FINAL

Remediation by Natural Attenuation Treatability Study for Facility 1381 (SWMU 21)



Cape Canaveral Air Station
Florida

Prepared For

Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base
San Antonio, Texas

and

45th Space Wing Facilities at
Cape Canaveral Air Station, Florida

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16 December 1999

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Subject: Submittal of the Final Remediation by Natural Attenuation Treatability Study for Facility 1381 (SWMU 21), Cape Canaveral Air Station, Florida (Contract F41624-92-D-8036-0025)

Dear Mr. Hansen:

Enclosed please find two copies of the December 1999 Final Remediation by Natural Attenuation Treatability Study for Facility 1381 (SWMU 21), Cape Canaveral Air Station, Florida. This report was prepared by Parsons Engineering Science, Inc. (Parsons ES) for the Air Force Center for Environmental Excellence Technology Transfer Division (AFCEE/ERT) and Cape Canaveral Air Station (CCAS).

The intent of the treatability study (TS) was to determine the role of natural attenuation in remediating fuel hydrocarbon and chlorinated solvent contamination in groundwater at Facility 1381. The draft TS was submitted to AFCEE and CCAS in October 1997. Comments on the draft TS were received from AFCEE as reviewed by Jon Atkinson dated 27 April 1999. Responses to these comments were prepared by Parsons ES and are contained in Appendix F.

In addition, sample data collected by the US Environmental Protection Agency (USEPA) National Risk Management Research Laboratory (NRMRL) in March 1998 has been incorporated into this report as an addendum (Appendix G). Conclusions and recommendations from the addendum have been added to the Final TS Executive Summary and Section 8, Conclusions and Recommendations.

If you have any questions or comments regarding this package please do not hesitate to contact me at (303) 831-8100.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC.

Bruce M. Henry

Bruce M. Henry, P.G.
Project Manager

Enclosures
c.c. Mr. Mark Kershner – Cape Canaveral Air Station (two copies)
Mr. Don Kampbell – USEPA NRMRL

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FINAL

REMEDIATION BY NATURAL ATTENUATION TREATABILITY STUDY FOR FACILITY 1381 (SWMU 21)

at

CAPE CANAVERAL AIR STATION FLORIDA

December 1999

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE TECHNOLOGY TRANSFER DIVISION BROOKS AIR FORCE BASE SAN ANTONIO, TEXAS

and

45TH SPACE WING FACILITIES AT CAPE CANAVERAL AIR STATION, FLORIDA

Prepared by:

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EXECUTIVE SUMMARY

This report presents the results of a treatability study (TS) performed by Parsons Engineering Science, Inc. (Parsons ES) at Facility 1381 (SWMU 21), Cape Canaveral Air Station (CCAS), Florida to evaluate remediation by natural attenuation (RNA) of chlorinated aliphatic hydrocarbons (CAHs) dissolved in the site groundwater. The TS focuses on the fate and transport of dissolved CAHs, particularly trichloroethene (TCE), dichloroethene (DCE), and vinyl chloride (VC). The exact location of residual non-aqueous phase liquid (NAPL) or sorbed solvents in the vadose and/or phreatic soils remains unknown, but nonetheless serves as a continuing source for the currently observed CAH plume. Site history and the results of previous investigations are summarized in this report. The use of RNA with LTM discussed in this report is intended to support remedial alternatives for Facility 1381.

Comparison of CAH, electron acceptor, and biodegradation byproduct isopleth maps for Facility 1381 provides strong qualitative evidence for the biodegradation of dissolved CAHs. These geochemical data strongly suggest that reductive dehalogenation of dissolved CAHs is occurring at the site as microbes utilize natural organic carbon as a substrate. Low-level BTEX compounds have been detected in the source area and suggest previous low-level fuel releases or large releases that have since been naturally attenuated; however, current BTEX levels are too low to be a significant substrate source. Patterns observed in the distribution of CAHs, daughter products of CAHs, electron acceptors, and biodegradation byproducts further indicate that biodegradation is reducing the concentration of CAHs dissolved in site groundwater. Field-scale first-order dehalogenation rates of 0.000001 day^{-1} to 0.00032 day^{-1} (equivalent to half-lives of 5.9 to 1,900 years) were calculated using site-specific CAH data.

Results from additional sampling performed in March 1998 further support the occurrence of natural biodegradation of CAHs at the site. The overall extent of the CAH plume and distribution of parent and daughter compounds in March 1998 were similar to that delineated in September 1996. However, migration of dissolved contaminants to the northern drainage canal appears to have been inhibited in March 1998 by a temporary reversal of groundwater flow directions near the canal, most likely caused by increased flow and higher surface water levels in the canal.

Overall, TCE concentrations dissolved in groundwater increased in the source area, indicating the continuing presence of a significant TCE source remaining in the soils at Facility 1381. Despite increased concentrations, the March 1998 TCE plume was still restricted to the vicinity of the source area due to the effects of reductive dehalogenation under Type 2 conditions (where a natural carbon source drives reductive dehalogenation).

cis-1,2-DCE continues to be the most widespread contaminant in site groundwater, and the March 1998 DCE plume still appeared to extend to the northern drainage canal.

The continued presence of VC and ethene plumes supports the conclusion that DCE and VC also continue to be reductively transformed to less-chlorinated daughter products. Available data suggest that some oxidation of VC also may be occurring in the plume area.

Geochemical results from the March 1998 sampling event indicate the continued presence of a generally anaerobic, reducing environment, especially in deeper zones of the surficial aquifer that are not influenced by precipitation recharge. Therefore, the reduction-oxidation (redox) environment continues to support the occurrence of reductive dehalogenation of CAHs. However, measured increases in redox potentials and dissolved oxygen (DO) concentrations and decreases in methane concentrations in some shallow monitoring wells/points suggest that increased precipitation rates had caused a more oxidizing environment to be present, at least in some portions of the plume area, in March 1998. As a result, it is likely that reductive dehalogenation rates in the shallow zone are temporally variable, and that the significance of aerobic degradation of less-chlorinated CAHs (e.g., DCE and VC) also varies.

An important component of this study was an assessment of the time required to attain groundwater standards. To perform this task, a numerical groundwater flow and solute transport model was developed for the site using the USGS groundwater flow modeling code MODFLOW and the transport modeling code MT3D. After calibration and sensitivity analyses, the combined model was used to evaluate the fate and transport of dissolved CAHs in the shallow groundwater under the influence of advection, dispersion, sorption, and biodegradation. Input parameters for the model were obtained from data collected by Parsons ES. Model parameters that were not measured at the site were estimated using reasonable literature values.

Model simulations were prepared for two scenarios. The first scenario was a baseline scenario constructed with the assumption that the contaminant source would not be removed, but that CAH dissolution from source area LNAPL and soils into groundwater would naturally decrease at a rate of 4 percent per year (each concentration was decreased by a factor equal to 4 percent of the previous year's concentration). The results of this model suggest that the groundwater plume will continue to expand and that state maximum contaminant levels (MCLs) for groundwater concentrations of TCE, DCE, or VC would not be achieved within the next two centuries. Groundwater remedial goal options (RGOs) proposed for groundwater as part of the RFI are higher than State MCLs and would reduce the estimated time for groundwater remediation; however, RGOs are currently being negotiated and State MCLs should be used as interim groundwater standards. Model predictions suggest that the intersection of the groundwater plume with the northern drainage canal results in a CAH release rate of approximately 130 grams per year. CAH is diluted to below analytical detection limits, as supported by the historic absence of CAH in surface water samples.

The second model scenario incorporated the assumption of engineered source removal at rates of 25 to 50 percent per year (99 percent source removal in 7 to 16 years, respectively) beginning the model year corresponding to 1998. Results of both source removal scenarios suggest that after nearly complete source removal within the next several decades, the groundwater plume will have approximately the same areal extent as the original plume, but will be substantially reduced in magnitude in the source area. Still, CAH concentrations are not predicted to decrease below State MCLs through source

remediation within the next century. Insufficient LTM data were collected in March 1998 to support comparison of LTM results to numerical model predictions.

Several conservative assumptions were used in modeling CAH migration, specifically the use of relatively low CAH biodegradation rates, which may underestimate overall biodegradation at the site. Therefore, long-term monitoring (LTM) of groundwater chemistry at Facility 1381 is necessary to allow assessment of site conditions over time, to confirm the effectiveness of naturally occurring processes in reducing dissolved contaminant mass and minimizing dissolved contaminant migration (verify the groundwater model), and to facilitate evaluation of the need for additional remediation or reduced LTM, should conditions change. Therefore, an LTM plan involving sampling of groundwater from a minimum of ten wells within or on the periphery of the CAH plume is recommended, along with sampling of surface water at three locations. In addition to analyses used to verify the effectiveness of RNA, the groundwater samples should be analyzed for CAH compounds by US Environmental Protection Agency (USEPA) Method SW8260B.

If data collected under the LTM program indicate that the selected remedial actions are not sufficient to reduce groundwater CAH concentrations or surface water impact to levels considered protective of human health and the environment, additional corrective actions may be required to remediate groundwater at the site. If data indicate that the effects of RNA were underestimated and plume stabilization has occurred, the frequency or location of LTM may be reduced or modified, as necessary.

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LIST OF ACRONYMS AND ABBREVIATIONS

1,2-DCA	1,2-dichloroethane
1,2-DCE	1,2-dichloroethene
2D	2-dimensional
3D	3-dimensional
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AOCs	Areas of concern
ASCII	American Standard Code for Information Interchange
BRA	Base Realignment Authority
BTEX	benzene, toluene, etheylbenzene, and xylenes
CAHs	chlorinated aliphatic hydrocarbons
CCAS	Cape Canaveral Air Station
°C	degrees Celsius
CENTRAL OU	Central Operable Unit
CMS	Corrective Measures Study
CPT	cone penetrometer techniques
DCE	dichloroethene
DCE	dichloroethene
DO	dissolved oxygen
DSITMS	direct sampling ion trap mass spectrometer
ESE	Environmental Science and Engineering
°F	degrees Fahrenheit
FDEP	Florida Department of Environmental Protection
Fe^{2+}	ferric iron
Fe^{3+}	ferrous iron
f_{oc}	fraction of organic carbon
ft/day	feet per day
ft/ft	foot per foot
ft/yr	feet per year
ft^{-1}	per foot
g/cm^3	grams per cubic centimeter
gal/yr	gallons per year
GAT	Guidance Azimuth Transfer
H_2	dissolved hydrogen
HDPE	high-density polyethylene
ID	inside diameter
IRP	Installation Restoration Program
K_d	distribution coefficient
kg/L	kilograms per liter
K_{oc}	organic carbon coefficient
L/kg	liters per kilogram
LTM	long-term monitoring
MCLs	maximum contaminant levels
µg/L	micrograms per liter
µmol/L	micromoles per liter
mg/kg	milligrams per kilogram
MOC	method of characteristics

MP	monitoring point
msl	mean sea level
mV	millivolts
N	nitrogen
NAPL	nonaqueous-phase liquid
NASA	National Aeronatics and Space Administration
nM/L	nanomoles per liter
NRMRL	National Risk Management Research Laboratory
OD	outside diameter
OH-	hydroxyl
ORD	Office of Research and Development
ORNL	Oakridge National Laboratory
ORP	oxidation/reduction potential
OSWER	Office of Solid Waste and Emergency Response
OVA	organic vapor analyzer
PAFB	Patrick Air Force Base
Parsons ES	Parsons Engineering Science, Inc.
PCE	tetrachloroethene
POC	point of compliance
POL	petroleum, oil, and lubricants
ppmv	parts per million, by volume
PR	phytoremediation
PVC	polyvinyl chloride
QC	quality control
RCRA	Resource Conservation and Recovery Act
redox	reduction/oxidation
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigations
RGOs	remedial goal options
RMS	root mean squared
RNA	Remediation by Natural Attenuation
SI	site investigation
SS	stainless steel
TCA	trichloroethane
TCE	trichloroethene
TMB	trimethylbenzene
TOC	total organic carbon
TS	Treatability Study
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USU	Utah State University
VC	vinyl chloride
VFAs	volatile fatty acids
VOCs	volatile organic compounds
WWTP	wastewater treatment plant

SECTION 1

INTRODUCTION

This report presents the results of a treatability study (TS) conducted to evaluate the potential effectiveness of remediation by natural attenuation (RNA) for groundwater contaminated with chlorinated aliphatic hydrocarbons (CAHs) at Facility 1381 (SWMU 21), at Cape Canaveral Air Station (CCAS), Florida. As used in this report, RNA refers to a management strategy that relies on natural attenuation mechanisms to remediate contaminants dissolved in groundwater and to control receptor exposure risks associated with contaminants in the subsurface. The United States Environmental Protection Agency (USEPA) Offices of Research and Development (ORD) and Solid Waste and Emergency Response (OSWER) define natural attenuation as (Wilson, 1996):

> *The naturally-occurring processes in soil and groundwater environments that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in those media. These in-situ processes include biodegradation, dispersion, dilution, adsorption, volatilization, and chemical or biological stabilization or destruction of contaminants.*

As suggested by this definition, mechanisms for natural attenuation of CAHs include advection, dispersion, dilution from recharge, sorption, volatilization, abiotic chemical transformation, and biodegradation. Of these processes, biodegradation is the most common mechanism working to transform contaminants into innocuous byproducts. During biodegradation, indigenous microorganisms work to bring about a reduction in the total mass of contamination in the subsurface without artificial intervention (e.g., addition of nutrients). Patterns and rates of natural attenuation can vary markedly from site to site depending on governing physical and chemical processes.

1.1 SCOPE AND OBJECTIVES

Parsons ES was retained by the United States Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division to conduct site characterization and groundwater modeling to evaluate the scientific defensibility of RNA with long-term monitoring (LTM) as a remedial option for contaminated groundwater at Facility 1381. Specifically, the TS was conducted in support of an ongoing corrective measures study (CMS) being performed at Facility 1381 under the Installation Restoration Program (IRP). The information presented in this study is provided for the use of the Base and its prime environmental contractor(s) in the preparation of the CMS report or to support future decision-making regarding the site, as appropriate. In addition, this project is part of a larger, broad-based initiative being conducted by AFCEE in conjunction with the USEPA National Risk Management Research Laboratory (NRMRL) (formerly the

USEPA's Robert S. Kerr Environmental Research Laboratory) and Parsons ES to document and evaluate the biodegradation and resulting attenuation of solvents and fuel hydrocarbons dissolved in groundwater, and to model this degradation using numerical or analytical solute transport models. Therefore, field work conducted under this program was oriented toward the collection of supplementary hydrogeologic and chemical data necessary to document and model the effectiveness of RNA with LTM for restoration of CAH-contaminated groundwater to the north of the suspected source area at Facility 1381.

RNA is an advantageous groundwater technology for the protection of human health and the environment for several reasons:

- Contaminants are transformed to innocuous byproducts (e.g., carbon dioxide, ethene, or water), not just transferred to another phase or location within the environment;
- Current pump-and-treat technologies are energy-intensive and generally not as effective in reducing residual contamination;
- The process is nonintrusive and allows continuing use of infrastructure during remediation;
- Engineered remedial technologies may pose a greater risk to potential receptors than RNA (e.g., contaminants may be transferred into another medium during remediation activities); and
- RNA can be less costly than conventional, engineered remedial technologies.

The disadvantages of RNA include the following:

- Contaminants considered to be more mobile and toxic can be produced as byproducts of biodegradation [e.g., vinyl chloride (VC)];
- The effectiveness of RNA is generally limited by site geochemistry and the availability of substrates;
- RNA may require a larger groundwater remediation zone than other remedial alternatives; and
- RNA frequently takes longer to reach specified contaminant concentration limits than other remedial alternatives.

1.2 DESCRIPTION OF TASKS PERFORMED

Numerous site-specific data must be collected to adequately document the effectiveness and reliability of RNA. Typically, the data required to support such an evaluation are not collected during normal Resource Conservation and Recovery Act (RCRA) Facility Investigations (RFIs). Tasks performed to fulfill the project objective included:

- Reviewing existing hydrogeologic and soil and groundwater quality data for the site;
- Conducting supplemental site characterization activities to more thoroughly characterize the nature and extent of groundwater contamination;
- Collecting geochemical data in support of RNA;
- Developing a conceptual hydrogeologic model of the shallow saturated zone, including the current distribution of contaminants;
- Evaluating site-specific data to determine whether naturally occurring processes of contaminant attenuation and destruction are occurring in groundwater at the site;
- Designing and executing a groundwater flow and contaminant fate and transport model for site hydrogeologic conditions;
- Simulating the fate and transport of CAHs [e.g., trichloroethene (TCE)] in groundwater under the influence of advection, dispersion, adsorption, and biodegradation using the calibrated model;
- Evaluating a range of model input parameters to determine the sensitivity of the model to those parameters and to consider several contaminant fate and transport scenarios;
- Determining if natural processes are minimizing dissolved CAH plume expansion so that groundwater and surface water quality standards can be met at a downgradient point of compliance (POC);
- Conducting an exposure pathways analysis for potential current and future receptors; and
- Using the results of modeling to determine the adequacy of RNA to protect human health and the ecosystem and to formulate a LTM plan.

Site characterization activities in support of RNA included the installation of groundwater monitoring points using cone penetrometer techniques (CPT) and a Geoprobe®; collection of soil samples with a Geoprobe®; static groundwater level measurement; surface water sample collection and analysis; sediment sample collection and analysis; groundwater sample screening with a direct sampling ion trap mass spectrometer (DSITMS); groundwater sample collection and analysis from preexisting site monitoring wells and newly installed monitoring points; and an additional round of groundwater sample collection and analysis from source area monitoring wells. Additional groundwater sampling was performed by the USEPA NRMRL in March 1998. Data for this event were not available for analysis in preparation of this TS, but have been evaluated in addendum to this TS (Appendix G). Results of the addendum have been incorporated into the Executive Summary and Section 8, Conclusions and Recommendations.

Site-specific data collected in September 1997 were used to develop a solute fate and transport model for the site and to conduct a preliminary exposure pathways analysis. The model was used to predict the future extent and concentration of the dissolved CAH plume by simulating the combined effects of advection, dispersion, sorption, and biodegradation. Results of the model were used to predict future discharge to surface water, to assess the potential for completion of other exposure pathways involving groundwater, and to identify whether natural attenuation with LTM is an appropriate and defensible remedial option for contaminated groundwater. The results will be used to provide the necessary technical information to be used in the natural attenuation evaluation of the CMS.

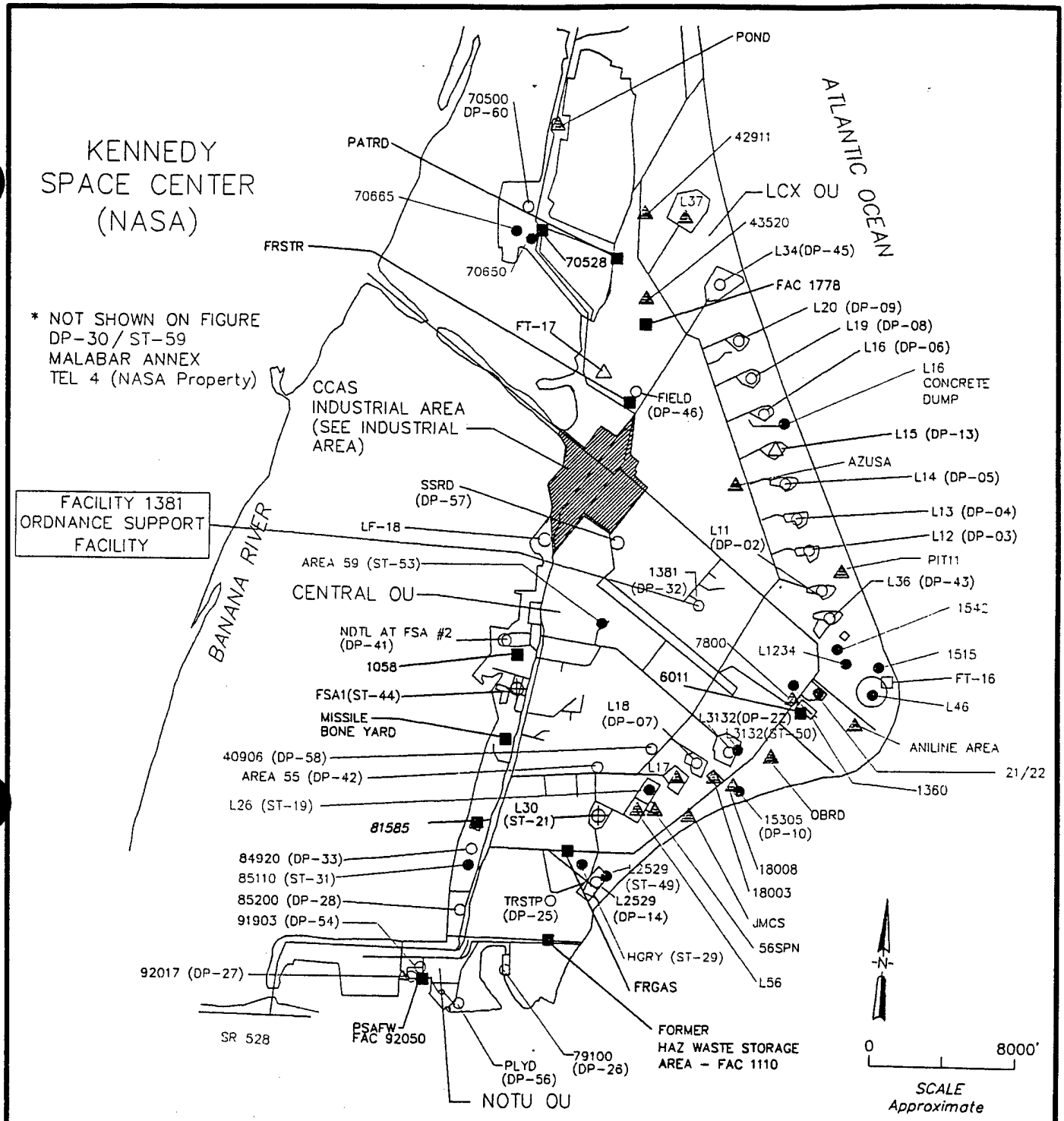
1.3 REPORT ORGANIZATION

This report contains eight sections and seven appendices. Section 2 summarizes site characterization activities. Section 3 summarizes the physical characteristics of the study area. Section 4 describes the nature and extent of soil, groundwater, and surface water contamination, and the geochemistry of soil and groundwater at the site. Section 5 describes the fate and transport model and design of the conceptual hydrogeologic model for the site; lists model assumptions and input parameters; and describes sensitivity analyses, model output, and the model results. Section 6 presents a proposed LTM plan for the site. Section 7 presents conclusions regarding the effectiveness of RNA at remediating CAH-contaminated groundwater at Facility 1381. Section 8 lists the references used to develop this document. Appendix A contains CPT push data and Geoprobe® borehole logs, monitoring point construction diagrams, and survey data. Appendix B presents soil, surface water, and groundwater analytical results that were collected as a part of this TS. Appendix C contains model input parameters and calculations related to model calibration. Appendix D contains model input and output in American Standard Code for Information Interchange (ASCII) format on a diskette. Appendix E presents summarized results of DSITMS sampling in memorandum format. Appendix F includes responses to comments on the draft TS Report, and Appendix G contains the Final Remediation by Natural Attenuation Treatability Study Addendum.

1.4 BASE AND FACILITY 1381 BACKGROUND

CCAS is located on the east coast of Florida on a barrier island in Brevard County. The main complex occupies about 25 square miles of assembly and launch facilities for missiles and space vehicles. The property is bounded by the Atlantic Ocean on the east and the Banana River on the west. The southern boundary is a man-made shipping channel, and the John F. Kennedy Space Center adjoins CCAS to the north. Since 1950, CCAS has been a proving ground for US Department of Defense military missile programs, including the Bomarc, Matador, Redstone, Atlas, Titan, and Navy Trident programs.

The Ordnance Support Facility (Facility 1381), formerly the Guidance Azimuth Transfer (GAT) building and the In-Place Cleaning Facility, is located along the landfill access road in Area 5 of CCAS. The site is part of the CCAS Central Area Operable Unit (CENTRAL OU). Figure 1.1 shows the location of Facility 1381 at CCAS. The site is



LEGEND

- ○ RI/FS (RFI/CMS)
- ▲ SI (CS)
- ● AF REC. NFA
- ⊕ STATE PETROLEUM
- □ LTM/LTO
- ■ CLOSED
- △ CMI

General Location (Site Size Not to Scale)

Source: Parsons ES, 1997a.

FIGURE 1.1

LOCATION OF FACILITY 1381

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

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enclosed within a chain-link fence, and access is controlled. South of the facility, across the drainage canal, is the CCAS landfill. There are no other facilities adjacent to the site. Figure 1.2 shows the location of Facility 1381 in relation to the north and south drainage canals. The following facilities are located within the chain-link fence and are depicted on Figure 1.3 Ordnance Support Facility (1381), Petroleum, Oils, and Lubrication (POL)/Hazardous Storage Base (1400), Sewage Septic Tank and Drain Field (20295), Electrical Substation (20296), and the Equipment Shed (20299). Areas of concern (AOCs) at Facility 1381 include the support Facility Equipment Shed (AOC-517), the former Acid Neutralization Pit (AOC-518), and the Drainfield/Septic Tank (AOC-519).

Over its 39-year history that began in 1958, ownership of and operations performed at Facility 1381 have changed several times. Facility 1381 originally may have been used for research, testing, and/or instruction of missile/space technology, although historic information about the site between 1958 and 1968 is limited. During the operation of an In-Place Precision Cleaning Lab (1968-1977), the building housed acid and solvent dip tanks for cleaning metal components. According to the Environmental Science and Engineering (ESE) (1984), waste TCE was generated at a rate of approximately 3,300 gallons per year (gal/yr) from a parts dip tank. Through 1972, the waste TCE was drummed, taken to Launch Complex 15 (L15 on Figure 1.1), and incinerated. Beginning in 1972, TCE was incinerated in a boiler at CCAS (ESE, 1984). Waste nitric and hydrochloric cleaning acids also were used within the facility. A 4-foot by 40-foot by 2.5-foot lined, stainless steel acid dip tank was used to clean pipe. The waste acids were disposed of by discharging them into a neutralization pit filled with crushed limestone, located southwest of the building.

The US Coast Guard has operated the site as the Ordnance Support Facility since 1977. According to site personnel, the only change that has occurred at the facility since the Coast Guard assumed ownership in 1977 was the addition of three dip tanks and electrical hardwiring (Parsons ES, 1997a). According to an interviewee, the dip tanks contained acid (Fozdip), oil, and, water (May 2-6, 1992).

The acid neutralization pit has not been clearly identified from site reconnaissance, nor clearly located in previous reports and construction blueprints. Previous descriptions of likely pit locations have placed it within the confines of the septic field or 30 to 40 feet southwest of Facility 1381 (ESE, 1984). The pit was reportedly filled with crushed limestone during operation, but was later filled with soil.

Blueprints and records describing the design of Facility 1381 noted that the septic field consisted of a 500-gallon septic tank and a 3-foot by 20-inch distribution box. The septic drain field has been in place since 1958, and no notable features, such as a limestone-filled pit, appear to have been incorporated into its design. Therefore, the septic drain field is not suspected to coincide with the former location of the acid neutralization pit.

Aerial photographs, blueprints, and a site reconnaissance have confirmed the presence of a concrete pit covered with a metal grate located approximately 45 to 50 feet southwest of Facility 1381 (Figure 1.3). The construction of this pit is not consistent with the reported design and function of the acid neutralization pit because the metal grate and

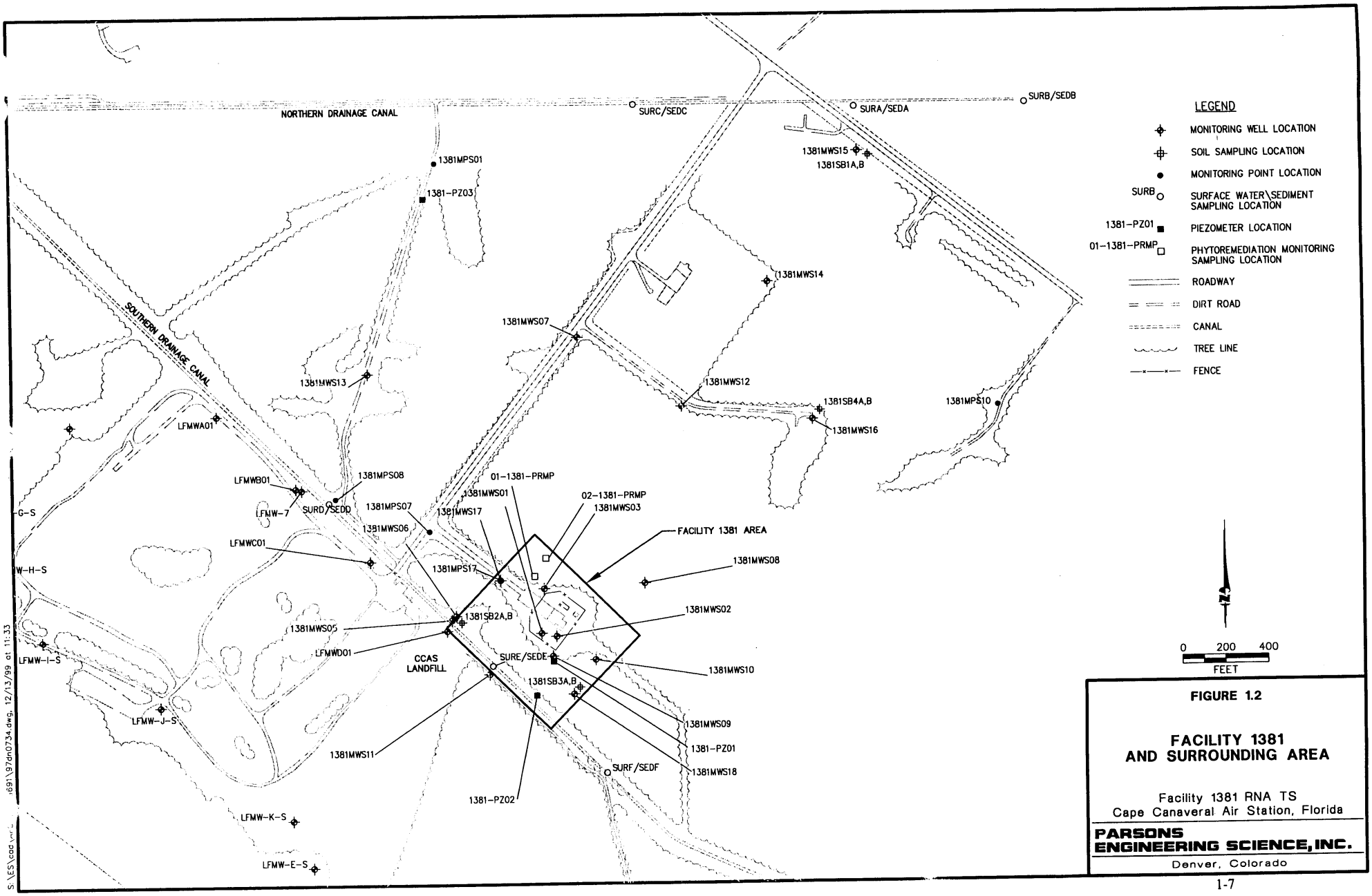
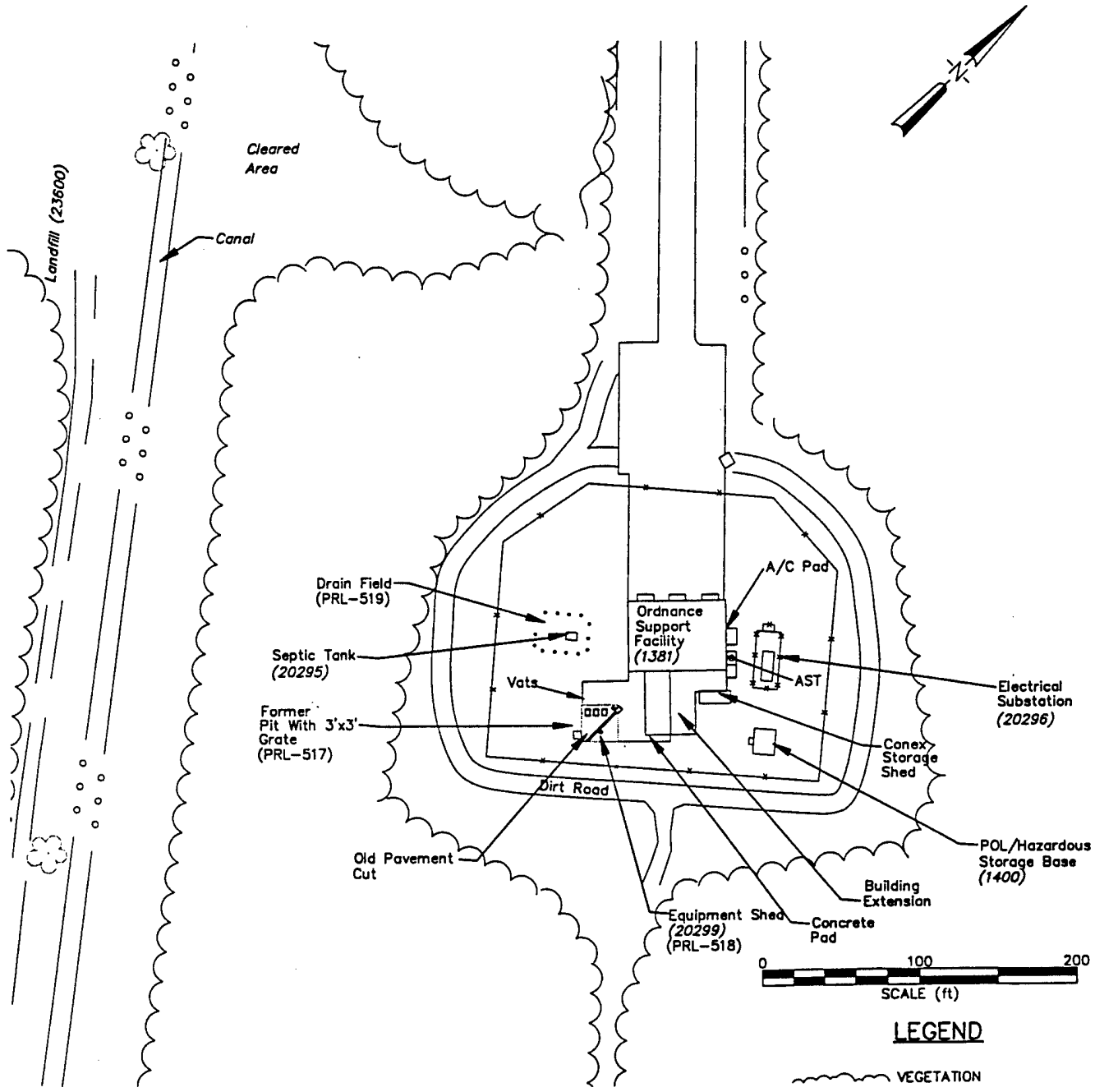


FIGURE 1.2

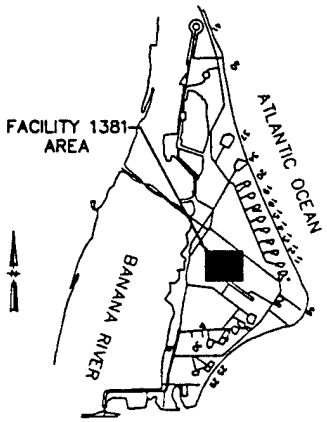
FACILITY 1381 AND SURROUNDING AREA

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

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KEY PLAN



Source: Parsons ES, 1997a.

FIGURE 1.3

SITE MAP OF FACILITY 1381

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

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concrete walls would be corroded by acid. Furthermore, the concrete pit was filled with water instead of soil (as previously described). Therefore, the observed concrete pit does not appear to be the acid neutralization pit, although it is in the general suspected location of the latter structure. To date, the exact location of the acid neutralization pit remains uncertain.

In June 1994, the concrete pit located at the southwestern corner of the concrete pad was drained in order to investigate the structural integrity of the concrete. The pit is approximately 4 feet deep, and no cracks or leaks were observed in the concrete sides and bottom. The pit was subsequently decontaminated and sealed. The contents of the pit were disposed of at a hazardous waste disposal facility.

Chlorinated solvent contamination at the site is suspected to have resulted from accidental releases from past metal cleaning operations. In the earliest available photograph of the site, taken in 1967, several drums were visible resting on the ground surface at various locations across the site. During site reconnaissance conducted as part of the 1989 RCRA Facility Assessment (RFA), several drums were discovered outside the fenced area southwest of Facility 1381 (USEPA, 1989). It is suspected that drums containing chlorinated volatile organic compounds (VOCs) were periodically stored at this location and contributed to soil and groundwater contamination. Solvents also were released at the site during the dumping of solvents from tanker trucks in the woods around the site. The length of practice of these disposal methods is unknown.

1.4 SITE INVESTIGATIONS AND REMEDIAL ACTIVITIES

Facility 1381 was first investigated for environmental concerns during a Phase I study (ESE, 1984). In 1989, an RFA Report (Mitchell, 1989) was issued for the site by the USEPA. Parsons ES performed a field reconnaissance in 1992, and issued a preliminary Assessment and Field Sampling Strategy Report (Parsons ES, 1993). This was followed by a site investigation (SI) that included sample collection and analysis, performed by Parsons ES (1995). A brief summary of the findings of each of the previous investigations is presented in the RFI report (Parsons ES, 1997a).

Work performed as part of the RFI conducted between December 1995 and June 1996 (Parsons ES, 1997a) included:

- Collection of groundwater samples from 67 HydroPunch® locations located throughout the Facility 1381 area;
- Installation and/or sampling of 17 shallow wells, 2 intermediate-depth wells, 13 deep wells, and 3 piezometers;
- Advancement of a total of 15 soil boreholes and the collection/analysis of 30 soil samples from these bore holes;
- Collection of 9 surface water samples and 7 sediment samples in the vicinity of the site; and
- Collection of groundwater elevation data from seven sampling events between December 1995 and June 1996.

Two additional piezometers were installed after May 1997 to monitor groundwater elevations and contaminant concentrations as part of ongoing RFI investigations.

Site characterization results obtained during the RFI at Ordnance Support Facility 1381 revealed that hydrogeologic conditions at the site create both northward and southward contaminant migration as the result of a groundwater divide. Contaminated groundwater that discharges to the geographically closer southern drainage canal contains elevated concentrations of TCE and DCE, creating a more urgent groundwater scenario that must be addressed by active treatment technologies (to be discussed in the CMS). The current consensus between CCAS, AFCEE, and Parsons ES is that groundwater contamination migrating north from Facility 1381 poses a lesser risk to potential receptors because the migration pathway to the northern drainage canal is longer, allowing the beneficial effects of natural attenuation to reduce dissolved contaminant concentrations prior to discharge to this canal. Therefore, natural attenuation will be addressed in the CMS as a potential remedial option for northward migrating groundwater, primarily through the investigative results and conclusions of this TS. The evaluation of RNA with LTM in this report is limited to that portion of the groundwater plume emanating from Facility 1381 and migrating north toward the northern drainage canal.

SECTION 2

SITE CHARACTERIZATION ACTIVITIES

To meet the requirements of the RNA demonstration, additional data were required to evaluate near-surface geology and hydrogeology, contaminant distribution, and groundwater geochemistry. Site characterization activities involved borehole advancement and groundwater monitoring point installation with a CPT or Geoprobe®; collection of soil samples using a Geoprobe®; collection of groundwater samples from existing monitoring wells and newly-installed monitoring points; collection of surface water and sediment samples from adjacent drainage canals; performance of slug tests on select groundwater monitoring wells; and surveying of the coordinates and elevations of the newly installed monitoring points, soil sample locations, and surface water/sediment sampling locations. These activities were performed from September 19 through 25, 1996.

The natural attenuation work plan for Facility 1381 proposed the exclusive use of a Geoprobe® to install monitoring points (Parsons ES, 1996). However, CPT installation of most monitoring points was used instead of Geoprobe® installation due to the unforeseen availability of a US Army Corps of Engineers (USACE) CPT rig just prior to the start of field work. The CPT device is capable of installing monitoring points more efficiently than a Geoprobe® and can collect stratigraphic data *in situ*. The procedures used for both CPT and Geoprobe® site investigation activities are described in the following sections.

Below is a summary of the physical and chemical data collected during the field work phase of this RNA demonstration project:

- Depth from measurement datum to the water table or potentiometric surface in monitoring wells and points;
- Stratigraphy of subsurface media;
- Groundwater geochemical data {pH, temperature, electrical conductivity, total alkalinity, oxidation-reduction potential (ORP), dissolved oxygen (DO), carbon dioxide, chloride, nitrate+nitrite [as nitrogen (N), ammonia, ferrous iron, manganese, sulfate, total organic carbon (TOC), dissolved hydrogen, phenols, aliphatic and aromatic acids, and methane/ethane/ethene};
- Groundwater concentrations of CAHs, aromatic VOCs, and metals;
- Concentrations of TOC in soil; and
- Concentrations of CAHs and aromatic VOCs in surface water.

An air sparging system was installed in the source area at Facility 1381 coincidental to the planned TS field work. The air sparging system was installed as an interim remedial measure, primarily to prevent the southward migration of CAH contamination. Because operation of the sparging system could affect the groundwater geochemistry, several groundwater wells within the treatment radius of the sparging unit were presampled on August 15, 1997 to provide baseline (pre-sparging) geochemical and chemical data. These preliminary groundwater samples were used in the natural attenuation evaluation; however, air sparging operations were eventually initiated after the September 1997 groundwater sampling event was completed, and did not impact the geochemical results. Air sparging operations were conducted for approximately 1 month; the results are currently unpublished and are unrelated to the natural attenuation analysis presented in this report..

The following sections describe the procedures that were followed when collecting site-specific data. Additional details regarding investigative activities are presented in the work plan (Parsons ES, 1996).

2.1 CONE PENETROMETRY

Subsurface conditions at the site were evaluated using a CPT apparatus from September 19 through 21, 1996. CPT pushes were performed at 12 locations to collect site stratigraphy data needed to optimize the placement of 21 monitoring points. Table 2.1 references CPT push locations, push depths, and monitoring point locations. All subsurface utility lines, man-made subsurface features, and proposed monitoring point locations were cleared or approved by the Base prior to any CPT activities.

CPT was conducted using the USACE cone penetrometer truck. This equipment consists of an instrumented probe that is forced into the ground using a hydraulic load frame mounted on a heavy truck, with the weight of the truck providing the necessary reaction mass. The penetrometer equipment is housed in a stainless steel, dual-compartment body mounted on a 43,000-pound, triple-axle Kenworth® truck chassis powered by a turbo-charged diesel engine. The weight of the truck and equipment is used as ballast to achieve the overall push capability of 39,000 pounds.

The penetrometer probe has a 1.8-inch-outside diameter (OD), 60-degree conical point with sacrificial tip, and an 8.0-inch-long by 1.8-inch-OD friction sleeve. Inside the probe, two load cells independently measure the vertical resistance against the conical tip and the side friction along the sleeve. Each load cell is a cylinder of uniform cross-section which is instrumented with four strain gauges in a full-bridge circuit. As the probe is pushed into the subsurface, resistive forces are sensed by the load cells, and the data are transmitted from the probe assembly via a cable running through the push tubes. The analog data are digitized, recorded, and plotted by computer in the penetrometry truck.

After collecting soil stratigraphy data or placing a monitoring point (Section 2.3) with the CPT, the push rods were cleaned during extraction with the CPT steam-cleaning system (rod cleaner) as the rods were withdrawn from the ground. A vacuum system located beneath the CPT truck was used to recover cleaning water. Use of this system resulted in nearly 100-percent recovery of steam-cleaning rinseate from the rod cleaner.

TABLE 2.1
INSTALLATION LOCATIONS AND DEPTHS FOR MONITORING POINTS AND SOIL SAMPLES
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Location	Installation Date	Proximity to Well Locations	CPT Log Identifier[a/]	Maximum Push/Installed Depth (ft bgs)
Monitoring Points				
1381[b/]MPI01[c/]	9/19/1996	1000' NE of 1381MWS13	01-1381	51.0
1381MPS01[d/]	9/20/1996	1000' NE of 1381MWS13	01-1381	51.0
1381MPI02	9/19/1996	near 1381MWS13	02-1381	38.2
1381MPI03	9/20/1996	near 1381MWS03	NA[e/]	NA
1381MPI05	9/20/1996	near 1381MWS11	09-1381	36.5
1381MPI06	9/20/1996	near 1381MWS01	NA	NA
1381MPI07	9/20/1996	400' NW of 1381MWS17	04-1381	33.2
1381MPS07	9/20/1996	400' NW of 1381MWS17	04-1381	33.2
1381MPI08	9/21/1996	600' S of 1381MWS13	03-1381	39.4
1381MPS08	9/20/1996	600' S of 1381MWS13	03-1381	38.0
1381MPI10	9/21/1996	800' East of 1381MWS16	10-1381	39.4
1381MPS10	9/21/1996	800' East of 1381MWS16	10-1381	39.4
1381MPI11	9/21/1996	near 1381MWS16	11-1381	36.2
1381MPI13	9/21/1996	near 1381MWS12	12-1381	32.7
1381MPI17	9/20/1996	at well 1381MWS17	NA	NA
1381MPI18	9/21/1996	near 1381MWS07	07-1381	38.0
1381MPI19	9/21/1996	near 1381MWS14	05-1381, 06-1381	17.8, 52.8
1381MPI20	9/24/1996	near 1381MWS18	NA	27.0
1381MPI21	9/21/1996	near 1381MWS15	08-1381	38.0
01-1381-PRMP[f/]	9/25/1996	North of 1381MWS03	NA	8.0
02-1381-PRMP	9/25/1996	North of 1381MWS03	NA	8.0
Soil Samples				
1381SB[g/]1A,B	9/24/1996	near 1381MWS15	NA	6.5
1381SB2A,B	9/24/1996	near 1381MWS05	NA	6.9
1381SB3A,B	9/24/1996	near 1381MWS18	NA	6.4
1381SB4A,B	9/24/1996	near 1381MWS16	NA	7.7

[a/] CPT Log Identifier refers to CPT log printouts describing soil type and resistivity (Appendix A).

[b/] The number 1381 identifies wells/piezometers/soil samples located within the perimeter of Facility 1381.

[c/] The letter I identifies monitoring points which are screened within the intermediate portion of the surficial aquifer.

[d/] The letter S identifies monitoring points which are screened within the shallow portion of the surficial aquifer.

[e/] NA = Not Applicable. Installed with a Geoprobe or no CPT prepush performed prior to point installation.

[f/] The letters PRMP identify a phytoremediation point screened within the shallow portion of the surficial aquifer.

[g/] The letters SB identify a soil borehole location in which soil samples were collected.

Rinseate was generated only as the rods moved past the cleaner, thereby minimizing liquid waste generation. Precautions were taken to minimize any impact to the surrounding area that might result from decontamination operations. Potable water used in CPT equipment cleaning or borehole grouting was obtained from the Base water supply. At soil stratigraphy push locations, the borehole was simultaneously sealed with a cement grout (introduced through an internal grout tube running the length of the push rod assembly) as the rods were withdrawn and steam cleaned.

2.2 GEOPROBE® BOREHOLE ADVANCEMENT AND SOIL SAMPLING

Geoprobe®-related field work occurred on September 23 to 25, 1996, and consisted of soil sampling at Geoprobe® push locations 1381SB1A and B, 1381SB2A and B, 1381SB3A and B, and 1381SB4A and B (Figure 2.1, Table 2.1). The Geoprobe® system is a truck-mounted, hydraulically powered percussion/probing machine used to advance sampling tools through unconsolidated soils. This system provides for the rapid collection of soil, soil gas, and groundwater samples at shallow depths while minimizing the generation of investigation-derived waste materials. All necessary clearances for subsurface sampling with the Geoprobe® were obtained as described in Section 2.1.

Prior to arriving at the site, all probe rods, tips, sleeves, pushrods, samplers, tools, and other downhole equipment were decontaminated using an Alconox® detergent and potable water solution followed by a high-pressure potable water wash. All sampling equipment also underwent an additional rinse with isopropyl alcohol followed by a final rinse with deionized water.

The Geoprobe®-collected soil samples were obtained using a probe-drive sampler. The probe-drive sampler serves as both the driving point and the sample collection device and is attached to the leading end of the probe rods. To collect a soil sample, the sampler was pushed or driven to the desired sampling depth, and the stop pin was removed, allowing the piston and drive point to retract as the sample barrel was pushed into undisturbed soil. The soil cores were retained within a clear acetate liner inside the sampling barrel. The probe rods were then retracted, bringing the sampling device to the surface. The soil sample was cut from the liners, composited over 1-foot intervals, and transferred to analyte-appropriate jars supplied by the analytical laboratory. A portion of the sample was retained for lithologic and stratigraphic logging.

The Parsons ES field hydrogeologist observed Geoprobe® soil sampling and maintained a descriptive log of the materials recovered. These logs, presented in Appendix A, contain:

- Sampled interval (top and bottom depths);
- Presence or absence of contamination based on odor and staining;
- Soil description, including color, major textural constituents, minor constituents, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, and any other significant observations; and,

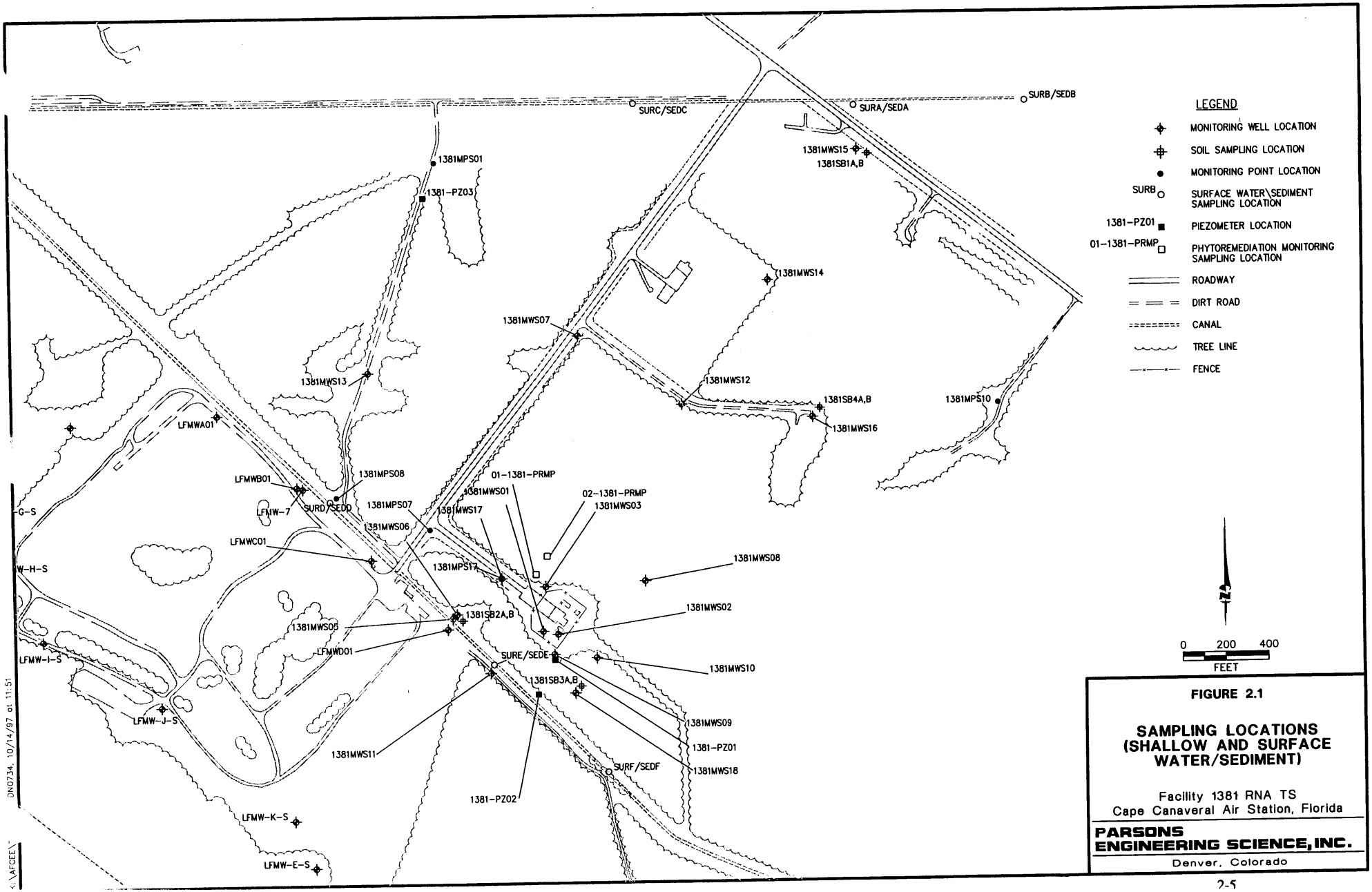


FIGURE 2.1

SAMPLING LOCATIONS (SHALLOW AND SURFACE WATER/SEDIMENT)

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

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- Lithologic contacts, with the depth of lithologic contacts and/or significant textural changes recorded to the nearest 0.1 foot, if evident.

The small volume of waste soils generated during monitoring point installation and sampling operations was spread on the ground surface in the vicinity of the site.

2.3 MONITORING POINT INSTALLATION

Using the CPT truck, USACE staff installed 17 2.0-inch-inside diameter (ID) and 1 0.5-inch ID monitoring points at 14 locations at Facility 1381. These monitoring points consisted of 4 shallow monitoring points screened between 7.0 and 14.4 feet bgs and 14 intermediate-depth wells screened between 23.7 and 33.0 feet bgs. Figures 2.1 and 2.2 and Table 2.2 show locations and the construction details of the monitoring points and previously-installed monitoring wells. Prior to the installation of any CPT-installed monitoring points, soil stratigraphy data was collected with the CPT device from the ground surface to between 18 and 50 feet bgs. These data were used to place intermediate-depth monitoring points in medium to fine sands above a silty/clayey sand interval located at approximately 35 feet bgs. CPT stratigraphy data is included in Appendix A.

2.0-inch-ID monitoring points were installed at all CPT locations except 1381MPI19. A 2.0-inch-ID monitoring point could not be installed at this location because an unidentified hard layer in the upper 10 feet of soil caused excessive shear force on the outside of the rods, preventing the insertion of 2-inch-ID polyvinyl chloride (PVC) pipe (which is pushed to depth on the outside of the CPT push rods). Therefore, a 0.5-inch-ID PVC screen was inserted inside the CPT pushrods and pushed to the desired depth to construct monitoring point 1381MPI19. No monitoring points were installed deeper than 35 feet bgs, which is approximately 15 feet above the lower confining clay layer of the Caloosahatchee Marl Formation (Section 3.2).

Monitoring point 1381MPI20 (southeast of Facility 1381) was installed with the Geoprobe® at the end of a heavily vegetated access road that prohibited the entry of the CPT vehicle. The monitoring point was constructed with a 0.25-inch-ID stainless steel (SS) mesh implant acting as a monitoring point screen that was connected to a 0.25-inch-ID high-density polyethylene (HDPE) tube that served as the monitoring point riser. Two phytoremediation monitoring points were installed with the Geoprobe® to the northwest of Facility 1381. These points also were constructed of SS mesh implants and HDPE riser material. The points were identified as 1381PRMP01 and 1381PRMP02 (Figure 2.1) and screened close to the groundwater surface as part of a separate phytoremediation study sponsored by AFCEE and Utah State University to evaluate the remediation of chlorinated ethenes through vegetative uptake (e.g., root systems).

All monitoring points were assigned a three-part identifier. The first part is "1381" which designates the point as associated with Facility 1381. The second part of the identifier is a prefix and number which corresponds to the monitoring point (MP)/ phytoremediation (PR) point number. The third part is a letter which identifies the location of the screened interval relative to the water table: the letter "S" is used for monitoring points screened in the sandy upper portion of the aquifer; the letter "I" is used

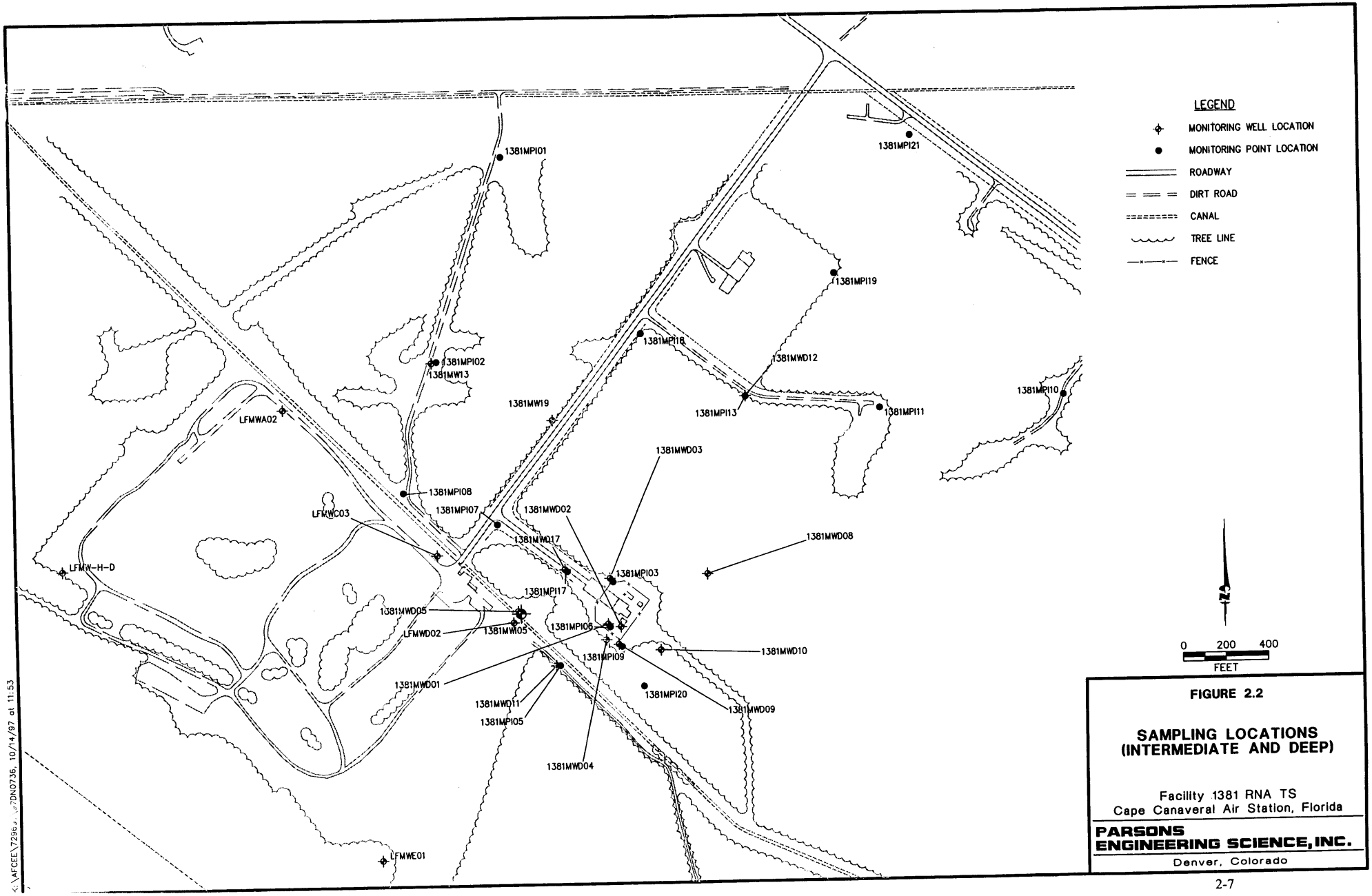


FIGURE 2.2

SAMPLING LOCATIONS (INTERMEDIATE AND DEEP)

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

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TABLE 2.2
MONITORING WELL/POINT CONSTRUCTION DETAILS
FACILITY 1381 RNS TS
CAPE CANAVERAL AIR STATION, FLORIDA

Well Location	Installation Date	Northing (ft)	Easting (ft)	Well ID (inches)	Datum Elevation (ft msl)[a]	Ground Elevation (ft msl)	Screen Interval Top (ft bgs)[b]	Screen Interval Bottom (ft bgs)
1381[c]-MWS[d]01	11/30/1993	1504383.31	797422.99	2.00	9.08	9.17	5.00	15.00
1381-MWD[e]01	11/30/1993	1504379.31	797428.44	2.00	9.04	9.17	38.00	48.00
1381-MWS02	12/1/1993	1504368.77	797491.99	2.00	9.14	9.30	5.00	15.00
1381-MWD02	9/22/1995	1504365.49	797489.60	2.00	9.15	9.30	46.00	51.00
1381-MWS03	12/8/1995	1504588.46	797436.66	2.00	8.38	8.24	3.00	13.00
1381-MWD03	1/25/1996	1504588.38	797440.25	2.00	8.30	8.24	46.50	51.50
1381-MWD04	1/25/1996	1504305.43	797418.48	2.00	12.23	9.52	72.50	77.50
1381-MWS05	1/29/1996	1504447.00	797005.30	2.00	11.18	7.68	3.00	13.00
1381-MWI05	1/25/1996	1504452.00	797001.80	2.00	11.28	7.68	30.00	35.00
1381-MWD05	1/21/1996	1504444.11	797009.79	2.00	10.32	7.68	44.00	49.00
1381-MWS06	1/21/1996	1504466.00	797024.70	2.00	10.69	7.68	3.00	13.00
1381-MWS07	1/21/1996	1505755.00	797602.10	2.00	10.20	NA[f]	3.00	13.00
1381-MWS08	3/2/1996	1504609.52	797903.21	2.00	9.76	7.17	3.00	13.00
1381-MWD08	5/17/1996	1504603.00	797900.19	2.00	10.08	7.38	43.00	48.00
1381-MWS09	3/3/1996	1504278.21	797469.30	2.00	7.14	7.45	7.50	12.50
1381-MWI09	2/27/1996	1504272.57	797478.96	2.00	6.77	7.22	30.00	35.00
1381-MWD09	3/2/1996	1504275.71	797474.19	2.00	7.05	7.14	44.80	49.80
1381-MWS10	2/28/1996	1504258.18	797671.13	2.00	10.55	7.97	3.00	13.00
1381-MWD10	2/28/1996	1504254.48	797674.51	2.00	10.84	7.97	44.50	49.50
1381-MWS11	3/3/1996	1504193.92	797178.06	2.00	10.86	8.08	4.00	14.00
1381-MWD11	3/4/1996	1504188.81	797182.42	2.00	10.96	8.33	44.50	49.50
1381-MWS12	3/13/1996	1505429.89	798083.35	2.00	9.62	6.88	3.00	13.00
1381-MWD12	3/12/1996	1505427.46	798088.61	2.00	9.60	6.96	44.00	49.00
1381-MWS13	3/12/1996	1505592.71	796624.10	2.00	10.91	8.24	2.50	12.50
1381-MWD13	3/19/1996	1505601.33	796626.89	2.00	10.85	8.62	44.50	49.50
1381-MWS14	3/12/1996	1506002.99	798494.39	2.00	8.24	8.23	4.00	14.00
1381-MWS15	5/20/1996	1506601.74	798915.22	2.00	10.44	7.79	3.00	13.00
1381-MWS16	5/18/1996	1505363.75	798696.50	2.00	10.08	7.81	3.00	13.00
1381-MWS17	5/18/1996	1504627.62	797234.30	2.00	8.51	8.70	4.80	14.80
1381-MWD17	5/17/1996	1504631.56	797229.40	2.00	8.48	8.72	45.50	50.50
1381-MWS18	5/19/1996	1504099.04	797568.54	2.00	9.16	6.65	2.50	12.50
1381-MWD19	5/19/1996	1505327.27	797182.71	2.00	7.86	5.29	44.50	49.50
1381-PZ01	NA	1504087.54	797374.32	2.00	10.29	8.12	2.50	12.50
1381-PZ02	NA	1504101.25	797389.02	2.00	10.39	7.66	2.50	12.50
1381-PZ03	NA	1506395.65	796890.28	2.00	11.75	8.97	2.50	12.50
LFMW-1[g] old	NA	1502840.56	797178.48	2.00	12.22	8.96	NA	NA
LFMW-4 old	NA	1504351.08	795173.14	NA	13.78	10.21	NA	NA
LFMW-5 old	NA	1506332.98	794385.85	4.00	8.46	7.31	NA	NA
LFMW-6 old	NA	1505631.78	793395.05	3.00	7.91	6.74	NA	NA
LFMW-7 old	NA	1505050.36	796313.77	NA	10.91	8.12	NA	NA
LFMW-A-S (LF-MWA01)	NA	1505400.64	795920.54	4.00	13.47	10.99	NA	NA
LFMW-A-D (LF-MWA02)	NA	1505393.49	795926.75	4.00	13.44	10.93	NA	NA
LFMW-B-S (MWB01)	NA	1505057.93	796286.79	4.00	11.83	9.35	NA	NA
LFMW-B-I (LF-MWB02)	NA	1505049.73	796293.74	4.00	11.59	9.25	NA	NA
LFMW-C-S (LF-MWC01)	NA	1504717.53	796627.80	4.00	11.24	8.83	NA	NA

TABLE 2.2 (Concluded)
MONITORING WELL/POINT CONSTRUCTION DETAILS
FACILITY 1381 RNS TS
CAPE CANAVERAL AIR STATION, FLORIDA

Well Location	Installation Date	Northing (ft)	Easting (ft)	Well ID (inches)	Datum Elevation (ft msl)[a/]	Ground Elevation (ft msl)	Screen Interval Top (ft bgs)[b/]	Screen Interval Bottom (ft bgs)
LFMW-C-I (LF-MWC02)	NA	1504711.76	796633.73	4.00	11.33	8.85	NA	NA
LFMW-C-D (LF-MWC03)	NA	1504705.82	796639.42	4.00	11.16	8.88	NA	NA
LFMW-D-S (LF-MWD01)	NA	1504397.11	796981.65	4.00	10.49	7.89	NA	NA
LFMW-D-D (LF-MWD02)	NA	1504391.41	796988.05	4.00	10.67	8.03	NA	NA
LFMW-E-S (LFE03)	NA	1503309.74	796348.25	4.00	12.26	9.32	NA	NA
LFMW-E-I (LFE02)	NA	1503306.69	796353.29	4.00	12.02	9.27	NA	NA
LFMW-E-D (LFE01)	NA	1503304.30	796358.15	4.00	11.87	9.01	NA	NA
LFMW-F-S	NA	1505359.72	795235.47	4.00	11.63	8.47	NA	NA
LFMW-G-S	NA	1504937.99	794839.62	4.00	11.84	9.16	NA	NA
LFMW-H-S	NA	1504672.65	794888.86	4.00	11.54	8.20	NA	NA
LFMW-H-I	NA	1504665.42	794886.38	4.00	11.18	8.41	NA	NA
LFMW-H-D	NA	1504658.13	794884.20	4.00	10.76	8.61	NA	NA
LFMW-I-S	NA	1504360.77	795091.71	4.00	14.93	11.91	NA	NA
LFMW-J-S	NA	1504052.61	795640.47	4.00	12.06	9.14	NA	NA
LFMW-K-S	NA	1503528.31	796256.00	4.00	10.50	8.11	NA	NA
1381MPI01	9/19/1996	1506558.32	796945.88	2.00	8.60	8.78	25.72	29.0
1381MPS01	9/20/1996	1506560.30	796946.63	2.00	8.53	8.78	8.72	12.0
1381MPI02	9/19/1996	1505618.13	796633.73	2.00	7.71	8.02	26.72	30.0
1381MPI03	9/20/1996	1504583.79	797439.54	2.00	7.93	8.15	29.72	33.0
1381MPI05	9/20/1996	1504201.84	797183.59	2.00	7.64	7.27	26.72	30.0
1381MPI06	9/20/1996	1504377.27	797422.15	2.00	8.86	9.05	26.72	30.0
1381MPI07	9/20/1996	1504856.55	796904.38	2.00	8.47	8.62	7.72	11.0
1381MPS07	9/20/1996	1504857.31	796903.08	2.00	8.44	8.62	23.72	27.0
1381MPI08	9/20/1996	1505008.58	796468.38	2.00	7.85	8.00	11.12	14.4
1381MPS08	9/21/1996	1505007.96	796469.56	2.00	7.99	8.00	26.72	30.0
1381MPI10	9/21/1996	1505420.81	799560.31	2.00	7.86	8.01	8.72	12.0
1381MPS10	9/21/1996	1505421.42	799559.17	2.00	7.91	8.01	29.72	33.0
1381MPI11	9/21/1996	1505374.70	798697.44	2.00	8.10	8.05	28.72	32.0
1381MPI13	9/21/1996	1505438.26	798073.35	2.00	7.06	7.15	26.72	30.0
1381MPI17	9/21/1996	1504636.20	797224.48	2.00	8.40	8.60	26.72	30.0
1381MPI18	9/21/1996	1505733.72	797588.70	2.00	6.12	6.44	27.72	31.0
1381MPI19	9/21/1996	1505998.92	798495.75	0.50	8.26	8.38	29.72	33.0
1381MPI20	9/24/1996	1504101.49	797576.40	0.25	6.01	6.01	26.50	27.0
1381MPI21	9/21/1996	1506631.68	798857.52	2.00	6.97	7.25	27.72	31.0
01-1381-PRMP	9/25/1996	1504644.76	797392.05	0.25	NP[h/]	6.41	7.50	8.00
02-1381-PRMP	9/25/1996	1504728.36	797444.07	0.25	NP	5.73	7.50	8.00

[a/] ft msl = feet above mean sea level.

[b/] ft bgs = feet below ground surface.

[c/] The number 1381 identifies wells/piezometers located within the perimeter of Facility 1381.

[d/] The letter S identifies wells/piezometers which are screened within the shallow portion of the surficial aquifer.

[e/] The letter D identifies wells/piezometers which are screened within the deep portion of the surficial aquifer.

[f/] NA = data not available.

[g/] The identifier LFMW indicates monitoring wells located in adjacent landfill site to the southwest of Facility 1381.

[h/] NP = not applicable.

for monitoring points screened in medium to fine sands layered above a silty/clayey sand layer located approximately 25 to 35 feet bgs. The locations of all installed shallow and intermediate monitoring points are shown on Figures 2.1 and 2.2, respectively. Monitoring point completion diagrams are provided in Appendix A.

2.3.1 Materials

Monitoring points were constructed of either flush-threaded, 2.0-inch-ID/0.5-inch-ID PVC casing and screen or with 0.25-inch-ID SS mesh screen implants connected to 0.25-inch-ID HDPE tubing (acting as riser material). Installed PVC screens were 3.3 feet in length and factory-slotted with 0.01-inch openings. Installed SS screens were 6 inches in length with a 0.0057-inch pore size. A sacrificial SS CPT or Geoprobe® tip was screwed into the PVC screen and served as the bottom cap of the monitoring point. Each monitoring point was fitted with a PVC top cap upon completion. Point construction materials were inspected for cleanliness prior to use. No glue or solvents were used with monitoring point materials.

2.3.2 Installation

With the exception of monitoring points 1381MPI19, 1381MPI20, 1381PRMP01, and 1381PRMP02, all monitoring points installed with the CPT were pressed into the ground on the outside of the 1.8-inch-OD CPT pushrods. To accomplish this, the CPT pushrods were threaded through the PVC screen/riser during push activities. A sacrificial tip was screwed into the bottom of the screen and pressed into the bottom of the CPT pushrod. As the pushrod was pressed into the ground, CPT pushrods were continuously threaded through PVC casing until the desired depth was reached. Upon removal of the pushrods, a fully-cased monitoring point remained. Stratigraphic data could not be collected with the CPT during monitoring point placement; however, CPT data were collected prior to monitoring point installation in order to select screen depth intervals. Monitoring point 1381MPI19 was installed with the CPT by threading the 0.5-inch-ID PVC screen and riser through the center of the 1.8-inch-OD CPT push rod until the desired depth was reached. Annular seals were not used in CPT push points because no annular space existed in the 2.0-inch boreholes.

Points installed with the Geoprobe® (1381MPI19, 1381PRMP01, and 1381PRMP02) were threaded through the 1-inch-OD pushrods during push activities. Monitoring point 1381MPI19 was installed using a van-mounted Geoprobe®. Monitoring points 01-1381-PRMP and 01-1381-PRMP were installed manually with a 30 pound rod hammer and lengths of Geoprobe® rod. As the push rods were pressed or hammered into the ground, the Geoprobe® pushrods were continuously added until the desired depth was reached. Upon removal of the pushrods, a finished monitoring point remained. Annular seals were not used in the Geoprobe®-installed monitoring points because minimal annular space remained after extraction of the Geoprobe® rods.

2.3.3 Development

Prior to sampling, newly-installed monitoring points were developed. Typically, well development removes sediment from inside the well casing and flushes fines, cuttings,

and drilling fluids from the sand pack and the portion of the formation adjacent to the well screen. Use of the CPT and Geoprobe® eliminates cuttings and drilling fluids. Therefore, development of monitoring points was primarily intended to minimize the amount of fine sediment that might accumulate in the casing.

Development of 2-inch-ID monitoring points was accomplished with disposable 3-feet by 1.5-inch-OD polyethylene bailers connected to disposable nylon rope. Development was continued until a minimum of 10 casing volumes of water was removed from the monitoring point. Development of 0.5-inch-ID PVC and 0.25-inch-ID SS monitoring points was accomplished using a peristaltic pump connected to either dedicated, disposable, 0.25-inch-ID HDPE sample tubing inserted into the 0.5-inch-ID points or to the 0.25-inch-ID HDPE riser tubing connected to the SS screens (at monitoring points 1381MPI20, 1381PRMP01 and 1381PRMP02). All groundwater derived from purging was collected in a portable, truck-mounted tank and transferred to holding tanks at the Trident Wastewater Treatment Plant (WWTP). The investigation-derived wastewater was then disposed of in accordance with Field Sampling Procedures, Volume 2, of the Program Wide Generic Work Plan for CCAS (Parsons ES, 1995).

2.3.4 At-Grade Completion

Eighteen monitoring points were completed with at-grade protective covers and a concrete pad that slopes gently away from the protective casing to facilitate runoff during precipitation. Because the points were finished at grade, the monitoring point top caps were not vented. Monitoring points 1381MPI20, 1381PRMP01, and 1381PRMP02 were not completed with a protective cover because of their remote location. Monitoring point 1381MPI20 was abandoned after sampling by pulling the riser tubing from the ground.

2.4 GROUNDWATER SAMPLING

This section describes the procedures used for collecting groundwater samples. In order to maintain a high degree of quality control (QC) during this sampling event, the procedures described in the site work plan (Parsons ES, 1996) and summarized in the following sections were followed.

2.4.1 Groundwater Sampling Locations and Analysis

As described on page 2-2, preliminary groundwater samples were collected from five wells prior to the September 1997 event to obtain baseline, pre-air sparging geochemical and water quality data. This initial sampling was performed on August 15, 1997. The five monitoring wells were resampled in September 1997, as described below.

Groundwater samples were collected from 18 site monitoring wells and 21 newly-installed monitoring points during the primary field event from September 19 through 24, 1996. Groundwater samples were analyzed by USEPA personnel in the field for DO, pH, conductivity, ORP, and temperature. Concentrations of free carbon dioxide, alkalinity, ferrous iron, hydrogen sulfide, and dissolved hydrogen were measured at a mobile, on-site laboratory run by USEPA personnel. Analyses for ammonia, chloride, methane/ethane/ethene, nitrate and nitrite, sulfate, TOC, aromatic VOCs, and CAHs were

performed at the USEPA NRMRL in Ada, Oklahoma. Groundwater sampling forms were used to document the details of the sampling event for each well and monitoring point and are included in Appendix C.

2.4.2 Preparation for Sampling

All equipment used for sampling was assembled and properly cleaned and calibrated (if required) prior to arriving in the field. Special care was taken to prevent contamination of the extracted samples from improperly cleaned equipment; therefore, all reusable equipment was thoroughly cleaned before and after field use and between uses at different sampling locations.

2.4.2.1 Equipment Decontamination/Calibration

All portions of sampling and test equipment that contacted the sample were thoroughly cleaned before use. The pump tubing, oil/water interface probe, and water level indicator were the only reusable pieces of equipment that came into contact with groundwater samples or that were used downhole. The following protocol was used to clean the water level indicator and oil/water interface probe:

- Wiped/rinsed with isopropanol;
- Wiped/rinsed with deionized water; and
- Air dried prior to use.

Generally, cleaning of the HDPE tubing used with the peristaltic pump was not required because a new length of tubing was dedicated to the well or monitoring point; however, when the HDPE tubing was reused, it was cleaned inside and out with acetone and rinsed with deionized water. Decontaminated tubing was dedicated to a particular monitoring point for development, purging, and sampling so that by the time sampling occurred, a large volume of groundwater had passed through the tubing. Any deviations from these procedures were documented on the groundwater sampling form.

All cleaning fluids were contained and transferred to truck-mounted tanks. The contents of the tanks were disposed of as described in Section 2.3.3. Field analytical equipment was calibrated according to the manufacturers' specifications prior to field use, and as required by the stability of the instrument.

2.4.2.2 Preparation of Location

Prior to proceeding with sampling, the area around the well or monitoring point was cleared of foreign materials, such as brush, rocks, and debris to prevent sampling equipment from inadvertently contacting debris around the monitoring well point. Location preparation also included an inspection of the integrity of the well or monitoring point. At this time, irregularities with the protective cover, cap, lock, external surface seal, internal surface seal, well identification, well datum, or pad were noted.

2.4.2.3 Water Level and Total Depth Measurements

Prior to removing any water from the well/point, the static water level was measured. An electronic water level probe or oil/water interface probe was used to measure the depth to groundwater below the well/monitoring point datum to the nearest 0.01 foot. After measurement of the static water level, the probe was lowered to the bottom of the well/point for measurement of total depth (recorded to the nearest 0.01 foot). Based on these measurements, the volume of water to be purged was calculated.

Static groundwater levels also were measured on September 26, 1996 at the conclusion of the field activities. Measurements were obtained at all permanent site wells and monitoring points.

2.4.3 Purging and Sample Collection

Well/monitoring point purging consisted of the removal of at least three casing volumes of water prior to sample collection, with the exception of groundwater monitoring points developed according to Section 2.3.3. and sampled immediately thereafter. At all 2-inch-ID monitoring points and wells requiring purging but not development, disposable bailers were used for purging. Once three casing volumes of water was removed from the well or monitoring point, a peristaltic pump with dedicated tubing was used to continue purging the well until the temperature and DO concentrations had stabilized, and if possible, until the purge water became clear. At all 0.5-inch ID PVC or 0.25-inch ID SS monitoring points, a peristaltic pump was used to purge the monitoring points.

A peristaltic pump was used to extract groundwater samples from each groundwater monitoring well/point. Where possible, purging and sampling constituted one continuous event, and there was no cessation of pumping prior to sample collection. For all monitoring points and wells, the dedicated HDPE tubing was lowered down the casing to approximately the middle of the screened interval. Sampling was accomplished by attaching the silicone peristaltic pump tubing directly to the top of the HDPE tubing inserted down the well, or directly to the top of the riser tubing if the monitoring point riser was constructed of HDPE. The samples were transferred directly into the appropriate sample containers. The water was carefully directed down the inner walls of each sample bottle to minimize aeration of the sample. Sample bottles for aromatic VOCs, CAHs, and methane/ethene/ethane were filled so that there was no headspace or air bubbles within the container. Table 2.3 lists the analyses performed on collected groundwater samples.

All groundwater derived from purging and sampling was contained in 5-gallon buckets and later transferred to truck-mounted tanks. The content of these tanks was disposed of as described in Section 2.3.3.

TABLE 2.3
ANALYTICAL PROTOCOL USED FOR GROUNDWATER, SURFACE WATER, SOIL, AND SEDIMENT SAMPLES
FACILITY 1381 RNA TS
CAPE CANAVERAL AS, FLORIDA

MATRIX Analyte	METHOD	FIELD (F) OR FIXED-BASE LABORATORY (L)
GROUNDWATER		
Total Iron	Colorimetric, Hach Method 8008	F
Ferrous Iron (Fe^{2+})	Colorimetric, Hach Method 8146	F
Ferric Iron (Fe^{3+})	Difference between total and ferrous iron	F
Sulfate	Colorimetric, Hach Method 8051	F
Nitrate	Titrimetric, Hach Method 8039	F
Nitrite	Titrimetric, Hach Method 8507	F
ORP	A2580B, direct-reading meter	F
Oxygen	Direct-reading meter	F
pH	USEPA method E150.1/SW9040, direct-reading meter	F
Conductivity	USEPA method E120.1/SW9050, direct-reading meter	F
Temperature	USEPA method E170.1, direct-reading meter	F
Carbon Dioxide	Titrimetric, Hach Method 1436-01	F
Alkalinity (Carbonate [CO_3^{2-}] and Bicarbonate [HCO_3^-])	F = Titrimetric, Hach Method 8221 L = USEPA Method 310.1	F L
Nitrate + Nitrite	USEPA Method 353.1	L
Chloride	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane, Ethane, Ethene	RSKSOP-147[a/]	L
Dissolved Organic Carbon	RSKSOP-102	L
VOCs (BTEX, CAHs, chloroform, chloromethane)	RSKSOP-148	L
SURFACE WATER		
VOCs (BTEX + CAHs)	RSKSOP-148	L
SOIL		
Total Organic Carbon	RSKSOP-102 & RSKSOP-120	L
Moisture	ASTM D-2216	L
VOCs (BTEX + CAHs)	RSKSOP-124, modified	L
SEDIMENT		
VOCs (BTEX + CAHs)	RSKSOP-124, modified	L

[a/] RSKSOP = Robert S. Kerr Laboratory (now NRMRL) Standard Operating Procedure.

2.4.4 Onsite Chemical Parameter Measurement

DO measurements were taken in a flow-through cell at the outlet of the peristaltic pump. DO concentrations were recorded after the readings stabilized, and in all cases represent the lowest DO concentration observed.

Because the electrical conductivity, pH, ORP, and temperature of the groundwater change significantly within a short time following sample acquisition, these parameters were measured in the field in the same flow-through cell used for DO measurements. Measured values were recorded on the groundwater sampling records (Appendix B).

2.4.5 Sample Handling

The fixed-base analytical laboratory (NRMRL) provided pre-preserved sample containers where appropriate. The sample containers were filled as described in Section 2.4.3, and the container lids were tightly closed. The samples were labeled as described in the work plan.

After the samples were sealed and labeled, they were transported to the onsite USEPA mobile laboratory. USEPA personnel packaged the samples to prevent breakage and leakage or vaporization from the containers. Sample shipment to the NRMRL and the associated chain-of-custody documentation was the responsibility of the USEPA/NRMRL field personnel.

2.5 SURFACE WATER SAMPLING

Six surface water samples (SURA through SURF) were collected from the two drainage canals located north and southwest of Facility 1381 (Table 2.4, Figure 2.1). The samples were collected at locations upgradient, within, and downgradient of potential groundwater and CAH discharge areas. Surface water samples were analyzed for the aromatic VOCs and CAHs (Table 2.3). The samples were collected directly into the sample bottle by placing the sample bottle in the drainage canal with the opening facing up and allowing the water to slowly fill the bottle. Sample handling proceeded as described in Section 2.4.5.

2.6 SEDIMENT SAMPLING

Six sediment samples (SEDA through SEDF) were collected from the bottom of the northwest/southeast flowing drainage canal at the same locations that surface water samples were collected (Table 2.4, Figure 2.1). The samples were collected in order to assess the potential accumulation in drainage canal sediments of fuel contaminants that may have migrated from Facility 1381 area. All sediment samples were collected from the uppermost 4 inches of the sediment column. The saturated sediments were immediately placed in analyte appropriate containers and handled according to procedures in Section 2.4.5.

TABLE 2.4
SURFACE WATER/SEDIMENT SAMPLING DETAILS
FACILITY 1381 RNS TS
CAPE CANAVERAL AIR STATION, FLORIDA

Sample Location	Sample Date	Northing (ft)	Easting (ft)	Ground Elevation (ft msl)[a/]
SURA	9/21/1996	1506802.27	798904.64	1.73
SEDA	9/21/1996	1506802.27	798904.64	0.73
SURB	9/21/1996	1506815.04	799698.45	1.71
SEDB	9/21/1996	1506815.04	799698.45	0.71
SURC	9/21/1996	1506820.44	797875.20	1.36
SEDC	9/21/1996	1506820.44	797875.20	0.36
SURD	9/21/1996	1504989.95	796439.41	1.85
SEDD	9/21/1996	1504989.95	796439.41	0.85
SURE	9/21/1996	1504232.38	797193.63	1.95
SEDE	9/21/1996	1504232.38	797193.63	0.95
SURF	9/21/1996	1503735.84	797717.46	2.04
SEDF	9/21/1996	1503735.84	797717.46	1.04

[a/] ft msl = feet above mean sea level.

2.7 DIRECT MEASUREMENT OF CHLORINATED ETHENES

As part of a comparative study sponsored by AFCEE and Oakridge National Laboratory (ORNL), direct measurements of chlorinated ethene concentrations in groundwater were obtained from existing monitoring wells with a DSITMS. The benefits of DSITMS include speed, accuracy, and elimination of all sampling waste. The unit was operated by personnel from the Chemical and Analytical Science Division of Oakridge National Laboratory.

The DSITMS method involves the use of an *in situ* water sampling module which is connected to the mass spectrometer by a capillary umbilical cord. VOCs from the water sample are transferred through the umbilical cord to the mass spectrometer, where they are analyzed. Analysis time is generally less than one minute. DSITMS, as opposed to other non-mass spectrometry analytical methods, is capable of immediately identifying unknown compounds. Quantitation is accomplished by comparing the integrated area for a one minute sample to a curve generated from an external standard calibration. Detection limits for the method range from mid-level parts-per-trillion to low parts-per-billion. Precision of replicate samples is typically within 10%.

DSITMS for analysis of organics in a variety of matrices has been developed at ORNL and licensed to Teledyne Electronic Technologies and Finnigan MAT. Sampling processes have been extensively field tested (>30 tests) at a variety of government and industrial sites. DSITMS instrumentation is now being used for a variety of applications. However, the further study of the accuracy of DSITMS at Facility 1381 is part of an AFCEE evaluation to evaluate this technology for use at natural attenuation sites involving CAH compounds. An analytical screening method (Method # 8265) for VOCs in gases, soils, and water that is based on DSITMS, has been developed and is in the process of being approved by the USEPA.

Thirty-one existing groundwater monitoring wells were sampled with the direct sampling spectrometer between September 19 and 21, 1996 and analyzed for TCE, dichloroehtene (DCE), and VC. Data were collected both prior to and after purging to evaluate the accuracy of the unit under different groundwater sampling scenarios. The DSITMS study compared differences between the analytical results for conventional groundwater samples collected during this field effort with those collected with the portable DSITMS device. This study was a research effort, and the results were not instrumental in the location of groundwater monitoring points due to the large array of currently existing monitoring wells. Therefore, the results are only briefly addressed in this report where appropriate.

2.8 AQUIFER TESTING

Slug tests were performed in wells 1381MWS09, 1381MWI09, 1381MWD09, 1381MWS12, and 1381MWD12 (Figure 2.1) to provide estimates for the hydraulic conductivity of the shallow and lower semi-confined aquifers in the vicinity of Facility 1381. Slug tests are single-well hydraulic tests used to estimate the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug testing can be performed using either a rising head or a falling head test. Only rising head tests were

used at this site. Detailed slug testing procedures are presented in the *Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater* (Wiedemeier *et al.*, 1995).

Data obtained during slug testing were analyzed using the computer program AQTESOLV® (Geraghty and Miller, Inc., 1994) and the methods of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions. The results of slug testing are presented in Section 3.3.2.2 and Appendix A.

2.9 SURVEYING

After completion of field work, the locations and elevations of new monitoring points were surveyed by Southeastern Surveying, a licensed land surveyor from Winterpark, Florida. The horizontal locations and elevations of the measurement datum (top of PVC well casing with the exception of wells 01- and 02-1381-PRMP), the ground surface adjacent to the well casing, and other site features (e.g., roads, surface water elevations in adjacent drainage canals, and buildings) were measured relative to state plane coordinates to the nearest 0.01 foot. Survey data are presented in Table 2.2 and Appendix A.

SECTION 3

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section describes the physical characteristics of Facility 1381. Existing site-specific data were reviewed and supplemented with data collected by Parsons ES in September 1996 to develop a synopsis of Facility 1381 physical characteristics. The following sections include data from the following sources:

- Phase I Report (ESE, 1984);
- RFA Report (USEPA, 1989);
- RFA Preliminary Assessment Report (Parsons ES, 1993);
- SI Report (Parsons ES, 1995a); and
- RFI Report (Parsons ES, 1997a).

3.1 TOPOGRAPHY, SURFACE HYDROLOGY, AND CLIMATE

CCAS is located on a barrier island between the Atlantic Ocean (to the east) and the Banana River. The topography of the site is relatively flat, with ground elevations ranging from approximately 5 to 8 feet above mean sea level (msl). Vertical relief in the area is limited to drainage canal shoulders that slope from the ground surface to the canal bed.

The cover types in the area immediately surrounding Facility 1381 consist mainly of mowed grass, pavement, and bare soils. Terrestrial vegetation in undeveloped portions of the study area consist primarily of periodically mowed coastal scrub. Aquatic and wetland habitats are present along the drainage canals to the southwest and north/northwest. Emergent wetlands are located near Central Control Road (to the north).

Typical of the barrier islands, a dune ridge just inland from the Atlantic Ocean beach provides a natural surface drainage divide. Very little runoff is naturally conveyed directly to the ocean; more than 90 percent flows into canals or percolates and flows westward as groundwater to the Banana River. The primary function of the drainage canal system at CCAS was land reclamation by lowering the water table. Therefore, in addition to providing drainage for the area, the drainage canal system exerts a major influence on shallow groundwater flow.

The drainage canal closest to Facility 1381 is located between the facility and the CCAS landfill, approximately 300 feet south/southwest of the facility. This canal flows from the southeast to the northwest. A second, westerly flowing canal is located approximately 2,500 feet north/northwest of the facility. Two surface water gauging stations and one stilling gauge are located in the canal southwest of Facility 1381 adjacent to the landfill. Surface water elevation measurements have been consistently lower than the surrounding groundwater elevations, indicating that groundwater discharges to surface water.

The climate of the barrier island is humid subtropical. Monthly mean high temperatures range from 69 degrees Fahrenheit (°F) in January to 87°F in July and August. Extreme high and low temperatures for the period from 1950 to 1980 were 99°F and 27°F, respectively. Rainfall is unevenly distributed throughout the year, with the period from June through October receiving distinctly more precipitation than the rest of the year. A 30-year (1950 to 1980) mean of the annual precipitation recorded at Patrick Air Force Base (AFB) approximately 15 miles south of CCAS, is 44.7 inches, with a mean annual evapotranspiration of 40.3 inches (ESE, 1991).

3.2 REGIONAL GEOLOGY AND HYDROGEOLOGY

Unconsolidated sediments in the CCAS area include undifferentiated marine sands overlying the Pleistocene-age Anastasia Formation and Caloosahatchee Marl Formation. The Anastasia Formation is a discontinuous layer of undifferentiated sands with silt and shells, and has not been documented in the Facility 1381 area. The Caloosahatchee Marl Formation consists primarily of calcareous sand and shell deposits with interbedded calcareous sand, silt, and clay deposits.

Underlying the Caloosahatchee Formation is the Tamiami Formation, which consists of limestones, marls, silty sands, and clay. The Tamiami Formation forms a shallow bedrock aquifer. The marine sands, clays, and limestones of the Hawthorn Formation underlie the Tamiami Formation. Interspersed limestone layers form localized aquifers within the Hawthorn Formation. Beneath the Hawthorn Formation is Ocala Formation limestone that extends to a depth of over 1,500 feet below msl. Figure 3.1 shows the generalized stratigraphic sequence for the area.

The unconfined surficial aquifer at CCAS includes the undifferentiated marine sands, the Anastasia Formation, the Caloosahatchee Marl, and the Tamiami Formation. The bottom of the surficial aquifer at CCAS is about 110 feet below msl, and is formed by clay units of the Hawthorn Formation (ESE, 1991).

The likelihood of contamination of the deep aquifers from sources in the shallow aquifer is thought to be minimal. This is because the deep aquifers in the region generally have a sufficient hydraulic pressure head to cause the potentiometric surface for the deep aquifers to be higher than the water table within the shallow unconfined aquifer, thus preventing downward vertical groundwater flow (and the associated migration of contaminants) from the shallow aquifer into the deeper units.

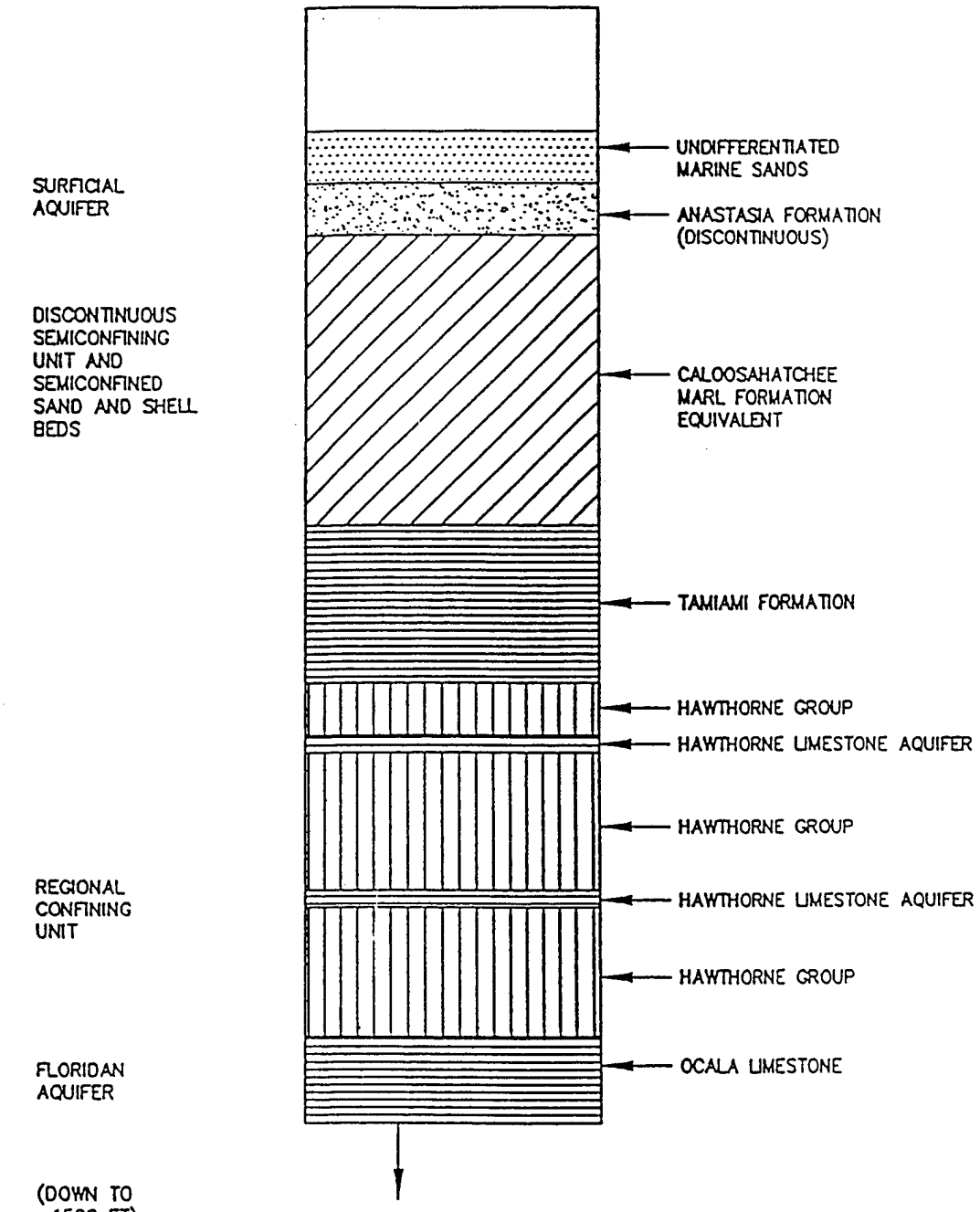


FIGURE 3.1

REGIONAL STRATIGRAPHIC SEQUENCE

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

ource: ESE, 1991

EE\729691\97DN0735, 10/03/97 at 14:59

3.3 SITE GEOLOGY AND HYDROGEOLOGY

3.3.1 Site Specific Geology

Geologic cross-sections A-A' and B-B' were developed using available lithologic information obtained from boreholes during the installation of shallow and deep monitoring wells at the site (Figures 3.2 and 3.3). Borehole logs are included in Appendix A. The cross sections indicate that from the ground surface to approximately 35 feet bgs, the sediments consist of poorly sorted, coarse to fine sands and shell material, with little or no silt and clay present. The shell material is generally much coarser than the accompanying sands, and may be present as distinct lenses or layers, or disseminated throughout the sand units.

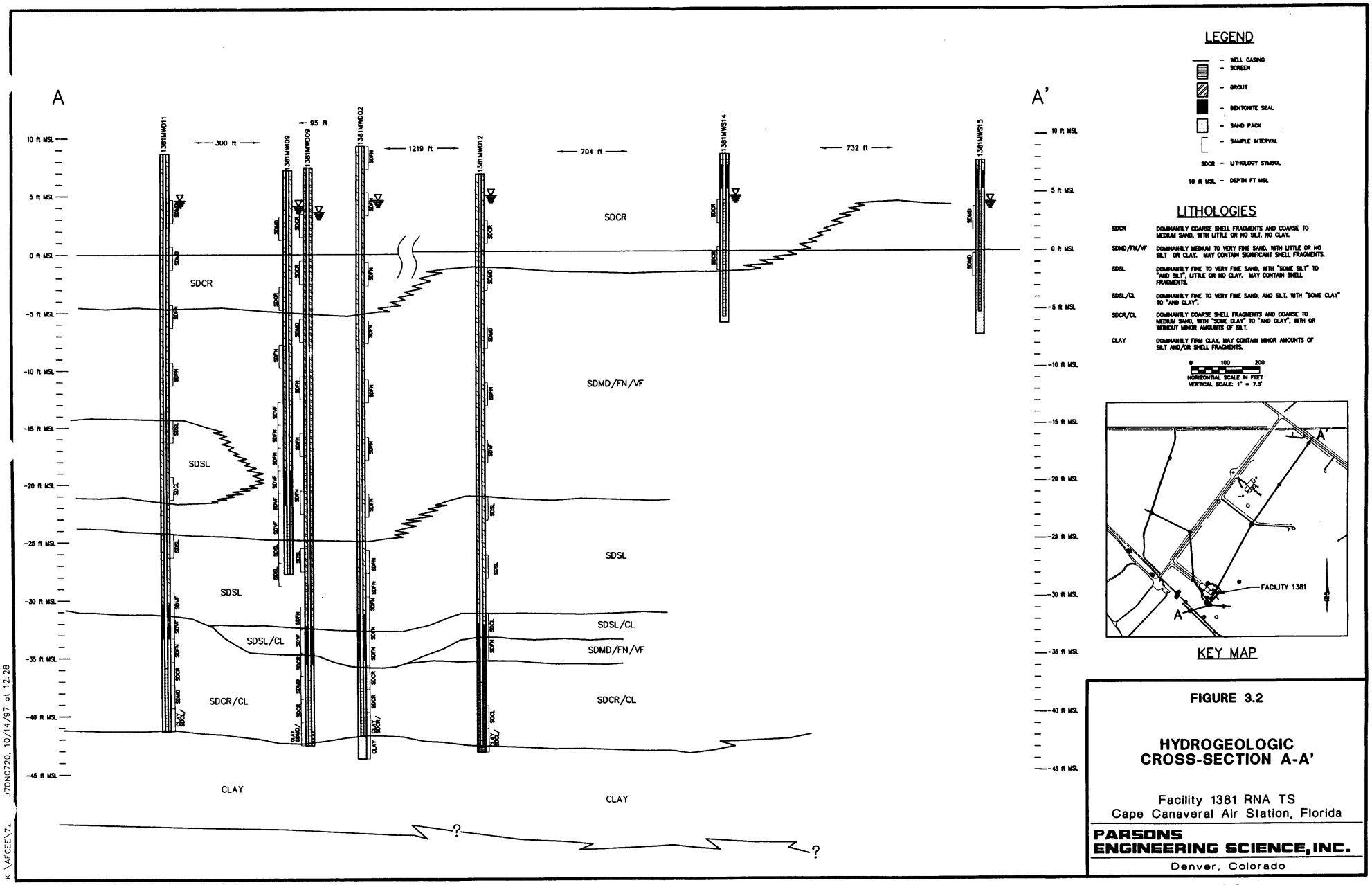
From approximately 35 feet bgs to approximately 50 feet bgs, sands show a decrease in grain size from the shallower depths, and the silt and clay content increases. Shell material is generally still present in varying percentages within this interval. Silt occurs as distinct layers or lenses within the sand and shell materials, or disseminated throughout some of the sandy layers. Clay to sand and clay begins to appear as distinct, but generally thin, discontinuous, firm layers and lenses within the upper portions of this interval, ranging in thickness from less than 1 inch to 6 inches or greater. These layers occur sporadically within the interval and are difficult to correlate from one boring to another. In the lower portion of the 35- to 50-foot interval, a mixture of sand, silty sand, coarse oyster shell fragments, and unconsolidated clay was penetrated in most of the borings at Facility 1381. The clay at this depth generally is not present as layers, but is disseminated throughout the sand/shell material as very loose layers or as "muddy" groundwater between shell fragments.

At depths ranging from 48.5 to 51 feet bgs, borings encountered a continuous clay unit underlying the entire Facility 1381 area. This is interpreted to be the uppermost significant clay layer within the Caloosahatchee Marl. This clay unit is dark greenish gray to dark brown, very firm, and contains little to no sand or shell material. The presence of wood fragments and other plant material suggests a terrestrial source for the clay. Based on split-spoon samples collected while drilling well 1381MWD04 to 80 feet bgs, this uppermost continuous clay unit appears to be approximately 9 feet thick. Deeper lithologic samples from the 1381MWD04 boring were predominantly sand, but indicated the presence of two 1-foot-thick clay layers between 74 and 79 feet bgs. Given the thickness, composition, and continuity of the upper 9-foot-thick clay layer, this unit probably acts as a significant confining layer within the Facility 1381 area.

3.3.2 Groundwater Hydraulics

3.3.2.1 Flow Direction and Gradient

As part of the RFI at Facility 1381, seven rounds of groundwater level measurements were completed between December 18, 1995 and June 19, 1996 for the purpose of identifying potential contaminant migration pathways. These groundwater elevation data were supplemented by groundwater elevations measured on September 26, 1996 as part of the RNA TS. Groundwater elevation data collected on September 26, 1996 are listed



LEGEND

- WELL CASING
- SCREEN
- GROUT
- BENTONITE SEAL
- SAND PACK
- SAMPLE INTERVAL

SDCR – LITHOLOGY SYMBOL

10 ft MSL – DEPTH FT MSL

LITHOLOGIES

SDCR	DOMINANTLY COARSE SHELL FRAGMENTS AND COARSE TO MEDIUM SAND, WITH LITTLE OR NO SILT, NO CLAY.
SDMD/FN/VF	DOMINANTLY MEDIUM TO VERY FINE SAND, WITH LITTLE OR NO SILT OR CLAY. MAY CONTAIN SIGNIFICANT SHELL FRAGMENTS.
SDSL	DOMINANTLY FINE TO VERY FINE SAND, WITH "SOME SILT" TO "AND SILT", LITTLE OR NO CLAY. MAY CONTAIN SHELL FRAGMENTS.
SDSL/CL	DOMINANTLY FINE TO VERY FINE SAND, AND SILT, WITH "SOME CLAY" TO "AND CLAY".
SDCR/CL	DOMINANTLY COARSE SHELL FRAGMENTS AND COARSE TO MEDIUM SAND, WITH "SOME CLAY" TO "AND CLAY", WITH OR WITHOUT MINOR AMOUNTS OF SILT.
CLAY	DOMINANTLY FIRM CLAY, MAY CONTAIN MINOR AMOUNTS OF SILT AND/OR SHELL FRAGMENTS.

0 100 200
HORIZONTAL SCALE IN FEET
VERTICAL SCALE: 1" = 7.5'

KEY MAP

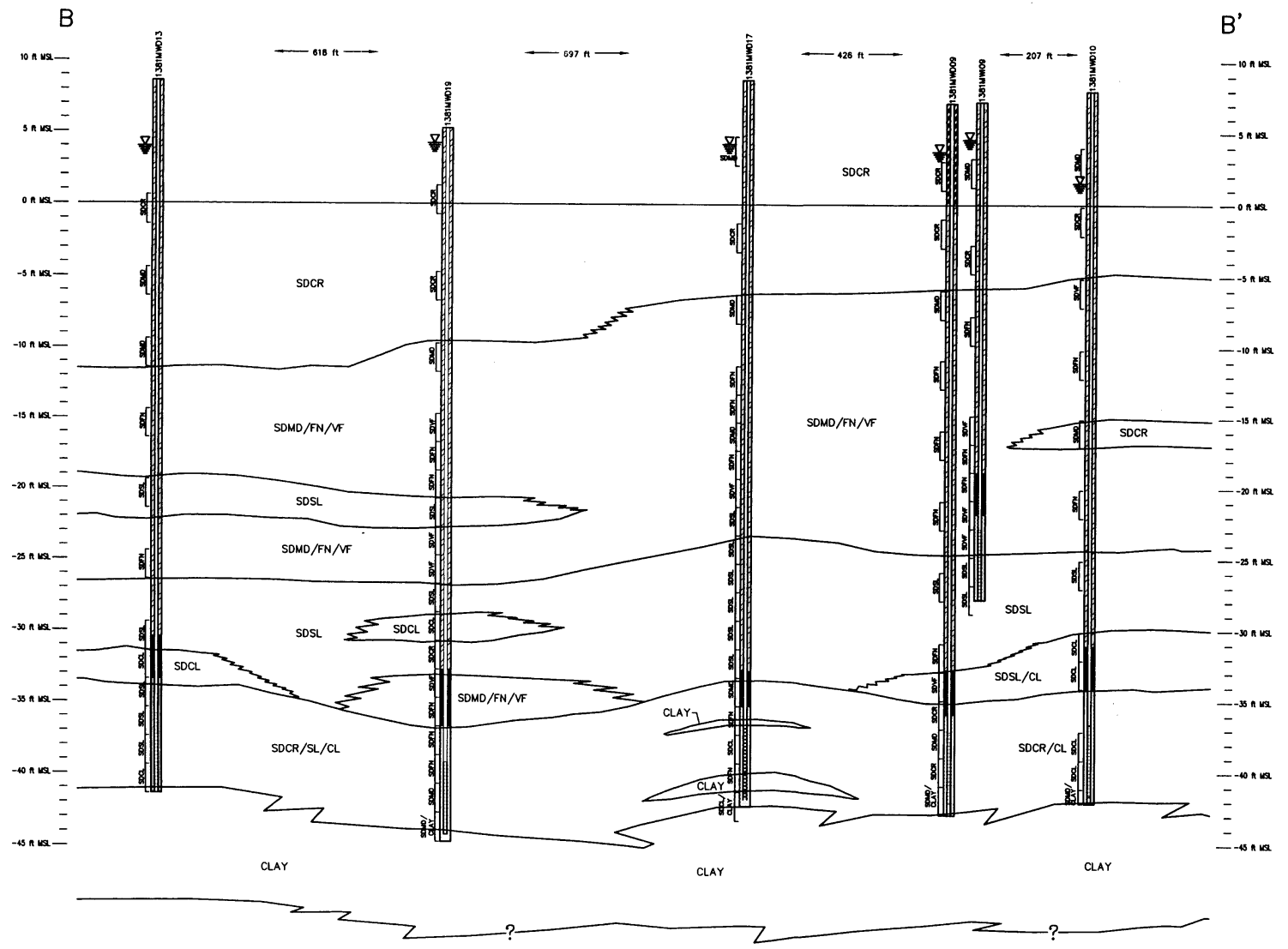
FIGURE 3.2

HYDROGEOLOGIC CROSS-SECTION A-A'

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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LEGEND

- WELL CASING
- SCREEN
- GROUT
- BENTONITE SEAL
- SAND PACK
- SAMPLE INTERVAL

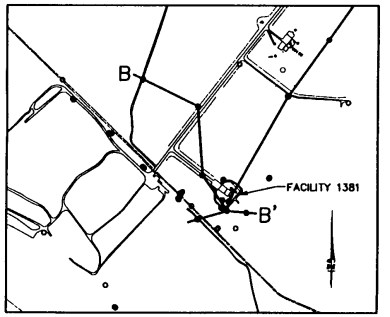
SDCR – LITHOLOGY SYMBOL

10 ft MSL – DEPTH FT MSL

LITHOLOGIES

SDCR	DOMINANTLY COARSE SHELL FRAGMENTS AND COARSE TO MEDIUM SAND, WITH LITTLE OR NO SILT, NO CLAY.
SDMD/FN/VF	DOMINANTLY MEDIUM TO VERY FINE SAND, WITH LITTLE OR NO SILT OR CLAY. MAY CONTAIN SIGNIFICANT SHELL FRAGMENTS.
SDSL	DOMINANTLY FINE TO VERY FINE SAND, WITH "SOME SILT" TO "AND SILT", LITTLE OR NO CLAY. MAY CONTAIN SHELL FRAGMENTS.
SDSL/CL	DOMINANTLY FINE TO VERY FINE SAND, AND SILT, WITH "SOME CLAY" TO "AND CLAY".
SDCR/CL	DOMINANTLY COARSE SHELL FRAGMENTS AND COARSE TO MEDIUM SAND, WITH "SOME CLAY" TO "AND CLAY", WITH OR WITHOUT MINOR AMOUNTS OF SILT.
CLAY	DOMINANTLY FIRM CLAY, MAY CONTAIN MINOR AMOUNTS OF SILT AND/OR SHELL FRAGMENTS.

0 100 200
HORIZONTAL SCALE IN FEET
VERTICAL SCALE: 1" = 7.5'



KEY MAP

FIGURE 3.3

HYDROGEOLOGIC CROSS-SECTION B-B'

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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in Table 3.1. Groundwater data collected during previous sampling events are reported in the RFI report (Parsons ES, 1997a).

