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November 27, 1998

DEC 1998
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Hazardous Waste Section

Mr. Thomas J. Walker
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401 Oberlin Road, Suite 150
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Reference: Phase II RFI Report
Alcatel Network Systems, Inc.
Raleigh, North Carolina
NCD 003 185 238
Triangle Project Nº 01-003-0209

Dear Mr. Walker:

Triangle Environmental, Inc. (Triangle), on behalf of Alcatel Network Systems, Inc. is pleased to submit three copies of the *Phase II RCRA Facility Investigation* report. The work was performed following review and approval of the *Phase II RCRA Facility Investigation Work Plan* for the Alcatel Network Systems, Inc. facility in Raleigh, North Carolina.

If you have any questions please contact me at (910) 392-1747, ext. 23.

Sincerely,

TRIANGLE ENVIRONMENTAL, INC.

Michael H. Haseltine, L.G.
Project Geologist
MHH/kf

enclosures
cc: Dikran Kabbendjian - Alcatel Network Systems, Inc.

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PHASE II RCRA FACILITY INVESTIGATION

ALCATEL NETWORK SYSTEMS, INC.
2912 WAKE FOREST ROAD
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DEC 1998
Received
Hazardous Waste
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Prepared for:
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November 1998

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CERTIFICATION OF PHASE II RCRA FACILITY INVESTIGATION

ALCATEL NETWORK SYSTEMS, INC.
2912 WAKE FOREST ROAD
RALEIGH, NORTH CAROLINA

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information including the possibility of fine and imprisonment for knowing violations.

Date: November 25, 1998

Signature: [illegible]

Project Manager - Triangle Environmental, Inc.
Title

TABLE OF CONTENTS

SECTION		PAGE
1.0	**INTRODUCTION**	**1**
1.1	Background Information	1
1.1.1	Facility Location and Use	1
1.1.2	Environmental Assessment/Remediation History	2
1.1.2.1	Description of Areas of Concern	2
1.1.2.2	Further Investigations	6
1.1.2.3	RCRA Facility Investigation for AOC #1 and #2	8
1.1.2.4	Interim Corrective Actions	11
1.2	Regional Environmental Setting	13
1.2.1	Surrounding Land Usage	13
1.2.2	Demographics	13
1.2.3	Regional Climatology	13
1.2.4	Regional Hydrology and Surface Water Usage	14
1.2.5	Regional Geology and Hydrogeology	14
1.2.6	Ground Water Usage	15
1.3	Local Environmental Setting	16
1.3.1	Topography and Hydrology	16
1.3.2	Geology and Hydrogeology	17
2.0	**INVESTIGATION OBJECTIVES**	**19**
3.0	**INVESTIGATION RESULTS**	**20**
3.1	Assessment of VOC Source	20
3.2	Assessment of Background Ground Water	23
3.3	Assessment of Background Copper and Lead	23

TABLE OF CONTENTS (continued)

SECTION		PAGE
	3.3.1 Statistical Analysis	24
	3.3.1.1 Background	24
	3.3.1.2 Data Selection	26
	3.3.1.3 Distributional Characteristics	26
	3.3.1.4 Homogeneity of Variance	27
	3.3.1.5 Selection of the Appropriate Statistical Method	27
3.4	Vertical Extent of Contamination	29
	3.4.1 Bedrock Investigations	29
	3.4.2 Fracture Zones	31
	3.4.3 Ground Water Elevation and Sampling	32
	3.5 Horizontal Extent of Contamination	32
	3.5.1 Geoprobe Investigation	33
	3.5.2 Monitoring Well Installation	34
	3.5.3 Off-Site Facilities	35
	3.5.4 Survey	36
3.6	Natural Attenuation Evaluation	37
	3.6.1 Background	38
	3.6.2 Transformation of the Target Compounds	39
	3.6.2.1 Daughter Products	40
	3.6.2.2 Indicators of Biodegradation	41
	3.6.3 Natural Attenuation Screening and Evaluation	42
	3.6.3.1 Investigation	42
	3.6.3.2 Results	43
	3.6.3.3 Parent and Daughter Contaminant Distributions	45
	3.6.3.4 Degradation Rates	46
	3.6.3.5 Former Solid Waste Disposal Site	48
3.7	Ground Water Potentiometric Surfaces	50

TABLE OF CONTENTS (continued)

SECTION		PAGE
4.0	CONCLUSIONS	51
5.0	RECOMMENDATIONS	54

LIST OF FIGURES

FIGURE 1	LOCATION MAP
FIGURE 2	SITE MAP
FIGURE 3	SOURCE AREA SOIL SAMPLING LOCATIONS
FIGURE 4	BACKGROUND VOC'S AND METALS, AND OFFSITE GEOPROBE LOCATIONS
FIGURE 5	LOCATION OF FORMER SOLID WASTE DISPOSAL FACILITY
FIGURE 6	AREAL EXTENT OF PCE PLUME
FIGURE 7	AREAL EXTENT OF TCE PLUME
FIGURE 8	AREAL EXTENT OF TCA PLUME
FIGURE 9	AREAL EXTENT OF DCE PLUME
FIGURE 10	AREAL EXTENT OF DCA PLUME

FIGURE 11 GROUND WATER POTENTIOMETRIC SURFACE OF UNCONSOLIDATED AQUIFER

FIGURE 12 GROUND WATER POTENTIOMETRIC SURFACE OF BEDROCK AQUIFER

LIST OF TABLES

TABLE 1 FIELD SCREENING AND LABORATORY RESULTS OF SOIL SAMPLES COLLECTED AT SOURCE AREA

TABLE 2 COPPER AND LEAD CONCENTRATIONS FROM SOURCE AND BACKGROUND AREAS

TABLE 3 RESULTS OF STATISTICAL ANALYSIS OF BACKGROUND AND SOURCE AREA COPPER AND LEAD CONCENTRATIONS

TABLE 4 RESULTS OF OFF-SITE GEOPROBE INVESTIGATION

TABLE 5 SUMMARY OF DAUGHTER PRODUCTS AND HALF-LIVES

TABLE 6 NATURAL ATTENUATION SCREENING RESULTS

TABLE 7 NATURAL ATTENUATION RANKING

TABLE 8 COMPARISON OF DECAY RATE AND TRACER ATTENUATION RATES

TABLE 9 GROUND WATER ELEVATIONS

LIST OF APPENDICES

APPENDIX A	LOCATION OF AREAS OF CONCERN
APPENDIX B	WELL COMPLETION FORM (GW-1) AND SELECTED BORING LOGS
APPENDIX C	SAMPLE METHODOLOGIES
APPENDIX D	LABORATORY REPORTS
APPENDIX E	STATISTICAL ANALYSIS OF BACKGROUND AND SOURCE AREA COPPER AND LEAD
APPENDIX F	OCCURRENCE OF BEDROCK FRACTURES
APPENDIX G	DRAFT EPA REGION 4 SUGGESTED PRACTICES FOR EVALUATION OF A SITE FOR NATURAL ATTENUATION OF CHLORINATED SOLVENTS AND DEGRADATION RATE CALCULATIONS
APPENDIX H	EVIDENCE OF THE FORMER SOLID WASTE DISPOSAL SITE

EXECUTIVE SUMMARY

This Phase II RCRA Facility Investigation report is submitted in accordance with Condition II.E of the Hazardous Waste Management Permit which became effective June 3, 1994 for the ALCATEL Network System, Inc. facility (ALCATEL) located in Raleigh, North Carolina.

The work described in this report was conducted following the *Phase II RCRA Facility Investigation Work Plan*, dated October 1997. Approval of the work plan was provided in correspondence from Hazardous Waste Section, dated February 13, 1998. The objectives of the work plan were to identify and implement additional assessment tasks not performed during previous investigative activities. These tasks included continuation of the assessment of the solvent source area; determination of the vertical and horizontal extent of the solvent contamination; determination of background soil Copper and Lead concentrations; and refinement of the ground water potentiometric surfaces through the incorporation of off-site monitoring wells.

Additional objectives not specified in the work plan but approved by the Hazardous Waste Section included: 1) Determination of the presence or absence of contaminants in the ground water located up-gradient of the suspected source area; and 2) Investigation of the conditions of the water quality parameters within the plume and in the vicinity for evaluation of natural attenuation.

Additional source area investigations included the installation of two bedrock monitoring wells, MW-13d and MW-14d, the advancement of a Geoprobe boring, and reevaluation of previous soil investigations. Results of this investigation did not reveal an existing soil source. In addition, Dense-Phase Non-Aqueous Liquids (DNAPLs) were not encountered.

The vertical and horizontal extent of the contamination within the unconsolidated aquifer was defined through the installation of the down-gradient monitoring well, MW-15s, and numerous down-gradient Geoprobe borings. However, the vertical extent of the contamination has not

been completely defined. Laboratory results from the down-gradient well, MW-15d, and the deep bedrock monitoring well, MW-4dd, revealed the presence of target compounds. A packer test was attempted during construction of MW-4dd to isolate and identify the contaminated fracture zones. Unfortunately, the well did not produce sufficient water below 55 feet to conduct the testing.

A much greater understanding of the area's ground water flow was provided following the incorporation of eight off-site monitoring wells. As anticipated, regional hydraulic gradient is toward the Crabtree Creek. The ground water elevation data may be applied to future fate and transport modeling requirements.

Up-gradient Copper and Lead soil concentrations were determined through sample collection and laboratory analysis. A statistical analysis revealed that there was no evidence of contamination in comparison of up-gradient Copper and Lead soil concentrations to those concentrations within the "source areas."

The natural attenuation evaluation was conducted in accordance with the recently completed U.S. Environmental Protection Agency's Directive and associated guidance documents. Field measurements and laboratory analyses revealed evidence of both biotic and abiotic degradation. In addition, the presence of 1,1,1-Trichloroethane; 1,1-Dichloroethane; 1,1-Dichloroethane; and 1,2-Dichloroethane may be the result of the transformation of the two parent compounds, Tetrachloroethane, and 1,1,1-Trichloroethane.

During the investigations for this report, a former solid waste disposal facility was encountered. Results of field screening ground water samples collected indicated anaerobic subsurface conditions. A common solvent degradation end product, vinyl chloride, was also detected. Consequently, subsurface conditions at the former landfill may be suitable for the reductive dehalogenation of solvents.

1.0 INTRODUCTION

The purpose of this report is to summarize the findings of the Phase II RCRA Facility Investigation (RFI) work as proposed in the *Phase II RFI Work Plan*.

1.1 Background Information

The ALCATEL facility is located at 2912 Wake Forest Road in the City of Raleigh, Wake County, North Carolina. The facility is located in an industrial-zoned area near the intersection of Wake Forest Road and the Raleigh Belt-Line (I-440) (**Figure 1**). The facility is situated on a 24-acre site consisting of a 234,000 ft^2 main building, storage and maintenance buildings, security buildings, parking lots, and landscaped "natural" areas. The main building is now used for business administration and research and development. The site layout is shown in **Figure 2**.

1.1.1 Facility Location and Use

The Kellogg Corporation, a division of ITT, began operation of the facility in 1958. At that time, the facility produced electronic and telecommunications equipment. In 1987, ALCATEL Network Systems Corporation bought the facility. Electroplating operations were conducted at the facility as part of printed circuit board manufacture until 1990.

During the time that the facility conducted manufacturing processes, a wastewater treatment plant (WWTP) was in operation at the site. The WWTP treated 300,000 to 400,000 gallons of wastewater per day. The waste was generated from several sources including the printed circuit board manufacturing area, the non-contact cooling/heating water, the compressor drainage water, and the cooling tower water. Treated effluent generated by the WWTP was discharged to the City of Raleigh publicly owned treatment works

(POTW). Processes that generated hazardous waste at the facility ceased in 1990 when the electroplating operations at the facility ended. (*RCRA Facility Investigation for area of concern (AOC) #1 and #2 Work Plan*, October 1994).

1.1.2 Environmental Assessment/Remediation History

During the construction of a storm water management system in 1989, contaminated soil was discovered in three areas along the alleyway on the North side of the facility. A fourth area was discovered in 1990 after printed circuit board manufacturing processes were terminated. Preliminary investigations were conducted immediately following the discovery of the contaminated soil. Four areas of concern were identified. The investigations included the installation of twelve monitoring wells, a soil gas survey, twenty-five soil borings, and the excavation and disposal of contaminated soil. The reader should reference the *RCRA Facility Investigation for AOC #1 and #2 Work Plan*, dated October 1994, for specific details regarding these preliminary subsurface investigations of AOC #1 and AOC #2. The RFI Work Plan, approved by the Hazardous Waste Section in a letter dated July 14, 1995, focused on AOC #2 (the former printed circuit board manufacturing area). The following is a brief summary of those investigations and remedial actions conducted prior to implementation of the Phase II RFI Work Plan.

1.1.2.1 Description of Areas of Concern

Two areas of concern (AOCs), designated AOC #1 and AOC #2, were noted in the RCRA permit for the ALCATEL facility. AOC #1 is located in an alleyway on the North side of the main building. AOC #2 is the former printed circuit board manufacturing area, located within and beneath the main building. Characteristics of each AOC are provided below. Diagrams of AOC #1 and AOC #2 are included in

Appendix A. (*RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994).

AOC #1

AOC #1 is located in an alleyway on the North side of the main building. Previous uses of this area have included waste and chemical storage. The area has also been the location of holding tanks for process materials. A WWTP was formerly located on the Eastern end of the alleyway. The storage areas for wastes and process materials, as well as the WWTP, have been decontaminated and closed since decommissioning of the former manufacturing process. Previous environmental investigations in this area identified four sub areas (**Area 1**, **Area 2**, **Area 3**, **and Area 4**) which have exhibited soil contamination. Previous studies also included the installation of two ground water monitoring wells in the alleyway.

Area 1 is an area approximately 15 feet by 14 feet located along the main building, approximately mid-way in the drainage alleyway.

Area 2 is an area approximately 40 feet by 20 feet located along the former process sump on the East end of the alleyway. Within these areas, soil contaminated by copper and lead was identified and excavated. The contamination has been attributed to leaks in subsurface process lines located in the vicinity. To date, approximately 277 tons of soil have been excavated from the two areas as part of a voluntary remediation effort. The excavated soil was shipped to GSX in Pinewood, South Carolina for disposal.

Results of Toxicity Characteristic Leaching Procedure (TCLP) tests from both Areas 1 and 2 indicated that no further remedial action was required.

Area 3 is located on the Western end of the alleyway and covers an area of approximately 30 feet by 10 feet. Soil sampling from this area indicated the presence of volatile organic compounds (VOCs). Specifically, the chlorinated compounds 1,1,1-Trichloroethane (TCA); 1,1,2-Trichloroethane (1,1,2-TCA); 1,1-Dichloroethane (DCA); 1,2-Dichloroethane (1,2-DCA); 1,1-Dichloroethene (DCE); and Tetrachloroethane (PCE) were detected in varying concentrations. Approximately 92 tons of soil have been excavated from this area during remedial efforts. The excavated soil was shipped to GSX in Pinewood, South Carolina, for disposal. Additional VOC impacted soil was identified around the Area 3 excavation; however, due to the presence of foundations, these soils were inaccessible to further excavation.

Area 4 is located in the central portion of the alleyway and measures approximately 30 feet by 25 feet. Area 4 previously contained a shed-like structure housing two chemical reaction tanks. Analytical results for Lead and Copper ranged from below quantification limit (BQL) to 1.3 mg/L in TCLP extracts and from Below Quantification Limit to 21,100 mg/Kg as total lead in soil. The Westinghouse environmental report indicated that "the lead contamination is limited in the soil to a depth of approximately one foot and in the overlying paving materials." No subsequent remedial action was performed in Area 4.

Additional assessment work was conducted in the vicinity of the facility's former wastewater treatment plant, located at the extreme

Eastern end of AOC #1. During decommissioning of the treatment plant, and prior to converting the plant's equalization basin to its current use, a chilled water holding tank and monitoring wells MW-6 through MW-9 were installed in order to determine if a release had occurred from the treatment plant basin. Examination of basin and monitoring well chemical data has indicated that no impact has occurred.

With the exception of Area 4, remedial efforts have been successful in the removal of contaminated soil from AOC #1. Confirmatory samples collected following excavation activities in Area 1, Area 2, and Area 3 verified soil contamination has been significantly reduced or removed. Because of this, and the fact that no process, chemical, or waste storage areas remain active within the area, no additional investigative activities are designated for AOC #1.

AOC #2

AOC #2 is the former printed circuit board manufacturing area, located within and beneath the main building. During previous manufacturing operations, electroplating and chemical plating processes were conducted in this area. The process incorporated coated, concrete, in-ground trenches which acted as conduit for rinse water and as secondary containment for process piping. These trenches were located in the floor of the building, within the area designated as *Former Printed Circuit Board Area*. In addition to the trenches, TCA was used in this area for the cleaning of printed circuit boards. A distillation unit (still), used to purify TCA, was also located in this area.

All process areas (troughs, distillation equipment, etc.) and/or chemical/waste storage areas which formerly operated in this area have

been decontaminated and decommissioned. The former process trenches were thoroughly decontaminated. The concrete was examined for evidence of corrosion and/or deterioration. Deteriorated concrete was removed and wipe tests were performed to determine if process chemicals had perforated into the concrete. The results of these tests were negative, and the trenches were filled with concrete. The area is now used for office and laboratory space and as a print shop.

1.1.2.2 Further Investigations

The National Environmental Technologies, Inc. (NET) report titled *Phase I Soil and Groundwater Impact Assessment* (RCRA Facility Investigation for AOC #1 and #2) was the first of three reports which addressed soil and ground water contamination in the area now referred to as AOC #2. Objectives of the report included assessment of ground water quality and characterization of the hydrogeological conditions at the site. Pursuant to these objectives a passive soil gas survey was conducted, five monitoring wells were installed and aquifer tests were performed. Laboratory results of the five shallow monitoring wells (MW-1s through MW-5s) confirmed this suspicion by the identification of certain VOCs in ground water samples recovered from the wells.

During the ground water investigation beneath the former manufacturing area, five soil samples were collected to determine if soil beneath the area was impacted by former operations. Copper was detected in each sample. Lower concentrations *(< 100 ug/L)* were thought to be naturally occurring, while the higher concentrations, detected in samples collected closer to the Northern side of the main building, were thought to be the result of previous operations at the facility. Target VOC's were

detected at elevated concentrations in SB-2 and SB-9. The soil in the vicinity of SB-2 and SB-9 was later excavated.

The aquifer characterization study revealed uniform weathering to the PWR/bedrock interface. Hydraulic conductivities, calculated from slug tests, ranged from 3.02 to 5.72 ft/day with gradients ranging from 0.16 to 0.19 ft/ft.

Additional ground water quality work was accomplished during closure of ALCATEL's on-site wastewater treatment plant. This work was performed independently of the above mentioned assessment activities and resulted in the installation of four additional ground water monitoring wells. Monitoring wells MW-6s through MW-9s were installed up-gradient and down-gradient of the treatment building. Sampling results from these wells indicated that no impact to ground water occurred as a result of the operation of the treatment plant.

Further voluntary ground water investigative work was initiated in June 1993, and continued through October of the same year. This work is summarized in two NET reports dated August 11, 1993, and October 22, 1993, and titled *Results of Ground Water Investigation* and *Report of Ground Water Investigation*, respectively (RCRA Facility Investigation for AOC #1 and #2, Appendix D). During these investigations, several borings were advanced inside the ALCATEL main building for the purpose of water quality and soil assessment. Results indicated that little, if any, soil contamination was present; however, VOC impacted ground water encompassed an area of approximately four acres in the vicinity of the main building. The installation of monitoring wells MW-10s through MW-12s was accomplished during the studies to address VOC contamination.

S&ME Soil Sampling on the former Keebler Property

During environmental audit activities associated with development of the Keebler property, Soil & Materials Engineers (S&ME) sampled soils on the Keebler property to establish baseline conditions. Their assessment was conducted during the period February through April 1995.

During their study, S&ME collected soil samples from 11 points on the former Keebler property. No volatile compounds were detected during analysis of the soil samples.

1.1.2.3 RCRA Facility Investigation for AOC #1 and #2

The complete description of the field methodologies and investigation results conducted under the approved Work Plan can be obtained in the report *RCRA Facility Investigation for AOC #1 and #2*, dated February 1996. The following is a brief summary of that report.

Soil Investigation

During the months of May and June 1995, a soil investigation was conducted beneath ALCATEL's main building. Ten soil borings were advanced beneath the floor of the main building to depths of approximately 11 feet below grade, or to auger refusal, whichever was first. Soil borings were concentrated in two areas; in the area along the exterior wall of the original 1958 building, and in the vicinity of the former plating trenches. Laboratory analyses did not indicate impact by volatile constituents; however, several samples showed elevated concentrations of copper and/or lead. The majority of samples exhibiting higher metals concentrations were collected near the north wall of the building bordering AOC #1. Please reference the *RCRA*

Facility Investigation for AOC #1 and #2 for the locations of these borings and laboratory results.

Monitoring Well Installation

Prior to this investigation, twelve monitoring wells (MW-1 through MW-12) existed on the ALCATEL property and none on the adjacent Keebler property. Coincidental to this investigation, eleven monitoring wells were installed on the Keebler property during pre-acquisition auditing activities. The discovery of off-site contamination prompted the submittal of an addendum to ALCATEL's RFI Work Plan, resulting in the installation of four monitoring wells (all on the Keebler property; MW-8SK, MW-8DK, MW-9SK and MW-9DK) in addition to MW-2D, MW-3D, MW-4D, MW-7D, MW-13S, RW-1 and RW-2.

MW-13s was installed inside ALCATEL's main building using a stainless steel hand auger. The remaining Type II wells were installed with a power drilling rig using hollow-stem augers.

The two recovery wells (RW-1 and RW-2) were advanced using air percussion drilling techniques (air hammer) and were screened in the saprolite and weathered/highly fractured rock zones. The recovery wells, RW-1 and RW-2, were installed for aquifer testing.

Each of the seven Type III monitoring wells were installed within the competent bedrock using the air hammer.

Well Sampling and Analysis

Ground water samples were collected during this investigation from monitoring wells at the site to characterize ground water quality within the aquifer system. Samples were collected from the fifteen wells on the ALCATEL property and sixteen monitoring wells on the former Keebler property.

The total VOC plume at the water table appeared to be roughly a symmetrical and elliptical feature having a longitudinal axis oriented northeast-southwest. The plume encompassed approximately 9.75 acres in lateral extent. In the bedrock, the lower extent of the plume also appeared as a symmetrical, ellipsoidal feature with a longitudinal axis oriented north-south. The lateral extent of the bedrock plume encompassed approximately 10.5 acres.

Stream Sampling

Surface water samples were collected from the unnamed stream, which transects the western portion of the study area, but now primarily serves the storm runoff. The stream is a tributary of the Crabtree Creek. Water samples were collected up-gradient (CS-1) and down-gradient (CS-2) of the study area to determine if target constituents impacted the stream. during its flow across the property. Carbon disulfide, copper, and lead were detected in both samples. Carbon disulfide was detected by Method 8240 analysis at concentrations of 11.0 ug/L and 14.0 ug/L in samples CS-1 and CS-2, respectively. No other VOC compounds were detected. Copper was detected at 2.5 ug/L and 3.5 ug/L in samples CS-1 and CS-2, respectively; and lead was detected at 1.7 ug/L and 1.1 ug/L in samples CS-1 and CS-2, respectively. From these results, it may be concluded that the stream is not impacted by regulated constituents from the ALCATEL property.

During this sampling an average flow velocity of 31.9 ft/minute was measured. The resulting base flow discharge is 15.9 ft^3/minute.

Aquifer Testing

Aquifer testing was performed on well RW-2. The aquifer testing consisted of a four-hour step-drawdown pumping test, followed by a 72-hour constant discharge aquifer test. The step test indicated a discharge on the order of 7.5 gpm would produce a suitable drawdown (about 4 feet) and limit turbulent flow conditions during the 72-hour pump test. In addition to wells RW-1, RW-2, and MW-2ik that were connected to the data logger, water levels were routinely monitored by hand in wells MW-4d and MW-2sk. Data collected during the 72-hour aquifer test for pumping well RW-1 and observation wells RW-2, MW-2sk, MW-2ik, and MW-4d were evaluated using GWAP (Graphical Well Analysis Package).

Based upon the constant rate pumping test, the geometric mean hydraulic conductivity (K_h), 19.40 ft/day, was calculated. Earlier slug testing results in the saprolite hydrolithologic unit provide a mean hydraulic conductivity of 3.99 ft/day. The constant rate pumping test data was considered more accurate. Based upon the (K_h) of 19.40 ft/day a transmissivity of 1218 ft^2/day was calculated. Storativity ranged from 0.0014 to 0.156.

1.1.2.4 Interim Corrective Actions

The Interim Corrective Measure (ICM) Plan was prepared in response to the conclusions and recommendations presented in the February 1996, *RCRA Facility Investigation (RFI)*. The ICM Plan proposed ground water recovery, treatment, and injection. The target VOC compounds include DCE, DCA, TCA, TCE, and PCE. The system was designed

to create a hydraulic barrier and capture the up-gradient contaminated ground water using the recovery wells, capture and recirculate the injected ground water to create a semi-closed loop system, and reduce or eliminate the contaminant plume. Construction of the remedial system was completed in September 1996, following verbal approval of the ICM Plan. The system construction details are summarized in the *Remediation System Construction Report* dated August 1997.

The ground water is recovered through an array of 22 recovery and containment wells. The treatment system currently removes greater than 99.99 percent of the contaminants through volatilization (shallow tray air stripper) and adsorption (two granular activated carbon units). The treated water is injected in up-gradient locations through an array of eight injection wells and a treatment system on the site.

The subsurface injection of the effluent from the ground water remediation system is permitted under NCDENR, permit #WQ0012221 and NPDES permit # NC 0089126.

ALCATEL started the shake-down of the treatment system in September 1996. The shake-down and testing period continued until December 1996, at which time ALCATEL and National Environmental Technologies, Inc. (now Triangle Environmental, Inc. (Triangle)) were comfortable with the system operation. The first Interim Measures Progress Report (IMPR) of the treatment system effectiveness included the period from September 1996, through April 1997. The second IMPR included the period from April 1997, through October 1997. The third report includes the period from November 1997, through April 1998. Subsequent reports will be issued on a semi-annual basis following each monitoring period.

1.2 Regional Environmental Setting

1.2.1 Surrounding Land Usage

The ALCATEL facility is located within the city limits of Raleigh, North Carolina, and is situated within an industrial park setting. Although residential areas are located within one-half mile of the site, surrounding property uses are primarily industrial and commercial. (*RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994.)

1.2.2 Demographics

The site is located within the city limits of Raleigh, located in Wake County, North Carolina. Approximately 350 major employers are located in the city of Raleigh, with the predominant industry being technical/research based. Research Triangle Park, an adjunct of the city of Raleigh, presently accommodates over 100 such firms. Technical/research-related commerce is anticipated to accelerate in the Raleigh area throughout the 1990's and beyond. Raleigh's population is presently 235,000, with an increase of 38.4 percent from 1980 to 1990. Wake County's total population is 440,000. Approximately 93.9 square miles comprise Raleigh's city limits. (*RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994.)

1.2.3 Regional Climatology

The Raleigh area is characterized by a humid, subtropical climate with mild winter and warm summer seasons. Typically July is the warmest month and January is the coldest month, with mean monthly temperatures of 77.7° F and 39.6° F, respectively. The annual mean humidity is 70 percent, with humidity values typically higher in the summer and fall months.

Average monthly precipitation varies by season. On average, the month with the greatest precipitation is August with an average 4.44 inches; the month with the least precipitation is October with an average 2.73 inches. The normal

mean annual precipitation is 41.76 inches, and the 10-year, 24-hour storm event for this area produces approximately 5.50 inches of rainfall.

The predominant wind direction is from the Southwest, at an average velocity of 7.7 mph. The wind data was collected at Raleigh-Durham Airport. (*RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994.)

1.2.4 Regional Hydrology and Surface Water Usage

Several surface water features are located in the region. These features include streams, ponds, storm water detention basins, lakes, and rivers. The City of Raleigh relies on surface water for the public potable water supply. Falls Lake Reservoir, located approximately 16 miles North of the site, is the source for the public water supply. The Crabtree Creek, a perennial stream, is located approximately 0.5 miles South and down-gradient of the site. (*RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994)

1.2.5 Regional Geology and Hydrogeology

Wake County is located within the Northeastern portion of the Piedmont physiographic province of North Carolina. The regional terrain is generally rolling, with elevations (within the county) ranging between 200 and 500 feet above Mean Sea Level (M.S.L). The topography is dissected by dendritic streams which allow for relatively good drainage.

The Piedmont physiographic province is comprised of several somewhat parallel metamorphic "belts". The metamorphic belts are areas of regionally metamorphosed rocks which have been delineated and characterized based on their metamorphic grade. Wake County resides within a high grade metamorphic zone known as the Raleigh Metamorphic Belt, or the Raleigh Terrane. The region is bounded on the West by rocks of the Carolina Slate Belt, and on the East by rocks of the Eastern Slate Belt. The Raleigh Terrane is

comprised primarily of medium to high grade, felsic gneiss and mica schists. Local granitoid intrusions are also common in the region (Stoddard, et.al. in Wright and Zullo, 1991).

The Piedmont is characterized by a soil veneer derived from weathered bedrock, or saprolite, which overlies competent bedrock. The thickness of the saprolitic soil varies considerably between locations, but is generally thicker in areas where topographic slope is low, and infiltration from precipitation is abundant. Competent bedrock occurs at varying depths below the saprolite, and is typically fractured by jointing and/or faulting. Joints are most abundant at shallow depths where overburden pressures are minimal, whereas faults commonly extend to considerable depths.

The primary mode of ground water storage within the saprolite is between the intergranular pore spaces, while storage within the bedrock occurs largely within the fracture system. Ground water recharge to the saprolite and bedrock is generally accomplished by infiltration from precipitation, with surplus conditions beginning in the autumn and continuing through winter. Discharge of stored water occurs primarily as baseflow into surface water bodies. Movement of stored ground water varies considerably with rock type and the degree of weathering. Common hydraulic conductivity values for saprolite range from less than one (1) to several feet per day; values for fractured rock vary greatly.

1.2.6 Ground Water Usage

Properties surrounding the ALCATEL facility are provided water via public water supply. There are no known active supply wells in the vicinity of the ALCATEL facility. Conversations with representatives of the Wake County Health Department indicate no permits have been issued for the installation of

water supply wells in the area surrounding the ALCATEL facility for at least the past nine years.

A review of North Carolina Groundwater Classification and Standards (15A NCAC 2L) indicates that, except on a case by case basis, all ground water in the state is classified as either GA or GSA, both of which are suitable for sources of potable water supplies. Water classification is based initially on the concentration of naturally occurring chloride. It is assumed that ground water in the region is largely GA. (*RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994.)

1.3 Local Environmental Setting

1.3.1 Topography and Hydrology

The area immediately surrounding the ALCATEL facility is characterized by moderate to steep slopes. To the North, East, and South of the facility, the natural grade slopes moderately toward the South and Southwest. To the West of the facility, the natural grade steepens and slopes toward the East. The topography of the site and surrounding properties has been extensively modified by construction and landscape activities.

An unnamed gaining perennial stream traverses the western portion of the facility. The stream apparently begins approximately 4,000 feet upgradient of the facility and discharges approximately 2,500 feet down gradient into Crabtree Creek. The baseflow of the unnamed stream is likely attributed to shallow ground water discharge. Discharge from storm sewers and runoff from parking areas, as well as natural overland flow during precipitation events, also contribute to the flow. The direction of water flow in the unnamed stream is towards the South. At its confluence with Crabtree Creek, the streamflow changes to the Southeast.
(*RCRA Facility Investigation for AOC #1 and #2 Work Plan.*)

1.3.2 Geology and Hydrogeology

The overall system effectiveness is controlled by site specific subsurface conditions. The site specific geology was more clearly understood following installation of the ten recovery wells, twelve containment recovery wells and eight injection wells. In addition, the recently completed horizontal and vertical investigation included the installation of five additional monitoring wells. The Well Completion Form (GW-1) for each well, well construction details for the previously installed monitoring wells, and selected boring logs are included in **Appendix B**.

Two hydrolithic zones, characterized by distinctly different hydraulic parameters, have been identified at the site and are coincident with the unconsolidated and bedrock geology. It is important to note that although each zone is well defined, no substantial difference in ground water elevations exists between the Type II and Type III wells. Consequently, the ground water system is considered a single aquifer.

The unconsolidated zone consists of saprolite and Quaternary alluvium. The saprolite represents a residuum of a granitic protolith with thicknesses varying from 3.5 to greater than 20 feet. The top of the unconsolidated unit consists of a highly weathered saprolite typified by tan to brown, micaceous, silty clay to clayey sand and silty fine sand (CL to SC/SM). The particle sizes increase with depth and proximity to the weathered bedrock surface. The weathered saprolite/weathered bedrock interface is defined by a change in color from light brown to gray and a dramatic increase in gravel sized particles (SM/GM and SC/GC) with the occurrence of gravel and cobble sized fragments. The partially weathered bedrock exhibits structural texture and foliation similar to that of the parent material but not as apparent.

The Quaternary alluvial deposits typified by poorly sorted sediments ranging in particle sizes from clay to cobble (CL to GW) and varying in thickness from 20 to 45 feet. A gravel deposit consisting of gravel and cobble sized particles with little or no fines (GP to GW) and approximately four feet in thickness was recently mapped South of Six Forks Road. This unit is underlying the finer grained alluvium and was encountered at approximately 23 feet below ground service (bgs). These larger, rounded particles are comprised of igneous and metamorphic mineral assemblages typical of the local country rock. The origin of the Alluvium can be attributed to the Crabtree Creek flood plain.

The bedrock hydrolithic zone consists of the Precambrian-age Raleigh Gneiss intruded by a more recent felsic to mafic, pegmatoidal granite. The Raleigh Gneiss is a strongly foliated, highly fractured, biotite/hornblend gneiss. Due to the general lack of bedrock outcrops at the study area, the fracture trace information was obtained from a researcher familiar with the local geology. Extensive geological mapping in the Raleigh West USGS Quadrangle resulted in the identification of a primary lineation set in the area. Mr. D.E. Blake, Ph.D. of the University of North Carolina at Wilmington, under a grant from the North Carolina Geological Survey has classified this lineation as a primary foliation set that is oriented N 20° E and dipping near vertical.

The granite, based upon field observations, is felsic to mafic and pegmatoidal. This unit is less fractured than the gneiss and structural texture is not apparent. The gneiss-granite contact occurs near the recovery well array and is oriented in approximately the same direction as the gneiss foliation. The granite occurs on the Eastern side of the site and the gneiss occurs on the Western side of the site. (*RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994.)

2.0 INVESTIGATION OBJECTIVES

The purpose of this document is to report the findings of the Phase II RFI work. The work was required by the Hazardous Waste Section (letter dated February 13, 1998). The work was conducted following the *Phase II RCRA Facility Investigation Work Plan*, dated October 1997. Approval of the work plan was provided in correspondence dated February 13, 1998.

The work plan described the activities necessary to identify and implement additional assessment tasks not performed during previous investigative activities and to complete the assessment of impacted soil and ground water. The site specific objectives of the work plan included the following:

1. Determine the presence or absence of a continued VOC source area and the extent of contaminated soil beneath the former solvent storage and former circuit board manufacturing areas (AOC #1 and AOC #2) in the vicinity of MW-13s and soil borings #2 and #9 (see *RCRA Facility Investigation for AOC #1 and #2, February 1996, Appendix D)*;

2. Determine the vertical extent of the contamination through implementation of an aquifer test in the vicinity of MW-4d and MW-4s;

3. Determine the horizontal extent of the contaminated ground water through installation of additional monitoring wells in locations down-gradient and East of the plume. Incorporate existing monitoring wells at off-site facilities located West and South of ALCATEL into the existing well network; and

4. Determine the background concentration of metals in the soil.

Although not specified in the work plan, additional investigation work was also conducted following verbal approval by the Hazardous Waste Section. This work is reported in this document and included the following activities: 1) Determine the presence or absence of contaminants in the ground water located up-gradient of the suspected source area, and 2) Investigate the water quality parameters and evaluate the site's propensity for natural degradation of chlorinated compounds.

3.0 INVESTIGATION RESULTS

The work, outlined in the investigation objectives, was conducted during the period of August 1997, through August 1998. Monitoring wells MW-4dd, MW-13d, and MW-14d were installed between August 18 and August 23, 1997. These wells were developed on August 24 and 25, 1997. Following completion of right-of-access agreements, the on-site and off-site (Pepsi) Geoprobe investigations were conducted on April 6 and 7, 1998. Additional Geoprobe investigations were conducted at the Pepsi facility on May 5, 1998. The Hazardous Waste Section agreed with the locations of the off-site monitoring wells.

On June 29, 1998, a Type II monitoring well, MW-15s, was installed on the Pepsi facility. This well was developed on June 30, 1998. The accompanying Type III monitoring well, MW-15d, was constructed on July 13 and 14, 1998. The natural attenuation evaluation was performed on selected wells on August 13 and 14, 1998.

The boring and Geoprobe logs and Well Construction Forms are attached in **Appendix B**. The sample methodologies are presented in **Appendix C**. The laboratory reports are included in **Appendix D.**

3.1 Assessment of VOC Source

The VOC source area has been previously investigated *(RCRA Facility Investigation for AOC #1 and #2, February 1996, Appendix D, "Previous Reports")*. The investigation included the advancement of soil borings and the collection of soil samples within the vicinity of the suspected source area. These borings are identified by the prefixes SB, SBR, and GW (**Figure 3**).

The investigation of the source area was continued for this work. Two Type III monitoring wells, MW-13d and MW-14d, were installed. In addition, a Geoprobe boring, GP-2, was also advanced. The locations of the soil borings were limited by

the adjacent buildings and underground utilities (main water line and numerous power lines). A main power transformer is located within a few feet of the area of interest. Soil samples were field screened and samples were collected for laboratory analysis. The unconsolidated fill and saprolite overlies bedrock and ranges in thickness from 10 to 15 feet.

The locations of the these soil borings as well as the historical boring locations are depicted in **Figure 3**. A summary of the field screening and laboratory results are presented in **Table 1**.

Geoprobe (GP-2)

Evidence of the reported TCA release is documented through laboratory analyses of soil samples from historical borings SB-2 and SB-9. Contamination was identified between 2.5 and 6 feet bgs. The Geoprobe boring GP-2 (**Figure 3**), was located between SB-2 and SB-9. The laboratory analyses of samples collected at 13 to 15 feet bgs, at or near the bedrock surface, indicated that no VOCs were present.

MW-14d

Field screening data was collected during the construction of MW-14d (**Figure 3**). The results indicated low readings from five foot intervals to a depth of 15 feet bgs. However, no observable evidence of contamination was noted. Bedrock was encountered at 15 feet bgs. MW-14d is located between historical borings SB-1 and SB-2.

MW-13d

MW-13d (**Figure 3**) was constructed within the vicinity of what is suspected as the source area and along the primary fracture orientation. Specialized "indoor" drilling equipment, SIMCOE, was used to advance the borehole. The SIMCOE drill rig was capable of roller cone drilling and coring. Soil samples were collected from the saprolite. The results of the field screening at 10 feet and 25 to 27 feet bgs did not indicate the presence of VOCs. The samples were not submitted for laboratory analysis because the roller bit did not allow a completely discrete soil sample.

The borehole was advanced beyond 27 feet bgs using the equipment's coring capability and drillers mud. A significant fracture zone was encountered at 32 feet bgs. Although the boring was advanced to 35 feet bgs, the fractures and loss of drillers mud prohibited further drilling.

Both Type III monitoring wells MW-13d and MW-14d were constructed to intercept the source area and establish the presence or absence of Dense Phase Non-aqueous liquids.

Soil samples were collected at two intervals, four to five feet bgs and nine to ten feet bgs, during the construction of MW-13s in May 1995. The laboratory analysis indicated that no VOC contaminants were present above quantitation limits.

Evidence of a release that extended vertically to the bedrock surface was not encountered during all soil borings and monitoring well construction. Three borings were located within Area of Concern #3; MW-14d, GP-2, and SB-1. Soil screening and laboratory analysis results did not indicate the presence of contamination to extend to the bedrock surface.

However, approximately 92 tons of soil had been excavated from within Area of Concern #3. Although the details of this activity were not well documented, reported laboratory results from the excavation indicated the presence of VOCs.

3.2 Assessment of Background Ground Water

Three Geoprobe borings were advanced to ground water in locations up-gradient of the suspected source area during the Geoprobe actitivies in April 1998. The purpose of this activity was to identify the presence or absence of background VOCs. The locations of these borings, GP-3, GP-4, and GP-5, are shown in **Figure 4**.

Ground water was encountered between 10.9 and 12.0 feet bgs. Probe refusal occurred between 10.5 and 15.5 feet bgs. Ground water samples were collected from GP-3 and P-5. The results indicated that no target VOCs were detected above quantitation limits. However, Methyl-tert-butyl ether (MTBE), Naphthalene, and Toluene wereencountered in the most up-gradient boring, GP-5. The concentrations were below NCAC 2L standards.

ALCATEL concluded that following this assessment no further up-gradient ground water investigations for target VOCs should be conducted.

3.3 Assessment of Background Copper and Lead

Historically, soil samples have been collected to provide data regarding the concentrations of Copper and Lead in background locations *(RCRA Facility Investigation for AOC #1 and #2, February 1996).*

In an effort to determine the background Copper and Lead concentrations discrete Geoprobe boring or sampling points were collected from up-gradient positions of AOC#1 and AOC#2. The sampling was conducted on April 6, and August 8, 1998. The sample locations, GP-1, BK-1, BK-2, and BK-3 are shown in **Figure 4**.

The sample at GP-1 was collected at 15 to 17 feet bgs. Two samples were collected at each background location. The samples are identified by the suffix' a' or "b" to identify the sample depth, four and eight feet bgs, respectively. The results of the laboratory analyses as well as all of the historical laboratory results, are summarized in **Table 2.**

To complete the assessment of the metals issue (Copper and Lead) a statistical analysis was performed.

3.3.1 Statistical Analysis

A statistical analysis was performed with the results of the background and source area copper and lead soil concentrations. The purpose of the analysis was to determine the significance of the metals concentrations within the source area.

3.3.1.1 Background

Most statistical tests assume that the subject data sets are derived from a normal distribution. Normally distributed data can be mathematically described as a bell-shaped curve. Statistical tests of normally distributed data can include analysis of variance (ANOVA), t-tests, tolerance intervals, or prediction intervals. If the data cannot be normally predicted, then other methods of statistical analysis, such as the nonparametric ANOVA, should be conducted. Consequently, the first logical step is to establish the normality of the data sets.

Several methods can be used to determine the normality of any data sets. These include the Coefficient-of-Variation test (CV), Probability plots, the Chi-squared test, Coefficient of Skewness, and the Shapiro-Francia test. The Coefficient of Skewness test is the measure of the degree of

asymmetry with respect to the sample mean. The coefficient is the cubed residual divided by the cubed standard deviation. The assumption of normality is accepted in the coefficient value is less than one.

The Shapiro-Wilk Test of Normality determines a test statistic and compares the calculated value to a critical tabulated value as provided in Table A-3 of the USEPA guidance documents. If the test statistic is greater than the critical value then the assumption of normality should be accepted.

Another data set characteristic, used to determine the distributional nature of the data in order to establish the proper statistical analysis, is the homogeneity of variance. Variance is a measure of the dispersion of the values in a data set. A test for the equality of variances indicates the degree to which well variances differ from each other. Methods for determining equal variances include Box plots, Levene's test, or Bartlett's test. The test is conducted by determining the F statistic of a one-way ANOVA on the data residual means. The assumption of equal variances is accepted if the calculated F statistic is less that the tabulated F statistic. Levene's Test is more powerful than other tests of variance because it is not sensitive to non-normal data sets.

The appropriate statistical analysis can be selected following the determination of the distribution characteristics and equality of variance.

The ANOVA procedures compare the sample means of different data sets to determine whether there are any significant differences among groups. The parametric ANOVA technique may is used when both of the following conditions occur: 1) the data is normally distributed, and

2) the data set variances are approximately equal. The non-parametric ANOVA method is applied when the data cannot meet the two parametric conditions.

3.3.1.2 Data Selection

The source area Copper and Lead soil samples were collected between September 1993, to April 1998. Background samples were collected in the upper parking lot in April and August 1998. The samples were collected in an area that Triangle is not aware of ever having served any manufacturing purpose. The Copper data consisted of twenty-two source area points and seven background points. The Lead data set incorporated twenty-seven source area points and seven background points (**Table 2**).

3.3.1.3 Distributional Characteristics

The normality tests employed here included the Coefficient of Skewness and theShapiro-Wilk methods. The normality of Copper and Lead was analyzed using these procedures.

<u>Normality Test Results</u>

The Coefficient of Skewness test determines to what degree a data set is skewed or asymmetric with respect to the mean. The assumption was made that all data for Copper and Lead is rejected by the Coefficient of Skewness test; the skewness coefficient for Copper was 2.12 and for Lead was 1.96. The Shapiro-Wilk method is applied to further clarify the distributional characteristics.

The assumption that all data for Copper and Lead are normal is rejected by this test. The test statistic (W) for Copper, 0.624, was less than the

tabulated statistic for normality, 0.96, and the test statistic for Lead, 0.707, was also less that the tabulated statistic, 0.933.

The following interim conclusion based upon the results of both the Coefficient of Skewness and Shapiro-Wilk tests, can be established;

a) The occurrence of both Copper and Lead are not normally distributed.

3.3.1.4 Homogeneity of Variance

Equality of variance is the second criteria that must be met to perform the parametric ANOVA analysis. The test for equality of variances was performed using Levene's Test for Homogeneity of Variance.

Because of high occurrence of non-detects of Lead in the source area data set, 62 percent the guidance documents recommend the analysis using the non-parametric ANOVA rather than the parametric ANOVA. Consequently, the homogeneity of variance was only conducted on the Copper data set.

<u>Variance Test Results</u>

The test statistic (F) was calculated as 7.64 and the tabulated statistic is 4.21. As a result, the test results indicate that the assumption of equal variances can be rejected for the Copper data set.

3.3.1.5 Selection of the Appropriate Statistical Method

The assumption that the occurrence of Copper and Lead is normally distributed can be rejected based upon the Coefficient of Skewness and the Shapiro-Wilk test. Levene's test indicated that the assumption of

equal variances for Copper was rejected. *Because of the high occurrence of non-detects in the Lead data set and because normality and equal variance conditions do simultaneously exist within the Copper data set, the parametric ANOVA analysis cannot be applied to Copper or Lead.*

Consequently, the non-parametric ANOVA was selected because the data set for each target compound exhibits either non-normal distribution or inequality of variance. The Kruskal-Wallis test, a non-parametric ANOVA method, uses the ranks of the observations and treats all nondetects as tied values. However, the Kruskal-Wallis test is not amenable to two-group comparisons (background to source area) and was not selected. The Wilcoxon-Rank Sum maybe employed when a non-parametric analysis is required, the non-detects are greater than 15 percent two or more groups are studied, and each group contains at least four samples.

Wilcoxon-Rank Sum

The rational for this test is that if the ranks of the source area data are large relative to the background ranks then the hypothesis that the compliance and background values came from the same population should be rejected. A Z score is calculated based upon the test statistic (W). The Z score is compared to the Z score under a normal distribution. If the Z data set score is greater than the tabulated Z score, then the hypothesis is rejected: indicating that there is significant evidence of contamination in the source area data set.

The Z scores for Copper and Lead were -0.23 and -2.3, respectively. The tabulated Z scores at the upper 1 percent of the normal distribution was 2.326. Consequently, the hypothesis was accepted; there is no

significant evidence of contamination. The results of the Statistical Analysis are presented in **Table 3** and the calculations are provided in **Appendix E.**

3.4 Vertical Extent of Contamination

The vertical extent of the contamination was assessed through the installation, packer testing and sampling of the deep bedrock, MW-4dd, and the review of historical bedrock investigations and literature.

3.4.1 Bedrock Investigations

The deep bedrock investigations included the installation and packer testing of MW-4dd, and the reevaluation of two previous bedrock investigations at MW-4d and MW-2dk.

<u>MW-4dd</u>

The well drilling commenced on August 18, 1997. Mud rotary equipment was used to advance a 10-inch boring to 27 feet bgs and within at least two feet of competent bedrock. The bore hole was vertically extended on August 19, 1997, using an 8-inch drill bit. The bedrock consisted of alternating fine grained mafic gneiss and felsic and pegmatoidal granite. No significant fractures were encountered beyond 53 feet bgs. Upon concurrence with the Hazardous Waste Section, this portion of the boring was terminated at 85 feet bgs.

A packer test was conducted to isolate the higher yielding water bearing zones (greater than 5 gpm) and establish the approximate concentrations of VOCs through field screening techniques and laboratory analyses of collected water samples. The packer test utilized the double-packer configuration to completely isolate the interval above 55 feet bgs. Unfortunately, the tested interval did not produce a sufficient yield to collect a sample.

On August 21, 1997, the drilling activities were continued using the four inch drill bit. At the interval of 97 to 102 feet bgs a fracture was encountered that produced approximately are (1) gpm. The bedrock in this fracture zone was characterized by the alternating gneiss and granite and indicative of the contact zone. A sample was collected from blown water at 102 feet bgs. The sample was field screened using the portable Gas Chromatograph. The results indicated the presence of DCA and TCA **(Appendix C)**.

Following discussions of alternatives and final guidance from the Hazardous Waste Section, the following protocol was followed: the boring would be continued to a maximum of 150 feet bgs if no other fractures were encountered. However, if another fracture is encountered another packer test would be conducted. The borehole was then advanced to a depth of 142 bgs. The bedrock consisted of mafic gneiss from the interval of 102 to 142 feet bgs. No fractures were encountered. Consequently, and following guidance from the Hazardous Waste Section, the monitoring well was completed and screened from 142 to 132 feet bgs.

<u>Bedrock Core at MW-4d</u>

In addition to the installation of MW-4dd, other activities have been conducted to determine the nature of the bedrock aquifer. These activities have included a bedrock core collected during the construction of MW-4d and a telescoping boring, MW-2dk, located on the former Keebler property. *(RCRA Facility Investigation for AOC #1 and #2, February 1996.)*

A bedrock core was collected during the construction of MW-4d in November 1994. The core, a 37.5 bedrock interval collected from 30 to 67.5 feet bgs, revealed the nature of the upper portion of the competent bedrock. The bedrock at this interval consisted of alternating mafic gneiss and felsic granite. The

contact is steeply dipping to near vertical as described by the orientation of the gneissic foliation. Fractures were present at the contacts of the granite and gneiss and also within each respective formation. The fractures were also near vertical to steeply dipping. The fractures in the weathered bedrock were more pronounced while the fractures in the competent bedrock were "paper" thin.

MW-2dk

In October of 1994, Aquaterra attempted to install a telescoping Type III well, MW-2dk, on the Keebler property. The boring construction log revealed the following profile; unconsolidated sediments consisting of micaceous fine to coarse sand (SM) were encountered to a depth of 21 feet bgs, slightly weathered and highly fractured gneiss from 21 to 28.5 feet bgs, and competent bedrock (gneiss) from 28.5 feet bgs to 150 feet bgs. The log described few fractures near the surface of the bedrock and no fractures in competent rock. The boring grouted at 80 feet bgs for the construction of this well. However, drilling tools became lodged in the borehole and the boring was abandoned. The log indicated that no ground water was encountered between 80 and 150 feet bgs.

Previous investigations, including these three deep bedrock investigations have revealed a contact between the Precambrian-aged Raleigh Gneiss and the recent granite intrusion. Based upon the previous Type III monitoring well borings, this contact trends Northeast to Southwest. The bedrock surface is encountered at a range of depths from 20 to 55 feet below ground surface.

3.4.2 Fracture Zones

Based upon the slug and constant rate pumping tests, the sapprolite and weathered bedrock exhibited hydraulic conductivity and transmissivity within ranges provided in the literature. Primary and secondary porosity are key elements in the transmission of ground water in the unconsolidated zone.

Ground water flow in the competent bedrock, however, is likely controlled by the characteristics of the fracture system.

Two significant competent bedrock fracture zones have been identified, based upon their occurrence, in the vicinity of the site: 1) The zone associated with the gneiss-granite contact identified in MW-4d and MW-4dd and 2) A zone ranging from approximately 60 to 70 feet below ground surface and tentatively characterized by up to three distinct sub-zones. The sub-zones range in thickness of three to five feet. The occurrence of fractures from selected borings/wells are included in **Appendix F.**

3.4.3 Ground Water Elevation and Sampling

Samples collected from approximately 97 to 102 feet bgs during drilling indicated the presence of VOCs. Samples collected from MW-4dd in October 1997 and April 1998, also indicated the presence of VOCs, including PCE, DCE and TCE.

The occurrence of ground water at elevations substantially lower than other Type III and Type II wells (50 to 100 feet), and the presence of the targeted contaminants in MW-4dd, may indicate a downward gradient from the unconsolidated and shallow bedrock zone to the deep bedrock zone. Also, the Type III wells have historically exhibited ground water elevations of one to three feet less than elevations of their Type II sister wells.

3.5 Horizontal Extent of Contamination

The horizontal extent of the ground water contamination was established by the expansion of the site characterization through a Geoprobe investigation, the installation and sampling of additional monitoring wells, and the assimilation of existing off-site wells.

3.5.1 Geoprobe Investigation

The down-gradient extent of the VOC-contaminated ground water was investigated using the Geoprobe technology. The investigation was conducted immediately down-gradient of the historical configuration of the plume and in the approximated orientation of the unconsolidated and bedrock plume axis.

This investigation included nine (P-1 through P-9) Geoprobe borings (**Figure 4**). Borings P-1 through P-6 were advanced on April 4, 1998. Borings P-7 through P-9 were advanced on May 12, 1998. The soil was logged in three of the borings (P-1 through P-3) by advancing the Macro core soil sampler. The geology encountered consisted of Alluvium that ranged in classification from a silty to clayey micaceous sand (SM-SC) to clay (CL). Borings GP-4, GP-5, and GP-6 were advanced to refusal (24 to 27 feet bgs).

Ground water samples were collected from all of the nine borings. Dissolved oxygen was also measured at each sample location. These measurements and the laboratory results are summarized in **Table 4** and presented in **Appendix D.**

The four borings, P-3, P-4, P-8, and P-9, were positioned to intercept a possible down-gradient extension of the plume. Except for P-9, the laboratory results of ground water samples collected from those locations indicated that all VOCs were below the quantitation limits. Location P-9 indicated low concentrations of the target VOCs that were below the State standards.

However, the laboratory results from samples collected at P-1, P-2, P-5 and P-6, indicated the presence of chlorinated organic compounds or gasoline constituents. Releases from adjacent retail gasoline business are the likely sources of the gasoline constituents detected during this investigation.

However, the source of the chlorinated organic compounds has yet to be determined. Results from P-7 did not indicate the presence of VOCs.

3.5.2 Monitoring Well Installation

One Type II (MW-15s) and one Type III (MW-15d) ground water monitoring wells were installed on the Pepsi-Cola property. These wells were installed to define the expected terminal edge of the VOC plume. The locations were based on the laboratory results from Geoprobe borings P-3 and P-9.

MW-15s

Monitoring well MW-15s was installed to a depth of 23 feet bgs and at auger refusal. The geology consisted of fine grained Alluvium characterized by micaceous sand silt and clay.

MW-15d

Monitoring well MW-15d was installed as a telescoping, bedrock well to a depth of 77 feet bgs. A six inch borehole was cut using a mud rotary to a depth of 60 feet bgs. Following proper casing, the well was completed with air hammer techniques. The geology consisted of Alluvium underlain by bedrock at a depth of 55 feet bgs.

Both MW-15D and MW-15S were sampled on August 14, 1998, and analyzed by Method 6230D. The laboratory results indicated that no method constituents were detected in MW-15S. However, the following constituents and their respective concentrations (ppb) were detected in MW-15d; DCA (1.76), DCE (73.2), PCE (17), TCA (3.04), and TCE (12.1).

3.5.3 Off-Site Facilities

A better understanding of the hydraulic characteristics of the aquifer was gained through the assimilation of existing off-site monitoring wells. Off-site monitoring wells were identified at facilities that had previously conducted site investigations. All of these off-site facility investigations appear to have been conducted with respect to storage tank releases or suspected releases. Facilities that were incorporated in the data set included those identified within a 0.25 mile radius of the site and cross-gradient or down-gradient facilities between the site and Crabtree Creek. Those facilities include the following:

Facility Name and Address	Incident # or Facility ID#	Classification
AMOCO Service Station #60092 411 E. Six Forks Rd.. Raleigh, NC	NCD986204287 12244	Small Quantity Generator Leaking Underground Storage Tank (Waste Oil/Gasoline)
BP (Han-Dee Hugo #45) 2837 Wake Forest Road Raleigh, NC	14094	Leaking Underground Storage Tank (#2 Heating Oil/Gasoline)
Pepsi-Cola Bottling of Raleigh 2838 Wake Forest Rd. Raleigh, NC	13534	Leaking Underground Storage Tank (Gasoline/Diesel&chlorinatedsolvents)
Sears Roebuck and Co. 819 E. Six Forks Road Raleigh, NC		Underground Storage Tank
K-Mart (former) 8701 Six Forks Road Raleigh, NC		Underground Storage Tank (Waste Oil)
Al Smith Auto Dealership 2511 Wake Forest Road Raleigh, NC		Leaking Underground Storage Tank (Petroleum)

The AMOCO Service Station maintains eight monitoring wells and four storage tank observation wells (B&M, 1997). All of the wells intercept the water table. Historically, no chlorinated organic compounds have been detected at this site.

The BP facility maintains nine monitoring wells which intercept the first water bearing zone. Historically, no target chlorinated organic compounds have been detected at this site.

The Pepsi-Cola facility maintains ten monitoring wells and one recovery well. All of the wells intercept the first water bearing zone. The targeted chlorinated organic compounds, TCA, PCE, DCE, and DCA have been detected at low concentrations in MW-4. This well is located immediately adjacent to an underground oil/water separator.

Information regarding the purpose of the monitoring wells at the Sears and Roebuck, Al Smith Auto dealership, and the former K-Mart facility is not readily available. However, monitoring well construction details were provided through the construction tags placed within the well covers.

3.5.4 Survey

The survey activities included a land survey and collection of water level and well construction data. The land survey included the determination of the horizontal and vertical elevations of the top of casing of each well relative to the ALCATEL datum point. These activities were conducted on July 23, 1998.

The survey included the following recently installed ALCATEL (on and off-site) wells and the existing off-site wells:

MW-A9d	Amoco Service Station (MW-9d);
MW-BP6	Han-Dee Hugos Service Station (MW-6)
MW-K1	K-mart (former)
MW-AS1	Al Smith Automobile Dealership
MW-AS2	Al Smith Automobile Dealership

MW-AS3	Al Smith Automobile Dealership
MW-S1	Sears Roebuck and Co
MW-4dd	ALCATEL
MW-13s	ALCATEL
MW-14d	ALCATEL
MW-15s	Pepsi
MW-15d	Pepsi

Monitoring wells from each off-site facility were surveyed and incorporated into the existing network of system and monitoring wells. The data collected from these wells was used to provide a local and more precise ground water potentiometric surface of the site area.

3.6 Natural Attenuation Evaluation

Recent efforts by the US EPA have been undertaken to evaluate the applicability of natural attenuation of sites impacted by chlorinated solvents. The work conducted in this investigation was performed to meet those expectations as outlined in the USEPA directive, *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*, November, 1997. This directive defines natural attenuation and establishes it as a viable remedial option under favorable site-specific conditions.

This evaluation was conducted in accordance with the US EPA document, *Draft EPA Region 4 Suggested Practices for Evaluation of a Site For Natural Attenuation (Biological Degradation) of Chlorinated Solvents*, November, 1997. This document outlines the site specific natural attenuation parameters that are necessary to evaluate a site and a method to quantify those results.

A brief overview of the natural attenuation processes of chlorinated organic compounds is provided followed by the results of the site evaluation.

3.6.1 Background

Natural attenuation is defined by the US EPA Office's of Research and Development and Solid Waste and Emergency Response as "The biodegradation, dispersion, dilution, sorption, volatilization, and/or chemical and biochemical stabilization of contaminants to effectively reduce contaminant toxicity, mobility, or volume to levels that are protective of human health and the ecosystem." Contaminant fate and transport is on-going through ground water processes including advection, dilution and dispersion, and has been demonstrated through modeling efforts. However, the biodegradation of site contaminants must be demonstrated to occur at rates sufficient to be protective of human health and the environment. Evidence to support biological degradation of chlorinated aliphatic compounds include:

1) Observed reduction in contaminant concentrations along the flow path down-gradient from the source contamination. Reduction will occur through advection, dilution, and dispersion as well as biodegradation.

2) Documented loss of contaminant mass at the field scale. This can be established through decreasing parent compound or increasing daughter compound concentrations, depletion of electron donors or acceptors, and increased metabolic byproduct compounds.

3) Microbiological laboratory or field data that support the occurrence of biodegradation and provide rates of biodegradation.

According to the USEPA directive, the proponent should demonstrate the first two, or the first and third, lines of evidence. A basic understanding of the fate of the target compounds provided a basis for the evaluation techniques.

3.6.2 Transformation of the Target Compounds

Confirmation of a historic release of TCA has been documented (RFI, 1996). Although no evidence of the historical use of PCE in the site's manufacturing process has been confirmed, evidence of a release of PCE is provided through the laboratory results and previous assessment work. Consequently, it is assumed for the purpose of this report that two parent compounds, TCA and PCE, exist in the subsurface.

The transformation of these compounds occurs abiotically, through physical/chemical reactions including hydrolysis and dehydrohalogenation, and biotically through biochemical processes, primarily reductive dehalogenation. Reductive dehalogenation is the most prevalent process governing biotransformation of chlorinated solvents and generally preceded by sequential dechlorination; PCE to TCE to DCE to Vinyl Chloride to ethane. Unlike aerobic processes, the chlorinated compound serves as the electron acceptor; a hydrogen replaces a chlorine atom. Consequently, a carbon source must also be present to serve as the energy source.

The hydrolysis reaction is the replacement of a chlorine atom by an hydroxyl molecule. Dehydrohalogenation involves the elimination of an HCL from an alkane to form and alkene; TCA to DCE.

During these processes, the parent compounds are transformed to daughter compounds and by-products. The presence of these compounds and by-products are important elements in the documentation of line of evidence #2.

3.6.2.1 Daughter Products

Biodegradation of TCA and PCE will occur under anaerobic conditions primarily through the process of reductive dehalogenation. Abiotic processes will also degrade these compounds through hydrolysis and dehydrohalogenation.

Degradation of TCA has been shown to occur through abiotic and biotic processes. In addition, it is reportedly the only major chlorinated solvent that can be readily transformed through abiotic processes (USEPA, 1997). The transformations are simplified and summarized in **Table 5**. The primary abiotic degradation products of TCA are DCE and acetic acid. Biologic degradation products of TCA include trans-1,2-DCE; DCA; vinyl chloride; ethane; and chloroethane.

Degradation of PCE has been shown to primarily occur through biotic processes under reducing conditions. The transformation products of PCE include TCE; cis-1,2-DCE; trans-1,2-DCE; 1,2-DCA; ethane; vinyl chloride; ethane; and chloroethane. The primary biodegradation product of PCE is TCE and, the significant biodegradation product of TCE is cis-1,2-DCE.

The simplified end products of the degradation of TCA and PCE are vinyl chloride, ethane, ethane, and chloroethane.

Daughter products of TCA that have been historically observed at the site include DCE and DCA. Daughter products of PCE have included TCE and 1,2-DCA.

3.6.2.2 Indicators of Biodegradation

Water quality parameters that are indicative of the favorable biochemical degradation of chlorinated aliphatic compounds as well as the by-products of these microbial processes can be measured. Because degradation is likely to occur under anaerobic conditions, those parameters and by-products that reflect those conditions are of importance.

Oxygen serves as an terminal electron acceptor in the microbial assimilation of a carbon-based substrate. Following depletion of oxygen, the Nitrate, Ferric Iron, Sulfate, and Carbon Dioxide, in that order, will serve as electron acceptors. The reduction-oxidation potential (eH) decreases as each of these acceptors is depleted. Optimum dehalogenation of chlorinated compounds occurs in the Sulfate reducing to Methanogenesis range (eH of <-100). The optimum temperature is $>20°$ C and the pH should range between 5 and 9. The target water quality parameters include dissolved Oxygen, Nitrate, Sulfate, Ferrous Iron, Methane eH, pH, Temperature, CO_2, Alkalinity, and Hydrogen.

By-products from these processes should also be evaluated and measured. Under favorable conditions Sulfate is reduced to Sulfide, Ferric Iron is reduced to Ferrous Iron, and/or methane is produced.

3.6.3 Natural Attenuation Screening and Evaluation

On August 13 and 14, 1998 a natural attenuation field screening assessment was conducted by Triangle. The assessment was performed to establish the likelihood of biological degradation of the parent compounds. The work was conducted in accordance with the USEPA guidance and directive (USEPA, 1997). A total of eleven monitoring wells were selected for this study including both Type II and Type III wells at upgradient, source area, down-gradient, and side-gradient locations. For the purpose of this evaluation, MW-14d and MW-13s were selected as the source area wells. The background wells, MW-10s and MW-7d, were identified based upon their absence of any targeted VOCs. MW-12s was selected as a side-gradient well. Several down-gradient monitoring wells were selected at increasing distances from the source areas. These include MW-4s, MW-4d, MW-9sk, MW-9dk, MW-15s and MW-15d. In addition, a Geoprobe boring, L-1, was advanced near the Crabtree Creek.

3.6.3.1 Investigation

The investigation included the field measurements of Dissolved Oxygen (D.O.), Temperature, pH, and Reduction-Oxidation potential (eH). Samples were collected for laboratory analysis for Chloride, Nitrate, Sulfate, Ferrous Iron, and Methane. In addition, laboratory analysis from the Geoprobe location L-1 **(Figure 5)**, and the recently installed down-gradient monitoring wells, MW-15s and MW-15d, included detection for VOCs.

All instruments were calibrated prior to use. Dissolved Oxygen was measured prior to well purging and down-hole within the screened interval using a YSI model 51B D.O. meter. Following well purging, temperature, pH and eH were measured using a flow-through bottle. The water was pumped from the well using a double-diaphragm

pneumatic pump. Temperature was recorded using the temperature function on the D.O. meter. Both pH and eH were measured with a Hanna model 948 Redox meter. Contact with the atmosphere was limited. A peristaltic pump was used to collect water from Geoprobe location L-1.

3.6.3.2 Results

A summary of the results of the investigation are provided in **Table 6** and the laboratory results are included in **Appendix D.** The VOC laboratory results of L-1 are provided in **Table 4.**

Background conditions are provided by the screening results from MW-7d and MW-10s. The field measurements provide general evidence of the presence of an aerobic environment, though D.O. levels of greater than 1 mg/l and Redox potential greater than 100. The laboratory results of samples collected from the background wells confirm the field measurements. Consequently, these two wells are assumed to represent the background aquifer conditions.

Dissolved Oxygen concentrations of less than 1 mg/l were observed in MW-13s and L-1. Accordingly, the lowest redox potential (<50 mv) and highest chloride concentrations were also measured from these two locations. The highest Methane concentrations (>0.1 mg/l) were observed in MW-9sk, MW-15s, and L-1.

The results were quantified in accordance with the USEPA ranking system and evaluation for the natural attenuation of chlorinated solvents (USEPA, 1997). The system is designed to estimate the likelihood of the occurrence of biodegradation of parent chlorinated compounds. A

rank is assigned to each field screening parameter, metabolic by-product, and daughter product. The rank is based upon the field and laboratory measurements and values. A copy of the ranking system is attached in **Appendix G.**

The two ranking source area monitoring wells, MW-13s and MW-14d, were selected for the evaluation. The results are presented in **Table 7.** The results of the L-1 sample and background wells are included for reference. A score of 9 was established for MW-13s and a score of 2 for MW-14d. According to the USEPA, a score of less than 5 is interpreted as inadequate evidence for biodegradation of chlorinated organics. A score in the range of 6 to 14 is interpreted as limited evidence for biodegradation of chlorinated organics.

The score for MW-14d is reasonable. Under normal conditions, the abiotic degradation of TCA would likely result in the daughter compound, DCE. If the aquifer environment is aerobic, as evidenced by the field and laboratory measurements, then the biotic degradation of TCA is not likely and its biodegradation daughter products (DCA) would not be present. Coincidentally, the only target compounds identified in MW-14d are TCA and DCE.

The environment for biological degradation is favorable for MW-13s as based upon the score and coupled with the well's location relative to the source area. The presence of DCE is likely the product of abiotic degradation of TCA. In addition, the presence of DCA may indicate the product of biotic degradation of TCA. PCE is also present in MW-13s. The historical presence of TCE may reflect the biotic degradation of

PCE, and, the historical presence of 1,2-DCA may indicate the degradation of TCE.

Because the specific location of the PCE release (source) has not been reported nor identified, the concentration relationships of parent to daughter products may not be accurately defined. Distributions of the parent and daughter products are presented in the following section.

3.6.3.3 Parent and Daughter Contaminant Distributions

The areal extent of the specific compounds, PCE, TCE, TCA, DCE, and DCA in the bedrock and unconsolidated aquifers are graphically presented in **Figure 6** through **Figure 10**, respectively. The plume configurations represent the April 1998, semi-annual event. MW-15d and MW-15s were sampled during the August 1998, natural attenuation evaluation.

