike from Monitor Well C5.
DF = Drilling Fluids

Table 5-9 (Continued)

Quality Assurance/Quality Control Sample Analyses Results
ABC One-Hour Cleaners
Operable Unit 2

September 1993

Well Designation	Parameter	Results (μg/l)	MDL (μg/l)
TBL-04	Acetone	6J	5
	Methyl Ethyl Ketone	15J	5
	1,1,1-Trichloroethane	0.2J	1
*TBL-05 (9/30/93)	Toluene	0.2J	1
*TBL-05 (10/02/93)	1,1,1-Trichloroethane	0.2J	1
TBL-06	ND	-	-
P2-RBL-01	ND	-	-
RBL-02	Acetone	81	10
RBL-03	ND	-	-
RBL-04	ND	-	-
RBL-05	1,1,1-Trichloroethane	0.2J	1
MW-C5-MS	Acetone	4JN	5

NOTES: MDL indicates method detection limit.
ND indicates not detected above the MDL.
μg/l indicates micrograms per liter.
J indicates estimated value.
N indicates presumptive evidence of presence of material.
* During OU2 field operations, the sample number TBL-05 was inadvertently used twice.
FBL = Field (Atmosphere) Blank.
RBL = Rinse Blank.
TBL = Trip Blank.
MW - C5-MS = Matrix Spike from Monitor Well C5.
DF = Drilling Fluids

Table 5-9 (Continued)

Quality Assurance/Quality Control Sample Analyses Results
ABC One-Hour Cleaners
Operable Unit 2

September 1993

Well Designation	Parameter	Results (μg/l)	MDL (μg/l)
MW-DF-01	Acetone	10J	5
	Chloroform	2	1
	Bromodichloromethane	4	1
	Dibromochloromethane	7	1
	Bromoform	3	1
	Tetrachloroethene	0.7J	1

NOTES:
MDL indicates method detection limit.
ND indicates not detected above the MDL.
μg/l indicates micrograms per liter.
J indicates estimated value.
N indicates presumptive evidence of presence of material.
* During OU2 field operations, the sample number TBL-05 was inadvertently used twice.
FBL = Field (Atmosphere) Blank.
RBL = Rinse Blank.
TBL = Trip Blank.
MW - C5-MS = Matrix Spike from Monitor Well C5.
DF = Drilling Fluids

5.3.4 QA/QC Sample Analysis

Whether or not groundwater and/or soil sample analysis results were affected by the contaminants detected within the blanks is difficult to determine because the reported concentrations are, in many cases, estimated (Table 5-9). For all acetone detections, the response is considered to be non-site related. If contaminants at relatively high levels had been detected within the rinse blanks, then sample results could have been considered tainted; however, only one contaminant, 1,1,1-TCA, was detected at an estimated concentration. Also, 1,1,1-TCA was not detected within any soil samples and only one (S11) groundwater sample.

Trip blanks are collected to determine if samples have been exposed to contamination during shipment. It is believed that the blanks were exposed to contamination prior to shipment. For example, field blank FBL-08 contained the exact contaminants that were detected in trip blank TBL-04. FBL-08 also contained 1,1,1-TCA that was observed in three of five contaminated trip blanks. These similarities indicate that the trip blanks were more likely contaminated prior to shipment and that the contamination occurred at the point of trip blank collection.

Field blanks were collected in order to define whether or not VOCs that may exist in the atmosphere around the ABC site as a result of the ongoing ABC facility processes or WESTON's investigation may have affected the analytical results of other samples collected within and outside of the ABC building, especially during ABC operating hours. The analytical results of field blanks FBL-04, -05, and -06 (Table 5-9), indicate that PCE present in the atmosphere within the ABC building could increase a sample result as much as 49 μg/L. Only soil samples were collected in the ABC building and, because of the high concentrations of VOCs detected in the soil samples, it is not known as to what extent the atmospheric PCE would have affected the samples. Due to several exhaust fans that are present on the outer walls of the ABC building, some of the atmospheric PCE was vented to the outside. It is possible that PCE vented to the outside of the ABC building could impact the analytical results of sampling occurring at the same time, including collection of trip blanks as previously discussed.

5.3.5 Monitor Well Construction Materials Samples

One sample was collected from well construction materials and submitted for TCL-VOC analysis (drilling fluid using during mud rotary drilling). The results of the analysis can be found in Table 5-9.

The drilling fluid consisted of potable water and bentonite powder. The sample was collected prior to circulation of the mud down the borehole. Five VOC contaminants were detected above the laboratory detection limit above the laboratory detection limit in the drilling fluid. The presence of these contaminants is not unexpected because of the presence of trihalomethanes in the local water supply. During the OU1 RI, a sample of the potable water supply from the City of Jacksonville was collected and analyzed for TCL-VOCs. This sample (FB-000-02) contained trihalomethane VOCs as follows:

Analyte	Concentration (in μg/L)
Chloroform	14
Bromodichloromethane	10
Dibromochloromethane	5.1

In comparison to the drilling fluid sample from OU2, it appears that these same VOCs and the bromoform detected in the drilling fluid sample are very likely still present within the City of Jacksonville potable water supply.

The presence of PCE within the drilling fluid is more difficult to understand. The estimated amount of PCE (0.7 J μg/l) could possibly have originated from contamination that existed on the drilling equipment (specifically the mud tub) prior to initiation of drilling activities at well C10, which is where the drilling fluid sample was collected.

Since the VOCs detected in the drilling fluid (except for PCE) were not detected in the groundwater sample from C10, it does not appear that they have influenced the groundwater sample from well C10 installed at the site. PCE, which was detected in both samples, is of higher concentration in the groundwater sample (4.8 μg/L versus 0.7 μg/L). In addition, during the drilling of well C10, the drilling fluid was not used below 97 feet bgs, which is 69 feet above the screen zone for well C10. It is speculative that 0.7 μg/L of PCE in the drilling fluid could have been carried to the screen interval during the drilling.

5.4 REFERENCES

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WESTON (Roy F. Weston, Inc.), 1992. Remedial Investigation Report. Revision 1. ABC One-Hour Dry Cleaners, Jacksonville, North Carolina. For Region IV, United States Environmental Protection Agency. November 5, 1992. Contract No. 68-W9-0057.

SECTION 6

CONTAMINANT FATE AND TRANSPORT

This section describes the contaminants detected within the soils at the ABC facility and the chemical fate and transport of these contaminants when subjected to physical, biological, and chemical interactions within the soil horizon.

6.1 CONTAMINANT PRESENCE

Since 1955, PCE has been used to dry clean clothes at ABC. For a short period of time, spent PCE was reclaimed through a filtration-distillation process. As a result of the process, still bottoms were created and were subsequently disposed of on-site until 1985. A septic tank and an associated soil absorption system were utilized for wastewater disposal.

Previous studies have indicated that the septic tank and associated absorption system are the source of groundwater contamination in the area. Results of analyses conducted during the RI for OU1 and OU2 confirmed the presence of PCE in both the surficial and Castle Hayne aquifers, as well as septic tank wastes. Other contaminants were detected within the groundwater that were attributable to commercial grades of PCE and/or breakdown products of PCE.

Previous studies and this RI have also shown that the septic system and historical operational practices are the source of PCE and other chlorinated hydrocarbons contamination in the unsaturated soil profile (0 to 15 feet bgs) underlying the ABC facility. Analytical results indicate that the highest concentrations of PCE and other contaminants are directly beneath the ABC

According to Ney (1990), adsorption to soil, in almost all cases, can prevent phototransformation, hydrolysis, volatilization, mobility by water solubility, and microbial biodegradation; however, this is all dependent upon the binding strength of the soil, which is a factor of the organic carbon present in the soil and the hydrophobicity of the chemical. "Soil adsorption, chemical adsorption, or bound chemical(s) in soil may be expressed as the extent that an organic chemical partitions between a solid phase and a liquid phase. This value is better known as the adsorption coefficient (K_{oc})" (Ney, 1990). In order to predict whether or not a chemical may adsorb to soil organic carbon, the K_{oc} value is utilized. Soils must contain organic carbon/organic matter to produce a K_{oc}. Chemicals with a high K_{oc} of $>10{,}000$ mL/g will adsorb to organic carbon: whereas, a K_{oc} value of less than 1,000 mL/g indicates that chemical will not adsorb to soil organic carbon.

In the case where a contaminant is weakly adsorbed, contaminant-soil particle bonds can be dissolved by water thus releasing the contaminant particle, which is called desorption. Chemicals that behave in this way usually have a water solubility of less than 10 parts per million (ppm). Other solvents that do not occur naturally in the environment may solubilize the chemical. This phenomenon usually occurs in areas of solvent spills or in leaking storage areas (Ney, 1990).

Depending upon the concentration of the chemical and the quantity of adsorption by the soil, chemicals will move through the environment by means of volatilization, leaching, runoff, or food-chain uptake. Each of these migration processes will be discussed below.

Volatilization refers to mass transfer from liquid and soil to the gaseous phase. A chemical that transforms to gas may be derived from the presence of non-aqueous phase liquids (NAPL), dissolved chemicals, or adsorbed chemicals (Cohen and Mercer, 1993); however, vapor pressure and water solubility affect volatilization. The volatilization rate of a chemical in soil is also dependent upon the concentrations introduced to the soil, the amount of moisture present in the soil, movement of air through the soil, sorptive and diffusive characteristics, soil temperature, clay content, organic-carbon content, porosity, and density.

VOCs that have volatilized into the soil gas phase can move into various phases or become part of another phase without changing form. According to Cohen and Mercer (1993) the gas can: (1) migrate and ultimately condense; (2) sorb onto soil particles; (3) dissolve in groundwater; (4) degrade; and/or (5) escape to the atmosphere.

Within the unsaturated soil profile, the partitioning of VOCs between the solid, gas, aqueous, and NAPL phases depends upon the volatility and solubility of the VOC, the soil moisture content, and the type and amount of soil solids present (Silka and Jordan, 1993). For example, researchers (Acher et al., 1989) have concluded that adsorption of vapors from VOCs decreased with increasing soil moisture content. In addition, greater PCE adsorption to soil with higher organic carbon content resulted in reduced volatilization rate for both aqueous and pure PCE (Zytner et al., 1989). Conversely, increasing soil air movement and/or soil temperature elevates the volatilization rate. Volatilization losses from subsurface NAPL are expected where NAPL is close to the ground surface or in dry permeable sandy soils, or where NAPL has a very high vapor pressure (Feenstra and Cherry, 1988).

Calculation of the volatilization of a VOC from soil involves (1) estimating the organic partitioning between water and air, and the NAPL and air through Henry's Law and Raoult's Law and (2) estimating the vapor transport from the soil (Cohen and Mercer, 1993). Henry's

Law relates the concentration of a dissolved chemical in water to the partial pressure of the chemical in gas. The tendency of a chemical to volatilize increases with an increase in Henry's Law constant. Other guidelines for determining if a chemical will volatilize are: (1) a chemical with a low vapor pressure, high adsorptive capacity, or high water solubility is less likely to volatilize; (2) a chemical with a high vapor pressure, low sorptive capacity, or very low water solubility is more likely to volatilize (Ney, 1990).

Leaching of chemicals from soil is another process of migration involving the movement of a chemical downward through soil through percolation of water. Typically, the more precipitation, the greater the chance for chemicals to leach (Ney, 1990). Leaching is of concern because of the potential for a chemical to move through the soil and contaminate the groundwater. Many factors affect whether or not a chemical leaches in soil, including solubility, biodegradation, hydrolysis, dissociation, sorption, volatility, rainfall, and evapotranspiration. A chemical that is water-soluble can leach in soil and is likely to be biodegraded by soil microbes. If biodegradation is rapid, then leaching may be minimal. A chemical that is insoluble in water can be adsorbed in soil, moved with soil particles, and perhaps very slowly biodegraded, if at all.

Surface runoff may spread contamination to a more widespread area. This can occur when: (1) a water-soluble chemical is solubilized in rainwater and snow melt, and is transported to uncontaminated areas; (2) chemicals that are ad- or absorbed by soil particles can migrate as soil erosion occurs; and (3) solvents other than water may solubilize and transport chemicals. If the land slopes, resulting in water runoff, it is likely that soil and any chemicals that are present will migrate. Moreover, the amount of rainfall and snow strongly influences the amount and distance of such movement.

6.3 CONTAMINANT PERSISTENCE

There are several mechanisms active within the natural environment that affect the persistence of chemicals once they are released to the environment. These mechanisms include:

1. Photolysis
2. Biodegradation
3. Metabolic reactions
4. Hydrolysis
5. Bioaccumulation
6. Dissociation/Redox Reactions
7. Sorption

Each of these mechanisms is discussed in this section.

Photolysis of a chemical can occur as long as it can absorb sunlight. Phototransformation of a chemical can occur in air, soil, or water and on surfaces of water, soil, plants, and animals. Environmental influences can have an effect on the rate of phototransformation, such as depth of the chemical in soil and water, sorption to soil, sensitizers, and pH. The rate of phototransformation is the time that it takes for a parent chemical to be transformed to one-half ($t_{1/2}$) of its original amount. This rate could differ in soil, in water, and on surfaces. The faster the photolytic rate the less likelihood of continued exposure in the environment. If the photolytic half-life is less than 30 days, then accumulation, bioaccumulation, or food-chain contamination is unlikely; if it is 30 to 90 days, some food-chain contamination is possible; and if it is greater than 90 days, food-chain contamination is likely.

Biodegradation is the biological process by which aerobic microbes or anaerobic microbes break down organic chemicals to either a higher- or a lower-molecular-weight chemical(s). This is a very important process by which soil microbes or aquatic microbes can detoxify chemicals (Ney, 1981); however; the process may also result in the formation of a more toxic chemical. Chemicals that are highly water-soluble can biodegrade, but those with low water solubility usually will not. Other factors affecting the rate of biodegradation include pH, temperature, sorption, populations of microbes, moisture, the presence of and concentration of other chemicals, and the concentrations of chemicals present.

Metabolic reactions involve uptake by plants into their root systems and uptake by animals through normal feeding habits. These reactions produce metabolites. These metabolites are usually translocated throughout the plant. Also, animals producing metabolites translocate these throughout their bodies.

Hydrolysis is one of the most important mechanisms in the environment for the breakdown of a parent chemical (Ney, 1981). It occurs in soils, water, plants, animals, and possibly air. The hydrolysis of pesticides has even occurred on plant surfaces. Hydrolysis is the chemical interaction of water with the contaminant which alters the chemical's structure and, in turn, alters its transport within the environment. Many environmental factors influence the rate of hydrolytic degradation, such as temperature, pH, solubility, sunlight, ad- or absorption, and volatility. The rate of hydrolyzation of a chemical is the time that it takes to reach one-half of its original concentration ($t_{1/2}$).

Bioaccumulation is the uptake of chemicals by a plant or animal and the storage of the chemicals or its degradation product within the tissues of that organism.