Figure 3.4 shows the shallow groundwater elevations measured in shallow monitoring wells/points. Figure 3.5 shows the groundwater elevations measured in intermediate-depth monitoring wells/points. On the basis of these groundwater elevation maps, the drainage canal system has a major influence on groundwater flow in the vicinity of Facility 1381. As a result, groundwater flow directions and gradients in the surface aquifer at CCAS are variable and dependent on surface water depths in the drainage canals. One drainage canal is located approximately 300 feet south-southwest of the facility, and the other is located approximately 2,500 feet north-northwest of the facility. Both canals flow westward toward the Banana River, and merge into a single canal approximately 0.65 mile northwest of Facility 1381.

Groundwater elevations at shallow monitoring wells/points on September 26, 1996 ranged from 1.67 feet above msl (at monitoring well 1381MWS15 adjacent to the northern drainage canal) to 2.47 feet above msl (at monitoring well 1381MWS05 adjacent to the southwest drainage canal). As illustrated on Figure 3.4, an influential recharge zone exists along the wide grassy edges of the northeast/southwest access road leading to the to the Facility 1381 driveway. This recharge zone creates a northwest/southeast groundwater to north/south mound in a "tongue" shape that acts as a hydraulic wall and influences groundwater migration northeast from the source area. As described in Section 4, observed contaminant migration is to the northeast, toward the northern drainage canal. Groundwater data collected at landfill monitoring wells southwest of Facility 1381 indicate that groundwater from the landfill (across the southern drainage canal) flows to the northeast and discharges to the drainage canal separating Facility 1381 from the landfill area.

Groundwater elevations measured at intermediate wells/points on September 26, 1996 are shown on Figure 3.5. The data suggest the presence of a divide south of Facility 1381 that causes intermediate-depth groundwater south of the divide to migrate toward the south, and groundwater beneath Facility 1381 to migrate toward the north. Groundwater migration trends in deeper zones could only be evaluated near to Facility 1381 were deep groundwater wells are located. Deep groundwater data collected on September 26, 1996 (Figure 3.6) indicate the presence of a groundwater divide in approximately the same location as the intermediate-depth divide shown on Figure 3.5. Deep groundwater beneath Facility 1381 appears to migrate to the northeast. Previous groundwater elevation data collected from deep monitoring wells also support that groundwater migration at deep intervals is generally to the northeast (Parsons ES, 1997a).

On the basis of previous RFI data, an average northward gradient of 0.00059 foot/foot (ft/ft) was observed at the site (Parsons ES, 1997a). However, temporal variations in groundwater elevations and positions of the groundwater divide imply that gradients are transient. For instance, groundwater elevations measured between June 1996 and September 1996 decreased by approximately 2 feet. A groundwater gradient in April 1996 of 0.00053 ft/ft was calculated from data collected at wells along the observed flow path of the CAH plume (Section 4). A gradient of 0.00011 ft/ft was measured in September 1996 from data collected along this same path, during TS field activities. The

TABLE 3.1
GROUNDWATER ELEVATIONS (SEPTEMBER 1996)
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Well Location	Sample Collection Date	Datum Elevation (ft msl)[a]	Ground Elevation (ft msl)	Groundwater Elevation (ft btoc)[b]	Groundwater Elevation (ft msl)
1381[c]-MWS[d]01	9/26/1996	9.08	9.17	6.93	2.15
1381-MWD[e]01	9/26/1996	9.04	9.17	6.89	2.15
1381-MWS02	9/26/1996	9.14	9.30	NS[f]	NS
1381-MWD02	9/26/1996	9.15	9.30	NS	NS
1381-MWS03	9/26/1996	8.38	8.24	6.25	2.13
1381-MWD03	9/26/1996	8.30	8.24	6.25	2.05
1381-MWD04	9/26/1996	12.23	9.52	NS	NS
1381-MWS05	9/26/1996	11.18	7.68	8.71	2.47
1381-MWI05	9/26/1996	11.28	7.68	8.79	2.49
1381-MWD05	9/26/1996	10.32	7.68	8.19	2.13
1381-MWS06	9/26/1996	10.69	7.68	NS	NS
1381-MWS07	9/26/1996	10.20	NA[g]	8.01	2.19
1381-MWS08	9/26/1996	9.76	7.17	NS	NS
1381-MWD08	9/26/1996	10.08	7.38	NS	NS
1381-MWS09	9/26/1996	7.14	7.45	5.02	2.12
1381-MWI09	9/26/1996	6.77	7.22	4.17	2.60
1381-MWD09	9/26/1996	7.05	7.14	4.87	2.18
1381-MWS10	9/26/1996	10.55	7.97	NS	NS
1381-MWD10	9/26/1996	10.84	7.97	NS	NS
1381-MWS11	9/26/1996	10.86	8.08	8.68	2.18
1381-MWD11	9/26/1996	10.96	8.33	8.82	2.14
1381-MWS12	9/26/1996	9.62	6.88	7.60	2.02
1381-MWD12	9/26/1996	9.60	6.96	7.55	2.05
1381-MWS13	9/26/1996	10.91	8.24	9.09	1.82
1381-MWD13	9/26/1996	10.85	8.62	8.85	2.00
1381-MWS14	9/26/1996	8.24	8.23	6.30	1.94
1381-MWS15	9/26/1996	10.44	7.79	8.77	1.67
1381-MWS16	9/26/1996	10.08	7.81	8.19	1.89
1381-MWS17	9/26/1996	8.51	8.70	6.41	2.10
1381-MWD17	9/26/1996	8.48	8.72	6.35	2.13
1381-MWS18	9/19/1996	9.16	6.65	6.85	2.31
1381-MWD19	9/26/1996	7.86	5.29	NS	NS
1381-PZ01	9/26/1996	10.29	8.12	8.10	2.19
1381-PZ02	9/26/1996	10.39	7.66	NS	NS
1381-PZ03	9/26/1996	11.75	8.97	10.01	1.74
LFMW-1[g] old	9/26/1996	12.22	8.96	NS	NS
LFMW-4 old	9/26/1996	13.78	10.21	NS	NS
LFMW-5 old	9/26/1996	8.46	7.31	NS	NS
LFMW-6 old	9/26/1996	7.91	6.74	NS	NS
LFMW-7 old	9/26/1996	10.91	8.12	NS	NS
LFMW-A-S	9/26/1996	13.47	10.99	NS	NS
LFMW-B-S	9/26/1996	11.83	9.35	NS	NS
LFMW-C-S	9/26/1996	11.24	8.83	NS	NS
1381MPI01	9/26/1996	8.60	8.78	6.85	1.75

TABLE 3.1 (Concluded)
GROUNDWATER ELEVATIONS (SEPTEMBER 1996)
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Well Location	Sample Collection Date	Datum Elevation (ft msl)[a/]	Ground Elevation (ft msl)	Groundwater Elevation (ft btoc)[b/]	Groundwater Elevation (ft msl)
1381MPS01	9/26/1996	8.53	8.78	6.91	1.62
1381MPI02	9/26/1996	7.71	8.02	5.82	1.89
1381MPI03	9/26/1996	7.93	8.15	5.95	1.98
1381MPI05	9/26/1996	7.64	7.27	5.81	1.83
1381MPI06	9/26/1996	8.86	9.05	6.77	2.09
1381MPI07	9/26/1996	8.47	8.62	6.49	1.98
1381MPS07	9/26/1996	8.44	8.62	6.51	1.93
1381MPI08	9/26/1996	7.85	8.00	5.91	1.94
1381MPS08	9/26/1996	7.99	8.00	6.06	1.93
1381MPI10	9/26/1996	7.86	8.01	5.89	1.97
1381MPS10	9/26/1996	7.91	8.01	5.85	2.06
1381MPI11	9/26/1996	8.10	8.05	6.37	1.73
1381MPI13	9/26/1996	7.06	7.15	5.31	1.75
1381MPI17	9/26/1996	8.40	8.60	6.42	1.98
1381MPI18	9/26/1996	6.12	6.44	4.73	1.39
1381MPI19	9/26/1996	8.26	8.38	NA[h/]	NA
1381MPI20	9/26/1996	6.01	6.01	NA	NA
1381MPI21	9/26/1996	6.97	7.25	5.12	1.85
SURA	9/26/1996	1.73	1.73	NA	1.73
SURB	9/26/1996	1.71	1.71	NA	1.71
SURC	9/26/1996	1.36	1.36	NA	1.36
SURD	9/26/1996	1.85	1.85	NA	1.85
SURE	9/26/1996	1.95	1.95	NA	1.95
SURF	9/26/1996	2.04	2.04	NA	2.04
01-1381-PRMP	NA	6.41	6.41	NA	NA
02-1381-PRMP	NA	6.76	5.73	NA	NA

[a/] ft msl = feet above mean sea level.

[b/] ft btoc = feet below top of casing.

[c/] The number 1381 identifies wells/piezometers located within the perimeter of Facility 1381.

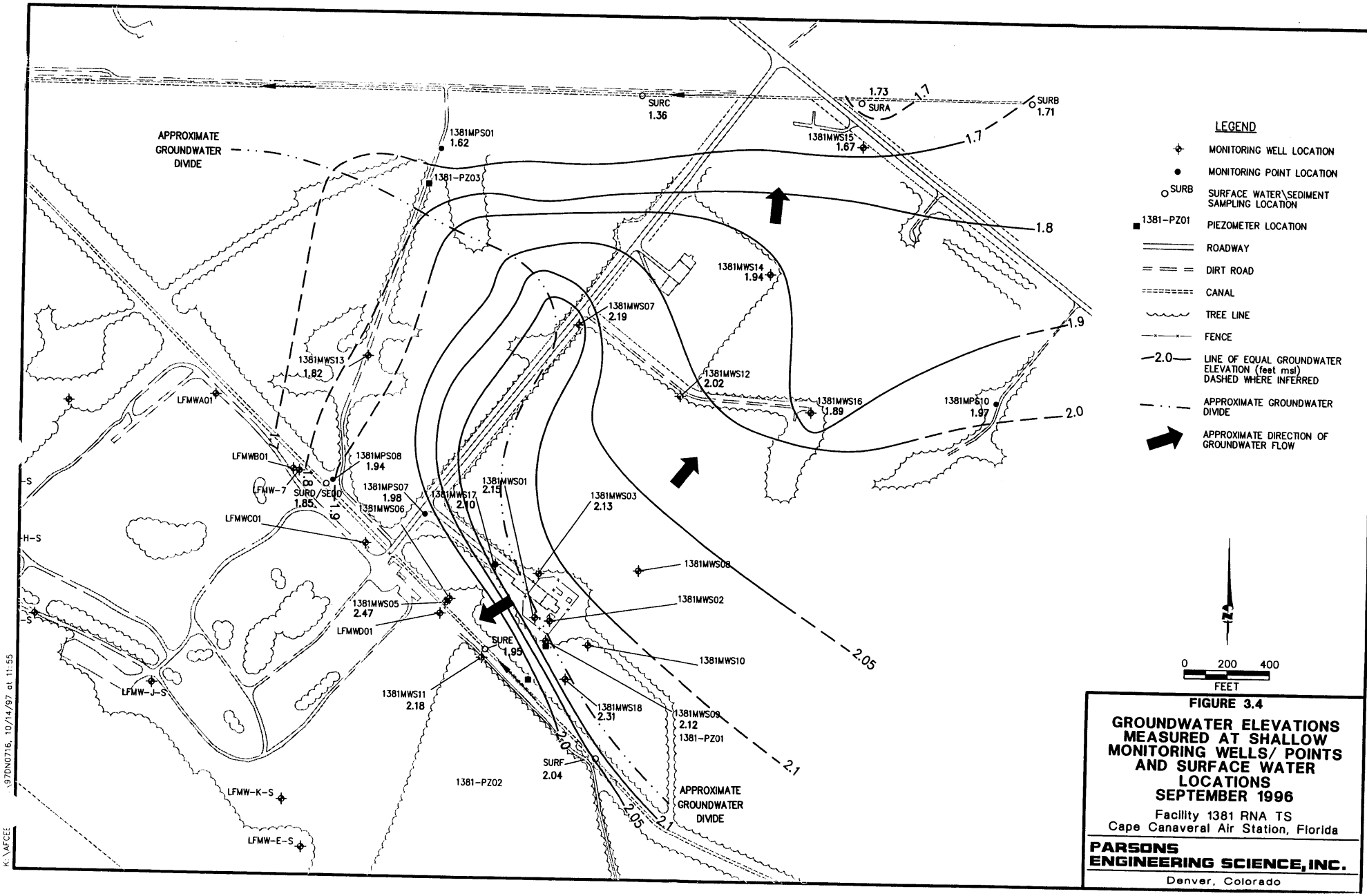
[d/] The letter S identifies wells/piezometers within the shallow portion of the surficial aquifer.

[e/] The letter D identifies wells/piezometers within the deep portion of the surficial aquifer.

[f/] NS = data not collected.

[g/] The identifier LFMW indicates monitoring wells located in adjacent landfill site to the southwest of Facility 1381.

[h/] NA = data not available or applicable.



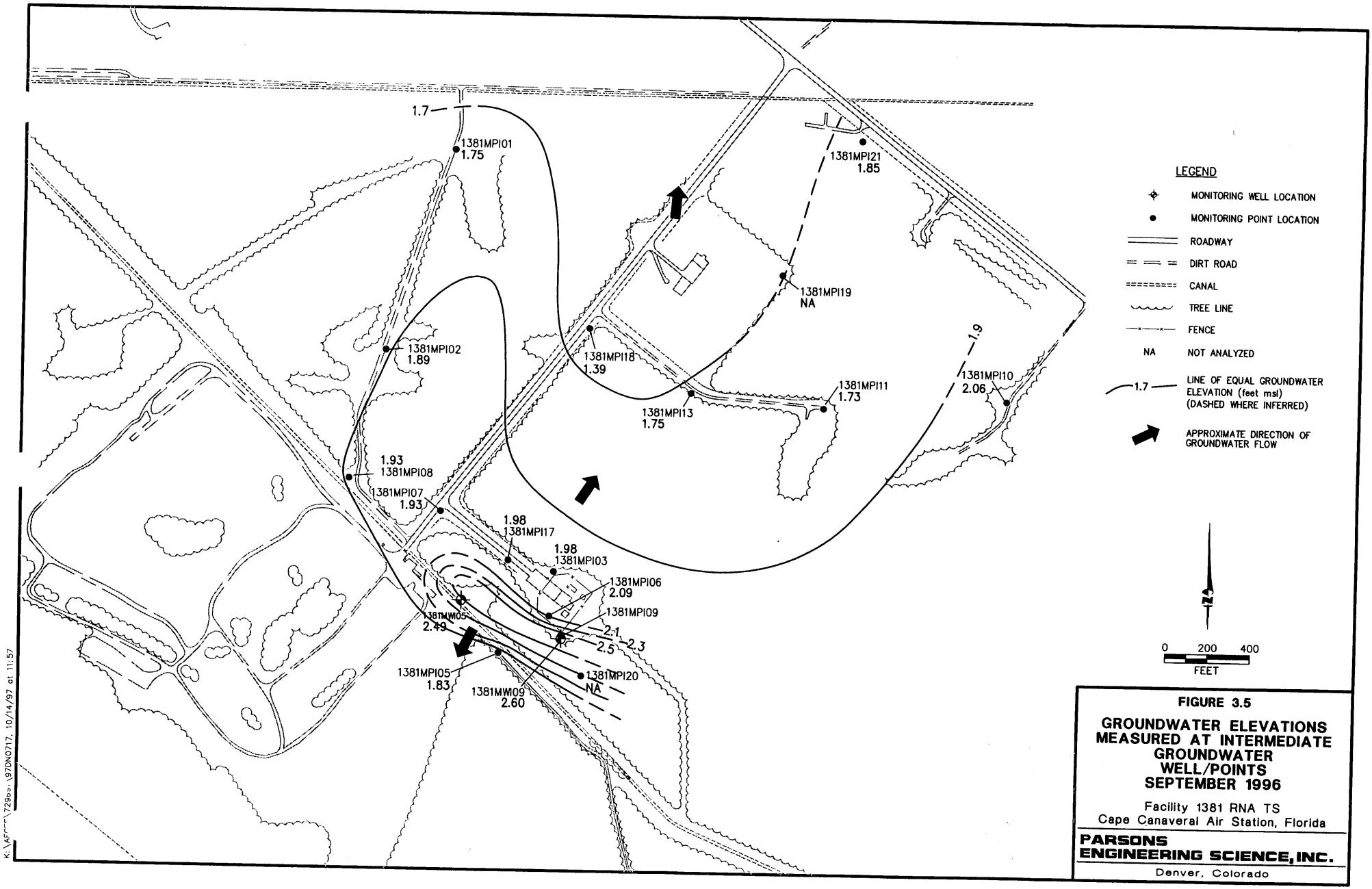
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FIGURE 3.4

GROUNDWATER ELEVATIONS MEASURED AT SHALLOW MONITORING WELLS/ POINTS AND SURFACE WATER LOCATIONS SEPTEMBER 1996

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado



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FIGURE 3.5

GROUNDWATER ELEVATIONS MEASURED AT INTERMEDIATE GROUNDWATER WELL/POINTS SEPTEMBER 1996

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

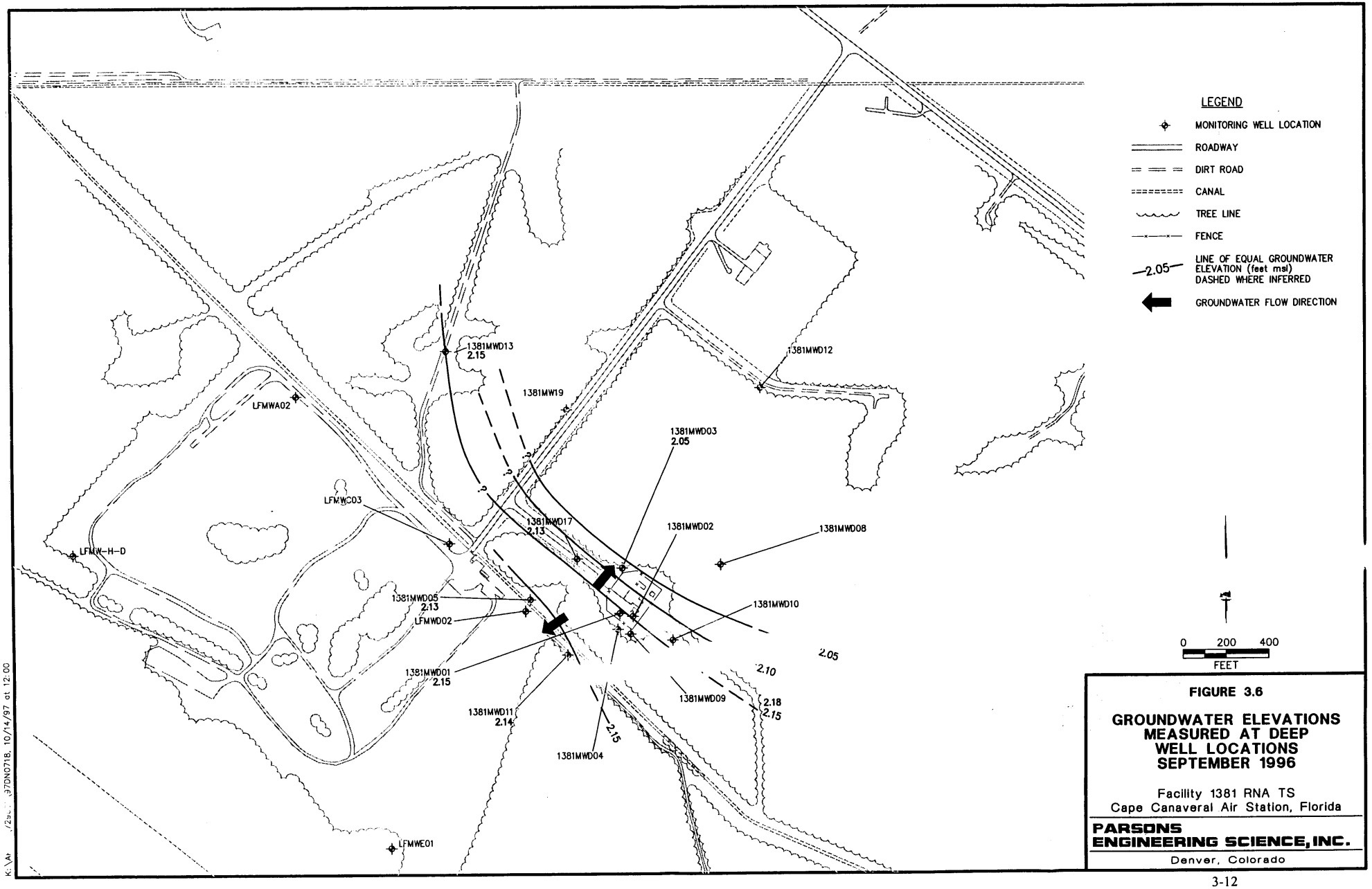


FIGURE 3.6

GROUNDWATER ELEVATIONS MEASURED AT DEEP WELL LOCATIONS SEPTEMBER 1996

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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larger gradients may be more representative of site conditions as described in Section 3.3.2.4.

Vertical gradients measured in September 1996 were variable in magnitude and direction. The maximum vertical gradient between shallow and intermediate wells/ points was 0.0428 ft/ft downward between monitoring well 1381MWS07 and monitoring point 1381MPI18. The minimum vertical gradient between shallow and intermediate wells/points was -0.00099 ft/ft upward between monitoring wells 1381MWS05 and 1381MWS05. The vertical gradients were downward at 9 of 16 shallow/intermediate nested well point locations. The maximum vertical gradient between intermediate and deep wells/points was 0.011 ft/ft downward between monitoring wells 1381MWI09 and 1381MWD09. The minimum vertical gradients between at intermediate and deep well/point depths was 0.0017 ft/ft downward between monitoring wells 1381MWI01 and 1381MWD09. Four of nine vertical gradients were upward between intermediate and deep monitoring well/point locations.

Previous data collected from monitoring well 1381MWD04 (screened from 72.5 to 77.5 feet bgs and below the Caloosahatche Marl clay layer) indicate a potentiometric surface above the land surface. This indicates a significant upward vertical gradient between the surficial aquifer and the underlying confined aquifer.

3.3.2.2 Hydraulic Conductivity

Parsons ES estimated the hydraulic conductivity at one shallow monitoring well (1381MWS09), one intermediate monitoring well (1381MWI09), and two deep monitoring wells (1381MWD09 and 1381MWD12) using rising head slug tests and the analysis method of Bouwer and Rice (1976), as described in Section 2.8. The calculated hydraulic conductivity for shallow monitoring well 1381MWS09 is 11.57 feet per day (ft/day). This hydraulic conductivity value is within the range of 10 to 20 ft/day estimated in pumping tests performed at the site as part of the RFI (Parsons ES, 1997a). The estimated hydraulic conductivity for intermediate monitoring well 1381MWI09 is 0.39 ft/day. The average hydraulic conductivity for deep monitoring wells 1381MWD09 and 1381MWD12) is 0.23 ft/day. Available slug test data are included in Appendix A. The hydraulic conductivity values measured at depth in the aquifer seem low with respect to the relatively sandy sediments observed at the same interval (Section 3.3.1). Rising lead slug test data reproduced in Appendix A exhibit linear head decreases rather than the asymptotic head decreases that are typical in sandy soils. Therefore, compromised well screens or damaged slug test equipment may have affected slug test results. Although low hydraulic conductivities are possible, hydraulic conductivities measured in deep zones at Facility 1381 are lower than the value of 88.7 feet/day measured for a similar site in the industrial area (Parsons ES, 1997a).

3.3.2.3 Effective Porosity

Because of the difficulty involved in accurately determining effective porosity, accepted literature values for the type of sandy soil comprising the shallow and intermediate monitoring well/point depths of the aquifer was used in groundwater velocity calculations. Walton (1988) gives ranges of effective porosity for fine to

medium sand of 0.1 to 0.3, for silt of 0.01 to 0.3, and for sandy clay of 0.03 to 0.2. Because coarse to medium grained sands may represent a preferred migration pathway at the site, an effective porosity of 0.25 was assumed to be representative of all depth intervals in the surficial aquifer.

3.3.2.4 Advective Groundwater Velocity

The advective velocity of groundwater in the direction parallel to groundwater flow is given by:

$$\bar{v} = \frac{K}{n_e}\frac{dH}{dL}$$

Where: $\bar{v}$ = Average advective groundwater velocity (seepage velocity) [L/T]

K=Hydraulic conductivity [L/T]

dH/dL=Gradient [L/L]

n_e=Effective porosity.

Assuming an average hydraulic conductivity of 15 ft/day; an effective porosity of 0.25; and a September 27, 1997 gradient of 0.00011 ft/ft, the average advective groundwater velocity across the site is 0.0065 ft/day (2.4 feet per year [ft/yr]). If it assumed that the maximum hydraulic conductivity is 88.7 ft/day, the effective porosity is 0.25, and the maximum groundwater gradient is 0.00059 ft/ft, then the maximum advective groundwater velocity across the site is 0.21 ft/day (77 ft/yr). Based on the 39-year operational history of Facility 1381, and the fact that the CAH plume has migrated approximately 2,500 feet to the northern canal (Section 4), the larger groundwater velocity (77 ft/yr) may be more representative of site conditions.

3.4 GROUNDWATER USE

Groundwater from beneath CCAS is not used for water supply purposes; the Air Station receives potable water from the city of Cocoa, Florida. When necessary, CCAS has access to a second potable water supply originating from the City of Melbourne and delivered by way of Patrick AFB. The groundwater at CCAS is currently classified as G-II by the Florida Department of Environmental Protection (FDEP) based on total dissolved solid levels, which permits possible future use (Parsons ES, 1997a). However, the potential for future development of CCAS groundwater as a potable water supply may be limited due to the potential for saline intrusion and the controlled land use at CCAS.

Within CCAS boundaries, there is only one well listed inside a one-mile radius of Facility 1381 (Parsons ES, 1997a). Currently, this well is not being used for water supply (drinking or industrial), and it is officially classified as unused. Based on the availability of a reliable public supply from the City of Cocoa and potential concerns over water quality, future use of this or other wells is not likely.

Within a four-mile radius, most of the 15 unused wells are accountable to the National Aeronautics and Space Administration (NASA) and were related to launch uses. According to records, three of the 15 wells have been plugged. The six wells classified for mosquito control use are located along the Banana River. These wells were originally artesian wells that were free flowing to prevent water stagnation. Two wells (one of which is plugged) are classified as unknown, one is for future use, and six (two or which are plugged) are for irrigation.

SECTION 4

CONTAMINANT DISTRIBUTION AND EVIDENCE FOR BIODEGRADATION

As discussed in Section 1, contaminants at Facility 1381 were introduced as a result of metal cleaning operations that involved acid and solvent dip tanks. The RFI performed by Parsons ES (1997) focused on defining the nature and extent of contamination at the site. Results of the RFI were used to supplement data collected during the field work phase of the RNA TS to evaluate and model the natural attenuation of CAHs.

4.1 RESULTS OF SOIL/SEDIMENT SAMPLING

4.1.1 Soil/Sediment Contamination Detected As Part of the SI and RFI

The previous characterization of soils at the Facility 1381 site during the RFI did not reveal any significant soil contamination. The only VOCs detected in soil at the site were toluene, methylene chloride, tetrachloroethylene (PCE), and chloroform at concentrations below screening levels of 0.2, 0.01, 0.03, and 0.02 mg/kg, respectively. The locations where the four contaminants were detected exhibited no obvious pattern of contaminant release. Therefore, any significant source of soil contamination that may be leaching to groundwater was not found. The following paragraphs summarize volatile organic soil sampling results from RFI soil sampling efforts.

As part of Phases 1, 4, and 5 of the RFI, soil samples were collected for headspace analysis with an organic vapor analyzer (OVA) during the installation of 27 groundwater monitoring wells, 3 piezometers, and 16 soil borings. Soil samples collected at the groundwater monitoring well and piezometer locations were generally collected at 5 foot intervals to a depth of 35 feet bgs, and then continuously below 35 feet bgs. Soil samples from soil borings were collected at the surface and immediately above the water table. Headspace OVA readings from all samples in the vadose zone ranged from 0 to 1.5 parts per million, volume per volume (ppmv), and therefore were not considered to be contaminated. Soil samples collected below groundwater were impacted by groundwater contamination and were not considered representative of soil conditions. However, the elevated OVA readings obtained in the saturated zone were used to optimize the vertical placement of monitoring well and piezometer screens in the aquifer. Headspace OVA readings are summarized in the RFI report (Parsons ES, 1997a). A total of 35 soil samples from 15 soil borings at depths from 0 to 4 feet bgs were collected during the RFI (Parsons ES, 1997a). Toluene, methylene chloride, PCE, and chloroform were detected at trace concentrations below 0.0078 milligrams per kilogram (mg/kg).

Eight sediment samples were collected at Facility 1381 between December 1995 and March 1996 as part of the RFI. Six of the eight sediment samples were collected along the northwest-flowing canal located 300 feet southwest of Facility 1381. A single sediment sample was collected at an unidentified pit located approximately 50 feet northwest of the northwest corner of the perimeter fence. The final sediment sample was collected immediately southeast of the equipment shed within the perimeter fence (location 1381SE01). Generally, sediment samples had low concentrations of VOCs, most of which was below reporting limits. The highest-detected VOC concentration in a sediment sample was 16,000 mg/kg of TCE from the upper 1 foot of sediment at sediment sampling location 1381SE01. The second highest CAH concentration measured at the site was 0.029 mg/kg of total 1,2-dichloroethene (1,2-DCE) at sampling location 1381SE03. This sampling station is located along the section of the southern drainage canal suspected to be receiving the highest concentrations of CAH on the basis of the observed groundwater plume. The low concentration of DCE measured at this location, and the extremely low concentrations of other CAHs detected in drainage canal sediments, suggests that CAHs are not accumulating within the canal sediments. Elevated CAH concentrations in sediments appear to be limited to the immediate vicinity of Facility 1381.

4.1.2 Soil/Sediment Contamination Detected As Part of the RNA TS

Soil sampling conducted during the field-work phase of the RNA TS was limited to eight soil samples collected at four locations (Figure 2.1). The soil samples were collected immediately above and below the water table at locations cross-gradient to the primary migration pathway of dissolved CAH contamination. CAHs and benzene, toluene, ethylebenzene, and xylenes (BTEX) were not detected in any soil samples. The primary purpose of the eight soil samples was to evaluate the TOC content in saturated and unsaturated portions of the aquifer (Section 4.2).

The six sediment samples collected as part of the RNA demonstration (SEDA through SEDF) were located along the northern and southern drainage canals (Figure 2.1). CAH and BTEX contamination were not detected in any sediment sample, confirming that contaminants migrating from Facility 1381 are not significantly impacting drainage canal sediments.

4.1.3 Total Organic Carbon in Soil

TOC concentrations are used to estimate the amount of organic matter sorbed to soil particles or trapped in the interstitial passages of a soil matrix. The TOC concentration in the saturated zone is an important parameter used to estimate the amount of contaminant that could potentially be sorbed to the aquifer matrix. Sorption results in retardation of the contaminant plume relative to the average advective groundwater velocity. In addition, TOC can be used as a gross indicator of organic compounds that are available as a source of carbon and electrons (i.e., substrate) for microbial activity.

Soil TOC concentrations were measured in eight samples that were collected at four locations in September 1996. Samples from each location were collected approximately 6 inches above and below the water table with a Geoprobe® Macrocore sampler. The

soils collected for TOC analyses consisted of fine to medium sand with shell fragments, which is generally the same soil type observed in the top 30 feet of the soil column across the site. Results for each sample are presented in Table 4.1. Soil TOC concentrations ranged from 0.034 percent to 0.823 percent, with the highest TOC concentration measured below the water table. Saturated TOC samples were consistently higher than vadose TOC samples collected at the same location. The TOC values measured at Facility 1381 are generally higher than values reported for other sites with sandy soils [e.g., the TOC data compiled by Wiedemeier *et al.* (1995) or in the RNA TS report for Site FT-17 at CCAS (Parsons ES, 1997b)]. High TOC values at Facility 1381 are plausible because of ocean overwash and natural deposition of organics in discrete intervals in the soil column prior to development at CCAS. In general, the soil TOC data for Facility 1381 suggests that, in addition to having sufficient organic carbon to retard organic contaminant migration, there may be enough organic matter to provide a suitable substrate for microbial activity.

TABLE 4.1
TOTAL ORGANIC CARBON CONCENTRATIONS IN SOIL AND SEDIMENT
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

LOCATION	PERCENT TOTAL ORGANIC CARBON
1381SB1A[a/]	0.045
1381SB1B[b/]	0.146
1381SB2A	0.034
1381SB2B	0.800
1381SB3A	0.039
1381SB3B	0.051
1381SB4A	0.327
1381SB4B	0.823

[a/] The suffix "A" represents a sample collected above the water table.
[b/] The suffix "B" represents a sample collected below the water table.

4.2 OVERVIEW OF CAH BIODEGRADATION

Groundwater quality data obtained during the RFI (Parsons ES, 1997a) and this TS indicate that CAH compounds are the primary contaminants of concern in groundwater; dissolved petroleum hydrocarbons are not present in sufficient concentrations in groundwater to be considered contaminants of concern. Therefore, this section focuses on natural attenuation (specifically biodegradation) of CAHs. Mechanisms for natural attenuation of CAHs include biodegradation, dispersion, dilution from recharge, sorption, and volatilization. Of these processes, biodegradation is the only mechanism working to transform contaminants into innocuous byproducts. When indigenous microorganisms work to bring about a reduction in the total mass of contamination in the subsurface without the addition of nutrients, these biodegradation processes are considered intrinsic.

Numerous studies have demonstrated the effective natural biodegradation of BTEX-related compounds, as summarized by Wiedemeier *et al.* (1995). In the past several years, numerous studies have demonstrated that chlorinated solvents also can be

transformed, directly or indirectly, by natural biological processes (e.g., Bouwer *et al.*, 1981; Miller and Guengerich, 1982; Wilson and Wilson, 1985; Nelson *et al.*, 1986; Bouwer and Wright, 1988; Little *et al.*, 1988; Mayer *et al.*, 1988; Arciero *et al.*, 1989; Cline and Delfino, 1989; Freedman and Gossett, 1989; Folsom *et al.*, 1990; Harker and Kim, 1990; Alvarez-Cohen and McCarty, 1991a, 1991b; DeStefano *et al.*, 1991; Henry, 1991; McCarty *et al.*, 1992; Hartmans and de Bont, 1992; McCarty and Semprini, 1994; Vogel, 1994). Biodegradation of CAHs, while similar in principle to biodegradation of BTEX, typically results from a more complex series of processes.

Microorganisms produce energy for life processes (i.e., cell production and maintenance) by oxidizing organic matter. Microorganisms facilitate the degradation of these organic compounds by transferring electrons from an electron donor to available electron acceptors in an oxidation/reduction (redox) reaction. The amount of energy that can be released when a reaction occurs or is required to drive the reaction to completion is quantified by the free energy of the reaction (Stumm and Morgan, 1981; Bouwer, 1994; Chapelle, 1993; Godsey, 1994; Mueller *et al.*, 1994). Microorganisms will facilitate only those redox reactions that will yield energy. By coupling the oxidation of the electron donor (e.g., fuel hydrocarbon compounds, native organic carbon, low-molecular weight CAHs) which requires energy, to the reduction of the electron acceptor (e.g., oxygen, nitrate, manganese, ferric iron, sulfate, carbon dioxide, and possibly CAHs), which yields energy, the overall reaction will yield energy.

In a pristine aquifer, native organic carbon is utilized as an electron donor and DO is utilized first as the prime electron acceptor. Where anthropogenic carbon (e.g., fuel hydrocarbons or low-molecular-weight CAHs) is present, it also will be utilized as an electron donor. After the DO is consumed, anaerobic microorganisms typically use native electron acceptors (as available) in the following order of preference: nitrate, ferric iron oxyhydroxide, sulfate, and finally carbon dioxide.

Whereas BTEX is biodegraded in essentially one step by acting as an electron donor/carbon source, CAHs may undergo several types of biodegradation involving several steps. CAHs may undergo biodegradation through three different pathways: use as an electron acceptor, use as an electron donor, or cometabolism, which is degradation resulting from exposure to a catalytic enzyme fortuitously produced during an unrelated process. At a given site, one or all of these processes may be operating, although at many sites the use of CAHs as electron acceptors appears to be the most likely. Because CAHs may be used as electron acceptors or electron donors (in competition with other acceptors or donors), isopleth maps showing the distribution of these compounds can provide evidence on the types and locations of biodegradation processes acting at a site. In order to provide a foundation for interpreting site data, the following sections present the major bioremediation processes that act upon CAHs.

4.2.1 Electron Acceptor Reactions (Reductive Dehalogenation)

Under anaerobic conditions, biodegradation of chlorinated solvents usually proceeds through a process called reductive dehalogenation. During this process, the halogenated hydrocarbon is used as an electron acceptor, not as a source of carbon, and a halogen atom (i.e., chlorine) is removed and replaced with a hydrogen atom. Figure 4.1 illustrates

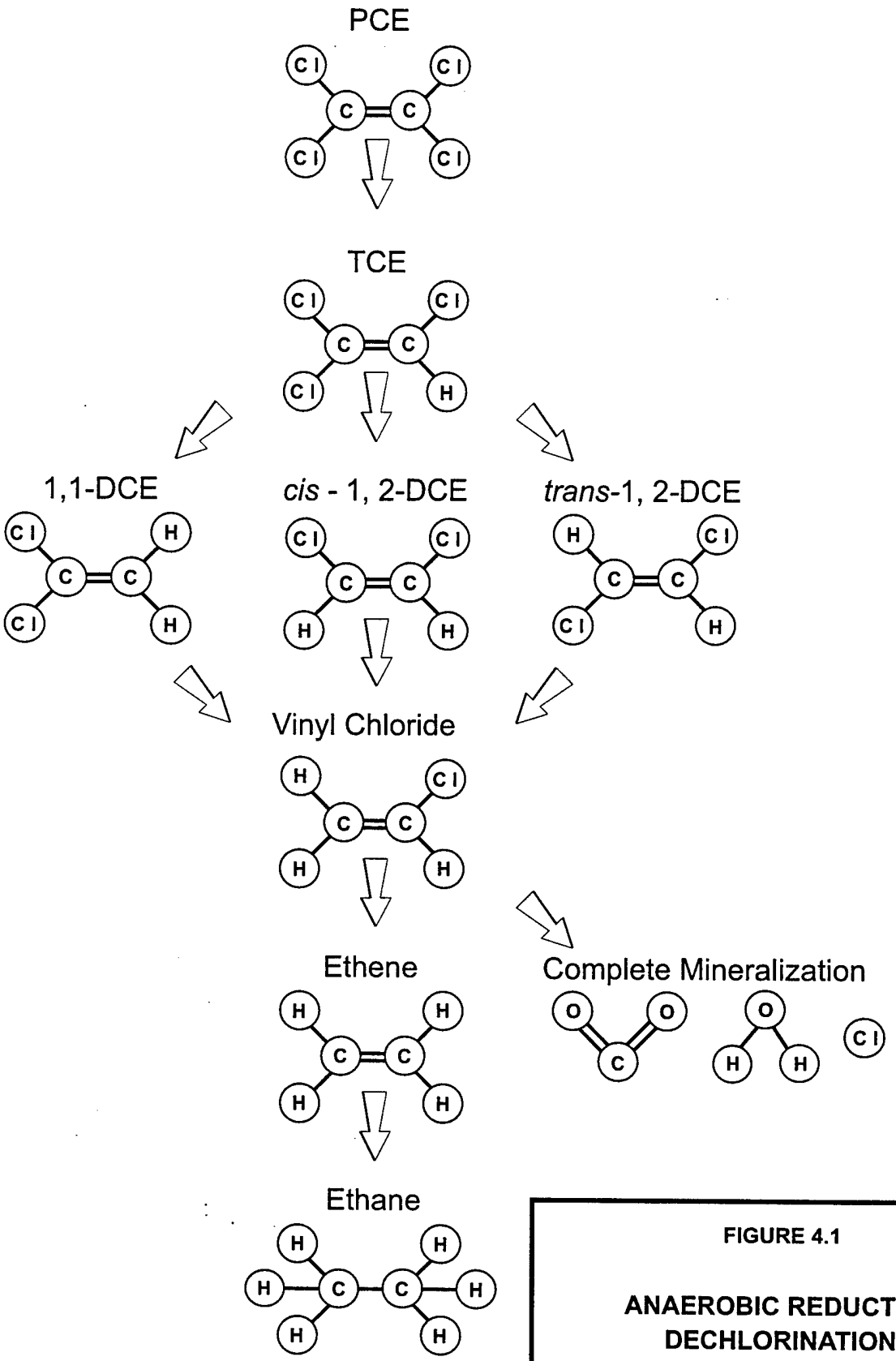


FIGURE 4.1

ANAEROBIC REDUCTIVE DECHLORINATION

Facility 1381 RNA TS
Cape Canaveral Air Station Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

the transformation of chlorinated ethenes via reductive dehalogenation. In general, reductive dehalogenation occurs by sequential dehalogenation from PCE to TCE to DCE to VC to ethene. Depending upon environmental conditions, this sequence may be interrupted, with other processes then acting upon the products. During reductive dehalogenation, all three isomers of DCE can theoretically be produced; however, Bouwer (1994) reports that under the influence of biodegradation, *cis*-1,2-DCE is a more common intermediate than *trans*-1,2-DCE, and that 1,1-DCE is the least prevalent intermediate of the three DCE isomers. Reductive dehalogenation of chlorinated solvent compounds is associated with the accumulation of daughter products and an increase in chloride.

Reductive dehalogenation affects each of the chlorinated ethenes differently. Of these compounds, PCE is the most susceptible to reductive dehalogenation because it is the most oxidized. Conversely, VC is the least susceptible to reductive dehalogenation because it is the least oxidized of these compounds. The rate of reductive dehalogenation also has been observed to decrease as the degree of chlorination decreases (Vogel and McCarty, 1985; Bouwer, 1994). Murray and Richardson (1993) have postulated that this rate decrease may explain the accumulation of VC in PCE and TCE plumes that are undergoing reductive dehalogenation.

In addition to being affected by the degree of chlorination of the CAH, reductive dehalogenation can also be controlled by the redox conditions of the site groundwater system. In general, reductive dehalogenation has been demonstrated under anaerobic nitrate- and sulfate-reducing conditions, but the most rapid biodegradation rates, affecting the widest range of CAHs, occur under methanogenic conditions (Bouwer, 1994). Dehalogenation of PCE and TCE to DCE can proceed under mildly reducing conditions such as nitrate reduction or iron (III) reduction (Vogel *et al.*, 1987), while the transformation of DCE to VC, or the transformation from VC to ethene requires more strongly reducing conditions (Freedman and Gossett, 1989; DeStefano *et al.*, 1991; DeBruin *et al.*, 1992).

Because CAH compounds are used as electron acceptors, there must be an appropriate source of carbon for microbial growth in order for reductive dehalogenation to occur (Bouwer, 1994). Potential carbon sources can include low-molecular-weight compounds (e.g., lactate, acetate, methanol, or glucose) present in natural organic matter, or fuel hydrocarbons.

4.2.2 Electron Donor Reactions

Under aerobic conditions some CAH compounds can be utilized as the primary substrate (i.e., electron donor) in biologically mediated redox reactions (McCarty and Semprini, 1994). In this type of reaction, the facilitating microorganism obtains energy and organic carbon from the degraded CAH. In contrast to reactions in which the CAH is used as an electron acceptor, only the least oxidized CAHs (e.g., VC, DCE, or chlorobenzene) may be utilized as electron donors in biologically mediated redox reactions.

For example, while Murray and Richardson (1993) write that microorganisms are generally believed to be incapable of growth using TCE and PCE, other less chlorinated

CAHs have been shown to be used as substrates. Davis and Carpenter (1990) describe the aerobic oxidation of VC in groundwater. McCarty and Semprini (1994) describe investigations in which VC and 1,2-dichloroethane (1,2-DCA) were shown to serve as primary substrates. These authors also document that dichloromethane has the potential to function as a primary substrate under either aerobic or anaerobic environments. Klier *et al.* (1996) describe aerobic mineralization of all three isomers of DCE. In addition, Bradley and Chapelle (1996) show evidence of oxidation of VC under iron-reducing conditions so long as there is sufficient bioavailable iron (III).

4.2.3 Cometabolism

When a CAH is biodegraded through cometabolism, it serves as neither an electron acceptor nor a primary substrate in a biologically mediated redox reaction. Instead, the degradation of the CAH is catalyzed by an enzyme or cofactor that is fortuitously produced by organisms for other purposes. The organism receives no known benefit from the degradation of the CAH; rather the cometabolic degradation of the CAH may in fact be harmful to the microorganism responsible for the production of the enzyme or cofactor (McCarty and Semprini, 1994).

Cometabolism is best documented in aerobic environments, although it potentially could occur under anaerobic conditions. Aerobic degrading pathways for chlorinated ethenes are illustrate in Figure 4.2. It has been reported that under aerobic conditions chlorinated ethenes, with the exception of PCE, are susceptible to cometabolic degradation (Murray and Richardson, 1993; Vogel, 1994; McCarty and Semprini, 1994). Vogel (1994) further elaborates that the cometabolism rate increases as the degree of dehalogenation decreases.

In the cometabolic process, TCE is indirectly transformed by bacteria as they use BTEX or another substrate to meet their energy requirements. Therefore, TCE does not enhance the degradation of BTEX or other carbon sources, nor will its cometabolism interfere with the use of electron acceptors involved in the oxidation of those carbon sources. It is likely that depletion of suitable substrates (BTEX or other organic carbon sources) may limit cometabolism of CAHs.

4.2.4 Behavior of Chlorinated Solvent Plumes

Chlorinated solvent plumes can exhibit three types of behavior depending on the amount of solvent, the amount of organic (native and/or anthropogenic) carbon in the aquifer, the distribution and concentration of natural electron acceptors, and the types of electron acceptors being utilized. Individual plumes may exhibit all three types of behavior in different portions of the plume. The different types of plume behavior are summarized below.

4.2.4.1 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

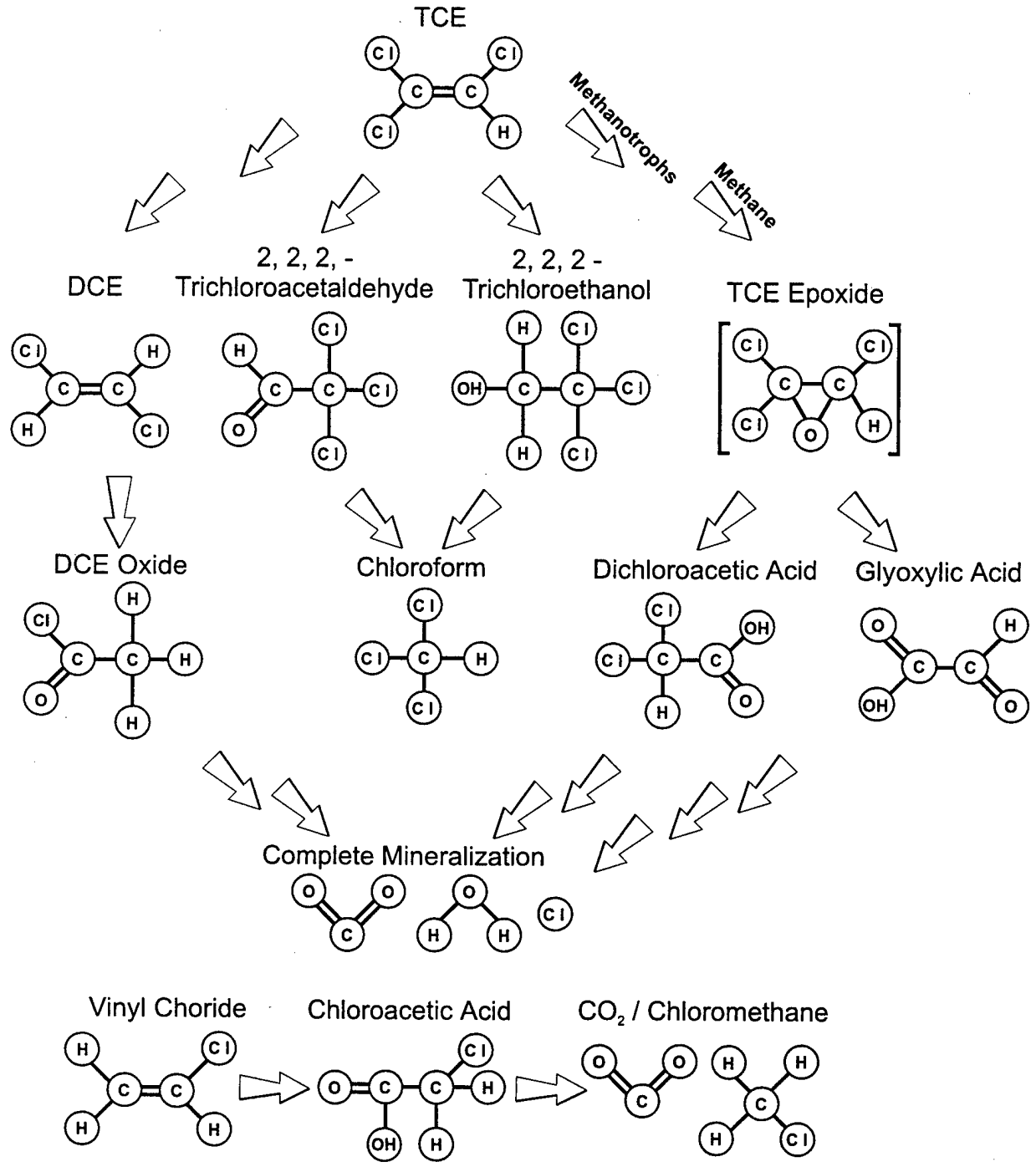


FIGURE 4.2

AEROBIC DEGRADATION

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Denver, Colorado

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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" [i.e., will they run out of chlorinated aliphatic hydrocarbons (electron acceptors) before they run out of primary substrate (anthropogenic carbon)]?

2) What is the role of competing electron acceptors (e.g., DO, nitrate, iron (III) and sulfate)?

3) Is VC oxidized, or is it reduced?

Type 1 behavior results in the rapid and extensive degradation of the highly chlorinated solvents such as PCE, TCE, or DCE.

4.2.4.2 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 dehalogenation (i.e., the primary substrate for microorganism growth is native organic carbon). When evaluating natural attenuation of a type 2 chlorinated solvent plume, the same questions as those posed in the description of 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 these compounds.

4.2.4.3 Type 3 Behavior

Type 3 behavior dominates in areas that are characterized by low concentrations of native and/or anthropogenic carbon, and concentrations of DO that are greater than 1.0 mg/L. Under these aerobic conditions reductive dehalogenation will not occur. Thus there is little or no removal of PCE and TCE. Biodegradation may proceed via the much slower process of cometabolism, but will be limited by the low concentrations of native or anthropogenic carbon. The most significant natural attenuation mechanisms for CAHs will be advection, dispersion, and sorption. However, VC can be rapidly oxidized under these conditions, DCE may be oxidized, and cometabolism may also occur.

4.2.4.4 Mixed Behavior

As mentioned above, 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 CAH plumes. For example, Wiedemeier *et al.* (1996b) describe a plume at Plattsburgh AFB, New York that exhibits Type 1 behavior in the source area and Type 3 behavior downgradient from the source. The best scenario involves a plume in which PCE, TCE, and DCE are reductively dehalogenated (Type 1 or Type 2 behavior), then VC is oxidized (Type 3 behavior), either aerobically or via iron reduction.

VC 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.

$$PCE \rightarrow TCE \rightarrow DCE \rightarrow VC \rightarrow \text{Carbon Dioxide}$$

In general, the TCE, DCE, and VC 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. VC is removed from the system much faster under these conditions than it is under VC-reducing conditions.

A less desirable scenario, but one in which all contaminants may be entirely biodegraded, involves a plume in which all CAHs are reductively dehalogenated via Type 1 or Type 2 behavior. VC is reduced to ethene, which may be further reduced to ethane or methane. The following sequence of reactions occur in this type of plume.

$$PCE \rightarrow TCE \rightarrow DCE \rightarrow VC \rightarrow \text{Ethene or Ethane}$$

This sequence has been investigated by Freedman and Gossett (1989). In this type of plume, VC degrades more slowly than TCE, and thus tends to accumulate.

4.3 DISTRIBUTION OF CAHS AND DAUGHTER PRODUCTS

One of the most straightforward methods for evaluating the site-specific occurrence and method(s) of biodegradation of CAHs is to measure the distribution of target CAHs and the products of biodegradation of those compounds. At the same time, it is also useful to measure the distribution of other contaminants that may be acting as sources of electron donors (e.g., BTEX).

Because reductive dehalogenation is the most common biodegradation reaction, a typical pattern (for example, as presented by Vogel, 1994) would have TCE (and or PCE) concentrations being highest in the source area, with elevated DCE concentrations (consisting mostly of *cis*-1,2-DCE) in and just downgradient of the source area. VC concentrations could be present along the entire plume length, with the highest VC concentrations likely to be found near the downgradient end of the CAH plume. If VC is also being reductively dehalogenated, dissolved ethene will also be present downgradient of the source area, in the vicinity of the highest concentrations of VC. Data collected at Facility 1381 are discussed in the following subsections.

4.3.1 Distribution of TCE in Groundwater

Groundwater analytical data collected as part of the RFI (November 1995 to May 1996) indicated that TCE contamination was limited to a 200-foot radius from Facility 1381. TCE was detected at seven wells (1381MWS01, 1381MWS02, 1381MWS09, 1381MWS17, 1381MWI09, 1381MWD02, and 1381MWD09) at concentrations ranging from 3.7 to 35,000 micrograms per liter (µg/L), with the maximum TCE concentration detected at monitoring well 1381MWS09. A TCE concentration of 65 µg/L at

monitoring well 1381MWD09 indicated that TCE had penetrated the full depth of the surficial aquifer in the source area. The relatively confined extent of the TCE groundwater plume suggests that TCE solvent releases were limited to the immediate vicinity of Facility 1381 and the suspected dumping location within the forested area immediately south of the facility (Parsons ES, 1997a).

Groundwater TCE contamination was detected in fewer monitoring wells during the field-work phase of the RNA TS (September 1996) than during in the RFI sampling event (December 1995 to May 1996). Analytical results for groundwater TCE contamination are summarized in Table 4.2 and shown on Figure 4.3. TCE concentrations at monitoring well 1381MWS09 increased from 35,000 µg/L to 39,400 µg/L between March and September 1996. This increase in TCE contamination indicates that a significant TCE source remains in soils at Facility 1381 and that seasonal variability of precipitation and groundwater levels affect the leaching rate of TCE from this source. The remaining three monitoring wells/points where TCE was detected include 1381MWI09, 1381MWD09, and 1381MPI06 at concentrations of 26.9, 6.6, and <1.0 µg/L, respectively. Similar to TCE concentrations measured during the RFI, TCE contamination in September 1997 was not detected in groundwater more than 200 feet from Facility 1381.

4.3.2 Distribution of PCE in Groundwater

PCE is not a compound of major concern at Facility 1381. During the RFI, PCE was detected at concentrations below 10 µg/L in two groundwater samples collected at HydroPunch® locations HP032 and HP042 (Parsons ES, 1997a); however, PCE was not detected in any monitoring well. During RNA field work (September 1996), PCE was detected at monitoring well 1381MWS09 at a concentration of 3.3 µg/L (Table 4.2, Figure 4.3). The exact source of PCE contamination is unknown. Because PCE was detected only in trace concentrations near the source area, the PCE contamination may have been a minor component or impurity of solvents used in cleaning operations and may have been intermittently released with TCE contamination.

4.3.3 Distribution of Trichloroethane (TCA) in Groundwater

Low detections of TCA suggest that TCA was used as a solvent at Facility 1381 during its operational history. 1,1,1-TCA concentrations were identified from the same three samples where PCE also was identified. During the RFI, 1,1,1-TCA detections were located south and southeast of Facility 1381 (1381HP032 and 1381HP042) at concentrations of 23 and 5.3 µg/L, respectively. In September 1996, 1,1,1-TCA was detected at 130 µg/L at monitoring well location 1381MWS09, which is near the RFI HydroPunch® locations referenced above. Analytical results for 1,1,1-TCA from September 1996 are summarized in Table 4.2.

A number of biological or chemical processes are known to destroy 1,1,1-TCA, including reductive dechlorination, hydrolysis, and dehydrohalogenation (Vogel, 1994). The reductive dechlorination of 1,1,1-TCA would lead to the intermediate byproduct 1,1-DCA, which was detected at 10 wells/points at the site. Small concentrations of 1,1,1-TCA may have also been transformed by hydrolysis [a substitution reaction caused by the reaction of contaminant with water or a water ion component, and a halogen substituent is

TABLE 4.2
CHLORINATED ALIPHATIC COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Sample Location	Sample Collection	PCE (mg/L)[w]	TCE (mg/L)	Cis-1,2-DCE (mg/L)	Trans-1,2-DCE (mg/L)	1,1-DCE (mg/L)	1,1-DCA (mg/L)	1,2-DCA (mg/L)	1,1,1-TCA (mg/L)	Vinyl Chloride (mg/L)
1381MWS01	9/19/1996	ND	239	2400	9.1	14.6	4.1	ND	ND	210
1381MWS03	9/20/1996	ND	ND	2590	15.1	12.6	4.6	ND	ND	836
1381MWD03	9/23/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWS05	9/20/1996	ND	< 1.0	43.7	1.8	ND	< 1.0	ND	ND	51.3
1381MWI05	9/20/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWS07	9/20/1996	ND	ND	10.2	ND	ND	ND	ND	ND	1.3
1381MWS09	9/19/1996	3.3	39400	4120	25.1	238	26.4	< 1.0	130	240
1381MWI09	9/19/1996	ND	26.9	1210	145	6.1	< 1.0	ND	ND	795
1381MWD09	9/19/1996	ND	6.6	3.6	ND	ND	ND	ND	ND	1.6
1381MWS11	9/20/1996	ND	ND	< 1.0	ND	ND	< 1.0	ND	ND	ND
1381MWS12	9/21/1996	ND	ND	751	10.8	1.4	1.4	ND	ND	510
1381MWD12	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWS13	9/21/1996	ND	ND	4.6	ND	ND	ND	ND	ND	< 1.0
1381MWS14	9/21/1996	ND	ND	65.6	< 1.0	ND	ND	ND	ND	2.3
1381MWS15	9/21/1996	ND	ND	130	< 1.0	ND	ND	ND	ND	16.3
1381MWS16	9/21/1996	ND	ND	2.1	ND	ND	ND	ND	ND	1.2
1381MWS17	9/20/1996	ND	ND	901	21.2	2.3	2.6	ND	ND	1040
1381MWS18	9/19/1996	ND	< 1.0	ND	ND	ND	ND	ND	ND	ND
1381MPS01	9/19/1996	ND	ND	3.6	ND	ND	ND	ND	ND	ND
1381MPI01	9/21/1996	ND[b/]	ND	ND	ND	ND	ND[a]	ND	ND	ND
1381MPI02	9/21/1996	ND	ND	< 1.0	ND	ND	ND	ND	ND	ND
1381MPI03	9/23/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI05	9/24/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI06	9/24/1996	ND	< 1.0	4.7	ND	ND	ND	ND	ND	1.6
1381MPS07	9/23/1996	ND	ND	78.3	2.3	ND	ND	ND	ND	39.5
1381MPI07	9/23/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 4.2 (Concluded)
CHLORINATED ALIPHATIC COMPOUNDS DETECTED IN GROUNDWATER AND SURFACE WATER
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Sample Location	Sample Collection	PCE (mg/L)[a/]	TCE (mg/L)	Cis-1,2-DCE (mg/L)	Trans-1,2-DCE (mg/L)	1,1-DCE (mg/L)	1,1-DCA (mg/L)	1,2-DCA (mg/L)	1,1,1-TCA (mg/L)	Vinyl Chloride (mg/L)
1381MPS08	9/23/1996	ND	ND	26.6	< 1.0	ND	< 1.0	ND	ND	13.8
1381MPI08	9/24/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPS10	9/24/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI10	9/24/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI11	9/24/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI13	9/24/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI17	9/23/1996	ND	ND	< 1.0	ND	ND	ND	ND	ND	ND
1381MPI18	9/24/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI19	9/23/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI20	9/25/1996	ND	ND	4.4	ND	ND	ND	ND	ND	1.6
1381MPI21	9/24/1996	NA[c/]	NA	NA	NA	NA	NA	NA	NA	NA
SURA	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURB	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURC	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURD	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURE	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURF	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
PRMP01	9/25/1996	ND	< 1.0	1210	11	4.6	2.4	ND	ND	767
PRMP02	9/25/1996	ND	< 1.0	1760	17.6	5.5	ND	ND	ND	1350

[a/] mg/L = micrograms per liter.
[b/] ND = not detected.
[c/] NA=not applicable.

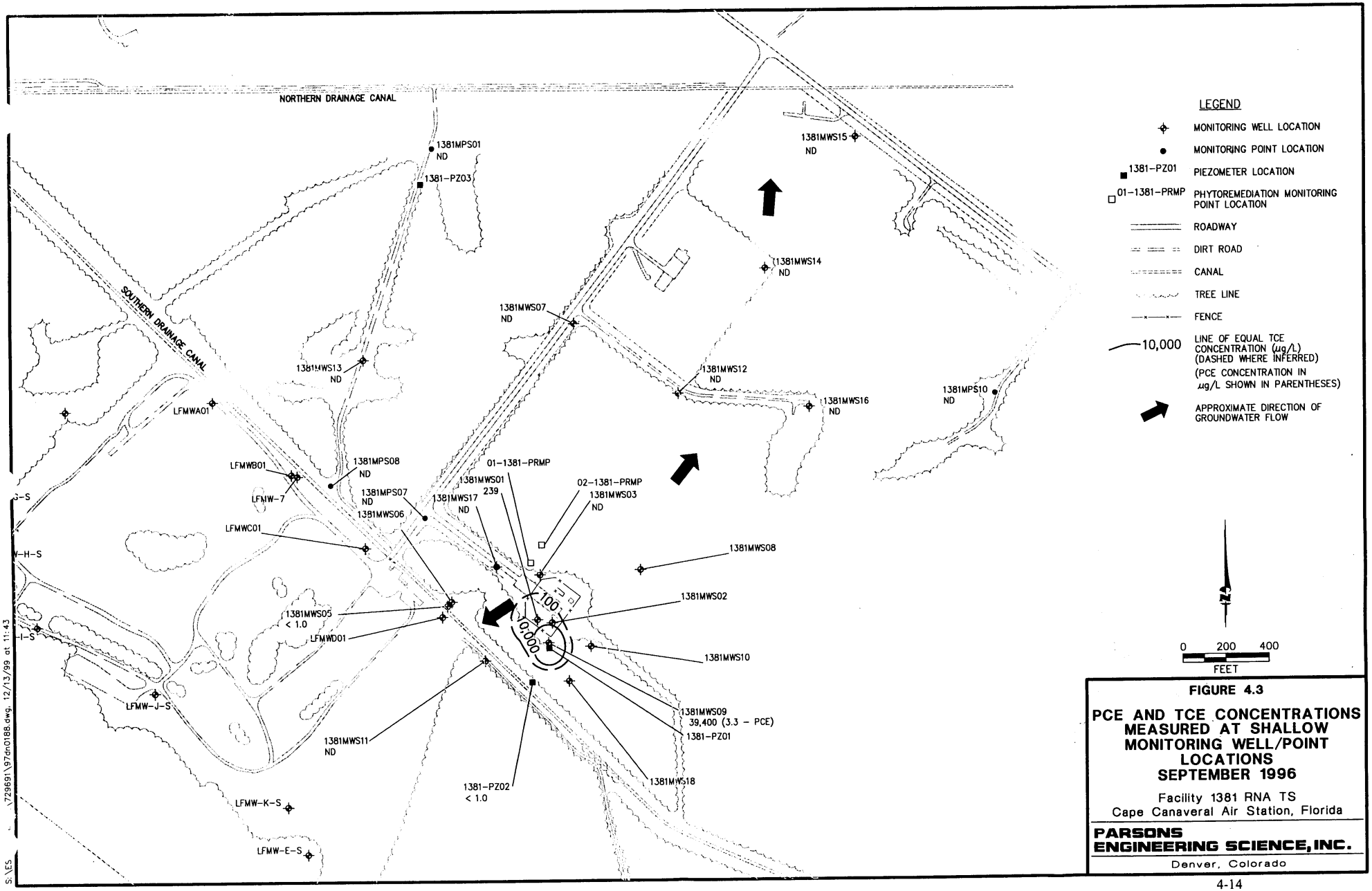


FIGURE 4.3

PCE AND TCE CONCENTRATIONS MEASURED AT SHALLOW MONITORING WELL/POINT LOCATIONS SEPTEMBER 1996

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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replaced with a hydroxyl (OH-) group] to form halogenated alchohols or by dehydrohalogenation (an elimination reaction that removes a halogen and adjacent hydrogen to form an ethene compound) to form 1,1-DCE. Overall, the impact of TCA contamination relative to other CAHs is minor and limited to the approximate vicinity of the source area.

4.3.4 Distribution of DCE in Groundwater

The extent of groundwater DCE contamination measured during the RNA field study in September 1996 closely reflected previous DCE plume characteristics identified during the RFI. To briefly summarize the RFI results, DCE was the most widespread CAH detected in groundwater, comprising a plume oriented along a southwest/northeast axis approximately 3,200 feet in length. DCE data collected during the RNA TS indicated that the general shape of the DCE plume remained stable, but DCE concentrations in most groundwater wells increased during the 6 months between field sampling conducted for the RFI and the RNA TS. The compounds 1,1-DCE, *trans*-1,2-DCE, and *cis*-1,2-DCE increased in concentration at 21 of 29 groundwater monitoring wells between the RFI and RNA sampling events. This increase in DCE concentrations may be the result of temporarily drier site conditions, resulting in lower groundwater levels, diminished leaching, and decreased potential for the dilution of contaminant concentrations by recharge. Figure 4.4 shows the dissolved DCE concentrations measured in September 1996. The concentration ranges of the individual DCE isomers that were measured at shallow monitoring wells in September 1996 are as follows: <1 to 4,120 µg/L for *cis*-1,2-DCE, <1 to 145 µg/L for *trans*-1,2-DCE, and 1.4 to 238 µg/L for 1,1-DCE.

DCE isomers detected at intermediate and deep monitoring well/point locations were limited to the source area at concentrations of up to 1,361 µg/L. DCE does not appear to be migrating from the source area in either intermediate (25 to 25 feet bgs) or deep (45 to 50 feet bgs) intervals.

It is worth noting that monitoring well 1381MWS09 contained the maximum concentrations of both 1,1,1-TCA and 1,1-DCE, suggesting that the abiotic dehydrohalogenation of 1,1,1-TCA (Section 4.3.2) is occurring. However, the reductive dechlorination of TCE likely is the major source of DCE at the site.

4.3.5 Distribution of VC in Groundwater

VC is widespread at the site and was detected in most groundwater samples collected as part of the RFI and RNA studies. Results from the RNA study suggest the extent of VC contamination is comparable to that of DCE (Figure 4.5). The maximum measured VC concentration during the RFI study was 1,300 µg/L (at monitoring well 1381MWS01), which is located within 150 feet of the suspected source area.

Table 4.2 lists groundwater VC concentrations measured in September 1996. The maximum groundwater VC concentration measured in September 1996 was 1,350 µg/L at monitoring point PRMP02, which is located northwest of Facility 1381 along the centerline of plume migration (Figure 4.5). Overall, VC concentrations increased at 9 of 13 shallow monitoring wells sampled during the RFI and the RNA TS. Relatively high

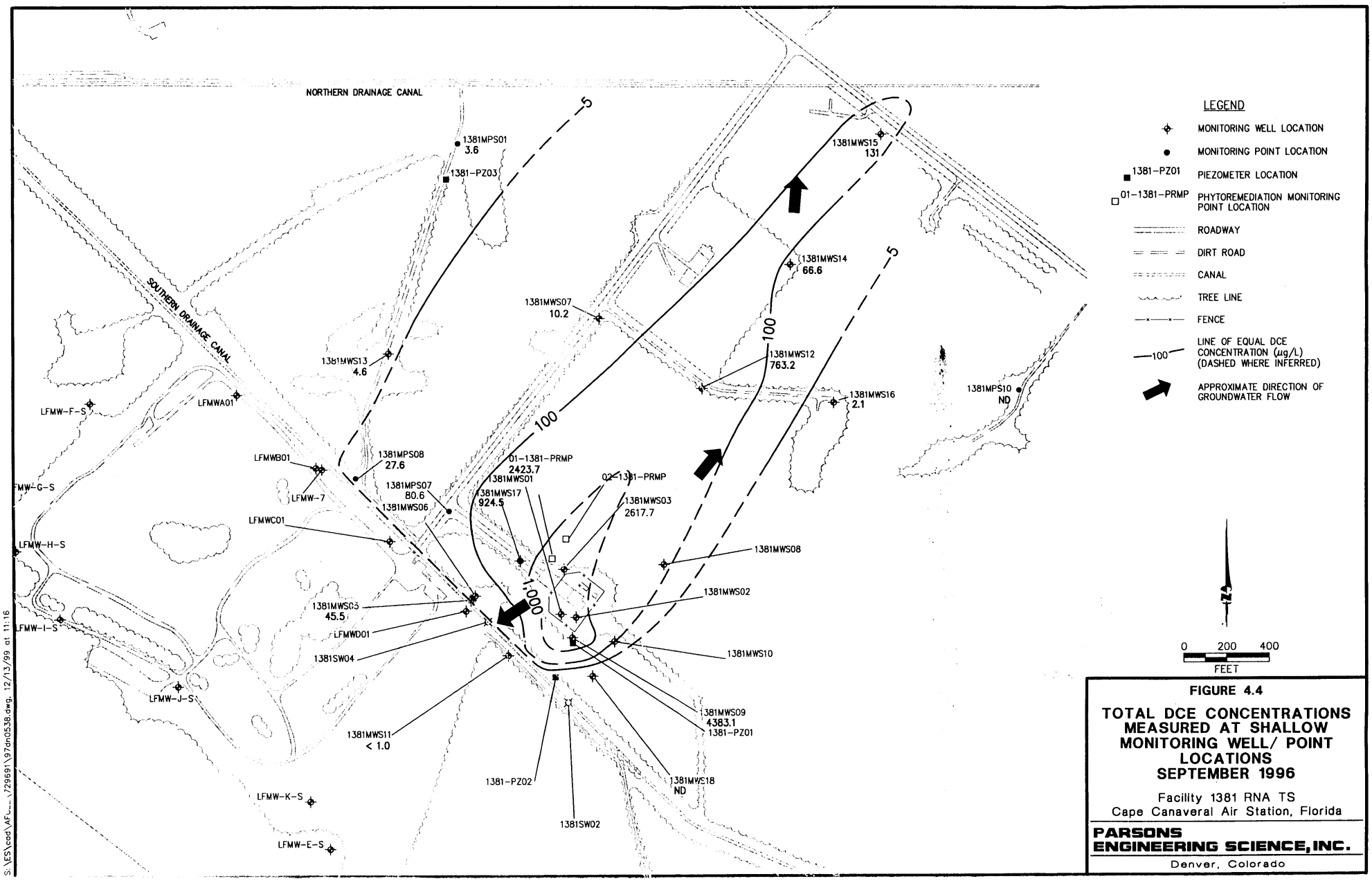


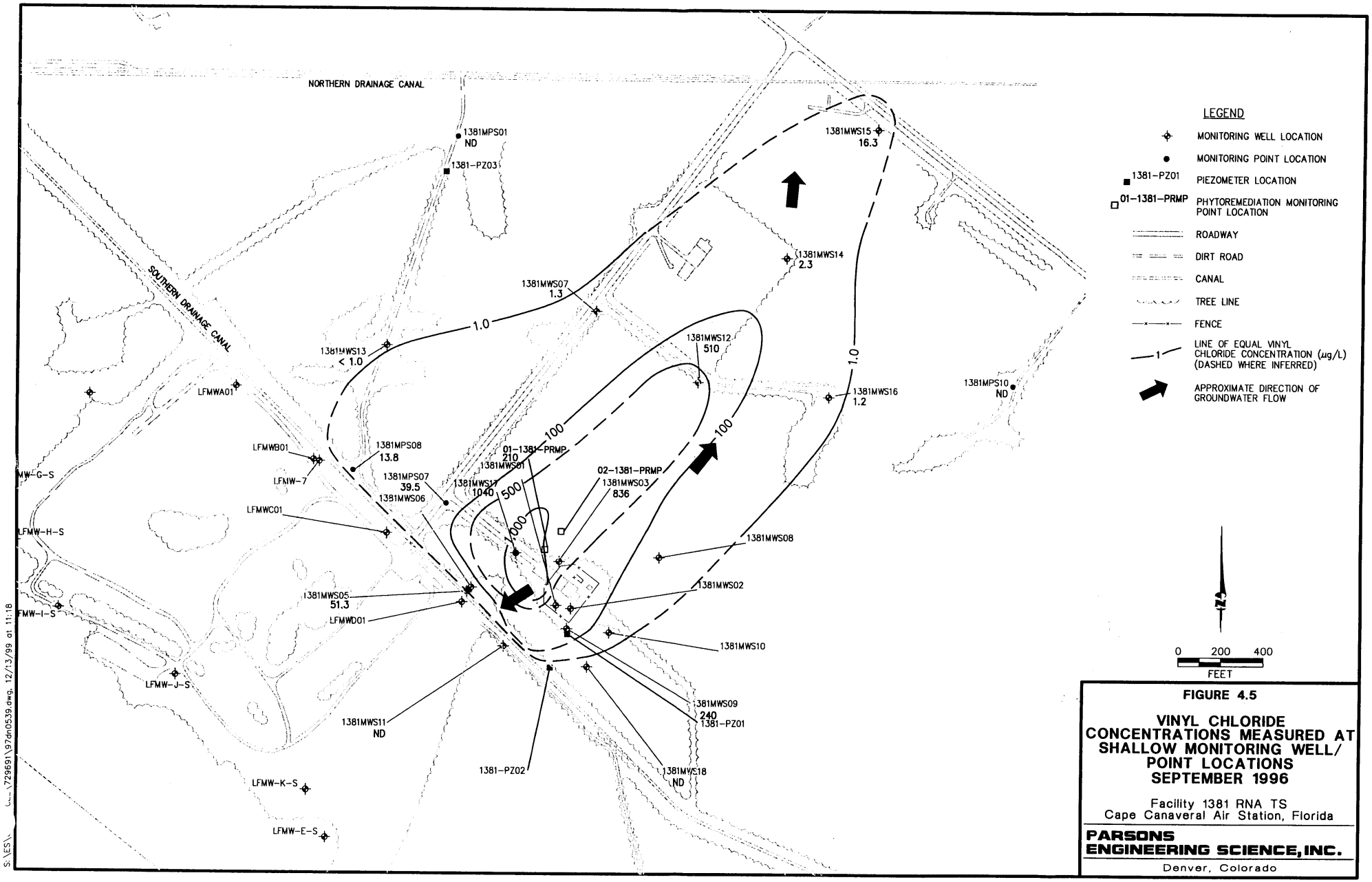
FIGURE 4.4

TOTAL DCE CONCENTRATIONS MEASURED AT SHALLOW MONITORING WELL/ POINT LOCATIONS SEPTEMBER 1996

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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FIGURE 4.5

VINYL CHLORIDE CONCENTRATIONS MEASURED AT SHALLOW MONITORING WELL/ POINT LOCATIONS SEPTEMBER 1996

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

VC concentrations were detected immediately downgradient of monitoring well 1381MWS09 (source area vicinity) which contained elevated TCE and DCE concentrations, providing evidence of DCE dechlorination. Similar to the other CAHs, VC does not appear to be migrating downgradient at intermediate or deep depths. However, VC contamination was detected at the base of the surficial aquifer (at monitoring well 1381MWD09) at a concentration of 1.6 µg/L.

4.3.6 Distribution of Ethene in Groundwater

Ethene is the final end product in the series of chlorinated ethene reductive dehalogenation reactions that begins with PCE. The widespread presence of VC detections in shallow groundwater at Facility 1381 indicates that ethene (which is produced during biodegradation of VC) could also exist in the groundwater. As shown on Table 4.3 and Figure 4.6, ethene was detected in shallow monitoring wells/points at concentrations below 18 µg/L. A small ethene plume appears to extend from the suspected source area to monitoring well 1381MWS12. The presence of ethene indicates that vinyl chloride is being reductively dechlorinated.

Ethene was detected in intermediate and deep monitoring wells at the site at concentrations between <0.003 mg/L and 0.159 mg/L. The increase in ethene concentrations with aquifer depth corresponds with an increase in the ORP of the groundwater suggesting that the potential for VC reductive dechlorination and ethene formation is increased in deeper intervals. All ethene detections in intermediate and deep wells at the site were limited to locations near the source area (e.g., wells 1381MPI06, 1381MPI07, 1381MPI17, and 1381MWD03) where chlorinated ethenes also were detected.

4.3.7 Field Verification of Groundwater CAHs with DSITMS

The presence of TCE, total DCE, and VC also was evaluated through real-time analysis with a DSITMS (Section 2.7). The results of DSITMS sampling indicate that little correlation exists between CAH concentrations measured with field DSITMS analysis versus fixed-base laboratory analysis. In general, DSITMS results exceeded those measured at the fixed-base laboratory, suggesting that the ability of the DSITMS to measure CAH concentrations in a discrete (undiluted) groundwater sample within a well results in more accurate interpretations of the actual high and low CAH concentrations at a given location. Because the QA/QC procedures associated with the DSITMS sampling were not as rigorous as at the fixed-based laboratory, the DSITMS results were not used for the RNA TS; however, they are included in Appendix E.

4.3.8 Distribution of Other CAHs in Groundwater

Chlorinated ethanes detected in the September 1996 groundwater samples include 1,1-DCA, 1,2-DCA, and 1,1,1-TCA (Table 4.2). Low concentrations of 1,1-DCA (ranging from <1 µg/L to 26.4 µg/L) were detected in 10 wells; 1,2-DCA was only detected in one well at <1 µg/L. The maximum concentration of 1,1,-DCA (26.4 µg/L) was detected at monitoring well 1381MWS09, where the highest concentration of 1,1,1-TCA also was measured (Section 4.3.3). DCA is an intermediate product of the microbially-mediated

TABLE 4.3
GEOCHEMICAL INDICATORS AND METABOLIC BYPRODUCTS DETECTED IN GROUNDWATER
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Sample Location	Sample Collection	Temp. (°C)[a/]	pH	Conductivity (µs/cm²)[b/]	Dissolved Oxygen (mg/L)[c/]	Nitrate + Nitrite (mg/L)	Sulfate (mg/L)	Alkalinity (mg/L)	Ferrous Iron (mg/L)	Methane (mg/L)	Ethene (µg/L)	Carbon Dioxide (mg/L)	Ammonia (mg/L)	Hydrogen Sulfide (mg/L)
1381MWS01	9/19/1996	26.1	7.3	1020	3.2	NA[d/]	NA	239	< .05	0.637	6	60	NA[b/]	NA
1381MWD01	9/19/1996	25.0	7.5	4090	<0.1	< .05	< 1	457	< .05	19.090	ND	120	9.37	NA
1381MWS02	NA	NA	NA	NA	NA	1.85	47.3	NA	NA	NA	NA	NA	0.34	NA
1381MWS03	9/20/1996	26.3	7.2	1100	0.1	< .05	44.6	301	2	1.040	18	140	0.38	< .1
1381MWD03	9/23/1996	NA	8.1	4300	NA	< .05	< 1	458	< .05	16.810	114	102	9.63	< .1
1381MWS05	9/20/1996	21.2	7.4	2540	0.6	< .05	24.3	326	0.2	2.600	<3.0	208	2.86	0.1
1381MWI05	9/20/1996	26	7.4	3680	0.1	0.15	< 1	668	0.2	15.210	ND[e/]	208	14.7	0.1
1381MWS07	9/20/1996	26.1	7.3	609	<0.1	< .05	8.77	271	0.5	0.215	ND	120	0.27	< .1
1381MWS09	9/19/1996	27.8	7.2	1393	0.1	< .05	55.10	354	1.3	4.000	6	160	0.91	NA
1381MWI09	9/19/1996	25	7.7	6480	0.1	0.19	< 1	960	0.3	15.420	64	308	19.1	NA
1381MWD09	NA	NA	NA	NA	NA	< .05	< 1	NA	NA	17.500	ND	NA	8.73	NA
1381MWS11	9/20/1996	26.5	7	1260	0.2	< .05	138	NA	8.7	0.484	ND	360	1.52	< .1
1381MWS12	9/21/1996	24.6	7.3	3560	<0.1	< .05	67.7	328	8.5	1.230	13	182	0.46	< .1
1381MWD12	9/21/1996	25.5	8.3	1360	0.1	0.07	< 1	487	0.2	18.930	<3.0	196	8.64	0.3
1381MWS13	9/21/1996	27.9	7.7	326	4.8	0.15	25.2	178	< .05	0.074	ND	100	< .05	NA
1381MWS14	9/21/1996	27.8	7.2	660	1.0	0.13	31.3	270	0.18	0.098	ND	120	< .05	NA
1381MWS15	9/21/1996	25.1	7.2	1430	0.1	< .05	38.6	315	2.3	0.793	<3.0	188	0.33	< .1
1381MWS16	9/21/1996	26.1	7.4	500	0.2	< .05	17.8	223	< .05	0.078	ND	60	< .05	NA
1381MWS17	9/20/1996	27.7	7.3	1360	0.1	< .05	71.4	342	1.6	1.520	13	158	0.76	< .1
1381MWS18	9/19/1996	24.8	7.3	1170	0.2	< .05	22	311	1.8	0.228	ND	172	0.35	NA
1381MPS01	9/21/1996	27.3	7.5	600	0.3	< .05	16.3	195	0.6	0.134	ND	130	< .05	< .1
1381MPI01	9/21/1996	27	7.8	2130	0.1	0.1	< 1	554	< .05	NA	NA	170	11.2	< .1
1381MPI02	9/21/1996	27	7.8	2380	0.2	0.19	< 1	537	< .05	18.490	ND	252	18.3	NA
1381MPI03	9/23/1996	24.6	7.7	5420	0.1	0.13	< 1	863	< .05	30.100	ND	416	16.5	< .1
1381MPI05	9/24/1996	24.3	7.7	6620	<0.1	< .05	< 0.1	955	< .05	32.550	ND	388	18.6	< .1

TABLE 4.3 (Concluded)
GEOCHEMICAL INDICATORS AND METABOLIC BYPRODUCTS DETECTED IN GROUNDWATER (Concluded)
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Sample ID	Sampling Date	Temp. (°C)[a/]	pH	Conductivity (µs/cm²)[b/]	Dissolved Oxygen (mg/L)[c/]	Nitrate + Nitrite (mg/L)	Sulfate (mg/L)	Alkalinity (mg/L)	Ferrous Iron (mg/L)	Methane (mg/L)	Ethene (mg/L)	Carbon Dioxide (mg/L)	Ammonia (mg/L)	Hydrogen Sulfide (mg/L)
1381MPI06	9/24/1996	25.4	7.7	5710	0.1	< .05	< 0.1	789	< .05	27.960	51	294	16.2	< .1
1381MPS07	9/23/1996	29.2	7.4	618	0.2	< .05	28.5	225	0.04	0.463	<3.0	92	0.48	< .1
1381MPI07	9/23/1996	27.2	7.7	2330	<0.1	0.06	< 1	485	< .05	21.630	159	210	11.3	< .1
1381MPS08	9/23/1996	24.9	7.2	1458	0.1	0.06	9.12	386	1.50	3.360	ND	204	6.01	< .1
1381MPI08	9/24/1996	21.4	8.3	3760	0.1	< .05	< 0.1	524	< .05	0.103	ND	232	9.04	0.1
1381MPS10	9/24/1996	26.4	7.8	7520	0.3	< .05	2.76	834	< .05	0.228	ND	386	0.56	0.1
1381MPI10	9/24/1996	26.6	7.3	972	0.1	< .05	< 0.1	321	0.80	0.212	ND	196	0.55	< .1
1381MPI11	9/24/1996	24.4	7.7	7910	<0.1	< .05	< 0.1	905	< .05	27.130	ND	358	15.3	0.1
1381MPI13	9/24/1996	24.6	7.8	4370	0.1	< .05	< 0.1	744	0.20	26.270	ND	332	14.5	0.1
1381MPI17	9/23/1996	26.3	7.8	4730	0.2	0.16	< 1	770	< .05	27.260	<3.0	296	15.5	< .1
1381MPI18	9/24/1996	23.9	7.8	4770	0.2	< .05	< 0.1	801	NA	29.980	ND	306	14.7	0.1
1381MPI19	9/23/1996	25.4	7.8	5440	0.1	NA	NA	755	< .05	NA	NA	438	NA	< .1
1381MPI20	9/25/1996	24.1	7.7	5870	0.2	< .05	< .1	877	< .05	25.510	ND	347	15.8	0.1
1381MPI21	9/24/1996	23.8	7.8	5110	0.3	< .05	< 0.1	670	0.3	20.270	ND	258	14.7	0.3
1381PRMP01	9/25/1996	25.2	7.3	1129	0.4	< .05	9.46	337	2.00	1.290	12	112	0.49	< .1
1381PRMP02	9/25/1996	24.9	7.2	1270	<0.1	< .05	12.5	345	1.60	1.820	18	345	0.74	< .1

[a/] °C = degrees Celsius.

[b/] µs/cm² = microsiemens per square centimeter.

[c/] mg/L = milligrams per liter.

[d/] NA = not available.

[e/] ND = not detected.

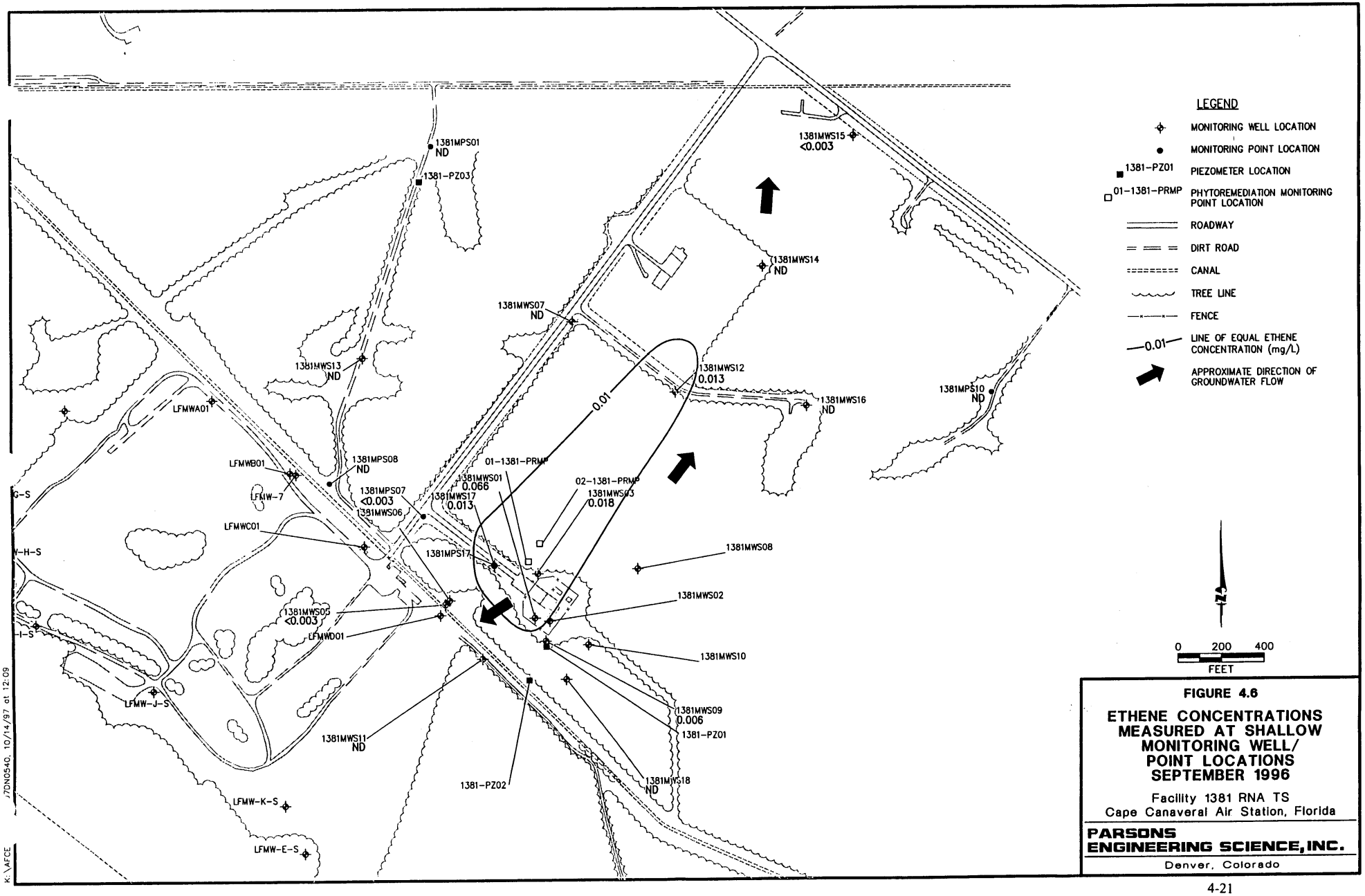


FIGURE 4.6

ETHENE CONCENTRATIONS MEASURED AT SHALLOW MONITORING WELL/ POINT LOCATIONS SEPTEMBER 1996

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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reductive dehalogenation of TCA, with the ultimate end product of this series of reactions being ethane (Bouwer, 1994). Therefore, it is reasonable to infer that DCA concentrations measured at the site may result from TCA reductive dechlorination, although DCA concentrations are more widespread than TCA concentrations. In general, DCA detections coincided with detections of 1,1-DCE which can be produced as a result of an alternate 1,1,1-TCA degradation pathway.

Chloroform was detected in one groundwater sample and three surface water samples collected from Facility 1381 during the RNA study (Appendix A). Chloroform can result from the aerobic oxidation of TCE or TCE daughter products (e.g., 2,2,2-trichloracetaldehyde or 2,2,2-tricyloroethanol) produced during aerobic oxidation. Chloroform was detected in monitoring well 1381MWS09, a shallow well susceptible to oxygen enrichment from precipitation or from adjacent air-sparging testing related to the CMS. Therefore, the aerobic production of chloroform is plausible. However, the detection of chloroform in surface water may be the result of laboratory contamination (although chloroform was not detected in laboratory blanks) as no other CAHs were detected in surface water samples.

Carbon tetrachloride was detected at 15.9 µg/L at a single monitoring well (1381MWD12) (Appendix A). Carbon tetrachloride is not a byproduct of CAH degradation, and its presence suggests that a carbon tetrachloride was released at the site, possibly cosolvenated with other CAH compounds. The presence of carbon tetrachloride in a single, deep monitoring well suggests that it is a compound of minor impact and concern.

4.3.9 CAHs in Surface Water

In September 1996, six surface water samples for VOC analysis were collected from the drainage canals north and south of Facility 1381. Figure 2.1 shows the surface water sampling locations and Table 4.2 presents surface water CAH results. The extent of DCE and VC contamination at the site (Figures 4.3 and 4.4) suggest that these contaminants may discharge to the northern drainage canal. Furthermore, on the basis of historic and current groundwater investigations, CAH contamination (particularly TCE) also is discharging into the southern canal.

Despite the potential for CAH discharge to surface water, the only analyte detected in the surface water samples during the RNA study was chloroform (<4.9 µg/L) at three sampling locations along the southern drainage canal. The lack of CAH concentrations in the northern canal is consistent with the results of the RFI; however, during the RFI, TCE was detected at two of the six sampling locations along the southern drainage canal. The disappearance of TCE in the southern drainage canal samples between the RFI and RNA sampling events is unexpected. However, the appearance of chloroform over the same interval may provide a partial explanation. As stated in Section 4.3.8, chloroform can be produced as a result of abiotic TCE degradation under aerobic conditions, possibly with activation energy provided by sunlight. In addition, aerobic conditions that could favor the TCE to chloroform pathway are prevalent. The absence of TCE in September 1996 surface water samples suggests that the rate of TCE discharge was lower in September, or that stream flow volume was higher. Therefore, the discrepancy may reflect seasonal

changes rather than long-term trends. The absence of DCE and other reductive dechlorination daughter products of TCE is reasonable because: 1) reductive dechlorination does not occur in surface water and; 2) any DCE entering the surface water degrades rapidly to innocuous byproducts.

4.4 INTRINSIC REMEDIATION ANALYSIS

Biodegradation of TCE in Facility 1381 groundwater appears to be occurring, primarily by reductive dehalogenation of TCE to DCE. DO concentrations below 0.5 mg/L throughout most of the plume area, substantial TOC concentrations, and the absence of significant anthropogenic carbon (e.g., BTEX compounds or other SVOCs), indicates that type 2 behavior is prevalent (Section 4.2.4.2). TCE concentrations were not detected more than 200 feet from the source area, suggesting relatively rapid degradation to DCE. However, DCE and VC contamination extends from the source area to the northern canal, suggesting that dechlorination of DCE and VC are slower processes. The presence of ethene indicates dechlorination of VC is occurring. Available evidence further suggests that type 1 behavior may have occurred in the source area at one time, perhaps driven by leaching of petroleum hydrocarbons (anthropogenic organic carbon) from source area soils. The analytical data (including contaminant and geochemical data) that indicate the type(s) of biodegradation processes operating in Facility 1381 groundwater, and the degree to which biodegradation is occurring, are discussed in the following subsections.

4.4.1 Field-Scale Contaminant Mass Losses

One line of evidence that should be assessed to evaluate the occurrence of natural attenuation of contaminants in groundwater at Facility 1381 is whether dissolved concentrations of contaminants are decreasing over time. TCE contamination at the site is limited. Groundwater quality data for 7 monitoring wells that have contained TCE during previous RFI sampling events (December 1995 to May 1996) were reviewed to assess temporal changes in TCE concentrations. Historically, TCE has only been detected in source area wells, including: 1381MWS01, 1381MWS05, 1381MWS09, 1381MWS17, 1381MWS18, 1381MWI09, and 1381MWD09. In the six-month period between March 1996 and September 1997, TCE concentrations at well 1381MWS09 increased by 4,400 µg/L, most likely resulting from seasonal variation of the groundwater level and soil leaching rate. Despite the fact that the areal extent of TCE appears to have decreased between the RFI and RNA sampling events, TCE concentrations in the 9 wells that have historically exhibited TCE contamination have increased and decreased erratically. Therefore, the available data do not conclusively indicate an overall trend in dissolved TCE concentrations between 1995 and 1996.

4.4.2 Presence of Daughter Products

The presence of daughter products that were not used in operations at Facility 1381, particularly *cis*-1,2-DCE and VC, is a direct indication that TCE is being reductively dehalogenated. The large magnitude of daughter product concentrations relative to TCE indicate that biological transformation is widespread.

Progressive transformation of TCE to DCE as the contamination migrates away from the source area can be evaluated by computing the ratio of daughter products to parent compounds at different distances from the source area. Table 4.4 shows CAH ratios at five shallow wells located along the approximate northeastern axis of the CAH plume (1381MWS09, 1381MWS01, 1381MWS03, 1381MWS12, and 1381MWS15). Computation of all TCE to DCE ratios was limited to two monitoring wells where both TCE and DCE were detected (1381MWS09 and 1381MWS01). TCE to DCE ratios at monitoring well 1381MWS09 (within the source area) remained reasonably constant at an average ratio of approximately 10:1. The TCE/DCE ratio drops by 2 orders of magnitude between monitoring well 1381MWS09 and 1381MWS01, indicating that a significant transformation of TCE has occurred. At these same locations, DCE to VC ratios increased between the RFI and RNA sampling events, especially at monitoring well 1381MWS09 (VC was not detected at this well in the RFI sampling event, but was detected at 240 µg/L in September 1996). This trend indicates more favorable conditions for the reductive dechlorination of TCE to DCE and DCE to VC. DCE to VC ratios downgradient of the source area (e.g., wells 1381MWS12 and 1381MWS15) fluctuate within a half-order of magnitude between sampling events. Ethene was generated along the entire length of the groundwater CAH plume in September 1996, confirming the complete transformation of TCE to ethene by reductive dechlorination.

A general comparison of TCE, DCE, and VC concentrations between RFI and RNA sampling events revealed increases in chlorinated ethene concentrations from March to September 1996. TCE concentrations increased at 4 of 7 monitoring wells; 1,1-DCE increased at 5 of 6 monitoring wells; *trans*-1,2,-DCE increased at 7 of 9 wells; *cis*-1,2-DCE increased at 9 of 14 wells; and VC increased at 9 of 13 wells. These trends suggest that groundwater conditions were more reducing in September 1996, resulting in increased daughter product concentrations. The conditions supporting the additional reductive dechlorination may have resulted from low monthly precipitation and lowered groundwater levels that ultimately limited oxygen recharge to the shallow aquifer. The observed concentration trends support the observation that CAH biodegradation rates are seasonally variable.

4.4.3 Chloride as an Indicator of Dehalogenation

Chlorine is removed from CAHs during reductive dehalogenation and enters solution. Therefore, chloride concentrations in groundwater should increase above background in areas where reductive dehalogenation occurs. At Facility 1381, the mass of CAHs undergoing reductive dehalogenation is significant, and chloride concentrations may be substantially enhanced.

Chloride concentrations measured in September 1996 are presented in Table 4.5 and on Figure 4.7. Chloride concentrations at shallow monitoring points/wells cross-gradient to groundwater contamination ranged from 13.3 to 28.2 mg/L, and averaged 19.3 mg/L. The highest chloride concentration (242 µg/L) was detected at well 1381MWS15, located approximately 2,800 feet northeast of the suspected source area.

Elevated chloride concentrations detected in shallow aquifer intervals are present along a narrow corridor extending from the source area to the northern drainage canal

TABLE 4.4
RATIOS OF CAH COMPOUNDS ALONG THE PLUME CENTERLINE
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Monitoring Well	Date Collected	TCE (mg/L)[a/]	DCE (mg/L)	VC (mg/L)	Ethene (mg/L)	TCE/DCE Ratio	DCE/VC Ratio	VC/Ethene Ratio
RFI Data								
1381MWS09	3/8/1996	35000	3000	0	ND[b/]	11.67	NA	NA
1381MWS01	12/15/1995	190	8800	1300	ND	0.02	6.77	NA
1381MWS03	12/15/1995	ND	2500	330	ND	NA	7.58	NA
1381MWS12	3/13/1996	ND	605.8	130	ND	NA	4.66	NA
1381MWS15	3/22/1996	ND	18	1.5	ND	NA	12.00	NA
RNA Data								
1381MWS09	9/19/1996	39400	4383.1	240	6	9.0	18.3	40.0
1381MWS01	9/19/1996	239	2423.7	210	6	0.1	11.5	35.0
1381MWS03	9/20/1996	ND	2617.7	836	18	NA[c/]	3.1	46.4
1381MWS12	9/21/1996	ND	763.2	510	13	NA	1.5	39.2
1381MWS15	9/21/1996	ND	130	16.3	ND	NA	8.0	NA

a/ mg/L=milligrams per liter.
b/ ND=not detected.
c/ NA=not applicable.

TABLE 4.5
INDICATORS OF REDOX PROCESSES
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Sample Location	Sample Collection	Dissolved Hydrogen (nM)[a/]	Redox Potential (mV)[b/]	Chloride (mg/L)[c/]
1381MWS01	9/19/1996	2.23	15	NA[d]
1381MWD01	9/19/1996	5.31	-50.0	989
1381MWS02	NA	NA	NA	121
1381MWS03	9/20/1996	1.34	-136	106
1381MWD03	9/23/1996	7.11	-176	1110
1381MWS05	9/20/1996	1.96	-179	151
1381MWI05	9/20/1996	2.5	-270	859
1381MWS07	9/20/1996	4.05	-109	33.9
1381MWS09	9/19/1996	NA	-50.0	207
1381MWI09	9/19/1996	NA	-296	1790
1381MWD09	NA	NA	NA	1050
1381MWS11	9/20/1996	5.1	-159	64.8
1381MWS12	9/21/1996	1.75	-340	227
1381MWD12	9/21/1996	6.44	-186	919
1381MWS13	9/21/1996	1.35	184	17.8
1381MWS14	9/21/1996	1.37	172	37.6
1381MWS15	9/21/1996	1.16	-154	242
1381MWS16	9/21/1996	1.62	120	13.3
1381MWS17	9/20/1996	5.97	-102	171
1381MWS18	9/19/1996	1.44	277	195
1381MPS01	9/21/1996	NA	-172	28.2
1381MPI01	9/21/1996	NA	-250	486
1381MPI02	9/21/1996	NA	-238	451
1381MPI03	9/23/1996	NA	-86	1260
1381MPI05	9/24/1996	NA	-185	295
1381MPI06	9/24/1996	NA	-98	250
1381MPS07	9/23/1996	NA	-138	39.4
1381MPI07	9/23/1996	NA	-212	445
1381MPS08	9/23/1996	NA	-96	221
1381MPI08	9/24/1996	NA	-290	161
1381MPS10	9/24/1996	NA	-109	18
1381MPI10	9/24/1996	NA	-118	17.8
1381MPI11	9/24/1996	NA	-225	365
1381MPI13	9/24/1996	NA	-190	171
1381MPI17	9/23/1996	NA	-206	1050
1381MPI18	9/24/1996	NA	-211	189
1381MPI19	9/23/1996	NA	-40	NA
1381MPI20	9/25/1996	NA	-60	261

TABLE 4.5 (Concluded)
INDICATORS OF REDOX PROCESSES
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Sample Location	Sample Collection	Dissolved Hydrogen (nM)[a/]	Redox Potential (mV)[b/]	Chloride (mg/L)[c/]
1381MPI21	9/24/1996	NA	-243	227
1381PRMP01	9/25/1996	NA	-92	21.8
1381PRMP02	9/25/1996	NA	-125	30.5

[a/] nM = nanomoles.

[b/] mV = millivolts

[c/] mg/L = milligrams per liter.

[d/] NA = not available.

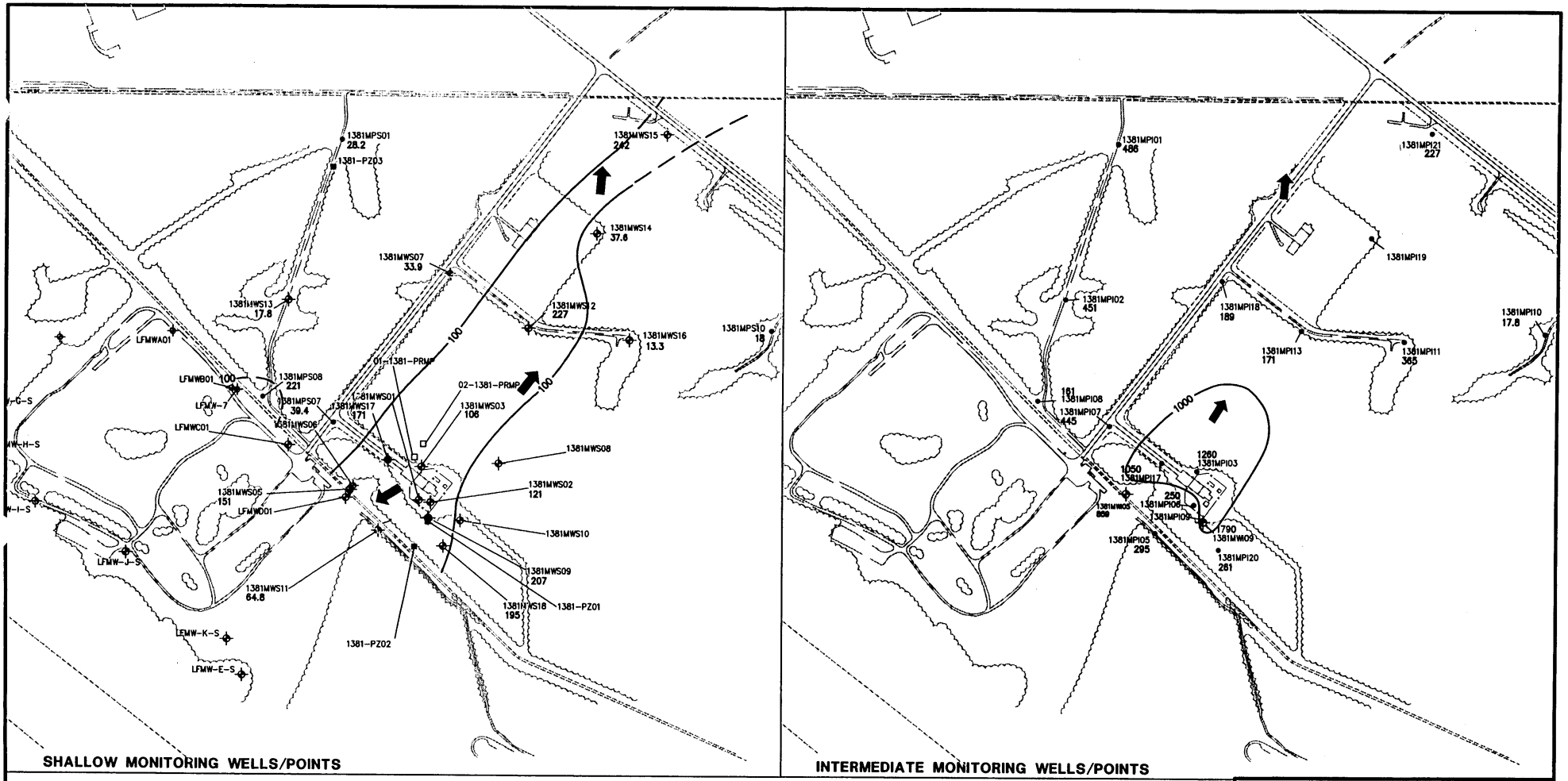


FIGURE 4.7

CHLORIDE CONCENTRATIONS MEASURED AT SHALLOW AND INTERMEDIATE GROUNDWATER WELL/POINT LOCATIONS SEPTEMBER 1996

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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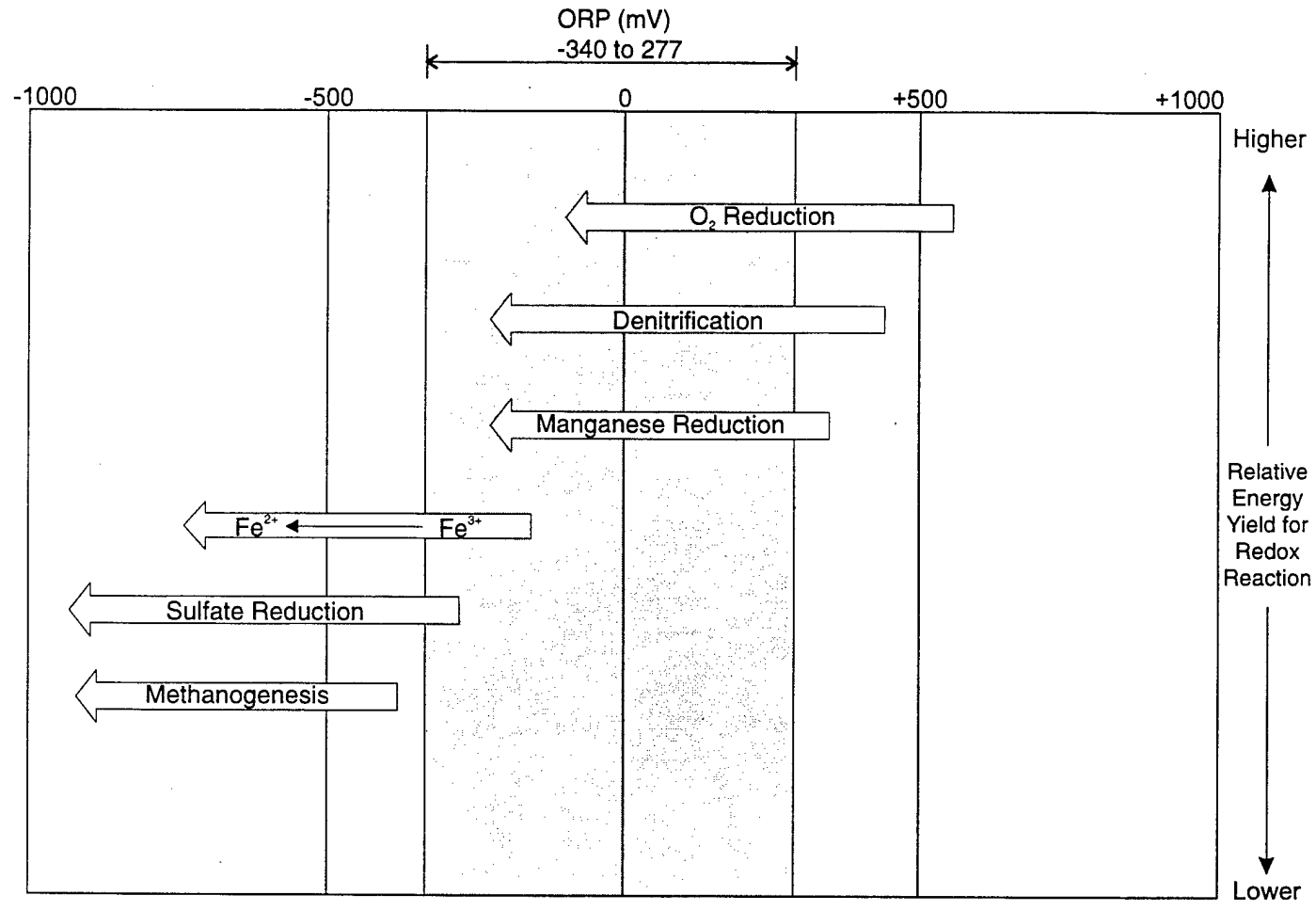
(Figure 4.7). This corridor coincides with the CAH plume, and is defined by relatively low chloride concentrations at monitoring wells/points that are cross-gradient of the plume (e.g., background wells). Chloride concentrations do not steadily decrease from the source area to the northern canal, as do CAH concentrations. Rather, chloride concentrations increase from generally less than 200 mg/L in the source area to more than 200 mg/L northeast of the source area. The gradual increase in chloride concentrations may be attributed to continued chloride generation along the length of the CAH plume. In addition, since chloride is often conservative in groundwater systems (not readily degraded or retarded), the elevated downgradient chloride concentrations may have migrated from the source area.