Recently an increased PCE concentration in the bedrock aquifer was noted in MW-2d. However, the low concentration of PCE historically noted in MW-2s had precluded this area as a source. The confirmed release area of TCA is located near MW-14d.

The occurrences of PCE, TCE, TCA, DCE extend Southward and were detected a low concentrations in MW-15d. The target compound concentrations (ug/l) in MW-15d were; PCE (17), TCE (12), TCA (3), and DCE (73). It appears that MW-15d, although installed at that location based upon the absence of targeted contaminants (Geoprobe investigation), is within the contaminant plumes.

The DCE bedrock distribution is similar to the distribution described by TCA. TCA was used as a solvent and released in the source area. The presence of DCE at the site may be the result of the degradation of TCA because ALCATEL has no record of the use or release of DCE. In addition, the occurrence of DCA may also be the result of the degradation of TCA.

ALCATEL has no record of the release of TCE. The first down-gradient presence of TCE occurs in the bedrock plume at MW-4dd. However, TCE has historically occurred further up-gradient in MW-13s, MW-3s and MW-2d. The occurrence of TCE at the site may be the result of the degradation of PCE.

3.6.3.4 Degradation Rates

The determination of specific degradation rates can provide insight to the compound fate and transport. The EPA guidance proposes the comparison of the first order rate with a tracer decay rate. The first order decay rates include attenuation processes of abiotic and biotic transformations, dilution, sorption, and volatilization and can be determined using a one-dimensional, steady-state analytical advection-dispersion solution such as the Domenico's Equation. The tracer decay rate estimation was conducted using a conservative, recalcitrant compound associated with the target compound. Chloride can be used as a conservative tracer at chlorinated solvent sites. In this process, the end-point compound concentration is corrected with the ratio of initial to endpoint chloride concentrations. Following that correction, the first order decay according to the first order kinetic equation can be calculated. This method normalizes the decay rate such that the effects of dilution, sorption, and volatilization are excluded. The normalized

rate should reflect biotic and abiotic processes. A comparison of the Domenico and the tracer solutions should provide insight to the fate and transport.

Decay rates for PCE and TCA were determined for both the unconsolidated and bedrock aquifers. Pre-system data was evaluated. Bioscreen, Ver., 1.4 was used to calibrate the first order decay rate. Chloride was used as the conservative tracer decay rate. The results are summarized in **Table 8** and presented in **Appendix G**.

The unconsolidated tracer decay rates for PCE and DCE are approximately twice the overall decay rates. This may be the result of the apparent loss of contaminant that likely occurs through the vertical migration to the bedrock zone.

The overall and tracer bedrock rates of PCE and DCE are similar; 0.69 to 1.20/year. The PCE and DCE decay rates are similar to published first order decay rates (Olsen, 1990). However, the bedrock rates of TCA, 5.47 and 6.9/year, are substantially greater than those of PCE and DCE. The published abiotic half-life of TCA ranges from 6 to 9.6 months. The site half-life, however, is 1.2 and 2.4 months for the bedrock and unconsolidated, respectively. The occurrence of degradation processes other than hydrolysis or dehydrohalogenation may explain the observed short half-lives. Biotic processes would produce daughter products such as DCA or vinyl chloride. DCA is present at the site (**Figure 10**) and has historically been observed in both bedrock and unconsolidated wells.

It may be difficult to accurately measure the tracer decay rate for each specific contaminant because each compound may be contributing Chloride to the ground water system at different rates. In addition, some loss of Chloride and contaminant mass may occur through vertical migration.

3.6.3.5 Former Solid Waste Disposal Site

A former City of Raleigh municipal landfill is located between Six Forks Road and Crabtree Creek and Old Wake Forest and the CSX Railroad right-of-way (**Figure 5**). The landfill was identified through documentation from the City of Raleigh Solid Waste Section, Inventory of Solid Waste Disposal Sites (**Appendix H**). The landfill was identified on an areal photograph from the NC DOT Office in Raleigh. The landfill was physically observed during field activities at a storm drain outfall at the Southern most end of Industrial drive. The thickness of the landfill at this location was measured at 15 feet. The down-gradient investigation also included the advancement of two Geoprobe borings in this vicinity.

Strong methane odors were noted at approximately six feet bgs during the advancement of Geoprobe boring, L-1, located at the Southern end of Industrial Drive. A heavy sheen and strong methane odor was noted on ground water encountered at approximately 12 feet bgs. Unfortunately, the low yield did not furnish sufficient water to conduct the natural attenuation field screening nor to collect water samples for laboratory analysis. The boring was cautiously advanced at intervals of six feet. Despite soil sampling efforts the nature of the material prohibited solid recovery. Ground water was encountered at approximately 18 feet bgs. Samples were collected at this depth. The

laboratory results indicated the presence of two likely biodegradation end product compounds; cis-1,2-DCE and Vinyl Chloride. The results also indicated the presence of Chlorobenzene, MTBE, Toluene, 1,2,4-Trimethylbenzene, Vinyl Acetate, and Xylenes. The laboratory results are included in **Appendix D.** The field screening results, shown in **Table 6,** indicate conditions of an anaerobic environment and likely suitable for reductive dehalogenation.

Geoprobe boring L-2, located on Creekside Drive near the intersection of Wake Forest Road, was advanced to a depth of 16 feet bgs. Continuous soil sampling revealed Alluvium that consisted of a fine-grained, green to grey, micaceous silty sand (SM) to a depth of 12 feet bgs. A green to grey silty/sandy clay was encountered from 12 to 16 feet bgs. No evidence of solid waste activities was observed. Ground water was encountered at approximately 12 feet bgs. No samples were collected.

The absence of the landfill at location L-2 can be explained. It is likely that Creekside Drive was constructed above the former landfill service road (based upon the areal photograph). Consequently, the landfill may be discontinuous along the roadway.

The estimated areal extent of the landfill was produced from the evaluation of data collected during this RFI assessment, other investigations, and information furnished by the City of Raleigh. The approximate location of the landfill is illustrated in **Figure 5.**

3.7 Ground Water Potentiometric Surfaces

The depth to ground water was measured at the off-site monitoring wells during the survey. The ground water elevations were compiled and summarized in **Table 9.** The potentiometric surface maps are presented in **Figures 11** and **12** for the unconsolidated and bedrock aquifers, respectively. It can be observed that the recovery system provides hydraulic control at and near contaminant plumes and may have some effect on the local flow. However, it is anticipated that ground water is discharged to the Crabtree Creek.

In addition, it is observed that, under no decay, the contaminants would be transported down-gradient and intersect the former landfill. Additional natural attenuation modeling may predict the fate and transport of the contaminants.

4.0 CONCLUSIONS

The following conclusions are based upon the findings of the Phase II investigation. In addition, the conclusions reflect previous investigative work conducted at the subject property.

- Only one chlorinated organic compound., TCA, is known to have been released at the subject property. Evidence of release(s) of PCE exists although ALCATEL maintains niether documentation nor knowledge its use. In addition, ALCATEL maintains no record of the use nor release of other compounds detected including TCE, DCE, and DCA. The presence of these compounds is likely the result of the degradation of PCE and TCA.

- No evidence of an existing source area in the subsurface soil/saprolite was observed during the RFI investigation activities. The source(s) may have been excavated during initial remedial activities or are inaccessible. DNAPL was neither encountered during the bedrock investigation nor has been historically observed at the site.

- The target contaminants have migrated vertically and at depth within the bedrock. The fractured gneiss/granite contact likely served as the method of vertical migration. The occurrence of the fractures significantly diminishes at depth. The deepest well, MW-4dd terminates at 142 feet bgs. Target compounds have been identified in this well.

- The target contaminants have migrated horizontally and down-gradient within the bedrock and across Six Forks Road. The presence of the target contaminants in the bedrock has been confirmed through laboratory results of ground water collected at MW-15d. However, the absence of the target compounds in MW-15s indicate the terminus of the shallow contaminant plumes.

- The Geoprobe investigation conducted down-gradient of MW-15s and MW-15d revealed other contaminants including gasoline constituents and chlorinated compounds. Additional down-gradient monitoring wells would inevitably intersect these unrelated releases including the leachate from the former solid waste disposal site. Consequently, further investigation was not pursued.

- It is believed that the unconsolidated and bedrock aquifers discharge to the Crabtree Creek. Consequently, Crabtree Creek may be the terminal receptor for recalcitrant contaminants and associated metabolic by-products and daughter products released at up-gradient locations.

- Conditions for reductive dehalogenation of chlorinated solvents likely exist in the subsurface at the former solid waste disposal site. The conditions are characterized by low D.O., negative eH and the presence of vinyle chloride.

- The statistical analysis of variance of the comparison of the source area to background Copper and Lead soil concentrations indicated that there is *no* significant evidence of contamination in the source area.

- No chlorinated organic compounds were detected in ground water at borings located up-gradient of the source area. However, some gasoline constituents were detected at concentrations below State standards.

- Two lines of evidence for the occurrence of natural attenuation, in accordance with the USEPA guidance, are presented.

    1) The reduction of target contaminant concentrations along the flow path down-gradient from the source contamination is established.

2) Documented loss of contaminant mass at the field scale. This is established through decreasing parent compounds TCA and PCE; the depletion of oxygen and the low redox potential; and increased metabolic byproduct, chloride. In addition, the presence of daughter compounds have been documented. The presence of TCE as a daughter product is indicative of the biodegradation of PCE and the historical presence of 1,2-DCA is indicative of the biodegradation of TCE. The presence of 1,1-DCE is indicative of the abiotic degradation of TCA and the presence of DCA is indicative of the biotic degradation of TCA.

In addition to the two lines of evidence, the source area was ranked according to the USEPA guidance. The results indicated limited evidence of biodegradation of chlorinated organic compounds.

5.0 RECOMMENDATIONS

The following recommendations are based upon all investigative work completed to date.

- Further characterization of the vertical and horizontal extent of the contamination may not be necessary because the anticipated final receptor of the contaminant plumes is the Crabtree Creek. In addition, further characterization may not provide information that would assist in the selection of the best available technology for the remediation of chlorinated organic compounds in the bedrock aquifer. No human exposure pathway exists.

- ALCATEL should proceed with a Corrective Measures Study as outlined in the USEPA Directive 9902.3-2A, "RCRA Corrective Action Plan."

- The background Lead and Copper in ground water should be contrasted with that in the source area and the down gradient monitoring wells using statistical procedures. The purpose is to determine the necessity of the current permit requirements for Lead and Copper analyses at each and every well.

REFERENCES

Devore, Jay, 1991. Probability and Statistics for Engineering and the Sciences. Third Edition. Brooks/Cole Publishing Company.

ENSR Constructors, March 1990. Closure Letter Regarding Kmart #4075.

Fetter, C.W., 1988. Applied Hydrogeology. Second Edition. Merrill Publishing Company.

HANDEX of the Carolinas, Inc., May 1996. "Corrective Action Plan - Amoco Service Station #60092."

Howard, P.H., Boethling, R.S., Jarvis, W.F., Meylan, W.M., Michalenko, E.M. 1991. Environmental Degradation Rates. Lewis Publishers, Inc.

Hyndman, D.W. 1985. Petrology of Igneous and Metamorphic Rocks. Second Edition. McGraw-Hill, Inc.

National Environmental Technologies, Inc., October 1994. "RCRA Facility Investigation Work Plan for AOC#1 and #2." Wilmington, North Carolina.

National Environmental Technologies, Inc., February 1996. "RCRA Facility Investigation for AOC#1 and #2, Volumes 1 and 2." Wilmington, North Carolina.

National Environmental Technologies, Inc., February 1996. "Interim Corrective Measures Plan AOC#1 and AOC#2." Wilmington, North Carolina.

National Environmental Technologies, Inc., October 1997. "Interim Measures Progress Report." Wilmington, North Carolina.

National Environmental Technologies, Inc., October 1997. "Phase II RCRA Facility Investigation Work Plan." Wilmington, North Carolina.

National Environmental Technologies, Inc., August 1997. "Remediation System Construction Report." Wilmington, North Carolina.

North Carolina Department of Environment and Natural Resources, May, 1994. Hazardous Waste Management Permit No. NCD 003 185 238-R1., Raleigh, North Carolina.

North Carolina Department of Environment and Natural Resources, December, 1997. National Pollutant Discharge Elimination System Permit No. NC0086126, Raleigh, North Carolina.

Mid-Atlantic Associates, P.A., April 1995. "Corrective Action Plan for The Restoration of Petroleum-Impacted Groundwater, Pepsi-Cola Bottling Company of Raleigh."

Olsen, Rodger L. and Davis, Andy, 1990. "Predicting the Fate and Transport of Organic Compounds in Groundwater, Part 1." HMC, May/June 1990.

Stoddard, Edward, F. et. al., 1991. "The Eastern Piedmont in North Carolina," in Horton, J. Wright and Victor A. Zullo, The Geology of the Carolinas.

Smith, Leverett R., and Dragun, James, 1984. "Degradation of Volatile Chlorinated Aliphatic Priority Pollutants in Groundwater."

U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, 1994. U.S. EPA Document EPA 749-F-94-020a, "Chemical Summary for Perchloroethylene."

U.S. Environmental Protection Agency, Office of Waste Programs Enforcement, 1994. U.S. EPA Directive # 9902.3-2A, "RCRA Corrective Action Plan."

U.S. Environmental Protection Agency, Center for Environmental Research Information and Robert S. Kerr Environmental Research Laboratory, 1989. U.S. EPA Seminar Publication EPA/625/4-89/019, "Transport and Fate of Contaminants in the Subsurface."

U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, 1993. U.S. EPA Document EPA/540-R-93-080, "Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration."

U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, 1997. U.S. EPA Directive 9200.4-17, "*Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites.*".

U.S. Environmental Protection Agency, Draft EPA Region 4, 1997. "Suggested Practices for Evaluation of a Site For Natural Attenuation (Biological Degradation) of Chlorinated Solvents."

U.S. Environmental Protection Agency, Office of Research and Development, 1997. U.S. EPA 540-R-97-504, "Proceedings of the Symposium on Natural Attenuation of Chlorinated Organics in Ground Water."

U.S. Environmental Protection Agency, Office of Research and Development, 1997. U.S. EPA 540-R-96-509, "Symposium on Natural Attenuation of Chlorinated Organics in Ground Water."

U.S. Environmental Protection Agency, Office of Research and Development, 1996. USEPA 600-R-96-087, "BIOSCREEN Natural Attenuation Decision Support System, User's Manual Version 1.3."

U.S. Environmental Protection Agency, Office of Solid Waste, 1989. U.S. EPA Document EPA 530-SW-89-026, "Guidance Document on the Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities."

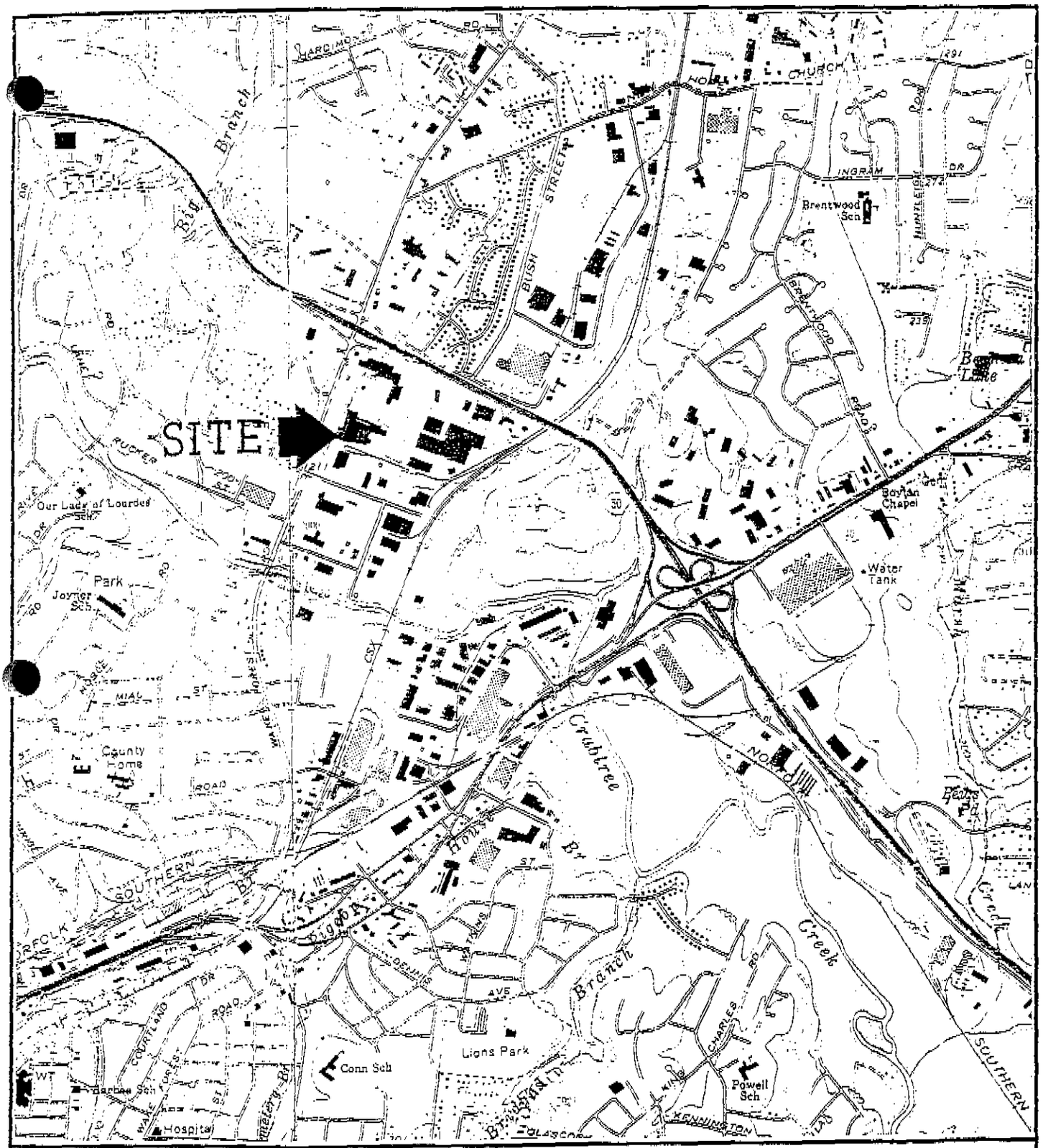
U.S. Environmental Protection Agency, Office of Research and Development, 1992. User Documentation EPA/625/11-91/002, "A Ground Water Information Tracking System with Statistical Analysis Capability - GRITS/STAT ver. 4.2."

U.S. Environmental Protection Agency, Office of Solid Waste, 1992. U.S. EPA DRAFT document, "Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance."

U.S. Geological Survey, 1997. Water-Resources Investigations Report 97-4003, "Transport and Transformations of Chlorinated-Solvent Contamination in a Saprolite and Fractured Rock Aquifer Near a Former Wastewater-Treatment Plant, Greenville, South Carolina."

Westinghouse Environmental Services, May 1989. "Ground Water Assessment and Remedial Action Plan For Snead's Exxon Site Gasoline Release."

FIGURES



N

NORTH

RALEIGH EAST & RALEIGH WEST
QUADRANGLE
(7.5 Minute Series - Topographic)
(Contour Interval 10')

0 1/2 MILE

Scale 1:24000

CLIENT/TITLE

ALCATEL NETWORK SYSTEMS
Raleigh, North Carolina

FIGURE 1
TOPOGRAPHIC LOCATION MAP

DRAWN	MH
CHECKED	
DATE	5/97

NATIONAL ENVIRONMENTAL TECHNOLOGIES, INC.
Wilmington, NC

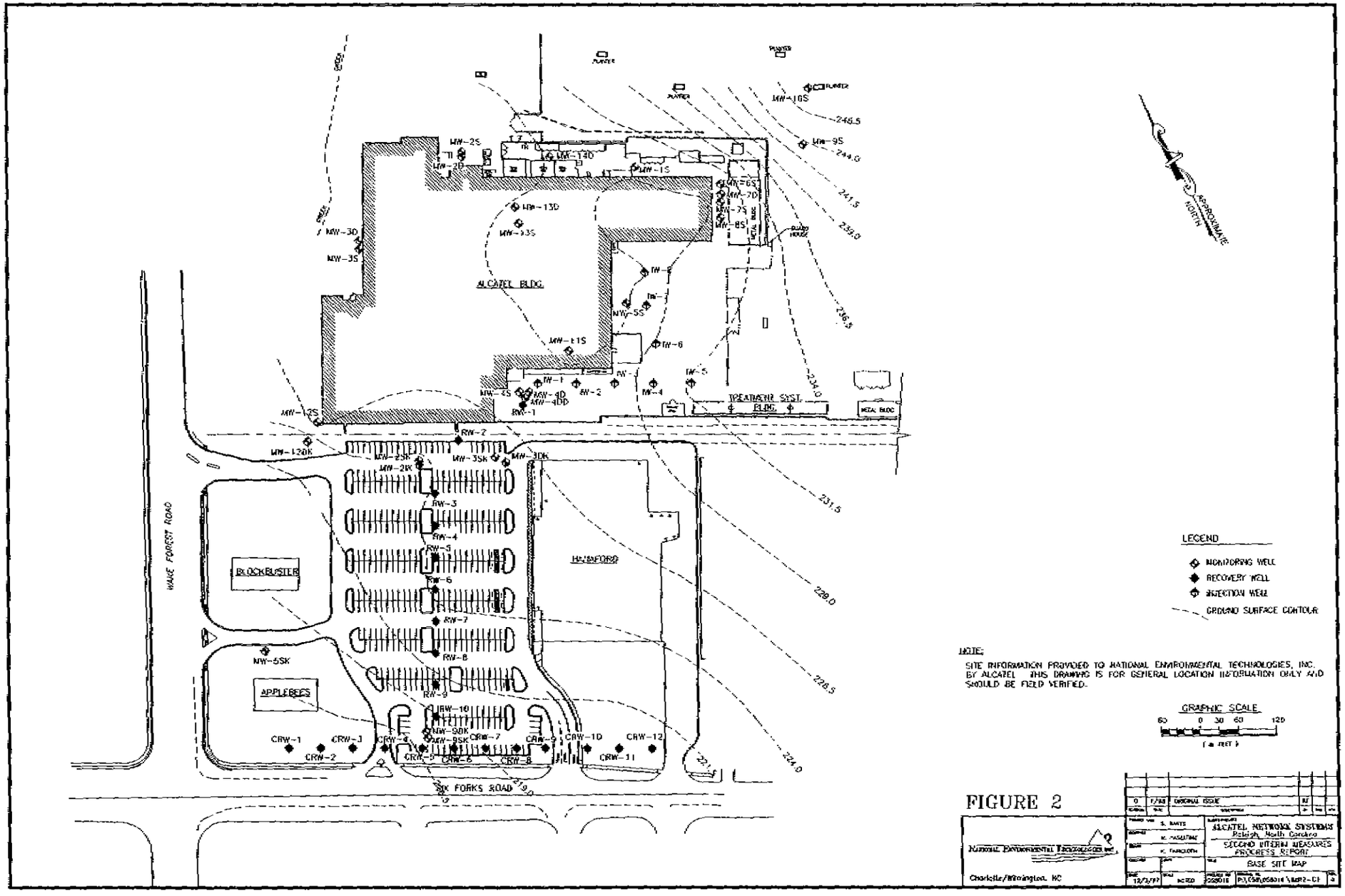
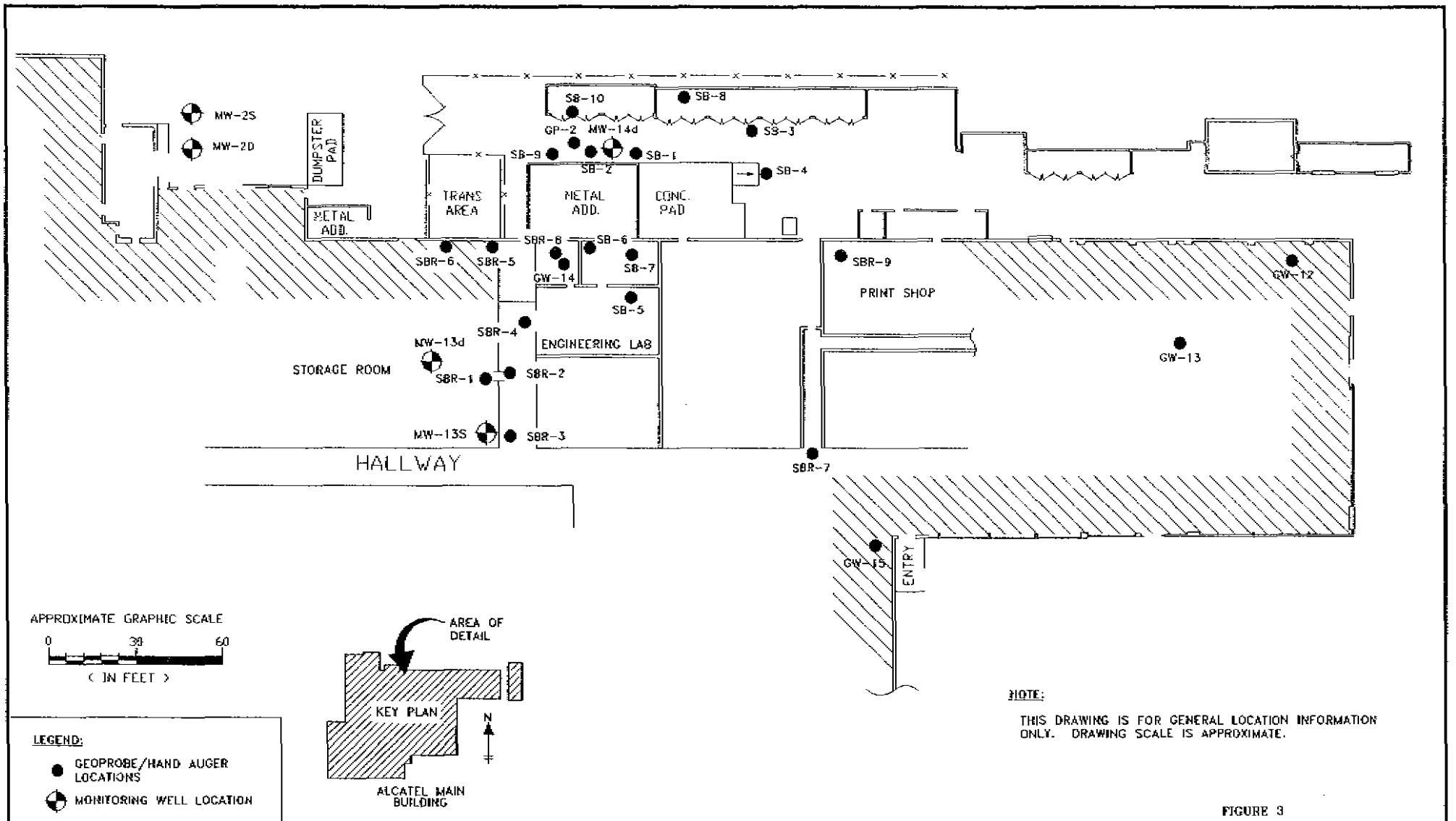

ALCATEL BLDG.
TREATMENT SYST. BLDG.
METAL BLDG.
PUMP HOUSE
BLOCKBUSTER
APPLEBEES
HARDFORD
WAKE FOREST ROAD
SIX FORKS ROAD
APPROXIMATE NORTH
LEGEND
MONITORING WELL
RECOVERY WELL
INJECTION WELL
GROUND SURFACE CONTOUR
NOTE:
SITE INFORMATION PROVIDED TO NATIONAL ENVIRONMENTAL TECHNOLOGIES, INC. BY ALCATEL. THIS DRAWING IS FOR GENERAL LOCATION INFORMATION ONLY AND SHOULD BE FIELD VERIFIED.
GRAPHIC SCALE
60 0 30 60 120
(IN FEET)
NATIONAL ENVIRONMENTAL TECHNOLOGIES INC.
Charlotte/Wilmington, NC
ALCATEL NETWORK SYSTEMS
Raleigh, North Carolina
SECOND INTERIM MEASURES PROGRESS REPORT
BASE SITE MAP

FIGURE 2



NOTE:

THIS DRAWING IS FOR GENERAL LOCATION INFORMATION ONLY. DRAWING SCALE IS APPROXIMATE.

FIGURE 3

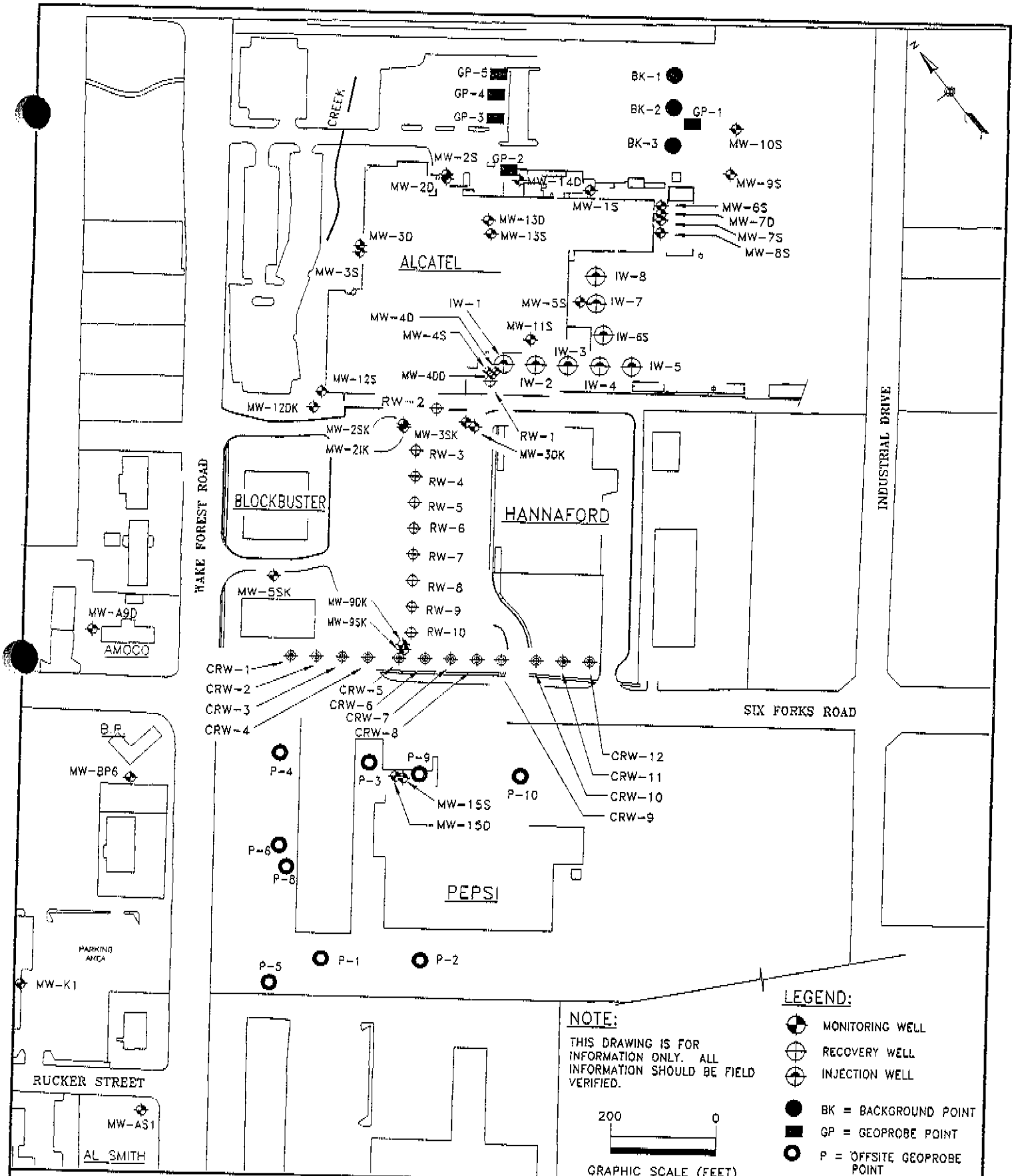
REV.	DATE	DESCRIPTION	BY	APPR
0	9/98	ORIGINAL ISSUE		

TRIANGLE ENVIRONMENTAL INC.
RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

DRAWN BY: KLF
DESIGNED: MHH
DATE: SEPT. 23, 1998
CHECKED BY:
APPROVED:
SCALE: NOTED

CLIENT/TITLE
ALCATEL NETWORK SYSTEMS, INC.
RALEIGH, NORTH CAROLINA
SOURCE AREA SOIL SAMPLE LOCATIONS

PROJECT NO. 01-003-0209
SHEET NO. P:\058\0209\0209-A
REV. 0



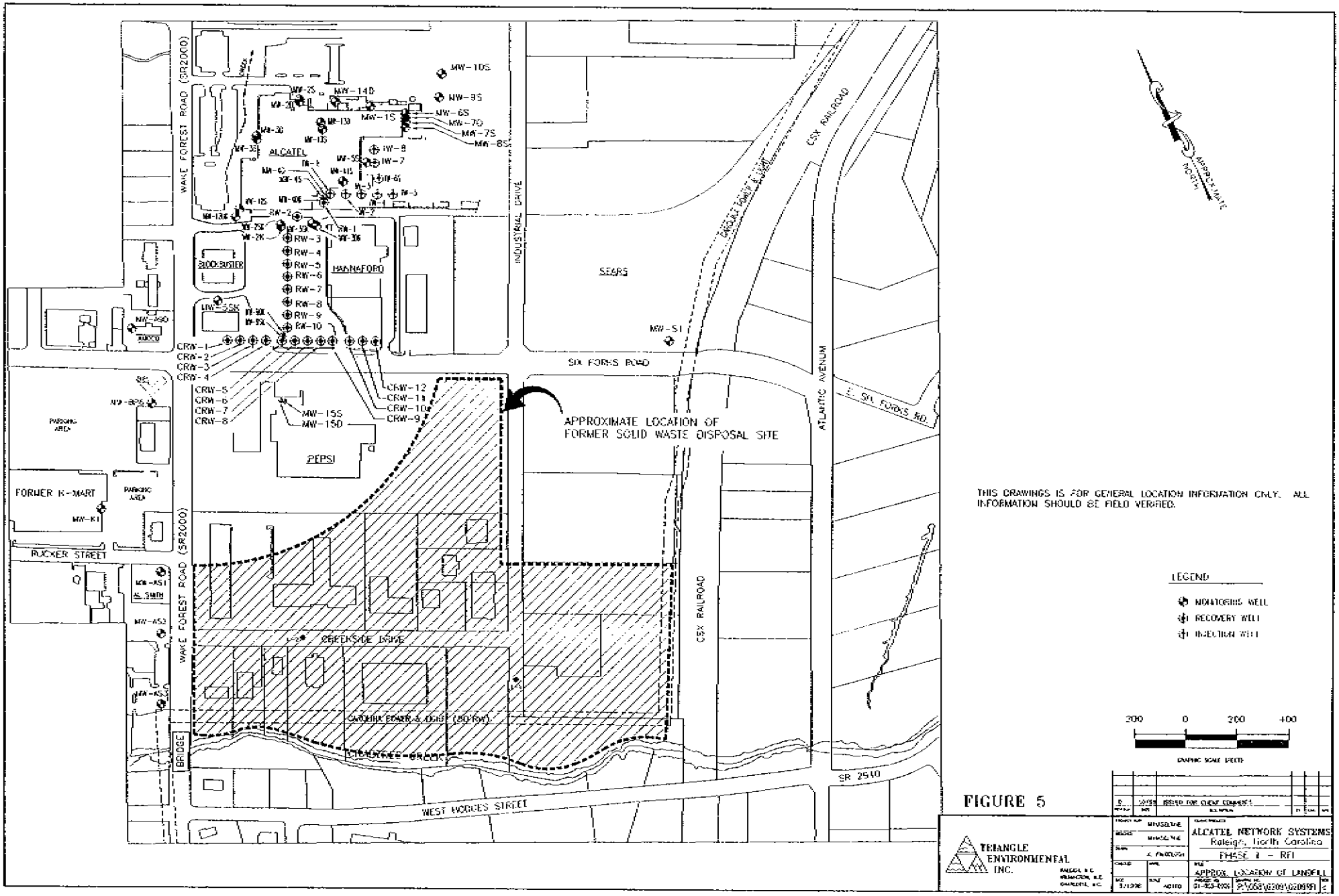
TRIANGLE ENVIRONMENTAL INC.

RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

ALCATEL NETWORK SYSTEMS, INC.
Raleigh, NC

BACKGROUND VOCS AND METALS, AND OFFSITE GEOPROBE LOCATIONS – FIGURE 4

FILE:P:\058\0209\0209RFI2 | PROJ.#01-003-0209 | DATE: 10/98


WAKE FOREST ROAD (SR2000)
INDUSTRIAL DRIVE
CSX RAILROAD
ATLANTIC AVENUE
SIX FORKS ROAD
E. SIX FORKS RD.
SEARS
ALCATEL
HANNAFORD
BOOKSTORE
PEPSI
FORMER K-MART
PARKING AREA
BUCKER STREET
CREEKSIDE DRIVE
CAROLINA POWER & LIGHT (80'ROW)
BRIDGE
SR 2540
WEST MODES STREET
APPROXIMATE LOCATION OF FORMER SOLID WASTE DISPOSAL SITE
MW-10S
MW-14D
MW-9S
MW-6S
MW-7D
MW-7S
MW-8S
MW-15S
MW-15D
MW-51
CRW-1
CRW-2
CRW-3
CRW-4
CRW-5
CRW-6
CRW-7
CRW-8
CRW-9
CRW-10
CRW-11
CRW-12
RW-3
RW-4
RW-5
RW-6
RW-7
RW-8
RW-9
RW-10
IW-8
IW-7
IW-5
MW-K1
MW-AS1
MW-AS2
MW-AS3
MW-AS4
MW-AS5
MW-AS6
MW-AS7
MW-AS8
MW-AS9
MW-AS10
MW-AS11
MW-AS12
MW-AS13
MW-AS14
MW-AS15
MW-AS16
MW-AS17
MW-AS18
MW-AS19
MW-AS20
MW-AS21
MW-AS22
MW-AS23
MW-AS24
MW-AS25
MW-AS26
MW-AS27
MW-AS28
MW-AS29
MW-AS30
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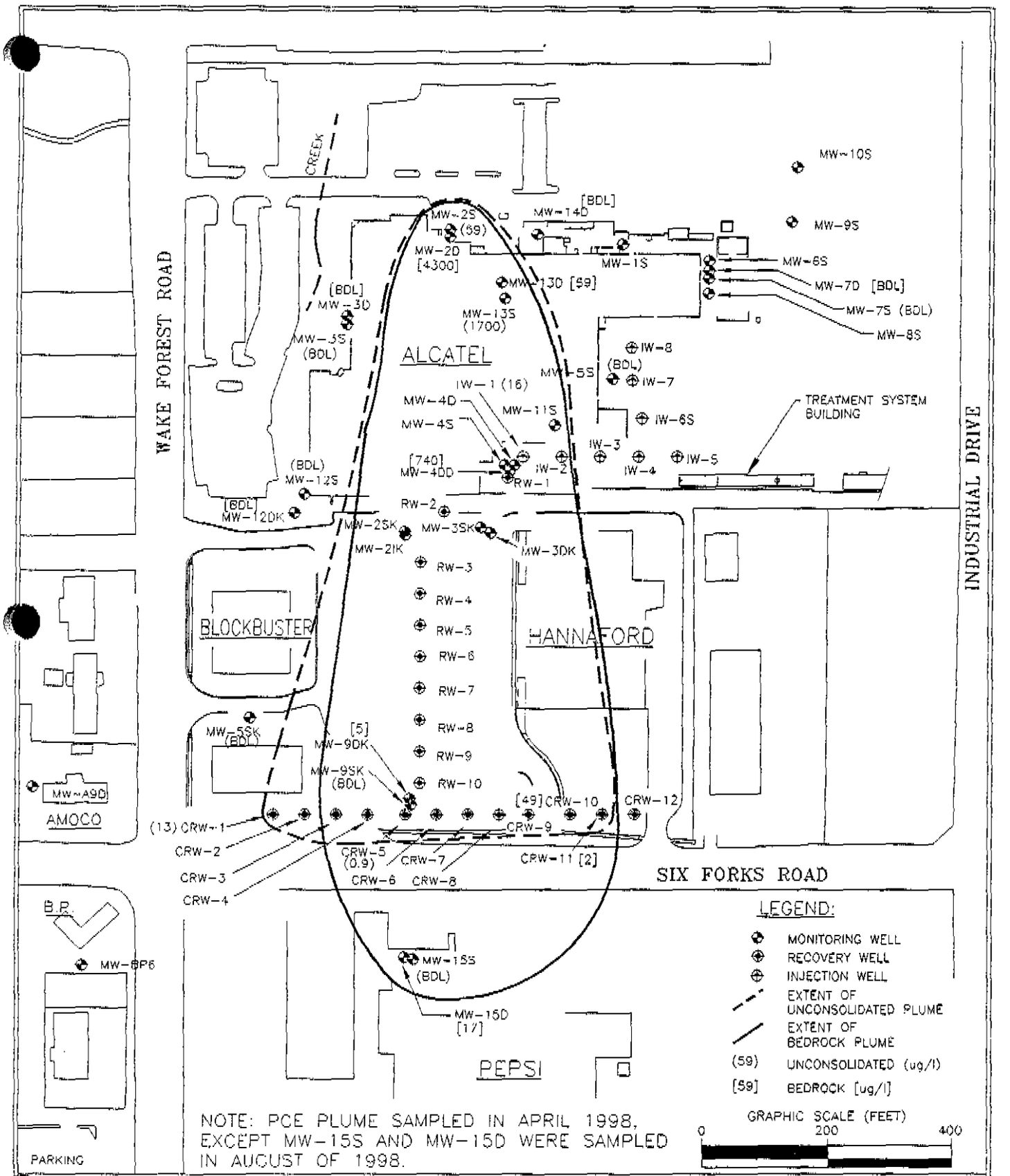
MW-AS39
MW-AS40



NOTE: PCE PLUME SAMPLED IN APRIL 1998, EXCEPT MW-15S AND MW-15D WERE SAMPLED IN AUGUST OF 1998.

TRIANGLE ENVIRONMENTAL INC.
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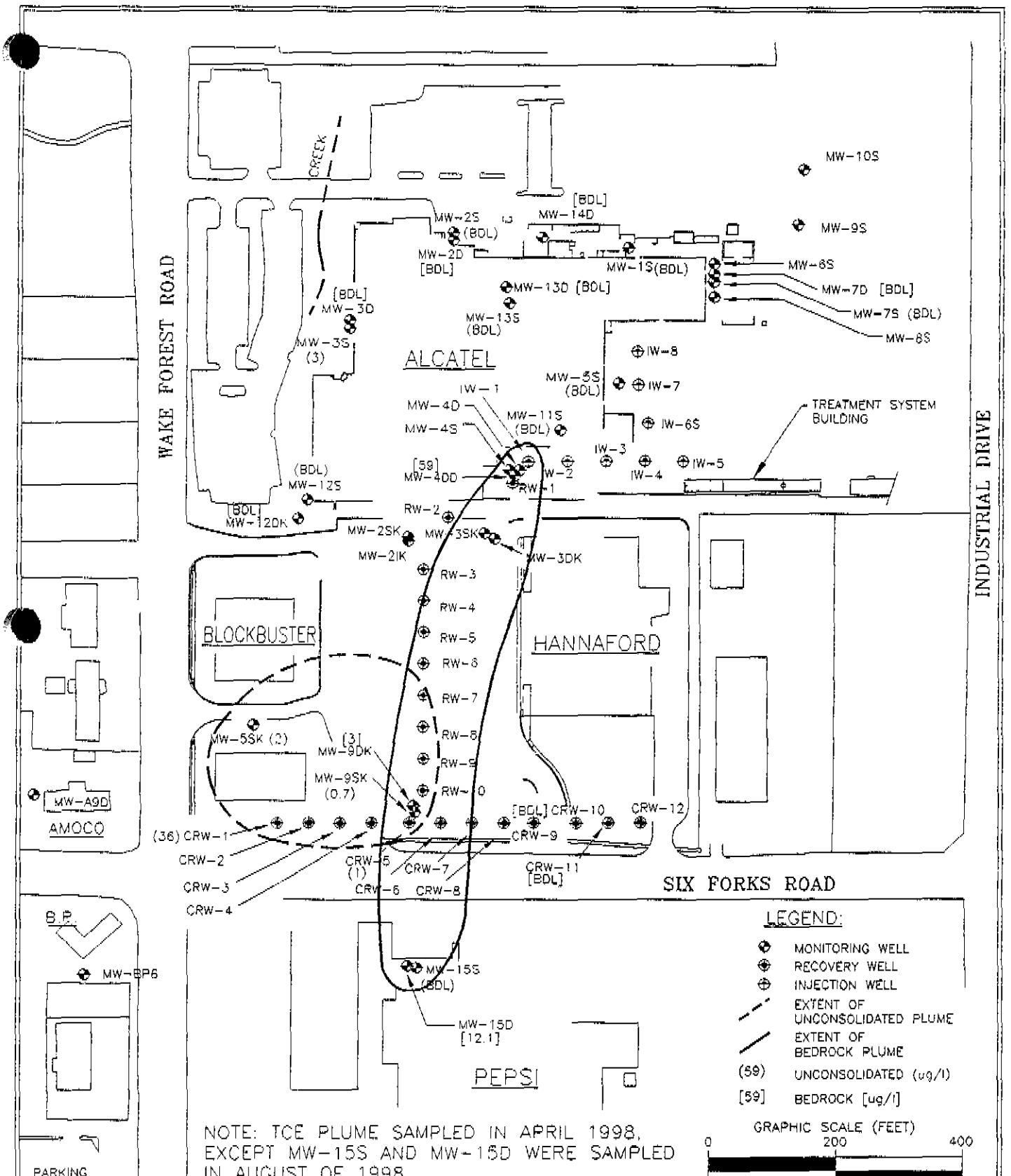
Raleigh, North Carolina

PCE PLUME – FIGURE 6

FILE:P:\058\0209\0209RFI | PROJ.#01-003-0209 | DATE: OCT. 1998



NOTE: TCE PLUME SAMPLED IN APRIL 1998, EXCEPT MW-15S AND MW-15D WERE SAMPLED IN AUGUST OF 1998.

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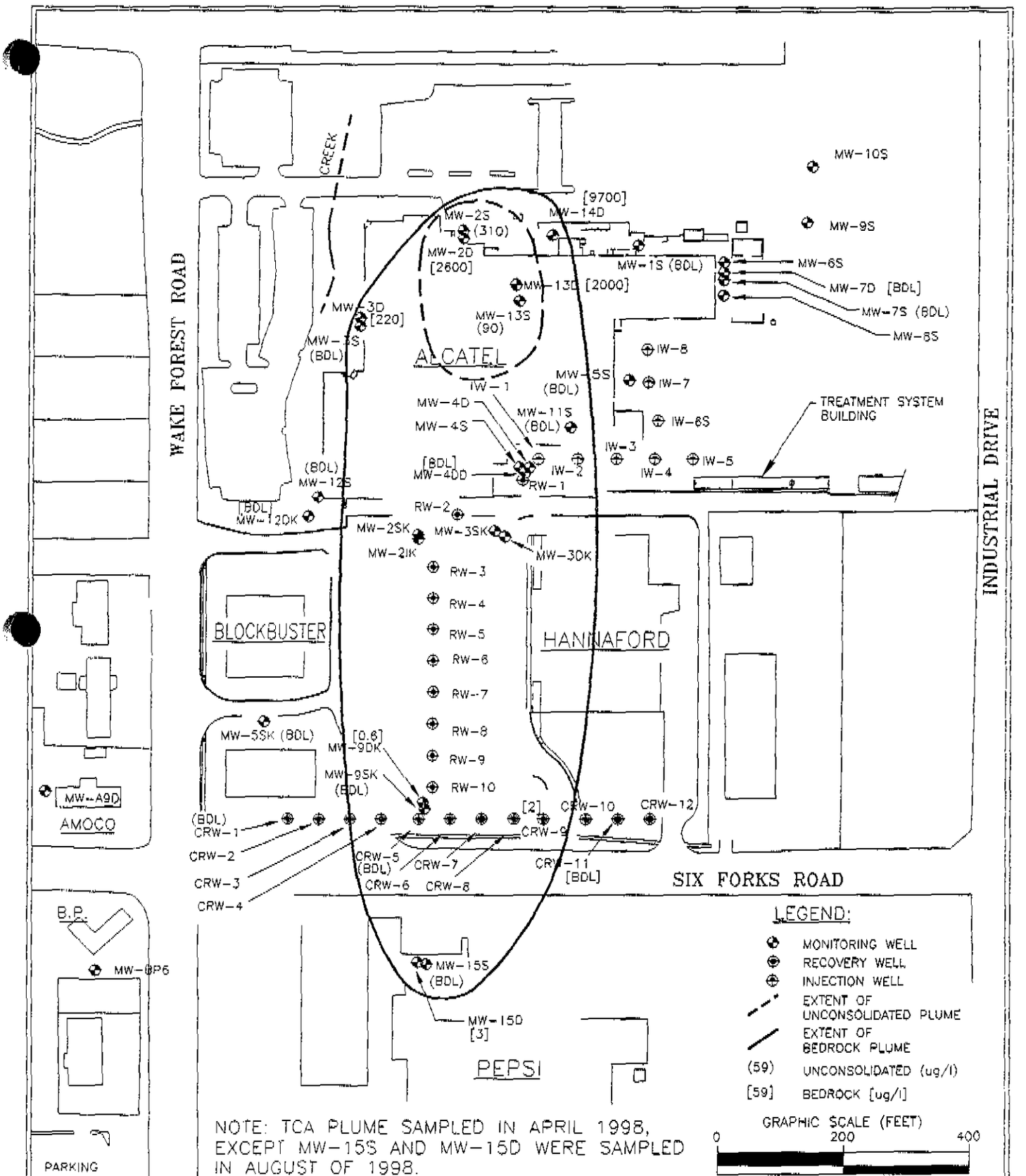
Raleigh, North Carolina

TCE PLUME – FIGURE 7

FILE:P:\058\0209\0209RFI | PROJ.#01-003-0209 | DATE: OCT. 1998



TRIANGLE ENVIRONMENTAL INC.
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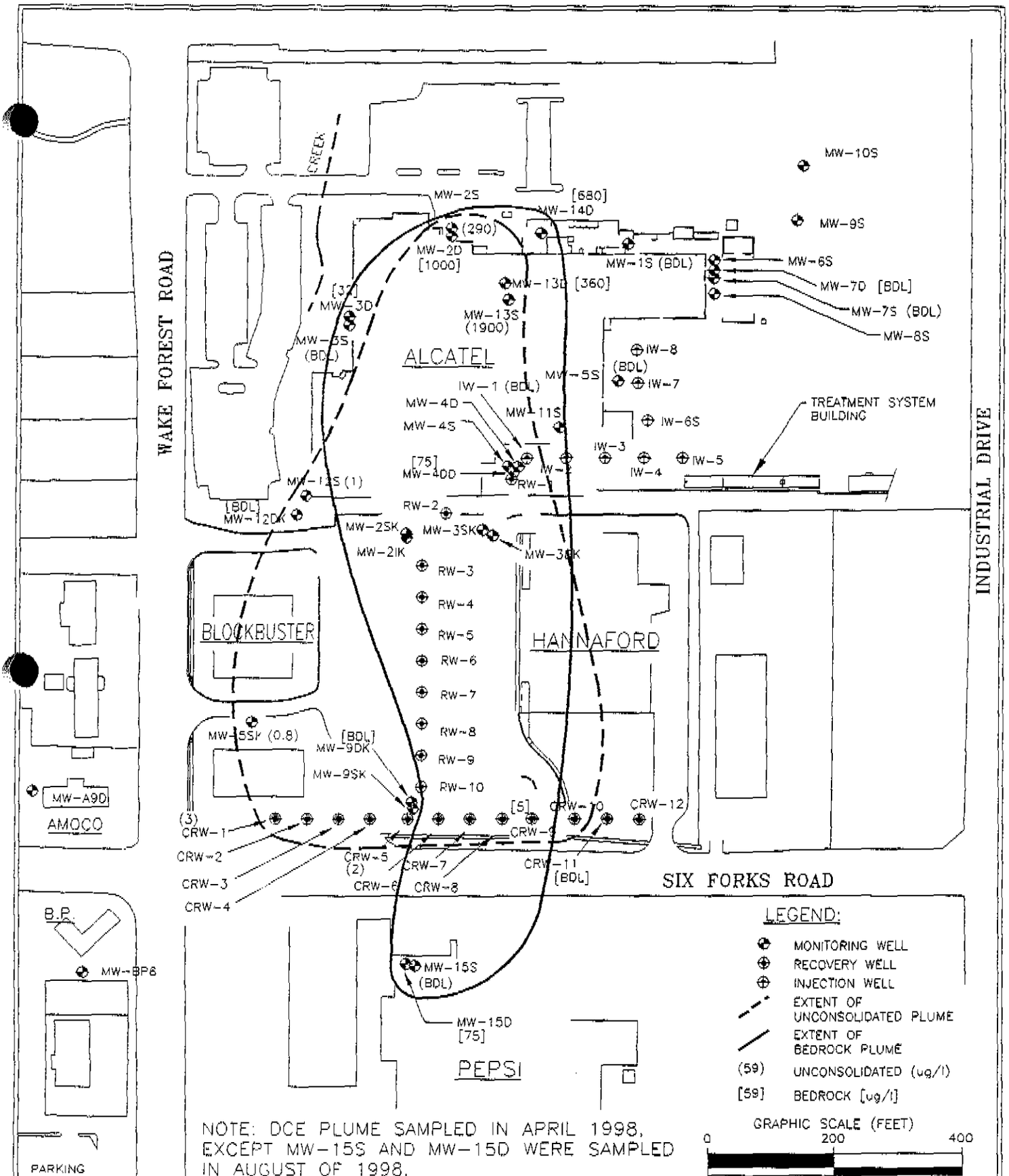
CHARLOTTE, N.C.

ALCATEL NETWORK SYSTEMS, INC.
Raleigh, North Carolina

TCA PLUME – FIGURE 8

FILE:P:\058\0209\0209RFI	PROJ.#01-003-0209	DATE: OCT. 1998

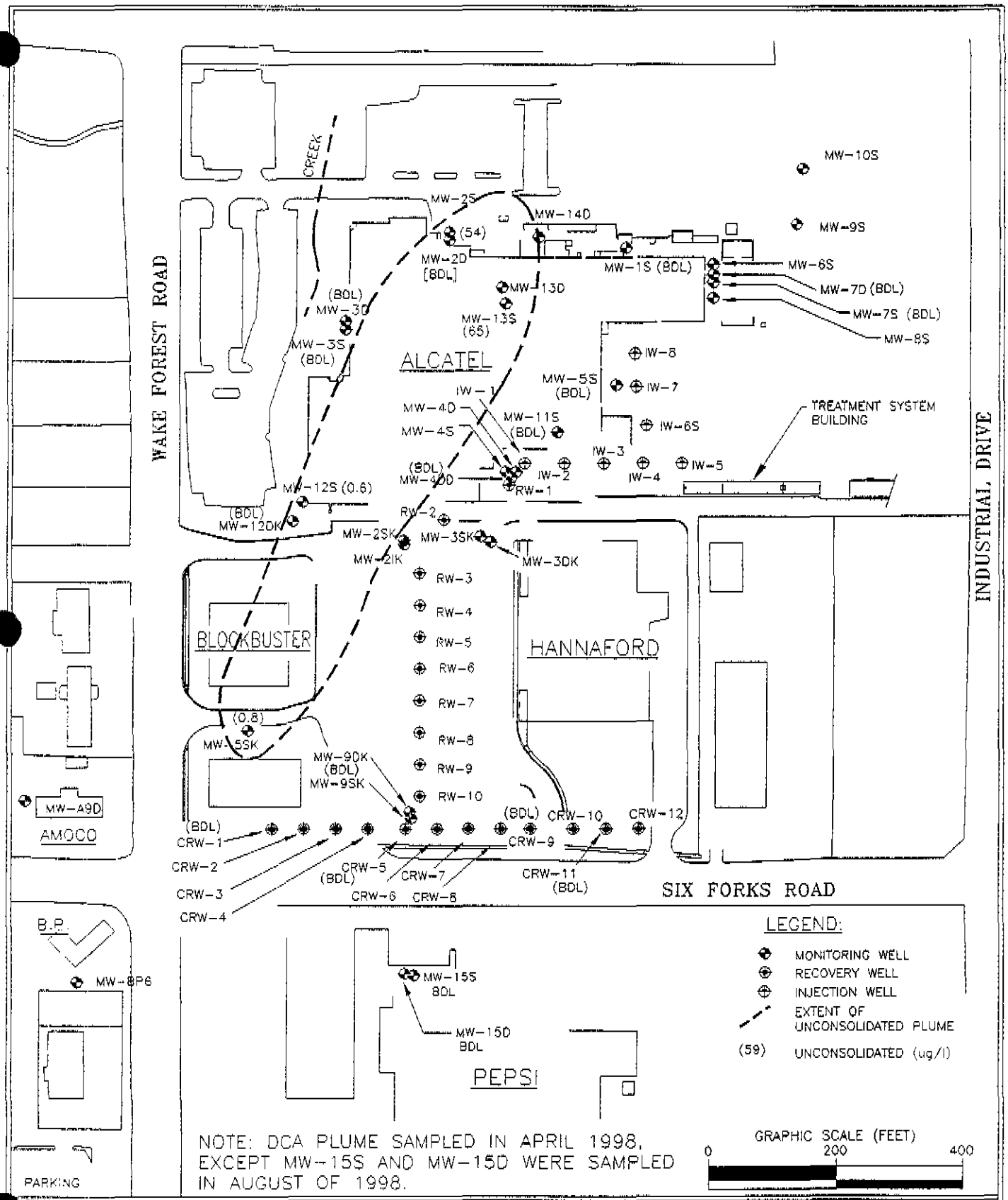


TRIANGLE ENVIRONMENTAL INC.
RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

ALCATEL NETWORK SYSTEMS, INC.
Raleigh, North Carolina

DCE PLUME — FIGURE 9

FILE:P:\058\0209\0209RFI	PROJ.#01-003-0209	DATE: OCT. 1998



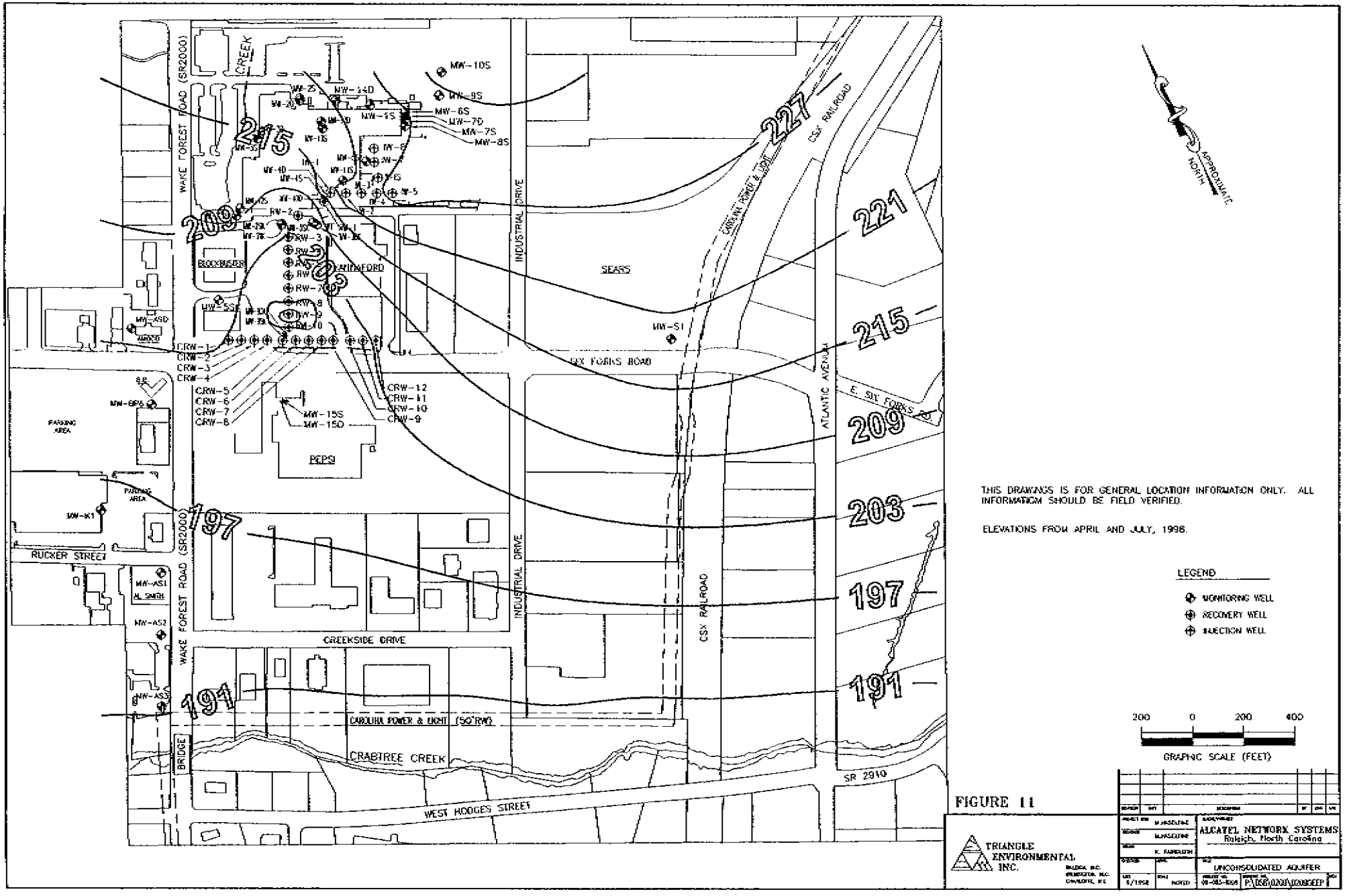
NOTE: DCA PLUME SAMPLED IN APRIL 1998, EXCEPT MW-15S AND MW-15D WERE SAMPLED IN AUGUST OF 1998.

TRIANGLE ENVIRONMENTAL INC.
RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

ALCATEL NETWORK SYSTEMS, INC.
Raleigh, North Carolina

DCA PLUME – FIGURE 10

FILE:P:\058\0209\0209RFI	PROJ.#01-003-0209	DATE: OCT. 1998



THIS DRAWINGS IS FOR GENERAL LOCATION INFORMATION ONLY. ALL INFORMATION SHOULD BE FIELD VERIFIED.

ELEVATIONS FROM APRIL AND JULY, 1998.

LEGEND

- MONITORING WELL
- RECOVERY WELL
- INJECTION WELL

200 0 200 400

GRAPHIC SCALE (FEET)

FIGURE 11

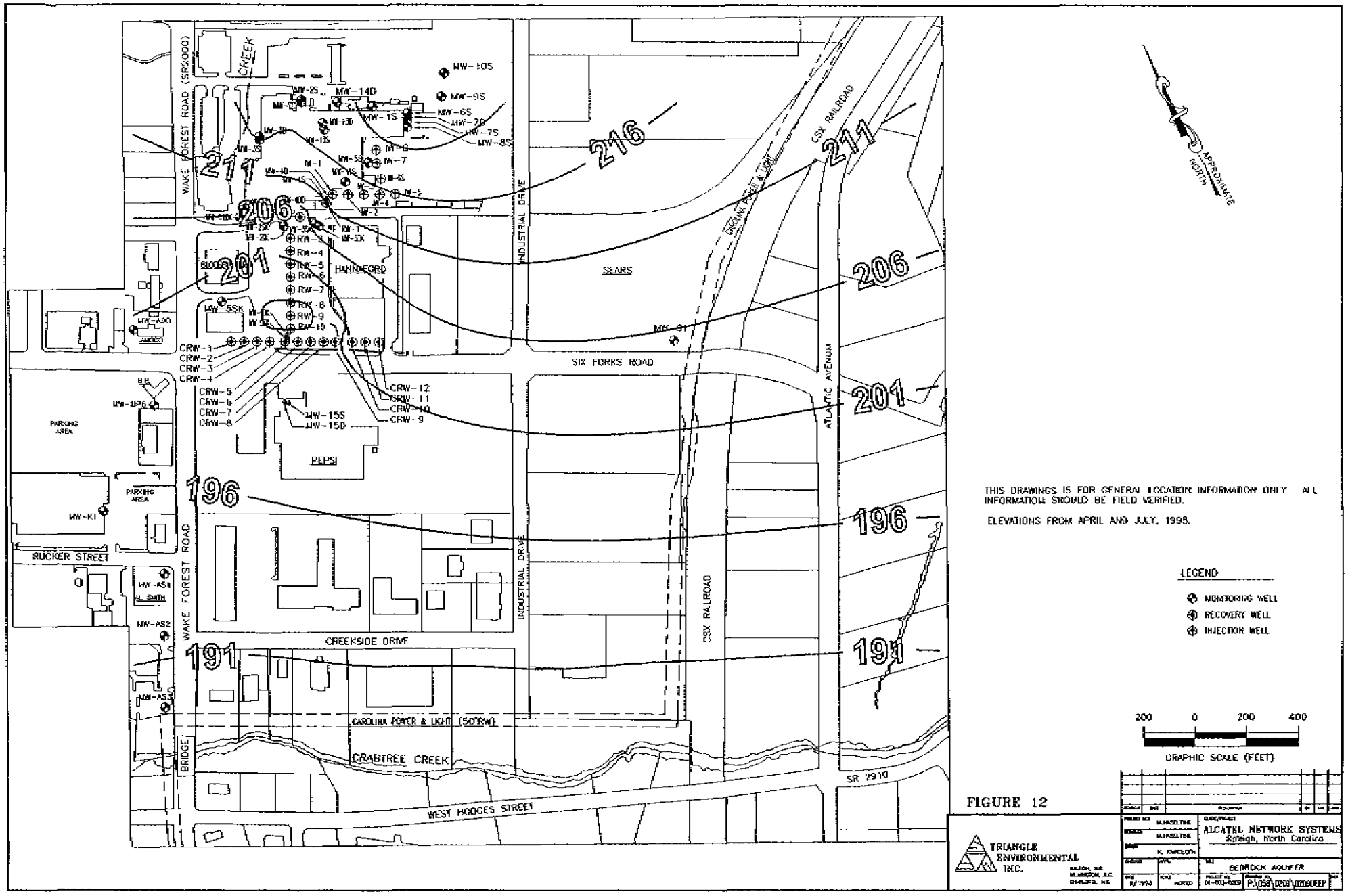
TRIANGLE ENVIRONMENTAL INC.

RALEIGH, N.C. ATLANTA, GA. CHARLOTTE, N.C.

ALCATEL NETWORK SYSTEMS
Raleigh, North Carolina

UNCONSOLIDATED AQUIFER

5/1998 NOTED P:\DGN\0XX\0XXSEEP



THIS DRAWINGS IS FOR GENERAL LOCATION INFORMATION ONLY. ALL INFORMATION SHOULD BE FIELD VERIFIED.

ELEVATIONS FROM APRIL AND JULY, 1998.

LEGEND

- MONITORING WELL
- RECOVERY WELL
- INJECTION WELL

200 0 200 400

GRAPHIC SCALE (FEET)

FIGURE 12

TRIANGLE ENVIRONMENTAL INC.

RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

PROJECT MGR	M.HASELTINE
DESIGNED	M.HASELTINE
DRAWN	K. FARGUSON
DATE	8/1998
SCALE	AS NOTED

ALCATEL NETWORK SYSTEMS
Raleigh, North Carolina

BEDROCK AQUIFER

PROJECT NO. 01-000-0209

TABLES

Table 1
Field Screening and Laboratory Results of Soil Samples Collected at Source Area
ALCATEL Network Systems, Inc.
Raleigh, North Carolina

Sample Identification	Sample Date	Sample Depth (feet bgs)	OVA Reading (PID)	Laboratory Results 1,2-DCA (ug/Kg)	PCE (ug/Kg)	1,1-DCE (ug/Kg)	1,1-DCA (ug/Kg)	1,1,1-TCA (ug/Kg)	TCE (ug/Kg)	1,1,2-TCA (ug/Kg)	VOC total (ug/Kg)	Copper (mg/Kg)	Lead (mg/Kg)
SBR-1	5/26/95	1-2	<2	bql	bql	bql	bql	bql	bql	bql	bql	2.7	bql
"	5/26/95	5-6	<2	na	na	na	na	na	na	na	na	na	bql
"	5/26/95	10-11	<2	bql	bql	bql	bql	bql	bql	bql	bql	0.72	bql
SBR-2	5/26/95	1-2	<2	bql	bql	bql	bql	bql	bql	bql	bql	1.7	bql
SBR-3	5/26/95	1-2	<2	bql	bql	bql	bql	bql	bql	bql	bql	1.6	bql
"	5/26/95	5-6	2	na	na	na	na	na	na	na	na	na	bql
"	5/26/95	10-11	2	bql	bql	bql	bql	bql	bql	bql	bql	1.3	bql
SBR-4	5/27/95	1-2	2	bql	bql	bql	bql	bql	bql	bql	bql	0.61	bql
"	5/27/95	5-6	4	na	na	na	na	na	na	na	na	na	bql
"	5/27/95	9-10	>2	bql	bql	bql	bql	bql	bql	bql	bql	1.6	bql
SBR-5	6/27/95	1-2	0	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c-16	bql
"	6/27/95	4-5	>2	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c-16	bql
SBR-6	6/27/95	1-2	>2	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c-16	bql
"	6/27/95	4-5	>2	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c-16	bql
SBR-7	6/27/95	1-2	>2	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c-13	bql
"	6/27/95	4-5	>2	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c - bql	c-13	bql
SBR-8	6/27/95	1-2	>2	bql	bql	bql	bql	bql	bql	bql	bql	50	bql
"	6/27/95	4-5	>2	bql	bql	bql	bql	bql	bql	bql	bql	74	9.5
"	6/27/95	9-10	>2	na	na	na	na	na	na	na	na	na	bql
SBR-9	6/28/95	1-2	>2	bql	bql	bql	bql	bql	bql	bql	bql	16	bql
"	6/28/95	4-5	>2	na	na	na	na	na	na	na	na	na	bql
"	6/28/95	9-10	>2	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql

Table 1
Field Screening and Laboratory Results of Soil Samples Collected at Source Area
ALCATEL Network Systems, Inc.
Raleigh, North Carolina

Sample Identification	Sample Date	Sample Depth (feet bgs)	OVA Reading (PID)	Laboratory Results 1,2-DCA (ug/Kg)	PCE (ug/Kg)	1,1-DCE (ug/Kg)	1,1-DCA (ug/Kg)	1,1,1-TCA (ug/Kg)	TCE (ug/Kg)	1,1,2-TCA (ug/Kg)	VOC total (ug/Kg)	Copper (mg/Kg)	Lead (mg/Kg)
SB-1	9/12/90	5-6	na	bql	bql	bql	bql	55	bql	bql	55	na	na
SB-2	9/12/90	2.5-3	na	bql	610	290	210	9600	bql	bql	10710	na	na
SB-3	9/12/90	2.5-3	na	11	2	7	5	bql	bql	1	26	na	na
SB-4	9/13/90	5.5-6	na	bql	bql	bql	bql	bql	bql	bql	bql	na	na
SB-5	9/13/90	8.5-9	na	7	2	3	4	12	bql	4	32	na	na
SB-6	9/13/90	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
SB-7	9/13/90	ns	na	ns	ns	ns	ns	ns	ns	ns	ns	n	n
SB-8	9/13/90	8.5-9	na	bql	3	77	4	23	bql	2	109	na	na
SB-9	9/13/90	5.5-6	na	bql	130	63	bql	1500	bql	bql	1693	na	na
SB-10	9/13/90	8.5-9	na	6	bql	8	bql	5	bql	bql	19		
GW-12s	9/11/93	0-10	na	c-bql	c-bql	c-bql	c-bql	c-bql	c-bql	c-bql	c-bql	c-44.2	c-5.4
GW-13s	9/11/93	0-10	na	c-bql	c-bql	c-bql	c-bql	c-bql	c-bql	c-bql	c-bql	c-4.5	c-5.1
GW-14s	9/11/93	0-10	na	c-bql	c-bql	c-bql	c-bql	c-bql	c-bql	c-bql	c-bql	c-21.4	c-10.7
GW-14s,11	9/11/93	11	na	bql	bql	bql	380	bql	bql	bql	380	11.4	6.3
GW-15s	9/11/93	0-10	na	c-bql	c-bql	c-bql	c-bql	c-bql	c-bql	c-bql	c-bql	c-2.8	c-4.2

Table 1
Field Screening and Laboratory Results of Soil Samples Collected at Source Area
ALCATEL Network Systems, Inc.
Raleigh, North Carolina

Sample Identification	Sample Date	Sample Depth (feet bgs)	OVA Reading (PID)	Laboratory Results 1,2-DCA (ug/Kg)	PCE (ug/Kg)	1,1-DCE (ug/Kg)	1,1-DCA (ug/Kg)	1,1,1-TCA (ug/Kg)	TCE (ug/Kg)	1,1,2-TCA (ug/Kg)	VOC total (ug/Kg)	Copper (mg/Kg)	Lead (mg/Kg)
MW-14d	8/1/97	0-5	2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
"	8/1/97	5-10	5	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
"	8/1/97	10-15	3	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
MW-13d	8/1/97	10	0	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
"	8/1/97	25-27	0	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
MW-13s	5/26/95	4-5	2	bql	bql	bql	bql	bql	bql	bql	bql	1.5	bql
"	5/26/95	9-10	2	bql	bql	bql	bql	bql	bql	bql	bql	0.49	bql
GP-2	4/6/98	13-15	na	bql	bql	bql	bql	bql	bql	bql	bql	2.56	bql

c - bql indicates that the intervals were composited

SBR - method 601 and 602 for VOCs

SB - method 8260 for VOCs and 6010 for metals

GW - method 601 and 602 for VOCs and RCRA metals

GP - method 8260 for VOCs and 6010 for metals

bql - indicates below quatitation limit

ns - indicates not sampled

na - indicates not analyzed

Table 2
Copper and Lead Concentrations from Source and Background Areas
ALCATEL Network Systems, Inc.
Raleigh, North Carolina

Sample Identification	Sample Date	Sample Depth (feet bgs)	Copper (mg/Kg)	Lead (mg/Kg)
Source Area				
SBR-1	5/26/95	1-2	2.7	bql
"	5/26/95	5-6	na	bql
"	5/26/95	10-11	0.72	bql
SBR-2	5/26/95	1-2	1.7	bql
SBR-3	5/26/95	1-2	1.6	bql
"	5/26/95	5-6	na	bql
"	5/26/95	10-11	1.3	bql
SBR-4	5/27/95	1-2	0.61	bql
"	5/27/95	5-6	na	bql
"	5/27/95	9-10	1.6	bql
SBR-5	6/27/95	1-2	c-16	bql
"	6/27/95	4-5	c-16	bql
SBR-6	6/27/95	1-2	c-16	bql
"	6/27/95	4-5	c-16	bql
SBR-7	6/27/95	1-2	c-13	bql
"	6/27/95	4-5	c-13	bql
SBR-8	6/27/95	1-2	50	bql
"	6/27/95	4-5	74	9.5
"	6/27/95	9-10	na	bql
SBR-9	6/28/95	1-2	16	bql
"	6/28/95	4-5	na	bql
"	6/28/95	9-10	bql	bql

Table 2
Copper and Lead Concentrations from Source and Background Areas
ALCATEL Network Systems, Inc.
Raleigh, North Carolina

Sample Identification	Sample Date	Sample Depth (feet bgs)	Copper (mg/Kg)	Lead (mg/Kg)
Source Area				
GW-12s	9/11/93	0-10	c-44.2	c-5.4
GW-13s	9/11/93	0-10	c-4.5	c-5.1
GW-14s	9/11/93	0-10	c-21.4	c-10.7
GW-14s.11	9/11/93	11	11.4	6.3
GW-15s	9/11/93	0-10	c-2.8	c-4.2
MW-13s	5/26/95	4-5	1.5	bql
"	5/26/95	9-10	0.49	bql
GP-2	4/6/98	13-15	2.56	bql
Background Area				
GP-1	4/6/98	17	3.73	2.40
BK-1a	8/13/98	4	7.50	6.30
BK-1b	8/13/98	8	2.80	8.60
BK-2a	8/13/98	4	4.90	6.00
BK-2b	8/13/98	8	2.80	7.00
BK-3a	8/13/98	4	3.70	17.00
BK-3b	8/13/98	8	2.30	4.00

c - bql indicates that the intervals were composited

SBR - method 601 and 602 for VOCs

GW - method 601 and 602 for VOCs and RCRA metals

GP - method 8260 for VOCs and 6010 for metals

bql - indicates below quatitation limit

ns - indicates not sampled

na - indicates not analyzed

Table 3
Results of Statistical Analysis of Background and Source Area Copper and Lead Concentrations
ALCATEL Network Systems, Inc.
Raleigh, North Carolina

		Copper	Lead
NORMALITY			
Skewness Coefficient =		**2.116**	**1.963**
		2.166 > 1	1.963 > 1
		not normally distributed	not normally distributed
Shapiro-Wilk Test of Normality			
data set	W =	0.624	0.708
Table A-2	.05,29 =	0.926	W.05,34 = .933
		0.624 < 0.926	**0.708 < 0.933**
		not normally distributed	not normally distributed
LEVENE'S TEST OF HOMOGENEITY			
data set	f-ratio =	7.640	
from table	f =	4.210	
		7.64 > 4.21	
		assumption of equal variances rejected	
WILCOXON RANK-SUM TEST FOR TWO GROUPS			
data set	Z =	**-0.23**	**-2.3**
from table	Z.01 =	2.326	
		-0.23 < 2.326	**-2.3 < 2.326**
		no significant evidence of contamination at 1% significance level	

Table 4
Results of Off-site Geoprobe Investigation
ALCATEL Network Systems, Inc.
Raleigh, North Carolina

Sample Identification	Date Sampled	Dissolved Oxygen (mg/l)	Laboratory Results												
			1,1,1-TCA (ug/l)	1,1-DCE (ug/l)	1,2-DCE (ug/l)	TCE (ug/l)	PCE (ug/l)	Chloro-benzene (ug/l)	cis-1,2 DCE (ug/l)	Vinyl hlorid (ug/l)	Toluene (ug/l)	Trimethyl-benzene (ug/l)	Xylenes (ug/l)	MTBE (ug/l)	Naphthalene (ug/l)
P-1	4/7/98	4.5	bql	bql	bql	bql	bql	bql	bql	bql	0.6	0.5	bql	bql	bql
P-2	4/7/98	3.8	51	1,500	bql	52	210	bql	bql	bql	bql	bql	bql	bql	bql
P-3	4/7/98	6.2	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql
P-4	4/7/98	1.8	bql	bql	bql	bql	bql	bql	bql	bql	1	bql	bql	1	0.6
P-5	4/7/98	4.9	bql	0.6	1	13	2	bql	bql	bql	bql	bql	bql	bql	bql
P-6	4/7/98	5.0	bql	2	bql	4	1	bql	bql	bql	bql	bql	bql	bql	bql
P-7	5/12/98	na	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql
P-8	5/12/98	na	bql	3	bql	2	bql	bql	bql	bql	0.8	bql	bql	bql	bql
P-9	5/12/98	na	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql
L-1	8/13/98	0.9	bql	bql	bql	bql	bql	1.3	1.27	6.36	1.43	0.54	1.93	1.4	bql

VOC's by Method 6210D
D.O. - field measurement

Table 4
Results of Off-site Geoprobe Investigation
ALCATEL Network Systems, Inc.
Raleigh, North Carolina

Sample Identification	Date Sampled	Dissolved Oxygen (mg/l)	Laboratory Results												
			1,1,1-TCA (ug/l)	1,1-DCE (ug/l)	1,2-DCE (ug/l)	TCE (ug/l)	PCE (ug/l)	Chloro-benzene (ug/l)	cis-1,2 DCE (ug/l)	Vinyl hlorid (ug/l)	Toluene (ug/l)	Trimethyl-benzene (ug/l)	Xylenes (ug/l)	MTBE (ug/l)	Naphthalene (ug/l)
P-1	4/7/98	4.5	bql	bql	bql	bql	bql	bql	bql	bql	0.6	0.5	bql	bql	bql
P-2	4/7/98	3.8	51	1,500	bql	52	210	bql	bql	bql	bql	bql	bql	bql	bql
P-3	4/7/98	6.2	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql
P-4	4/7/98	1.8	bql	bql	bql	bql	bql	bql	bql	bql	1	bql	bql	1	0.6
P-5	4/7/98	4.9	bql	0.6	1	13	2	bql	bql	bql	bql	bql	bql	bql	bql
P-6	4/7/98	5.0	bql	2	bql	4	1	bql	bql	bql	bql	bql	bql	bql	bql
P-7	5/12/98	na	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql
P-8	5/12/98	na	bql	3	bql	2	bql	bql	bql	bql	0.8	bql	bql	bql	bql
P-9	5/12/98	na	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql	bql
L-1	8/13/98	0.9	bql	bql	bql	bql	bql	1.3	1.27	6.36	1.43	0.54	1.93	1.4	bql

VOC's by Method 6210D
D.O. - field measurement

Table 5
Sumary of Daughter Products and Half-Lives
ALCATEL Network Systems, Inc.
Raleigh, North Carolina

Compound	Process		Daughter Products	Half-Life (yr)
PARENT				
1,1,1 TCA	Abiotic	hydrolysis or dehydrohalogenation	*1,1-DCE, t1,2-DCE* acetic acid	0.7 to 0.8 0.5
	Biotic	Sulfate reduction Methanogenesis	*1,1-DCA* CO2 and Cl-	0.005 to 17
PCE	Abiotic	hydrolysis or dehydrohalogenation	----- -----	0.73
	Biotic	Sulfate reduction Methanogenesis	*TCE* ethene	0.63
DAUGHTER PRODUCTS				
TCE	Abiotic	hydrolysis or dehydrohalogenation	----- -----	0.89
	Biotic	Sulfate reduction or Methanogenesis	*c1,2-DCE, t1,2-DCE* 1,2-DCA ethane	0.11 to 0.63
1,1-DCE	Abiotic	hydrolysis or dehydrohalogenation	----- -----	1
	Biotic	Sulfate reduction Methanogenesis	vinyl chloride ethene	0.22 to 0.47
cis1,2-DCE	Biotic	Sulfate reduction Methanogenesis	----- vinyl chloride	0.24 to 0.93
trans1,2-DCE	Biotic	Sulfate reduction Methanogenesis	----- vinyl chloride	0.24 to 0.93
1,1-DCA	Biotic	Sulfate reduction Methanogenesis	----- chloroethane	>0.16
vinyl chloride	Abiotic	hydrolosis	-----	<10
	Biotic	Sulfate reduction Methanogenesis	CO2 and Cl-	>0.16

(compilation from Smith and Dragun, 1884 and Olsen and Davis, 1990)

Table 6
Natural Attenuation Screening Results
ALCATEL Network Systems, Inc.
Raleigh, North Carolina

Sample Location	Sample Date	Field Screening Results				Laboratory Results (mg/l)				
		D.O. (mg/l)	Temp (C)	pH	eH (mv)	Chloride	Nitrate	Sulfate	Ferrous Iron	Methane
MW-4d	8/14/98	2	22	6.36	250	35.82	6.68	50.9	bql	0.647
MW-4s	8/14/98	7.4	24	6.82	220	22.67	1.25	35.59	0.12	0.654
MW-7d	8/14/98	1.8	24	8.71	228	8.48	0.59	38.58	0.09	0.736
MW-9dk	8/14/98	4.2	23	6.34	190	10.89	0.82	5.98	bql	3.893
MW-9sk	8/14/98	1.2	20	6.15	177	27.94	bql	6.66	0.08	*1.881
MW-10s	8/14/98	5.3	21	6.10	254	22.67	2.35	13.49	0.08	0.619
MW-12s	8/14/98	2.8	21	5.80	180	19.71	3.19	26.91	bql	10.514
MW-13s	8/13/98	0.3	21	5.74	1.44	80.86	2.2	49.3	0.06	4.737
MW-14d	8/14/98	1.8	22	5.42	190	30.41	0.16	93.24	bql	1.359
MW-15s	8/14/98	2.9	21	6.11	195	42.72	bql	6.41	bql	*2.899
MW-15d	8/14/98	4.2	23	7.02	177	11.92	1.01	36.73	bql	3.007
L-1	8/13/98	0.9	23	6.30	-20.5	87.81	0.11	22.42	0.09	429.519
Field Blank	8/14/98	2.5	20	6.00	300	bql	bql	bql	bql	0.669

Chloride	EPA Method 325.3, detection limit - 0.5 mg/l
Nitrate	EPA Method 352.1, detection limit - 0.1 mg/l (Nitrate samples exceeded protocol for holding time at laboratory)
Sulfate	EPA Method 375.4, detection limit - 1.0 mg/l
Ferrous Iron	3500D, detection limit - 0.05 mg/l
Methane	Method AM18.01, detection limit - 0.7 mg/l where noted *, all others 0.015 ug/l

Table 7
Natural Attenuation Ranking
ALCATEL Network Systems, Inc.
Raleigh, North Carolina

	Source Area Wells				Landfill	Background Wells	
Parameter/indicator	MW-13s	Rank	MW-14d	Rank	L-1	MW-10s	MW-7d
D.O. (mg/l)	0.3	3	1.8	-3	0.9	5.3	1.8
Temp (C)	21	1	22.00	1	23	21	24
pH	5.74	0	5.42	0	6.3	6.1	8.71
eH (mv)	1.44	1	190.00	0	-20.5	254	228
Chloride (mg/l)	80.86	2	30.41	2	87.81	22.67	8.48
Nitrate (mg/l)	2.2	0	0.16	2	0.11	2.35	0.59
Sulfate (mg/l)	49.3	0	93.24	0	22.42	13.49	38.58
Ferrous Iron (mg/l)	0.06	0	bdl	0	0.09	0.08	0.09
Methane (ug/l)	4.7	0	1.4	0	0.43	0.619	0.74
PCE -released (mg/l)	1.7	0	bdl	0	bdl	bdl	bdl
TCE (mg/l)	bdl	0	bdl	0	bdl	bdl	bdl
DCE (mg/l)	1.9	0	0.68	0	bdl	bdl	bdl
1,1,1-TCA - released (mg/l)	0.09	0	9.7	0	bdl	bdl	bdl
1,1-DCA (mg/l)	0.065	2	bdl	0	bdl	bdl	bdl
cis-1,2-DCE (mg/l)	bdl	0	bdl	0	1.27	bdl	bdl
vinyl chloride (mg/l)	bdl	0	bdl	0	6.36	bdl	bdl
	score = 9		score = 2				

VOC's from 4/98 sampling event (ALCATEL IMPR, 1998)
Ranking system as proposed by USEPA Region 4 (US EPA 1997)
MW-13s - source area for PCE and 1,1,1-TCA
MW-14d - source area for 1,1,1-TCA
background Chloride for Type II wells - 22.67 (from MW-10s)
background Chloride for Type III wells - 8.48 (from MW-7d)

Table 8
Comparison of Decay Rate and Tracer Attenuation Rate
ALCATEL Network Systems, Inc.
Raliegh, North Carolina

Constituent	Bedrock		Unconsolidated	
	Bioscreen Model ($year^{-1}$)	Chloride Tracer ($year^{-1}$)	Bioscreen Model ($year^{-1}$)	Chloride Tracer ($year^{-1}$)
PCE	-1.2	-1.17	-0.99	-1.93
1,1-DCE	-0.69	-1.1	-1.2	-3.3
1,1,1-TCA	-6.9	-5.47	-3.5	-2.56

Table 9
Ground Water Elevations
ALCATEL Network Systems, Inc.
Raliegh, North Carolina

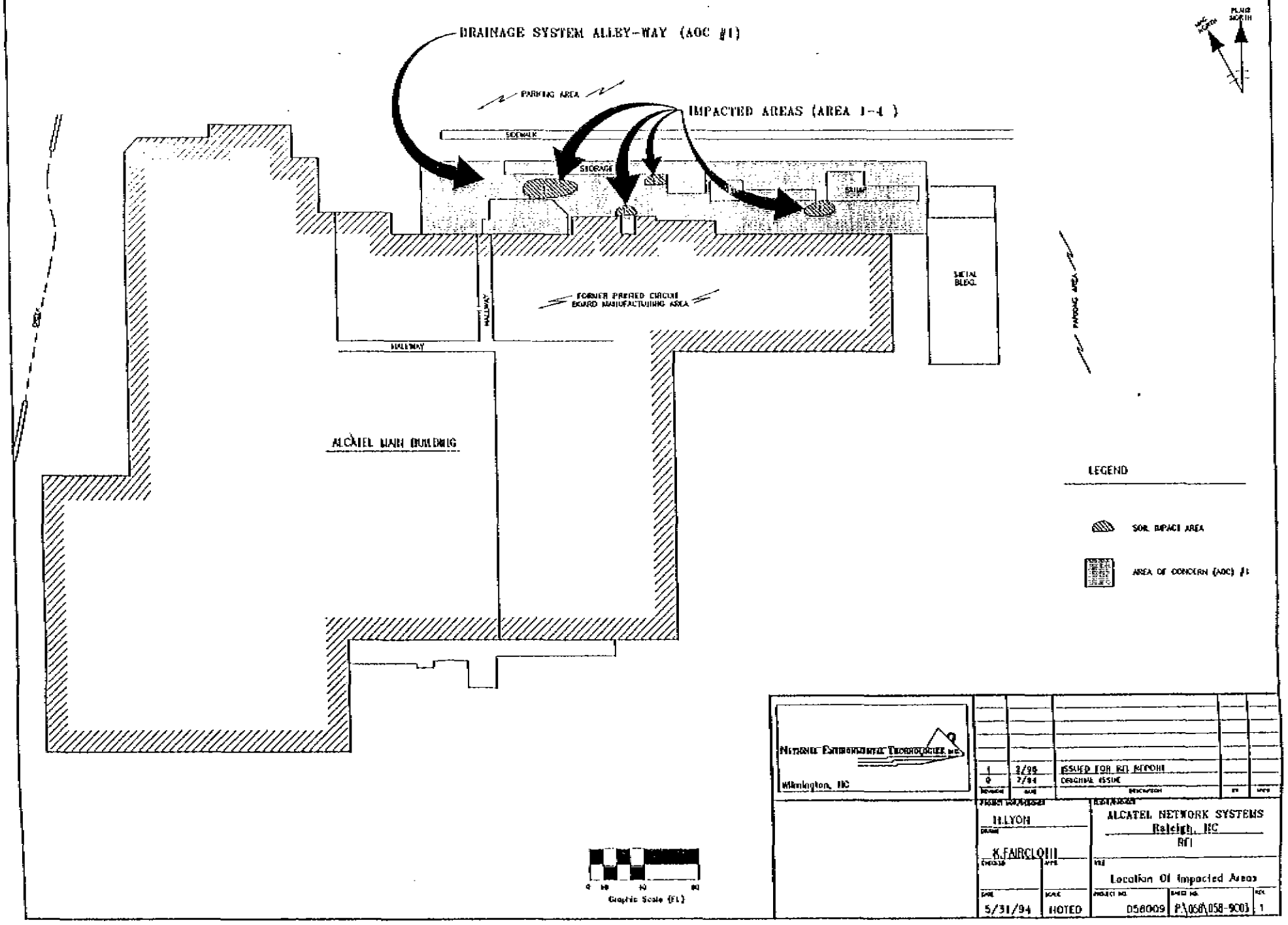
Well	TOC elevation (feet)	Depth to water (feet)	GW elevation (feet)
		4/27/98	
MW-1s	228.40	3.58	224.82
MW-2s	225.59	6.99	218.60
MW-2d	225.81	10.07	215.74
MW-3s	228.55	14.07	214.48
MW-3d	228.48	11.91	216.57
MW-4s	226.71	14.00	212.71
MW-4d	227.20	15.40	211.80
MW-4dd	226.53	54.63	171.90
MW-5s	228.40	5.63	222.77
MW-6s	229.16	2.66	226.50
MW-7s	229.27	2.85	226.42
MW-7d	229.35	5.19	224.16
MW-8s	229.34	2.99	226.35
MW-9s	243.17	11.72	231.45
MW-10s	252.71	17.40	235.31
MW-11s	229.63	11.41	218.22
MW-12s	227.05	16.77	210.28
MW-13s	229.48	11.45	218.03
MW-13d	229.42	11.15	218.27
MW-14d	227.40	7.68	219.72
*MW-15s	210.47	8.72	201.75
*MW-15d	210.82	11.62	199.20
MW-2ik	223.36	19.29	204.07
MW-2sk	223.47	dry	dry
MW-3sk	225.51	dry	dry
MW-3dk	225.90	17.87	208.03
MW-5sk	215.28	9.11	206.17
MW-9sk	217.04	16.48	200.56
MW-9dk	216.95	17.17	199.78
MW-12dk	221.85	16.18	205.67
RW-1	223.80	12.17	211.63
RW-2	220.61	17.97	202.64
RW-3	221.50	18.65	202.85
RW-4	221.18	19.19	201.99
RW-5	220.83	20.56	200.27
RW-6	220.98	22.67	198.31
RW-7	220.29	21.53	198.76
RW-8	219.18	20.57	198.61
RW-9	217.97	34.30	183.67
RW-10	215.35	15.35	200.00

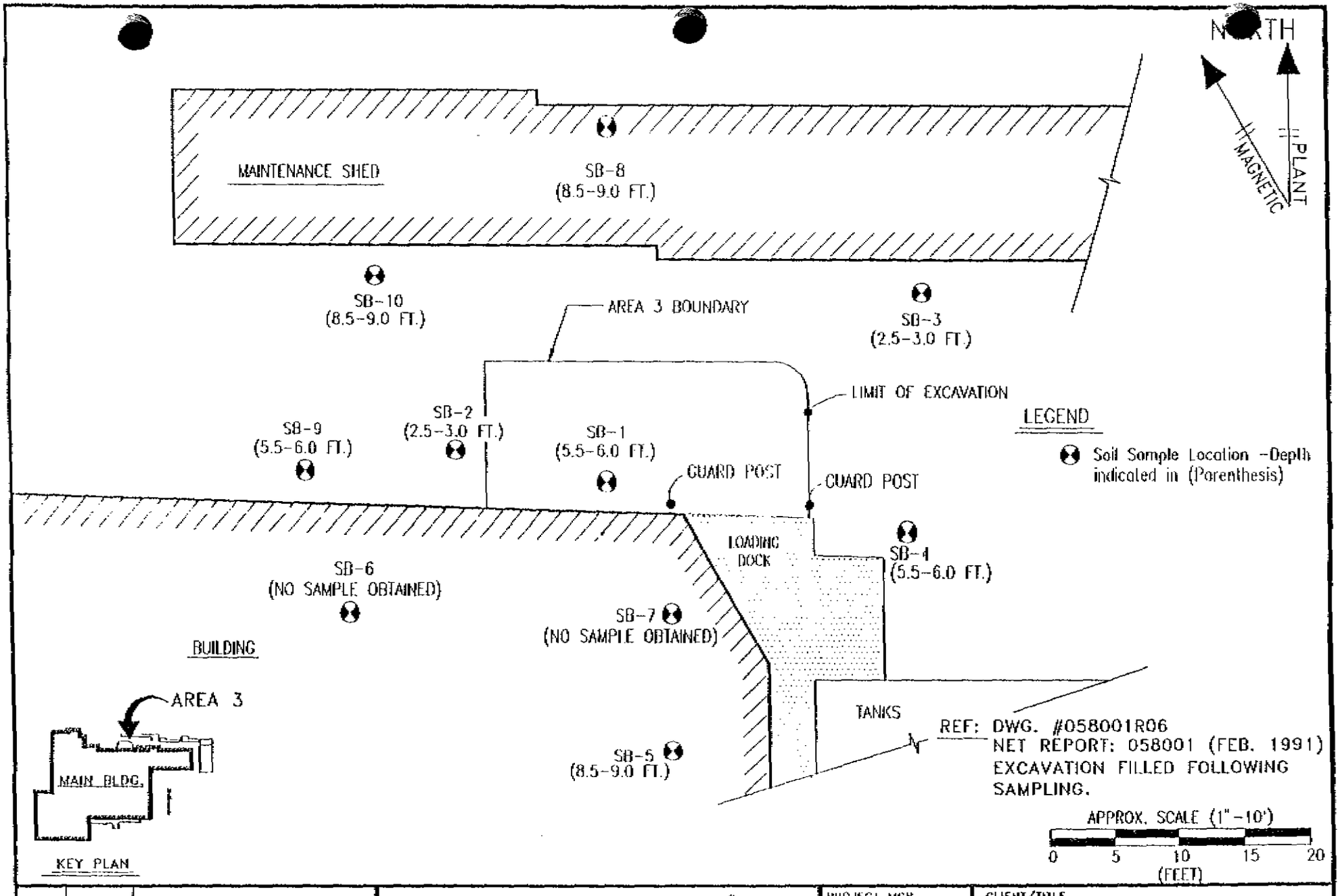
Table 9
Ground Water Elevations
ALCATEL Network Systems, Inc.
Raliegh, North Carolina

Well	TOC elevation (feet)	Depth to water (feet)	GW elevation (feet)
CRW-1	211.74	8.78 4/27/98	202.96
CRW-2	212.10	10.40	201.70
CRW-3	212.44	9.15	203.29
CRW-4	211.64	11.98	199.66
CRW-5	213.87	13.91	199.96
CRW-6	214.77	15.62	199.15
CRW-7	215.90	17.27	198.63
CRW-8	216.61	18.66	197.95
CRW-9	216.78	15.40	201.38
CRW-10	216.97	15.58	201.39
CRW-11	217.12	15.15	201.97
CRW-12	217.46	47.52	169.94
IW-1	223.87	1.42	222.45
IW-2	228.80	4.62	224.18
IW-3	224.50	0.83	223.67
IW-4	225.28	nm	nm
IW-5	228.68	0.00	228.68
IW-6	225.66	nm	nm
IW-7	225.11	1.04	224.07
IW-8	225.86	2.00	223.86
*MW-A9d	212.50	12.00	200.50
*MW-BP6	208.39	8.94	199.45
*MW-K1	205.56	9.58	195.98
*MW-AS1	205.30	9.53	195.77
*MW-AS2	205.18	10.38	194.80
*MW-AS3	207.52	15.98	191.54
*MW-S1	240.61	20.92	219.69

* elevatations measured on 7/23/1998

APPENDIX A
LOCATION OF AREAS OF CONCERN


DRAINAGE SYSTEM ALLEY-WAY (AOC #1)
PARKING AREA
IMPACTED AREAS (AREA 1-4)
SIDEWALK
STORAGE
SUMP
METAL BLDG.
FORMER PRINTED CIRCUIT BOARD MANUFACTURING AREA
HALLWAY
HALLWAY
PARKING AREA
ALCATEL MAIN BUILDING
LEGEND
SOIL IMPACT AREA
AREA OF CONCERN (AOC) #1
Graphic Scale (FT)
Wilmington, NC
1 3/95 ISSUED FOR RFI REPORT
0 7/94 ORIGINAL ISSUE
H.LYON
K.FAIRCLOTH
5/31/94
NOTED
ALCATEL NETWORK SYSTEMS
Raleigh, NC
RFI
Location Of Impacted Areas
058009
P:\058\058-9003
1



REV.	DATE	DESCRIPTION
1	2/96	ISSUED FOR RFI REPORT
0	7/94	ORIGINAL ISSUE

NATIONAL ENVIRONMENTAL TECHNOLOGIES, INC.

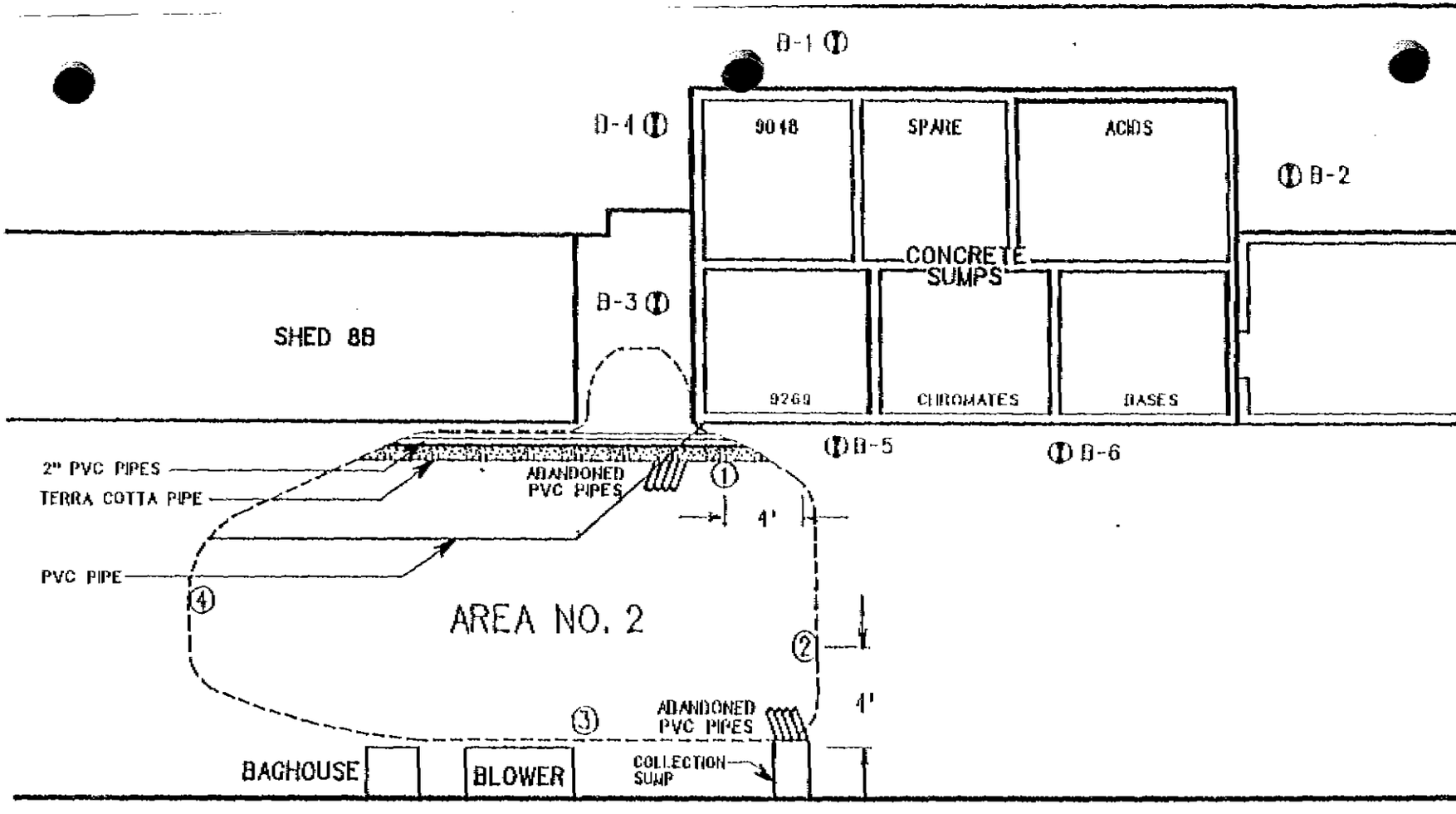
Wilmington, NC

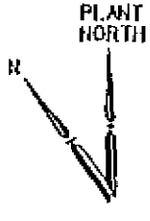
PROJECT MGR. H.LYON
DRAWN K.FAIRCLOTH
CHECKED
DATE 6/2/94
SCALE NOTED

CLIENT/TITLE
ALCATEL NETWORK SYSTEMS
Raleigh, NC

RFI
Area 3

PROJECT NO. 058009
SHEET NO. P:\058\058-9R04
REV. 1





NOTE: NORTH IN THE TEXT REFERS TO THE TOP OF THE FIGURE TO FACILITATE DESCRIPTIONS

MAIN BUILDING

KEY

1. SAMPLE NO. 1 - DEPTH 5'-0"
2. SAMPLE NO. 2 - DEPTH 5'-0"
3. SAMPLE NO. 3 - CORNER OF BLOWER DEPTH 8'-0"
4. SAMPLE NO. 4 - DEAD CENTER, DEPTH 8'-0"

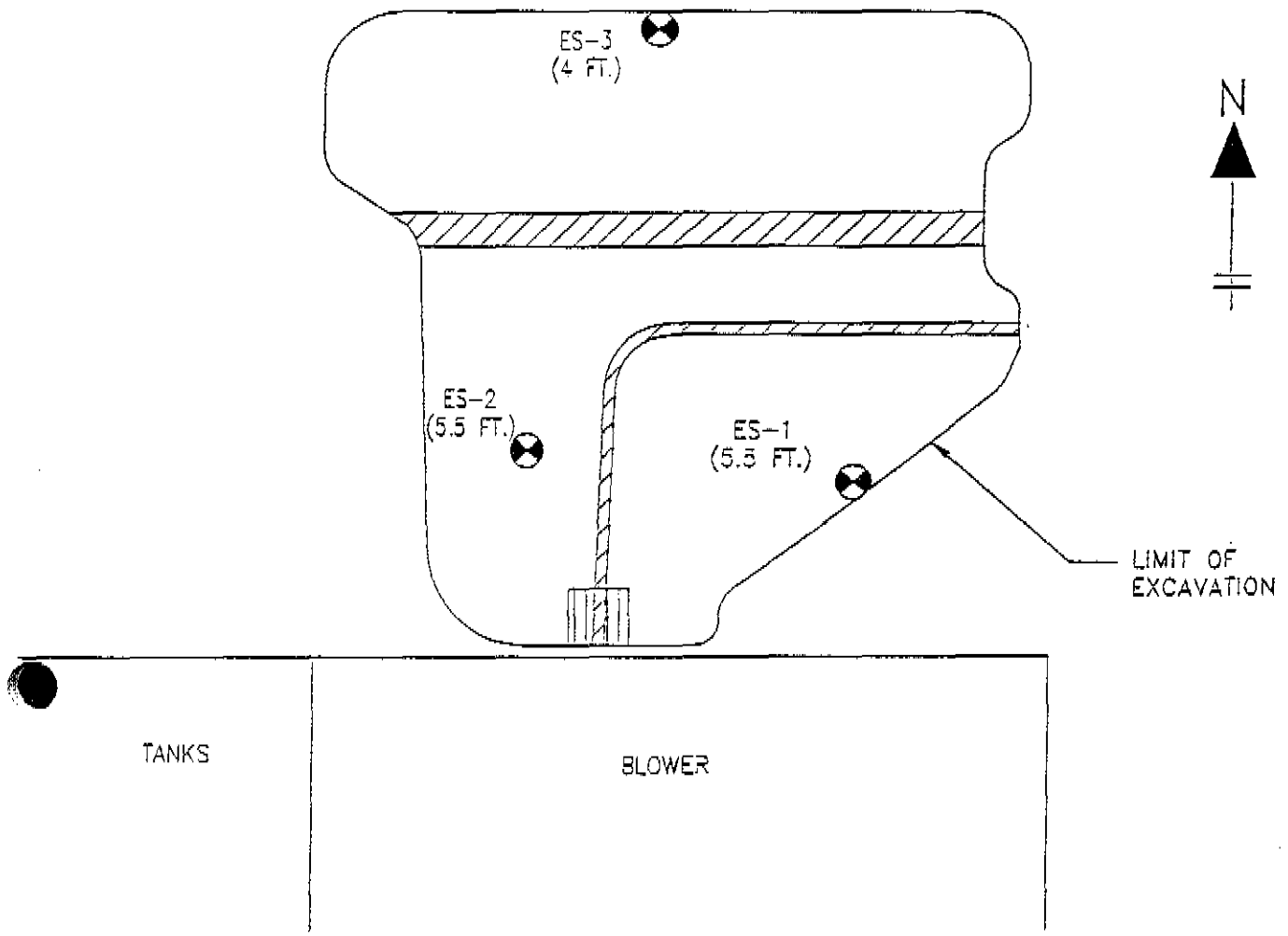
B SOIL BORING LOCATIONS

Westinghouse Environmental And Geotechnical Services, Inc.

AREA NO. 2
ALCATEL NETWORK SYSTEMS
RALEIGH, N.C.

PROJECT NO. 415-90-502	2
CHECKED BY: PBT	SCALE: 1" = 10'
DRAWN BY: DOW	DATE: 7-20-90

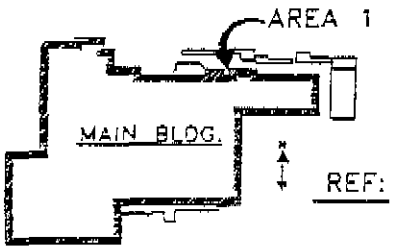
REV.	DATE	DESCRIPTION
	7/94	ORIGINAL ISSUE
1	2/96	ISSUED FOR RFI REPORT



LEGEND

PIPES

SOIL SAMPLING LOCATION



KEY PLAN

REF: DWG. #058001R02
NET REPORT: 058001 (FEB. 1991)
MODIFICATION OF WESTINGHOUSE FIG. 2
FOR MAY REPORT (MAY 1990)
EXCAVATION FILLED FOLLOWING SAMPLING.

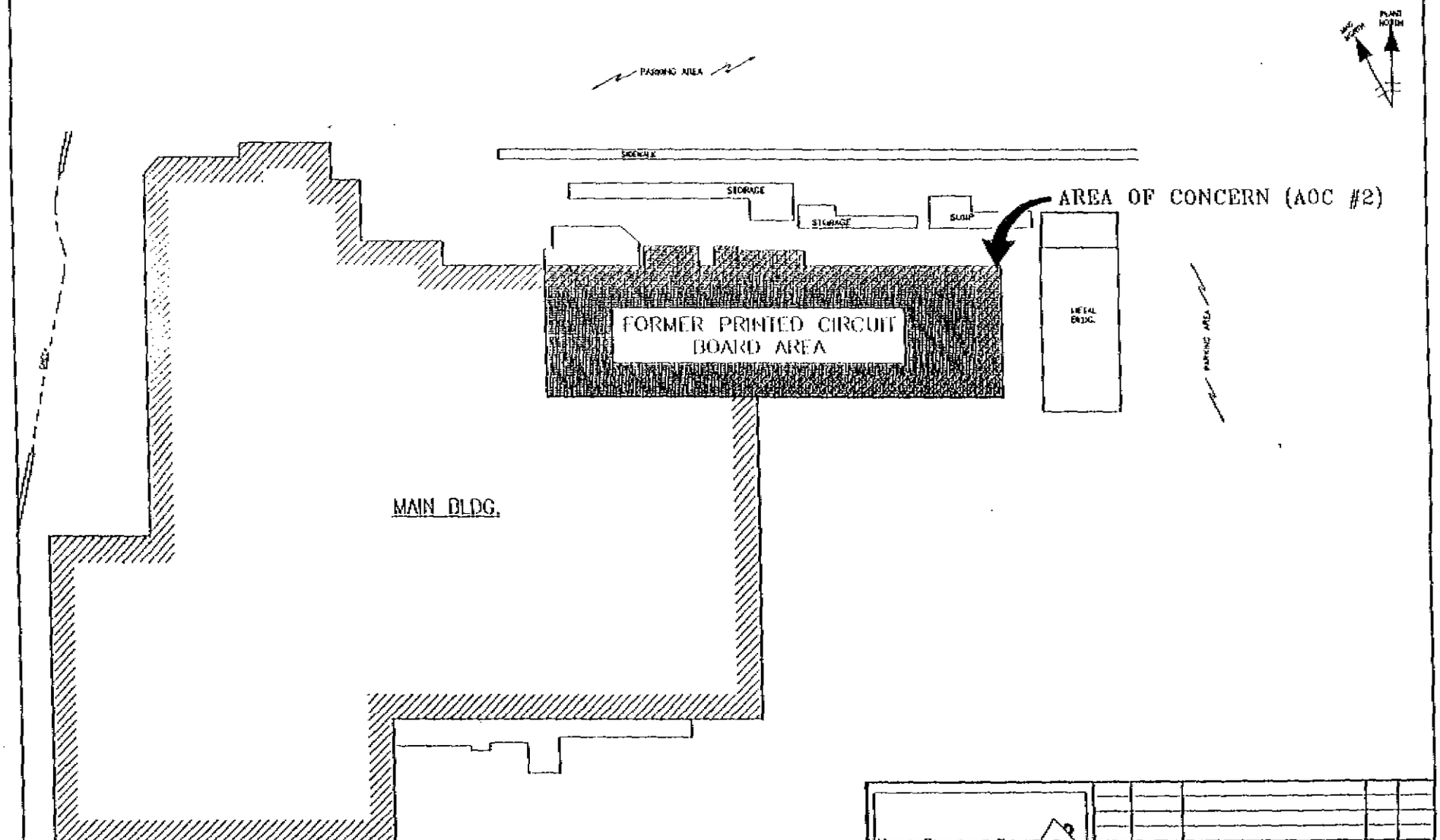
APPROX. GRAPHIC SCALE (FT.)

0 1 2 3 4

NATIONAL ENVIRONMENTAL TECHNOLOGIES, INC.

Wilmington, NC

PROJECT MGR.	H.LYON
DRAWN	K.FAIRCLOTH
CHECKED	
DATE	6/2/94
SCALE	NOTED
CLIENT/TITLE	ALCATEL NETWORK SYSTEMS Raleigh, NC
	RFI Area 1
PROJECT NO.	058009
SHT. No.	P:\058\058-9R02
REV.	1



APPROX. SCALE

0 10 20 30

Graphic Scale (ft)

Nanoco Environmental Technologies, Inc.
Wilmington, NC

NUMBER	DATE	DESCRIPTION	BY	APPR.
1	2/94	ISSUED FOR RFI REPORT		
0	3/93	ORIGINAL ISSUE		

PROJECT MANAGER: H. LYON

DRAWN: K.FAIRCLOTH

DATE: 6/20/94

SCALE: NOTED

SUBJECT: ALCATEL NETWORK SYSTEMS
Raleigh, NC
RFI

TITLE: Former Printed Circuit Board Area

PROJECT NO.: 058009

FILE NO.: P:\058\058-9R05

REV: 1

APPENDIX B
WELL COMPLETION FORM (GW-1) AND SELECTED BORING LOGS

North Carolina - Department of Environment, Health, and Natural Resources
Division of Environmental Management - Groundwater Section
P.O. Box 29535 - Raleigh, N.C. 27626-0535
Phone (919) 733-3221

FOR OFFICE USE ONLY
QUAD. NO. SERIAL NO.
Lat. Long. RO
Minor Basin
Basin Code
Header Ent. GW-1 Ent.

WELL CONSTRUCTION RECORD

DRILLING CONTRACTOR: American Env. Drilling

DRILLER REGISTRATION NUMBER: 1436

STATE WELL CONSTRUCTION PERMIT NUMBER: MW-15d

1. WELL LOCATION: (Show sketch of the location below)
Nearest Town: Raleigh County: Wake
Wake Forest Road
(Road, Community, or Subdivision and Lot No.)

2. OWNER PEPSI Cola Bottling of Raleigh
ADDRESS 2838 Wake Forest Road
(Street or Route No.)
Raleigh, N.C. 27609
City or Town State Zip Code

3. DATE DRILLED 7/14/98 USE OF WELL MW
4. TOTAL DEPTH 77 ft.
5. CUTTINGS COLLECTED YES [x] NO [ ]
6. DOES WELL REPLACE EXISTING WELL? YES [ ] NO [x]
7. STATIC WATER LEVEL Below Top of Casing: 12 FT.
(Use "+" if Above Top of Casing)
8. TOP OF CASING IS 0 FT. Above Land Surface*
* Casing Terminated at/or below land surface is illegal unless a variance is issued in accordance with 15A NCAC 2C .0118
9. YIELD (gpm): n/a METHOD OF TEST
10. WATER ZONES (depth): n/a

DEPTH From	To	DRILLING LOG Formation Description
0	23	alluvium (fine sand gravel
23	27	alluvium (gravel & cobbles
27	47	alluvium (fine gravel sand
47	55	alluvium (fine gravel sand
55	77	Bedrock

If additional space is needed use back of form

11. CHLORINATION: Type n/a Amount

12. CASING:

	Depth From	To	Diameter	Wall Thickness or Weight/Ft.	Material
	0	60	6	sch. 40	PVC

13. GROUT:

Depth From	To	Material	Method
0	52	grout	slurry
52	62	bentonite	

14. SCREEN:

Depth From	To	Diameter	Slot Size	Material
62	77	2 in.	.010 in.	PVC
		in.	in.	
		in.	in.	

15. SAND/GRAVEL PACK:

Depth From	To	Size	Material
62	77		silica sand

LOCATION SKETCH
(Show direction and distance from at least two State Roads, or other map reference points)

SEE BACK

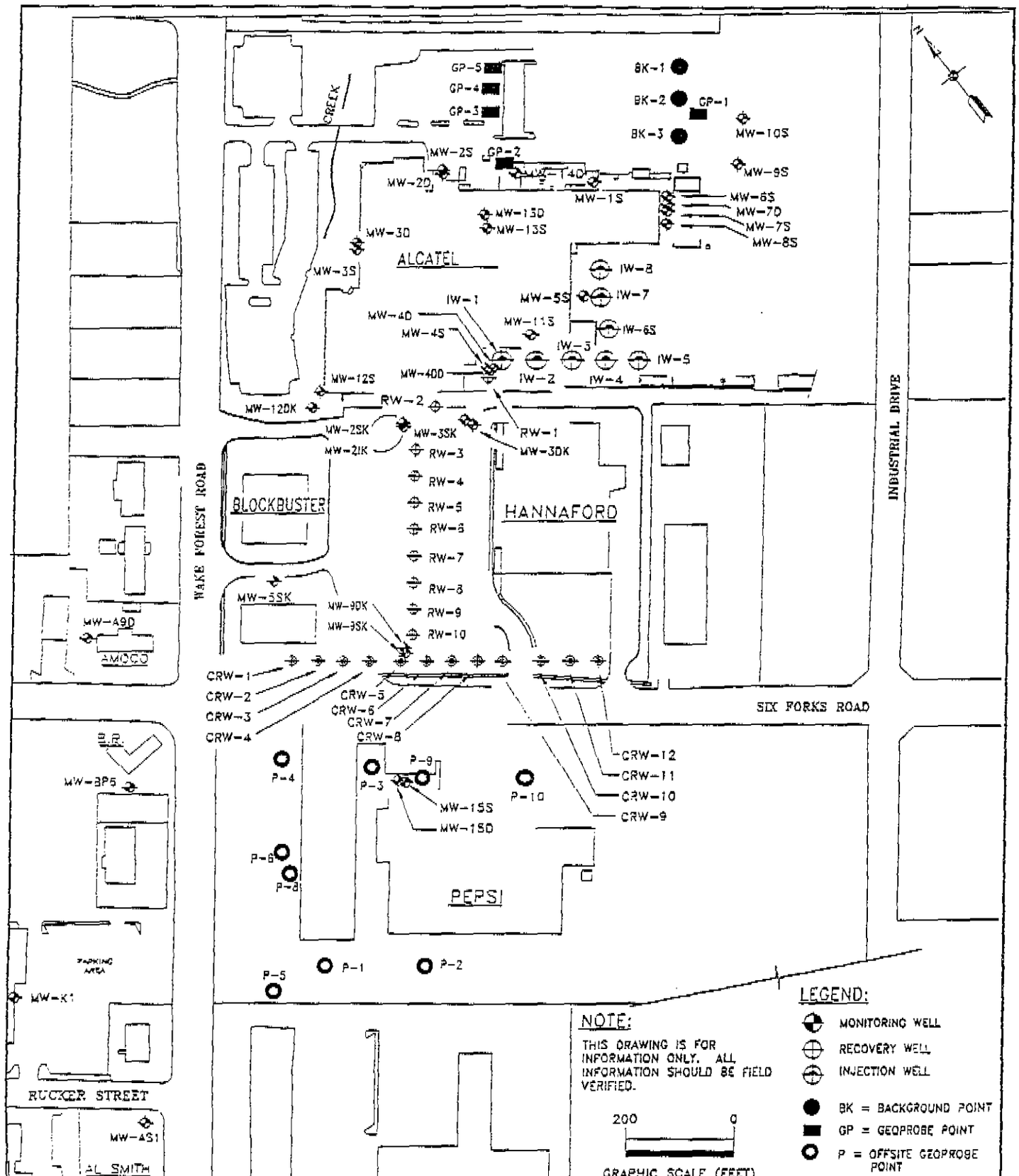
16. REMARKS:

I DO HEREBY CERTIFY THAT THIS WELL WAS CONSTRUCTED IN ACCORDANCE WITH 15A NCAC 2C, WELL CONSTRUCTION STANDARDS, AND THAT A COPY OF THIS RECORD HAS BEEN PROVIDED TO THE WELL OWNER.

SIGNATURE OF CONTRACTOR OR AGENT DATE

Submit original to Division of Environmental Management and copy to well owner.

GW-1 REV. 9/91



TRIANGLE ENVIRONMENTAL INC.

RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

ALCATEL NETWORK SYSTEMS, INC.
Raleigh, NC

BACKGROUND VOCS AND METALS, AND OFFSITE GEOPROBE LOCATIONS – FIGURE 4

FILE:P:\058\0209\0209RFI2 | PROJ.#01-003-0209 | DATE 10/98

North Carolina - Department of Environment, Health, and Natural Resources
Division of Environmental Management - Groundwater Section
P.O. Box 29535 - Raleigh, N.C. 27626-0535
Phone (919) 733-3221

FOR OFFICE USE ONLY
QUAD. NO. SERIAL NO.
Lat. Long. RO
Minor Basin
Basin Code
Header Ent. GW-1 Ent.

WELL CONSTRUCTION RECORD

DRILLING CONTRACTOR: American Env. Drilling

DRILLER REGISTRATION NUMBER: 1436

STATE WELL CONSTRUCTION PERMIT NUMBER: MW-15s

1. WELL LOCATION: (Show sketch of the location below)
   Nearest Town: Raleigh County: Wake
   Wake Forest Road
   (Road, Community, or Subdivision and Lot No.)
2. OWNER PEPSI Cola Bottling of Raleigh
   ADDRESS 2838 Wake Forest Road
   (Street or Route No.)
   Raleigh, N.C. 27609
   City or Town State Zip Code
3. DATE DRILLED 6/29/98 USE OF WELL MW
4. TOTAL DEPTH 23 ft.
5. CUTTINGS COLLECTED YES [x] NO [ ]
6. DOES WELL REPLACE EXISTING WELL? YES [ ] NO [x]
7. STATIC WATER LEVEL Below Top of Casing: 12 FT.
   (Use "-" if Above Top of Casing)
8. TOP OF CASING IS 0 FT. Above Land Surface*
   * Casing Terminated at/or below land surface is illegal unless a variance is issued in accordance with 15A NCAC 2C .0118
9. YIELD (gpm): n/a METHOD OF TEST n/a
10. WATER ZONES (depth): n/a
11. CHLORINATION: Type n/a Amount
12. CASING:

	Depth From	Depth To	Diameter	Wall Thickness or Weight/Ft.	Material
	0	5	2	sch. 40	PVC

13. GROUT:

	Depth From	Depth To	Material	Method
	2	4	bentonite	
	1	2	grout	slurry

14. SCREEN:

	Depth From	Depth To	Diameter	Slot Size	Material
	5	22	2 in.	.010 in.	PVC
			in.	in.	
			in.	in.	

15. SAND/GRAVEL PACK:

	Depth From	Depth To	Size	Material
	4	22	12-20	fine silica sand

16. REMARKS:

DEPTH From To	DRILLING LOG Formation Description
0 - 23	alluvium
refusal at 23'	

If additional space is needed use back of form

LOCATION SKETCH
(Show direction and distance from at least two State Roads, or other map reference points)

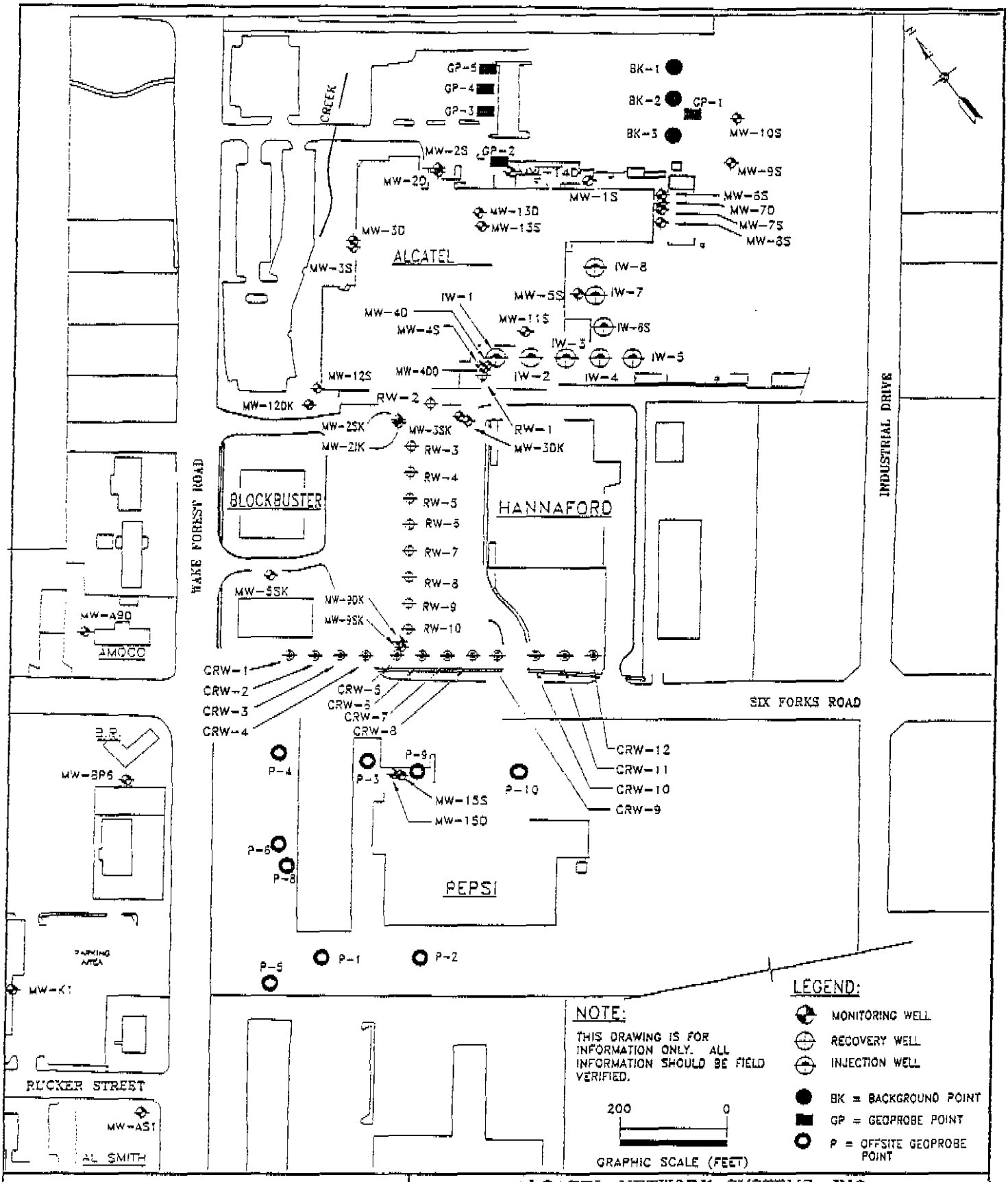
SEE BACK

I DO HEREBY CERTIFY THAT THIS WELL WAS CONSTRUCTED IN ACCORDANCE WITH 15A NCAC 2C, WELL CONSTRUCTION STANDARDS, AND THAT A COPY OF THIS RECORD HAS BEEN PROVIDED TO THE WELL OWNER.

SIGNATURE OF CONTRACTOR OR AGENT DATE

Submit original to Division of Environmental Management and copy to well owner.

GW-1 REV. 9 91



TRIANGLE ENVIRONMENTAL INC.

RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

ALCATEL NETWORK SYSTEMS, INC.
Raleigh, NC

BACKGROUND VOCS AND METALS, AND OFFSITE GEOPROBE LOCATIONS – FIGURE 4

FILE:P:\058\0209\0209RF12 | PROJ.#01-003-0209 | DATE: 10/98

Division of Environmental Management - Groundwater Section
P.O. Box 29535 - Raleigh, N.C. 27626-0535
Phone (919) 733-3221

WELL CONSTRUCTION RECORD

DRILLING CONTRACTOR: Geologic Exploration, Inc.

FOR OFFICE USE ONLY
QUAD NO _____ SERIAL NO _____
Lat _____ Long _____ RO _____
Minor Basin _____
Basin Code _____
Header Ent _____ GW-1 Ent _____

STATE WELL CONSTRUCTION
DRILLER REGISTRATION NUMBER: 1175 PERMIT NUMBER: N/A

1. WELL LOCATION: (Show sketch of the location below)

Nearest Town: RALEIGH County: WAKE

2912 WAKE FOREST RD
(Road, Community, or Subdivision and Lot No.)

2. OWNER ALCATEL NETWORK SYSTEMS

ADDRESS 2912 WAKE FOREST RD
(Street or Route No.)

RALEIGH NC 27609
City or Town State Zip Code

3. DATE DRILLED 8-20-97 USE OF WELL MONITOR
4. TOTAL DEPTH 142.0 FEET
5. CUTTINGS COLLECTED YES |X| NO | |
6. DOES WELL REPLACE EXISTING WELL? YES |_| NO |X|
7. STATIC WATER LEVEL Below Top of Casing: _____ FT
(Use "+" if Above Top of Casing)
8. TOP OF CASING IS 0.0 FT Above Land Surface*

***Casing Terminated at/or below land surface is illegal unless a variance is issued in accordance with 15A NCAC 2C .0118**

9. YIELD (gpm): N/A METHOD OF TEST N/A
10. WATER ZONES (depth): N/A

11. CHLORINATION: Type N/A Amount N/A
12. CASING:

Depth From	Depth To	Diameter	Wall Thickness or Weight/Ft.	Material
0.0	132.0	2 INCH	SCH 40	PVC
0.0	87.0	6 1/4 INCH	.188	GALVANIZED
0.0	26.0	10 INCH	SCH 40	PVC

13. GROUT:

Depth From	Depth To	Material	Method
0.0	74.0	PORTLAND BENTONITE	SLURRY
0.0	87.0	PORTLAND BENTONITE	SLURRY

14. SCREEN:

Depth From	Depth To	Diameter	Slot Size	Material
132.0	142.0	2.0 in.	.010 in.	PVC
		in.	in.	
		in.	in.	

15. SAND/GRAVEL PACK:

Depth From	Depth To	Size	Material
130.0	142.0	12-20	FINE SILICA SAND

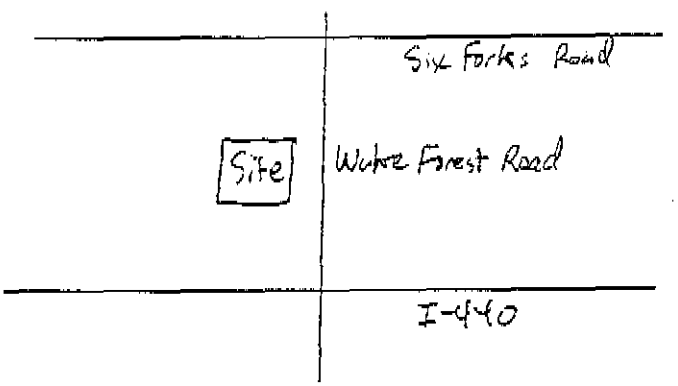
DEPTH — DRILLING LOG

From	To	Formation Description
0.0'	10.0'	BROWN SANDY CLAY
10.0'	20.0'	BROWN SANDY WITH ROCK FRAGMENTS
20.0'	25.0'	TAN SAND (PWR)
25.0'	26.0'	GRAY GRANITE
26.0'	142.0'	GRAY/WHITE GRANITE

If additional space is needed use back of form

LOCATION OF SKETCH

(Show direction and distance from at least two State Roads, or othe map reference points.)



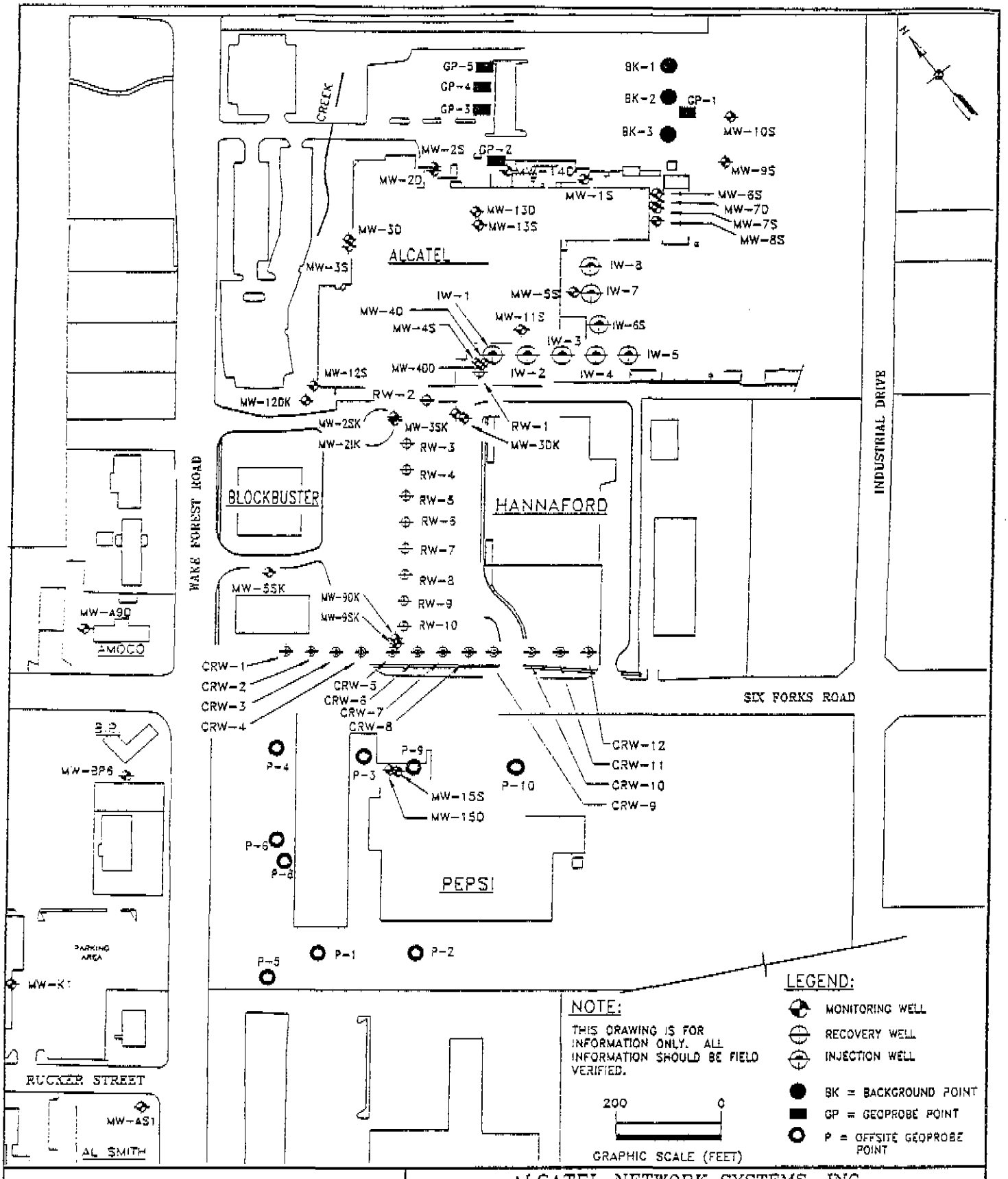
16. REMARKS: MW-4DD BENTONITE SEAL FROM 74.0 TO 130.0 FEET

I DO HEREBY CERTIFY THAT THIS WELL WAS CONSTRUCTED IN ACCORDANCE WITH 15A NCAC 2C, WELL CONSTRUCTION STANDARDS, AND THAT A COPY OF THIS RECORD HAS BEEN PROVIDED TO THE WELL OWNER.

Steve [illegible] 9-25-97
SIGNATURE OF CONTRACTOR OR AGENT DATE

GW-1 REV. 9/91

Submit original to Division of Environmental Management and copy to well owner.



TRIANGLE ENVIRONMENTAL INC.

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WILMINGTON, N.C.
CHARLOTTE, N.C.

ALCATEL NETWORK SYSTEMS, INC.
Raleigh, NC

BACKGROUND VOCS AND METALS, AND OFFSITE GEOPROBE LOCATIONS - FIGURE 4

FILE:P:\058\0209\0209RFI2 | PROJ.#01-003-0209 | DATE: 10/98

Division of Environmental Management - Groundwater Section
P.O. Box 29535 - Raleigh, N.C. 27626-0535
Phone (919) 733-3221

WELL CONSTRUCTION RECORD

DRILLING CONTRACTOR: Geologic Exploration, Inc.

FOR OFFICE USE ONLY	
QUAD NO	SERIAL NO
Lat	Long RO
Minor Basin	
Basin Code	
Header Ent	GW-1 Ent

STATE WELL CONSTRUCTION
DRILLER REGISTRATION NUMBER: 1175 PERMIT NUMBER:

1. WELL LOCATION: (Show sketch of the location below)

Nearest Town: RALEIGH County: WAKE

2912 WAKE FOREST RD
(Road, Community, or Subdivision and Lot No.)

2. OWNER ALCATEL NETWORK SYSTEMS

ADDRESS 2912 WAKE FOREST RD
(Street or Route No.)

RALEIGH NC 27609
City or Town State Zip Code

3. DATE DRILLED 8-22-97 USE OF WELL MONITOR
4. TOTAL DEPTH 56.0 FEET
5. CUTTINGS COLLECTED YES [X] NO [ ]
6. DOES WELL REPLACE EXISTING WELL? YES [ ] NO [X]
7. STATIC WATER LEVEL Below Top of Casing: FT
(Use "+" if Above Top of Casing)
8. TOP OF CASING IS 0.0 FT Above Land Surface*

*Casing Terminated at/or below land surface is illegal unless a variance is issued in accordance with 15A NCAC 2C .0118

9. YIELD (gpm): N/A METHOD OF TEST N/A
10. WATER ZONES (depth): N/A

11. CHLORINATION: Type N/A Amount N/A
12. CASING:

	Depth From	To	Diameter	Wall Thickness or Weight/Ft.	Material
	0.0	36.0	2 INCH	SCH 40	PVC
	0.0	30.0	5 1/4 INCH	.188	GALVANIZED

13. GROUT:

Depth From	To	Material	Method
0.0	27.0	PORTLAND BENTONITE	SLURRY
0.0	30.0	PORTLAND BENTONITE	SLURRY

14. SCREEN:

Depth From	To	Diameter	Slot Size	Material
36.0	56.0	2.0 in.	.010 in.	PVC
		in.	in.	
		in.	in.	