Bioaccumulation is a key consideration in predicting whether food-chain contamination can occur. The process may occur in two ways: (1) contaminated plants eaten by animals cause contamination in animals, and (2) contaminated animals eaten by animals move the contaminants up the food chain. Most chemicals do not bioaccumlate appreciably.

Dissociation or ionization of a chemical takes place in the solid, aqueous, or volatilized state. The ionization takes place when the chemical becomes electrically charged through the loss or gain of electrons. When an atom, molecule, or ion loses electrons, it is oxidized; when electrons are gained, it is reduced. These reactions are referred to as oxidation-reduction, or redox, reactions.

Oxidation typically involves the loss of electrons during a chemical reaction. In general, substituted aromatic compounds such as ethylbenzene, naphthalene, and phenol can be oxidized. Oxidation rates for aromatic compounds are typically an order of magnitude faster than for chlorinated aliphatic compounds. Overall, abiotic (without biological life) oxidation of organic compounds in groundwater systems is extremely limited (Olson and Davis, 1990).

Reduction reactions transfer electrons to a compound. For a chlorinated aliphatic compound, this results in a less chlorinated compound (e.g., the formation of vinyl chloride from 1,1-DCE). Dehydrohalogenation involves the loss of both a hydrogen ion and a halogen and the resultant formation of a double carbon bond (e.g., the formation of 1,1-DCE from TCA).

6.4 SITE SPECIFIC CHEMICAL PROPERTIES

The various VOCs detected in soils and septage at the ABC site can be classified as halogenated aliphatic hydrocarbons (PCE, TCE, and 1,2-DCE). Only halogenated aliphatic hydrocarbons (HACs) were observed in significant quantities at the ABC site. Table 6-1 lists physical properties for the various organic contaminants detected in soils at the ABC site (ranked by their aqueous solubility). Table 6-2 lists physical properties that can affect fate and transport of contaminants in the surface and subsurface, as discussed in the previous sections.

HACs are characterized by open-chain structures; a variable number of single, double, and triple bonds; and the presence of chlorine, bromine, fluorine, or iodine. HACs have many applications, such as solvents, degreasers, dry cleaning agents, refrigerants, and organics synthesis agents (Moore et al, 1984). PCE was the most frequently detected HAC in ABC soil samples.

In general, HACs have low to moderate solubilities, high volatilities, low to moderate partition coefficients, high mobilities, and densities greater than water (see Table 6-1). As a result, they are relatively easily leached from the soil into the groundwater (if conditions are suitable). Once in the subsurface, the HACs typically undergo progressive dehalogenation. These dehalogenation steps are presented in Figure 6-1. Generally, the time required for each step may be widely variable and degradation may or may not occur, depending on subsurface conditions (the presence of nutrients, microorganisms, etc.).

Table 6-1

Physical Properties of Contaminants Detected Within the Unsaturated Soil Profile ABC One-Hour Cleaners Operable Unit 2

Chemical	Absolute Viscosity (Cp)	Boiling Point (°C)	Melting Point (°C)	Aqueous Solubility (mg/L)	Vapor Pressure (mm Hg)
Chloroform	[o] 0.58	[a] 62	[a] -63	[a] 8.00E+03	[a] 1.60E+02
1,1-Dichloroethene	[o] 0.36	[a] 37	[a] -122	[a] 4.00E+02	[a] 4.95E+02
trans-1,2-Dichloroethene	[o] 0.40	[a] 47	[a] -50	[a] 6.00E+02	[a] 2.65E+02
cis-1,2-Dichloroethene	-	[oc] 60	[oc] -81	[oc] 800	[oc] 200 mm @ 25°C
Vinyl chloride	-	[oc] -13.9	[oc] -153/-160	[oc] 1.10 @ 25°C	[oc] 580 mm
Trichloroethene	[o] 0.57	[a] 87	[a] -73	[a] 1.10E+03	[a] 5.78E+01
Tetrachloroethene	[o] 0.89	[a] 121	[a] -19	[a] 1.50E+02	[a] 1.40E+01

- = Value not provided

References:

a = Montgomery, J.H., and Welkom, L.M., 1990. Groundwater Chemicals Desk Reference. Lewis Publ., Chelsea, Michigan, 640p.
c = Lucius, J.E. et al., 1990. Properties and hazards of 108 selected substances. USGS Open File Report 90-408, 559p.
e = Mercer, J.W., and Cohen, R.M., 1990. A review of immiscible fluids in the subsurface: Properties, models, characterization, and remediation. Jour. of Contam. Hydrology. Vol. 6, p. 107-163.
h = Tetra Tech, Inc., 1988. Chemical data for predicting the fate of organic chemicals in water, Volume 2. Database EPRI EA-5818, Vol. 2, Elec. Power Res. Inst., Palo Alto, CA, 411p.
i = Mendoza, C.A., and Frind, E.O., 1990b. Advective-dispersive transport of dense organic vapors in the unsaturated zone, 2. Sensitivity Analysis. Water Res. Research, Vol. 26, p. 388-398.
j = Dean, J.A. (ed.), 1973. Lange's Handbook of Chemistry, 11th Ed., McGraw-Hill Book Co., New York.
oc = Verschueren, K., 1983. Handbook of Environmental Data on Organic Chemicals, 2nd Ed., Van Nostrand Reinhold, New York, 1310p.

Table 6-1 (Continued)

Physical Properties of Contaminants Detected Within the Unsaturated Soil Profile ABC One-Hour Cleaners Operable Unit 2

Chemical	Henry's Law (atm-m^3/mol)	Log K_{oc} (mL/g)	Log K_{ow}	Vapor Density (g/L)	Relative Vapor Density	Interfacial Liquid Tension (dyn/cm)
Chloroform	[a] 3.20E-03	[a] 1.64	[a] 1.95	[a] 4.88	1.664	[j] 32.8
1,1-Dichloroethene	[a] 2.10E-02	[a] 1.81	[a] 2.13	[a] 3.96	2.545	[e] 37.0
trans-1,2-Dichloroethene	[a] 3.84E-01	[a] 1.77	[a] 2.09	[a] 3.96	1.827	[c] 30.0
cis-1,2-Dichloroethene	-	-	-	[oc] 3.34	-	-
Vinyl chloride	[a] 0.056	[a] 0.39	[a] 0.60	[oc] 2.15	-	-
Trichloroethene	[a] 87	[a] 2.10	[a] 2.53	[a] 5.37	1.272	[e] 34.5
Tetrachloroethene	[a] 121	[a] 2.42	[a] 2.60	[a] 6.78	1.088	[c] 44.4

References:

a = Montgomery, J.H., and Welkom, L.M., 1990. Groundwater Chemicals Desk Reference. Lewis Publ., Chelsea, Michigan, 640p.
c = Lucius, J.E. et al., 1990. Properties and hazards of 108 selected substances. USGS Open File Report 90-408, 559p.
e = Mercer, J.W., and Cohen, R.M., 1990. A review of immiscible fluids in the subsurface: Properties, models, characterization, and remediation. Jour. of Contam. Hydrology. Vol. 6, p. 107-163.
h = Tetra Tech, Inc., 1988. Chemical data for predicting the fate of organic chemicals in water, Volume 2. Database EPRI EA-5818, Vol. 2, Elec. Power Res. Inst., Palo Alto, CA, 411p.
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Table 6-1 (Continued)

Physical Properties of Contaminants Detected Within the Unsaturated Soil Profile ABC One-Hour Cleaners Operable Unit 2

Chemical	Surface Tension (dyn/cm)	Air Diffusion Coefficient (sq. cm/sec)	Water Diffusion Coefficient (sq. cm/sec)	Estimated Half-Life in Soil (days)
Chloroform	[c] 27.2	[i] 9.90E-02	[h] 9.1E-06	28 - 180
1,1-Dichloroethene	[c] 24.0	[i] 9.11E-02	[h] 9.5E-06	28 - 180
trans-1,2-Dichloroethene	[c] 25.0	[i] 9.11E-02	[c] 9.5E-06	-
cis-1,2-Dichloroethene	-	-	-	-
Vinyl chloride	-	-	-	-
Trichloroethene	[c] 29.3	[i] 8.11E-02	[c] 8.3E-06	180 - 360
Tetrachloroethene	[c] 31.3	[i] 7.40E-02	[c] 7.5E-06	180 - 360

References:

a = Montgomery, J.H., and Welkom, L.M., 1990. Groundwater Chemicals Desk Reference. Lewis Publ., Chelsea, Michigan, 640p.
c = Lucius, J.E. et al., 1990. Properties and hazards of 108 selected substances. USGS Open File Report 90-408, 559p.
e = Mercer, J.W., and Cohen, R.M., 1990. A review of immiscible fluids in the subsurface: Properties, models, characterization, and remediation. Jour. of Contam. Hydrology. Vol. 6, p. 107-163.
h = Tetra Tech, Inc., 1988. Chemical data for predicting the fate of organic chemicals in water, Volume 2. Database EPRI EA-5818, Vol. 2, Elec. Power Res. Inst., Palo Alto, CA, 411p.
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Table 6-1 (Continued)

Physical Properties of Contaminants Detected Within the Unsaturated Soil Profile ABC One-Hour Cleaners Operable Unit 2

Chemical	Estimated Half-Life in Groundwater (days)
Chloroform	56 - 1,800
1,1-Dichloroethene	56 - 132
trans-1,2-Dichloroethene	-
cis-1,2-Dichloroethene	-
Vinyl chloride	-
Trichloroethene	321 - 1,653
Tetrachloroethene	360 - 720

References:

a = Montgomery, J.H., and Welkom, L.M., 1990. Groundwater Chemicals Desk Reference. Lewis Publ., Chelsea, Michigan, 640p.
c = Lucius, J.E. et al., 1990. Properties and hazards of 108 selected substances. USGS Open File Report 90-408, 559p.
e = Mercer, J.W., and Cohen, R.M., 1990. A review of immiscible fluids in the subsurface: Properties, models, characterization, and remediation. Jour. of Contam. Hydrology. Vol. 6, p. 107-163.
h = Tetra Tech, Inc., 1988. Chemical data for predicting the fate of organic chemicals in water, Volume 2. Database EPRI EA-5818, Vol. 2, Elec. Power Res. Inst., Palo Alto, CA, 411p.
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j = Dean, J.A. (ed.), 1973. Lange's Handbook of Chemistry, 11th Ed., McGraw-Hill Book Co., New York.
oc = Verschueren, K., 1983. Handbook of Environmental Data on Organic Chemicals, 2nd Ed., Van Nostrand Reinhold, New York, 1310p.

Table 6-1 (Continued)

Physical Properties of Contaminants Detected Within the Unsaturated Soil Profile ABC One-Hour Cleaners Operable Unit 2

Chemical	Specific Gravity (g/cc)	Solubility (mg/L)	Adsorption Capacity	Mobility	Volatility
Volatile Organics					
Chloroform	1.48	8200	W	Slight	V. High
t-1,2-Dichloroethene	1.21	6300	W	V. High	High
c-1,2-Dichloroethene	1.28	3500	W	V. High	V. High
Vinyl Chloride	0.91	1100	W	High	V. High
Trichloroethene	1.46	1000	M	Mod	High
1,1-Dichloroethene	1.22	400	VW	Slight	V. High
Tetrachloroethene	1.62	150	M	Mod	High

Sorption Qualifiers: VW-very weakly adsorbed; W-weak; M-moderate; MS-moderate to strong; S-strong; VS-very strong.

Table 6-2

Physical Properties of Organic Contaminants

Property	Range	Qualitative Description	Source
Sorption- Soil Adsorption Coefficient (K_{oc})	< 10	Very weakly sorbed	Little, A.D. Inc., 1989
	10 - 100	Weakly sorbed	
	100 - 1000	Moderately sorbed	
	1000 - 10,000	Moderately to strongly sorbed	
	10,000 - 100,000	Strongly sorbed	
	> 100,000	Very strongly sorbed	
Mobility- Based on a combination of solubility(s) (mg/L) and soil adsorption (K_{oc})	$x > 3500$ and $K_{oc} < 50$	Very high mobility	Cohen and Mercer, 1993; Ney, 1990
	$3500 > s > 850$ and $50 < K_{oc} < 500$	High mobility	
	$800 > s > 150$ and $150 < K_{oc} < 2000$	Moderate mobility	
	$150 > s > 15$ and $500 < K_{oc} < 20,000$	Low mobility	
	$15 > s > 0.2$ and $2000 < K_{oc} < 20,000$	Slight mobility	
	$s < 0.2$ and $K_{oc} > 20,000$	Immobile	
Volatility- Henry's Law Constant - (H) (atm m^3/mol)	$H < 3x10^{-7}$	Non-volatile	Fetter, C.W., 1988
	$3x10^{-7} < H < 10^{-5}$	Low volatility	
	$10^{-6} < H < 10^{-3}$	Moderate volatility	
	$H > 10^{-3}$	High volatility	

Sorption Qualifiers: VW-very weakly adsorbed; W-weak; M-moderate; MS-moderate to strong; S-strong; VS-very strong.

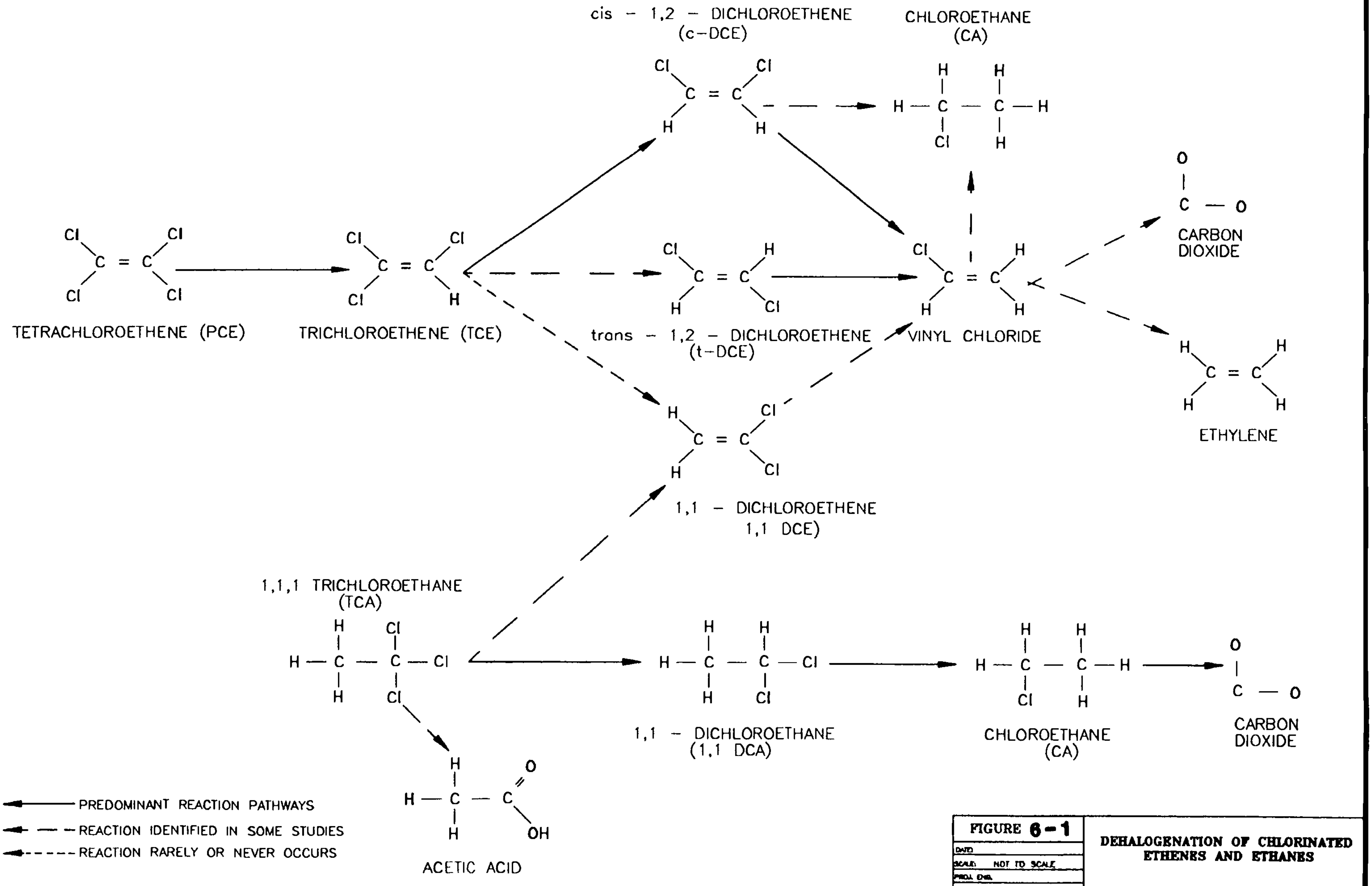

FIGURE 6-1

DEHALOGENATION OF CHLORINATED ETHENES AND ETHANES

DATE
SCALE: NOT TO SCALE
PROJ. ENG.
CHECKED
REV. NO. 2
DRAWN BY: J.C.
DWG NO.
DWG NO.