Chloride concentrations increase with depth in the aquifer. Figure 4.7 shows chloride concentrations at intermediate groundwater monitoring well/point locations. The average background chloride concentration estimated from locations transverse or downgradient from the intermediate depth CAH plume (e.g., monitoring points 1381MPI01, 1381MPI02, 1381MPI10, 1381MPI11, 1381MPI18, and 1381MPI13) is 280 mg/L. However, the average chloride concentration at intermediate wells in the source area is 1,367 mg/L (e.g., monitoring wells/points 1381MPI17, 1381MPI03, and 1381MPI20), suggesting that significant reductive dechlorination is occurring at depth, possibly as a result of reduced oxygen concentration. Deep monitoring wells 1381MWD01 and 1381MWD03 have an average chloride concentration of 1,050 mg/L, and there is no observable increase in the source area. This average background concentration is higher than the average intermediate-depth background concentration, but lower than the elevated chloride concentration detected in the source area at intermediate depths. High chloride concentrations at deep aquifer intervals likely is a combination of CAH reductive dechlorination and naturally high chloride levels.

4.4.4 Redox Potential and Dissolved Hydrogen as Indicators of Redox Processes

As described in Section 4.2, microorganisms will facilitate only those redox reactions that will yield energy. For example, by coupling the oxidation of fuel hydrocarbon compounds (or native organic carbon), which requires energy, to the reduction of other compounds (e.g., oxygen, nitrate, manganese, ferric iron, sulfate, carbon dioxide, and possibly *cis*-1,2-DCE), which yields energy, the overall reaction will yield energy.

Figure 4.8 illustrates the sequence of microbially mediated redox processes and identifies the approximate ranges of redox potentials that are favorable for each process. In general, reactions yielding more energy tend to take precedence over processes that yield less energy (Stumm and Morgan, 1981; Godsey, 1994; Reinhard, 1994). As Figure 4.8 shows, oxygen reduction would be expected to occur in an aerobic environment with microorganisms capable of aerobic respiration because oxygen reduction yields significant energy (Bouwer, 1992; Chapelle, 1993). However, once the available oxygen is depleted and anaerobic conditions dominate the interior regions of the contaminant plume, anaerobic microorganisms can utilize other electron acceptors in the following order of preference: nitrate (denitrification), manganese (manganese reduction), ferric iron (iron reduction), sulfate (sulfate reduction), and finally carbon dioxide (methanogenesis). Each successive redox reaction provides less energy to the system,



Notes

ORP = Oxidation Reduction Potential

Range of ORP measured at Facility 1381

1. These reactions would be expected to occur in sequence if the system is moving toward equilibrium.

2. These redox processes occur in order of their energy-yielding potential (provided microorganisms are available to mediate a specific reaction). Reduction of a highly oxidized species decreases the ORP of the system.

3. The ORP of the system determines which electron acceptors are available for organic carbon oxidation.

4. Redox sequence is paralleled by an ecological succession of biological mediators.

Adapted from Stumm and Morgan, 1981.

FIGURE 4.8

SEQUENCE OF MICROBIALLY MEDIATED REDOX PROCESSES

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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and each step down in redox energy yield would have to be paralleled by an ecological succession of microorganisms capable of facilitating the pertinent redox reactions.

Redox potentials measured in Facility 1381 groundwater in September 1996 ranged from -340 millivolts (mV) to 277 mV (Table 4.5). The maximum and minimum redox potentials were measured at shallow monitoring wells/points. With the exception of monitoring wells 1381MWS01 and 1381MWS09, redox potentials in the source area and along the centerline of the plume were below -100 mV, which is characteristic of waters that are more amenable to reductive dechlorination. Monitoring wells 1381MWS01 and 1381MWS09 are located near a former air-sparging system installed as part of the CMS that may have aerated waters in this area and elevated the redox potential during installation and testing (the air-sparging system was not fully operational prior to RNA TS field sampling). Redox potentials measured in shallow background wells fluctuated between -172 and 277 mV.

Redox potentials measured in intermediate monitoring wells/points were consistently below -40 mV and ranged from -40 mV to -296 mV. Similarly, redox potentials measured at deep monitoring wells ranged from -50 to -176 mV. No noticeable areal trend in redox potentials is apparent in these intervals. The redox potential data does suggest that deeper groundwater tends to be more reducing, and thus more conducive to the occurrence of reductive dehalogenation than shallower groundwater. However, many authors have noted that field redox potential data alone cannot be used to reliably predict the electron accepting processes that may be operating at a site, because the platinum electrode probes are not sensitive to some redox couples (e.g., sulfate/sulfide) (Stumm and Morgan, 1981; Godsey, 1994; Lovley *et al.*, 1994).

Concentrations of dissolved hydrogen (H_2) also can be used to evaluate redox processes in groundwater systems (Lovley and Goodwin, 1988; Lovley *et al.*, 1994; Chapelle *et al.*, 1995). H_2 is continuously produced in anaerobic groundwater systems by fermentative microorganisms that decompose natural and anthropogenic organic matter. This H_2 is then consumed by respiratory microorganisms that use nitrate, ferric iron, sulfate, or CO_2 as terminal electron acceptors. These, nitrate-, ferric iron-, sulfate- and CO_2-reducing (methanogenic) microorganisms exhibit different efficiencies in utilizing the H_2 that is being continually produced. Nitrate reducers are highly efficient H_2 utilizers and maintain very low steady-state H_2 concentrations. Ferric iron reducers are slightly less efficient and thus maintain somewhat higher H_2 concentrations. Sulfate reducers and methanogenic bacteria are progressively less efficient and maintain even higher H_2 concentrations. Because each terminal electron accepting process has a characteristic H_2 concentration associated with it, H_2 concentrations can be an indicator of predominant redox processes. These characteristic ranges are given in Table 4.6.

Dissolved H_2 concentrations measured in Facility 1381 groundwater in September 1996 are summarized in Table 4.5. Concentrations ranged from 1.34 nanomoles per liter (nM/L) to 5.97 nM/L at shallow monitoring wells/points. The two highest H_2 concentrations were measured outside of the main TCE plume at wells 1381MWS17 (5.97 nM/L) and 1381MWS07 (4.05 nM/L). The remaining H_2 values, which ranged from 1.34 to 2.23 nM/L, were obtained at wells scattered across the site, with no apparent trends in concentration. The magnitude of these values suggests that sulfate reduction

TABLE 4.6
RANGE OF HYDROGEN CONCENTRATIONS FOR A GIVEN TERMINAL ELECTRON-ACCEPTING PROCESS
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Terminal Electron-Accepting Process	Dissolved Hydrogen Concentration (nanomoles per liter)
Denitrification	<0.1
Ferric Iron Reduction	0.2 to 0.8
Sulfate Reduction	1 to 4
Methanogenesis	5 to 20

should be the dominant electron accepting process in the plume area at shallow monitoring wells/points. As shown on Figure 4.8, sulfate reduction occurs under relatively reducing conditions that are also conducive to the occurrence of reductive dehalogenation.

No dissolved hydrogen measurements were collected at intermediate well locations to the north of Facility 1381. A single dissolved hydrogen concentration was collected at intermediate well 1381MWI05 (southwest of the groundwater plume); the magnitude of the detected H_2 concentration (2.5 nM/L) suggests that sulfate reducing conditions also may be predominant at intermediate depths. Dissolved H_2 concentrations measured at three deep monitoring well locations ranged from 5.31 to 7.11 nM/L. These monitoring wells are located in the source area (1381MWD01 and 1381MWD03) or downgradient of the source area (1381MWD12). These values suggest that methanogenic conditions persist near the bottom of the surficial aquifer; however, negligible contamination exists at depth that could be reductively dehalogenated in the highly reducing conditions.

The relatively low redox potentials and moderate dissolved H_2 concentrations measured in Facility 1381 groundwater indicate that reductive dehalogenation, primarily under sulfate reducing or methanogenic conditions, is possible at most locations within the aquifer. This supports the occurrence of reductive dehalogenation of CAHs, because the most rapid dehalogenation rates, affecting the widest range of CAHs, occurs under increasingly reduced environments (Bouwer, 1994).

4.4.5 Electron Donors

When investigating the biodegradation of CAHs, it is also necessary to look at the distribution of other compounds that are used in the microbially mediated reactions that facilitate CAH degradation. The distribution of potential electron donors, including BTEX compounds and dissolved native organic carbon, is useful for evaluating the feasibility of reductive dehalogenation or cometabolism (i.e., CAH degradation reactions involving another substrate).

4.4.5.1 BTEX and Fuel Carbon in Groundwater

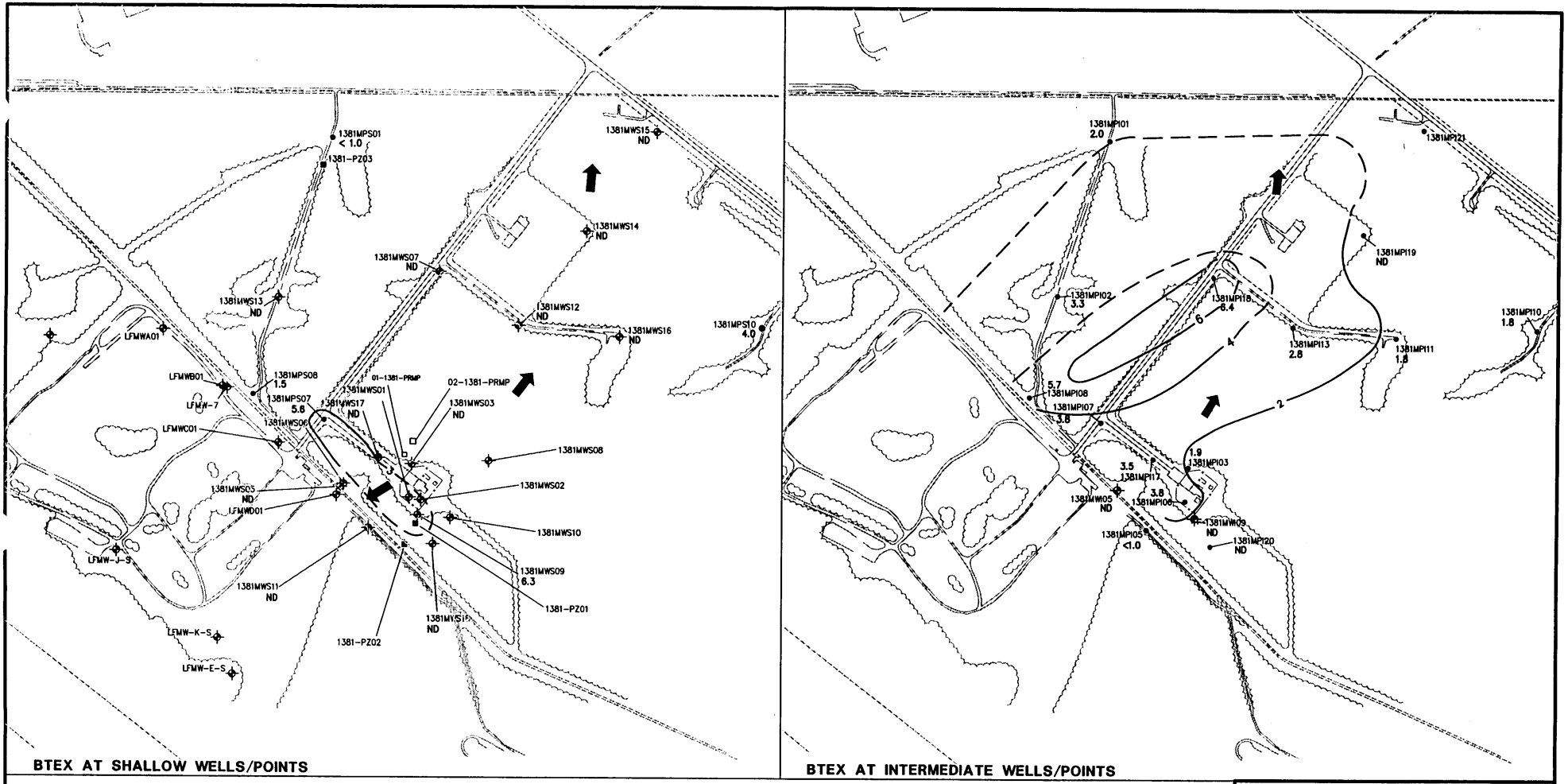
The presence of BTEX in the same area as the CAH plume could create favorable conditions for reductive dehalogenation, because the BTEX can provide a source of electron donors to drive the reductive dechlorination reaction as well as facilitate microbial reactions that reduce the local groundwater ORP. Petroleum hydrocarbons in the form of BTEX and fuel carbon were detected at minor concentrations at the site. BTEX concentrations at shallow monitoring wells/points ranged from <1.0 to 6.3 µg/L and from 1.8 to 6.4 µg/L at intermediate wells (Figure 4.9; Table 4.7). BTEX contamination appears to be spread to the northwest of the source area in a shape that does not coincide with the shape of the TCE, DCE, or VC plumes and may suggest incidental spill locations and/or declining source concentrations that limit plume extension to the northeast. Fuel carbon concentrations were detected at concentrations from <1.0 to 1,450 µg/L at every location with BTEX contamination (Table 4.7).

4.4.5.2 Organic Carbon in Groundwater

Dissolved native organic carbon also can act as a source of electron donors (an energy source) during the reductive dehalogenation of CAHs. The dissolved TOC results can be used as an indicator of native carbon compounds in wells outside of the area containing dissolved fuel/CAH contamination (anthropogenic organic compounds, such as CAHs, also will be measured by this method).

TOC dissolved in groundwater was measured in samples collected in September 1996. These concentrations are presented in Table 4.7. Dissolved TOC concentrations in shallow groundwater at Facility 1381 ranged from 0.61 mg/L to 12.3 mg/L. Elevated TOC concentrations were not limited to the source area as might be expected. Monitoring points 1381MWS08 and 1381MPS10 are located at least 1,000 feet northwest and northeast, respectively of the source area and contained TOC concentrations of 5.67 mg/L (1381MWS08) and 6.96 mg/L (1381MWS10). However, the average TOC concentration in five background wells located transverse to contaminant migration (1381MPS01, 1381MPS10, 1381MWS07, 1381MWS13, and 1381MWS16) is 2.57 mg/L, which is lower than the average TOC concentration of 7.00 mg/L (1381MWS01, 1381MWS03, 1381MWS09, and 1381MWS17). It is likely that TOC concentrations measured in the source area are elevated by the presence of CAHs. Nonetheless, substantial TOC concentrations were detected at intermittent locations across the site, indicating that organic material exists within the shallow portion of the aquifer.

TOC measurements from intermediate wells, which ranged from 2.56 to 192 mg/L, indicated that concentrations increase with depth. The maximum TOC concentration of 192 mg/L was measured at monitoring point 1381MPI11, located transverse (east) of the main groundwater plume. The elevated TOC concentration at this location is not associated with significant groundwater contamination (the maximum total CAH concentration measured at monitoring point 1381MPI11 was 3.2 µg/L). However, the monitoring point is screened near the surface of a silty, clayey sand zone. Clay can add carbon to water, thereby increasing TOC concentrations. Similar conditions may exist at monitoring points 1381MPI03 and 1381MPI08 that have TOC concentrations of 57.3 mg/L and 83.2 mg/L, respectively, but did not contain detectable CAH concentrations



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FIGURE 4.9

TOTAL BTEX CONCENTRATIONS MEASURED AT SHALLOW AND INTERMEDIATE MONITORING WELL/POINT LOCATIONS, SEPTEMBER 1996

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

TABLE 4.7
POTENTIAL ELECTRON DONORS DETECTED IN GROUNDWATER AND SURFACE WATER
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Sample Location	Sample Collection	Benzene (µg/L)[a/]	Toluene (µg/L)	Ethyl-benzene (µg/L)	Xylenes (µg/L)	Total BTEX (µg/L)	1,3,5-TMB (µg/L)	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	Fuel Carbon (µg/L)	Total Organic Carbon (mg/L)
1381MWS01	9/19/1996	ND	ND	ND	2	2	ND	ND	ND	34.1	6.5
1381MWS03	9/20/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.2
1381MWD03	9/23/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
1381MWS05	9/20/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.2
1381MWI05	9/20/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	10.9
1381MWS07	9/20/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.0
1381MWS09	9/19/1996	ND	2.4	1	2.9	6.3	ND	1.6	ND	1450	9.0
1381MWI09	9/19/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	18.8
1381MWD09	9/19/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.3
1381MWS11	9/20/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	12.2
1381MWS12	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	7.8
1381MWD12	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
1381MWS13	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.6
1381MWS14	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.3
1381MWS15	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	12.3
1381MWS16	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.2
1381MWS17	9/20/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.6
1381MWS18	9/19/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.0
1381MPS01	9/19/1996	ND	< 1.0	ND	ND	< 1.0	ND	ND	ND	< 1.0	1.2
1381MPI01	9/21/1996	ND[b/]	2	ND	ND	2	ND	ND	ND	2.6	NA
1381MPI02	9/21/1996	ND	3.3	ND	ND	3.3	ND	ND	ND	4.2	8.3
1381MPI03	9/23/1996	ND	1.9	ND	ND	1.9	ND	ND	ND	5.5	57.3
1381MPI05	9/24/1996	ND	< 1.0	ND	ND	< 1.0	ND	ND	ND	< 1.0	15.2
1381MPI06	9/24/1996	ND	3.8	ND	ND	3.8	ND	ND	ND	9.2	11.4
1381MPS07	9/23/1996	ND	5.6	ND	ND	5.6	ND	ND	ND	12.5	2.6
1381MPI07	9/23/1996	ND	3.8	ND	ND	3.8	ND	ND	ND	4.5	8.2

TABLE 4.7 (Concluded)
POTENTIAL ELECTRON DONORS DETECTED IN GROUNDWATER AND SURFACE WATER
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Sample Location	Sample Collection	Benzene (µg/L)[a/]	Toluene (µg/L)	Ethyl-benzene (µg/L)	Xylenes (µg/L)	Total BTEX (µg/L)	1,3,5-TMB (µg/L)	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	Fuel Carbon (µg/L)	Total Organic Carbon (mg/L)
1381MPS08	9/23/1996	ND	1.5	ND	ND	1.5	ND	ND	ND	8	5.7
1381MPI08	9/24/1996	ND	5.7	ND	ND	5.7	ND	ND	ND	6.4	83.2
1381MPS10	9/24/1996	ND	4.0	ND	ND	4.0	ND	ND	ND	3.4	7.0
1381MPI10	9/24/1996	ND	1.8	ND	ND	1.8	ND	ND	ND	1.6	2.6
1381MPI11	9/24/1996	ND	1.8	ND	ND	1.8	ND	ND	ND	1.8	192.0
1381MPI13	9/24/1996	ND	2.8	ND	ND	2.8	ND	ND	ND	4.6	13.0
1381MPI17	9/23/1996	ND	3.5	ND	ND	3.5	ND	ND	ND	3.6	14.9
1381MPI18	9/24/1996	ND	6.4	ND	ND	6.4	ND	ND	ND	5.4	13.8
1381MPI19	9/23/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
1381MPI20	9/25/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	11.7
1381MPI21	9/24/1996	NA[c/]	NA	NA	NA	NA	NA	NA	NA	NA	9.9
SURA	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
SURB	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
SURC	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
SURD	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
SURE	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
SURF	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA
PRMP01	9/25/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	6.2
PRMP02	9/25/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.9

[a/] µg/L = micrograms per liter.

[b/] ND = not detected.

[c/] NA=not applicable.

and only minor BTEX concentrations (1.9 and 5.7 µg/L, respectively). TOC concentrations measured at the two deep monitoring well locations ranged from 6.3 to 7.4 mg/L, which is similar to the range of TOC concentrations detected in shallow portion of the aquifer.

The background concentrations of dissolved TOC at every interval in the aquifer are noteworthy because they represent additional organic matter that is available for use as a substrate in biodegradation reactions in the absence of detectable concentrations of petroleum compounds. The background concentrations likely represent compounds dissolved from organic matter dispersed throughout the aquifer. In addition to the soil TOC, this native carbon source should provide a continuing source of electron donors to be used in microbial redox reactions. Dissolved TOC concentrations in excess of 20 mg/L are desirable to drive dehalogenation reactions (Wiedemeier *et al.*, 1996a). This condition is only fulfilled at sporadic locations in the intermediate intervals of the surficial aquifer (approximately 30 feet bgs). Therefore, dissolved TOC concentrations may limit biotransformation reactions.

4.4.6 Alternate Electron Acceptors and Metabolic Byproducts

Biodegradation of organic compounds, whether natural or anthropogenic, brings about measurable changes in the chemistry of groundwater in the affected area. Concentrations of compounds used as electron acceptors (e.g., DO, nitrate, and sulfate) are depleted, and byproducts of electron acceptor reduction (e.g., ferrous iron, methane, and sulfide) are enhanced. By measuring these changes, it is possible to evaluate the importance of natural attenuation at a site.

4.4.6.1 Dissolved Oxygen

Reductive dehalogenation is an anaerobic process, and DO concentrations in excess of 0.5 mg/L may cause the reductive transformation pathway to be suppressed. Therefore, highly chlorinated compounds such as PCE, TCE, and TCA are biologically recalcitrant under aerobic conditions. DO concentrations were measured at monitoring wells and points during the September 1996 sampling event. These concentrations are summarized in Table 4.3, and DO concentrations measured from shallow monitoring wells/point are displayed on Figure 4.10. DO concentrations measured in the shallow portion of the aquifer ranged from <0.1 mg/L at monitoring well/point locations 1381MWS07 and 1381MWS12 to 4.8 mg/L at cross-gradient well 1381MWS13. The average background DO concentration measured at cross-gradient wells/point transverse is 1.14 mg/L (averaged from wells/points 1381MPS01, 1381MPS07, 1381MPS10, 1381MWS13, and 1381MWS16). The average DO concentrations in the source area is 0.9 mg/L (averaged from wells 1381MWS01, 1381MWS03, 1381MWS09, and 1381MWS17). The elevated DO concentration in the source area likely is the result of air sparging system installation and testing (prior to October 1997 system startup) which may have increased the DO content of the aquifer in this area. If it is assumed that monitoring well 1381MWS01 is not representative of normal DO concentrations in the aquifer, then the average source area DO concentration is approximately 0.1 mg/L. Consistently low (<0.5 mg/L) DO concentrations favors the occurrence of reductive dehalogenation. DO concentrations

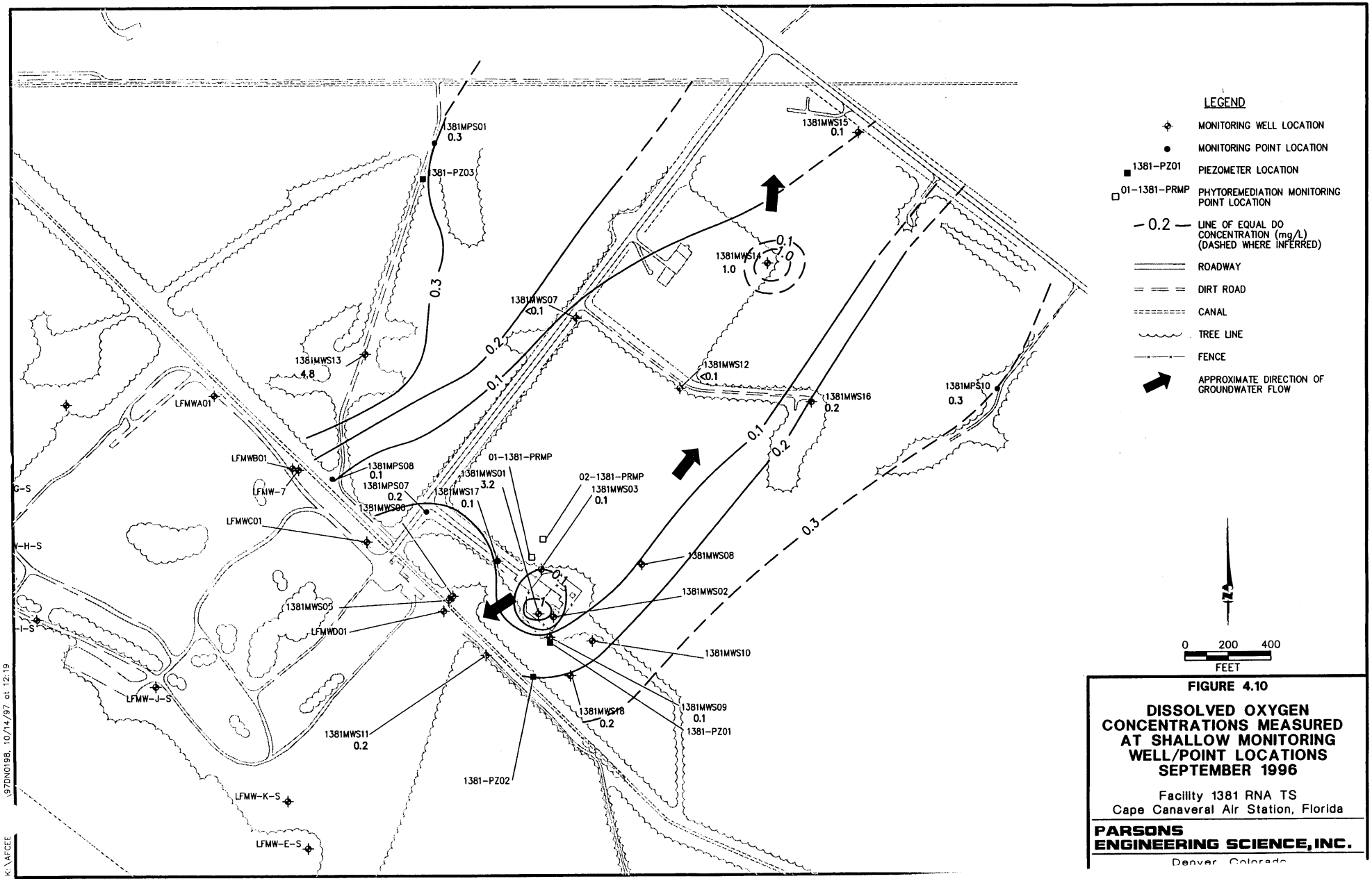


FIGURE 4.10

DISSOLVED OXYGEN CONCENTRATIONS MEASURED AT SHALLOW MONITORING WELL/POINT LOCATIONS SEPTEMBER 1996

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

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Denver, Colorado

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measured at intermediate and deep well/point locations are below 0.3 mg/L, suggesting widespread anaerobic conditions at depth in both background and source areas.

4.4.6.2 Nitrate/Nitrite

After dissolved oxygen has been depleted in the microbiological treatment zone, nitrate may be used as an electron acceptor for anaerobic biodegradation of organic carbon via denitrification. Nitrate concentrations below background in areas with high organic carbon concentrations are indicative of denitrification. The oxidation of organic carbon via the process of denitrification (using nitrate as an electron acceptor) yields a relatively high amount of free energy to microbial populations, and therefore is energetically favorable (preferred) compared to using CAHs as electron acceptors. If nitrate concentrations exceed 1 mg/L, then microorganisms may preferentially use nitrate instead of CAHs to produce energy for their use (Wiedemeier *et al.*, 1996b).

Concentrations of nitrate + nitrite (as N) were measured at monitoring wells and points during the September 1996 sampling event. These concentrations are summarized in Table 4.3. Nitrate/nitrite (as N) was detected in 26 of 39 samples. Nitrate/nitrite (as N) was detected at only three shallow monitoring well locations at concentrations ranging from 0.13 to 1.85 mg/L. The highest nitrate/nitrite concentration (1.85 mg/L) was detected at monitoring well 1381MWS02, which is located in the source area. Nitrate may have entered the groundwater at this location as a result of nitrate compounds disposed of near the former leachfield or possibly as a result of lawn fertilizer applied to the grass around Facility 1381.

Nitrate/nitrite concentrations detected at intermediate monitoring well/point locations are relatively low, ranging from <0.05 to 0.19 mg/L. Similarly, nitrate/nitrite concentrations at deep monitoring well/point locations are low, ranging from <0.05 to 0.07 mg/L. Therefore, reductive dehalogenation of TCE in groundwater at the site in any depth interval will not be inhibited by preferential use of nitrate as an electron acceptor.

4.4.6.3 Sulfate

Sulfate also may be used as an electron acceptor during microbial degradation of fuel hydrocarbons under anaerobic conditions (Grbic-Galic, 1990). This redox reaction is commonly called sulfate reduction. Sulfate is reduced to sulfide during the oxidation of natural or anthropogenic organic carbon. Wiedemeier *et al.* (1996b) report that sulfate may compete with CAHs as an electron acceptor (sulfate may be preferentially used by microorganisms instead of CAHs) if sulfate concentrations exceed 20 mg/L. To investigate the potential for sulfate reduction at Facility 1381, total sulfate concentrations were measured at groundwater monitoring wells and monitoring points during the September 1996 sampling event. Sampling results are summarized in Table 4.3.

Sulfate concentrations in shallow groundwater monitoring wells/points at the site ranged from 8.8 mg/L to 138 mg/L. Shallow background sulfate concentrations at five well/point locations that are cross-gradient to the CAH plume (1381MPS01, 1381MWS13, 1381MWS07, 1381MWS16, and 1381MPS10) ranged from 2.8 mg/L to 25.2 mg/L, and averaged 14.2 mg/L. Sulfate concentrations in the source area ranged

from 44.6 to 71.4 mg/L, and averaged 57.0 mg/L. Sulfate concentrations are typically increased in the source area relative to background concentrations, (contrary to the pattern observed at shallow monitoring wells/points in the shallow portion of the surficial groundwater aquifer). No use or release of sulfate compounds have been recorded at Facility 1381 that might cause elevated sulfate concentrations in source area groundwater. Cleaning acids used at Facility 1381 were limited to nitric and hydrochloric acids that were disposed of in the former limestone neutralization pit located southwest of the building. Sulfate concentrations in intermediate and deep monitoring points/wells were below 1 mg/L at every location. These data indicate that sulfate concentrations could be expected to compete with CAHs for use as electron acceptors in the source area, and might therefore limit reductive dechlorination. Competition between CAHs and sulfate should not be a factor at depth in the aquifer because of the low sulfate concentrations.

4.4.6.4 Ferrous Iron

Although relatively little is known about the anaerobic metabolic pathways involving the reduction of ferric iron (Fe^{3+}), this process has been shown to be a major metabolic pathway for some microorganisms (Lovley and Phillips, 1988; Chapelle, 1993). The reduction of ferric iron results in the formation of ferrous iron (Fe^{2+}). Elevated concentrations of ferrous iron often are found in anaerobic groundwater systems. These concentrations once were attributed to the spontaneous and reversible reduction of ferric oxyhydroxides, which are thermodynamically unstable in the presence of organic compounds such as BTEX, trimethylbenzene (TMB), and naphthalene. However, recent evidence suggests that the reduction of ferric iron cannot proceed at all without microbial mediation (Lovley and Phillips, 1988; Lovley *et al.*, 1991; Chapelle, 1993). None of the common organic compounds found in low-temperature, neutral, reducing groundwater could reduce ferric oxyhydroxides to ferrous iron under sterile laboratory conditions (Lovley *et al.*, 1991). This means that the reduction of ferric iron requires mediation by microorganisms with the appropriate enzymatic capabilities.

Ferrous iron concentrations were measured at selected groundwater monitoring wells and monitoring points in September 1996. These concentrations are summarized in Table 4.3 and ferrous iron concentrations at shallow monitoring wells/points are displayed on Figure 4.11. Dechlorination of PCE and TCE to DCE is possible under mildly-reducing conditions such as nitrate or ferric iron reduction, but the transformation from DCE to VC or from VC to ethene seems to require the more strongly reducing conditions of methanogenesis. Therefore, the presence of redox conditions that are favorable to the occurrence of iron reduction suggests that reductive dehalogenation of the more highly-chlorinated CAHs (e.g., PCE and TCE) is likely, and the reductive dehalogenation of DCE or VC is possible.

Ferrous iron was detected in shallow monitoring wells/points at concentrations ranging from <0.05 to 8.7 mg/L (Figure 4.11). Background ferrous iron concentrations averaged less than 0.23 mg/L at well/points located cross-gradient of the CAH plume (1381MPS01, 1381MWS13, 1381MWS16, and 1381MPS10). In the source area, ferrous iron concentrations averaged 1.45 mg/L (1381MWS01, 1381MWS09, and 1381MWS17). Therefore, limited ferrous iron reduction is occurring at shallow depths in the surficial aquifer. The maximum ferrous iron detection downgradient of the source area was

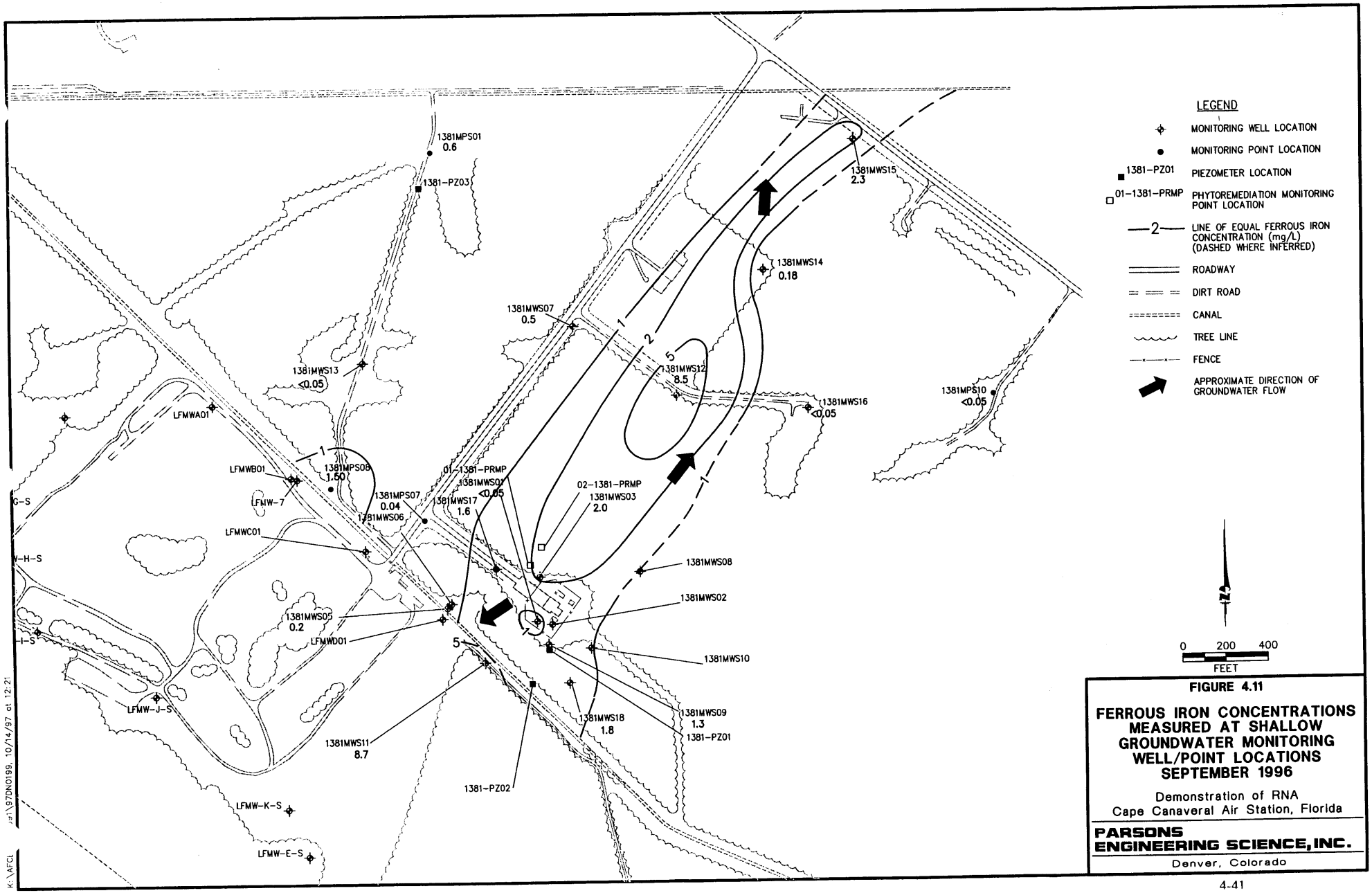


FIGURE 4.11

FERROUS IRON CONCENTRATIONS MEASURED AT SHALLOW GROUNDWATER MONITORING WELL/POINT LOCATIONS SEPTEMBER 1996

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8.5 mg/L at monitoring well 1381MWS12; the maximum ferrous iron concentration detected at the site was 8.7 mg/L at monitoring well 1381MWS11, located beyond the southern drainage canal. Figure 4.11 suggests that localized conditions favoring ferrous iron reduction exist near monitoring well 1381MWS12, possibly as a result of the depletion of more thermodynamically favorable electron acceptors (DO and nitrate).

Ferrous iron was not detected at 11 of 16 intermediate monitoring wells/points and ferrous iron concentrations detected at the remaining five wells ranged from 0.2 to 0.8 mg/L. Ferrous iron concentrations at deep monitoring wells were below 0.2 mg/L. Therefore, iron reducing processes at Facility 1381 appear to become less important with increasing depth in the surficial aquifer.

4.4.6.5 Methane in Groundwater

Although reductive dehalogenation may occur under nitrate- and sulfate-reducing conditions (Vogel *et al.*, 1987 and Chapelle, 1996), the most rapid biodegradation rates, affecting the widest range of CAHs, occurs under methanogenic conditions (Bouwer, 1994). Methane concentrations were measured in groundwater samples collected in September 1996 to assess whether methanogenic conditions are present in Facility 1381 groundwater. Table 4.3 lists methane concentrations, and Figure 4.12 shows the distribution of methane in shallow site groundwater. The presence of methane within and downgradient from the TCE source area and at background locations indicates that petroleum hydrocarbons and/or native organic matter are being used to support methanogenesis. In the shallow portion of the surficial aquifer, the maximum methane concentration of 4 mg/L is located in the source area at 1381MWS09. However, elevated methane concentrations also were detected at other locations not in the primary path of contaminant migration (e.g., 1381MPS08), suggesting that methanogenesis of available natural carbon sources occurs under background conditions in some portions of the surficial aquifer.

Methanogenic conditions increase with depth in the aquifer, as indicated by an order of magnitude increase in methane concentrations between shallow and intermediate-depth monitoring wells (Figure 4.12). Therefore, it appears that redox conditions in this depth interval are more favorable to the oxidation of available carbon through methanogenesis. Methane concentrations ranged from 0.103 mg/L to 32.6 mg/L at intermediate wells/points across the site, with an average methane concentration in the source area of 23.5 mg/L. The average methane concentration at two intermediate monitoring points positioned cross gradient to the CAH plume (1381MPI02 and 1381MPI10) was 9.35 mg/L. Methanogenic conditions also are present in deep intervals as evidenced by average deep methane concentrations of 18.1 mg/L. The fact that methanogenesis is occurring at Facility 1381, particularly at intermediate and deep intervals, indicates that the aquifer redox conditions are favorable for the reductive dehalogenation of CAHs.

4.4.6.6 Volatile Fatty Acids and Phenols

Fatty acids are synthesized by microorganisms to be used in the production of lipids necessary for incorporation into various membranes. A portion of these fatty acids are volatile. Volatile fatty acids (VFAs) are produced when the bacterial cell has obtained

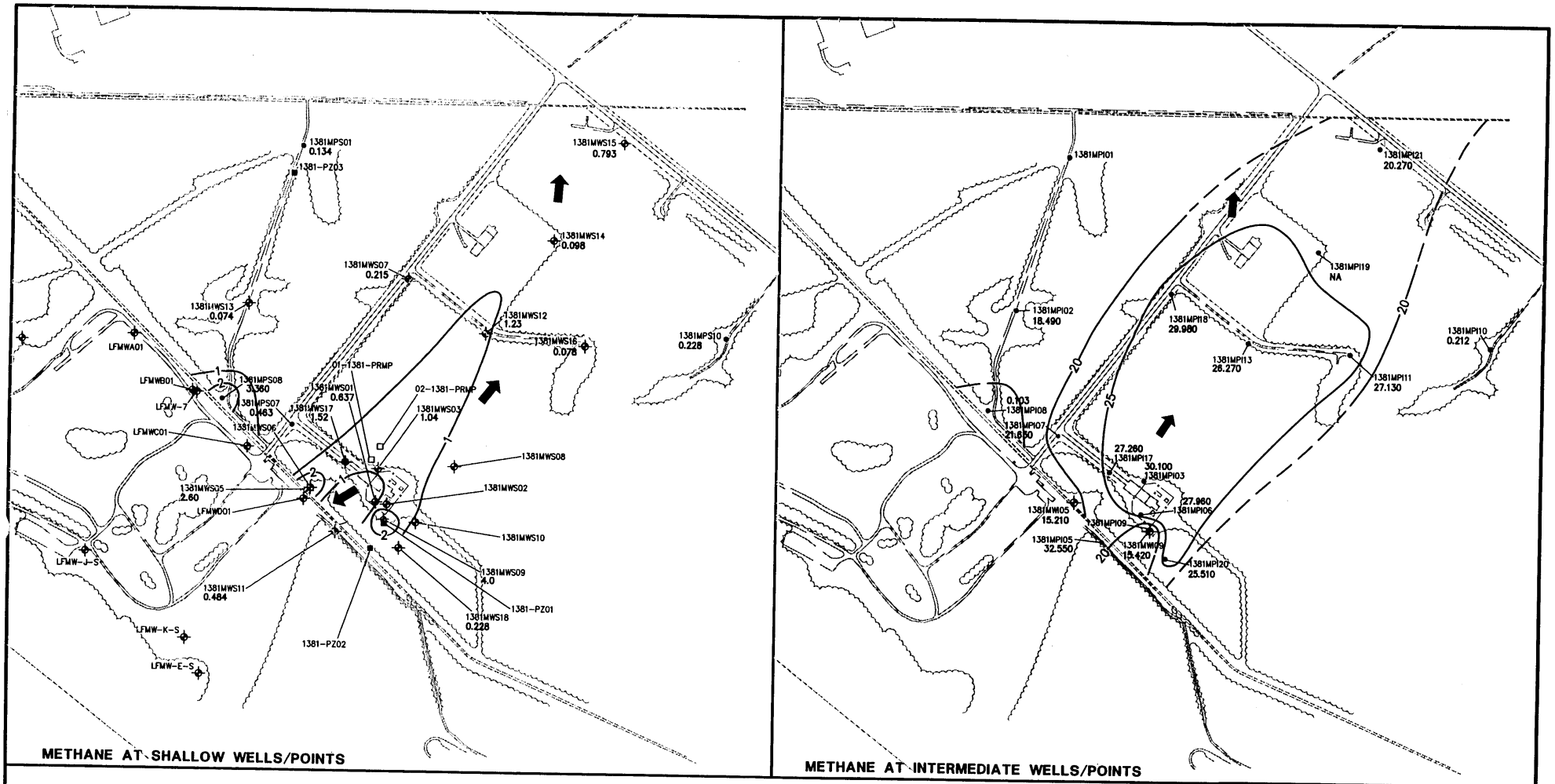


FIGURE 4.12

METHANE CONCENTRATIONS MEASURED AT SHALLOW AND INTERMEDIATE GROUNDWATER WELL/POINT LOCATIONS, SEPTEMBER 1996

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the required energy from metabolism of a carbon source (i.e., BTEX, CAHs, or naturally occurring organic carbon). After VFAs are secreted from the bacterial cell, they volatilize fairly rapidly; therefore detection of VFAs in groundwater is a strong indication of recent metabolic activity, and possibly biodegradation of BTEX or CAHs. The standard method of VFA analysis performed by USEPA researchers is a gas chromatography/mass spectrometry method in which groundwater samples are compared to a standard mixture containing 58 phenols, aromatic acids, and aliphatic acids.

Samples for VFA analysis were collected at wells 1381MWS01, 1381MWD01, 1381MWS09, and 1381MWI06. Monitoring wells 1381MWS01 and 1381MWS09 have historically contained significant concentrations of TCE. Analysis results are presented in Appendix A. Collectively, 9 of the 58 compounds in the standard mixture were detected at concentrations exceeding the reporting limit of 5 µg/L, providing some evidence that the oxidation of organic matter is occurring. However, 46 of the 58 analytes were detected at low concentrations below the reporting limit in at least one well, indicating that the oxidation processes that produce the acids are not areally prolific.

4.4.6.7 Ammonia

The presence of ammonia in groundwater can result from either nitrate reduction (facilitated by microbes) or fixing of atmospheric nitrogen (also a microbial process). Nitrate is not widespread in groundwater within the aquifer; however, the fixation of atmospheric nitrogen may occur under the anaerobic, methanogenic conditions observed at the site. The presence of ammonia in groundwater is a strong indication of microbial activity.

Ammonia concentrations measured in groundwater samples collected in September 1996 are summarized in Table 4.3. Ammonia was detected in 35 of the 39 samples analyzed. Ammonia concentrations detected in shallow monitoring wells/points varied across the site with slightly elevated ammonia concentrations occurring in the (but not limited to) source area. For example, cross-gradient monitoring points 1381MPS08 and 1381MPS10 contained 6.01 and 0.56 mg/L ammonia, respectively. The average background ammonia concentration was 0.23 mg/L (1381MPS01, 1381MWS07, 1381MWS16, and 1381MPS10), whereas the source area concentration averaged 0.60 mg/L (1381MWS02, 1381MWS09, 1381MWS03, and 1381MWS17). Therefore, microbial production of ammonia appears to be occurring at only slightly higher rate in the source area. As described in Section 4.4.6.2, nitrate/nitrite concentrations detected in most wells and points at Facility 1381 were relatively low. Thus the nitrate nitrogen deficit at the site in shallow portions of the surficial aquifer may be overcome by microbial communities that fixate atmospheric nitrogen.

Ammonia concentrations detected in intermediate or deep monitoring wells/points increased relative to shallow monitoring wells/points. Similar to shallow wells/points, the increase in ammonia concentrations in the source area relative to background concentrations was minor. Background concentrations averaged 10.4 mg/L (1381MPI10, 1381MPI11, 1381MPI01, and 1381MPI18), as compared to an average source area concentration of 16.8 mg/L (1381MPI17, 1381MPI03, 1381MPI06, and 1381MWI09).

4.4.7 Additional Geochemical Indicators

Other geochemical data collected for this evaluation can be used to further interpret and support the contaminant, electron donor, electron acceptor, and byproduct data previously discussed. These parameters provide additional qualitative indications of what processes may be operating at the site.

4.4.7.1 Alkalinity and Carbon Dioxide

Total alkalinity (as $CaCO_3$) was measured in groundwater samples collected in September 1996 (Table 4.3). Alkalinity is a measure of the ability of groundwater to buffer changes in pH caused by the addition of biologically generated acids. In general, contaminated areas should have a total alkalinity that is higher than in background areas if microbially-mediated reactions are occurring. Total alkalinity measured at all site locations varied from 178 mg/L to 960 mg/L. Alkalinity concentrations measured in shallow monitoring points/wells suggests the presence of increased alkalinity along the plume centerline (Figure 4.13). Alkalinity concentrations in the plume area were generally greater than 300 mg/L as $CaCO_3$, whereas background locations were mostly below this level.

Alkalinity increased between shallow and deeper monitoring wells. In the vicinity of the source area, alkalinity concentrations in intermediate-depth wells averaged 846 mg/L (1381MPI03, 1381MPI06, 1381MWI09, 1381MPI17) as compared to 645 mg/L at background locations (1381MPI01, 1381MPI18, 1381MPI10, and 1381MPI11). The average alkalinity value for deep monitoring wells was 467 mg/L. The range of alkalinity measured at every location at the site was sufficient to buffer potential changes in pH caused by biologically mediated reactions, and suggests that aerobic and/or anaerobic biodegradation processes should not cause detrimental shifts in pH.

Carbon dioxide concentrations measured at shallow monitoring well/point locations in September 1996 ranged from 60 mg/L to 386 mg/L (Table 4.3). A pattern of elevated carbon dioxide concentrations in shallow source area wells/points was not noted; therefore, carbon dioxide concentrations in the shallow portion of the surficial aquifer do not provide direct evidence of the occurrence of methanogenesis or of the complete mineralization of VC.

Carbon dioxide concentrations at intermediate depths ranged from 170 mg/L to 438 mg/L, with an apparent increase in carbon dioxide concentrations and downgradient of the source area. The average background concentrations of carbon dioxide at intermediate depths was 244 mg/L (1381MPI01, 1381MPI02, 1381MPI10, and 1381MPI11), whereas the average source area concentrations at intermediate depths was 339 mg/L (1381MPI03, 1381MWI09, and 1381MPI17). Therefore, carbon dioxide concentrations at intermediate wells/points suggest that complete mineralization of contaminants under methanogenic conditions with subsequent generation of carbon dioxide is occurring. Furthermore, increases in carbon dioxide coincide with increases in dissolved organic carbon, which provides a significant carbon source (electron donor) at the site. The average carbon dioxide concentration at deep monitoring well locations was

139 mg/L, suggesting decreased production of this compound near the base of the surficial aquifer.

4.4.7.2 pH

pH was measured for groundwater samples collected from monitoring points and monitoring wells in September 1996 (Table 4.3). The pH of a solution is the negative logarithm of the hydrogen ion concentration [H^+]. The groundwater pH measured at the site ranged from 7.2 to 8.3 standard units, which is within the optimal range for most microbial populations that degrade organic matter. The neutral to slightly basic range of site pH measurements also indicates that microbial reactions have a minimal effect on groundwater pH, likely due to the moderately high alkalinity of site groundwater. The pH values measured in deeper samples are similar to the values measured at shallower depths.

4.4.7.3 Temperature

Groundwater temperature was measured at monitoring points and wells in September 1996 (Table 4.3). Temperature affects the types and growth rates of bacteria that can be supported in the groundwater environment, with higher temperatures generally resulting in higher growth rates. Temperatures in the surficial aquifer varied from 21.2 degrees Celsius (°C) to 29.2°C. Wiedemeier *et al.* (1996b) report that biochemical processes are accelerated at groundwater temperatures greater than 20°C. It is likely that the biodegradation of CAHs at the site is enhanced by the relatively warm groundwater temperatures.

4.5 APPROXIMATION OF BIODEGRADATION RATES

Estimation of biodegradation rate constants is necessary to accurately simulate the fate and transport of contaminants dissolved in groundwater. Several methodologies, including first- and second-order approximations, may be used to estimate the rate of biodegradation of chlorinated compounds. Use of the first-order approximation can be appropriate to estimate biodegradation rates for chlorinated compounds where the rate of biodegradation is assumed to be controlled solely by the concentration of the contaminant. However, the use of a first-order approximation may not be appropriate when more than one substrate is limiting microbial degradation rates or when microbial mass is increasing or decreasing. In such cases, a second- or higher-order approximation may provide a better estimate of biodegradation rates. The preferred method of contaminant biodegradation rate-constant determination is by use of field data.

Buscheck and Alcantar (1995) derive a relationship that allows calculation of first-order biodegradation rate constants for steady-state plumes. This method involves coupling the regression of contaminant concentration (plotted on a logarithmic scale) versus distance downgradient (plotted on a linear scale) to an analytical solution for one-dimensional, steady-state, contaminant transport that includes advection, dispersion, sorption, and biodegradation (Bear, 1979). For an expanding plume, this first-order approximation can be viewed as an upper bound on the biodegradation rate because a typical expanding plume exhibits decreasing source area concentrations, increasing

downgradient concentrations, or both. Over time, these changes result in a decreasing slope on a log-linear plot, and consequently a decreasing biodegradation rate.

Another method for estimating dehalogenation rates of CAHs is described by Moutoux *et al.* (1996). This method can be used to estimate the theoretical contaminant concentration resulting from reductive dechlorination alone for every point along a flow path on the basis of the measured contaminant concentration at the point of plume origin and the contaminant/tracer ratios between consecutive points along the flow path. This series of points can then be used to estimate a first-order rate of biodegradation. The carbon core of the CAH compounds, which is subject to the same non-destructive attenuation mechanisms that act on the larger chlorinated molecule, but is unaffected by biologically mediated reductive dechlorination, is used as the tracer. This method provides a total dechlorination rate for all dechlorination steps. All rates (including the rapid TCE to DCE rate and the slow VC to ethene) are averaged using the Moutoux *et al.* (1996) method. Because abiotic reactions and reactions that involve CAHs in the role of an electron donor are not included in this rate, the rate should be considered to be a lower bound on the destructive attenuation rate.

Although a first-order rate assumption may provide a reasonable approximation of how CAH compounds are degrading in groundwater systems, this approach may not provide the best approximation of how CAH compounds are dechlorinated in the presence of an electron donor such as BTEX. These reactions may be more appropriately approximated by a second-order rate expression. This approach was not used for the Facility 1381 plume due to the lack of BTEX in the groundwater and because current models are incapable of using a second-order degradation rate.

The two first-order methods described above were used to estimate first-order biodegradation rate constants for CAHs at Facility 1381. The decay rate calculations are summarized in Appendix C. As described in Section 4.3.1, the relatively rapid decrease in TCE concentrations measured between wells 1381MWS09 (39,400 µg/L) and 1381MWS03 (not detected) may be related to site hydrogeology (the presence of a groundwater divide) and to the operation of natural attenuation processes. Therefore, biodegradation rates calculated for the flow path 1381MWS09 - 1381MWS03 may be inaccurate. As a result, several flowpath were used to calculate a range of CAH biodegradation rates. The first flowpath extended, from the source area (1381MWS09) to the toe of the plume (1381MWS15). The second flow path limited to the source area between wells 1381MWS09 and 1381MWS03. The third flow path encompassed the downgradient segment of the plume north of the primary source area (from 1381MWS03 to 1381MWS15). The decay rates computed for total CAHs along the flow paths are summarized in Table 4.8.

The rates computed using the method of Buscheck & Alcantar (1995) are approximately one order-of-magnitude higher than the rates derived for reductive dechlorination using the method of Moutoux *et al.* (1996). As described above, the Buscheck and Alcantar method can be viewed as an upper bound on the biodegradation rate, and the reductive dechlorination rates as a lower bound. The biodegradation rates assume groundwater velocities of 0.11 and 0.03 ft/day for the source area and downgradient of the source area, respectively. These velocities are within the range of

TABLE 4.8
SUMMARY OF CAH DECAY RATES
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Plume Segment	Analysis Method	Selected Flow Path	Date of Sampling Data	First Order Decay Rate (day^{-1})	Half Life (year)
Total	B&A[a/]	1381MWS09, -S03, -S12, -S15	Winter 1995/Spring 1996	3.5×10^{-5}	54
Total	B&A	1381MWS09, -S03, -S12, -S15	September 1996	5.6×10^{-5}	34
Total	Reduc. Dechlor[b/]	1381MWS09, -S03, -S12, -S15	Winter 1995/Spring 1996	1.3×10^{-6}	1400
Total	Reduc. Dechlor	1381MWS09, -S03, -S12, -S15	September 1996	1.0×10^{-6}	1900
Upgradient	B&A	1381MWS09 - 1381MWS03	Winter 1995/Spring 1996	3.2×10^{-4}	5.9
Upgradient	B&A	1381MWS09 - 1381MWS03	September 1996	3.0×10^{-4}	6.4
Upgradient	Reduc. Dechlor	1381MWS09 - 1381MWS03	Winter 1995/Spring 1996	4.1×10^{-5}	46
Upgradient	Reduc. Dechlor	1381MWS09 - 1381MWS03	September 1996	4.8×10^{-5}	40
Downgradient	B&A	1381MWS03, -S12, -S15	Winter 1995/Spring 1996	4.6×10^{-5}	41
Downgradient	B&A	1381MWS03, -S12, -S15	September 1996	2.6×10^{-5}	75
Downgradient	Reduc. Dechlor	1381MWS03, -S12, -S15	Winter 1995/Spring 1996	c/	c/
Downgradient	Reduc. Dechlor	1381MWS03, -S12, -S15	September 1996	c/	c/

a/ B&A = Method of Buscheck and Alcantar (1995) for steady-state plumes.
b/ Reduc. Dechlor. = Method of Moutoux et al. (1996), which gives decay rate attributable to reductive dechlorination.
c/ Corrected CAH concentrations increased with distance along flow path; reductive dechlorination rate or half-life not calculated.

values computed for the site (Section 3.3.2.4), but maybe lower than the maximum velocity present at the site. Because higher velocities result in higher calculated biodegradation rates, the computed rates may be conservative.

4.6 SUMMARY

The dissolved CAH plume has migrated to the northern drainage canal located approximately 2,600 feet north/northeast of Facility 1381. Dissolved CAH contamination has also migrated to the southern drainage canal approximately 300 feet to the south/southwest. However, this report focuses on the natural attenuation of CAH mass migrating north from Facility 1381, because more active (engineered) treatment technologies are being used for groundwater contamination migrating to the south (Parsons ES, 1997a). The CAH mass that is reaching the northern drainage canal is insignificant relative to the mass that is migrating in the groundwater. This is supported by the absence of CAH detections is surface water samples collected from the northern drainage canal. Relatively low CAH concentrations were detected at intermediate and deep monitoring wells in the source area; however, CAH contamination has not migrated outside of the source area vicinity at these depth intervals.

Several lines of chemical and geochemical evidence indicate that dissolved CAHs at Facility 1381 are undergoing biologically facilitated reductive dehalogenation. The occurrence of reductive dehalogenation is pronounced in the source area, where the parent CAH (TCE) is rapidly biodegraded. As a result, all TCE contamination appears to be transformed to DCE, VC, and ethene within 200 feet downgradient from the source area. Some 1,1,1-TCA was detected in the source area together with subsequent breakdown products in the form of DCA isomers and 1,1-DCE. The dissolved CAH plume at Facility 1381 exhibits mixed type 2/type 1 behavior. Type 2 behavior appears to dominate across the site, and results from the presence of significant natural organic carbon in the groundwater and low DO concentrations across the site. Type 1 behavior is localized in the source area as supported by elevated methane concentrations (relative to background) and minor BTEX/fuel carbon detections in shallow and intermediate monitoring wells. These detections suggest that at least small amounts of petroleum hydrocarbons were introduced in the source area near Facility 1381, stimulating additional microbial activity and making the groundwater system more reducing and favorable for the reductive dehalogenation of CAHs (localized Type 1 behavior). Further evidence supporting the occurrence of CAH biodegradation is summarized below:

- The presence of *cis*-1,2-DCE, VC, and ethene is a direct indication that TCE, DCE, and VC are being reductively dehalogenated. The high magnitude of daughter product concentrations relative to TCE indicates that the reductive transformation of TCE has been extensive. DCE isomers also are being reductively dechlorinated to VC, and VC to ethene. However, the reductive transformation of these daughter products is much slower than the transformation of TCE to DCE.

- The presence of elevated chloride concentrations (above background levels) along a narrow corridor from the source area to the northern drainage canal indicates that reductive dehalogenation reactions are prevalent enough to significantly impact chloride concentrations;

- Redox potentials measured in the source area and along the centerline of the plume were less than -100 mV, indicating that groundwater is reducing and therefore amenable to reductive dehalogenation.

- Dissolved H_2 data indicate that the groundwater is reduced to a level that is optimal for sulfate-reducing microorganisms in shallow and intermediate depth intervals and methanogenic microorganisms in deep intervals. These redox conditions support the occurrence of reductive dehalogenation.

- Dissolved BTEX concentrations are not sufficient to sustainably drive dehalogenation reactions; however, dissolved native organic carbon acting as an electron donors are sufficient to drive dehalogenation reactions, although possibly to a less extent.

- The lack of DO throughout the majority of the CAH plume supports the occurrence of reductive dehalogenation, which is an anaerobic process.

- Most nitrate concentrations in the aquifer are low, but sulfate concentrations across the plume are sufficiently high that use of CAHs as electron acceptors may be inhibited due to preferential use of sulfate (supported by dissolved H_2 concentrations) as an alternate electron acceptor. However, available sulfate data do not support the occurrence of significant levels of sulfate reduction.

- The evidence that methanogenic conditions are or were present near the source area indicates that conditions favorable for reductive dehalogenation of CAHs are or were locally present. Methane concentrations increased with depth in the surficial aquifer, thereby suggesting the presence of more methanogenic conditions and reductive dehalogenation potential at depth.

- The significant ammonia concentrations detected at the site suggest that microbial activity is occurring in the plume area. Considering the low nitrate levels detected at the site, much of the ammonia (at least in shallow zones) may be derived from the fixation of atmospheric nitrogen.

Wiedemeier *et al.* (1996b) present a worksheet to allow an initial assessment of the prominence of reductive dehalogenation at a site. The worksheet, including the point values determined for Facility 1381, are included as Table 4.9. The interpretation of points awarded during the screening process is shown in Table 4.10. The score for Facility 1381 computed using Table 4.9 is 27, indicating that strong evidence for reductive dehalogenation of chlorinated organics is present.

As discussed in Section 4.5, rates of CAH biodegradation estimated from data collected for this investigation range from 3.2×10^{-4} day^{-1} to 1.0×10^{-6} day^{-1}, corresponding to half-lives ranging from 5.9 to 1,900 years, respectively. Higher decay rates are believed to be present in the Facility 1381 source area, and lower decay rates appear to be present in downgradient portion of the plume.

TABLE 4.9
ANALYTICAL PARAMETERS AND WEIGHTING FOR PRELIMINARY SCREENING[a/]
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Analysis	Concentration in Most Contaminated Zone	Interpretation	Value	Facility 1381 Score
Oxygen	<0.5 mg/L	Tolerated, suppresses the reductive pathway at higher concentrations	3	3
Oxygen	>1 mg/L	VC may be oxidized aerobically	-3	--
Nitrate	<1 mg/L	At higher concentrations may compete with reductive pathway	2	2
Iron II	>1 mg/L	Reductive pathway possible	3	3
Sulfate	<20 mg/L	At higher concentrations may compete with reductive pathway	2	0
Sulfide	>1 mg/L	Reductive pathway possible	3	0
Methane	<0.5 mg/L >0.5 mg/L	VC oxidizes Ultimate reductive daughter product, VC Accumulates	0 3	3
Oxidation Reduction Potential (redox potential)	<50 millivolts (mV) <-100mV	Reductive pathway possible Reductive pathway likely	1 2	2
pH*	5 < pH < 9 5 > pH >9	Optimal range for reductive pathway Outside optimal range for reductive pathway	0 -2	0
TOC	> 20 mg/L	Carbon and energy source; drives dechlorination; can be natural or anthropogenic	2	2
Temperature	> 20°C	At T >20°C biochemical process is accelerated	1	1
Carbon Dioxide	>2x background	Ultimate oxidative daughter product	1	0
Alkalinity	>2x background	Results from interaction of carbon dioxide with aquifer minerals	1	0
Chloride	>2x background	Daughter product of organic chlorine	2	2
Hydrogen	>1 nM	Reductive pathway possible, VC may accumulate	3	1
Hydrogen	<1 nM	VC oxidized	0	0

TABLE 4.9 (Concluded)
ANALYTICAL PARAMETERS AND WEIGHTING FOR PRELIMINARY SCREENING[a/]
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Analysis	Concentration in Most Contaminated Zone	Interpretation	Value	Facility 1381 Score
Volatile Fatty Acids	> 0.1 mg/L	Intermediates resulting from biodegradation of aromatic compounds; carbon and energy source	2	0
BTEX	> 0.1 mg/L	Carbon and energy source; drives dechlorination	2	0
PCE		Material released	0	0
TCE		Material released	0	0
		Daughter product of PCE	2	0
DCE		Material released	0	0
		Daughter product of TCE.	2	2
		If cis is greater than 80% of total DCE it is likely a daughter product of TCE		
VC		Material released	0	0
		Daughter product of DCE	2	2
Ethene/Ethane	>0.01mg/L	Daughter product of VC/ethene	2	2
	>0.1 mg/L		3	0
Chloroethane		Daughter product of VC under reducing conditions	2	0
1,1,1-Trichloroethane		Material released	0	0
1,2-dichlorobenzene		Material released	0	0
1,3-dichlorobenzene		Material released	0	0
1,4-dichlorobenzene		Material released	0	0
chlorobenzene		Material released or daughter product of dichlorobenzene	2	0
1,1-DCE		Daughter product of TCE or chemical reaction of 1,1,1-TCA	2[a/]	2
			Total	27

a/ Points awarded only if it can be shown that the compound is a daughter product (i.e., not a constituent of the source NAPL).

TABLE 4.10
INTERPRETATION OF POINTS AWARDED DURING NATURAL ATTENUATION SCREENING
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

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

SECTION 5

GROUNDWATER FLOW AND CONTAMINANT TRANSPORT MODEL

5.1 GENERAL OVERVIEW AND MODEL DESCRIPTION

In order to help predict the future migration and fate of CAHs dissolved in groundwater at CCAS Facility 1381, Parsons ES modeled shallow groundwater flow and the fate and transport of the dissolved CAH plume. The modeling effort had three primary objectives: 1) predict the future extent and concentrations of the dissolved contaminant plume by modeling the combined effects of advection, dispersion, sorption, and biodegradation; 2) assess the potential for downgradient receptors to be exposed to contaminants at concentrations above regulatory levels of concern; and 3) if applicable, provide technical support for the natural attenuation remedial option at post-modeling regulatory negotiations. The model was developed using site-specific data and conservative assumptions about governing physical and chemical processes. The model input data are believed to be reasonably conservative so that the actual reduction in contaminant mass caused by natural attenuation should meet or exceed model predictions.

The model codes MODFLOW (McDonald and Harbaugh, 1988) and MT3D$^{96®}$ (S.S. Papadopulos & Associates, Inc., 1996) were used to estimate the potential for dissolved CAH migration and degradation by naturally occurring mechanisms operating at the Facility 1381 site. MODFLOW was used to generate a groundwater flow model for the site. The MODFLOW flow field was then incorporated into the transport solution computed by MT3D$^{96®}$. The pre- and post-processors contained in Visual MODFLOW, version 2.20 (Waterloo Hydrogeologic Software, 1996) were used to facilitate model development and analysis and presentation of model results. The MT3D$^{96®}$ code incorporates advection, dispersion, sorption, and biodegradation to simulate contaminant plume migration and degradation through the method of characteristics (MOC) solute transport model [e.g., as developed by Konikow and Bredehoeft (1978) for the USGS two-dimensional (2D) MOC model code]. The MOC model code was modified by Zheng (1990) to allow three-dimensional (3D) solutions, and to allow the use of a modified MOC method that reduces numerical dispersion. MT3D$^{96®}$ is an improvement on MT3D that allows for spatial variation of solute transport parameters (e.g., retardation and first-order decay) for improved functionality and performance of the model.

Ideally, a code for simulating degradation of CAHs would track parent compounds and daughter products and allow specification of varying retardation coefficients and decay rates for each compound. Although not yet available, Battelle National Laboratories is in the process of developing such a code by modifying MT3D.

5.2 CONCEPTUAL MODEL DESIGN AND ASSUMPTIONS

Prior to developing a groundwater model, it is important to determine if sufficient data are available to provide a reasonable estimate of aquifer conditions. In addition, it is important to ensure that any limiting assumptions can be justified. Available site data were used to construct a conceptual site model, define boundary conditions, and assume hydrogeological and contaminant properties required to simulate contaminant fate and transport phenomenon at the site.

Hydrogeologic data presented in Section 3 indicate that the surficial aquifer at Facility 1381 is a shallow, heterogeneous, unconfined aquifer. The top 15 feet of the subsurface consists of unconsolidated, highly transmissive, medium- to coarse-grained sand with occasional silt and shell fragments. Below approximately 15 feet bgs, the lithology generally grades into fine-grained sand with traces of silt and discontinuous clay stringers and lenses. A confining clay layer was identified at approximately 50 feet bgs in the Facility 1381 area, and an interval of increased silt and clay is present just above the layer.

Groundwater flow at the site is influenced by variable seasonal precipitation rates that result in groundwater elevation fluctuations, specifically along deforested roads or fields, and also affect drainage canal elevations that affect groundwater discharge rates. Generally, groundwater elevations are lowest early in the year, rising during the rainy season in the summer and fall (Parsons ES, 1997). The combined influence of recharge in less vegetated areas and groundwater discharge into surrounding drainage canals has created a curving groundwater divide. September 1996 groundwater elevations indicate that the groundwater divide resembles a reversed "S" where the top and bottom curves bend to parallel the drainage canals and the middle length is approximately parallel to the major northeast/southwest road in the area (Figure 3.4).

It is assumed that groundwater hydraulics observed in September 1996 are representative of the overall groundwater flow pattern for at least the previous 38 years of facility operation. Dynamic groundwater hydraulics will shift the groundwater divide and alter the magnitude of hydraulic gradients. However, the large distance that the groundwater CAH plume has migrated north of the source area (Figures 4.3 and 4.4) verifies a general northward migration trend, despite variable flow conditions in the past. Maximum horizontal groundwater gradients and groundwater flow directions observed in September 1996 are consistent with the current position of the groundwater plume.

For the purposes of source loading in the model, it was assumed that contaminants were introduced to the groundwater at the site in 1958 when the facility was first used in the research and testing of missiles. The rate of contaminant dissolution into groundwater was conservatively assumed to be constant for the 38 year period between 1958 and 1996. Possible sources of CAH compounds both above and below the water table are from solvents sorbed to the soil matrix or trapped in NAPL pockets. CAH compounds are assumed to reach groundwater through a combination of dissolution into percolating surface recharge through the thin vadose zone and dissolution into groundwater below the water table.

The most important assumption made when using the MT3D[96®] code is that dispersion, sorption, and biodegradation are major factors controlling contaminant fate and transport at the site. Dispersivity is a characteristic of the porous medium and is a measure of the longitudinal and lateral spreading of the contaminant caused by local heterogeneities that cause deviations from the average linear migration velocity. The magnitude of dispersivity is generally believed to be scale-dependent; the longer the plume flowpath, the higher the dispersivity. Given the considerable length of the CAH plume flowpath (3,000 feet), it is reasonable to assume that dispersivity is an important parameter influencing solute transport at Facility 1381. According to data presented in Section 4, detectable concentrations of organic carbon present within the deposits through which the CAH plume is migrating indicate that some sorption of organic contaminants is likely. Available data also suggest that there is strong evidence that biodegradation of CAHs is occurring within the plume. Selection of values for these parameters is discussed in Section 5.3.

5.3 INITIAL MODEL SETUP

Where possible, the initial setup for this model was based on site-specific data. Where site-specific data were not available (e.g., effective porosity), reasonable assumptions were made on the basis of widely-accepted literature values for materials similar to those found in the shallow aquifer. The following sections describe the basic model setup.

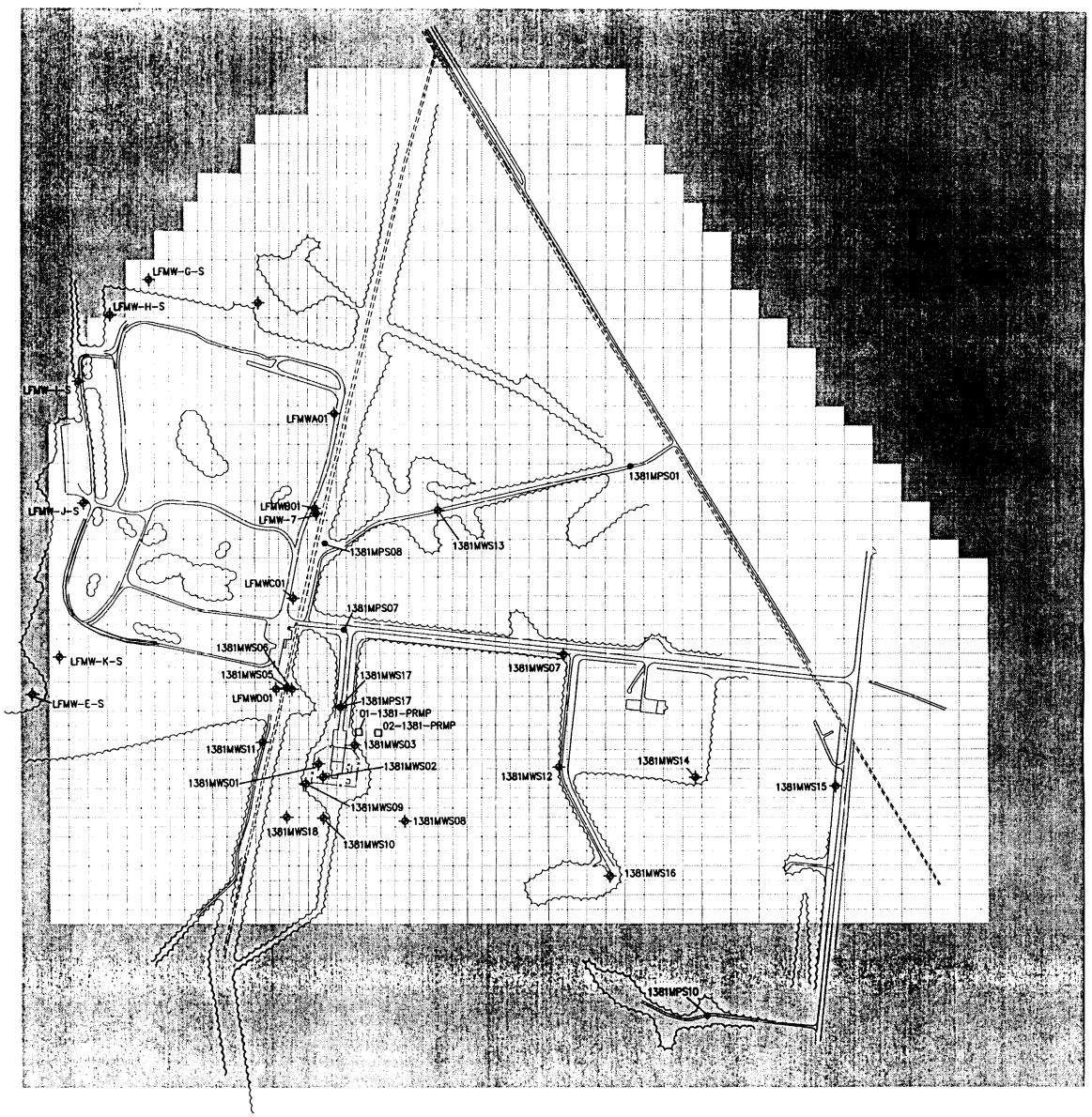
5.3.1 Grid Design

The model domain was represented using 2 layers defined by 57 columns and 58 rows. The spacing of the model grid was designed to provide adequate resolution in critical areas, while keeping the number of cells (and, therefore, run time and file size) to a minimum. Cell size is 50 feet by 50 feet in the source area. Cell size is progressively expanded away from the source area to a maximum of 300 feet by 300 feet near the grid boundaries. Figure 5.1 presents the model grid. The grid was extended past the northern and southern drainage canals to allow simulation of potential contaminant underflow. The grid is oriented approximately 50 degrees east of north in order to align the grid axes with directions of maximum hydraulic gradient and the longitudinal axis of the contaminant plume. The total thickness of the grid domain is 50 feet, divided into a 15-foot top layer and a 35-foot bottom layer.

5.3.2 Groundwater Flow Model

5.3.2.1 Boundary Conditions

In defining the model domain, the area of interest must be separated from the surrounding system. Boundary conditions describe the interaction between the system being modeled and its surroundings or, for transport models, the loading of contaminant mass into the system. Boundary conditions are used to include the effects of the system outside the area being modeled with the system being modeled, while at the same time allowing the isolation of the desired model domain from the larger system. In effect, the boundaries of the model tell the area immediately inside the boundaries what to expect from the outside world. The solution of any differential equation requires specification of



LEGEND

- MONITORING WELL LOCATION
- MONITORING POINT LOCATION
- 01-1381-PRMP — PHYTOREMEDIATION MONITORING SAMPLING LOCATION
- ROADWAY
- DIRT ROAD
- CANAL
- TREE LINE
- FENCE
- MODEL CELL
- NO-FLOW BOUNDARY

0 300 600 1200
FEET

FIGURE 5.1

MODEL GRID

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

K:\AFC\970N0769, 09/22/97 at 09:07

the conditions at the periphery of the system. Model boundaries are thus mathematical statements that specify the dependent variable (head or contaminant concentration) or the flux (derivative of the head or contaminant concentration with respect to time) at the model grid boundaries.

Three types of boundary conditions generally are used to describe groundwater flow and solute transport. Boundary conditions are referred to as type one (Dirichlet), type two (Neumann), and type three (Cauchy). Table 5.1 summarizes boundary conditions for groundwater flow and solute transport.

In flow models, boundary conditions are ideally used to specify actual hydrogeologic boundaries to the system, such as streams, lakes, confining units, groundwater divides, or any geologic or anthropogenic feature that may bound a system. Also, the boundaries may be defined as areas where properties (e.g., flux) are known and can be defined. When using a numerical flow model, hydrologic boundaries such as constant-head features (e.g., lakes, etc.) or constant-flux features should, when possible, coincide with the perimeter of the model. In areas that lack obvious hydrologic boundaries, constant-head or constant-flux boundaries can be specified at the numerical model perimeter as long as the perimeter is far enough removed from the contaminant plume that transport calculations will not be affected by inaccuracies in the boundary conditions.

TABLE 5.1
COMMON DESIGNATIONS FOR SEVERAL IMPORTANT BOUNDARY CONDITIONS[a/]
CCAS Facility 1381

Boundary Condition	Boundary Type	Formal Name	General Mathematical Description	
			Groundwater Flow	Contaminant Transport
Specified-Head or Specified-Concentration	Type One	Dirichlet	$H = f(x,y,z,t)$	$C = f(x,y,z,t)$
Specified Flux	Type Two	Neumann	$\frac{\partial H}{\partial n} = f(x,y,z,t)$	$\frac{\partial C}{\partial n} = f(x,y,z,t)$
Head-Dependent or Concentration-Dependent Flux	Type Three (mixed-boundary condition)	Cauchy	$\frac{\partial H}{\partial n} + cH = f(x,y,z,t)$	$\frac{\partial C}{\partial n} + cC = f(x,y,z,t)$

[a/] Modified from Franke *et al.* (1987).

Because the groundwater system is assumed to be influenced by the two drainage canals and higher net recharge along roads and in less vegetated areas, boundary conditions of the model domain were set up to reflect these influences. The MODFLOW river package was used to simulate the northern and southern drainage ditches (Appendix C). Each drainage canal was defined based on measured surface water elevations, depth of the canal, and the conductance of the canal. Conductance is defined as the area of the

base of the canal in contact with the aquifer multiplied by the vertical conductivity of the canal base divided by the thickness of the sediment layer at the base of the canal. Recharge was initially assumed as 40 inches per year (typical for the humid, subtropical region of Florida) along roads and in clearings at the site where drainage collects in surface depressions to infiltrate the groundwater system. A no-flow (specified flux) boundary was set up around the perimeter of the model domain because little data was available to estimate a constant head boundary, but the model domain is far enough removed from the contaminant plume that transport calculations were not affected.

5.3.2.2 Aquifer Properties

Hydraulic Conductivity. Hydraulic conductivity was estimated using accepted literature values and field data obtained during this and previous investigations. Hydraulic conductivity values obtained from specific capacity testing, presented in the RFI, and presented in literature were all considered when arriving at model values for hydraulic conductivity. Based on the lithology of the Facility 1381 area, the hydraulic conductivity of the surficial, coarse-grained sand is assumed to be in the range of 3 to 300 ft/day (Fetter, 1988). Hydraulic conductivity of the lower, fine to medium-grained silty sand is assumed to be in the range of 0.3 to 30 ft/day (Fetter, 1988). Initially, the top layer of the model grid, which corresponds to the coarse-grained sand observed in the field, was assigned a hydraulic conductivity of 30 ft/day. The lower layer, which corresponds to the fine- to medium-grained silty sand, was assigned a hydraulic conductivity of 3 ft/day.

Effective Porosity. A widely-accepted value of total porosity for homogeneous fine to medium sands is 35 percent (0.35). This porosity, combined with a particle mass density of 2.65 grams per cubic centimeter (g/cm^3) (for quartz sand), yields a bulk density of 1.72 g/cm^3. An effective porosity of 0.25 was assumed for the site, which is a widely accepted value for the type of sand encountered at Facility 1381 (Fetter, 1989).

Specific Yield/Specific Storage. Aquifer storage is a measure of the capacity of a saturated formation to store (or release) water when stressed. Since the flow portion of this model is steady-state, storage is not used. Storage is used in the transport model in the mass balance calculations. Aquifer storage values were estimated based on literature values for similar lithologies, and data collected in pumping and specific capacity tests performed in the industrial area at CCAS during the hydrogeologic investigation of the industrial area (November 1996). Storage was defined at 0.0002 per foot (ft^{-1}).

5.3.3 Contaminant Transport Model

5.3.3.1 CAH Source

Transport models use boundary conditions to specify contaminant sources such as NAPL bodies and dissolved mass entering through recharge, injection wells, surface water bodies, and leaking structures. Sources such as NAPL bodies may be represented as specified-concentration boundaries (limited by solubility constraints or observed maximum concentrations) or as specified-flux boundaries (for which the chemical loading rate must be known or estimated). However, in most cases, only the effects of

the source are measured, not the source characteristics (Spitz and Moreno, 1996). The source must therefore be represented as a "black box" that produces appropriate contaminant concentrations or fluxes at selected points in the model. The source may be misrepresented under such a scenario, but there is often little choice in the matter. Estimating contaminant flux into groundwater from NAPL or dissolved mass entering through recharge is difficult and is dependent upon several parameters, most of which cannot be measured (Feenstra and Guiguer, 1996; Abriola, 1996).

Rather than using various calculations to attempt to estimate CAH partitioning from NAPL into groundwater, the "black box" source approach was used. Experience modeling contaminated sites as part of the AFCEE Natural Attenuation Initiative has suggested that this is the best method for reproducing observed plumes.

The total dissolved chlorinated ethene concentrations obtained from September 1996 laboratory analytical results for each monitoring well/point location were used as targets for model calibration. Table 4.2 presents dissolved CAH concentration data for September 1996, and Figures 4.2 to 4.4 show the spatial distribution of dissolved CAHs in September 1996. For the purposes of this model, the concentrations of the individual compounds were converted from µg/L to micromoles per liter (µmol/L) before being summed. This was done because the primary biodegradation reaction operating at Facility 1381 is reductive dechlorination. As discussed in Section 4.2, reductive dechlorination is a mole-to-mole transformation from parent to daughter product, involving replacement of one chlorine atom with a hydrogen atom. The process results in decreased contaminant mass because the mass of the daughter compound is significantly lower; however, the molar concentration is unchanged. Because the biodegradation rates calculated from site data and used in the model represent rates of dechlorination only, simulation of molar concentrations (rather than mass concentration) is a more appropriate manner in which to simulate progressive dechlorination of CAHs. The CAH plume expressed in terms of total molar concentrations is presented in Appendix C. The shape of the plume depicted in this figure is the result of transport under the influence of advection, dispersion, sorption, and biodegradation.

5.3.3.2 Dispersivity

The longitudinal dispersivity is commonly assumed to be one-tenth the length of the plume. Based on an observed plume length of approximately 3000 feet, the longitudinal dispersivity was estimated to be 300 feet. Transverse dispersivity was assigned a value two orders of magnitude less than longitudinal dispersivity (3 feet) to limit lateral spreading of the plume, and vertical dispersivity was assigned a value one order of magnitude less than transverse dispersivity (0.3 feet).

5.3.3.3 Sorption/Retardation

The distribution coefficient (K_d) is calculated for each contaminant using the field measurement of the fraction of organic carbon (f_{oc}) and the literature value of the organic carbon coefficient (K_{oc}) for each contaminant. The values are presented in Table 5.2. The range of average K_d values is 0.011 liters per kilogram (L/kg) to 1.197 L/kg. A

conservative value of 0.030 L/kg was initially defined for the model domain. The retardation coefficient is 1.21 .

TABLE 5.2
CALCULATION OF RETARDATION COEFFICIENTS
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Compound	K_{oc} (L/kg[a/])	Fraction Organic Carbon[b/]	Distribution Coefficient K_d (L/kg)	Bulk Density (kg/L)[c/]	Effective Porosity[d/]	Coefficient of Retardation
PCE	263	0.00455	1.197	1.72	0.25	9.23
TCE	107	0.00455	0.487	1.72	0.25	4.35
1,1-DCE	64.6	0.00455	0.294	1.72	0.25	3.02
cis-1,2-DCE	64.6	0.00455	0.294	1.72	0.25	3.02
trans-1,2-DCE	58.9	0.00455	0.268	1.72	0.25	2.84
VC	2.45	0.00455	0.011	1.72	0.25	1.08

NOTES:

a/ Values of the organic carbon coefficient (Koc) in liters per kilogram (L/kg) from technical protocol (Wiedemeier *et al.*, 1996b) and Knox *et al.* (1993).

b/ Average of saturated TOC samples collected from the site (Section 4.1.3).

c/ Assumes an aquifer grain density of 2.65 (quartz sand) and a volumetric porosity of 35 percent [Section 3.2.1.2 of RFI (Parsons ES, 1997a).

d An effective porosity of 0.25 was estimated in the RFI (Parsons ES, 1997a), which is consistent with literature values.

5.3.3.4 Biodegradation

Using the methods of Buscheck and Alcantar (1995) and Moutoux *et al.* (1996), biodegradation rates ranging from 0.0004 to 0.117 yr^{-1} were calculated. An initial conservative value of 0.0004 yr^{-1} was defined for the model domain. The actual degradation rate is likely higher in the source area, but the selected rate of 0.0004 yr^{-1} is more representative of the rate for the entire degradation pathway throughout the plume. Calculations for each method are provided in Appendix C.

5.4.1 Groundwater Flow Model Calibration

Groundwater elevation data collected in September 1996 and presented on Figure 3.4 were used to calibrate the flow model. Water level elevation data from eight monitoring wells and three surface water measurement stations were used to compare measured and simulated heads for calibration. The selected locations were 1381MWS01, -S03, -S07, -S09, -S11, -S12, -S14, -S15, -S16, -S17, SURB, SURD, and SURF.

The numerical flow model was calibrated by altering hydraulic conductivity, river package parameters, and recharge rates in a trial-and-error fashion until simulated heads approximated observed field values within a prescribed accuracy. The final calibrated hydraulic conductivity is 150 ft/day in Layer 1 and 5 ft/day in Layer 2. The northern drainage canal is simulated with a river package line defined from 2.04 ft msl to 1.01 ft msl with a conductance of 38,000 ft^2/yr. The southwestern canal is simulated with a river package line defined from 1.8 ft msl to 0.5 ft msl with a conductance of 42,000 ft^2/yr.

Recharge rates along roads and in clearings were adjusted within the range of 20 in/yr to 40 in/yr to better match observed groundwater elevations. Figure 5.2 shows the calibrated water table. Calibrated model input is presented in Appendix C.

The root mean squared (RMS) error is commonly used to express the average difference between simulated and measured heads. RMS error is the average of the squared differences between measured and simulated heads, and can be expressed as:

$$\mathrm{RMS} = \left[\frac{1}{n} \sum_{i=1}^{n} \left(h_m - h_s \right)_i^2 \right]^{0.5}$$

where: n = the number of points where heads are being compared,

h_m = measured head value, and

h_s = simulated head value.

The RMS error between observed and calibrated values at the 13 comparison points was 0.048, an error of less than 10 percent.

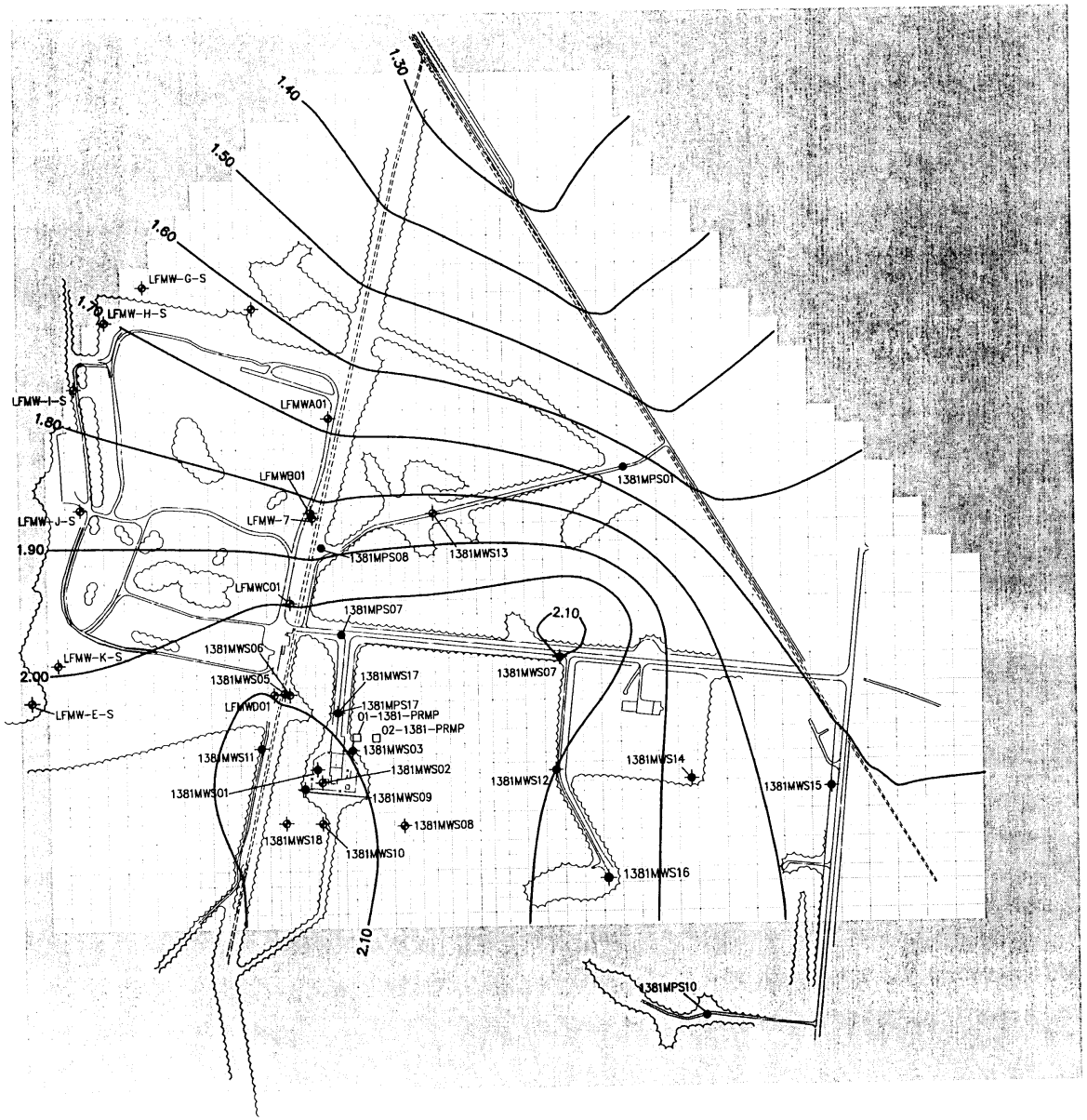
In solving the groundwater flow equation, Visual MODFLOW establishes the water table surface and calculates an overall hydraulic balance that accounts for the numerical difference between flux into and out of the system. The hydraulic mass balance for the calibrated model was adequate to accomplish the objectives of this modeling effort, with a zero-percent discrepancy.

5.4.2 Plume Calibration

After calibration of the flow model, the numerical solute transport model was calibrated by altering the contaminant source term (specified-flux rate) and contaminant transport parameters (dispersivity, retardation, and decay) in a trial-and-error fashion until the simulated plume approximated observed field values. The dissolved CAH concentrations obtained from the September 1996 sampling of 9 monitoring wells/points were used to calibrate the contaminant transport model.

The "black box" source cells contain a specified-flux, recharge concentration boundary. This parameter was varied cell by cell until calculated concentrations in the source area and at the downgradient plume extent were equal to or slightly greater than observed concentrations.

The initial longitudinal dispersivity (Section 5.3.3.2), the initial retardation coefficient (5.3.3.3), and the initial first-order decay rate used in the model setup (Section 5.3.3.4) were not varied during the calibration process. Use of these conservative values computed from site-specific data yielded a good match between simulated and measured CAH concentrations. Figure 5.3 shows the calibrated groundwater plume converted from modeled molarity to an equivalent mass concentration of DCE.



LEGEND

- 1381MWS18 — MONITORING WELL LOCATION
- 1381MWS14 — MONITORING WELL LOCATION USED TO CALIBRATE FLOW MODEL
- 1381MPS10 — MONITORING POINT LOCATION
- 01-1381-PRMP — PHYTOREMEDIATION MONITORING SAMPLING LOCATION
- ROADWAY
- DIRT ROAD
- CANAL
- TREE LINE
- FENCE
- 1.20 — LINE OF EQUAL CALIBRATED GROUNDWATER ELEVATION
- MODEL CELL
- NO-FLOW BOUNDARY

0 300 600 1200
FEET

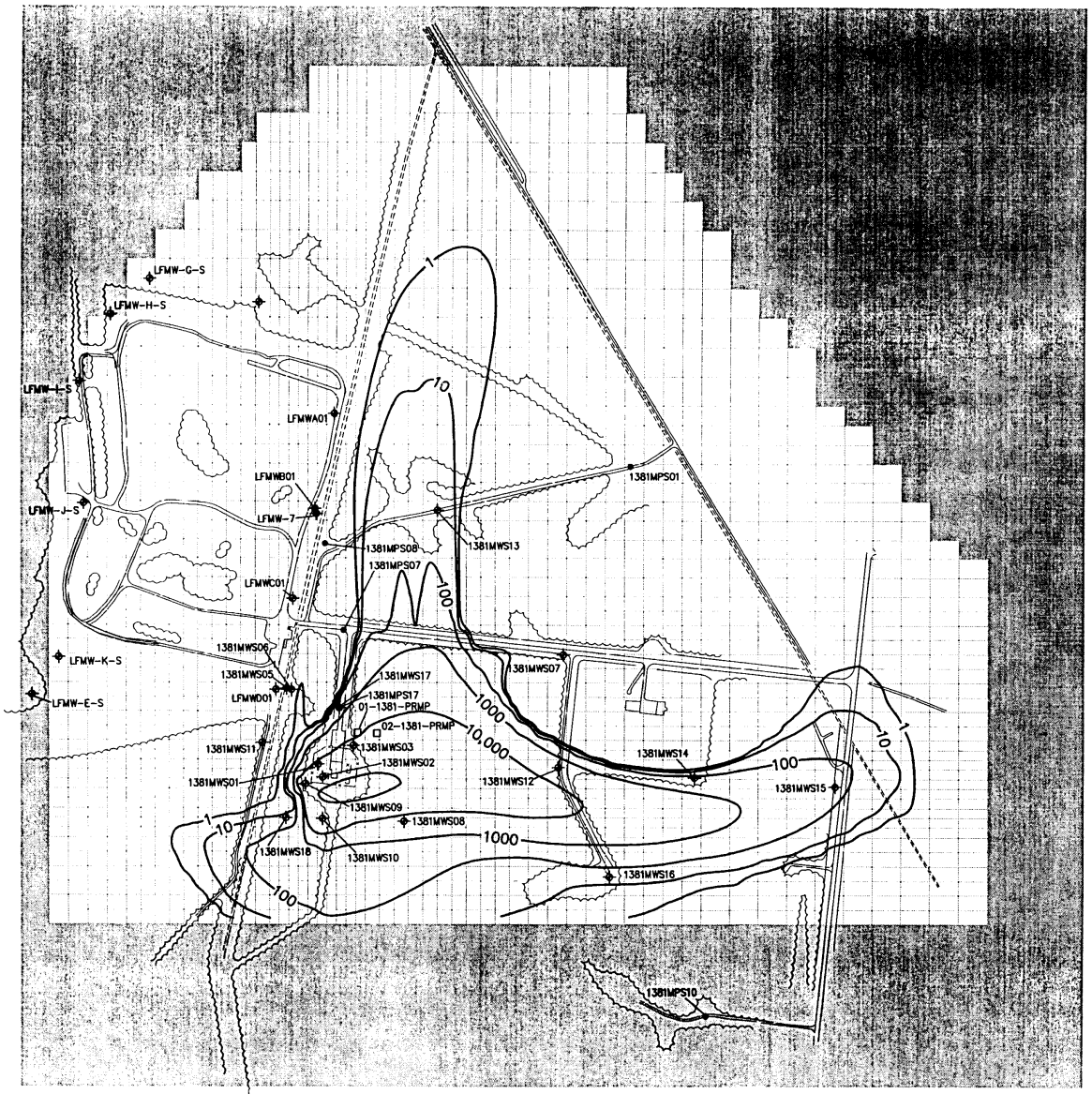
FIGURE 5.2

CALIBRATED WATER TABLE

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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LEGEND

- MONITORING WELL LOCATION
- MONITORING POINT LOCATION
- 01-1381-PRMP □ PHYTOREMEDIATION MONITORING SAMPLING LOCATION
- ROADWAY
- DIRT ROAD
- CANAL
- TREE LINE
- FENCE
- 100 LINE OF EQUAL CALIBRATED CAH CONCENTRATION IN µg/L
- MODEL CELL
- NO-FLOW BOUNDARY

0 300 600 1200
FEET

FIGURE 5.3

CALIBRATED PLUME

Facility 1381 RNS TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

K:\AF 2691\97DN0774, 09/22/97 at 09:58

The overall shape of the groundwater CAH plume could not be perfectly reproduced because of the complexity of site hydraulics. For instance, the calibrated plume is characterized by two thin northwest- and northeast-trending lobes, rather than a single wide contaminant lobe to the northeast (see total CAH plume in Appendix C). The reason for the modeled incongruency stems from complex site hydraulics arising from the groundwater divide and recharge zone along the cleared northeast/southwest roadway. The modeled groundwater divide along the northeast/southwest road caused the simulated CAH plume to "channel" along the east side of the divide, as was generally observed at the site. In addition to complex hydrogeology, the spacing of groundwater monitoring locations allows for varying interpretations of the site data, as extrapolation must be performed between data points. Both the interpretation of the total CAH and the modeled interpretation shown on Figure 5.3 are consistent with observed site CAH concentrations.

Although the calibrated groundwater plume is not areally identical to the observed plume as depicted in Section 4, the calibrated plume does correlate well to the observed plume along the plume centerline. This correlation is important because it facilitates accurate prediction of downgradient receptor impact (i.e., at the northern drainage canal) and of plume persistence by accurately simulating maximum CAH concentrations in the plume core. In these respects, the model is conservative, and simulated concentrations near the northern drainage canal and along the plume centerline meet or exceed observed CAH concentrations. For example, simulated concentrations at monitoring wells 1381MWS01 and 1381MWS03 (source area) are 175 µmoles/L and 145 µmoles/L, respectively, as compared to observed concentrations of 30.2 µmoles/L and 40.4 µmoles/L, respectively. High modeled source area concentrations were partially a result of the relatively large size of source area grid cells. For example, source concentrations at 1381MWS01 and 1381MWS03 are comprised in part of CAH mass that has migrated from well 1381MWS09, which also contains high CAH concentrations homogeneously distributed throughout the model cell. Downgradient, simulated CAH concentrations at shallow groundwater monitoring wells 1381MWS12 and 1381MWS15 are 22.3 µmol/L and 1.7 µmol/L, as compared to observed concentrations of 16 µmol/L and 1.6 µmol/L, respectively.

5.5 SENSITIVITY ANALYSIS

The purpose of a sensitivity analysis is to determine the effect of varying model input parameters on model output. The sensitivity analysis was conducted by varying hydraulic conductivity, retardation, first-order decay rates, dispersivity, and CAH source age within appropriate parameter ranges discussed in Sections 5.3.2 and 5.3.3 or considered reasonably justifiable at Facility 1381.

To perform the sensitivity analyses, the calibrated model was adjusted by systematically changing the aforementioned parameters individually, and then comparing the new simulations to the calibrated plume. The models were run for a 38-year period from 1958 to 1996 (identical process to model calibration) so that the independent effect of each variable could be assessed. Nine sensitivity runs of the calibrated model were made, with the following variations:

1. Hydraulic conductivity uniformly increased by a factor of 2;

2. Hydraulic conductivity uniformly decreased by a factor of 2;

3. Coefficient of retardation increased by an order of magnitude;

4. Coefficient of retardation decreased by an order of magnitude;

5. Dispersivity increased by a factor of 2;

6. Dispersivity decreased by a factor of 2;

7. First-order decay rate increased by an order of magnitude;

8. First-order decay rate decreased by an order of magnitude; and

9. Date of CAH introduction into the surficial aquifer changed from 1958 to 1968.

The results of the sensitivity analyses are summarized in Table 5.3.

5.5.1 Sensitivity to Variations in Hydraulic Conductivity

The effects of varying hydraulic conductivity are shown in Table 5.3. Uniformly increasing the hydraulic conductivity by a factor of two increased the lateral travel distance of the contaminant plume far beyond the observed plume extent. The result was a lower source area concentration, but higher downgradient concentrations, relative to the observed and calibrated concentrations. For example, the simulated CAH concentration at well 1381MWS09 is 211 µmol/L compared to the observed September 1996 concentration of 349 µmol/L; the simulated CAH concentration at well 1381MWS15 is 2.9 µmol/L, compared to the September 1996 observed concentration of 1.6 µmol/L. In contrast, decreasing the hydraulic conductivity by a factor of two produced a plume with higher concentrations in the source area and lower concentrations downgradient. The result was a shorter, more concentrated plume. For example, the simulated CAH concentration at well 1381MWS09 is 854 µmol/L compared to the observed September 1996 concentration of 349 µmol/L, and the simulated CAH concentration at well 1381MWS15 is 0.0 µmol/L compared to the September 1996 observed concentration of 1.6 µmol/L. The model does appear to be sensitive to values selected within a reasonable range for hydraulic conductivity at the site, indicating that the value chosen for the simulation is valid.

5.5.2 Sensitivity to Variations in the Coefficient of Retardation

The effects of varying the coefficient of retardation are shown in Table 5.3. Uniformly increasing the coefficient of retardation had very little effect in the source area. For example, the simulated CAH concentration at well 1381MWS09 is 359 µmol/L compared to the observed September 1996 concentration of 349 µmol/L. However, the resultant plume did not travel the distance that the observed measurements indicate, as indicated by the lack of simulated CAH detections at wells 1381MWS12 and 1381MWS14. In contrast, decreasing the coefficient of retardation produced a plume with higher downgradient concentrations than the calibrated or observed concentrations. For example,

TABLE 5.3
SENSITIVITY ANALYSIS RESULTS
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Well No.	Measured CAH Concentration Sep-96 (µmol/L)[a/]	Calibrated CAH Concentration (µmol/L)	K[b/] Increased (µmol/L)	K Decreased (µmol/L)	Retardation Increased (µmol/L)	Retardation Decreased (µmol/L)	Dispersivity Increased (µmol/L)	Dispersivity Decreased (µmol/L)	Decay Rate Increased (µmol/L)	Decay Rate Decreased (µmol/L)	Source Start 1968 (µmol/L)
MW9	348.9	362.3	210.5	853.5	359.1	362.6	372.8	355.7	358.7	362.7	361.4
MW12	16.03	22.27	140.7	0	0	31.6	32.3	11.2	20	22.5	6.16
MW14	0.714	0.511	37.6	0.006	0	1.5	2.4	0.0089	0.437	0.519	0
MW15	1.6	1.65	2.9	0	0.003	3.2	5.6	0.21	1.48	1.67	0.184

a/ µmol/L = micromoles per liter.
b/ K = hydraulic conductivity.
Note: The edits made to the calibrated model during the various sensitivity analysis runs are more fully described in the Section 5.5 text.

the simulated CAH concentration at well 1381MWS15 is 3.2 µmol/L, compared to the September 1996 observed concentration of 1.6 µmol/L. The model is sensitive to variations in retardation coefficients within a reasonable range for the site, indicating that the value chosen for the calibrated model is valid.

5.5.3 Sensitivity to Variations in Dispersivity

The effects of varying dispersivity are shown in Table 5.3. Longitudinal, transverse, and vertical dispersivity were varied for this analysis, as the ratio of the values remained constant. Increasing the dispersivity by a factor of two slightly increased simulated concentrations throughout the plume and expanded the plume downgradient. For example, the simulated CAH concentration at well 1381MWS09 is 373 µmol/L compared to the observed September 1996 concentration of 349 µmol/L; the simulated CAH concentration at well 1381MWS15 is 5.6 µmol/L, compared to the September 1996 observed concentration of 1.6 µmol/L. Likewise, decreasing the dispersivity by a factor of two decreased modeled concentrations throughout the plume relative to the calibrated plume. When compared to observed concentrations, however, a decrease in dispersivity produced mixed results. For example, the simulated CAH concentration at well 1381MWS09 is 356 µmol/L, which is actually a few micromoles per liter closer to the observed September 1996 concentration of 349 µmol/L. However, the simulated CAH concentration at well 1381MWS15 is 0.21 µmol/L, compared to the September 1996 observed concentration of 1.6 µmol/L. Overall, the model is relatively insensitive to a reasonable range for dispersivity at the site; however, the selected dispersivity approximates the downgradient concentration better than other dispersivities used.

5.5.4 Sensitivity to Variations in the Anaerobic Decay Rate Constant

The effects of varying the first order CAH decay rate are documented in Table 5.3. The sensitivity analysis results indicate that the model is relatively insensitive to one-order-of-magnitude changes in the decay rate. Increasing the decay rate resulted in concentrations throughout the plume that were slightly lower than in the modeled plume. Overall, this resulted in a slightly closer approximation at the source area and a slightly worse approximation at the leading edge of the plume. For example, the simulated CAH concentration at well 1381MWS09 is 359 µmol/L compared to the observed September 1996 concentration of 349 µmol/L, and the simulated CAH concentration at well 1381MWS15 is 1.5 µmol/L, compared to the September 1996 observed concentration of 1.6 µmol/L. Conversely, decreasing the decay rate slightly increased concentrations throughout the plume. For example, the simulated CAH concentration at well 1381MWS09 is 363 µmol/L compared to the observed September 1996 concentration of 349 µmol/L, and the simulated CAH concentration at well 1381MWS15 is 1.7 µmol/L, compared to the September 1996 observed concentration of 1.6 µmol/L. Sensitivity to variations in decay rate indicate that the rate chosen for the calibrated model is valid.

5.5.5 Sensitivity to Variation in Date of CAH Introduction

The effects of introducing the contaminant into the surficial aquifer starting in 1968 as opposed to 1958 are shown in Table 5.3. Because the contaminant has less time to

migrate downgradient, the calculated plume (as defined by the 1 μg/L isopleth) is shorter than the calibrated plume. The simulated CAH concentration at well 1381MWS09 is 361 μmol/L compared to the observed September 1996 concentration of 349 μmol/L. Correspondingly, simulated CAH concentrations in the central to downgradient portions of the plume (e.g., at wells 1381MWS12, 1381MWS14, and 1381MWS15) are lower than calibrated concentrations. For example, the simulated CAH concentration at well 1381MWS15 is 0.18 μmol/L, compared to the September 1996 observed concentration of 1.6 μmol/L. A pre-1958 date for TCE introduction into the surficial aquifer was not simulated because historical data presented in Section 1.2 indicates that 1958 is the earliest known possible date of CAH introduction. This sensitivity analysis indicates that 38 years is a good estimate for the length of time required for the plume to migrate from the source area and achieve the observed areal extent.

5.5.6 Summary of Sensitivity Analysis Results

The results of the sensitivity analysis suggest that the calibrated model depicted in Figure 5.3 is reasonable. Varying the model parameters within the prescribed ranges generally caused the extent and magnitude of the dissolved plume to differ from measured conditions. Varying the hydraulic conductivity within a reasonable range caused substantial changes in both the lateral extent of the plume and the magnitude of simulated CAH concentrations, indicating that the model is relatively sensitive to variations in this parameter. The effects on plume extent and magnitude through variation of the retardation coefficient within a reasonable range also were significant, although less substantial than with the hydraulic conductivity. The sensitivity of the model to variations of dispersivity within a reasonable range appears to be low to moderate. Variation of this parameter has the greatest effect on the downgradient extents of the 1 μg/L and 10 μg/L isopleths. The model was relatively insensitive to the evaluated range of first-order decay rates. Moving the date of contaminant introduction into the surficial aquifer from 1958 to 1968 resulted in a plume that is both shorter and narrower than the calibrated plume.

SECTION 6

ANALYSIS OF MODELED REMEDIAL ALTERNATIVES

This section presents the predicted impact of planned and probable engineered remedial actions on dissolved CAHs in the northward-migrating groundwater in the surficial water-bearing zone at Facility 1381. The intent of this evaluation is to assist the Base in developing final remedial strategies for the site. General strategies introduced in this section will be developed more fully as a part of the forthcoming CMS.

6.1 SUMMARY OF PLANNED AND PROBABLE REMEDIAL ACTIONS

Several demonstration projects are being conducted at the site that were not documented in the RFI report (Parsons ES, 1997), but will be presented in the Facility 1381 CMS report or other technical documents. The following descriptions briefly summarize these activities:

- A vapor extraction demonstration project consisting of three triple-nested sparge wells extending to a depth of 50 feet and a horizontal vapor extraction well were installed at the site in September 1996. Off-gas from the vapor extraction system as treated with activated carbon. The air sparging system was placed in the CAH source area to determine the effectiveness in reducing dissolved CAH concentrations and mitigating the impact of CAHs on the southern drainage canal. The scope of work for the Air Sparging/Soil Vapor Extraction Pilot Test was presented in the Pilot Test Work Plan (Parsons ES, 1996b), and the final demonstration results will be discussed in a future report.

- Parsons ES in cooperation with Utah State University (USU), is performing a demonstration of phytoremediation of CAHs for AFCEE. The specific work being completed at Facility 1381 attempts to evaluate the phytoremediation potential of mature trees and shrubs for possible application at AFBs nationwide. The work being performed includes the measurement of transpiration rates, measurement of transpiration stream concentration factors for TCE, and the analysis of TCE and its associated metabolites (trichloroethanol, trichloroacetic acid, and dichloroacetic acid) in plant tissue (root, stem, and leaf) of three plant species. In addition, soil gas (12 points), soil (12 points), groundwater (12 points), and surface flux (6 points) sampling is being completed near each plant species to assess the significance of potential loss mechanisms for TCE. The results of this demonstration effort will be summarized in a comprehensive technical report detailing the field methods, results, and the significance of phytoremediation at the site.