15. SAND/GRAVEL PACK:

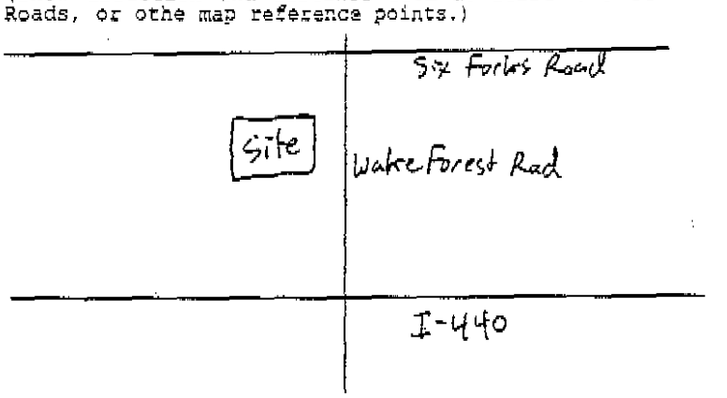
Depth From	To	Size	Material
33.0	56.0	12-20	FINE SILICA SAND

DEPTH From	To	DRILLING LOG Formation Description
0.0'	7.0'	CONCRETE/FILL
7.0'	25.0'	BROWN SILTY CLAY
25.0'	27.0'	GRAY BROWN SAND
27.0'	56.0'	GRAY GRANITE

If additional space is needed use back of form

LOCATION OF SKETCH

(Show direction and distance from at least two State Roads, or othe map reference points.)



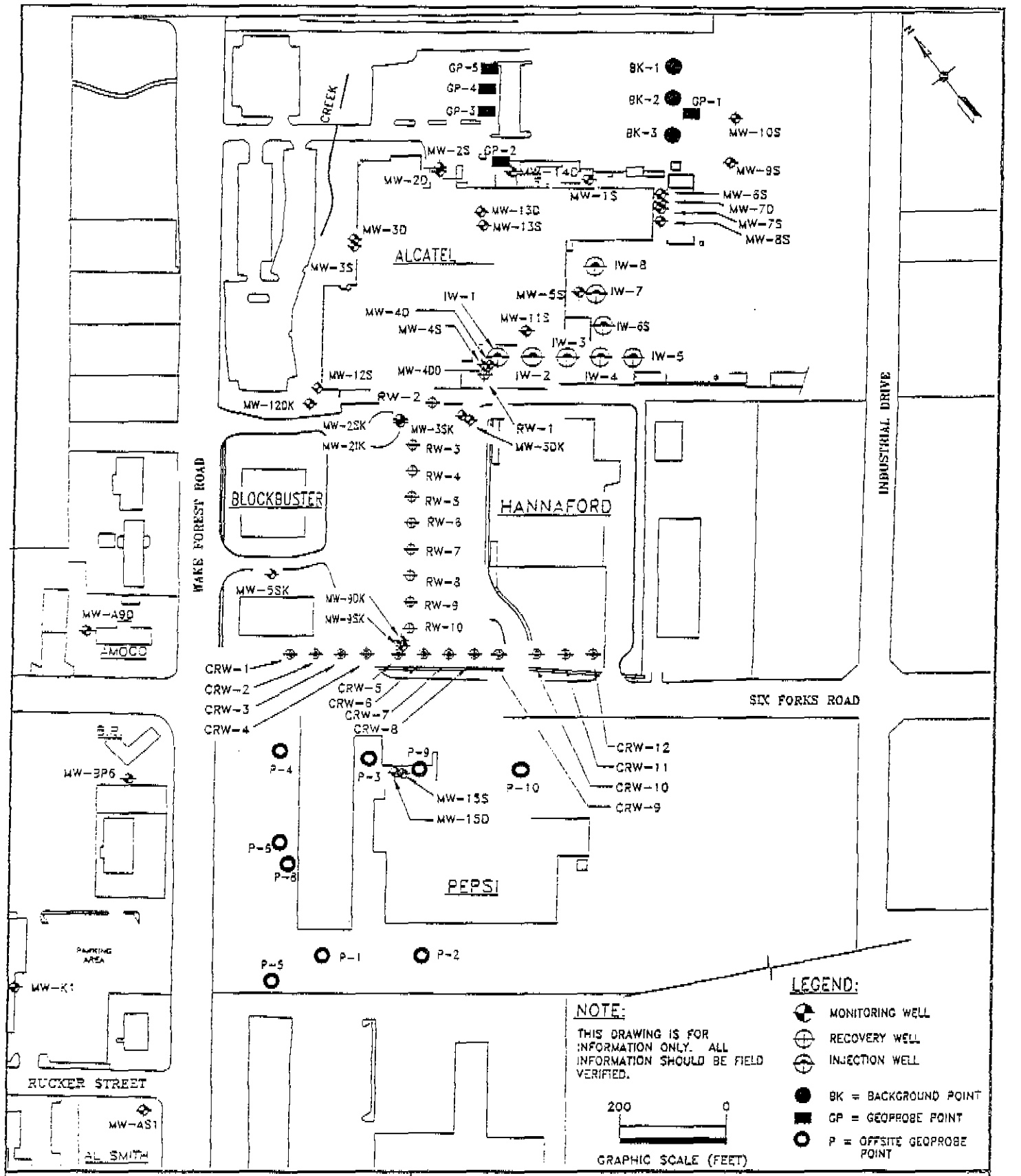
16. REMARKS: MW-14D BENTONITE SEAL FROM 27.0 TO 33.0 FEET

I DO HEREBY CERTIFY THAT THIS WELL WAS CONSTRUCTED IN ACCORDANCE WITH 15A NCAC 2C, WELL CONSTRUCTION STANDARDS, AND THAT A COPY OF THIS RECORD HAS BEEN PROVIDED TO THE WELL OWNER.

SIGNATURE OF CONTRACTOR OR AGENT 9-25-97 DATE

GW-1 REV. 9/91

Submit original to Division of Environmental Management and copy to well owner.



TRIANGLE ENVIRONMENTAL INC.
RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

ALCATEL NETWORK SYSTEMS, INC.
Raleigh, NC

BACKGROUND VOCS AND METALS, AND OFFSITE GEOPROBE LOCATIONS - FIGURE 4

FILE:P:\058\0209\0209RF12 | PROJ.#01-003-0209 | DATE 10/98

Division of Environmental Management - Groundwater Section
P.O. Box 29535 - Raleigh, N.C. 27626-0535
Phone (919) 733-3221

WELL CONSTRUCTION RECORD

DRILLING CONTRACTOR: Geologic Exploration, Inc.

FOR OFFICE USE ONLY
QUAD NO _____ SERIAL NO _____
Lat _____ Long _____ RO _____
Minor Basin _____
Basin Code _____
Header Ent _____ GW-1 Ent _____

STATE WELL CONSTRUCTION
DRILLER REGISTRATION NUMBER: 1175 PERMIT NUMBER: _____

1. WELL LOCATION: (Show sketch of the location below)

Nearest Town: RALEIGH County: WAKE

2912 WAKE FOREST RD
(Road, Community, or Subdivision and Lot No.)

2. OWNER ALCATEL NETWORK SYSTEMS

ADDRESS 2912 WAKE FOREST RD
(Street or Route No.)

RALEIGH NC 27609
City or Town State Zip Code

3. DATE DRILLED 8-23-97 USE OF WELL MONITOR
4. TOTAL DEPTH 35.0 FEET
5. CUTTINGS COLLECTED YES |X| NO | |
6. DOES WELL REPLACE EXISTING WELL? YES | | NO |X|
7. STATIC WATER LEVEL Below Top of Casing: 22.0 FT
(Use "+" if Above Top of Casing)
8. TOP OF CASING IS 0.0 FT Above Land Surface*

***Casing Terminated at/or below land surface is illegal unless a variance is issued in accordance with 15A NCAC 2C .0118**

9. YIELD (gpm): N/A METHOD OF TEST N/A
10. WATER ZONES (depth): N/A
11. CHLORINATION: Type N/A Amount N/A
12. CASING:

Depth From	Depth To	Diameter	Wall Thickness or Weight/Ft.	Material
0.0	27.5 Ft.	1 INCH	.188	CARBON STEEL
	Ft.			
	Ft.			

13. GROUT:

Depth From	Depth To	Material	Method
0.0	27.5 Ft.	PORTLAND BENTONITE	SLURRY
	Ft.		

14. SCREEN:

Depth From	Depth To	Diameter	Slot Size	Material
	Ft.	in.	in.	
	Ft.	in.	in.	
	Ft.	in.	in.	

15. SAND/GRAVEL PACK:

Depth From	Depth To	Size	Material
	Ft.		
	Ft.		

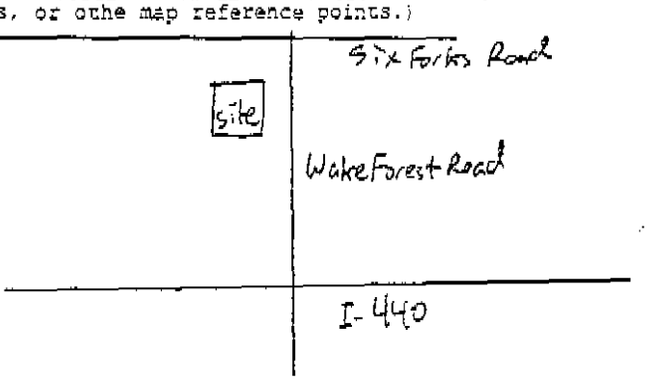
16. REMARKS: ~~RW-1~~ MW-13d OPEN HOLE COMPLETION FROM 27.5 FEET TO 35.0 FEET.

DEPTH From	DEPTH To	DRILLING LOG Formation Description
0.0'	1.0'	CONCRETE/GRAVEL
1.0'	16.0'	ORANGE RED SANDY SILT
16.0'	16.5	QUARTZ
16.5'	27.5'	ORANGE TAN SANDY SILT
27.5'	35.0'	WHITE QUARTZ-WHITE BLACK GRANITE

If additional space is needed use back of form

LOCATION OF SKETCH

(Show direction and distance from at least two State Roads, or othe map reference points.)

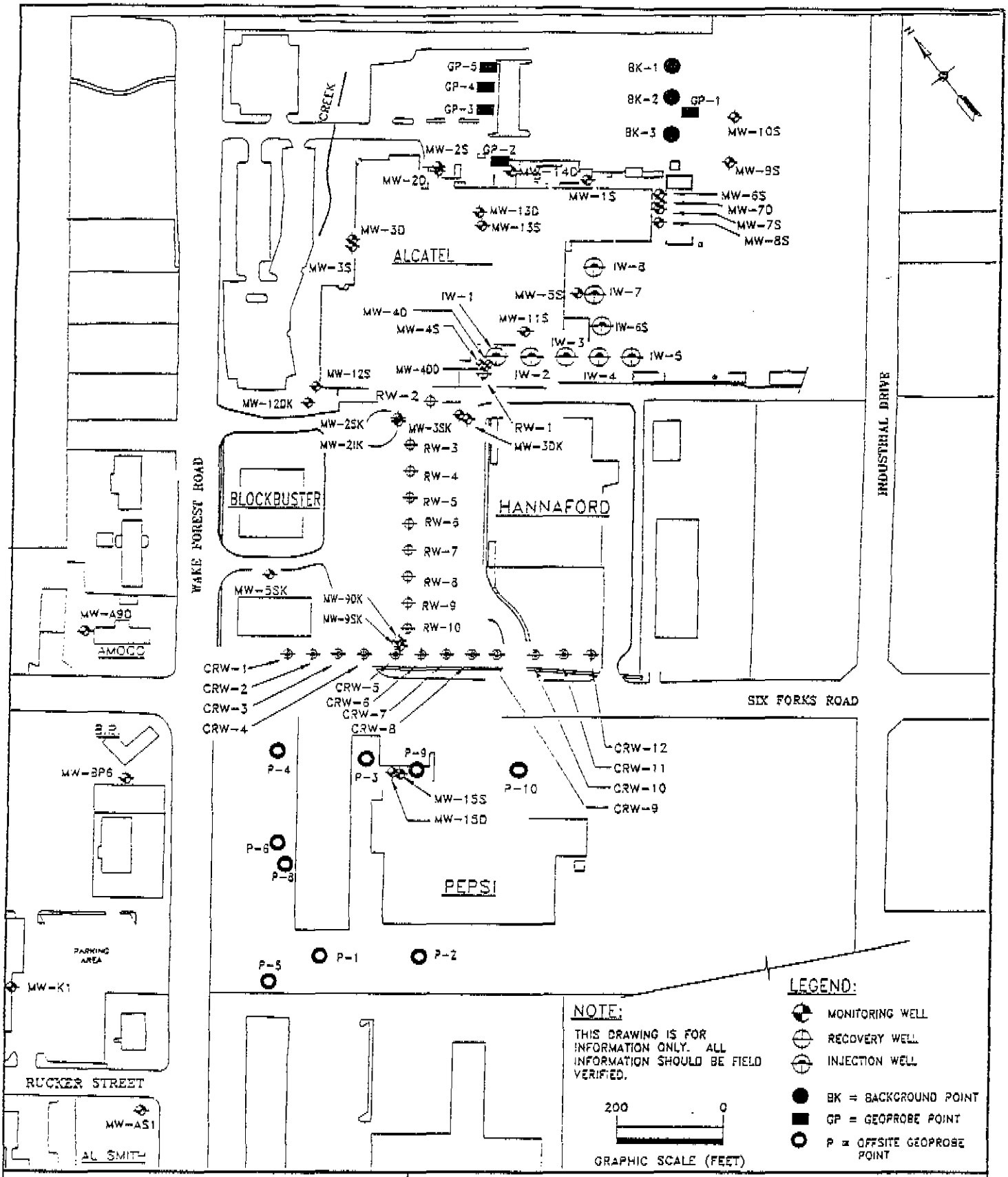


I DO HEREBY CERTIFY THAT THIS WELL WAS CONSTRUCTED IN ACCORDANCE WITH 15A NCAC 2C, WELL CONSTRUCTION STANDARDS, AND THAT A COPY OF THIS RECORD HAS BEEN PROVIDED TO THE WELL OWNER.

Steve Z 9-25-97
SIGNATURE OF CONTRACTOR OR AGENT DATE

GW-1 REV. 9/91

Submit original to Division of Environmental Management and copy to well owner.



TRIANGLE ENVIRONMENTAL INC.

RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

ALCATEL NETWORK SYSTEMS, INC.
Raleigh, NC

BACKGROUND VOCS AND METALS, AND OFFSITE GEOPROBE LOCATIONS – FIGURE 4

FILE:P:\058\0209\0209RFI2 | PROJ.#01-003-0209 | DATE: 10/99

BORING LOG

BORING NO. *P-1*		PAGE *1* OF *1*	
LOCATION: *Pepsi Bottling of Raleigh*	DATE COMPLETED: *4/7/98*	PROJECT No. *01-003-0109*	
TOTAL DEPTH (FT.): *11'*	GRDWTR. DEPTH: *~9'*	SCREEN DEPTH: *none*	LOGGED BY: *MHH*
GROUND ELEV. (MSL): -	T/C ELEV (MSL): -	SCREEN INTER.	CHECKED BY:

DEPTH (FEET)	ELEV. (MSL)	UNIFIED CLASSIFICATION	LITH-OLOGY	BLW CNT (/FT)	SAMPLE NO.	SI	COMMENTS
		Gray to Tan Silty Micaceous Sand (SM)					
4							
		Gray to Tan Silty Micaceous Sand (SM)					*Alluvium*
8							
		Gray Clayey Micaceous Sand (SC)					*Water Elev. ~9'*
							Alluvium
12		*Boring Terminated at 12'*					

EQUIPMENT: GEOPROBE

NOTES: SI - SCREEN INTERVAL -
ALL DEPTHS SHOWN IN FEET. -
MSL - MEAN SEA LEVEL (FT.) -

Form Prepared By KF

TRIANGLE ENVIRONMENTAL INC.

RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

BORING LOG

BORING NO. P-2		PAGE 1 OF 1	
LOCATION: Pepsi Bottling of Raleigh	DATE COMPLETED: 4/7/98	PROJECT No. 01-003-0109	
TOTAL DEPTH (FT.): 19'	GRDWTR. DEPTH: ~10'	SCREEN DEPTH: none	LOGGED BY: MHH
GROUND ELEV. (MSL): -	T/C ELEV (MSL): -	SCREEN INTER.	CHECKED BY:

DEPTH (FEET)	ELEV. (MSL)	UNIFIED CLASSIFICATION	LITH-OLOGY	BLW CNT (/FT)	SAMPLE NO.	SI	COMMENTS
		Silty to Clayey Micaceous Sand (SM-SC)					
6		Gray-Tan Clay (CL)					
7		Silty to Clayey Micaceous Sand (SM-SC)					
9		Gray-Tan Clay (CL)					Water Elev. ~10'
							Alluvium
12		Gray Clay (CL)					
15		Silty to Clayey Micaceous Sand (SM-SC)					
20		Boring Terminated at 20'					

EQUIPMENT: GEOPROBE

NOTES: SI - SCREEN INTERVAL -
ALL DEPTHS SHOWN IN FEET. -
MSL - MEAN SEA LEVEL (FT.) -
-

Form Prepared By KF

TRIANGLE ENVIRONMENTAL INC.
RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

BORING LOG

BORING NO. *P-3*		PAGE *1* OF *1*	
LOCATION: *Pepsi Bottling of Raleigh*	DATE COMPLETED: *4/7/98*	PROJECT No. *01-003-0109*	
TOTAL DEPTH (FT.): *19'*	GRDWTR. DEPTH: *~15'*	SCREEN DEPTH: *none*	LOGGED BY: *MHH*
GROUND ELEV. (MSL): –	T/C ELEV (MSL): –	SCREEN INTER.	CHECKED BY:

DEPTH (FEET)	ELEV. (MSL)	UNIFIED CLASSIFICATION	LITH-OLOGY	BLW CNT (/FT)	SAMPLE NO.	SI	COMMENTS
		Silty to Clayey Micaceous Sand (SM-SC)					
6		*Dark Gray to Brown Clay (CL)*					*Alluvium*
8		*Gray to Tan Sandy Clay (CL)*					*Water Elev. ~15'*
19		*Boring Terminated at 19'*					

EQUIPMENT: GEOPROBE

NOTES: SI – SCREEN INTERVAL –
ALL DEPTHS SHOWN IN FEET. –
MSL – MEAN SEA LEVEL (FT.) –
Form Prepared By KF –

TRIANGLE ENVIRONMENTAL INC.
RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

BORING LOG

BORING NO. *MW-4dd*		PAGE *1* OF *1*	
LOCATION: *Alcatel Network Systems*	DATE COMPLETED: *8/21/97*	PROJECT No. *01-003-0109*	
TOTAL DEPTH (FT.): *142*	GRDWTR. DEPTH: *100'*	SCREEN DEPTH: *132'*	LOGGED BY: *MHH*
GROUND ELEV. (MSL): -	T/C ELEV (MSL): -	SCREEN INTER. *132'-142'*	CHECKED BY:

DEPTH (FEET)	ELEV. (MSL)	UNIFIED CLASSIFICATION	LITH-OLOGY	BLW CNT (/FT)	SAMPLE NO.	SI	COMMENTS
		Sapprolite (SM-SC)					
20		*Partially Weathered Bedrock*					
25		*Granite*					
37		*Gneiss*					
49		*Granite*					
85		*Gneiss*					
97		*Granite*					*Water Elev. 100'*
102		*Granite*					
142		*End of Boring*					

EQUIPMENT: MUD ROTARY

NOTES: SI - SCREEN INTERVAL
ALL DEPTHS SHOWN IN FEET.
MSL - MEAN SEA LEVEL (FT.)

Form Prepared By KF

TRIANGLE ENVIRONMENTAL INC.
RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

BORING LOG

BORING NO. *MW-14d*	PAGE *1* OF *1*		
LOCATION: *Alcatel Network Systems*	DATE COMPLETED: *8/20/97*	PROJECT No. *01-003-0109*	
TOTAL DEPTH (FT.): *56'*	GRDWTR. DEPTH: *8'*	SCREEN DEPTH: *36'*	LOGGED BY: *MHH*
GROUND ELEV. (MSL): –	T/C ELEV (MSL): –	SCREEN INTER. *36'-56'*	CHECKED BY:

DEPTH (FEET)	ELEV. (MSL)	UNIFIED CLASSIFICATION	LITH-OLOGY	BLW CNT (/FT)	SAMPLE NO.	SI	COMMENTS
		Concrete/fill					
7							*Water Elev. 8'*
		Sapprolite (SM-SC)					
25							
		Partially Weathered Bedrock					
27							
		Bedrock-Granite					
56							
		End of Boring					

EQUIPMENT: MUD ROTARY

NOTES: SI – SCREEN INTERVAL –
ALL DEPTHS SHOWN IN FEET. –
MSL – MEAN SEA LEVEL (FT.) –
–

Form Prepared By KF

TRIANGLE ENVIRONMENTAL INC.

RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

BORING LOG

BORING NO. *MW-13d*	PAGE *1* OF *1*		
LOCATION: *Alcatel Network Systems*	DATE COMPLETED: *8/21/97*	PROJECT No. *01-003-0109*	
TOTAL DEPTH (FT.): *35'*	GRDWTR. DEPTH: *~11'*	SCREEN DEPTH: *none*	LOGGED BY: *MHH*
GROUND ELEV. (MSL): -	T/C ELEV (MSL): -	SCREEN INTER.	CHECKED BY:

DEPTH (FEET)	ELEV. (MSL)	UNIFIED CLASSIFICATION	LITH-OLOGY	BLW CNT (/FT)	SAMPLE NO.	SI	COMMENTS
1		*Concrete/fill*					
		Sapprolite SM to GM					*Water Elev. ~11'*
27		*Competant Bedrock-Granite*					
35		*End Of Boring*					

EQUIPMENT: SIMCOE

NOTES: SI - SCREEN INTERVAL -
ALL DEPTHS SHOWN IN FEET. -
MSL - MEAN SEA LEVEL (FT.) -
-

Form Prepared By KF

TRIANGLE ENVIRONMENTAL INC.

RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

BORING LOG

BORING NO. *MW-15d*	PAGE *1* OF *1*		
LOCATION: *Pepsi Bottling of Raleigh*	DATE COMPLETED: *7/14/98*	PROJECT No. *01-003-0209*	
TOTAL DEPTH (FT.): *77'*	GRDWTR. DEPTH: *~ 12'*	SCREEN DEPTH: *77'*	LOGGED BY: *NEB*
GROUND ELEV. (MSL): -	T/C ELEV (MSL): -	SCREEN INTER. *62-77'*	CHECKED BY:

DEPTH (FEET)	ELEV. (MSL)	UNIFIED CLASSIFICATION	LITH-OLOGY	BLW CNT (/FT)	SAMPLE NO.	SI	COMMENTS
		Alluvium micaceous Silty Sand (SM)					*Water Elev. ~12'*
23		*Alluvium Gravel & Cobble Sized Particles (GP)*					
27		*Alluvium Micaceous Silty Sand (SM)*					
47		*Alluvium Micaceous Silty Clayey Sandy Silt (SM-SC)*					
55		*Bedrock Granite*					
77	*End of boring with air rotary*						

EQUIPMENT: *mud rotary/air rotary*

NOTES: SI - SCREEN INTERVAL -
ALL DEPTHS SHOWN IN FEET. -
MSL - MEAN SEA LEVEL (FT.) -
-

Form Prepared By KF

TRIANGLE ENVIRONMENTAL INC.
RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

BORING LOG

BORING NO. *MW-15s*	PAGE *1* OF *1*		
LOCATION: *Pepsi Bottling of Raleigh*	DATE COMPLETED: *6/29/98*	PROJECT No. *01-003-0109*	
TOTAL DEPTH (FT.): *23'*	GRDWTR. DEPTH: *~12'*	SCREEN DEPTH: *23'*	LOGGED BY: *MHH*
GROUND ELEV. (MSL): –	T/C ELEV (MSL): –	SCREEN INTER. *5-23'*	CHECKED BY:

DEPTH (FEET)	ELEV. (MSL)	UNIFIED CLASSIFICATION	LITH-OLOGY	BLW CNT (/FT)	SAMPLE NO.	SI	COMMENTS
		Alluvium micaceous Silty Sand (SM)					*Water Elev. ~11'*
23		*Refusal at 23' with auger*					

EQUIPMENT: *Auger*

NOTES: SI – SCREEN INTERVAL –
ALL DEPTHS SHOWN IN FEET. –
MSL – MEAN SEA LEVEL (FT.) –
Form Prepared By KF –

TRIANGLE ENVIRONMENTAL INC.
RALEIGH, N.C.
WILMINGTON, N.C.
CHARLOTTE, N.C.

APPENDIX C
METHODOLOGIES

This section details the technical requirements and procedures for equipment, equipment decontamination, sample collection, and sample/data analysis.

A.1 Health and Safety Procedures for Facility Investigation

The Health and Safety Procedures are provided in the *RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994, Section 4.1 - Health and Safety Procedures for Facility Investigation.

A.2 Field Instrument Calibration Procedures

All field instruments were calibrated prior to use. The calibration was accomplished in accordance with standard manufacturer's instructions and schedules for the subject instrument(s) to assure that the equipment is functioning within tolerances established by the manufacturer. The calibration of the FID and PID, Specific Conductivity meter, pH meter, and temperature meter is described in detail in the *RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994, Section 4.2.1 through Section 4.2.4.

A.3 Procedures for Documentation of Field Activities

All document control, including the field notebook, sample identification, sample labels, and custodian forms was performed as described in the *RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994, Sections 4.3.1 through 4.3.2.

3.4 Soil Sampling and Analysis

3.4.1 Soil Sample Collection Procedure

Soil samples for laboratory and field screening analysis were collected using a stainless steel Geoprobe® soil sampler.

Discrete samples were collected at a predetermined depth using the Geoprobe MacroCore soil sampler. This technique uses a 2.0-inch O.D. by four-foot long stainless steel tube sampler. The borehole was advanced to a depth just above the desired sampling depth. The sampler was retrieved and cleaned, or replaced with a clean sampler prior to the collection of the sample.

The sampler is hydraulically pushed into the undisturbed soil for collection of the sample. Samples are collected in transparent "zero-contamination" sleeves. The top several inches of soil in each sampler shall be discarded to prevent cross-contamination. Each sample was field-characterized for color, grain size, odor, etc. This data was entered in the project field notebook.

Samples were collected in the order described in **Section 4.7: Order of Sample Collection.** The samples were stored and/or shipped in EPA-

approved containers. The location, depth, sample number and any other pertinent information were recorded in the field notebook for each sample. All reagents, containers and preservatives which will be associated with the laboratory sample were prepared by the analytical laboratory prior to shipping sample containers to the site. Samples collected for laboratory analysis were immediately be maintained on ice in coolers in preparation for transport to the analytical laboratory.

3.4.2 Equipment Decontamination

Equipment used for soil sampling (e.g., hand auger, sampling spoon, compositing bucket) will be decontaminated upon arrival at the site and between borings according to the following procedure:

1. Pressure rinse with tap water to remove large particulate matter,
2. Wash with Alconox solution, or equivalent. The interior and exterior of sampling equipment will be thoroughly scrubbed to remove particulate matter and/or surface films,
3. Thorough rinse with tap water to remove soap,
4. Allow to completely air dry,

Drilling equipment (hollow-stem auger, drilling rods, split-spoon sampler, etc.) and Geoprobe equipment (drive rods, samplers, etc.) will be decontaminated upon arrival at the site and between borings according to the following procedure:

1. Pressure rinse with tap water to remove large particulate matter,
2. Pressure wash with hot water (steam cleaning) and Alconox soap, or equivalent. The interior and exterior of sampling equipment will be thoroughly scrubbed to remove particulate matter and/or surface films,
3. Thorough rinse with hot water to remove all wash solution.

3.4.3 Sample Containers, Preservation, and Analytical Parameters

Soil samples will be collected and analyzed in a manner sufficient to

characterize potential soil contaminants. Constituents of concern are: Copper, lead, DCA, 2-DCA, DCE, TCA, 2-TCA, TCE, and PCE. Immediately after collection, each laboratory sample will be placed in a labeled, laboratory supplied container, maintained on ice (water or CO_2), and stored in a cooler. Sample containers and volumes will be consistent with the requirements of the analytical methodology. The samples will be individually packaged in bubble-wrap in order to reduce the possibility of container breakage.

3.4.4 Analytical Methods

All samples were be analyzed as specified in "Test Methods for Evaluating Solid Waste, EPA Publication SW-846 (Fourth Edition)." Soil samples were analyzed for selected VOCs by EPA Method 8260 and selected metals by Method. (Reference *RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994, Section 4.4.4 - Equipment Decontamination, page 37).

3.5 Ground Water Investigation

3.5.1 Monitoring Well Installation Procedures

All wells will be constructed in accordance with NCAC Title 15, Subchapter 2C, "Well Construction Standards Criteria and Standard Applicable to Water Supply and Certain Other Wells." Casing sizes and boring diameters may vary as appropriate.

The Type II wells were installed using mud rotary and hollow stem auger equipment. Soil cuttings and mud shall be examined and logged by the supervising field geologist. The wells, constructed of two-inch PVC casing and manufactured screen, shall be installed within the borehole. The annulus between the well and the wall of the borehole shall be backfilled with clean filter sand to a depth equivalent to two feet above the well screen. A two-foot

bentonite seal shall be placed atop the sand pack. The bentonite shall be allowed to hydrate for a minimum of one hour. The remaining annulus shall be backfilled with a neat Portland cement grout to the surface. The well head will be completed with a locking cap, concrete pad, and flush-mount, bolt-down cover.

Boreholes for the Type III wells were advanced using 6.25-inch I.D. hollow-stem auger or mud rotary equipment. The boreholes were advanced to the bedrock surface. The boreholes were advanced within the bedrock using mud rotary and air rotary hammer equipment. Cuttings were examined and logged by the supervising geologist.

A six-inch PVC surface casing shall be installed, anchored into the bedrock, and grouted in place. Once the grout has cured, a four-inch borehole was advanced into the bedrock using air rotary techniques, or other Division approved methods. One borehole into the bedrock will be cored. This core shall be examined for fractures, degree of weathering, lithology, etc. Once at the desired depth, a two-inch PVC well shall be installed within the open borehole. The annulus between the wall of the borehole and the well will be backfilled with sand to a depth approximately two feet above the top of the well screen. A bentonite seal, minimum five feet in thickness, shall be placed atop the filter pack. The bentonite will be allowed to hydrate for a minimum of three hours. The remaining annulus shall be backfilled to the surface with a neat Portland cement grout. The well head will be completed with a locking cap, concrete pad, and flush-mount, bolt-down cover.

The drilling rig shall be thoroughly steam cleaned prior to the initiation of drilling activities. All equipment (split-spoons, tremie pipes, etc.) was thoroughly decontaminated following the procedure described in **Section 4.4.4: Equipment Decontamination**. This procedure was repeated between boreholes.

The development of the wells was accomplished by manual and mechanical pumping. All equipment which may come into contact with water in the well shall be thoroughly decontaminated following the procedure described in **Section 4.5.4**. Development continued until the water is reasonably clear. The volume of purged water, its appearance, and monitoring values were recorded in the field notebook.

Cuttings produced during drilling were containerized separately in 55-gallon drums at the discretion of the supervising field geologist. The drums were labeled appropriately. The drums shall be stored on site pending receipt of laboratory analytical results for samples collected from the wells. Disposal of all contained materials shall be in accordance with applicable State and Federal regulations. Additional analyses may be required for waste characterization profiling.

Water generated during the drilling procedures as well as development and purge water was transferred to the treatment system influent through two 500 gallon High Density Polyethylene tanks.

(Reference *RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994, Section 4.5.1 - Monitoring Well Installation Procedures, page 39).

3.5.2 Ground Water Sampling and Analysis

3.5.2.1 Water Level Measurements

Prior to the collection of ground water samples from Geoprobe® points, open boreholes, or wells, and prior to the purging of wells for sampling, the depth to static water level was measured and recorded. Water levels were determined by lowering a measuring device to the water surface, and measuring the total distance between the water

surface and the reference point. For boreholes and Geoprobe® points, the water level measurement were taken after water has been allowed to equilibrate in the open borehole, or Geoprobe® point. The water level measurement will be referenced to the undisturbed ground surface for these points.

Prior to measuring the water level in wells, the wells will be opened and allowed to equilibrate for approximately one (1) hour before water level measurements are taken. The reference points for measurements in wells will be top of casing (T/C). In each measurement, the total distance, or depth, will be recorded to the nearest 0.01 foot. For each well, the depth to water value will be subtracted from the top of casing elevation to determine the water level elevation at the measuring point. Water level measurements for all wells for a given sampling event will be obtained within a one (1) hour period to reduce the effects of water level fluctuation trends.

The portion of the water level measuring device that will enter the well shall be decontaminated prior to and between each use according to the procedure documented in **Section 4.5.4** . (Reference *RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994, Section 4.5.2.2 - Water Level Measurements, page 43).

3.5.2.2 Ground Water Sample Collection from Geoprobe® Points/Open Boreholes

Water samples collected using Geoprobe method. This incorporated the use of a two-foot slotted intake sampler. Upon reaching the desired sampling depth, the sampler was attached and advanced at least 3 feet below the water table surface. Compressed nitrogen gas was then used

to "purge" the intake portion of the samplers and allow aquifer water to enter the intake interval.

A 1/4" O.D. (3/16" I.D.) flexible Polyethylene tubing was then inserted into the probe. Two methods of borehole development and sample collection were employed; 1) The sample tubing is in turn connected to ½" O.D. (1/4" I.D.) PVC hose attached to a peristaltic pump, and 2) a small stainless steel check valve was attached to the end of the tubing and the sample was collected by gently thrusting and withdrawing the tubing within the rods. The method selected depended upon the borehole yield.

Following probe development, a clean laboratory supplied 40 ml VOA vial is placed on the discharge end of the pump or tubing. A ground water sample is then drawn into the container in a manner such that sample agitation and volatilization of organic constituents is minimized. New tubing was used for each sample location. The sample is then placed in a previously prepared laboratory container and maintained on ice pending analysis.

3.5.2.3 Ground Water Sample Collection from Wells

Ground water samples were collected from each monitoring well (both new and existing) at the site. Prior to sampling, the water levels were measured according to the procedures described in **Sections 4.5.2.2**. The wells will be purged of a minimum of three (3) well volumes or until dry, whichever occurs first. Purging was accomplished by either manual bailing with a dedicated, disposable PVC bailer or pumping with a pneumatic pump. New tubing (when pumping) and rope (when bailing) are used If a pump is used, it will be thoroughly decontaminated prior to and between uses according to the procedures documented in **Section 4.5.4**. The volume of water in each two-inch

well shall be calculated per the following formula:

$$V = (\textit{length of water column in well}) * 0.163\ \textit{gal/ft.}$$

The volume of water purged from each well and any observations is recorded in the proper notebook. All purge water is containerized and transferred to the treatment system influent tank.

Sampling shall be performed as soon as practical following the purging or development of the wells. The samples shall be collected using dedicated, disposable, PVC bailers and dedicated nylon rope.

Samples shall be collected by slowly lowering the bailer in the well to a depth just beneath the surface of the water in the well. The bailer will be carefully retrieved and the sample shall be decanted into laboratory-supplied containers and clean containers for field screening. Once collected, laboratory samples shall immediately be maintained on ice. Following collection, each sample shall be field characterized for color, odor, etc. This data shall be entered in the project field notebook. The location, sample number, and other pertinent information shall also be recorded in the field notebook for each sample. Samples for metals analysis will not be filtered in the field, therefore, samples will not be preserved with acid.

The samples shall be stored and/or shipped in laboratory supplied containers. All reagents, containers and preservatives which will be associated with the laboratory analysis of samples will be prepared by the analytical laboratory prior to shipping sample container to the site. Samples collected for laboratory analysis will immediately be maintained on ice in coolers in preparation for transport to the analytical laboratory.(Reference *RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994, Section 4.5.2.5 - Ground Water

Sample Collection from Wells, page 44).

4.5.2.6 Packer Test Method

The packer test methodology for the isolation and sample collection of higher yielding water bearing zones was modified from the Packer Hydraulic Conductivity Test procedures outlined in the *Standard Handbook for Solid and Hazardous Waste Facility Assessments*, Chapter 5 - Environmental Testing and Chapter 6 - Fractured Rock Assessments (Martin Sara, 1993).

The double packer method using bottom pump placement will be applied during the construction of the telescoping borehole. The boring is drilled to the desired depth and 10" PVC casing is grouted in-place and allowed to set for twenty four hours. The six inch diameter air hammer hole is advanced to within two feet below the bottom of the water bearing zone. The drill rods are removed and replaced with the packer assembly. The assembly consists of two inflatable packers placed end-to-end connected to a two inch OD steel pipe and a submersible pump attached to the bottom of the pipe.

The packer assembly is lowered into the borehole to a depth near the top of the subject water bearing zone. Water level measurements are collected to determine the water level in the borehole. The packers are inflated to isolate the subject zone from other zones. The gas pressure is monitored and the borehole water level is measured for approximately 15 minutes. No significant changes in pressure and stabilization of the water level indicates that an adequate seal has been created and maintained.

The ground water is then evacuated from the borehole through the steel piping. The physical characteristics of the ground water, pH,

conductivity, and temperature, are periodically measured. Stabilization of these parameters indicate that the borehole water is representative of the aquifer. Samples will be collected for field screening procedures as outlined in **Section 4.5.2.7 Ground Water Field Screening** and for laboratory analyses as outlined in **Section 4.5.2.5: Ground Water Sample Collection from Wells**

4.5.2.7 Ground Water Field Screening

A portable SRI gas chromatograph instrument may be used for field screening analysis of ground water samples. The instrument provides detection of organic compounds using a photo ionization detector (PID) or flame ionization detector (FID) using head space or purge and trap procedures.

The following Table illustrates the applicability of the use of both the PID and FID for field screening of chlorinated VOCs by comparing the response factors vs ionization potentials of those targeted compounds.

Compound	Response Factor		Ionization Potential (eV)	
PCE	1.47		9.32	
TCE	1.85		9.45	
1,1,1-TCA		0.95		11.00
1,1,2-TCA	1.05		11.00	
1,1-DCE		2.04		9.79
1,2-DCA		1.12		11.05
1,1-DCA		1.43		11.06

note - The response factors are from the "Foxboro OVA Century Response Chart Relative to Methane Calibration" table. The

Ionization Potential is from the *NIOSH Pocket Guide to Chemical Hazards.*

Headspace Method

Approximately 20 ml of water will be placed in a 40 ml VOA sample container following confirmation of the stabilization pH, temperature, and specific conductivity. The sample and container will then be placed in a water bath to heat the sample to a constant temperature for five minutes. Dissolved volatile compounds will be transferred to vapor phase and collected in the headspace of the sample container during the heating process. Once heated, a sample of headspace gas will be collected by injecting a syringe into the sample container via the Teflon® septa in the lid of the container. (See SRI User's Manual and Reference Guide, 1991)

To obtain separation of the various compounds in a sample, a stream of ultra-zero air (carrier gas) passes through a gas chromatograph column and then into the detector. The collected 100 μl (may vary depending on concentration) headspace air sample will then be injected into the carrier gas stream through a manual injection port using a sample syringe. The separation of compounds from the ultra-zero air is accomplished within the chromatograph column, each chemical taking its own characteristic time (retention time) to be carried through the column to the detector. Calibration standards will be prepared and run for the target compounds. Standard runs, quality control syringe blanks and ultra-zero air runs will be made periodically to ensure sampling equipment integrity and instrument response.

4.5.3 Quality Control for Ground Water Sample Collection

In addition to the certified laboratory's quality control procedures, trip blanks

were also collected.

4.5.4 Equipment Decontamination

Equipment used for the sampling of water from borings, Geoprobe® points, and wells, with the exception of field screening meters, vacuum pumps, etc., shall be dedicated for each boring. The vacuum pumps, etc., do not come into contact with water samples; therefore, no formal decontamination procedures are required. Containers used for the collection/holding of field screening samples shall be decontaminated between borings according to the following procedure:

1. Rinse with tap water to remove large particulate matter,

2. Wash with Alconox soap, or equivalent. The interior and exterior of containers will be thoroughly scrubbed to remove particulate matter and/or surface films. Meters will only be thoroughly rinsed,

3. Thorough rinse with tap water to remove soap,

4. Allow to completely air dry,

4.5.5 Sample Containers, Preservation, and Analytical Parameters

Ground water samples will be collected and analyzed in a manner sufficient to characterize potential water contaminants. Constituents of concern are: Copper, lead, DCA, 2-DCA, DCE, TCA, 2-TCA, TCE, and PCE. Immediately after collection, each laboratory sample will be placed in labeled, laboratory supplied containers, maintained on ice (water only), and stored in a cooler. Sample containers and volumes will be consistent with the requirements of the analytical methodology. The samples will be individually packaged in bubble-wrap in order to reduce the possibility of container breakage. (Reference *RCRA Facility Investigation for AOC #1 and #2 Work*

Plan, October 1994, Section 4.5.5 - Sample Containers, Preservation, and Analytical Parameters, page 47).

4.5.6 Analytical Methods

All samples will be analyzed as specified in "Test Methods for Evaluating Solid Waste, EPA Publication SW-846 (Third Edition)." Ground water samples will be laboratory analyzed for selected VOCs by Method 8260. Samples shall be analyzed for selected metals (total) by Method 6010. Field filtering of samples shall not be conducted. If the quality assurance/quality control (QA/QC) procedures followed by the analytical laboratory chosen for this project differ from the QA/QC procedures followed by a typical CLP, the Division shall be notified.(Reference *RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994, Section 4.5.4 - Equipment Decontamination, page 46).

(Reference *RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994, Section 4.5.6 - Analytical Methods, page 47).

4.7 Order of Sample Collection

Samples shall be collected in order, starting with the suspected "clean" and ending with the suspected most-contaminated sample. This sequence will be followed for both solid and liquid samples. Sample aliquot from each location will be collected and containerized in the order of volatilization sensitivity of the parameters of concern. Samples will be collected in the following order: First - VOCs, Second - Metals, Third - Field Parameters.(Reference *RCRA Facility Investigation for AOC #1 and #2 Work Plan*, October 1994, Section 4.7 - Order of Sample Collection, page 53).

APPENDIX D
LABORATORY REPORTS

Natural Attenuation Survey and Background Copper and Lead Soil Concentrations

HYDROLOGIC, INC.

ANALYTICAL AND QUALITY CONTROL REPORT

RECEIVED
SEP 21 1998

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Enclosed is the Analytical and Quality Control Reports for the following samples submitted to HydroLogic - Frankfort for analysis:

Project Description: 98-1158

Sample Number	Sample Description	Matrix	Date Sampled	Date Received
21345	FIELD BLANK	WATER	08/14/1998	08/18/1998
21346	L-1	WATER	08/13/1998	08/18/1998
21365	MW-15S	WATER	08/14/1998	08/18/1998
21366	MW-15D	WATER	08/14/1998	08/18/1998
21419	BK-1A	SOIL	08/13/1998	08/18/1998
21420	BK-1B	SOIL	08/13/1998	08/18/1998
21421	BK-2A	SOIL	08/13/1998	08/18/1998
21422	BK-2B	SOIL	08/13/1998	08/18/1998
21423	BK-3A	SOIL	08/13/1998	08/18/1998
21424	BK-3B	SOIL	08/13/1998	08/18/1998
21425	MW-13S	WATER	08/13/1998	08/18/1998
21426	MW-10S	WATER	08/14/1998	08/18/1998
21427	MW-9SK	WATER	08/14/1998	08/18/1998
21428	MW-9DK	WATER	08/14/1998	08/18/1998
21429	MW-12S	WATER	08/14/1998	08/18/1998
21430	MW-14D	WATER	08/14/1998	08/18/1998

The Quality Control report is generated on a batch basis. All information contained in this report is for the analytical batch(es) in which your sample(s) were analyzed. All anlytical batch(es) are initiated at 8:00 a.m. unless otherwise flagged on report.

All samples were analyzed according to the RCRA guidelines described in SW-846, NPDES regulations, and Standard Methods for the Examination of Water and Wastewater.

Project Representative

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
502-223-0251 FAX: 502-875-8018 TOLL FREE 800-728-2251

HYDROLOGIC, INC.

ANALYTICAL AND QUALITY CONTROL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Enclosed is the Analytical and Quality Control Reports for the following samples submitted to HydroLogic - Frankfort for analysis:

Project Description: 98-1158

Sample Number	Sample Description	Matrix	Date Sampled	Date Received
21431	MW-7D	WATER	08/14/1998	08/18/1998
21432	MW-4S	WATER	08/14/1998	08/18/1998
21433	FIELD BLANK	WATER	08/14/1998	08/18/1998
21434	MW-4D	WATER	08/14/1998	08/18/1998

The Quality Control report is generated on a batch basis. All information contained in this report is for the analytical batch(es) in which your sample(s) were analyzed. All anlytical batch(es) are initiated at 8:00 a.m. unless otherwise flagged on report.

All samples were analyzed according to the RCRA guidelines described in SW-846, NPDES regulations, and Standard Methods for the Examination of Water and Wastewater.

Project Representative

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21345	FIELD BLANK	08/14/1998 14:45

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
6230D (GC/MS CONFIRMED AQ)	6230D					
Benzene		<0.50	0.50	ug/L		08/25/1998
Bromobenzene		<0.50	0.50	ug/L		08/25/1998
Bromochloromethane		<0.50	0.50	ug/L		08/25/1998
Bromodichloromethane		<0.50	0.50	ug/L		08/25/1998
Bromoform		<0.50	0.50	ug/L		08/25/1998
Bromomethane		<0.50	0.50	ug/L		08/25/1998
n-Butylbenzene		<0.50	0.50	ug/L		08/25/1998
sec-Butylbenzene		<0.50	0.50	ug/L		08/25/1998
tert-Butylbenzene		<0.50	0.50	ug/L		08/25/1998
Carbon tetrachloride		<0.50	0.50	ug/L		08/25/1998
Chlorobenzene		<0.50	0.50	ug/L		08/25/1998
Chlorodibromomethane		<0.50	0.50	ug/L		08/25/1998
Chloroethane		<0.50	0.50	ug/L		08/25/1998
Chloroform		<0.50	0.50	ug/L		08/25/1998
Chloromethane		<0.50	0.50	ug/L		08/25/1998
2-Chlorotoluene		<0.50	0.50	ug/L		08/25/1998
4-Chlorotoluene		<0.50	0.50	ug/L		08/25/1998
2-Chloroethyl vinyl ether		<0.50	0.50	ug/L		08/25/1998
1,2-Dibromo-3-chloropropane		<0.50	0.50	ug/L		08/25/1998
1,2-Dibromoethane		<0.50	0.50	ug/L		08/25/1998
Dibromomethane		<0.50	0.50	ug/L		08/25/1998
1,2-Dichlorobenzene		<0.50	0.50	ug/L		08/25/1998
1,3-Dichlorobenzene		<0.50	0.50	ug/L		08/25/1998
1,4-Dichlorobenzene		<0.50	0.50	ug/L		08/25/1998
Dichlorodifluoromethane		<0.50	0.50	ug/L		08/25/1998
trans-1,4-Dichloro-2-butene		<0.50	0.50	ug/L		08/25/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21345	FIELD BLANK	08/14/1998 14:45

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
1,1-Dichloroethane		<0.50	0.50	ug/L		08/25/1998
1,2-Dichloroethane		<0.50	0.50	ug/L		08/25/1998
1,1-Dichloroethene		<0.50	0.50	ug/L		08/25/1998
cis-1,2-Dichloroethene		<0.50	0.50	ug/L		08/25/1998
trans-1,2-Dichloroethene		<0.50	0.50	ug/L		08/25/1998
1,[illegible]-Dichloropropane		<0.50	0.50	ug/L		08/25/1998
1,3-Dichloropropane		<0.50	0.50	ug/L		08/25/1998
2,2-Dichloropropane		<0.50	0.50	ug/L		08/25/1998
1,1-Dichloropropene		<0.50	0.50	ug/L		08/25/1998
cis-1,3-Dichloropropene		<0.50	0.50	ug/L		08/25/1998
trans-1,3-Dichloropropene		<0.50	0.50	ug/L		08/25/1998
Ethylbenzene		<0.50	0.50	ug/L		08/25/1998
Hexachlorobutadiene		<0.50	0.50	ug/L		08/25/1998
Isopropylbenzene		<0.50	0.50	ug/L		08/25/1998
Isopropryl ether (IPE)		<0.50	0.50	ug/L		08/25/1998
p-Isopropyltoluene		<0.50	0.50	ug/L		08/25/1998
Methylene chloride		<0.50	0.50	ug/L		08/25/1998
Methyl-tert-butyl ether (MTBE)		<0.50	0.50	ug/L		08/25/1998
Naphthalene		<0.50	0.50	ug/L		08/25/1998
n-Propylbenzene		<0.50	0.50	ug/L		08/25/1998
Styrene		<0.50	0.50	ug/L		08/25/1998
1,1,1,2-Tetrachloroethane		<0.50	0.50	ug/L		08/25/1998
1,1,2,2-Tetrachloroethane		<0.50	0.50	ug/L		08/25/1998
Tetrachloroethene		<0.50	0.50	ug/L		08/25/1998
Toluene		0.68	0.50	ug/L		08/25/1998
1,2,3-Trichlorobenzene		<0.50	0.50	ug/L		08/25/1998
1,2,4-Trichlorobenzene		<0.50	0.50	ug/L		08/25/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21345	FIELD BLANK	08/14/1998 14:45

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
1,1,1-Trichloroethane		<0.50	0.50	ug/L		08/25/1998
1,1,2-Trichloroethane		<0.50	0.50	ug/L		08/25/1998
Trichloroethene		<0.50	0.50	ug/L		08/25/1998
Trichlorofluoromethane		<0.50	0.50	ug/L		08/25/1998
1,2,3-Trichloropropane		<0.50	0.50	ug/L		08/25/1998
1,2,4-Trimethylbenzene		<0.50	0.50	ug/L		08/25/1998
1,3,5-Trimethylbenzene		<0.50	0.50	ug/L		08/25/1998
Vinyl acetate		<0.50	0.50	ug/L		08/25/1998
Vinyl chloride		<0.50	0.50	ug/L		08/25/1998
m+p-Xylenes		<0.50	0.50	ug/L		08/25/1998
o-Xylene		<0.50	0.50	ug/L		08/25/1998
SURR: Toluene-d8		104		%		08/25/1998
SURR: 1,2-Dichloroethane-d4		103		%		08/25/1998
SURR: 4-Bromofluorobenzene		81.0		%		08/25/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21346	L-1	08/13/1998 17:00

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
8260B (AQ)	8260B					
Acetone		<50.0	50.0	ug/L		08/25/1998
Acrolein		<50.0	50.0	ug/L		08/25/1998
Acrylonitrile		<50.0	50.0	ug/L		08/25/1998
Benzene		<0.50	0.50	ug/L		08/25/1998
Bromobenzene		<0.50	0.50	ug/L		08/25/1998
Bromochloromethane		<0.50	0.50	ug/L		08/25/1998
Bromodichloromethane		<0.50	0.50	ug/L		08/25/1998
Bromoform		<0.50	0.50	ug/L		08/25/1998
Bromomethane		<0.50	0.50	ug/L		08/25/1998
n-Butylbenzene		<0.50	0.50	ug/L		08/25/1998
sec-Butylbenzene		<0.50	0.50	ug/L		08/25/1998
tert-Butylbenzene		<0.50	0.50	ug/L		08/25/1998
Carbon disulfide		6.44	0.50	ug/L		08/25/1998
Carbon tetrachloride		<0.50	0.50	ug/L		08/25/1998
Chlorobenzene		1.30	0.50	ug/L		08/25/1998
Chlorodibromomethane		<0.50	0.50	ug/L		08/25/1998
Chloroethane		<0.50	0.50	ug/L		08/25/1998
Chloroform		<0.50	0.50	ug/L		08/25/1998
Chloromethane		<0.50	0.50	ug/L		08/25/1998
2-Chlorotoluene		<0.50	0.50	ug/L		08/25/1998
4-Chlorotoluene		<0.50	0.50	ug/L		08/25/1998
2-Chloroethyl vinyl ether		<0.50	0.50	ug/L		08/25/1998
1,2-Dibromo-3-chloropropane		<0.50	0.50	ug/L		08/25/1998
1,2-Dibromoethane		<0.50	0.50	ug/L		08/25/1998
Dibromomethane		<0.50	0.50	ug/L		08/25/1998
1,2-Dichlorobenzene		<0.50	0.50	ug/L		08/25/1998

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
502-223-0251 FAX: 502-873-3016 TOLL FREE 800-728-2251

HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21346	L-1	08/13/1998 17:00

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
1,3-Dichlorobenzene		<0.50	0.50	ug/L		08/25/1998
1,4-Dichlorobenzene		<0.50	0.50	ug/L		08/25/1998
Dichlorodifluoromethane		<0.50	0.50	ug/L		08/25/1998
trans-1,4-Dichloro-2-butene		<0.50	0.50	ug/L		08/25/1998
1,1-Dichloroethane		<0.50	0.50	ug/L		08/25/1998
1,2-Dichloroethane		<0.50	0.50	ug/L		08/25/1998
1,1-Dichloroethene		<0.50	0.50	ug/L		08/25/1998
cis-1,2-Dichloroethene		1.27	0.50	ug/L		08/25/1998
trans-1,2-Dichloroethene		<0.50	0.50	ug/L		08/25/1998
1,2-Dichloropropane		<0.50	0.50	ug/L		08/25/1998
1,3-Dichloropropane		<0.50	0.50	ug/L		08/25/1998
2,2-Dichloropropane		<0.50	0.50	ug/L		08/25/1998
1,1-Dichloropropene		<0.50	0.50	ug/L		08/25/1998
cis-1,3-Dichloropropene		<0.50	0.50	ug/L		08/25/1998
trans-1,3-Dichloropropene		<0.50	0.50	ug/L		08/25/1998
Ethanol		<1000	1.0	mg/L		08/25/1998
Ethyl acetate		<20.0	0.020	mg/L		08/25/1998
Ethylbenzene		<0.50	0.50	ug/L		08/25/1998
Ethyl methacrylate		<10.0	10.0	ug/L		08/25/1998
2-Hexanone		<50.0	50.0	ug/L		08/25/1998
Hexachlorobutadiene		<0.50	0.50	ug/L		08/25/1998
Iodomethane		<10.0	10.0	ug/L		08/25/1998
Isopropylbenzene		<0.50	0.50	ug/L		08/25/1998
Isopropyl ether (IPE)		<0.50	0.50	ug/L		08/25/1998
p-Isopropyltoluene		<0.50	0.50	ug/L		08/25/1998
Methylene chloride		<0.50	0.50	ug/L		08/25/1998
2-Butanone (MEK)		<50.0	50.0	ug/L		08/25/1998

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
502-223-0251 FAX: 502-875-3015 TOLL FREE 800-728-2251

HYDROLOGIC, INC.

ANALYTICAL REPORT

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ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21346	L-1	08/13/1998 17:00

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Methyl-tert-butyl ether (MTBE)		1.40	0.50	ug/L		08/25/1998
4-Methyl-2-pentanone (MIBK)		<50.0	50.0	ug/L		08/25/1998
Naphthalene		<0.50	0.50	ug/L		08/25/1998
n-Propylbenzene		<0.50	0.50	ug/L		08/25/1998
Styrene		<0.50	0.50	ug/L		08/25/1998
1,1,1,2-Tetrachloroethane		<0.50	0.50	ug/L		08/25/1998
1,1,2,2-Tetrachloroethane		<0.50	0.50	ug/L		08/25/1998
Tetrachloroethene		<0.50	0.50	ug/L		08/25/1998
Toluene		1.43	0.50	ug/L		08/25/1998
1,2,3-Trichlorobenzene		<0.50	0.50	ug/L		08/25/1998
1,2,4-Trichlorobenzene		<0.50	0.50	ug/L		08/25/1998
1,1,1-Trichloroethane		<0.50	0.50	ug/L		08/25/1998
1,1,2-Trichloroethane		<0.50	0.50	ug/L		08/25/1998
Trichloroethene		<0.50	0.50	ug/L		08/25/1998
Trichlorofluoromethane		<0.50	0.50	ug/L		08/25/1998
1,2,3-Trichloropropane		<0.50	0.50	ug/L		08/25/1998
1,2,4-Trimethylbenzene		0.54	0.50	ug/L		08/25/1998
1,3,5-Trimethylbenzene		<0.50	0.50	ug/L		08/25/1998
Vinyl acetate		<0.50	0.50	ug/L		08/25/1998
Vinyl chloride		6.36	0.50	ug/L		08/25/1998
m&p-Xylenes		1.26	0.50	ug/L		08/25/1998
o-Xylene		0.57	0.50	ug/L		08/25/1998
SURR: Toluene-d8		98.0		%		08/25/1998
SURR: 1,2-Dichloroethane-d4		92.0		%		08/25/1998
SURR: 4-Bromofluorobenzene		86.0		%		08/25/1998

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
502-223-0251 FAX: 502-875-8018 TOLL FREE 800-728-2251

HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21346	L-1	08/13/1998 17:00

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
6230D (GC/MS CONFIRMED AQ)	6230D					
Benzene		<0.50	0.50	ug/L		08/26/1998
Bromobenzene		<0.50	0.50	ug/L		08/26/1998
Bromochloromethane		<0.50	0.50	ug/L		08/26/1998
Bromodichloromethane		<0.50	0.50	ug/L		08/26/1998
Bromoform		<0.50	0.50	ug/L		08/26/1998
Bromomethane		<0.50	0.50	ug/L		08/26/1998
n-Butylbenzene		<0.50	0.50	ug/L		08/26/1998
sec-Butylbenzene		<0.50	0.50	ug/L		08/26/1998
tert-Butylbenzene		<0.50	0.50	ug/L		08/26/1998
Carbon tetrachloride		<0.50	0.50	ug/L		08/26/1998
Chlorobenzene		1.30	0.50	ug/L		08/26/1998
Chlorodibromomethane		<0.50	0.50	ug/L		08/26/1998
Chloroethane		<0.50	0.50	ug/L		08/26/1998
Chloroform		<0.50	0.50	ug/L		08/26/1998
Chloromethane		<0.50	0.50	ug/L		08/26/1998
2-Chlorotoluene		<0.50	0.50	ug/L		08/26/1998
4-Chlorotoluene		<0.50	0.50	ug/L		08/26/1998
2-Chloroethyl vinyl ether		<0.50	0.50	ug/L		08/26/1998
1,2-Dibromo-3-chloropropane		<0.50	0.50	ug/L		08/26/1998
1,2-Dibromoethane		<0.50	0.50	ug/L		08/26/1998
Dibromomethane		<0.50	0.50	ug/L		08/26/1998
1,2-Dichlorobenzene		<0.50	0.50	ug/L		08/26/1998
1,3-Dichlorobenzene		<0.50	0.50	ug/L		08/26/1998
1,4-Dichlorobenzene		<0.50	0.50	ug/L		08/26/1998
Dichlorodifluoromethane		<0.50	0.50	ug/L		08/26/1998
trans-1,4-Dichloro-2-butene		<0.50	0.50	ug/L		08/26/1998

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
502-223-0251 FAX: 502-875-8018 TOLL FREE 800-728-2251

HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21346	L-1	08/13/1998 17:00

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
1,1-Dichloroethane		<0.50	0.50	ug/L		08/26/1998
1,2-Dichloroethane		<0.50	0.50	ug/L		08/26/1998
1,1-Dichloroethene		<0.50	0.50	ug/L		08/26/1998
cis-1,2-Dichloroethene		1.27	0.50	ug/L		08/26/1998
trans-1,2-Dichloroethene		<0.50	0.50	ug/L		08/26/1998
1,[illegible]-Dichloropropane		<0.50	0.50	ug/L		08/26/1998
1,3-Dichloropropane		<0.50	0.50	ug/L		08/26/1998
2,2-Dichloropropane		<0.50	0.50	ug/L		08/26/1998
1,1-Dichloropropene		<0.50	0.50	ug/L		08/26/1998
cis-1,3-Dichloropropene		<0.50	0.50	ug/L		08/26/1998
trans-1,3-Dichloropropene		<0.50	0.50	ug/L		08/26/1998
Ethylbenzene		<0.50	0.50	ug/L		08/26/1998
Hexachlorobutadiene		<0.50	0.50	ug/L		08/26/1998
Isopropylbenzene		<0.50	0.50	ug/L		08/26/1998
Isopropyl ether (IPE)		<0.50	0.50	ug/L		08/26/1998
p-Isopropyltoluene		<0.50	0.50	ug/L		08/26/1998
Methylene chloride		<0.50	0.50	ug/L		08/26/1998
Methyl-tert-butyl ether (MTBE)		1.40	0.50	ug/L		08/26/1998
Naphthalene		<0.50	0.50	ug/L		08/26/1998
n-Propylbenzene		<0.50	0.50	ug/L		08/26/1998
Styrene		<0.50	0.50	ug/L		08/26/1998
1,1,1,2-Tetrachloroethane		<0.50	0.50	ug/L		08/26/1998
1,1,2,2-Tetrachloroethane		<0.50	0.50	ug/L		08/26/1998
Tetrachloroethene		<0.50	0.50	ug/L		08/26/1998
Toluene		1.43	0.50	ug/L		08/26/1998
1,2,3-Trichlorobenzene		<0.50	0.50	ug/L		08/26/1998
1,2,4-Trichlorobenzene		<0.50	0.50	ug/L		08/26/1998

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21346	L-1	08/13/1998 17:00

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
1,1,1-Trichloroethane		<0.50	0.50	ug/L		08/26/1998
1,1,2-Trichloroethane		<0.50	0.50	ug/L		08/26/1998
Trichloroethene		<0.50	0.50	ug/L		08/26/1998
Trichlorofluoromethane		<0.50	0.50	ug/L		08/26/1998
1,2,3-Trichloropropane		<0.50	0.50	ug/L		08/26/1998
1,[illegible],4-Trimethylbenzene		0.54	0.50	ug/L		08/26/1998
1,3,5-Trimethylbenzene		<0.50	0.50	ug/L		08/26/1998
Vinyl acetate		<0.50	0.50	ug/L		08/26/1998
Vinyl chloride		6.36	0.50	ug/L		08/26/1998
m+p-Xylenes		1.26	0.50	ug/L		08/26/1998
o-Xylene		0.57	0.50	ug/L		08/26/1998
SURR: Toluene-d8		98.0		%		08/26/1998
SURR: 1,2-Dichloroethane-d4		92.0		%		08/26/1998
SURR: 4-Bromofluorobenzene		86.0		%		08/26/1998
MISC. GC COMPOUNDS	NET					
Methane		Attached				08/26/1998

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
502-223-0251 FAX: 502-875-8016 TOLL FREE 800-728-2251

HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21365	MW-15S	08/14/1998 11:30

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
6230D (GC/MS CONFIRMED AQ)	6230D					
Benzene		<0.50	0.50	ug/L		08/26/1998
Bromobenzene		<0.50	0.50	ug/L		08/26/1998
Bromochloromethane		<0.50	0.50	ug/L		08/26/1998
Bromodichloromethane		<0.50	0.50	ug/L		08/26/1998
Bromoform		<0.50	0.50	ug/L		08/26/1998
Bromomethane		<0.50	0.50	ug/L		08/26/1998
n-Butylbenzene		<0.50	0.50	ug/L		08/26/1998
sec-Butylbenzene		<0.50	0.50	ug/L		08/26/1998
tert-Butylbenzene		<0.50	0.50	ug/L		08/26/1998
Carbon tetrachloride		<0.50	0.50	ug/L		08/26/1998
Chlorobenzene		<0.50	0.50	ug/L		08/26/1998
Chlorodibromomethane		<0.50	0.50	ug/L		08/26/1998
Chloroethane		<0.50	0.50	ug/L		08/26/1998
Chloroform		<0.50	0.50	ug/L		08/26/1998
Chloromethane		<0.50	0.50	ug/L		08/26/1998
2-Chlorotoluene		<0.50	0.50	ug/L		08/26/1998
4-Chlorotoluene		<0.50	0.50	ug/L		08/26/1998
2-Chloroethyl vinyl ether		<0.50	0.50	ug/L		08/26/1998
1,2-Dibromo-3-chloropropane		<0.50	0.50	ug/L		08/26/1998
1,2-Dibromoethane		<0.50	0.50	ug/L		08/26/1998
Dibromomethane		<0.50	0.50	ug/L		08/26/1998
1,2-Dichlorobenzene		<0.50	0.50	ug/L		08/26/1998
1,3-Dichlorobenzene		<0.50	0.50	ug/L		08/26/1998
1,4-Dichlorobenzene		<0.50	0.50	ug/L		08/26/1998
Dichlorodifluoromethane		<0.50	0.50	ug/L		08/26/1998
trans-1,4-Dichloro-2-butene		<0.50	0.50	ug/L		08/26/1998

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
502-223-0251 FAX: 502-875-8018 TOLL FREE 800-728-2251

HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21365	MW-15S	08/14/1998 11:30

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
1,1-Dichloroethane		<0.50	0.50	ug/L		08/26/1998
1,2-Dichloroethane		<0.50	0.50	ug/L		08/26/1998
1,1-Dichloroethene		<0.50	0.50	ug/L		08/26/1998
cis-1,2-Dichloroethene		<0.50	0.50	ug/L		08/26/1998
trans-1,2-Dichloroethene		<0.50	0.50	ug/L		08/26/1998
1,[illegible]-Dichloropropane		<0.50	0.50	ug/L		08/26/1998
1,3-Dichloropropane		<0.50	0.50	ug/L		08/26/1998
2,2-Dichloropropane		<0.50	0.50	ug/L		08/26/1998
1,1-Dichloropropene		<0.50	0.50	ug/L		08/26/1998
cis-1,3-Dichloropropene		<0.50	0.50	ug/L		08/26/1998
trans-1,3-Dichloropropene		<0.50	0.50	ug/L		08/26/1998
Ethylbenzene		<0.50	0.50	ug/L		08/26/1998
Hexachlorobutadiene		<0.50	0.50	ug/L		08/26/1998
Isopropylbenzene		<0.50	0.50	ug/L		08/26/1998
Isopropyl ether (IPE)		<0.50	0.50	ug/L		08/26/1998
p-Isopropyltoluene		<0.50	0.50	ug/L		08/26/1998
Methylene chloride		<0.50	0.50	ug/L		08/26/1998
Methyl-tert-butyl ether (MTBE)		<0.50	0.50	ug/L		08/26/1998
Naphthalene		<0.50	0.50	ug/L		08/26/1998
n-Propylbenzene		<0.50	0.50	ug/L		08/26/1998
Styrene		<0.50	0.50	ug/L		08/26/1998
1,1,1,2-Tetrachloroethane		<0.50	0.50	ug/L		08/26/1998
1,1,2,2-Tetrachloroethane		<0.50	0.50	ug/L		08/26/1998
Tetrachloroethene		<0.50	0.50	ug/L		08/26/1998
Toluene		<0.50	0.50	ug/L		08/26/1998
1,2,3-Trichlorobenzene		<0.50	0.50	ug/L		08/26/1998
1,2,4-Trichlorobenzene		<0.50	0.50	ug/L		08/26/1998

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
502-223-0251 FAX: 502-875-[illegible] TOLL FREE 800-728-2251

HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21365	MW-15S	08/14/1998 11:30

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
1,1,1-Trichloroethane		<0.50	0.50	ug/L		08/26/1998
1,1,2-Trichloroethane		<0.50	0.50	ug/L		08/26/1998
Trichloroethene		<0.50	0.50	ug/L		08/26/1998
Trichlorofluoromethane		<0.50	0.50	ug/L		08/26/1998
1,2,3-Trichloropropane		<0.50	0.50	ug/L		08/26/1998
1,[illegible]-Trimethylbenzene		<0.50	0.50	ug/L		08/26/1998
1,3,5-Trimethylbenzene		<0.50	0.50	ug/L		08/26/1998
Vinyl acetate		<0.50	0.50	ug/L		08/26/1998
Vinyl chloride		<0.50	0.50	ug/L		08/26/1998
m+p-Xylenes		<0.50	0.50	ug/L		08/26/1998
o-Xylene		<0.50	0.50	ug/L		08/26/1998
SURR: Toluene-d8		92.0		%		08/26/1998
SURR: 1,2-Dichloroethane-d4		119		%		08/26/1998
SURR: 4-Bromofluorobenzene		85.0		%		08/26/1998
MISC. GC COMPOUNDS	NET					
Methane		Attached				08/26/1998

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
502-223-0251 FAX: 502-875-8016 TOLL FREE 800-728-2251

HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21366	MW-15D	08/14/1998 11:45

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
6230D (GC/MS CONFIRMED AQ)	6230D					
Benzene		<0.50	0.50	ug/L		08/26/1998
Bromobenzene		<0.50	0.50	ug/L		08/26/1998
Bromochloromethane		<0.50	0.50	ug/L		08/26/1998
Bromodichloromethane		<0.50	0.50	ug/L		08/26/1998
Bromoform		<0.50	0.50	ug/L		08/26/1998
Bromomethane		<0.50	0.50	ug/L		08/26/1998
n-Butylbenzene		<0.50	0.50	ug/L		08/26/1998
sec-Butylbenzene		<0.50	0.50	ug/L		08/26/1998
tert-Butylbenzene		<0.50	0.50	ug/L		08/26/1998
Carbon tetrachloride		<0.50	0.50	ug/L		08/26/1998
Chlorobenzene		<0.50	0.50	ug/L		08/26/1998
Chlorodibromomethane		<0.50	0.50	ug/L		08/26/1998
Chloroethane		<0.50	0.50	ug/L		08/26/1998
Chloroform		0.77	0.50	ug/L		08/26/1998
Chloromethane		<0.50	0.50	ug/L		08/26/1998
2-Chlorotoluene		<0.50	0.50	ug/L		08/26/1998
4-Chlorotoluene		<0.50	0.50	ug/L		08/26/1998
2-Chloroethyl vinyl ether		<0.50	0.50	ug/L		08/26/1998
1,2-Dibromo-3-chloropropane		<0.50	0.50	ug/L		08/26/1998
1,2-Dibromoethane		<0.50	0.50	ug/L		08/26/1998
Dibromomethane		<0.50	0.50	ug/L		08/26/1998
1,2-Dichlorobenzene		<0.50	0.50	ug/L		08/26/1998
1,3-Dichlorobenzene		<0.50	0.50	ug/L		08/26/1998
1,4-Dichlorobenzene		<0.50	0.50	ug/L		08/26/1998
Dichlorodifluoromethane		<0.50	0.50	ug/L		08/26/1998
trans-1,4-Dichloro-2-butene		<0.50	0.50	ug/L		08/26/1998

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
502-223-0251 FAX: 502-875-8016 · TOLL FREE 800-728-2251

HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21366	MW-15D	08/14/1998 11:45

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
1,1-Dichloroethane		1.76	0.50	ug/L		08/26/1998
1,2-Dichloroethane		<0.50	0.50	ug/L		08/26/1998
1,1-Dichloroethene		73.2	0.50	ug/L		08/26/1998
cis-1,2-Dichloroethene		<0.50	0.50	ug/L		08/26/1998
trans-1,2-Dichloroethene		<0.50	0.50	ug/L		08/26/1998
1,[illegible]-Dichloropropane		<0.50	0.50	ug/L		08/26/1998
1,3-Dichloropropane		<0.50	0.50	ug/L		08/26/1998
2,2-Dichloropropane		<0.50	0.50	ug/L		08/26/1998
1,1-Dichloropropene		<0.50	0.50	ug/L		08/26/1998
cis-1,3-Dichloropropene		<0.50	0.50	ug/L		08/26/1998
trans-1,3-Dichloropropene		<0.50	0.50	ug/L		08/26/1998
Ethylbenzene		<0.50	0.50	ug/L		08/26/1998
Hexachlorobutadiene		<0.50	0.50	ug/L		08/26/1998
Isopropylbenzene		<0.50	0.50	ug/L		08/26/1998
Isopropryl ether (IPE)		<0.50	0.50	ug/L		08/26/1998
p-Isopropyltoluene		<0.50	0.50	ug/L		08/26/1998
Methylene chloride		<0.50	0.50	ug/L		08/26/1998
Methyl-tert-butyl ether (MTBE)		<0.50	0.50	ug/L		08/26/1998
Naphthalene		<0.50	0.50	ug/L		08/26/1998
n-Propylbenzene		<0.50	0.50	ug/L		08/26/1998
Styrene		<0.50	0.50	ug/L		08/26/1998
1,1,1,2-Tetrachloroethane		<0.50	0.50	ug/L		08/26/1998
1,1,2,2-Tetrachloroethane		<0.50	0.50	ug/L		08/26/1998
Tetrachloroethene		17.0	0.50	ug/L		08/26/1998
Toluene		<0.50	0.50	ug/L		08/26/1998
1,2,3-Trichlorobenzene		<0.50	0.50	ug/L		08/26/1998
1,2,4-Trichlorobenzene		<0.50	0.50	ug/L		08/26/1998

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21366	MW-15D	08/14/1998 11:45

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
1,1,1-Trichloroethane		3.04	0.50	ug/L		08/26/1998
1,1,2-Trichloroethane		<0.50	0.50	ug/L		08/26/1998
Trichloroethene		12.1	0.50	ug/L		08/26/1998
Trichlorofluoromethane		<0.50	0.50	ug/L		08/26/1998
1,2,3-Trichloropropane		<0.50	0.50	ug/L		08/26/1998
1,2,4-Trimethylbenzene		<0.50	0.50	ug/L		08/26/1998
1,3,5-Trimethylbenzene		<0.50	0.50	ug/L		08/26/1998
Vinyl acetate		<0.50	0.50	ug/L		08/26/1998
Vinyl chloride		<0.50	0.50	ug/L		08/26/1998
m+p-Xylenes		<0.50	0.50	ug/L		08/26/1998
o-Xylene		<0.50	0.50	ug/L		08/26/1998
SURR: Toluene-d8		92.0		%		08/26/1998
SURR: 1,2-Dichloroethane-d4		121		%		08/26/1998
SURR: 4-Bromofluorobenzene		86.0		%		08/26/1998
MISC. GC COMPOUNDS	NET					
Methane		Attached				08/26/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: SOIL

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21419	BK-1A	08/13/1998 10:45

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Copper, ICP		Attached				08/26/1998
Lead, ICP		Attached				08/27/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: SOIL

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21420	BK-1B	08/13/1998 10:45

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Copper, ICP		Attached				08/26/1998
Lead, ICP		Attached				08/27/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: SOIL

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21421	BK-2A	08/13/1998 11:15

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Copper, ICP		Attached				08/26/1998
Lead, ICP		Attached				08/27/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: SOIL

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21422	BK-2B	08/13/1998 11:15

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Copper, ICP		Attached				08/26/1998
Lead, ICP		Attached				08/27/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: SOIL

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21423	BK-3A	08/13/1998 11:41

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Copper, ICP		Attached				08/26/1998
Lead, ICP		Attached				08/27/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: SOIL

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21424	BK-3B	08/13/1998 11:41

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Copper, ICP		Attached				08/26/1998
Lead, ICP		Attached				08/27/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21425	MW-13S	08/13/1998 20:26

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Chloride		Attached				08/28/1998
Nitrogen, Nitrate		Attached				08/20/1998
Sulfate		Attached				08/21/1998
Iron, ICP		Attached		mg/L		08/28/1998
M[illegible]. GC COMPOUNDS	NET					
Methane		Attached				08/26/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21426	MW-10S	08/14/1998 09:41

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Chloride		Attached				08/28/1998
Nitrogen, Nitrate		Attached				08/20/1998
Sulfate		Attached				08/21/1998
Iron, ICP		Attached		mg/L		08/28/1998
M[illegible]. GC COMPOUNDS	NET					
Methane		Attached				08/26/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21427	MW-9SK	08/14/1998 12:25

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Chloride		Attached				08/28/1998
Nitrogen, Nitrate		Attached				08/20/1998
Sulfate		Attached				08/21/1998
Iron, ICP		Attached		mg/L		08/28/1998
M[illegible]. GC COMPOUNDS	NET					
Methane		Attached				08/26/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21428	MW-9DK	08/14/1998 12:47

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Chloride		Attached				08/28/1998
Nitrogen, Nitrate		Attached				08/20/1998
Sulfate		Attached				08/21/1998
Iron, ICP		Attached		mg/L		08/28/1998
MI[illegible] GC COMPOUNDS	NET					
Methane		Attached				08/26/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21429	MW-12S	08/14/1998 13:10

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Chloride		Attached				08/28/1998
Nitrogen, Nitrate		Attached				08/20/1998
Sulfate		Attached				08/21/1998
Iron, ICP		Attached		mg/L		08/28/1998
M[illegible]. GC COMPOUNDS	NET					
Methane		Attached				08/26/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21430	MW-14D	08/14/1998 13:45

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Chloride		Attached				08/28/1998
Nitrogen, Nitrate		Attached				08/20/1998
Sulfate		Attached				08/21/1998
Iron, ICP		Attached		mg/L		08/28/1998
M[illegible], GC COMPOUNDS	NET					
Methane		Attached				08/26/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21431	MW-7D	08/14/1998 14:15

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Chloride		Attached				08/28/1998
Nitrogen, Nitrate		Attached				08/20/1998
Sulfate		Attached				08/21/1998
Iron, ICP		Attached		mg/L		08/28/1998
M[illegible]. GC COMPOUNDS	NET					
Methane		Attached				08/26/1998

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21432	MW-4S	08/14/1998 14:45

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Chloride		Attached				08/28/1998
Nitrogen, Nitrate		Attached				08/20/1998
Sulfate		Attached				08/21/1998
Iron, ICP		Attached		mg/L		08/28/1998
MI[illegible] GC COMPOUNDS	NET					
Methane		Attached				08/26/1998

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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21433	FIELD BLANK	08/14/1998 14:45

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Chloride		Attached				08/28/1998
Nitrogen, Nitrate		Attached				08/20/1998
Sulfate		Attached				08/21/1998
Iron, ICP		Attached		mg/L		08/28/1998
MI[illegible] GC COMPOUNDS	NET					
Methane		Attached				08/26/1998

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
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HYDROLOGIC, INC.