If conditions are favorable, PCE may be progressively broken down to TCE, 1,2-DCE, vinyl chloride, and possibly to ethylene and carbon dioxide. As is shown on Figure 6-1, of the three possible dichloroethene isomers, 1,1-DCE is the least common and several studies report that cis-1,2-DCE is formed preferentially over trans-1,2-DCE. One possible explanation is that during reductive dechlorination, a chloride ion and free radical are formed. Because water is typically the medium in which the reaction occurs, the most polar form of the radical is favored (cis-1,2-DCE). As also shown on Figure 6-1, chloroethane may form from the reductive dechlorination of cis-1,2-DCE (or as shown, from the degradation of 1,1-DCA) without the intermediate formation of vinyl chloride); however, the preferred product from the dechlorination of cis-1,2-DCE is vinyl chloride. The relative rate of dechlorination decreases as chlorines are sequentially removed; therefore, degradation of PCE is much faster than that of TCE or the DCE isomers; and reductive dechlorination of vinyl chloride is slower still. As such, vinyl chloride is persistent and the formation of carbon dioxide or ethylene is rather slow. Its degradation is enhanced by the presence of methane (Vogel et al, 1987). Carbon dioxide is the end product of complete organic degradation (oxidation). Several PCE/TCE degradation products (shown on Figure 6-1) through vinyl chloride have been detected in soils and groundwater at the ABC site.

Studies have shown that the presence of alkylbenzenes (e.g., toluene) can accelerate the anaerobic dechlorination of chlorinated solvents (Sewell and Gibson, 1991). Aerobic biodegradation may be important for the less halogenated hydrocarbons (Vogel et al, 1987). Abiotic dehalogenization has also been reported in the literature (Vogel et al, 1987).

Other studies have shown that metals and transition metal complexes reduce halogenated aliphatic compounds. Since transition metal complexes are frequently located at the active site of macromolecules employed for electron transfer in living organisms, reactions between metal complexes and HACs result in transformations of the HAC to a degradation product (Vogel et al., 1987).

6.5 SITE-SPECIFIC FATE AND TRANSPORT

Based on available analytical data, chlorinated hydrocarbons (principally PCE) are the primary contaminants of concern at the ABC site. PCE has been used, stored, and disposed of on the ABC site. This and previous investigations have shown the ABC site to be a source for PCE and associated degradation products detected in nearby surficial and Castle Hayne aquifer wells.

The primary source of the PCE detected in soil samples is the ABC septic system. PCE concentrations in the septic tank sludge indicate that PCE is present at concentrations above the solubility limit. Other sources of PCE include historical operations and disposal practices involving spent still bottoms.

Contaminants discharged to the septic system via incidental spillage and/or discharge from the dry-cleaning equipment have entered the drain field and percolated outward into the unsaturated soil profile. Constituents within the still bottoms, once used for filler for pot holes, have also entered the unsaturated soil profile after disposal. Other factors were also allowing contaminants to enter the soil. These included the structure of the concrete flooring near the septic tank, solution channels that were present in the concrete that made up the floor, and possible leaks in the drain pipe to the drain field. Once the contaminants entered the soil, physical, chemical, and biological processes began working on the exposed concentration.

Physiochemical processes acting on the presence of the contaminants included dispersion, volatilization, sorption, leaching, and breakdown by dehalogenization. Depending upon the amount of VOCs released over time, saturation, and in turn, reduction of the effects of sorption, of the soil with PCE may have also occurred, allowing PCE and other constituents to migrate through the soil profile at a higher rate. Biological processes also began to degrade the contaminants.

The chlorinated hydrocarbon content is very widespread within the unsaturated soil profile (vertically and horizontally) directly underneath the concrete floor of ABC and the asphalt covered areas outside the building, even though the disposal of PCE through the septic system has ended. This is partly due to the fact that infiltration of rainwater and subsequent leaching has been reduced by the presence of the concrete floor and the asphalt.

Since infiltration has been reduced, other factors including diffusion, vapor phase transport, and ratio of saturation will influence vertical and lateral spreading. As additional contaminants were introduced into the unsaturated soil profile, the ratio of saturation of the soil by contaminants increased and, under gravitational pressure, vertical (downward) movement of the contaminant plume increased; however lateral spreading due to effects of capillary forces and layering within the soil also took effect. "Even small differences in soil water content and grain size, such as those associated with bedding plane textural variations, can provide sufficient capillary resistance contrast to cause lateral spreading in the unsaturated zone" (Cohen and Mercer, 1993). In addition, a significant portion of a contaminant is trapped in the porous media as residual saturation due to interfacial tension effects.

Contaminants in the soil may also spread under the process of diffusion; which is defined as the movement of a solute from an area of greater concentration toward an area where it is less concentrated. The process usually occurs in the presence of groundwater flow; however, it will occur as long as a concentration gradient exists, even if the fluid is not moving. Underneath the ABC building, given the locations of possible containment leakage, diffusion characteristics would act to increase the area of contamination by transporting the solutes from the point of injection.

For a given contaminant release volume, the depth of infiltration will be influenced by the area over which the release occurs and the release rate (Cohen and Mercer, 1993). Experiments conducted by Paulsen and Kueper (1992) showed that PCE spilled over a large area tends to penetrate to a shallower depth than a PCE spill covering a much smaller area. The difference was attributed to: (1) smaller infiltration area of the small area release; and (2) a higher PCE residual content at shallow depth when ponding from the large area spill release increased the gravity force and induced PCE movement into a higher proportion of soil layers (Cohen and Mercer, 1993). The results of the Paulsen and Kueper (1992) study suggest that small chlorinated hydrocarbon releases on the order of a few gallons have potential to penetrate to depths of many feet below ground surface within hours or days.

Although the effect of volatilization of VOCs into the atmosphere from underneath the concrete floor and paved areas is somewhat limited, transformation of VOCs in the soil underneath ABC into the vapor phase is most likely occurring. Most dense organic solvents have high vapor pressures, and where DNAPL exists in the vadose zone, a plume of solvent vapor develops in the soil air surrounding the source. These vapors and their migration due to diffusion actually increase the contamination of soil and groundwater by VOCs. For example, the vapors will condense on soil water and the water table, causing additional groundwater contamination. Studies have shown that contaminated vapors can diffuse tens of yards or more from the source in the vadose zone within a period of weeks to months (Cohen and Mercer, 1993). Thus, if vapor underneath ABC diffused outward from the source, it may, upon encountering soil moisture, condense onto the soil, thus spreading the VOC contamination. This process may be one of the causes for the widespread contamination directly underneath the ABC building.

In addition to the volatilization, infiltration, and lateral spreading of the contamination directly underneath the ABC building and paved areas, the process of dehalogenization or degradation of PCE has been active as well. As the PCE migrated from the source, it underwent the dehalogenization process described in Section 6.4. This process is the most likely source of the TCE, 1,2-DCE, vinyl chloride, chloroform, and 1,1-DCE seen in soil samples. These chemicals are also subject to processes described above and can continue to contaminate soil and groundwater.

Contamination that migrates from underneath the building or was disposed of outside the building (still bottoms) and is not covered in any way, is directly affected by volatilization, leaching, sorption, and biodegradation. As discussed in Section 5.1, samples collected from outside the building in unpaved areas tend to have low or non-detectable contaminant concentrations. This is a result of the continuous onslaught of biophysiochemical processes acting on the contaminants, which eventually degrade the contaminants into other chemicals, reduce their concentrations, and/or transport the contaminants into the groundwater.

For example, soil boring SB-24, which was located in a grassy strip between the asphalt driveway to the east of ABC and the ABC building itself, contained samples that revealed non-detectable concentrations of PCE, but did have concentrations of the degradation products of PCE. Obviously, some PCE contamination was present at some time but has since been degraded to another chemical, volatilized, or has been transported into the groundwater.

In summary, contamination by VOCs in the unsaturated soil profile, underneath the ABC building or paved areas outside the building, will be present for much longer than under normal conditions because chemical, physical, and biological process are limited by the lack of infiltration and the reduction of other degrading processes. This will result in a continuous, slowly migrating source for VOC contamination in groundwater and soil. In unpaved areas outside the ABC building, contamination by VOCs is sharply reduced by those same processes.

6.6 CALCULATION OF SOIL GOALS TO PROTECT GROUNDWATER

The Summers model was used to derive soil remediation levels for the protection of groundwater based on physical/chemical transport mechanisms. This model incorporates estimates of infiltration, desorption of contaminants based on equilibrium partitioning, and mixing with groundwater.

The first step in the model is to estimate the concentration of the contaminant infiltration that results in groundwater concentrations at or below cleanup goals. The cleanup goals were taken from the January 1993 ROD and the NCGWQSs. The model estimates groundwater contaminant concentrations based on mixing of infiltration and groundwater. Groundwater contaminant concentrations resulting from the mix of uncontaminated groundwater with contaminated infiltration are defined by the equation:

Table 6-3

Parameters Used In Summers Model
ABC One-Hour Cleaners OU2

Symbol	Units	Represents	Value	Data Acquired From
C_{gw}	μg/L	Contaminant concentration in groundwater	Varies	ROD, NCGWQS, or quantification limit
Q_p	ft^3/day ft^3/yr	Volumetric flowrate of infiltration into the aquifer	Calculation	Equation $Q_p = VD_ZA_p$
VD_z	ft/yr	Infiltration rate	0.543	HELP Model
i	ft/ft	Hydraulic gradient	0.0025	Geotechnical testing of vadose zone; water level measurements
θ	%	Effective porosity	20	Typical value
A_p	ft^2	Horizontal area of spill or contamination	Scenario 1 = 3176 Scenario 2 = 11735	Measured from maps
Q_A	ft^3/day	Volumetric flow rate of groundwater	Calculation	Equation $Q_A = V_DhW$
K	ft/day	Hydraulic conductivity	21 ft/day	Aquifer tests
h	ft	Thickness of aquifer	50	Measurements from well drilling
W	ft	Width of contaminated area perpendicular to groundwater flow direction	160	Measurement from maps
C_A	μg/L	Initial or background concentration of pollutant in aquifer	0	Conservative assumption

Table 6-3 (Continued)

Parameters Used In Summers Model
ABC One-Hour Cleaners OU2

Symbol	Units	Represents	Value	Data Acquired From
C_S	µg/kg	Soil goal in vadose zone	Calculation	Equation $C_S = (K_d)(C_p)$
C_p	µg/L	Concentration in the infiltration	Calculation	Equation (see text)
K_d	mL/g	Partition coefficient	Varies	Lab test or K_d = (Koc)(foc)
K_{oc}	mL/g	Organic carbon partition coefficient	Chemical specific	EPA (a)
f_{oc}	g/g	Fraction of organic carbon in the lowest layer above capillary zone	0.01	EPA/North Carolina DEHNR

a = "Basics of Pump-and-Treat Groundwater Remediation Technology," EPA, March 1990.

$$C_{gw}=\frac{(Q_pC_p)+(Q_AC_A)}{Q_p+Q_A}$$

(Parameters are defined in Table 6-3.)

The maximum allowable contaminant concentration in the infiltration (leachate) that would not result in groundwater concentration exceeding a ROD groundwater cleanup goal or NCGWQSs is calculated by inserting the groundwater goal for a contaminant in place of C_{gw} in the previous equation and solving for the infiltration contaminant concentration as follows:

$$C_p=\frac{C_{gw}(Q_p+Q_A)-Q_AC_A}{Q_p}$$

Once the Cp value has been determined, the average soil concentration that would theoretically maintain groundwater concentrations at or below the groundwater goals is calculated. This soil concentration is derived from the following soil:water partitioning equation:

$$C_s=(K_d)(C_p)$$

(Parameters are defined in Table 6-3.)

The use of K_d is based on the assumption that equilibrium conditions are maintained between the distribution of pollutant in solution and on the solid phase. K_d is calculated by the equation:

$$K_d=(K_{oc})(f_{oc})$$

6.6.1 Site Specific Summers Model Input

In order to determine the soil cleanup goals for ABC, site specific parameters were obtained from various sources (Table 6-3). The equations described above were defined within a spreadsheet and the pertinent data entered onto the spreadsheet.

One of the parameters necessary to calculate Summers model goals is the recharge rate. The Hydrologic Evaluation of Landfill Performance (HELP) model was used to estimate an annual recharge rate for the ABC site. This model takes into account site-specific parameters, such as climatic data for the area, soil types, and surface vegetation and cover characteristics. For the ABC site, an annual recharge rate of 0.543 ft/yr was calculated.

To determine the distribution coefficient (K_d) for each compound, concentrations in an untreated composite soil sample and its TCLP leachate from the laboratory treatability study were used as follows:

$$K_d = \frac{\text{untreated soil concentration (mg/kg)}}{\text{TCLP leachate concentration } (\mu\text{g/L})} \times 1{,}000$$

K_d values could not be directly calculated for compounds that were not detected in either soil or leachate. For these compounds, K_d was calculated using an assumed fraction organic carbon (foc) of 0.01. K_d is estimated using the following equation:

$$K_d = K_{oc} \times foc$$

The calculation of K_d for each contaminant is presented in Table 6-4.