The CMS will evaluate several remedial alternatives for groundwater contamination and may include components of the air sparging, phytoremediation, and natural attenuation demonstration projects that are being conducted at Facility 1381. The primary focus of the remainder of this section will be on using natural attenuation as a complete or combined remedial solution (e.g., natural attenuation combined with source treatment) for CAHs dissolved in groundwater. The two most likely remedial alternatives were simulated using the numerical model described in Section 5, including:

- RNA combined with LTM and institutional controls; and
- RNA, LTM, institutional controls, and source reduction (e.g., a full-scale air sparging system near monitoring well 1381MWS09) that may potentially be implemented on the basis of recommendations issued in the forthcoming CMS report.

Remedial goal options (RGOs) were calculated for each individual compound in the baseline risk assessment component of the RFI (Parsons ES, 1997)a. The use of RGOs as remedial groundwater standards is being negotiated; therefore, in the interim, Florida State Maximum Contaminant Levels (MCLs) are used for the evaluation of each remedial alternative. (Table 6.1).

Evaluation of the adequacy of natural attenuation or any remedial alternative to achieve cleanup criteria is dependent on an awareness of current and potential future land uses and exposure pathways. These topics are discussed in the following sections.

TABLE 6.1
WATER QUALITY STANDARDS
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Compound	Florida State MCL[a/] (µg/L)	Proposed RGO[b/]
TCE	3	53.2
DCE	7	0.7[c/]
VC	1	36.3

[a/] Primary Drinking Water Standards (FDEP, 1996).
[b/] Assumes a target cancer risk of 1×10^{-5} (Parsons ES, 1997a).
[c/] Represents total 1,2 dichloroethene.

6.2 POTENTIAL EXPOSURE PATHWAYS

A pathways analysis identifies the human and ecological receptors that could potentially come into contact with site-related contamination and the pathways through which these receptors might be exposed. To have a completed exposure pathway, there must be a source of contamination, a potential mechanism(s) of release, a pathway of transport to an exposure point, an exposure point, and a receptor. If any of these elements do not exist, the exposure pathway is considered incomplete, and receptors will not come into contact with site-related contamination. Evaluation of the potential long-term effectiveness of any remedial technology or remedial alternative as part of this

demonstration project includes determining if the approach will be sufficient and adequate to minimize pathway completion.

Facility 1381 is located along the landfill access road in Area 5 within the central portion of CCAS. The current land use at the site is industrial, with no foreseeable changes in use as a result of residential expansion into CCAS. Residential development near Facility 1381 is nonexistent as CCAS resides on a thin coastal landmass that is bordered by the Atlantic Ocean on the east and the Banana River on the west. Potable water at Facility 1381 is provided by the City of Cocoa Beach and groundwater at the site is not used for human consumption. When necessary, a secondary potable water supply for CCAS can be obtained through Patrick Air Force Base (PAFB) from the City of Melbourne. Upwards of 2,000 wells may exist within four miles of CCAS; however, only one well is located within a one-mile radius of Facility 1381 and is classified as unused. Although the surficial aquifer is currently classified at G-II (permitting possible future use), future development of the groundwater as a potable supply is unlikely due to the restricted nature of CCAS, the intended continuation of existing industrial activities, and the potential for saline intrusion (Parsons ES, 1997a).

The drainage canals that border the site to the north, west, and south have been constructed to lower the water table and facilitate development. CAHs are discharging to the southern drainage canal and potentially also discharge to the northern drainage canal. Therefore, the northern drainage canal (which is threatened by the northward flowing contamination addressed in this study) represents a potential discharge point for the CAH plume based on currently available information. No other surface water bodies exist at the site. These drainage canals are unlikely to be used for recreational purposes considering the restricted nature of CCAS; however, they do support potential environmental receptors. CAHs have not been detected in the northern drainage canal during previous surface water sampling events.

Under reasonable current land use assumptions, potential receptors of groundwater-related contamination include onsite industrial workers and surface water biota in the bordering drainage canals. Because of the large area comprising CCAS (approximately 25 square miles), the central location of Facility 1381, and the intended continued viability of CCAS as a whole, likely future use of the area will continue to be industrial. On-Base workers could be exposed to site-related contamination in phreatic soils or shallow groundwater during construction-related excavations (the depth to groundwater at Facility 1381 is approximately 4 to 7 feet bgs), via dermal contact, inhalation of particles and volatiles, and incidental ingestion. It is also possible that a trespasser could jump the fence at Facility 1381 and incur limited incidental direct contact with and ingestion of surface soil, and inhalation of windblown particles and volatiles. According to the baseline risk assessment (BRA) performed for the site as part of the RFI, all carcinogenic risks and noncarcinogenic hazards associated with the potential contact of industrial workers or potential trespassers to soil and groundwater contamination were determined to be within the USEPA target range of 1E-04 to 1E-06, with none of the risks exceeding 2E-05 (Parsons ES, 1997a). Therefore, no unacceptable risks associated with exposure to soil and groundwater contamination at Facility 1381 have been identified under current industrial exposure assumptions.

Assumptions about hypothetical future land uses also must be made to ensure that the remedial technology or alternative considered for shallow groundwater at the site is

adequate and sufficient to provide long-term protection. Except for the remote possibility that current industrial land could be converted to residential use as a result of decreasing operations at CCAS, the future use of Facility 1381 is projected to remain unchanged from the current uses described above. However, a hypothetical residential scenario has been evaluated in the BRA at the direction of the USEPA Region IV. The residential scenario assumes that hypothetical residents will use groundwater for drinking and showering, will freely contact surface and subsurface soil, and will regularly use the drainage canal for recreational purposes. Residential exposure would potentially occur through incidental ingestion of and dermal contact with soil and inhalation of fugitive dust and volatiles from soil; and ingestion of and dermal contact with groundwater from the site as well as inhalation of volatiles from groundwater; ingestion of and dermal contact with surface water through swimming or washing. The appropriateness of regulating the Facility 1381 site under a conservative residential exposure scenario is currently being negotiated as part of the RFI/CMS process.

Whether regulated under industrial or residential scenarios, restrictions on shallow groundwater use are likely to be a necessary component of any GW remediation strategy for this site until natural attenuation, or natural attenuation in combination with engineered remediation, reduces contaminants to concentrations that meet cleanup goals. The required duration of these institutional controls may vary depending on the effectiveness of the selected remedial technology at reducing contaminant mass and concentration in the groundwater. For the purpose of this report, the cleanup goals for this site are assumed to be state MCLs until RGOs are formally negotiated. Assuming that plume remediation technologies such as air sparging and groundwater extraction and treatment are recommended by the CMS and subsequently implemented, they will have some impact on the short- and long-term land use options and will require some level of institutional control and worker protection during remediation.

6.3 EVALUATION OF REMEDIAL ALTERNATIVES

The predicted effectiveness of each of the two remedial alternatives presented in Section 6.1 are described in this section using output from numerical model simulations. The implementability and cost of the remedial alternatives will be addressed in the CMS.

6.3.1 Alternative 1-- RNA Combined with LTM and Institutional Controls - 4 Percent Per Year Source Weathering

The numerical model developed for Facility 1381 and described in Section 5 was used to simulate the future effects of natural attenuation on the groundwater plume. Simulations with the calibrated model were continued into the future under the assumption that groundwater hydraulics at the site will not be significantly altered through additional construction or drainage activities related to future industrial or residential land uses. The restricted nature of CCAS and its importance as a research and launch facility is likely to continue for many years, thereby minimizing the chance for altered site conditions that may impact the fate and transport of contaminants.

Although CAH sources were not definitively identified through field sampling efforts, the continuation of high groundwater CAH concentrations at Facility 1381 indicate that a continuing source of chlorinated solvents exists. These sources may take the form of small concentrated sources such as trapped NAPL pockets or a more dilute source

consisting of contamination sorbed to organics in the soil matrix. Either of these sources could occur in saturated or unsaturated soils. Above the groundwater table, contact with infiltrating rainwater would cause leachate formation. Below the groundwater table, dissolution of CAHs directly into groundwater would result in a continuing source. The gradual loss of CAH compounds into groundwater and via volatilization results in natural weathering of the source. This natural weathering process was incorporated into model 1381_4% which was designed as a baseline model to evaluate the effects of long-term natural attenuation without engineered source removal.

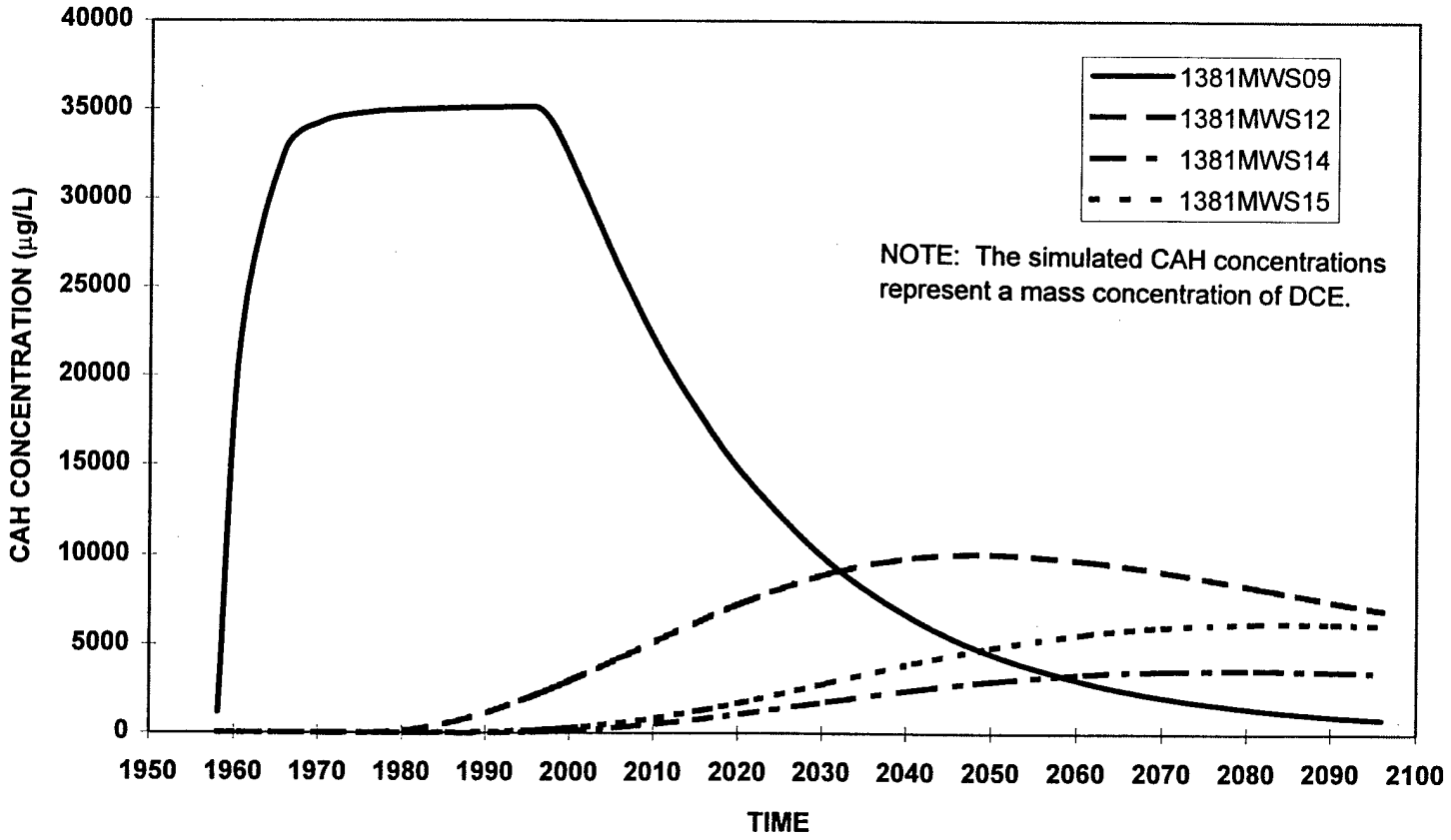
Source weathering in model 1381_4% was assumed to proceed at a geometric rate of 4 percent per year. This weathering rate translates into a 50 percent reduction in the CAH leaching rate every 18 years. The assumption of a 4 percent weathering rate is reasonably low and consistent with similar AFCEE TSs performed by Parsons ES. Source reduction in the model simulation was accomplished by uniformly reducing the loading rates in model source cells (see Appendix D) by 4 percent each year.

The results for Model 1381_4% are plotted on Figure 6.1. This figure depicts locations along the centerline of the groundwater plume from the source area (1381MWS09) to the plume's leading edge (1381MWS15). Because CAH concentrations were modeled as a combined total of all CAH molar concentrations, the vertical scale represent the sum of TCE, DCE, and VC molar concentrations converted to the mass equivalent of DCE. Therefore, the predicted concentration of CAHs (as DCE) at monitoring well 1381MWS09 in 1996 in Figure 6.1 is approximately 34,800 µg/L, as compared to the actual concentration of 39,400 µg/L of TCE (TCE has a higher molecular weight than DCE). In contrast, modeled CAH concentrations are high at the leading edge of the plume (180 µg/L at monitoring well 1381MWS15, as compared to a measured concentration of 147 µg/L), due to the fact that VC has a lower molecular weight than DCE. The conversion of CAH concentrations to a DCE mass equivalent is justified on the basis that DCE concentrations predominate at the site, especially at the leading edge of the plume where the DCE/VC ratio is approximately 8:1.

Model 1381_4% indicates that groundwater CAH concentrations in the source area will continue decreasing through natural attenuation, but will not reach state MCLs of 7 and 1 µg/L for DCE and VC, respectively, within the next century. Although source area concentrations are predicted to decrease, simulated groundwater CAH concentrations increase at downgradient monitoring wells 1381MWS12, 1381MWS14, and 1381MWS15 into the mid to late 21st century. This trend is the result of an expanding groundwater plume that is propelled by low groundwater velocities over large distances.

The current size and shape of the groundwater plume is hydraulically defined by the bordering drainage canals. Because groundwater contamination downgradient of the source appears to reside primarily in the top 20 feet of the saturated zone (the mid-point between the bottom of shallow well screens and the top of intermediate-depth), most of the contaminants that reach the canal are predicted to discharge into the canal. This prediction is supported by Strack (1989) who provides an example in which a stream penetrates one-tenth of the aquifer thickness and captures approximately 94 percent of the groundwater flow from its upgradient side. Water depth in the canals was assumed to typically vary from one to two feet, therefore penetrating approximately 5 to 10 percent into the upper 20 feet of the aquifer and providing a significant hydraulic sink to capture groundwater contaminants.

FIGURE 6.1
SIMULATED CAH CONCENTRATIONS AT WELLS 1381MWS09, 0S12, -S14, AND -S15
(4 PERCENT SOURCE REDUCTION PER YEAR)
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA



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Although the northern drainage canal can functionally receive the majority of groundwater contamination, the relatively slow groundwater velocities at the site dictate that contaminant mass flux into the stream also will be slow. Figure 6.2 shows the estimated mass discharge rate of total CAH contaminants entering the northern drainage canal based on model 1381_45%. Currently, approximately 130 grams per year of CAH is discharging to the northern canal. Assuming an average width, depth, an velocity of the northern drainage canal of 6 feet, 1 foot, and 0.2 feet/sec, a conservative surface water concentration of 0.12 µg/L might be achieved under these assumptions (see Appendix C for calculations). Total CAH mass entering the creek may increase in the future because groundwater CAH concentrations are predicted to increase at downgradient wells. To date, CAH compounds have never been detected in surface water samples collected from the northern drainage canal.

6.3.1 Alternative 2-- RNA Combined with Source Removal, LTM, and Institutional Controls - 25 to 50 Percent-Per-Year Source Removal

Models 1381_25% and 1381_50% were designed to simulate engineered groundwater treatment in the source area (Remedial Alternative 2). Each of these models is identical to the calibrated model, with the exception of accelerated removal rates of CAH mass in the source area. Source reduction was assumed to be in the form of a full-scale air sparging system, dual-phase extraction system, or similar treatment technology that would affect several thousand square feet of aquifer within the zone of highest dissolved CAH contamination (near 1381MWS09). Models 1381_25% and 1381_50% were used to evaluate these source reduction technologies over a range of plausible treatment efficiencies.

Model 1381_25% assumes a 25 percent per year reduction in CAH mass loading to the groundwater. This loading reduction translates into the remediation of 99 percent of the dissolvable CAH source after 16 years of treatment. Under this scenario, Model 1381_25% indicates that more-rapid decreases of dissolvable CAH contamination would accelerate groundwater remediation in the source area, especially in the vicinity of monitoring well 1381MWS09. Groundwater CAH concentrations at 1381MWS09 are estimated at 20,000 µg/L by calendar year 2001 and 4,000 µg/L by calendar year 2008. Figure 6.3 shows simulated concentration trends at select wells along the plume centerline.

The model results indicate that the accelerated source removal simulated by Model 1381_25% will not immediately influence the majority of the groundwater plume. Significant changes in the overall magnitude of the plume downgradient from the source area are predicted to occur after the year 2034 at which time CAH concentrations along the centerline of the plume will begin to decline. For example, CAH concentrations at monitoring wells 1381MWS12 and 1381MWS14 are predicted to peak in calendar years 2034 and 2060 at concentrations that are 18 and 43 percent, respectively, below corresponding CAH concentrations simulated using Model 1381_4% (Figures 6.1 and 6.3).

Model 1381_25% predicts that after a century of combined source reduction (achieving near complete source removal in the first 16 years) and natural attenuation, the groundwater plume will have approximately the same areal extent as the original plume, but will be substantially reduced in magnitude (concentration). For instance, CAH

FIGURE 6.2
SIMULATED DISCHARGE OF CAH MASS TO THE NORTHERN DRAINAGE CANAL
(4 PERCENT SOURCE REDUCTION PER YEAR)
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

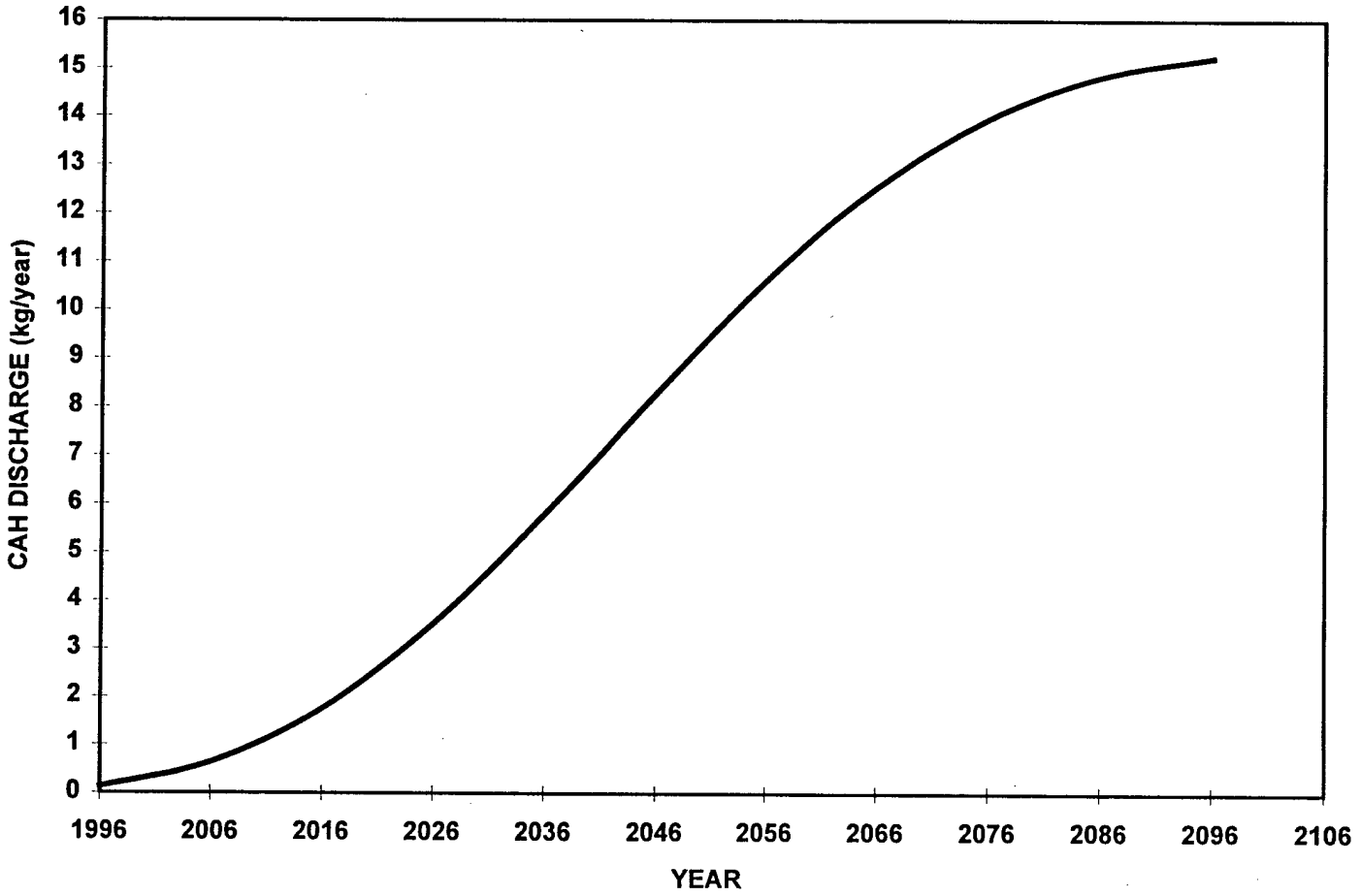
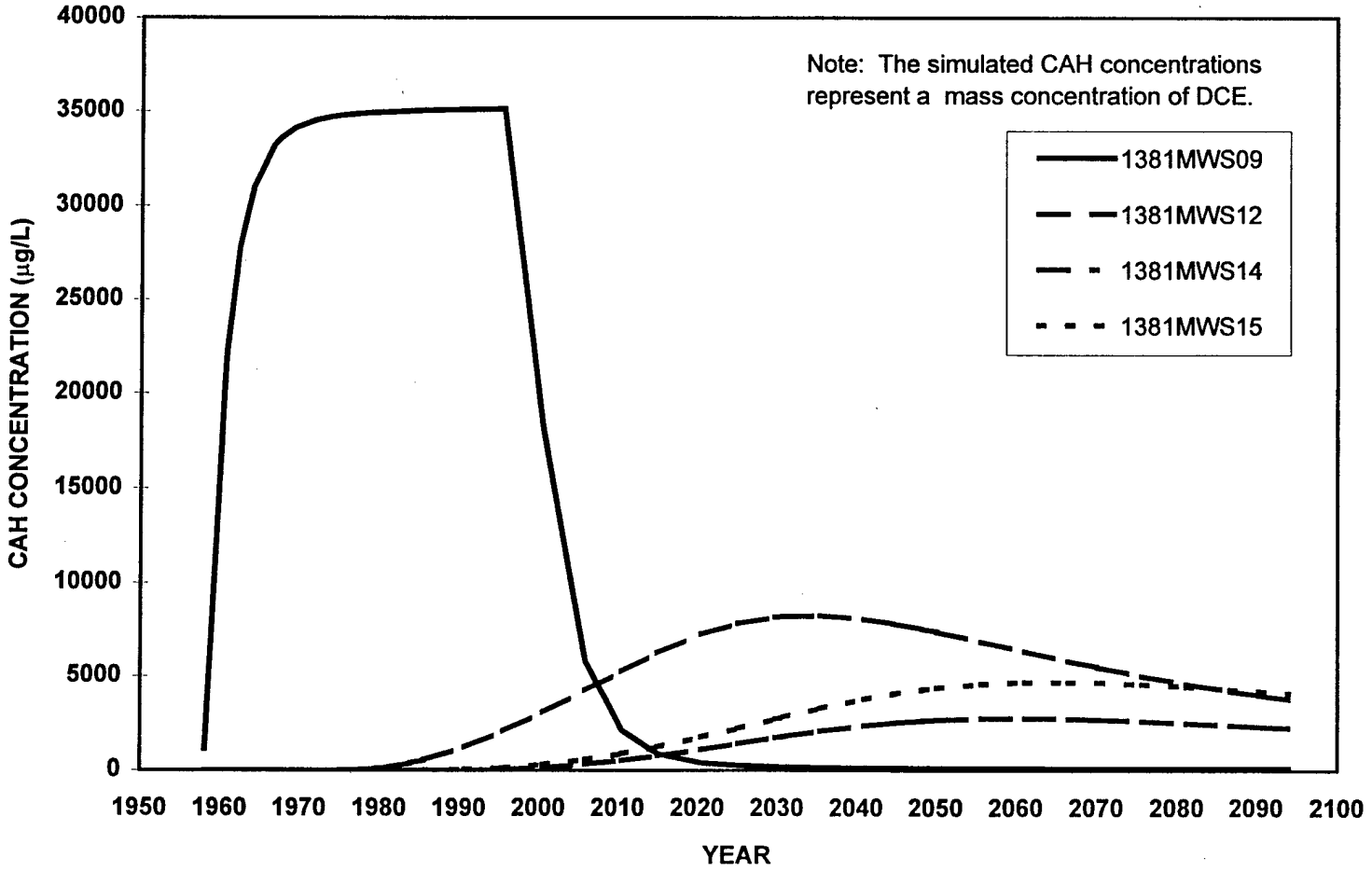


FIGURE 6.3
SIMULATED CAH CONCENTRATIONS AT WELLS 1381MWS09, -S12, -S14, AND -S15
(25 PERCENT SOURCE REDUCTION PER YEAR)
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA



concentrations of 110, 3760, 2240, and 4070 µg/L are predicted to be achieved at monitoring wells 1381MWS09, 1381MWS12, 1381MWS14, and 1381MWS15, respectively, in 2096. Therefore, groundwater CAH concentrations over the majority of the plume are not predicted to achieve state MCLs during this timeperiod. Mass loading to the northern drainage canal is predicted to be similar to trends described in Section 6.3.1 for the next several decades.

A more aggressive treatment scenario was evaluated with Model 1381_50%, which assumes yearly source loading reductions of 50 percent. This treatment scenario translates to a 99 percent removal of leachable contaminant mass in approximately 7 years. As a result, dissolved CAH concentrations at monitoring well 1381MWS09 are predicted to be 7,000 and 1,340 µg/L in years 2001 and 2007, respectively. However, aggressive source removal rates of 50 percent per year do not immediately impact downgradient CAH concentrations. Similar to model 1381_25%, downgradient CAH concentrations remain relatively unchanged until after the year 2034 (Appendix D).

Temporal groundwater concentration trends simulated by Model 1381_50% are shown in Figure 6.4. Because of the expanding nature of the groundwater plume, groundwater CAH concentrations are predicted to continue increasing until the effects of source reduction are more fully realized. Simulated groundwater CAH concentrations reach maximum levels at the following dates: monitoring well 1381MWS12 (7930 µg/L in 2032), monitoring well 1381MWS14 (2059 µg/L in 2059), and monitoring well 1381MWS15 (4490 µg/L in 2064). After 100 years of combined source treatment and natural attenuation, final CAH concentrations at monitoring wells 1381MWS09, -S12, -S14, and S-15 are predicted to be 110, 3,500, 2,110, and 3,840 µg/L, respectively. Model 1381_50% predicts that groundwater CAH concentrations will not achieve state MCLs over the length of the plume within the next century.

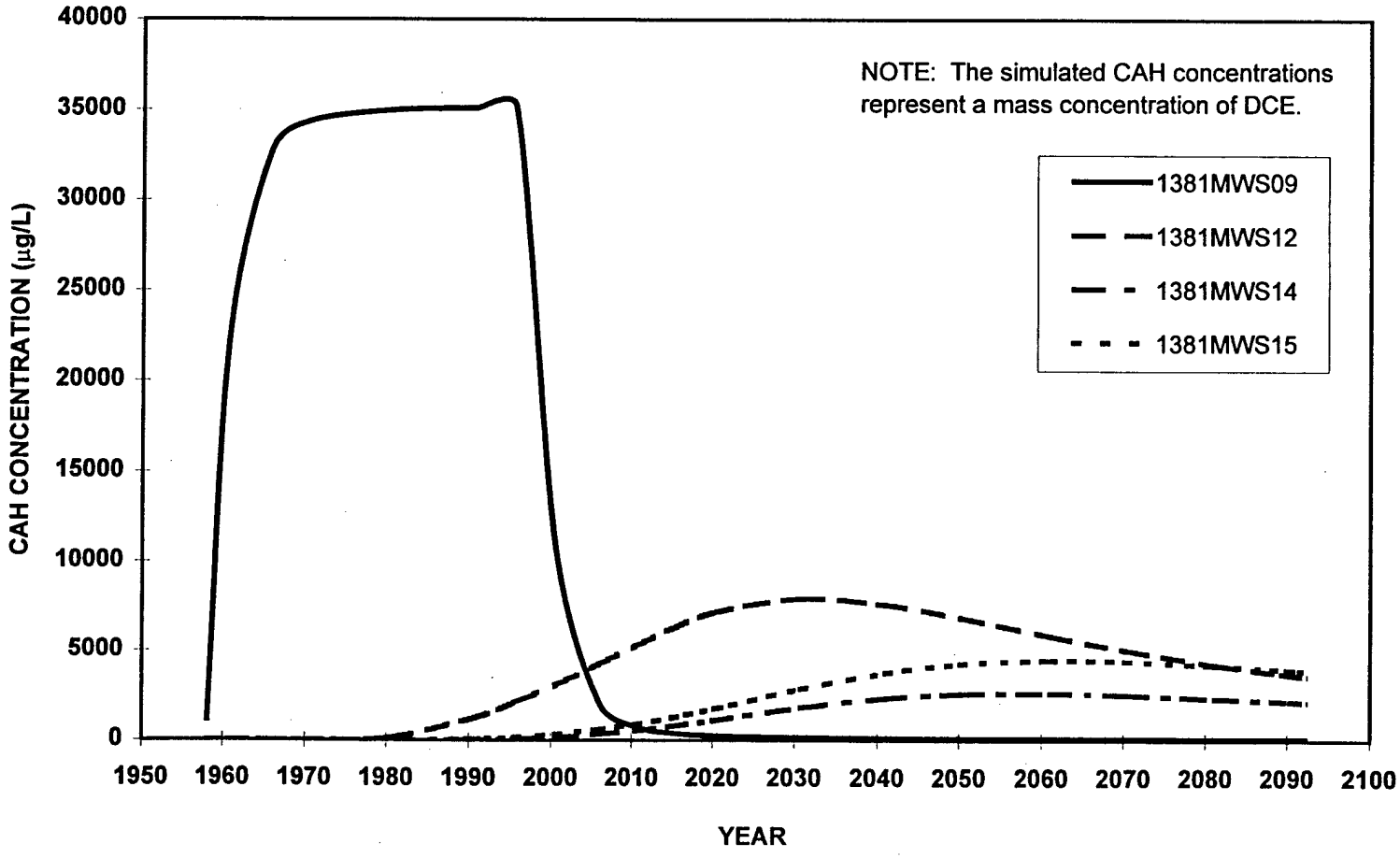
6.4 SUMMARY AND CONCLUSIONS

The effectiveness of two remedial scenarios has been evaluated for the shallow groundwater at Facility 1381. A 4-percent-per-year geometric source reduction rate was used in remedial Alternative 1 to consider the beneficial and unaided effects of natural attenuation on plume persistence and concentration. Alternative 2, which assumed implementation of engineered remedial action, used geometric source reduction rates of 25- and 50-percent per year. These removal rates are reasonable when considering air sparging or dual-phase extraction technologies. Other technologies to be evaluated as part of the CMS may be capable of achieving similar source reduction rates. The predicted effectiveness of RNA and engineered remediation at reducing the extent and magnitude of the CAH plume over time was simulated by the numerical models.

On the basis of available hydrogeologic and chemical data, the numerical model results indicate that dissolved CAH contamination, although undergoing biodegradation, will continue to discharge into the northern drainage canal for more than 100 years.

The results of all models suggest that migration of DCE and VC will continue to occur, even if engineered source reduction actions are implemented. The current plume extent is the result of relatively low migration velocities over a long time frame. Therefore, source reduction will have an immediate benefit on the source area, but only a long-term benefit on downgradient wells. Concentrations of VC above the state MCL of

FIGURE 6.4
SIMULATED CAH CONCENTRATIONS AT WELLS 1381MWS09, -S12, -S14, AND -S15
(50 PERCENT SOURCE REDUCTION PER YEAR)
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA



1 µg/L are predicted to persist for over 100 years. The accuracy of these predictions is dependent on the magnitude and stability of contaminant transport parameters (e.g., biodegradation rates) along the plume flowpath; the seasonal discharge of contaminated groundwater to drainage canals, and the impact of other natural attenuation mechanisms (such as volatilization and phytoremediation) that were not explored as a part of this investigation. Furthermore, the future magnitude of dissolved CAH concentrations in the source area in any of the model scenarios will be dependent on the actual persistence and magnitude of the source over time.

As described in Section 7, at least two additional monitoring wells should be installed near the north and south banks of the northern drainage canal to assess the discharge or underflow of contaminated groundwater. Further information on potential impacts to surface water will facilitate a decision as to whether to employ active groundwater treatment to reduce discharge of contaminated groundwater to the canal. If the magnitudes of the dissolved DCE/VC concentrations that are predicted to be present over time at downgradient wells and near the northern drainage canal are unacceptably high, then groundwater treatment in the form of an air sparging trench, pump-and-treat system, reactive wall, or similar technology should be considered.

SECTION 7

LONG-TERM MONITORING PLAN

7.1 OVERVIEW

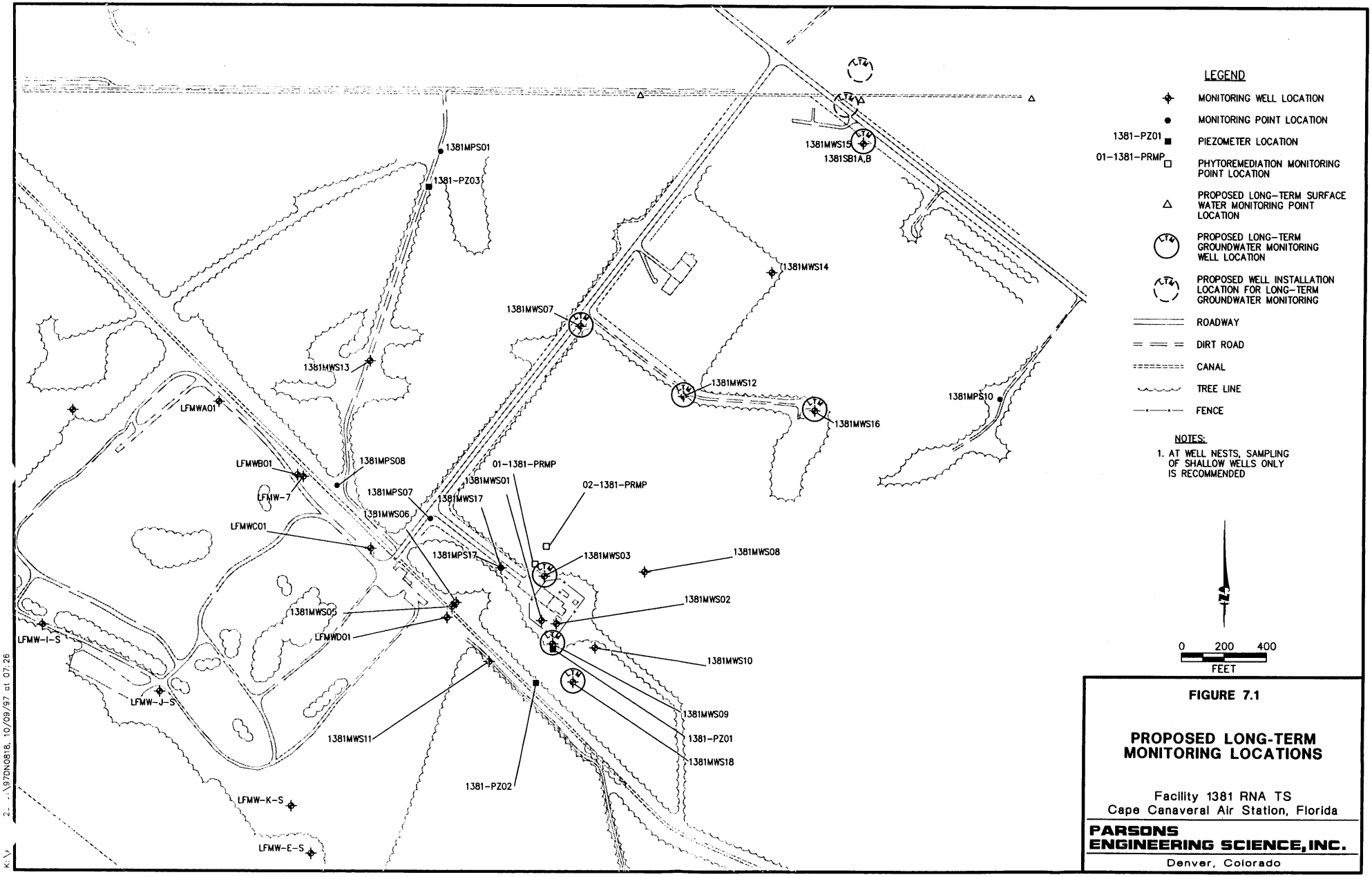
The long-term groundwater monitoring plan for Facility 1381 presented in this section describes a monitoring scheme for the next 20 years for planning and budgeting purposes. It should be noted that this plan was devised on the basis of currently available data; the LTM program may be progressively revised as new data are obtained during this 20-year period. The LTM plan consists of identifying the locations of LTM wells and developing a groundwater sampling and analysis strategy to accomplish the following objectives:

- Monitor changes in site conditions, including plume magnitude and extent, over time;
- Assess the effectiveness of engineered remedial actions (if implemented) and naturally occurring processes at reducing contaminant mass and minimizing contaminant migration;
- Assess the degree to which site-specific remediation goals (Section 6.1) are being attained and facilitate the evaluation of the need for additional remediation; and
- Verify the predictions of the numerical contaminant fate and transport model.

The strategy described in this section is designed to monitor plume migration over time and to verify that natural and engineered remedial processes are adequately protecting potential receptors. In the event that data collected under this LTM program indicate that the planned combination of naturally occurring processes and engineered remedial actions is insufficient to protect human health and the environment, contingency controls to more aggressively remediate the dissolved TCE plume would be necessary.

7.2 GROUNDWATER MONITORING NETWORK

LTM of a minimum of 7 existing shallow monitoring wells, 1 existing intermediate monitoring well, and 2 newly installed shallow monitoring well is proposed for Facility 1381. These wells include: 1381MWS09, 1381MWS03, 1381MWS12, 1381MWS15, 1381MWS18, 1381MWS07, 1381MWS16, and 1381MWI09 (Figure 7.1). The wells suggested for LTM were chosen to provide a range of information on site groundwater conditions. Well 1381MWS18 has historically not contained CAH contamination, and was chosen to provide a location for collecting background geochemical data for comparison to conditions within the CAH plume, and to monitor any changes in



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FIGURE 7.1

PROPOSED LONG-TERM MONITORING LOCATIONS

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

background concentrations. Data from wells lateral to the plume (e.g., wells 1381MWS07 and 1381MWS16) will help monitor lateral changes in plume concentration and migration over time. Samples collected from the remaining monitoring wells along the centerline of the plume will provide data on plume expansion or contraction and the degree of groundwater remediation over time. A new proposed monitoring well should be placed at a shallow interval at the point of maximum-predicted discharge into the northern drainage canal to monitor groundwater discharge concentrations. A second new proposed monitoring well should be placed north of the northern drainage canal to confirm that significant contaminant underflow is not occurring beneath the drainage canal.

Periodic sampling of these wells will allow continuing evaluation of the effectiveness of RNA (and other potential remedial actions) at reducing CAH concentrations prior to groundwater discharge to surface water. In addition, the LTM results can be compared to model-predicted concentrations to assess whether the numerical model has accurately simulated plume migration over time.

7.3 SURFACE WATER MONITORING

In order to assess the potential future impact of groundwater discharge, surface water samples will be collected along the drainage canal north of Facility 1381. Data from these samples will be used to evaluate the impact of groundwater discharge on the quality of the surface water, and the effects of natural attenuation (e.g., dilution, volatilization) on contaminant concentrations (if any) in the drainage canal.

Surface water samples will be collected at three locations along the northern canal, as illustrated on Figure 7.1. These sampling locations have been selected to assess surface water quality upstream from, within, and immediately downstream from the length of the canal projected to receive contaminant plume discharge.

7.4 ANALYTICAL PROTOCOL

All LTM wells should be sampled and analyzed to determine compliance with chemical-specific remediation goals and to verify the effectiveness of remediation at the site. Groundwater level measurements should be made during each sampling event. Groundwater samples from LTM wells should be analyzed for the parameters listed in Table 7.1. Surface water samples should be analyzed for VOCs using USEPA Methods SW8260B or SW8021B.

7.5 SAMPLING FREQUENCY

Under the current remedial strategy, dissolved CAH concentrations in excess of the state standards may be present for substantially more than 100 years. Considering that less stringent groundwater standards may eventually apply to the site through negotiated RGOs (Section 6), the time for LTM may be greatly reduced. However, model predictions presented in Section 6 suggest that CAH concentrations along the plume centerline may still exceed proposed RGOs for the next century.

Annual LTM should be provided for the first 20 years to assess if RNA (and other potential remedial actions) are removing dissolved contaminants and controlling plume

TABLE 7.1
LONG-TERM GROUNDWATER MONITORING ANALYTICAL PROTOCOL
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Ferrous Iron (Fe^{2+})	Colorimetric A3500-Fe D	Filter if turbid	May indicate an anaerobic degradation process due to the depletion of oxygen, nitrate, and manganese	Each sampling event	Collect 100 mL of water in a glass container; acidify with hydrochloric acid per method	Field
Ferrous Iron (Fe^{2+})	Colorimetric Hach 25140-25	Alternate method	Same as above.	Same as above	Collect 100 mL of water in a glass container	Field
Temperature	E170.1, direct-reading meter	Measure at well-head	Purging adequacy; metabolism rates for microorganisms depend on temperature	Each sampling event	Measure at well-head using a flow-through cell	Field
Dissolved Oxygen	Dissolved oxygen meter	Measure at well-head; refer to Method A4500 for a comparable laboratory procedure	Purging adequacy; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Each sampling event	Measure at well-head using a flow-through cell	Field
pH	E150.1/SW9040, direct-reading meter	Measure at well-head	Purging adequacy; aerobic and anaerobic processes are pH-sensitive	Each sampling event	Measure at well-head using a flow-through cell	Field
Conductivity	E120.1/SW9050, direct-reading meter	Measure at well-head	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling event	Collect 100–250 mL of water in a glass or plastic container	Field
Nitrate (NO_3^{-1})	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook[a/] method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C; analyze within 48 hours	Fixed-base

TABLE 7.1 (CONCLUDED)
LONG-TERM GROUNDWATER MONITORING ANALYTICAL PROTOCOL
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Analyte	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Sulfate (SO_4^{2-})	IC method E300 or method SW9056 or Hach SulfaVer 4 method	Method E300 is a Handbook method; method SW9056 is an equivalent procedure. Hach method is Photometric	Substrate for anaerobic microbial respiration	Each sampling event	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C	Fixed-base or field (for Hach method)
Oxidation-Reduction Potential (ORP)	A2580 B, direct-reading meter	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by biologically mediated reactions; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Each sampling event	Measure at well-head using a flow-through cell	Field
Methane, Ethane, and Ethene	RSKSOP-114 modified to analyze water samples for methane by headspace sampling with dual thermal conductivity and flame ionization detection.	Method published and used by the USEPA Robert S. Kerr Laboratory	The presence of methane indicates the presence of sufficiently reducing conditons for reductive dehalogenation to occur	Each sampling event	Collect water samples in 40 mL volatile organic analysis (VOA) vials with butyl gray/Teflon-lined caps (zero headspace); cool to 4°C	Fixed-base
Volatile Organics	GS/MS method SW8260	Handbook method	Measured for regulatory compliance	Each sampling event	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH < 2	Fixed-base

a/ Handbook refers to "AFCEE Handbook to Support the Installation Restoration Program (IRP) Remedial Investigation / Feasibility Study (RI/FS).

expansion. The LTM plan should be periodically reviewed and revised as appropriate on the basis of available groundwater quality data. For example, if LTM data indicate that the plume has stabilized or is receding more quickly than predicted by the model, then the sampling frequency could be reduced, selected LTM wells could be eliminated (e.g., if underflow is not occurring based on LTM results, sampling of the proposed LTM well north of the drainage canal could be discontinued), or analysis of stable geochemical parameters could be discontinued. If the data collected at any time during the monitoring period indicate plume expansion or concentrations increases that exceed model predictions, the need for additional remedial activities at the site should be considered and sampling frequency should be maintained or increased accordingly. At the conclusion of the designated 20-year LTM period, the site should be reevaluated to decide upon the appropriate future course of action.

SECTION 8

CONCLUSIONS AND RECOMMENDATIONS

Results of this TS indicate that RNA is a viable alternative for treatment of the northward-migrating CAH-contaminated groundwater in the vicinity of Facility 1381 at Cape Canaveral Air Station, Florida. RNA, however, may not be the sole remedy for site remediation as several source removal technologies will be evaluated as part of the CMS. Air sparging in the source area is a candidate technology for the site, and an air sparging demonstration project has already been performed within the source area. Although source reduction technologies are being implemented primarily to address the southward-migrating lobe of the plume, these same technologies also will reduce the amount of contamination continuing to enter the northward-migrating lobe of the plume.

Comparison of CAH, TOC, electron acceptor, and byproduct data provides strong evidence that CAHs dissolved in groundwater at Facility 1381 are being reductively dehalogenated (i.e., used as electron acceptors). Microbial consumption of natural organic carbon is producing the reducing conditions required for the reductive dechlorination of CAHs to proceed. Low BTEX concentrations detected in groundwater suggest that previous hydrocarbon releases also may have contributed to the reducing conditions observed at the site.

In the source area, TCE reductive dechlorination occurs at a rate sufficient to attenuate all TCE within 200 feet of the source area. DCE generated through TCE reductive dechlorination is eventually dechlorinated to form VC, and some VC also is slowly dechlorinated to ethene. Reductive dechlorination rates of DCE to VC are slower than from TCE to DCE; therefore, both DCE and VC are detected at significant concentrations more than 2,500 feet beyond the extent of TCE contamination. The highly anaerobic nature of the site inhibits the eventual loss of VC, which is more easily biodegraded through oxidative processes.

Site-specific geologic, hydrologic, and laboratory analytical data were used to create a numerical groundwater flow and solute transport model (using the codes MODFLOW and MT3D96®) to simulate the effects of advection, dispersion, sorption, and biodegradation on the fate and transport of the dissolved CAH plume. Extensive site-specific data were used for model calibration. Model parameters that could not be obtained from existing site data were estimated using reasonable literature values for aquifer materials similar to those found at the site. After calibration, the effects of long-term RNA and source remediation were included in the model to assess the future extent and concentration of dissolved CAHs under the influence of these processes.

The inclusive effects of natural attenuation were simulated in model 1381_4% by assuming that CAH dissolution from source area NAPL and soils into groundwater would naturally decrease at a geometric rate of four percent per year. The results of this model suggest that CAH concentrations will continue to increase at downgradient monitoring wells due to an expanding groundwater plume, and that CAH concentrations are not predicted to decrease below either MCLs or proposed RGOs throughout most of the site for substantially more than 100 years. Modeled groundwater discharge rates to the northern canal suggest that current releases of CAHs to the canal are too low to be detectable; this observation is supported by the lack of historical CAH detections in surface water samples.

The effects of engineered source removal were simulated by models 1381_25% and 1381_50%, which assume geometric decreases in the leaching capability of the source area of 25 and 50 percent per year, respectively. At a 25-percent annual source decay rate, 99 percent of the leachable CAH mass is eliminated after 16 years of remediation. This falls to only 7 years if a 50-percent rate is sustained. Results of both models predict that dissolved CAHs in the source area will decrease rapidly in concentration, but that concentrations in the downgradient portion of the plume will continue to increase before the beneficial effects of source reduction are experienced. As a result, most groundwater CAH concentrations along the centerline of the plume are predicted to exceed state MCLs for more than a century.

It should be emphasized that the numerical model is believed to be reasonably conservative. Therefore, contaminant destruction attributed to natural attenuation is expected to meet or exceed model predictions. For example, the model uses a conservative biodegradation rate and more rapid attenuation of the plume would occur if biodegradation rates are nearer to the high end of the range of rates computed for the site (Section 4.5)

LTM is a necessary component for the implementation of RNA. To verify that natural attenuation mechanisms will continue to reduce contaminant mass, LTM involving annual sampling of groundwater at nine locations and of surface water at three locations is recommended for 20 years (Figure 7.1). The sampling frequency, target analytes, and number of sampled locations may be changed in response to the LTM results. Should LTM data suggest that RNA is not effective in reducing CAH concentrations, additional (engineered) remedial action may be necessary, perhaps in the form of an air sparging network or reactive wall designed to intercept and remove groundwater CAH contamination before it discharges to the northern canal.

The overall extent of the CAH plume and distribution of parent and daughter compounds in March 1998 were similar to that delineated in September 1996. However, migration of dissolved contaminants to the northern drainage canal appears to have been inhibited in March 1998 by a temporary reversal of groundwater flow directions near the canal, most likely caused by increased flow and higher surface water levels in the canal.

Overall, TCE concentrations dissolved in groundwater increased in the source area, indicating the continuing presence of a significant TCE source remaining in the soils at Facility 1381. Despite increased concentrations, the March 1998 TCE plume was still restricted to the vicinity of the source area due to the effects of reductive dehalogenation under type 2 conditions (where a natural carbon source drives reductive dehalogenation).

cis-1,2-DCE continues to be the most widespread contaminant in site groundwater, and the March 1998 DCE plume still appeared to extend to the northern drainage canal. The continued presence of VC and ethene plumes supports the conclusion that DCE and VC also continue to be reductively transformed to less-chlorinated daughter products. Available also data suggest that some oxidation of VC also may be occurring in the plume area.

Geochemical results from the March 1998 sampling event indicate the continued presence of a generally anaerobic, reducing environment, especially in deeper zones of the surficial aquifer that are not influenced by precipitation recharge. Therefore, the redox environment continues to support the occurrence of reductive dehalogenation of CAHs. However, measured increases in redox potentials and DO concentrations and decreases in methane concentrations in some shallow monitoring wells/points suggest that increased precipitation rates had caused a more oxidizing environment to be present, at least in some portions of the plume area, in March 1998. As a result, it is likely that reductive dehalogenation rates in the shallow zone are temporally variable, and that the significance of aerobic degradation of less-chlorinated CAHs (e.g., DCE and VC) also varies. Insufficient LTM were collected in March 1998 to support comparison of LTM results to numerical model predictions.

SECTION 9

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APPENDIX A

BOREHOLE LOGS, WELL CONSTRUCTION DIAGRAMS, SLUG TEST ANALYSES, AND SURVEY DATA

DATE 9/16/96

PROJECT Cape Canaveral

Employee	Hours	Vehicle #	Remarks	Gas	Diesel
Campbell	10				
Vany	10	43263	10		
Veldhouse	10	scaps	10		

Weather and Ground Conditions

DAILY REMARKS (include visits, problems, site type, and suspected contaminant type; cross reference any other notes)

- LU KC
- Arnim Clarksville Tn.

Direct Push Information

Well / HydroPunch / Soils Information

Hole ID	Type	depth Start	depth End	size	depth interval of screen/ soil / WTM	depth to water	backfill
TOTAL							

LIF	
RES	
WELL	
HP	
Dummy	
Other	

Phone Calls, include type, city to and from, and person called

SIGNATURE

3

DATE Fri 9/20/96	PROJECT Cape Cinema					Weather and Ground Conditions	DAILY REMARKS (include visits, problems, site type, and suspected contaminant type; cross reference any other notes)
Employee	Hours	Vehicle #	Remarks	Gas	Diesel		- Arrive 6:30
Vann	10						- Get radio from Bob Sorrillo.
Veldhaugh	10						
Campbell	10						

Direct Push Information				Well / HydroPunch / Soils Information			
Hole ID	Type	depth Start	depth End	size	depth interval of screen/ soil / WTM	depth to water	backfill
03-1381	Res	0	39.4		near 1381HP181		
02-1381	Res	0	33.2		near HP201		
05-1381	Res	0	17.8		near mws14	about	
06-1318	Res	0	52.9		"		
07-1318	Res	0	38.0		near mws07		
08-1318	Res	0	38.0		near mws15		
09-1318	Res	0	36.5		near mws11	Landfill	
04-1384	well	0	30.0		(Loc#3-1384 Overflow)	Leg per Todd Landfill area	
01-1384	well	0	30.0		(Loc#6-1384 Overflow)	in [illegible]	
04-1384	well	0	27.0		(Loc#7-1384 Overflow)	By Res 04	
04-1381	well	0	37.0		(Loc#7-1381 Overflow)	By Res 04	
03-1381	shallow well	0	14.4 ~~30.0~~		(Loc#8=1381W Overflow)	By Res 03	
04-1381	shallow well	0	11.0		(Loc#7-1381 Overflow)	By Res 04	
99-1381	well	0	12.0		(Loc#Boondocks)	well site 09	
TOTAL							

LIF	Phone Calls, include type, city to and from, and person called
RES	
WELL	
HP	
Dummy	
Other	

SIGNATURE

DATE 9/21/01

PROJECT Cape Carneval

Weather and Ground Conditions

DAILY REMARKS (include visits, problems, site type, and suspected contaminant type; cross reference any other notes)

Employee	Hours	Vehicle #	Remarks	Gas	Diesel
Dunn					
Campbell					
Wedhouse					

Direct Push Information

Well / HydroPunch / Soils Information

Hole ID	Type	depth Start	depth End	size	depth interval of screen/ soil / WTM	depth to water	backfilll
10-1381	RES	0	39.4		Boondocks		
11-1381	RES	0	36.2		mws 16. near by		formate. by heather Emmett
~~12~~ 06-1381	3/4"	0	33		Res Loc 5:6 by mws 14		10-06
12-1381	RES	0	32.7		near mws 18		
12-1381	WELL	0	30.0		By RES 12-1381		near [illegible] ?
11-1381W	WELL	0	32.0		By RES 11-1381		
~~08-1381W~~	~~WELL~~						
99-1381W	WELL	0	33.6		Boondocks.		
08-1381W	WELL	0	31.0		By RES 08-1381		
07-1381W	WELL	0	31.0		By RES 07-1381		
03-1381W	WELL	0	30.0		By RES 03.		
TOTAL							

LIF	
RES	
WELL	
HP	
Dummy	
Other	

Phone Calls, include type, city to and from, and person called

SIGNATURE

DATE 9/19/96 | PROJECT Thor Cape Canaveral

Employee	Hours	Vehicle #	Remarks	Gas	Diesel
Campbell	10				
Vann	10	CE4263	10		
Veldhouse	10	SCAPS	10		

Weather and Ground Conditions

DAILY REMARKS (include visits, problems, site type, and suspected contaminant type; cross reference any other notes)

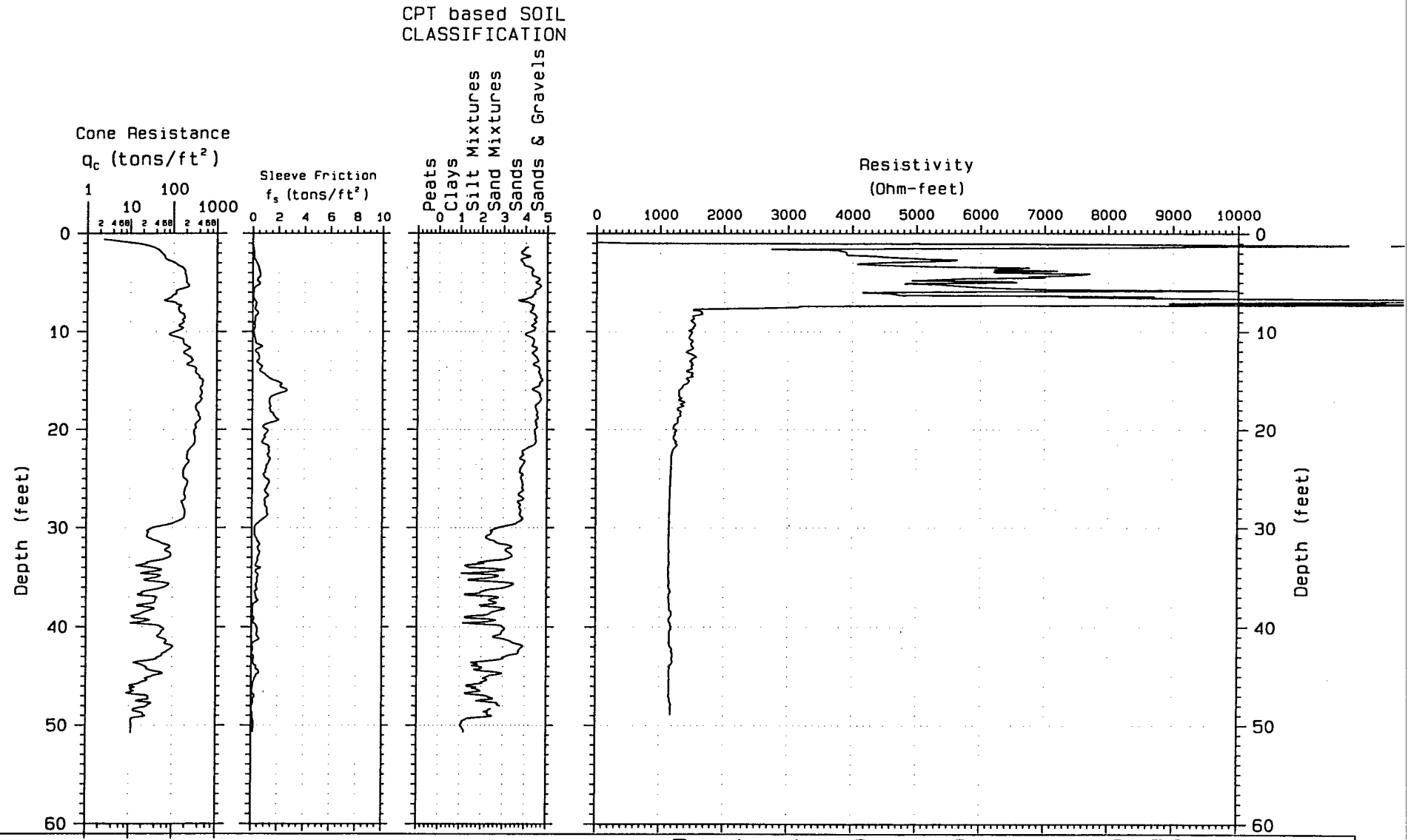
- Arrive 6:30
- new rubbers on decon
- Safety meeting 9:00 avoid pools
-

Direct Push Information / Well / HydroPunch / Soils Information

Hole ID	Type	depth Start	depth End	size	depth interval of screen/ soil / WTM	depth to water	backfill
	Dummy	0	39.7		near E(I) I(J) on Location map		
01-1381	Res	0	51.0		" " " " "		
02-1381	"	0	38.2		near ~~mw~~ 1381 mw513		
02-1381A	well(s)	0	30.0				
01-1381B	well(I)	0	29.0				
01-1381	well(s)	0	12.0				
~~0~~-1381A	well(I)	0	33.0	(LOC #03)	NOTE PUSH	#Eq	-1381 will be same as strat#
-1381B	well(I)	0	30.0	(LOC # 17)	NOTE PUSH	#Eq	-1381 will be same as " " - NEAR MW1 MW513
~~03-1381~~	~~Res~~	~~0~~		1			→ No LIF/GPT Angle @ this location.
TOTAL							

LIF	Phone Calls, include type, city to and from, and person called
RES	
WELL	
HP	
Dummy	
Other	

SIGNATURE



Project; Cape Canaveral Bldg 1381

Probe Depth; 50.99

Pre-Push Depth; 0

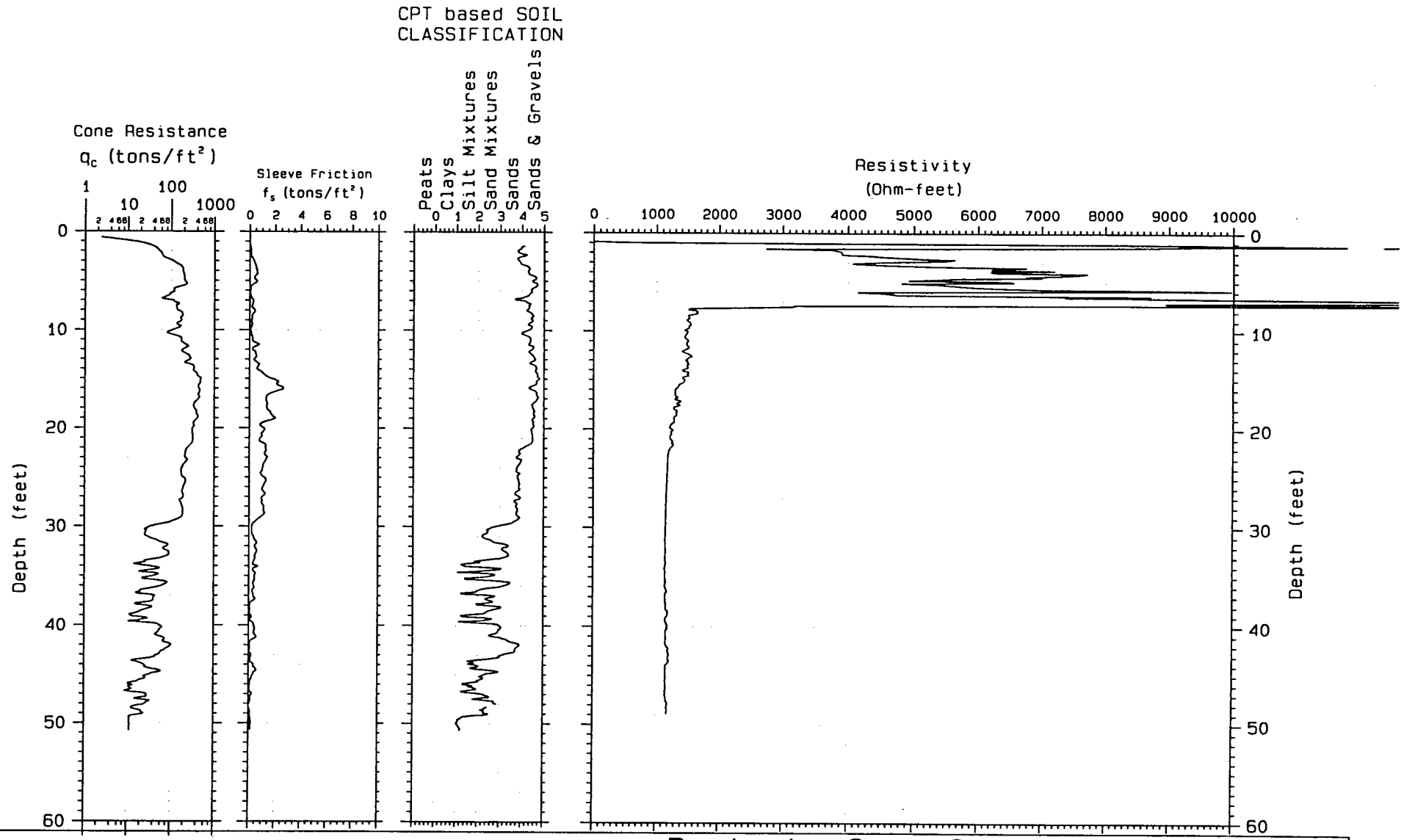
MRK SCAPS

U.S.Army Engineer District Kansas City Geotechnical Branch

Site Characterization and Analysis Penetrometer System

Probing date; 09-19-1996

CPT; 01 1381



Project; Cape Canaveral Bldg 1381

Probe Depth; 50.99

Pre-Push Depth; 0

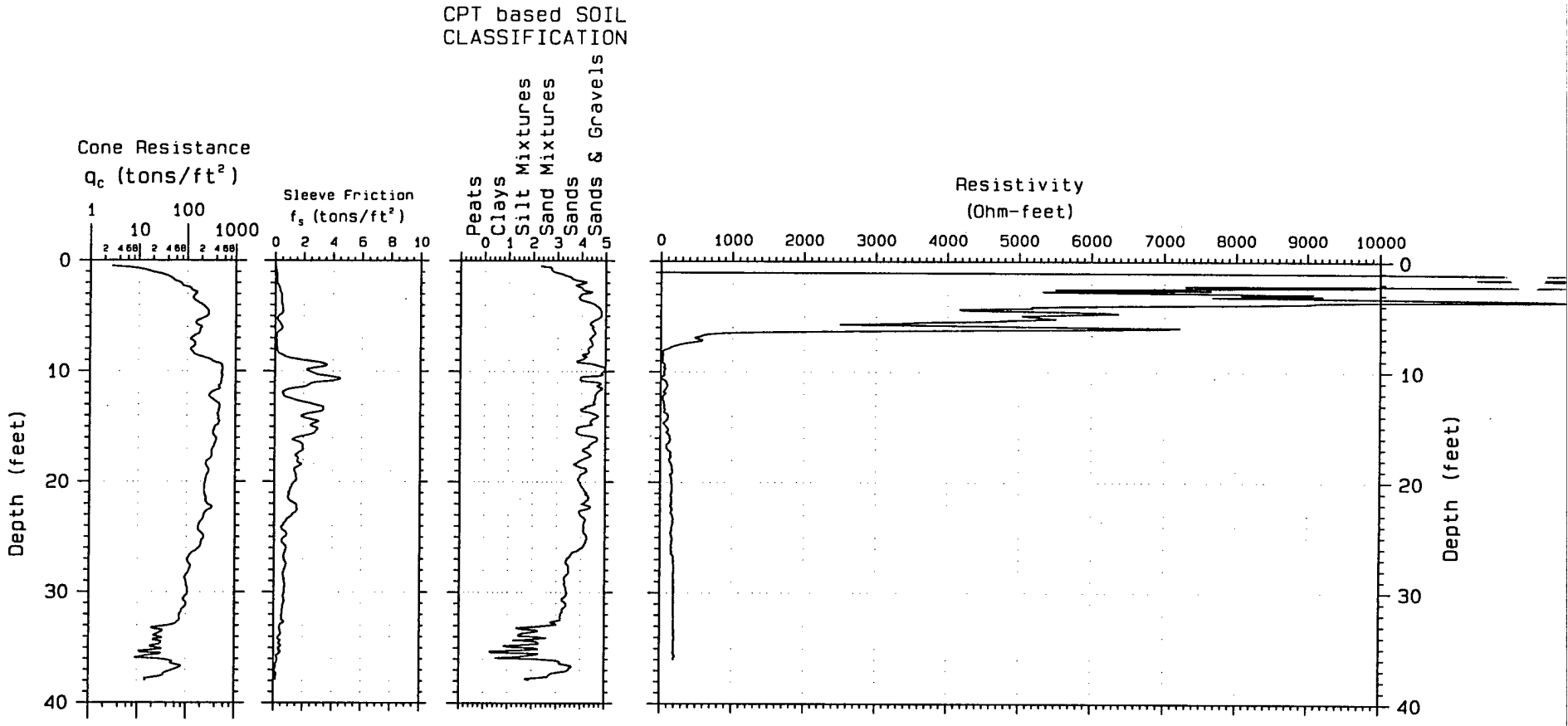
MRK SCAPS

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Site Characterization and Analysis Penetrometer System

Probing date; 09-19-1996

CPT; 01 1381



Project; Cape Canaveral Bldg 1381

Probe Depth; 38.16

Pre-Push Depth; 0

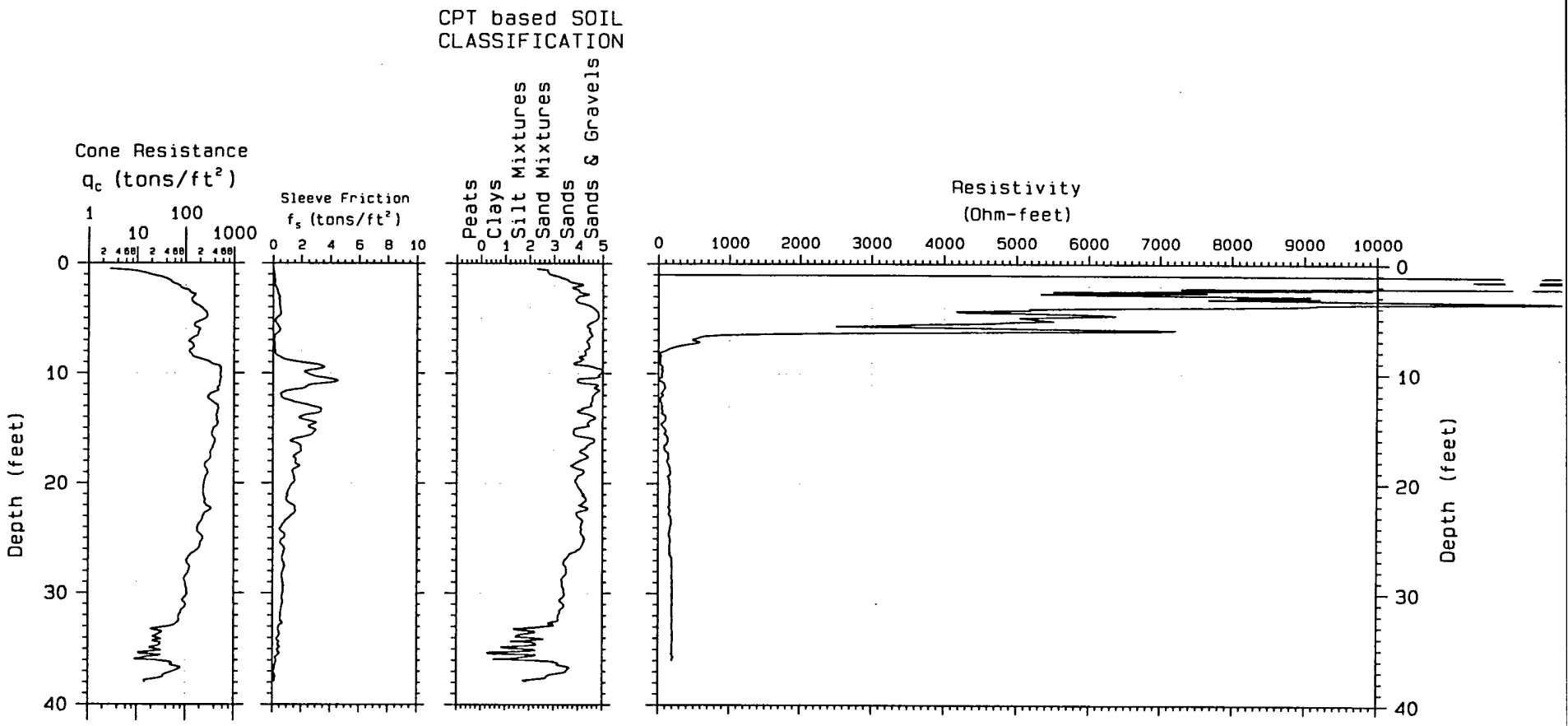
Probing date; 09-19-1996

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Kansas City
Geotechnical Branch

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Site
Characterization
and Analysis
Penetrometer System

CPT; 2 1381



Project; Cape Canaveral Bldg 1381

Probe Depth; 38.16

Pre-Push Depth; 0

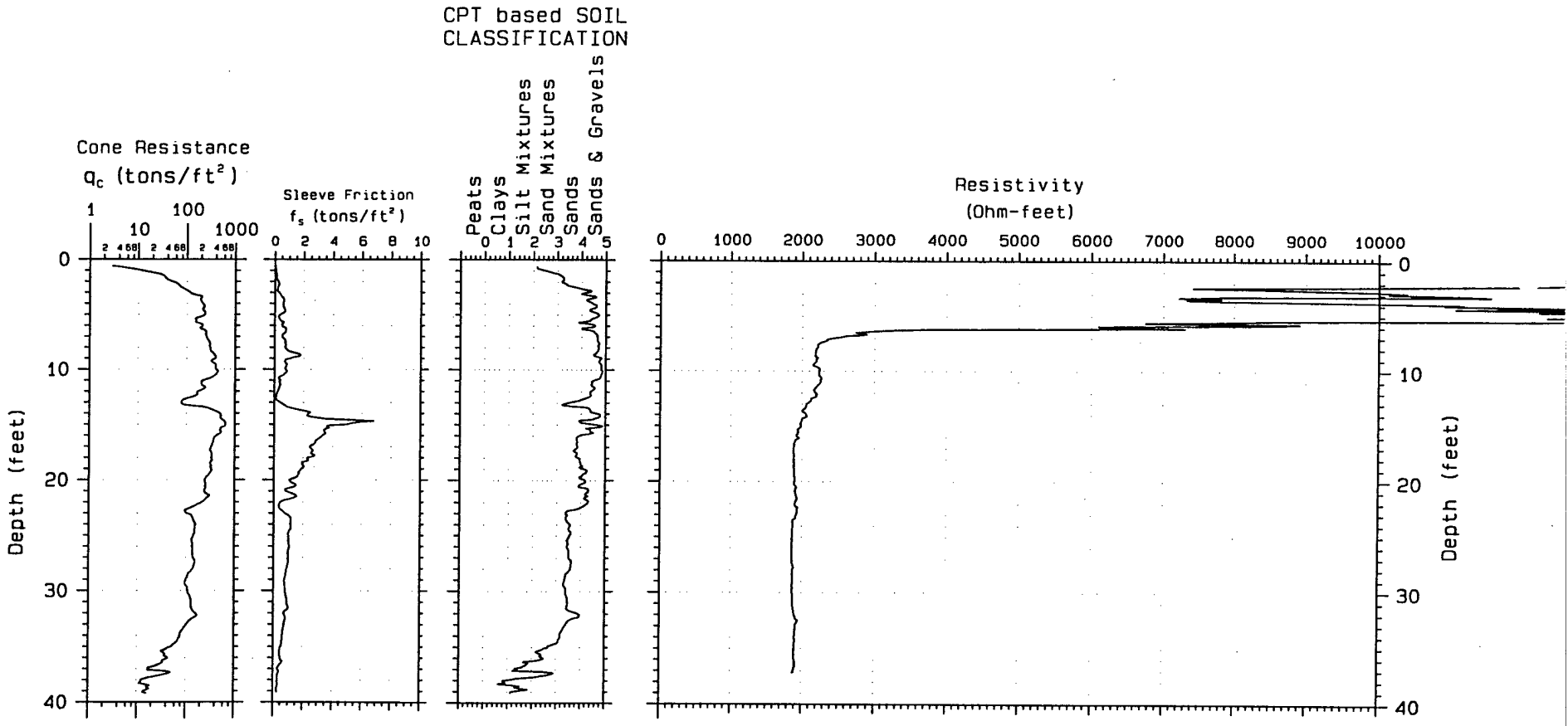
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Site
Characterization
and Analysis
Penetrometer System

CPT; 2 1381



Project; Cape Canaveral Bldg 1381

Probe Depth; 39.35

Pre-Push Depth; 0

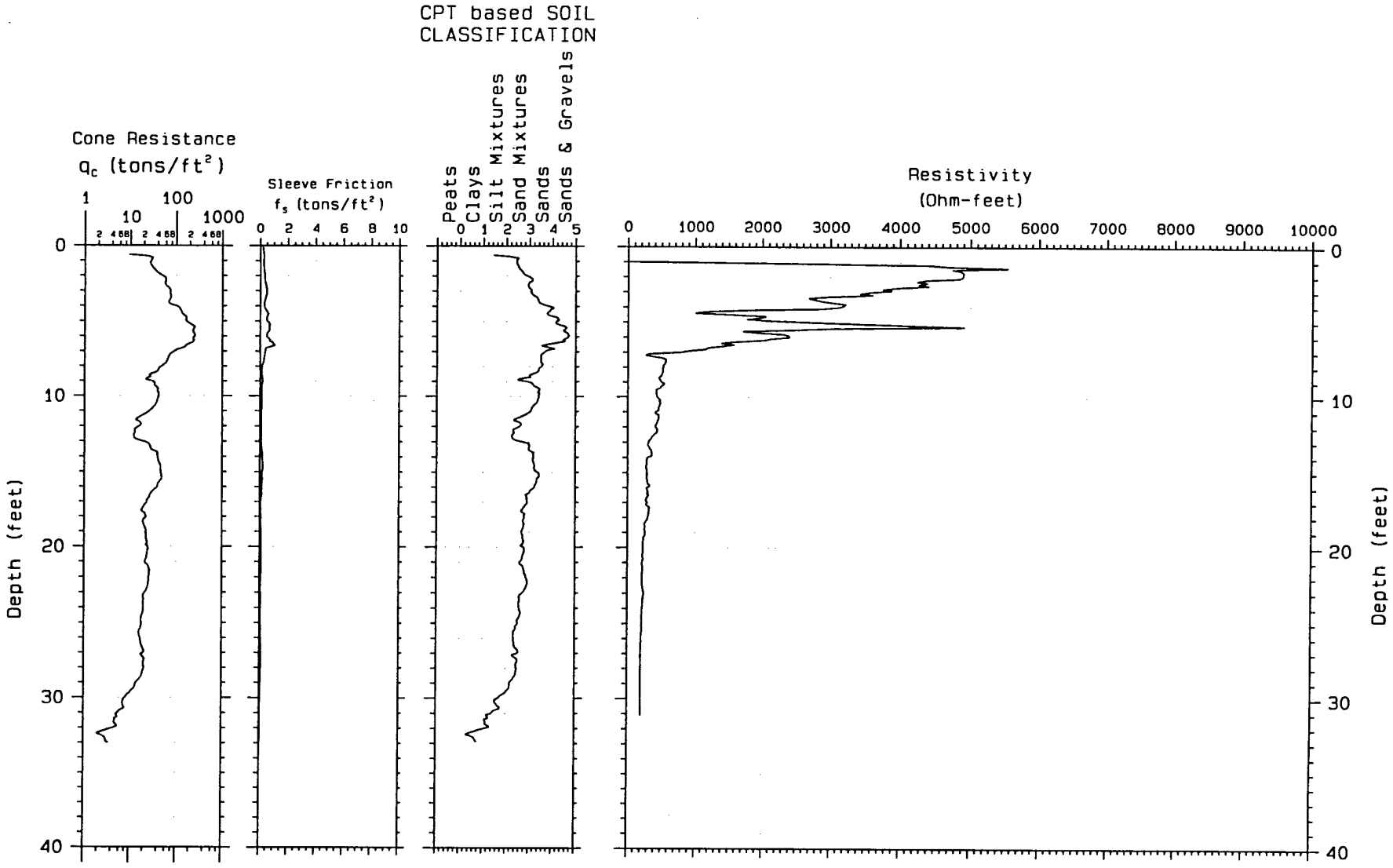
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Site Characterization and Analysis Penetrometer System

CPT; 3 1381



Project; Cape Canaveral Bldg 1381

Probe Depth; 33.20

Pre-Push Depth; 0

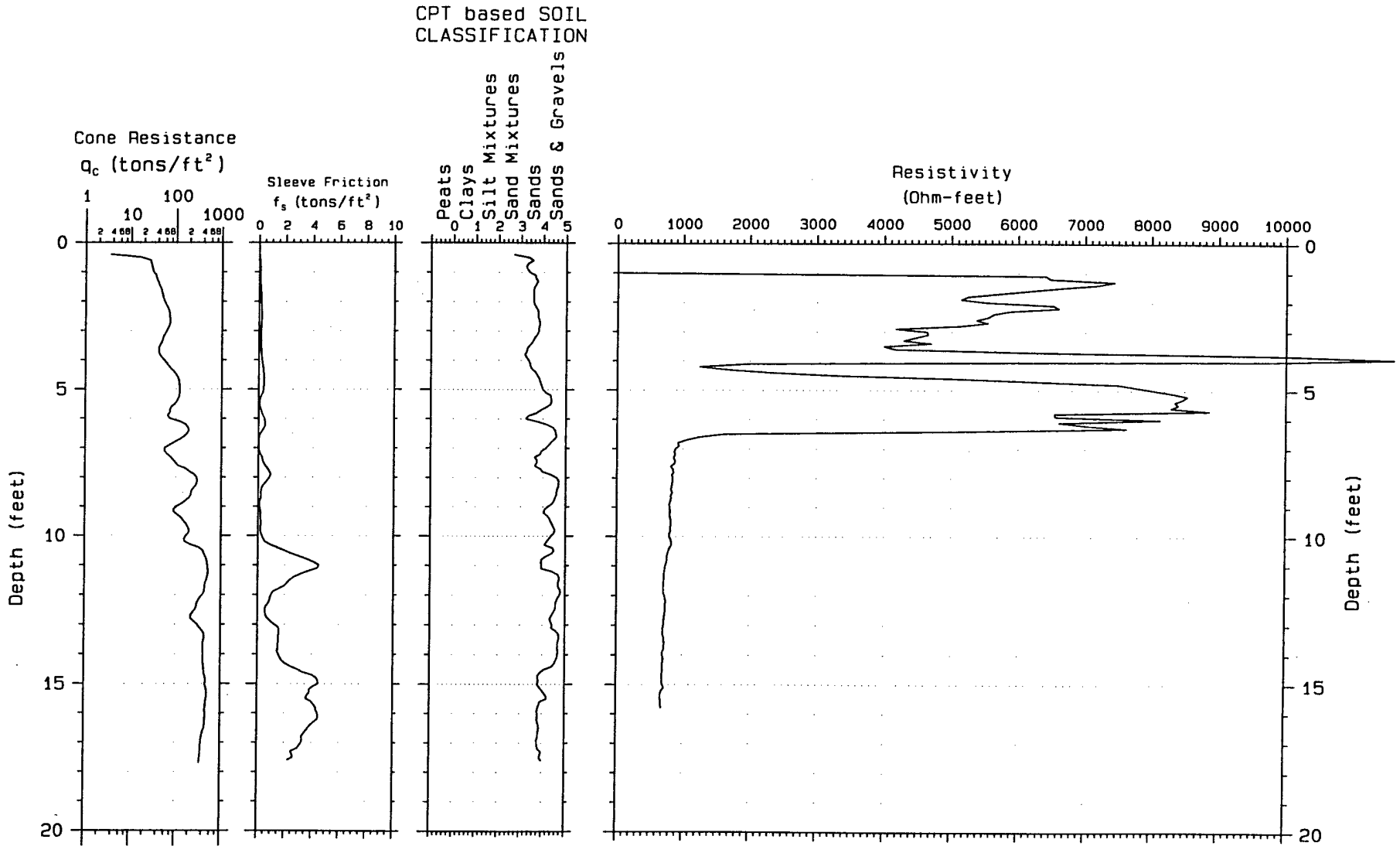
Probing date; 09-20-1996

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Site
Characterization
and Analysis
Penetrometer System

CPT; 4 1381



Project; Cape Canaveral Bldg 1381

Probe Depth; 17.92

Pre-Push Depth; 0

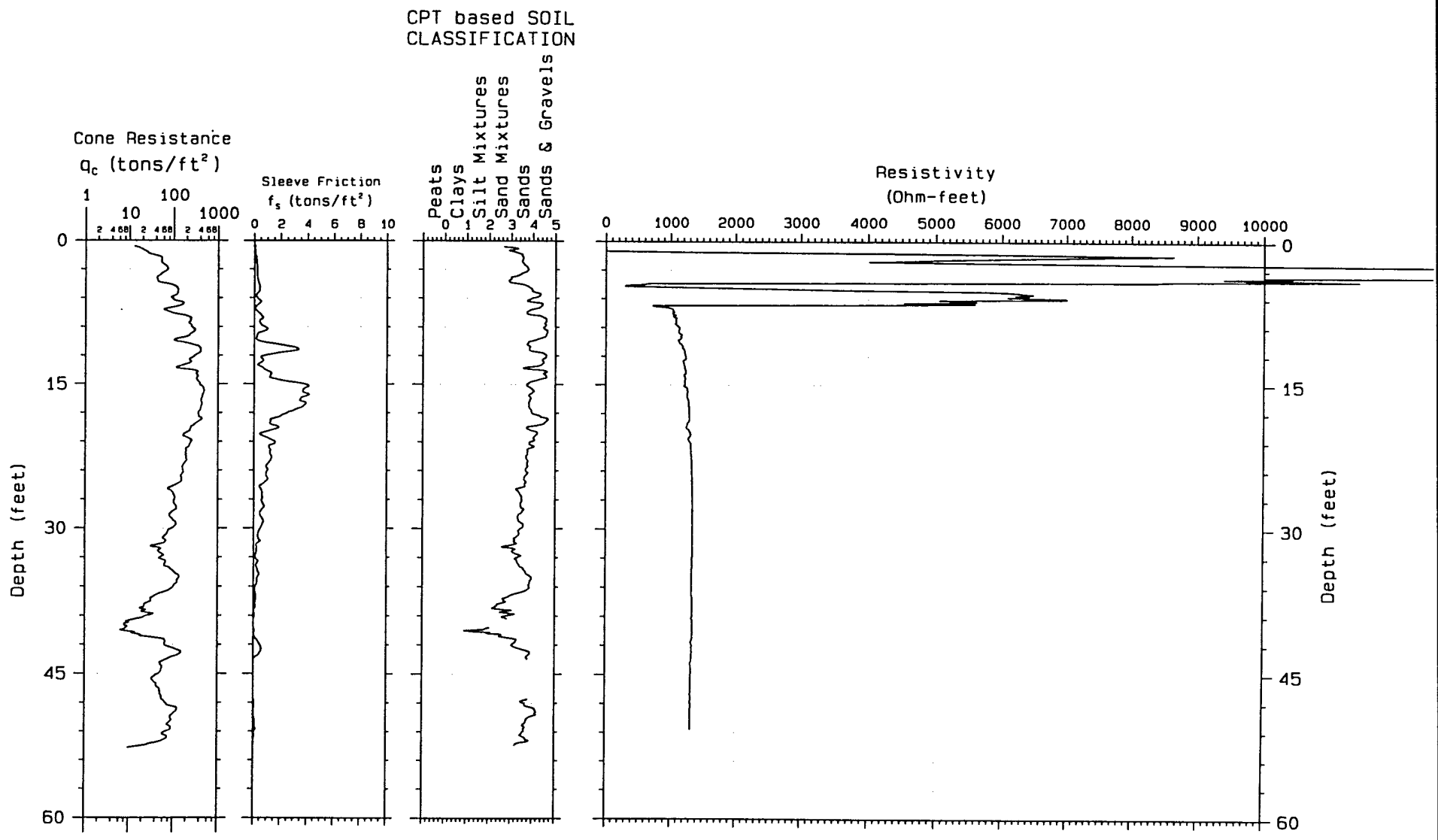
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Characterization
and Analysis
Penetrometer System

CPT; 5 1381



Project; Cape Canaveral Bldg 1381

Probe Depth; 52.83

Pre-Push Depth; 0

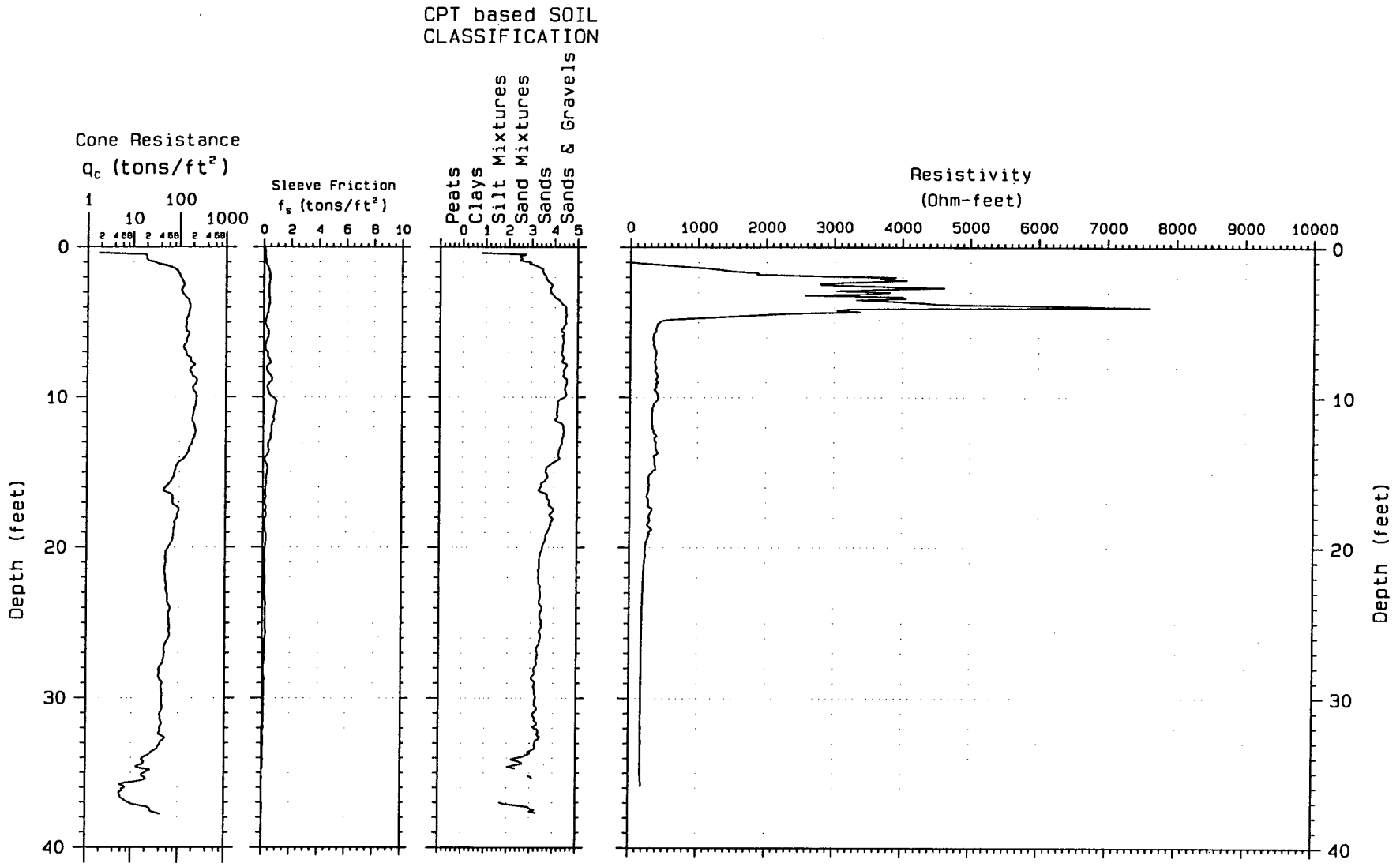
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and Analysis
Penetrometer System

CPT; 6 1381



Project; Cape Canaveral Bldg 1381

Probe Depth; 37.99

Pre-Push Depth; 0

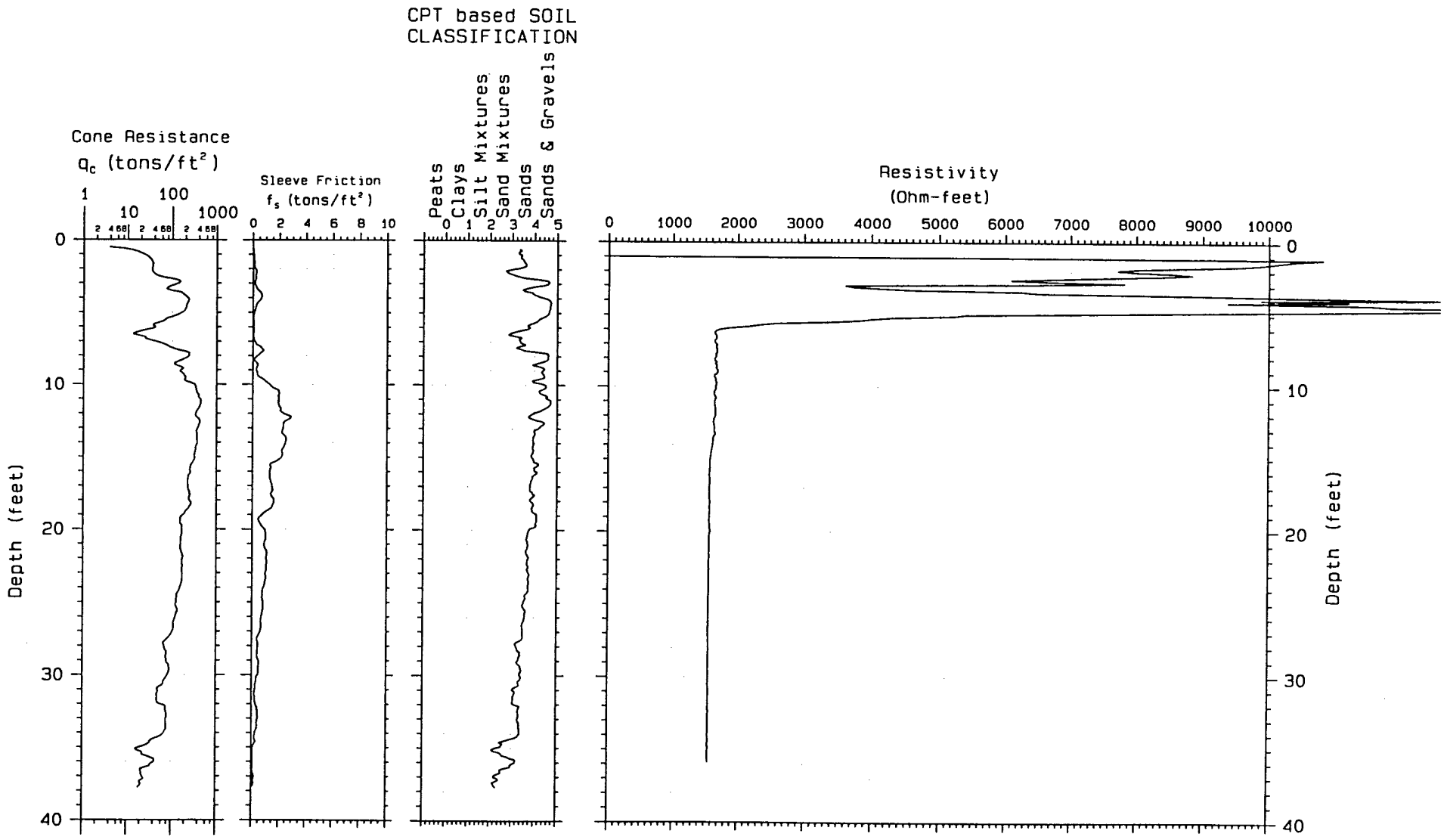
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Characterization
and Analysis
Penetrometer System

CPT; 7 1381



Project; Cape Canaveral Bldg 1381

Probe Depth; 38.04

Pre-Push Depth; 0

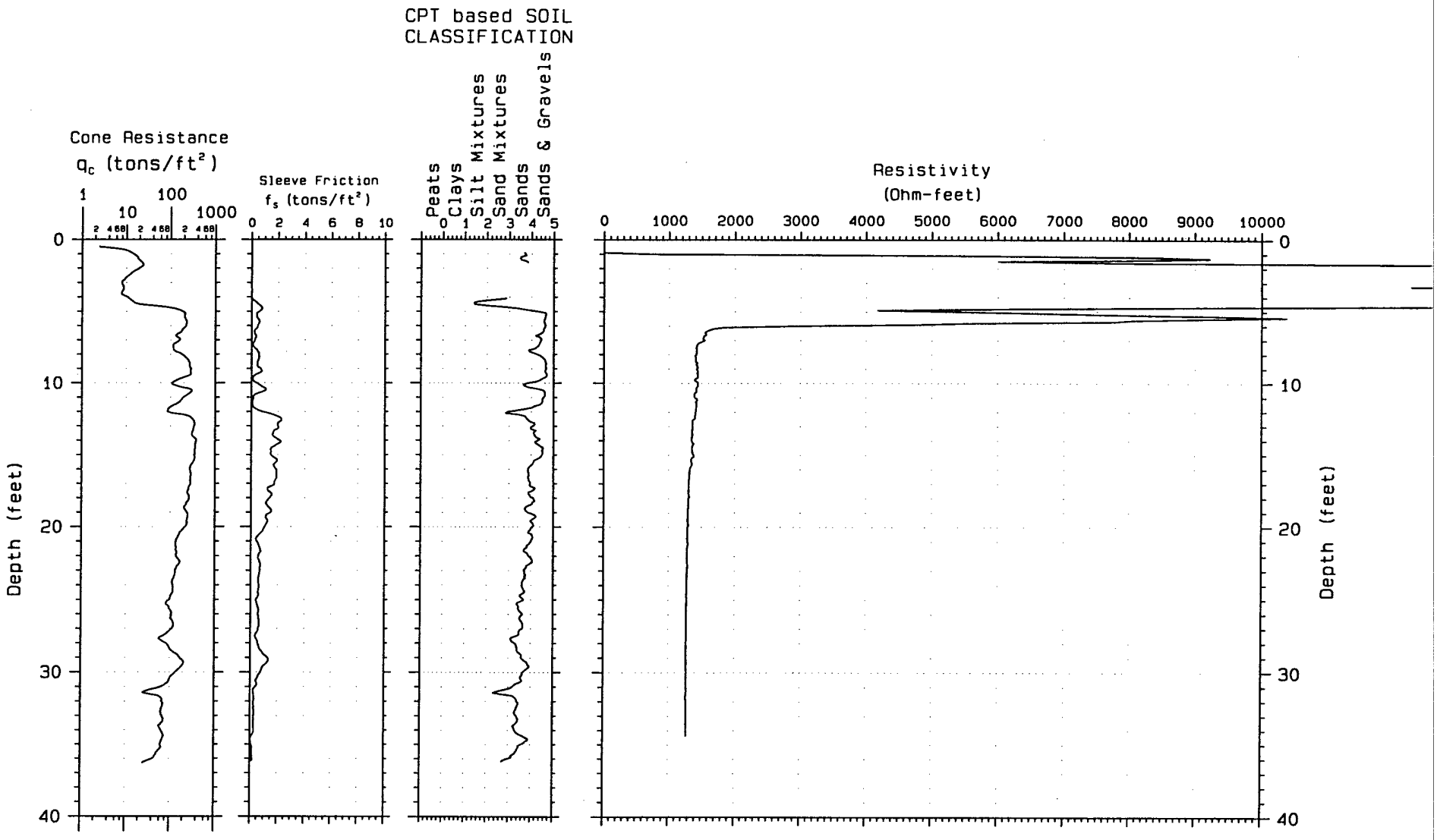
Probing date; 09-20-1996

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Site
Characterization
and Analysis
Penetrometer System

CPT; 8 1381



Project; Cape Canaveral Bldg 1381

Probe Depth; 36.51

Pre-Push Depth; 0

Probing date; 09-20-1996

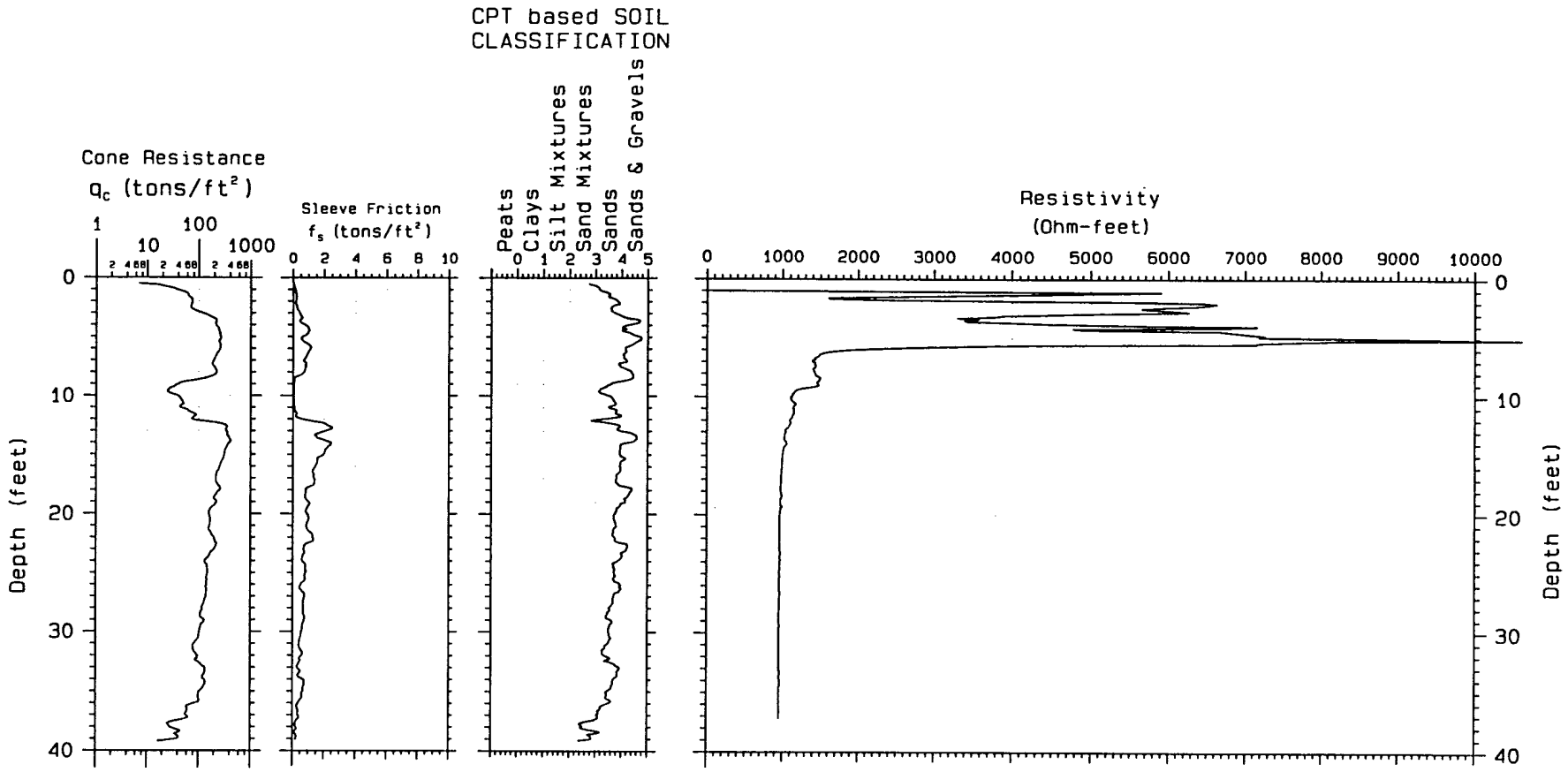
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MRK SCAPS

Site
Characterization
and Analysis
Penetrometer System

CPT; 9 1381

well location 13B1MP105



Project; Cape Canaveral Bldg 1381

Probe Depth; 39.38

Pre-Push Depth; 0

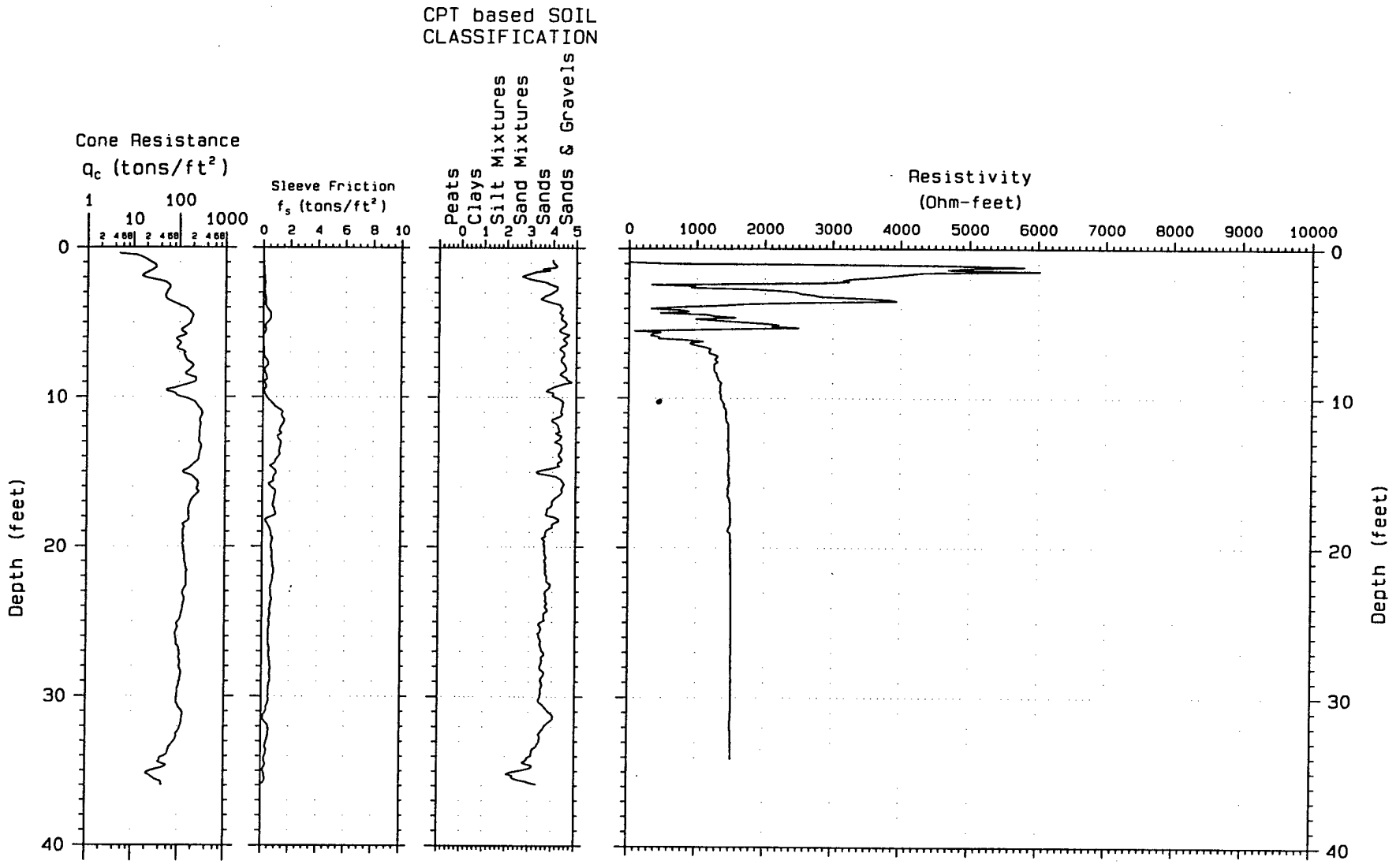
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Site Characterization and Analysis Penetrometer System

Probing date; 09-21-1996

CPT; 10 1381



Project; Cape Canaveral Bldg 1381

Probe Depth; 36.20

Pre-Push Depth; 0

Probing date; 09-21-1996

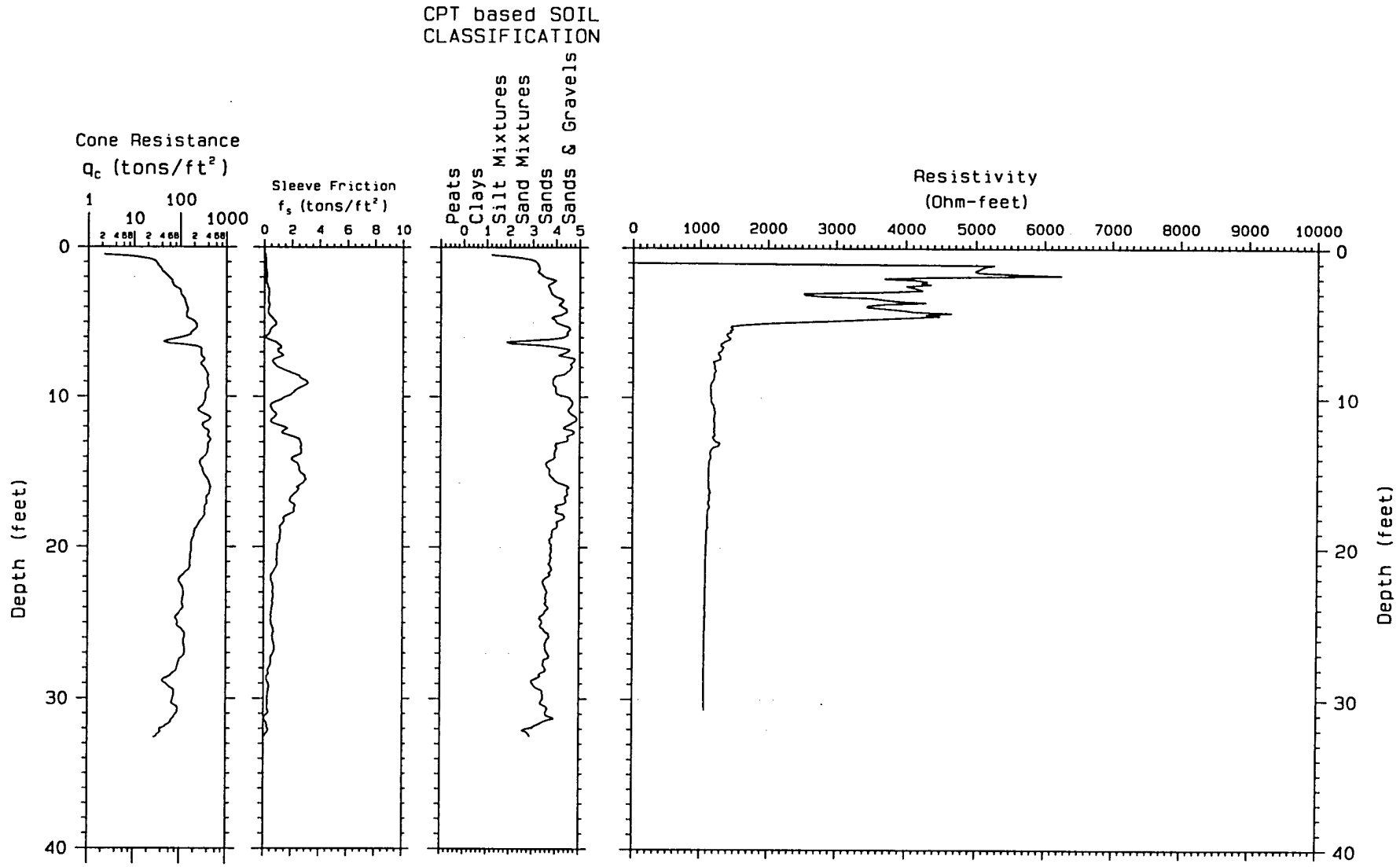
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Characterization
and Analysis
Penetrometer System