ANALYTICAL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21434	MW-4D	08/14/1998 15:15

Analyte	Method	Result	Rep. Limit	Units	Flags	Date Analyzed
Chloride		Attached				08/28/1998
Nitrogen, Nitrate		Attached				08/20/1998
Sulfate		Attached				08/21/1998
Iron, ICP		Attached		mg/L		08/28/1998
MI[illegible] GC COMPOUNDS	NET					
Methane		Attached				08/26/1998

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
502-223-0251 FAX: 502-875-8016 , TOLL FREE 800-728-2251

HYDROLOGIC, INC.

LIBRARY SEARCH REPORT

ALCATEL
Mike Haseltine
2912 Wake Forest Road
Raleigh, NC 27609

09/16/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1158

Tenatively Identified Compound	TIC Number	Estimated Concentration	Units	Flags

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21346	L-1	17:00

Volatile Library Search 8901
NO TICS FOUND

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
502-223-0251 FAX: 502-875-8016 / TOLL FREE 800-728-2251

HYDROLOGIC, INC.

Chain of Custody Record

☐ Asheville, (828) 254-5169 ☐ Norcross, GA (770) 368-0636 ☐ Charlotte, NC (704) 392-1164 ☐ Frankfort KY (502) 223-0251 ☒ Morrisville, NC (919) 380-9699

☐ Lumberton, NC (910) 738-6190 ☐ Lexington, SC (803) 796-8989 ☐ Brighton, CO (303) 659-0497 ☐ Macon, GA (912) 757-0811 ☐ Orlando, FL (407) 851-2560

Client: Triangle Env

Project No.: 01-003-009

Report Address:

Invoice Address: ALCATEL

Attn: Mike Haselline

Attn: Dikran Kabbardjian

Phone No.: (910) 392-1747

Sampled By: Mike Haselline

Fax No.:

P.O. No:

State Samples Collected

TURNAROUND TIME

☐ 24 Hours ☐ 48 Hours

☐ 5 Days ☐ 10 Days Date Needed: _____

REQUESTED PARAMETERS

98-1158

LAB CODE I.D.
= Asheville, NC
= Charlotte, NC
= Denver, CO
= Lexington, SC
= Macon, GA
= Frankfort, KY
L = Lumberton, NC
M = Morrisville, NC
N = Norcross, GA
O = Orlando, FL
S = Subcontracted

Sample ID	Date	Time	Comp/ Grab	Matrix	Containers	4C	4C	HCV									← Preserv.	REMARKS
✓ MW-15d	8/14	1145	G	Water		✓	✓	✓										
✓ MW-9sK	8/14	1225	G	Water		✓	✓											
✓ MW-9dK	8/14	1247	G	Water		✓	✓											
✓ MW-12S	8/14	1310	G	Water		✓	✓											
✓ MW-14d	8/14	1345	G	Water		✓	✓											
✓ MW-7d	8/14	1405	G	Water		✓	✓											
✓ MW-4S	8/14	1445	G	Water		✓	✓											
✓ Field Blank	8/14	1445	G	Water		✓	✓											
✓ MW-4d	8/14	1515	G	Water		✓	✓											
Field Blank	8/14	1445		"				X										
Lab Use Only						Mike	A	K									Init Lab Temp.	Rec. Lab Temp

Custody Seal: ☐ Yes ☐ No ☐ N/A

COMMENTS:

Relinquished By:	Date	Time	Received By:	Date	Time	Lab Use Only:
[signature]	8/14/98	1710	[signature]	8/14/98	5:10	98.02395
Relinquished By:	Date	Time	Received By: Valerie S. Maddox	8/17/98	10:30	
Relinquished By:	Date	Time	Received By:	Date	Time	
Relinquished By:	Date	Time	Received By:	Date	Time	

Chain of Custody Record

HYDROLOGIC, INC.

☐ Asheville (828) 254-5169 ☐ Norcross, GA (770) 368-0636 ☐ Charlotte, NC (704) 392-1164 ☐ Frankfort KY (502) 223-0251 ☒ Morrisville, NC (919) 380-0690

☐ Lumberton, NC (910) 738-6890 ☐ Lexington, SC (803) 796-8989 ☐ Brighton, CO (303) 659-0497 ☐ Macon, GA (912) 757-0814 ☐ Orlando, FL (407) 851-2560

Client: Triangle Env.
Project No.: 01-003-0209
Report Address:
Invoice Address: Alcatel
Attn: Mike Hoseltine
Attn: Dikran Kabbanjian
Phone No.: (910) 392-1747
Sampled By: Mike Hoseltine
Fax No.:
P.O. No:
State Samples Collected

TURNAROUND TIME
☐ 24 Hours ☐ 48 Hours
☐ 5 Days ☐ 10 Days Date Needed: _____

REQUESTED PARAMETERS: 6230D; Methane; Sulfate, Nitrate, Chloride, Ferrous Iron; Lead & Copper; 98-1158

LAB CODE I.D.
A = Asheville, NC
C = Charlotte, NC
D = Denver, CO
E = Lexington, SC
G = Macon, GA
K = Frankfort, KY
L = Lumberton, NC
M = Morrisville, NC
N = Norcross, GA
O = Orlando, FL
S = Subcontracted

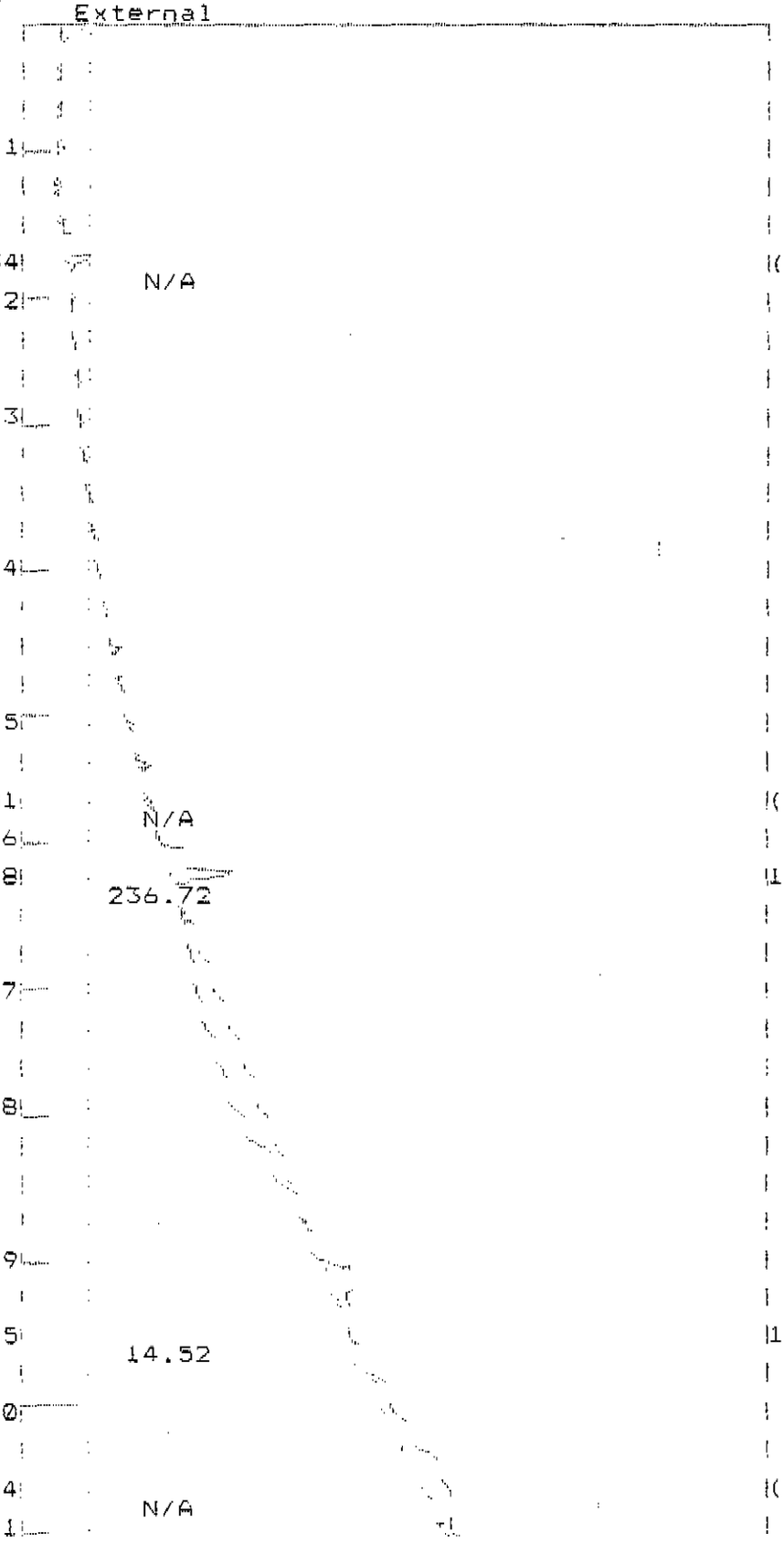
	Sample ID	Date	Time	Comp/Grab	Matrix	Containers	HCl	4°C	4°C	4°C							← Preserv.	REMARKS
✓	BK-1A	8/13	1045	G	Soil					✓								
✓	BK-1B	8/13	1045	G	Soil					✓								
✓	BK-2A	8/13	1115	G	Soil					✓								
✓	BK-2B	8/13	1115	G	Soil					✓								
✓	BK-3A	8/13	1145	G	Soil					✓								
✓	BK-3B	8/13	1145	G	Soil					✓								
✓	L-1	8/13	1700	G	Water		✓	✓	✓									
✓	MW-13S	8/13	2026	G	Water		✓	✓	✓									
✓	MW-10S	8/14	0941	G	Water			✓	✓									
✓	MW-15S	8/14	1130	G	Water		✓	✓	✓									
	Lab Use Only			Custody Seal: ☐ Yes ☐ No ☐ N/A			K	none	A	A							Init Lab Temp.	Rec. Lab Temp

COMMENTS:

Relinquished By:	Date	Time	Received By:	Date	Time	Lab Use Only:
[signature]	8/14/98	1710	[signature]	8/14/98	5:10	98.02395
[signature]	8/15/98	1800	Valerie S. Moddix	8/18/98	10:30	
Relinquished By:	Date	Time	Received By:	Date	Time	
Relinquished By:	Date	Time	Received By:	Date	Time	

GC Field Screening Results

Lab name : NET Field Screening Lab
Client : Alcatel Network Systems
Client ID : 058016
Collected : August 22, 1997
Description : FID Hydrogen
Sample : MW-4 DD 97'-102'
Operator : S. Harts



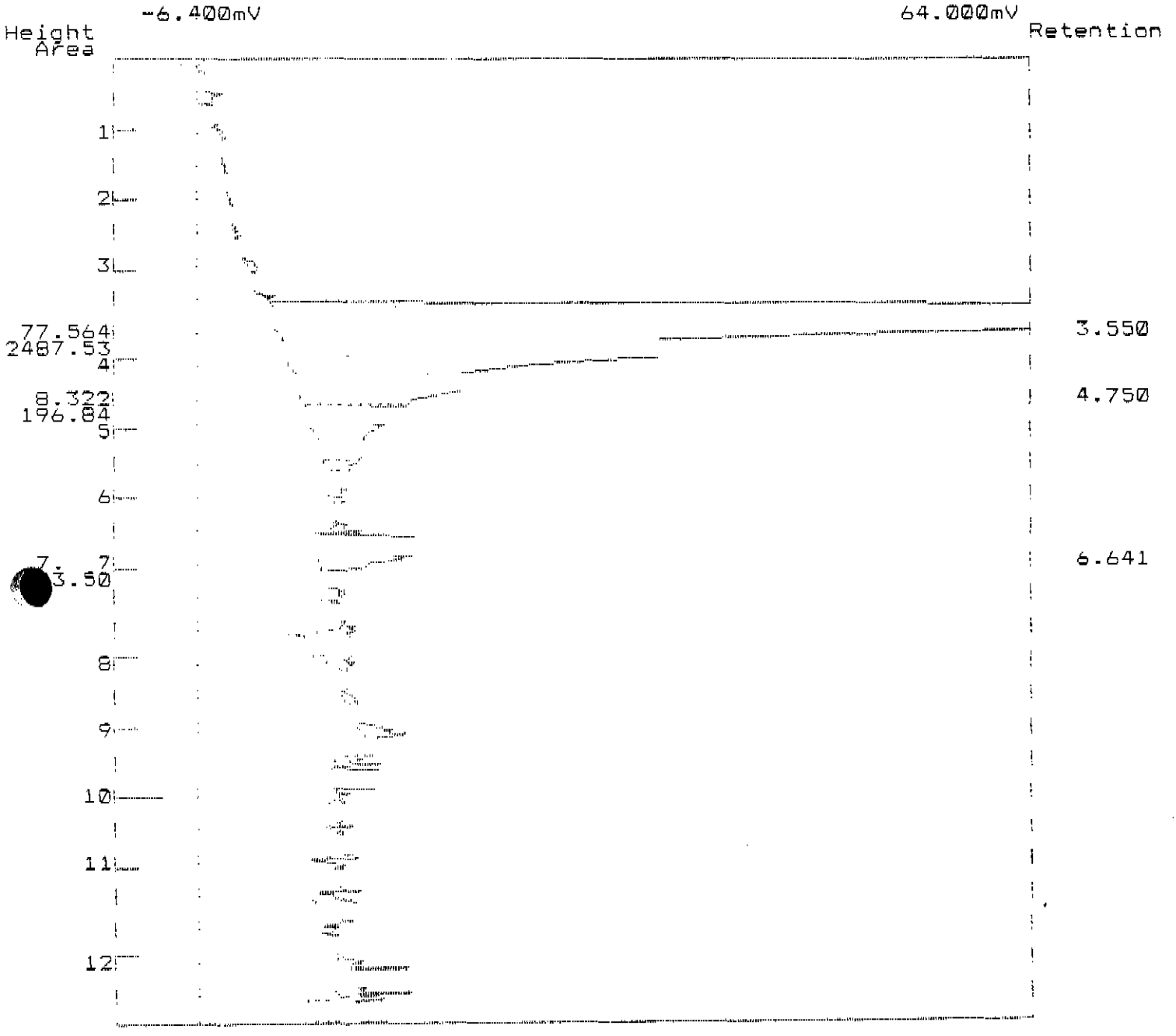
Height / Area	External	Component	Retention
2.334 / 17.41	N/A	(unknown)	1.683
0.501 / 11.81	N/A	(unknown)	5.700
6.058 / 51.02	236.72	1.1-DCA	6.150
0.855 / 14.52	14.52	1.1.1-TCA	9.416
2.504 / 89.51	N/A	(unknown)	10.733

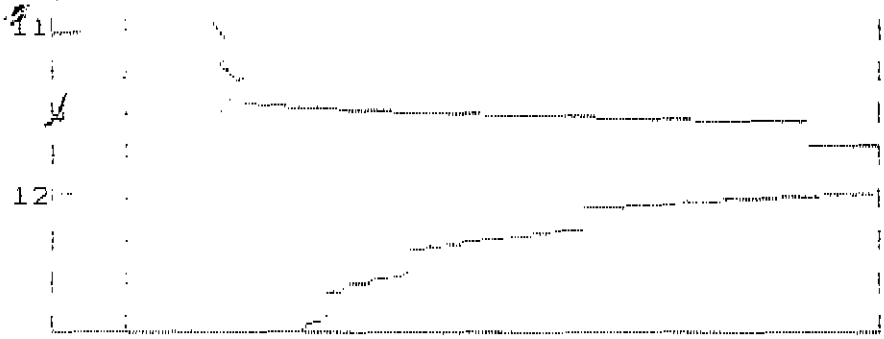
.87	12	N/A	(unknown)	12.083

Component	Retention	Area
(unknown)	1.683	17.41
(unknown)	5.700	11.81
1.1-DCA	6.150	51.02
1.1.1-TCA	9.416	14.52
(unknown)	10.733	89.51
(unknown)	12.083	71.87
6		256.12

Pp 6

Lab name : SRI Instruments
Analysis date : 08/22/1997 13:24:58
Method : Direct Injection
Description : CHANNEL TWO
Column : MXT-1 0.53mm x 15 M
Carrier : Helium
Data file : 2DATA1.CHR ()
Sample : 1 microliter of Std.





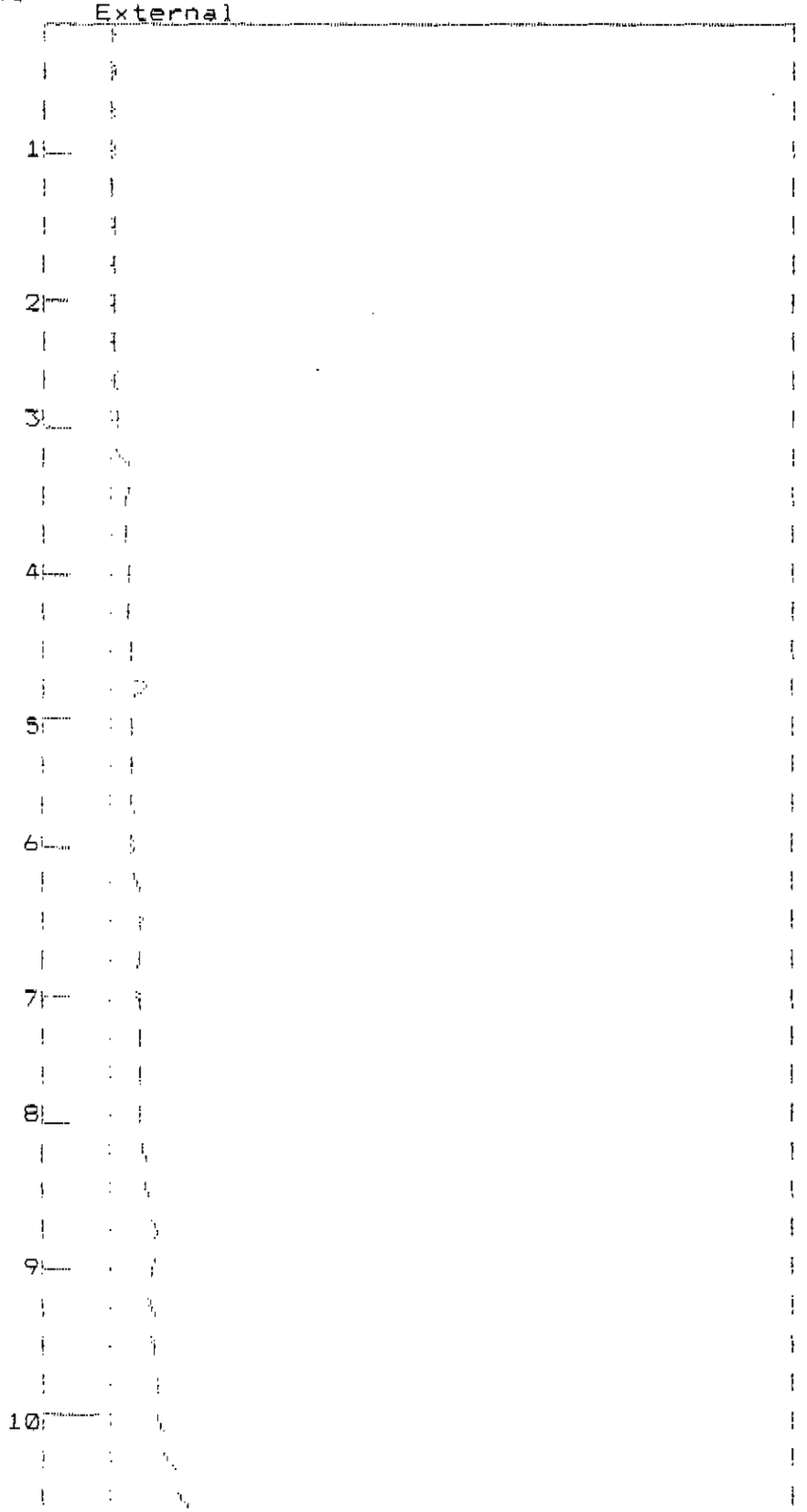
Component	Retention	Area
0		0.00

Lab name : SRI Instruments
Analysis date : 08/22/1997 13:24:58
Method : Direct Injection
Description : CHANNEL ONE
Column : MXT-1 0.53mm x 15 M
Carrier : Helium
Data file : 1data1.chr ()
Sample : 1 microliter of Std.

-51.200mV 512.000mV

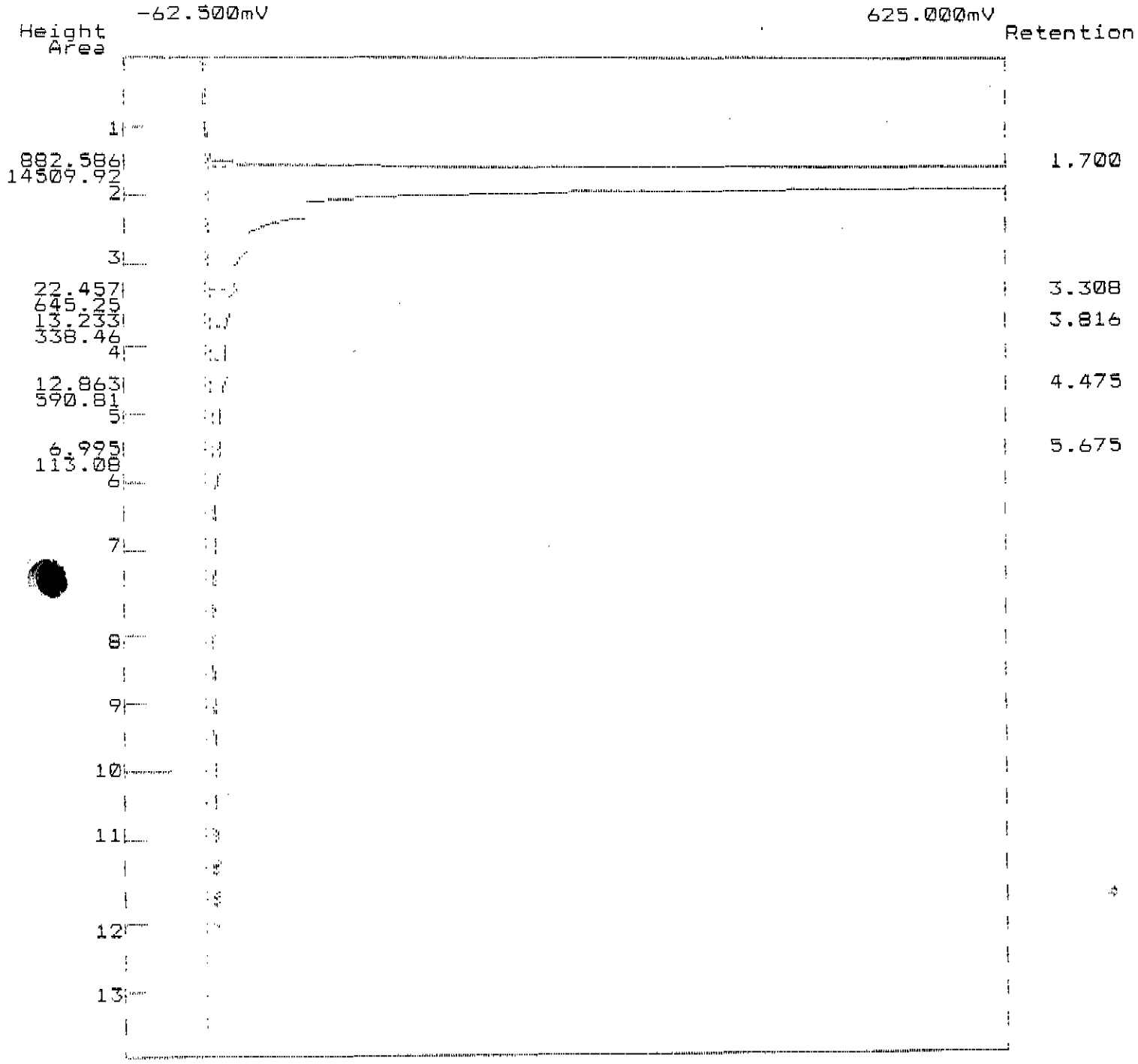
Height
Area

External



Component	Retention

Lab name : SRI Instruments
Analysis date : 08/22/1997 10:54:18
Method : Direct Injection
Description : CHANNEL TWO
Column : MXT-1 0.53mm x 15 M
Carrier : Helium
Data file : 2DATA1.CHR ()
Sample : 1 microliter of Std.



Component	Retention	Area	External
Tetrachloroethe	1.533	150.64	135.90
Tetrachloroethe	1.700	14509.92	3611.77
1.1 DCA	3.308	645.25	1581.90
1.1 DCA	3.816	338.46	829.78
(unknown)	4.475	590.81	N/A
Trichloroethene	5.675	113.08	349.99

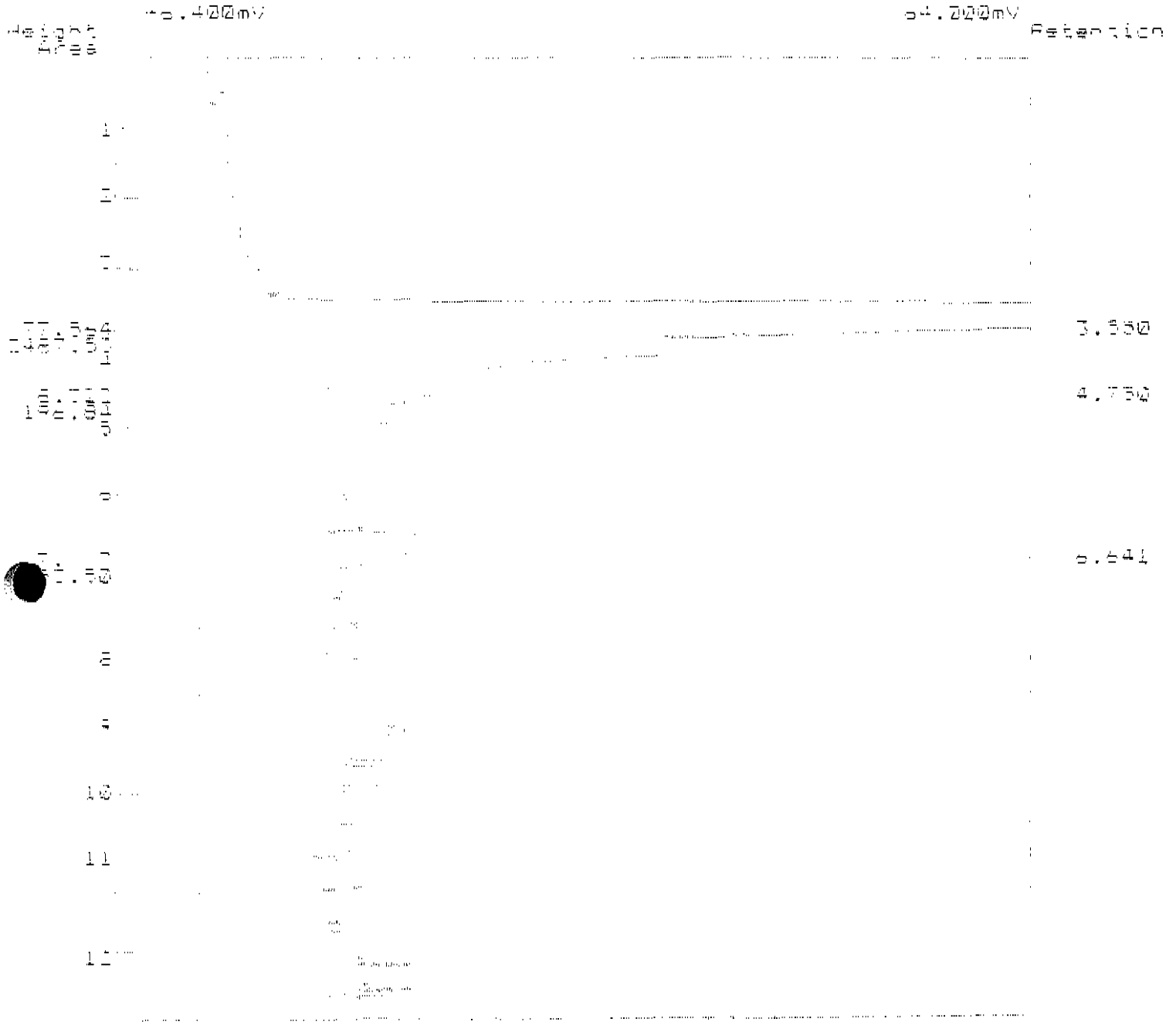
[illegible]	N/A		(unknown)	11.087

Component	Retention	Area
(unknown)	1.587	17.11
(unknown)	5.700	11.81
1,1-DCA	6.150	51.02
1,1,1-TCA	9.416	14.82
(unknown)	10.[illegible]	[illegible]
(unknown)	11.087	71.8[illegible]

ppb

6	256.12

Lab name : SRI Instruments
Analysis date : 08/22/1997 13:24:58
Method : Direct Injection
Description : CHANNEL TWO
Column : MXT-1 0.53mm x 15 M
Carrier : Helium
Data file : 2DATA1.CHR ()
Sample : 1 microliter of Std.



Component	Retention	Area
0		0.00

Lab name : SRI Instruments
Analysis date : 08/22/1997 13:24:58
Method : Direct Injection
Description : CHANNEL ONE
Column : MXT-1 0.53mm x 15 M
Carrier : Helium
Data file : 1data1.chr ()
Sample : 1 microliter of Std.

-51.200mv 512.000mv

Height Area	External	Component	Retention

1

2

3

4

5

6

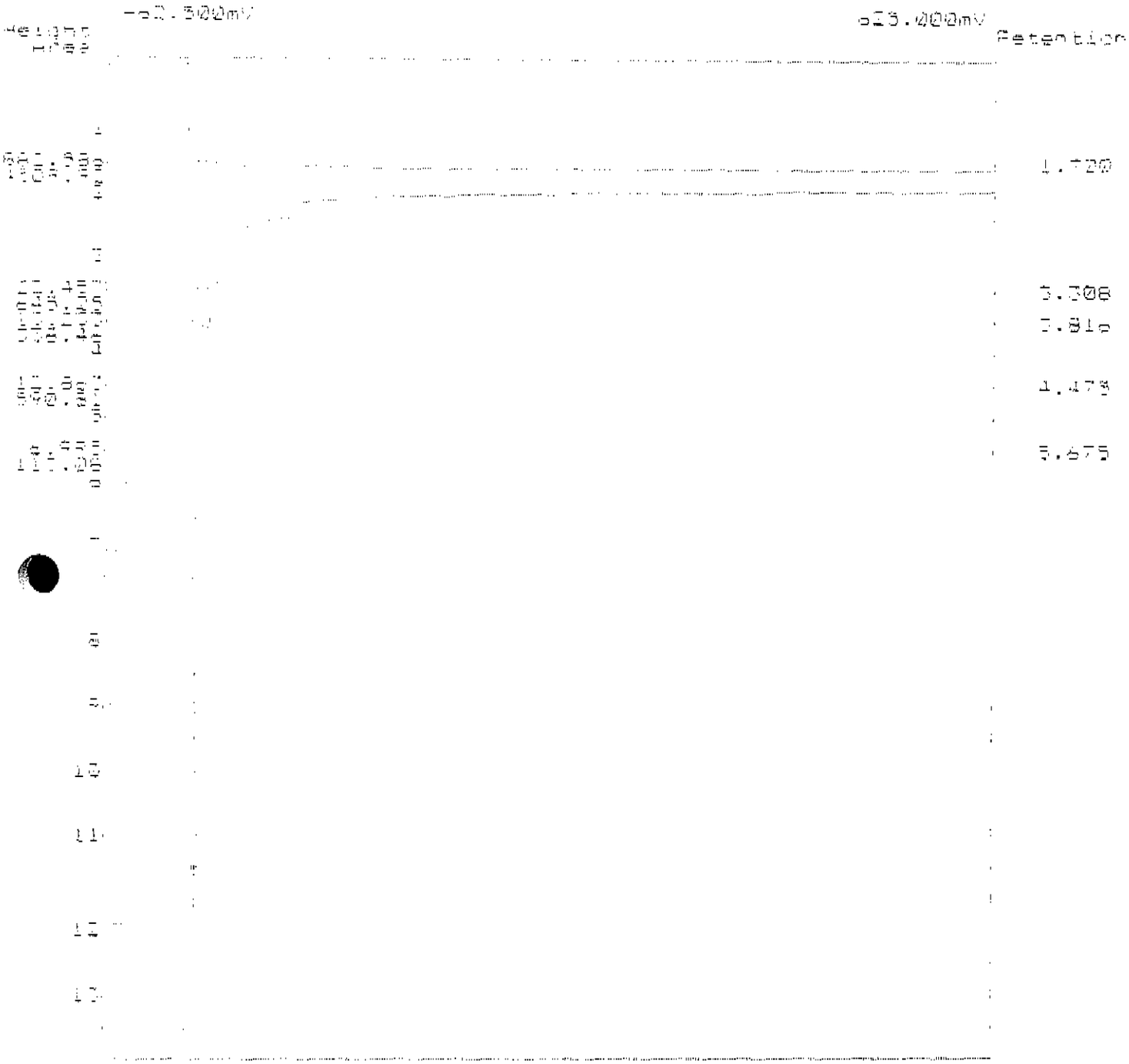
7

8

9

10

Lab name : SRI Instruments
Analysis date : 08/22/1997 10:54:18
Method : Direct Injection
Description : CHANNEL TWO
Column : MXT-1 0.53mm x 15 M
Carrier : Helium
Data file : 2DATA1.CHR ()
Sample : 1 microliter of Std.



Component	Retention	Area	External
Tetrachloroethe	1.533	150.64	135.90
Tet[illegible]hloroethe	1.700	14509.92	10611.77
[illegible]	3.308	649.25	1581.50
[illegible]	3.816	378.46	809.78
[illegible]	4.473	350.81	[illegible]
Trichloroethene	5.675	113.08	349.66

Down-gradient Geoprobe Survey (Horizontal Extent)

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: P-01
Client Project ID: 01 003 0109
Lab Sample ID: 39357
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/14/98
Analyzed By: MES
Date Collected: 4/7/98
Date Received: 4/8/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Benzene	0.5	BQL
Bromobenzene	0.5	BQL
Bromochloromethane	0.5	BQL
Bromodichloromethane	0.5	BQL
Bromoform	0.5	BQL
Bromomethane	0.5	BQL
n-Butylbenzene	0.5	BQL
sec-Butylbenzene	0.5	BQL
tert-Butylbenzene	0.5	BQL
Carbon tetrachloride	0.5	BQL
Chlorobenzene	0.5	BQL
Chloroethane	0.5	BQL
Chloroform	0.5	BQL
Chloromethane	0.5	BQL
2-Chlorotoluene	0.5	BQL
4-Chlorotoluene	0.5	BQL
Dibromochloromethane	0.5	BQL
1,2-Dibromo-3-chloropropane	5	BQL
Dibromomethane	0.5	BQL
1,2-Dibromoethane (EDB)	0.5	BQL
1,2-Dichlorobenzene	0.5	BQL
1,3-Dichlorobenzene	0.5	BQL
1,4-Dichlorobenzene	0.5	BQL
1,1-Dichloroethane	0.5	BQL
1,1-Dichloroethene	0.5	BQL
1,2-Dichloroethane	0.5	BQL
cis-1,2-Dichloroethene	0.5	BQL
trans-1,2-dichloroethene	0.5	BQL
1,2-Dichloropropane	0.5	BQL
1,3-Dichloropropane	0.5	BQL
2,2-Dichloropropane	0.5	BQL
1,1-Dichloropropene	0.5	BQL
Dichlorodifluoromethane	5	BQL
Diisopropyl ether (DIPE)	0.5	BQL
Ethylbenzene	0.5	BQL
Hexachlorobutadiene	0.5	BQL
Isopropylbenzene	0.5	BQL
4-Isopropyltoluene	0.5	BQL
Methylene chloride	5	BQL
Methyl-tert-butyl ether (MTBE)	0.5	BQL
Naphthalene	0.5	**0.8**
n-Propyl benzene	0.5	BQL

Reviewed by: PTV

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: P-01
Client Project ID: 01 003 0109
Lab Sample ID: 39357
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/14/98
Analyzed By: MES
Date Collected: 4/7/98
Date Received: 4/8/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Styrene	0.5	BQL
1,1,1,2-Tetrachloroethane	0.5	BQL
1,1,2,2-Tetrachloroethane	0.5	BQL
Tetrachloroethene	0.5	BQL
Toluene	0.5	**0.6**
1,2,3-Trichlorobenzene	0.5	BQL
1,2,4-Trichlorobenzene	0.5	BQL
Trichloroethene	0.5	BQL
1,1,1-Trichloroethane	0.5	BQL
1,1,2-Trichloroethane	0.5	BQL
Trichlorofluoromethane	0.5	BQL
1,2,3-Trichloropropane	0.5	BQL
1,2,4-Trimethylbenzene	0.5	**0.5**
1,3,5-Trimethylbenzene	0.5	BQL
Vinyl chloride	0.5	BQL
m-,p-Xylene	1	BQL
o-Xylene	0.5	BQL

Surrogate Spike Recoveries Compound	Spike Added (ug/L)	Surrogate Result (ug/L)	%Rec
Bromofluorobenzene	10.0	10	100
1,2-Dichloroethane-d4	10.0	12	120
Toluene-d8	10.0	10	100

Comments:
All results are corrected for dilution.

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: P-02
Client Project ID: 01 003 0109
Lab Sample ID: 39358
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/14/98
Analyzed By: MES
Date Collected: 4/7/98
Date Received: 4/8/98
Dilution: 100.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Benzene	50	BQL
Bromobenzene	50	BQL
Bromochloromethane	50	BQL
Bromodichloromethane	50	BQL
Bromoform	50	BQL
Bromomethane	50	BQL
n-Butylbenzene	50	BQL
sec-Butylbenzene	50	BQL
tert-Butylbenzene	50	BQL
Carbon tetrachloride	50	BQL
Chlorobenzene	50	BQL
Chloroethane	50	BQL
Chloroform	50	BQL
Chloromethane	50	BQL
2-Chlorotoluene	50	BQL
4-Chlorotoluene	50	BQL
Dibromochloromethane	50	BQL
1,2-Dibromo-3-chloropropane	500	BQL
Dibromomethane	50	BQL
1,2-Dibromoethane (EDB)	50	BQL
1,2-Dichlorobenzene	50	BQL
1,3-Dichlorobenzene	50	BQL
1,4-Dichlorobenzene	50	BQL
1,1-Dichloroethane	50	BQL
1,1-Dichloroethene	50	**1500**
1,2-Dichloroethane	50	BQL
cis-1,2-Dichloroethene	50	BQL
trans-1,2-dichloroethene	50	BQL
1,2-Dichloropropane	50	BQL
1,3-Dichloropropane	50	BQL
2,2-Dichloropropane	50	BQL
1,1-Dichloropropene	50	BQL
Dichlorodifluoromethane	500	BQL
Diisopropyl ether (DIPE)	50	BQL
Ethylbenzene	50	BQL
Hexachlorobutadiene	50	BQL
Isopropylbenzene	50	BQL
4-Isopropyltoluene	50	BQL
Methylene chloride	500	BQL
Methyl-tert-butyl ether (MTBE)	50	BQL
Naphthalene	50	BQL
n-Propyl benzene	50	BQL

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

Results for Volatiles

by GCMS 6210D

Client Sample ID: P-02
Client Project ID: 01 003 0109
Lab Sample ID: 39358
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/14/98
Analyzed By: MES
Date Collected: 4/7/98
Date Received: 4/8/98
Dilution: 100.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Styrene	50	BQL
1,1,1,2-Tetrachloroethane	50	BQL
1,1,2,2-Tetrachloroethane	50	BQL
Tetrachloroethene	50	**210**
Toluene	50	BQL
1,2,3-Trichlorobenzene	50	BQL
1,2,4-Trichlorobenzene	50	BQL
Trichloroethene	50	**52**
1,1,1-Trichloroethane	50	**51**
1,1,2-Trichloroethane	50	BQL
Trichlorofluoromethane	50	BQL
1,2,3-Trichloropropane	50	BQL
1,2,4-Trimethylbenzene	50	BQL
1,3,5-Trimethylbenzene	50	BQL
Vinyl chloride	50	BQL
m-,p-Xylene	100	BQL
o-Xylene	50	BQL

Surrogate Spike Recoveries Compound	Spike Added (ug/L)	Surrogate Result (ug/L)	%Rec
Bromofluorobenzene	10.0	9.7	97
1,2-Dichloroethane-d4	10.0	10	100
Toluene-d8	10.0	10	100

Comments:

All results are corrected for dilution.

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: P-03
Client Project ID: 01 003 0109
Lab Sample ID: 39359
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/18/98
Analyzed By: MES
Date Collected: 4/7/98
Date Received: 4/8/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Benzene	0.5	BQL
Bromobenzene	0.5	BQL
Bromochloromethane	0.5	BQL
Bromodichloromethane	0.5	BQL
Bromoform	0.5	BQL
Bromomethane	0.5	BQL
n-Butylbenzene	0.5	BQL
sec-Butylbenzene	0.5	BQL
tert-Butylbenzene	0.5	BQL
Carbon tetrachloride	0.5	BQL
Chlorobenzene	0.5	BQL
Chloroethane	0.5	BQL
Chloroform	0.5	BQL
Chloromethane	0.5	BQL
2-Chlorotoluene	0.5	BQL
4-Chlorotoluene	0.5	BQL
Dibromochloromethane	0.5	BQL
1,2-Dibromo-3-chloropropane	5	BQL
Dibromomethane	0.5	BQL
1,2-Dibromoethane (EDB)	0.5	BQL
1,2-Dichlorobenzene	0.5	BQL
1,3-Dichlorobenzene	0.5	BQL
1,4-Dichlorobenzene	0.5	BQL
1,1-Dichloroethane	0.5	BQL
1,1-Dichloroethene	0.5	BQL
1,2-Dichloroethane	0.5	BQL
cis-1,2-Dichloroethene	0.5	BQL
trans-1,2-dichloroethene	0.5	BQL
1,2-Dichloropropane	0.5	BQL
1,3-Dichloropropane	0.5	BQL
2,2-Dichloropropane	0.5	BQL
1,1-Dichloropropene	0.5	BQL
Dichlorodifluoromethane	5	BQL
Diisopropyl ether (DIPE)	0.5	BQL
Ethylbenzene	0.5	BQL
Hexachlorobutadiene	0.5	BQL
Isopropylbenzene	0.5	BQL
4-Isopropyltoluene	0.5	BQL
Methylene chloride	5	BQL
Methyl-tert-butyl ether (MTBE)	0.5	BQL
Naphthalene	0.5	BQL
n-Propyl benzene	0.5	BQL

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles

by GCMS 6210D

Client Sample ID: P-03
Client Project ID: 01 003 0109
Lab Sample ID: 39359
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/18/98
Analyzed By: MES
Date Collected: 4/7/98
Date Received: 4/8/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Styrene	0.5	BQL
1,1,1,2-Tetrachloroethane	0.5	BQL
1,1,2,2-Tetrachloroethane	0.5	BQL
Tetrachloroethene	0.5	BQL
Toluene	0.5	BQL
1,2,3-Trichlorobenzene	0.5	BQL
1,2,4-Trichlorobenzene	0.5	BQL
Trichloroethene	0.5	BQL
1,1,1-Trichloroethane	0.5	BQL
1,1,2-Trichloroethane	0.5	BQL
Trichlorofluoromethane	0.5	BQL
1,2,3-Trichloropropane	0.5	BQL
1,2,4-Trimethylbenzene	0.5	BQL
1,3,5-Trimethylbenzene	0.5	BQL
Vinyl chloride	0.5	BQL
m-,p-Xylene	1	BQL
o-Xylene	0.5	BQL

Surrogate Spike Recoveries Compound	Spike Added (ug/L)	Surrogate Result (ug/L)	%Rec
Bromofluorobenzene	10.0	6.7	67
1,2-Dichloroethane-d4	10.0	9.8	98
Toluene-d8	10.0	8.9	89

Comments:

All results are corrected for dilution.

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles

by GCMS 6210D

Client Sample ID: P-04
Client Project ID: 01 003 0109
Lab Sample ID: 39360
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/18/98
Analyzed By: MES
Date Collected: 4/7/98
Date Received: 4/8/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Benzene	0.5	BQL
Bromobenzene	0.5	BQL
Bromochloromethane	0.5	BQL
Bromodichloromethane	0.5	BQL
Bromoform	0.5	BQL
Bromomethane	0.5	BQL
n-Butylbenzene	0.5	BQL
sec-Butylbenzene	0.5	BQL
tert-Butylbenzene	0.5	BQL
Carbon tetrachloride	0.5	BQL
Chlorobenzene	0.5	BQL
Chloroethane	0.5	BQL
Chloroform	0.5	BQL
Chloromethane	0.5	BQL
2-Chlorotoluene	0.5	BQL
4-Chlorotoluene	0.5	BQL
Dibromochloromethane	0.5	BQL
1,2-Dibromo-3-chloropropane	5	BQL
Dibromomethane	0.5	BQL
1,2-Dibromoethane (EDB)	0.5	BQL
1,2-Dichlorobenzene	0.5	BQL
1,3-Dichlorobenzene	0.5	BQL
1,4-Dichlorobenzene	0.5	BQL
1,1-Dichloroethane	0.5	BQL
1,1-Dichloroethene	0.5	BQL
1,2-Dichloroethane	0.5	BQL
cis-1,2-Dichloroethene	0.5	BQL
trans-1,2-dichloroethene	0.5	BQL
1,2-Dichloropropane	0.5	BQL
1,3-Dichloropropane	0.5	BQL
2,2-Dichloropropane	0.5	BQL
1,1-Dichloropropene	0.5	BQL
Dichlorodifluoromethane	5	BQL
Diisopropyl ether (DIPE)	0.5	BQL
Ethylbenzene	0.5	BQL
Hexachlorobutadiene	0.5	BQL
Isopropylbenzene	0.5	BQL
4-Isopropyltoluene	0.5	BQL
Methylene chloride	5	BQL
Methyl-tert-butyl ether (MTBE)	0.5	**1**
Naphthalene	0.5	**0.6**
n-Propyl benzene	0.5	BQL

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID:	P-04	Date Analyzed:	4/18/98
Client Project ID:	01 003 0109	Analyzed By:	MES
Lab Sample ID:	39360	Date Collected:	4/7/98
Lab Project ID:	G247-1	Date Received:	4/8/98
Matrix:	Water	Dilution:	1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Styrene	0.5	BQL
1,1,1,2-Tetrachloroethane	0.5	BQL
1,1,2,2-Tetrachloroethane	0.5	BQL
Tetrachloroethene	0.5	BQL
Toluene	0.5	1
1,2,3-Trichlorobenzene	0.5	BQL
1,2,4-Trichlorobenzene	0.5	BQL
Trichloroethene	0.5	BQL
1,1,1-Trichloroethane	0.5	BQL
1,1,2-Trichloroethane	0.5	BQL
Trichlorofluoromethane	0.5	BQL
1,2,3-Trichloropropane	0.5	BQL
1,2,4-Trimethylbenzene	0.5	BQL
1,3,5-Trimethylbenzene	0.5	BQL
Vinyl chloride	0.5	BQL
m-,p-Xylene	1	BQL
o-Xylene	0.5	BQL

Surrogate Spike Recoveries Compound	Spike Added (ug/L)	Surrogate Result (ug/L)	%Rec
Bromofluorobenzene	10.0	6.7	67
1,2-Dichloroethane-d4	10.0	12	120
Toluene-d8	10.0	9.8	98

Comments:

All results are corrected for dilution.
Surrogate failure cannot be confirmed due to limited sample volume.

Reviewed by: [illegible]

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: P-05
Client Project ID: 01 003 0109
Lab Sample ID: 39361
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/18/98
Analyzed By: MES
Date Collected: 4/7/98
Date Received: 4/8/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Benzene	0.5	BQL
Bromobenzene	0.5	BQL
Bromochloromethane	0.5	BQL
Bromodichloromethane	0.5	BQL
Bromoform	0.5	BQL
Bromomethane	0.5	BQL
n-Butylbenzene	0.5	BQL
sec-Butylbenzene	0.5	BQL
tert-Butylbenzene	0.5	BQL
Carbon tetrachloride	0.5	BQL
Chlorobenzene	0.5	BQL
Chloroethane	0.5	BQL
Chloroform	0.5	BQL
Chloromethane	0.5	BQL
2-Chlorotoluene	0.5	BQL
4-Chlorotoluene	0.5	BQL
Dibromochloromethane	0.5	BQL
1,2-Dibromo-3-chloropropane	5	BQL
Dibromomethane	0.5	BQL
1,2-Dibromoethane (EDB)	0.5	BQL
1,2-Dichlorobenzene	0.5	BQL
1,3-Dichlorobenzene	0.5	BQL
1,4-Dichlorobenzene	0.5	BQL
1,1-Dichloroethane	0.5	BQL
1,1-Dichloroethene	0.5	**0.6**
1,2-Dichloroethane	0.5	BQL
cis-1,2-Dichloroethene	0.5	**1**
trans-1,2-dichloroethene	0.5	BQL
1,2-Dichloropropane	0.5	BQL
1,3-Dichloropropane	0.5	BQL
2,2-Dichloropropane	0.5	BQL
1,1-Dichloropropene	0.5	BQL
Dichlorodifluoromethane	5	BQL
Diisopropyl ether (DIPE)	0.5	BQL
Ethylbenzene	0.5	BQL
Hexachlorobutadiene	0.5	BQL
Isopropylbenzene	0.5	BQL
4-Isopropyltoluene	0.5	BQL
Methylene chloride	5	BQL
Methyl-tert-butyl ether (MTBE)	0.5	BQL
Naphthalene	0.5	BQL
n-Propyl benzene	0.5	BQL

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: P-05
Client Project ID: 01 003 0109
Lab Sample ID: 39361
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/18/98
Analyzed By: MES
Date Collected: 4/7/98
Date Received: 4/8/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Styrene	0.5	BQL
1,1,1,2-Tetrachloroethane	0.5	BQL
1,1,2,2-Tetrachloroethane	0.5	BQL
Tetrachloroethene	0.5	2
Toluene	0.5	BQL
1,2,3-Trichlorobenzene	0.5	BQL
1,2,4-Trichlorobenzene	0.5	BQL
Trichloroethene	0.5	13
1,1,1-Trichloroethane	0.5	BQL
1,1,2-Trichloroethane	0.5	BQL
Trichlorofluoromethane	0.5	BQL
1,2,3-Trichloropropane	0.5	BQL
1,2,4-Trimethylbenzene	0.5	BQL
1,3,5-Trimethylbenzene	0.5	BQL
Vinyl chloride	0.5	BQL
m-,p-Xylene	1	BQL
o-Xylene	0.5	BQL

Surrogate Spike Recoveries Compound	Spike Added (ug/L)	Surrogate Result (ug/L)	%Rec
Bromofluorobenzene	10.0	6.8	68
1,2-Dichloroethane-d4	10.0	12	120
Toluene-d8	10.0	7.7	77

Comments:

All results are corrected for dilution.
Surrogate failure cannot be confirmed due to limited sample volume.

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: P-06
Client Project ID: 01 003 0109
Lab Sample ID: 39362
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/18/98
Analyzed By: MES
Date Collected: 4/7/98
Date Received: 4/8/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Benzene	0.5	BQL
Bromobenzene	0.5	BQL
Bromochloromethane	0.5	BQL
Bromodichloromethane	0.5	BQL
Bromoform	0.5	BQL
Bromomethane	0.5	BQL
n-Butylbenzene	0.5	BQL
sec-Butylbenzene	0.5	BQL
tert-Butylbenzene	0.5	BQL
Carbon tetrachloride	0.5	BQL
Chlorobenzene	0.5	BQL
Chloroethane	0.5	BQL
Chloroform	0.5	BQL
Chloromethane	0.5	BQL
2-Chlorotoluene	0.5	BQL
4-Chlorotoluene	0.5	BQL
Dibromochloromethane	0.5	BQL
1,2-Dibromo-3-chloropropane	5	BQL
Dibromomethane	0.5	BQL
1,2-Dibromoethane (EDB)	0.5	BQL
1,2-Dichlorobenzene	0.5	BQL
1,3-Dichlorobenzene	0.5	BQL
1,4-Dichlorobenzene	0.5	BQL
1,1-Dichloroethane	0.5	BQL
1,1-Dichloroethene	0.5	2
1,2-Dichloroethane	0.5	BQL
cis-1,2-Dichloroethene	0.5	BQL
trans-1,2-dichloroethene	0.5	BQL
1,2-Dichloropropane	0.5	BQL
1,3-Dichloropropane	0.5	BQL
2,2-Dichloropropane	0.5	BQL
1,1-Dichloropropene	0.5	BQL
Dichlorodifluoromethane	5	BQL
Diisopropyl ether (DIPE)	0.5	BQL
Ethylbenzene	0.5	BQL
Hexachlorobutadiene	0.5	BQL
Isopropylbenzene	0.5	BQL
4-Isopropyltoluene	0.5	BQL
Methylene chloride	5	BQL
Methyl-tert-butyl ether (MTBE)	0.5	BQL
Naphthalene	0.5	BQL
n-Propyl benzene	0.5	BQL

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: P-06
Client Project ID: 01 003 0109
Lab Sample ID: 39362
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/18/98
Analyzed By: MES
Date Collected: 4/7/98
Date Received: 4/8/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)	
Styrene	0.5	BQL	
1,1,1,2-Tetrachloroethane	0.5	BQL	
1,1,2,2-Tetrachloroethane	0.5	BQL	
Tetrachloroethene	0.5		1
Toluene	0.5	BQL	
1,2,3-Trichlorobenzene	0.5	BQL	
1,2,4-Trichlorobenzene	0.5	BQL	
Trichloroethene	0.5		4
1,1,1-Trichloroethane	0.5	BQL	
1,1,2-Trichloroethane	0.5	BQL	
Trichlorofluoromethane	0.5	BQL	
1,2,3-Trichloropropane	0.5	BQL	
1,2,4-Trimethylbenzene	0.5	BQL	
1,3,5-Trimethylbenzene	0.5	BQL	
Vinyl chloride	0.5	BQL	
m-,p-Xylene	1	BQL	
o-Xylene	0.5	BQL	

Surrogate Spike Recoveries Compound	Spike Added (ug/L)	Surrogate Result (ug/L)	%Rec
Bromofluorobenzene	10.0	6.2	62
1,2-Dichloroethane-d4	10.0	10	100
Toluene-d8	10.0	6.6	66

Comments:

All results are corrected for dilution.
Surrogate failure cannot be confirmed due to limited sample volume.

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: Trip Blank
Client Project ID: 01 003 0109
Lab Sample ID: 39363
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/10/98
Analyzed By: MES
Date Collected: 4/7/98
Date Received: 4/8/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Benzene	0.5	BQL
Bromobenzene	0.5	BQL
Bromochloromethane	0.5	BQL
Bromodichloromethane	0.5	BQL
Bromoform	0.5	BQL
Bromomethane	0.5	BQL
n-Butylbenzene	0.5	BQL
sec-Butylbenzene	0.5	BQL
tert-Butylbenzene	0.5	BQL
Carbon tetrachloride	0.5	BQL
Chlorobenzene	0.5	BQL
Chloroethane	0.5	BQL
Chloroform	0.5	BQL
Chloromethane	0.5	BQL
2-Chlorotoluene	0.5	BQL
4-Chlorotoluene	0.5	BQL
Dibromochloromethane	0.5	BQL
1,2-Dibromo-3-chloropropane	5	BQL
Dibromomethane	0.5	BQL
1,2-Dibromoethane (EDB)	0.5	BQL
1,2-Dichlorobenzene	0.5	BQL
1,3-Dichlorobenzene	0.5	BQL
1,4-Dichlorobenzene	0.5	BQL
1,1-Dichloroethane	0.5	BQL
1,1-Dichloroethene	0.5	BQL
1,2-Dichloroethane	0.5	BQL
cis-1,2-Dichloroethene	0.5	BQL
trans-1,2-dichloroethene	0.5	BQL
1,2-Dichloropropane	0.5	BQL
1,3-Dichloropropane	0.5	BQL
2,2-Dichloropropane	0.5	BQL
1,1-Dichloropropene	0.5	BQL
Dichlorodifluoromethane	5	BQL
Diisopropyl ether (DIPE)	0.5	BQL
Ethylbenzene	0.5	BQL
Hexachlorobutadiene	0.5	BQL
Isopropylbenzene	0.5	BQL
4-Isopropyltoluene	0.5	BQL
Methylene chloride	5	BQL
Methyl-tert-butyl ether (MTBE)	0.5	BQL
Naphthalene	0.5	BQL
n-Propyl benzene	0.5	BQL

Reviewed by: [illegible]

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: Trip Blank
Client Project ID: 01 003 0109
Lab Sample ID: 39363
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/10/98
Analyzed By: MES
Date Collected: 4/7/98
Date Received: 4/8/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Styrene	0.5	BQL
1,1,1,2-Tetrachloroethane	0.5	BQL
1,1,2,2-Tetrachloroethane	0.5	BQL
Tetrachloroethene	0.5	BQL
Toluene	0.5	BQL
1,2,3-Trichlorobenzene	0.5	BQL
1,2,4-Trichlorobenzene	0.5	BQL
Trichloroethene	0.5	BQL
1,1,1-Trichloroethane	0.5	BQL
1,1,2-Trichloroethane	0.5	BQL
Trichlorofluoromethane	0.5	BQL
1,2,3-Trichloropropane	0.5	BQL
1,2,4-Trimethylbenzene	0.5	BQL
1,3,5-Trimethylbenzene	0.5	BQL
Vinyl chloride	0.5	BQL
m-,p-Xylene	1	BQL
o-Xylene	0.5	BQL

Surrogate Spike Recoveries Compound	Spike Added (ug/L)	Surrogate Result (ug/L)	%Rec
Bromofluorobenzene	10.0	10	100
1,2-Dichloroethane-d4	10.0	11	110
Toluene-d8	10.0	10	100

Comments:
All results are corrected for dilution.

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.
2627 Northchase Parkway S.E.
Wilmington, North Carolina 28405
(910) 350-1903
Fax (910) 350-1557

Mr. Mike Haseltine
Triangle Environmental
295A N. Green Meadows Dr.
Wilmington N,C 28405

Date 05-22-98

Report Number: G 247-4

Client Project Number : 01-003-0109

Dear Mr. Haseltine:

Enclosed are the results of the analytical services performed under the referenced project. Copies of this report and supporting data will be retained in our files for a period of five years in the event they are required for future reference. Any samples submitted to our laboratory will be retained for a maximum of thirty (30) days from date of this report unless other arrangements are requested.

If there are any questions about the report or the services performed during this project, please call for assistance. We will be happy to answer any questions or concerns which you may have.

Thank you for using Paradigm Analytical Labs for your analytical service projects. We look forward to working with you again on any additional needs which you may have.