Two scenarios were modeled for the ABC site in calculating potential soil remediation goals. In the first scenario, the area of soil contamination currently exposed to infiltration was used. This consists of a thin strip along the driveway on the eastern side of the ABC building and an area on the western side of the ABC building. For this scenario, the building and driveway act as a cover over the contamination, thereby decreasing the amount of contamination introduced to groundwater.

In the second scenario, it was assumed that at some time in the future (due to remediation or future use of the site) the asphalt driveway between ABC and Major Furniture could be removed, and that Major Furniture, the entire ABC building, and approximately 15 feet of the driveway to the west of the ABC building could also be removed. With the driveway and the buildings removed, infiltration increases over the site. This creates more exposure of the contaminants to leaching and subsequent introduction into groundwater; therefore lower soil cleanup levels are necessary for protection of groundwater.

Table 6-4

Determination of K_d Values for Contaminants of Concern at the ABC Site

Contaminant	Untreated Soil Concentration[a] (mg/kg)	TCLP Soil Leachate Concentration[a] (μg/L)	K_{oc}[b] (mL/g)	K_d (mL/g)
Tetrachloroethene	7.5	190	364	39.47 (c)
cis-1,2-Dichloroethene	0.110	20 J	49	5.50 (c)
trans-1,2-Dichloroethene	0.002	ND	59	0.59 (d)
Trichloroethene	0.100	17 J	126	5.88 (c)
Chloroform	ND	ND	47	0.47 (d)
1,1-Dichloroethene	ND	ND	65	0.65 (d)
Vinyl chloride	ND	ND	57	0.57 (d)

[a] Concentrations obtained from lab data developed for treatability study sample.

[b] K_{oc} values from "Basics of Pump-and-Treat Groundwater Remediation Technology." EPA, March 1990.

(c) K_d values based on lab-measured untreated soil and TCLP leachate concentrations in a site-wide composite sample.

(d) K_d value calculated as K_{oc} x foc, with foc = 0.01, as requested by the State of North Carolina.

The vertical mixing zone in the aquifer (i.e., the aquifer thickness over which groundwater will dilute the contaminated groundwater recharge) was calculated using Equation 5.49 from "A Subtitle D Landfill Application Manual for the Multimedia Exposure Assessment Model (MULTIMED)," Allison et. al., 1990, prepared under EPA Contract 68-03-3513 for the U.S. Environmental Protection Agency, Athens, GA:

$$H=(2\alpha_v L)^{0.5}=B(1-\exp(LQ_f/V_S\Theta B))$$

where:

H = mixing zone thickness
Q_f = recharge rate (length/time)
α_v = vertical dispersivity (length)
L = length of contaminated area parallel to groundwater flow direction (length)
B = aquifer thickness (length)
V_S = groundwater seepage velocity (length/time)
Θ = effective porosity (dimensionless)

The recharge rate was used from the MULTIMED model, as described above. The vertical dispersivity is a function of the groundwater flow path length. Generally, the longitudinal dispersivity is approximately 10 percent of the flow path length. The vertical dispersivity is conservatively assumed to be 1 percent of the longitudinal dispersivity. For the ABC site, the following values were used:

Q_f = 0.543 ft/yr (from HELP model)
α = 0.6 ft
L = 160 ft
B = 50 ft

$V_S = 19.16$ ft/yr
$\Theta = 0.1$

From these values, a mixing zone thickness of 32.08 ft was calculated. The mixing zone thickness and the infiltration rate were then used to complete the Summers model equation.

6.6.2 Results of the Summers Model Analysis

As stated in Section 6.6.1, the main purpose in utilizing the Summers model is to establish levels of soil contaminant concentrations that are necessary to be protective of groundwater. For the ABC site, the groundwater cleanup goals for four contaminants were reported in the January 1993 ROD. Other levels were obtained using the NCGWQSs. Once all data required for the Summers model had been generated, it was processed through the Summers model, and soil goals concentrations for the seven contaminants listed in Tables 6-5 and 6-6 were calculated.

As a sample calculation, using the parameters for Scenario 1, the potential PCE concentration in leachate (C_p) would be:

$$C_p = \frac{1\ \mu g/L\ [(0.543\ ft/yr \times 3{,}176\ ft^2) + (21\ ft/d \times 0.0025\ ft/ft \times 160\ ft \times 32.08\ ft \times 365\ d/yr)] - 0}{0.543\ ft/yr \times 3{,}176\ ft^2}$$

$C_p = 58.03\ \mu g/L$

Table 6-5

Soil Remediation Goals to Protect Groundwater Using Summers Model Scenario Number One - Building/Pavement Remain ABC One-Hour Cleaners Operable Unit 2

Contaminant	Groundwater Goals [a] (µg/L)	K_d [b] (mL/g)	Summers Soil Goals [c] (mg/kg)
Tetrachloroethene	1	39.47	2.29
cis-1,2-DCE	70	5.5	22.34
trans-1,2-DCE	100	0.59	3.42
Trichloroethene	2.8	5.88	0.96
Chloroform	1	0.47	0.027
1,1-Dichloroethene	7	0.65	0.26
Vinyl chloride	1	0.57	0.033

Notes:

(a) Groundwater Goals are based on January 1993 ROD for groundwater at ABC site and on NCGWQSs where ROD goals were not issued, with the exception of chloroform, for which the Low Concentration Contract Required Quantitation Limit has been used.

(b) K_d based on Table 3-1.

(c) Goals calculated using Summers Model (from "Determining Soil Response Action Levels Based on Potential Contaminant Migration to Ground Water: A Compendium of Examples," EPA/540/2-89/057, October 1989).

Assumptions for Summers Model calculations:

3,176 sq ft = area of soil contamination exposed to infiltration
160 ft = width of contamination area normal to GW flow direction
0.543 ft/yr = annual infiltration
21 ft/d = hydraulic conductivity (surficial aquifer)
0.0025 ft/ft = hydraulic gradient (surficial aquifer)
32.08 ft = aquifer mixing zone thickness
0.01 = fraction organic carbon

Table 6-6

Soil Remediation Goals to Protect Groundwater Using Summers Model
Scenario Number Two - All of Buildings and Pavement Removed
ABC One-Hour Cleaners
Operable Unit 2

Contaminant	Groundwater Goals (a) (μg/L)	K_d (b) (mL/g)	Summers Soil Goals (c) (mg/kg)
Tetrachloroethene	1	39.47	0.65
cis-1,2-DCE	70	5.5	6.33
trans-1,2-DCE	100	0.59	0.97
Trichloroethene	2.8	5.88	0.26
Chloroform	1	0.47	0.0077
1,1-Dichloroethene	7	0.65	0.075
Vinyl chloride	1	0.57	0.0094

Notes:

(a) Groundwater Goals are based on January 1993 ROD for groundwater at ABC site and on NCGWQSs where ROD goals were not issued, with the exception of chloroform, for which the Low Concentration Contract Required Quantitation Limit has been used.
(b) K_d based on Table 3-1.
(c) Goals calculated using Summers Model (from "Determining Soil Response Action Levels Based on Potential Contaminant Migration to Ground Water: A Compendium of Examples," EPA/540/2-89/057, October 1989).

Assumptions for Summers Model calculations:

11,735 sq ft = area of soil contamination exposed to infiltration
160 ft = width of contamination area normal to GW flow direction
0.543 ft/yr = annual infiltration
21 ft/d = hydraulic conductivity (surficial aquifer)
0.0025 ft/ft = hydraulic gradient (surficial aquifer)
32.08 ft = aquifer mixing zone thickness
0.01 = fraction organic carbon

The allowable soil concentration derived from this leachate concentration would be:

$$C_S = 39.47 \text{ mL/g} \times 58.03\ \mu\text{g/L} \times 1\text{L}/1000 \text{ mL} = 2.29\ \mu\text{g/g}$$

The cleanup levels defined if the buildings remain range from a low of 0.027 mg/kg for chloroform to a high of 22.34 mg/kg for cis-1,2-DCE.

The soil cleanup levels for Scenario 2 range from a low of 0.0001 μg/kg (or 0.1 μg/kg) for vinyl chloride to a high of 0.0077 mg/kg for chloroform to a high of 6.33 mg/kg for cis-1,2-DCE. In this scenario, the contaminated area of soil exposed to infiltration is much larger (relative to the area used in Scenario 1) and, because of the higher infiltration rate, the leaching rate is increased, which, in turn, reduces the soil cleanup goals necessary to be protective of groundwater.

In summary, in the first scenario, the ABC building and the driveway to the east are in place and infiltration is low. For this scenario, the building and driveway act as a cover over the contamination, thereby decreasing the amount of contamination introduced to groundwater. In Scenario 2, the driveway and all of the building are removed thereby increasing infiltration over the site. This creates more exposure of the contaminants to leaching and subsequent introduction into groundwater; therefore lower soil cleanup levels are necessary for protection of groundwater.

6.7 REFERENCES

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SECTION 7

BASELINE RISK ASSESSMENT

The baseline risk assessment for the ABC One-Hour Cleaners (OU2) site was prepared according to United States Environmental Protection Agency (U.S. EPA) guidelines for risk assessments at Superfund sites. This methodology is presented in the U.S. EPA Risk Assessment Guidance for Superfund -- Volume I (Human Health Evaluation Manual) (U.S. EPA, 1989a), the Volume I Supplemental Guidance (U.S. EPA, 1991a), as well as U.S. EPA Region IV Risk Assessment Guidance (1992b).

In accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (EPA, 1990), a baseline risk assessment should evaluate the potential human health impacts associated with a site under the no-action alternative (i.e., in the absence of remedial (corrective) action). For this risk assessment, the no-action alternative was defined for both present and potential future uses of the site.

This baseline risk assessment summarizes and interprets data collected during the site investigation to identify and characterize site contaminants; describes contaminant exposure pathways and receptors; and assesses potential adverse impacts on human health from contaminants associated with the ABC site. This risk assessment report includes four components:

- Identification of Chemicals of Potential Concern
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization

"Identification of Chemicals of Potential Concern" presents a summary of the evidence of environmental contamination at the site and selects the contaminants of potential concern to be evaluated in the risk assessment.

"Exposure Assessment" presents the important contaminant migration pathways, exposure routes, estimated daily intakes for human receptors, and site characteristics affecting the migration of contaminants. This information is then combined to develop a conceptual exposure model for the site and to select exposure pathways. The exposure assessment also presents a series of mathematical exposure models which are used to calculate the estimated daily intakes of contaminants by the receptors.

"Toxicity Assessment" presents the human toxicity data for both noncarcinogenic and carcinogenic effects for the chemicals of concern. Dose-response criteria are identified for chronic health effects for each contaminant and for each potential exposure route (e.g., oral, dermal).

"Risk Characterization" integrates the information developed in the three preceding sections. Carcinogenic and noncarcinogenic human health risks are quantified and presented for the chemicals of concern. Relevant uncertainties associated with the Risk Assessment are discussed.

Appendix E contains documentation and detailed tables for completing the risk assessment. They are as follows:

- Appendix E1 - Site Data
- Appendix E2 - Dose Intakes
- Appendix E3 - Risk Tables
- Appendix E4 - Remedial Goal Options (RGOs)

7.1 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

7.1.1 Approach

The objectives of the data reduction and evaluation are to review and summarize the analytical data for groundwater at the ABC One-Hour Cleaner site and to select the chemicals of concern to be evaluated in the human health risk assessment. Appendix E contains reference materials for contaminant of concern evaluation. Since the RI/FS is being conducted only for Operable Unit No. 2 (soils), the reviewed data currently include sampling results for soils only. The soil samples were analyzed for volatile organic compounds (VOCs) only.

Analytical data from soil sampling were used to calculate the exposure point concentrations. The preliminary summaries include the frequency of detection, the range of detected concentrations, and the mean of the detected concentrations for each chemical (Table 7-1). In accordance with guidance from EPA Region IV (EPA, 1992a), the mean concentrations reported in the preliminary summaries are the arithmetic averages of only the detected concentrations. The information provided in the preliminary summary table was used to select the chemicals of concern for soil.

The list of potential chemicals of concern in soil is small and only includes organic compounds. Since organic compounds are often evidence of anthropomorphic activities, all of the chemicals will be retained for the quantitative risk assessment.

Table 7-1

Soil Data Summary
(mg/kg)

Chemical	Frequency of Detection	Range of Detection	Mean Concentration
Acetone	5/55	0.02 - 1.9	0.58
Chloroform	2/55	0.01 - 0.017	0.014
1,1-Dichloroethene	1/55	0.29	NA
1,2-Dichloroethene	35/55	0.012 - 110	5.0
Tetrachloroethene	46/55	0.01 - 2,100	86
Toluene	1/55	0.002	NA
Trichloroethene	36/55	0.002 - 260	14
Vinyl Chloride	2/55	0.079 - 0.19	0.135

NA - Not Applicable, detected only once.

7.2 EXPOSURE ASSESSMENT

The objective of the exposure assessment is to estimate the magnitude of potential human exposure to contaminants of potential concern at ABC OU2. The results of the exposure assessment are subsequently combined with chemical-specific toxicity information to quantitatively estimate the potential human health risks associated with chemical exposure.

The exposure assessment involves several key elements including:

1. Definition of local land and water uses (Section 4.7)
2. Identification of the potential receptors
3. Development of applicable exposure scenarios and exposure routes
4. Quantification of exposure concentrations using the appropriate exposure models

The following narrative discusses each of the key technical elements of the exposure assessment.

7.2.1 Potential Receptors/Exposure Scenarios

As described in the draft work plan (WESTON, 1990), the applicable receptors exposed to surficial soils are evaluated in this risk assessment. The following subsections present the current and future receptors that were considered for selection or were selected based on current and potential land uses. Assumptions regarding the frequency of exposure for each selected receptor are also indicated.