CPT; 11 1381



Project; Cape Canaveral Bldg 1381

Probe Depth; 32.76

Pre-Push Depth; 0

MRK SCAPS

U.S.Army Engineer District Kansas City Geotechnical Branch

Site Characterization and Analysis Penetrometer System

Probing date; 09-21-1996

CPT; 12 1381

GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: Ø1-1381-SB
CONTRACTOR: [illegible]
DATE SPUD: 9/24/96
CLIENT: AFCEE
RIG TYPE: Geoprobe ®
DATE CMPL.: 9/24/96
JOB NO.: 729691
DRLG METHOD: Direct Push
ELEVATION:
LOCATION: FACILITY 1381
BORING DIA.: 1.5
TEMP: 90°F
GEOLOGIST: T.H.
DRLG FLUID:
WEATHER: HOT
COMENTS:

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1											
2.5				Light Brown - shell fragments - mostly medium sand								
	5	SI		light Brown/grey sand - medium grained with shell fragments								
6.5												
	10											
	15											
	20											
	25											
	30											
	35											

NOTES

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE

D – DRIVE
C – CORE
G – GRAB

▼ Water level drilled

FIGURE 3.3

GEOLOGIC BORING LOG

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

K:\AFCEE\729691\96DN0634, 08/27/96 at 12:22

GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: Ø2-1381-SB
CLIENT: AFCEE
JOB NO.: 729691
LOCATION: FACILITY 1381
GEOLOGIST: TH.
COMENTS:

CONTRACTOR: EA
RIG TYPE: Geoprobe®
DRLG METHOD: Direct Push
BORING DIA.: 1.5" ID
DRLG FLUID:

DATE SPUD: 9/24/96
DATE CMPL.: 9/24/96
ELEVATION:
TEMP: 90°F
WEATHER: Hot

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
2.9	1			3.5' of sample recovery of 4.0' Dark, peaty loam, soil (top 1 foot) blends to lighter sand with shell frags - medium - to fine.								
	5		SP	Fine to medium sand - light tan - bottom 6" is gray sand.								
6.9												
	10											
	15											
	20											
	25											
	30											
	35											

NOTES

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE

D – DRIVE
C – CORE
G – GRAB

▼ Water level drilled

FIGURE 3.3

GEOLOGIC BORING LOG

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

K:\AFCEE\729691\96DN0634, 08/27/96 at 12:22

GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: Ø3-1381-SB
CLIENT: AFCEE
JOB NO.: 729691
LOCATION: FACILITY 1381
GEOLOGIST: TH
COMMENTS:

CONTRACTOR: EPA
RIG TYPE: Geoprobe
DRLG METHOD: Direct Push
BORING DIA.: ~~2~~ 1.5"
DRLG FLUID:

DATE SPUD: 9/24/96
DATE CMPL.: 9/24/96
ELEVATION: —
TEMP: —
WEATHER: 90 - Hot

Elev (ft)	Depth (ft)	Profile	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1			Tan sand, medium to coarse, small pebbles, some shell fragments		2.4-6.4'						
	5	▼										
	10											
	15											
	20											
	25											
	30											
	35											

NOTES

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE

D – DRIVE
C – CORE
G – GRAB

▼ Water level drilled

FIGURE 3.3

GEOLOGIC BORING LOG

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

K:\AFCEE\729691\96DN0634, 08/27/96 at 12:22

GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: 04-1381-SB
CONTRACTOR: EPA
DATE SPUD: 9/24/96
CLIENT: AFCEE
RIG TYPE: Geoprobe®
DATE CMPL.: 9/24/96
JOB NO.: 729691
DRLG METHOD: Direct Push
ELEVATION:
LOCATION: FACILITY 1381
BORING DIA.: 1.5
TEMP: 90°F
GEOLOGIST: TH
DRLG FLUID:
WEATHER: hot
COMENTS:

Elev (ft)	Depth (ft)	Pro-file	US CS	Geologic Description	Sample No.	Sample Depth (ft)	Sample Type	Penet Res	PID(ppm)	TLV(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
	1											
3.7'		—		Darker, slightly grey - although not saturated. Moist - medium grained sand.								
	5	▽										
				Wet - light Tan - no grey - medium to coarse sand with shell frags.								
7.7'		—										
	10											
	15											
	20											
	25											
	30											
	35											

NOTES

bgs – Below Ground Surface
GS – Ground Surface
TOC – Top of Casing
NS – Not Sampled
SAA – Same As Above

SAMPLE TYPE

D – DRIVE
C – CORE
G – GRAB

▼ Water level drilled

FIGURE 3.3

GEOLOGIC BORING LOG

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

K:\AFCEE\729691\96DN0634, 08/27/96 at 12:22

ENGINEERING - SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

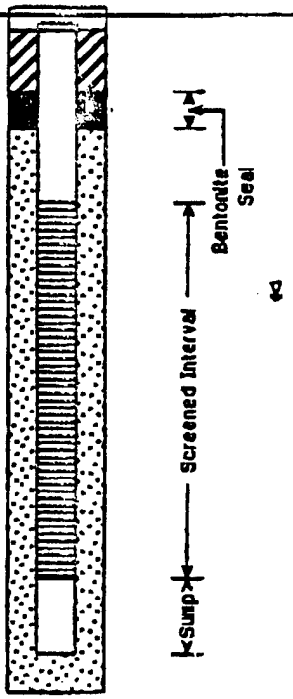
Page 1 of 1

Project I.D. AT509 SI #2
Installation Cape Canaveral AFS
Site Fac. 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS01
Geologist/Engineer Federico Artioli
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 30-Nov-93
Date Completed 30-Nov-93
Driller Groundwater Protection, Inc.
Borehole Diameter (in) 10.25
Depth Drilled (ft) 18
Ground Elevation (ft) 8.393
X-Coordinate 797423.170
Y-Coordinate 1504383.270

Client 45th Space Wing
Date Installed 30-Nov-93
Date Grouted 02-Dec-93
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 0 to -5
Screened Interval (ft) -5 to -15
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 17
Depth to Water BTOC (ft) 7.34
Date Measured 07-Dec-93
TOC Elevation (ft) 8.251
Water Level MSL (ft) 0.91

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		N/A	-	0	0	SAND, fine, tr silt, little to some shell frag, loose, very pale brown (10YR8/3), dry, T=23C.	SDFN	SP	
5		5,9, 13,15	65	0	0	SAND, fine to med, tr silt, some shell frag, very firm, pale yellow (2.5Y8/4), dry, T=24C.	SDMD	SP	
10		7,9, 18,35	70	0	0	SAND, fine to med, tr silt, some shell frag, very firm, light olive brown (2.5Y5/4), wet, T=24C.	SDMD		
15		9,12, 12,28	65	30-22 =8	2.8	SAND, fine to med, tr silt, some shell frag, very firm, light olive brown (2.5Y5/4), wet, T=24C. At 15.7-15.9 SAND, fine to med, and shell frag, light olive brown (2.5Y5/4). At 15.9-17 SAND, fine to med, tr silt, some shell frag, greenish gray (Gley 5G6/1).	SDMD		
20						Boring terminated at 18'.			
25									

WELL DIAGRAM



Post-It™ brand fax transmittal memo 7671 # of pages ▸ 4

To	From
Todd Herrington	Anthony Ciavola
Co. Arcom ES / Beaver	Co. Parsons ES / Orlando
Dept.	Phone #
Fax #	Fax #

CAPEKST1

ENGINEERING - SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. AT509 SI #2
Installation Cape Canaveral AFS
Site Fac. 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD01
Geologist/Engineer Federico Artioli
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 30-Nov-93
Date Completed 30-Nov-93
Driller Groundwater Protection, Inc.
Borehole Diameter (in) 8.25
Depth Drilled (ft) 51
Ground Elevation (ft) 8.393
X-Coordinate 797428.817
Y-Coordinate 1504379.287

Client 45th Space Wing
Date Installed 30-Nov-93
Date Grouted 30-Nov-93
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 0 to -38
Screened Interval (ft) -38 to -48
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 50
Depth to Water BTOC (ft) 7.38
Date Measured 07-Dec-93
TOC Elevation (ft) 8.220
Water Level MSL (ft) 0.84

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE GRAPHIC LOG	WELL DIAGRAM
0		N/A	-	0	0	SAND, fine, tr silt, little to some shell frag, loose, grayish brown (10YR5/2), dry, T=22C.	SOFN	SP	
5		6,11, 12,23	80	0	0	SAND, fine to med, tr silt, little to some shell frag, very firm, pale yellow (2.5Y8/2), dry, T=24C.	SOMD	SP	
10		6,8, 21,25	60	0	0	SAND, fine to med, tr silt, little to some shell frag, very firm,light yellowish brown (2.5Y6/4), wet, T=24C.	SOMD		
15		4,10, 14,30	65	0	0	SAND, fine to med, tr silt, some shell frag, very firm, greenish gray (Gley 5G6/1), wet, T=24C.	SOMD		Grout
20		31,14, 17,24	75	50-45 =5	0	SAND, fine, tr silt, tr shell frag, dense, greenish gray (Gley 5G6/1), wet, T=24C.	SOFN	SP	
25		7,5, 8,11	75	80-50 =30	1000	SAND, fine, tr silt, tr shell frag, firm, greenish gray (Gley 5G6/1), wet, T=24C.	SOFN		

CAPEWELL

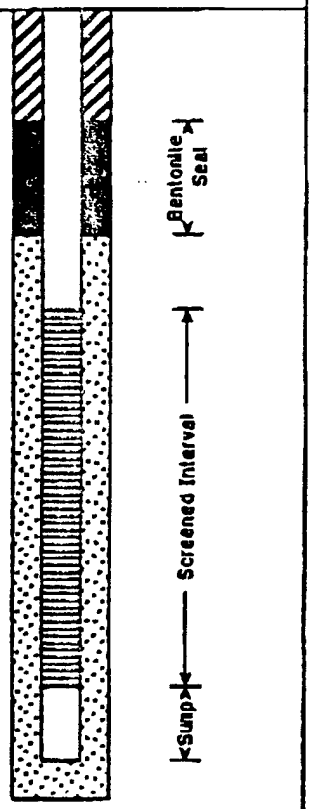
ENGINEERING - SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AFS
Site Fac. 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD01
Geologist/Engineer Federico Artioli

Project I.D. AT509 SI #2
Client 45th Space Wing
Date Installed 30-Nov-93

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
30		5,10, 13,18	75	85-38 =48	500	SAND, fine, tr silt, tr shell frag, very firm, greenish gray (Gley 5G8/1), wet, T=24C.	SDFN	SP	
35		8,5, 4,4	100	85-46 =18	400	SAND, fine, little to some silt, little shell frag, little clay, loose, greenish gray (Gley 5G5/1), wet, T=24C.	SDSL	SM	
		1,2, 2,4	100	80-34 =46	1000	SAND, fine, little to some silt, little shell frag, little clay, very loose, greenish gray (Gley 5G5/1), wet, T=24C.	SDSL		
40		4,2, 2,2	80	58-46 =12	700	SAND, fine to med, little to some silt, little to some shell frag, little clay, very loose, greenish gray (Gley 5G5/1), wet, T=24C. At 39-39.1 and 39.4-39.5 CLAY, greenish gray (Gley 5G5/1), moist.	SDSL CLAY	SM CL	
		3,3, 4,9	100	60-53 =7	550	SAND, fine to med, some silt, some shell frag, some clay, loose, greenish gray (Gley 5G5/1), wet, T=24C.	SDSL	SM	
45		3,4, 5,8	100	70-60 =10	1000	SAND, fine to med, some silt, and shell frag, some clay, loose, greenish gray (Gley 5G5/1), wet, T=24C.	SDSL		
		4,4, 5,5	100	60-57 =3	100	SAND, fine to med, some silt, and shell frag, some clay, loose, greenish gray (Gley 5G5/1), wet T=24C.	SDSL		
		4,6, 7,8	85	32-38 =0	180	SAND, fine to med, some silt, some shell frag, some clay, firm, greenish gray (Gley 5G5/1), wet, T=24C.	SDSL		
50		10,2, 3,3	100	42-35 =7	1000	SAND, fine to med, some silt, some shell frag, some clay, loose, greenish gray (Gley 5G5/1), wet, T=24C.	CLAY	CL	
		3,4, 5,3	100	38-42 =0	400	CLAY, tr sand, tr organics, tr shell frag, stiff, dark greenish gray (Gley 5G4/1), moist to dry, T=24C.			
55						Boring terminated at 51'.			
60									

WELL DIAGRAM



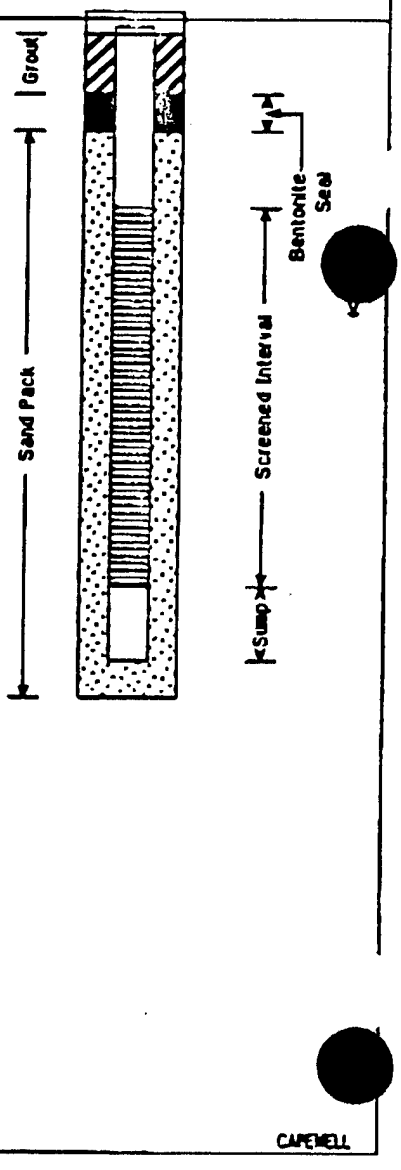
ENGINEERING - SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. AT509 SI #2
Installation Cape Canaveral AFS
Site Fac. 1391 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS02
Geologist/Engineer Federico Artioli
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 01-Dec-93
Date Completed 01-Dec-93
Driller Groundwater Protection, Inc.
Borehole Diameter (in) 10.25
Depth Drilled (ft) 18
Ground Elevation (ft) 8.639
X-Coordinate 797491.974
Y-Coordinate 1504368.771

Client 45th Space Wing
Date Installed 01-Dec-93
Date Grouted 02-Dec-93
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 0 to -5
Screened Interval (ft) -5 to -15
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 17
Depth to Water BTOC (ft) 7.44
Date Measured 07-Dec-93
TOC Elevation (ft) 8.347
Water Level MSL (ft) 0.91

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		N/A	-	0	0	SAND, fine to medium, trace of silt, some shell fragments, loose, very pale brown (10YR7/4), dry, T=23C.	SDMD	SP	
5		7,10, 15,21	80	0.1	0	SAND, fine to medium, trace of silt, some shell fragments, very firm, yellow (10YR7/8), dry, T=24C.	SDMD		
10		2,4, 12,21	65	0.2	0.1	SAND, fine to medium, trace of silt, and shell fragments, firm, dark yellow brown (10YR4/6), wet, T=24C.	SDMD		
15		5,14, 13,33	80	65-18 50	43	SAND, fine to medium, trace to little silt, some shell fragments, very firm, pale olive (5Y6/4), wet, T=24C. At 16.1-16.4 SAND, fine to medium, little silt, and shell fragments, pale olive (5Y6/4).	SDFN	SP	
20						Boring terminated at 18'.			
25									

WELL DIAGRAM



CAPEWELL

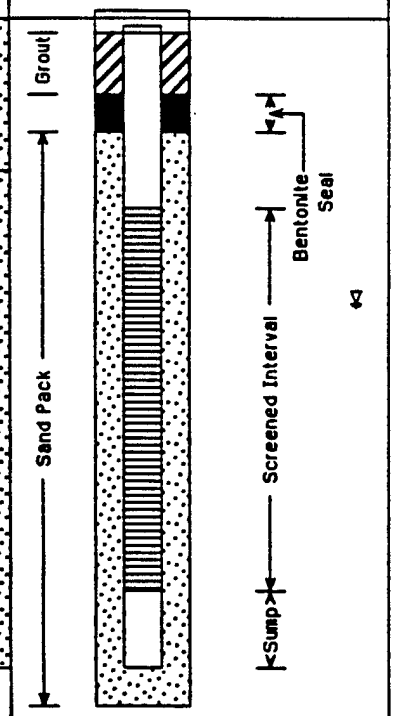
ENGINEERING - SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. AT509 SI #2
Installation Cape Canaveral AFS
Site Fac. 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS01
Geologist/Engineer Federico Artioli
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 30-Nov-93
Date Completed 30-Nov-93
Driller Groundwater Protection, Inc.
Borehole Diameter (in) 10.25
Depth Drilled (ft) 18
Ground Elevation (ft) 8.393
X-Coordinate 797423.170
Y-Coordinate 1504383.270

Client 45th Space Wing
Date Installed 30-Nov-93
Date Grouted 02-Dec-93
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 0 to -5
Screened Interval (ft) -5 to -15
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 17
Depth to Water BTOC (ft) 7.34
Date Measured 07-Dec-93
TOC Elevation (ft) 8.251
Water Level MSL (ft) 0.91

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0									
		N/A	-	0	0	SAND, fine, tr silt, little to some shell frag, loose, very pale brown (10YR8/3), dry, T=23C.	SDFN	SP	
5		5,9, 13,15	85	0	0	SAND, fine to med, tr silt, some shell frag, very firm, pale yellow (2.5Y8/4), dry, T=24C.	SDMD	SP	
		7,9, 18,35	70	0	0	SAND, fine to med, tr silt, some shell frag, very firm, light olive brown (2.5Y5/4), wet, T=24C.	SDMD		
10									
15		9,12, 12,26	95	30-22 =8	2.8	SAND, fine to med, tr silt, some shell frag, very firm, light olive brown (2.5Y5/4), wet, T=24C. At 15.7-15.9 SAND, fine to med, and shell frag, light olive brown (2.5Y5/4). At 15.9-17 SAND, fine to med, tr silt, some shell frag, greenish gray (Gley 5G8/1).	SDMD		
						Boring terminated at 18'.			
20									
25									

WELL DIAGRAM



CAPEWELL

ENGINEERING - SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. AT509 SI #2
Installation Cape Canaveral AFS
Site Fac. 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD01
Geologist/Engineer Federico Artioli
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 30-Nov-93
Date Completed 30-Nov-93
Driller Groundwater Protection, Inc.
Borehole Diameter (in) 8.25
Depth Drilled (ft) 51
Ground Elevation (ft) 8.393
X-Coordinate 797428.617
Y-Coordinate 1504379.287

Client 45th Space Wing
Date Installed 30-Nov-93
Date Grouted 30-Nov-93
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 0 to -38
Screened Interval (ft) -38 to -48
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 50
Depth to Water BTOC (ft) 7.38
Date Measured 07-Dec-93
TOC Elevation (ft) 8.220
Water Level MSL (ft) 0.84

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG	WELL DIAGRAM
0		N/A	-	0	0	SAND, fine, tr silt, little to some shell frag, loose, grayish brown (10YR5/2), dry, T=22C.	SDFN	SP		
5		6,11, 12,23	80	0	0	SAND, fine to med, tr silt, little to some shell frag, very firm, pale yellow (2.5Y8/2), dry, T=24C.	SDMD	SP		
10		6,8, 21,25	60	0	0	SAND, fine to med, tr silt, little to some shell frag, very firm,light yellowish brown (2.5Y6/4), wet, T=24C.	SDMD			
15		4,10, 14,30	65	0	0	SAND, fine to med, tr silt, some shell frag, very firm, greenish gray (Gley 5G6/1), wet, T=24C.	SDMD			Grout
20		31,14, 17,24	75	50-45 =5	0	SAND, fine, tr silt, tr shell frag, dense, greenish gray (Gley 5G6/1), wet, T=24C.	SDFN	SP		
25		7,5, 8,11	75	80-50 =30	1000	SAND, fine, tr silt, tr shell frag, firm, greenish gray (Gley 5G6/1), wet, T=24C.	SDFN			

CAPEWELL

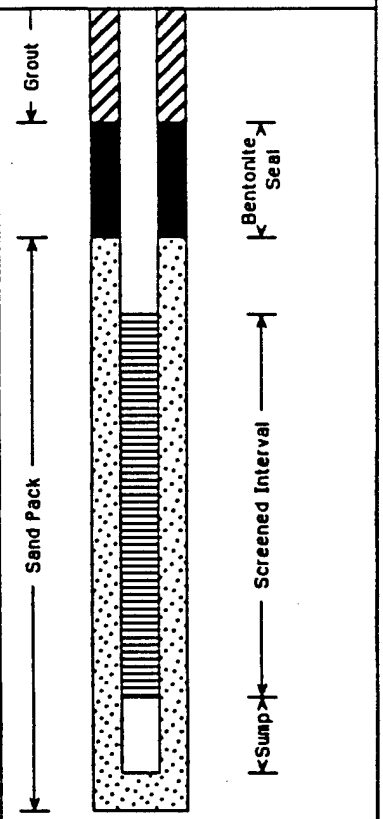
ENGINEERING - SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AFS
Site Fac. 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD01
Geologist/Engineer Federico Artioli

Project I.D. AT509 SI #2
Client 45th Space Wing
Date Installed 30-Nov-93

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd - Filtrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE GRAPHIC LOG
30		5,10, 13,18	75	85-36 =49	500	SAND, fine, tr silt, tr shell frag, very firm, greenish gray (Gley 5G8/1), wet, T=24C.	SDFN	SP
35		8,5, 4,4	100	65-46 =19	400	SAND, fine, little to some silt, little shell frag, little clay, loose, greenish gray (Gley 5G5/1), wet, T=24C.	SDSL	SM
		1,2, 2,4	100	80-34 =46	1000	SAND, fine, little to some silt, little shell frag, little clay, very loose, greenish gray (Gley 5G5/1), wet, T=24C.	SDSL	
40		4,2, 2,2	80	58-46 =12	700	SAND, fine to med, little to some silt, little to some shell frag, little clay, very loose, greenish gray (Gley 5G5/1), wet, T=24C. At 39-39.1 and 39.4-39.5 CLAY, greenish gray (Gley 5G5/1), moist.	SDSL CLAY	SM CL
		3,3, 4,9	100	60-53 =7	550	SAND, fine to med, some silt, some shell frag, some clay, loose, greenish gray (Gley 5G5/1), wet, T=24C.	SDSL	SM
45		3,4, 5,8	100	70-60 =10	1000	SAND, fine to med, some silt, and shell frag, some clay, loose, greenish gray (Gley 5G5/1), wet, T=24C.	SDSL	
		4,4, 5,5	100	60-57 =3	100	SAND, fine to med, some silt, and shell frag, some clay, loose, greenish gray (Gley 5G5/1), wet T=24C.	SDSL	
		4,6, 7,8	85	32-38 =0	180	SAND, fine to med, some silt, some shell frag, some clay, firm, greenish gray (Gley 5G5/1), wet, T=24C.	SDSL	
50		10,2, 3,3	100	42-35 =7	1000	SAND, fine to med, some silt, some shell frag, some clay, loose, greenish gray (Gley 5G5/1), wet, T=24C.	CLAY	CL
		3,4, 5,3	100	38-42 =0	400	CLAY, tr sand, tr organics, tr shell frag, stiff, dark greenish gray (Gley 5G4/1), moist to dry, T=24C.		
55						Boring terminated at 51'.		
60								
65								

WELL DIAGRAM



CAPEWELL

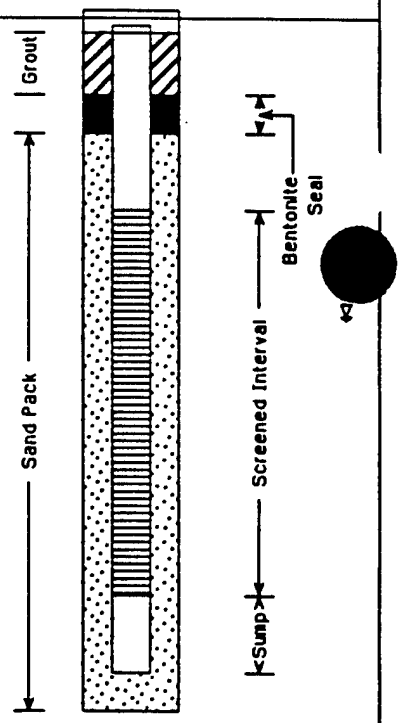
ENGINEERING - SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. AT509 SI #2
Installation Cape Canaveral AFS
Site Fac. 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS02
Geologist/Engineer Federico Artioli
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 01-Dec-93
Date Completed 01-Dec-93
Driller Groundwater Protection, Inc.
Borehole Diameter (in) 10.25
Depth Drilled (ft) 18
Ground Elevation (ft) 8.639
X-Coordinate 797491.974
Y-Coordinate 1504368.771

Client 45th Space Wing
Date Installed 01-Dec-93
Date Grouted 02-Dec-93
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 0 to -5
Screened Interval (ft) -5 to -15
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 17
Depth to Water BTOC (ft) 7.44
Date Measured 07-Dec-93
TOC Elevation (ft) 8.347
Water Level MSL (ft) 0.91

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		N/A	-	0	0	SAND, fine to medium, trace of silt, some shell fragments, loose, very pale brown (10YR7/4), dry, T=23C.	SDMD	SP	
5		7,10, 15,21	80	0.1	0	SAND, fine to medium, trace of silt, some shell fragments, very firm, yellow (10YR7/8), dry, T=24C.	SDMD		
10		2,4, 12,21	65	0.2	0.1	SAND, fine to medium, trace of silt, and shell fragments, firm, dark yellow brown (10YR4/6), wet, T=24C.	SDMD		
15		5,14, 13,33	80	68-18 50	43	SAND, fine to medium, trace to little silt, some shell fragments, very firm, pale olive (5Y6/4), wet, T=24C. At 16.1-16.4 SAND, fine to medium, little silt, and shell fragments, pale olive (5Y6/4).	SDFN	SP	
20						Boring terminated at 18'.			
25									

WELL DIAGRAM



CAPEWELL

PARSONS ENGINEERING SCIENCE

SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD02
Geologist/Engineer Federico Artioli
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 25-Sep-95
Date Completed 25-Sep-95
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 53.0
Ground Elevation (ft) 9.30
X-Coordinate 797489.60
Y-Coordinate 1504365.49

Client 45th Space Wing
Date Installed 22-Sep-95
Date Grouted 22-Sep-95
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) -0.25 to -46
Screened Interval (ft) -46 to -51
Sump Installed? No
Pad Installed? Yes
Well Depth (ft) 51
Depth to Water BTOC (ft) 4.61
Date Measured 04-Apr-96
TOC Elevation (ft) 9.15
Water Level MSL (ft) 4.54

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG	WELL DIAGRAM
0										
		N/A	-	0.1	0.1	SAND, fine to med, trace silt, ltl shell, loose, pale yellow (2.5Y7/4), dry.	SDFN	SP		
5		15,15, 14,11	88	0	0	SAND, fine to med, tarce silt, ltl shell, v. firm, pale yellow (2.5Y7/4), moist to wet.	SDFN			
10		5,7, 12,17	100	42	1.2	SAND, fine to coarse, trace silt, ltl shell, firm, olive (5Y5/4), wet.	SDFN			
15		12,23, 40,35	58	227	8.8	SAND, fine, trace silt, trace shell, v. dense, olive (5Y5/4), wet.	SDFN			
20		12,18, 24,26	58	206	56.2	SAND, fine, trace silt, trace shell, dense, bluish gray (5B6/1), wet.	SDFN			
25		5,5, 14,10	42	13.2	0.1	SAND, fine, trace silt, trace shell, firm, bluish gray (5B5/1), wet.	SDFN			

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Grout

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PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AS
Site Facility 1381 – Ordnance Support Facility
Boring/Well I.D. 1381-MWD02
Geologist/Engineer Federico Artioli

Project I.D. CCAS RFI - 727576
Client 45th Space Wing
Date Installed 22-Sep-95

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG	WELL DIAGRAM
30		4,4, 5,8	67	25.1	10.6	SAND, fine, trace silt, trace shell, loose, bluish gray (5B5/1), wet.		SP		
35		3,3, 4,5	100	39.5	71.2	SAND, fine, ltl silt, trace shell, trace clay, loose, bluish gray (5B5/1), wet.	SDFN			Grout
		2,2, 2,9	100	40.1	46.5	SAND, fine, ltl silt, trace shell, ltl clay, v. loose, drk greenish gray (5BG4/1), wet.	SDFN			
40		7,3, 6,4	100	51.4	20.9	SAND, fine to med, trace silt, trace shell, loose, greenish gray (5G5/1), wet.	SDFN			
		6,8, 6,9	100	30.7	13	SAND, fine to med, trace silt, ltl to and shell, firm, dark greenish gray (5BG4/1), wet.	SDFN			
		6,6, 9,10	100	40.1	14.2	SAND, fine, trace silt, trace clay, ltl shell, firm, greenish gray, (5BG5/1), wet.	SDFN			
45		12,12, 16,20	67	0.2	15.2	SAND, coarse to fine, trace silt, and shell, v. firm, drk greenish gray (5BG4/1), wet.	SDCR	SW		Sand Pack
		12,20, 21,22	100	5.4	23.7	SAND, coarse to fine, trace to ltl silt, some shell, trace clay, dense, drk greenish gray (5BG4/1), wet.	SDCR			
50		2,2, 2,2	100	0.1	1.5	SAND, coarse to fine, ltl silt, and shell, ltl clay, v. loose, (5BG4/1), wet; at 50.3 to 51.0 CLAY.	SDCR/ CLAY			
		2,2, 3,3	71	0.3	1.3	CLAY, trace organics, firm, drk greenish gray (5G4/1), moist	CLAY	CL		Bentonite Seal / Screened Interval
						Boring terminated at 53 ft.				
55										
60										
65										

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PARSONS ENGINEERING SCIENCE

SOIL BORING LOG AND WELL CONSTRUCTION RECORD

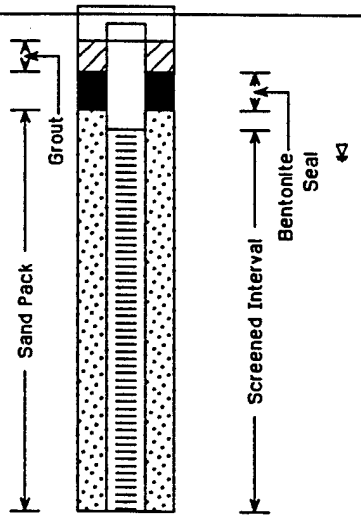
Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS03
Geologist/Engineer Federico Artioli
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 22-Sep-95
Date Completed 22-Sep-95
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 16.0
Ground Elevation (ft) 8.24
X-Coordinate 797436.66
Y-Coordinate 1504588.46

Client 45th Space Wing
Date Installed 22-Sep-95
Date Grouted 22-Sep-95
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) -0.25 to -3.0
Screened Interval (ft) -3.0 to -13.0
Sump Installed? No
Pad Installed? Yes
Well Depth (ft) 13.0
Depth to Water BTOC (ft) 3.82
Date Measured 04-Apr-96
TOC Elevation (ft) 8.38
Water Level MSL (ft) 4.56

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		N/A	-	0.6	0	SAND, fine grained, trace silt, little shell ragments, loose, light gray, (2.5 Y 7/2), dry.	SDFN	SP	
5		10,10 8,12	88	1.5	0	SAND, fine to medium grained, trace silt, little to some shell fragments, firm, light yellowish brown (2.5 Y 6/3), wet.	SDFN		
10		6,8, 8,10	100	8.7	0	SAND, fine to medium grained, trace silt, little shell fragments, firm, light yellowish brown (2.5 Y 6/3), wet; at 11.0 to 12.0 SAND, coarse to fine grained, little silt, and shell fragments, firm greenish gray (5BG 5/1), wet.	SDFN/ SDCR	SW	
15		6,6, 12,10	100	1.5	0	SAND, coarse to fine grained, trace silt, little to some shell fragments, firm, bluish gray (5B 5/1), wet.	SDMD		
20									
25									

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WELL DIAGRAM



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PARSONS ENGINEERING SCIENCE

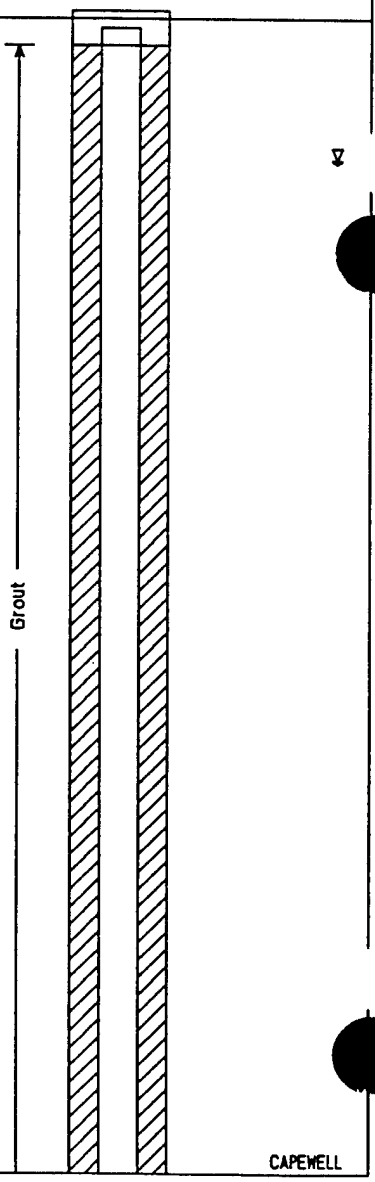
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD03
Geologist/Engineer Federico Artioli
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 22-Sep-95
Date Completed 22-Sep-95
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 53.0
Ground Elevation (ft) 8.24
X-Coordinate 797440.25
Y-Coordinate 1504588.38

Client 45th Space Wing
Date Installed 22-Sep-95
Date Grouted 22-Sep-95
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) -0.25 to -46.5
Screened Interval (ft) -46.5 to -51.5
Sump Installed? No
Pad Installed? Yes
Well Depth (ft) 51.5
Depth to Water BTOC (ft) 3.75
Date Measured 04-Apr-96
TOC Elevation (ft) 8.30
Water Level MSL (ft) 4.55

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		N/A	-	0	0	SAND, fine, trace silt, ltl shell, loose, lgt gray (2.5Y7/2), dry.	SDFN	SP	
5		12,10, 8,12	71	0	0	SAND, fine to med, trace silt, trace shell, firm, brownish yellow (10YR6/8), wet; at 5.5 to 6.0 SAND, fine to med, trace silt, some shell, firm, pale yellow (2.5Y7/3), wet.	SDFN		
10		2,4, 5,10	100	7.4	0	SAND, fine to med, trace silt, ltl shell, loose, lgt yellowish brown (2.5Y6/3), wet; at 11.1 to 12.0 SAND, coarse to fine, ltl silt, some to and shell, firm, greenish gray (5BG5/1), wet.	SDFN/ SDCR	SW	
15		5,10, 18,20	100	1.7	1.5	SAND, coarse to fine, trace silt, ltl to some shell, firm, greenish gray (5G5/1), wet.	SDCR	SP	
20		3,5, 12,15	100	0.1	0	SAND, fine, trace silt, trace shell, firm, greenish gray (5G5/1), wet.	SDFN		
25		6,5, 10,10	83	0	0	SAND, fine, trace silt, trace shell, ltl clay, loose, drk greenish gray (5G4/1), wet.	SDFN		

WELL DIAGRAM



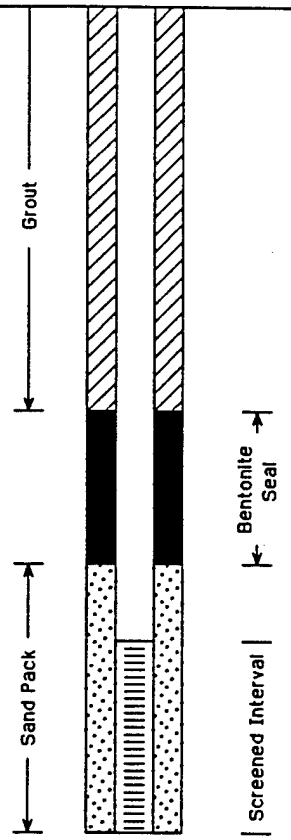
PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AS
Site Facility 1381 – Ordnance Support Facility
Boring/Well I.D. 1381-MWD03
Geologist/Engineer Federico Artioli

Project I.D. CCAS RFI - 727576
Client 45th Space Wing
Date Installed 22-Sep-95

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
30		4,4, 5,6	71	0	0	SAND, fine, trace to ltl silt, ltl shell, trace clay, loose, drk greenish gray (5G4/1), wet.		SP	
35		1,2, 3,1	88	0.2	0	SAND, fine, trace silt, trace shell, ltl clay, loose, drk greenish gray (5G4/1), wet.	SDFN		
		2,2, 7,7	100	0.1	0	SAND, fine, ltl silt, trace shell, ltl to some clay, loose, (5G4/1), wet.	SDCL	SC	
40		2,3, 7,5	83	0.3	0	SAND, fine, ltl silt, trace shell, ltl to some clay, loose, drk greenish gray (5G4/1),wet.	SDCL		
		7,10, 14,10	88	0.3	0	SAND, fine, ltl silt, ltl to and shell, trace to ltl clay, v. firm, (5G4/1), wet.	SDCL	SP	
		2,2, 6,6	83	0.9	0	SAND, fine, trace silt, and shell, some to and clay, loose, drk greenish gray, (5G4/1), wet.	SDCL	SC	
45		10,8, 10,14	100	1.0	0	SAND, coarse to fine, trace silt, and shell, trace clay, firm, (5G4/1), wet.	SDCR	SW	
		6,9, 6,7	100	1.1	0	SAND, coarse to fine, trace silt, some to and shell, ltl clay, firm, drk greenish gray (5G4/1), wet.	SDCR		
50		6,4, 4,4	100	0.3	0	SAND, coarse to fine, trace silt, and shell, ltl clay loose, (5G4/1), wet.	SDCR		
		2,3, 3,5	79	0.9	0	CLAY, firm, ltl organics, drk greenish gray (5BG4/1), dry to moist	CLAY	CL	
55						Boring terminated at 53 ft.			
60									
65									

WELL DIAGRAM



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PARSONS ENGINEERING SCIENCE

SOIL BORING LOG AND WELL CONSTRUCTION RECORD

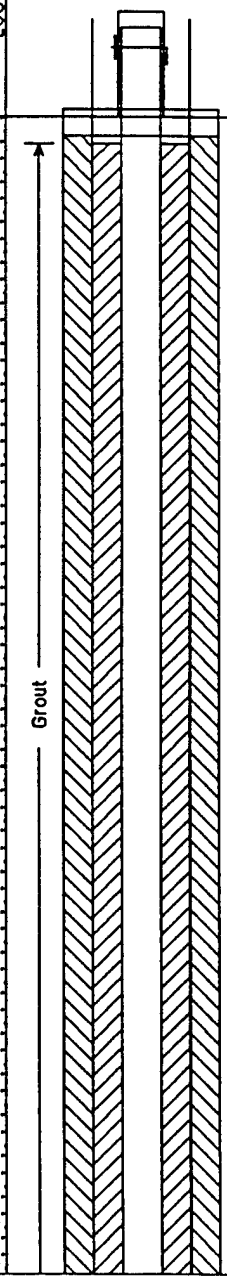
Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD04
Geologist/Engineer Federico Artioli
Drilling Method Mud Rotary
Sampling Method 2 1/4" Split Spoon
Date Started 04-Dec-95
Date Completed 08-Dec-95
Driller EDS
Borehole Diameter (in) 6.00/10.00
Depth Drilled (ft) 80.0
Ground Elevation (ft) 9.52
X-Coordinate 797418.48
Y-Coordinate 1504305.43

Client 45th Space Wing
Date Installed 08-Dec-95
Date Grouted 08-Dec-95
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) -0.25 to -72.5
Screened Interval (ft) -72.5 to -77.5
Sump Installed? No
Pad Installed? Yes
Well Depth (ft) 77.5
Depth to Water BTOC (ft) 2.05
Date Measured 04-Apr-96
TOC Elevation (ft) 12.23
Water Level MSL (ft) 10.18

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adistd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0						Slit spoons collected from 42 feet to 80 feet bls due to previously defined lithology.		SP	

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WELL DIAGRAM



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PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD04
Geologist/Engineer Federico Artioli

Project I.D. CCAS RFI - 727576
Client 45th Space Wing
Date Installed 08-Dec-95

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG	WELL DIAGRAM
30								SP		
35						DRAFT				
40										
		5,4 5,4	30	0.2	0	SAND, fine, trace silt, trace clay, and shell, loose, drk greenish gray (5GY4/1), wet.	SDFN			
45		4,5, 8,6	40	0.4	0	SAND, coarse to fine, trace silt, and shell, ltl clay, firm, (5GY4/1).	SDCR	SW		
		8,7, 9,7	30	1.1	0	SAND, coarse to fine, ltl silt, trace clay, and shell, firm, drk greenish gray (5GY4/1), wet.	SDCR			
		6,9, 6,5	70	0.9	0	SAND, coarse to fine, ltl silt, ltl clay, and shell, firm, (5GY4/1), wet.	SDCR			
50		7,8, 9,10	100	1.1	0	SAND, coarse to fine, ltl silt, ltl clay, and shell, firm (5GY4/1), wet; at 51.7 ft CLAY, stiff, (5G4/1), moist.	SDCR/ CLAY	CL		
		N/A	0	N/A	0	No recovery.				
55		5,4, 4,5	100	1.1	0	CLAY, trace organics, firm, dark greenish gray (5G4/1), moist.	CLAY			
		0,0, 0,0	42	0.8	0	CLAY, ltl shell, v. loose, grey (5G4/1), moist.	CLAY			
60								SP		
		6,5 5,4	75	0.4	0	SAND, fine to med, ltl silt, and shell, firm, lgt greenish grey (5GY7/1), wet.	SDFN			
65		11,8 6,5	100	1.5	0	SAND, fine to med, ltl silt, some shell, firm (5GY7/1), wet.	SDFN			

Grout

CAPEWELL

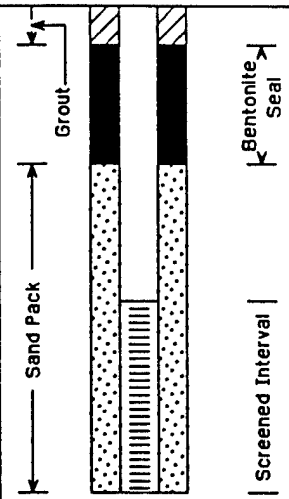
PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AS
Site Facility 1381 – Ordnance Support Facility
Boring/Well I.D. 1381-MWD04
Geologist/Engineer Federico Artioli

Project I.D. CCAS RFI – 727576
Client 45th Space Wing
Date Installed 08-Dec-95

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd – Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
65									
		7,7 9,8	29	2.0	0	SAND, fine, trace silt, ltl shell, firm, greenish gray (5G5/1), wet.	SDFN	SP	
		7,6, 8,6	33	4.8	0	SAND, fine, trace silt, ltl shell, firm, (5G5/1), wet.	SDFN		
70		5,4, 4,4	25	9.6	0	SAND, fine, trace silt, ltl shell, loose, (5G5/1), wet.	SDFN		
		3,3, 4,4	17	8.7	0	SAND, fine, trace silt, ltl shell, ltl to some clay, loose, (5G5/1), wet.	SDFN		
		28,21 14,14	100	0.4	0	CLAY, ltl shell, hard, (5G5/1), moist. At 75.3 ft, SAND, med to fine, trace silt, some shell, v. firm, (5G5/1), wet.	CLAY/ SDMD	CL SP	
		16,20 30,30	100	0.2	0	SAND, coarse to fine, trace silt, some shell, dense, (5G5/1), wet.	SDCR/ SDMD		
		28,29 39,27	100	0.6	0	CLAY, trace shell, hard, (5G5/1), wet.	CLAY/ SDCR	CL SW	
80						Boring terminated at 80.0'			
85									
90									
95									
100									

WELL DIAGRAM



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PARSONS ENGINEERING SCIENCE

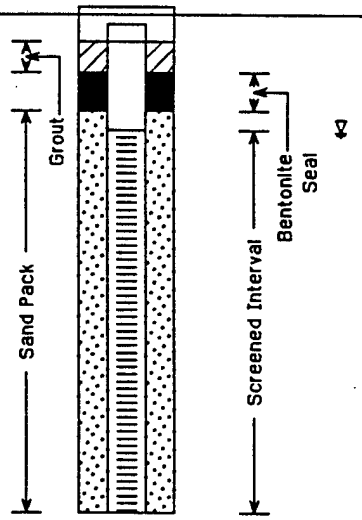
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS05
Geologist/Engineer Federico Artioli
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 25-Jan-96
Date Completed 25-Jan-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 13.0
Ground Elevation (ft) 7.68
X-Coordinate 797005.30
Y-Coordinate 1504447.00

Client 45th Space Wing
Date Installed 22-Sep-95
Date Grouted 22-Sep-95
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) -0.25 to -3.0
Screened Interval (ft) -3.0 to -13.0
Sump Installed? No
Pad Installed? Yes
Well Depth (ft) 13.0
Depth to Water BTOC (ft) 6.55
Date Measured 04-Apr-96
TOC Elevation (ft) 11.18
Water Level MSL (ft) 4.63

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adistd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		N/A	-	0.6	0	SAND, fine, trace silt, ltl shell, loose, lgt gray, (2.5Y7/2), dry.	SDFN	SP	
5		10,10 8,12	88	1.5	0	SAND, fine to med, trace silt, ltl to some shell, firm, lgt yellowish brown (2.5Y6/3), wet.	SDFN		
10		6,8, 8,10	100	8.7	0	SAND, fine to med, trace silt, ltl shell, firm, lgt yellowish brown (2.5Y6/3), wet; at 11.0 to 12.0 SAND, coarse to fine, ltl silt, and shell, firm greenish gray (5BG5/1), wet.	SDFN/ SDCR	SW	
15						Boring terminated at 13.0 ft.			
20						Lithologic descriptions based on split spoon samples collected from monitoring well 1381-MWD05 borehole.			
25									

WELL DIAGRAM



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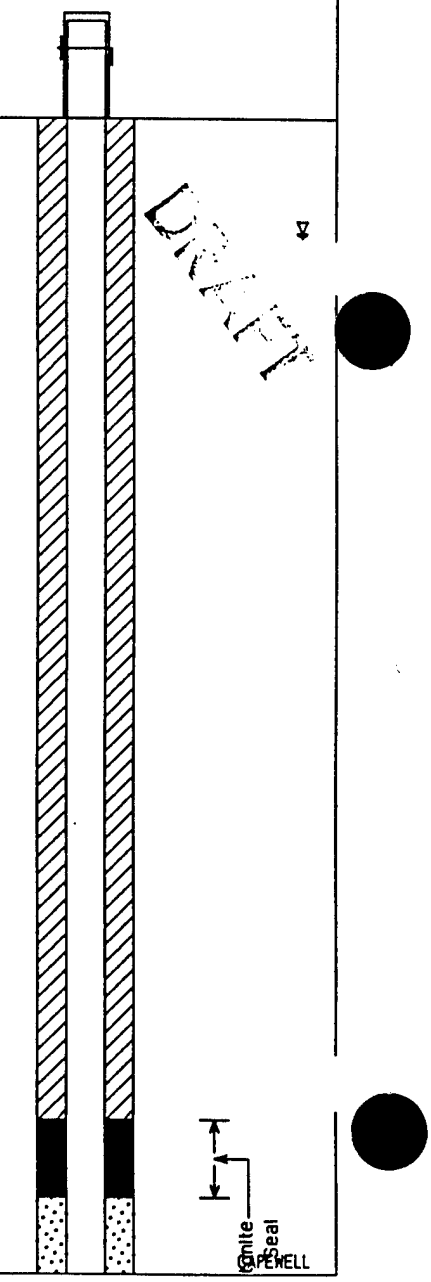
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWI05
Geologist/Engineer Federico Artioli
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 25-Jan-96
Date Completed 25-Jan-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 35.0
Ground Elevation (ft) 7.68
X-Coordinate 797001.80
Y-Coordinate 1504452.00

Client 45th Space Wing
Date Installed 25-Jan-96
Date Grouted 25-Jan-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 3 to -30
Screened Interval (ft) -30 to -35
Sump Installed? No
Pad Installed? Yes
Well Depth (ft) 35.0
Depth to Water BTOC (ft) 6.61
Date Measured 04-Apr-96
TOC Elevation (ft) 11.28
Water Level MSL (ft) 4.67

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	0	0	Lithology defined by nearby monitoring well 1381-MWD05 soil boring log. No split spoon samples taken at this location.		SP	
5		5,5, 4,5	60	0	0	SAND, med to fine, some shell, loose, light yellow brown, (10YR6/4), wet.	SDMD	SM	
10		4,9, 12,14	70	7	0	SAND, med to v. fine, ltl shell, trace silt, loose, greenish gray (5GY5/1).	SDFN		
15		10,5, 20,23	30	50	30	SAND, v. fine, firm, greenish gray (5GY5/1).	SDVF		
20		3,5, 7,7	70	40	>1000	SAND, v. fine, firm, greenish gray (5GY5/1).	SDVF		
25		6,4, 6,8	70	0	>1000	SAND, coarse to fine, some shell, loose, greenish gray (5G5/1).	SDMD		
		3,3, 2,2	60	0	>1000	SAND, fine to v. fine, trace shell, firm, greenish gray (5GY5/1).	SDFN		

WELL DIAGRAM



PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AS
Site Facility 1381 – Ordnance Support Facility
Boring/Well I.D. 1381-MWI05
Geologist/Engineer Federico Artioli

Project I.D. CCAS RFI – 727576
Client 45th Space Wing
Date Installed 25-Jan-96

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd – Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG	WELL DIAGRAM
30		1,3, 3,2	40	0	>1000	SAND, med to fine, some silt, trace shell, trace clay, firm, dark greenish gray (5GY4/1).	SDSL	SM		Sand Pack
35						Boring terminated at 35 ft.		SC		Screened Interval
40										
45										
50										
55										
60										
65										

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CAPEWELL

PARSONS ENGINEERING SCIENCE

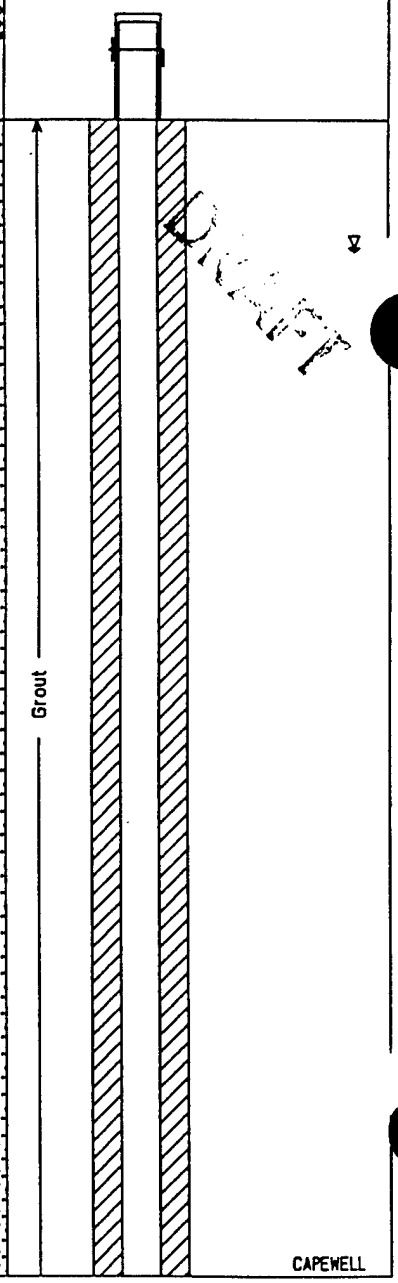
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD05
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 29-Feb-96
Date Completed 29-Feb-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 49.5
Ground Elevation (ft) 7.68
X-Coordinate 797009.79
Y-Coordinate 1504444.11

Client 45th Space Wing
Date Installed 29-Feb-96
Date Grouted 29-Feb-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) +2.5 to -44.0
Screened Interval (ft) -44.0 to -49.0
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 49.5
Depth to Water BTOC (ft) 5.96
Date Measured 04-Apr-96
TOC Elevation (ft) 10.32
Water Level MSL (ft) 4.36

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Filtrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	NA	0	Fill material with vegetative cover.		SP	
5		5,5, 4,5	60	0	0	SAND, medium to fine, some shell, loose, lgt yellow brown, (10YR6/4), wet.	SDMD		
10		4,9, 12,14	70	7	0	SAND, med to v. fine, ltl shell, trace silt, loose, greenish gray (5GY5/1).	SDFN		
15		10,5, 20,23	30	50	30	SAND, v. fine, firm, greenish gray (5GY5/1).	SDVF		
20		3,5, 7,7	70	40	>1000	SAND, v. fine, firm, greenish gray (5GY5/1).	SDVF		
25		6,4, 6,8	70	0	>1000	SAND, coarse to fine, some shell, loose, greenish gray (5G5/1).	SDMD		
		3,3, 3,4	60	0	>1000	SAND, fine to v. fine, trace shell, firm, greenish gray (5GY5/1).	SDFN		

WELL DIAGRAM



PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AS
Site Facility 1381 – Ordnance Support Facility
Boring/Well I.D. 1381-MWD05
Geologist/Engineer Phil Potter

Project I.D. CCAS RFI – 727576
Client 45th Space Wing
Date Installed 29-Feb-96

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE GRAPHIC LOG
30								SP
		1,3, 3,2	40	0	>1000	SAND, med to fine, some silt, trace shell, trace clay, firm, dark greenish gray (5GY4/1).	SDSL	SM
35								
		HW,HW, 2,2	40	0	>1000	SHELL, coarse, loose, some clay, dark greenish gray (5GY4/1).	SDCL	SC
40		HW,12, 2,2	40	40	>1000	SHELL, coarse, loose, and silt, and clay, greenish gray (5GY5/1).	SDCL	
		2,3, 3,4	50	0	>1000	SHELL, coarse, loose, some clay stringers to 1/2-inch, drk greenish gray (5GY4/1).	SDCL	
45		2,1, 2,2	30	20	>1000	SAND, coarse to med, and shell, some clay, loose, drk greenish gray (5GY4/1).	SDCL	
		2,3, 3,3	50	150	>1000	SAND, coarse to med, and shell, some clay, loose, drk greenish gray (5GY4/1).	SDCL	
		HW,1, 2,1	60	70	>1000	SAND, med to fine, and shell, some silt, some clay, loose, drk greenish gray (5GY4/1). At 48.5, CLAY, firm.	SDCL/ CLAY	OH
50						Boring terminated at 49.5 ft.		
55								
60								
65								

WELL DIAGRAM: Grout; Sand Pack; Bentonite Seal; Screened Interval

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PARSONS ENGINEERING SCIENCE

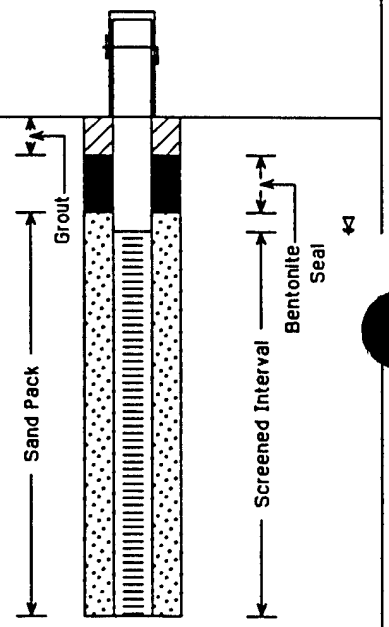
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS06
Geologist/Engineer Federico Artioli
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 25-Jan-96
Date Completed 25-Jan-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 13.0
Ground Elevation (ft) 7.68
X-Coordinate 797024.70
Y-Coordinate 1504466.00

Client 45th Space Wing
Date Installed 25-Jan-96
Date Grouted 25-Jan-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 3 to -3
Screened Interval (ft) -3 to -13
Sump Installed? No
Pad Installed? Yes
Well Depth (ft) 13.0
Depth to Water BTOC (ft) 5.94
Date Measured 04-Apr-96
TOC Elevation (ft) 10.69
Water Level MSL (ft) 4.75

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	0	0	Lithology defined by nearby monitoring well 1381-MWD05 soil boring log. No spoon samples taken at this location.		SP	
5		5,5, 4,5	60	0	0	SAND, med to fine, some shell, loose, light yellow brown, (10YR 6/4), wet.	SDMD	SM	
10		4,9, 12,14	70	7	0	SAND, medm to v. fine, ltl shell, trace silt, loose, greenish gray (5GY 5/1).	SDFN		
						Boring terminated at 13'.			
15									
20									
25									

WELL DIAGRAM



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SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS07
Geologist/Engineer Federico Artioli
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 25-Jan-96
Date Completed 21-Jan-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 13.0
Ground Elevation (ft)
X-Coordinate 797602.10
Y-Coordinate 1505755.00

Client 45th Space Wing
Date Installed 25-Jan-96
Date Grouted 25-Jan-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) +2.5 to -3.0
Screened Interval (ft) -3.0 to -13.0
Sump Installed? No
Pad Installed? Yes
Well Depth (ft) 13.0
Depth to Water BTOC (ft) 5.28
Date Measured 04-Apr-96
TOC Elevation (ft) 10.2
Water Level MSL (ft) 4.92

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG	WELL DIAGRAM
0						No split spoon samples associated with this monitoring well location.		SP		Grout, Sand Pack, Bentonite Seal, Screened Interval
5										
10										
15						Boring terminated at 13'.				
20										
25										

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SOIL BORING LOG AND WELL CONSTRUCTION RECORD

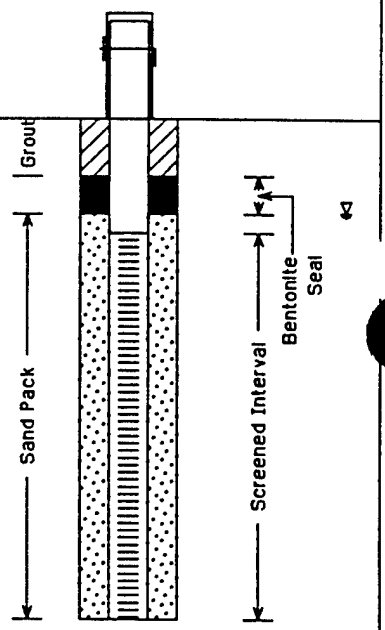
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Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS08
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 21-Feb-96
Date Completed 21-Feb-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 13.0
Ground Elevation (ft) 7.17
X-Coordinate 797903.21
Y-Coordinate 1504609.52

Client 45th Space Wing
Date Installed 21-Feb-96
Date Grouted 21-Feb-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) +2.5 to -3.0
Screened Interval (ft) -3.0 to -13.0
Sump Installed? No
Pad Installed? Yes
Well Depth (ft) 13.0
Depth to Water BTOC (ft) 5.07
Date Measured 04-Apr-96
TOC Elevation (ft) 9.76
Water Level MSL (ft) 4.69

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	NA	0	Fill material with vegetative cover.		SP	
5		3,4, 5,8	80	200	0	SAND, coarse grained, and shell fragments, loose, yellowish brown (10YR 5/4), wet.	SDCR		
10		6,12, 8,17	80	8	0	SAND, fine to coarse grained, some shell fragments, loose, gray (N 6/)	SDCR		
						Boring terminated at 13'.			
15									
20									
25									

WELL DIAGRAM



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PARSONS ENGINEERING SCIENCE

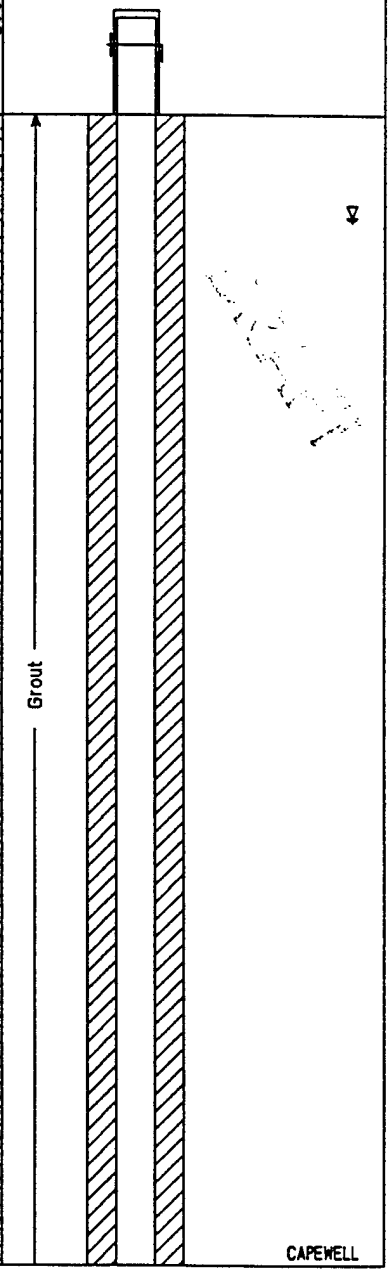
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD08
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 21-Feb-96
Date Completed 22-Feb-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 49.5
Ground Elevation (ft) 7.38
X-Coordinate 797900.19
Y-Coordinate 1504603.00

Client 45th Space Wing
Date Installed 21-Feb-96
Date Grouted 22-Feb-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) +2.5 to -43
Screened Interval (ft) -43 to -48
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 48.5
Depth to Water BTOC (ft) 5.38
Date Measured 04-Apr-96
TOC Elevation (ft) 10.08
Water Level MSL (ft) 4.70

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	NA	0	Fill material with vegetative cover.		SP	
5		3,3, 5,6	70	0	100	SAND, medium to fine grained, and shell, yellowish brown (10YR 5/4), wet.	SDMD		
10		3,5, 10,12	70	0	6	SAND, coarse to fine grained, some shell, gray (N 6/).	SDCR		
15		3,5, 9,14	100	130	>1000	SAND, fine to v. fine grained, trace silt, greenish gray (5GY 6/1).	SDFN		
20		4,4, 8,11	40	0	4	SAND, coarse to medium grained, some shell, greenish gray (5GY 5/1).	SDCR		
25		2,2, 3,3	40	0	>1000	SAND, fine grained, dark greenish gray (5GY 4/1).	SDFN		

WELL DIAGRAM



PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

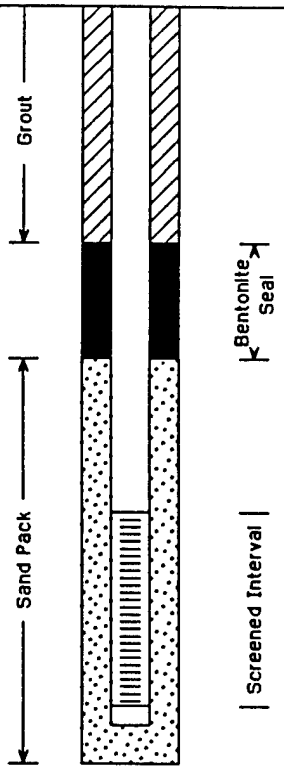
Installation Cape Canaveral AS
Site Facility 1381 – Ordnance Support Facility
Boring/Well I.D. 1381-MWD08
Geologist/Engineer Phil Potter

Project I.D. CCAS RFI – 727576
Client 45th Space Wing
Date Installed 21-Feb-96

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd – Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE
30								SP
35		HW,1, 1,1	60	0	>1000	SAND, very fine grained, some silt, trace clay, dark greenish gray (5GY 4/1).	SDVF	SM
		2,1, 1,1	50	0	>1000	SAND, very fine, and silt, dark greenish gray (5GY 4/1).	SDSL	
40		2,5, 5,3	60	0	>1000	SAND, fine grained, some silt, dark greenish gray (5GY 4/1).	SDFN	
		2,3, 3,5	30	180	>1000	SAND, fine grained, and shell, dark greenish gray (5GY 4/1).	SDFN	SP
						No sample, no recovery.	NSNR	
45		NR	40	0	>1000	SAND, fine grained, trace shell, dark greenish gray (5GY 4/1), wet.	SDFN	
		HW,HW, 1,1	60	20	>1000	SAND, fine grained, trace shell, dark greenish gray (5GY 4/1), wet. CLAY at 48.5 feet, firm.	SDCL/ CLAY	CL
50						Boring terminated at 49.5 ft.		
55								
60								
65								

GRAPHIC LOG

WELL DIAGRAM



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PARSONS ENGINEERING SCIENCE

SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS09
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 02-Mar-96
Date Completed 02-Mar-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 13.0
Ground Elevation (ft) 7.45
X-Coordinate 797469.30
Y-Coordinate 1504278.21

Client 45th Space Wing
Date Installed 02-Mar-96
Date Grouted 02-Mar-96
Casing Material 2" Stainless Steel
Screen Material 2" Stainless Steel 0.01 slot
Casing Interval (ft) 0.0 to -7.5
Screened Interval (ft) -7.5 to -12.5
Sump Installed? No
Pad Installed? Yes
Well Depth (ft) 12.5
Depth to Water BTOC (ft) 2.71
Date Measured 04-Apr-96
TOC Elevation (ft) 7.14
Water Level MSL (ft) 4.43

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adistd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG	WELL DIAGRAM
0						Lithology defined by adjacent monitoring well 1881-MWD09 soil boring log. No split spoon samples taken at this location.		SP		Grout
5						SAND, coarse to med, and shell, v. loose, lgt yellowish brown (10YR6/4), wet.				Sand Pack
10						SAND, coarse to med, and shell, v. loose, lgt olive brown (25Y5/3), wet.				Bentonite Seal
15						Boring terminated at 13 ft.				Screened Interval
20										
25										

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PARSONS ENGINEERING SCIENCE

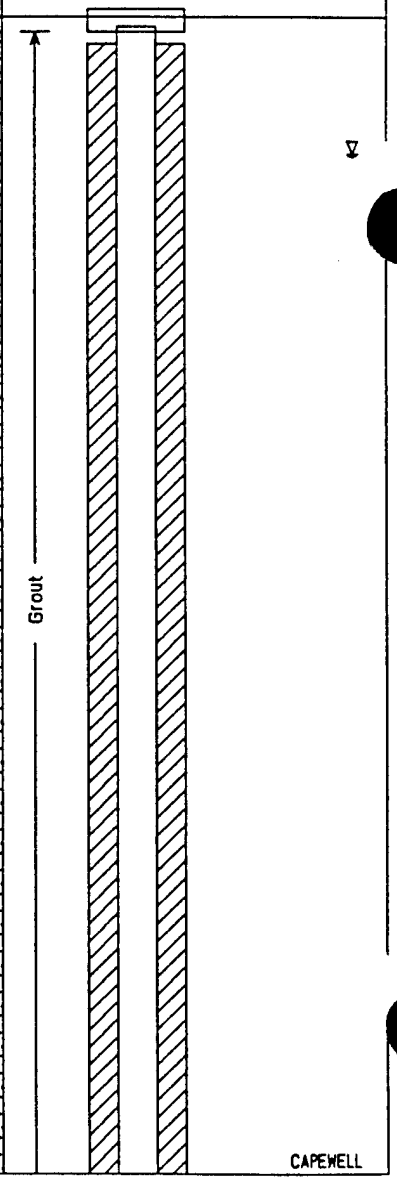
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD09
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 02-Mar-96
Date Completed 03-Mar-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 50.0
Ground Elevation (ft) 7.14
X-Coordinate 797474.19
Y-Coordinate 1504275.71

Client 45th Space Wing
Date Installed 03-Mar-96
Date Grouted 03-Mar-96
Casing Material 2" Stainless Steel
Screen Material 2" Stainless Steel 0.01 slot
Casing Interval (ft) 0.0 to -44.8
Screened Interval (ft) -44.8 to -49.8
Sump Installed? No
Pad Installed? Yes
Well Depth (ft) 49.8
Depth to Water BTOC (ft) 3.44
Date Measured 04-Apr-96
TOC Elevation (ft) 7.05
Water Level MSL (ft) 3.61

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	NA	0	Fill material with vegetative cover.		SP	
5		3,4, 4,5	80	0	0	SAND, coarse to medium grained, and shell, v. loose, light yellow brown (10YR 6/4), wet.	SDCR		
10		2,4, 7,6	80	0	0	SAND, coarse to medium grained, and shell, very loose, light olive brown (2.5Y 5/3).	SDCR		
15		4,8, 15,19	70	880	150	SAND, coarse to fine grained, some shell, loose, light olive brown (2.5Y 5/3).	SDMD		
20		5,8, 12,15	50	720	>1000	SAND, fine grained, little shell, loose, greenish gray (5GY 6/1).	SDFN		
25		3,3, 4,4	70	780	12	SAND, medium to very fine grained, trace shell, loose, greenish gray (5GY 6/1).	SDFN		
		1,2, 3,3	40	180	500	SAND, medium to very fine grained, some shell, loose, greenish gray (5GY 5/1).	SDFN		

WELL DIAGRAM



PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AS
Site Facility 1381 – Ordnance Support Facility
Boring/Well I.D. 1381-MWD09
Geologist/Engineer Phil Potter

Project I.D. CCAS RFI – 727576
Client 45th Space Wing
Date Installed 03-Mar-96

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd – Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
30								SP	
		1,1, 2,1	60	0	500	SAND, very fine, and silt, trace clay, firm, greenish gray (5GY 5/1).	SDSL	SM	
35									
		1,1, 1,2	40	0	>1000	SAND, medium to fine, some silt, firm, greenish gray (5GY 5/1).	SDFN		
40		1,2, 3,4	80	0	>1000	SAND, fine to v. fine, and shell, and clay, loose, greenish gray (5GY 5/1).	SDVF		
		2,3, 4,7	60	0	>1000	SAND, coarse to fine, little shell, trace silt, trace clay, loose, dark greenish gray (5GY 4/1).	SDCR	SP	
45		1,3, 6,9	50	0	>1000	SAND, medium to fine, some shell, trace silt, trace clay, loose, dark greenish gray (5GY 4/1).	SDMD		
		2,3, 3,1	90	0	>1000	SAND, coarse to medium, some shell, trace clay, loose, dark greenish gray (5GY 4/1).	SDCR		
		HW,HW, 2,3	80	0	>1000	SAND, medium to fine, little shell, trace silt, loose, dark greenish gray (5GY 4/1). At 49.8, CLAY, firm.	SDMD/ CLAY	OH	
50						Boring terminated at 50'.			
55									
60									
65									

WELL DIAGRAM

Grout
Sand Pack
Bentonite Seal
Screened Interval

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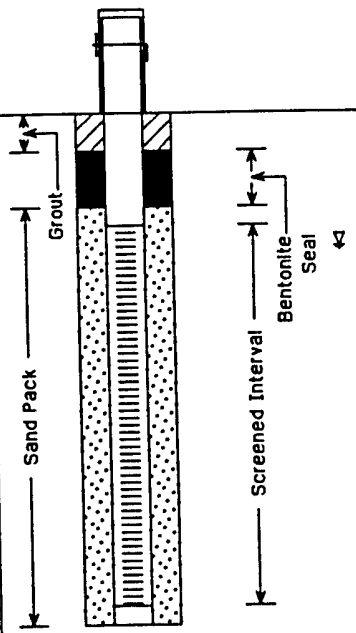
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS10
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 27-Feb-96
Date Completed 27-Feb-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 13.5
Ground Elevation (ft) 7.97
X-Coordinate 797671.13
Y-Coordinate 1504258.18

Client 45th Space Wing
Date Installed 27-Feb-96
Date Grouted 27-Feb-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) +2.5 to -3.0
Screened Interval (ft) -3.0 to -13.0
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 13.0
Depth to Water BTOC (ft) 6.15
Date Measured 04-Apr-96
TOC Elevation (ft) 10.55
Water Level MSL (ft) 4.40

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0						Lithology defined by adjacent monitoring well 1381-MWD10 soil boring log. No split spoon samples takn at this location		SP	
5						SAND, med to fine, and shell, loose, v. pale brown (10YR7/4), wet.	SDMD		
10						SAND, coarse to med, and shell, loose, greenish gray (5GY5/1).	SDCR		
15						Boring terminated at 13.5'.			
20									
25									

WELL DIAGRAM



CAPEWELL

PARSONS ENGINEERING SCIENCE

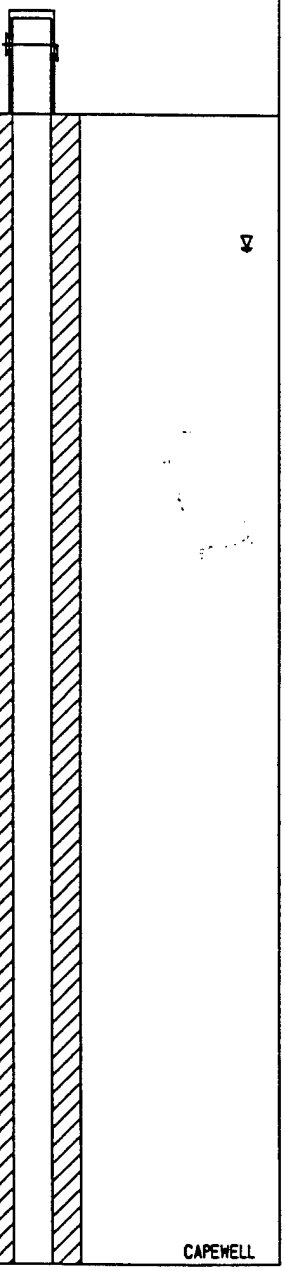
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD10
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 01-Mar-96
Date Completed 02-Mar-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 50.0
Ground Elevation (ft) 7.97
X-Coordinate 797674.51
Y-Coordinate 1504254.48

Client 45th Space Wing
Date Installed 02-Mar-96
Date Grouted 02-Mar-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) +2.5 to -44.5
Screened Interval (ft) -44.5 to -49.5
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 50
Depth to Water BTOC (ft) 6.31
Date Measured 04-Apr-96
TOC Elevation (ft) 10.84
Water Level MSL (ft) 4.53

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	NA	0	Fill material with vegetative cover.		SP	
5		4,5, 6,9	80	0	0	SAND, medium to fine grained, and shell, loose, very pale brown (10YR 7/4), wet.	SDMD		
10		2,5, 4,3	80	7	0	SAND, coarse to medium grained, and shell, loose, greenish gray (5GY 5/1).	SDCR		
15		5,6, 10,15	70	7	0	SAND, very fine grained, trace silt, firm, greenish gray (5GY 5/1).	SDVF	SM	
20		5,6, 12,14	80	110	500	SAND, medium to fine grained, some shell, firm, greenish gray (5GY 5/1).	SDFN	SP	
25		1,2, 2,5	40	0	500	SAND, coarse to fine grained, some shell, loose, greenish gray (5 G 4/1)	SDMD		
		1,2, 2,1	40	30	500	SAND, fine to very fine grained, trace shell, firm, greenish gray (5GY 5/1).	SDFN		

WELL DIAGRAM



PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AS
Site Facility 1381 – Ordnance Support Facility
Boring/Well I.D. 1381-MWD10
Geologist/Engineer Phil Potter

Project I.D. CCAS RFI – 727576
Client 45th Space Wing
Date Installed 02-Mar-96

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd – Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE GRAPHIC LOG	WELL DIAGRAM
30								SP	
		1,3, 2,3	80	0	>1000	SAND, coarse to fine, some silt, some shells, loose, dark greenish gray (5GY 4/1).	SDSL	SM	Grout
35									
		1,2, 2,1	70	40	600	SAND, very fine grained, and silt, and clay, firm, greenish gray (5GY 5/1).	SDCL		
40		NR	60	0	>1000	SAND, very fine grained, and silt, and clay, little shell, firm, greenish gray (5GY 4/1).	SDCL		Bentonite Seal
									Sand Pack
45		NR	50	0	>1000	SAND, coarse to fine, and clay, some shell, some silt, loose to firm, greenish gray (5GY 5/1).	SDCL		
		2,1, 1,1	60	80	>1000	SAND, coarse to fine, and shell, and clay, loose, greenish gray (5GY 5/1).	SDCL		
50		1,2	80	0	>1000	SAND, medium to fine, loose, greenish gray (5GY 5/1), wet. CLAY at 49.5 feet, firm.	SDMD/ CLAY	SP OH	Screened Interval
						Boring terminated at 50'.			
55									
60									
65									

CAPEWELL

PARSONS ENGINEERING SCIENCE

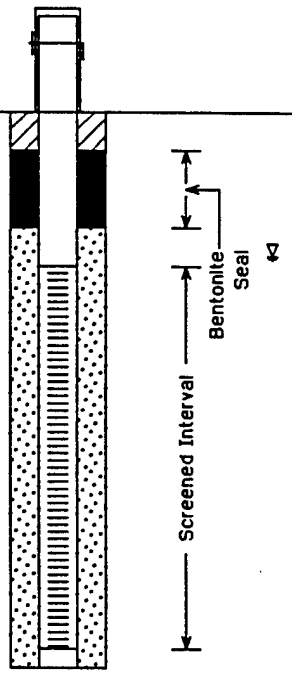
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS11
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 28-Feb-96
Date Completed 28-Feb-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 14.5
Ground Elevation (ft) 8.08
X-Coordinate 797178.06
Y-Coordinate 1504193.92

Client 45th Space Wing
Date Installed 28-Feb-96
Date Grouted 28-Feb-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) +2.5 to -4.0
Screened Interval (ft) -4.0 to -14.0
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 14.5
Depth to Water BTOC (ft) 6.51
Date Measured 04-Apr-96
TOC Elevation (ft) 10.86
Water Level MSL (ft) 4.35

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0						LIthology defined by adjacent monitoring well 1381-MWD11 soil boring log. No split spoon samples taken at this location.		SP	
5						SAND, med to fine, some shell, loose, pale brown (10YR7/4)			
10						SAND, med to fine, trace silt, ltl shell, gray (N5/)			
15						Boring terminated at 14.5 ft.			
20									
25									

WELL DIAGRAM



CAPEWELL

PARSONS ENGINEERING SCIENCE

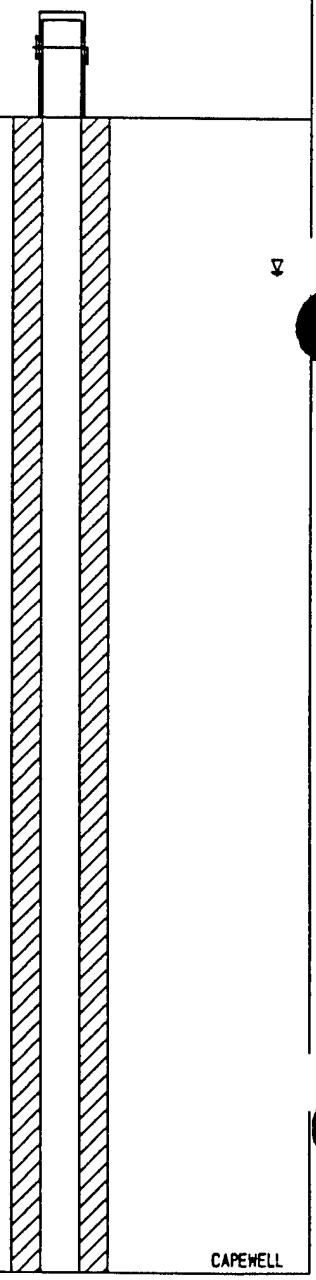
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD11
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 28-Feb-96
Date Completed 28-Feb-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 50.0
Ground Elevation (ft) 8.33
X-Coordinate 797182.42
Y-Coordinate 1504188.81

Client 45th Space Wing
Date Installed 28-Feb-96
Date Grouted 28-Feb-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) +2.5 to -44.5
Screened Interval (ft) -44.5 to -49.5
Sump Installed? No
Pad Installed? Yes
Well Depth (ft) 50
Depth to Water BTOC (ft) 6.62
Date Measured 04-Apr-96
TOC Elevation (ft) 10.96
Water Level MSL (ft) 4.34

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adistd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	NA	0	Fill material with vegetative cover.		SP	
5	X	5,6, 9,9	80	0	0	SAND, medium to fine grained, some shell, loose, pale brown (10YR 7/4), wet.	SDMD		
10	X	2,2, 2,2	50	2	0	SAND, medium to fine grained, trace silt, little shell, gray (N 5/).	SDMD		
15	X	3,3, 9,10	60	2	0	SAND, fine to very fine grained, trace shell, greenish gray (5GY 6/1).	SDFN		
20	X	3,4, 5,4	30	80	0	SAND, fine to very fine grained, greenish gray (5GY 6/1).	SDFN		
25	X	2,3, 3,4	30	0	0	SAND, fine to very fine grained, and silt, greenish gray (5GY 5/1).	SDSL	SM	
	X	2,3, 3,3	30	0	0	SAND, fine to very fine grained, and silt, greenish gray (5GY 5/1).	SDSL		

WELL DIAGRAM



CAPEWELL

PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AS
Site Facility 1381 – Ordnance Support Facility
Boring/Well I.D. 1381-MWD11
Geologist/Engineer Phil Potter

Project I.D. CCAS RFI – 727576
Client 45th Space Wing
Date Installed 28-Feb-96

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd – Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG	WELL DIAGRAM
30								SM		Grout
		2,2, 3,4	30	70	0	SAND, very fine, and silt, trace clay, trace shell, dark greenish gray (5GY 4/1).	SDSL			
35										
		1,1, 1,1	70	0	0	SAND, fine to v. fine grained, some silt, greenish gray (5GY 5/1).	SDVF			
40		1,2, 4,5	50	0	0	SAND, very fine grained, and shell, and clay, greenish gray (5GY 6/1).	SDVF			Bentonite Seal
		1,2, 4,1	80	0	0	SAND, fine, some clay, and shell, greenish gray (5GY 5/1).	SDFN			
		1,0, 0,5	60	0	0	SHELLS, coarse, some clay, loose, very dark gray (N 3/).	SDCR	SP		Sand Pack
45		3,5, 6,5	80	0	0	SAND, medium to fine, and shell, trace clay, dark greenish gray (5GY 4/1).	SDMD			
		1,2, 1,2	80	30	0	SAND, and clay, some shell, greenish gray (5GY 5/1). CLAY at 49.5, firm.	SDCL/ CLAY	SM		Screened Interval
50						Boring terminated at 50'.		OH		
55										
60										
65										

CAPEWELL

PARSONS ENGINEERING SCIENCE

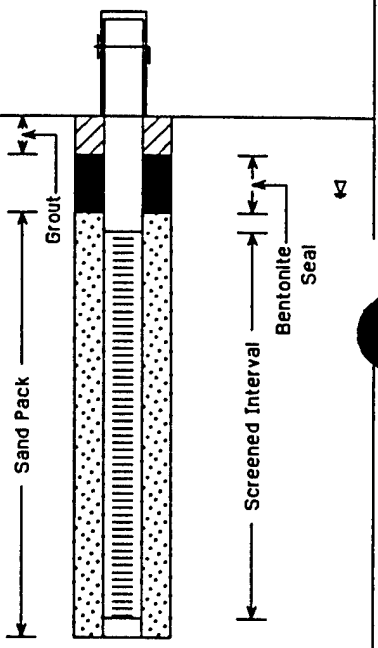
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS12
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 03-Mar-96
Date Completed 03-Mar-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 14.0
Ground Elevation (ft) 6.88
X-Coordinate 798083.35
Y-Coordinate 1505429.89

Client 45th Space Wing
Date Installed 03-Mar-96
Date Grouted 03-Mar-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) +2.5 to -3.0
Screened Interval (ft) -3.0 to -13.0
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 13.5
Depth to Water BTOC (ft) 4.71
Date Measured 04-Apr-96
TOC Elevation (ft) 9.62
Water Level MSL (ft) 4.91

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0						Lithology defined by adjacent monitoring well 1381-MWD12 soil boring log. No split spoon samples taken at this location.		SP	
5						SAND, coarse to med, and shell, loose, brownish yellow (10YR6/6), wet.			
10						SAND, med to fine, trace shell, firm, greenish gray (5GY6/1)			
15						Boring terminated at 14.0 ft.			
20									
25									

WELL DIAGRAM



CAPEWELL

PARSONS ENGINEERING SCIENCE

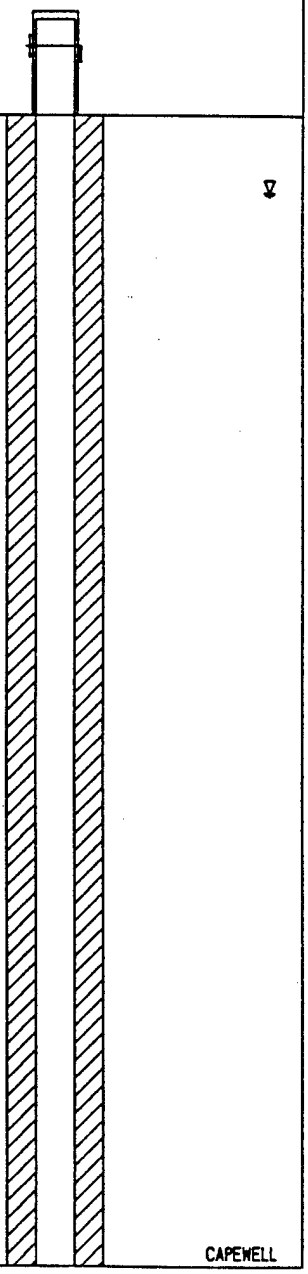
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD12
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 04-Mar-96
Date Completed 04-Mar-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 50.0
Ground Elevation (ft) 6.96
X-Coordinate 798088.61
Y-Coordinate 1505427.46

Client 45th Space Wing
Date Installed 04-Mar-96
Date Grouted 04-Mar-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) +2.5 to -44.0
Screened Interval (ft) -44.0 to -49.0
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 49.5
Depth to Water BTOC (ft) 4.63
Date Measured 04-Apr-96
TOC Elevation (ft) 9.60
Water Level MSL (ft) 4.97

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	NA	0	Fill material with vegetative cover.		SP	
5		4,4, 7,7	80	0	0	SAND, coarse to medium grained, and shell, loose, brownish yellow (10YR 6/6), wet.	SDCR		
10		8,8, 12,19	90	4	0	SAND, medium to fine grained, trace shell, firm, greenish gray (5GY 6/1).	SDMD		
15		8,9, 17,29	80	0	18	SAND, medium to fine grained, little shell, very firm, greenish gray (5GY 6/1).	SDMD		
20		4,4, 6,7	60	0	6	SAND, fine to very fine, trace shell, greenish gray (5GY 6/1).	SDFN		
25		4,4, 5,5	70	0	0	SAND, fine to very fine grained, trace silt, trace shell, greenish gray (5GY 5/1).	SDVF		
		HW,2, 1,1	70	0	>1000	SAND, very fine grained, some silt, trace shell, firm, greenish gray (5GY 5/1).	SDSL	SM	

WELL DIAGRAM



PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AS
Site Facility 1381 – Ordnance Support Facility
Boring/Well I.D. 1381-MWD12
Geologist/Engineer Phil Potter

Project I.D. CCAS RFI – 727576
Client 45th Space Wing
Date Installed 04-Mar-96

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd – Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG	WELL DIAGRAM
30								SM		Grout
		1,2, 2,1	80	0	>1000	SAND, very fine, and silt, trace shell, firm, greenish gray (5GY 5/1).	SDSL			
35										
		HW,1, 5,5	70	0	>1000	SAND, medium to fine, and shell, and silt, some clay, loose to firm, greenish gray (5GY 5/1).	SDCL			
40		3,4, 4,3	60	0	>1000	SAND, fine to v. fine, and shell, loose, dark greenish gray (5GY 4/1).	SDFN	SP		Bentonite Seal
										Sand Pack
45		HW,HW, 1,1	80	0	>1000	SAND, coarse to fine, and shell, some clay, loose, dark greenish gray (5GY 4/1).	SDCL	SM		
		HW,HW, 2,2	100	200	>1000	SAND, coarse to fine, and shell, and clay, loose, dark greenish gray (5GY 4/1). At 49.5; CLAY, little wood chips, dark greenish gray (5GY 4/1).	SDCL/ CLAY	OH		Screened Interval
50						Boring terminated at 50'.				
55										
60										
65										

CAPEWELL

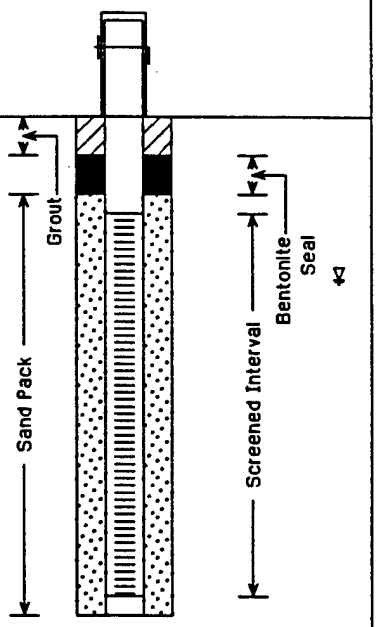
PARSONS ENGINEERING SCIENCE

SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS13
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 13-Mar-96
Date Completed 13-Mar-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 13.0
Ground Elevation (ft) 8.62
X-Coordinate 796624.10
Y-Coordinate 1505592.71

Client 45th Space Wing
Date Installed 13-Mar-96
Date Grouted 13-Mar-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 3 to -2.5
Screened Interval (ft) -2.5 to -12.5
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 13.0
Depth to Water BTOC (ft) 6.50
Date Measured 04-Apr-96
TOC Elevation (ft) 10.91
Water Level MSL (ft) 4.41

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG	WELL DIAGRAM
0						Lithology defined by split spoon samples collected at adjacent monitoring well 1381-MWD13.		SP		
5						SAND, coarse to med, and shell, v. loose, yellow, 10YR7/6, wet.				
10						SAND, v. coarse to med, and shell, v. loose, greenish gray, 5Y5/1, wet. DRAFT				
15						Boring terminated at 13 ft.				
20										
25										



CAPEWELL

PARSONS ENGINEERING SCIENCE

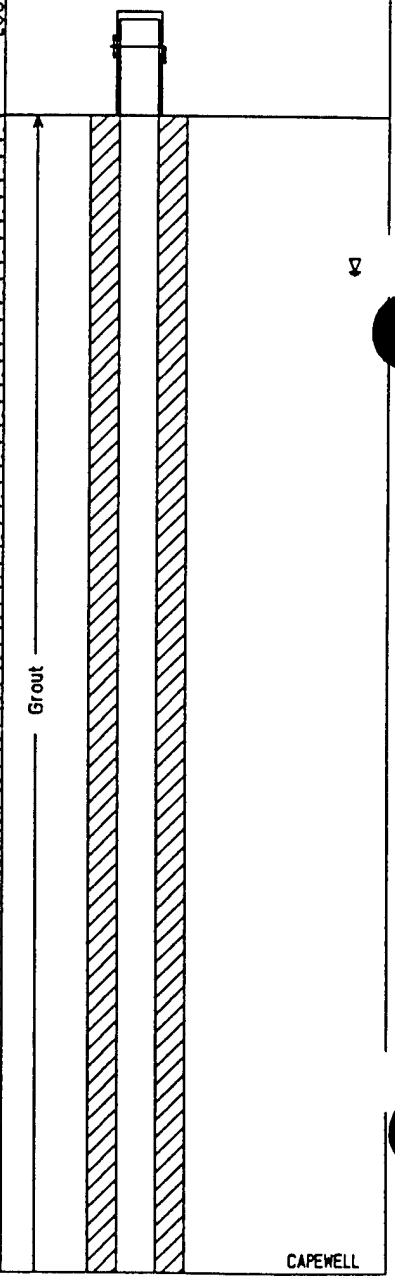
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD13
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 12-Mar-96
Date Completed 12-Mar-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 50.0
Ground Elevation (ft) 8.62
X-Coordinate 796626.89
Y-Coordinate 1505601.33

Client 45th Space Wing
Date Installed 12-Mar-96
Date Grouted 12-Mar-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 3 to -44.5
Screened Interval (ft) -44.5 to -49.5
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 50.0
Depth to Water BTOC (ft) 6.21
Date Measured 04-Apr-96
TOC Elevation (ft) 10.85
Water Level MSL (ft) 4.64

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0						Vegetation at surface.		SP	
5	X	6,7, 5,10	60	2	0	SAND, coarse to med, and shell, v. loose, yellow, 10YR7/6, wet.	SDCR		
10	X	2,3, 5,8	30	0	0	SAND, v. coarse to med, and shell, v. loose, greenish gray, 5Y5/1, wet.	SDCR		
15	X	2,4, 5,5	40	0	0	SAND, coarse to fine, some shell, loose, greenish gray, 5GY5/1, wet.	SDMD		
20	X	3,4, 4,8	20	0	400	SAND, coarse to fine, some shell, loose, greenish gray, 5GY5/1, wet.	SDMD		
25	X	3,4, 4,4	10	0	100	SAND, med to v. fine, ltl shell, firm, greenish gray, 5GY5/1, wet.	SDFN		
	X	4,3, 4,4	30	90	30	SAND, v. fine, and silt, firm, greenish gray, 5GY5/1, wet.	SDSL	SM	

WELL DIAGRAM



PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AS
Site Facility 1381 – Ordnance Support Facility
Boring/Well I.D. 1381-MWD13
Geologist/Engineer Phil Potter

Project I.D. CCAS RFI – 727576
Client 45th Space Wing
Date Installed 12-Mar-96

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd – Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG	WELL DIAGRAM
30								SM		
		1,2, 2,1	60	0	>1000	SAND, med to fine, ltl shell, firm, greenish gray, 5GY5/1, wet.	SDFN	SP		
35										
		HW,1, 1,1	30	0	>1000	SAND, v. fine, and silt, some clay, firm, dk. greenish gray, 5GY5/1, wet.	SDSL	SM		
40		1,3, 2,7	30	0	>1000	SAND, v. fine, and silt, and clay, ltl shell, firm, dk. greenish gray, 5GY4/1, wet.	SDCL	CL		
		3,1, 3,5	30	110	>1000	SAND, med to v. fine, and silt, some clay, some shell, firm, dk. greenish gray, 5GY4/1, wet.	SDSL	SM		
45		1,1, 1,1	20	0	>1000	SAND, v. fine, and silt, ltl clay, firm, dk. greenish gray, 5GY4/1, wet.	SDSL			
		HW,HW, HW,3	20	0	>1000	SAND, med to v. fine, and silt, some clay, ltl shell, firm, greenish gray, 5GY5/1, wet.	SDSL			
		1,1, 1,1	20	0	>1000	SAND, fine to v. fine, some silt, ltl shell, firm, greenish gray, 5GY5/1, wet. 3" CLAY layer	SDCL	CL		
50						Boring terminated at 50'.				
55										
60										
65										

WELL DIAGRAM: Grout; Sand Pack; Bentonite Seal; Screened Interval

CAPEWELL

PARSONS ENGINEERING SCIENCE

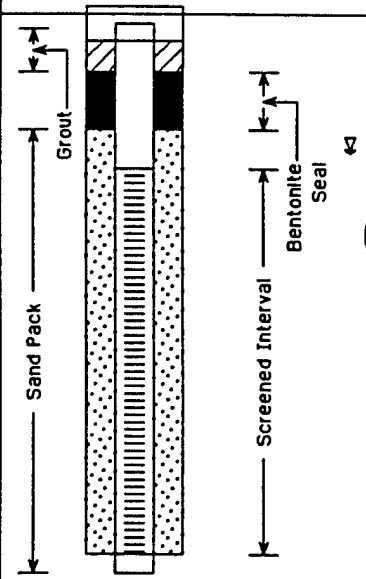
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Page 1 of 1

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS14
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 12-Mar-96
Date Completed 12-Mar-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 14.5
Ground Elevation (ft) 8.23
X-Coordinate 798494.39
Y-Coordinate 1506002.99

Client 45th Space Wing
Date Installed 12-Mar-96
Date Grouted 12-Mar-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 0.0 to -4.0
Screened Interval (ft) -4.0 to -14.0
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 14.5
Depth to Water BTOC (ft) 3.50
Date Measured 04-Apr-96
TOC Elevation (ft) 8.24
Water Level MSL (ft) 4.74

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG	WELL DIAGRAM
0		NA	NA	NA	0	Fill material with vegetative cover.		SP		
5		2,4, 6,4	80	0	0	SAND, coarse to medium grained, and shell, loose, yellowish brown (10YR 5/4), wet.	SDCR			
10		1,1, 1,2	20	3	0	SAND, very coarse to medium, and shell, loose, gray (N 5/), wet.	SDCR			
15						Boring terminated at 14.5'.				
20										
25										



CAPEWELL

PARSONS ENGINEERING SCIENCE

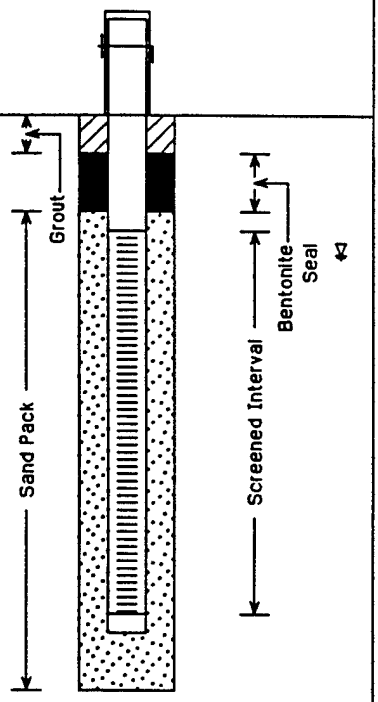
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS15
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 19-Mar-96
Date Completed 19-Mar-96
Driller EDS
Borehole Diameter (in) 10.25
Depth Drilled (ft) 15.0
Ground Elevation (ft) 7.79
X-Coordinate 798915.22
Y-Coordinate 1506601.74

Client 45th Space Wing
Date Installed 19-Mar-96
Date Grouted 19-Mar-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) +2.5 to -3.0
Screened Interval (ft) -3.0 to -13.0
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 13.5
Depth to Water BTOC (ft) 6.27
Date Measured 04-Apr-96
TOC Elevation (ft) 10.44
Water Level MSL (ft) 4.17

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	0	0	Fill material with vegetative cover.	SDMD	SP	
5		5,8, 8,5	90	0	0	SAND, medium to fine grained, little shell, very loose, very pale (10YR 7/3), wet.	SDMD		
10		4,7, 9,4	30	0	10	SAND, medium to fine, trace shell, very loose, greenish gray (5GY 6/1), wet.	SDMD		
15						Boring terminated at 15.0 ft.			
20									
25									

WELL DIAGRAM



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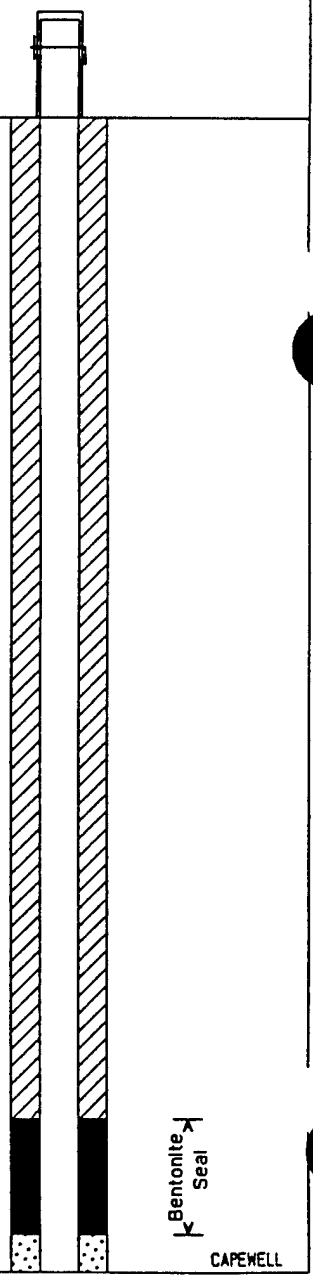
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWI09
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 17-May-96
Date Completed 17-May-96
Driller EDS
Borehole Diameter (in) 9.00
Depth Drilled (ft) 36.0
Ground Elevation (ft)
X-Coordinate
Y-Coordinate

Client 45th Space Wing
Date Installed 17-May-96
Date Grouted 17-May-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 3 to -30.0
Screened Interval (ft) -30.0 to -35.0
Sump Installed? No
Pad Installed? Yes
Well Depth (ft) 35.0
Depth to Water BTOC (ft)
Date Measured
TOC Elevation (ft)
Water Level MSL (ft)

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	NA	0	Fill with vegetative cover.		SP	
5		5,4, 4,3	40	0	0	SAND, medium to fine grained, and shell, very loose, light yellowish brown (10YR6/4), wet.	SDMD		
10		4,3, 4,4	30	20	180	SAND, coarse to fine, and shell, very loose, olive brown (2.5Y4/4).	SDCR		
15		5,5, 4,5	40	760	450	SAND, medium to fine, and shell, very loose, gray (2.5YR5/1).	SDFN		
20		7,7, 6,5	60	500	600	SAND, coarse to fine, trace shell, loose, greenish gray (5GY5/1).	SDVF		
		4,4, 7,6	70	540	600	SAND, fine to very fine, trace shell, firm, greenish gray (5GY5/1).	SDFN		
25		3,3, 2,3	80	0	>1000	SAND, fine to very fine, little shell, firm, greenish gray (5GY5/1).	SDFN		
		4,4, 3,2	70	130	330	SAND, fine to very fine, firm, greenish gray (5GY5/1).	SDVF		
		4,4, 3,4	70	0	400	SAND, fine to very fine, very firm, greenish gray (5GY5/1).	SDVF		

WELL DIAGRAM



PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AS
Site Facility 1381 – Ordnance Support Facility
Boring/Well I.D. 1381-MWI09
Geologist/Engineer Phil Potter

Project I.D. CCAS RFI – 727576
Client 45th Space Wing
Date Installed 17-May-96

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd – Filtrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG	WELL DIAGRAM
30		2,2, 3,5	70	180	>1000	SAND, fine to very fine, trace silt, trace shell, very firm, greenish gray (5GY5/1).		SP		Sand Pack
		2,2, 2,2	100	0	12	SAND, very fine, some silt, little shell, trace clay, firm, greenish gray (5GY5/1).	SDSL	SM		Screened Interval
35		2,2, 3,4	90	0	>1000	SAND, very fine, and silt, little clay, little shell, firm, greenish gray (5GY5/1), wet.	SDSL			
						Boring terminated at 36.0'.				
40										
45										
50										
55										
60										
65										

CAPEWELL

PARSONS ENGINEERING SCIENCE

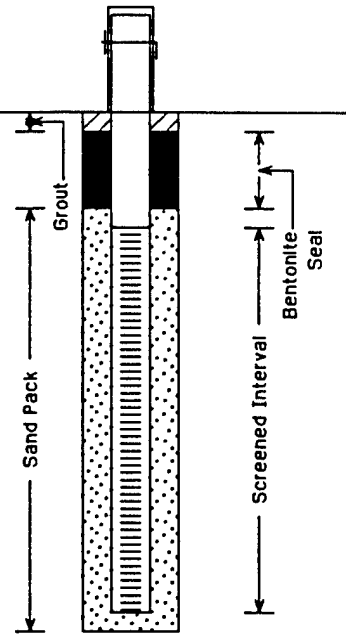
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS16
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 20-May-96
Date Completed 20-May-96
Driller EDS
Borehole Diameter (in) 9.00
Depth Drilled (ft) 13.5
Ground Elevation (ft)
X-Coordinate
Y-Coordinate

Client 45th Space Wing
Date Installed 20-May-96
Date Grouted 20-May-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) +2.5 to -3.0
Screened Interval (ft) -3.0 to -13.0
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 13.5
Depth to Water BTOC (ft)
Date Measured
TOC Elevation (ft)
Water Level MSL (ft)

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	0	0	Fill material with vegetative cover.	SDMD	SP	
5		4,6, 7,5	40	0	3	SAND, coarse to fine grained, and shell, very loose, yellowish brown (10YR 6/4), wet.	SDMD		
10		5,5, 6,5	40	0	0	SAND, medium to very fine, little shell, firm, gray (10YR5/1), wet.	SDFN		
						Boring terminated at 13.5 ft.			
15									
20									
25									

WELL DIAGRAM



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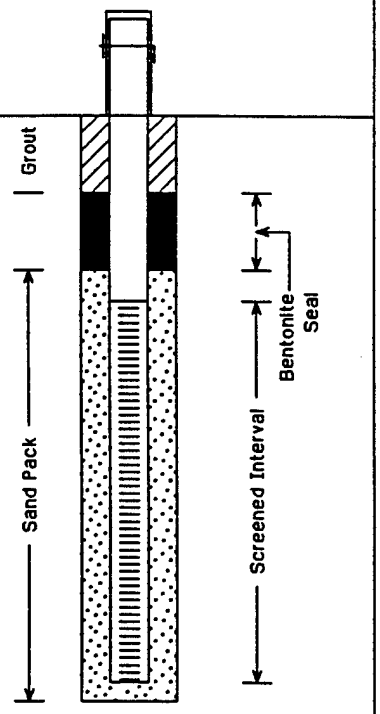
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS17
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 18-May-96
Date Completed 18-May-96
Driller EDS
Borehole Diameter (in) 9.00
Depth Drilled (ft) 15.3
Ground Elevation (ft)
X-Coordinate
Y-Coordinate

Client 45th Space Wing
Date Installed 18-May-96
Date Grouted 18-May-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 3 to -4.8
Screened Interval (ft) -4.8 to -14.8
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 15.3
Depth to Water BTOC (ft)
Date Measured
TOC Elevation (ft)
Water Level MSL (ft)

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE GRAPHIC LOG
0		NA	NA	NA	0	Fill with vegetative cover.		SP
5		4,4, 3,5	70	0	0	SAND, medium to fine grained, little shell, very loose, light yellowish brown (10YR6/4), wet at 7' bls.	SDMD	
10		5,7, 7,9	60	0	1	SAND, medium to fine, some shell, firm, gray (10YR6/1), wet.	SDMD	
15						Boring terminated at 15.3'.		
20								
25								

WELL DIAGRAM



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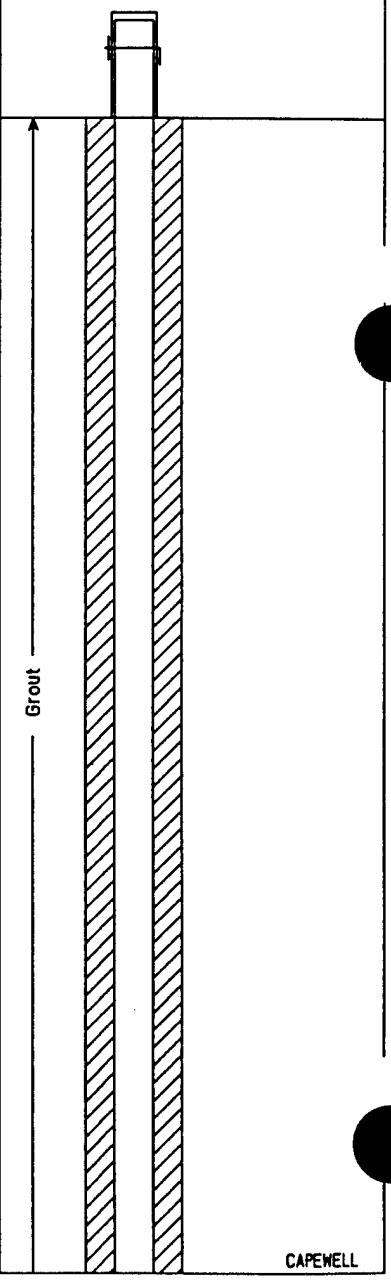
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD17
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 18-May-96
Date Completed 18-May-96
Driller EDS
Borehole Diameter (in) 9.00
Depth Drilled (ft) 51.0
Ground Elevation (ft)
X-Coordinate
Y-Coordinate

Client 45th Space Wing
Date Installed 18-May-96
Date Grouted 18-May-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 3 to -45.5
Screened Interval (ft) -45.5 to -50.5
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 51.0
Depth to Water BTOC (ft)
Date Measured
TOC Elevation (ft)
Water Level MSL (ft)

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE
0		NA	NA	NA	0	Fill with vegetative cover.		SP
5		5,4, 3,6	40	0	0	SAND, medium to fine grained, trace shell, very loose, very pale brown (10YR7/3), moist.	SDMD	
10		3,4, 4,6	70	0	3	SAND, coarse to fine, some shell, loose, gray (10YR5/). wet.	SDCR	
15		5,5, 6,5	80	0	12	SAND, medium to fine, little shell, loose, gray (10YR5/).	SDMD	
20		4,4, 3,4	50	0	0	SAND, fine to very fine, trace shell, firm, greenish gray (5GY5/1).	SDFN	
		5,5, 6,7	80	0	>1000	SAND, fine, little shell, firm, greenish gray (5GY5/1).	SDFN	SW
25		5,5, 5,6	90	0	>1000	SAND, medium to fine, little shell, firm, gray 10YR6/1).	SDMD	SP
		4,4, 4,4	60	0	>1000	SAND, medium to fine, little shell, firm, gray (10YR6/1).	SDFN	
		3,3, 4,4	60	0	>1000	SAND, fine to very fine, trace shell, firm, greenish gray (5GY5/1).	SDVF	

WELL DIAGRAM



CAPEWELL

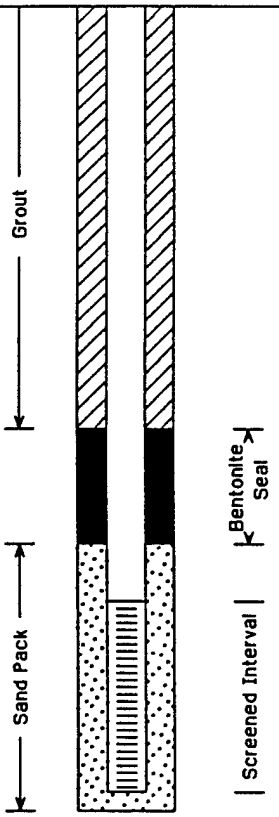
PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AS
Site Facility 1381 – Ordnance Support Facility
oring/Well I.D. 1381-MWD17
eologist/Engineer Phil Potter