Sincerely,

Paradigm Analytical Laboratories

Laboratory Director
Mark Randall

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: GP-8(R-7
Client Project ID: 01-003-0109
Lab Sample ID: 41213
Lab Project ID: G247-4
Matrix: Water

Date Analyzed: 5/19/98
Analyzed By: MES
Date Collected: 5/12/98
Date Received: 5/13/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Benzene	0.5	BQL
Bromobenzene	0.5	BQL
Bromochloromethane	0.5	BQL
Bromodichloromethane	0.5	BQL
Bromoform	0.5	BQL
Bromomethane	0.5	BQL
n-Butylbenzene	0.5	BQL
sec-Butylbenzene	0.5	BQL
tert-Butylbenzene	0.5	BQL
Carbon tetrachloride	0.5	BQL
Chlorobenzene	0.5	BQL
Chloroethane	0.5	BQL
Chloroform	0.5	BQL
Chloromethane	0.5	BQL
2-Chlorotoluene	0.5	BQL
4-Chlorotoluene	0.5	BQL
Dibromochloromethane	0.5	BQL
1,2-Dibromo-3-chloropropane	5	BQL
Dibromomethane	0.5	BQL
1,2-Dibromoethane (EDB)	0.5	BQL
1,2-Dichlorobenzene	0.5	BQL
1,3-Dichlorobenzene	0.5	BQL
1,4-Dichlorobenzene	0.5	BQL
1,1-Dichloroethane	0.5	BQL
1,1-Dichloroethene	0.5	BQL
1,2-Dichloroethane	0.5	BQL
cis-1,2-Dichloroethene	0.5	BQL
trans-1,2-dichloroethene	0.5	BQL
1,2-Dichloropropane	0.5	BQL
1,3-Dichloropropane	0.5	BQL
2,2-Dichloropropane	0.5	BQL
1,1-Dichloropropene	0.5	BQL
Dichlorodifluoromethane	5	BQL
Diisopropyl ether (DIPE)	0.5	BQL
Ethylbenzene	0.5	BQL
Hexachlorobutadiene	0.5	BQL
Isopropylbenzene	0.5	BQL
4-Isopropyltoluene	0.5	BQL
Methylene chloride	5	BQL
Methyl-tert-butyl ether (MTBE)	0.5	BQL
Naphthalene	0.5	BQL
n-Propyl benzene	0.5	BQL

Reviewed by: [illegible]

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: GP-8 (P-7)
Client Project ID: 01-003-0109
Lab Sample ID: 41213
Lab Project ID: G247-4
Matrix: Water

Date Analyzed: 5/19/98
Analyzed By: MES
Date Collected: 5/12/98
Date Received: 5/13/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Styrene	0.5	BQL
1,1,1,2-Tetrachloroethane	0.5	BQL
1,1,2,2-Tetrachloroethane	0.5	BQL
Tetrachloroethene	0.5	BQL
Toluene	0.5	BQL
1,2,3-Trichlorobenzene	0.5	BQL
1,2,4-Trichlorobenzene	0.5	BQL
Trichloroethene	0.5	BQL
1,1,1-Trichloroethane	0.5	BQL
1,1,2-Trichloroethane	0.5	BQL
Trichlorofluoromethane	0.5	BQL
1,2,3-Trichloropropane	0.5	BQL
1,2,4-Trimethylbenzene	0.5	BQL
1,3,5-Trimethylbenzene	0.5	BQL
Vinyl chloride	0.5	BQL
m-,p-Xylene	1	BQL
o-Xylene	0.5	BQL

Surrogate Spike Recoveries Compound	Spike Added (ug/L)	Surrogate Result (ug/L)	%Rec
Bromofluorobenzene	10.0	8.8	88
1,2-Dichloroethane-d4	10.0	8.2	82
Toluene-d8	10.0	9.3	93

Comments:
All results are corrected for dilution.

Reviewed by: [illegible]

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: GP-9 (P-8)
Client Project ID: 01-003-0109
Lab Sample ID: 41214
Lab Project ID: G247-4
Matrix: Water

Date Analyzed: 5/19/98
Analyzed By: MES
Date Collected: 5/12/98
Date Received: 5/13/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Benzene	0.5	BQL
Bromobenzene	0.5	BQL
Bromochloromethane	0.5	BQL
Bromodichloromethane	0.5	BQL
Bromoform	0.5	BQL
Bromomethane	0.5	BQL
n-Butylbenzene	0.5	BQL
sec-Butylbenzene	0.5	BQL
tert-Butylbenzene	0.5	BQL
Carbon tetrachloride	0.5	BQL
Chlorobenzene	0.5	BQL
Chloroethane	0.5	BQL
Chloroform	0.5	BQL
Chloromethane	0.5	BQL
2-Chlorotoluene	0.5	BQL
4-Chlorotoluene	0.5	BQL
Dibromochloromethane	0.5	BQL
1,2-Dibromo-3-chloropropane	5	BQL
Dibromomethane	0.5	BQL
1,2-Dibromoethane (EDB)	0.5	BQL
1,2-Dichlorobenzene	0.5	BQL
1,3-Dichlorobenzene	0.5	BQL
1,4-Dichlorobenzene	0.5	BQL
1,1-Dichloroethane	0.5	BQL
1,1-Dichloroethene	0.5	3
1,2-Dichloroethane	0.5	BQL
cis-1,2-Dichloroethene	0.5	BQL
trans-1,2-dichloroethene	0.5	BQL
1,2-Dichloropropane	0.5	BQL
1,3-Dichloropropane	0.5	BQL
2,2-Dichloropropane	0.5	BQL
1,1-Dichloropropene	0.5	BQL
Dichlorodifluoromethane	5	BQL
Diisopropyl ether (DIPE)	0.5	BQL
Ethylbenzene	0.5	BQL
Hexachlorobutadiene	0.5	BQL
Isopropylbenzene	0.5	BQL
4-Isopropyltoluene	0.5	BQL
Methylene chloride	5	BQL
Methyl-tert-butyl ether (MTBE)	0.5	BQL
Naphthalene	0.5	BQL
n-Propyl benzene	0.5	BQL

Reviewed by: MES

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: GP-9 (7-8)
Client Project ID: 01-003-0109
Lab Sample ID: 41214
Lab Project ID: G247-4
Matrix: Water

Date Analyzed: 5/19/98
Analyzed By: MES
Date Collected: 5/12/98
Date Received: 5/13/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Styrene	0.5	BQL
1,1,1,2-Tetrachloroethane	0.5	BQL
1,1,2,2-Tetrachloroethane	0.5	BQL
Tetrachloroethene	0.5	BQL
Toluene	0.5	**0.8**
1,2,3-Trichlorobenzene	0.5	BQL
1,2,4-Trichlorobenzene	0.5	BQL
Trichloroethene	0.5	**2**
1,1,1-Trichloroethane	0.5	BQL
1,1,2-Trichloroethane	0.5	BQL
Trichlorofluoromethane	0.5	BQL
1,2,3-Trichloropropane	0.5	BQL
1,2,4-Trimethylbenzene	0.5	BQL
1,3,5-Trimethylbenzene	0.5	BQL
Vinyl chloride	0.5	BQL
m-,p-Xylene	1	BQL
o-Xylene	0.5	BQL

Surrogate Spike Recoveries Compound	Spike Added (ug/L)	Surrogate Result (ug/L)	%Rec
Bromofluorobenzene	10.0	8.9	89
1,2-Dichloroethane-d4	10.0	8.3	83
Toluene-d8	10.0	9.4	94

Comments:
All results are corrected for dilution.

Reviewed by: [illegible]

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: GP-10 (P-2)
Client Project ID: 01-003-0109
Lab Sample ID: 41215
Lab Project ID: G247-4
Matrix: Water

Date Analyzed: 5/19/98
Analyzed By: MES
Date Collected: 5/12/98
Date Received: 5/13/98
Dilution: 1.5

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Benzene	0.77	BQL
Bromobenzene	0.77	BQL
Bromochloromethane	0.77	BQL
Bromodichloromethane	0.77	BQL
Bromoform	0.77	BQL
Bromomethane	0.77	BQL
n-Butylbenzene	0.77	BQL
sec-Butylbenzene	0.77	BQL
tert-Butylbenzene	0.77	BQL
Carbon tetrachloride	0.77	BQL
Chlorobenzene	0.77	BQL
Chloroethane	0.77	BQL
Chloroform	0.77	BQL
Chloromethane	0.77	BQL
2-Chlorotoluene	0.77	BQL
4-Chlorotoluene	0.77	BQL
Dibromochloromethane	0.77	BQL
1,2-Dibromo-3-chloropropane	7.7	BQL
Dibromomethane	0.77	BQL
1,2-Dibromoethane (EDB)	0.77	BQL
1,2-Dichlorobenzene	0.77	BQL
1,3-Dichlorobenzene	0.77	BQL
1,4-Dichlorobenzene	0.77	BQL
1,1-Dichloroethane	0.77	BQL
1,1-Dichloroethene	0.77	BQL
1,2-Dichloroethane	0.77	BQL
cis-1,2-Dichloroethene	0.77	BQL
trans-1,2-dichloroethene	0.77	BQL
1,2-Dichloropropane	0.77	BQL
1,3-Dichloropropane	0.77	BQL
2,2-Dichloropropane	0.77	BQL
1,1-Dichloropropene	0.77	BQL
Dichlorodifluoromethane	7.7	BQL
Diisopropyl ether (DIPE)	0.77	BQL
Ethylbenzene	0.77	BQL
Hexachlorobutadiene	0.77	BQL
Isopropylbenzene	0.77	BQL
4-Isopropyltoluene	0.77	BQL
Methylene chloride	7.7	BQL
Methyl-tert-butyl ether (MTBE)	0.77	BQL
Naphthalene	0.77	BQL
n-Propyl benzene	0.77	BQL

Reviewed by: [illegible]

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: GP-10 (P-9)
Client Project ID: 01-003-0109
Lab Sample ID: 41215
Lab Project ID: G247-4
Matrix: Water

Date Analyzed: 5/19/98
Analyzed By: MES
Date Collected: 5/12/98
Date Received: 5/13/98
Dilution: 1.5

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Styrene	0.77	BQL
1,1,1,2-Tetrachloroethane	0.77	BQL
1,1,2,2-Tetrachloroethane	0.77	BQL
Tetrachloroethene	0.77	BQL
Toluene	0.77	BQL
1,2,3-Trichlorobenzene	0.77	BQL
1,2,4-Trichlorobenzene	0.77	BQL
Trichloroethene	0.77	BQL
1,1,1-Trichloroethane	0.77	BQL
1,1,2-Trichloroethane	0.77	BQL
Trichlorofluoromethane	0.77	BQL
1,2,3-Trichloropropane	0.77	BQL
1,2,4-Trimethylbenzene	0.77	BQL
1,3,5-Trimethylbenzene	0.77	BQL
Vinyl chloride	0.77	BQL
m-,p-Xylene	1.5	BQL
o-Xylene	0.77	BQL

Surrogate Spike Recoveries Compound	Spike Added (ug/L)	Surrogate Result (ug/L)	%Rec
Bromofluorobenzene	10.0	8.8	88
1,2-Dichloroethane-d4	10.0	7.7	77
Toluene-d8	10.0	8.9	89

Comments:

All results are corrected for dilution.
Diluted due to limited sample volume.

Reviewed by: [illegible]

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: Trip Blank
Client Project ID: 01-003-0109
Lab Sample ID: 41216
Lab Project ID: G247-4
Matrix: Water

Date Analyzed: 5/19/98
Analyzed By: MES
Date Collected: 5/12/98
Date Received: 5/13/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Benzene	0.5	BQL
Bromobenzene	0.5	BQL
Bromochloromethane	0.5	BQL
Bromodichloromethane	0.5	BQL
Bromoform	0.5	BQL
Bromomethane	0.5	BQL
n-Butylbenzene	0.5	BQL
sec-Butylbenzene	0.5	BQL
tert-Butylbenzene	0.5	BQL
Carbon tetrachloride	0.5	BQL
Chlorobenzene	0.5	BQL
Chloroethane	0.5	BQL
Chloroform	0.5	BQL
Chloromethane	0.5	BQL
2-Chlorotoluene	0.5	BQL
4-Chlorotoluene	0.5	BQL
Dibromochloromethane	0.5	BQL
1,2-Dibromo-3-chloropropane	5	BQL
Dibromomethane	0.5	BQL
1,2-Dibromoethane (EDB)	0.5	BQL
1,2-Dichlorobenzene	0.5	BQL
1,3-Dichlorobenzene	0.5	BQL
1,4-Dichlorobenzene	0.5	BQL
1,1-Dichloroethane	0.5	BQL
1,1-Dichloroethene	0.5	BQL
1,2-Dichloroethane	0.5	BQL
cis-1,2-Dichloroethene	0.5	BQL
trans-1,2-dichloroethene	0.5	BQL
1,2-Dichloropropane	0.5	BQL
1,3-Dichloropropane	0.5	BQL
2,2-Dichloropropane	0.5	BQL
1,1-Dichloropropene	0.5	BQL
Dichlorodifluoromethane	5	BQL
Diisopropyl ether (DIPE)	0.5	BQL
Ethylbenzene	0.5	BQL
Hexachlorobutadiene	0.5	BQL
Isopropylbenzene	0.5	BQL
4-Isopropyltoluene	0.5	BQL
Methylene chloride	5	BQL
Methyl-tert-butyl ether (MTBE)	0.5	BQL
Naphthalene	0.5	BQL
n-Propyl benzene	0.5	BQL

Reviewed by: [illegible]

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: Trip Blank
Client Project ID: 01-003-0109
Lab Sample ID: 41216
Lab Project ID: G247-4
Matrix: Water

Date Analyzed: 5/19/98
Analyzed By: MES
Date Collected: 5/12/98
Date Received: 5/13/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Styrene	0.5	BQL
1,1,1,2-Tetrachloroethane	0.5	BQL
1,1,2,2-Tetrachloroethane	0.5	BQL
Tetrachloroethene	0.5	BQL
Toluene	0.5	BQL
1,2,3-Trichlorobenzene	0.5	BQL
1,2,4-Trichlorobenzene	0.5	BQL
Trichloroethene	0.5	BQL
1,1,1-Trichloroethane	0.5	BQL
1,1,2-Trichloroethane	0.5	BQL
Trichlorofluoromethane	0.5	BQL
1,2,3-Trichloropropane	0.5	BQL
1,2,4-Trimethylbenzene	0.5	BQL
1,3,5-Trimethylbenzene	0.5	BQL
Vinyl chloride	0.5	BQL
m-,p-Xylene	1	BQL
o-Xylene	0.5	BQL

Surrogate Spike Recoveries Compound	Spike Added (ug/L)	Surrogate Result (ug/L)	%Rec
Bromofluorobenzene	10.0	9.7	97
1,2-Dichloroethane-d4	10.0	10	100
Toluene-d8	10.0	9.7	97

Comments:
All results are corrected for dilution.

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

ARADIGM ANALYTICAL LABORATORIES, INC.
627 Northchase Highway SE, Wilmington, NC 28405
hone: (910)-350-1903 FAX: (910)-350-1557

Chain-of Custody Record & Analytical Request

COC# 1529

Page 1 of 1

lient: Triangle Environmental Project ID: 01-003-0109 Date: 5/13/98 Report To: Mike Haselhuie
ddress: 295-A N. Green Meadows P.O. Number: Turnaround: Standard
ddress: Wilmington, NC Contact: Job Number:
uote #: Phone: 392-1747 Invoice To:

Sample ID	Date	Time	Matrix	Preservatives: HC	Preservatives: HCL			Analyses: 6210D										Comments: Please specify any special reporting requirements
																		G247-4
GP-8	5/12/98	1030	H_2O	✓	✓			✓										
GP-9	5/12/98	1300	H_2O	✓	✓			✓										
GP-10	5/12/98	1510	H_2O	✓	✓			✓										

Relinquished By	Date	Time	Received By	Date	Time	Temperature	Sampled By	Airbill #
[illegible]	5/13/98	1:16	Mark L. Marshall	5-13	1:16	on ice		

ORIGINAL

HYDROLOGIC, INC.

ANALYTICAL AND QUALITY CONTROL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/08/1998

HydroLogic Job Number: 98.02395

Enclosed is the Analytical and Quality Control Reports for the following samples submitted to HydroLogic - Frankfort for analysis:

Project Description: 98-1158

Sample Number	Sample Description	Matrix	Date Sampled	Date Received
21345	FIELD BLANK	WATER	08/14/1998	08/18/1998
21346	L-1	WATER	08/13/1998	08/18/1998
21365	MW-15S	WATER	08/14/1998	08/18/1998
21366	MW-15D	WATER	08/14/1998	08/18/1998
21419	BK-1A	SOIL	08/13/1998	08/18/1998
21420	BK-1B	SOIL	08/13/1998	08/18/1998
21421	BK-2A	SOIL	08/13/1998	08/18/1998
21422	BK-2B	SOIL	08/13/1998	08/18/1998
21423	BK-3A	SOIL	08/13/1998	08/18/1998
21424	BK-3B	SOIL	08/13/1998	08/18/1998
21425	MW-13S	WATER	08/13/1998	08/18/1998
21426	MW-10S	WATER	08/14/1998	08/18/1998
21427	MW-9SK	WATER	08/14/1998	08/18/1998
21428	MW-9DK	WATER	08/14/1998	08/18/1998
21429	MW-12S	WATER	08/14/1998	08/18/1998
21430	MW-14D	WATER	08/14/1998	08/18/1998

The Quality Control report is generated on a batch basis. All information contained in this report is for the analytical batch(es) in which your sample(s) were analyzed. All anlytical batch(es) are initiated at 8:00 a.m. unless otherwise flagged on report.

All samples were analyzed according to the RCRA guidelines described in SW-846, NPDES regulations, and Standard Methods for the Examination of Water and Wastewater.

Project Representative

Post-It® Fax Note 7671	Date	# of pages ▶
To Mike	From Charles	
Co./Dept.	Co.	
Phone #	Phone #	
Fax #	Fax #	

f 34

FORT, KY 40601
502-223-0251 FAX: 502-875-8016 / TOLL FREE 800-728-2251

HYDROLOGIC, INC.

ANALYTICAL AND QUALITY CONTROL REPORT

Mike Haseltine
ALCATEL
2912 Wake Forest Road
Raleigh, NC 27609

09/08/1998

HydroLogic Job Number: 98.02395

Enclosed is the Analytical and Quality Control Reports for the following samples submitted to HydroLogic - Frankfort for analysis:

Project Description: 98-1158

Sample Number	Sample Description	Matrix	Date Sampled	Date Received
21431	MW-7D	WATER	08/14/1998	08/18/1998
21432	MW-4S	WATER	08/14/1998	08/18/1998
21433	FIELD BLANK	WATER	08/14/1998	08/18/1998
21434	MW-4D	WATER	08/14/1998	08/18/1998

The Quality Control report is generated on a batch basis. All information contained in this report is for the analytical batch(es) in which your sample(s) were analyzed. All anlytical batch(es) are initiated at 8:00 a.m. unless otherwise flagged on report.

All samples were analyzed according to the RCRA guidelines described in SW-846, NPDES regulations, and Standard Methods for the Examination of Water and Wastewater.

Project Representative

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
502-223-0251 FAX: 502-875-8016 / TOLL FREE 800-728-2251

HYDROLOGIC, INC.

LIBRARY SEARCH REPORT

ALCATEL
Mike Haseltine
2912 Wake Forest Road
Raleigh, NC 27609

09/08/1998

HydroLogic Job Number: 98.02395

Matrix Type: WATER

Client Project ID: 98-1159

Tentatively Identified Compound	TIC Number	Estimated Concentration	Units	Flags

SAMPLE NO.	SAMPLE DESCRIPTION	DATE-TIME SAMPLED
21346	L-1	17:00

Volatile Library Search 8901
NO TICS FOUND

1491 TWILIGHT TRAIL FRANKFORT, KY 40601
502-223-0251 FAX: 502-875-8016 / TOLL FREE 800-728-2251

Train of Custody Record

HYDROLOGIC, INC.

Page 7 of

☐ Asheville, NC (828) 254-5169 ☐ Norcross, GA (770) 368-0636 ☐ Charlotte, NC (704) 392-1164 ☐ Frankfort KY (502) 223-0251 ☒ Morrisville, NC (919) 380-8600
☐ Lumberton, NC (910) 738-6190 ☐ Lexington, SC (803) 796-9989 ☐ Brighton, CO (303) 659-0493 ☐ Macon, GA (912) 757-0811 ☐ Orlando, FL (407) 851-2560

Client: Temple Env.
Report Address:
Attn: Mike Hoselton
Phone No.: (910) 392-1747
Fax No.: 910/392-8654 Extr
Project No.: 01-203-0209
Invoice Address: Alcatel
Attn: Dickon Kabbanjian
Sampled By: Mike Hoselton
P.O. No.:
State Samples Collected

TURNAROUND TIME
☐ 24 Hours ☐ 48 Hours
☐ 5 Days ☐ 10 Days Date Needed:

REQUESTED PARAMETERS

LAB CODE LB
A = Asheville, NC
C = Charlotte, NC
D = Denver, CO
E = Lexington, SC
G = Macon, GA
K = Frankfort, KY
L = Lumberton, NC
M = Morrisville, NC
N = Norcross, GA
O = Orlando, FL
S = Subcontracted

Sample ID	Date	Time	Comp/Grab	Matrix	Containers	6230D	Methane Sulfate Nitrate Chloride Ferrous Iron	Lead & Copper	98-1151							← Preserv.	REMARKS
						HCl	4°C	4°C	4°C								
BK-1A	8/13	1045	G	Soil					✓								
BK-1B	8/13	1045	G	Soil					✓								
BK-2A	8/13	1115	G	Soil					✓								
BK-2B	8/13	1115	G	Soil					✓								
BK-3A	8/13	1148	G	Soil					✓								
BK-3B	8/13	1148	G	Soil					✓								
L-1	8/13	1700	G	Water		✓	✓	✓									
MW-13S	8/13	2026	G	Water		✓	✓	✓									
MW-10S	8/14	0941	G	Water			✓	✓									
MW-15S	8/14	1130	G	Water		✓	✓	✓									
Lab Use Only						K	none	A	A							Init Lab Temp.	Rec. Lab Temp

Custody Seal: ☐ Yes ☐ No ☐ N/A

COMMENTS:

Relinquished By:	Date	Time	Received By:	Date	Time	Lab Use Only:
[signature]	8/14/98	1710	[signature]	8/14/98	5:20	98.02395
[signature]	8/15/98	1800	Valerie S. Moodd	8/18/98	10:30	
Relinquished By:	Date	Time	Received By:	Date	Time	
Relinquished By:	Date	Time	Received By:			

HYDROLOGIC CHARLOTTE MORRISVILLE FRANKFORT

HYDROLOGIC, INC.

hain of Custody Record

Page 2 of

☐ Asheville, NC (828) 254-5169 ☐ Norcross, GA (770) 368-9656 ☐ Charlotte, NC (704) 392-1164 ☐ Frankfort KY (502) 223-9251 ☒ Morrisville, NC (919) 380-9609

☐ Lumberton, NC (910) 738-6190 ☐ Lexington, SC (803) 796-8989 ☐ Brighton, CO (303) 659-0497 ☐ Macon, GA (912) 757-0811 ☐ Orlando, FL (407) 831-1360

Client: Triangle Env
Report Address:
Attn: Mike Haselline
Phone No.: (910) 392-1747
Fax No.:

Project No.: 01-003-009
Invoice Address: ALCATEL
Attn: Dikran Kabbadjian
Sampled By: Mike Haselline
P.O. No.:
State Samples Collected

TURNAROUND TIME
☐ 24 Hours ☐ 48 Hours
☐ 5 Days ☐ 10 Days Date Needed:

REQUESTED PARAMETERS

98-1158

LAB CODE L
= Asheville, NC
= Charlotte, NC
= Denver, CO
= Lexington, SC
= Macon, GA
= Frankfort, KY
L = Lumberton, NI
M = Morrisville, NI
N = Norcross, GA
O = Orlando, FL
S = Subcontracted

Sample ID	Date	Time	Comp/Grab	Matrix	Containers	4C (Methane)	4C (Sulfate, Nitrate, Chloride)	HCV (Volatiles 6230 D)								← Preserv.	REMARKS
MW-15d	8/14	1145	G	Water		✓	✓	✓									
MW-9sK	8/14	1225	G	Water		✓	✓										
MW-9dK	8/14	1277	G	Water		✓	✓										
MW-12S	8/14	1310	G	Water		✓	✓										
MW-14d	8/14	1345	G	Water		✓	✓										
MW-7d	8/14	1405	G	Water		✓	✓										
MW-4S	8/14	1445	G	Water		✓	✓										
Field Blank	8/14	1445	G	Water		✓	✓										
MW-4d	8/14	1515	G	Water		✓	✓										
Trip Blank	8/14	1445		"				X									
						HNO3	H	K									

Lab Use Only Custody Seals ☐ Yes ☐ No ☐ N/A

Init Lab Temp. Rec. Lab Temp

COMMENTS:

Relinquished By:	Date	Time	Received By:	Date	Time	Lab Use Only:
[signature]	8/14/98	1710	[signature]	8/14/98	5:10	98.12205
Relinquished By:	Date	Time	Received By: Valerie S. Maddox	8/17/98	10:30	
Relinquished By:	Date	Time	Received By:	Date	Time	
Relinquished By:	Date	Time	Received By:			

Up-gradient Geoprobe Survey (Background VOCs)

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Inorganics

Client Sample ID:	GP-01	Analyzed By:	JMF
Client Project ID:	01 003 0109	Date Collected:	4/6/98
Lab Sample ID:	39353	Date Received:	4/8/98
Lab Project ID:	G247-1	Matrix:	Soil
	Solids 94.59		

Metals	Result	Quantitation Limit	Units	Procedure	Date Analyzed
Copper	**3.73**	1.01	MG/KG	6010A	4/19/98
Lead	**2.40**	1.01	MG/KG	6010A	4/19/98

Comments
BQL = Below Quantitation Limits

Reviewed By: _____

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Inorganics

Client Sample ID:	GP-02	Analyzed By:	JMF
Client Project ID:	01 003 0109	Date Collected:	4/6/98
Lab Sample ID:	39354	Date Received:	4/8/98
Lab Project ID:	G247-1	Matrix:	Soil
	Solids 89.80		

Metals	Result	Quantitation Limit	Units	Procedure	Date Analyzed
Copper	2.56	1.05	MG/KG	6010A	4/19/98
Lead	BQL	1.05	MG/KG	6010A	4/19/98

Comments
BQL = Below Quantitation Limits

Reviewed By: _____

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 8260B

Client Sample ID:	GP-02	Date Analyzed:	4/13/98
Client Project ID:	01 003 0109	Analyzed By:	MES
Lab Sample ID:	39354	Date Collected:	4/6/98
Lab Project ID:	G247-1	Date Received:	4/8/98
Matrix:	Soil %Solids: 89.8	Dilution:	1

Compound	Quantitation Limit (ug/KG)	Result (ug/KG)
Acetone	56	BQL
Acrolein	110	BQL
Acrylonitrile	110	BQL
Benzene	11	BQL
Bromobenzene	11	BQL
Bromochloromethane	11	BQL
Bromodichloromethane	11	BQL
Bromoform	11	BQL
Bromomethane	11	BQL
2-Butanone	28	BQL
n-Butylbenzene	11	BQL
sec-Butylbenzene	11	BQL
tert-Butylbenzene	11	BQL
Carbon disulfide	11	BQL
Carbon tetrachloride	11	BQL
Chlorobenzene	11	BQL
Chloroethane	11	BQL
2-Chloroethyl vinyl ether	11	BQL
Chloroform	11	BQL
Chloromethane	11	BQL
2-Chlorotoluene	11	BQL
4-Chlorotoluene	11	BQL
Dibromochloromethane	11	BQL
1,2-Dibromo-3-chloropropane	11	BQL
Dibromomethane	11	BQL
1,2-Dibromoethane (EDB)	11	BQL
1,2-Dichlorobenzene	11	BQL
1,3-Dichlorobenzene	11	BQL
1,4-Dichlorobenzene	11	BQL
trans-1,4-Dichloro-2-butene	11	BQL
1,1-Dichloroethane	11	BQL
1,1-Dichloroethene	11	BQL
1,2-Dichloroethane	11	BQL
cis-1,2-Dichloroethene	11	BQL
trans-1,2-dichloroethene	11	BQL
1,2-Dichloropropane	11	BQL
1,3-Dichloropropane	11	BQL
2,2-Dichloropropane	11	BQL
1,1-Dichloropropene	11	BQL
cis-1,3-Dichloropropene	11	BQL
trans-1,3-Dichloropropene	11	BQL
Dichlorodifluoromethane	11	BQL
Diisopropyl ether (DIPE)	11	BQL
Ethylbenzene	11	BQL
Hexachlorobutadiene	11	BQL
2-Hexanone	11	BQL
Iodomethane	11	BQL
Isopropylbenzene	11	BQL

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 8260B

Client Sample ID:	GP-02	Date Analyzed:	4/13/98
Client Project ID:	01 003 0109	Analyzed By:	MES
Lab Sample ID:	39354	Date Collected:	4/6/98
Lab Project ID:	G247-1	Date Received:	4/8/98
Matrix:	Soil %Solids: 89.8	Dilution:	1

Compound	Quantitation Limit (ug/KG)	Result (ug/KG)
4-Isopropyltoluene	11	BQL
Methylene chloride	22	BQL
4-Methyl-2-pentanone	11	BQL
Methyl-tert-butyl ether (MTBE)	11	BQL
Naphthalene	11	BQL
n-Propyl benzene	11	BQL
Styrene	11	BQL
1,1,1,2-Tetrachloroethane	11	BQL
1,1,2,2-Tetrachloroethane	11	BQL
Tetrachloroethene	11	BQL
Toluene	11	BQL
1,2,3-Trichlorobenzene	11	BQL
1,2,4-Trichlorobenzene	11	BQL
Trichloroethene	11	BQL
1,1,1-Trichloroethane	11	BQL
1,1,2-Trichloroethane	11	BQL
Trichlorofluoromethane	11	BQL
1,2,3-Trichloropropane	11	BQL
1,2,4-Trimethylbenzene	11	BQL
1,3,5-Trimethylbenzene	11	BQL
Vinyl chloride	11	BQL
m-,p-Xylene	22	BQL
o-Xylene	11	BQL

Surrogate Spike Recoveries Compound	Spike Added (ug/KG)	Surrogate Result (ug/KG)	%Rec
Bromofluorobenzene	50	47.2	94
1,2-Dichloroethane-d4	50	53.1	106
Toluene-d8	50	50.9	102

Comments:
All results are corrected for dilution.

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: GP-03
Client Project ID: 01 003 0109
Lab Sample ID: 39355
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/14/98
Analyzed By: MES
Date Collected: 4/6/98
Date Received: 4/8/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Benzene	0.5	BQL
Bromobenzene	0.5	BQL
Bromochloromethane	0.5	BQL
Bromodichloromethane	0.5	BQL
Bromoform	0.5	BQL
Bromomethane	0.5	BQL
n-Butylbenzene	0.5	BQL
sec-Butylbenzene	0.5	BQL
tert-Butylbenzene	0.5	BQL
Carbon tetrachloride	0.5	BQL
Chlorobenzene	0.5	BQL
Chloroethane	0.5	BQL
Chloroform	0.5	BQL
Chloromethane	0.5	BQL
2-Chlorotoluene	0.5	BQL
4-Chlorotoluene	0.5	BQL
Dibromochloromethane	0.5	BQL
1,2-Dibromo-3-chloropropane	5	BQL
Dibromomethane	0.5	BQL
1,2-Dibromoethane (EDB)	0.5	BQL
1,2-Dichlorobenzene	0.5	BQL
1,3-Dichlorobenzene	0.5	BQL
1,4-Dichlorobenzene	0.5	BQL
1,1-Dichloroethane	0.5	BQL
1,1-Dichloroethene	0.5	BQL
1,2-Dichloroethane	0.5	BQL
cis-1,2-Dichloroethene	0.5	BQL
trans-1,2-dichloroethene	0.5	BQL
1,2-Dichloropropane	0.5	BQL
1,3-Dichloropropane	0.5	BQL
2,2-Dichloropropane	0.5	BQL
1,1-Dichloropropene	0.5	BQL
Dichlorodifluoromethane	5	BQL
Diisopropyl ether (DIPE)	0.5	BQL
Ethylbenzene	0.5	BQL
Hexachlorobutadiene	0.5	BQL
Isopropylbenzene	0.5	BQL
4-Isopropyltoluene	0.5	BQL
Methylene chloride	5	BQL
Methyl-tert-butyl ether (MTBE)	0.5	BQL
Naphthalene	0.5	BQL
n-Propyl benzene	0.5	BQL

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: GP-03
Client Project ID: 01 003 0109
Lab Sample ID: 39355
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/14/98
Analyzed By: MES
Date Collected: 4/6/98
Date Received: 4/8/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Styrene	0.5	BQL
1,1,1,2-Tetrachloroethane	0.5	BQL
1,1,2,2-Tetrachloroethane	0.5	BQL
Tetrachloroethene	0.5	BQL
Toluene	0.5	BQL
1,2,3-Trichlorobenzene	0.5	BQL
1,2,4-Trichlorobenzene	0.5	BQL
Trichloroethene	0.5	BQL
1,1,1-Trichloroethane	0.5	BQL
1,1,2-Trichloroethane	0.5	BQL
Trichlorofluoromethane	0.5	BQL
1,2,3-Trichloropropane	0.5	BQL
1,2,4-Trimethylbenzene	0.5	BQL
1,3,5-Trimethylbenzene	0.5	BQL
Vinyl chloride	0.5	BQL
m-,p-Xylene	1	BQL
o-Xylene	0.5	BQL

Surrogate Spike Recoveries Compound	Spike Added (ug/L)	Surrogate Result (ug/L)	%Rec
Bromofluorobenzene	10.0	7.2	72
1,2-Dichloroethane-d4	10.0	11	110
Toluene-d8	10.0	7	70

Comments:

All results are corrected for dilution.
Surrogate failure confirmed by reanalysis.

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: GP-05
Client Project ID: 01 003 0109
Lab Sample ID: 39356
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/14/98
Analyzed By: MES
Date Collected: 4/6/98
Date Received: 4/8/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Benzene	0.5	BQL
Bromobenzene	0.5	BQL
Bromochloromethane	0.5	BQL
Bromodichloromethane	0.5	BQL
Bromoform	0.5	BQL
Bromomethane	0.5	BQL
n-Butylbenzene	0.5	BQL
sec-Butylbenzene	0.5	BQL
tert-Butylbenzene	0.5	BQL
Carbon tetrachloride	0.5	BQL
Chlorobenzene	0.5	BQL
Chloroethane	0.5	BQL
Chloroform	0.5	BQL
Chloromethane	0.5	BQL
2-Chlorotoluene	0.5	BQL
4-Chlorotoluene	0.5	BQL
Dibromochloromethane	0.5	BQL
1,2-Dibromo-3-chloropropane	5	BQL
Dibromomethane	0.5	BQL
1,2-Dibromoethane (EDB)	0.5	BQL
1,2-Dichlorobenzene	0.5	BQL
1,3-Dichlorobenzene	0.5	BQL
1,4-Dichlorobenzene	0.5	BQL
1,1-Dichloroethane	0.5	BQL
1,1-Dichloroethene	0.5	BQL
1,2-Dichloroethane	0.5	BQL
cis-1,2-Dichloroethene	0.5	BQL
trans-1,2-dichloroethene	0.5	BQL
1,2-Dichloropropane	0.5	BQL
1,3-Dichloropropane	0.5	BQL
2,2-Dichloropropane	0.5	BQL
1,1-Dichloropropene	0.5	BQL
Dichlorodifluoromethane	5	BQL
Diisopropyl ether (DIPE)	0.5	BQL
Ethylbenzene	0.5	BQL
Hexachlorobutadiene	0.5	BQL
Isopropylbenzene	0.5	BQL
4-Isopropyltoluene	0.5	BQL
Methylene chloride	5	BQL
Methyl-tert-butyl ether (MTBE)	0.5	**2**
Naphthalene	0.5	**0.7**
n-Propyl benzene	0.5	BQL

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.

Results for Volatiles
by GCMS 6210D

Client Sample ID: GP-05
Client Project ID: 01 003 0109
Lab Sample ID: 39356
Lab Project ID: G247-1
Matrix: Water

Date Analyzed: 4/14/98
Analyzed By: MES
Date Collected: 4/6/98
Date Received: 4/8/98
Dilution: 1.0

Compound	Quantitation Limit (ug/L)	Result (ug/L)
Styrene	0.5	BQL
1,1,1,2-Tetrachloroethane	0.5	BQL
1,1,2,2-Tetrachloroethane	0.5	BQL
Tetrachloroethene	0.5	BQL
Toluene	0.5	**0.7**
1,2,3-Trichlorobenzene	0.5	BQL
1,2,4-Trichlorobenzene	0.5	BQL
Trichloroethene	0.5	BQL
1,1,1-Trichloroethane	0.5	BQL
1,1,2-Trichloroethane	0.5	BQL
Trichlorofluoromethane	0.5	BQL
1,2,3-Trichloropropane	0.5	BQL
1,2,4-Trimethylbenzene	0.5	BQL
1,3,5-Trimethylbenzene	0.5	BQL
Vinyl chloride	0.5	BQL
m-,p-Xylene	1	BQL
o-Xylene	0.5	BQL

Surrogate Spike Recoveries Compound	Spike Added (ug/L)	Surrogate Result (ug/L)	%Rec
Bromofluorobenzene	10.0	9.5	95
1,2-Dichloroethane-d4	10.0	11	110
Toluene-d8	10.0	6.8	68

Comments:
All results are corrected for dilution.

Reviewed by: _____

Flags: BQL = Below Quantitation Limit

PARADIGM ANALYTICAL LABORATORIES, INC.
2627 Northchase Parkway S.E.
Wilmington, North Carolina 28405
(910) 350-1903
Fax (910) 350-1557

Mr. Mike Haseltine
Triangle Environmental
295A N. Green Meadows Dr.
Wilmington N,C 28405

Date 04-22-98

Report Number: G 247-1

Client Project Number : 01 003 0109

Dear Mr. Haseltine:

Enclosed are the results of the analytical services performed under the referenced project. Copies of this report and supporting data will be retained in our files for a period of five years in the event they are required for future reference. Any samples submitted to our laboratory will be retained for a maximum of thirty (30) days from date of this report unless other arrangements are requested.

If there are any questions about the report or the services performed during this project, please call for assistance. We will be happy to answer any questions or concerns which you may have.

Thank you for using Paradigm Analytical Labs for your analytical service projects. We look forward to working with you again on any additional needs which you may have.

Sincerely,

Paradigm Analytical Laboratories

Laboratory Director
Mark Randall

PARADIGM ANALYTICAL LABORATORIES, INC.
2627 Northchase Parkway SE, Wilmington, NC 28405
Phone: (910)-350-1903 FAX: (910)-350-1557

Chain-of Custody Record & Analytical Request

COC# 15079

Page 1 of 1

Client: Mike Haseltine
Address: Triangle Environmental
Address: 295-A N. Green Meadows Dr
Quote #:

Project ID: 01 003 0109
P.O. Number:
Contact: M. Haseltine
Phone: 392-1747 x23

Date: 4/8/98
Turnaround: Standard
Job Number:

Report To:
Invoice To:

Sample ID	Date	Time	Matrix	Preservatives: 4°C	Preservatives: HCL			Analyses: total Lead	total Copper	8260	G2100							Comments: Please specify any special reporting requirements
																		G247-1
GP-01	4/6/98	1400	Soil	✓				✓	✓									
GP-02	4/6/98	1606	Soil	✓				✓	✓	✓								
GP-03	4/6/98	1645	H_2O	✓	✓						✓							
GP-05	4/6/98	1830	H_2O	✓	✓						✓							
P01	4/7/98	1100	H_2O	✓	✓						✓							
P-02	4/7/98	1115	H_2O	✓	✓						✓							
P-03	4/7/98	1331	H_2O	✓	✓						✓							
P-04	4/7/98	1420	H_2O	✓	✓						✓							
P-05	4/7/98	1522	H_2O	✓	✓						✓							
P-06	4/7/98	1600	H_2O	✓	✓						✓							

Relinquished By	Date	Time	Received By	Date	Time	Temperature	Sampled By	Airbill #
[illegible]	4/8/98	1220	[illegible]	4/8/98	1220	Received at lab - walk in		

APPENDIX E
STATISTICAL ANALYSIS OF BACKGROUND AND SOURCE AREA COPPER AND LEAD

Shapiro-Wilk Test of Normality

Copper

	x(i)	x(n-i+1)	x(n-i+1)-x(i)	an-i+1	bi
1	0.1	74	73.9	0.4291	31.71049
2	0.49	50	49.51	0.2968	14.69457
3	0.61	44.2	43.59	0.2499	10.89314
4	0.72	21.4	20.68	0.215	4.4462
5	1.3	16	14.7	0.1864	2.74008
6	1.5	16	14.5	0.1616	2.3432
7	1.6	16	14.4	0.1395	2.0088
8	1.6	13	11.4	0.1192	1.35888
9	1.7	11.4	9.7	0.1002	0.97194
10	2.3	7.5	5.2	0.0822	0.42744
11	2.56	4.9	2.34	0.065	0.1521
12	2.7	4.5	1.8	0.0483	0.08694
13	2.8	3.7	0.93	0.032	0.02976
14	2.8	3.7	0.9	0.0159	0.01431
15	2.8	2.8	0	0	0
16	3.7	2.8	-0.9		
17	3.7	2.8	-0.93	**b =**	**71.87785**
18	4.5	2.7	-1.8		**17.20015**
19	4.9	2.56	-2.34	**SD =**	**0.789739**
20	7.5	2.3	-5.2	**W =**	**0.623688**
21	11.4	1.7	-9.7		
22	13	1.6	-11.4		
23	16	1.6	-14.4		**Table A-2**
24	16	1.5	-14.5		**W .05,29 = .926**
25	16	1.3	-14.7		
26	21.4	0.72	-20.68		since W<.926
27	44.2	0.61	-43.59		non-normality
28	50	0.49	-49.51		
29	74	0.1	-73.9		

Skewness Coefficient = **2.11598942**

Shapiro-Wilk Test of Normality

Lead

	x(i)	x(n-i+1)	x(n-i+1)-x(i)	an-i+1	bi
1	0.1	17.0	16.9	0.4127	6.97463
2	0.1	10.7	10.6	0.2854	3.02524
3	0.1	9.5	9.4	0.2439	2.29266
4	0.1	8.6	8.5	0.2132	1.8122
5	0.1	7.0	6.9	0.1882	1.29858
6	0.1	6.3	6.2	0.1667	1.03354
7	0.1	6.3	6.2	0.1475	0.9145
8	0.1	6.0	5.9	0.1301	0.76759
9	0.1	5.4	5.3	0.114	0.6042
10	0.1	5.1	5	0.0988	0.494
11	0.1	4.2	4.1	0.0844	0.34604
12	0.1	4.0	3.9	0.0706	0.27534
13	0.1	2.4	2.3	0.0572	0.13156
14	0.1	0.1	0	0.0441	0
15	0.1	0.1	0	0.0314	0
16	0.1	0.1	0	0.0187	0
17	0.1	0.1	0	0.0062	0
18	0.1	0.1	0	**b =**	**19.97008**
19	0.1	0.1	0	**SD =**	**4.13283**
20	0.1	0.1	0		**0.841154**
21	0.1	0.1	0	**W =**	**0.707539**
22	2.4	0.1	-2.3		
23	4.0	0.1	-3.9		A-2
24	4.2	0.1	-4.1		W.05,34 =.933
25	5.1	0.1	-5		
26	5.4	0.1	-5.3		since W< .933
27	6.0	0.1	-5.9		non-normality
28	6.3	0.1	-6.2		
29	6.3	0.1	-6.2		
30	7.0	0.1	-6.9		
31	8.6	0.1	-8.5		
32	9.5	0.1	-9.4		
33	10.7	0.1	-10.6		
34	17.0	0.1	-16.9		

Skewness Coefficient = 1.962845

	TCA	PCE&TCA						
Concentrations								
	MW-14d	MW-2d	MW-4d	MW-9dk	MW-15d		MW-13s	MW-9sk
PCE	0.5	729	240	81	17		242	0.5
1,1,1-TCA	16000	828	130	37	3.04		562	0.5
1,1-DCE	810	418	230	225	73.2		2610	0.5
Organic Cl	13358.74	1569.467	476.8	272.5707	74.09472	0	2712.992	1.192

	MW-14d	MW-2d	MW-4d	MW-9dk	MW-15d		MW-13s	MW-9sk
Chloride	30.41	85	35.82	10.89	11.92		80.86	27.94
Organic Chlorine	13358.35	1569.467	476.8	272.5707	74.09472	0	2712.992	0.5
sum	13388.76	1654.467	512.62	283.4607	86.01472	0	2793.852	28.44

Levenes Test of Homogeniety of Variance

		Copper	
		mean	residual m
	compliance	12.92	13.39
	background	3.96	8.96
Copper		z =	overall mean
(mg/Kg)			11.17
	residual	sqrd	
2.7	10.217273	104.3927	
0.72	12.197273	148.7735	
1.7	11.217273	125.8272	
1.6	11.317273	128.0807	
1.3	11.617273	134.961	
0.61	12.307273	151.469	
1.6	11.317273	128.0807	
16	3.0827273	9.503207	
16	3.0827273	9.503207	
13	0.0827273	0.006844	
50	37.082727	1375.129	
74	61.082727	3731.1	
16	3.0827273	9.503207	
0.1	12.817273	164.2825	
44.2	31.282727	978.609	
4.5	8.4172727	70.85048	
21.4	8.4827273	71.95666	
11.4	1.5172727	2.302117	
2.8	10.117273	102.3592	
1.5	11.417273	130.3541	
0.49	12.427273	154.4371	
2.56	10.357273	107.2731	

	BACKGROUND	
3.7	9.1872727	84.40598
7.5	5.4172727	29.34684
2.8	10.117273	102.3592
4.9	8.0172727	64.27666
2.8	10.117273	102.3592
3.7	9.2172727	84.95812
2.3	10.617273	112.7265

Levenes Test of Homogeniety of Variance

Copper

sum of squared residuals	8419.19
sum of residuals	357.21

	Sum-of-Squares	Degrees of freedom	Mean-Square	f ratio
Sstotal	4019.11	28	143.54	
SS Error	3133.04	27	116.04	
SS wells	886.07	1	886.07	7.64

from tables f = 4.21

since f>4.21 assumption of equal variancs is rejected.

Wilcoxon Rank-Sum Test for Two Groups

Copper (mg/Kg)	Rank
0.1	1
0.49	2
0.61	3
0.72	4
1.3	5
1.5	6
1.6	7.5
1.6	7.5
1.7	9
2.3	10
2.56	11
2.7	12
2.8	13.5
2.8	13.5
2.8	15
3.7	16.5
3.7	16.5
4.5	18
4.9	19
7.5	20
11.4	21
13	22
16	24
16	24
16	24

Lead (mg/Kg)	Rank
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
0.1	11
2.4	22
4.0	23
4.2	24
5.1	25

Copper

(mg/Kg)	Rank
21.4	26
44.2	27
50	28
74	29
Rank sum =	435

W = compliance rank sum-(n(n+1)/2) = 73.00

E(W) = mn/2 = 77.00

SD(W) = sqrt((mn(N+1)/12(1-sum(t**3-t)/(N**3-N) = 19.60

Z= (W-E(W)-0.5)/SD(W) = -0.23

background

cu	pb
2.3	2.4
2.8	4.0
2.8	6.0
3.7	6.3
3.7	7.0
4.9	8.6
7.5	17.0

Lead

(mg/Kg)	Rank
5.4	26
6.0	27
6.3	28
6.3	29
7.0	30
8.6	31
9.5	32
10.7	33
17.0	34
Rank sum =	540

W = compliance rank sum-(n(n+1)/2) = 47

E(W) = mn/2 = 94.5

SD(W) = sqrt((mn(N+1)/12(1-sum(t**3-t)/(N**3-N) = 20.54

Z= (W-E(W)-0.5)/SD(W) = -2.3

APPENDIX F
OCCURRENCE OF BEDROCK FRACTURES

Ocuurence of Observed Fractures
ALCATEL Network Systems, Inc.
Raleigh, North Carolina

Well/boring Identification	Fracture Interval elevation (feet)		
RW-2	194-192	153-152	-------
RW-4	196-192	188-186	159-158
RW-5	159-156	154-153	-------
RW-6	178-176	164-161	-------
RW-7	164-162	-------	-------
RW-10	166-156	-------	-------
CRW-7	179-178	159-157	-------
CRW-8	173-172	155-154	-------
CRW-11	192-186	-------	-------
MW-2d	198-196	171-169	-------
MW-7d	187-186	174-173	169-167
MW-3d	178-176	172-169	-------
MW-4d & 4dd	197-192	170-168	125-130
MW-9dk	165-164	-------	-------
MW-12dk	177-176	167-166	160-157

APPENDIX G

DRAFT EPA REGION 4 SUGGESTED PRACTICES FOR EVALUATION OF A SITE FOR NATURAL ATTENUATION OF CHLORINATED SOLVENTS and DEGRADATION RATE CALCULATIONS

Draft EPA Region 4 Suggested Practices for Evaluation of a Site For Natural Attenuation (Biological Degradation) of Chlorinated Solvents[1]

November, 1997

Version 3.0

[1]This document was formerly titled Draft Region 4 Approach to Natural Attenuation of Chlorinated Solvents

Table of Contents

Overview of the Technical Protocol ..... Page 5

Overview of Chlorinated Aliphatic Hydrocarbon Biodegradation ..... Page 7

Mechanisms of Chlorinated Aliphatic Hydrocarbon Biodegradation ..... Page 8

Behavior of Chlorinated Solvent Plumes ..... Page 9

Protocol for Quantifying Biological Degradation During the Remedial Investigation Process ..... Page 10

- Determining Whether Biodegradation is Occurring ..... Page 13
- Groundwater Characterization ..... Page 18

Refine the Conceptual Model, Complete Premodeling Calculations, and Document Indicators of Biological Degradation ..... Page 21

References ..... Page 25

Appendix ..... Page 29

Draft EPA Region 4 Suggested Practices for Evaluation of a Site For Natural Attenuation (Biological Degradation) of Chlorinated Solvents[2]

November, 1997

This document is an amalgamation of technical information obtained from the Draft AFCEE[3] *Protocol for Evaluation of Natural Attenuation of Chlorinated Solvents in Ground Water*, articles in professional journals, and meeting presentations by experts in the field (see references).

Preface

The intent of this document is to provide a resource for the characterization of sites where natural attenuation (biological degradation) is being proposed or considered. Region 4 wishes to specify that the Draft Interim Final OSWER Directive on Monitored Natural Attenuation (OSWER Directive 9200.4-17) is a compliment to this document. The hope within EPA nationwide is that a guidance document will be put forth from EPA's Office of Research and Development that will also compliment or supersede this document. At this time a date for this guidance is unknown.

The **Draft EPA Region 4 Suggested Practices for Evaluation of a Site for Natural Attenuation (Biological Degradation) of Chlorinated Solvents** is being provided by U.S. EPA Region 4 in DRAFT form due to the evolving nature of the research being performed in labs and on sites on the biological degradation of chlorinated solvents in ground water. In addition, on sites where natural attenuation is being implemented and/or considered, site characterization methods, analytical methods and sampling techniques are changing rapidly. The site characterization for karst and fractured rock would be subject to additional requirements.

At a minimum U.S. EPA Region 4 expects the following in a natural attenuation demonstration report: 1) a site characterization presented and supported, 2) remedial action for the 'source' to be provided 3) a long term monitoring (including O&M) plan provided. 4) a comparison of the natural attenuation remedy (if this is an appropriate determination for the site) to an engineered remedy, 5) the enumeration of institutional controls that are currently operational and enforceable for the site and 6) determination of the carbon source and it's sustainability for chlorinated solvent degradation.

If you have comments or questions concerning this document contact Kay Wischkaemper at 404-562-8641 or wischkaemper.kay@epamail.epa.gov. The web page location is *http://www.epa.gov/region4/wastepgs/oftecser/protoexp.htm.*

Introduction

Region 4 acknowledges that natural attenuation due to advection, adsorption, biological degradation, dispersion, and volatilization can effectively reduce contaminant toxicity, mobility, or volume to levels that are protective of human health and the ecosystem. Natural attenuation in conjunction with source treatment can be the sole remedial alternative for many sites in Region 4. The framework behind the evaluation requirements in this document are The National Contingency Plan (NCP) citations which are the basis for Natural Attenuation remedy selections made in EPA Region 4.

> '...Natural attenuation is generally recommended only when active restoration is not practicable, cost effective or warranted because of site-specific conditions (e.g., Class III ground water or ground water which is unlikely to be used in the foreseeable future and there fore can be remediated over an extended period of

[2]This document was formerly titled Draft Region 4 Approach to Natural Attenuation of Chlorinated Solvents

[3]Air Force Center for Environmental Excellence

> time) or where natural attenuation is expected to reduce the concentration of contaminants in the ground water to the remediation goals-levels determined to be protective of human health and sensitive ecological environments--in a reasonable time-frame. Further, in situations where there would be little likelihood of exposure due to the remoteness of the site, alternate points of compliance may be considered, **provided contamination in the aquifer is controlled from further migrations.** The selection of natural attenuation by EPA does not mean that the ground water has been written off and not cleaned up but rather that biodegradation, dispersion, dilution, and adsorption will effectively reduce contaminants in the ground water to concentrations protective of human health in a time frame comparable to that which could be achieved through active restoration (p.8734).

Another NCP citation stating EPA's position on ground water that is not a current source of drinking water but has the ability to be used for drinking water purposes is:

> ...It is EPA policy to consider the beneficial use of the water and to protect against current and future exposures. Ground water is a **valuable resource** and should be protected and restored if necessary and practicable...(p. 8733)

The expectation of EPA in the above citations is that ground water will be restored and when natural attenuation and source treatment are determined to be the appropriate remedial alternative, or part of a remedial alternative for site ground water, the following provisions are understood.

- Measures are taken to "cut off" continued addition of contaminants to ground water and control migration of contaminants in ground water. This embodies removing, remediating, and/or containing the source (see NCP and OSWER Directive No. 9283.1-2).

- All portions of the plume within the area of attainment shall be remediated to the ground water protection standard's which are MCL's, non-zero MCLG's and health-based standards for current and potential sources of drinking water. An onsite (within the site property boundary) downgradient compliance boundary will be established beyond which accepted limits cannot be exceeded so that further degradation of large expanses of uncontaminated ground water will be prevented. In other words, the condition in which the property boundary is at a significant distance from the plume the compliance boundary must be located near the existing terminus of the plume. Additionally the area of contamination that exceeds the standards may not be allowed to increase prior to attenuation or discharge into surface water (see NCP and OSWER Directive No. 9283.1-2).

Institutional controls are required to ensure that such ground waters are not used before levels protective of human health are reached. On DOE and some DoD sites the enforceable institutional control issue is more easily provided for; whereas on RCRA and CERCLA sites this poses a considerable problem.

Another issue that is of concern regulatorily is the condition where plume 'starvation' occurs. In short, this is where the carbon source necessary for biological degradation of chlorinated solvents runs out and the plume is back to the concentrations that could exceed the ground water protection standards. This 'starvation' issue forces the need for identifying what that carbon source is and making a prediction about the ability of the carbon source to sustain biological degradation of the solvent plume. When identifying the carbon source is not possible, then long term monitoring will be the sole method of ensuring that biological degradation will continue until the contaminant concentrations are below the ground water protection standard. This poses a problem with predicting the length of time for biological degradation to occur and the ultimate cost of using intrinsic degradation as part of the final remedial alternative.

The U.S. Environmental Protection Agency's (EPA) Office of Research and Development and Office of Solid Waste and Emergency Response define natural attenuation as:

The biodegradation, dispersion, dilution, sorption, volatilization, and/or chemical and biochemical stabilization of contaminants to effectively reduce contaminant toxicity, mobility, or volume to levels that are protective of human health and the ecosystem.

Natural attenuation processes, such as biodegradation, can often be dominant factors in the fate and transport of contaminants. Thus, consideration and quantification of biodegradation processes is essential to more thoroughly understand contaminant fate and transport.

This paper presents suggested practices for data collection and analysis for the evaluation of a remedial option of natural attenuation (through biological degradation processes). In some cases, the information collected using this protocol will show that natural attenuation processes, with or without source removal, will reduce the concentrations of these contaminants to below risk-based corrective action criteria or will attain regulatory standards within an acceptable, site-specific time period.

Overview of the Technical Protocol

Natural attenuation in ground-water systems results from the integration of several subsurface attenuation mechanisms that are classified as either destructive or nondestructive. Biodegradation is the most important destructive attenuation mechanism. Nondestructive attenuation mechanisms include sorption, dispersion, dilution from recharge, and volatilization.

Biodegradation of fuel hydrocarbons, especially benzene, toluene, ethyl benzene, and xylenes (BTEX), is mainly limited by electron acceptor availability, and biodegradation of these compounds generally will proceed until all of the contaminants are destroyed. In the experience of many researchers, there appears to be an inexhaustible supply of electron acceptors in most, if not all, hydrogeologic environments. On the other hand, the more highly chlorinated solvents (e.g., perchloroethene and trichloroethene) typically are biodegraded under natural conditions via reductive dechlorination, a process that requires both electron acceptors (the chlorinated aliphatic hydrocarbons) and an adequate supply of electron donors. Electron donors include fuel hydrocarbons or other types of anthropogenic carbon (e.g., landfill leachate, BTEX, or natural organic carbon). If the subsurface environment is depleted of electron donors before the chlorinated aliphatic hydrocarbons are removed, reductive dechlorination will cease, and natural attenuation may no longer be protective of human health and the environment. The need for adequate electron donors is the most significant difference between the processes of fuel hydrocarbon and chlorinated aliphatic hydrocarbon biodegradation. For this reason, it is more difficult to predict the long-term behavior of chlorinated aliphatic hydrocarbon plumes than fuel hydrocarbon plumes. Thus, it is important to have a thorough understanding of the operant natural attenuation mechanisms.

In addition to having a better understanding of the processes of advection, dispersion, dilution from recharge, and sorption, it is necessary to better quantify biodegradation. Quantification of biodegradation requires a thorough understanding of the interactions between chlorinated aliphatic hydrocarbons, anthropogenic/natural carbon, and inorganic electron acceptors at the site. Detailed site characterization is required to adequately understand these processes.

The proponent must scientifically demonstrate that biodegradation of site contaminants is occurring at rates sufficient to be protective of human health and the environment in order to support remediation by natural attenuation. Three lines of evidence can be used to support biological degradation of chlorinated solvents:

1. Observed reduction in contaminant concentrations along the flow path downgradient from the source of contamination;

2. Documented loss of contaminant mass at the field scale:

   - Using chemical and geochemical analytical data (e.g., decreasing parent compound concentrations, increasing daughter compound concentrations, depletion of electron acceptors and donors, and increasing metabolic byproduct

concentrations);

- A conservative tracer and a rigorous estimate of residence time along the flow path to document contaminant mass reduction and to calculate biological decay rates at the field scale.

3. Microbiological laboratory[4] or field data that support the occurrence of biodegradation and give rates of biodegradation.

In an evaluation for the demonstration of biological contaminant degradation, the investigator must obtain either the first two lines of evidence.

The second and third lines of evidence are crucial to the natural attenuation demonstration of biodegradation because they provide biodegradation rate constants. The biodegradation rate constants are used in conjunction with the other fate-and-transport parameters to predict contaminant concentrations and to assess risk at downgradient points of compliance.

The first line of evidence is simply an observed reduction in the concentration of released contaminants downgradient from the NAPL source area along the groundwater flow path. The observed reduction does not prove that contaminants are being destroyed because the reduction in contaminant concentration could be the result of advection, dispersion, dilution from recharge, sorption, and volatilization with no loss of contaminant mass. Conversely, an increase in the concentrations of some contaminants, most notably degradation products such as vinyl chloride, could be indicative of natural attenuation.

The second line of evidence relies on chemical and physical data to show that contaminant mass is being destroyed via biodegradation, not just diluted. The second line of evidence is divided into two components. The first component is the use of chemical analytical data in mass balance calculations to show that decreases in contaminant and electron acceptor and donor concentrations can be directly correlated to increases in metabolic end products and daughter compounds. The mass balance calculation can be used to show that electron acceptor and donor concentrations in ground water are sufficient to facilitate degradation of dissolved contaminants. Solute fate-and-transport models can be used to aid mass balance calculations and to collate information on degradation. The second component is the use of measured concentrations of contaminants and/or biologically recalcitrant tracers in conjunction with aquifer hydrogeologic parameters, such as seepage velocity and dilution, to show that a reduction in contaminant mass is occurring at the site and to calculate biodegradation rate constants.

The third line of evidence, microbiological laboratory data, can be used to provide additional evidence that indigenous biota are capable of degrading site contaminants at a particular rate. The most useful type of microbiological laboratory data is the microcosm study, because it is necessary to show that biodegradation is occurring and to obtain biodegradation rate constants.

This paper presents a technical course of data gathering that allows converging lines of evidence to be

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[4]Microcosm studies are strongly influenced by the nature of the geologic material submitted for study, the physical properties of the microcosm, the sampling strategy, and the duration of the study. Noted here is that some researchers feel that microcosm studies for low levels of contamination are difficult to perform. In some cases the microcosm is 'killed' prior to any data being obtained to evaluate rate constants. Some researchers feel that rate constants obtained from microcosm studies are significant underestimates of actual conditions and therefore in some cases are not useful. In other cases microcosm studies are a productive tool with the following stipulation: if additional evidence (beyond contaminant and geochemical data and supporting calculations) supporting biological degradation is required, a microcosm study using site-specific aquifer materials and contaminants can be undertaken. An overall suggestion is that because microcosm studies are time-consuming and expensive, they should be undertaken only at sites where there is considerable uncertainty concerning the biodegradation of contaminants.

used to scientifically document the occurrence and quantify the rates of natural attenuation. Ideally, the first two lines of evidence should be used in the natural attenuation demonstration. To further document natural attenuation, or at sites with complex hydrogeology, obtaining a field-scale biodegradation rate may not be possible; in this case, microbiological laboratory data can be used. Such a "weight-of-evidence" approach will greatly increase the likelihood of successfully verifying natural attenuation at sites where natural processes are restoring the environmental quality of ground water.

Collection of an adequate database during the iterative site characterization process is an important step in the documentation of natural attenuation. Site characterization should provide data on the location, nature, and extent of contaminant sources. Site characterization also should provide information on the location, extent, and concentrations of dissolved contamination; ground-water geochemical data; geologic information on the type and distribution of subsurface materials; and hydrogeologic parameters such as hydraulic conductivity, hydraulic gradients, and potential contaminant migration pathways to human or ecological receptor exposure points. The data collected during site characterization can be used to simulate the fate and transport of contaminants in the subsurface. Such simulation allows prediction of the future extent and concentrations of the dissolved contaminant plume. Several models[5] can be used to simulate dissolved contaminant transport and attenuation. The natural attenuation modeling effort has three primary objectives: 1) to predict the future extent and concentration of a dissolved contaminant plume by simulating the combined effects of advection, dispersion, sorption, and biodegradation; 2) to assess the potential for downgradient receptors to be exposed to contaminant concentrations that exceed regulatory or risk-based levels intended to be protective of human health and the environment; and 3) to provide technical support for the natural attenuation remedial option at postmodeling regulatory negotiations to help design a more accurate verification and monitoring strategy and to help identify early source removal strategies.

Upon completion of the fate-and-transport modeling effort, model predictions can be used in an exposure pathways analysis. If natural attenuation is sufficient to mitigate risks to potential receptors, the proponent of natural attenuation has a reasonable basis for negotiating this option with regulators. The exposure pathways analysis allows the proponent to show that potential exposure pathways to receptors will not be completed.

Overview of Chlorinated Aliphatic Hydrocarbon Biodegradation

An accurate estimate of the potential for natural biodegradation is important to obtain when determining whether ground-water contamination presents a substantial threat to human health and the environment, because biodegradation is the most important process acting to remove contaminants from ground water, . The information also is useful when selecting the remedial alternative that will be most cost-effective in eliminating or abating these threats should natural attenuation not prove to be sufficient.

Over the past two decades, numerous laboratory and field studies have demonstrated that subsurface microorganisms can degrade a variety of hydrocarbons and chlorinated solvents (3, 23). Whereas fuel hydrocarbons are biodegraded through use as a primary substrate (electron donor), chlorinated aliphatic hydrocarbons may undergo biodegradation through three different pathways: through use as an electron acceptor, through use as an electron donor, or through co-metabolism, where degradation of the chlorinated organic is fortuitous and there is no benefit to the microorganism. Although at many sites the use of chlorinated aliphatic hydrocarbons as electron acceptors appears to be most important, under natural conditions at a given site, one or all of these processes may be operating (Figure 1). For example, Figure 1 shows vinyl chloride can aerobically mineralize to CO_2, aerobically cometabolize to CO_2 in the presence of toluene, aerobically cometabolize to CO_2 in the presence of methane, and reductively dechlorinate to ethene. In general, but in the electron acceptor pathway especially, biodegradation of chlorinated solvents will be an electron-donor-limited process. Conversely, biodegradation of fuel hydrocarbons is an electron-acceptor-limited process.

[5] Among the available models are MT3D, BIOMOD3D, BioREDOX, RT3D and others.

In a pristine aquifer, native organic carbon is used as an electron donor, and dissolved oxygen (DO) is used first as the prime electron acceptor. Where anthropogenic carbon (e.g., fuel hydrocarbon) is present, it also will be used as an electron donor. Following DO consumption, anaerobic microorganisms typically use additional electron acceptors (as available) in the following order of preference: nitrate, ferric iron oxyhydroxide, sulfate, and finally carbon dioxide. Evaluation of the distribution of these electron accepting compounds can provide evidence of where and how chlorinated aliphatic hydrocarbon biodegradation is occurring. In addition, because chlorinated aliphatic hydrocarbons may be used as electron acceptors or electron donors (in competition with other acceptors or donors), isopleth maps showing the distribution of the electron acceptor/donor compounds can provide evidence of the mechanisms of biodegradation working. As with BTEX, the driving force behind oxidation-reduction reactions resulting in chlorinated aliphatic hydrocarbon degradation is electron transfer. Although thermodynamically favorable, most of the reactions involved in chlorinated aliphatic hydrocarbon reduction and oxidation do not proceed abiotically. Microorganisms are capable of carrying out the reactions, but they will facilitate only those oxidation reduction reactions that have a net yield of energy.

Mechanisms of Chlorinated Aliphatic Hydrocarbon Biodegradation

Electron Acceptor Reactions (Reductive Dechlorination)

The most important process for the natural biodegradation of the more highly chlorinated solvents is reductive dechlorination. During the reductive dechlorination, the chlorinated hydrocarbon is used as an electron acceptor, not as a source of carbon, and a chlorine atom is removed and replaced with a hydrogen atom. In general, reductive dechlorination occurs by sequential dechlorination, for example, reductive dechlorination from perchloroethene to trichloroethene to dichloroethene to vinyl chloride to ethene. Depending on environmental conditions, the reductive dechlorination process sequence may be interrupted, with other processes then acting on the products. Reductive dechlorination of chlorinated solvent compounds is associated with all accumulation of daughter products and an increase in the concentration of chloride ions.

Reductive dechlorination affects each of the chlorinated ethenes differently. Of the chlorinated ethene compounds, perchloroethene is the most susceptible to reductive dechlorination because it is the most oxidized. Conversely, vinyl chloride is the least susceptible to reductive dechlorination because it is the least oxidized of these compounds. The rate of reductive dechlorination also has been observed to decrease as the degree of chlorination decreases (24, 25). Murray and Richardson (26) have postulated that this rate decrease may explain the accumulation of vinyl chloride in perchloroethene and trichloroethene plumes that are undergoing reductive dechlorination.

Reductive dechlorination has been demonstrated under nitrate-reducing and sulfate-reducing conditions, but the most rapid biodegradation rates, affecting the widest range of chlorinated aliphatic hydrocarbons, occur under methanogenic conditions (24). Nitrate/sulfate-reducing condition discussion will be presented in greater detail in subsequent parts of this document. Because chlorinated aliphatic hydrocarbon compounds are used as electron acceptors during reductive dechlorination, there must be an appropriate source of carbon for microbial growth to occur (24). Potential carbon sources include natural organic matter, fuel hydrocarbons, or other organic compounds such as those found in landfill leachate.

Electron Donor Reactions

Murray and Richardson (26) write that microorganisms are generally believed to be incapable of growth using trichloroethene and perchloroethene as a primary substrate (i.e., electron donor). Under aerobic and some anaerobic conditions, the less-oxidized chlorinated aliphatic hydrocarbons (e.g., vinyl chloride) can be used as the primary substrate in biologically mediated redox reactions (22). In the electron donor reaction, the facilitating microorganism obtains energy and organic carbon from the degraded chlorinated aliphatic hydrocarbon. Fuel hydrocarbons are biodegraded by the electron donor process.

In contrast to reactions in which the chlorinated aliphatic hydrocarbon is used as an electron acceptor, only the least oxidized chlorinated aliphatic hydrocarbons can be used as electron donors in biologically mediated redox reactions. McCarty and Semprini (22) describe investigations in which vinyl chloride and 1,2-dichloroethane were shown to serve as primary substrates under aerobic conditions. These authors also document that dichloromethane has the potential to function as a primary substrate under either aerobic or anaerobic environments. In addition, Bradley and Chapelle (27) show evidence of mineralization of vinyl chloride under iron reducing conditions so long as there is sufficient bioavailable iron(III). Aerobic metabolism of vinyl chloride may be characterized by a loss of vinyl chloride mass and a decreasing molar ratio of vinyl chloride to other chlorinated aliphatic hydrocarbon compounds.

Co-metabolism

When a chlorinated aliphatic hydrocarbon is biodegraded via co-metabolism, the degradation is catalyzed by an enzyme or cofactor that is fortuitously produced by the organisms for other purposes. The organism receives no known benefit from the degradation of the chlorinated aliphatic hydrocarbon; in fact, the co-metabolic degradation of the chlorinated aliphatic hydrocarbon may be harmful to the microorganism responsible for the production of the enzyme or cofactor (22).

Co-metabolism is best documented in aerobic environments, although it could occur under anaerobic conditions. It has been reported that under aerobic conditions chlorinated ethenes, with the exception of perchloroethene, are susceptible to co-metabolic degradation (22, 23, 26). Vogel (23) further elaborates that the co-metabolism rate increases as the degree of dechlorination decreases. During co-metabolism, trichloroethene is indirectly transformed by bacteria as they use BTEX or another substrate to meet their energy requirements. Therefore, trichloroethene does not enhance the degradation of BTEX or other carbon sources, nor will its co-metabolism interfere with the use of electron acceptors involved in the oxidation of those carbon sources.

Behavior of Chlorinated Solvent Plumes

Chlorinated solvent plumes can exhibit three types of behavior depending on the amount of solvent, the amount of biologically available organic carbon in the aquifer, the distribution and concentration of natural electron acceptors, and the types of electron acceptors being used. It must be noted that individual plumes may exhibit all three types of behavior in different portions of the plume. The different types of plume behavior are summarized below.