7.2.1.1 Current Use

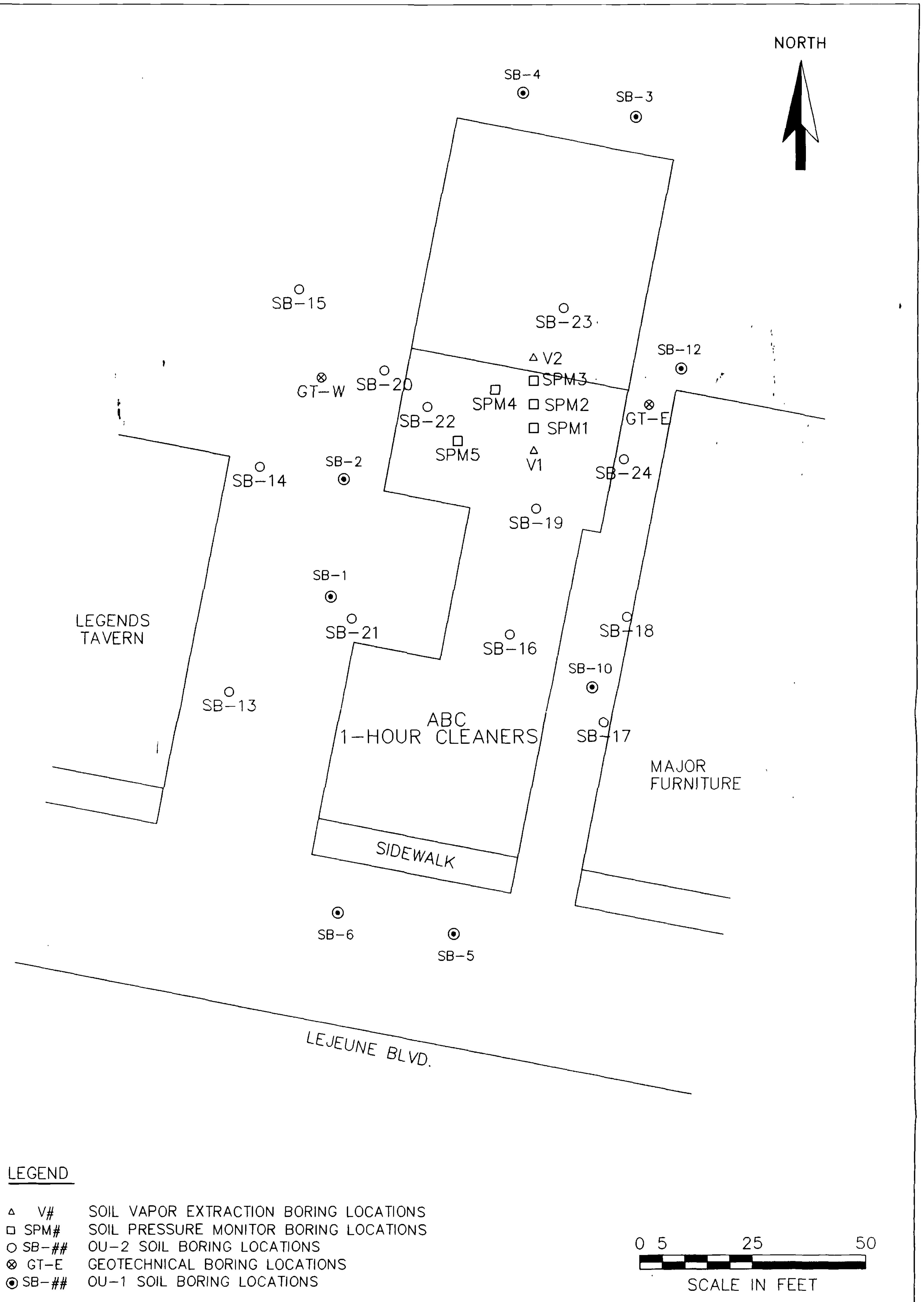
Currently, there are workers on-site. Thus, there is an exposure pathway for a current adult worker for surface soil. The exposure pathway for the current worker scenario group includes the dermal contact with and the incidental ingestion of contaminants in 0 - 1' surficial soils surrounding the ABC building.

7.2.1.2 Future Use

It was assumed that the site will be available for unrestricted use in the future. It was also assumed that the current residential areas located on the adjacent Marine base would remain residential for the foreseeable future. A future resident scenario was evaluated in which it was assumed the residence would be located on or close enough to the ABC site to access surficial soil contamination. Three age groups were evaluated for the future resident -- a child aged 1 to 6 years, a youth aged 7 to 16, and an adult.

The future resident was assumed to be on-site on a daily basis, year-round. Exposure to surface soil (0 - 1') was assumed for the future child, youth, and adult residents based on general contact with surrounding soil. Contact with surface soil occurs through a number of activities resulting in dermal exposure and ingestion. A year-round exposure of 350 days/year to surface soil was assumed.

The future resident was assumed to be exposed to all soil sample sites mapped out in Figure 7-1. This assumption is based on the possibility that the ABC One-Hour Cleaners building may no longer be in place. As a result the land may be available for future residential use.



WESTON
MANAGERS DESIGNERS/CONSULTANTS

FIGURE 7-1
DATE 10/25/93
REVISION 0
DRAWN BY J.C., W.M.
FILE 04400-XX.DWG

SOIL BORING LOCATIONS

REMEDIAL INVESTIGATION FOR THE ABC ONE-HOUR CLEANERS SITE JACKSONVILLE, NORTH CAROLINA

The exposure duration for residential exposure routes was assumed to be 30 years based on national upper 90th percentile estimates of time spent at one residence (EPA, 1991a). The residential exposure duration was divided into a six-year duration for young children ages 1 to 6, a ten-year duration for the youth aged 7 to 16, and a 14-year duration for adults.

The future on-site construction worker includes the dermal contact with and the incidental ingestion of contaminants in surficial and subsurface soils. A conservative exposure duration of six months was chosen based on the prediction that most demolition or rehabilitative work on the site would not take any more time than this amount. All other factors considering exposure doses for the future construction workers are the same as those for the current on-site workers.

7.2.2 Exposure Routes

The potential exposure routes that were considered for soil are listed below:

- Incidental surface soil ingestion - incidental ingestion of soil taking into account the ingestion of outdoor soil and indoor dust during domestic activities.
- Dermal contact - dermal adsorption of substances resulting from contact with surface soil.
- Incidental subsurface soil ingestion and dermal contact - scenarios for the future construction worker where rehabilitative or destructive work may call for subsurface construction work. Hence, ingestion and dermal contact of subsurface soil are applicable to the future construction worker.

7.2.3 Exposure Concentrations

Potential risks were addressed for soils based on the upper 95% confidence limit of the mean. The upper 95% confidence limit concentration was used for the risk estimation in the reasonable maximum exposure scenarios.

Calculation of the Upper 95% Confidence Limit

The following formula (Gilbert, 1987, EPA, 1992a) was used to determine the upper 95% confidence limit (UCL) of the arithmetic mean:

$$\text{UCL} = e^{\left(\overline{x_i} + 0.5\, s^2 + \frac{sH}{\sqrt{n-1}}\right)}$$

Where:

e = constant (natural log).
$\bar{x}_i$ = arithmetic mean of the log-transformed data for contaminant i.
H = statistic determined by the standard deviation and sample size.
s = standard deviation of the log-transformed data.

$$\left(s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - x)^2}{n-1}} \right)$$

and:

n = Sample size for contaminant in the particular medium set.

Where the upper 95% confidence limit concentration exceeded the maximum detected concentration for a chemical, the maximum detected concentration was used to estimate risks in the reasonable maximum exposure scenarios.

The soil exposure concentrations that are used in the risk assessment are summarized in Tables 7-2, 7-3, and 7-4.

7.2.4 Exposure Models and Assumptions

7.2.4.1 Approach

This subsection presents the mathematical models that were used to calculate the intakes (i.e., doses) of the chemicals of concern for each receptor through the applicable exposure routes (Tables 7-5 and 7-6). Each table defines the variables for the exposure route and includes the assumptions (i.e., exposure parameters) used in the model. Additional information regarding the assumptions is presented in the text.

7.3 TOXICITY ASSESSMENT

7.3.1 Introduction

The purpose of the toxicity assessment is to assign toxicity values (criteria) to each chemical evaluated in the risk assessment. The toxicity values are used in combination with the estimated doses to which a human could be exposed (as discussed in the Risk Characterization, Subsection 7.4) to evaluate the potential human health risks associated with each chemical. Human health

Table 7-2

Exposure Point Concentrations For Current On-Site Work* (mg/kg)

Potential Chemical of Concern	Maximum Detection	Upper Confidence Limit	Exposure Point Concentration
Acetone	1.9	88,458	1.9
Tetrachloroethene	2,100	12,300	2,100
Toluene	0.002	10,670	0.002
Trichloroethene	33	17,994	33

* = Includes soil samples from depth of 0 to 1 feet outside ABC building.
> = greater than the identified quantitation limit.

Table 7-3

Exposure Point Concentrations For Future Resident* (mg/kg)

Potential Chemical of Concern	Maximum Detection	Upper Confidence Limit	Exposure Point Concentration
Acetone	1.9	15,806	1.9
Chloroform	0.017	13,384	0.017
1,1-Dichloroethene	0.029	14,084	0.029
1,2-Dichloroethene	20	15,789	20
Tetrachloroethene	2,100	1,300,000	2,100
Toluene	0.02	16,510	0.02
Trichloroethene	120	1,150,000	120

* = Includes all soil samples from depth of 0 to 1 feet.
> = greater than the identified quantitation limit.

Table 7-4

Exposure Point Concentrations For Future Construction Worker* (mg/kg)

Potential Chemical of Concern	Maximum Detection	Upper Confidence Limit	Exposure Point Concentration
Acetone	1.9	9.8	1.9
Chloroform	0.017	8.5	0.017
1,1-Dichloroethene	0.029	8.7	0.029
1,2-Dichloroethene	110	48	48
Tetrachloroethene	2,100	10,939	2,100
Toluene	0.002	18.9	0.002
Trichloroethene	260	83	83
Vinyl Chloride	0.19	9.1	0.19

* = Includes all soil samples at all depths.

Table 7-5

Model for Calculating Doses from Incidental Ingestion of Soil

$$\text{Soil Ingestion Dose (mg/kg-day)} = \frac{CS \times IR \times CF \times EF \times ED}{BW \times AT}$$

Where:

CS = Chemical concentration in soil (mg/kg)
IR = Soil ingestion rate (mg/day)
CF = Conversion factor (1E-6 kg/mg)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

Assumptions:

CS = The reasonable maximum exposure concentration in soil (Tables 7-2 through 7-4).

IR = 200 mg/day for the future child (1-6) resident (EPA, 1991a).
100 mg/day for the future youth resident (7-16) (EPA, 1991a).
100 mg/day for the future adult resident (EPA, 1991a).
50 mg/day for the current and future worker (EPA, 1991a).

EF = 350 days/year for the future children, youth, and adult residents (EPA, 1991a).
250 days/year for the current and future worker (EPA, 1991a).

ED = 0.5 years for the future on-site construction worker.
6 years for the future child (1-6) resident (EPA, 1991a).
10 years for the future youth (7-16) resident (EPA, 1991a).
14 years for the future adult resident (EPA, 1991a).
= 25 years for the current on-site worker (EPA, 1991a).

BW = 15 kg for the future child resident (EPA, 1991a).
45 kg for the future youth resident (7-16) (EPA, 1991a)
70 kg for the future adult resident (EPA, 1991a).
70 kg for the current and future worker (EPA, 1991a).

AT = Exposure duration (years) x 365 days/year for evaluating noncancer risk.
= 70 years x 365 days/year for evaluating cancer risk.

Example calculation for future child resident with noncancer risk to acetone:

$$\frac{1.9 \times 200 \times 1E^{-6} \times 350 \times 6}{15\ (6 \times 365)} = 2.4E^{-5} \qquad \text{(Table E-2)}$$

Table 7-6

Model for Calculating Doses from Dermal Contact with Soil

$$\text{Soil Dermal Absorption Dose (mg/kg-day)} = \frac{CS \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

Where:

CS = Chemical concentration in soil (mg/kg)
CF = Conversion factor (1E-6 kg/mg)
SA = Skin surface area available for contact (cm^2/day)
AF = Soil to skin adherence factor (mg/cm^2)
ABS = Dermal absorption factor (unitless)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

Assumptions:

CS = The reasonable maximum exposure concentration in soil (Tables 7-2 through 7-4).

SA = 2,125 cm^2/day for the future child (1-6) resident. It represents the 50th percentile surface area of the arms, hands, lower legs, and feet (50% of the exposure events) and forearms and hands (50% of the exposure events) of a 1-6 year old (EPA, 1985).
= 4,397 cm^2/day for the future youth (7-16). It represents the 50th percentile surface area of the arms, hands, lower legs, and feet (100% of the exposure events) (EPA, 1985).
= 4,145 cm^2/day for the future adult resident. It represents the 50th percentile surface area of the arms, hands, lower legs, and feet (50% of the exposure events) and forearms and hands (50% of the exposure events) of an adult male (EPA, 1985).
= 1,980 cm^2/day for the current and future worker. It represents the 50th percentile surface area of the forearms and hands of an adult male (EPA, 1985).

AF = 0.6 mg/cm^2, soil adherence factor (EPA, 1992a).

ABS = 0.01 - Organic compounds (EPA, 1992)
0.001 - Inorganic compounds (EPA, 1992).

EF = 350 days/year for the future child, youth, and adult residents (EPA, 1991a).
250 days/year for the current and future worker (EPA, 1991a).

Table 7-6 (Continued)

Model for Calculating Doses from Dermal Contact with Soil

Soil Dermal Absorption Dose (mg/kg-day) $= \dfrac{CS \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$

Where:

CS = Chemical concentration in soil (mg/kg)
CF = Conversion factor (1E-6 kg/mg)
SA = Skin surface area available for contact (cm^2/day)
AF = Soil to skin adherence factor (mg/cm^2)
ABS = Dermal absorption factor (unitless)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (days)

ED = 0.5 years for the future on-site construction worker.
6 years for the future child (1-6) resident (EPA, 1991a).
10 years for the future youth (7-16) resident (EPA, 1991a).
25 years for the on-site current worker (EPA, 1991a).
= 14 years for the adult resident (EPA, 1991a).

BW = 15 kg for the future child resident (EPA, 1991a).
45 kg for the future youth (7-16) resident (EPA, 1991a)
70 kg for the current and future worker, and future adult resident (EPA, 1991a).

AT = Exposure duration (years) x 365 days/year for evaluating noncancer risk.
= 70 years x 365 days/year for evaluating cancer risk.

Example calculation for future child resident with noncancer risks to acetone:

$$\frac{1.9 \times 1E^{-6} \times 2{,}125 \times 1.0 \times 0.01 \times 350 \times 6}{15 \times (6 \times 365)} = 1.5E^{-6} \quad \text{(Table E-2)}$$

criteria (cancer slope factors and reference doses) developed by the EPA were obtained from the Integrated Risk Information System (IRIS, 1993) or the Health Effects Assessment Summary Tables (HEAST) (EPA, 1992a).

7.3.2 Carcinogenic and Noncarcinogenic Toxicity Values

In evaluating potential health risks, both carcinogenic and noncarcinogenic health effects must be considered. The potential for producing carcinogenic effects is limited to substances that have been shown to be carcinogenic in animals and/or humans. Excessive exposure to all substances, carcinogens and noncarcinogens, can produce adverse noncarcinogenic effects. Therefore, reference doses are identified for every chemical selected regardless of its classification, and cancer slope factors are identified for those chemicals classified as carcinogenic.