Project I.D. CCAS RFI – 727576
Client 45th Space Wing
Date Installed 18-May-96

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd – Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
30		3,5, 7,8	90	0	>1000	SAND, fine to very fine, trace shell, firm, greenish gray (5GY5/1).		SP	
		3,3, 4,4	70	0	100	SAND, fine to very fine, some silt, firm, greenish gray (5GY5/1).	SDSL	SM	
35		4,4, 4,4	80	0	80	SAND, fine to very fine, some silt, little clay, trace shell, greenish gray (5GY5/1).	SDSL		
		3,3, 2,3	80	10	>1000	SAND, medium to fine grained, and silt, and clay (stringers to 1"), loose to firm, greenish gray (5GY5/1).	SDSL		
		3,3, 3,3	90	0	>1000	SAND, medium to very fine, and silt, some shell, some clay, loose, dark greenish gray (5GY4/1).	SDSL		
40		4,7, 7,4	90	0	>1000	SAND, fine, and shell, some clay, loose, dark greenish gray (5GY4/1).	SDSL		
		3,3, 3,5	90	20	>1000	SHELLS, coarse to medium, some clay, loose, dk. greenish gray (5GY4/1)	SDMD	SP	
		3,6 6,5	60	0	>1000	SAND, medium to very fine, and shell, little silt, little clay, loose, dark greenish gray (5GY4/1). 2-inch silty clay layer at 45'.	SDFN		
		4,4, 5,4	90	0	320	SAND, medium to fine, and shell, some clay, loose, dark greenish gray (5GY4/1).	SDCL		
		5,7, 7,10	90	0	>1000	SAND, medium to fine, and shell, some to little clay, firm to loose, dark greenish gray (5GY4/1), wet.	SDFN		
50		5,7, 7,10	100	70	>1000	SAND, medium to fine, and shell, some clay, firm, dark greenish gray (5GY4/1), wet.	SDCL/ CLAY	SM	
						CLAY, very firm, dark greenish gray (5GY4/1), moist.		CL	
						Boring terminated at 51.0'.			
55									
60									

WELL DIAGRAM



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PARSONS ENGINEERING SCIENCE

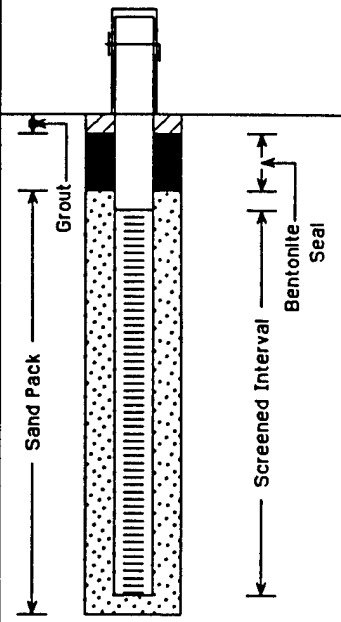
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWS18
Geologist/Engineer Louis Bustamante
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 17-May-96
Date Completed 17-May-96
Driller EDS
Borehole Diameter (in) 9.00
Depth Drilled (ft) 13.0
Ground Elevation (ft)
X-Coordinate
Y-Coordinate

Client 45th Space Wing
Date Installed 17-May-96
Date Grouted 17-May-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 3 to -2.5
Screened Interval (ft) -2.5 to -12.5
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 13.0
Depth to Water BTOC (ft)
Date Measured
TOC Elevation (ft)
Water Level MSL (ft)

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	NA	0	Fill.		SP	
5		NA	80	0	1	SAND, coarse to medium grained, and shell, very loose, brown (10YR5/3) wet.	SDMD		
10		NA	30	11	3	SAND, coarse to fine, and shell, very loose, gray (10YR5/), wet.	SDMD		
						Boring terminated at 13.0'.			
15									
20									
25									

WELL DIAGRAM



CAPEWELL

PARSONS ENGINEERING SCIENCE

SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-MWD19
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 19-May-96
Date Completed 19-May-96
Driller EDS
Borehole Diameter (in) 9.00
Depth Drilled (ft) 50.0
Ground Elevation (ft)
X-Coordinate
Y-Coordinate

Client 45th Space Wing
Date Installed 19-May-96
Date Grouted 19-May-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) 3 to -44.5
Screened Interval (ft) -44.5 to -49.5
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 50.0
Depth to Water BTOC (ft)
Date Measured
TOC Elevation (ft)
Water Level MSL (ft)

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adistd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG	WELL DIAGRAM
0		NA	NA	NA	0	Fill with vegetative cover.		SP		
5		5,4, 4,5	30	0	0	SAND, coarse to fine, some shell, loose, gray (10YR6/1), wet.	SDCR			
10		4,4, 7,9	20	0	1	SAND, coarse to medium, and shell, loose, gray (10YR6/1).	SDCR			
15		7,7, 8,12	70	0	>1000	SAND, medium to fine, little shell, firm, greenish gray (5GY5/1).	SDMD			
20		5,5, 6,5	50	0	>1000	SAND, very fine, trace silt, trace shell, firm, greenish gray (5GY5/1).	SDVF	SW		
		5,7, 7,10	70	0	>1000	SAND, fine to v. fine, trace shell, firm, greenish gray (5GY5/1).	SDFN	SP		
25		7,7, 5,7	90	0	600	SAND, fine to v. fine, trace silt, firm, greenish gray (5GY5/1).	SDFN			
		7,10, 11,9	90	0	>1000	SAND, very fine, some silt, trace clay, firm, greenish gray (5GY5/1).	SDSL	SM		
		6,6, 5,7	90	0	280	SAND, fine to v. fine, trace silt, trace shell, firm, greenish gray (5GY5/1).	SDVF	SP		

Grout

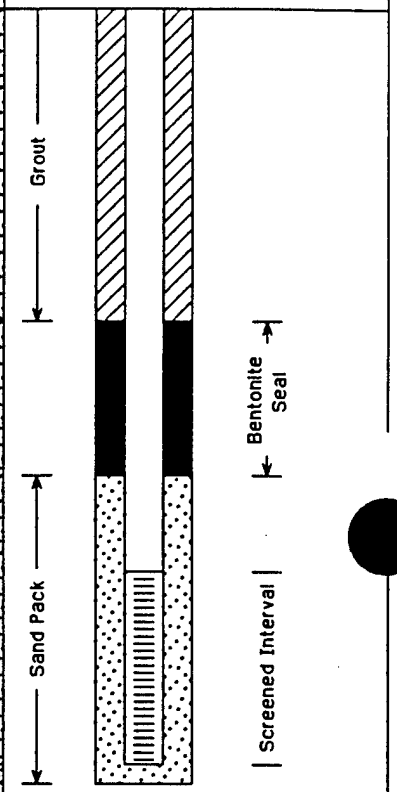
CAPEWELL

PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Installation Cape Canaveral AS
Site Facility 1381 – Ordnance Support Facility
Boring/Well I.D. 1381-MWD19
Geologist/Engineer Phil Potter

Project I.D. CCAS RFI – 727576
Client 45th Space Wing
Date Installed 19-May-96

DEPTH (feet)	SAMPLE	BLOWS/6 IN	%REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
30		4,4, 3,4	70	0	200	SAND, v. fine, little to some silt, trace shell, firm, greenish gray (5GY5/1).		SP	
		3,3, 3,3	80	0	>1000	SAND, v. fine, and silt, little clay, firm, greenish gray (5GY5/1).	SDSL	SM	
35		5,4, 3,3	90	0	>1000	SAND, medium to fine, some silt, some clay, little shell, firm, greenish gray (5GY5/1). 2-inch CLAY layer at 35.5'.	SDCL		
		3,3, 2,3	80	0	>1000	SHELLS, some silt, little clay, loose, dark greenish gray (5GY4/1).	SDCR		
		2,2, 3,2	70	0	>1000	SAND, v. fine, little silt, and shell, little clay, loose, dark greenish gray (5GY4/1).	SDVF	SP	
40		5,8, 3,3	90	0	520	SAND, medium to very fine, and shell, little silt, little clay, loose, dark greenish gray (5GY4/1).	SDFN		
		3,4, 4,7	100	0	760	SAND, medium to fine, and shell, and clay, loose to firm, dark greenish gray (5GY4/1). 1-foot clay layer at 42.5' to 43.5'.	SDFN	SM	
45		5,5 7,8	100	0	230	SAND, fine, and shell, little silt, little clay, loose to firm, dark greenish gray (5GY4/1). 2-inch clay stringer at 45'.	SDFN	SP	
		4,3, 3,3	100	0	230	SAND, coarse to fine, some shell, little silt, little clay, loose, dark greenish gray (5GY4/1).	SDMD		
		3,4, 5,7	100	10	>1000	SAND, coarse to fine, little silt, little clay, loose to firm, dark greenish gray (5GY4/1), wet.	SDMD/ CLAY		
50						CLAY, very firm, dark greenish gray (5GY4/1), moist.		CL	
						Boring terminated at 50.0'.			
55						Boring terminated at 50'.			
60									
65									



CAPEWELL

PARSONS ENGINEERING SCIENCE

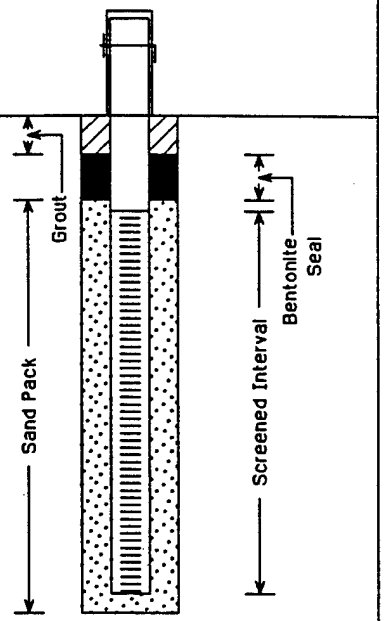
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-PZ01
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 04-Jun-96
Date Completed 04-Jun-96
Driller EDS
Borehole Diameter (in) 9.00
Depth Drilled (ft) 13.0
Ground Elevation (ft)
X-Coordinate
Y-Coordinate

Client 45th Space Wing
Date Installed 04-Jun-96
Date Grouted 04-Jun-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) +2.5 to -2.5
Screened Interval (ft) -2.5 to -12.5
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 13.0
Depth to Water BTOC (ft)
Date Measured
TOC Elevation (ft)
Water Level MSL (ft)

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	0	0	Fill material with vegetative cover.		SP	
5		3,3, 2,3	60	0	0	SAND, medium to fine grained, trace silt, very loose, pinkish gray (7.5YR7/1), moist.	SDMD		
10		5,5, 6,5	60	7	0	SAND, medium to fine, and shell, very loose.	SDMD		
						Boring terminated at 13.0 ft.			
15									
20									
25									

WELL DIAGRAM



CAPEWELL

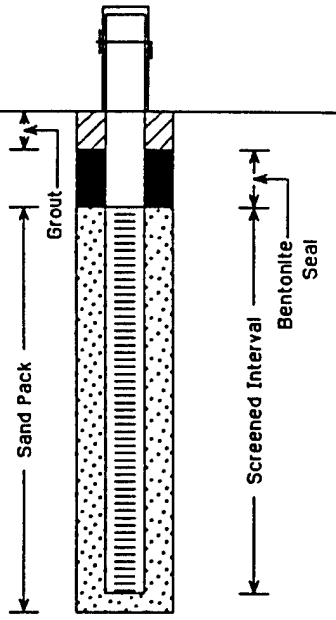
PARSONS ENGINEERING SCIENCE
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-PZ02
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 04-Jun-96
Date Completed 04-Jun-96
Driller EDS
Borehole Diameter (in) 9.00
Depth Drilled (ft) 13.0
Ground Elevation (ft)
X-Coordinate
Y-Coordinate

Client 45th Space Wing
Date Installed 04-Jun-96
Date Grouted 04-Jun-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) +2.5 to -2.5
Screened Interval (ft) -2.5 to -12.5
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 13.0
Depth to Water BTOC (ft)
Date Measured
TOC Elevation (ft)
Water Level MSL (ft)

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	0	0	Fill material with vegetative cover.		SP	
5		4,4, 3,4	60	0	0	SAND, medium to fine grained, little shell, very loose, pale yellow (2.57/3), wet.	SDMD		
10		5,5, 4,5	70	0	0	SAND, coarse, and shell, trace silt, very loose, gray (N5/), wet.	SDCR		
						Boring terminated at 13.0 ft.			
15									
20									
25									

WELL DIAGRAM



CAPEWELL

PARSONS ENGINEERING SCIENCE

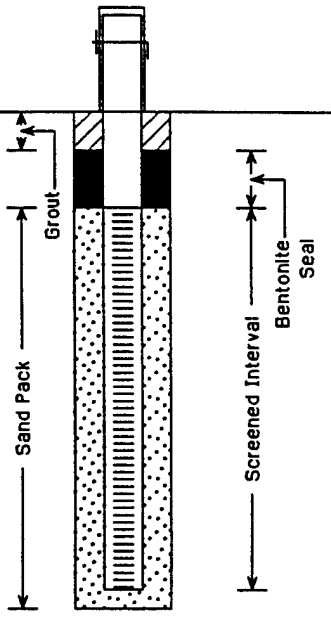
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Project I.D. CCAS RFI - 727576
Installation Cape Canaveral AS
Site Facility 1381 - Ordnance Support Facility
Boring/Well I.D. 1381-PZ03
Geologist/Engineer Phil Potter
Drilling Method Hollow Stem Auger
Sampling Method 2 1/4" Split Spoon
Date Started 04-Jun-96
Date Completed 04-Jun-96
Driller EDS
Borehole Diameter (in) 9.00
Depth Drilled (ft) 13.0
Ground Elevation (ft)
X-Coordinate
Y-Coordinate

Client 45th Space Wing
Date Installed 04-Jun-96
Date Grouted 04-Jun-96
Casing Material 2" PVC
Screen Material 2" PVC 0.01 slot
Casing Interval (ft) +2.5 to -2.5
Screened Interval (ft) -2.5 to -12.5
Sump Installed? Yes
Pad Installed? Yes
Well Depth (ft) 13.0
Depth to Water BTOC (ft)
Date Measured
TOC Elevation (ft)
Water Level MSL (ft)

DEPTH (feet)	SAMPLE	BLOWS/6 IN	% REC.	OVA (sample) Unfiltrd - Fltrd = Adjstd (ppm)	OVA (borehole) (ppm)	LITHOLOGIC DESCRIPTION	LITHCODE	ASTMCODE	GRAPHIC LOG
0		NA	NA	0	0	Fill material with vegetative cover.		SP	
5		NR	30	0	0	SAND, coarse to medium grained, very loose, pinkish white (7YR8/2), wet.	SDCR		
10		NR	60	0	0	SAND, medium to fine grained, and shell, very loose, gray (N5/), wet.	SDMD		
						Boring terminated at 13.0 ft.			
15									
20									
25									

WELL DIAGRAM



CAPEWELL

MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER 01-1381-MP1

JOB NUMBER 729691 INSTALLATION DATE 9/19/96 LOCATION CCAS-Facility 1381

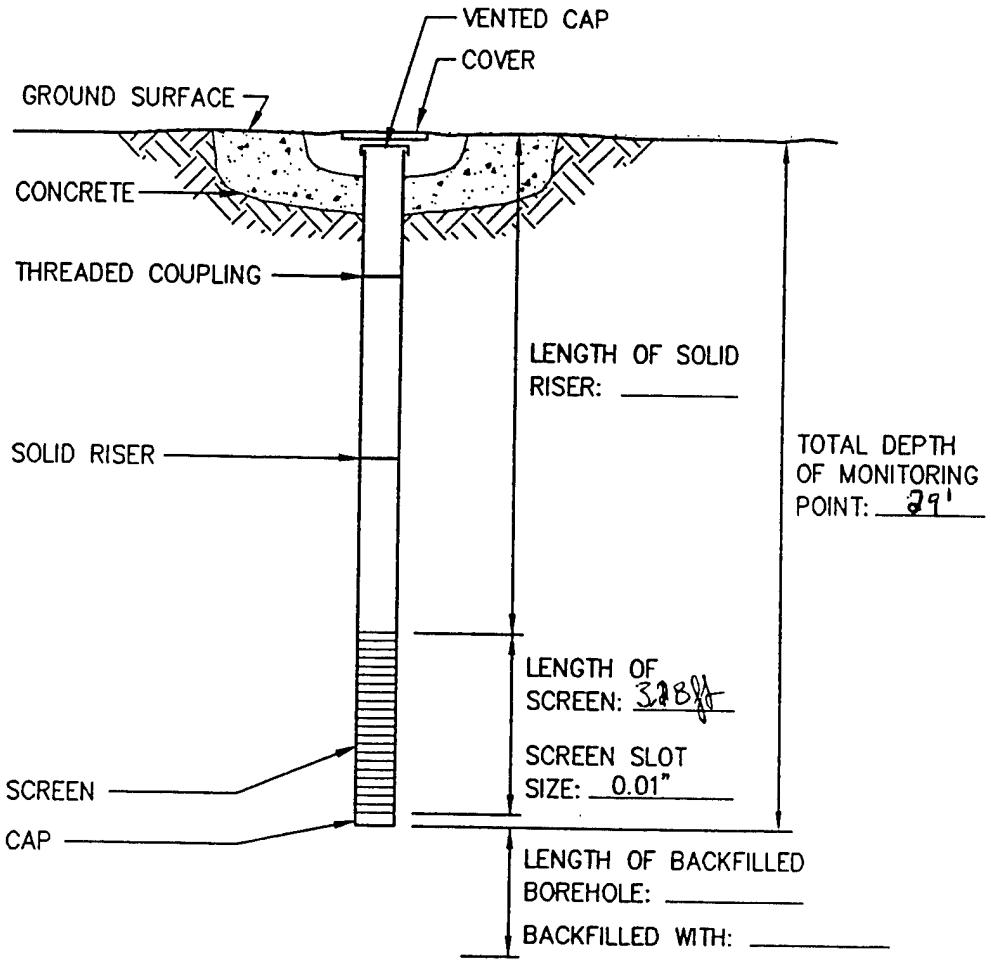
DATUM ELEVATION TOC GROUND SURFACE ELEVATION 0

DATUM FOR WATER LEVEL MEASUREMENT

SCREEN DIAMETER & MATERIAL PVC - 2" x 1 mtr SLOT SIZE

RISER DIAMETER & MATERIAL PVC - 2" BOREHOLE DIAMETER

CONE PENETROMETER CONTRACTOR Army Corps ES REPRESENTATIVE Todd H.



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 29 FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER Φ1-1381-MS

JOB NUMBER 729691 INSTALLATION DATE 9/20/96 LOCATION CCAS-Facility 1381

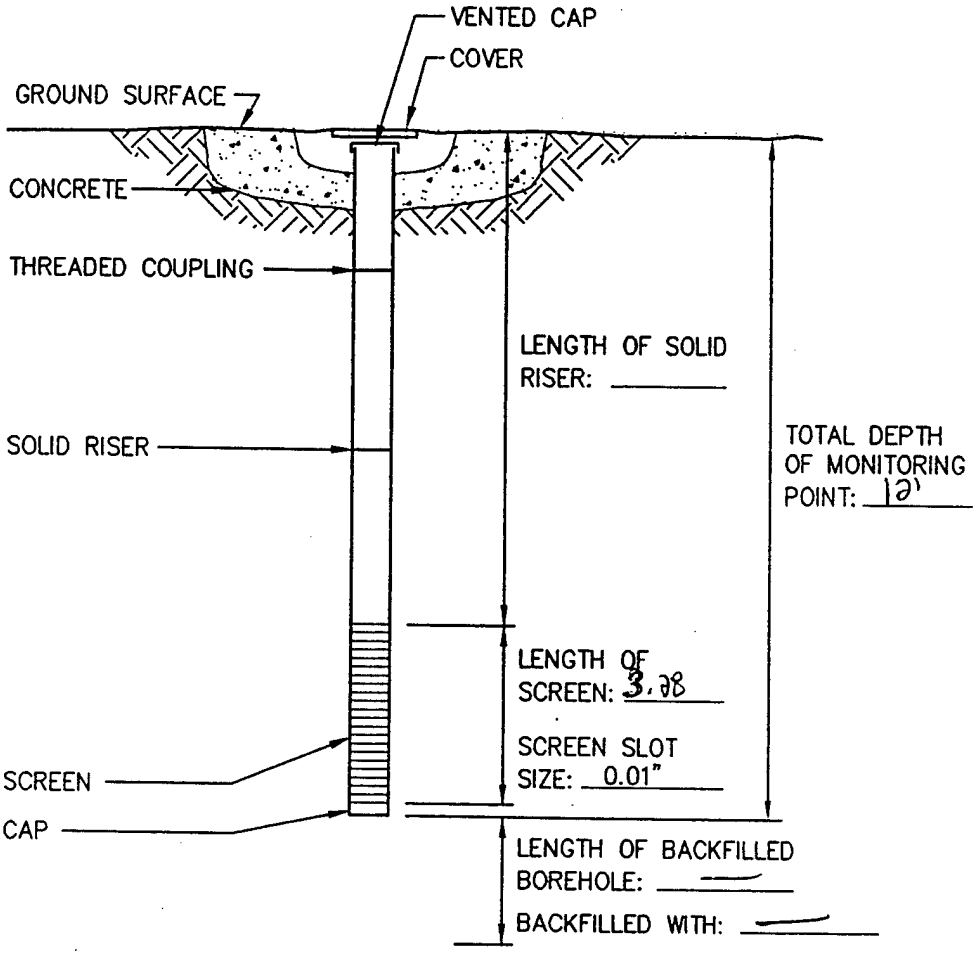
DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT TOC

SCREEN DIAMETER & MATERIAL PVC - 2" ID SLOT SIZE _____

RISER DIAMETER & MATERIAL PVC - 2" ID BOREHOLE DIAMETER —

CONE PENETROMETER CONTRACTOR Army Corps ES REPRESENTATIVE J.H



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 12 FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER 03-1381-MP1

JOB NUMBER 729691 INSTALLATION DATE 9/19/96 LOCATION CCAS - Facility 1381

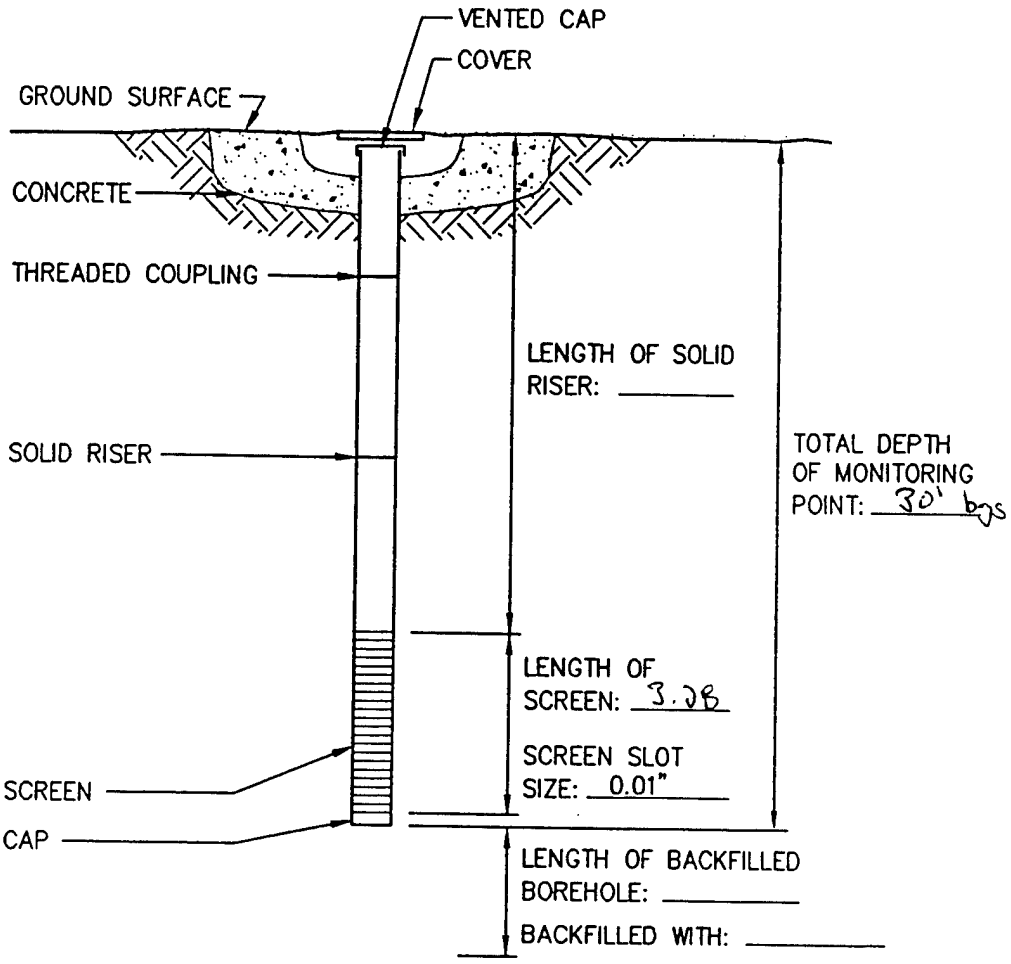
DATUM ELEVATION — GROUND SURFACE ELEVATION —

DATUM FOR WATER LEVEL MEASUREMENT —

SCREEN DIAMETER & MATERIAL 2"ID SLOT SIZE —

RISER DIAMETER & MATERIAL 2" ID BOREHOLE DIAMETER —

CONE PENETROMETER CONTRACTOR USACE ES REPRESENTATIVE TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 30' FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

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MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER ~~03 MP~~ CB-1381-MP1

JOB NUMBER 729691 INSTALLATION DATE 9/20/96 LOCATION CCAS/Facility 1381

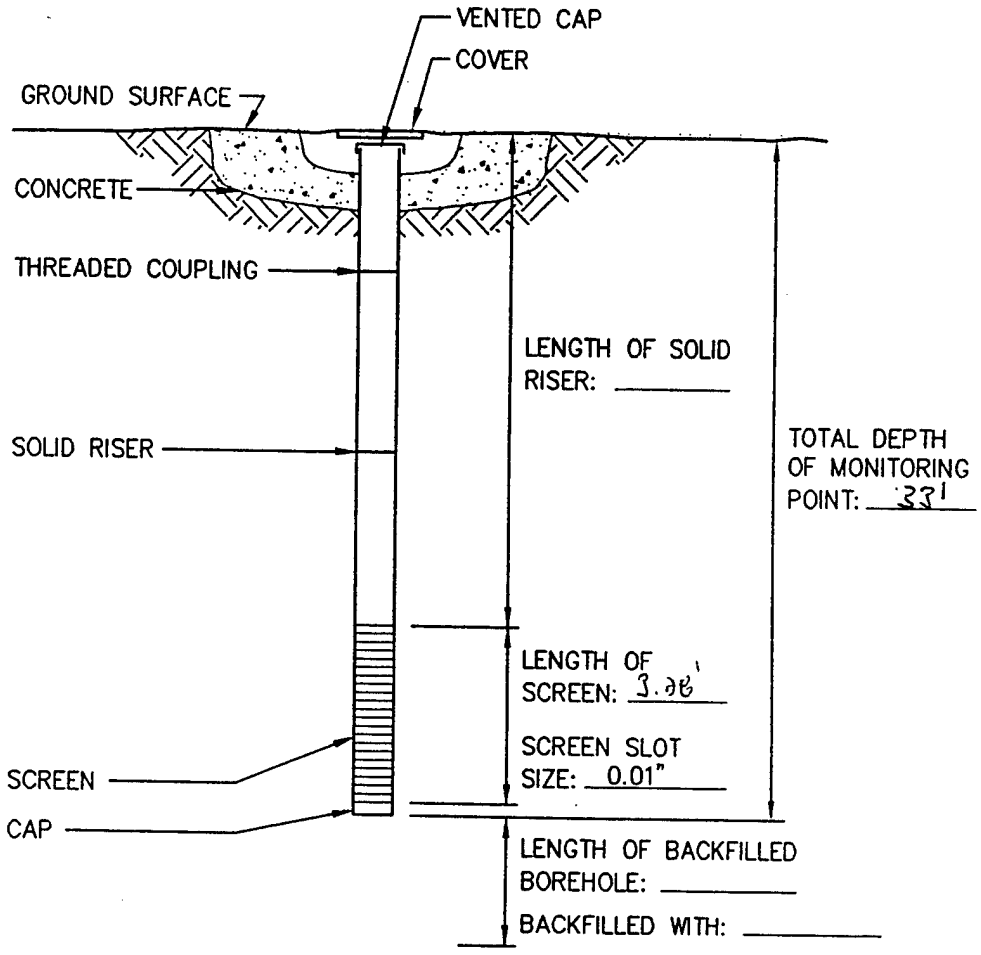
DATUM ELEVATION TOC (Ground) GROUND SURFACE ELEVATION —

DATUM FOR WATER LEVEL MEASUREMENT —

SCREEN DIAMETER & MATERIAL 2"ID PVC SLOT SIZE —

RISER DIAMETER & MATERIAL " " BOREHOLE DIAMETER —

CONE PENETROMETER CONTRACTOR Army Corps ES REPRESENTATIVE TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 33 FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER GS-1381-MPI

JOB NUMBER 729691 INSTALLATION DATE 9/20/96 LOCATION CCAS - Fac. 1381

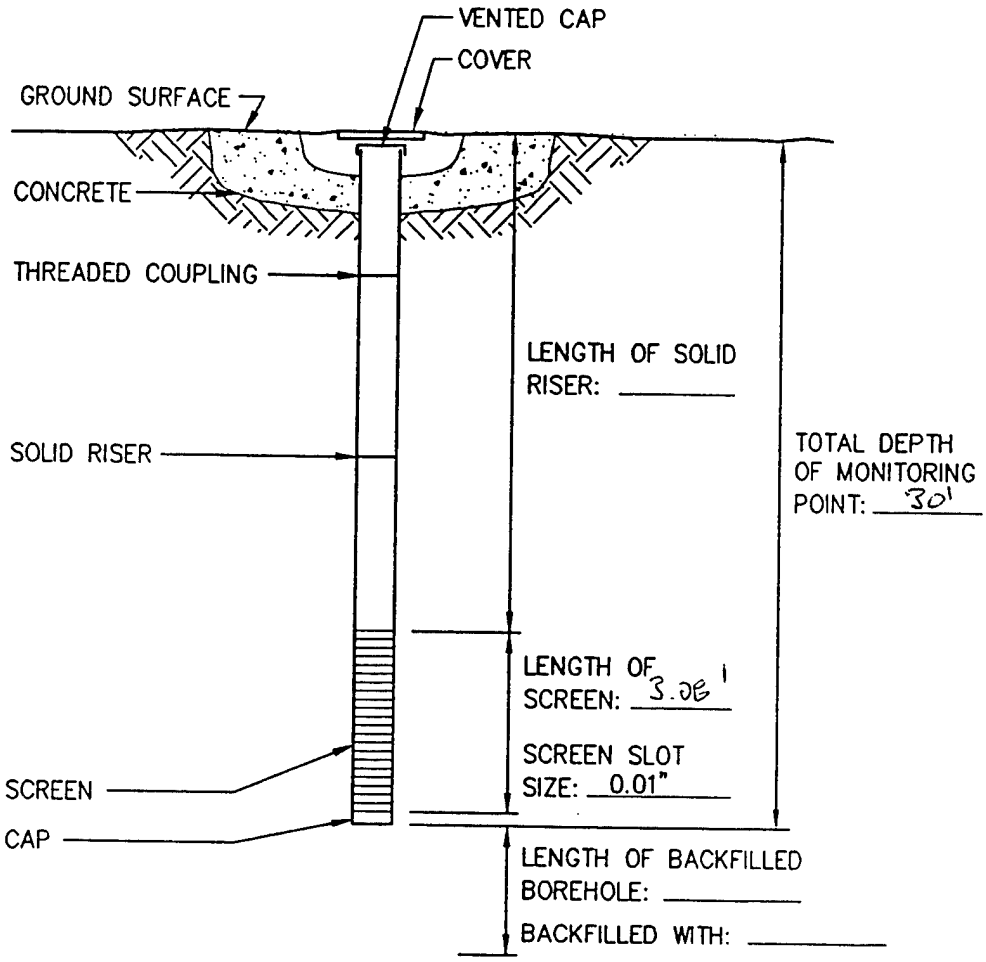
DATUM ELEVATION Ground GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT _____

SCREEN DIAMETER & MATERIAL 2" ID SLOT SIZE —

RISER DIAMETER & MATERIAL 2" ID BOREHOLE DIAMETER —

CONE PENETROMETER CONTRACTOR ACE ES REPRESENTATIVE TH.



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 30' FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER 06-1381-MPI

JOB NUMBER 729691 INSTALLATION DATE 9/20/96 LOCATION CCAS-Facility 1381

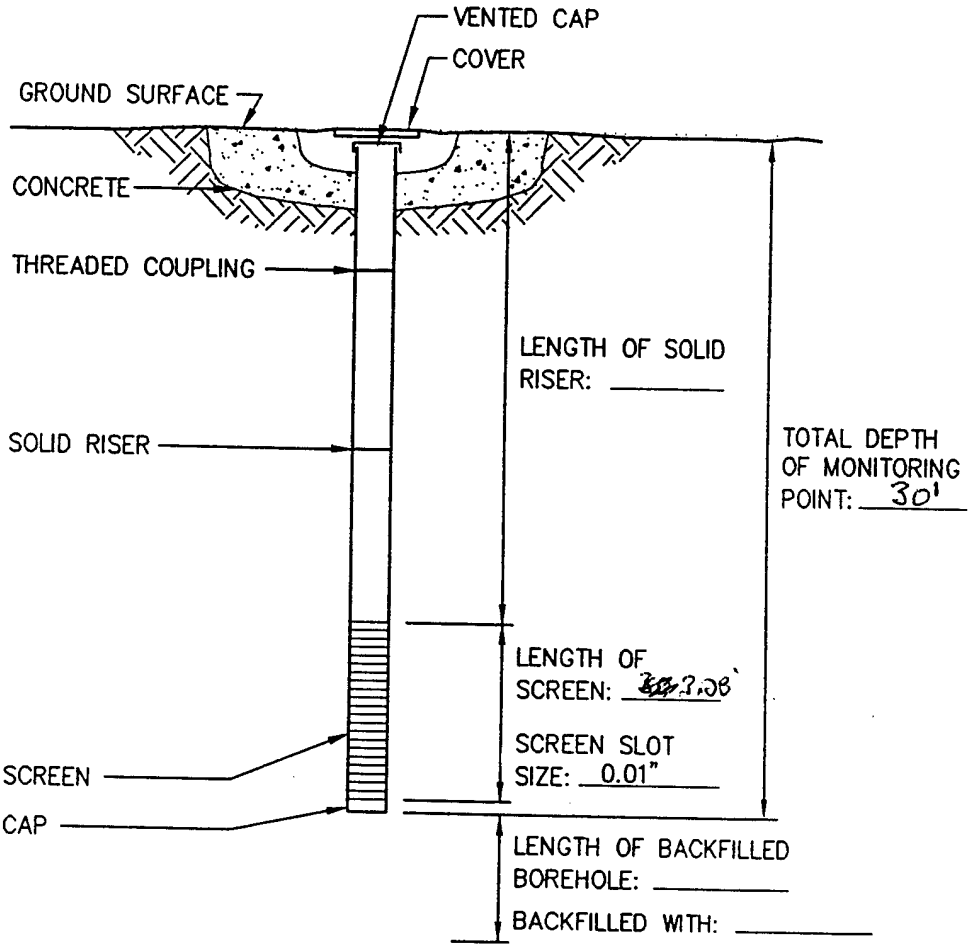
DATUM ELEVATION Ground GROUND SURFACE ELEVATION —

DATUM FOR WATER LEVEL MEASUREMENT —

SCREEN DIAMETER & MATERIAL 2"ID SLOT SIZE —

RISER DIAMETER & MATERIAL 2"ID BOREHOLE DIAMETER

CONE PENETROMETER CONTRACTOR USACE ES REPRESENTATIVE TH.



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 30' bgs FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER 07-1381-MPS

JOB NUMBER 729691 INSTALLATION DATE 9/20/96 LOCATION CCAS - Fac. 1381

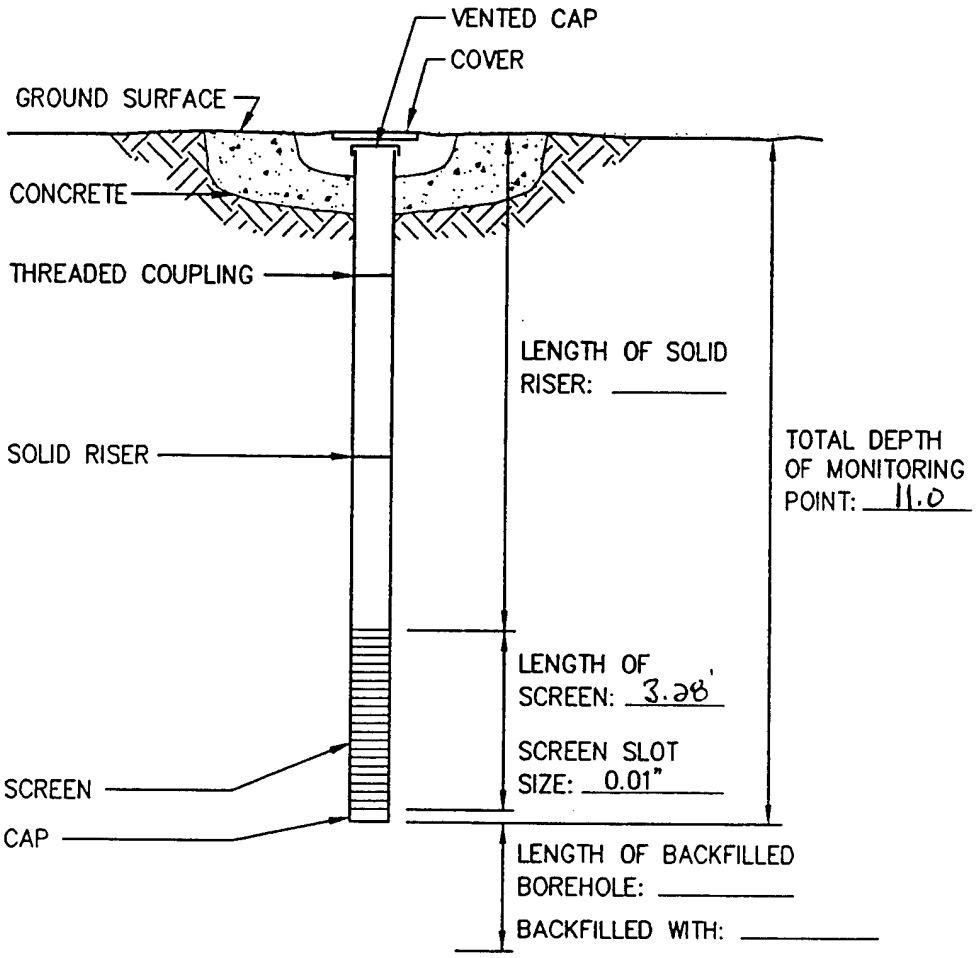
DATUM ELEVATION Ground GROUND SURFACE ELEVATION —

DATUM FOR WATER LEVEL MEASUREMENT —

SCREEN DIAMETER & MATERIAL 2" ID SLOT SIZE —

RISER DIAMETER & MATERIAL 2" ID BOREHOLE DIAMETER —

CONE PENETROMETER CONTRACTOR USACE ES REPRESENTATIVE TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 11.0' FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER 07-1381-MP1

JOB NUMBER 729691 INSTALLATION DATE 9 LOCATION CCAS-1381

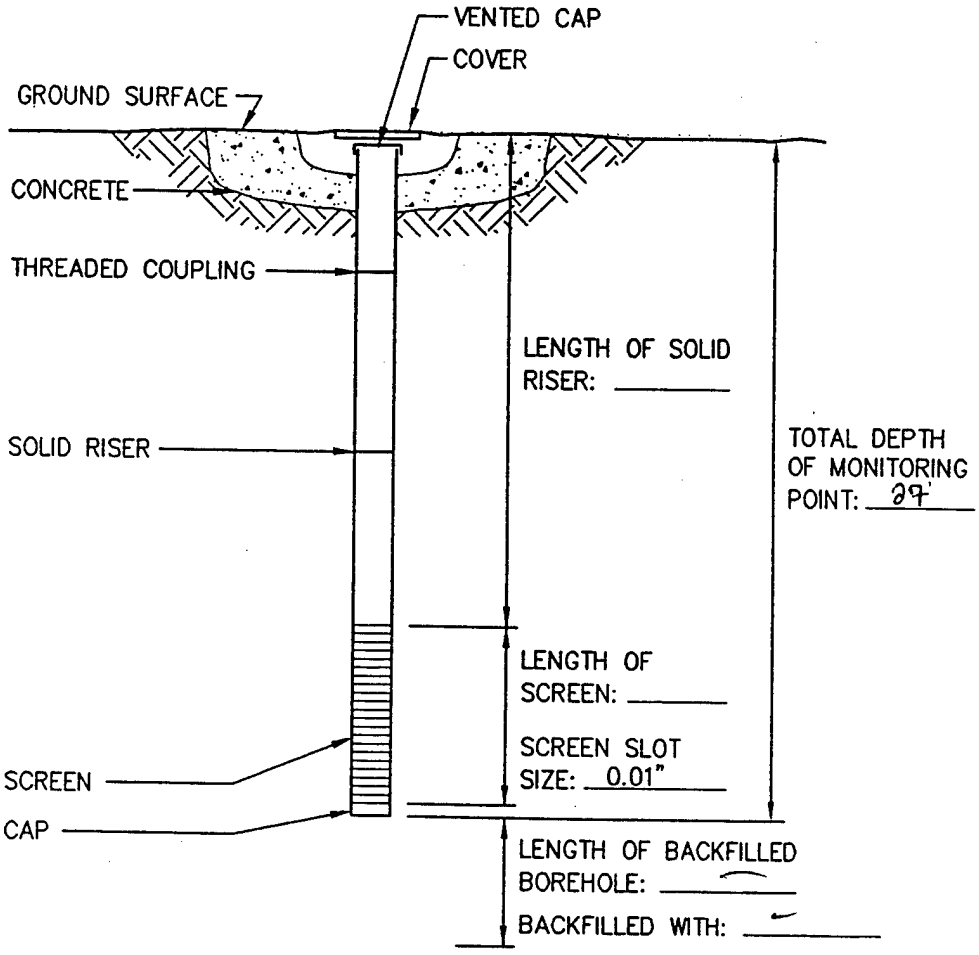
DATUM ELEVATION Ground GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT _____

SCREEN DIAMETER & MATERIAL 2" ID SLOT SIZE _____

RISER DIAMETER & MATERIAL 2"ID BOREHOLE DIAMETER —

CONE PENETROMETER CONTRACTOR USACE ES REPRESENTATIVE TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 3.08' FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER DB-1381-MPS

JOB NUMBER 729691 INSTALLATION DATE 9/20/96 LOCATION CCAS-Fac-1381

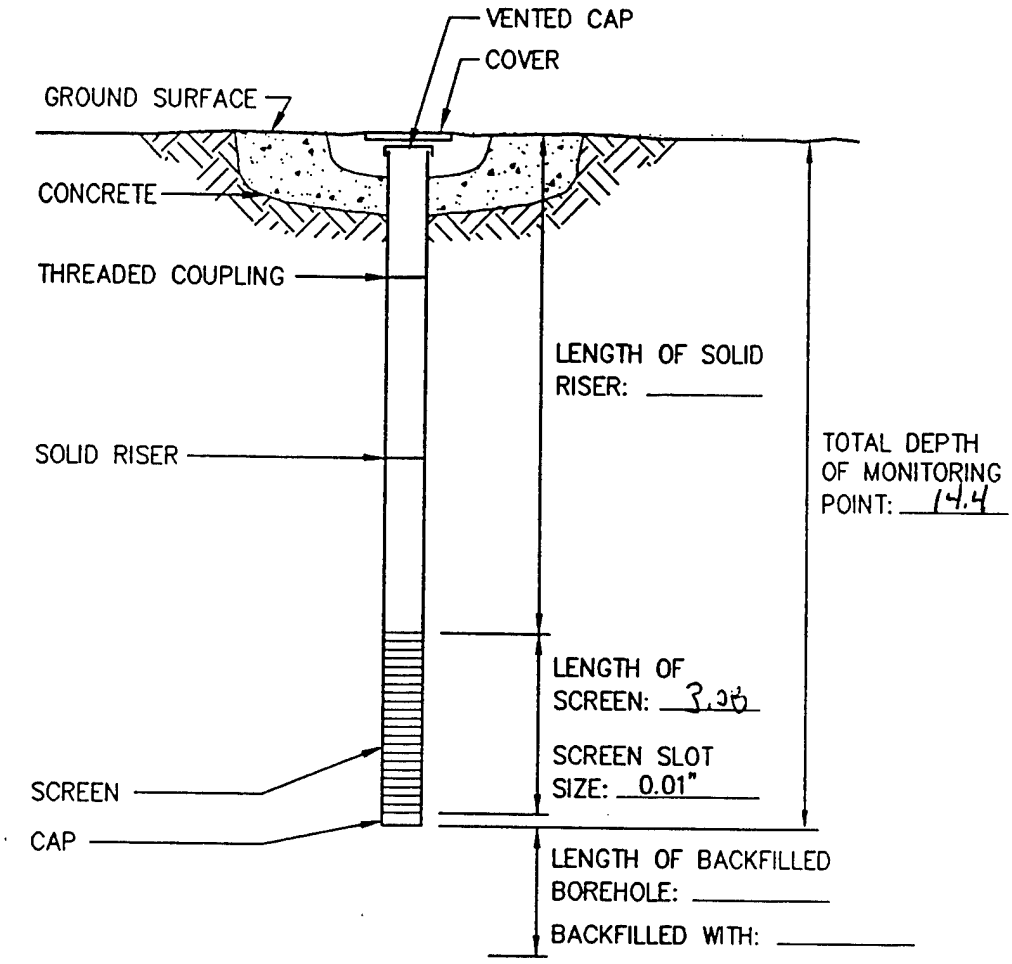
DATUM ELEVATION Ground GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT _____

SCREEN DIAMETER & MATERIAL 2" SV SLOT SIZE _____

RISER DIAMETER & MATERIAL 2" SD BOREHOLE DIAMETER _____

CONE PENETROMETER CONTRACTOR USACE ES REPRESENTATIVE TB TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 14.4 FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER 08-1381-MP1

JOB NUMBER 729691 INSTALLATION DATE 9/21/96 LOCATION CCAS-Fac. 1381

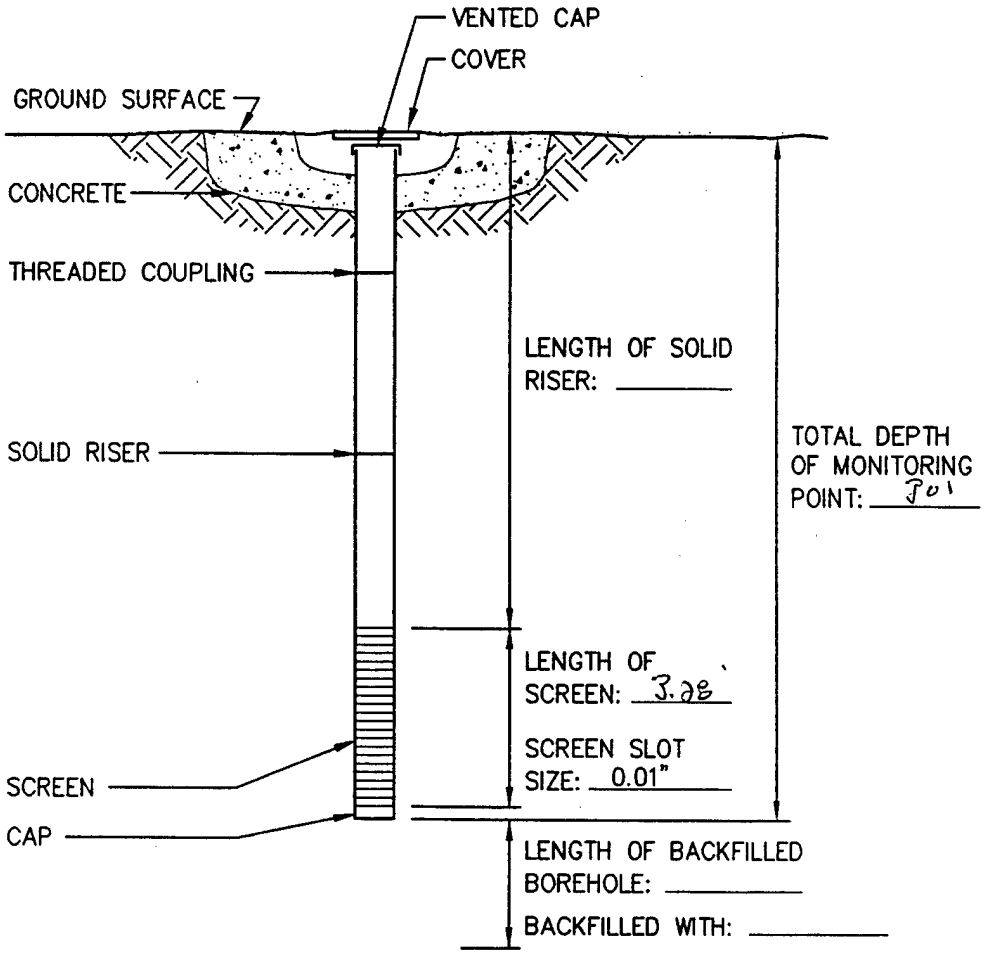
DATUM ELEVATION Ground GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT _____

SCREEN DIAMETER & MATERIAL 2"-ID SLOT SIZE _____

RISER DIAMETER & MATERIAL 0"ID BOREHOLE DIAMETER _____

CONE PENETROMETER CONTRACTOR USACE ES REPRESENTATIVE TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 30' FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER 1C-1381-MP5

JOB NUMBER 729691 INSTALLATION DATE 9/21/96 LOCATION CCAS - Fac. 1381

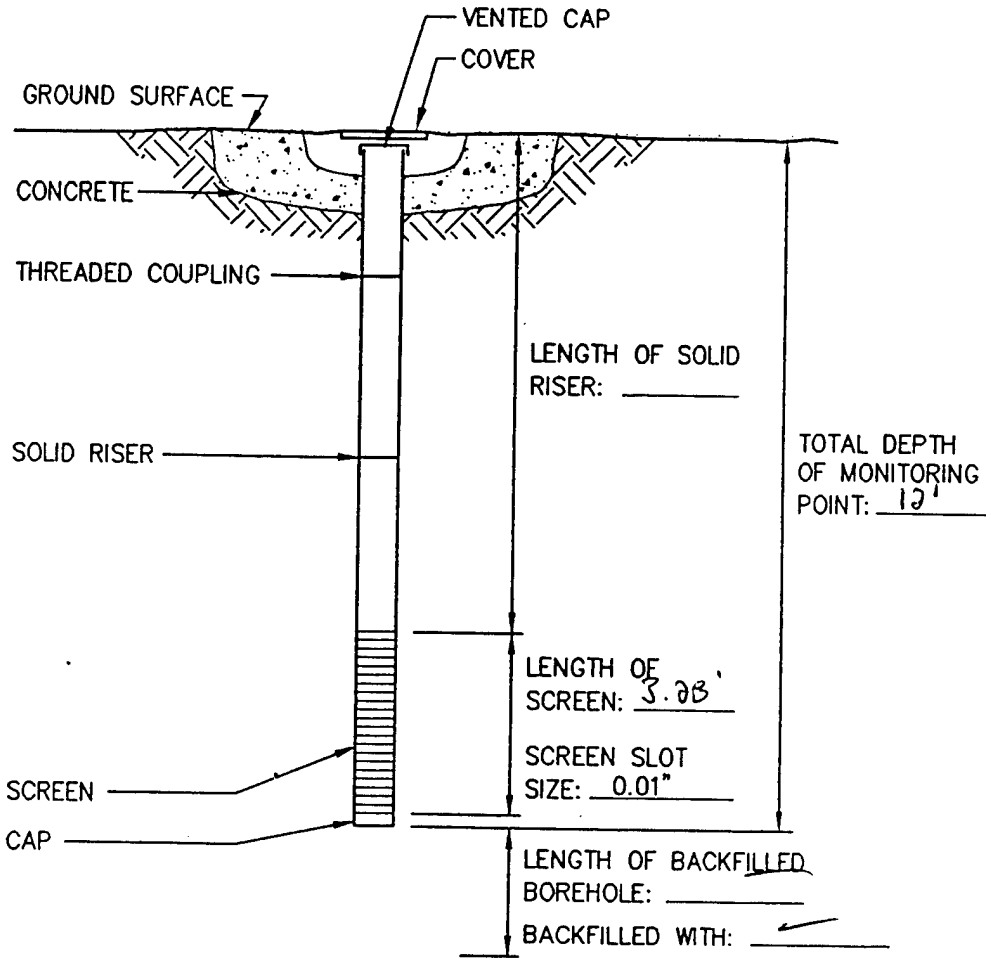
DATUM ELEVATION Ground GROUND SURFACE ELEVATION -

DATUM FOR WATER LEVEL MEASUREMENT -

SCREEN DIAMETER & MATERIAL 2" ID SLOT SIZE -

RISER DIAMETER & MATERIAL 2" ID BOREHOLE DIAMETER -

CONE PENETROMETER CONTRACTOR LABE ES REPRESENTATIVE TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH ~~3.28'~~ 13' FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER 1c-1381-MP1

JOB NUMBER 729691 INSTALLATION DATE 9/21/96 LOCATION CCAS-1341

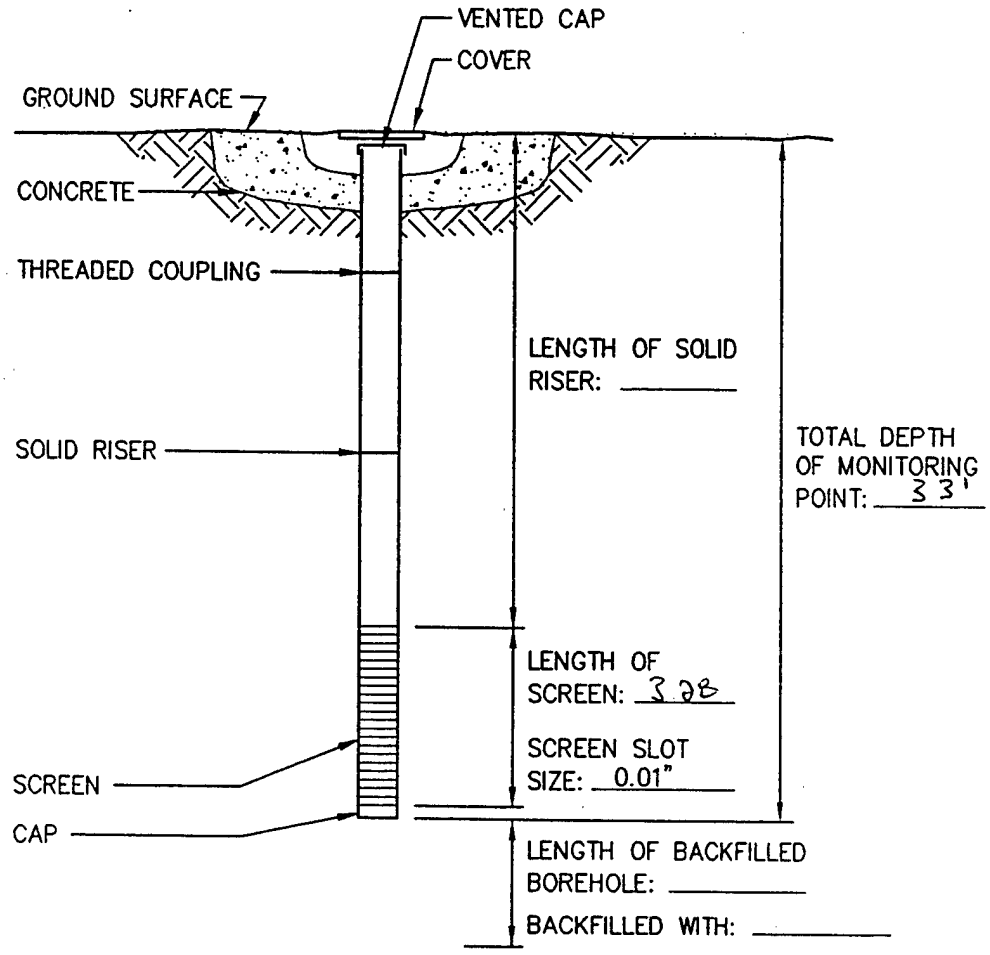
DATUM ELEVATION Ground. GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT —

SCREEN DIAMETER & MATERIAL 2" ID SLOT SIZE _____

RISER DIAMETER & MATERIAL 2" ID BOREHOLE DIAMETER _____

CONE PENETROMETER CONTRACTOR USACE ES REPRESENTATIVE TH.



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 33' FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER 11-1381-MP5

JOB NUMBER 729691 INSTALLATION DATE 9/21/96 LOCATION CCAS-1381

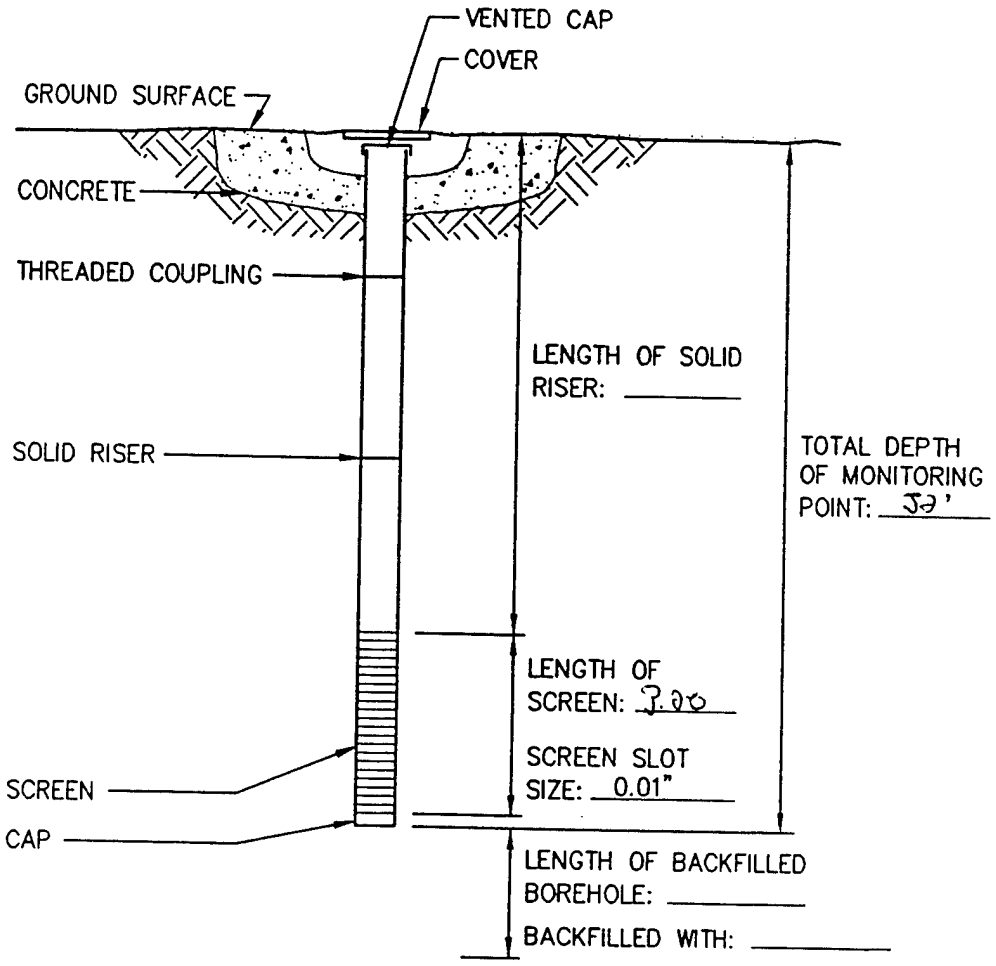
DATUM ELEVATION 6.2 msl GROUND SURFACE ELEVATION —

DATUM FOR WATER LEVEL MEASUREMENT —

SCREEN DIAMETER & MATERIAL 2" ID SLOT SIZE —

RISER DIAMETER & MATERIAL 2" ID BOREHOLE DIAMETER —

CONE PENETROMETER CONTRACTOR USACE ES REPRESENTATIVE TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 39' FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER 13-1381-MP1

JOB NUMBER 729691 INSTALLATION DATE 9/21/96 LOCATION 1381-CCAS

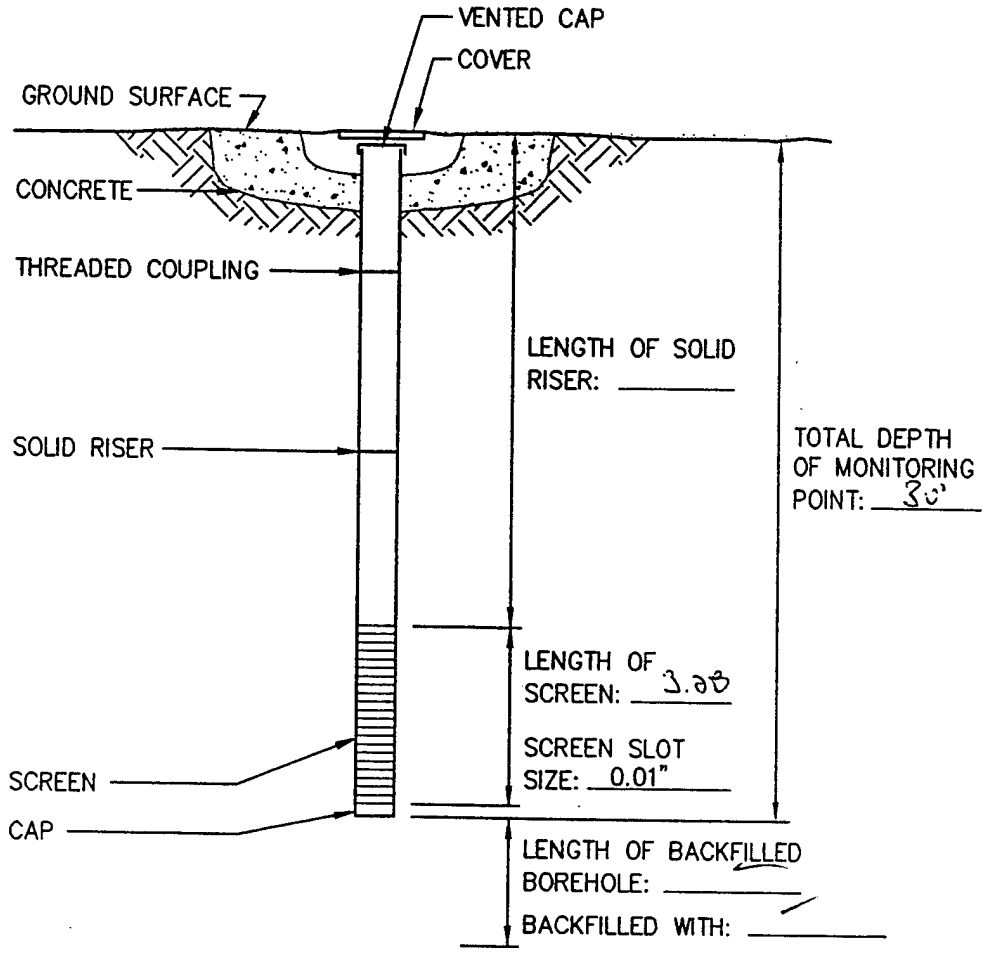
DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT _____

SCREEN DIAMETER & MATERIAL 2" ID SLOT SIZE _____

RISER DIAMETER & MATERIAL 2" ID BOREHOLE DIAMETER —

CONE PENETROMETER CONTRACTOR USACE ES REPRESENTATIVE TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 30' FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER 19-1381-MPI

JOB NUMBER 729691 INSTALLATION DATE 9/21/96 LOCATION CCAS - Facility 1381

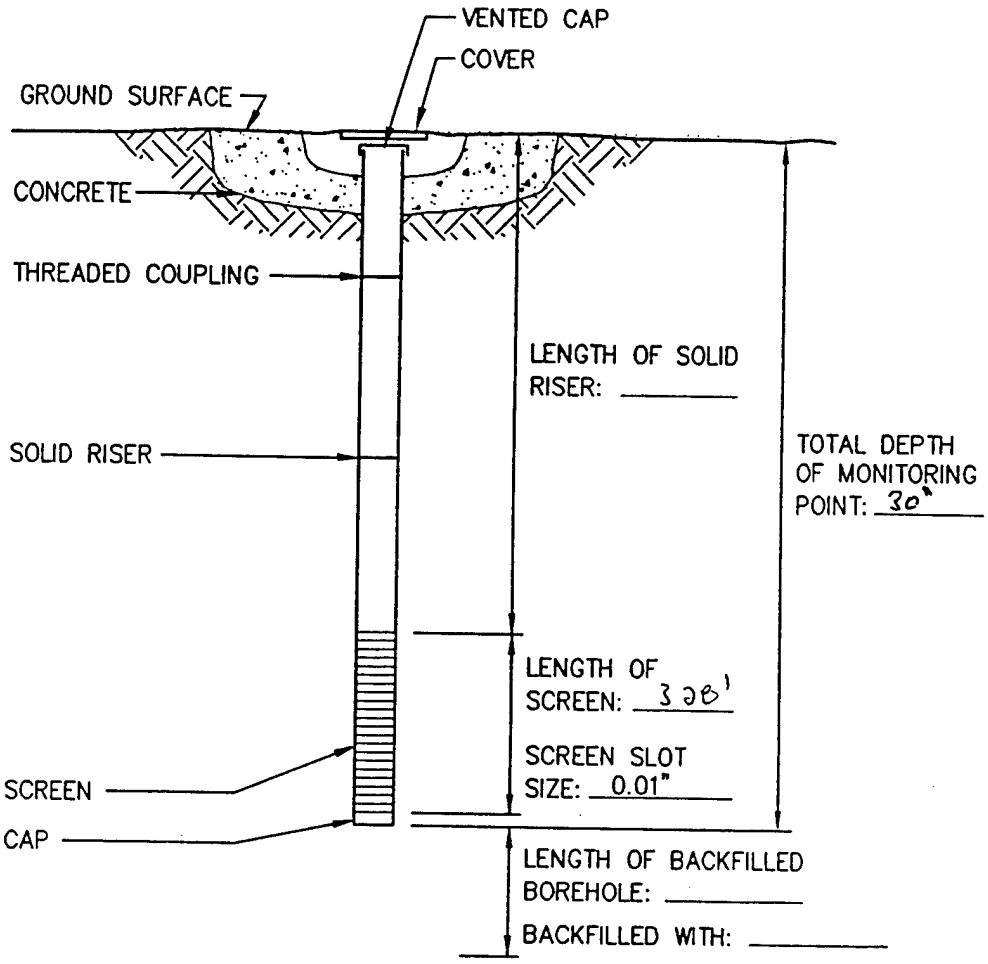
DATUM ELEVATION Ground GROUND SURFACE ELEVATION --

DATUM FOR WATER LEVEL MEASUREMENT

SCREEN DIAMETER & MATERIAL 2" ID SLOT SIZE

RISER DIAMETER & MATERIAL 2" ID BOREHOLE DIAMETER

CONE PENETROMETER CONTRACTOR USACE ES REPRESENTATIVE TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 30' FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

K:\AFCEE\729691\96DN0635, 08/27/96 at 12:23

MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER 18-1381-MW

JOB NUMBER 729691 INSTALLATION DATE 9/21/96 LOCATION B CCAS-1381

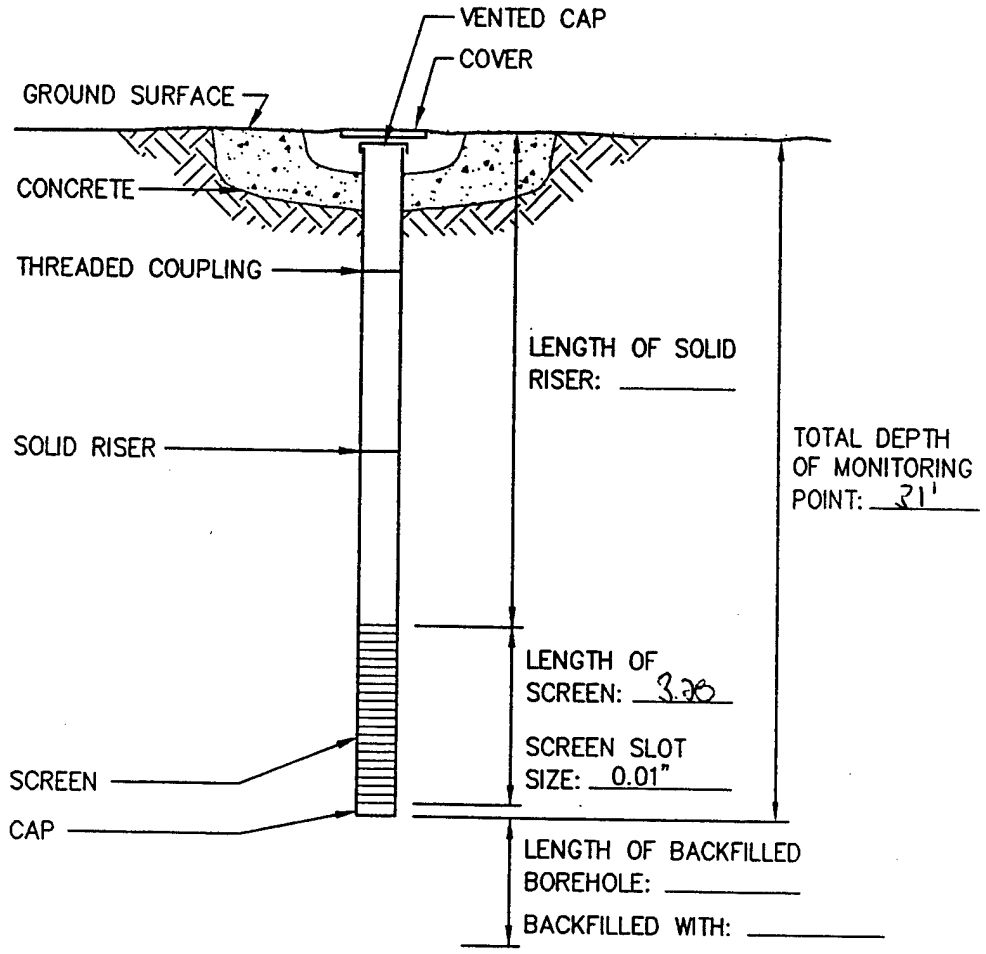
DATUM ELEVATION Ground GROUND SURFACE ELEVATION —

DATUM FOR WATER LEVEL MEASUREMENT

SCREEN DIAMETER & MATERIAL 2"ID SLOT SIZE —

RISER DIAMETER & MATERIAL 2"ID BOREHOLE DIAMETER

CONE PENETROMETER CONTRACTOR USACE ES REPRESENTATIVE TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 21' FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

K:\AFCEE\729691\96DN0635, 08/27/96 at 12:23

MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER 19-1381-MP1

JOB NUMBER 729691 INSTALLATION DATE 9/21/96 LOCATION CCAS-1381

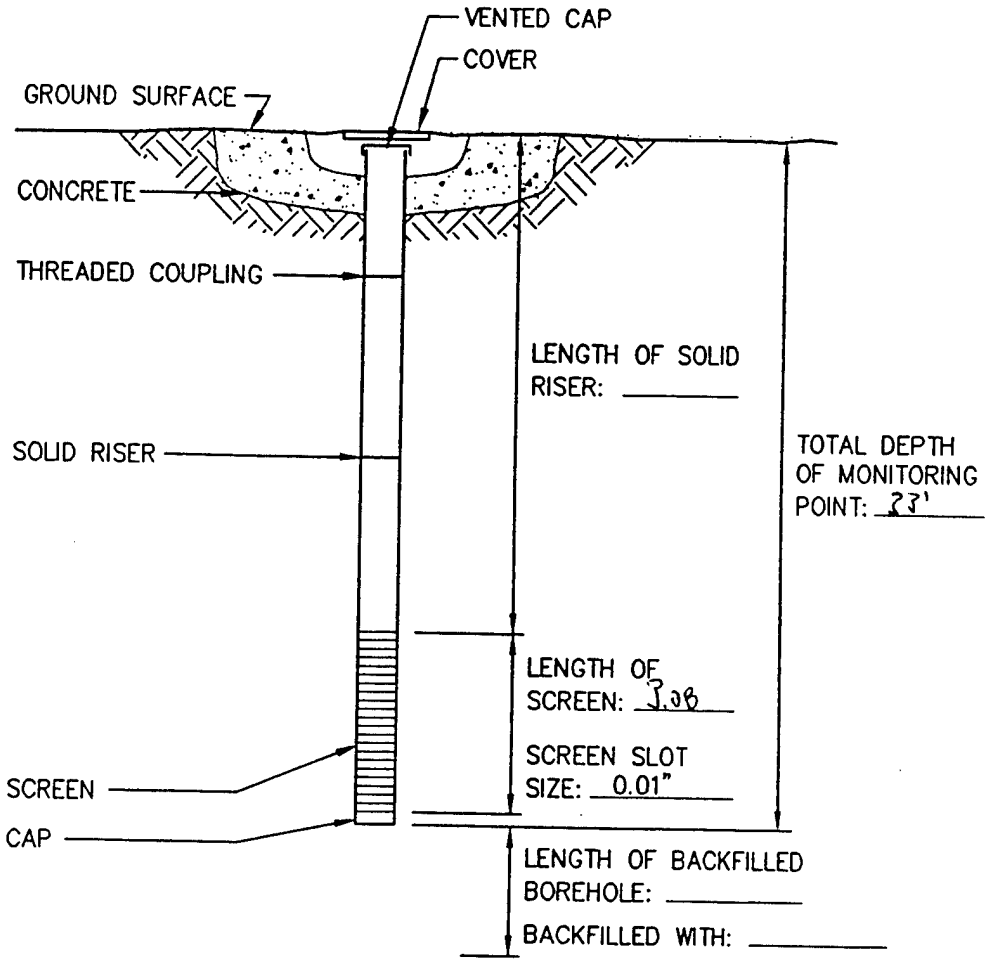
DATUM ELEVATION Ground GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT _____

SCREEN DIAMETER & MATERIAL ~~2"ID~~ 0.5"ID SLOT SIZE —

RISER DIAMETER & MATERIAL ~~2"ID~~ 0.5"ID BOREHOLE DIAMETER —

CONE PENETROMETER CONTRACTOR USACE ES REPRESENTATIVE TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 33' FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

K:\AFCEE\729691\96DN0635, 08/27/96 at 12:23

MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER 20-1381-MPI

JOB NUMBER 729691 INSTALLATION DATE 9/24/96 LOCATION CCAS-Fac. 1381

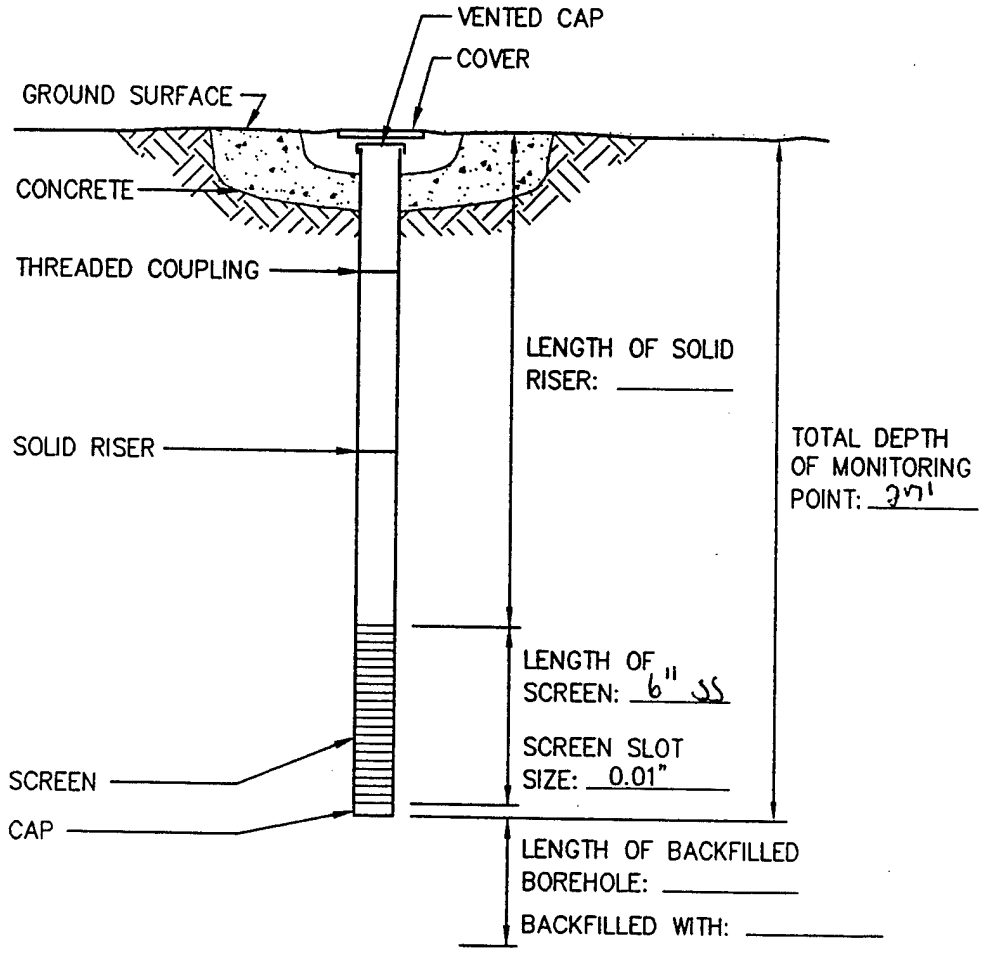
DATUM ELEVATION Ground GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT _____

SCREEN DIAMETER & MATERIAL 1/4" ID Tube 6' SS SLOT SIZE _____

RISER DIAMETER & MATERIAL 1/4" ID Tube BOREHOLE DIAMETER _____

CONE PENETROMETER CONTRACTOR USACE ES REPRESENTATIVE TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 37' FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

K:\AFCEE\729691\96DN0635, 08/27/96 at 12:23

MONITORING POINT INSTALLATION RECORD

JOB NAME FACILITY 1381 MONITORING POINT NUMBER 21-1381-MPI

JOB NUMBER 729691 INSTALLATION DATE 9/21/96 LOCATION CCAS-Fac-1381

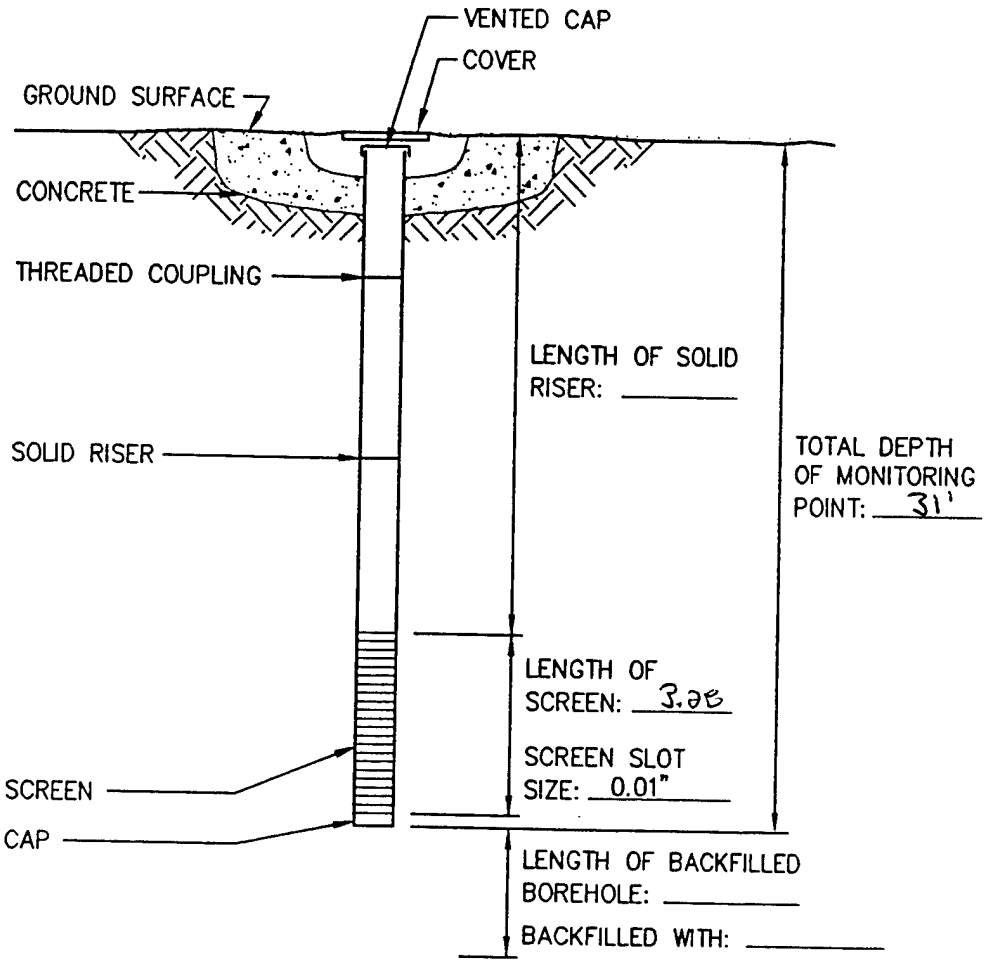
DATUM ELEVATION Ground GROUND SURFACE ELEVATION _____

DATUM FOR WATER LEVEL MEASUREMENT _____

SCREEN DIAMETER & MATERIAL 2" ID SLOT SIZE _____

RISER DIAMETER & MATERIAL 2" ID BOREHOLE DIAMETER _____

CONE PENETROMETER CONTRACTOR USACE ES REPRESENTATIVE TH



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET BELOW DATUM.

TOTAL MONITORING POINT DEPTH 31' FEET BELOW DATUM.

GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

K:\AFCEE\729691\96DN0635, 08/27/96 at 12:23

Southeastern Surveying

Gary B. Krick, P.L.S.
Roger Lonsway, P.L.S.
James L. Petersen, P.L.S.

SOUTHEASTERN SURVEYING & MAPPING CORP.

CCAFS Monitoring Points Surveyed Sept. 24 and 25, 1996

Account No. 729691.29220

Ident.	Northing	Easting	Casing	Ground
01-1381-MPS	1506560.30	796946.63	8.60	8.78
01-1381-MPI	1506558.32	796945.88	8.53	8.78
02-1381-MPI	1505618.13	796633.73	7.71	8.02
03-1381-MPI	1504583.79	797439.54	7.93	8.15
05-1381-MPI	1504201.84	797183.59	7.64	7.27
06-1381-MPI	1504377.27	797422.15	8.86	9.05
07-1381-MPI	1504857.31	796903.08	8.47	8.62
07-1381-MPS	1504856.55	796904.38	8.44	8.62
08-1381-MPS	1505008.58	796468.38	7.85	8.00
08-1381-MPI	1505007.96	796469.56	7.99	8.00
09-1381-MWS	1504278.18	797469.28	7.08	7.02
09-1381-MWI	1504272.57	797478.90	6.65	7.02
09-1381-MWD	1504275.70	797474.14	6.91	7.02
10-1381-MPI	1505420.81	799560.31	7.86	8.01
10-1381-MPS	1505421.42	799559.17	7.91	8.01
11-1381-MPI	1505374.70	798697.44	8.10	8.05
13 1381-MPI	1505438.26	798073.35	7.06	7.15
17-1381-MPI	1504636.20	797224.48	8.40	8.60
17-1381-MPS	1504627.56	797234.20	8.43	8.60
18-1381-MPI	1505733.72	797588.70	6.12	6.44
19-1381-MPI	1505998.92	798495.75	8.26	8.38
20-1381-MPI	1504101.49	797576.40	6.01	6.01
21-1381-MPI	1506631.68	798857.52	6.97	7.25
			Surface/Bottom	
SURA/SEDA	1506802.27	798904.64	1.73/0.73	
SURB/SEDB	1506815.04	799698.45	1.71/0.71	
SURC/SEDC	1506820.44	797875.20	1.36/0.36	
SURD/SEDD	1504989.95	796439.41	1.85/0.85	
SURE/SEDE	1504232.38	797193.63	1.95/0.95	
SURF/SEDF	1503735.84	797717.46	2.04/1.04	
			Casing	Ground
01-1381-SB	1505014.78	796461.61		8.00
02-1381-SB	1504201.95	797183.53		7.27
03-1381-SB	1504103.66	797575.36		5.98
04-1381-SB	1505376.77	798694.26		8.05
01-1381-PRMP	1504644.76	797392.05		6.41
02-1381-PRMP	1504728.36	797444.07	6.76	5.73

Account No. 729807.01

44501MWS03	1511522.98	792371.16	8.64	9.18

Account No. 727576.05

INDAMWDD16	1511748.40	790829.94	7.83	8.12
1798MWS04	1513210.88	789691.07	11.40	8.39

925 South Semoran Boulevard, Suite 112 Winter Park, Florida 32792 407/678-8729 Fax 407/679-3437

Southeastern Surveying

SOUTHEASTERN SURVEYING & MAPPING CORP.

Gary B. Krick, P.L.S.
Roger Lonsway, P.L.S.
James L. Petersen, P.L.S.

CCAFS Monitoring Points Surveyed Sept. 24 and 25, 1996

Account No. 729691.29220

Ident.	Northing	Easting	Casing	Ground
01-1381-MPS	1506560.30	796946.63	8.60	8.78
01-1381-MPI	1506558.32	796945.88	8.53	8.78
02-1381-MPI	1505618.13	796633.73	7.71	8.02
03-1381-MPI	1504583.79	797439.54	7.93	8.15
05-1381-MPI	1504201.84	797183.59	7.64	7.27
06-1381-MPI	1504377.27	797422.15	8.86	9.05
07-1381-MPI	1504857.31	796903.08	8.47	8.62
07-1381-MPS	1504856.55	796904.38	8.44	8.62
08-1381-MPS	1505008.58	796468.38	7.85	8.00
08-1381-MPI	1505007.96	796469.56	7.99	8.00
09-1381-MWS	1504278.18	797469.28	7.08	7.02
09-1381-MWI	1504272.57	797478.90	6.65	7.02
09-1381-MWD	1504275.70	797474.14	6.91	7.02
10-1381-MPI	1505420.81	799560.31	7.86	8.01
10-1381-MPS	1505421.42	799559.17	7.91	8.01
11-1381-MPI	1505374.70	798697.44	8.10	8.05
13 1381-MPI	1505438.26	798073.35	7.06	7.15
17-1381-MPI	1504636.20	797224.48	8.40	8.60
17-1381-MPS	1504627.56	797234.20	8.43	8.60
18-1381-MPI	1505733.72	797588.70	6.12	6.44
19-1381-MPI	1505998.92	798495.75	8.26	8.38
20-1381-MPI	1504101.49	797576.40	6.01	6.01
21-1381-MPI	1506631.68	798857.52	6.97	7.25
			Surface/Bottom	
SURA/SEDA	1506802.27	798904.64	1.73/0.73	
SURB/SEDB	1506815.04	799698.45	1.71/0.71	
SURC/SEDC	1506820.44	797875.20	1.36/0.36	
SURD/SEDD	1504989.95	796439.41	1.85/0.85	
SURE/SEDE	1504232.38	797193.63	1.95/0.95	
SURF/SEDF	1503735.84	797717.46	2.04/1.04	
			Casing	Ground
01-1381-SB	1505014.78	796461.61		8.00
02-1381-SB	1504201.95	797183.53		7.27
03-1381-SB	1504103.66	797575.36		5.98
04-1381-SB	1505376.77	798694.26		8.05
01-1381-PRMP	1504644.76	797392.05		6.41
02-1381-PRMP	1504728.36	797444.07	6.76	5.73

Account No. 729807.01

44501MWS03	1511522.98	792371.16	8.64	9.18

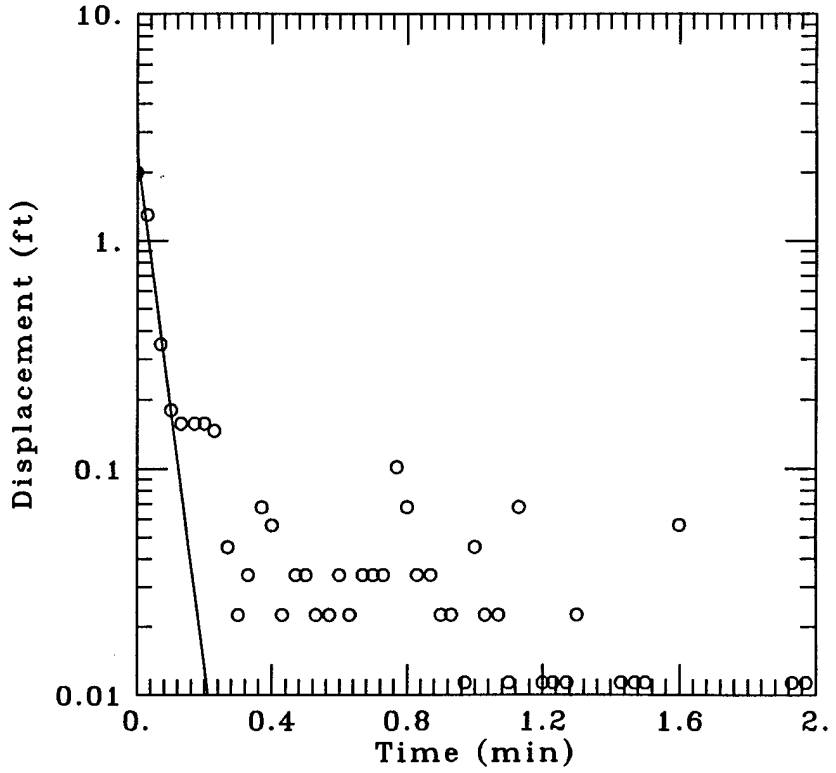
Account No. 727576.05

INDAMWDD16	1511748.40	790829.94	7.83	8.12
1798MWS04	1513210.88	789691.07	11.40	8.39

Please

925 South Semoran Boulevard, Suite 112 Winter Park, Florida 32792 407/678-8729 Fax 407/679-3437

ccas-well cc-09s rising head test 1



DATA SET:

10/04/96

AQUIFER TYPE:

Unconfined

SOLUTION METHOD:

Bouwer-Rice

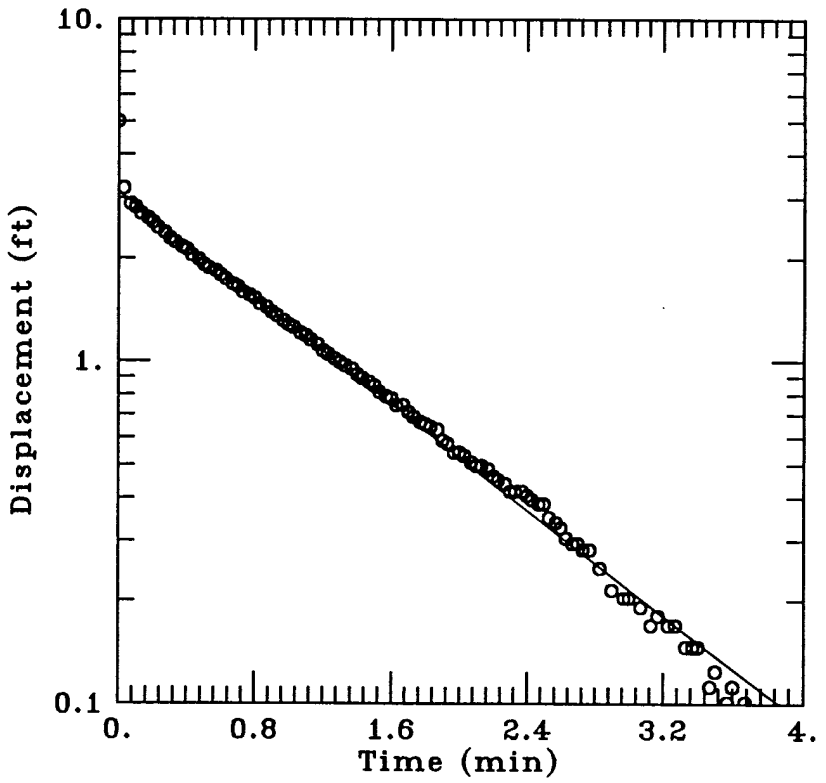
ESTIMATED PARAMETERS:

K = 0.008038 ft/min
y0 = 2.387 ft

TEST DATA:

H0 = 2. ft
rc = 0.083 ft
rw = 0.33 ft
L = 10. ft
b = 10. ft
H = 1. ft

ccas-well cc-09i rising head test 1



DATA SET:

10/04/96

AQUIFER TYPE:

Unconfined

SOLUTION METHOD:

Bouwer Rice

ESTIMATED PARAMETERS:

K = 0.0002249 ft/min

y0 = 3.123 ft

TEST DATA

H0 = 5 ft

rc = 0.083 ft

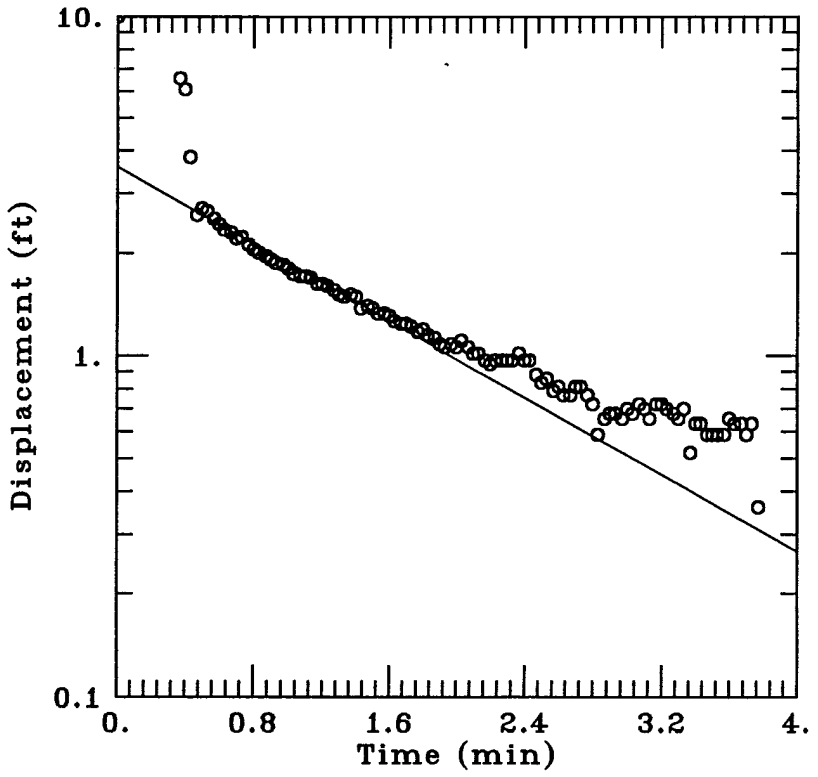
rw = 0.33 ft

L = 10 ft

b = 10 ft

n = 1 ft

ccas–well cc–09d rising head test 1



DATA SET:

10/04/96

AQUIFER TYPE

Unconfined

SOLUTION METHOD

Bouwer-Rice

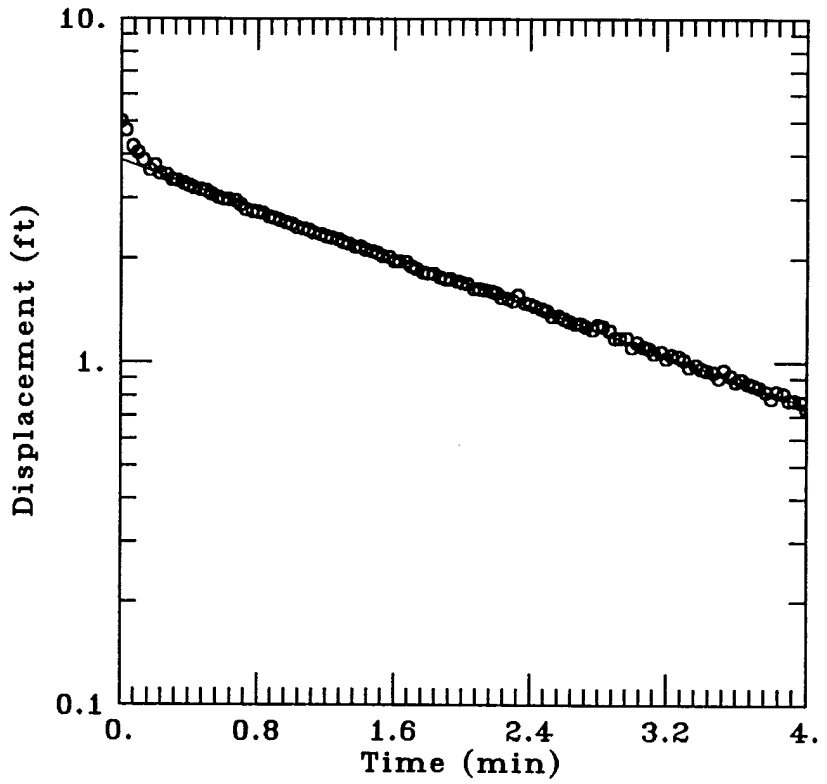
ESTIMATED PARAMETERS:

K = 0.0002004 ft/min
y0 = 3.588 ft

TEST DATA

H0 = 10 ft
rc = 0.083 ft
rw = 0.33 ft
L = 10 ft
b = 10 ft
H = 1 ft

ccas-well cc-12d rising head test 1



DATA SET

10/04/96

AQUIFER TYPE

Unconfined

SOLUTION METHOD

Bouwer Rice

ESTIMATED PARAMETERS

K = 0.0001264 ft/min

y0 = 3.82 ft

TEST DATA

H0 = 5 ft

rc = 0.083 ft

rw = 0.33 ft

L = 10 ft

b = 10 ft

n = 1 ft

APPENDIX B

LABORATORY ANALTYICAL DATA

MANTECH

Ref: 96-SH102/vg

October 8, 1996

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection & Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Don:

Attached are TOC results for 37 Cape Canaveral liquids submitted October 1, 1996 under Service Request #SF-2-233. Sample analysis was begun October 1, 1996 and completed October 7, 1996 using RSKSOP-102.

Blanks, duplicates, and AQC samples were analyzed along with your samples, as appropriate, for quality control. If you have any questions concerning this data, please feel free to ask me.

Sincerely,

Sharon Hightower

Sharon Hightower

xc: R.L. Cosby
G.B. Smith
J.L. Seeley SV for

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

MANTECH ENVIRONMENTAL TECHNOLOGY

Ref: 96-NV157/vg

October 16, 1996

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection & Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: J.L. Seeley SVFor

Dear Don:

Attached is the metal analysis report (4592.LST) for 12 samples (Cape Canaveral) submitted to MERSC as part of Service Request #71 under EPA Contract #68-C3-0322. The samples were received on October 2, 1996 and analyzed October 3 and 8, 1996. The samples did not receive any further treatment and they were analyzed using the ICAP system. Lead was determined by GF-AAS and results can be found in report Pb61008.Lis;1. SOP for the ICP GF-AAS and sample calculations were according to the procedure and instructions provided by Mr. Don Clark.

If you have any questions, please feel free to contact me.

Sincerely,

Nohora Vela

Nohora Vela

xc: R.L. Cosby
R. Puls
J.T. Wilson

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

ELEMENTAL CONCENTRATION ANALYSIS BY: ICAP (DATA.DAT)

THIS REPORT (USER$DISK:[CLARK.ICAP]LIST[illegible], WAS GENERATED FROM USER$DISK:[CLARK.ICAP]OUTPUT[illegible].