Type 1 Behavior

Type 1 behavior occurs where the primary substrate is anthropogenic carbon (e.g., BTEX or landfill leachate), and this anthropogenic carbon drives reductive dechlorination. When evaluating natural attenuation of a plume exhibiting Type 1, behavior the following questions must be answered:

1. Is the electron donor supply adequate to allow microbial reduction of the chlorinated organic compounds? In other words, will the microorganisms "strangle" before they "starve", will they run out of chlorinated aliphatic hydrocarbons (electron acceptors) before they run out of electron donors?

2. What is the role of competing electron acceptors (e.g., DO, nitrate, iron(III), and sulfate)?

3. Is vinyl chloride oxidized, or is it reduced?

Type 1 behavior results in the rapid and extensive degradation of the highly chlorinated solvents such as perchloroethene, trichloroethene, and dichloroethene.

Type 2 Behavior

Type 2 behavior dominates in areas that are characterized by relatively high concentrations of biologically available native organic carbon. This natural carbon source drives reductive dechlorination (i.e., is the primary substrate for microorganism growth). When evaluating natural attenuation of a Type 2 chlorinated solvent plume, the same questions as those posed for Type 1 behavior must be answered. Type 2 behavior generally results in slower biodegradation of the highly chlorinated solvents than Type 1 behavior, but under the right conditions (e.g., areas with high natural organic carbon contents) this type of behavior also can result in rapid degradation of chlorinated solvent compounds.

Type 3 Behavior

Type 3 behavior dominates in areas that are characterized by low concentrations of native and/or anthropogenic carbon and by DO concentrations greater than 1.0 milligrams per liter. Under these aerobic conditions, reductive dechlorination will not occur; thus, there is no removal of perchloroethene, trichloroethene, and dichloroethene. Advection, dispersion, and sorption are the most significant natural attenuation mechanisms for perchloroethene, trichloroethene, and dichloroethene in this setting. However, vinyl chloride can be rapidly oxidized under these conditions.

Mixed Behavior

A single chlorinated solvent plume can exhibit all three types of behavior in different portions of the plume. This can be beneficial for natural biodegradation of chlorinated aliphatic hydrocarbon plumes. For example, Wiedemeier et al. (28) describe a plume at Plattsburgh Air Force Base, New York, that exhibits Type 1 behavior in the source area and Type 3 behavior downgradient from the source. The most fortuitous scenario involves a plume in which perchloroethene, trichloroethene, and dichloroethene are reductively dechlorinated (Type 1 or 2 behavior), then vinyl chloride is oxidized (Type 3 behavior) either aerobically or via iron reduction. Vinyl chloride is oxidized to carbon dioxide in this type of plume and does not accumulate. The following sequence of reactions occurs in a plume that exhibits this type of mixed behavior:

Perchloroethene – Trichloroethene –
Dichloroethene – Vinyl chloride – Carbon dioxide

The trichloroethene, dichloroethene, and vinyl chloride may attenuate at approximately the same rate, and thus these reactions may be confused with simple dilution. Note that no ethene is produced during this reaction. Vinyl chloride is removed from the system much faster under these conditions than it is under vinyl chloride-reducing conditions.

A less desirable scenario, but one in which all contaminants may be entirely biodegraded, involves a plume in which all chlorinated aliphatic hydrocarbons are reductively dechlorinated via Type 1 or Type 2 behavior. Vinyl chloride is chemically reduced to ethene, which may be further reduced to ethane or methane. The following sequence of reactions occurs in this type of plume:

Perchloroethene – Trichloroethene –
Dichloroethene – Vinyl chloride – Ethene – Ethane

This sequence has been investigated by Freedman and Gossett (13). In this type of plume, vinyl chloride degrades more slowly than trichloroethene and thus vinyl chloride tends to accumulate.

Protocol for Quantifying Natural Attenuation During the Remedial Investigation Process

The primary objective of the natural attenuation investigation is to show that natural processes of contaminant degradation will reduce contaminant concentrations in ground water to below risk-based corrective action or regulatory levels within an acceptable distance and/or time frame. The natural attenuation investigation requires a prediction of the potential extent and concentration of the contaminant plume in time and space. The prediction should be based on historic variations in, and the current extent and concentrations of, the contaminant plume, as well as the measured rates of contaminant attenuation. Because of the inherent uncertainty associated with such predictions, the investigator must provide sufficient evidence to demonstrate that the mechanisms of natural attenuation will reduce contaminant concentrations to acceptable levels before potential receptors are reached. The demonstration requires the use of conservative solute fate-and-transport model input parameters and numerous sensitivity analyses so that consideration is given to all plausible contaminant migration scenarios. When possible, both historical data and modeling should be used to provide information that collectively and consistently

supports the natural reduction and removal of the dissolved contaminant plume.

Figure 2 outlines the steps involved in the natural attenuation demonstration. Figure 2 also shows the important regulatory decision points in the process of implementing natural attenuation. Predicting the fate of a contaminant plume requires the quantification of solute transport and transformation processes.

Quantification of contaminant migration and attenuation rates and successful implementation of the natural attenuation remedial option requires completion of the following steps:

1. Review available site data, and develop a preliminary conceptual model.

2. Screen the site, and assess the potential for natural attenuation.

3. Collect additional site characterization data to support natural attenuation, as required.

4. Refine the conceptual model, complete premodeling calculations, and document indicators of natural attenuation.

5. Simulate natural attenuation using analytical or numerical solute fate-and-transport models that allow incorporation of a biodegradation term, as necessary.

6. Identify current and future receptors, and conduct an exposure-pathway analysis.

7. Determine whether source treatment will be remediation, removal, containment or a combination of these.

8. If natural attenuation (after source treatment) is acceptable, prepare a long-term monitoring plan.

9. Present findings to regulatory agencies.

Review Available Site Data, and Develop a Preliminary Groundwater Flow and Transport Conceptual Model

Existing site characterization data should be reviewed and used to develop a site-specific conceptual model. The preliminary conceptual model will help identify any shortcomings in the data and will allow placement of additional data collection points in the most scientifically advantageous and cost-effective manner. A site-specific conceptual model is a three-dimensional representation of the ground-water flow and solute transport system based on available geological, biological, geochemical, hydrological, climatological, and analytical data. This type of conceptual model differs from the conceptual site models that risk assessors commonly use that qualitatively consider the location of contaminant sources, release mechanisms, transport pathways, exposure points, and receptors. The groundwater system conceptual model, however, facilitates identification of these risk-assessment elements for the exposure pathways analysis. After development, the conceptual model can be used to help determine optimal placement of additional data collection points (as necessary) to aid in the natural attenuation investigation and to develop the solute fate-and-transport model.

Contracting and management controls must be flexible enough to allow for the potential for revisions to the conceptual model and thus the data collection effort. In cases where little or questionable site-specific data are available, all future site characterization activities should be designed to collect the data necessary to screen the site to determine the potential for remediation by natural attenuation. The data collected in support of natural attenuation can be used to design and support other remedial measures.

Table 1A. lists a standard set of methods, while Table 1B. lists methods that are under development and/or consideration for the soil and ground water analytical protocol for natural attenuation of chlorinated

aliphatic hydrocarbons and/or fuel hydrocarbons. Any plan to collect additional ground-water and soil quality data should include targeting the analytes listed in Table 1A., and Table 1B., where the technique is finalized.

Screen the Site, and Assess the Potential for Natural Attenuation

After reviewing available site data and developing a preliminary groundwater flow and transport conceptual model, an assessment of the potential for natural attenuation must be made. As stated previously, existing data can be useful in determining whether natural attenuation will be sufficient to prevent a dissolved contaminant plume from completing exposure pathways, or from reaching a predetermined point of compliance, in concentrations above applicable regulatory or risk-based corrective action standards. Determining the likelihood of exposure pathway completion is an important component of the natural attenuation investigation. The determination is achieved by estimating the migration and future extent of the plume based on contaminant properties, including volatility, sorptive properties, and biodegradability; aquifer properties, including hydraulic gradient, hydraulic conductivity, effective porosity, and total organic carbon (TOC) content; and the location of the plume and contaminant source relative to potential receptors (i.e., the distance between the leading edge of the plume and the potential receptor exposure points). These parameters (estimated or actual) are used in the example that follows to make a preliminary assessment of the effectiveness of natural attenuation in reducing contaminant concentrations.

If, after completing the steps outlined in this Quantification of biological natural attenuation section, it appears that natural attenuation will be a significant factor in contaminant removal, detailed site characterization activities in support of the natural attenuation remediation is necessary. If exposure pathways have already been completed and contaminant concentrations exceed regulatory levels, or if such completion is likely, other remedial measures should be considered, possibly in conjunction with natural attenuation. Even so, the collection of data in support of the natural attenuation option can be integrated into a comprehensive remedial plan and may help reduce the cost and duration of other remedial measures, such as intensive source removal operations or pump-and-treat technologies. For example, dissolved iron concentrations can have a profound influence on the design of pump-and-treat systems.

The screening process presented in this Quantification of biological natural attenuation section is outlined in Figure 3. The screening process allows the investigator to determine whether natural attenuation is likely to be a viable remedial alternative before additional time and money are expended. The data required to make the preliminary assessment of natural attenuation can also be used to aid the design of an engineered remedial solution, should the screening process suggest that natural attenuation alone is not feasible. The following information is required for the screening process:

- The chemical and geochemical data presented in Table 2 for monitoring wells located in zones upgradient, within the plume and downgradient. Figures 4A and 4B show the approximate locations of data collection points all of which are substantiated in the appropriate flow and contaminant site investigation. If other contaminants are suspected, then data on the concentration and distribution of these compounds also must be obtained.

- Locations of source(s) and receptor(s).

- An estimate of the contaminant transport velocity and direction of ground-water flow.

Once these data have been collected, the screening process can be undertaken. The following steps summarize the screening process:

1. Determine whether biodegradation is occurring using geochemical data. If biodegradation is occurring, proceed to Step 2. If it is not, assess the amount and types of data available. If data are insufficient to determine whether biodegradation is occurring, collect supplemental data.

2. Determine ground-water flow and solute transport parameters. Hydraulic conductivity and effective porosity may be estimated, but the ground-water gradient and flow direction may not. The investigator should use the highest hydraulic conductivity measured at the site during the preliminary screening because solute plumes tend to follow the path of least resistance (i.e., highest hydraulic conductivity). This will give the "worst case" estimate of solute migration over a given period.

3. Locate sources and current and future receptor exposure points.

4. Estimate the biodegradation rate constant. In ideal cases, biodegradation rate constants can be estimated using a conservative tracer found co-mingled with the contaminant plume, as described by Wiedemeier et al. (36). When dealing with a plume that contains only chlorinated solvents, this procedure will have to be modified to use chloride as a tracer. Rate constants derived from microcosm studies can also be used. If it is not possible to estimate the biodegradation rate using these procedures, then use a range of accepted literature values for biodegradation of the contaminants of concern.

5. Compare the rate of transport to the rate of attenuation, using analytical solutions or a screening model such as BIOSCREEN .

6. Determine whether the screening criteria are met.

Each step is described in detail below.

Step 1: Determine Whether Biodegradation Is Occurring

The first step in the screening process is to sample a minimum of six nested well location areas that are representative of the contaminant flow system and to analyze the samples for the parameters listed in Table 2. Samples should be taken 1) from the most contaminated portion of the aquifer (within or as close to the source area as possible ; 2) downgradient from the source area, in the dissolved contaminant plume (2 sample locations); 3) downgradient from the dissolved contaminant plume; and 4) from upgradient and lateral locations that are not affected by the plume.

Samples collected in the Source Area allow determination of the dominant terminal electron-accepting processes at the site. Figure 5 is supplied in order to illustrate the hierarchy of the terminal electron-accepting process. In conjunction with samples collected in the Source Area, samples collected in the Dissolved Contaminant Plume downgradient from the Source Area allow the investigator to determine whether the plume is degrading with distance along the flow path and what the distribution of electron acceptors and donors and metabolic byproducts might be along the flow path. The sample collected downgradient from the Dissolved Contaminant Plume aids in plume delineation and allows the investigator to determine whether metabolic byproducts are present in an area of ground water that has apparently been unaffected by the source. The upgradient and lateral samples allow delineation of the plume and indicate background concentrations of the electron acceptors and donors.

After these samples have been analyzed for the parameters listed in Table 2 (groundwater matrix parameters), the investigator should analyze the data to determine whether biodegradation is occurring. The reason for using the water (groundwater) matrix only in the analysis described in the previous sentence is because the scoring procedure is based on ground water concentrations and parameter data. The right-hand column of Table 2 contains scoring values that can be used for this task. For example, if the DO concentration in the area of the plume with the highest contaminant concentration is less than 0.5 milligrams per liter, this parameter is awarded 3 points. Table 3 summarizes the range of possible scores and gives an interpretation for each score. If the site scores a total of 15 or more points, biodegradation is probably occurring, and the investigator can proceed to Step 2. This method relies on the fact that biodegradation will cause predictable changes in ground-water chemistry.

Table 3. Interpretation of Points Awarded During Screening Step I

Score	Interpretation
0 to 5	Inadequate evidence for biodegradation of chlorinated organics
6 to 14	Limited evidence for biodegradation of chlorinated organics

15 to 20	Adequate evidence for biodegradation of chlorinated organics
> 20	Strong evidence for biodegradation of chlorinated organics

Consider the following two examples. Example 1 contains data for a site with strong evidence that reductive dechlorination is occurring. Example 2 contains data fora site with strong evidence that reductive dechlorination is not occurring.

Example 1. Strong Evidence for Biodegradation of Chlorinated Organics

Analyte	Concentration in Contaminated Zone	Most points Awarded
DO	0. 1 mg/L	3
Nitrate	0.3 mg/L	2
Iron(II)	10 mg/L	3
Sulfate	2 mg/L	2
Methane	5 mg/L	3
Oxidation/ reduction potential	-190 mv	2
Chloride	3x background	2
Perchloroethene (released)	1,000 mg/L	0
Trichloroethene (none released)	1,200 ug/L	2

Example 1. Strong Evidence for Biodegradation of Chlorinated Organics (cont.)

Analyte	Concentration in Contaminated Zone	Most points Awarded
cis-1,2-DCE (none released)	500 ug/L	2
Vinyl chloride (none released)	50 ug/L	2
Total points awarded	23	

In this example, the investigator can infer that biodegradation is occurring and may proceed to Step 2.

Example 2. Biodegradation of Chlorinated organics Unlikely

Analyte	Concentration in Most Contaminated Zone	Points Awarded
DO	3 mg/1	-3
Nitrate	0.3 mg/L	2
Iron(II)	Not detected	0
Sulfate	10 mg/L	2
Methane	ND	0
Oxidation-reduction potential	100 mv	0
Chloride	Background	0
Trichloroethene (released)	1,200 ug/L	0
cis-1,2-Dichloroethene	Not detected	0
Vinyl chloride	ND	0
Total points awarded	1	

In this example, the investigator can infer that biodegradation is probably not occurring or is occurring too slowly to be a viable remedial option. In this case, the investigator cannot proceed to Step 2 and will likely have to implement an engineered remediation system.

This scoring system was developed by Dr. John Wilson at EPA's RSDERC and Todd Weidemeier of Parsons Engineering and has been peer reviewed.

Step 2: Determine Groundwater Flow and Solute Transport Parameters

If the interpretation of the score indicates biodegradation is occurring, it is important to quantify groundwater flow and solute transport parameters. U.S. EPA strongly recommends obtaining site specific parameter data for supporting natural attenuation to the fullest extent possible. Parameter Quantification will make it possible to use a solute transport model to quantitatively estimate the concentration of the plume and its direction and rate of travel. To use an analytical model, it is necessary to know the hydraulic gradient and hydraulic conductivity for the site and to have estimates of the effective porosity and dispersivity. The coefficient of retardation also is helpful to know. Quantification of these parameters is discussed by Wiedemeier et al. (1); the textbook Contaminant Hydrogeology (Fetter, 1992), The Soil Chemistry of Hazardous Materials (Dragun, 1988), Basics of Pump-and-Treat Ground-Water Remediation Technology (Mercer et al, 1990), Principles of Groundwater Engineering (Walton, 1991), and Ground Water Issue Paper Basic Concepts of Organic Contaminant Sorption at Hazardous Waste Sites (Piwoni et al, 1990) also contain information on these variables.

To make modeling as accurate as possible, the investigator must have site-specific hydraulic gradient and hydraulic conductivity data. To determine the ground-water flow and solute transport direction, the site must have at least three accurately surveyed wells, for the most simplistic site hydrogeologic conditions. The effective porosity and dispersivity are generally estimated using accepted literature values for the

types of sediments found at the site. If the investigator does not have total organic carbon data for soil, the coefficient of retardation can still be estimated using default literature values for total organic carbon, soil bulk density, and the aquifer effective porosity; however, assuming that the solute transport and ground-water velocities are the same is usually conservative.

Step 3: Locate Sources and Receptor Exposure Points

To determine the length of flow for the predictive modeling conducted in Step 5, it is important to know the distance between the source of contamination, the downgradient end of the dissolved plume, and any potential downgradient or cross-gradient receptors.

Step 4: Estimate the Biodegradation Rate Constant

Estimated biodegradation rates can be used only after biodegradation has been shown to be occurring (see Step 1). The biodegradation rate is one of the most important model input parameters. Biodegradation of chlorinated aliphatic hydrocarbons can commonly be represented as a first-order rate constant. Site-specific biodegradation rates are required due to the sensitivity of this parameter to modeling results and because of the dependence biological degradation has on the physical properties of the site. If gathering site specific degradation rates is absolutely not possible the a method for obtaining this value should be negotiated with the technical parties for U.S. EPA.

Step 5: Compare the Rate of Transport to the Rate of Attenuation

At this early stage in the natural attenuation demonstration, comparison of the rate of solute transport to the rate of attenuation is best accomplished using an analytical model. Several analytical models are available, but the BIOSCREEN model is probably the simplest currently available model to use. BIOSCREEN was developed to simulate biological degradation of hydrocarbons and the suggestions below should be incorporated into running the model for use on chlorinated solvent plumes. The model is nonproprietary and is available from the Robert S. Karr Laboratory's home page on the Internet (www.epa.gov/ada/kerriab.html). The BIOSCREEN model is based on Domenico's solution to the advection dispersion equation (38), and allows use of either a first-order biodegradation rate or an instantaneous reaction between contaminants and electron acceptors to simulate the effects of biodegradation. To model transport of chlorinated aliphatic hydrocarbons using BIOSCREEN, only the first-order decay rate option should be used. The model BIOCHLOR is under development by the Technology Transfer Division of Air Force Center for Environmental Excellence (AFCEE). The BIOCHLOR model will be geared towards evaluating transport of chlorinated compounds under the influence of biodegradation. BIOPLUME III is currently being peer reviewed by U.S. EPA and will be a numerical model that will simulate biological decay of organic compounds. Other models exist and a literature search for these models is recommended.

The primary purpose of comparing the rate of transport with the rate of attenuation is to determine whether the residence time along the flow path is adequate to be protective of human health and the environment (i.e., to qualitatively estimate whether the contaminant is attenuating at a rate fast enough to allow degradation of the contaminant to acceptable concentrations before receptors, or potential receptors, are reached). It is important to perform a sensitivity analysis to help evaluate the confidence in the preliminary screening modeling effort. If modeling indicates that natural attenuation may attain remedial action objectives, then the screening criteria are met, and the investigator can proceed with the natural attenuation feasibility study.

Step 6: Determine Whether the Screening Criteria Are Met

Before proceeding with the full-scale natural attenuation feasibility study, the investigator should ensure that the answers to all of the following criteria are "yes":

- Has the plume moved a distance less than expected, based on the known (or estimated) time since the contaminant release and the contaminant velocity, as calculated from site-specific measurements of hydraulic conductivity and hydraulic gradient, as well as estimates of effective effective porosity and contaminant retardation? The time of release is often difficult to ascertain and it is recommended that conferring with the regulatory and facility parties involved with the site be performed in order to prevent costly time and effort with an unsuitable time.

- Is it likely that the contaminant mass is attenuating at rates sufficient to be protective of human health and the environment at a compliance point, or point of discharge to a sensitive environmental receptor?

- Is the plume going to attenuate to concentrations less than risk-based corrective action guidelines or regulatory criteria before reaching potential receptors, or a compliance point?

Collect Additional Site Characterization Data To Support Natural Attenuation, As Required

Detailed site characterization is necessary to document the potential for natural attenuation. Review of existing site characterization data is particularly useful before initiating site characterization activities. Such review should allow identification of data gaps and guide the most effective placement of additional data collection points. There are two goals during the site characterization phase of a natural attenuation investigation. The first is to collect the data needed to determine whether natural mechanisms of contaminant attenuation are occurring at rates sufficient to protect human health and the environment. The second is to provide sufficient site-specific data to allow prediction of the future extent and concentration of a contaminant plume through solute fate and transport modeling. Because the burden of proof for natural attenuation is on the proponent, detailed site characterization is required to achieve these goals and to support this remedial option. Adequate site characterization in support of natural attenuation requires that the following site-specific parameters be determined:

- The extent and type of soil and ground-water contamination.

- The location and extent of contaminant source area(s) (i.e., areas containing mobile or residual NAPL).

- The potential for a continuing source due to leaking tanks or pipelines.

- Aquifer geochemical parameters.

- Regional hydrogeology, including ground water that is a current or potential source of drinking water or discharges into an ecologically sensitive area and regional confining units.

- Local and site-specific hydrogeology, including local drinking water supplies; location of industrial, agricultural, and domestic water wells; patterns of ground water use (current and future); lithology; site stratigraphy, including identification of transmissive and nontransmissive units; grain-size distribution (sand versus silt versus clay); partitioning coefficients; aquifer hydraulic conductivity; groundwater hydraulic information; preferential flow paths; locations and types of surface water bodies; and areas of local ground-water recharge and discharge.

- Identification of potential exposure pathways and receptors.

The following sections describe the methodologies that should be implemented to allow successful site characterization in support of natural attenuation. Additional information can be obtained from Wiedemeier et al. (1, 37).

Soil Characterization

To adequately define the subsurface hydrogeologic system and to determine the amount and three-dimensional distribution of contaminant mass that can act as a continuing source of ground-water contamination, extensive soil characterization must be completed. Soil characterization may have been completed during previous remedial investigation activities. The results of soils characterization will be used as input into a solute fate-and-transport model to help define a contaminant source term and to support the natural attenuation investigation.

The analytical protocol to be used for soil, aquifer matrix and soil gas sample analysis is presented in Table 1A. and 1B. The analytical methods includes all of the parameters necessary to document natural attenuation, including the effects of sorption and biodegradation. Knowledge of the location, distribution, concentration, and total mass of contaminants of regulatory concern in soils or present as residual and/or mobile NAPL is required to calculate the mass transfer rate from the contaminant source to the ground water. Knowledge of the TOC content of the aquifer matrix is important for sorption and solute-retardation calculations. TOC samples should be collected from a background location in the stratigraphic horizon(s) where most contaminant transport is expected to occur. Oxygen and carbon dioxide measurements of soil gas can be used to find areas in the unsaturated zone where biodegradation is occurring. Knowledge of the distribution of contaminants in soil gas can be used as a cost-effective way to estimate the extent of soil volatile organic compound contamination.

Groundwater Characterization

To adequately determine the amount and three-dimensional distribution of dissolved contamination and to document the occurrence of natural attenuation, ground-water samples must be collected and analyzed. Biodegradation of organic compounds, whether natural or anthropogenic, brings about measurable changes in the chemistry of ground water in the affected area. By measuring these changes, documentation and quantitative evaluation of natural attenuation's importance at a site are possible.

Groundwater sampling is conducted to determine the concentrations and distribution of contaminants, daughter products, and ground-water geochemical parameters. The analytical protocol for ground-water sample analysis is presented in Table 1A. and 1B. The analytical protocol includes all of the parameters necessary to document natural attenuation, including the effects of sorption and biodegradation. Data obtained from the analysis of ground water for these analytes is used to scientifically document natural attenuation and can be used as input into a solute fate-and-transport model. The following paragraphs describe each ground-water analytical parameter and the use of each analyte in the natural attenuation demonstration.

Volatile organic compound analysis (by Method SW8260a) is used to determine the types, concentrations, and distributions of contaminants and daughter products in the aquifer. Figure 1 (44) is included in the text for illustrative purposes. DO is the electron acceptor most thermodynamically favored by microbes for the biodegradation of organic carbon, whether natural or anthropogenic. Reductive dechlorination will not occur, however, if DO concentrations are above approximately 0.5 milligrams per liter. During aerobic biodegradation of a substrate, DO concentrations decrease because of the microbial oxygen demand. After DO depletion, anaerobic microbes will use nitrate containing compounds as an electron acceptor, followed by iron(III) containing compounds, then sulfate containing compounds, and finally carbon dioxide (methanogenesis). Each sequential reaction drives the oxidation-reduction potential of the ground water further toward conditions that favor reductive dechlorination. The oxidation-reduction potential range of sulfate reduction and methanogenesis is optimal, but reductive dechlorination may occur under nitrate- and iron(III)-reducing conditions as well. Because reductive dechlorination works best in the sulfate reduction and methanogenesis oxidation-reduction potential range, competitive exclusion between microbial sulfate reducers, methanogens, and reductive dechlorinators can occur.

After DO has been depleted in the area of the plume where chlorinated aliphatic compounds are being

anaerobically remediated (treatment zone), nitrate-containing compounds may be used as an electron acceptor for anaerobic biodegradation via denitrification. In some cases iron(III)-containing compounds are used as an electron acceptors during anaerobic biodegradation of electron donors. During this process, iron(III) is reduced to the more soluble iron(II). Iron(II) concentrations can thus be used as an indicator of anaerobic degradation of fuel compounds. After DO, nitrate, and bioavailable iron(III) have been depleted in the area of the plume where chlorinated aliphatic compounds are being anaerobically remediated, sulfate-containing compounds may be used as an electron acceptor for anaerobic biodegradation. This process is termed sulfate reduction and results in the production of sulfide-containing compounds. During methanogenesis (an anaerobic biodegradation process), carbon dioxide (or acetate)-containing compounds are used as an electron acceptors, and methane is produced. Methanogenesis generally occurs after oxygen, nitrates, bioavailable iron(III)s, and sulfates have been depleted in the treatment zone. The presence of methane in ground water is indicative of strongly reducing conditions. Because methane is not present in fuel, the presence of methane in ground water above background concentrations in contact with fuels is indicative of microbial degradation of fuel hydrocarbons.

The total alkalinity of a ground-water system is indicative of a water's capacity to neutralize acid. Alkalinity results from the presence of hydroxides, carbonates, and bicarbonates of elements such as calcium, magnesium, sodium, potassium, or ammonia. Alkalinity is important in the maintenance of ground-water pH because it buffers the ground-water system against acids generated during both aerobic and anaerobic biodegradation.

In general, areas contaminated by fuel hydrocarbons exhibit a total alkalinity that is higher than that seen in background areas. This is expected because the microbially mediated reactions causing biodegradation of fuel hydrocarbons cause an increase in the total alkalinity in the system. Changes in alkalinity are most pronounced during aerobic respiration, denitrification, iron reduction, and sulfate reduction, and are less pronounced during methanogenesis (40). In addition, Willey et al. (41) show that short-chain aliphatic acid ions produced during biodegradation of fuel hydrocarbons can contribute to alkalinity in ground water.

The oxidation-reduction potential of ground water is a measure of electron activity and an indicator of the relative tendency of a solution to accept or transfer electrons. Redox reactions in ground water containing organic compounds (natural or anthropogenic) are usually biologically mediated; therefore, the oxidation-reduction potential of a ground-water system depends on and influences rates of biodegradation. Knowledge of the oxidation-reduction potential of ground water also is important because some biological processes operate only within a prescribed range of redox conditions. The oxidation-reduction potential of ground water generally ranges from -400 to 800 millivolts (mV). Figure 6 shows the typical redox conditions for ground water when different electron acceptors are used.

Oxidation-reduction potential can be used to provide real-time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation. Mapping the oxidation-reduction potential of the ground water while in the field helps the field scientist to determine the approximate location of the contaminant plume. To perform this task, it is important to have at least one redox measurement (preferably more) from a well located upgradient from the plume. Oxidation-reduction potential measurements should be taken during well purging and immediately before and after sample acquisition using a direct-reading meter. Because most well purging techniques can allow aeration of collected ground-water samples (which can affect oxidation-reduction potential measurements), it is important to minimize potential aeration.

Dissolved hydrogen (gas) concentrations can be used to determine the dominant terminal electron-accepting process in an aquifer. Table 4 and Figure 5 are presented to respectively present the range of hydrogen concentrations for a given terminal electron-accepting process and the hierarchical scheme for diagnosing the terminal electron-accepting process. Much research has been done on the topic of using hydrogen measurements to delineate terminal electron-accepting processes (42,44). Because the efficiency of reductive dechlorination differs for methanogenic, sulfate-reducing, iron(III)-reducing, or

denitrifying conditions, it is helpful to have hydrogen concentrations to help delineate redox conditions when evaluating the potential for natural attenuation of chlorinated ethenes in ground-water systems. Collection and analysis of ground-water samples for dissolved hydrogen content is not yet commonplace or standardized.

Table 4. Range of Hydrogen Concentrations for a Given Terminal Electron-Accepting Process

Terminal Electron-Accepting Process	Hydrogen Concentration (nanomoles per liter)
Denitrification	< 0.1
Iron(III) reduction	0.2 to 0.8
Sulfate reduction	1 to 4
Methanogenesis	> 5

Because the pH, temperature, and conductivity of a ground-water sample can change significantly shortly following sample acquisition, these parameters must be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for DO and redox analyses. The measurements should be made in a clean glass container separate from those intended for laboratory analysis, and the measured values should be recorded in the ground-water sampling record.

The pH of ground water has an effect on the presence and activity of microbial populations in the ground water. This is especially true for methanogens. Microbes capable of degrading chlorinated aliphatic hydrocarbons and petroleum hydrocarbon compounds generally prefer pH values varying from 6 to 8 standard units. Ground-water temperature directly affects the solubility of oxygen and other geochemical species. The solubility of DO is temperature dependent, being more soluble in cold water than in warm water. Ground-water temperature also affects the metabolic activity of bacteria. Rates of hydrocarbon biodegradation roughly double for every 10°C increase in temperature ("$Q"_{10}$ rule) over the temperature range between 5°C and 25°C. Ground-water temperatures less than about 5°C tend to inhibit biodegradation, and slow rates of biodegradation are generally observed in such waters.

Conductivity is a measure of the ability of a solution to conduct electricity. The conductivity of ground water is directly related to the concentration of ions in solution; conductivity increases as ion concentration increases. Conductivity measurements are used to ensure that ground water samples collected at a site are representative of the water in the saturated zone containing the dissolved contamination. If the conductivities of samples taken from different sampling points are radically different, the waters may be from different hydrogeologic zones.

Elemental chlorine is the most abundant of the halogens. Although chlorine can occur in oxidation states ranging from Cl^{+} to Cl^{+7}, the chloride form (C^{-}) is the only form of major significance in natural waters (45). Chloride forms ion pairs or complexations with some of the cations present in natural waters, but these complexes are not strong enough to be of significance in the chemistry of fresh water (45). Chloride ions generally do not enter into oxidation-reduction reactions, form no important solute complexes with other ions unless the chloride concentration is extremely high, do not form salts of low solubility, are not significantly adsorbed on mineral surfaces, and play few vital biochemical roles (45). Thus, physical processes control the migration of chloride ions in the subsurface, and chloride is an effective conservative tracer of ground-water contaminant plume migration.

During biodegradation of chlorinated hydrocarbons dissolved in ground water, chloride is released into the ground water. This process results in chloride concentrations in the ground water of the contaminant plume that are elevated relative to background concentrations. Because of the nonreactive behavior of

chloride, it can be used as a conservative tracer to estimate biodegradation rates using methods similar to those discussed by Wiedemeier et al. (36).

Field Measurement of Aquifer Hydraulic Parameters

The properties of an aquifer that have the greatest impact on contaminant fate and transport include hydraulic conductivity, hydraulic gradient, effective porosity, and dispersivity. Estimating hydraulic conductivity and gradient in the field is fairly straightforward, but obtaining field-scale information on effective porosity and dispersivity can be difficult.

Therefore, most investigators rely on field data for hydraulic conductivity and hydraulic gradient and on literature values for effective porosity and dispersivity for the types of sediments present at the site. Methods for field measurement of aquifer hydraulic parameters are described by Wiedemeier et al. (1, 37). Additional sources of information is found in Groundwater (Freeze & Cherry, 1979), Applied Hydrogeology (Fetter, 1988), and Contaminant Hydrogeology (Fetter, 1993).

Microbiological Laboratory Data

Microcosm studies are used to show that the microorganisms necessary for biodegradation are present and to help quantify rates of biodegradation. If properly designed, implemented, and interpreted, microcosm studies can provide very convincing documentation of the occurrence of biodegradation. The most common technique used to show explicitly that microorganisms capable of degrading contaminants present at a site is the microcosm study. The results of a well-designed microcosm study will be easy for decision-makers with nontechnical backgrounds to interpret. Results of such studies are strongly influenced by the nature of the geological material submitted for study, the physical properties of the microcosm, the sampling strategy, and the duration of the study. Because microcosm studies are time-consuming and expensive, they should be undertaken only at sites where there is considerable uncertainty concerning the biodegradation of contaminants.

Biodegradation rate constants determined by microcosm studies often are much greater than rates achieved in the field. Microcosms are most appropriate as indicators of the potential for natural bioremediation and to prove that losses are biological, but it may be inappropriate to use them to generate rate constants. The preferable method of contaminant biodegradation rate-constant determination is in situ field measurement. The collection of material for the microcosm study, the procedures used to set up and analyze the microcosm, and the interpretation of the results of the microcosm study are presented by Wiedemeier et al. (1).

Refine the Conceptual Model, Complete Premodeling Calculations, and Document Indicators of Biological Degradation

Site investigation data should first be used to refine the conceptual model and quantify ground-water flow, sorption, dilution, and biodegradation. The results of these calculations are used to scientifically document the occurrence and rates of natural attenuation and to help simulate natural attenuation over time. Because the burden of proof is on the proponent, all available data must be integrated in such a way that the evidence is sufficient to support the conclusion that natural attenuation is occurring.

Conceptual Model Refinement

Conceptual model refinement involves integrating newly gathered site characterization data to refine the preliminary conceptual model that was developed based on previously existing site-specific data. During conceptual model refinement, all available site-specific data should be integrated to develop an accurate three-dimensional representation of the hydrogeologic and contaminant transport system. This conceptual model can then be used for contaminant fate-and-transport modeling. Conceptual model refinement consists of several steps, including preparation of geologic logs, hydrogeologic sections.

potentiometric surface/water table maps, contaminant contour (isopleth) maps, and electron acceptor and metabolic byproduct contour (isopleth) maps. Refinement of the conceptual model is described by Wiedemeier et al. (1).

Premodeling Calculations

Several calculations must be made prior to implementation of the solute fate-and-transport model. These calculations include sorption and retardation calculations, NAPL water-partitioning calculations, ground-water flow velocity calculations, and biodegradation rate-constant calculations. Each of these calculations is discussed in the following sections. Most of the specifics of each calculation are presented in the fuel hydrocarbon natural attenuation technical protocol by Wiedemeier et al. (1), and all will be presented in the protocol incorporating chlorinated aliphatic hydrocarbon attenuation (37).

Biodegradation Rate Constant Calculations

Biodegradation rate constants are necessary to simulate accurately the fate and transport of contaminants dissolved in ground water. In many cases, biodegradation of contaminants can be approximated using first-order kinetics. To calculate first-order biodegradation rate constants, the apparent degradation rate must be normalized for the effects of dilution and volatilization. Two methods for determining first-order rate constants are described by Wiedemeier et al. (36). One method involves the use of a biologically recalcitrant compound found in the dissolved contaminant plume that can be used as a conservative tracer. The other method, proposed by Buscheck and Alcantar (47) involves interpretation of a steady-state contaminant plume and is based on the one-dimensional steady-state analytical solution to the advection-dispersion equation presented by Bear (48). The first-order biodegradation rate constants for chlorinated aliphatic hydrocarbons are also presented (J. Wilson et al., Dallas Symposium Notes).

Simulate Natural Attenuation Using Solute Fate-and-Transport Models

Simulating natural attenuation using a solute fate and transport model allows prediction of the migration and attenuation of the contaminant plume through time. Natural attenuation modeling is a tool that allows site-specific data to be used to predict the fate and transport of solutes under governing physical, chemical, and biological processes. Hence, the results of the modeling effort are not in themselves sufficient proof that natural attenuation is occurring at a given site. The results of the modeling effort are only as good as the original data input into the model; therefore, an investment in thorough site characterization will improve the validity of the modeling results. In some cases, straightforward analytical models of contaminant attenuation are adequate to simulate natural attenuation.

Several well-documented and widely accepted solute fate-and-transport models are available for simulating the fate-and-transport of contaminants under the influence of advection, dispersion,'sorption, and biodegradation. The use of solute fate-and-transport modeling in the natural attenuation investigation is described by Wiedemeier et al. (1).

Identify Potential Receptors, and Conduct an Exposure-Pathway Analysis

After the rates of natural attenuation have been documented and predictions of the future extent and concentrations of the contaminant plume have been made using the appropriate solute fate-and-transport model, the case for natural attenuation should combine all available data and information to present the basis for using this as a remedial option. Supporting the natural attenuation option generally will involve performing a receptor exposure-pathway analysis. This analysis includes identifying potential human and ecological receptors and points of exposure under current and future land and ground-water use scenarios and the 9 criteria in the Feasibility Study. The results of solute fate-and-transport modeling are central to the exposure pathways analysis. If conservative model input parameters are used, the solute fate-and-transport model should give conservative estimates of contaminant plume migration. From this information, the potential for impacts on human health and the environment from contamination present at

the site can be estimated.

Evaluate Source Control

Source removal, treatment or containment will be necessary to reduce plume expansion. Several technologies suitable for source reduction or removal are listed in Figure 2. Other technologies may also be used as dictated by site conditions and local regulatory requirements. Source removal can be very effective at limiting plume migration and decreasing the remediation time frame, especially at sites where biodegradation is contributing to natural attenuation of a dissolved contaminant plume.

Prepare a Long-Term Monitoring Plan

Experience at 40 Air Force sites contaminated with fuel hydrocarbons using the protocol presented by Wiedemeier et al. (1) suggests that many fuel hydrocarbon plumes are relatively stable or are moving very slowly with respect to ground-water flow. These examples demonstrate the efficacy of long-term monitoring to track plume migration and to validate or refine modeling results. There is not a large enough database available at this time to assess the stability of chlorinated solvent plumes, but in the authors' experience chlorinated solvent plumes are likely to migrate further downgradient than fuel hydrocarbon plumes before reaching steady-state equilibrium or before receding.

The long-term monitoring plan consists of locating ground-water monitoring wells and developing a ground-water sampling and analysis strategy. This plan is used to monitor plume migration over time and to verify that natural attenuation is occurring at rates sufficient to protect potential downgradient receptors. The long-term monitoring plan should be developed based on site characterization data, the results of solute fate and transport modeling, and the results of the exposure pathway analysis.

The long-term monitoring plan includes monitoring wells for long-term monitoring that are intended to determine whether the behavior of the plume is changing; for monitoring additional plume growth and contaminant distribution , and to trigger an action to manage the risk associated with such expansion. Figures 4A and 4B depict schematics for potential performance evaluation wells. The final number and placement of long-term monitoring and performance evaluation wells is determined through regulatory requirements and may change as conditions at the site change. Locations of long-term monitoring wells are based on the behavior of the plume as revealed during the initial site characterization and on regulatory considerations.

The results of a solute fate-and-transport model can be used to help locate the long-term monitoring wells. To provide a valid monitoring system, all monitoring wells must be screened in the same hydrogeologic unit as the contaminant plume. This generally requires detailed stratigraphic correlation. To facilitate accurate stratigraphic correlation, detailed visual descriptions of all subsurface materials encountered during borehole drilling should be prepared prior to monitoring-well installation.

A ground-water sampling and analysis plan is required in conjunction with long-term monitoring well placement. For long-term monitoring, groundwater analyses should include volatile organic compounds, DO, nitrates, iron(II)s, sulfates, metals and methane. For wells known to be considerably downgradient, groundwater analyses should be limited to determining volatile organic compounds, metals, and DO concentrations. Any site-specific analytical requirements also should be addressed in the sampling and analysis plan to ensure that all data required for regulatory decision-making are collected. Water level and any NAPL thickness measurements must be made during each sampling event. Except at sites with very low hydraulic conductivity and gradients, bi-monthly sampling of long-term monitoring wells is recommended during the first year to help determine the direction of plume migration and to determine baseline data. Monthly precipitation data should also be collected from the nearest Weather Service Center. Based on the results of the first year's sampling, the sampling frequency may be reduced to annual sampling in the quarter showing the greatest extent of the plume. Long-term sampling frequency depends on the final placement of the point-of-compliance monitoring wells and ground-water flow velocity and other regulatory considerations made during risk management decision making.

Present Findings and Obtain Consensus for Remediation by Natural Attenuation

A natural attenuation remedial alternative will be evaluated using the nine criteria used to evaluate other remedial alternatives. All available site-specific data and information developed during the site characterization, conceptual model development, premodeling calculations, biodegradation rate calculation, ground-water modeling, model documentation, and long-term monitoring plan preparation phases of the natural attenuation investigation should be presented in a consistent and complementary manner during the Feasibility Study (FS)/ Corrective Measures Study (CMS) process. Evidence that natural aftenuation is occurring at rates sufficient to meet regulatory requirements, and to protect human health and the environment will be presented during the FS/CMS or Remedial Design/Remedial Action (RD/RA) or Corrective Remedial Action (CRA) stage of site work. A "weight-of-evidence" argument is necessary to support this remedial option. For this reason, all model assumptions should be conservative, and all available evidence in support of natural attenuation must be presented with regulatory requirements in mind.

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References

1. Wiedemeier, TH., J.T. Wilson, D.H. Kampbell, R.N. Miller, and J.E. Hansen. 1995. Technical protocol for implementing intrinsic remediation with long-term monitoring for natural attenuation of fuel contamination dissolved in groundwater. San Antonio, TX: U.S. Air Force Center for Environmental Excellence.

2. National Research Council. 1993. In-situ bioremediation: When does it work? Washington, DC: National Academy Press.

3. Bouwer, E.J., B.E. Rittman, and RL. McCarty. 1981. Anaerobic degradation of halogenated I - and 2-carbon organic compounds. Environ. Sci. Technol. 15 (5):596-599.

4. Wilson, J.T, and B.H. Wilson. 1985. Biotransformation of trichloroethylene in soil. Appl. Environ. Microbiol. 49(I):242-243.

5. Miller, R.E., and F.R Guengedch. 1982. Oxidation of trichloroethylene by liver microsomal cytochrome P-450: Evidence for chlorine migration in a transition state not involving trichloroethylene oxide. Biochemistry 21:1090-1097.

6. Nelson, M.J.K., S.O. Montgomery, E.J. O'Neille, and P.H. Pritchard. 1986. Aerobic metabolism of trichloroethylene by a bacterial isolate. Appl. Environ. Microbiol. 52 (2):949-954.

7. Bouwer, E.J., and J.P. Wright. 1988. Transformations of trace halogenated aliphatics in anoxic biofilm columns. J. Contam. Hydrol. 2:155-169.

8. Lee, M.D. 1988. Biorestoration of aquifers contaminated with organic compounds. CRC Crit. Rev. Environ. Control 18:29-89.

9. Little, C.D., A.V. Palumbo, S.E. Herbes, M.E. Lidstrom, R.L. Tyndall, and P.J. Gilmer. 1988. Trichloroethylene biodegradation by a methane-oxidizing bacterium. Appl. Environ. Microbiol. 54(4):951-956.

10. Mayer. K.R, D. Grbi-Gail, L. Semprini, and P.L. McCarty. 1988. Degradation of trichloroethylene by methanotrophic bacteria in a laboratory column of saturated aquifer material. Water Sci. Tech. 20(11/12):175-178.

11. Arciero, D., T. Vannelli, M. Logan, and A.B. Hooper. 1989. Degradation of trichloroethylene by the ammonia-oxidizing bacterium *Nitrosomonas europaea*. Biochem. Biophys. Res. Commun. 159:640-643.

12. Cline, RV., and J.J. Delfino. 1989. Transformation kinetics of 1,1,1-trichloroethane to the stable product 1,1-Dichloroethene. In: Biohazards of drinking water treatment. Chelsea, MI: Lewis Publishers.

13. Freedman, D.L., and J.M. Gossett. 1989. Biological reductive dechlorination of tetrachloroethylene and trichloroethylene tc ethylene under methanogenic conditions. Appl. Environ. Microbial. 55:2144-2151.

14. Folsom, B.R., P.J. Chapman, and P.H. Pritchard. 1990. Phenol and trichloroethylene degradation by *Pseudomonas cepacia G4:* Kinetics and interactions between substrates. Appl. Environ. Microbial. 56(5):1279-1285.

15. Harker, A.R., and Y. Kim 1990. Trichloroethylene degradation by two independent aromatic-

degrading pathways in *Alcaligenes eutrophus* JMP134. Appl. Environ. Microbial. 56(4):1179-1181.

16. Alvarez-Cohen, L.M., and P.L. McCarty. 1991. Effects of toxicity, aeration, and reductant supply on trichloroethylene transformation by a mixed methanotrophic culture. Appl. Environ. Microbial. 57(I):228-235.

17. Alvarez-Cohen, L.M., and P.L. McCarty. 1991. Product toxicity and cometabolic competitive inhibition modeling of chloroform and trichloroethylene transformation by methanotrophic resting cells. Appl. Environ. Microbial. 57(4):1031-1037.

18. DeStefano, T.D, J.M. Gossen, and SH. Zinder. 1991. Reductive dehalogenation of high concentrations of tetrachloroethene to ethene by an anaerobic enrichment culture in the absence of methanogenesis. Appl. Environ. Microbial. 57(8):2287-2292.

19. Henry, S.M. 1991. Transformation of trichloroethylene by methanotrophs from a groundwater aquifer. Ph.D. thesis. Stanford University, Palo Alto, CA.

20. McCarty, P.L., P.V. Roberts, M. Reinhard, and G. Hopkins. 1992. Movement and transformations of halogenated aliphatic compounds in natural systems. In: Schnoor, J.L., ed. Fate of pesticides and chemicals in the environment. New York, NY: John Wiley & Sons.

21. Hartmans, S., and J.A.M. de Bont 1992. Aerobic vinyl chloride metabolism in *Mycobacterium aurum* Li. Appl. Environ. Microbiol. 58(4):1220-1226.

22. McCarty, P.L., and L. Semprini. 1994. Ground-water treatment for chlorinated solvents. In: Norris, R.D., R.E. Hinchee, R. Brown, P.L. McCarty, L. Semprini, J.T Wilson, D.H. Kampbell, M. Reinhard, E.J. Bouwer, R.C. Borden, T.M. Vogel, J.M. Thomas, and C.H. Ward, eds. Handbook of bioremediation. Boca Raton, FL: Lewis Publishers.

23. Vogel, T.M. 1994. Natural bioremediation of chlorinated solvents. In: Norris, R.D., R.E. Hinchee, R. Brown, P.L. McCarty, L. Semprini, J.T. Wilson, D.H. Kampbell, M. Reinhard, E.J. Bouwer, R.C. Borden, T.M. Vogel, J.M. Thomas, and C.H. Ward. eds. Handbook of bioremediation. Boca Raton, FL: Lewis Publishers.

24. Bouwer, E.J. 1994. Bioremediation of chlorinated solvents using alternate electron acceptors. In: Norris, R.D., R.E. Hinchee, R. Brown, P.L. McCarty, L. Semprini, J.T. Wilson, D.H. Kampbell, M. Reinhard, E.J. Bouwer, R.C. Borden, T.M. Vogel, J.M. Thomas, and C.H. Ward, eds. Handbook of bioremediation. Boca Raton, FL: Lewis Publishers.

25. Vogel, T.M., and P.L. McCarty. 1985. Biotransformation of tetrachloroethylene to trichloroethylene, dichloroethylene, vinyl chloride, and carbon dioxide under methanogenic conditions. Appl. Environ. Microbiol. 49(5):1080-1083.

26. Murray, W.D., and M. Richardson. 1993. Progress toward the biological treatment of Cl and C2 halogenated hydrocarbons. Crit. Rev. Environ. Sci. Technol. 23(3):195-217.

27. Bradley, P.M., and F.H. Chapelle. 1996. Anaerobic mineralization of vinyl chloride in Fe(III)-reducing aquifer sediments. Environ. Sci. Technol. 40:2084-2086.

28. Wiedemeier, T.H., L.A. Benson, J.T. Wilson, D.H. Kampbell, J.E. Hansen, and R. Miknis. 1996. Patterns of natural attenuation of chlorinated aliphatic hydrocarbons at Plattsburgh Air Force Base, New York. Platform abstracts presented at the Conference on Intrinsic Remediation of Chlorinated Solvents, Salt Lake City, UT, April 2.

29. U.S. EPA. 1986. Test methods for evaluating solid waste, physical and chemical methods, 3rd ed.

SW-846. Washington, DC.

30. U.S. EPA. 1983. Methods for chemical analysis of water and wastes. EPA/16020-07-71. Cincinnati, OH.

31. Hach Co. 1990. Hach Company Catalog: Products for Analysis. Ames, IA.

32. American Public Health Association. 1992. Standard methods for the examination of water and wastewater, 18th ed. Washington, DC.

33. AFCEE. 1993. Handbook to support the Installation Restoration Program (IRP) remedial investigations and feasibility studies (RI/FS). U.S. Air Force Center for Environmental Excellence. September. Brooks Air Force Base, TX.

34. AFCEE. 1992. Environmental chemistry function Installation Restoration Program analytical protocols. June.

35. Kampbell, D.H., J.T. Wilson, and S.A. Vandegrift. 1989. Dissolved oxygen and methane in water by a GC headspace equilibrium technique. Int. J. Environ. Anal. Chem. 36:249-257.

36. Wiedemeier, T.H., M.A. Swanson, J.T Wilson, D.H. Kampbell, R.N. Miller, and J.E. Hansen. 1996. Approximation of biodegradation rate constants for monoaromatic hydrocarbons (BTEX) in groundwater. Ground Water Monitoring and Remediation. In press.

37. Wiedemeier, T.H., M.A. Swanson, D.E. Moutoux, J.T. Wilson, D.H. Kampbell, J.E. Hansen. P. Haas, and F.H. Chapelle. 1996. Technical protocol for natural attenuation of chlorinated solvents in groundwater. San Antonio, TX: U.S. Air Force Center for Environmental Excellence. In preparation.

38. Domenico, RA. 1987. An analytical model for multidimensional transport of a decaying contaminant species. J. Hydrol. 91:49-58.

39. Domenico, P.A., and F.W. Schwartz. 1990. Physical and chemical hydrogeology New York. NY: John Wiley and Sons.

40. Morel, F.M.M., and J.G. Hering. 1993. Principles and applications of aquatic chemistry. New York, NY: John Wiley & Sons.

41. Willey, L.M., Y.K. Kharaka, T.S. Presser, J.B. Rapp, and 1. Barnes.1975. Short chain aliphatic acid anions in oil field waters and their contribution to the measured alkalinity. Geochim. Cosmochim. Acta 39:1707-1711.

42. Lovley, D.R., and S. Goodwin. 1988. Hydrogen concentrations as an indicator of the predominant terminal electron-accepting reaction in aquatic sediments. Geochim. Cosmochim. Acta 52:2993-3003.

43. Lovley, D.R., F.H. Chapelle, and J.C. Woodward. 1994. Use of dissolved H_2 concentrations to determine distribution of microbially catalyzed redox reactions in anoxic groundwater. Environ. Sci. Technol. 28(7):1205-1210.

44. Chapelle, F.H., P.B. McMahon, N.M. Dubrovsky, R.F. Fujii, E.T. Oaksford, and D.A. Vroblesky. 1995. Deducing the distribution of terminal electron-accepting processes in hydrologically diverse groundwater systems. Water Resour. Res. 31:359-371.

45. Hem, J.D. 1985. Study and interpretation of the chemical characteristics of natural water. U.S. Geological Survey Water Supply Paper 2254.

46. Kaufman, W.J., and G.T Orlob. 1956. Measuring ground water movement with radioactive and chemical tracers. Am. Water Works Assn. J. 48:559-572.

47. Buscheck, T.E.G., and C.M. Alcantar. 1995. Regression techniques and analytical solutions to demonstrate intrinsic bioremediation. In: Proceedings of the 1995 Battelle International Conference on In-Situ and On Site Bioreclamation. April.

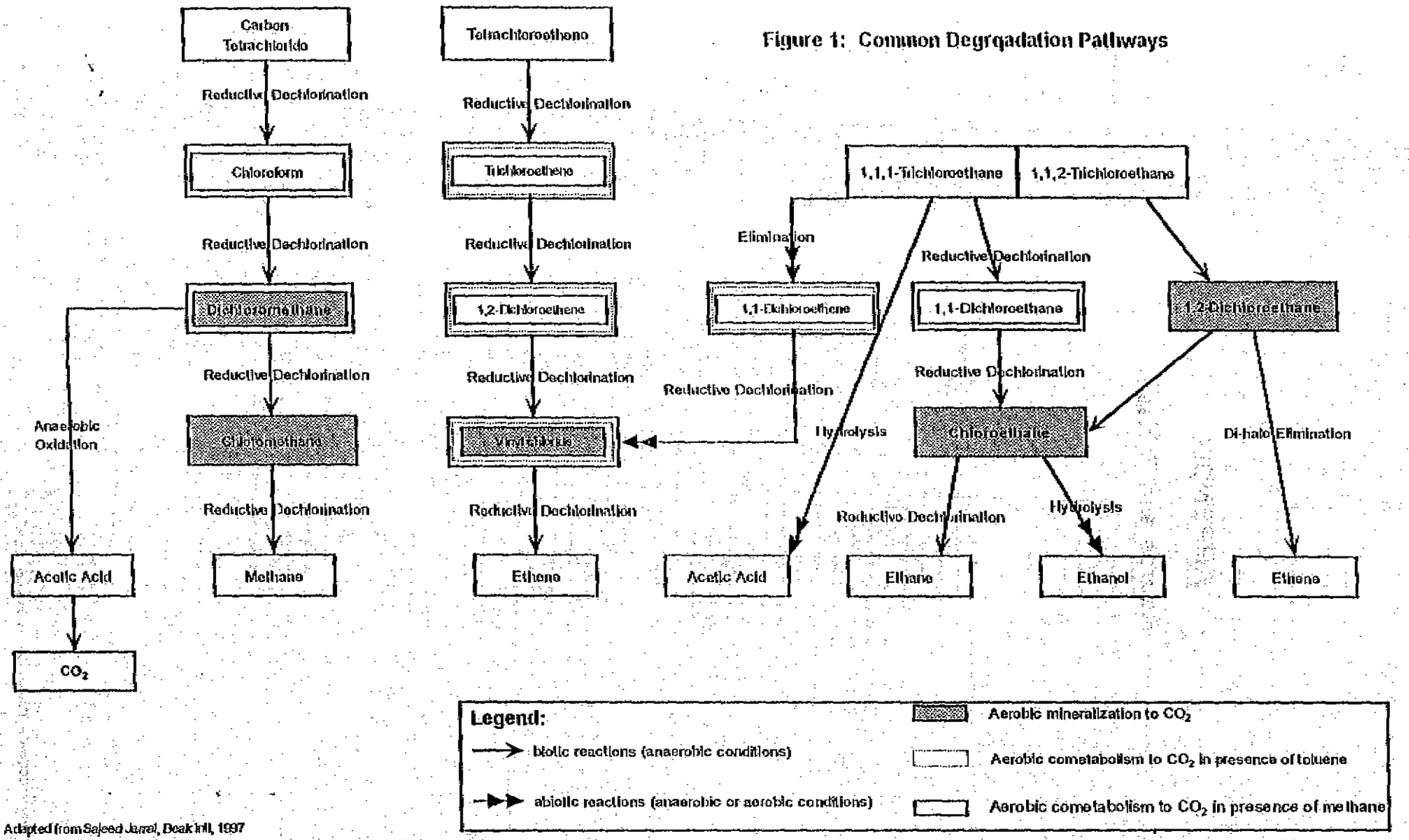
48. Bear, J. 1979. Hydraulics of groundwater. New York, NYMcGraw-Hill.

49. Rice, D.W., R.D. Grose, J.C. Michaelsen, B.P. Dooher, D.H. MacQueen, S.J. Cullen, W.E. Kastenberg, L.G. Everett, and M.A. Marino. 1995. California leaking underground fuel tank (LUFT)historical case analyses. California State Water Resources Control Board.

APPENDIX

Figures and Tables

Figure 1: Common Degrqadation Pathways



Adapted from *Saleed Jamal*, Beak Intl, 1997

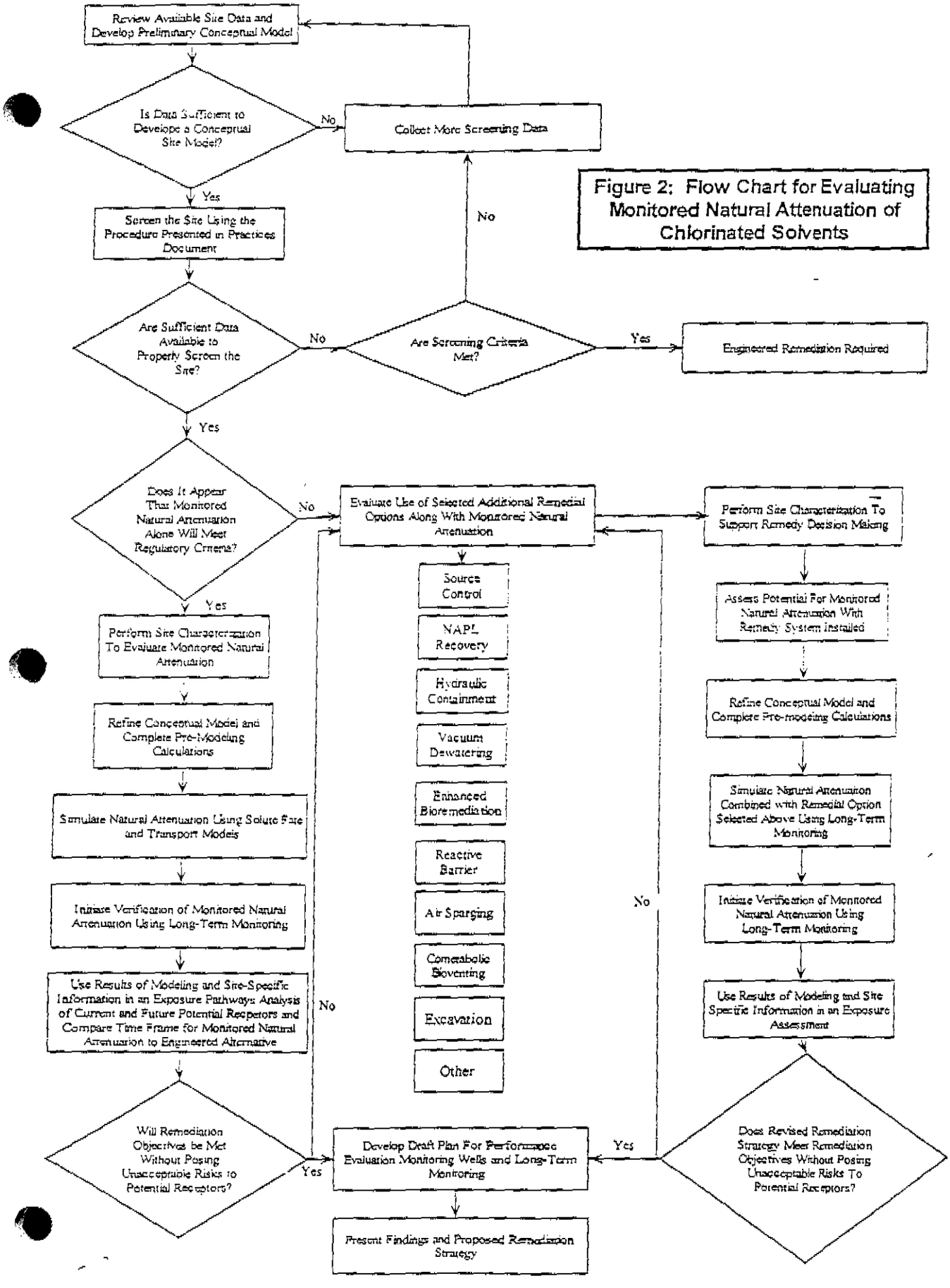


Figure 2: Flow Chart for Evaluating Monitored Natural Attenuation of Chlorinated Solvents

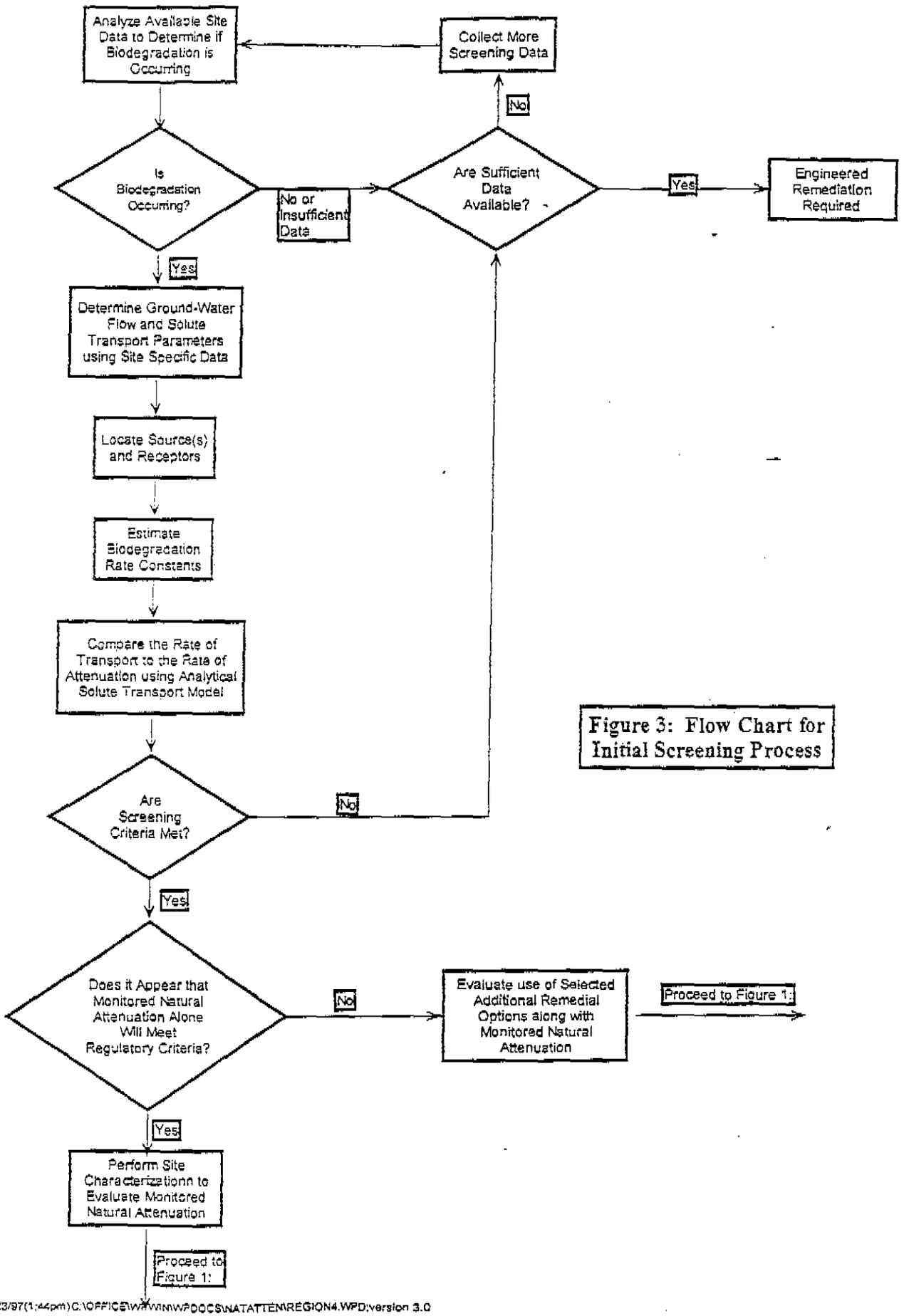


Figure 3: Flow Chart for Initial Screening Process

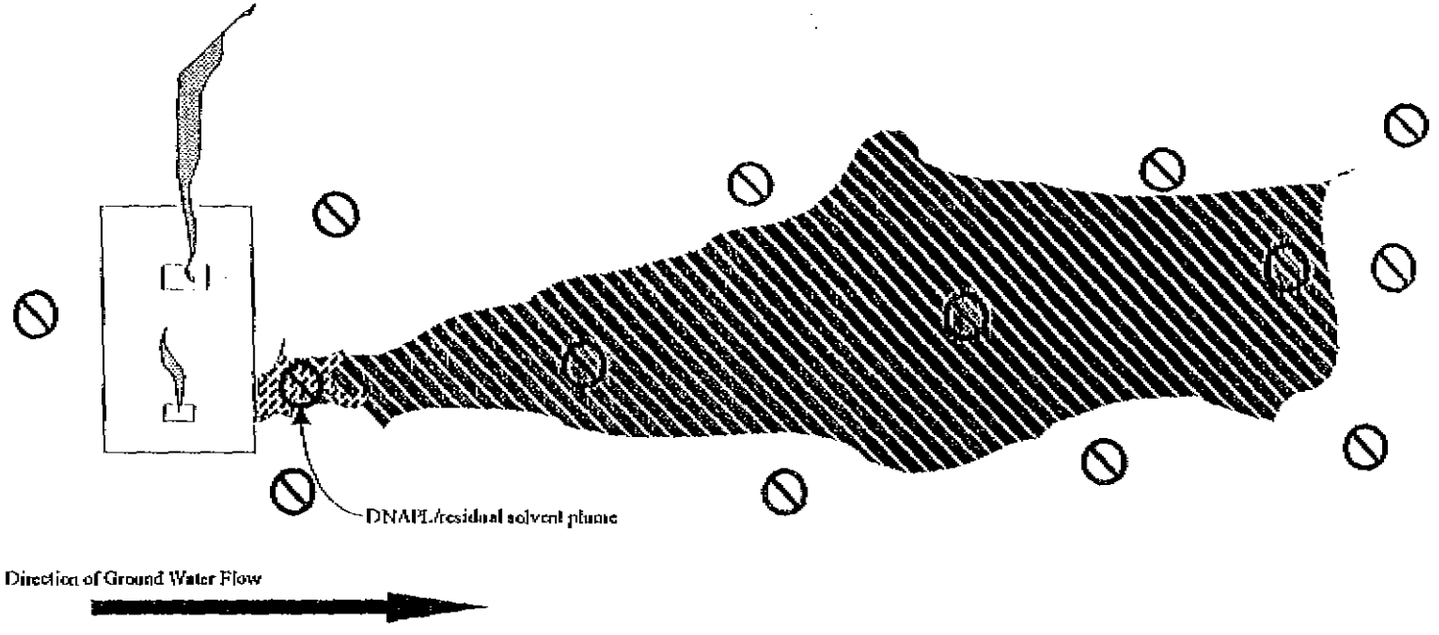
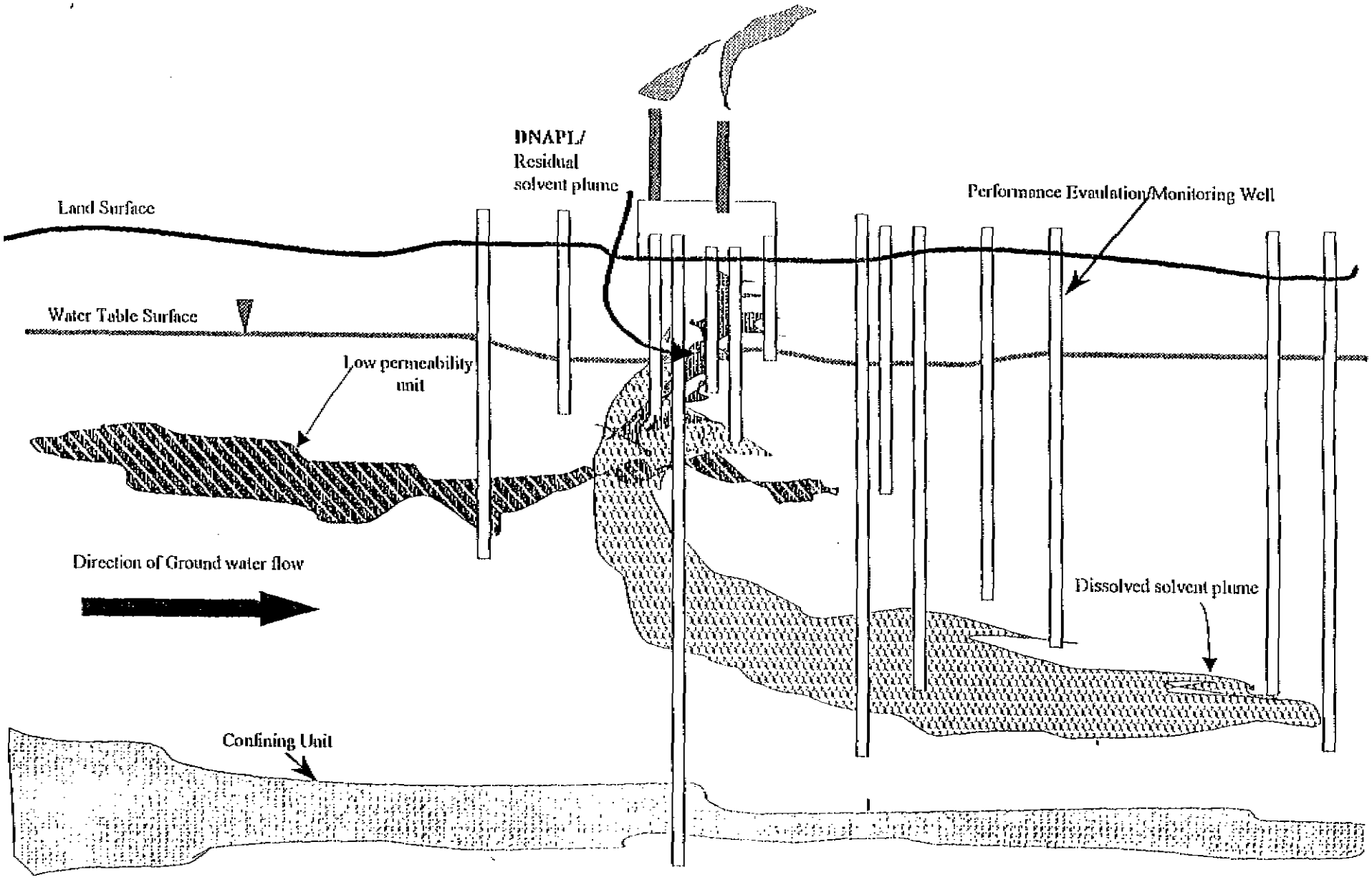


Figure 4A: Plan View of Generic Schematic for Monitoring/Performance evaluation well locations

Monitoring/Performance Evaluation locations

Note: In some instances more wells will be required; In most instances nested wells will be necessary



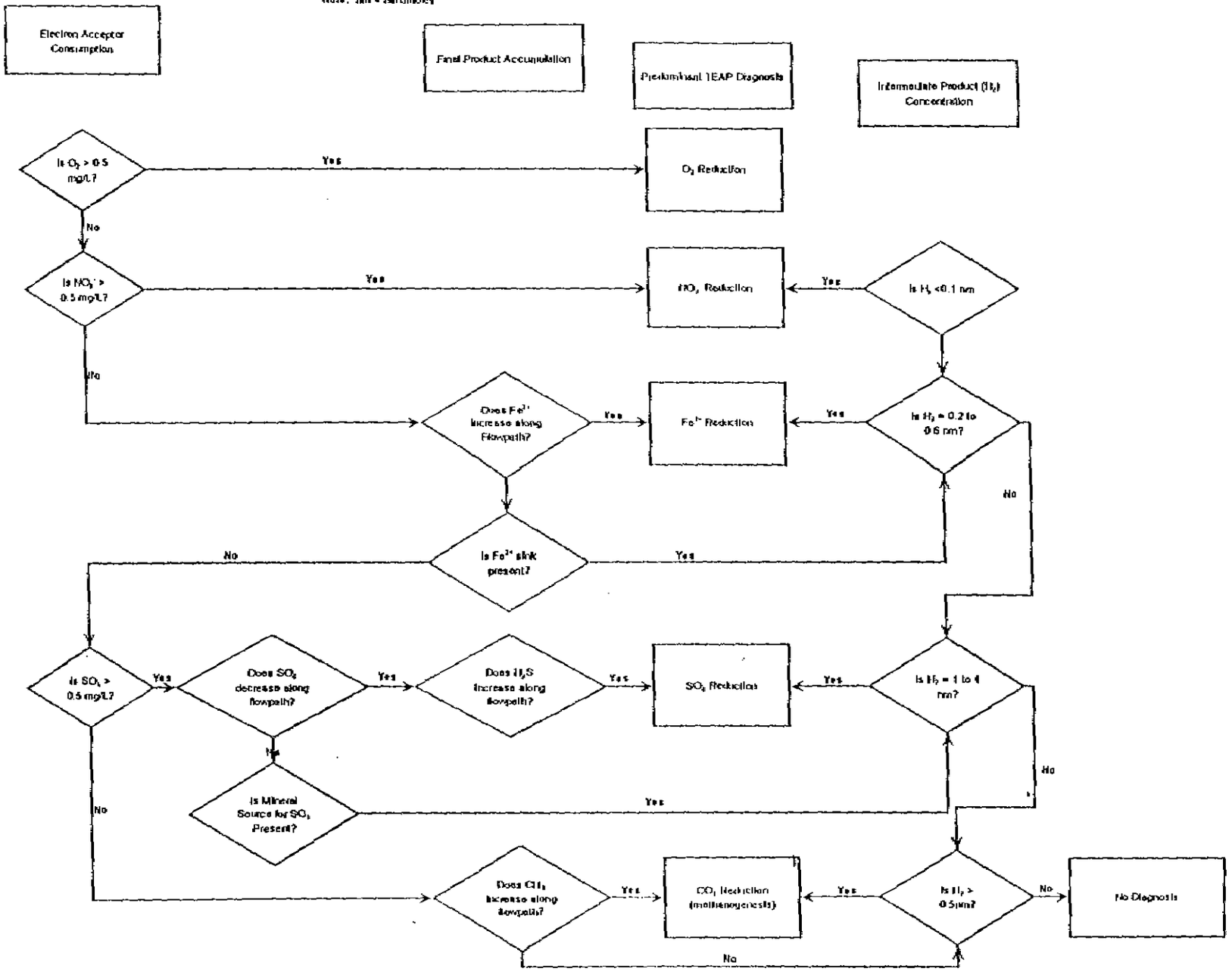
Note: In some areas of the plume more wells will be necessary; in most instances nested wells will

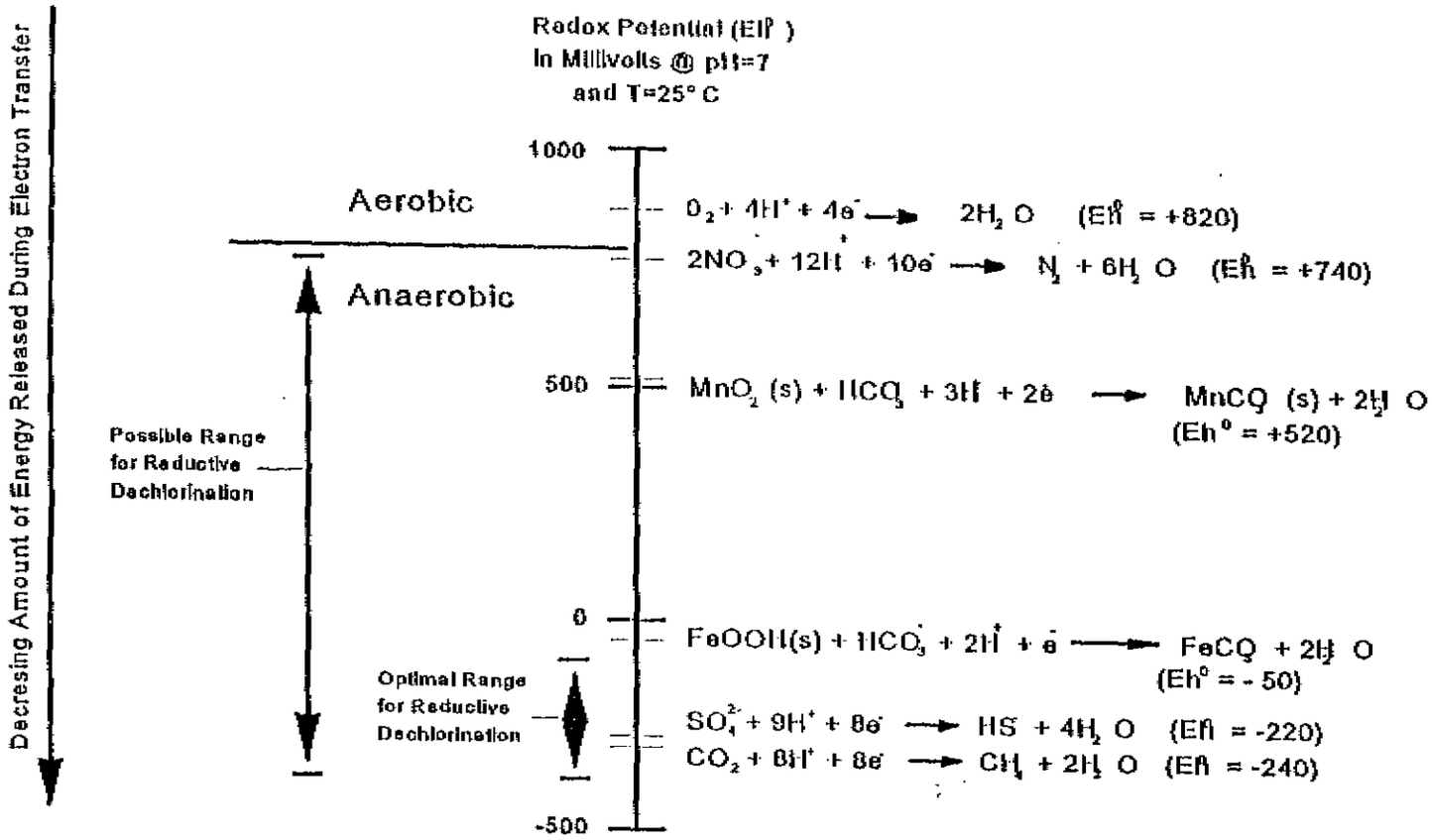
Figure 4B: A Generic Schematic of monitoring well/performance evaluation well placement

Figure 5: Hierarchical Scheme For Diagnosis c[illegible]inal Electron-Accepting Processes[1] (TEAPs)

[1]Taken from: "Deducing the Distribution of Terminal Electro[illegible]ing Processes In Hydrologically Diverse Groundwater Systems" Chapelle, [illegible] WRR, vol. 31, no. 2, pages 359-371, February 1995.