7.3.2.1 Estimates of Carcinogenic Potency

Cancer slope factors (CSFs) are developed by the EPA under the assumption that the risk of cancer from a given chemical is linearly related to dose. EPA may develop cancer slope factors from laboratory animal or epidemiological studies in which relatively high doses of the chemical were administered. It is conservatively assumed that these high doses can be extrapolated downward to extremely small doses, with some incremental risk of cancer always remaining until the dose is zero. Figure 7-2 illustrates this approach. This nonthreshold theory assumes that even a small number of molecules (possibly even one molecule) of a carcinogen may cause changes in a single cell that could result in uncontrolled cell division, eventually leading to cancer. There is some dispute as to whether the extrapolation from high to low doses is a

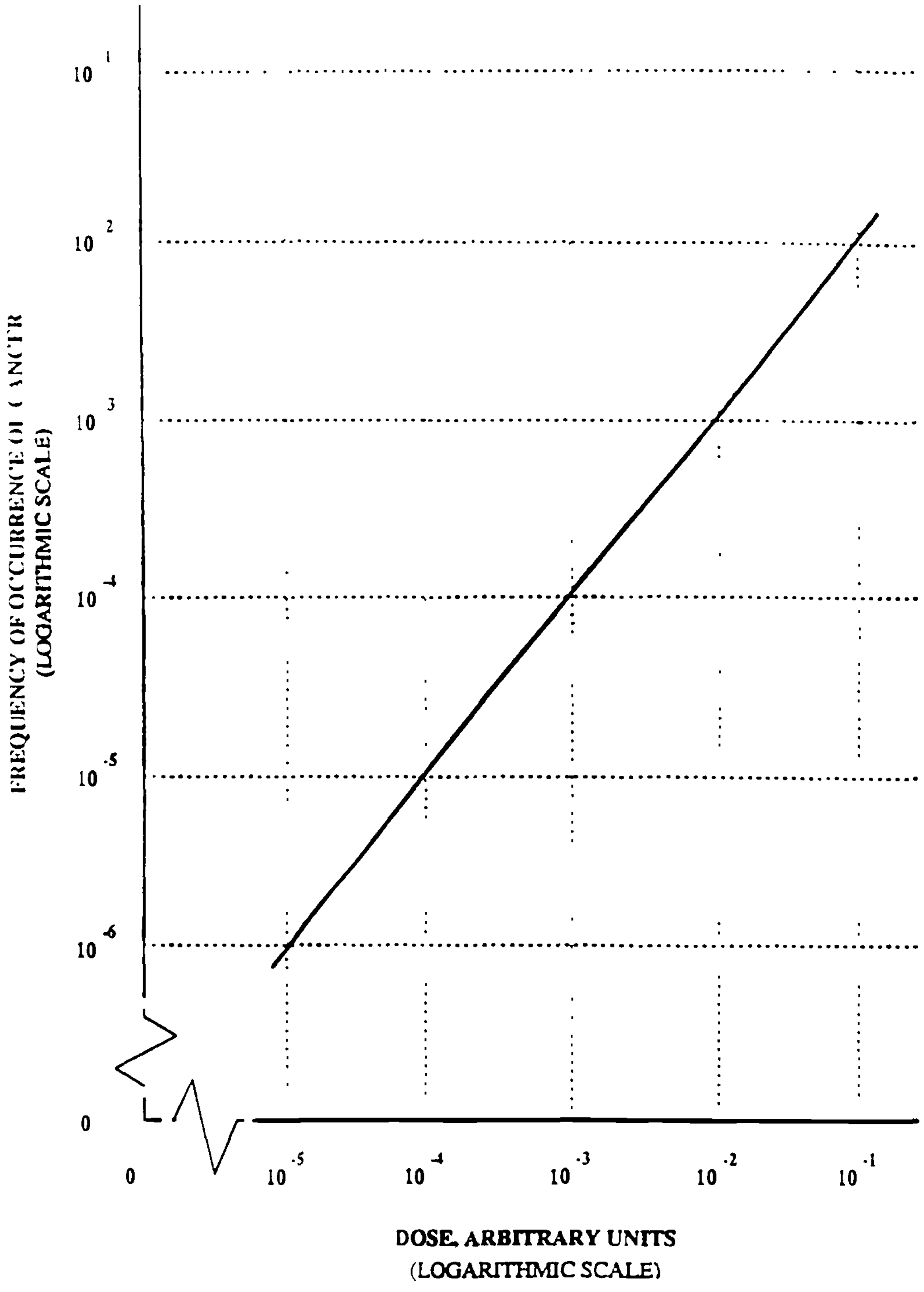


FIGURE 7-2 HYPOTHETICAL DOSE-RESPONSE CURVE FOR A "NO THRESHOLD" OR CARCINOGENIC CHEMICAL

realistic approach. It has been argued that at low doses, cells may have the ability to detoxify carcinogens or repair chemically induced cellular damage. Although it is important to recognize the possibility that some carcinogens may have a threshold for noncarcinogenic toxicity, it was assumed in the cancer risk estimates that no threshold exists.The slope factor for a chemical is usually derived by EPA using a linearized multistage model and reflects the upper-bound limit of the cancer potency of the chemical. As a result, the estimated carcinogenic risk is likely to represent a plausible upper limit to the risk. The actual risk is unknown but is likely to be considerably lower than the predicted risk (EPA, 1989), and may even be as low as zero.

The classifications of carcinogens according to the EPA (IRIS, 1993) and the International Agency for Research on Cancer (IARC) (WHO, 1987) are summarized in Table 7-8. Specific carcinogenicity classifications for carcinogenic chemicals of potential concern at the ABC One-Hour Cleaners site are presented in Table 7-7. Risk assessments follow the rationale used by EPA in developing these categories of classification, but the IARC categories are very similar. Only those chemicals classified by the EPA as "A" have sufficient human evidence of carcinogenicity. Carcinogens classified as "B" and "C" have insufficient human data to support their cancer-causing potential but have varying degrees of supportive animal data. It should be noted that both known and potential A, B, and C carcinogens are evaluated through the carcinogenic exposures in risk assessments or as carcinogens according to EPA guidance (EPA, 1989). Finally, it is important to note that slope factors are periodically under review by the EPA. In some cases, the EPA may withdraw the criteria until the review is completed.

Table 7-7

Carcinogenic Chemicals of Concern and Their EPA and IARC Classification

Chemical	EPA Carcinogenicity Classification	IARC Carcinogenicity Classification
ORGANICS		
Chloroform	B2	2B
1,1-Dichloroethene	C	--
Tetrachloroethene	--[1]	2B
Trichloroethene	--	3
Vinyl Chloride	A	--

[1] Cancer classification under review.

Key:

Group A	Human carcinogen (sufficient evidence from epidemiological studies).
Group B1	Probable human carcinogen (at least limited evidence of carcinogenicity to humans).
Group B2	Probable human carcinogen (a combination of sufficient evidence in animals and inadequate data in humans).
Group C	Possible human carcinogen (limited evidence in animals in the absence of human data).
Group D	Not classified (inadequate animal and human data).
Group E	No evidence for carcinogenicity (no evidence for carcinogenicity in at least two adequate animals tests in different species, or in both epidemiological and animal studies).

IARC Categorization of Carcinogenicity (WHO, 1987)

Group 1	Human carcinogen (sufficient evidence of carcinogenicity in humans).
Group 2A	Probable human carcinogen (at least limited evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in experimental animals).
Group 2B	Possible human carcinogen (limited evidence of carcinogenicity in humans and insufficient evidence of carcinogenicity in experimental animals; insufficient evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in experimental animals; or insufficient evidence of carcinogenicity in humans and limited evidence of carcinogenicity in experimental animals with supporting evidence from other relevant data).
Group 3	Not classifiable (substances in this category do not fall into any other category).
Group 4	Probably not carcinogenic to humans.

Table 7-8

EPA Categorizations of Carcinogens Based on Human and Animals Evidence

	EPA Categorization of Carcinogens (EPA, 1989) Human Evidence				
Animal Evidence	**Sufficient**	**Limited**	**Inadequate**	**No Data**	**No Evidence**
Sufficient	A	A	A	A	A
Limited	B1	B1	B1	B1	B1
Inadequate	B2	C	D	D	D
No Data	B2	C	D	D	E
No Evidence	B2	C	D	D	E

Key:

Group A	Human carcinogen (sufficient evidence from epidemiological studies).
Group B1	Probable human carcinogen (at least limited evidence of carcinogenicity to humans).
Group B2	Probable human carcinogen (a combination of sufficient evidence in animals and inadequate data in humans).
Group C	Possible human carcinogen (limited evidence in animals in the absence of human data).
Group D	Not classified (inadequate animal and human data).
Group E	No evidence for carcinogenicity (no evidence for carcinogenicity in at least two adequate animals tests in different species, or in both epidemiological and animal studies).

7.3.2.2 Estimates of Carcinogenicity

The carcinogenic potency of a substance depends on its route of entry into the body (e.g., oral, inhalation or dermal). Therefore, slope factors are developed and classified according to the route of administration. In some cases, a carcinogen may produce tumors only at or near a specific route of entry (e.g., nasal passages) and may not be carcinogenic through other exposure routes. Table 7-9 presents the cancer slope factors by route of exposure. In some cases, unit risk factors $[mg/m^3]^{-1}$) or ($[mg/L]^{-1}$ are used by the EPA to express cancer risk as the inhalation or oral unit risk per liter or cubic meter. To convert the unit risk factors to units of $(mg/kg\text{-}day)^{-1}$ which are complementary to exposure doses calculated as mg/kg-day, the unit risk factor is adjusted by assumptions that two liters of water are consumed per day or 20 m^3 of air are inhaled per day, respectively, and that the human body weight is 70 kg.

Oral

Oral slope factors are used to evaluate the risk from exposure to potential carcinogens through oral exposure pathways such as surface soil ingestion. Oral slope factors were available for all of the carcinogens listed in Table 7-9.

Dermal

The dermal exposure at this site requires dermal reference doses (RfDs) and CSFs. Since the U.S. EPA has not developed dermal RfDs or CSFs, these critical toxicity values were derived based on available oral RfDs and CSFs. This derivation involves converting the oral RfDs and CSFs to absorbed dose (using oral absorption factors) rather than the administered dose since

Table 7-9

Health Criteria
Contaminants of Concern in Soil

Chemical	Oral Slope Factor $(mg/kg/day)^{-1}$	Reference	Dermal Slope Factor[1]	Oral Reference Dose (mg/kg/day)	Reference	Dermal Reference Dose[2]
Acetone	NTV	--	--	1×10^{-1}	IRIS, 1993	8×10^{-2}
Chloroform	6.1×10^{-3}	IRIS, 1993	7.6×10^{-3}	1×10^{-2}	IRIS, 1993	8×10^{-3}
1,1-Dichloroethene	6×10^{-1}	IRIS, 1993	7.5×10^{-1}	9×10^{-3}	IRIS, 1993	7.2×10^{-3}
1,2-Dichloroethene	NTV	--	--	1×10^{-2}	IRIS, 1993	8×10^{-3}
Tetrachloroethene	5.2×10^{-2}	ECAO, 1993	6.5×10^{-2}	1×10^{-2}	IRIS, 1993	8×10^{-3}
Toluene	NTV	--	--	2×10^{-1}	HEAST, 1993	1.6×10^{-1}
Trichloroethene	1.1×10^{-2}	ECAO, 1993	1.4×10^{-2}	6×10^{-3}	IRIS, 1993	4.8×10^{-3}
Vinyl Chloride	1.9×10^{0}	HEAST, 1993	2.4×10^{0}	NTV	--	--

NTV = No Toxicity Value.

ECAO = Environmental Criteria Assessment Office, Cincinnati, Ohio

[1] The dermal CSF was derived based on the following Absorption Factors (ABS):

0.2 - Inorganics
0.8 - Volatile Organics
0.5 - Semi-Volatile Organics/Pesticides/PCBs
Dermal Slope Factor = Oral SF/ABS

[2] The dermal RfD was derived based on the following Absorption Factors (ABS):

0.2 - Inorganics
0.8 - Volatile Organics
0.5 - Semi-Volatile Organics/Pesticides/PCBs
Dermal RfD = Oral RfD x ABS

dermal intakes are calculated as absorbed doses. Based on U.S. EPA health effects assessment documents, oral absorption factors are 0.8 for volatile organic chemicals, 0.5 for semi-VOCs, pesticides and dioxins, and 0.2 for inorganic compounds. Approximate values for dermal RfDs and CSFs were derived by simple extrapolation from oral RfDs and CSFs. For RfDs, this was done by multiplying the oral RfD by the oral absorption factor. For CSFs, this was done by dividing the oral CSF by the oral absorption factor. This approach has a high level of associated uncertainty as is inherent with any route to route extrapolation.

7.3.3 Estimates of Noncarcinogenic Toxicity

The toxicity criteria used to evaluate potential noncarcinogenic health effects are termed reference doses (RfDs). Unlike the approach used in evaluating carcinogenic risk, it is assumed in developing RfDs that a threshold dose exists below which there is no potential for human toxicity. The term RfD was developed by the EPA to refer to the daily intake of a chemical to which an individual can be exposed without any expectation of noncarcinogenic effects occurring during a given exposure period (e.g., organ damage, biochemical alterations, birth defects). The RfD is derived from a no-observed-adverse-effect level (NOAEL) or lowest-observed-adverse-effect level (LOAEL) obtained from human or animal studies by the application of standard uncertainty factors, and in certain cases, an additional modifying factor to account for professional assessment of scientific uncertainties in the available data (EPA, 1989).

A NOAEL is the highest dose of chemical at which no toxic effects are observed in any of the test subjects or animals. The study chosen to establish the NOAEL is based on the criterion that the measured toxic endpoint represents the most sensitive ("critical") target organ or tissue to that chemical (i.e., that target organ or tissue that shows evidence of damage at the lowest dose).

Since many chemicals can produce toxic effects on several organ systems, the distinction of the critical toxic effect provides added confidence that the NOAEL is protective of health. In contrast to a NOAEL, a LOAEL is the lowest dose at which the most sensitive toxic effect is observed in any of the test subjects or animals. If a LOAEL is used in place of a NOAEL to derive a RfD, an additional level of uncertainty is involved and, therefore, an additional uncertainty factor is applied. Figure 7-3 illustrates the threshold concept.

A variety of regulatory agencies have used the threshold approach for noncarcinogenic substances in the development of health effects criteria, such as worker-related threshold limit values (TLVs), air quality standards, and food additive and drinking water regulations. Chronic RfDs have been developed for the oral and inhalation routes, but not for the dermal route. As with carcinogenicity classification, human data are used preferentially if they are deemed adequate through scientific evaluation. However, in many cases, adequate human toxicity data are not available and animal studies must be used.

7.3.4 Reference Doses

Table 7-9 presents the route-specific RfDs for the chemicals of potential concern. The oral and dermal RfDs are described in the following subsections.

7.3.4.1 Oral

Chronic RfDs were available for all the chemicals of potential concern at the ABC One-Hour Cleaners site except for vinyl chloride.

7.3.4.2 Dermal

As in the case of cancer slope factors, no RfDs have been developed by EPA for the dermal route. Therefore, dermal RfDs were derived for the chemicals of potential concern in accordance with EPA guidelines (EPA, 1993). A chronic dermal RfD was derived for each chemical by multiplying the value used as the chronic oral RfD by an appropriate absorption factor. The approach used to select the absorption factor is the same as that previously described for cancer slope factors. The absorption factors are 0.2 (inorganics), 0.5 (semi-volatiles and pesticides), and 0.8 (volatiles).