PROJECT: AQUEOUS FILTERED SAMPLES. DIRECT READING. CAPE CANAVERAL
KAMBELL
SR71

CONCENTRATION IN: MG/L

TAG NO.	15104		15105		15106		15107		
STATION	1381 MW D01		1381 MW S09		1381 MW S05		1381 MW S07		
TIME	12:52		12:39		12:42		12:44		
DATE	03-OCT-96		03-OCT-96		03-OCT-96		03-OCT-96		
PR DIL	1.0000		1.0000		1.0000		1.0000		
DIL	1.0000		1.0000		1.0000		1.0000		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	609.	59.	124.	12.	167.	16.	30.3	3.0	0.1311
K	64.5	6.5	2.12	0.84	9.22	0.84	<0.84	0.84	0.8499
Ca	31.2	3.1	148.	14.	110.	11.	109.	10.	0.0216
Mg	80.0	8.0	22.7	2.2	21.4	2.1	8.89	0.88	0.0582
Fe	0.039	0.025	1.87	0.18	<0.024	0.024	0.495	0.050	0.0249
Mn	<0.012	0.012	0.134	0.014	<0.012	0.012	0.034	0.012	0.0120
Co	<0.0030	0.0030	<0.0030	0.0030	<0.0030	0.0030	<0.0030	0.0030	0.0030
Mo	<0.019	0.019	<0.019	0.019	<0.019	0.019	<0.019	0.019	0.0196
Al	<0.083	0.083	<0.083	0.083	<0.083	0.083	<0.083	0.083	0.0838
As	<0.011	0.011	<0.011	0.011	<0.011	0.011	<0.011	0.011	0.0112
Se	<0.021	0.021	<0.021	0.021	<0.021	0.021	<0.021	0.021	0.0215
Cd	<0.0011	0.0011	<0.0011	0.0011	<0.0011	0.0011	<0.0011	0.0011	0.0011
Be	<0.0012	0.0012	<0.0017	0.0017	<0.0015	0.0015	<0.0015	0.0015	0.0012
Cu	<0.0071	0.0071	<0.0071	0.0071	<0.0071	0.0071	<0.0071	0.0071	0.0071
Cr	<0.0013	0.0013	<0.0013	0.0013	<0.0013	0.0013	<0.0013	0.0013	0.0013
Ni	<0.0045	0.0045	<0.0045	0.0045	<0.0045	0.0045	<0.0045	0.0045	0.0045
Zn	0.0020	0.0010	0.0022	0.0009	0.0027	0.0009	<0.0009	0.0009	0.0009
Ag	<0.0077	0.0077	<0.0078	0.0078	<0.0078	0.0078	<0.0078	0.0078	0.0077
Tl	<0.014	0.014	<0.014	0.014	<0.014	0.014	<0.014	0.014	0.0148
Pb	<0.016	0.016	<0.016	0.016	<0.016	0.016	<0.016	0.016	0.0160
Sr	0.763	0.077	1.96	0.19	1.44	0.14	1.58	0.15	0.0007
V	<0.027	0.027	<0.027	0.027	<0.027	0.027	<0.027	0.027	0.0274
Ba	0.0050	0.0019	0.0024	0.0019	0.0022	0.0019	<0.0019	0.0019	0.0019
B	1.12	0.11	0.251	0.025	0.483	0.048	0.0809	0.0082	0.0057
Ti	<0.0023	0.0024	<0.0024	0.0024	<0.0029	0.0029	<0.0023	0.0023	0.0023

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

ELEMENTAL CONSTITUENTS ANALYSIS BY: ICAP (DATA.DAT)
THIS REPORT (USER$DISK:[CLARK.ICAP]LIST.LST;4592) WAS GENERATED FROM USER$DISK:[CLARK.ICAP]OUTPUT.DAT;3134

PROJECT: AQUEOUS FILTERED SAMPLES. DIRECT READING. CAPE CANAVERAL
KAMBELL
SR71

CONCENTRATION IN: MG/L

TAG NO.	15108		15109		15110		15111		
STATION	1381 MW S11		1381 MP I01		1381 MW S16		1381 MP S07		
TIME	12:47		12:50		13:23		13:02		
DATE	03-OCT-96		03-OCT-96		03-OCT-96		03-OCT-96		
PR DIL	1.0000		1.0000		1.0000		1.0000		
DIL	1.0000		1.0000		1.0000		1.0000		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	63.6	6.3	421.	42.	16.0	1.6	27.6	2.7	0.1311
K	7.12	0.84	35.4	3.4	<0.84	0.84	1.10	0.84	0.8499
Ca	215.	21.	27.8	2.7	98.1	9.9	101.	10.	0.0216
Mg	28.0	2.8	58.8	5.8	6.06	0.61	6.88	0.68	0.0582
Fe	7.57	0.75	<0.025	0.025	<0.024	0.024	0.477	0.048	0.0249
Mn	0.076	0.012	<0.012	0.012	<0.012	0.012	0.018	0.012	0.0120
Co	<0.0030	0.0030	<0.0030	0.0030	<0.0030	0.0030	<0.0030	0.0030	0.0030
Mo	<0.019	0.019	<0.019	0.019	<0.019	0.019	<0.019	0.019	0.0196
Al	<0.083	0.083	<0.083	0.083	<0.083	0.083	<0.083	0.083	0.0838
As	<0.011	0.011	<0.011	0.011	<0.011	0.011	<0.011	0.011	0.0112
Se	<0.022	0.022	<0.021	0.021	<0.021	0.021	<0.021	0.021	0.0215
Cd	<0.0011	0.0011	<0.0011	0.0011	<0.0011	0.0011	<0.0011	0.0011	0.0011
Be	<0.0021	0.0021	<0.0012	0.0012	<0.0014	0.0014	<0.0014	0.0014	0.0012
Cu	<0.0072	0.0072	<0.0071	0.0071	<0.0071	0.0071	<0.0071	0.0071	0.0071
Cr	0.0030	0.0013	<0.0013	0.0013	<0.0013	0.0013	<0.0013	0.0013	0.0013
Ni	<0.0045	0.0045	<0.0045	0.0045	<0.0045	0.0045	<0.0045	0.0045	0.0045
Zn	0.0063	0.0011	0.0013	0.0010	0.0011	0.0009	<0.0009	0.0009	0.0009
Ag	<0.0078	0.0078	<0.0077	0.0077	<0.0078	0.0078	<0.0078	0.0078	0.0077
Tl	<0.014	0.014	<0.014	0.014	<0.014	0.014	<0.014	0.014	0.0148
Pb	<0.016	0.016	<0.016	0.016	<0.016	0.016	<0.016	0.016	0.0160
Sr	2.96	0.29	0.351	0.035	1.12	0.11	1.14	0.11	0.0007
V	<0.027	0.027	<0.027	0.027	<0.027	0.027	<0.027	0.027	0.0274
Ba	0.0035	0.0020	0.0062	0.0019	0.0028	0.0019	0.0029	0.0019	0.0019
B	1.14	0.11	1.12	0.11	0.0413	0.0057	0.117	0.011	0.0057
Ti	<0.0024	0.0024	<0.0023	0.0023	<0.0023	0.0023	<0.0023	0.0023	0.0023

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

ELEMENTAL CON[redacted]UE ANALYSIS BY: ICAP (DATA.DAT)
THIS REPORT (USER$DISK:[CLARK.ICAP]LIST.[redacted]92, WAS GENERATED FROM USER$DISK:[CLARK.ICAP]OUTPUT.D[redacted]84

PROJECT: AQUEOUS FILTERED SAMPLES. DIRECT READING. CAPE CANAVERAL
KAMBELL
SR71

CONCENTRATION IN: MG/L

TAG NO.	15112		15113		15114		15115		
STATION	1381 MP S08		1381 MP I06		1381 MP I21		1381 MP S10		
TIME	13:05		13:07		13:10		13:20		
DATE	03-OCT-96		03-OCT-96		03-OCT-96		03-OCT-96		
PR DIL	1.0000		1.0000		1.0000		5.0000		
DIL	1.0000		1.0000		1.0000		1.0000		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	136.	13.	878.	87.	835.	83.	1200.	120.	0.1311
K	13.9	1.3	50.5	4.9	50.6	4.9	52.0	4.7	0.8499
Ca	112.	11.	23.9	2.3	25.5	2.5	23.0	2.3	0.0216
Mg	37.1	3.7	98.1	9.8	99.6	9.9	127.	12.	0.0582
Fe	1.72	0.17	0.025	0.025	0.025	0.025	<0.12	0.12	0.0249
Mn	0.012	0.012	<0.012	0.012	<0.012	0.012	<0.060	0.060	0.0120
Co	<0.0030	0.0030	<0.0030	0.0030	<0.0030	0.0030	<0.014	0.014	0.0030
Mo	<0.019	0.019	<0.019	0.019	<0.019	0.019	<0.098	0.098	0.0196
Al	<0.083	0.083	<0.083	0.083	<0.083	0.083	<0.41	0.41	0.0838
As	<0.011	0.011	<0.011	0.011	<0.011	0.011	<0.056	0.056	0.0112
Se	<0.021	0.021	<0.021	0.021	<0.021	0.021	<0.10	0.10	0.0215
Cd	<0.0011	0.0011	0.0017	0.0011	<0.0011	0.0011	<0.0056	0.0056	0.0011
Be	<0.0015	0.0015	<0.0012	0.0012	<0.0012	0.0012	<0.0059	0.0059	0.0012
Cu	<0.0071	0.0071	<0.0071	0.0071	<0.0071	0.0071	<0.035	0.035	0.0071
Cr	<0.0013	0.0013	0.0016	0.0013	<0.0013	0.0013	0.0191	0.0063	0.0013
Ni	<0.0045	0.0045	<0.0045	0.0045	<0.0045	0.0045	<0.022	0.022	0.0045
Zn	0.0049	0.0009	0.0016	0.0010	0.0015	0.0010	0.0450	0.0056	0.0009
Ag	<0.0078	0.0078	<0.0077	0.0077	<0.0077	0.0077	<0.038	0.038	0.0077
Tl	<0.014	0.014	<0.014	0.014	<0.014	0.014	<0.074	0.074	0.0148
Pb	<0.016	0.016	<0.016	0.016	<0.016	0.016	<0.080	0.080	0.0160
Sr	1.55	0.15	0.385	0.038	0.411	0.041	0.383	0.038	0.0007
V	<0.027	0.027	<0.027	0.027	<0.027	0.027	<0.13	0.13	0.0274
Ba	0.0058	0.0019	0.0066	0.0020	0.0063	0.0020	<0.0095	0.0095	0.0019
B	0.334	0.033	2.21	0.22	1.76	0.17	2.39	0.24	0.0057
Ti	<0.0023	0.0023	<0.0026	0.0026	<0.0027	0.0027	<0.011	0.011	0.0023

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

ELEMENTAL CONSTITUENTS ANALYSIS BY: ICAP (DATA.DAT)
THIS REPORT (USER$DISK:[CLARK.ICAP]LIST.LST;4592) WAS GENERATED FROM USER$DISK:[CLARK.ICAP]OUTPUT.DAT;3134

PROJECT: AQUEOUS FILTERED SAMPLES. DIRECT READING. CAPE CANAVERAL
KAMBELL
SR71

CONCENTRATION IN: MG/L

TAG NO.	ZSTD5		IECCHK2		
STATION	----------		----------		
TIME	15:17		15:20		
DATE	03-OCT-96		03-OCT-96		
PR DIL	1.0000		1.0000		
DIL	1.0000		1.0000		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	<0.13	0.13	<0.13	0.13	0.1311
K	<0.85	0.85	<0.85	0.85	0.8499
Ca	0.023	0.021	307.	30.	0.0216
Mg	<0.26	0.26	265.	26.	0.0582
Fe	102.	10.	<0.026	0.026	0.0249
Mn	103.	10.	<0.013	0.013	0.0120
Co	<0.0030	0.0030	<0.013	0.013	0.0030
Mo	<0.019	0.019	<0.019	0.019	0.0196
Al	103.	10.	<0.15	0.15	0.0838
As	<0.20	0.20	<0.035	0.035	0.0112
Se	<0.11	0.11	<0.021	0.021	0.0215
Cd	0.0024	0.0011	<0.0012	0.0012	0.0011
Be	0.0040	0.0012	<0.0073	0.0073	0.0012
Cu	<0.0082	0.0082	<0.016	0.016	0.0071
Cr	<0.0015	0.0015	0.0053	0.0014	0.0013
Ni	0.0071	0.0045	<0.0046	0.0046	0.0045
Zn	0.0019	0.0017	0.0060	0.0036	0.0009
Ag	<0.0081	0.0081	<0.034	0.034	0.0077
Tl	<0.049	0.049	1.6	1.1	0.0148
Pb	<0.058	0.058	<0.017	0.017	0.0160
Sr	<0.0007	0.0007	0.0010	0.0007	0.0007
V	<0.027	0.027	19.7	1.9	0.0274
Ba	<0.0019	0.0019	0.0112	0.0024	0.0019
B	<0.0083	0.0083	<0.0077	0.0077	0.0057
Ti	<0.0023	0.0023	46.9	4.7	0.0023

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

ELEMENTAL CONS[redacted]E1 ANALYSIS BY: ICAP (DATA.DAT)
THIS REPORT (USER$DISK:[CLARK.ICAP]LIST.L[redacted]92) WAS GENERATED FROM USER$DISK:[CLARK.ICAP]OUTPUT.DA[redacted]4

PROJECT: AQUEOUS FILTERED SAMPLES. DIRECT READING. CAPE CANAVERA 7-OCT-96 13:09:19
KAMBELL
SR71

THIS REPORT WAS GENERATED WITH THE FOLLOWING INFORMATION:

ERROR LEVEL PERCENTAGE : 10%

STATISTICAL SENSITIVITIES WITH A 2.0 SIGMA INTERVAL WERE USED

CONCENTRATION IN: MG/L

THE CONSTANT FILES USED:

USER$DISK:[CLARK.ICAP]TYPE1.AMAX;1
USER$DISK:[CLARK.ICAP]TYPE1.XQCA;1
USER$DISK:[CLARK.ICAP]TYPE1.XQCB;1
USER$DISK:[CLARK.ICAP]TYPE1.XQCC;1
USER$DISK:[CLARK.ICAP]TYPE1.STD1;1
USER$DISK:[CLARK.ICAP]TYPE1.STD2;1
USER$DISK:[CLARK.ICAP]TYPE1.STD3;1
USER$DISK:[CLARK.ICAP]TYPE1.STD4;1
USER$DISK:[CLARK.ICAP]TYPE1.STD5;1
USER$DISK:[CLARK.ICAP]TYPE1.XSS1;1
USER$DISK:[CLARK.ICAP]TYPE1.XSS2;1
USER$DISK:[CLARK.ICAP]TYPE1.FIXX;1
USER$DISK:[CLARK.ICAP]TYPE1.LCN;46
LCN TIME: 15:53:07 LCN DATE: 19-JUN-96 FILTER FACTOR: 0.000002

THE DATA FILES USED:

USER$DISK:[CLARK.ICAP]DATA.DAT;304 (INSTRUMENT RAW DATA)
USER$DISK:[CLARK.ICAP]IC0001.DAT;3946 (INSTRUMENT CALC. DATA)
USER$DISK:[CLARK.ICAP]TAG.DAT;4938 (ORIGINAL TAG FILE)
USER$DISK:[CLARK.ICAP]TAG.DAT;4940 (TAG FILE FOR CALC.)
USER$DISK:[CLARK.ICAP]OUTPUT.DAT;3134
USER$DISK:[CLARK.ICAP]OUTPUT.LST;3049
USER$DISK:[CLARK.ICAP]ARCH.DAT;16
USER$DISK:[CLARK.ICAP]LIST.LST;4592
USER$DISK:[CLARK.ICAP]TRAILER.LST;743

SAMPLE DESCRIPTION LIST FOR SERVICE REQUEST # 71 TO 71

SERVICE REQUEST NUMBER ONLY REPORT AS OF 961016

SAMPLE NUMBER	SAMPLE IDENTIFICATION	SERVICE REQ NO.	REQUESTOR	LAB NO.	SAMPLE ACQ DATE	SAMPLE TYPE	SUPERFUND (Y/N)	ENTRY DATE	PROJECT CODE
15104	1381MWD01 CAPE CANAVERAL	71	KAMPBELL	358	96/09/19	AQ-F	N	96/10/02	RPDK2
15105	1381MWS09 CAPE CANAVERAL	71	KAMPBELL	358	96/09/19	AQ-F	N	96/10/02	RPDK2
15106	1381MWS05 CAPE CANAVERAL	71	KAMPBELL	358	96/09/20	AQ-F	N	96/10/02	RPDK2
15107	1381MWSO7 CAPE CANAVERAL	71	KAMPBELL	358	96/09/20	AQ-F	N	96/10/02	RPDK2
15108	1381MWS11 CAPE CANAVERAL	71	KAMPBELL	358	96/09/20	AQ-F	N	96/10/02	RPDK2
15109	1381MPI01 CAPE CANAVERAL	71	KAMPBELL	358	96/09/21	AQ-F	N	96/10/02	RPDK2
15110	1381MWS16 CAPE CANAVERAL	71	KAMPBELL	358	96/09/21	AQ-F	N	96/10/02	RPDK2
15111	1381MPS07 CAPE CANAVERAL	71	KAMPBELL	358	96/09/23	AQ-F	N	96/10/02	RPDK2
15112	1381MPS08 CAPE CANAVERAL	71	KAMPBELL	358	96/09/23	AQ-F	N	96/10/02	RPDK2
15113	1381MPI06 CAPE CANAVERAL	71	KAMPBELL	358	96/09/23	AQ-F	N	96/10/02	RPDK2
15114	1381MPI21 CAPE CANAVERAL	71	KAMPBELL	358	96/09/24	AQ-F	N	96/10/02	RPDK2
15115	1381MPS10 CAPE CANAVERAL	71	KAMPBELL	358	96/09/24	AQ-F	N	96/10/02	RPDK2

Table I. Quantitative Report and QC Data for Phenols and Aliphatic and Aromatic Acids from Water Samples from Cape Canaveral (Service Request SF-2-233)

Concentration ppb

		1381 MWSO1	1381 MWDO1	1381 MWSO9	1381 MWIO6	Standard Blank	Extraction Blank	50 ppb Extraction Recovery	100 ppb Check Standard
1	PROPANOIC ACID – PFB	8	24	N.F.	13	N.F.	N.F.	27	100
2	2-METHYLPROPANOIC ACID – PFB	***	11	15	***	5	7	12	104
3	TRIMETHYL ACETIC ACID – PFB	***	***	***	5	***	6	50	111
4	BUTYRIC ACID – PFB	***	126	24	8	57	9	11	103
5	2-METHYLBUTYRIC ACID – PFB	***	N.F.	***	***	***	***	44	113
6	3-METHYLBUTYRIC ACID – PFB	***	***	***	***	***	***	41	113
7	3,3-DIMETHYLBUTYRIC ACID – PFB	N.F.	N.F.	***	***	***	***	60	106
8	PENTANOIC ACID – PFB	9	***	6	11	11	11	46	110
9	2,3-DIMETHYLBUTYRIC ACID – PFB	***	N.F.	N.F.	***	***	N.F.	58	103
10	2-ETHYLBUTYRIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	60	104
11	2-METHYLPENTANOIC ACID – PFB	N.F.	N.F.	N.F.	***	***	***	60	106
12	3-METHYLPENTANOIC ACID – PFB	***	N.F.	N.F.	***	***	***	56	103
13	4-METHYLPENTANOIC ACID – PFB	***	N.F.	***	***	***	***	59	107
14	HEXANOIC ACID – PFB	***	23	***	***	***	***	62	104
15	2-METHYLHEXANOIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	61	110
16	PHENOL – PFB	***	N.F.	***	***	***	11	53	92
17	CYCLOPENTANECARBOXYLIC ACID – PFB	N.F.	N.F.	N.F.	N.F.	***	N.F.	46	86
18	5-METHYLHEXANOIC ACID – PFB	N.F.	N.F.	N.F.	5	N.F.	N.F.	30	109
19	o-CRESOL – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	62	103
20	2-ETHYLHEXANOIC ACID – PFB	***	***	***	***	***	***	61	107
21	HEPTANOIC ACID – PFB	***	***	***	***	***	***	64	115
22	m-CRESOL – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	62	103
23	p-CRESOL – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	58	99
24	1-CYCLOPENTENE-1-CARBOXYLIC ACID – PFB	N.F.	***	N.F.	***	N.F.	***	51	119
25	o-ETHYLPHENOL – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	55	99
26	CYCLOPENTANEACETIC ACID – PFB	***	N.F.	***	***	***	N.F.	63	117
27	2,6-DIMETHYLPHENOL – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	39	95
28	2,5-DIMETHYLPHENOL – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	51	93
29	CYCLOHEXANECARBOXYLIC ACID – PFB	***	***	***	***	***	***	66	124
30	3-CYCLOHEXENE-1-CARBOXYLIC ACID – PFB	***	N.F.	N.F.	***	N.F.	***	65	127
31	2,4-DIMETHYLPHENOL – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	32	100
32	3,5-DIMETHYLPHENOL & M-ETHYLPHENOL – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	63	111
33	OCTANOIC ACID – PFB	***	***	***	***	***	***	62	107
34	2,3-DIMETHYLPHENOL – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	52	106
35	p-ETHYLPHENOL – PFB	N.F.	25	N.F.	N.F.	N.F.	N.F.	58	95
36	BENZOIC ACID – PFB	53	55	45	58	7	84	37	97
37	3,4-DIMETHYLPHENOL – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	51	97
38	m-METHYLBENZOIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	53	110
39	1-CYCLOHEXENE-1-CARBOXYLIC ACID – PFB	***	N.F.	N.F.	***	N.F.	N.F.	63	118
40	CYCLOHEXANEACETIC ACID – PFB	***	N.F.	N.F.	***	N.F.	N.F.	64	119
41	2-PHENYLPROPANOIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	62	116
42	o-METHYLBENZOIC ACID – PFB	***	***	N.F.	***	***	N.F.	63	114
43	PHENYLACETIC ACID – PFB	N.F.	N.F.	N.F.	***	***	N.F.	58	109
44	m-TOLYLACETIC ACID – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	56	107
45	o-TOLYLACETIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	67	100
46	2,6-DIMETHYLBENZOIC ACID – PFB	***	***	***	***	***	N.F.	66	121
47	p-TOLYLACETIC ACID – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	59	111
48	p-METHYLBENZOIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	57	108
49	3-PHENYLPROPANOIC ACID – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	55	108
50	2,5-DIMETHYLBENZOIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	56	113
51	DECANOIC ACID – PFB	N.F.	N.F.	N.F.	5	***	5	52	103
52	2,4-DIMETHYLBENZOIC ACID – PFB	N.F.	N.F.	***	N.F.	N.F.	N.F.	57	114
53	3,5-DIMETHYLBENZOIC ACID – PFB	N.F.	N.F.	***	***	N.F.	N.F.	56	107
54	2,3-DIMETHYLBENZOIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	58	114
55	4-ETHYLBENZOIC ACID – PFB	N.F.	N.F.	N.F.	N.F.	***	N.F.	54	106
56	2,4,6-TRIMETHYLBENZOIC ACID – PFB	***	N.F.	N.F.	***	***	N.F.	57	109
57	3,4-DIMETHYLBENZOIC ACID – PFB	N.F.	N.F.	N.F.	***	***	N.F.	50	102
58	2,4,5-TRIMETHYLBENZOIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	53	110

*** indicates concentration of extract was below lowest calibration standard (5 ppb).
N.F. indicates not found.

KAMPBELL CAPE CANAVERAL SOILS SF-2-233

SAMPLE	SOIL	FILTRATE % O.C.	SOLIDS % O.C.	TOTAL SOIL % TOC	MEAN %TOC	STD DEV.
SED A,	1-1	.017	.026	.043	.047	
	1-2	.019	.032	.051		
SED B,	1-1	.030	.147	.177	.174	
	1-2	.024	.147	.171		
SED C,	1-1	.017	.010	.027	.029	
	1-2	.023	.008	.031		
SED D,	1-1	.021	.030	.051	.052	
	1-2	.021	.032	.053		
SED E,	1-1	.020	.446	.466	.281	.163
	1-2	.020	.137	.157		
	1-3	.016	.205	.221		
SED F,	1-1	.016	.020	.036	.038	
	1-2	.017	.023	.040		
01-1381-SB,REP A						
	1-1	.021	.013	.034	.045	.011
	1-2	.020	.036	.056		
	1-3	.025	.021	.046		
01-1381-SB,REP B						
	1-1	.039	.008	.047	.146	.086
	1-2	.028	.166	.194		
	1-3	.015	.042	.198		
02-1381-SB,REP A						
	1-1	.025	.008	.033	.034	
	1-2	.020	.015	.035		
02-1381-SB,REP B						
	1-1	.010	.986	.996	.800	.388
	1-2	.025	1.02	1.05		
	1-3	.024	.329	.353		
03-1381-SB,REP A						
	1-1	.018	.028	.046	.039	.010
	1-2	.018	.009	.027		
	1-3	.018	.025	.043		
03-1381-SB,REP B						
	1-1	.018	.770	.788	.507	.364
	1-2	.011	.084	.095		
	1-3	.023	.614	.637		

SAMPLE	SOIL FILTRATE % O.C.	SOLIDS % O.C.	TOTAL SOIL % TOC	MEAN %TOC	STD DEV.
04-1381-SB,REP A					
1-1	.051	.228	.279	.327	.054
1-2	.057	.328	.385		
1-3	.048	.268	.316		
04-1381-SB,REP B					
1-1	.017	1.76	1.78	.823	.847
1-2	.020	.499	.519		
1-3	.017	.153	.170		
WPO35-II	39.4				
Leco std.		.902			

WPO35-II std. t.v.=40.1
Leco std. t.v.=.90+/-.04

Table 4. Quantitation Report for S.R. # SF-2-233 from Cape Canaveral.

Concentration = ppb

Compound	QC1108E 20 ppb	QC1108F 200 ppb	QC1108G 20 ppb	QC1108H 200 ppb	QC1108I 20 ppb	QC1108J 200 ppb	QC1108K 20 ppb	QC1112A 20 ppb	BL1108A	BL1108B
VINYL CHLORIDE	21.4	199	22.3	222	21.8	218	19.0	22.5	ND	ND
1,1-DICHLOROETHENE	21.7	195	22.6	225	23.0	217	21.0	24.2	ND	ND
T-1,2-DICHLOROETHENE	21.2	182	22.0	182	21.4	189	21.2	21.6	ND	ND
1,1-DICHLOROETHANE	21.2	187	21.4	190	21.8	188	23.3	20.2	ND	ND
C-1,2-DICHLOROETHENE	21.3	192	20.7	176	21.6	196	22.3	19.5	ND	ND
CHLOROFORM	21.4	194	20.2	182	22.2	190	22.5	18.7	ND	ND
1,1,1-TRICHLOROETHANE	20.3	177	21.3	199	21.9	188	21.1	22.1	ND	ND
CARBON TETRACHLORIDE	20.3	173	21.6	194	22.5	188	20.1	22.3	ND	ND
1,2-DICHLOROETHANE	20.4	208	17.3	181	19.7	207	24.5	17.8	ND	ND
TRICHLOROETHENE	18.8	176	18.8	186	19.5	186	19.0	19.4	ND	ND
TETRACHLOROETHENE	20.6	167	20.1	171	20.6	176	18.3	21.1	ND	ND
CHLOROBENZENE	23.4	184	20.8	176	22.6	182	23.1	19.8	ND	ND
1,4-DICHLOROBENZENE	23.4	169	20.5	158	21.5	170	22.1	19.2	---	ND
1,3-DICHLOROBENZENE	22.2	197	19.1	185	20.3	199	19.8	18.9	---	ND
1,2-DICHLOROBENZENE	24.0	200	20.6	183	22.5	198	22.9	18.6	---	ND

ND = None Detected --- = Below Calibration Limit(1.0 ppb) QC = Quality Control Std. Dup = Duplicate BL = Blank

[redacted]SH-2-233 Cape Canaveral Dr. Kampbell GC/MS ... M[redacted]ne Chloride Core Extracts [redacted]ts mg/kg

	Benzene	TCE	PCE	Toluene	EB	p-X	m-X	o-X	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB	Naphthalene	2-MN	1-MN
1381 SED A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SED B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SED C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SED D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SED E	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SED F	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-O1 A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-O1 B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-O2 A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-O2 B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-O3 A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-03 B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-04 A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-04 B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Analyst: David A. Kovacs

BLQ < 0.05 ug/ml

Printed: 11/25/96

LIMITS OF QUANTITATION.

METHANE	ETHYLENE	ETHANE
0.001	0.003	0.002

SAMPLE UNITS ARE mg/L.
STANDARDS UNITS CORRESPOND
TO THE SAMPLE COLUMN.

BLQ DENOTES BELOW LIMIT OF QUANTITATION.
ND DENOTES NONE DETECED.
NA DENOTES NOT ANALYZED.

ELEMENTAL CONSTIT[illegible] ANALYSIS BY: ICAP (DATA.DAT)

THIS REPORT (USER$DISK:[CLARK.ICAP]LIST[illegible]) WAS GENERATED FROM USER$DISK:[CLARK.ICAP]OUTPUT[illegible]

PROJECT: AQUEOUS FILTERED SAMPLES. DIRECT READING. CAPE CANAVERAL
KAMBELL
SR71

CONCENTRATION IN: MG/L

TAG NO.	15104		15105		15106		15107	
STATION	1381 MW D01		1381 MW S09		1381 MW S05		1381 MW S07	
TIME	12:52		12:39		12:42		12:44	
DATE	03-OCT-96		03-OCT-96		03-OCT-96		03-OCT-96	
PR DIL	1.0000		1.0000		1.0000		1.0000	
DIL	1.0000		1.0000		1.0000		1.0000	
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	609.	59.	124.	12.	167.	16.	30.3	3.0	0.1311
K	64.5	6.5	2.12	0.84	9.22	0.84	<0.84	0.84	0.8499
Ca	31.2	3.1	148.	14.	110.	11.	109.	10.	0.0216
Mg	80.0	8.0	22.7	2.2	21.4	2.1	8.89	0.88	0.0582
Fe	0.039	0.025	1.87	0.18	<0.024	0.024	0.495	0.050	0.0249
Mn	<0.012	0.012	0.134	0.014	<0.012	0.012	0.034	0.012	0.0120
Co	<0.0030	0.0030	<0.0030	0.0030	<0.0030	0.0030	<0.0030	0.0030	0.0030
Mo	<0.019	0.019	<0.019	0.019	<0.019	0.019	<0.019	0.019	0.0196
Al	<0.083	0.083	<0.083	0.083	<0.083	0.083	<0.083	0.083	0.0838
As	<0.011	0.011	<0.011	0.011	<0.011	0.011	<0.011	0.011	0.0112
Se	<0.021	0.021	<0.021	0.021	<0.021	0.021	<0.021	0.021	0.0215
Cd	<0.0011	0.0011	<0.0011	0.0011	<0.0011	0.0011	<0.0011	0.0011	0.0011
Be	<0.0012	0.0012	<0.0017	0.0017	<0.0015	0.0015	<0.0015	0.0015	0.0012
Cu	<0.0071	0.0071	<0.0071	0.0071	<0.0071	0.0071	<0.0071	0.0071	0.0071
Cr	<0.0013	0.0013	<0.0013	0.0013	<0.0013	0.0013	<0.0013	0.0013	0.0013
Ni	<0.0045	0.0045	<0.0045	0.0045	<0.0045	0.0045	<0.0045	0.0045	0.0045
Zn	0.0020	0.0010	0.0022	0.0009	0.0027	0.0009	<0.0009	0.0009	0.0009
Ag	<0.0077	0.0077	<0.0078	0.0078	<0.0078	0.0078	<0.0078	0.0078	0.0077
Tl	<0.014	0.014	<0.014	0.014	<0.014	0.014	<0.014	0.014	0.0148
Pb	<0.016	0.016	<0.016	0.016	<0.016	0.016	<0.016	0.016	0.0160
Sr	0.763	0.077	1.96	0.19	1.44	0.14	1.58	0.15	0.0007
V	<0.027	0.027	<0.027	0.027	<0.027	0.027	<0.027	0.027	0.0274
Ba	0.0050	0.0019	0.0024	0.0019	0.0022	0.0019	<0.0019	0.0019	0.0019
B	1.12	0.11	0.251	0.025	0.483	0.048	0.0809	0.0082	0.0057
Ti	<0.0023	0.0024	<0.0024	0.0024	<0.0029	0.0029	<0.0023	0.0023	0.0023

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

ELEMENTAL CONSTITUENTS ANALYSIS BY: ICAP (DATA.DAT)
THIS REPORT (USER$DISK:[CLARK.ICAP]LIST.LST;4592) WAS GENERATED FROM USER$DISK:[CLARK.ICAP]OUTPUT.DAT;3134

PROJECT: AQUEOUS FILTERED SAMPLES. DIRECT READING. CAPE CANAVERAL
KAMBELL
SR71

CONCENTRATION IN: MG/L

TAG NO.	15108		15109		15110		15111		
STATION	1381 MW S11		1381 MP I01		1381 MW S16		1381 MP S07		
TIME	12:47		12:50		13:23		13:02		
DATE	03-OCT-96		03-OCT-96		03-OCT-96		03-OCT-96		
PR DIL	1.0000		1.0000		1.0000		1.0000		
DIL	1.0000		1.0000		1.0000		1.0000		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	63.6	6.3	421.	42.	16.0	1.6	27.6	2.7	0.1311
K	7.12	0.84	35.4	3.4	<0.84	0.84	1.10	0.84	0.8499
Ca	215.	21.	27.8	2.7	98.1	9.9	101.	10.	0.0216
Mg	28.0	2.8	58.8	5.8	6.06	0.61	6.88	0.68	0.0582
Fe	7.57	0.75	<0.025	0.025	<0.024	0.024	0.477	0.048	0.0249
Mn	0.076	0.012	<0.012	0.012	<0.012	0.012	0.018	0.012	0.0120
Co	<0.0030	0.0030	<0.0030	0.0030	<0.0030	0.0030	<0.0030	0.0030	0.0030
Mo	<0.019	0.019	<0.019	0.019	<0.019	0.019	<0.019	0.019	0.0196
Al	<0.083	0.083	<0.083	0.083	<0.083	0.083	<0.083	0.083	0.0838
As	<0.011	0.011	<0.011	0.011	<0.011	0.011	<0.011	0.011	0.0112
Se	<0.022	0.022	<0.021	0.021	<0.021	0.021	<0.021	0.021	0.0215
Cd	<0.0011	0.0011	<0.0011	0.0011	<0.0011	0.0011	<0.0011	0.0011	0.0011
Be	<0.0021	0.0021	<0.0012	0.0012	<0.0014	0.0014	<0.0014	0.0014	0.0012
Cu	<0.0072	0.0072	<0.0071	0.0071	<0.0071	0.0071	<0.0071	0.0071	0.0071
Cr	0.0030	0.0013	<0.0013	0.0013	<0.0013	0.0013	<0.0013	0.0013	0.0013
Ni	<0.0045	0.0045	<0.0045	0.0045	<0.0045	0.0045	<0.0045	0.0045	0.0045
Zn	0.0063	0.0011	0.0013	0.0010	0.0011	0.0009	<0.0009	0.0009	0.0009
Ag	<0.0078	0.0078	<0.0077	0.0077	<0.0078	0.0078	<0.0078	0.0078	0.0077
Tl	<0.014	0.014	<0.014	0.014	<0.014	0.014	<0.014	0.014	0.0148
Pb	<0.016	0.016	<0.016	0.016	<0.016	0.016	<0.016	0.016	0.0160
Sr	2.96	0.29	0.351	0.035	1.12	0.11	1.14	0.11	0.0007
V	<0.027	0.027	<0.027	0.027	<0.027	0.027	<0.027	0.027	0.0274
Ba	0.0035	0.0020	0.0062	0.0019	0.0028	0.0019	0.0029	0.0019	0.0019
B	1.14	0.11	1.12	0.11	0.0413	0.0057	0.117	0.011	0.0057
Ti	<0.0024	0.0024	<0.0023	0.0023	<0.0023	0.0023	<0.0023	0.0023	0.0023

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

ELEMENTAL CO[redacted]TU . ANALYSIS BY: ICAP (DATA.DAT)
THIS REPORT (USER$DISK:[CLARK.ICAP]LIST[redacted]1592) WAS GENERATED FROM USER$DISK:[CLARK.ICAP]OUTPUT.[redacted]13.

PROJECT: AQUEOUS FILTERED SAMPLES. DIRECT READING. CAPE CANAVERAL
KAMBELL
SR71

CONCENTRATION IN: MG/L

TAG NO.	15112		15113		15114		15115		
STATION	1381 MP S08		1381 MP I06		1381 MP I21		1381 MP S10		
TIME	13:05		13:07		13:10		13:20		
DATE	03-OCT-96		03-OCT-96		03-OCT-96		03-OCT-96		
PR DIL	1.0000		1.0000		1.0000		5.0000		
DIL	1.0000		1.0000		1.0000		1.0000		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	136.	13.	878.	87.	835.	83.	1200.	120.	0.1311
K	13.9	1.3	50.5	4.9	50.6	4.9	52.0	4.7	0.8499
Ca	112.	11.	23.9	2.3	25.5	2.5	23.0	2.3	0.0216
Mg	37.1	3.7	98.1	9.8	99.6	9.9	127.	12.	0.0582
Fe	1.72	0.17	0.025	0.025	0.025	0.025	<0.12	0.12	0.0249
Mn	0.012	0.012	<0.012	0.012	<0.012	0.012	<0.060	0.060	0.0120
Co	<0.0030	0.0030	<0.0030	0.0030	<0.0030	0.0030	<0.014	0.014	0.0030
Mo	<0.019	0.019	<0.019	0.019	<0.019	0.019	<0.098	0.098	0.0196
Al	<0.083	0.083	<0.083	0.083	<0.083	0.083	<0.41	0.41	0.0838
As	<0.011	0.011	<0.011	0.011	<0.011	0.011	<0.056	0.056	0.0112
Se	<0.021	0.021	<0.021	0.021	<0.021	0.021	<0.10	0.10	0.0215
Cd	<0.0011	0.0011	0.0017	0.0011	<0.0011	0.0011	<0.0056	0.0056	0.0011
Be	<0.0015	0.0015	<0.0012	0.0012	<0.0012	0.0012	<0.0059	0.0059	0.0012
Cu	<0.0071	0.0071	<0.0071	0.0071	<0.0071	0.0071	<0.035	0.035	0.0071
Cr	<0.0013	0.0013	0.0016	0.0013	<0.0013	0.0013	0.0191	0.0063	0.0013
Ni	<0.0045	0.0045	<0.0045	0.0045	<0.0045	0.0045	<0.022	0.022	0.0045
Zn	0.0049	0.0009	0.0016	0.0010	0.0015	0.0010	0.0450	0.0056	0.0009
Ag	<0.0078	0.0078	<0.0077	0.0077	<0.0077	0.0077	<0.038	0.038	0.0077
Tl	<0.014	0.014	<0.014	0.014	<0.014	0.014	<0.074	0.074	0.0148
Pb	<0.016	0.016	<0.016	0.016	<0.016	0.016	<0.080	0.080	0.0160
Sr	1.55	0.15	0.385	0.038	0.411	0.041	0.383	0.038	0.0007
V	<0.027	0.027	<0.027	0.027	<0.027	0.027	<0.13	0.13	0.0274
Ba	0.0058	0.0019	0.0066	0.0020	0.0063	0.0020	<0.0095	0.0095	0.0019
B	0.334	0.033	2.21	0.22	1.76	0.17	2.39	0.24	0.0057
Ti	<0.0023	0.0023	<0.0026	0.0026	<0.0027	0.0027	<0.011	0.011	0.0023

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

ELEMENTAL CONSTITUENTS ANALYSIS BY: ICAP (DATA.DAT)
THIS REPORT (USER$DISK:[CLARK.ICAP]LIST.LST;4592) WAS GENERATED FROM USER$DISK:[CLARK.ICAP]OUTPUT.DAT;3134

PROJECT: AQUEOUS FILTERED SAMPLES. DIRECT READING. CAPE CANAVERAL
KAMBELL
SR71

CONCENTRATION IN: MG/L

TAG NO.	ZSTD5		IECCHK2		
STATION	---		---		
TIME	15:17		15:20		
DATE	03-OCT-96		03-OCT-96		
PR DIL	1.0000		1.0000		
DIL	1.0000		1.0000		
ELEMENT	VALUE	STDV +/-	VALUE	STDV +/-	LOD
Na-1	<0.13	0.13	<0.13	0.13	0.1311
K	<0.85	0.85	<0.85	0.85	0.8499
Ca	0.023	0.021	307.	30.	0.0216
Mg	<0.26	0.26	265.	26.	0.0582
Fe	102.	10.	<0.026	0.026	0.0249
Mn	103.	10.	<0.013	0.013	0.0120
Co	<0.0030	0.0030	<0.013	0.013	0.0030
Mo	<0.019	0.019	<0.019	0.019	0.0196
Al	103.	10.	<0.15	0.15	0.0838
As	<0.20	0.20	<0.035	0.035	0.0112
Se	<0.11	0.11	<0.021	0.021	0.0215
Cd	0.0024	0.0011	<0.0012	0.0012	0.0011
Be	0.0040	0.0012	<0.0073	0.0073	0.0012
Cu	<0.0082	0.0082	<0.016	0.016	0.0071
Cr	<0.0015	0.0015	0.0053	0.0014	0.0013
Ni	0.0071	0.0045	<0.0046	0.0046	0.0045
Zn	0.0019	0.0017	0.0060	0.0036	0.0009
Ag	<0.0081	0.0081	<0.034	0.034	0.0077
Tl	<0.049	0.049	1.6	1.1	0.0148
Pb	<0.058	0.058	<0.017	0.017	0.0160
Sr	<0.0007	0.0007	0.0010	0.0007	0.0007
V	<0.027	0.027	19.7	1.9	0.0274
Ba	<0.0019	0.0019	0.0112	0.0024	0.0019
B	<0.0083	0.0083	<0.0077	0.0077	0.0057
Ti	<0.0023	0.0023	46.9	4.7	0.0023

< VALUE=LIMIT OF DETECTION DETERMINED BY INSTRUMENT SENSITIVITY, SAMPLE DILUTION, AND MATRIX INTERFERENCE.
RESULTS ACCURATE TO 2 SIGNIFICANT DIGITS

EPA/RSKERL/ADA, OK

KAMPBELL CAPE CANAVERAL LIQUIDS SF-2-233

SAMPLE	MG/L TOC
MWIO1	10.6
MWIO5	10.9
MWI09	18.8
MWS09	8.97
MWS09 DUP	8.48
MWD01	7.43
MWD09	6.30
MWSO1	6.47
MWSO3	6.15
MWSO5	5.24
MWSO7	2.97
MWSO7 DUP	2.95
MWS11	12.2
MWS12	7.80
MWS13	.613
MWS14	2.33
MWS15	12.3
MWS16	1.18
MWS17	6.59
MWS18	5.04
MPIO2	8.25
MPIO3	57.3
MPIO5	15.2
MPIO6	11.4
MPIO7	8.18
MPI17	14.9
MPSO1	1.15
MPSO7	2.55
MPSO8	5.67
MPO8	83.2
MPI10	2.56
MPI11	192
MPI13	13.0
MPI18	13.8
MPI21	9.85
PRMPO1	6.15
PRMPO2	5.87
PRMP20	11.7
MPS10	6.96
MPS10 DUP	6.99
WPO35-II	40.2

WPO35-II Std. t.v.=40.1

ELEMENTAL CONSTITUENTS ANALYSIS BY AA MEASUREMENTS
THIS REPORT ([.REPORT]PB61008.LIS;1) WAS GENERATED FROM DATASET [.DATA]PB61008.DAT;2

PROJECT: AQ FILTERED SAMPLES. CAPE CANAVERAL.

METHOD: GF-AAS FOR LEAD. SR#71. KAMPBELL

CONCENTRATION UNITS: MG/L

TAG NUMBER	SAD #	STATION IDENT	MACHINE READING	PRIMARY DILUTION	REGULAR DILUTION	FINAL CONCENTRATION
15104	15104	1381 MW D01	0.000	1.000	1.000	0.000
15105	15105	1381 MW S09	0.001	1.000	1.000	0.001
15106	15106	1381 MW S05	0.001	1.000	1.000	0.001
15107	15107	1381 MW S07	0.000	1.000	1.000	0.000
15108	15108	1381 MW S11	0.001	1.000	1.000	0.001
15109	15109	1381 MP I01	0.001	1.000	1.000	0.001
15110	15110	1381 MW S16	0.000	1.000	1.000	0.000
15111	15111	1381 MP S07	0.001	1.000	1.000	0.001
15112	15112	1381 MP S08	0.001	1.000	1.000	0.001
15113	15113	1381 MP I06	0.000	1.000	1.000	0.000
15114	15114	1381 MP I21	0.000	1.000	1.000	0.000
15115	15115	1381 MP S10	0.001	1.000	1.000	0.001
BLANK	%%%%%	**********	0.000	1.000	1.000	0.000
BLANK	%%%%%	**********	0.001	1.000	1.000	0.001
STD5PPB	%%%%%	**********	0.006	1.000	1.000	0.006
STD5PPB	%%%%%	**********	0.006	1.000	1.000	0.006
STD10PPB	%%%%%	**********	0.011	1.000	1.000	0.011
STD10PPB	%%%%%	**********	0.011	1.000	1.000	0.011
STD20PPB	%%%%%	**********	0.020	1.000	1.000	0.020
STD20PPB	%%%%%	**********	0.022	1.000	1.000	0.022
STD50PPB	%%%%%	**********	0.050	1.000	1.000	0.050
STD50PPB	%%%%%	**********	0.046	1.000	1.000	0.046
ST100PPB	%%%%%	**********	0.100	1.000	1.000	0.100
ST100PPB	%%%%%	**********	0.095	1.000	1.000	0.095

MANTECH

Ref: 96-SH103/vg

October 11, 1996

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection & Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Don:

Attached are TOC results for 14 Cape Canaveral soils submitted October 2, 1996 under Service Request #SF-2-233. Sample analysis was begun October 7, 1996 and completed October 11, 1996 using RSKSOP-102 and RSKSOP-120.

Blanks, duplicates, and AQC samples were analyzed along with your samples, as appropriate, for quality control. If you have any questions concerning this data, please feel free to ask me.

Sincerely,

Sharon Hightower

Sharon Hightower

xc: R.L. Cosby
G.B. Smith
J.L. Seeley SV FW
J.T. Wilson

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

KAMPBELL CAPE CANAVERAL SOILS SF-2-233

SAMPLE	SOIL	FILTRATE % O.C.	SOLIDS % O.C.	TOTAL SOIL % TOC	MEAN %TOC	STD DEV.
SED A,	1-1	.017	.026	.043	.047	
	1-2	.019	.032	.051		
SED B,	1-1	.030	.147	.177	.174	
	1-2	.024	.147	.171		
SED C,	1-1	.017	.010	.027	.029	
	1-2	.023	.008	.031		
SED D,	1-1	.021	.030	.051	.052	
	1-2	.021	.032	.053		
SED E,	1-1	.020	.446	.466	.281	.163
	1-2	.020	.137	.157		
	1-3	.016	.205	.221		
SED F,	1-1	.016	.020	.036	.038	
	1-2	.017	.023	.040		
01-1381-SB,REP A						
	1-1	.021	.013	.034	.045	.011
	1-2	.020	.036	.056		
	1-3	.025	.021	.046		
01-1381-SB,REP B						
	1-1	.039	.008	.047	.146	.086
	1-2	.028	.166	.194		
	1-3	.015	.042	.198		
02-1381-SB,REP A						
	1-1	.025	.008	.033	.034	
	1-2	.020	.015	.035		
02-1381-SB,REP B						
	1-1	.010	.986	.996	.800	.388
	1-2	.025	1.02	1.05		
	1-3	.024	.329	.353		
03-1381-SB,REP A						
	1-1	.018	.028	.046	.039	.010
	1-2	.018	.009	.027		
	1-3	.018	.025	.043		
03-1381-SB,REP B						
	1-1	.018	.770	.788	.507	.364
	1-2	.011	.084	.095		
	1-3	.023	.614	.637		

SAMPLE	SOIL FILTRATE % O.C.	SOLIDS % O.C.	TOTAL SOIL % TOC	MEAN %TOC	STD DEV.
04-1381-SB,REP A					
1-1	.051	.228	.279	.327	.054
1-2	.057	.328	.385		
1-3	.048	.268	.316		
04-1381-SB,REP B					
1-1	.017	1.76	1.78	.823	.847
1-2	.020	.499	.519		
1-3	.017	.153	.170		
WPO35-II	39.4				
Leco std.		.902			

WPO35-II std. t.v.=40.1
Leco std. t.v.=.90+/-.04

MANTECH

Ref: 96-DF60

Sept. 11, 1996

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Don:

As requested in Service Request SF-2-234, GC/MS analysis for aromatic and semi-volatile compounds was done on four water samples from Cape Canaveral. These samples were labeled: MW-D09, MW-I09, MW-S09 and MW-S01. The samples were received on Aug. 16, 1996. Base/neutral extractions of the water samples were completed on Aug. 19, 1996. The GC/MS analyses of the samples were completed on Sept. 10, 1996. EPA method 8270A with the modifications listed below was used for this analysis.

The extracts were prepared by Brad Scroggins according to the standard operating procedure for base/neutral extraction. After the pH of one liter of each water sample was adjusted to slightly above 11.0 with 10N NaOH, the water sample was extracted three times with 60 ml of methylene chloride. After the methylene chloride fraction was passed through a Na_2SO_4 column, it was concentrated using the Turbo-Vap to a final volume near 1.0 ml.

For quantitative analysis, 10.0 μl of a 400 ppm internal standard mixture of benzene-d_6, toluene-d_8, ethylbenzene-d_{10}, p-xylene-d_{10}, o-xylene-d_{10}, p-dichlorobenzene-d_2, naphthalene-d_8, acenaphthene-d_{10}, phenanthrene-d_{10}, chrysene-d_{12} and perylene-d_{12} in methylene chloride was added to 200 μl of each standard or sample. Calibration curves were prepared from three dilutions of a Supleco P-I-A-N-O mixture containing 140 compounds. The Hewlett Packard 7673 autoinjector delivered 1.0 μl of the methylene chloride extract with a split flow of 20 ml/min to a 60 meter, 0.25 mm DB5-MS capillary column with 0.5 μm film thickness. The column was temperature programmed from -10°C to 60°C at 30°C/min and then to 300°C at 6°C/min. The Finnigan 4615 GC/MS was scanned from 42 to 650 m/z in 0.5 sec.

Attached please find chromatograms of the extracts of the four water samples. No aromatic or aliphatic compounds were found in the samples. The only peak of interest was found in sample MW-S09 and was identified as 2-ethylhexyldiphenyl-phosphate.

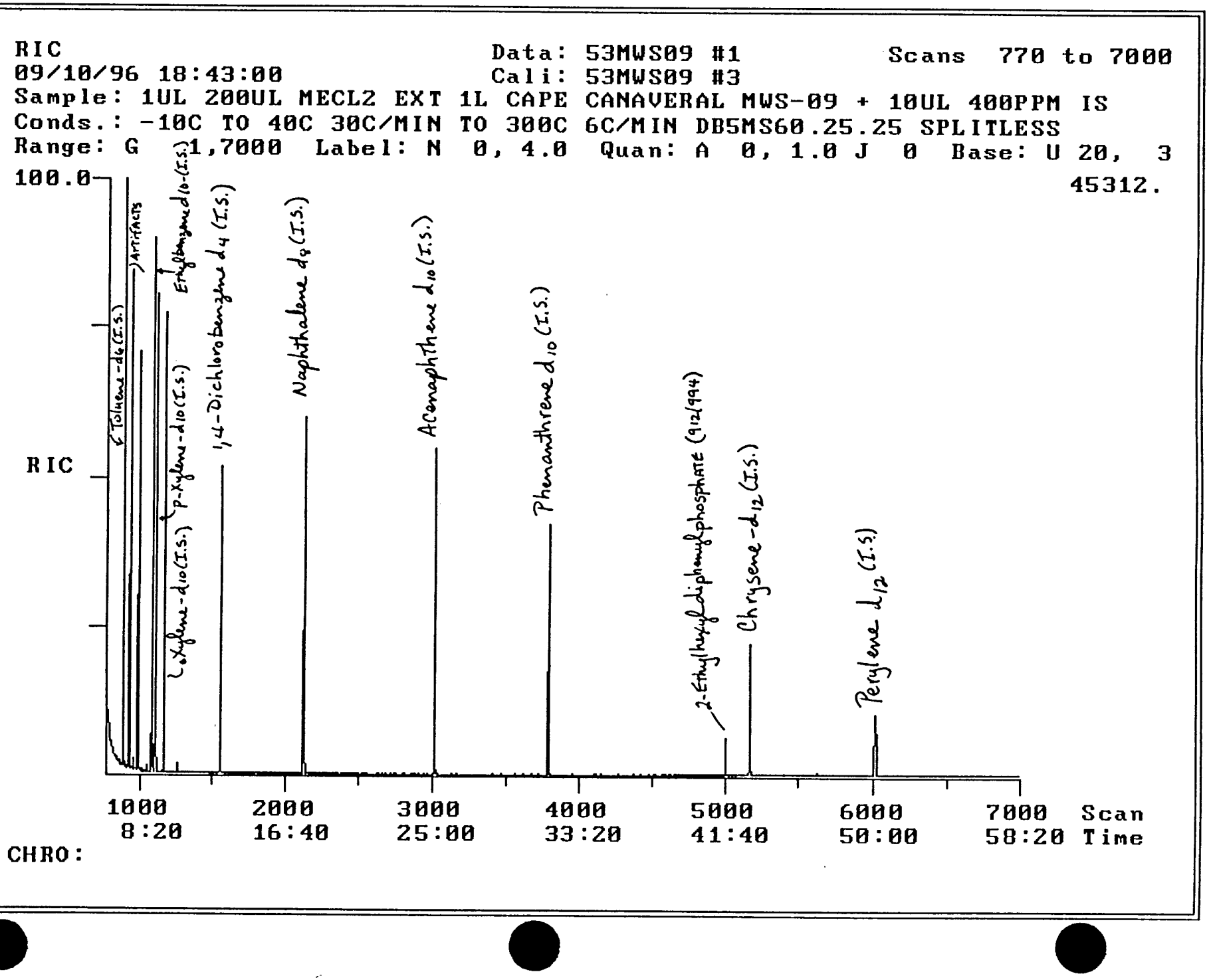
If you should have any questions, please feel free to contact me.

Sincerely,

Dennis D. Fine

Dennis D. Fine

xc: J. Seeley
G. Smith
R. Cosby
D. Fine
J. Wilson


RIC
09/10/96 18:43:00
Data: 53MWS09 #1
Cali: 53MWS09 #3
Scans 770 to 7000
Sample: 1UL 200UL MECL2 EXT 1L CAPE CANAVERAL MWS-09 + 10UL 400PPM IS
Conds.: -10C TO 40C 30C/MIN TO 300C 6C/MIN DB5MS60.25.25 SPLITLESS
Range: G 1,7000 Label: N 0, 4.0 Quan: A 0, 1.0 J 0 Base: U 20, 3
100.0
45312.
RIC
Toluene-d8 (I.S.)
Artifacts
Ethylbenzene d10 (I.S.)
p-Xylene-d10 (I.S.)
o-Xylene-d10 (I.S.)
1,4-Dichlorobenzene d4 (I.S.)
Naphthalene d8 (I.S.)
Acenaphthene d10 (I.S.)
Phenanthrene d10 (I.S.)
2-Ethylhexyldiphenylphosphate (912/994)
Chrysene-d12 (I.S.)
Perylene d12 (I.S.)
1000 8:20
2000 16:40
3000 25:00
4000 33:20
5000 41:40
6000 50:00
7000 58:20
Scan
Time
CHRO:

MANTECH ENVIRONMENTAL TECHNOLOGY

Ref: 96-MW98/vg
96-LP115/vg
October 16, 1996

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection & Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Don:

Attached are the results of 40 Cape Canaveral samples submitted to MERSC as part of Service Request #SF-2-233. The samples were received September 23, 24 and 27, 1996 and analyzed on the respective day of receipt. The methods used for analysis were EPA Methods 353.1 for NO_2 and NO_3 and 350.1 for NH_3 and Waters capillary electrophoresis Method N-601 for Cl and SO_4. Quality assurance measures performed on this set of samples included spikes, duplicates, known AQC samples and blanks.

If you have any questions concerning these results, please feel free to contact us.

Sincerely,

Mark White

Lynda Pennington

Lynda Pennington

xc: R.L. Cosby
G.B. Smith
J.L. Seeley
J.T. Wilson

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

Sample	mg/L Cl^-	mg/L $SO_4^=$	mg/L NO^-_2+NO^-_3 (N)	mg/L NH_3
1381 MWS02	121	47.3	1.85	.34
1381 MWS02 Dup	121	47.3	1.98	.36
1381 MWD01	989	<1	<.05	9.37
1381 MWS09	207	55.1	<.05	.91
1381 MWD09	1050	<1	<.05	8.73
1381 MWI09	1790	<1	.19	19.1
1381 MWS18	195	22.0	<.05	.35
1381 MWS05	151	24.3	<.05	2.86
1381 MWI05	859	<1	.15	14.7
1381 MWS17	171	71.4	<.05	.76
1381 MWS03	106	44.6	<.05	.38
1381 MWS11	64.8	138	<.05	1.52
1381 MWS11 Dup	64.3	139	<.05	1.52
1381 MWS07	33.9	8.77	<.05	.27
1381 MWD12	919	<1	.07	8.64
1381 MWS12	227	67.7	<.05	.46
1381 MWS16	13.3	17.8	<.05	<.05
1381 MWS14	37.6	31.3	.13	<.05
1381 MWS15	242	38.6	<.05	.33
1381 MWS13	17.8	25.2	.15	<.05
1381 MWS13 Dup	17.8	25.7	.14	<.05
1381 MPI02	451	<1	.19	18.3
1381 MPI01	486	<1	.10	11.2
1381 MPS01	28.2	16.3	<.05	<.05
1381 MPS08	221	9.12	.06	6.01
1381 MPI03	1260	<1	.13	16.5
1381 MWD03	1110	<1	<.05	9.63
1381 MPI17	1050	<1	.16	15.5
1381 MPS07	39.4	28.5	<.05	.48
1381 MPI07	445	<1	.06	11.3
1381 MPI07 Dup	441	<1	.05	11.4
1381 MPI06	1266	<1	.13	15.2
1381 MPI21	227	<.1	<.05	14.7
1381 MPI13	171	<.1	<.05	14.5
1381 MPI13 Dup	173	<.1	<.05	----
1381 MPI18	189	<.1	<.05	14.7
1381 MPS10	18.0	2.76	<.05	0.56
1381 MPI10	17.8	<.1	<.05	0.55
1381 MPI06	250	<.1	<.05	16.2
1381 MPI05	295	<.1	<.05	18.6
1381 MPI11	365	<.1	<.05	15.3

Sample	mg/L Cl^-	mg/L $SO_4^=$	mg/L NO^-_2+NO^-_3(N)	mg/L NH_3
1381 MPI11 D	----	----	<.05	15.3
1381 MPI08	161	<.1	<.05	9.04
1381 PRMP01	21.8	9.46	<.05	0.49
1381 PRMP20	261	<.1	<.05	15.8
1381 PRMP20 D	----	----	----	16.0
1381 PRMP02	30.5	12.5	<.05	0.74
Blank	<.1	<.1	<.05	<.05
AQC	56.2	53.5	0.40	1.62
AQC T.V.	56.0	52.0	0.39	1.40
Spike Rec.	97%	98%	100%	100%

MANTECH ENVIRONMENTAL TECHNOLOGY

Ref: 96-DK49/vg
November 25, 1996

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Dr. Kampbell:

This report contains the results of my GC/MSD analysis of methylene chloride core extracts from Cape Canaveral for quantitation of benzene, trichloroethene (TCE), tetrachloroethene (PCE), toluene, ethylbenzene (EB), p-xylene, m-xylene, o-xylene, 1,3,5-trimethylbenzene (1,3,5-TMB), 1,2,4-trimethylbenzene (1,2,4-TMB) and 1,2,3-trimethylbenzene (1,2,3-TMB), naphthalene, 2-methylnaphthalene (2-MN) and 1-methylnaphthalene (1-MN) (Service Request #SF-2-233).

No target compounds were detected in any of the samples.

The analytical method was a modification of RSKSOP-124. Cool on-column injection (0.5µl) was used with electronic pressure control set for a constant flow of 0.9ml/min. A 30m X 0.25mm Restek Stabilwax (Crossbonded Carbowax-PEG, 0.5µm film) capillary GC column with 9" X 0.53mm ID uncoated capillary precolumn was used. SIM mode was used with the ions chosen from those listed in EPA method 524.2 Revision 3.0. Multiple ions were acquired and ion ratios used to verify the accuracy of target compound identification. Standards calibration ranged from 0.025 to 250µg/ml. A check standard was analysed after each five samples and the precolumn was replaced as necessary. A quality control standard was analysed to verify quantitative accuracy. An extraction blank was also analyzed. Complete reports detailing the acquisition method and calibration curves has been recorded.

The sample extractions were completed October 2, 1996, with GC/MSD data acquisition on November 6, 1996.

Sincerely,

David A. Kovacs

xc: R.L. Cosby
J.L. Seeley
G.B. Smith

[redacted]#SF-2-233 Cape Canaveral Dr. Kampbell GC/MS ... M[redacted]ene Chloride Core Extracts [redacted]nits mg/kg

	Benzene	TCE	PCE	Toluene	EB	p-X	m-X	o-X	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB	Naphthalene	2-MN	1-MN
1381 SED A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SED B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SED C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SED D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SED E	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SED F	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-O1 A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-O1 B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-O2 A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-O2 B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-O3 A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-03 B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-04 A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 SB-04 B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Analyst: David A. Kovacs

BLQ < 0.05 ug/ml

Printed: 11/25/96

CAPE CANAVERAL AIRSTATION FIELD DATA

Sample	Date	Redox MV	PH Units	Cond	Carbon Dioxide mg/l	Total Alka-linity mg/l caco3	Ferrous Iron mg/l	Hydrogen sulfide mg/l
1381MP S08	9-23-96	-96	7.2	1458	204	386	1.5	<.1
1381MP I03	9-23-96	-86	7.7	5420	416	863	<.05	<.1
1381MP I17	9-23-96	-206	7.8	4730	296	770	<.05	<.1
1381MW D03	9-23-96	-176	8.1	4300	102	458	<.05	<.1
1381MP I07	9-23-96	-212	7.7	2330	210	485	<.05	<.1
1381MP S07	9-23-96	-138	7.4	618	92	225	.04	<.1
1381MP I019	9-23-96	-40	7.8	5440	438	755	<.05	<.1
1381MPI 21	9-24-96	-243	7.8	5110	258	670	.3	.3
1381MPI 13	9-24-96	-190	7.8	4370	332	744	.2	.1
1381MPI 18	9-24-96	-211	7.8	4770	306	801	-	.1
1381MP S10	9-24-96	-109	7.8	7520	386	834	<.05	.1
1381MPI 10	9-24-96	-118	7.3	972	196	321	.8	<.1
1381MPI 06	9-24-96	-98	7.7	5710	294	789	<.05	<.1
1381MPI 05	9-24-96	-185	7.7	6620	388	955	<.05	<.1
1381MPI 11	9-24-96	-225	7.7	7910	358	905	<.05	.1
1381MPI 08	9-24-96	-290	8.3	3760	232	524	<.05	.1

Sample	Date	Redox MV	PH Units	Cond	Carbon Dioxide mg/l	Total Alka-linity mg/l caco3	Ferrous Iron mg/l	Hydrogen sulfide mg/l
1381PR MP01	9-25-96	-92	7.3	1129	112	337	2.0	<.1
1381PR MP20	9-25-96	-60	7.7	5870	347	877	<.05	.1
1381PR M02	9-25-96	-125	7.2	1270	152	345	1.6	<.1

MANTECH ENVIRONMENTAL TECHNOLOGY

Ref: 96\LB78

October 3, 1996

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Don:

Please find attached the analytical results for Service Request SF-2-233 requesting the analysis of Cape Canaveral AFB groundwater samples to be analyzed by purge-and-trap/GC-FID:PID for Benzene, Toluene, Ethylbenzene, p-, m-, & o-Xylene, 1,3,5-, 1,2,4-, & 1,2,3-Trimethylbenzene, and Total Fuel Carbon. We obtained the 46 groundwater samples, in duplicate, in capped, 40 mL VOA autosampler vials September 30, 1996, and they were analyzed October 1-2, 1996. The samples were acquired and processed using the Millennium data system. A 4 place (1-500 ppb) external standard curve was used to quantitate sample concentration for the compounds of interest.

RSKSOP-133, "Simultaneous Analysis of Aromatics and Total Fuel Carbon by Dual Column-Dual Detector for Ground Water Samples" was used for these analyses. Autosampling was performed using a Dynatech Precision autosampler system in line with a Tekmar LSC 2000 concentrator.

Sincerely,

Lisa R. Black

Lisa R. Black

xc: R.L. Cosby
G.B. Smith
J.T. Wilson
J.L. Seeley JS

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

[redacted] 0/3/96 SF-2-233 Cape Canaver[redacted] Sa[redacted] Analyses for Dr. Don Kampbell Units = [redacted] A[redacted] st: L. Black

SampleName	BENZENE	TOLUENE	ETHYLBENZENE	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB	Fuel Carbon
10 PPB	9.9	9.5	9.5	9.4	9.5	9.4	9.1	9.2	9.3	N/A
QC, OBSERVED, PPB	51.5	51.2	53.0	50.4	50.9	51.8	53.1	52.6	52.1	N/A
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	N/A
1381 MWS 13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MWS 14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MWS 15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MWS 15 Duplicate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MWS 16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MWS 12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MWD 12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MWS 07	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MWS 11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MWS 03	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MWS 17	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
100 PPB	103	102	101	100	101	101	99	99	100	N/A
1381 MWI 05	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MWS 05	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MWS 18	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MWI 09	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MWS 09	ND	2.4	1.0	ND	1.4	1.5	ND	1.6	ND	1450
* 1381 MWD 01?	ND	ND	ND	ND	1.0	1.0	ND	ND	ND	34.1
1381 MWD 09	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MWD 09 Duplicate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
* 1381 MWD 01?	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MPI 13	ND	2.8	ND	ND	ND	ND	ND	ND	ND	4.6
1381 MPI 08	ND	5.7	ND	ND	ND	ND	ND	ND	ND	6.4
GC LAB BLANK, PPB	ND	ND	ND	ND	ND	ND	ND	ND	ND	N/A
1 PPB	1.1	1.2	1.3	1.3	1.4	1.3	1.5	1.5	1.4	N/A
1381 MPI 19	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MPI 07	ND	3.8	ND	ND	ND	ND	ND	ND	ND	4.5
1381 MPS 07	ND	5.6	ND	ND	ND	ND	ND	ND	ND	12.5
1381 MPI 17	ND	3.5	ND	ND	ND	ND	ND	ND	ND	3.6
1381 MWD 03	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MPS 08	ND	1.5	ND	ND	ND	ND	ND	ND	ND	8.0
1381 MPI 03	ND	1.9	ND	ND	ND	ND	ND	ND	ND	5.5
1381 MPS 01	ND	BLQ	ND	ND	ND	ND	ND	ND	ND	BLQ
1381 MPI 02	ND	3.3	ND	ND	ND	ND	ND	ND	ND	4.2
1381 MPI 02 Duplicate	ND	3.5	ND	ND	ND	ND	ND	ND	ND	4.1
1381 MPI 01	ND	2.0	ND	ND	ND	ND	ND	ND	ND	2.6

* Two samples and their duplicates were labelled with the same identification.

ND = None Detected; BLQ = Below Limit of Quantitation, 1 ppb; N/A = Not Analyzed

SampleName	BENZENE	TOLUENE	ETHYLBENZENE	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB	Fuel Carbon
QC, OBSERVED, PPB	47.9	47.9	50.2	47.7	48.4	49.1	50.1	49.8	49.4	N/A
QC, TRUE VALUE, PPB	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	N/A
SUR A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SUR B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SUR C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SUR D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SUR D Duplicate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SUR E	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SUR F	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 PRMP 02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 PRMP 20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 PRMP 01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381 MP I08	ND	BLQ	ND	ND	ND	ND	ND	ND	ND	BLQ
10 PPB	9.8	9.7	9.7	9.6	9.8	9.5	9.3	9.3	9.5	N/A
1381 MP I11	ND	1.8	ND	ND	ND	ND	ND	ND	ND	1.8
1381 MP I05	ND	BLQ	ND	ND	ND	ND	ND	ND	ND	BLQ
1381 MP I06	ND	3.8	ND	ND	ND	ND	ND	ND	ND	9.2
1381 MP I10	ND	1.8	ND	ND	ND	ND	ND	ND	ND	1.6
1381 MPI 10 Duplicate	ND	1.9	ND	ND	ND	ND	ND	ND	ND	2.5
1381 MP S10	ND	4.0	ND	ND	ND	ND	ND	ND	ND	3.4
1381 MP I18	ND	6.4	ND	ND	ND	ND	ND	ND	ND	5.4
1 PPB	1.1	1.2	1.3	1.3	1.4	1.3	1.5	1.4	1.4	N/A

ND = None Detected; BLQ = Below Limit of Quantitation, 1 ppb; N/A = Not Analyzed

MANTECH

Ref: 96-DF67

Oct. 2,1996

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Don:

As requested in Service Request SF-2-233, GC/MS analysis for phenols and aliphatic/aromatic acids was done on four water samples taken from Cape Canaveral. These samples were labeled: 1381 MWSO1, 1381 MSDO1, 1381 MWSO9 and 1381 MWIO6. These samples were received on Sept. 23 and 27, 1996 and were derivatized by Amy Zhao on Sept. 27, 1996. The extract was analyzed by GC/MS on Sept. 28, 1996. RSKERL SOP 177 was used for the extraction, derivatization and GC/MS analysis of the samples.

Table I provides the concentrations of the phenols and aliphatic/aromatic acids found in the water samples from Cape Canaveral. Derivative and extraction blanks, an extraction recovery and a 100 ppb check standard are also included in the table.

If you should have any questions, please feel free to contact me.

Sincerely,

Dennis D. Fine

xc: J. Seeley
G. Smith
R. Cosby
D. Fine
J. Wilson

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

Table I. Quantitative Report and QC Data for Phenols and Aliphatic and Aromatic Acids from Water Samples from Cape Canaveral (Service Request SF-2-233)

Concentration ppb

		1381 MWSO1	1381 MWDO1	1381 MWSO9	1381 MWIO6	Standard Blank	Extraction Blank	50 ppb Extraction Recovery	100 ppb Check Standard
1	PROPANOIC ACID – PFB	8	24	N.F.	13	N.F.	N.F.	27	100
2	2-METHYLPROPANOIC ACID – PFB	***	11	15	***	5	7	12	104
3	TRIMETHYL ACETIC ACID – PFB	***	***	***	5	***	6	50	111
4	BUTYRIC ACID – PFB	***	126	24	8	57	9	11	103
5	2-METHYLBUTYRIC ACID – PFB	***	N.F.	***	***	***	***	44	113
6	3-METHYLBUTYRIC ACID – PFB	***	***	***	***	***	***	41	113
7	3,3-DIMETHYLBUTYRIC ACID – PFB	N.F.	N.F.	***	***	***	***	60	106
8	PENTANOIC ACID – PFB	9	***	6	11	11	11	46	110
9	2,3-DIMETHYLBUTYRIC ACID – PFB	***	N.F.	N.F.	***	***	N.F.	58	103
10	2-ETHYLBUTYRIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	60	104
11	2-METHYLPENTANOIC ACID – PFB	N.F.	N.F.	N.F.	***	***	***	60	106
12	3-METHYLPENTANOIC ACID – PFB	***	N.F.	N.F.	***	***	***	56	103
13	4-METHYLPENTANOIC ACID – PFB	***	N.F.	***	***	***	***	59	107
14	HEXANOIC ACID – PFB	***	23	***	***	***	***	62	104
15	2-METHYLHEXANOIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	61	110
16	PHENOL – PFB	***	N.F.	***	***	***	11	53	92
17	CYCLOPENTANECARBOXYLIC ACID – PFB	N.F.	N.F.	N.F.	N.F.	***	N.F.	46	86
18	5-METHYLHEXANOIC ACID – PFB	N.F.	N.F.	N.F.	5	N.F.	N.F.	30	109
19	o-CRESOL – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	62	103
20	2-ETHYLHEXANOIC ACID – PFB	***	***	***	***	***	***	61	107
21	HEPTANOIC ACID – PFB	***	***	***	***	***	***	64	115
22	m-CRESOL – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	62	103
23	p-CRESOL – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	58	99
24	1-CYCLOPENTENE-1-CARBOXYLIC ACID – PFB	N.F.	***	N.F.	***	N.F.	***	51	119
25	o-ETHYLPHENOL – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	55	99
26	CYCLOPENTANEACETIC ACID – PFB	***	N.F.	***	***	***	N.F.	63	117
27	2,6-DIMETHYLPHENOL – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	39	95
28	2,5-DIMETHYLPHENOL – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	51	93
29	CYCLOHEXANECARBOXYLIC ACID – PFB	***	***	***	***	***	***	66	124
30	3-CYCLOHEXENE-1-CARBOXYLIC ACID – PFB	***	N.F.	N.F.	***	N.F.	***	65	127
31	2,4-DIMETHYLPHENOL – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	32	100
32	3,5-DIMETHYLPHENOL & M-ETHYLPHENOL – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	63	111
33	OCTANOIC ACID – PFB	***	***	***	***	***	***	62	107
34	2,3-DIMETHYLPHENOL – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	52	106
35	p-ETHYLPHENOL – PFB	N.F.	25	N.F.	N.F.	N.F.	N.F.	58	95
36	BENZOIC ACID – PFB	53	55	45	58	7	84	37	97
37	3,4-DIMETHYLPHENOL – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	51	97
38	m-METHYLBENZOIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	53	110
39	1-CYCLOHEXENE-1-CARBOXYLIC ACID – PFB	***	N.F.	N.F.	***	N.F.	N.F.	63	118
40	CYCLOHEXANEACETIC ACID – PFB	***	N.F.	N.F.	***	N.F.	N.F.	64	119
41	2-PHENYLPROPANOIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	62	116
42	o-METHYLBENZOIC ACID – PFB	***	***	N.F.	***	***	N.F.	63	114
43	PHENYLACETIC ACID – PFB	N.F.	N.F.	N.F.	***	***	N.F.	58	109
44	m-TOLYLACETIC ACID – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	56	107
45	o-TOLYLACETIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	67	100
46	2,6-DIMETHYLBENZOIC ACID – PFB	***	***	***	***	***	N.F.	66	121
47	p-TOLYLACETIC ACID – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	59	111
48	p-METHYLBENZOIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	57	108
49	3-PHENYLPROPANOIC ACID – PFB	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	55	108
50	2,5-DIMETHYLBENZOIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	56	113
51	DECANOIC ACID – PFB	N.F.	N.F.	N.F.	5	***	5	52	103
52	2,4-DIMETHYLBENZOIC ACID – PFB	N.F.	N.F.	***	N.F.	N.F.	N.F.	57	114
53	3,5-DIMETHYLBENZOIC ACID – PFB	N.F.	N.F.	***	***	N.F.	N.F.	56	107
54	2,3-DIMETHYLBENZOIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	58	114
55	4-ETHYLBENZOIC ACID – PFB	N.F.	N.F.	N.F.	N.F.	***	N.F.	54	106
56	2,4,6-TRIMETHYLBENZOIC ACID – PFB	***	N.F.	N.F.	***	***	N.F.	57	109
57	3,4-DIMETHYLBENZOIC ACID – PFB	N.F.	N.F.	N.F.	***	***	N.F.	50	102
58	2,4,5-TRIMETHYLBENZOIC ACID – PFB	N.F.	N.F.	N.F.	***	N.F.	N.F.	53	110

*** indicates concentration of extract was below lowest calibration standard (5 ppb).
N.F. indicates not found.

MANTECH

Ref: 96-MB10/vg
September 29,1996

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Don:

As per Service Request #SFTA-2-104, hydrogen analysis was performed onsite at Cape Canaveral AFS, FL, using a RGA3 Reduction Gas Analyzer (Trace Analytical). The analysis began on September 19, 1996 and was concluded on September 24, 1996. A six place (0.0 to 10.0 PPM) external standard curve was used to quantitate the samples. The following data represents the concentration in the dissolved phase.

CAPE CANAVERAL, AFS, FL

WELL	H_2 CONCENTRATION (nM)
1381MWS18	1.44
1381MWS05	1.96
1381MWI05	2.50
1381MWS17	5.97
1381MWS03	1.34
1381MWS11	5.10
1381MWS04	4.05
1381MWD12	6.44
1381MWS12	1.75
1381MWS16	1.62
1381MWS14	1.37
1381MWS15	1.16
1381MWS13	1.35
1381MWD03	7.11
1381MWS01	2.23
1381MWD01	5.31

If you have any questions, please feel free to contact me at your convenience.

Sincerely,
Mark Blankenship
Mark Blankenship

xc: R.L. Cosby
G.B. Smith
J.L. Seeley JLS

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

MANTECH ENVIRONMENTAL TECHNOLOGY

Ref: 96-JH83/vg

October 15, 1996

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection & Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Don:

Find attached results for methane, ethylene and ethane on samples received August 16, September 23, 24, and 27, 1996 from Cape Canaveral under Service Request #SF-2-233. Samples were prepared and calculations done as per RSKSOP-175. Analyses were performed as per RSKSOP-147.

If you have any questions concerning this data, please feel free to contact me.

Sincerely,

Jeff Hickerson

Jeff Hickerson

xc: R.L. Cosby
G.B. Smith
J.L. Seeley SV for
J.T. Wilson

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

SR# SF-2-233
CAPE CANAVERAL

ANALYSIS PERFORMED 9-3-96

SAMPLE	METHANE	ETHYLENE	ETHANE
LAB BLANK	BLQ	ND	ND
NO LABEL-1	18.72	BLQ	BLQ
NO LABEL-2	17.83	ND	ND
1381MWD09	16.20	ND	BLQ
1381MWS01	0.825	0.009	ND
1381WS09	4.00	0.004	ND
1381MWI09	16.55	0.054	ND
" LAB DUP	16.52	0.052	ND
1381MWD01	15.90	ND	ND
" FIELD DUP	17.51	ND	ND

ANALYSIS PERFORMED 9-25-96

SAMPLE	METHANE	ETHYLENE	ETHANE
LAB BLANK	BLQ	ND	ND
1381MW D01	19.09	ND	BLQ
1381MW D09	17.50	ND	BLQ
1381MW D12	18.93	BLQ	ND
1381MW I05	15.21	ND	ND
" LAB DUP	16.83	ND	ND
1381MW I09	15.42	0.064	ND
1381MW S01	0.637	0.006	ND
1381MW S03	1.04	0.018	ND
1381MW S05	2.60	BLQ	0.006
1381MW S07	0.215	ND	ND
" FIELD DUP	0.210	ND	ND

ANALYSIS PERFORMED 9-30-96

SAMPLE	METHANE	ETHYLENE	ETHANE
LAB BLANK	BLQ	ND	ND
1381MW S11	0.484	ND	ND
1381MW S09	1.22	0.006	ND
1381MW S12	1.23	0.013	ND
1381MW S14	0.098	ND	ND
" FIELD DUP	0.102	ND	ND
1381MW S16	0.078	ND	ND
1381MW S17	1.52	0.013	ND
1381MW S18	0.228	ND	ND
1381MW D03	16.81	0.114	BLQ
1381MP I03	15.37	ND	BLQ
" LAB DUP	16.33	ND	BLQ

SR# SF-2-233
CAPE CANAVERAL

ANALYSIS PERFORMED 10-2-96

SAMPLE	METHANE	ETHYLENE	ETHANE
LAB BLANK	BLQ	ND	ND
1381MP I02	18.49	ND	BLQ
1381MP I03	30.10	ND	BLQ
1381MP I06	27.96	ND	ND
1381MP I07	21.63	0.159	BLQ
" LAB DUP	21.05	0.155	BLQ
1381MP I17	27.26	BLQ	ND
1381MP S01	0.134	ND	ND
1381MP S07	0.463	BLQ	ND
1381MP S08	3.36	ND	BLQ
1381MW S13	0.074	ND	ND
" FIELD DUP	0.072	ND	ND
1381MW S15	0.793	BLQ	ND
1381MP I05	32.55	ND	ND
1381MP I06	24.14	0.051	ND
1381MP I08	0.103	ND	ND
1381MP I10	0.212	ND	ND
" LAB DUP	0.205	ND	ND

ANALYSIS PERFORMED 10-3-96

SAMPLE	METHANE	ETHYLENE	ETHANE
LAB BLANK	BLQ	ND	ND
1381MP I11	27.13	ND	ND
1381MP I13	26.27	ND	BLQ
1381MP I18	29.98	ND	ND
1381MP I21	20.27	ND	ND
1381PRMP01	1.29	0.012	ND
1381PRMP02	1.82	0.018	ND
1381PRMP20	25.51	ND	ND
" LAB DUP	24.93	ND	ND
1381MPS10	0.228	ND	ND
" FIELD DUP	0.227	ND	ND
10 PPM CH4	10.00	NA	NA
100 PPM CH4	99.92	NA	NA
1000 PPM CH4	1000.05	NA	NA
1% CH4	1.00	NA	NA
10% CH4	9.20	NA	NA
20% CH4	20.35	NA	NA
10 PPM C2H4	NA	10.19	NA
100 PPM C2H4	NA	99.99	NA
1000 PPM C2H4	NA	999.95	NA
10 PPM C2H6	NA	NA	9.71
100 PPM C2H6	NA	NA	100.02

LIMITS OF QUANTITATION.

METHANE	ETHYLENE	ETHANE
0.001	0.003	0.002

SAMPLE UNITS ARE mg/L.
STANDARDS UNITS CORRESPOND
TO THE SAMPLE COLUMN.

BLQ DENOTES BELOW LIMIT OF QUANTITATION.
ND DENOTES NONE DETECED.
NA DENOTES NOT ANALYZED.

MANTECH ENVIRONMENTAL TECHNOLOGY

Ref: 96JAD66

November 22, 1996

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Don:

As requested in Service Request # SF-2-233, headspace GC/MS analysis of 46 Cape Canaveral water samples for chlorinated volatile organics was completed. The samples were received on October 1, and analyzed on November 8, 1996. RSKSOP-148 (Determination of Volatile Organic Compounds in Water by Automated Headspace Gas Chromatography/Mass Spectrometry (Saturn II Ion Trap Detector) was used for this analysis.

An internal standard calibration method was established for the 15 compounds. The standard curves were prepared from 1.0 to 4000 ppb. The lower calibration limits were 1.0 ppb.

Samples marked with ?? in tables 1 & 2 were labeled the same name. These do not appear to be the same sample and could be mislabeled. The duplicate of each sample was also analyzed.

A dilution corrected quantitation report for the samples, lab duplicates, field duplicates, QC standards and lab blanks is presented in table 1-4.

If you should have any questions, please feel free to contact me.

Sincerely,

John Allen Daniel

xc: R.L. Cosby
G.B. Smith
D.D. Fine
J.L. Seeley JS
J.T. Wilson

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

Table 1. Quantitation Report for S.R. # SF-2-233 from Cape Canaveral.

Concentration = ppb

Compound	MWS13	MWS14	MWS15	MWS16	MWS12	MWD12	MWS07	MWS11	MWS03	MWSO3 Lab Dup
VINYL CHLORIDE	---	2.3	16.3	1.2	510	ND	1.3	ND	836	815
1,1-DICHLOROETHENE	ND	ND	ND	ND	1.4	ND	ND	ND	12.6	11.7
T-1,2-DICHLOROETHENE	ND	---	---	ND	10.8	ND	ND	ND	15.1	14.5
1,1-DICHLOROETHANE	ND	ND	ND	ND	1.4	ND	ND	---	4.6	4.4
C-1,2-DICHLOROETHENE	4.6	65.6	130	2.1	751	ND	10.2	---	2590	2510
CHLOROFORM	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-TRICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CARBON TETRACHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TETRACHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-DICHLOROBENZENE	ND	---	---	---	ND	ND	---	---	ND	ND
1,3-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROBENZENE	---	ND	ND	ND	ND	ND	---	ND	ND	ND

Compound	MWS17	MWI05	MWS05	MWS18	NWI09	MWS09	MWS09 Field Dup 1/20 Dil	?? MWD01	?? MWD01 Field Dup	MWD09
VINYL CHLORIDE	1040	ND	51.3	ND	795	240	238	ND	ND	1.6
1,1-DICHLOROETHENE	2.3	ND	ND	ND	6.1	238	251	ND	ND	ND
T-1,2-DICHLOROETHENE	21.2	ND	1.8	ND	145	25.1	32.2	ND	ND	ND
1,1-DICHLOROETHANE	2.6	ND	---	ND	---	26.4	27.3	ND	ND	ND
C-1,2-DICHLOROETHENE	901	ND	43.7	ND	1210	*****	4120	---	---	3.6
CHLOROFORM	ND	ND	ND	ND	ND	2.5	ND	ND	ND	ND
1,1,1-TRICHLOROETHANE	ND	ND	ND	ND	ND	130	141	ND	ND	ND
CARBON TETRACHLORIDE	ND	ND	ND	ND	ND	15.9	---	ND	ND	ND
1,2-DICHLOROETHANE	ND	ND	ND	ND	ND	---	ND	ND	ND	ND
TRICHLOROETHENE	ND	ND	---	---	26.9	*****	39,400	---	ND	6.6
TETRACHLOROETHENE	ND	ND	ND	ND	ND	3.3	ND	ND	ND	ND
CHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-DICHLOROBENZENE	ND	ND	---	ND	ND	---	ND	ND	ND	ND
1,3-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROBENZENE	ND	ND	---	ND	ND	ND	ND	ND	ND	ND

ND = None Detected --- = Below Calibration Limit(1.0 ppb) Dup = Duplicate Dil = Dilution ***** = Above Calibration Limit(4000 ppb)
?? = See Cover Letter

Table 2. Quantitation Report for S.R. # SF-2-233 from Cape Canaveral.

Concentration = ppb

Compound	?? MWD01	?? MWD01 Field Dup	MPI13	MPI08	MPI19	MPI19 Lab Dup	MPI07	MPSO7	MPI17	MWD03
VINYL CHLORIDE	210	215	ND	ND	ND	ND	ND	39.5	ND	ND
1,1-DICHLOROETHENE	14.6	14.2	ND	ND	ND	ND	ND	ND	ND	ND
T-1,2-DICHLOROETHENE	9.1	9.1	ND	ND	ND	ND	ND	2.3	ND	ND
1,1-DICHLOROETHANE	4.1	4.0	ND	ND	ND	ND	ND	---	ND	ND
C-1,2-DICHLOROETHENE	2400	2450	ND	ND	ND	ND	ND	78.3	---	ND
CHLOROFORM	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-TRICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CARBON TETRACHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRICHLOROETHENE	239	242	ND	ND	ND	ND	ND	ND	ND	ND
TETRACHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-DICHLOROBENZENE	---	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3-DICHLOROBENZENE	---	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROBENZENE	---	ND	ND	ND	ND	ND	ND	ND	ND	ND

	MPS08	MPI03	MPS01	MPI02	MPI01	SURA	SURA Lab Dup	SURB	SURC	SURD
VINYL CHLORIDE	13.8	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
T-1,2-DICHLOROETHENE	---	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-DICHLOROETHANE	---	ND	ND	ND	ND	ND	ND	ND	ND	ND
C-1,2-DICHLOROETHENE	26.6	ND	3.6	---	ND	ND	ND	ND	ND	ND
CHLOROFORM	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.7
1,1,1-TRICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CARBON TETRACHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRICHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TETRACHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHLOROBENZENE	---	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-DICHLOROBENZENE	---	ND	ND	---	ND	ND	ND	ND	ND	ND
1,3-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROBENZENE	---	ND	ND	ND	ND	ND	ND	ND	ND	ND

?? = See Cover Letter ND = None Detected --- = Below Calibration Limit(1.0 ppb) Dup = Duplicate

Table 3. Quantitation Report for S[redacted] # SF-2-233 from Cape Can[redacted]eral.

Concentration = ppb

Compound	SURE	SURF	PRMP02	PRMP02 Field Dup	PRMP20	PRMP01	PRMP01 Field Dup	MPI08	MPI08 Lab Dup	MPI11
VINYL CHLORIDE	ND	ND	1350	1420	1.6	767	814	ND	ND	ND
1,1-DICHLOROETHENE	ND	ND	5.5	5.7	ND	4.6	4.7	ND	ND	ND
T-1,2-DICHLOROETHENE	ND	ND	17.6	17.5	ND	11.0	11.8	ND	ND	ND
1,1-DICHLOROETHANE	ND	ND	5.0	4.8	ND	2.4	2.5	ND	ND	ND
C-1,2-DICHLOROETHENE	ND	ND	1760	1690	4.4	1210	1200	ND	ND	ND
CHLOROFORM	4.9	4.4	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-TRICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CARBON TETRACHLORIDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRICHLOROETHENE	ND	ND	---	---	ND	---	---	ND	ND	ND
TETRACHLOROETHENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	---	ND	ND
1,3-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	---	ND	ND

Compound	MPI05	MPI06	MPI10	MPS10	MPS10 Lab Dup	MPI18	QC1108A 20 ppb	QC1108B 200 ppb	QC1108C 20 ppb Sample Lost	QC1108D 200 ppb
VINYL CHLORIDE	ND	1.6	ND	ND	ND	ND	22.3	208		198
1,1-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	23.7	205		203
T-1,2-DICHLOROETHENE	ND	ND	ND	ND	ND	ND	21.7	196		181
1,1-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	20.8	191		188
C-1,2-DICHLOROETHENE	ND	4.7	ND	ND	ND	ND	20.5	200		189
CHLOROFORM	ND	ND	ND	ND	ND	ND	20.1	200		185
1,1,1-TRICHLOROETHANE	ND	ND	ND	ND	ND	ND	21.2	172		178
CARBON TETRACHLORIDE	ND	ND	ND	ND	ND	ND	21.8	169		176
1,2-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	18.5	236		205
TRICHLOROETHENE	ND	---	ND	ND	ND	ND	19.8	188		183
TETRACHLOROETHENE	ND	ND	ND	ND	ND	ND	21.1	173		173
CHLOROBENZENE	ND	ND	ND	ND	ND	ND	21.5	192		183
1,4-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	22.6	187		181
1,3-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	21.3	218		207
1,2-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	21.2	215		205

ND = None Detected --- = Below Calibration Limit(1.0 ppb) QC = Quality Control Std. Dup = Duplicate

Table 4. Quantitation Report for S.R. # SF−2−233 from Cape Canaveral.

Concentration = ppb

Compound	QC1108E 20 ppb	QC1108F 200 ppb	QC1108G 20 ppb	QC1108H 200 ppb	QC1108I 20 ppb	QC1108J 200 ppb	QC1108K 20 ppb	QC1112A 20 ppb	BL1108A	BL1108B
VINYL CHLORIDE	21.4	199	22.3	222	21.8	218	19.0	22.5	ND	ND
1,1−DICHLOROETHENE	21.7	195	22.6	225	23.0	217	21.0	24.2	ND	ND
T−1,2−DICHLOROETHENE	21.2	182	22.0	182	21.4	189	21.2	21.6	ND	ND
1,1−DICHLOROETHANE	21.2	187	21.4	190	21.8	188	23.3	20.2	ND	ND
C−1,2−DICHLOROETHENE	21.3	192	20.7	176	21.6	196	22.3	19.5	ND	ND
CHLOROFORM	21.4	194	20.2	182	22.2	190	22.5	18.7	ND	ND
1,1,1−TRICHLOROETHANE	20.3	177	21.3	199	21.9	188	21.1	22.1	ND	ND
CARBON TETRACHLORIDE	20.3	173	21.6	194	22.5	188	20.1	22.3	ND	ND
1,2−DICHLOROETHANE	20.4	208	17.3	181	19.7	207	24.5	17.8	ND	ND
TRICHLOROETHENE	18.8	176	18.8	186	19.5	186	19.0	19.4	ND	ND
TETRACHLOROETHENE	20.6	167	20.1	171	20.6	176	18.3	21.1	ND	ND
CHLOROBENZENE	23.4	184	20.8	176	22.6	182	23.1	19.8	ND	ND
1,4−DICHLOROBENZENE	23.4	169	20.5	158	21.5	170	22.1	19.2	---	ND
1,3−DICHLOROBENZENE	22.2	197	19.1	185	20.3	199	19.8	18.9	---	ND
1,2−DICHLOROBENZENE	24.0	200	20.6	183	22.5	198	22.9	18.6	---	ND

ND = None Detected --- = Below Calibration Limit(1.0 ppb) QC = Quality Control Std. Dup = Duplicate BL = Blank

CAPE CANAVERAL Site 1381

Field Data

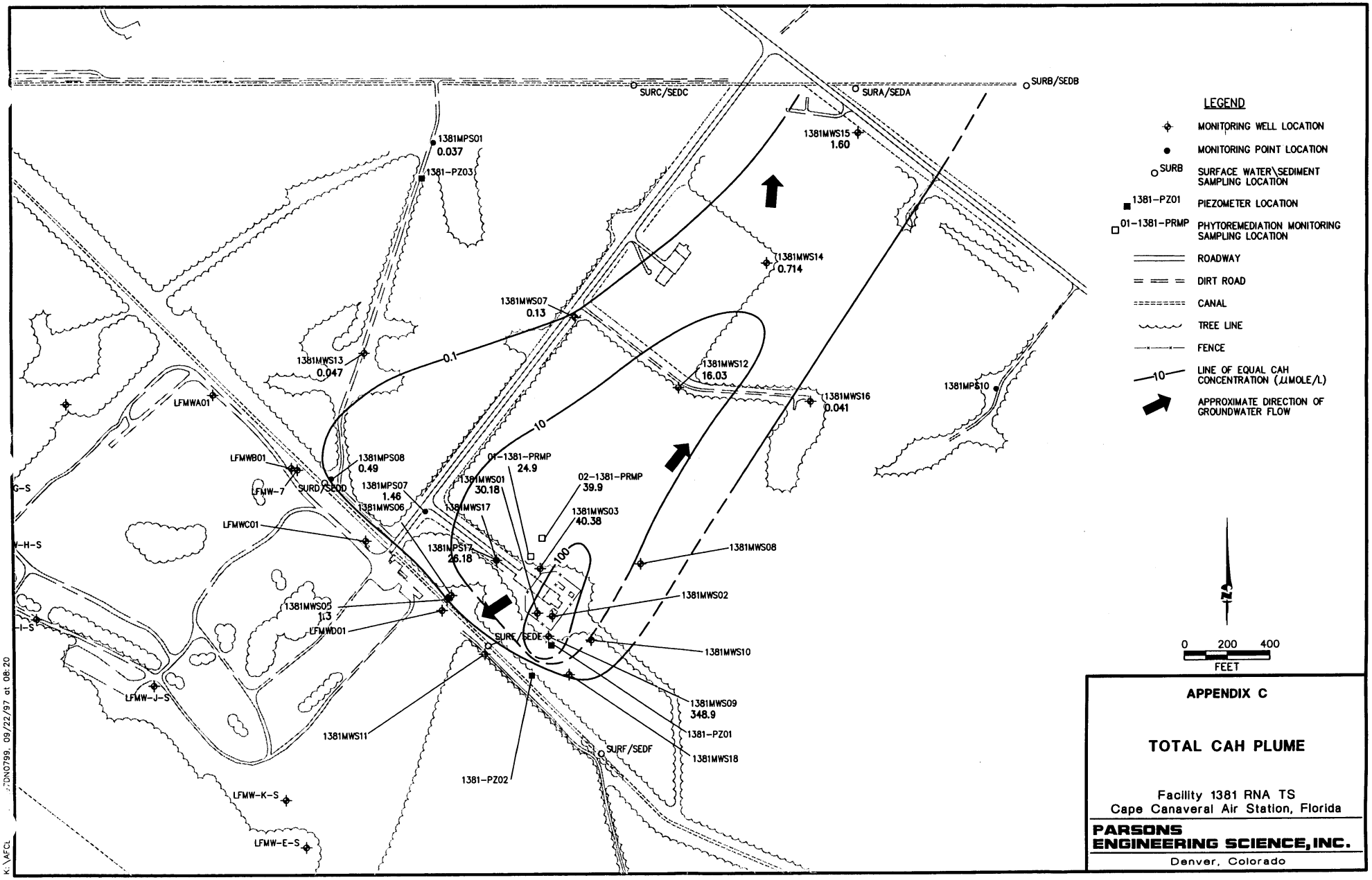
Sample	Date	Redox mv	pH units	Cond.	Calcium	Total Alkalinity mg/l CaCO3	Ferrous Iron mg/l	Hydrogen Sulfide mg/l
1381 MW S01	9-19-96	203	7.3	1020	60	239	<.05	
1381 MW S01		-13	7.5	4090	120	457	<.05	
1381 MW S09		-61	7.2	1440	160	304	1.3	
1381 MW S19		-113	7.4	4030	94	370	.1	
1381 MW S09		-125	7.7	6970	308	460	.3	
1381 MW S18	9-20-96	70	7.3	1267	172	311	1.8	
1381 MW S05		-50	7.4	1132	126	326	.5	<.1
1381 MW S05		-140	7.4	3920	208	668	.2	.1
1381 MW S17		-78	7.3	1322	158	342	1.6	<.1
1381 MW S03		-105	7.2	1020	140	301	2.0	<.1
1381 MW S11		-106	7.0	1368	360	—	8.7	<.1
1381 MW S07		-87	7.3	669	120	271	.5	<.1
MW S14	9-21-96	-253	8.3	3330	196	487	.2	.3
1381 MW S15		-127	7.3	1492	182	328	2.5	<.1
1381 MW S16		137	7.4	533	60	228	<.05	
1381 MW S14		120	7.2	728	120	370	.19	
1381 MW S15		-90	7.2	1489	188	315	2.3	<.1
1381 MW S12		132	7.7	419	100	178	<.05	
1381 MP I02		10	7.8	2480	262	537	<.05	
1381 MP S01		-120	7.5	554	130	195	.6	<.1
1381 MP I01		-129	7.8	2630	170	554	<.05	<.1

Cape Canaveral Station
Field Data

Sample	Date	Redox mV	pH units	cond	Carbon dioxide mg/L	Total Alkalinity mg/L $CaCO_3$	Ferrous iron mg/L	Hydrogen sulfide mg/L
1381 MP103	9-23-96	-96	7.2	1458	204	386	1.5	<.1
1381 MP102		-86	7.7	5420	416	863	<.05	<.1
1381 MPI17		-206	7.8	4730	296	770	<.05	<.1
1381 MW D02		-176	8.1	4300	102	458	<.05	<.1
1381 MPI07		-212	7.7	2330	210	495	<.05	<.1
1381 MP107		-138	7.4	618	92	225	<.05	<.1
1381 MPI06	↓	-40	7.3	5440	438	755	<.05	<.1
1381 MP21	9-24-96	-243	7.8	5110	258	670	.3	.3
1381 MPI 12		-190	7.8	4370	332	744	.2	.1
1381 MPI 18		-211	7.8	4770	306	801	.2	.1
1381 MP S10		-109	7.8	7520	386	834	<.05	.1
1381 MP I10		-118	7.3	972	196	321	.8	<.1
1381 MP I06		-98	7.7	5710	294	789	<.05	<.1
1381 MP I05		-185	7.7	6620	383	955	<.05	<.1
1381 MP I11		-225	7.7	7910	358	905	<.05	.1
1381 MP I09		-290	8.2	3760	232	524	<.05	.1

APPENDIX C

SUPPORTING MODEL INPUT AND CALCULATIONS FOR GROUNDWATER FATE AND TRANSPORT MODELING



APPENDIX C

TOTAL CAH PLUME

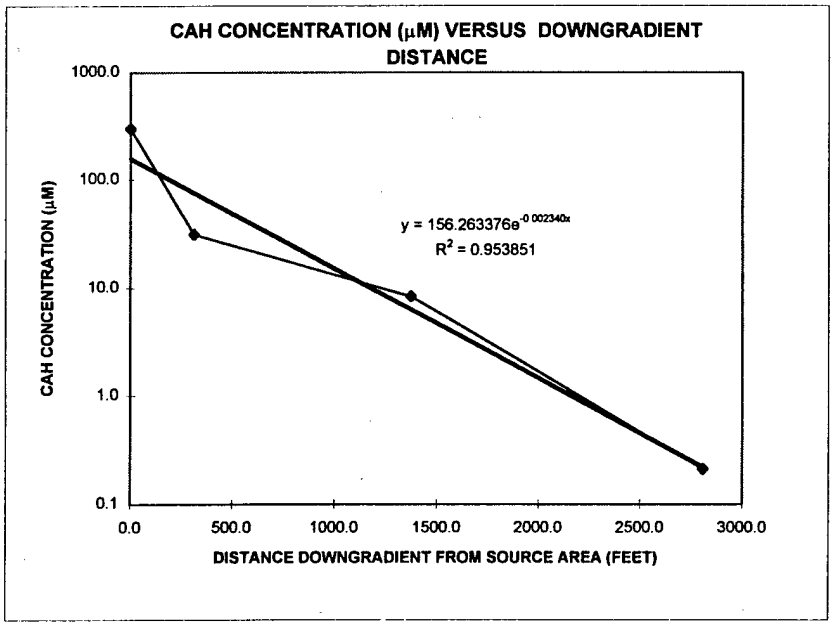
Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

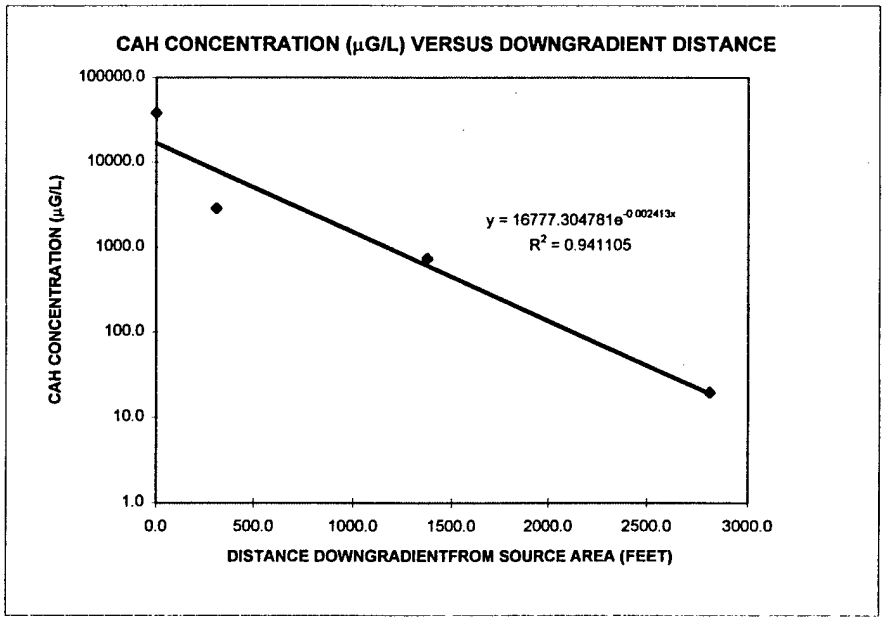
PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

K:\AFCL...7DN0799, 09/22/97 at 08:20

ESTIMATED MINIMUM FIRST-ORDER RATE CONSTANT CALCULATION FOR THE TOTAL PLUME LENGTH
USING THE METHOD OF BUSCHECK AND ALCANTAR (1995)
WINTER/SPRING, 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Well	Easting (feet)	Northing (feet)	Distance Downgradient	PCE (µg/L Sep-96	PCE (µM) Sep-96	TCE (µg/L) Sep-96	TCE (µM) Sep-96	Total DCE (µg/L) Sep-96	Total DCE (µM) Sep-96	VC (µg/L) Sep-96	VC (µM) Sep-96	Total CAH (µg/L) Sep-96	Total CAH (µM Sep-96
1381MWS09	797469.3	1504278.2	0.0	9.7	0.1	35000.0	266.4	3000.0	30.9	0.0	0.0	38009.7	297.4
1381MWS03	797436.7	1504588.5	312.0	0.0	0.0	0.0	0.0	2500.0	25.8	330.0	5.3	2830.0	31.1
1381MWS12	798083.4	1505429.9	1373.2	0.0	0.0	0.0	0.0	605.8	6.2	130.0	2.1	735.8	8.3
1381MWS15	798915.2	1506601.7	2810.3	0.0	0.0	0.0	0.0	18.0	0.2	1.5	0.0	19.5	0.2





Method of Buscheck & Alcantar (1995)

$$\lambda = v_c/4\alpha_x([1+2\alpha_x(k/v_x)]^2-1)$$

where v_c = 0.014 ft/day
α_x = 300 ft
k/v = 0.00234

therefore λ = 5.5758E-05 1/day
λ = 5.5758E-03 %/day

Method of Buscheck & Alcantar (1995)

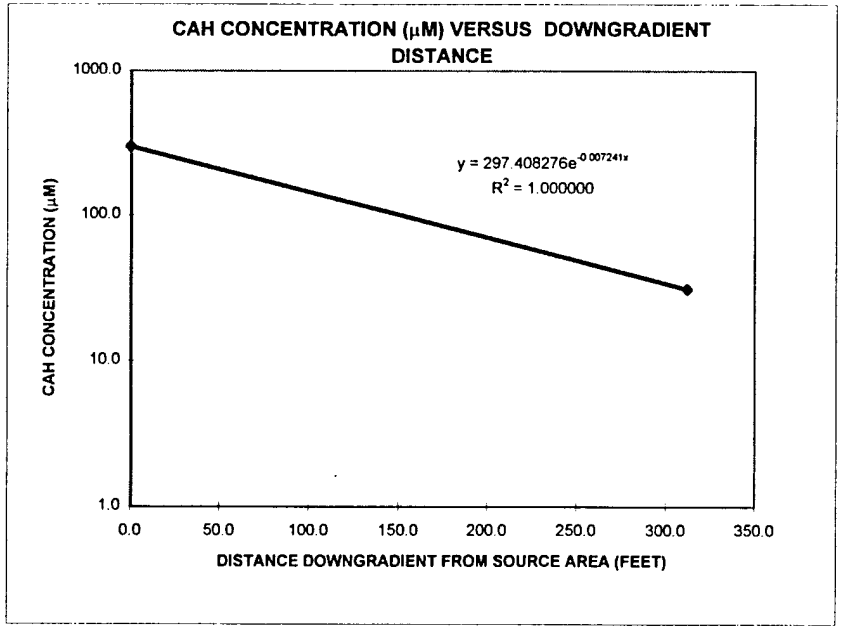
$$\lambda = v_c/4\alpha_x([1+2\alpha_x(k/v_x)]^2-1)$$

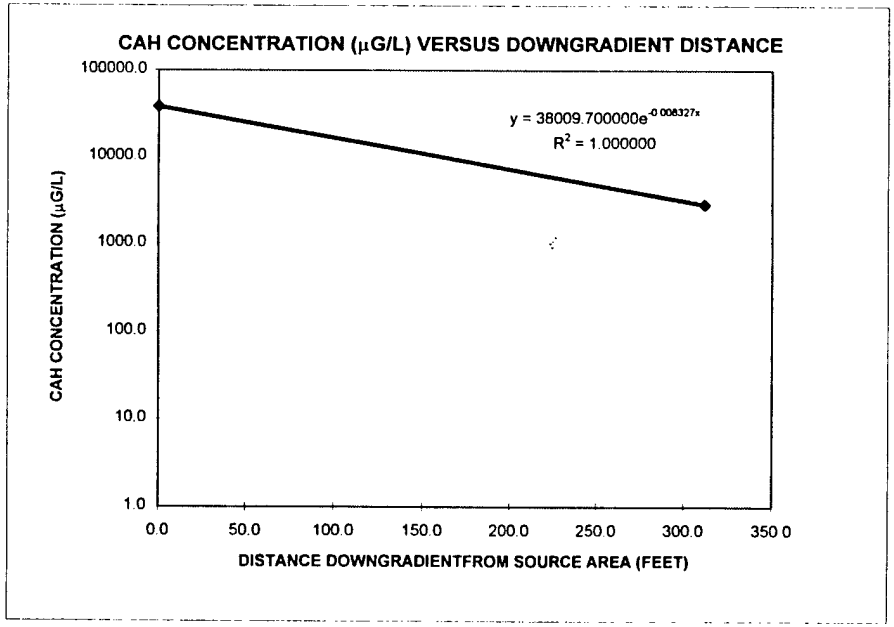
where v_c = 0.014 ft/day
α_x = 300 ft
k/v = 0.002413

therefore λ = 5.8237E-05 1/day
λ = 5.8237E-03 %/day

ESTIMATED MINIMUM FIRST-ORDER RATE CONSTANT CALCULATION FOR THE SOURCE AREA
USING THE METHOD OF BUSCHECK AND ALCANTAR (1995)
WINTER/SPRING, 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Well	Easting (feet)	Northing (feet)	Distance Downgradient	PCE (µg/L Sep-96	PCE (µM) Sep-96	TCE (µg/L) Sep-96	TCE (µM) Sep-96	Total DCE (µg/L) Sep-96	Total DCE (µM) Sep-96	VC (µg/L) Sep-96	VC (µM) Sep-96	Total CAH (µg/L) Sep-96	Total CAH (µM Sep-96
1381MWS09	797469.3	1504278.2	0.0	9.7	0.1	35000.0	266.4	3000.0	30.9	0.0	0.0	38009.7	297.4
1381MWS03	797436.7	1504588.5	312.0	0.0	0.0	0.0	0.0	2500.0	25.8	330.0	5.3	2830.0	31.1





Method of Buscheck & Alcantar (1995)

$\lambda = v_c/4\alpha_x([1+2\alpha_x(k/v_x)]^2-1)$

where	v_c =	0.014	ft/day
	α_x =	300	ft
	k/v =	0.007241	
therefore	λ =	3.2159E-04	1/day
	λ =	3.2159E-02	%/day

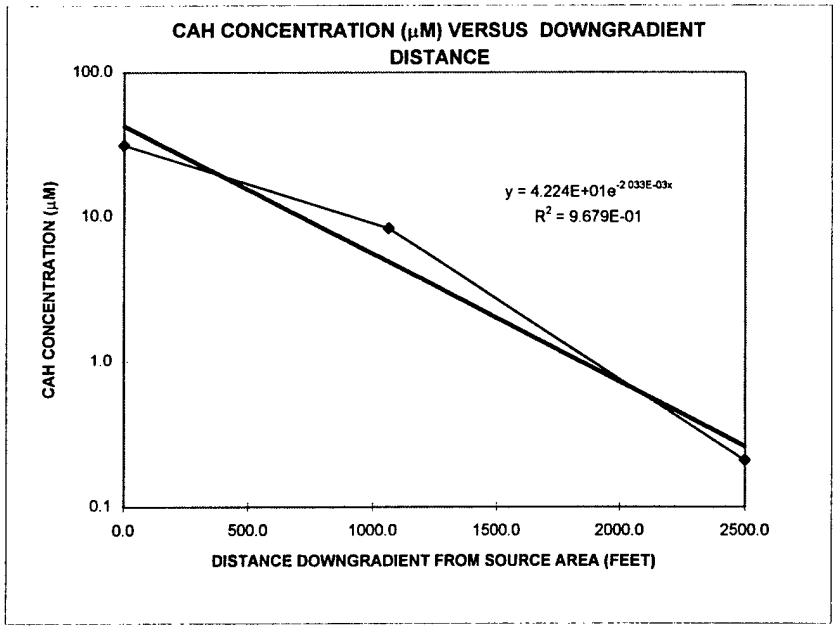
Method of Buscheck & Alcantar (1995)

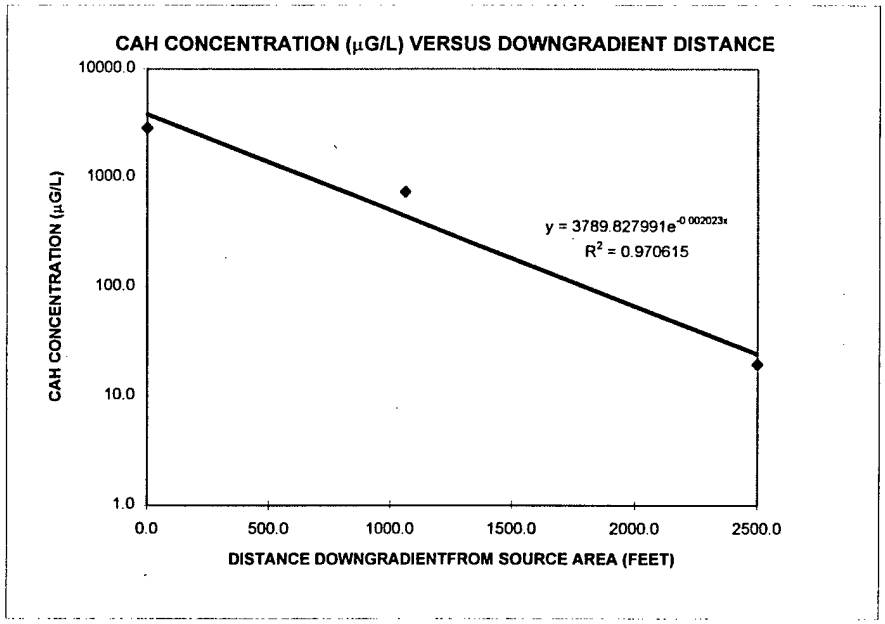
$\lambda = v_c/4\alpha_x([1+2\alpha_x(k/v_x)]^2-1)$

where	v_c =	0.014	ft/day
	α_x =	300	ft
	k/v =	0.008327	
therefore	λ =	4.0780E-04	1/day
	λ =	4.0780E-02	%/day

ESTIMATED MINIMUM FIRST-ORDER RATE CONSTANT CALCULATION FOR DOWNGRADIENT SECTION OF PLUME
USING THE METHOD OF BUSCHECK AND ALCANTAR (1995)
WINTER/SPRING, 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Well	Easting (feet)	Northing (feet)	Distance Downgradient	PCE (µg/L Sep-96	PCE (µM) Sep-96	TCE (µg/L) Sep-96	TCE (µM) Sep-96	Total DCE (µg/L) Sep-96	Total DCE (µM) Sep-96	VC (µg/L) Sep-96	VC (µM) Sep-96	Total CAH (µg/L) Sep-96	Total CAH (µM Sep-96
1381MWS03	797436.7	1504588.5	0.0	0.0	0.0	0.0	0.0	2500.0	25.8	330.0	5.3	2830.0	31.1
1381MWS12	798083.4	1505429.9	1061.2	0.0	0.0	0.0	0.0	605.8	6.2	130.0	2.1	735.8	8.3
1381MWS15	798915.2	1506601.7	2498.3	0.0	0.0	0.0	0.0	18.0	0.2	1.5	0.0	19.5	0.2





Method of Buscheck & Alcantar (1995)

$$\lambda = v_c/4\alpha_x([1+2\alpha_x(k/v_x)]^2-1)$$

where	v_c =	0.014	ft/day
	α_x =	300	ft
	k/v =	0.002033	
therefore	λ =	4.5821E-05	1/day
	λ =	4.5821E-03	%/day

Method of Buscheck & Alcantar (1995)

$$\lambda = v_c/4\alpha_x([1+2\alpha_x(k/v_x)]^2-1)$$

where	v_c =	0.014	ft/day
	α_x =	300	ft
	k/v =	0.002023	
therefore	λ =	4.5511E-05	1/day
	λ =	4.5511E-03	%/day

REDUCTIVE DECHLORINATION RATE
1381MWS09 > 1381MWS03 > 1381MWS12 > 1381MWS15
WINTER/SPRING, 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

The following procedures outlined by Moutoux et al. (1996)

Step 1: Enter Observed Contaminant Concentration (mg/L)

Well	PCE	TCE	DCE	VC	Ethene	Total CAHs
1381MWS09	9.7	35000.0	3000.0	0.0	0	38009.7
1381MWS03	0.0	0.0	2500.0	330.0	0	2830.0
1381MWS12	0.0	0.0	605.8	130.0	0	735.81
1381MWS15	0.0	0.0	18.0	1.5	0	19.5

Step 2: Compute Molar Concentrations (micromoles/Liter)

Well	M_{PCE}	M_{TCE}	M_{DCE}	M_{VC}	M_{Ethene}	Total M_{CAHs}
1381MWS09	0.06	266.40	30.95	0.00	0.00	297.41
1381MWS03	0.00	0.00	25.79	5.28	0.00	31.07
1381MWS12	0.00	0.00	6.25	2.08	0.00	8.33
1381MWS15	0.00	0.00	0.19	0.02	0.00	0.21

Step 3: Compute Carbon Equivalents

Well	Total M_{CAHs}	x 2	= Ceqi
1381MWS09	297.41		594.82
1381MWS03	31.07		62.14
1381MWS12	8.33		16.66
1381MWS15	0.21		0.42

Step 4: Compute Chlorine Equivalents

Well	M_{PCE} x 4	M_{TCE} x 3	M_{DCE} x 2	M_{VC}	S = $Cleq_i$
1381MWS09	0.23	799.21	61.89	0.00	861.34
1381MWS03	0.00	0.00	51.58	5.28	56.86
1381MWS12	0.00	0.00	12.50	2.08	14.58
1381MWS15	0.00	0.00	0.37	0.02	0.40

Step 5: Compute Corrected CAH Concentrations

$$C_{i,corr} = C_{i-1,corr} \times (Cleq_i / Cleq_{i-1}) \times (Ceq_{i-1} / Ceq_i)$$

Well	$C_{i-1,corr}$	$Cleq_i / Cleq_{i-1}$	Ceq_{i-1} / Ceq_i	$C_{i,corr}$
1381MWS09	38009.71			38009.71
1381MWS03	38009.71	0.07	9.57	24017.66
1381MWS12	24017.66	0.26	3.73	22969.83
1381MWS15	22969.83	0.03	39.71	24733.73

REDUCTIVE DECHLORINATION RATE
1381MWS09 > 1381MWS03 > 1381MWS12 > 1381MWS15
WINTER/SPRING, 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Step 6: Plot Exponential Trendline of Contaminant Concentration vs. Time

Well	Distance From Source (ft)	CAH avg. velocity (ft/day)*	CAH Travel Time (day)	$C_{i,corr}$
1381MWS09	0	0.028	0	38009.71
1381MWS03	312	0.028	11143	24017.66
1381MWS12	1373	0.014	86943	22969.83
1381MWS15	2810	0.014	189593	24733.73

*Assumes an unretarded velocity of 0.031 feet/day and a retardation coefficient of 2.25 for 1381MWS12 and 1381MWS15.
Assumes an unretarded velocity of 0.106 feet/day and a retardation coefficient of 3.79 for 1381MWS09 and 1381MWS03.