Note: nm = nanomoles





Modified From Bouwer (1994)

Figure 8. Redox potential for various electron acceptors.

Table 1A. Soil and Ground-Water Analytical Methods[a]

All monitoring well installation, well development, well purging, sampling, sample handling and sample analysis where recommended will be performed in accordance with the May 1996 Region 4 ESD *Environmental Investigations Standard Operating Procedures and Quality Assurance Manual* (ESD EISOP-QAM available from *ftp://www.epa.gov/pub/r4ftp/sesd*)

Matrix	Analysis	Method/ Reference[b-e]	Comments[f-g]	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Contain, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Volatile Organic Compounds	SW8250A	Handbook method modified for field extraction of soil using methanol	Useful for determining the extent of soil contamination, the contaminant mass present and the need for source removal	Each soil sampling round	Sample volume approximately 100 mL; subsample and extract in the field using methanol or appropriate solvent; cool to 4° C	Fixed-base
Soil	Total Organic Carbon (TOC)	SW9060, modified for soil samples	Procedure must be accurate over the range of 0.1 to 5% TOC	The amount of TOC in the aquifer matrix influences contaminant migration and biodegradation	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4° C	Fixed-base
Soil gas	Methane, O_2, CO_2	Field soil gas analyzer		useful for determining the bioactivity in the vadose zone	At initial sampling and respiration testing	Reusable 3-L Tedlar bags	Field
Soil gas	Fuel and chlorinated volatile organic compounds	EPA Method TO -14		Useful for determining the distribution of chlorinated and BTEX compounds in soil	At initial sampling	1-L Summa canister	Fixed-base
Water	Aromatic and chlorinated hydrocarbons (BTEX), trimethylbenzene isomers, chlorinated compounds	SW8260A	Handbook method; analysis may be extended to higher molecular-weight alkyl benzenes	Method of analysis for BTEX and chlorinated solvents/byproducts which are the primary target analytes for monitoring biological degradation; method can be extended to higher molecular weight alkylbenzenes; trimethylbenzenes are used to monitor plume dilution if degradation is primarily anaerobic.	Each sampling round	Collect water samples in a 40-mL volatile organic analysis vial; cool to 4° C; add hydrochloric acid to pH2	Fixed-base
Water	Polycyclic aromatic hydro-carbons (PAHs) (intended for diesel and/or and other heavy oils)	Gas chroma-tography Method SW8270B; high performance liquid chromo-tography Method SW8310	Analysis needed only when required for regulatory compliance	PAHs are components of fuel and are typically analyzed for regulatory compliance	As required by regulations	Collect 1 L of water in a glass container; cool to 4° C	Fixed-base
Water	Oxygen	DO meter (Note: DO meter should be calibrated between each well using the two point method)	Refer to Method A4500 for a comparable laboratory procedure.	Concentrations less than 1 mg/l generally indicate anaerobic pathway	Each sampling round	Measure DO on site using a flowthrough cell. A DO meter calibration is necessary and the flowthrough cell should be observed to make sure degassing is occurring, if so apparatus adjustment will be necessary.	Field

Table 1A.: Soil and Ground-Water Analytical Methods[a] (continued)

Matrix	Analysis	Method/ Reference[b-e]	Comments[f-g]	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Contain, Sample Preservation	Field or Fixed Laboratory
Water	Nitrate	IC method E-300	Method E300 is a Handbook Method	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect 40 mL of water in a glass or plastic container; add H_2SO_4 to pH < 2, keep cool	Field
Water	Iron(II) (Fe^{+2})	Colorimetric HACH Method 8146	Filter if turbid	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese	Each sampling round	Collect 100 mL of water in a headspace free container to eliminate introduction of oxygen and analyze as soon as possible	Field
Water	Sulfate (SO_4^{-2})	Ion Chromotograpy Method E300 or HACH Method 8051	Method E300 is a Handbook method; do not use the field method if this method is used.	Substrate for anaerobic microbial respiration	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4° C	Fixed-base
Water	Sulfate (SO_4^{-2})	HACH Method 8051	HACH Method 8051 is a colorometric method, use one or the other consistently	Substrate for anaerobic microbial respiration	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4° C	Field
Water	Methane, ethane and ethene	Kampbell et al, 1989 (35) or SW3810, modified	Method published by EPA researchers. Limited to few commercial labs.	The presence of CH_4 suggests biodegradation of organic carbon via methanogensis; ethane and ethene are produced during reductive dechlorination and the data is used where chlorinated solvents are suspected of undergoing biological transformation.	Each sampling round	Collect water samples in 50 mL glass serum bottles with butyl gray/Teflon-lined caps; add H^2SO^4 to pH < 2; cool to 4° C	Fixed-base
Water	Alkalinity	HACH alkalinity test kit Model AL AP MG-L	Phenolphthalein Method	Water quality parameter used (1)to measure the buffering capacity of ground water; (2) as a marker to verify that all site samples are obtained from the same groundwater system	Each sampling round	Collect 100 mL of water in glass container	Field
Water	Oxidation-reduction potential	A2580B	Measurements made with electrodes; results are displayed on a meter; protect samples from exposure to oxygen; report results against a silver/silver chloride reference electrode	The oxidation-reduction potential of ground water influences and is influenced by the nature of the biologically mediated degradation of contaminants; The oxidation-reduction potential of ground water may range from more than 800 mV to < -400 mV	Each sampling round	Collect 100 to 250 mL of water in a glass container, fulling container from bottom; analyze immediately	Field
Water	pH	Field probe with direct reading meter	Field	Aerobic and anaerobic processes are pH sensitive	Each sampling round	Collect 100 to 250 mL of water in a glass or plastic container analyze immediately	Field
Water	Temperature	Field probe with direct reading meter	Field only	Well development	Each sampling round	not applicable	Field

Table 1A.: Soil and Ground-Water Analytical Methods[a] (continued)

Matrix	Analysis	Method/ Reference[b-e]	Comments[f-g]	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Contain, Sample Preservation	Field or Fixed-Base Laboratory
Water	Conductivity	E120.1/ SW9050 direct reading meter	Protocols/ Handbook Methods	Water Quality parameter used as a marker to verify that the samples are obtained from the same ground-water system	Each sampling round	Collect 100 to 250 mL of water in a glass or plastic container	Field
Water	Major Cations	SW6010	Protocols/ Handbook Methods	Can be used to evaluate other remedial actions	Each sampling round	Collect 100 to 250 mL of water in a glass or plastic container	Field
Water	Chloride	IC Method E300	Method SW9050 may also be used	General water qulaity parameter used as a marker to verify that site samples are obtained from the same groundwater system. Final product of chlorinated solvent reduction.	Each sampling round	Collect 250 mL of water in a glass container	Fixed-base
Water	Chloride (optional, see data use)	Hach Chloride test kit Model 8-P	Silver Nitrate titration	As above, and to guide selecting of additional data points in real time while in the field	Each Sampling round	Collect 100 mL of water in a glass container	Field
Water	Total Organic carbon	SW9060	Laboratory	Used to classify plume and to determine if cometabolism is possible in the absence of anthropogenic carbon	Each sampling round	Collect 100 mL of water in a glass container, cool	Laboratory

[a] Analyses other than those listed in this table may be required for evaluation of biological degradation processes.
[b] "SW" refers to the *Test methods for Evaluating Solid Waste, Physical, and chemical Methods* (29)
[c] "E" refers to *Methods for Chemical Analysis of Water and Wastes* (30).
[d] "HACH" refers to the Hach Company catalog (31).
[e] "A" refers to *Standard Methods for the Examinantion of Water and Wastewater* (32).
[f] "Handbook" refers to the AFCEE *Handbook to Support the Installation Restoration Program Analytical Protocols* (34)
[g] "Protocols" refers to the AFCEE

NOTE: All monitoring well installation, well development, well purging, sampling, sample handling and sample analysis where recommended will be performed in accordance with the May 1996 Region 4 ESD *Environmental Investigations Standard Operating Procedures and Quality Assurance Manual* (ESD EISOP-QAM)

Table 1B: Soil and Ground-Water Analytical Protocol: Special Analyses Under Development and/or Considerdation[a,b]

Matrix	Analysis	Method/ Reference[b-c]	Comments[b-c]	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Contain, Sample Preservation	Field[a] or Fixed-Base Laboratory
Soil	Biologically available iron(III)	Under development	HCl extraction followed by quantification of released iron(III)	Optional method that should be used when fule hydrocarbons or vinyl chloride are present in the groundwater to predict the possible extent of removal of fule hydrocarbons and vinyl chloride via iron reduction.	One sampling round or as determined by site conditions	Collect minimum 1-inch diameter core samples into a plastic liner; cap and prevent aeration	Laboratory
Water	Hydrogen (H2)	Equilibration with gas in the field; determined with a reducing gas detector	Specialized analysis	To determine terminal electron accepting process; predicts the possibility for reductive dechlorination	At least one sampling round or as determined by site conditions	Sampling at well head requires the production of 100 mL per minute of water for 30 minutes	Field
Water	Nutritional quality of native organic matter	Under development	Spectro-photometric method	To determine the extent of reductive dechlorination allowed by the supply of electron donor	One round of sampling	Collect 1000 mL in an amber glass	Laboratory
Water	Oxygenates (including methyl-tert-butyl ether, ethers, acetic acid, methanol, and acetone)	SW8260/8015[c]	Laboratory	Contaminant or electron donors for dechlorination of solvents	At least one sampling round or as determined by regulators	Collect L of water in a glass container; preserve with HCl	Laboratory

[a] analyses other than those listed in this table may be required for regulatory compliance
[b] Site characterization should not be delayed if these methods are unavailable
[c] "SW" refers to the *Test methods for Evaluating Solid Waste, Physical, and chemical Methods* (29)

NOTE: EPA Region 4 is currently working on preparing a Protocol for sampling and analysis of certain field parameters for which their are no Standardized SOP's

Table 2: Analytical Parameters and Weighting for Preliminary Screening

Analyte	Concentration in Most Contaminated zone	Interpretation	Points Awarded
Oxygen*	< 0.5 mg/L	Tolerated; suppresses reductive dechlorination at higher concentrations	3
Oxygen*	> 1 mg/L	Vinyl chloride may be oxidized aerobically, but reductive dechlorination will not occur	-3
Nitrate*	< 1 mg/L	At higher concentrations may compete with reductive pathway at higher concentrations	2
Iron (II)*	> 1 mg/L	Reductive pathway possible; vinyl chloride may be oxidized under Fe(III)-reducing conditions	3
Sulfate*	< 20 mg/L	At higher concentrations may compete with reductive pathway	2
Sulfide*	> 1 mg/L	Reductive pathway possible	3
Methane*	<0.5 mg/L	vinyl chloride oxidizes	0
Methane*	> 0.5 mg/L	Ultimate reductive daughter product, vinyl chloride accumulates	3
Oxidation reduction potential* (ORP)	< 50 mV <-100 mV	Reductive pathway possible Reductive pathway likely	+ 2
pH*	5 < pH < 9 5 > pH> 9	Optimal range for reductive pathway Outside optimal range for reductive pathway	0 -2
TOC (total organic carbon)	> 20 mg/L	Carbon and energy source; drives dechlorination; can be natural or anthropogenic	2
T[illegible]ature	> 20°C	At T > 20°C, biochemical process is accelerated	1
[illegible]on Dioxide*	> 2 times background	Ultimate oxidative daughter product	1
Alkalinity	> 2 times background	Results from interaction of carbon dioxide with aquifer minerals	1
Chloride*	> 2 times background	Daughter product of organic chlorine	2
Hydrogen	> 1 nM	Reductive pathway possible; vinyl chloride may accumulate	3
Hydrogen	< 1 nm	Vinyl chloride oxidized	0
Volatile fatty acids	> 0.1 mg/L	Intermediates resulting from biodegradation of aromatic compounds; carbon and energy source	2
BTEX*	> 0.1 mg/L	Carbon and energy source; drives dechlorination	2
Perchloroethene		Material Released	0
Trichloroethene*		Material released Daughter product of perchloroethene	0 2*
Dichloroethene*		Material released or daughter product of trichloroethene Daughter product of trichloroethene if amount of cis-12-dichloroethene is greater than 80% of total dichloroethene, it is likely a daughter product of trichloroethene; 1,1-DCE can be chemical reaction product of TCA	0 2*
Vinyl chloride*		Material released Daughter product of dichloroethene	0 2*
Ethene/Ethane	> 0.01 mg/L > 0.1 mg/L	Daughter product of vinyl chloride/ethene	2 3
Di[illegible]thane		Daughter product of trichloroethene	2
[illegible]ethane*		Daughter product of vinyl chloride under reducing conditions	2

Analyte	Concentration in Most Contaminated zone	Interpretation	Points Awarded
1,1,1-Trichloroethane[a]		Material Released	0
Chloroform		Material Released Daughter product of Carbon Tetrachloride	0 2
Carbon Tetrachloride		Material Released	0
Dichloromethane		Material Released Daughter product of chloroform	0 2

[a] Required Analysis
[b] Points awarded only if it can be shown that the compound is a daughter product (i.e., not a constituent of the source NAPL).

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.4*

Alcatel
Bedrock dce
Run Name

Data Input Instructions:
115 — *1. Enter value directly... or*
2. Calculate by filling in grey cells below. (To restore formulas, hit button below).
0.02

Variable*	*Data used directly in model.*
20	*Value calculated by model. (Don't enter any data).*

1. HYDROGEOLOGY

Seepage Velocity*	Vs	931.2	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	2.5E-03	(cm/sec)
Hydraulic Gradient	i	0.018	(ft/ft)
Porosity	n	0.05	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	24.5	(ft)
Transverse Dispersivity*	alpha y	2.4	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	1000	(ft)

3. ADSORPTION

Retardation Factor*	R	1.0	(-)
or		↑ or	
Soil Bulk Density	rho	2.7	(Kg/l)
Partition Coefficient	Koc	65	(L/kg)
FractionOrganicCarbon	foc	1.0E-5	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	6.9E-1	(per yr)
or		↑ or	
Solute Half-Life	t-half	1.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO	4.4	(mg/L)
Delta Nitrate*	NO3	7.5	(mg/L)
Observed Ferrous Iron*	Fe2+	16.6	(mg/L)
Delta Sulfate*	SO4	8	(mg/L)
Observed Methane*	CH4	7.2	(mg/L)

5. GENERAL

Modeled Area Length*	1500	(ft)
Modeled Area Width*	500	(ft)
Simulation Time*	20	(yr)

6. SOURCE DATA

Source Thickness in Sat Zone* 70 (ft)

Vertical Plane Source. Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3.

Source Zones:

Width* (ft)	Conc. (mg/L)*
50	0.01
50	0.1
50	0.81
50	0.1
50	0.01

Source Halflife (see Help):

10	700	(yr)
Inst. React. (y/n)	1st Order	
Soluble Mass	5000	(Kg)
In Source NAPL Soil		

View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)	.81			.23			.22	.073			
Dist. from Source (ft)	0	150	300	450	600	750	900	1050	1200	1350	1500

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

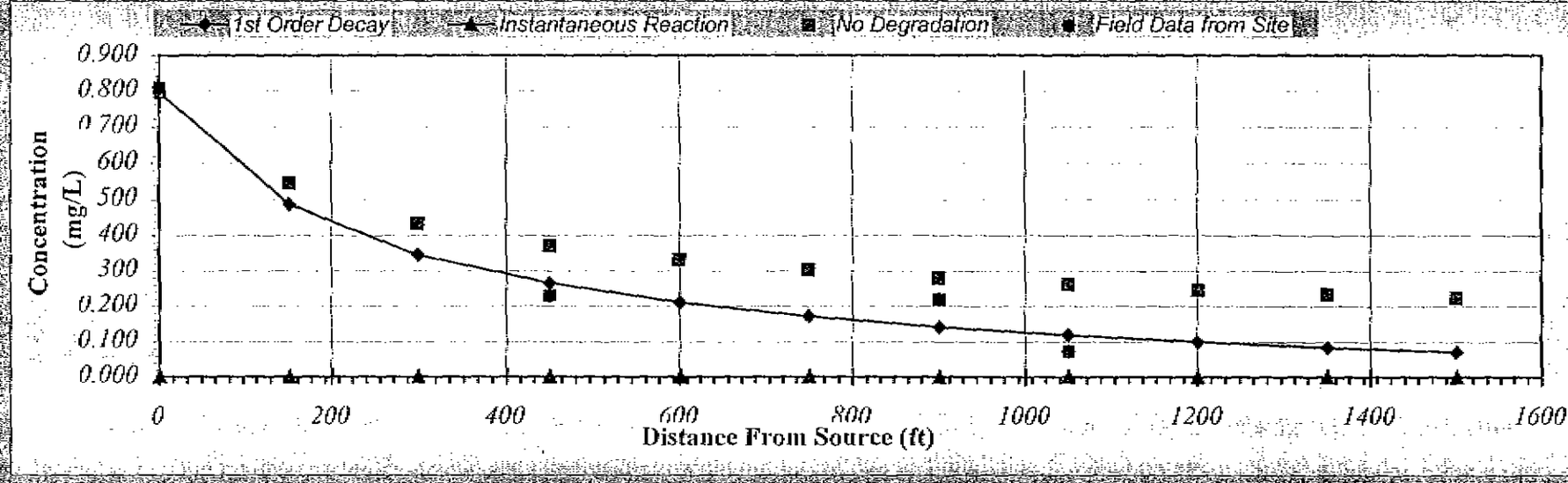
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft)										
	0	150	300	450	600	750	900	1050	1200	1350	1500
No Degradation	0.795	0.546	0.432	0.371	0.331	0.302	0.279	0.261	0.247	0.234	0.223
1st Order Decay	0.795	0.488	0.344	0.264	0.210	0.171	0.141	0.118	0.099	0.084	0.072
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site	0.810			0.230			0.220	0.073			



Calculate Animation

Time:
20 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — Version 1.4

Alcatel
shallow dce
Run Name

Data Input Instructions:
1. Enter value directly ... or
2. Calculate by filling in grey cells below. (To restore formulas, hit button below)

115 ft or 0.62

Variable* — Data used directly in model
20 — Value calculated by model (Don't enter any data)

1. HYDROGEOLOGY

Seepage Velocity*	Vs	352.3	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	6.0E-03	(cm/sec)
Hydraulic Gradient	i	0.021	(ft/ft)
Porosity	n	0.37	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	24.5	(ft)
Transverse Dispersivity*	alpha y	2.4	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	1000	(ft)

3. ADSORPTION

Retardation Factor*	R	1.0	(-)
or		↑ or	
Soil Bulk Density	rho	1.7	(kg/l)
Partition Coefficient	Koc	65	(L/kg)
FractionOrganicCarbon	foc	1.0E-1	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	8.7E-1	(per yr)
or		↑ or	
Solute Half-Life	t Half	0.80	(year)

or Instantaneous Reaction Model

Delta Oxygen*	DO	4.4	(mg/L)
Delta Nitrate*	NO3	7.5	(mg/L)
Observed Ferrous Iron*	Fe2+	16.6	(mg/L)
Delta Sulfate*	SO4	8	(mg/L)
Observed Methane*	CH4	7.2	(mg/L)

5. GENERAL

Modeled Area Length*	1000	(ft)
Modeled Area Width*	200	(ft)
Simulation Time*	20	(yr)

6. SOURCE DATA

Source Thickness in Sat Zone* 45 (ft)

Source Zones:

Width* (ft)	Conc. (mg/L)*
50	0.1
50	0.5
50	2.6
50	0.5
50	0.1

Source Halflife (see Help):

9	200	(yr)

Inst. React. (y/n) 1st Order

Soluble Mass 8000 (Kg)

In Source NAPL, Soil

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3

View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)	2.6				.434					.0	
Dist. from Source (ft)	0	100	200	300	400	500	600	700	800	900	1000

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

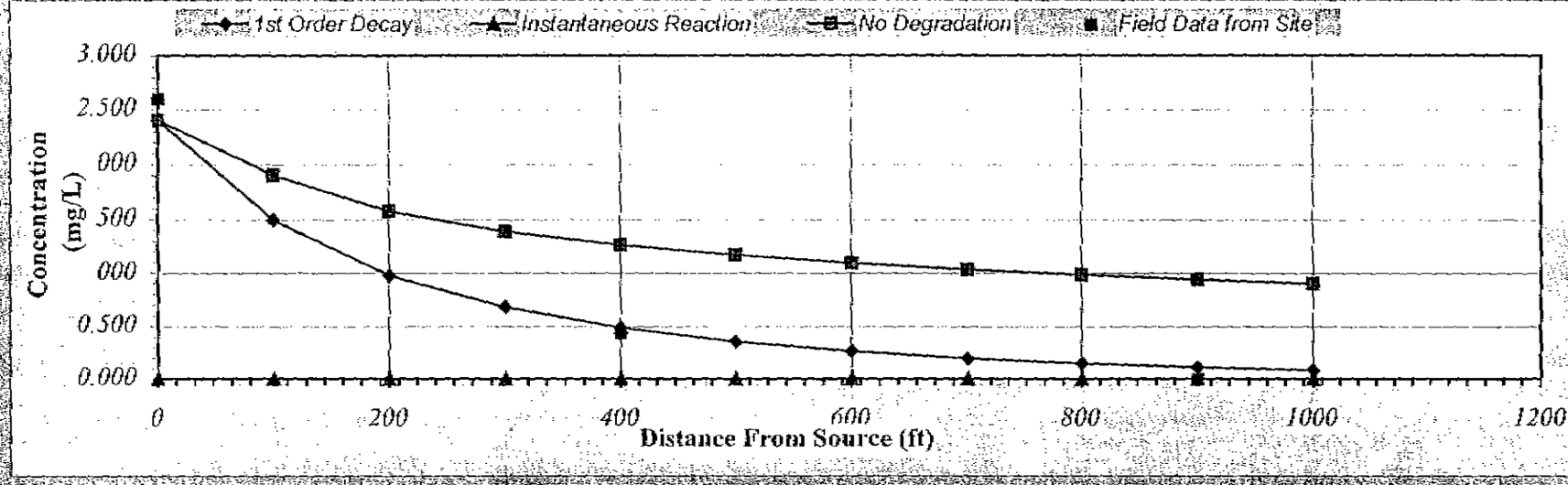
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	2.403	1.903	1.577	1.391	1.264	1.170	1.096	1.035	0.984	0.940	0.902
1st Order Decay	2.403	1.498	0.977	0.679	0.486	0.354	0.261	0.194	0.145	0.109	0.083
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site	2.600				0.434					0.000	



Calculate Animation

Time: 20 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — Version 1.4

Alcatel
shallow dce
Run Name

Data Input Instructions:

115 — 1. Enter value directly ... or
or — 2. Calculate by filling in grey
0.02 — cells below. (To restore formulas, hit button below)

Variable* — Data used directly in model
20 — Value calculated by model (Don't enter any data)

1. HYDROGEOLOGY

Seepage Velocity*	Vs	352.3	(ft/yr)
or		or	
Hydraulic Conductivity	K	6.0E-03	(cm/sec)
Hydraulic Gradient	i	0.021	(ft/ft)
Porosity	n	0.37	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	24.5	(ft)
Transverse Dispersivity*	alpha y	2.4	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	1000	(ft)

3. ADSORPTION

Retardation Factor*	R	1.0	(-)
or		or	
Soil Bulk Density	rho	1.7	(kg/l)
Partition Coefficient	Koc	65	(L/kg)
FractionOrganicCarbon	foc	1.0E-4	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	1.2E+0	(per yr)
or		or	
Solute Half-Life	t-half	0.60	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO	4.4	(mg/L)
Delta Nitrate*	NO3	7.5	(mg/L)
Observed Ferrous Iron*	Fe2+	16.6	(mg/L)
Delta Sulfate*	SO4	8	(mg/L)
Observed Methane*	CH4	7.2	(mg/L)

5. GENERAL

Modeled Area Length*	1000	(ft)
Modeled Area Width*	200	(ft)
Simulation Time*	20	(yr)

6. SOURCE DATA

Source Thickness In Sat Zone* 45 (ft)

Source Zones:

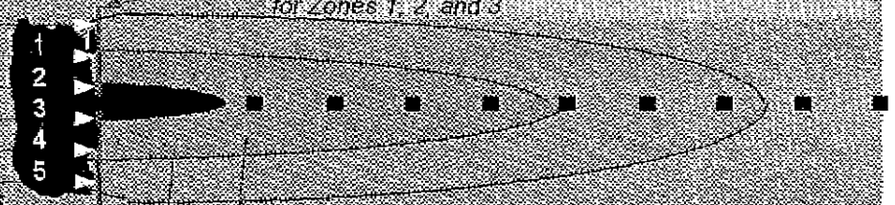
	Width (ft)	Conc. (mg/L)*
1	50	0.1
2	50	0.5
3	50	2.6
4	50	0.5
5	50	0.1

Source Halflife (see Help): 10 | 200 (yr)

Inst. React. | 1st Order

Soluble Mass In Source NAPL Soil: 10000 (Kg)

Vertical Plane Source. Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

7. FIELD DATA FOR COMPARISON

Observed Centerline Concentrations at Monitoring Wells If No Data Leave Blank or Enter "0"

Distance (ft)	Concentration (mg/L)
0	2.6
100	
200	
300	
400	.434
500	
600	
700	
800	
900	.0
1000	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

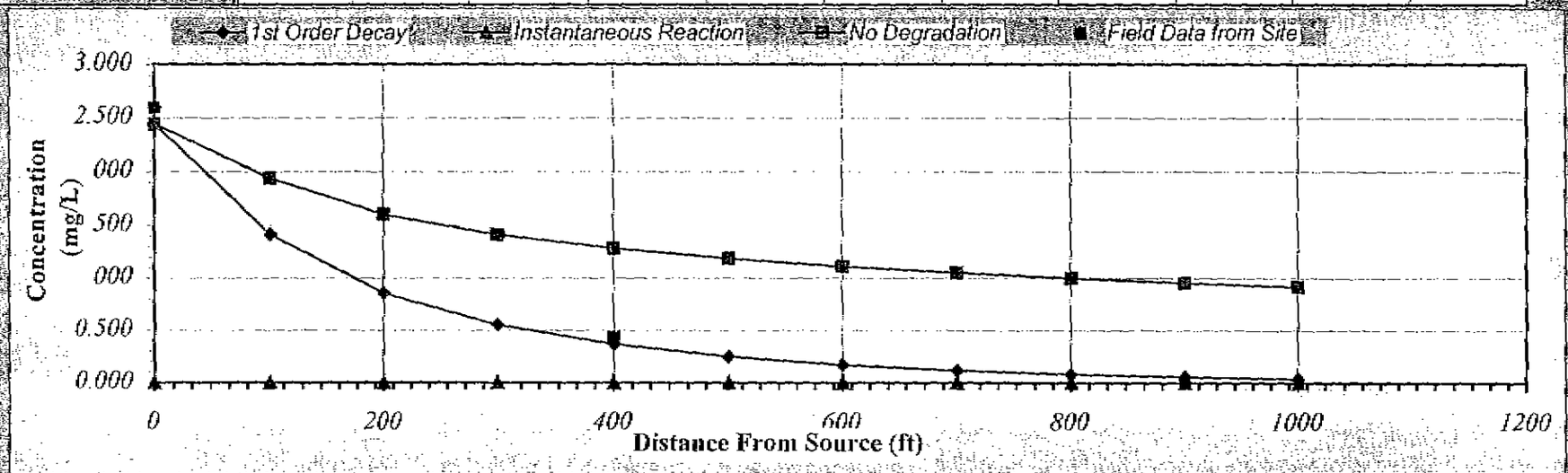
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	2.441	1.933	1.601	1.412	1.283	1.187	1.112	1.050	0.998	0.953	0.915
1st Order Decay	2.441	1.413	0.855	0.551	0.366	0.248	0.169	0.117	0.081	0.057	0.040
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site	2.600				0.434					0.000	



Calculate Animation

Time: 20 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — Version 1.4

Alcatel
Bedrock pce
Run Name

Data Input Instructions:
115 — 1. Enter value directly ... or
Vs or 2. Calculate by filling in gray
0.02 cells below. (To restore
formulas, hit button below)
Variable* — Data used directly in model
20 — Value calculated by model
(Don't enter any data)

1. HYDROGEOLOGY

Seepage Velocity*	Vs	931.2	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	2.5E-03	(cm/sec)
Hydraulic Gradient	I	0.018	(ft/ft)
Porosity	n	0.05	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	24.5	(ft)
Transverse Dispersivity*	alpha y	2.4	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	1000	(ft)

3. ADSORPTION

Retardation Factor*	R	1.2	(-)
or		↑ or	
Soil Bulk Density	rho	2.7	(kg/l)
Partition Coefficient	Koc	364	(L/kg)
FractionOrganicCarbon	foc	1.9E-5	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	1.2E+0	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.60	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO	4.4	(mg/L)
Delta Nitrate*	NO3	7.5	(mg/L)
Observed Ferrous Iron*	Fe2+	16.6	(mg/L)
Delta Sulfate*	SO4	8	(mg/L)
Observed Methane*	CH4	7.2	(mg/L)

5. GENERAL

Modeled Area Length*	1500	(ft)
Modeled Area Width*	500	(ft)
Simulation Time*	20	(yr)

6. SOURCE DATA

Source Thickness in Sat Zone* 70 (ft)

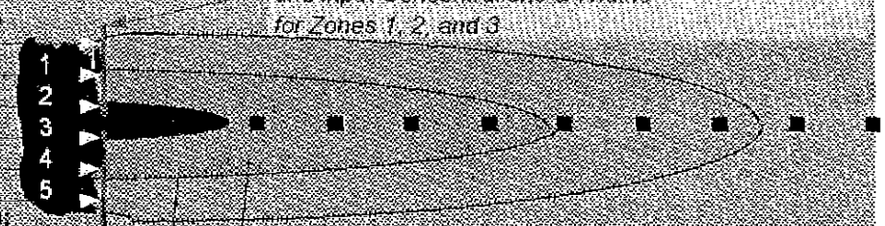
Source Zones:

Width* (ft)	Conc. (mg/L)*
50	0.01
50	0.1
50	0.729
50	0.1
50	0.01

Source Halflife (see Help):

6	500	(yr)
Inst. React.	1st Order	
Soluble Mass In Source NAPL, Soil	3000	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations of Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)	.729			.24			.081	.017			
Dist. from Source (ft)	0	150	300	450	600	750	900	1050	1200	1350	1500

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

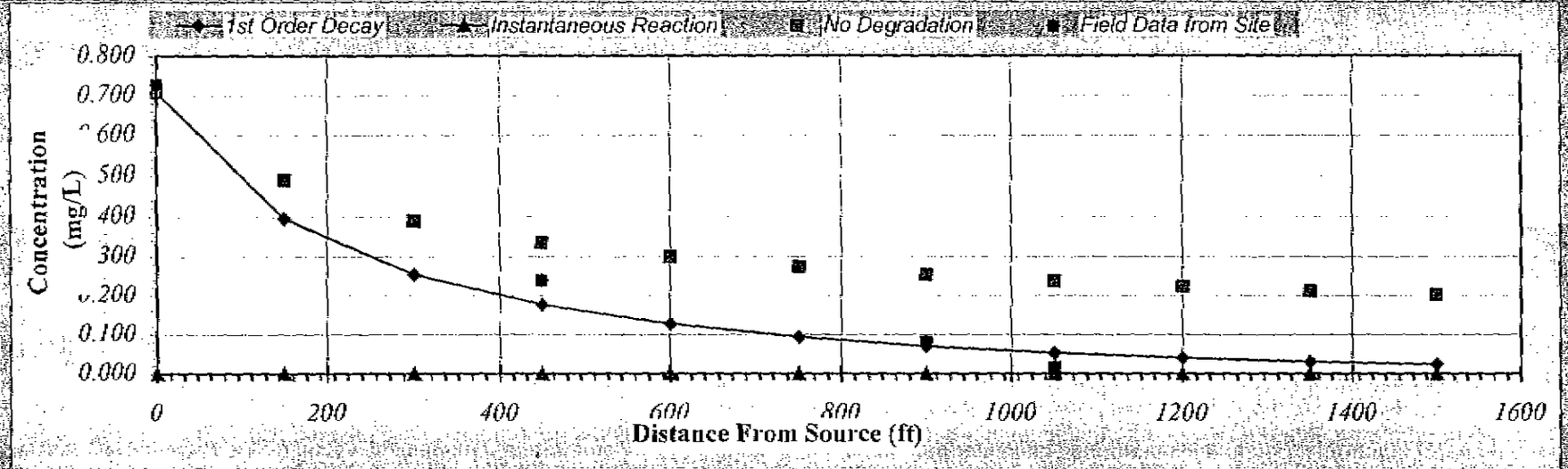
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L) (Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	150	300	450	600	750	900	1050	1200	1350	1500
No Degradation	0.708	0.490	0.390	0.336	0.300	0.274	0.254	0.238	0.224	0.213	0.203
1st Order Decay	0.708	0.395	0.253	0.176	0.127	0.093	0.070	0.053	0.040	0.031	0.024
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site	0.729			0.240			0.081	0.017			



Calculate Animation

Time: 20 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.4*

Alcatel
shallow pce
Run Name

Data Input Instructions:

115 — 1. Enter value directly ... or
↑ or
0.02 — 2. Calculate by filling in grey cells below. (To restore formulas, hit button below)

Variable* — Data used directly in model
20 — Value calculated by model (Don't enter any data)

1. HYDROGEOLOGY

Seepage Velocity*	Vs	352.3	(ft/yr)
or		↑ or	
Hydraulic Conductivity	k	6.0E-03	(cm/sec)
Hydraulic Gradient	i	0.021	(ft/ft)
Porosity	n	0.37	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	24.5	(ft)
Transverse Dispersivity*	alpha y	2.4	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	1000	(ft)

3. ADSORPTION

Retardation Factor*	R	1.2	(-)
or		↑ or	
Soil Bulk Density	rho	1.7	(kg/l)
Partition Coefficient	Koc	364	(L/kg)
FractionOrganicCarbon	foc	1.0E-4	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	9.9E-1	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.70	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO	4.4	(mg/L)
Delta Nitrate*	NO3	7.5	(mg/L)
Observed Ferrous Iron*	Fe2+	16.6	(mg/L)
Delta Sulfate*	SO4	8	(mg/L)
Observed Methane*	CH4	7.2	(mg/L)

5. GENERAL

Modeled Area Length*	1000	(ft)
Modeled Area Width*	200	(ft)
Simulation Time*	20	(yr)

6. SOURCE DATA

Source Thickness In Sat Zone* 45 (ft)

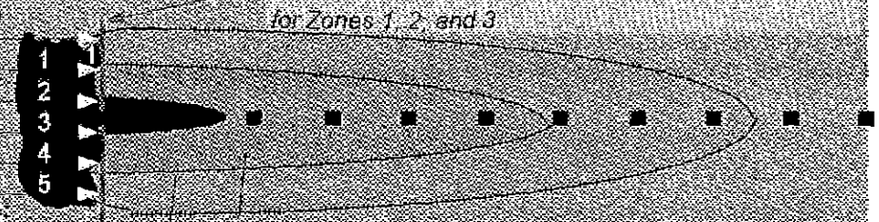
Source Zones:

Width* (ft)	Conc. (mg/L)*
50	0.01
50	0.05
50	0.242
50	0.05
50	0.01

Source Halflife (see Help):

1	200	(yr)
Inst. React.	1st Order	
Soluble Mass	1000	(Kg)
In Source NAPL, Soil		

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Distance (ft)	Concentration (mg/L)
0	.242
100	
200	
300	
400	.054
500	
600	
700	
800	
900	.0
1000	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

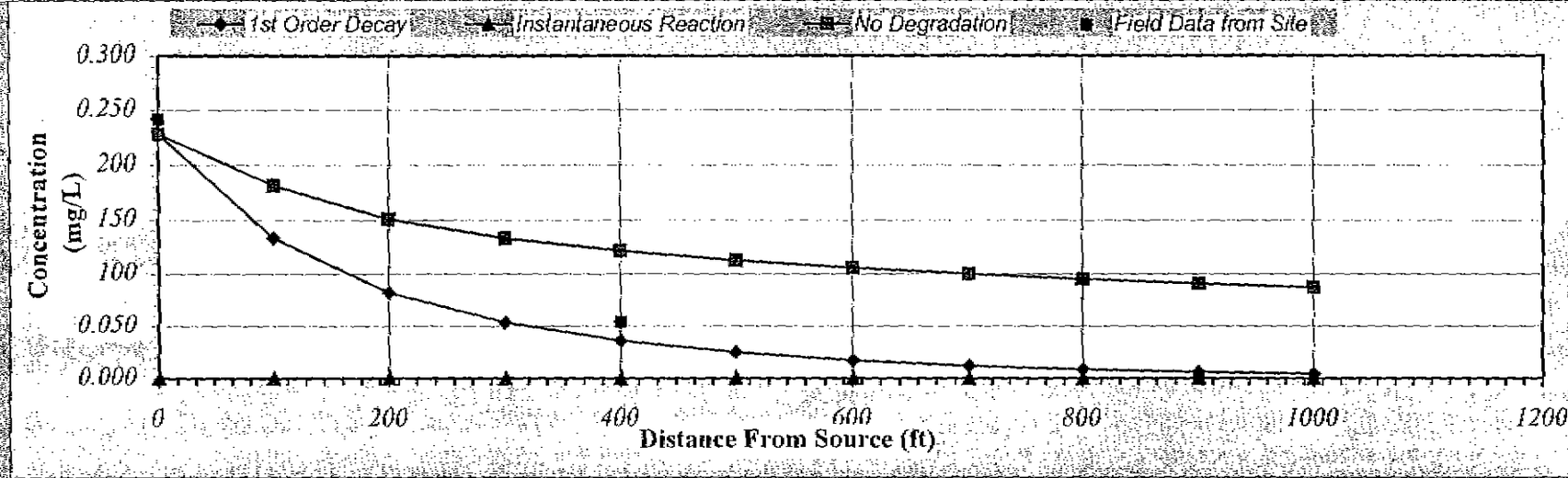
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.228	0.181	0.151	0.133	0.121	0.113	0.105	0.100	0.095	0.091	0.087
1st Order Decay	0.228	0.134	0.082	0.053	0.036	0.024	0.017	0.012	0.008	0.006	0.004
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site	0.242				0.054					0.000	



Calculate Animation

Time: 20 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.4*

Alcatel
bedrock TCA
Run Name

Data Input Instructions:

115 — 1. Enter value directly, or
1/0 or 0.02 — 2. Calculate by filling in grey cells below. (To restore formulas, hit button below).
Variable* — Data used directly in model
20 — Value calculated by model. (Don't enter any data)

1. HYDROGEOLOGY

Seepage Velocity*	Vs	931.2	(ft/yr)
or		1/0 or	
Hydraulic Conductivity	K	2.5E-03	(cm/sec)
Hydraulic Gradient	I	0.016	(ft/ft)
Porosity	n	0.05	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	24.5	(ft)
Transverse Dispersivity*	alpha y	2.4	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		1/0 or	
Estimated Plume Length	Lp	1000	(ft)

3. ADSORPTION

Retardation Factor*	R	1.1	(-)
or		1/0 or	
Soil Bulk Density	rho	2.7	(kg/l)
Partition Coefficient	Koc	152	(L/kg)
FractionOrganicCarbon	foc	1.0E-5	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	6.9E+0	(per yr)
or		1/0 or	
Solute Half-Life	t-half	0.10	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO	4.4	(mg/L)
Delta Nitrate*	NO3	7.5	(mg/L)
Observed Ferrous Iron*	Fe2+	16.6	(mg/L)
Delta Sulfate*	SO4	8	(mg/L)
Observed Methane*	CH4	7.2	(mg/L)

5. GENERAL

Modeled Area Length*	1000	(ft)
Modeled Area Width*	200	(ft)
Simulation Time*	20	(yr)

6. SOURCE DATA

Source Thickness in Sat.Zone* 70 (ft)

Source Zones:

	Width* (ft)	Conc. (mg/L)*
1	50	0.1
2	50	1
3	50	16
4	50	1
5	50	0.1

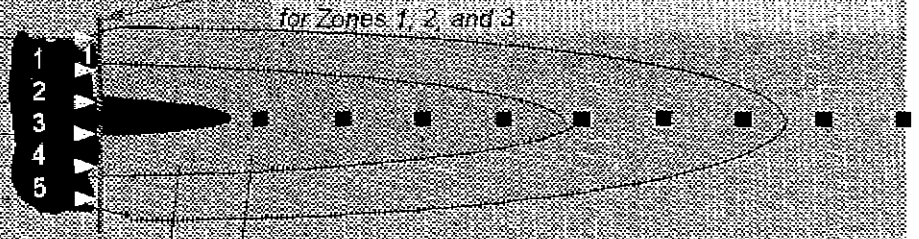
Source Halflife (see Help): 200 | 800 (yr)

Inst. React. (1/0): 1st Order

Soluble Mass 100000 (Kg)

In Source NAPL, Soil

Vertical Plane Source. Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	16.0
100	
200	
300	
400	.13
500	
600	
700	
800	
900	.037
1000	.003

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

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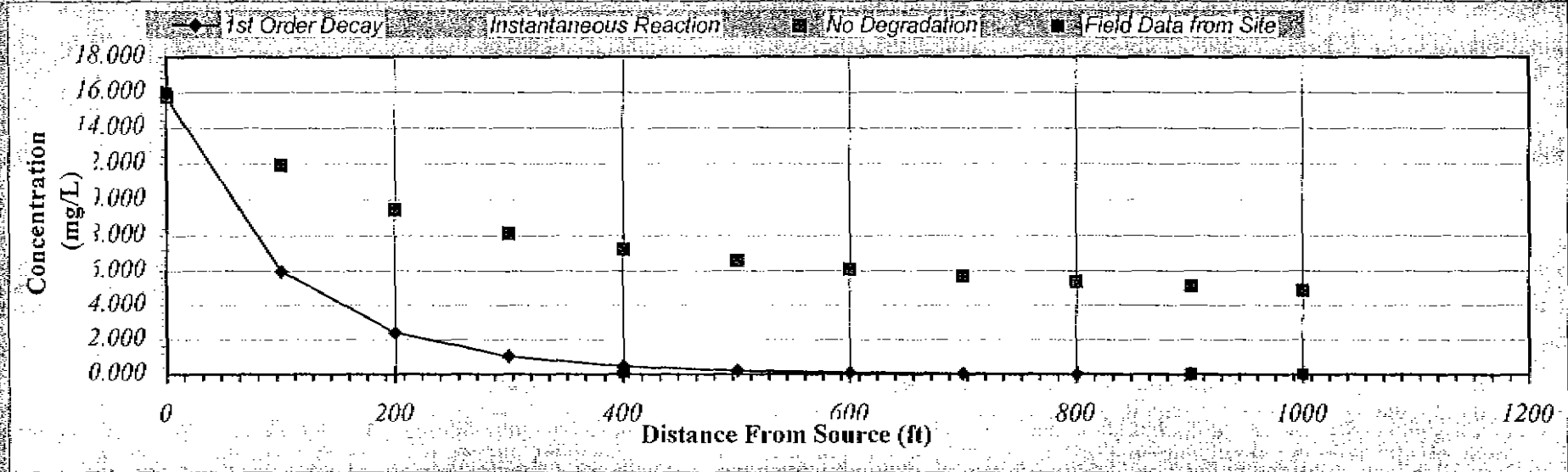
Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	15.734	11.920	9.461	8.106	7.217	6.573	6.079	5.684	5.357	5.082	4.846
1st Order Decay	15.734	5.984	2.385	1.026	0.458	0.210	0.097	0.046	0.022	0.010	0.005
Inst. Reaction	13.584	10.029	7.738	6.463	5.589	4.901	4.316	3.794	3.319	2.880	2.471
Field Data from Site	16.000				0.130					0.037	0.003



Calculate Animation

Time: 20 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.4*

Alcatel
shallow TCA
Run Name

Data Input Instructions:
115 — 1. Enter value directly ... or
or — 2. Calculate by filling in grey
0.02 — cells below. (To restore formulas, hit button below).
Variable* — Data used directly in model.
20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	352.3	(ft/yr)
or		or	
Hydraulic Conductivity	K	5.0E-03	(cm/sec)
Hydraulic Gradient	I	0.021	(ft/ft)
Porosity	n	0.37	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	24.5	(ft)
Transverse Dispersivity*	alpha y	2.4	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	1000	(ft)

3. ADSORPTION

Retardation Factor*	R	1.1	(-)
or		or	
Soil Bulk Density	rho	1.7	(kg/l)
Partition Coefficient	Koc	152	(L/kg)
FractionOrganicCarbon	foc	1.0E-4	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	1.4E+0	(per yr)
or		or	
Solute Half-Life	t half	0.50	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO	4.4	(mg/L)
Delta Nitrate*	NO3	7.5	(mg/L)
Observed Ferrous Iron*	Fe2+	16.6	(mg/L)
Delta Sulfate*	SO4	8	(mg/L)
Observed Methane*	CH4	7.2	(mg/L)

5. GENERAL

Modeled Area Length*	1000	(ft)
Modeled Area Width*	200	(ft)
Simulation Time*	20	(yr)

6. SOURCE DATA

Source Thickness in Sat Zone* 45 (ft)

Source Zones:

Width* (ft)	Conc. (mg/L)*
50	0.01
50	0.1
50	0.562
50	0.1
50	0.01

Source Halflife (see Help):

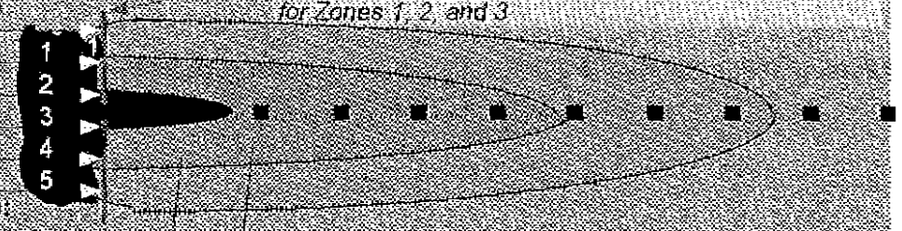
3	300	(yr)

Inst. React. or 1st Order

Soluble Mass 3000 (Kg)

In Source NAPL Soil

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells. If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Distance from Source (ft)	Concentration (mg/L)
0	.562
100	
200	
300	
400	.008
500	
600	
700	
800	
900	.0
1000	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

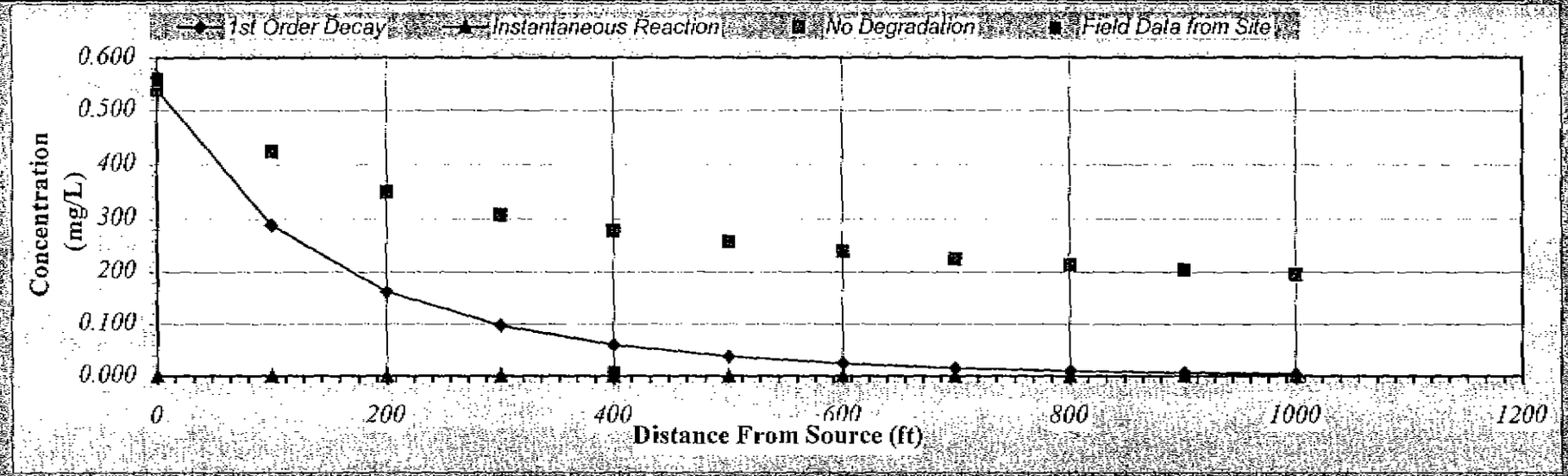
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.538	0.424	0.349	0.307	0.278	0.256	0.239	0.226	0.214	0.204	0.195
1st Order Decay	0.538	0.289	0.162	0.097	0.060	0.037	0.024	0.015	0.010	0.006	0.004
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site	0.562				0.008					0.000	



Calculate Animation

Time:
20 Years

Return to Input

Recalculate This Sheet

Calculated Contaminant Velocity

conductivity	17	7
porosity	0	0.05
gradient	0	0.018

R = 1 +(KOC*FOC*BD)/n
Velocity of contaminant = gw velocity/R
gw velocity = ki/n

gw velocity	(ft/day)
1,1,1-TCA	
shallow =	0.90188
deep =	2.328848
PCE	
shallow =	0.826619
deep =	2.106037
DCE	
shallow =	0.936885
deep =	2.434547

Calculated Contaminant Velocity

conductivity	17	7
porosity	0	0.05
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gw velocity	(ft/day)
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deep =	2.328848
PCE	
shallow =	0.826619
deep =	2.106037
DCE	
shallow =	0.936885
deep =	2.434547

Corrected concentration
for PCE from MW-2d to MW-15d(1,180 ft)
120.4166667

Ci/Co=e**kt

kt = ln(Ci/Co) 1.957606
k = 1.96/t
gw velocity =
deep = 2.106037 t= 561 k=.0035

Corrected concentration
for PCE from MW-13s to MW-9sk(800ft)
1.446428571

kt = ln(Ci/Co) 1.064711
k = 1.07/t
shallow = 0.826619 t =968 k= .001

Corrected concentration
for 1,1,1-TCA from MW-14d to MW-15d(1,160 ft)
7.75557047

gw velocity =
deep = 2.328848 t=504

kt = ln(Ci/Co) 0.929363
k = .929/t
k=0.002

Corrected concentration
for 1,1,1-TCA from MW-13s to MW-9sk(800ft)
1.446428571

kt = ln(Ci/Co) 1.064711
k = 1.07/t k=.002
shallow = 0.90188 t=889

Corrected concentration
for 1,1-DCE from MW-14d to MW-15d(1,160ft)
186.7459732

kt = ln(Ci/Co) 0.94165
k=.94/t
deep = 2.434547 t=477 k=.002

Corrected concentration
for 1,1-DCE from MW-13s to MW-9sk(800ft)
1.446428571

kt = ln(Ci/Co) 1.064711
k = 1.07/t
shallow = 0.936885 t=853 k=.001

APPENDIX H
EVIDENCE OF THE FORMER SOLID WASTE DISPOSAL SITE

INVENTORY OF SOLID WASTE

DISPOSAL SITES

MAP (CHRONOLOGICAL) NUMBER: 8

LOCATION: East of Weld Wake Forest Road between Six Forks Road and Crabtree Creek. (Plate 8)

DATES OF USAGE: 1961-62

SURFACE AREA: Approximately 45 acres

VOLUME: Approximately one million cubic yards

TYPES OF WASTE: Household, commercial, industrial, demolition, land clearing, etc.

METHOD OF OPERATION: Excauation of existing soil and filling of low swampy areas.

OWNER: (PAST) York Industrial Center

(PRESENT) Pepsi-Cola Bottling Company, Motor Bearing and Parts, Marguerite J. Thompson and others

GENERAL INFORMATION: Site was excaumted and filled up to 15 feet of depth. Area is now used for several businesses including restaurants, car dealerships, soft drink bottling company and others.

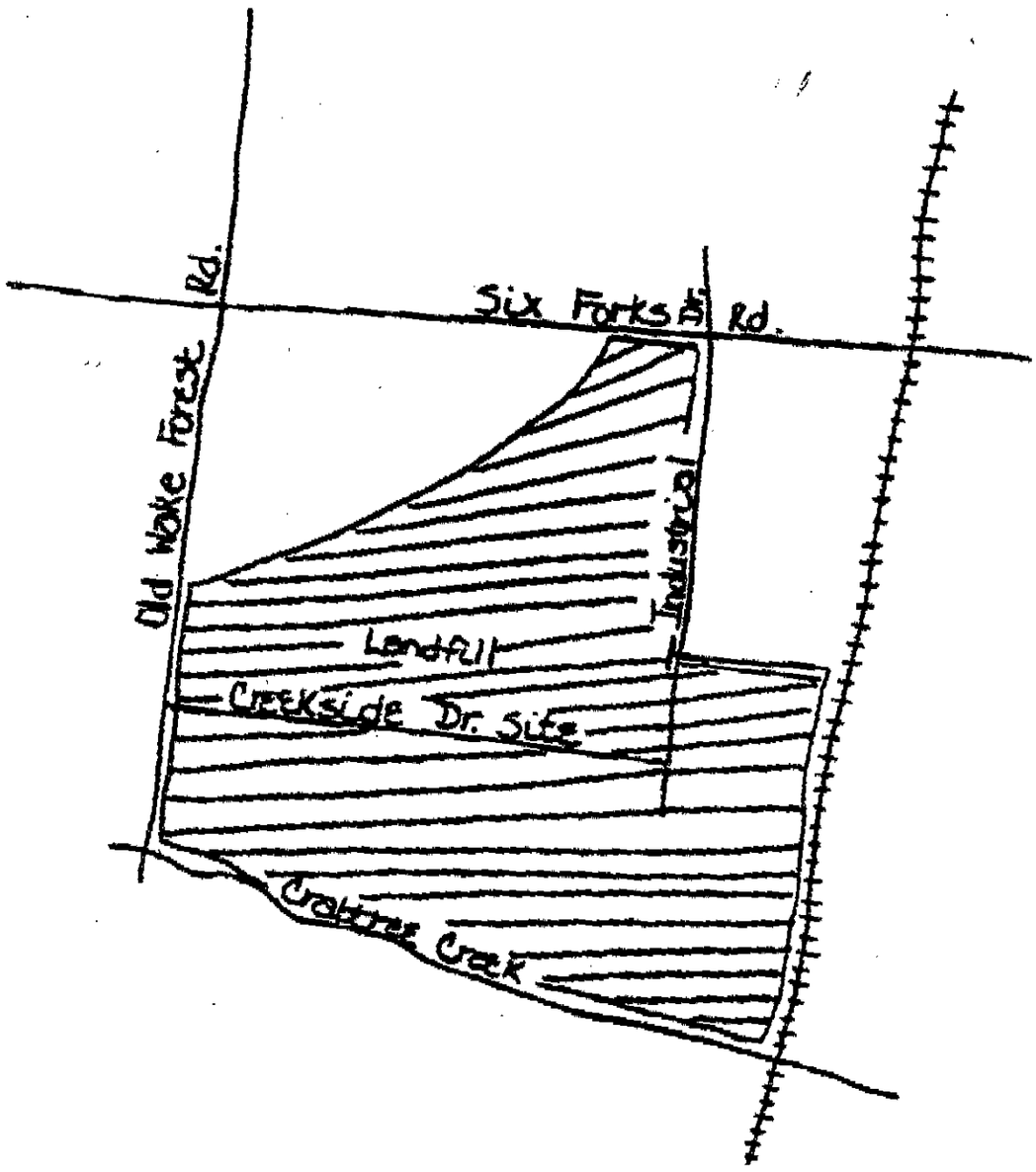

Plate 8

Not To Scale

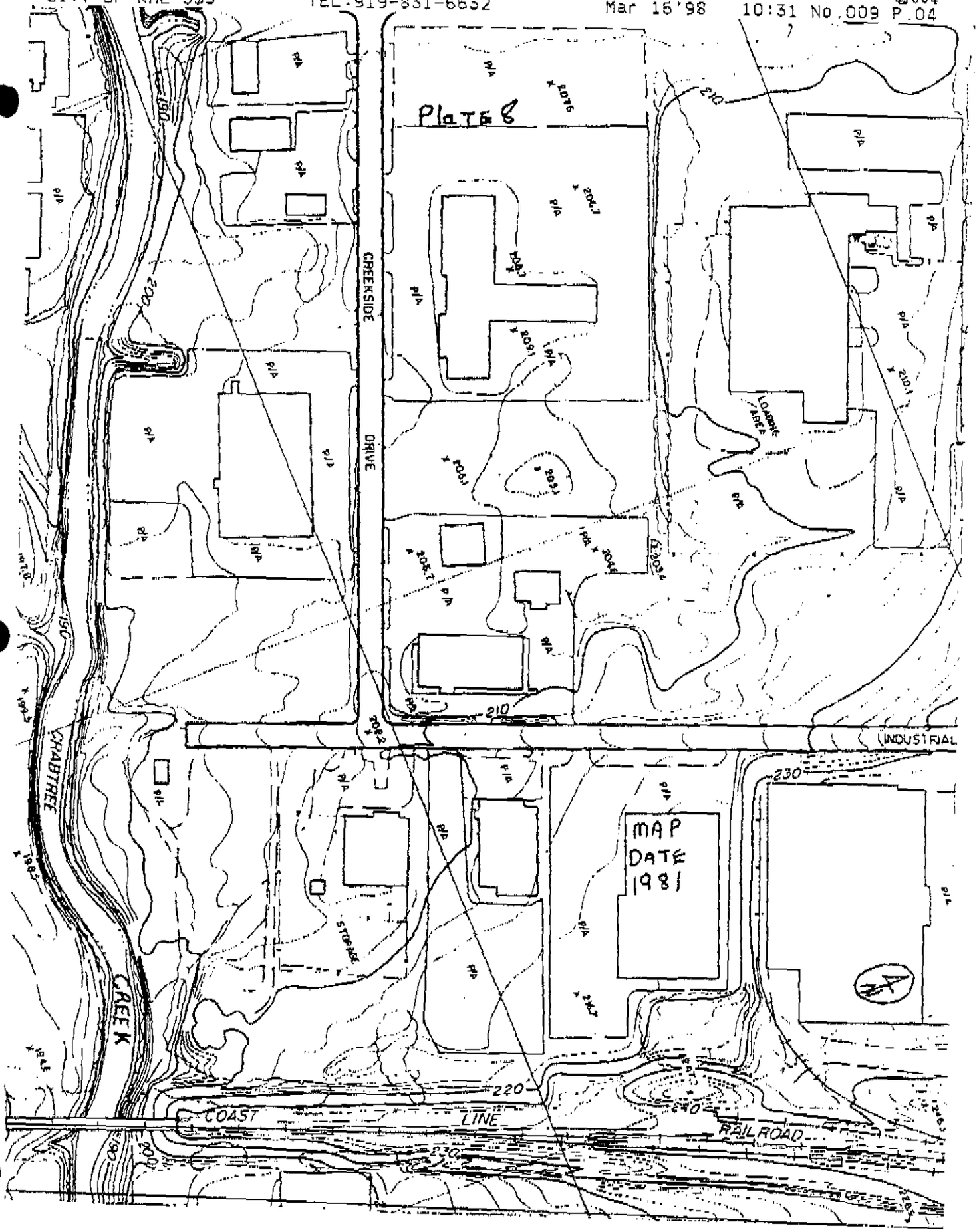
PLATE 6
CREEKSIDE DRIVE
INDUSTRIAL
CRABTREE CREEK
COAST LINE RAILROAD
MAP DATE 1981
STORAGE
LOADING AREA
210
220
230
240
190
200

6-3-60
1" = 500'
M-90
77