7.3.4.3 Other Issues Pertaining to Reference Doses

Only chronic RfDs, which are developed to evaluate potential toxicity at greater than seven years of exposure, are presented in Table 7-4 and were used to estimate both childhood and adult noncarcinogenic risks. Subchronic RfDs are sometimes used to evaluate subchronic exposures of a duration ranging from two weeks to seven years, which may be more appropriate to address childhood exposure (1-6 years). However, chronic RfDs, which are lower than subchronic RfDs, are used in this risk assessment to ensure conservative risk estimates.

7.4 RISK CHARACTERIZATION

7.4.1 Introduction

The risk characterization is an evaluation of the nature and degree of potential carcinogenic and noncarcinogenic health risks posed to the current worker and hypothetical future residential and construction worker receptors at the ABC site. In this section, human health risks for carcinogenic and noncarcinogenic effects are discussed independently because of differing toxicological endpoints, relevant exposure durations, and methods employed in characterizing risk. The potential for carcinogenic effects is limited to exposure to those chemicals classified as carcinogens, while both carcinogenic and noncarcinogenic chemicals are evaluated for potential noncarcinogenic effects.

Carcinogenic and noncarcinogenic risks were evaluated for each exposure pathway and scenario by integrating the exposure doses calculated in Section 7.2 (Exposure Assessment) with the toxicity criteria for the chemicals of potential concern determined in Section 7.3 (Toxicity Assessment). The general approaches to evaluating risk are summarized in Subsection 7.4.2, and the results of the risk characterization are summarized in Subsection 7.4.3.

7.4.2 Approaches to Evaluating Risk

7.4.2.1 Carcinogenic Risk

Carcinogenic risk is calculated by multiplying the estimated daily dose that is averaged over a lifetime (lifetime-averaged doses) by a compound and exposure route-specific (oral, inhalation, dermal) carcinogenic slope factor (CSF). The calculation of carcinogenic risk, assuming a low-dose, linear relationship is illustrated by the following equation:

$$\mathbf{Risk} = \mathbf{CDI * CSF}$$

Where:

CDI = Chronic daily intake (intake averaged over a 70-year lifetime) (mg/kg-day)

CSF = Compound and route-specific carcinogenic slope factor $(\text{mg/kg-day})^{-1}$

The linear equation is valid only at low risk levels (i.e., below estimated risks of 1 x 10^{-2} or 0.01). For sites where doses and risks may be high, the alternative one-hit equation should be used. This exponential equation takes into account doses that exceed the linear portion of the dose-response curve. The calculation of carcinogenic risk assuming a high-dose, non-linear relationship is illustrated by the following equation:

$$\mathbf{Risk} = \mathbf{1\text{-}exp^{(-CDI*CSF)}}$$

Where:

CDI = Chronic daily intake (intake averaged over a 70-year lifetime) (mg/kg-day)

CSF = Compound and route specific slope factor $(\text{mg/kg-day})^{-1}$

The combined potential upper bound cancer risk for a particular exposure route is then estimated by summing the risk estimates for all the chemicals of potential concern for that route. This approach is in accordance with the U.S. EPA guidelines on chemical mixtures, in which risks associated with carcinogens are considered additive (EPA, 1989). This approach assumes an independence of action by the chemicals (i.e., that there are no synergistic or antagonistic interactions), and that all of the chemicals have the same toxicological endpoint (i.e., cancer). The total potential upper bound cancer risk to an individual member of a receptor population is estimated by summing the combined cancer risks from all relevant exposure routes. For the future resident, child, youth, and adult risks are summed to provide an estimate of total lifetime cancer risk.

In assessing the carcinogenic risks posed by a site, the National Oil and Hazardous Substances Contingency Plan (NCP) has established an excess cancer risk of 1×10^{-6} as a "point of departure" for establishing remediation goals. Excess cancer risks lower than 1×10^{-6} are not addressed by the NCP. Excess cancer risks in the range of 1×10^{-6} to 1×10^{-4} may or may not be considered acceptable, depending on site-specific factors such as the potential for exposure, technical limitations to remediation, and data uncertainties.

In April 1991, OSWER Directive 9355.0-30 from the U.S. EPA Assistant Administrator to Regional Directors (EPA, 1991b), the U.S. EPA further clarified the acceptable carcinogenic risk range by stating that when the cancer risk resulting from reasonable maximum exposures for both current and future land uses is less than 1×10^{-4}, action is generally not warranted, unless there are adverse environmental impacts. However, it should be noted that the same directive indicates that the risk manager may decide that risk less than 1×10^{-4} is unacceptable due to site-specific issues.

7.4.2.2 Noncarcinogenic Risk

Noncarcinogenic health effects are evaluated by comparing the estimated daily intake of the chemical of potential concern, which is averaged over the period of exposure, to its respective reference dose (RfD). This is accomplished by the calculation of hazard quotients and hazard indices. The hazard quotient (HQ) for a particular chemical is the ratio of the estimated daily intake through a given exposure route and the applicable RfD. Estimated daily intakes for individual chemicals and routes of exposure are compared to RfDs. The RfD represents the daily intake of a chemical to which a receptor can be exposed over a given length of time without any reasonable expectation of adverse noncarcinogenic health effects. The HQ-RfD relationship is illustrated by the following equation:

$$\mathbf{HQ = CDI / RfD}$$

Where:

HQ = Hazard quotient
CDI = Chronic daily intake (averaged over the exposure period) (mg/kg-day)
RfD = Reference dose (mg/kg-day)

The hazard quotients determined for each chemical of potential concern by exposure pathway and age group are summed within an exposure scenario to obtain a hazard index (HI). The HI is an expression of the additivity of noncarcinogenic health effects. The principle of additivity assumes that similar organ systems and health endpoints will be affected by the chemicals of potential concern. Since the RfDs determined for the multiple chemicals in a given exposure scenario usually represent a range of target organs or systems, the calculated HI is conservative.

The methodology used to evaluate noncarcinogenic risk, unlike the methodology used to evaluate carcinogenic risk, is not a measure of quantitative risk. The HQ or HI is not a mathematical prediction of the incidence or severity of those effects (EPA, 1989). If an HQ or HI exceeds unity (one), there might be a potential for noncarcinogenic health effects occurring under the defined exposure conditions. Note, however, that the calculation of an individual RfD assumes a margin of safety (refer to "Toxicity Assessment"), and the range of RfDs for a series of chemicals in an exposure scenario can potentially represent a number of individual toxic endpoints (as discussed above). Therefore, an HQ or HI of greater than one does not necessarily indicate that an adverse noncarcinogenic effect is likely to occur. Furthermore, an HI of less than or equal to one indicates that it is unlikely for even sensitive populations to experience adverse noncarcinogenic health effects.

7.4.3 Risk Results

7.4.3.1 Noncarcinogenic Effects

Total noncarcinogenic risks are summarized in Table 7-10 by exposure medium for the current worker, future construction worker, and future residents (child, aged 1-6 yrs, youth, aged 7-16 yrs, and adult). Table 7-11 summarizes hazard index data by pathway for current and future potentially exposed individuals. Table 7-12 further presents the hazard index data by exposure medium by listing the chemicals that exceed a hazard index of 0.1. Detailed risk tables are presented in Appendix E-3.

Current Worker

The total hazard index for the current worker was 0.1 with exposure to surface soil (Table 7-10). Table 7-11 indicates that for the current worker, surface soil ingestion was the primary contributor to the hazard index. Subsurface soil exposure was not evaluated for the current worker. Only tetrachloroethene had a hazard quotient of 0.1 or greater (Table 7-12) for the current worker.

Table 7-10

Total Hazard Index Using Reasonable Maximum Exposure Concentrations Current and Future Scenarios

Exposure Medium	Current Worker	Future Resident			Future Construction Worker
	Adult	1-6 yr. old	7-16 yr. old	Adult	Adult
Surface Soil Only	0.1	3	0.7	0.4	NE
Surface Soil and Subsurface	NE	NE	NE	NE	1
Total	0.1	3	0.7	0.4	1

NE - Not Quantitatively Evaluated (See Section 7.2.1)

Table 7-11

Total Hazard Index by Exposure Pathway at Reasonable Maximum Exposure Concentrations

Exposure Pathway	Current Worker	Future Resident			Future Construction Worker
	Adult	1-6 yr. old	7-16 yr. old	Adult	Adult
Ingestion of Surface Soil Only	0.1	3	0.5	0.3	NE
Dermal Contact with Surface Soil Only	0.03	0.2	0.2	0.1	NE
Ingestion of Subsurface and Surface Soils	NE	NE	NE	NE	1
Dermal Contact with Subsurface and Surface Soils	NE	NE	NE	NE	0.05

NE - Not Quantitatively Evaluated (See Section 7.2.1)

Table 7-12

Hazard Indices for Substances of Concern (Using Reasonable Maximum Concentration) Which Exceed Hazard Quotient of 0.1

Exposure Medium	Current Worker	Future Resident			Future Construction Worker
	Adult	1-6 yr. old	7-16 yr. old	Adult	Adult
Surface Soil Only	Tetrachloroethene (0.1)	Tetrachloroethene (3) Trichloroethene (0.3)	Tetrachloroethene (0.6)	Tetrachloroethene (0.4)	NE
Subsurface and Surface Soils	NE	NE	NE	NE	Tetrachloroethene (1)

NE - Not Quantitatively Evaluated (See Section 7.2.1)
NC - Not of concern, pathway did not exceed 1.0.

Future Resident

For the future resident, surface soil exposure to the child (HQ = 3), youth (HQ = 0.7), and adult (HQ = 0.4) were the primary contributors to the total hazard indices (Table 7-10). The total risk was approximately split between surface soil ingestion (about 65% of total) and dermal contact (about 35% of total), with the difference being more skewed for the future child resident (93% due to ingestion and 7% due to dermal contact of surface soil).

Two chemicals exceeded a hazard quotient of 0.1 in a pathway exceeding a hazard index of 1.0. All risk was from surface soil contact (Table 7-11). These were:

- **Child** - Tetrachloroethene (3), and trichloroethene (0.3)

Future Construction Worker

For the future construction worker exposure to subsurface and surface soils was assumed. The total hazard index was 1, due entirely to the presence of tetrachloroethene.

7.4.3.2 Carcinogenic Risks

Total carcinogenic risks are summarized in Table 7-13 by exposure medium. Table 7-14 further presents the carcinogenic risk data by specific exposure pathway, and Table 7-15 summarizes the major contaminants of concern within the primary exposure pathway that were major contributors. Detailed carcinogenic risk results are presented in Appendix E, Table E-3.

Table 7-13

Lifetime Cancer Risk - Current and Future Scenarios Reasonable Maximum Exposure Concentrations

Exposure Medium	Current Worker	Future Resident	Future Construction Worker
Surface Soil Only	2×10^{-5}	2×10^{-4}	NE
Surface and Subsurface Soils	NE	NE	6×10^{-7}
Total	2×10^{-5}	2×10^{-4}	6×10^{-7}

NE - Not Quantitatively Evaluated (See Section 7.2.1)

Table 7-14

Total Carcinogenic Risk by Exposure Pathway at Reasonable Maximum Exposure Concentrations

Exposure Pathway	Current Worker	Future Resident	Future Construction Worker
Ingestion of Surface Soil Only	2×10^{-5}	2×10^{-4}	NE
Dermal Contact with Surface Soil Only	6×10^{-6}	3×10^{-5}	NE
Ingestion of Surface and Subsurface Soils	NE	NE	4×10^{-7}
Dermal Contact with Surface and Subsurface Soils	NE	NE	2×10^{-7}

NE = Not Quantitatively Evaluated (See Section 7.2.1)

Table 7-15

Carcinogenic Risks for Substances of Concern (Reasonable Maximum Concentration) That Pose a Carcinogenic Risk Exceeding One in One Million (10^{-6})

Exposure Medium	Current Worker	Future Resident	Future Construction Worker
Surface Soil Only	NC	Tetrachloroethene (2 x 10^{-4}) Trichloroethene (3 x 10^{-6})	NE
Subsurface and Surface Soils	NE	NE	Tetrachloroethene (2E-5)

NE - Not Quantitatively Evaluated (See Section 7.2.1)
NC - No concern, did not exceed 1 x 10^{-6} risk

Current Worker

Total carcinogenic risk for the current worker was 2 x 10^{-5} (Table 7-13). Soil ingestion contributed 70 percent of this risk while dermal contact with soil contributed the remaining 30 percent (Table 7-14). No chemicals exceeded an individual cancer risk of 1 x 10^{-6} in a pathway having a risk of 1 x 10^{-4} or greater.

Future Resident

Total carcinogenic risk for the future resident was 2 x 10^{-4} (Table 7-13). The major contributing exposure pathways was ingestion of surface soil (2 x 10^{-4}). Tetrachloroethene (2 x 10^{-4}) and trichloroethene (3 x 10^{-6}) accounted for the majority of risk in the ingestion of soil scenario. In the dermal contact with soil scenario, tetrachloroethene contributed 3 x 10^{-5} of the total risk and trichloroethene contributed 3 x 10^{-7} of the total.

Future Construction Worker

Total carcinogenic risk for the future construction worker was based upon exposure to surface and subsurface soils. This assumption is based upon the fact that the building may be demolished or pipelines may be reinstalled; as a result, a future construction worker may be exposed to both surface and subsurface soils. The combined risk for this construction worker was 6 x 10^{-7}. Sixty-seven percent of this was via incidental ingestion of soils (4 x 10^{-7}) while thirty-three percent was due to dermal contact with soil. The majority of this risk was attributed to tetrachloroethene.

7.5 CONCLUSIONS

7.5.1 Noncarcinogenic Risk

No chemical or medium exceeded a hazard quotient of unity for the current worker. In conclusion, noncarcinogenic risks for the current worker are not of concern.

For the future scenarios, hazard indices exceeded unity for the 1-6 year old child (3). For the 1-6 year old child, the majority of risk was through ingestion of tetrachloroethene (HQ = 3) and trichloroethene (HQ = 0.3) in surface soil.

7.5.2 Carcinogenic Risk

The total cancer risk for the current worker is 2×10^{-5}, which is less than the regulatory benchmark level of 1×10^{-4}. Based on the assumptions described for the current worker scenario, exposure to site contaminants would result in acceptable levels of risk.

The total lifetime cancer risk for the future resident scenario is 2×10^{-4}, which exceeds the regulatory risk level of 1×10^{-4} described in the NCP. The majority of cancer risk for the future resident is attributable to the ingestion of surface soil. Most of the total cancer risk is attributable to exposure to tetrachloroethene and trichloroethene in surface soils, as shown below:

- Tetrachloroethene - 2×10^{-4} (98.5%)
- Trichloroethene - 3×10^{-6} (1.5%)

7.6 UNCERTAINTIES

The principal goals of the uncertainty analysis are to provide to the appropriate decision makers a discussion of the key assumptions made in the risk assessment that significantly influence the risk results and to assess the contribution of these factors to the under- or overestimation of risk. The uncertainty analysis should show that the calculated risks are relative in nature and do not represent an absolute quantification.

The U.S. EPA has recently placed even more emphasis on the uncertainty analysis. In a February 26, 1992 memorandum from the Deputy Administrator to all assistant and regional administrators (EPA, 1992c), U.S. EPA provides additional guidance on explaining risks and all their underlying data so that the strengths and weaknesses of the assessment become clear. This section of the risk assessment attempts to explain the key assumptions used in this report and present a range of risks covering the variability inherent in these assumptions.

In the absence of empirical or site specific data, assumptions are developed based on best estimates of data quality, exposure parameters, and dose-response relationships. To assist in the development of these estimates, the EPA recommends the use of guidelines and standard factors in risk assessments conducted under CERCLA (EPA, 1989; 1991b). The use of these standard factors is intended to promote consistency among risk assessments where assumptions must be made. Although the use of standard factors no doubt promotes comparability, their usefulness in accurately predicting risk is directly proportional to their applicability to the site-specific conditions.

The carcinogenic and noncarcinogenic risk estimates for the ABC One-Hour Cleaners site were based on a number of assumptions that incorporated varying degrees of uncertainty resulting from several sources, including:

- Data evaluation
- Selection of exposure pathways, input parameters, algorithms, and scenarios
- Confidence in toxicological data used to estimate cancer potency factors and reference doses

These uncertainties are summarized in Table 7-16.

7.6.1 Uncertainties Associated With Data Evaluation

The data available for ABC OU2 only focused on soils and specifically organic compounds in soils. Two compounds, toluene and 1,1-dichloroethene, were detected once. These chemicals are quantitatively assessed which could overestimate their risk.

7.6.2 Uncertainties Associated With the Exposure Assessment

The estimated average daily exposure levels to chemical contaminants at the ABC One-Hour Cleaner site were generated with a number of uncertainties. A number of standard default assumptions are used regarding physiological parameters (e.g., body weight), media intake rates, exposure frequencies and exposure durations. Where possible, these values were adjusted for site-specific considerations. However, as a rule, the use of these values results in a moderate overestimate of exposure. In addition, many uncertainties are generally inherent in risk assessments associated with remedial investigations particularly because of the type of and amount of data that can be collected in the short durations of sampling episodes. The most important of these uncertainties are summarized below.

Although exposure levels were based on measured concentrations in the media of concern, these values are uncertain due to limited sampling and significant analytical variability. To account for this uncertainty, the 95th percentile upper confidence limits of the mean sample concentration values were used in dose calculations. This assumption results in a moderate overestimate of the actual dose.

When deriving exposure point concentrations, chemicals that were not detected in a given sample were assumed to be at one-half the quantitation limit (QL). This assumption may lead to a moderate overestimation of dose especially when the QL is significantly high.

The assumption that soil concentrations will remain constant over time highly overestimates the lifetime exposure. Chemicals dissolve in rainwater and migrate from the soil, degrade as a result of biological action (organics), are dispersed and diluted in groundwater, and otherwise are subject to a variety of attenuation processes. A minority of organics may degrade to a more toxic form, resulting in overestimation of risks in these cases.

Dermal uptake of chemicals from soil is especially difficult to estimate since this factor is dependent on the characteristics of the specific chemical as well as the soil chemistry. The absorption values employed to estimate dermal uptake are conservative, probably leading to a moderate overestimation of dose.

7.6.3 Uncertainties Associated With Toxicity Assessment

For a risk to exist, both significant exposure to the pollutants of concern and toxicity at these predicted exposure levels must exist. The toxicological uncertainties primarily relate to the methodology by which carcinogenic and noncarcinogenic criteria (i.e., cancer slope factors and reference doses) are developed. In general, the methodology currently used to develop cancer slope factors and reference doses is very conservative, and results in overestimation of human toxicity and resultant risk are likely (EPA, 1989). These and other factors are discussed in the following subsections.

7.6.3.1 Antagonism/Synergism

Since specific data concerning synergistic or antagonistic effects are not available, EPA and other Federal agencies require the summation of individual chemical risk values. Either over- or underestimation of risk may occur as a result.

7.6.3.2 Cancer Slope Factors

Although there is evidence to suggest some carcinogens may exhibit thresholds, cancer slope factors are developed assuming there is no safe level of exposure to any pollutant proven or suspected to cause cancer. This uncertainty implies that exposure to even a single molecule of a chemical may be associated with a finite risk, however small. The assumption is that even if relatively large doses of a pollutant were required to cause cancer in laboratory animals (i.e., much higher than a person would ever likely be exposed to over a lifetime), these exposure doses can be linearly extrapolated downward many orders of magnitude to estimate slope factors.

A significant uncertainty for the carcinogens is whether the cancer slope factors accurately reflect the carcinogenic potency of these chemicals at low exposure concentrations. The calculated slope factor is used to estimate an upperbound lifetime probability of an individual developing cancer as a result of exposure to a particular carcinogen level. Therefore, the cancer slope factors developed by EPA are generally conservative and represent the upperbound limit of the chemical's carcinogenic potency. The actual risk posed by each chemical is unknown but is likely to be lower than the calculated risk, and may even be as low as zero (EPA, 1989). The conclusion is that these toxicity assumptions will typically result in an overestimation of carcinogenic risk.

The assumption that all carcinogens (whether A, B1, B2, or C) can cause cancer in humans is also conservative. Only those chemicals classified as "A" carcinogens by the EPA are unequivocally considered human carcinogens. The other three classes are probable (B1, B2) or possible (C) human carcinogens. In this risk assessment, all "probable" and "possible" carcinogens are given the same weight in the toxicity assessment (and consequently in the estimation of risk) as true human carcinogens. This assumption most likely overestimates actual carcinogenic risk to human receptors.

7.6.3.3 Reference Doses

In the development of reference doses (RfDs) for each chemical by exposure route, it is assumed that a threshold dose exists below which there is no potential for adverse health effects to the most sensitive individuals in the population. The RfD is typically derived from dose-response studies in animals in which a NOAEL (no-observed-adverse-effect level) or a LOAEL (lowest-observed-adverse-effect level) is determined by applying several uncertainty factors of 10 each.

An additional modifying factor of up to 10 can be applied which accounts for a qualitative professional assessment of other uncertainties in the available toxicity data (EPA, 1989). The final degree of extrapolation for a given chemical can range anywhere between 10 and 100,000, resulting in a human subthreshold dose of one tenth to one-hundred thousandth of the study dose. In general, the calculated RfD is likely overly protective, and its use probably results in an overestimation of noncarcinogenic risk.

7.6.3.4 Use of Chronic RfDs in Children

Oral chronic RfDs were used in calculating hazard quotients for the 1 to 6 year old child. The use of chronic RfDs in this age group is conservative and will result in an overestimation of risk. Chronic RfDs are developed assuming a lifetime daily exposure. Subchronic RfDs, which are calculated assuming an exposure duration of 2 weeks to 7 years, generally tend to be higher than chronic RfDs and result in a lower hazard quotient and index.

7.6.4 Uncertainties Associated With Risk Characterization

Table 7-16 summarizes the primary uncertainties and their relative impacts on risk. In general, the assumptions made in this risk assessment probably overestimate actual risk associated with the ABC One-Hour Cleaners site.

7.7 REFERENCES

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SECTION 8

CONCLUSIONS AND RECOMMENDATIONS

The data obtained from the field program conducted as part of the OU2 RI at the ABC site has been reviewed and analyzed with respect to the nature and extent of contamination, hydrogeologic characteristics of the aquifers, fate and transport of the contaminants, and the risk posed to human health and the environment by the contaminants. Conclusions from this investigation and recommendations for further action are presented in this section.

8.1 NATURE AND EXTENT OF CONTAMINATION

Soil borings were installed on the interior and exterior of the ABC building in order to collect soil samples for TCL-VOC analysis. Samples collected from soil borings installed in the interior of the ABC building indicate that PCE, TCE, and 1,2-DCE are primary contaminants in the unsaturated soil profile (from 0 to 15 feet bgs). Chloroform, 1,1-DCE, vinyl chloride, and toluene were also detected. The highest levels of VOC contamination were detected in the 0- to 2-foot interval beneath the floor of the ABC building.

Exterior to the ABC building, VOC contamination in soil is much lower than concentrations in samples from beneath the building (except for the SB-18 samples). VOC contamination extends from the 0- to 15-foot bgs interval in areas outside the building. Free product, however, was not detected in any of the soil sampling locations.

A sample was collected from the septic tank in the ABC building in order to supplement and confirm OU1 VOC contamination data from another septic tank sample. The OU2 septic tank sludge sample provided an estimate of PCE contamination at 240,000,000 μg/kg. Due to the high laboratory dilution required for this sample, the analytical result could not be confirmed.

Groundwater samples were collected during the OU2 field investigation from the surficial and Castle Hayne aquifer monitor wells. Sample data indicated PCE, TCE, 1,2-DCE, vinyl chloride, and chloroform concentrations in excess of the ROD groundwater goals, EPA Maximum Contaminant Level (MCLs), and/or North Carolina Groundwater Quality Standards.

Based on septic tank, soil, and groundwater samples collected during the OU2 investigation, the ABC site, specifically the former septic tank system, is the primary source for VOCs, including PCE, TCE, 1,2-DCE, and vinyl chloride in soils underlying the ABC facility and hydraulically downgradient groundwater. However, an unidentified source of chlorinated and aromatic VOCs, located upgradient of the ABC site, appears to be contributing to groundwater contamination detected in upgradient and downgradient surficial aquifer wells.

8.2 HYDROGEOLOGIC CHARACTERISTICS OF THE AQUIFERS

The hydrogeologic characteristics of the surficial and Castle Hayne aquifers were defined by aquifer testing through wells C2 and S2. Transmissivity and storativity values were determined for both aquifers. An average transmissivity value calculated for the surficial aquifer from the pumping phase of the 72-hour was found to be 1,469 ft^2/day. Average transmissivity values calculated from the recovery phase of the 72-hour test was found to be 509 ft^2/day. A storativity value from the 72-hour test was calculated to be 1.731×10^{-3}.

Transmissivity and storativity values were calculated for the Castle Hayne aquifer from pumping and recovery phases of the testing. Pumping phases produced transmissivity values ranging from approximately 1,500 to 3,850 ft^2/day. Recovery phases produced transmissivity values ranging from 230 to 1,680 ft^2/day. A storativity value was calculated for the Castle Hayne from the 72-hour surficial aquifer test data and was found to be 3.3×10^{-5}. The aquifer testing conducted through surficial aquifer monitor well S2 for 72 hours at a rate of 13.1 gpm indicated a capture zone radius of over 960 feet in the surficial aquifer and over 870 feet in the Castle Hayne aquifer.

From the average transmissivity data for the surficial aquifer, hydraulic conductivity values were calculated. The average hydraulic conductivity was calculated to be 20 ft/day.

A downward hydraulic gradient exists between the surficial and Castle Hayne aquifers that will affect contaminant migration rates from the surficial aquifer into the Castle Hayne. The direction of horizontal groundwater flow is to the east-southeast in both aquifers.

8.3 FATE AND TRANSPORT OF CONTAMINANTS

VOCs detected at the site and attributed to release from ABC (PCE, TCE, 1,2-DCE, vinyl chloride, and chloroform) are characterized by high solubilities, high volatilities, low to moderate partition coefficients, high mobilities, and densities greater than water. They are the most mobile of the contaminants detected at the site. TCE, 1,2-DCE, and vinyl chloride are present on the site apparently as a result of progressive dehalogenation of PCE.

Soil concentrations of VOC contamination are highest within the 0- to 2-foot interval beneath the ABC building. The higher concentrations of contaminants in this interval are due to the proximity to sources such as the septic tank, and the lack of infiltration to flush the contaminants.

Exterior to the ABC building, VOC contamination is attributable to historical disposal processes and migration of contaminants from underneath the ABC building. Where asphalt driveways surrounding the ABC facility are not cracked or broken in some manner, the contamination has persisted. For example, the SB-18 soil boring located beside the Major Furniture building and within the asphalt driveway contained soil samples with the highest VOC contaminant levels. Otherwise, the contaminants have been degraded by biological, chemical, and physical processes.

8.4 RISK ASSESSMENT

8.4.1 Exposure Assessment

Based on a detailed evaluation of exposure pathways and receptors, the following exposure scenarios were selected for quantitative evaluation in this assessment:

- Current exposure of on-site workers to contaminants in soil through incidental ingestion and dermal contact.
- Future exposure of on-site residents to contaminants soil through incidental ingestion and dermal contact.
- Future exposure to on-site construction workers to contaminants in soil through incidental ingestion and dermal contact.

8.4.2 Non-Carcinogenic Risk

An evaluation of the results of the risk calculations indicates that hazard indices (HIs) for the current scenario is below 1.0, the level of concern for noncarcinogens. For future scenarios, however, the on-site child resident (1-6 yrs.) hazard index is above 1.0 (3.0). Adult and youth (7-16 yrs) on-site residents would have HIs of 0.4 and 0.7, respectively, primarily due to ingestion of soil PCE. The future construction worker hazard index would be 1.0 from exposure to PCE in surface and subsurface soil.

8.4.3 Carcinogenic Risk

For current on-site workers, the lifetime excess cancer risk is 2×10^{-5}. For future on-site resident, the lifetime excess cancer risk is 2×10^{-4} from ingestion of and dermal contact with PCE. For future construction worker, the lifetime excess cancer risk is 6×10^{-7}.

In April 1991, OSWER Directive 9355.0-30 from the U.S. EPA Assistant Administrator to Regional Directors (EPA, 1991b), the U.S. EPA stated that when the cancer risk resulting from reasonable maximum exposures for both current and future land use in less than 1×10^{-4}, action is generally not warranted, unless there are adverse environmental impacts. However, it should be noted that the same directive indicates that the risk manager may decide that risk less than 1×10^{-4} is unacceptable due to site-specific issues.

8.5 RECOMMENDATIONS

Recommendations for additional investigations for the ABC site are presented as follows:

- Additional sampling efforts should be undertaken for soils underlying the adjacent Major Furniture building. As indicated in Section 5, analytical data from soil boring SB-18 revealed the highest concentrations of PCE, TCE, and 1,2-DCE for all soil samples collected. The location of SB-18 was immediately adjacent to the Major Furniture building at the eastern edge of the ABC property.

- Soils in which the calculated risk exceeded 10^{-4} should be addressed in the feasibility study for OU2.

- Additional investigation is required to determine the source of aromatic hydrocarbons (benzene, toluene, ethylbenzene, and xylene). These contaminants are more characteristic of a leaking underground storage tank (UST) containing fuel products (i.e., gasoline) than dry-cleaning processes. In addition, the possibility of an upgradient source of TCE in groundwater (as exemplified by the sample from well S11) should be examined.