Reductive Dechlorination Rate

$C = C_0 e^{-kt}$ where:

C = Corrected Contaminant Concentration (mg/L) at time t (days)
C_0 = Initial Contaminant Concentration (mg/L)
k = Reductive Dechlorination Rate ($days^{-1}$)

from plot: $y = 29500e^{-1.318E-06x}$ $k = 1.318$ E-06 $days^{-1}$

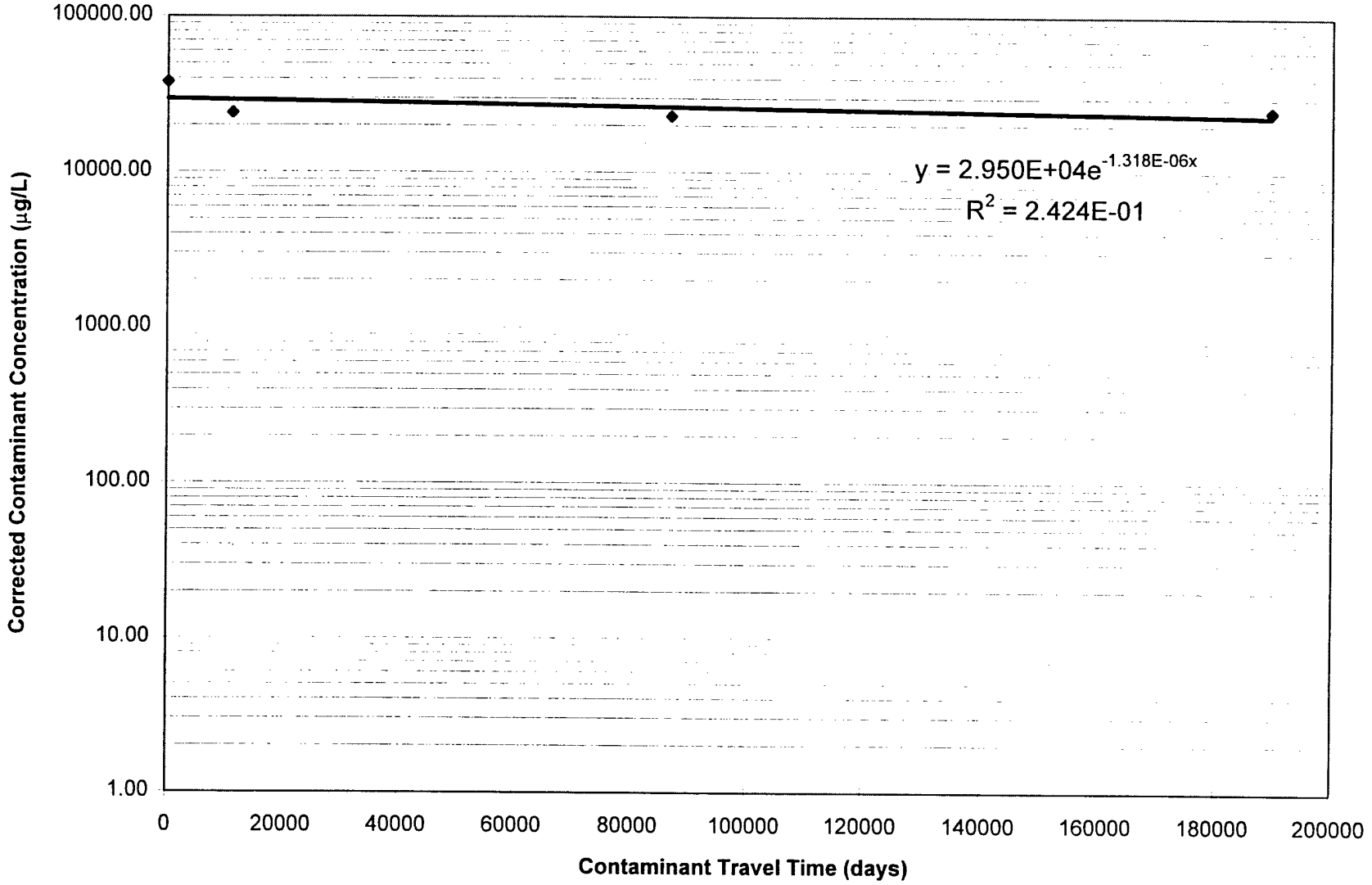
REDUCTIVE DECHLORINATION RATE

1381MWS09 > 1381MWS03 > 1381MWS12 > 1381MWS15

WINTER/SPRING, 1996

FACILITY 1381 RNA TS

CAPE CANAVERAL AIR STATION, FLORIDA



REDUCTIVE DECHLORINATION RATE
1381MWS09 > 1381MWS03
WINTER/SPRING, 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

The following procedures outlined by Moutoux et al. (1996)

Step 1: Enter Observed Contaminant Concentration (µg/L)

Well	PCE	TCE	DCE	VC	Ethene	Total CAHs
1381MWS09	9.7	35000.0	3000.0	0.0	0	38009.7
1381MWS03	0.0	0.0	2500.0	330.0	0	2830.0

Step 2: Compute Molar Concentrations (micromoles/Liter)

Well	M_{PCE}	M_{TCE}	M_{DCE}	M_{VC}	M_{Ethene}	Total M_{CAHs}
1381MWS09	0.06	266.40	30.95	0.00	0.00	297.41
1381MWS03	0.00	0.00	25.79	5.28	0.00	31.07

Step 3: Compute Carbon Equivalents

Well	Total M_{CAHs}	x 2	= Ceqi
1381MWS09	297.41		594.82
1381MWS03	31.07		62.14

Step 4: Compute Chlorine Equivalents

Well	M_{PCE} x 4	M_{TCE} x 3	M_{DCE} x 2	M_{VC}	$\Sigma = Cleq_i$
1381MWS09	0.23	799.21	61.89	0.00	861.34
1381MWS03	0.00	0.00	51.58	5.28	56.86

Step 5: Compute Corrected CAH Concentrations

$$C_{i,corr} = C_{i-1,corr} \times (Cleq_i / Cleq_{i-1}) \times (Ceq_{i-1} / Ceq_i)$$

Well	$C_{i-1,corr}$	$Cleq_i / Cleq_{i-1}$	Ceq_{i-1} / Ceq_i	$C_{i,corr}$
1381MWS09	38009.71			38009.71
1381MWS03	38009.71	0.07	9.57	24017.66

Step 6: Plot Exponential Trendline of Contaminant Concentration vs. Time

Well	Distance From Source (ft)	CAH avg. velocity (ft/day)*	CAH Travel Time (day)	$C_{i,corr}$
1381MWS09	0	0.028	0	38009.71
1381MWS03	312	0.028	11143	24017.66

*Assumes an unretarded velocity of 0.106 feet/day and a retardation coefficient of 3.79 for 1381MWS09 and 1381MWS03.

REDUCTIVE DECHLORINATION RATE
1381MWS09 > 1381MWS03
WINTER/SPRING, 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

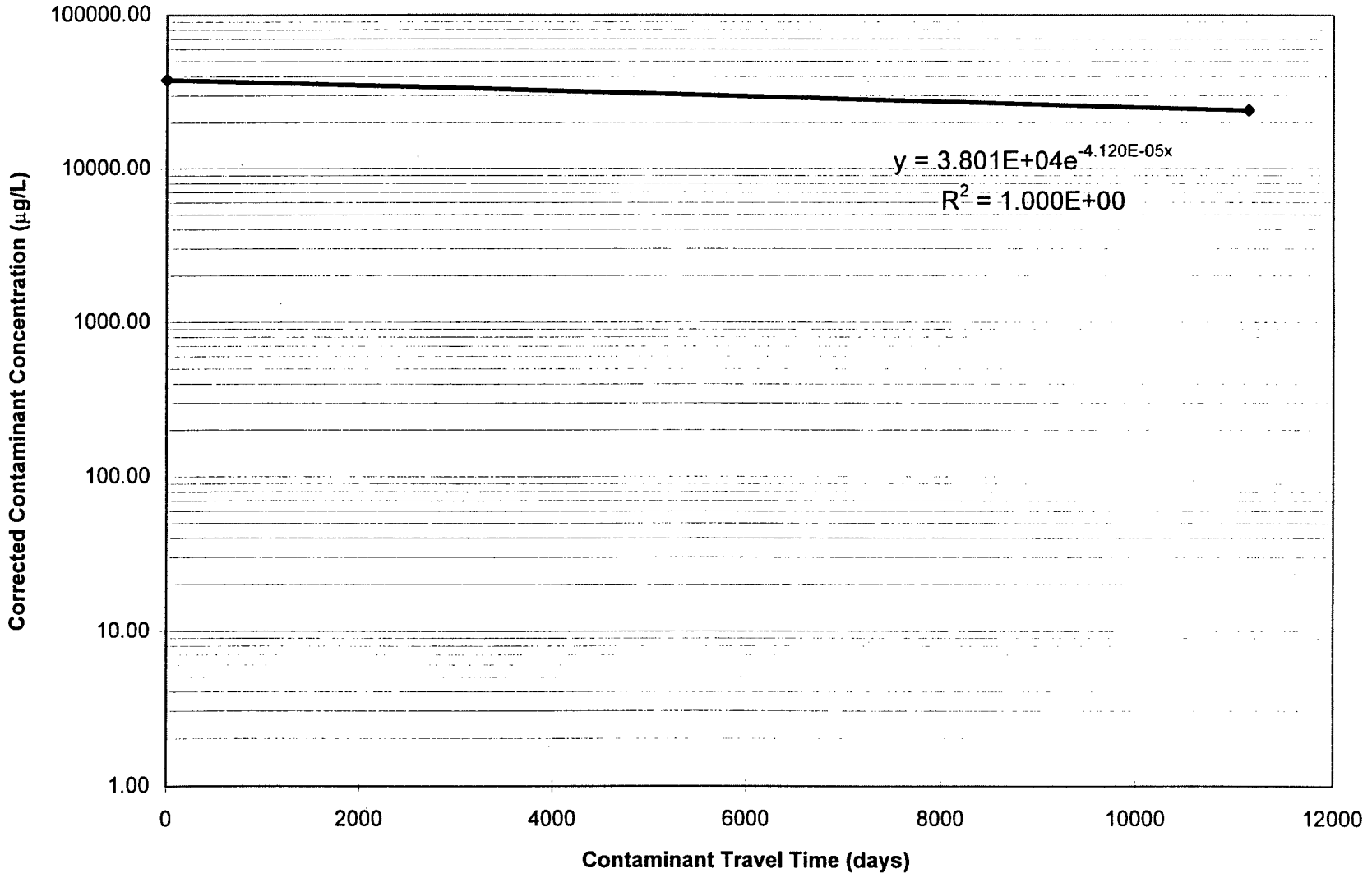
Reductive Dechlorination Rate

$C = C_0e^{-kt}$ where:

C = Corrected Contaminant Concentration (µg/L) at time t (days)
C_0 = Initial Contaminant Concentration (µg/L)
k = Reductive Dechlorination Rate ($days^{-1}$)

from plot: $y = 38010e^{-4.120E-05x}$ $k = 4.120E-05\ days^{-1}$

REDUCTIVE DECHLORINATION RATE
1381MWS09 > 1381MWS03
WINTER/SPRING, 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA



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REDUCTIVE DECHLORINATION RATE
1381MWS03 > 1381MWS12 > 1381MWS15
WINTER/SPRING, 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

The following procedures outlined by Moutoux et al. (1996)

Step 1: Enter Observed Contaminant Concentration (µg/L)

Well	PCE	TCE	DCE	VC	Ethene	Total CAHs
1381MWS03	0.0	0.0	2500.0	330.0	0	2830.0
1381MWS12	0.0	0.0	605.8	130.0	0	735.81
1381MWS15	0.0	0.0	18.0	1.5	0	19.5

Step 2: Compute Molar Concentrations (micromoles/Liter)

Well	M_{PCE}	M_{TCE}	M_{DCE}	M_{VC}	M_{Ethene}	Total M_{CAHs}
1381MWS03	0.00	0.00	25.79	5.28	0.00	31.07
1381MWS12	0.00	0.00	6.25	2.08	0.00	8.33
1381MWS15	0.00	0.00	0.19	0.02	0.00	0.21

Step 3: Compute Carbon Equivalents

Well	Total M_{CAHs}	x 2	= Ceqi
1381MWS03	31.07		62.14
1381MWS12	8.33		16.66
1381MWS15	0.21		0.42

Step 4: Compute Chlorine Equivalents

Well	M_{PCE} x 4	M_{TCE} x 3	M_{DCE} x 2	M_{VC}	$\Sigma = Cleq_i$
1381MWS03	0.00	0.00	51.58	5.28	56.86
1381MWS12	0.00	0.00	12.50	2.08	14.58
1381MWS15	0.00	0.00	0.37	0.02	0.40

Step 5: Compute Corrected CAH Concentrations

$$C_{i,corr} = C_{i-1,corr} \times (Cleq_i / Cleq_{i-1}) \times (Ceq_{i-1} / Ceq_i)$$

Well	$C_{i-1,corr}$	$Cleq_i / Cleq_{i-1}$	Ceq_{i-1} / Ceq_i	$C_{i,corr}$
1381MWS03	2830.02			2830.02
1381MWS12	2830.02	0.26	3.73	2706.55
1381MWS15	2706.55	0.03	39.71	2914.39

Step 6: Plot Exponential Trendline of Contaminant Concentration vs. Time

Well	Distance From Source (ft)	CAH avg. velocity (ft/day)*	CAH Travel Time (day)	$C_{i,corr}$
1381MWS03	0	0.021	0	2830.02
1381MWS12	1061	0.014	75786	2706.55
1381MWS15	2498	0.014	178429	2914.39

*Assumes an unretarded velocity of 0.031 feet/day and a retardation coefficient of 2.25 for 1381MWS12 and 1381MWS15.

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REDUCTIVE DECHLORINATION RATE
1381MWS03 > 1381MWS12 > 1381MWS15
WINTER/SPRING, 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Assumes an unretarded velocity of 0.106 feet/day and a retardation coefficient of 3.79 for 1381MWS09 and 1381MWS03.

Reductive Dechlorination Rate

$C = C_0 e^{-kt}$ where:

C = Corrected Contaminant Concentration (µg/L) at time t (days)
C_0 = Initial Contaminant Concentration (µg/L)
k = Reductive Dechlorination Rate ($days^{-1}$)

from plot: $y = 2769e^{+1.965E-07x}$ $k = +1.965E-07\ days^{-1}$
(no rate)

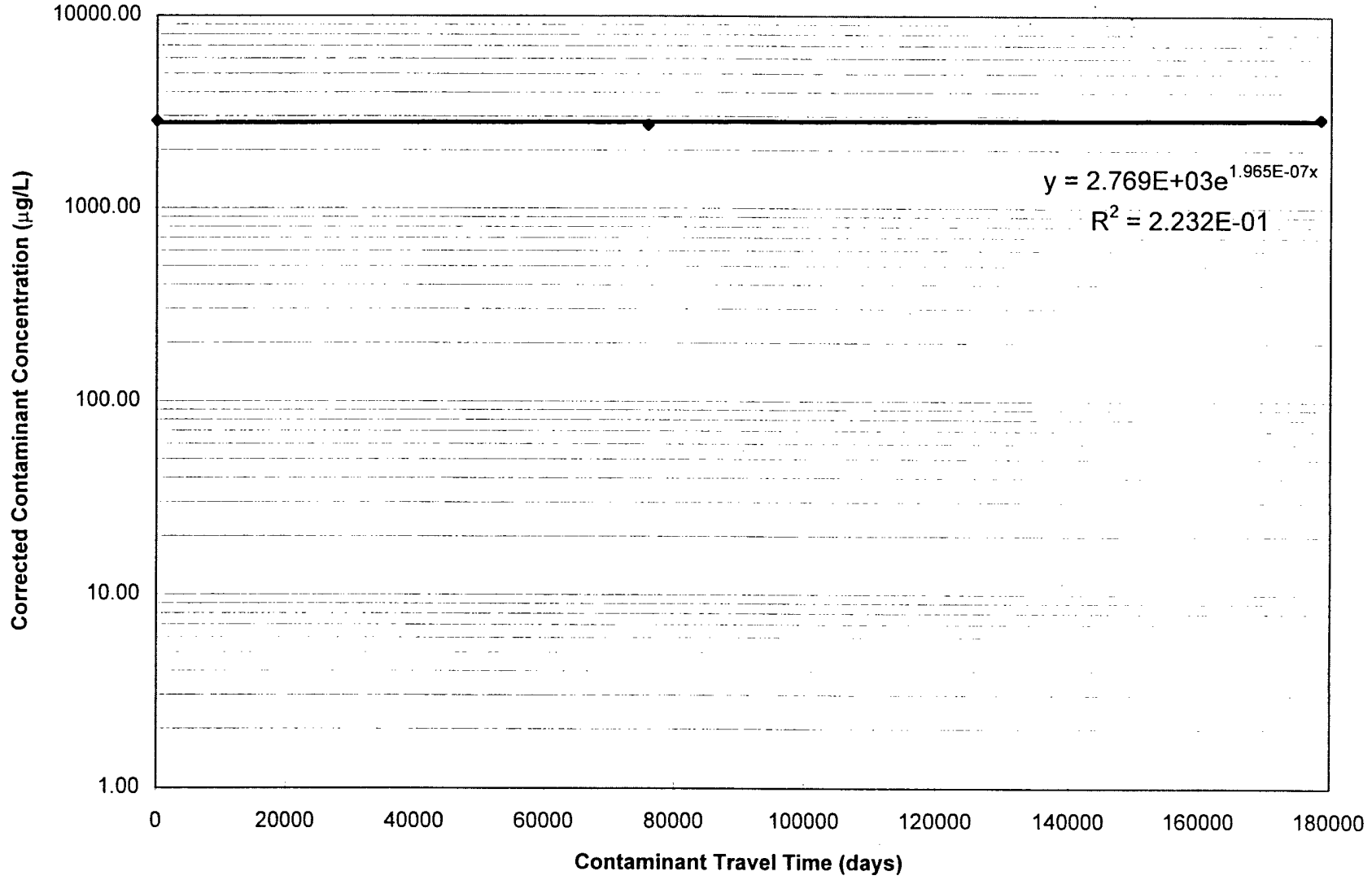
REDUCTIVE DECHLORINATION RATE

1381MWS03 > 1381MWS12 > 1381MWS15

WINTER/SPRING, 1996

FACILITY 1381 RNA TS

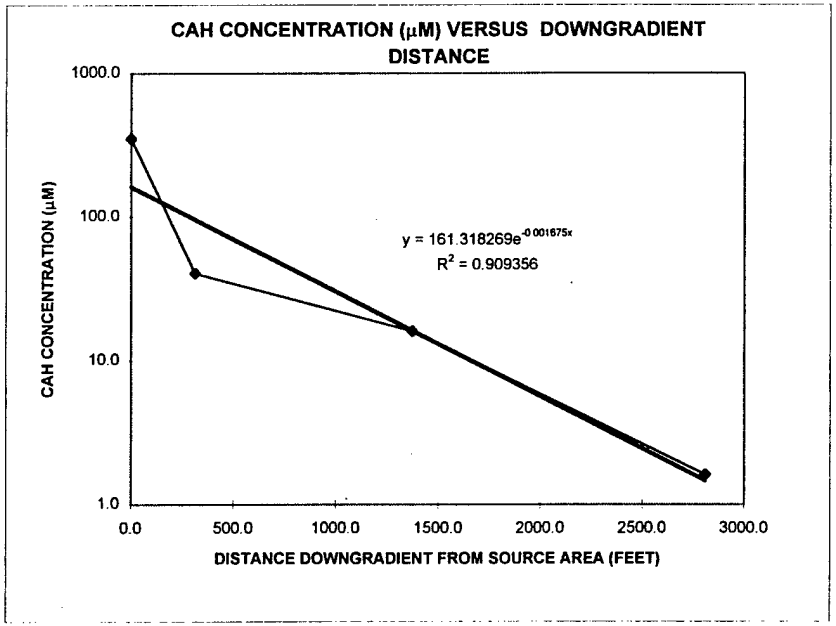
CAPE CANAVERAL AIR STATION, FLORIDA

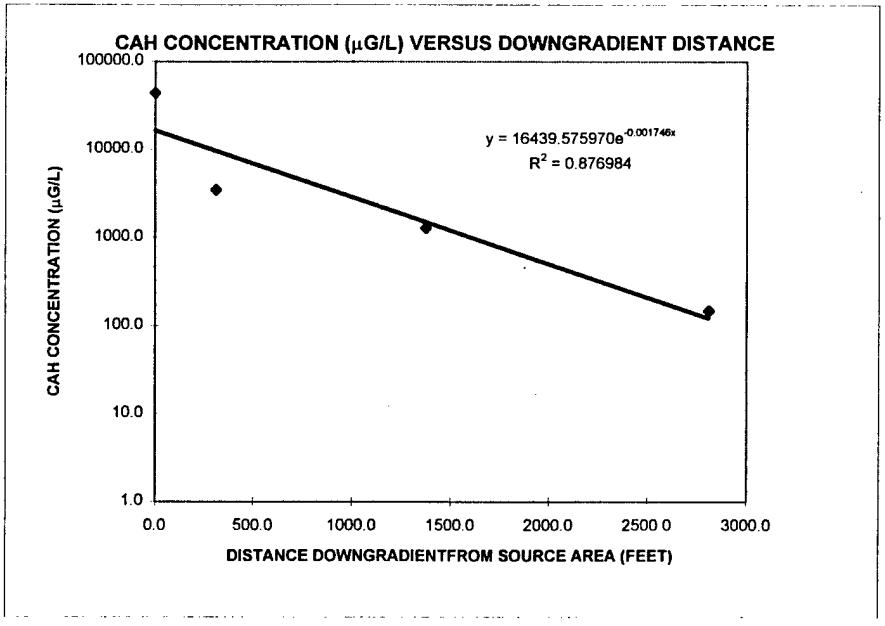


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ESTIMATED MINIMUM FIRST-ORDER RATE CONSTANT CALCULATION FOR THE TOTAL PLUME LENGTH
USING THE METHOD OF BUSCHECK AND ALCANTAR (1995)
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Well	Easting (feet)	Northing (feet)	Distance Downgradient	PCE (µg/L Sep-96	PCE (µM) Sep-96	TCE (µg/L) Sep-96	TCE (µM) Sep-96	Total DCE (µg/L) Sep-96	Total DCE (µM) Sep-96	VC (µg/L) Sep-96	VC (µM) Sep-96	Total CAH (µg/L) Sep-96	Total CAH (µM Sep-96
1381MWS09	797469.3	1504278.2	0.0	3.3	0.0	39400.0	299.9	4383.1	45.2	240.0	3.8	44026.4	349.0
1381MWS03	797436.7	1504588.5	312.0	0.0	0.0	0.0	0.0	2617.7	27.0	836.0	13.4	3453.7	40.4
1381MWS12	798083.4	1505429.9	1373.2	0.0	0.0	0.0	0.0	763.2	7.9	510.0	8.2	1273.2	16.0
1381MWS15	798915.2	1506601.7	2810.3	0.0	0.0	0.0	0.0	131.0	1.4	16.3	0.3	147.3	1.6





Method of Buscheck & Alcantar (1995)

$\lambda = v_c/4\alpha_x([1+2\alpha_x(k/v_x)]^2-1)$

where	v_c =	0.014	ft/day
	α_x =	300	ft
	k/v =	0.001675	
therefore	λ =	3.5234E-05	1/day
	λ =	3.5234E-03	%/day

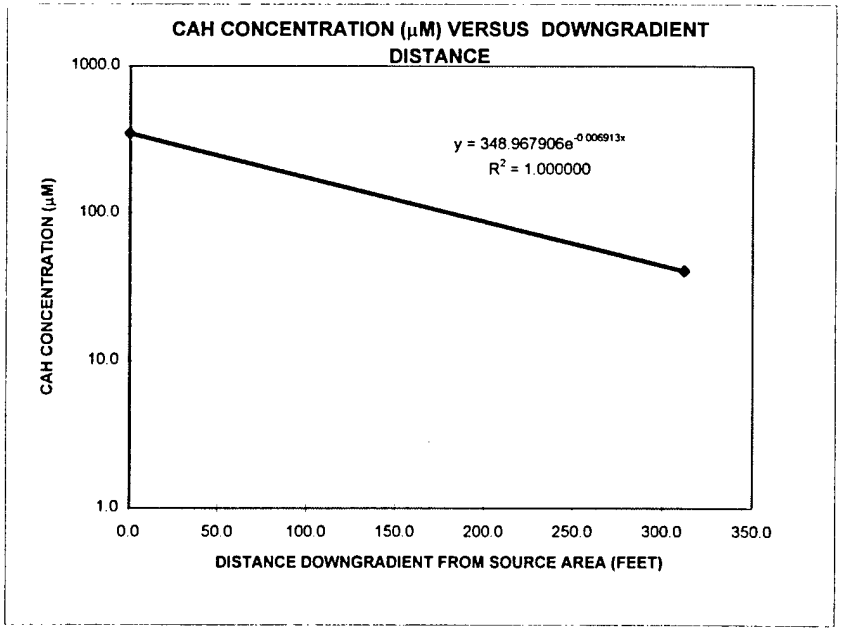
Method of Buscheck & Alcantar (1995)

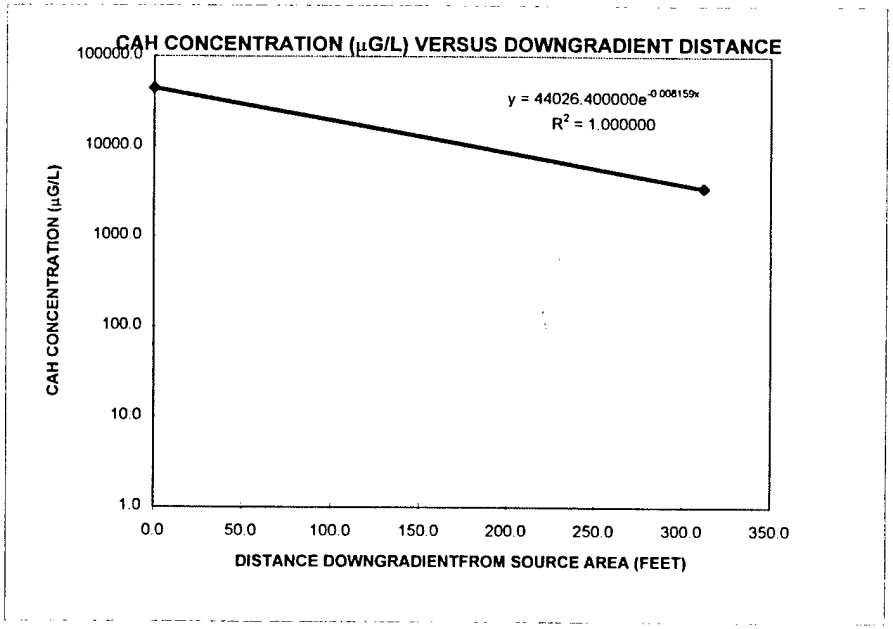
$\lambda = v_c/4\alpha_x([1+2\alpha_x(k/v_x)]^2-1)$

where	v_c =	0.014	ft/day
	α_x =	300	ft
	k/v =	0.001746	
therefore	λ =	3.7248E-05	1/day
	λ =	3.7248E-03	%/day

ESTIMATED MINIMUM FIRST-ORDER RATE CONSTANT CALCULATION FOR THE SOURCE AREA
USING THE METHOD OF BUSCHECK AND ALCANTAR (1995)
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Well	Easting (feet)	Northing (feet)	Distance Downgradient	PCE (µg/L Sep-96	PCE (µM) Sep-96	TCE (µg/L) Sep-96	TCE (µM) Sep-96	Total DCE (µg/L) Sep-96	Total DCE (µM) Sep-96	VC (µg/L) Sep-96	VC (µM) Sep-96	Total CAH (µg/L) Sep-96	Total CAH (µM Sep-96
1381MWS09	797469.3	1504278.2	0.0	3.3	0.0	39400.0	299.9	4383.1	45.2	240.0	3.8	44026.4	349.0
1381MWS03	797436.7	1504588.5	312.0	0.0	0.0	0.0	0.0	2617.7	27.0	836.0	13.4	3453.7	40.4





Method of Buscheck & Alcantar (1995)

$\lambda = v_c/4\alpha_x([1+2\alpha_x(k/v_x)]^2-1)$

where	v_c =	0.014	ft/day
	α_x =	300	ft
	k/v =	0.006913	
therefore	λ =	2.9750E-04	1/day
	λ =	2.9750E-02	%/day

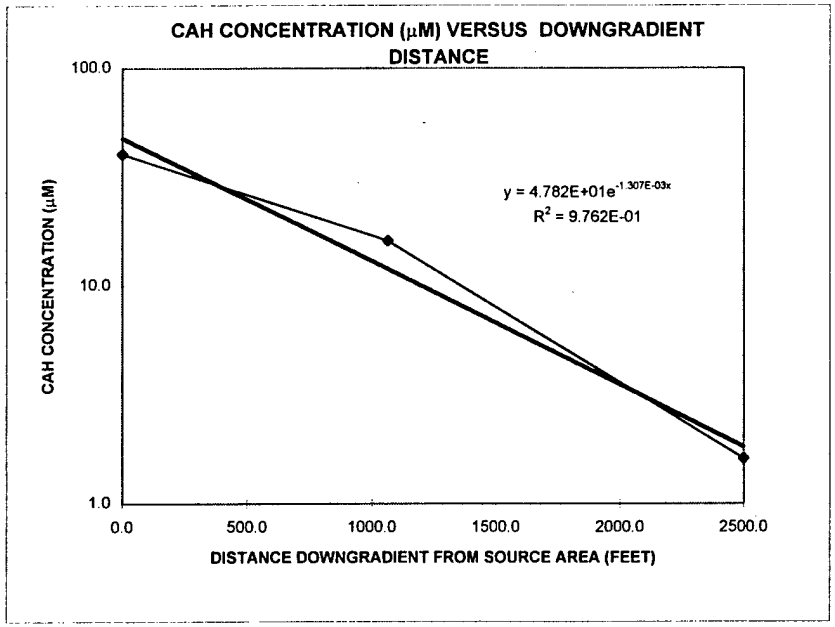
Method of Buscheck & Alcantar (1995)

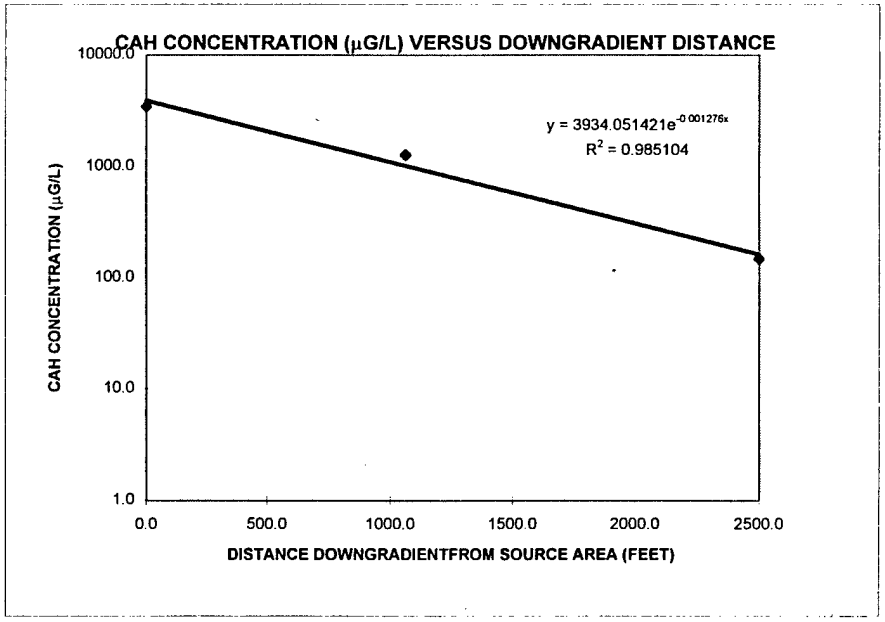
$\lambda = v_c/4\alpha_x([1+2\alpha_x(k/v_x)]^2-1)$

where	v_c =	0.014	ft/day
	α_x =	300	ft
	k/v =	0.008159	
therefore	λ =	3.9382E-04	1/day
	λ =	3.9382E-02	%/day

ESTIMATED MINIMUM FIRST-ORDER RATE CONSTANT CALCULATION FOR DOWNGRADIENT SECTION
USING THE METHOD OF BUSCHECK AND ALCANTAR (1995)
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Well	Easting (feet)	Northing (feet)	Distance Downgradient	PCE (µg/L Sep-96	PCE (µM) Sep-96	TCE (µg/L) Sep-96	TCE (µM) Sep-96	Total DCE (µg/L) Sep-96	Total DCE (µM) Sep-96	VC (µg/L) Sep-96	VC (µM) Sep-96	Total CAH (µg/L) Sep-96	Total CAH (µM Sep-96
1381MWS03	797436.7	1504588.5	0.0	0.0	0.0	0.0	0.0	2617.7	27.0	836.0	13.4	3453.7	40.4
1381MWS12	798083.4	1505429.9	1061.2	0.0	0.0	0.0	0.0	763.2	7.9	510.0	8.2	1273.2	16.0
1381MWS15	798915.2	1506601.7	2498.3	0.0	0.0	0.0	0.0	131.0	1.4	16.3	0.3	147.3	1.6





Method of Buscheck & Alcantar (1995)

$\lambda = v_c/4\alpha_x([1+2\alpha_x(k/v_x)]^2-1)$

where	v_c =	0.014	ft/day
	α_x =	300	ft
	k/v =	0.001307	
therefore	λ =	2.5473E-05	1/day
	λ =	2.5473E-03	%/day

Method of Buscheck & Alcantar (1995)

$\lambda = v_c/4\alpha_x([1+2\alpha_x(k/v_x)]^2-1)$

where	v_c =	0.014	ft/day
	α_x =	300	ft
	k/v =	0.001276	
therefore	λ =	2.4702E-05	1/day
	λ =	2.4702E-03	%/day

REDUCTIVE DECHLORINATION RATE
1381MWS09 > 1381MWS03 > 1381MWS12 > 1381MWS15
FALL 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

The following procedures outlined by Moutoux et al. (1996)

Step 1: Enter Observed Contaminant Concentration (mg/L)

Well	PCE	TCE	DCE	VC	Ethene	Total CAHs
1381MWS09	3.3	39400.0	4383.1	240.0	0	44026.4
1381MWS03	0.0	0.0	2617.7	836.0	0	3453.7
1381MWS12	0.0	0.0	763.2	510.0	0	1273.21
1381MWS15	0.0	0.0	131.0	16.3	0	147.3

Step 2: Compute Molar Concentrations (micromoles/Liter)

Well	M_{PCE}	M_{TCE}	M_{DCE}	M_{VC}	M_{Ethene}	Total M_{CAHs}
1381MWS09	0.02	299.89	45.21	3.84	0.00	348.97
1381MWS03	0.00	0.00	27.00	13.38	0.00	40.38
1381MWS12	0.00	0.00	7.87	8.16	0.00	16.03
1381MWS15	0.00	0.00	1.35	0.26	0.00	1.61

Step 3: Compute Carbon Equivalents

Well	Total M_{CAHs}	x 2	= Ceqi
1381MWS09	348.97		697.94
1381MWS03	40.38		80.76
1381MWS12	16.03		32.07
1381MWS15	1.61		3.22

Step 4: Compute Chlorine Equivalents

Well	M_{PCE} x 4	M_{TCE} x 3	M_{DCE} x 2	M_{VC}	S = $Cleq_i$
1381MWS09	0.08	899.68	90.43	3.84	994.03
1381MWS03	0.00	0.00	54.01	13.38	67.38
1381MWS12	0.00	0.00	15.75	8.16	23.91
1381MWS15	0.00	0.00	2.70	0.26	2.96

Step 5: Compute Corrected CAH Concentrations

$$C_{i,corr} = C_{i-1,corr} \times (Cleq_i / Cleq_{i-1}) \times (Ceq_{i-1} / Ceq_i)$$

Well	$C_{i-1,corr}$	$Cleq_i / Cleq_{i-1}$	Ceq_{i-1} / Ceq_i	$C_{i,corr}$
1381MWS09	44026.41			44026.41
1381MWS03	44026.41	0.07	8.64	25791.82
1381MWS12	25791.82	0.35	2.52	23045.10
1381MWS15	23045.10	0.12	9.94	28409.96

REDUCTIVE DECHLORINATION RATE
1381MWS09 > 1381MWS03 > 1381MWS12 > 1381MWS15
FALL 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Step 6: Plot Exponential Trendline of Contaminant Concentration vs. Time

Well	Distance From Source (ft)	CAH avg. velocity (ft/day)*	CAH Travel Time (day)	$C_{i,corr}$
1381MWS09	0	0.028	0	44026.41
1381MWS03	312	0.028	11143	25791.82
1381MWS12	1373	0.014	86943	23045.10
1381MWS15	2810	0.014	189593	28409.96

*Assumes an unretarded velocity of 0.106 feet/day and a retardation coefficient of 3.79 for 1381MWS09 and S03.
Assumes an unretarded velocity of 0.031 feet/day and a retardation coefficient of 2.25 for 1381MWS12 and S15.

Reductive Dechlorination Rate

$C = C_0 e^{-kt}$ where:

C = Corrected Contaminant Concentration (mg/L) at time t (days)
C_0 = Initial Contaminant Concentration (mg/L)
k = Reductive Dechlorination Rate ($days^{-1}$)

from plot: $y = 32136e^{-1E-06x}$ $k = 1E\text{-}06\ days^{-1}$

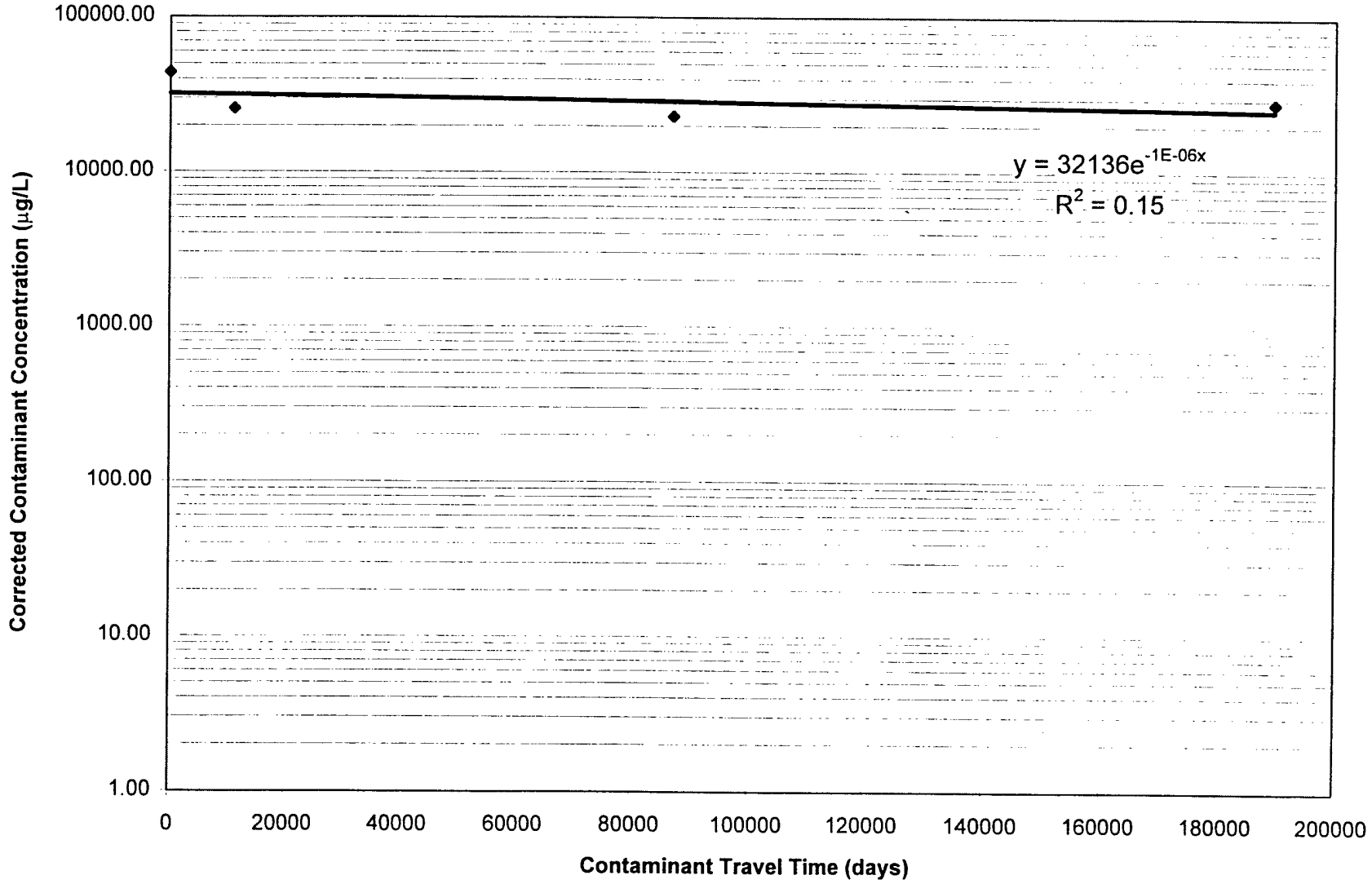
REDUCTIVE DECHLORINATION RATE

1381MWS09 > 1381MWS03 > 1381MWS12 > 1381MWS15

FALL 1996

FACILITY 1381 RNA TS

CAPE CANAVERAL AIR STATION, FLORIDA



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REDUCTIVE DECHLORINATION RATE
1381MWS09 > 1381MWS03
FALL 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

The following procedures outlined by Moutoux et al. (1996)

Step 1: Enter Observed Contaminant Concentration (µg/L)

Well	PCE	TCE	DCE	VC	Ethene	Total CAHs
1381MWS09	3.3	39400.0	4383.1	240.0	0	44026.4
1381MWS03	0.0	0.0	2617.7	836.0	0	3453.7

Step 2: Compute Molar Concentrations (micromoles/Liter)

Well	M_{PCE}	M_{TCE}	M_{DCE}	M_{VC}	M_{Ethene}	Total M_{CAHs}
1381MWS09	0.02	299.89	45.21	3.84	0.00	348.97
1381MWS03	0.00	0.00	27.00	13.38	0.00	40.38

Step 3: Compute Carbon Equivalents

Well	Total M_{CAHs}	x 2	= Ceqi
1381MWS09	348.97		697.94
1381MWS03	40.38		80.76

Step 4: Compute Chlorine Equivalents

Well	M_{PCE} x 4	M_{TCE} x 3	M_{DCE} x 2	M_{VC}	$\Sigma = Cleq_i$
1381MWS09	0.08	899.68	90.43	3.84	994.03
1381MWS03	0.00	0.00	54.01	13.38	67.38

Step 5: Compute Corrected CAH Concentrations

$$C_{i,corr} = C_{i-1,corr} \times (Cleq_i / Cleq_{i-1}) \times (Ceq_{i-1} / Ceq_i)$$

Well	$C_{i-1,corr}$	$Cleq_i / Cleq_{i-1}$	Ceq_{i-1} / Ceq_i	$C_{i,corr}$
1381MWS09	44026.41			44026.41
1381MWS03	44026.41	0.07	8.64	25791.82

Step 6: Plot Exponential Trendline of Contaminant Concentration vs. Time

Well	Distance From Source (ft)	CAH avg. velocity (ft/day)*	CAH Travel Time (day)	$C_{i,corr}$
1381MWS09	0	0.028	0	44026.41
1381MWS03	312	0.028	11143	25791.82

*Assumes an unretarded velocity of 0.106 feet/day and a retardation coefficient of 3.79 for 1381MWS09 and S03.

REDUCTIVE DECHLORINATION RATE
1381MWS09 > 1381MWS03
FALL 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Reductive Dechlorination Rate

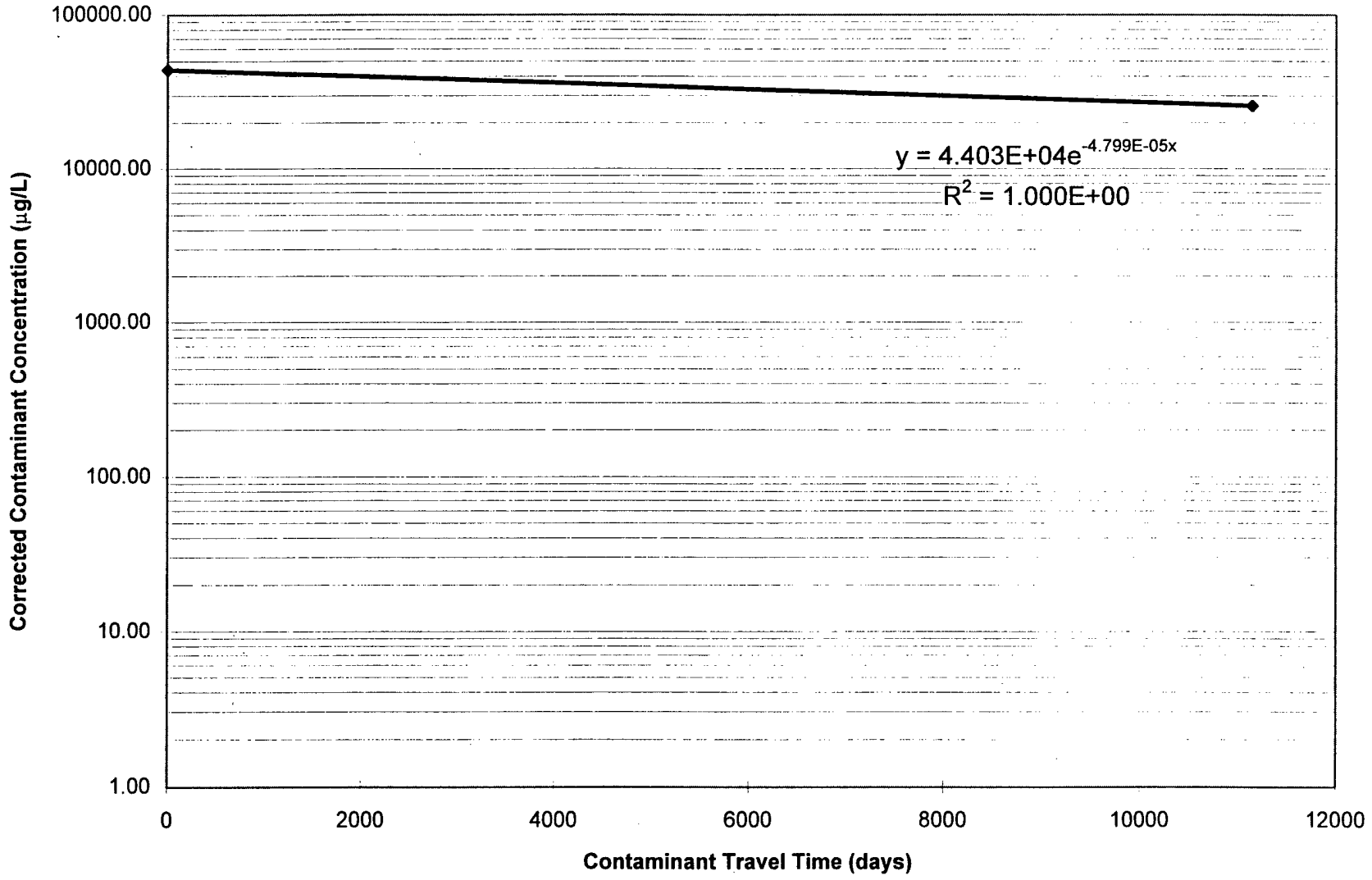
$C = C_0 e^{-kt}$ where:

C = Corrected Contaminant Concentration (μg/L) at time t (days)
C_0 = Initial Contaminant Concentration (μg/L)
k = Reductive Dechlorination Rate ($days^{-1}$)

from plot: $y = 44030e^{-4.799E-05x}$ $k = 4.799E\text{-}05\ days^{-1}$

REDUCTIVE DECHLORINATION RATE
1381MWS09 > 1381MWS03

FALL 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA



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REDUCTIVE DECHLORINATION RATE
1381MWS03 > 1381MWS12 > 1381MWS15

Fall 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

The following procedures outlined by Moutoux et al. (1996)

Step 1: Enter Observed Contaminant Concentration (µg/L)

Well	PCE	TCE	DCE	VC	Ethene	Total CAHs
1381MWS03	0.0	0.0	2617.7	836.0	0	3453.7
1381MWS12	0.0	0.0	763.2	510.0	0	1273.21
1381MWS15	0.0	0.0	131.0	16.3	0	147.3

Step 2: Compute Molar Concentrations (micromoles/Liter)

Well	M_{PCE}	M_{TCE}	M_{DCE}	M_{VC}	M_{Ethene}	Total M_{CAHs}
1381MWS03	0.00	0.00	27.00	13.38	0.00	40.38
1381MWS12	0.00	0.00	7.87	8.16	0.00	16.03
1381MWS15	0.00	0.00	1.35	0.26	0.00	1.61

Step 3: Compute Carbon Equivalents

Well	Total M_{CAHs}	x 2	= Ceqi
1381MWS03	40.38		80.76
1381MWS12	16.03		32.07
1381MWS15	1.61		3.22

Step 4: Compute Chlorine Equivalents

Well	M_{PCE} x 4	M_{TCE} x 3	M_{DCE} x 2	M_{VC}	$\Sigma = Cleq_i$
1381MWS03	0.00	0.00	54.01	13.38	67.38
1381MWS12	0.00	0.00	15.75	8.16	23.91
1381MWS15	0.00	0.00	2.70	0.26	2.96

Step 5: Compute Corrected CAH Concentrations

$$C_{i,corr} = C_{i-1,corr} \times (Cleq_i / Cleq_{i-1}) \times (Ceq_{i-1} / Ceq_i)$$

Well	$C_{i-1,corr}$	$Cleq_i / Cleq_{i-1}$	Ceq_{i-1} / Ceq_i	$C_{i,corr}$
1381MWS03	3453.72			3453.72
1381MWS12	3453.72	0.35	2.52	3085.91
1381MWS15	3085.91	0.12	9.94	3804.31

Step 6: Plot Exponential Trendline of Contaminant Concentration vs. Time

Well	Distance From Source (ft)	CAH avg. velocity (ft/day)*	CAH Travel Time (day)	$C_{i,corr}$
1381MWS03	0	0.028	0	3453.72
1381MWS12	1061	0.014	75786	3085.91
1381MWS15	2498	0.014	178429	3804.31

*Assumes an unretarded velocity of 0.106 feet/day and a retardation coefficient of 3.79 for 1381MWS09 and S03.
Assumes an unretarded velocity of 0.031 feet/day and a retardation coefficient of 2.25 for 1381MWS12 and S15.

REDUCTIVE DECHLORINATION RATE
1381MWS03 > 1381MWS12 > 1381MWS15
Fall 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

Reductive Dechlorination Rate

$C = C_0 e^{-kt}$ where:

C = Corrected Contaminant Concentration (μg/L) at time t (days)
C_0 = Initial Contaminant Concentration (μg/L)
k = Reductive Dechlorination Rate ($days^{-1}$)

from plot: $y = 3257e^{+6.276E-07x}$ $k = +6.276E-07\ days^{-1}$

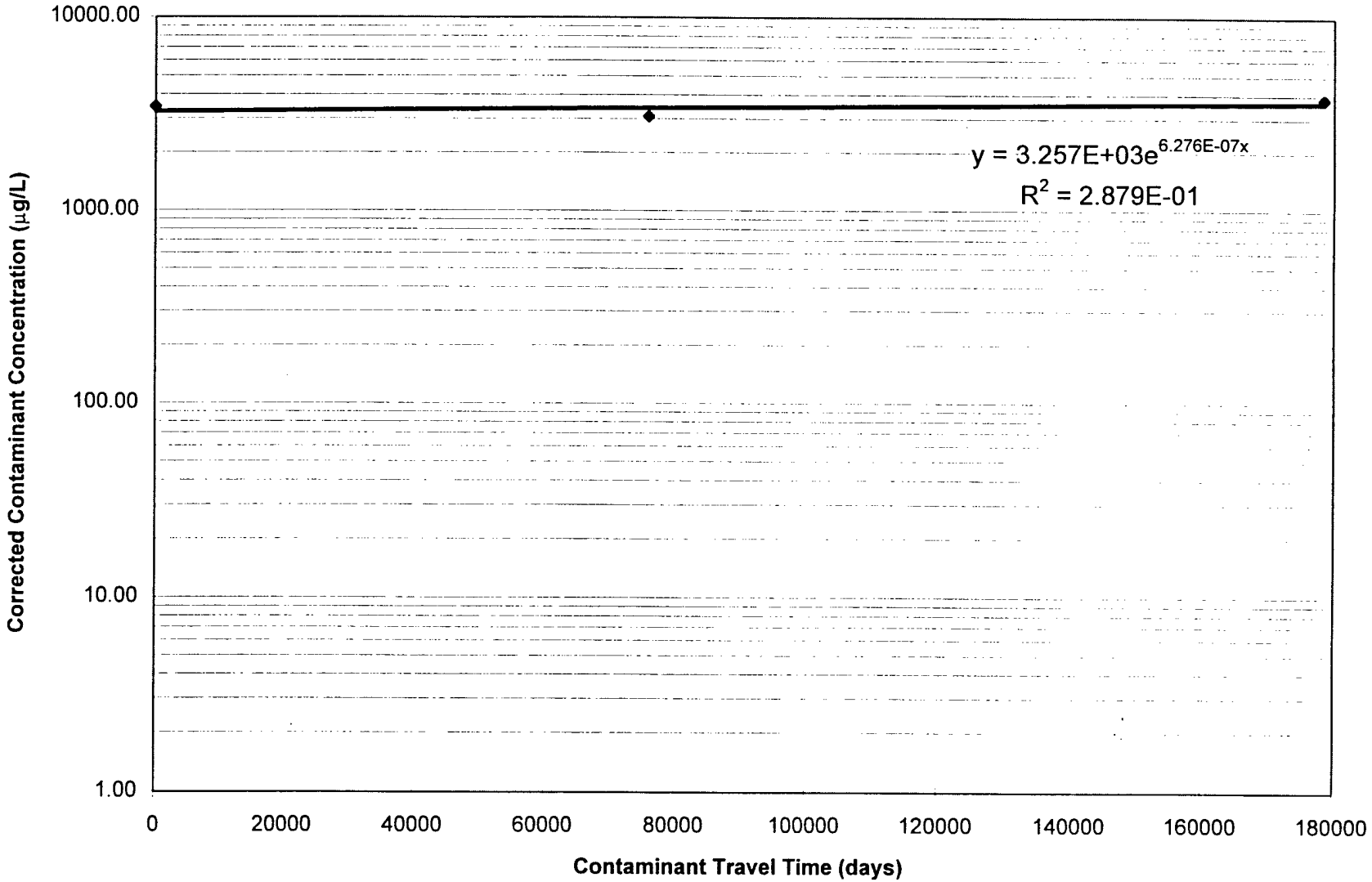
REDUCTIVE DECHLORINATION RATE

1381MWS03 > 1381MWS12 > 1381MWS15

FALL 1996

FACILITY 1381 RNA TS

CAPE CANAVERAL AIR STATION, FLORIDA



CALCULATION OF RETARDATION COEFFICIENTS

FACILITY 1381

DEMONSTRATION OF RNA

CAPE CANAVERAL AIR STATION, FLORIDA

Compound	K_{oc} (L/kg [a/])	Fraction Organic Carbon [b/]	Distribution Coefficient K_d (L/kg)	Bulk Density (kg/L) [c/]	Effective Porosity [d/]	Coefficient of Retardation
PCE	263	0.00455	1.197	1.72	0.25	9.23
TCE	107	0.00455	0.487	1.72	0.25	4.35
1,1-DCE	64.6	0.00455	0.294	1.72	0.25	3.02
cis-1,2-DCE	64.6	0.00455	0.294	1.72	0.25	3.02
trans-1,2-DCE	58.9	0.00455	0.268	1.72	0.25	2.84
VC	2.45	0.00455	0.011	1.72	0.25	1.08

NOTES:

[a/] From technical protocol (Wiedemeier *et al.*, 1996) and Knox *et al.* (1993).

[b/] Average of saturated TOC samples collected from the site (Section 7.2)

[c/] Assumes an aquifer grain density of 2.65 (quartz sand) and a volumetric porosity of 35% [Section 3.2.1.2 of RFI (Parsons ES, 1997)].

[d/] An effective porosity of 0.25 was estimated in the RFI (Parsons ES, 1997) and is consistent with literature values.

PARSONS

Calculation Sheet

Rev	By	Date	Ck	Date	Title: Estimation of Groundwater Gradients & Velocities CCAS - Facility 1381
					Author: RTH Sheet: 1 Of: 2

Estimated Groundwater Velocities:

The 1997 RFI states that Groundwater velocity is 0.21 ft/day (Parsons ES, 1997)
This velocity Assumes a hydraulic conductivity of ≈ 88.65 ft/day taken from the industrial Area (pumping tests). However, on the basis of a 3-19-97 phone conversation with Kevin Morrison at Parsons ES in Tampa, recent pumping tests at Facility 1381 indicate that Hyd. Cond. at the site may likely be in the range of 10-20 ft/day.
Groundwater gradients also fluctuate greatly at the site. For instance:

September 1996 → GW Elevation @ 1381MW503 = 2.13' MSL
GW Elevation @ 1381MW514 = 1.94' MSL
$\Delta X \approx 1766$ feet

$$i = \frac{2.13 - 1.94}{1766} = 0.0001075 \text{ ft/ft}$$ (Very low North)

In earlier studies
(Dec 1995 - March 1996) → GW Elevation @ 1381MW503 = 4.34' MSL
GW Elevation @ 1381MW514 = 4.58' MSL
$\Delta X \approx 1766$ feet

$$i = \frac{4.34 - 4.58}{1766} = -0.0001359$$ (Very low south)

Therefore.. a groundwater divide exists and fluctuates across the site and makes estimation of gradients difficult.
This is seen by gradients northward being inconsistent.

To obtain a possible gradient from April 1st, 1996 Data collected as Part of the RFI (Parsons ES, 1997; Figure 2.4):

April 1996 → GW Elevation @ 1381MW513 = 4.91' MSL
(Northward side of Groundwater Divide) GW Elevation @ 1381MW515 = 4.17' MSL
$\Delta X \approx 1400'$
$i = (4.91 - 4.17)/1400' = 0.000528$ ft/ft

PARSONS **Calculation Sheet**

Rev	By	Date	Ck	Date	Title
					Author Sheet Of

Furthermore, an estimated gradient of 0.000587 ft/ft was assumed in the RFI (Parsons ES, 1997; P-8 3-22).

Therefore, To summarize gradients and hydraulic conductivities

September 1996 (Full site) $i \simeq 0.0001075$ ft/ft

April 1996 (North ½ of site) $i \simeq 0.000538$ ft/ft

RFI (1997) $i \simeq 0.000587$ ft/ft

$k \simeq 10 - 20$ ft/day (Karen Morrison, 1997)

$k \simeq 88.65$ ft/day (Parsons ES, 1997)

i ranges from 0.0001075 → 0.000587 ft/ft

k ranges from 10 – 88.65 ft/day

Therefore - A possible Range of Velocities, assuming an effective porosity of ~~0.30~~ 0.25 is:

① $V = \frac{(10 \text{ ft/day})(0.0001075)}{0.25} = 0.00043$ ft/day

② $V = \frac{(88.65 \text{ ft/day})(0.0001075)}{0.25} = 0.00381$ ft/day

③ $V = \frac{(10 \text{ ft/day})(0.000587 \text{ ft/ft})}{0.25} = 0.02348$ ft/day

④ $V = \frac{(88.65)(0.000587 \text{ ft/ft})}{0.25} = 0.208$ ft/day

The RFI assumes an n_e of 0.25

ESTIMATING CAH DISCHARGE TO THE NORTHERN DRAINAGE CANAL:

ASSUMPTIONS: ① Current predicted CAH release is ~ 130 grams/year

② Assume Average canal width is 6 feet

③ Assume Ave canal depth is 1 foot

④ Assume Canal Vel - 0.2 ft/sec.

what is discharge?:

$Q_{stream} = V/A$

$= 6' \times 1' \times 0.2\ ft/sec \times \left(\frac{31,536,000\ sec}{year}\right) = 37,843,200\ ft^3/yr$

$= \left(\frac{37,843,200\ ft^3}{year}\right)\left(\frac{28.316\ l}{ft^3}\right) = 1.0716 \times 10^9\ l/year$

Average est. stream conc. $= \frac{130,000,000\ \mu g/year}{1.0716 \times 10^9\ l/year} = 0.12\ \mu g/L$

= < detection limits.

det x 1 µg/L

	CALC	OBS
MW9	362.29	348.9
MW1	174.49	30.18
MW3	144.72	40.38
MW12	22.268	16.03
MW15	1.6517	1.6
MW14	0.511102	0.714
MW5	6.63E-06	1.3
MW16	0.257186	0.041
MW7	-0.13	0.13

PARSONS ENGINEERING SCIENCE, INC.

Client AFCEE/Cape Canaveral F1381 Job No. ~~722150~~ 729691.29230 Sheet 1 of

Subject Model Review By Cindy Merrill Date

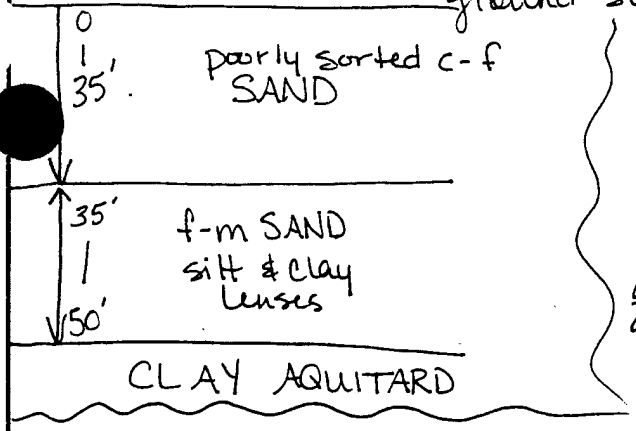
Notes from Sections 1-4 Checked Rev.

Facility 1381 - Ordnance Support facility

1958-1968 Research, Testing (Missile Tech)??
1968-1977 Solvent Dip Tanks - metal cleaning
3,300 gal/yr waste incinerated @ LNS

1977-present Coast Guard (little has changed since 1977)

1967 - photo - drums
1989 - drums SW of 71381 outside fence
additionally, tankers dumped solvents in woods for unknown length of time.



GW Elev
~~1.67 - 2.47' msl~~

GW flow controlled by canals

$\frac{dh}{dl}(i)$ = 0.000587 ft/ft (1997)
= 0.000528 ft/ft (April 1996)
0.000108 ft/ft (Sept. 1996)

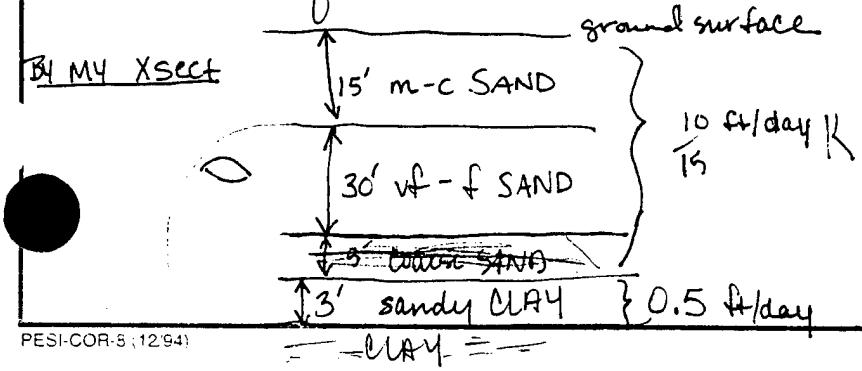
Recharge - 40"/yr precip.

Slug test data ⇒ K = 11.57 ft/day shallow 1381MWS09
= 0.39 ft/day intermediate
= 0.23 ft/day deep

(lit. values 0.9 - 2.2 ft/day med-c SAND (Daly 1982)
10 - 15 ft/day c-SAND)

n_e = 25% for sand

0.85 [illegible] silt



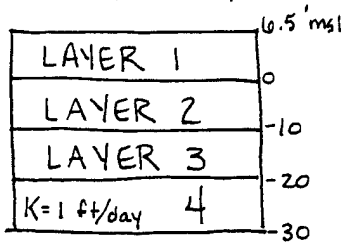
By MW Xsect

$V_{gw} = \frac{Ki}{n_e}$ $\frac{140 \times 0.003}{.25} = 1.68$ ft/day

1.68 ft/day × 365 day/yr × 38 yr = 23,302 ft

Current Model Setup

4 layers



Layers 1, 2, 3 K = 150 - 500 ft/day

α_L = 75 feet

ρ_b = 1.72 g/cm^3

n_e = 25%

R = 2
K_d = 0.15

λ = 2.5×10^{-4} days

½ life = 2829 days

Source 30 yrs

Changes

1 layer @ K = 15 ft/day
1 layer @ K = 0.05 ft/day ✓

α_L = 300 ft ✓

ρ_b = 1.65 kg/L

n_e = 25% no change

R = 1.64 AVG ✓
K_d = 0.097 AVG

λ = 5×10^{-2} yr^{-1}
↕
→ 3.7×10^{-4} yr^{-1} no change

Source 38 yrs ✓

GRID SETUP

SOURCE COORDINATES ≈ 796985.9 x 1504075.9

Every 50' { 796800 - 797300
1503800 - 1504300

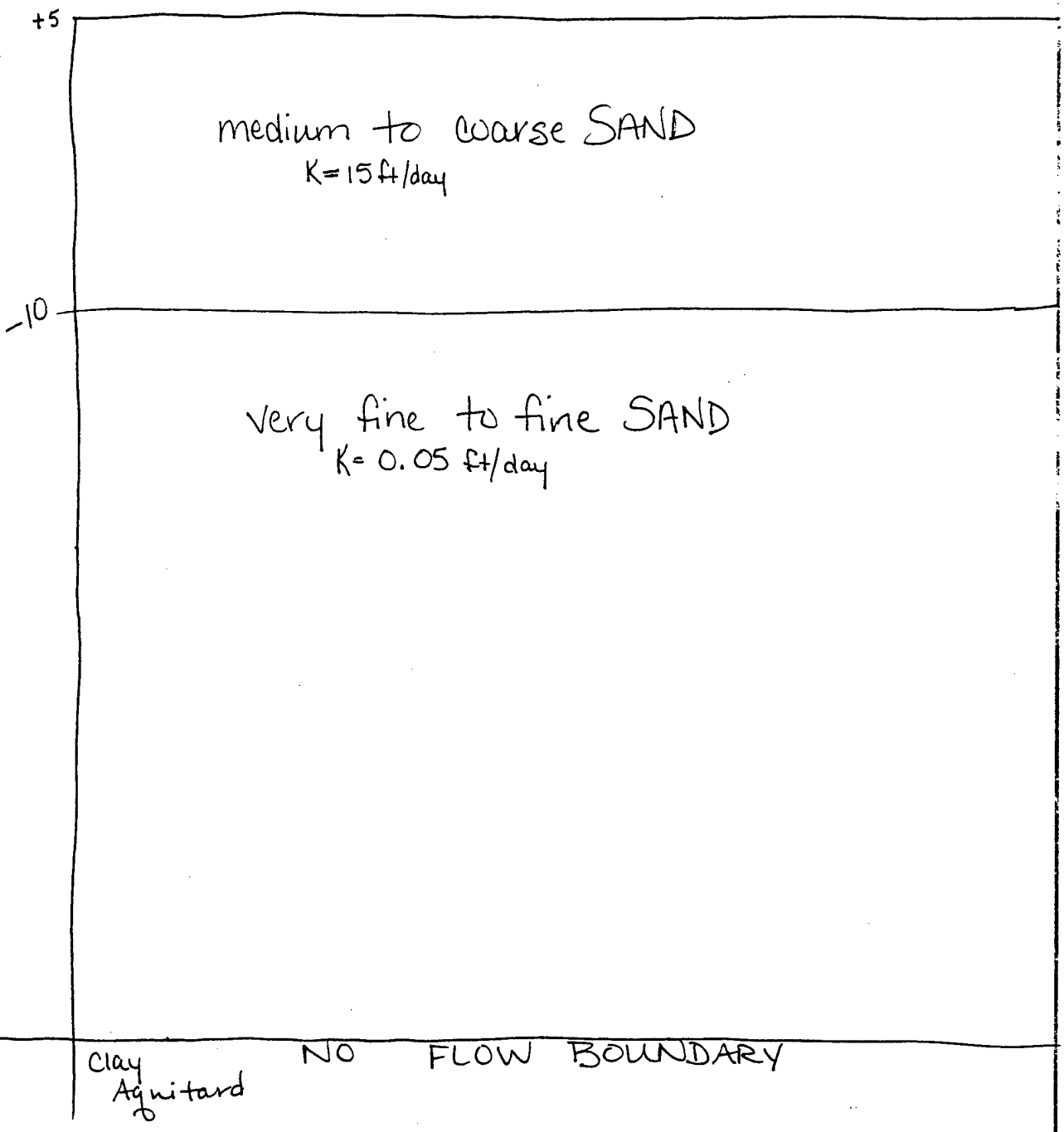
Every 75' { 796050 - 796800 & 797300 - 798050
1503050 - 1503800 & 1504300 - 1505050

Every 100 { 795050 - 796050 & 798050 - 799050
~~1502050~~ - 1503050 & 1505050 - 1506050

1502550.00

Every 150 { 1506050 - 1507550

2 layers


+5
medium to coarse SAND
K=15 ft/day
-10
very fine to fine SAND
K= 0.05 ft/day
-45
NO FLOW BOUNDARY
Clay
Aquitard

Calibration Points 9/96

Well	GW Elevation (ft msl)	Concentration (μM/L)
MW1	2.15	30.18
MW3	2.13	40.38
MW5	2.47	1.30
MW7	2.19	0.13
MW9	2.12	348.9
MW11	2.18	NS
MW12	2.02	16.03
MW13	1.82	0.047
MW14	1.94	0.714
MW15	1.67	1.60
MW16	1.89	0.041
MW17	2.10	NS
MW18	2.31	NS
SUR A	1.73	
SUR B	1.71	
SUR C	1.36	
SUR D	1.85	
SUR E	1.95	
SUR F	2.04	

Source – 1958 possible ⇒ 38 yrs
1968-1996 definite ⇒ 28 yrs

Max Concentrations

PCE	3.3 ug/L	} S09
TCE	39,400 ug/L	
DCE cis	4120 ug/L	
trans	145 ug/L	
1,1	238 ug/L	
Total CAHs	349 ~~uM/L~~	

α – plume length ~3000 ft

α_L 300 ft

α_t, α_v } 30 ft.

$\alpha = 0.83 \times (\text{log}_{10}(\text{plume length}))^{2.414}$

λ – Buscheck & Alcantar 1.3×10^{-4} days^{-1}
4.7×10^{-2} yrs^{-1}

Montoux 1×10^{-6} days^{-1}
3.65×10^{-4} yrs^{-1}

R – $K_{d\,avg} = 0.097$ L/kg $R_{avg} = 1.64$

Acceptable Parameter Ranges

K_d : 0.001 – 0.01 ft^3/kg

λ : 5×10^{-2} — 4×10^{-4} $years^{-1}$

α : 1/10 plume length = $\frac{3000\ ft}{10}$ = 300 ft

$0.83 \times [\log^{10}(\text{scale})]^{2.414} = 0.83 \times [\log^{10}(914.4\ m)]^{2.414} = 111\ m$

$= 37.4\ ft$

37.4 ft – 300 ft

K : med & coarse SAND 0.9 – 2.2 ft/day (Daly 1982)

coarse SAND 0.004 – 31 ft/day (Davis & DeWeist 1966)

well sorted coarse SAND (beach sand?) 141 ft/day (Davis & DeWeist 1966)

Aquifer Properties

Layer 1 — K_x = 150 ft/day K_y = 150 ft/day K_z = 15 ft/day

Layer 2 — K_x = 5 ft/day K_y = 5 ft/day K_z = 0.5 ft/day

Layers 1 & 2 — S_s = 0.0002 ft^{-1} S_y = 0.25 n = 0.35 n_e = 0.25

Boundary Conditions

River Package

Northern Canal - Cell 48,55 to Cell 2,32

	Start Time	Stop Time	River Stage Elev	River Bottom Elev	Conductance
Cell 48,55	0	38 yr	1.8 ft	-2.2 ft	42,000 ft^2/yr
Cell 2,32	0	38 yr	0.5 ft	-3.5 ft	42,000 ft^2/yr

Southwestern Canal - Cell 48,13 to Cell 2,29

Cell 48,13	0	38 yr	2.04 ft	-1.96 ft	38,000 ft^2/yr
Cell 2,29	0	38 yr	1.01 ft	-2.99 ft	38,000 ft^2/yr

Recharge (see printed figure)

Source

(see printed figure)

Transport Parameters

Dispersivity (α) — Longitudinal (α_L) = 300 ft

Transverse (α_T) / Longitudinal (α_L) = 0.01

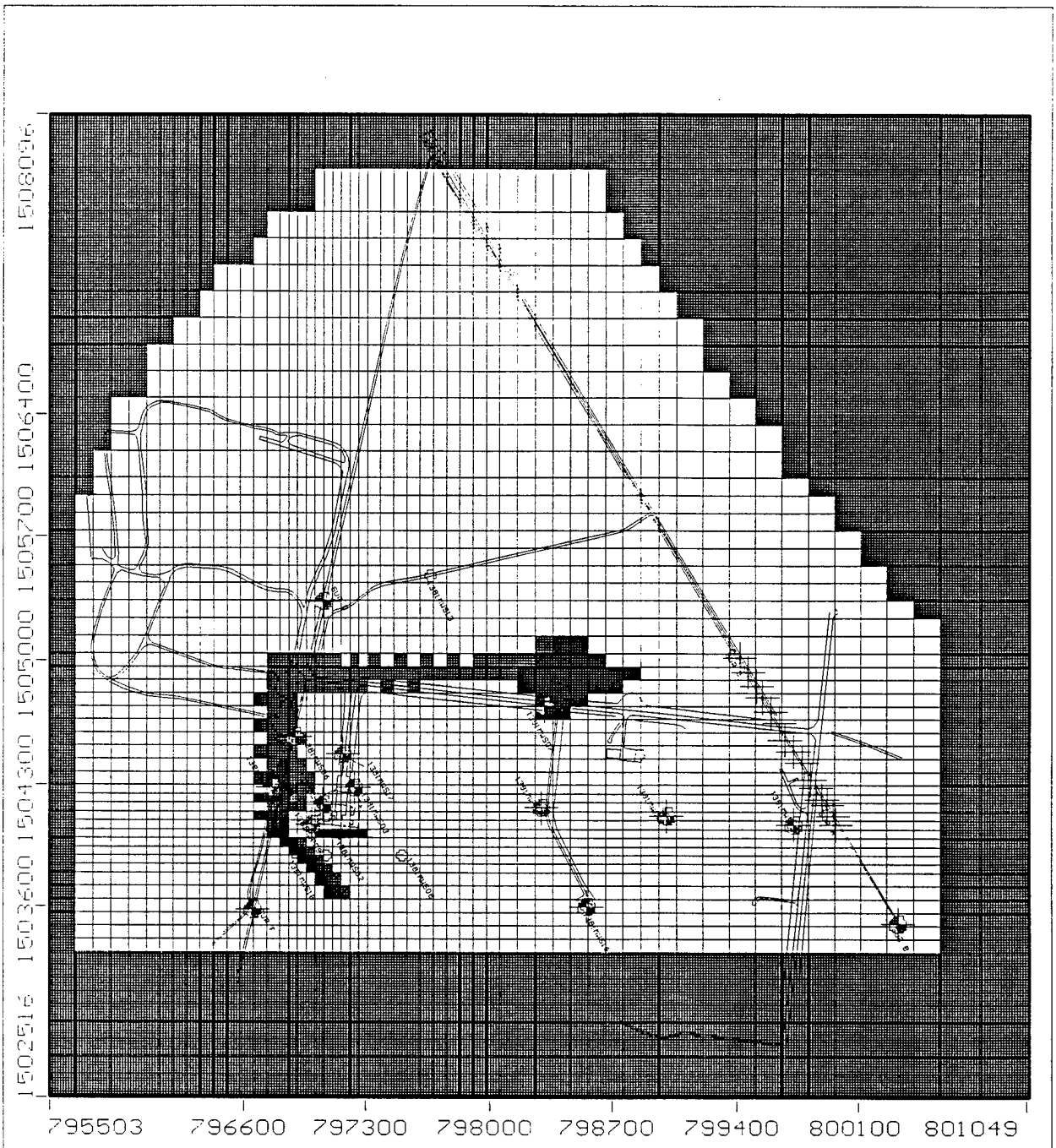
Vertical (α_V) / Longitudinal (α_L) = 0.001

Decay (λ) — Dissolved = 0.0004 yr^{-1}

Sorbed = 0.0002 yr^{-1}

ρ_b = 46.74 kg/ft^3

Retardation — Distribution Coefficient (K_d) = 0.001 ft^3/kg



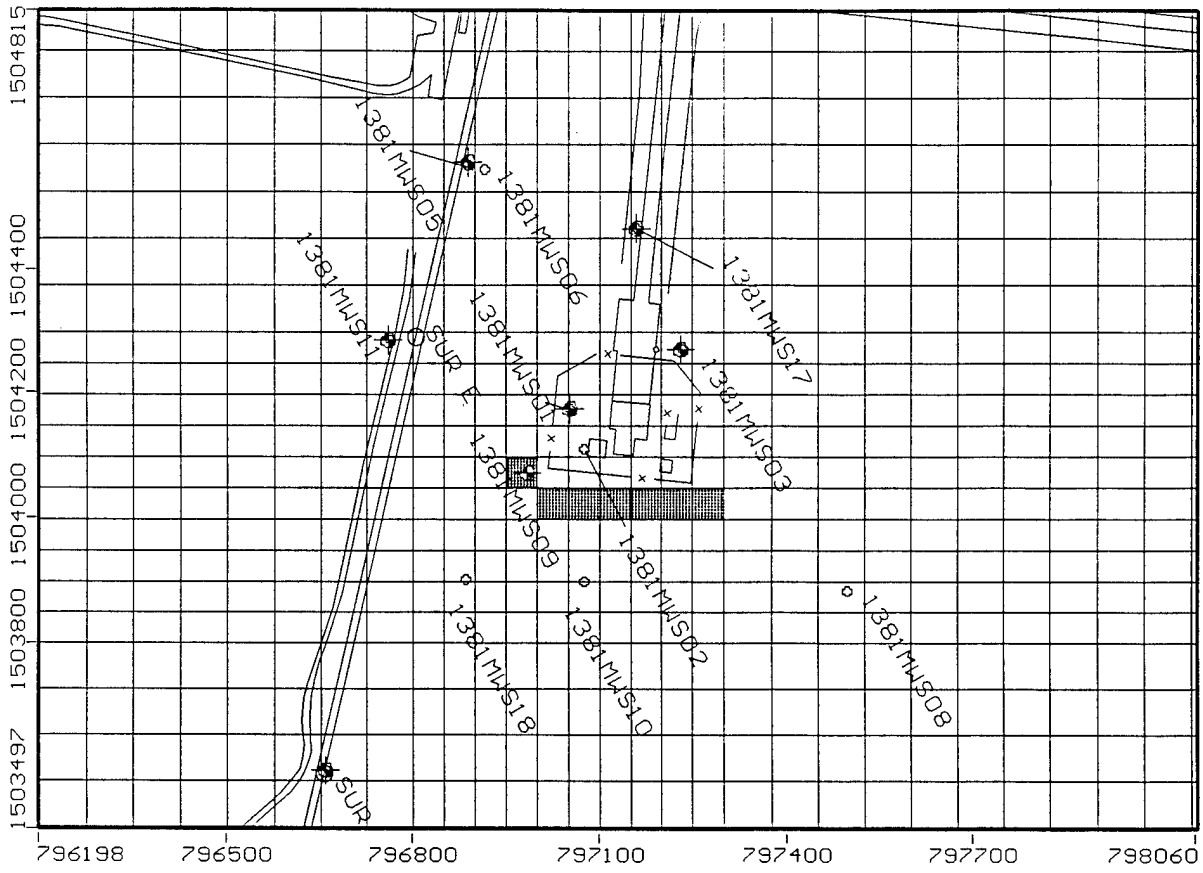
Parsons Eng. Science, Inc. Project: FACILITY 1381 Description: RECHARGE BOUNDARY Modeller: PARSONS ES 3 Sep 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 57 NR: 58 NL: 2 Current Layer: 1

20" per year

40" per year

0.045" per year

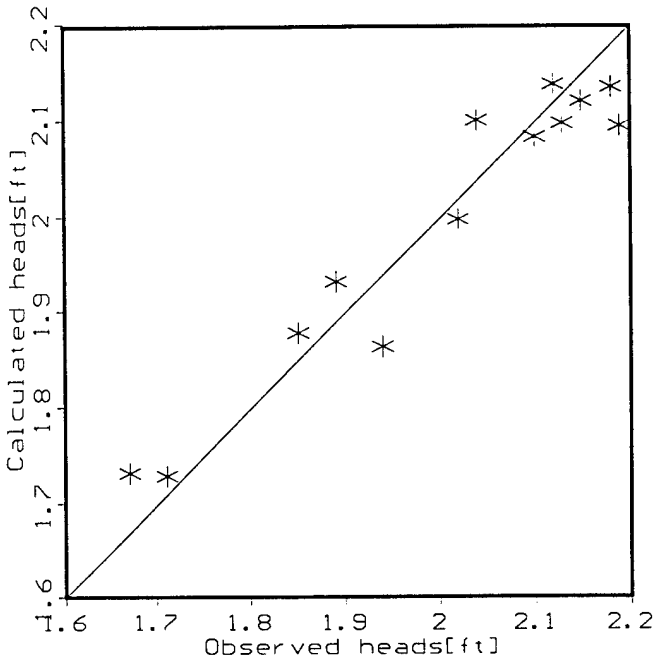
0.25" per year



Parsons Eng. Science, Inc. Project: FACILITY 1381 Description: RECHARGE CONC. BOUNDARY Modeller: PARSONS ES 3 Sep 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 57 NR: 58 NL: 2 Current Layer: 1

FLOW MODEL CALIBRATION DATA
SEPTEMBER 1996
FACILITY 1381 RNA TS
CAPE CANAVERAL AIR STATION, FLORIDA

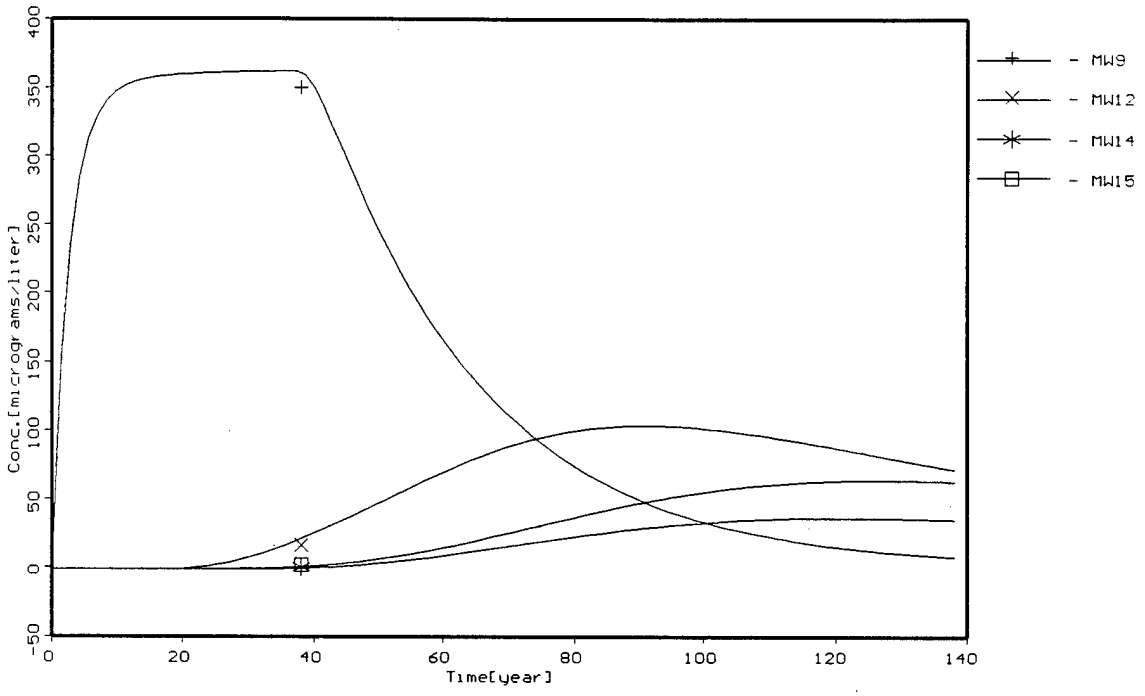
Calibration Location	Observed Head (feet)	Calculated Head (feet)	Residual Head (feet)
1381MWS01	2.12	2.15	-0.03
1381MWS03	2.10	2.13	-0.03
1381MWS07	2.10	2.19	-0.09
1381MWS09	2.14	2.12	0.02
1381MWS11	2.14	2.18	-0.04
1381MWS12	2.00	2.02	-0.02
1381MWS14	1.86	1.94	-0.08
1381MWS15	1.73	1.67	0.06
1381MWS16	1.93	1.89	0.04
1381MWS17	2.08	2.10	-0.02
SUR B	1.73	1.71	0.02
SUR D	1.88	1.85	0.03
SUR F	2.10	2.04	0.06



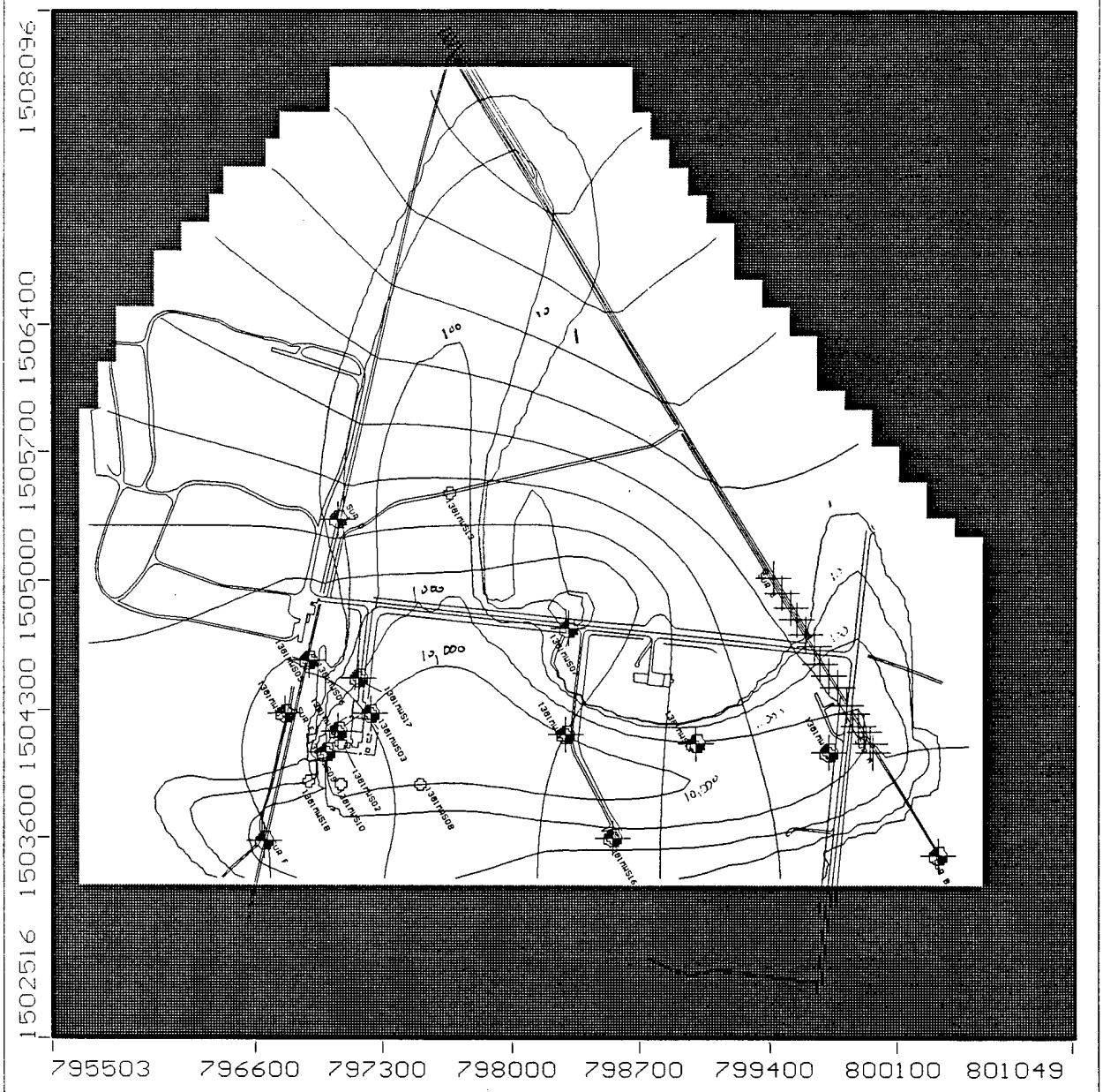
Period: 1
Step: 1

Mean error: -0.00684987 Mean abs. err: 0.0417618 RMS error: 0.0481281

Parsons Eng Science, Inc – Denver, CO Project: FACILITY 1381 Description: CALIBRATED WATER TABLE Modeller: PARSONS ES 13 Dec 99	Visual MODFLOW v.2.50, (C) 1995–1997 Waterloo Hydrogeologic Software NC: 57 NR: 58 NL: 2 Current Layer: 1

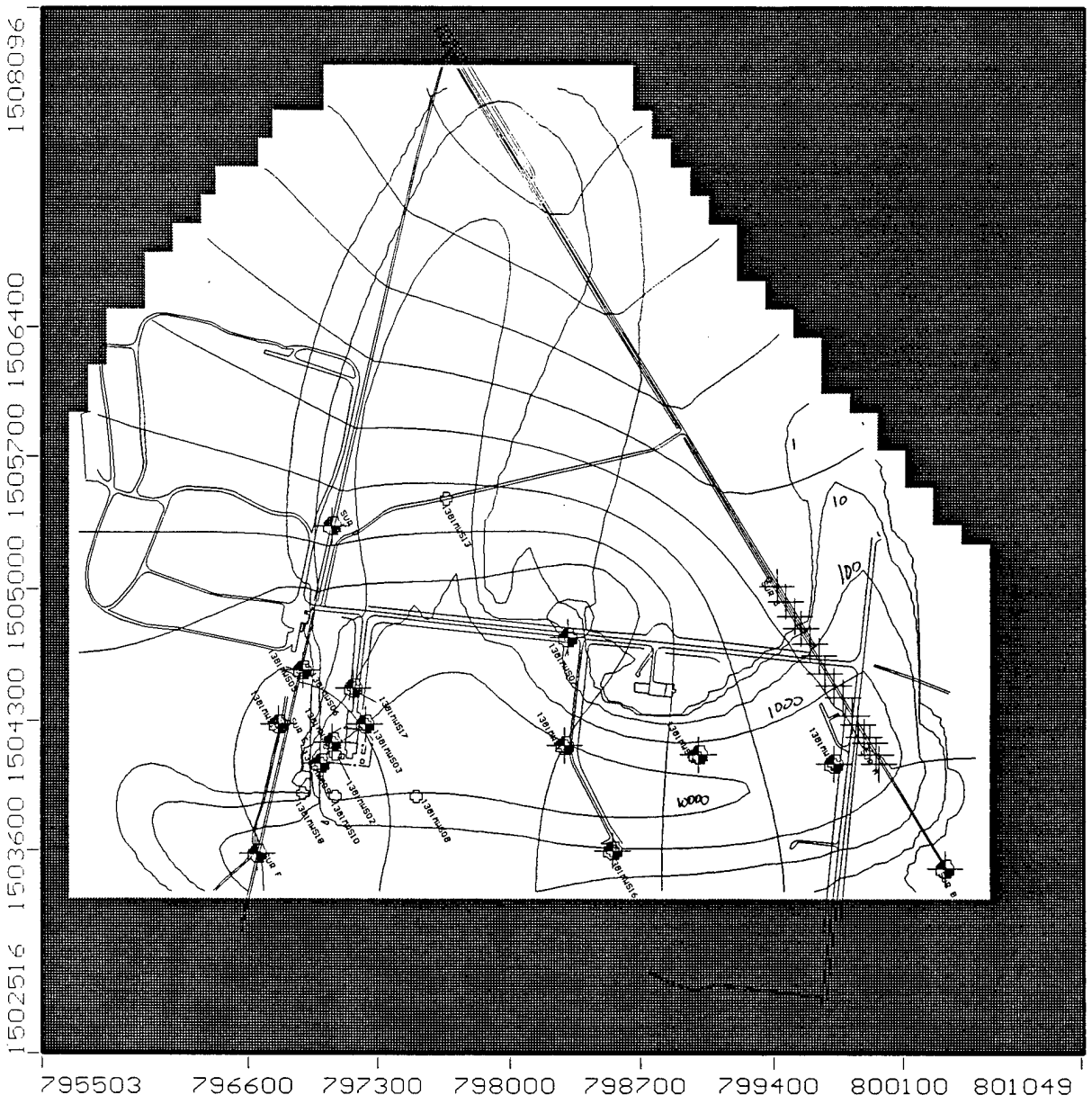


Parsons Eng. Science, Inc. Project: FACILITY 1381 Description: 4% SOURCE DECAY Modeller: PARSONS ES 2 Sep 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 57 NR: 58 NL: 2 Current Layer: 1



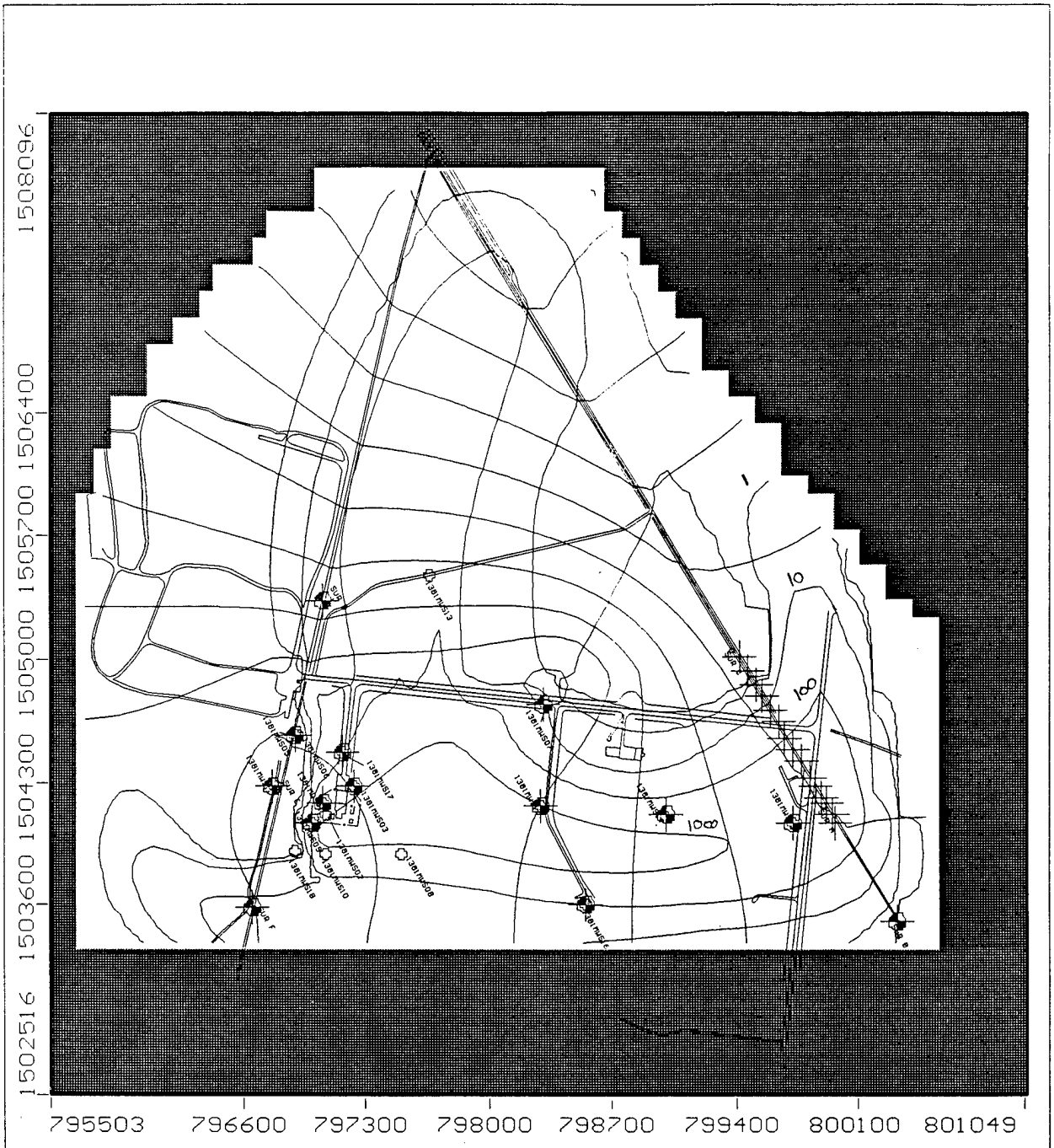
Parsons Eng. Science, Inc.
Project: FACILITY 1381
Description: 4% SOURCE DECAY--2021
Modeller: PARSONS ES
2 Sep 97

Visual MODFLOW v.2.20, (c) 1995
Waterloo Hydrogeologic Software
NC: 57 NR: 58 NL: 2
Current Layer: 1

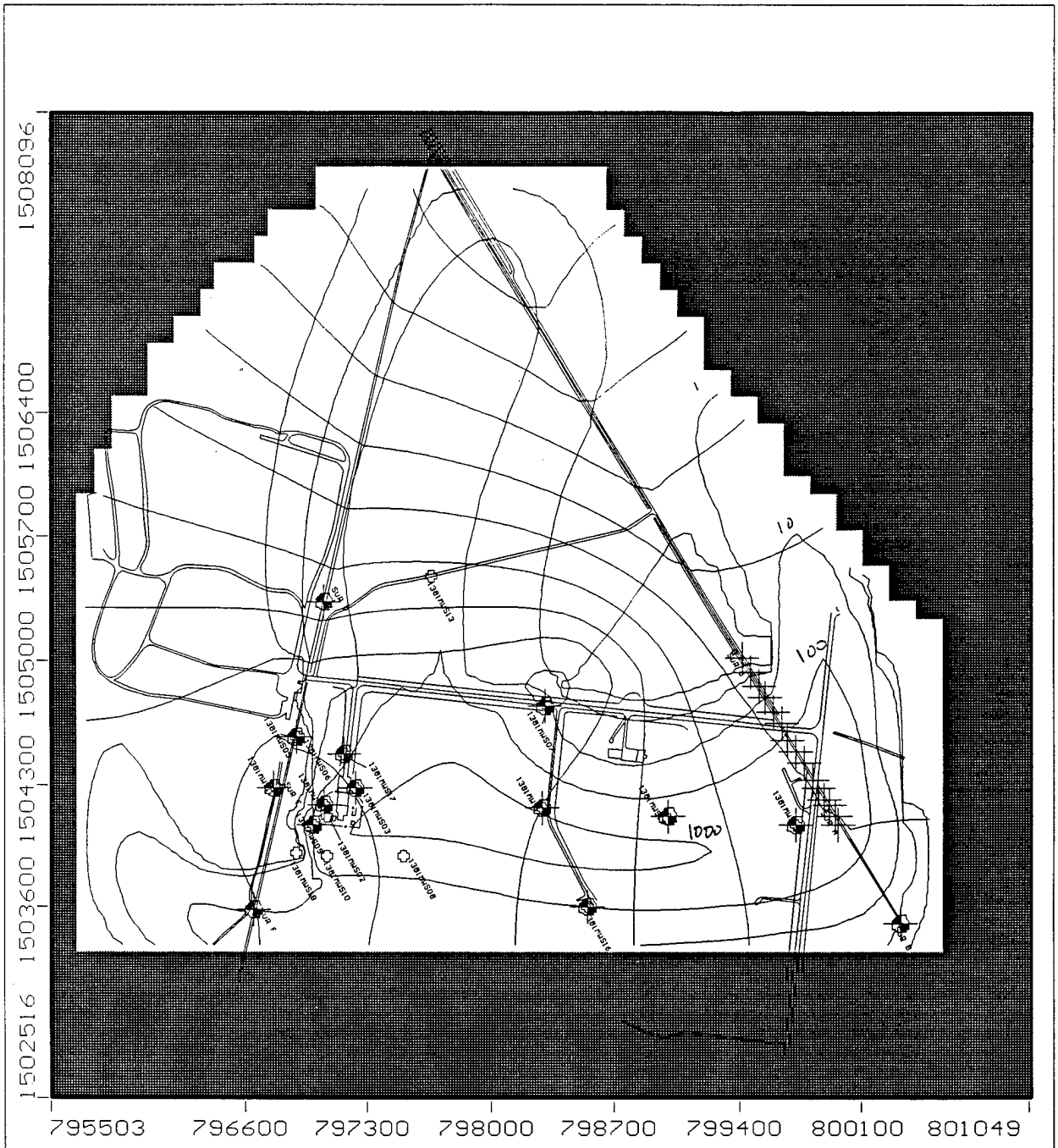


Parsons Eng. Science, Inc.
Project: FACILITY 1381
Description: 4% SOURCE DECAY--2046
Modeller: PARSONS ES
2 Sep 97

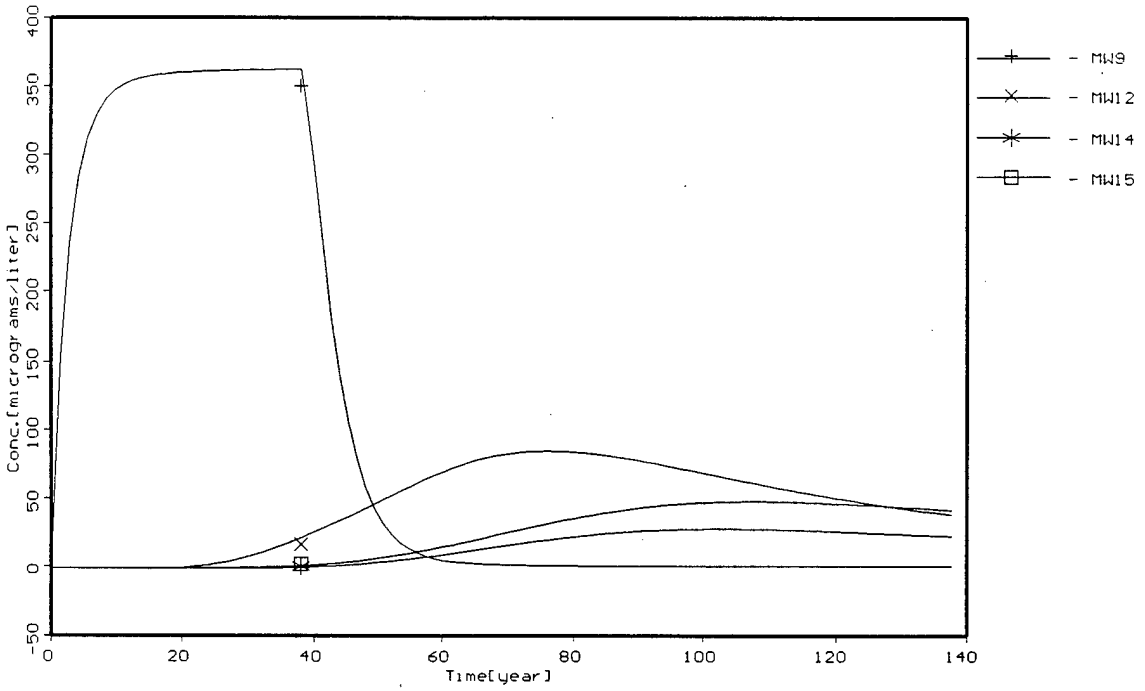
Visual MODFLOW v.2.20, (c) 1995
Waterloo Hydrogeologic Software
NC: 57 NR: 58 NL: 2
Current Layer: 1



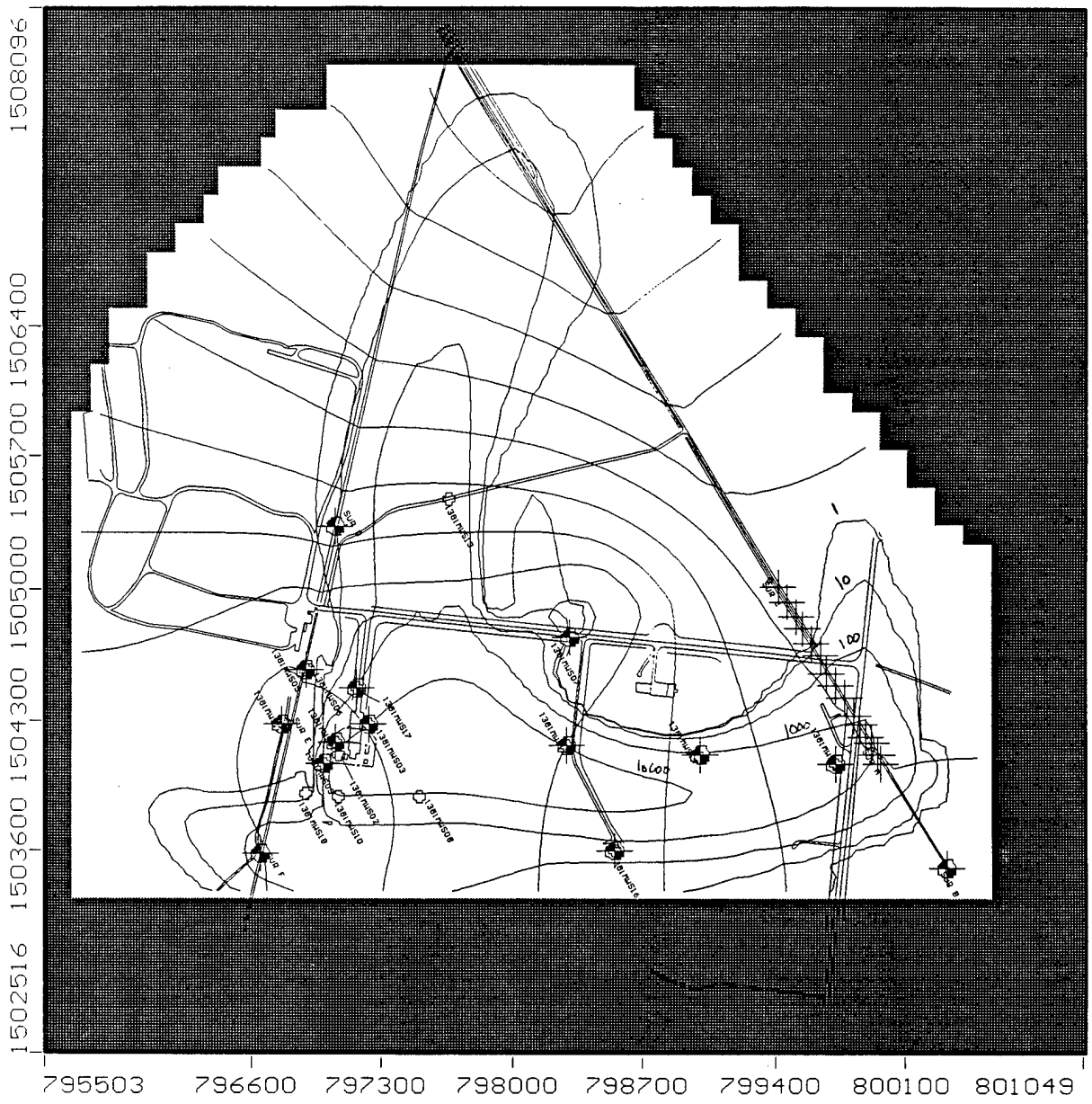
Parsons Eng. Science, Inc. Project: FACILITY 1381 Description: 4% SOURCE DECAY--2071 Modeller: PARSONS ES 2 Sep 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 57 NR: 58 NL: 2 Current Layer: 1



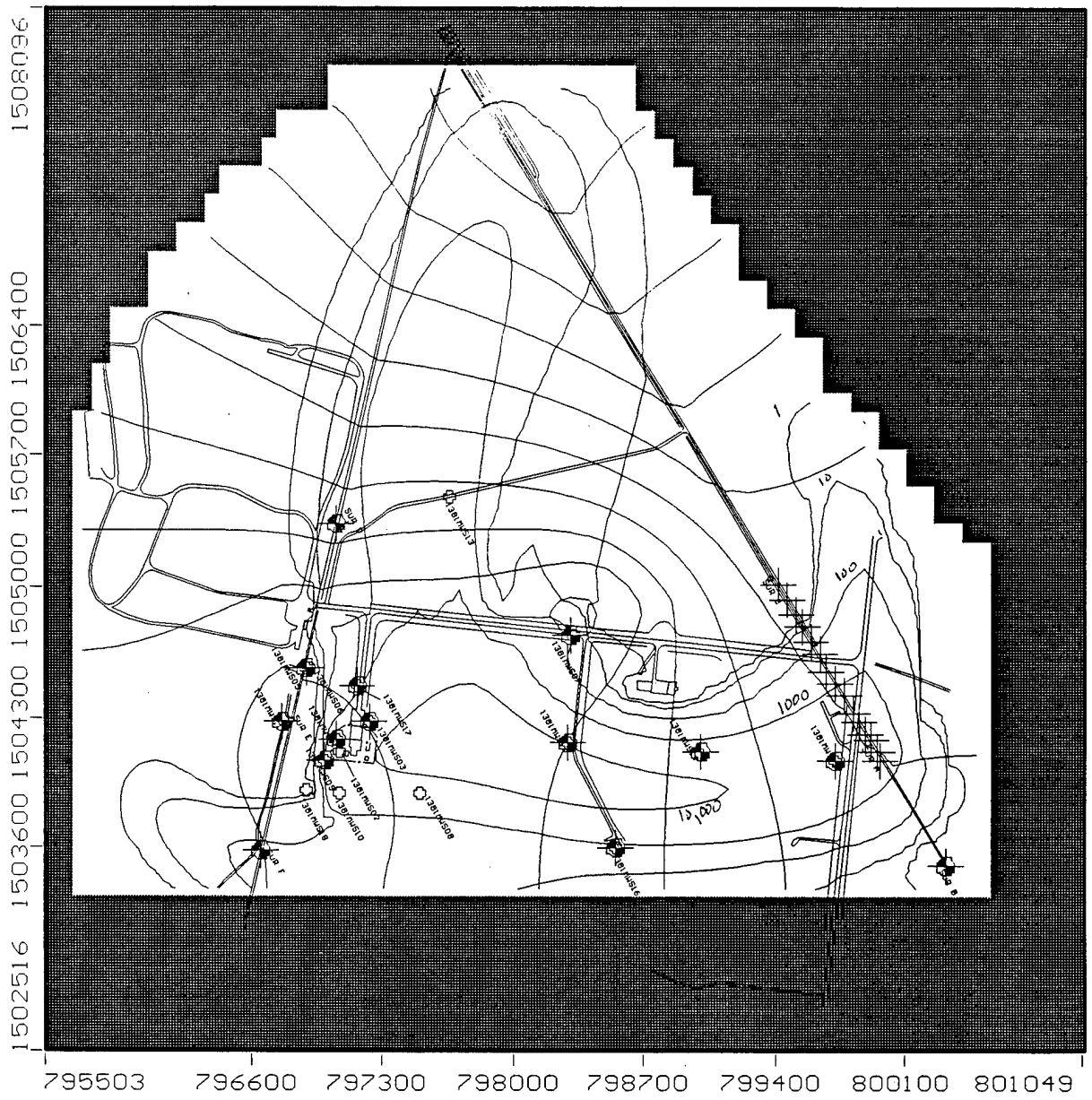
Parsons Eng. Science, Inc. Project: FACILITY 1381 Description: 4% SOURCE DECAY--2096 Modeller: PARSONS ES 2 Sep 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 57 NR: 58 NL: 2 Current Layer: 1

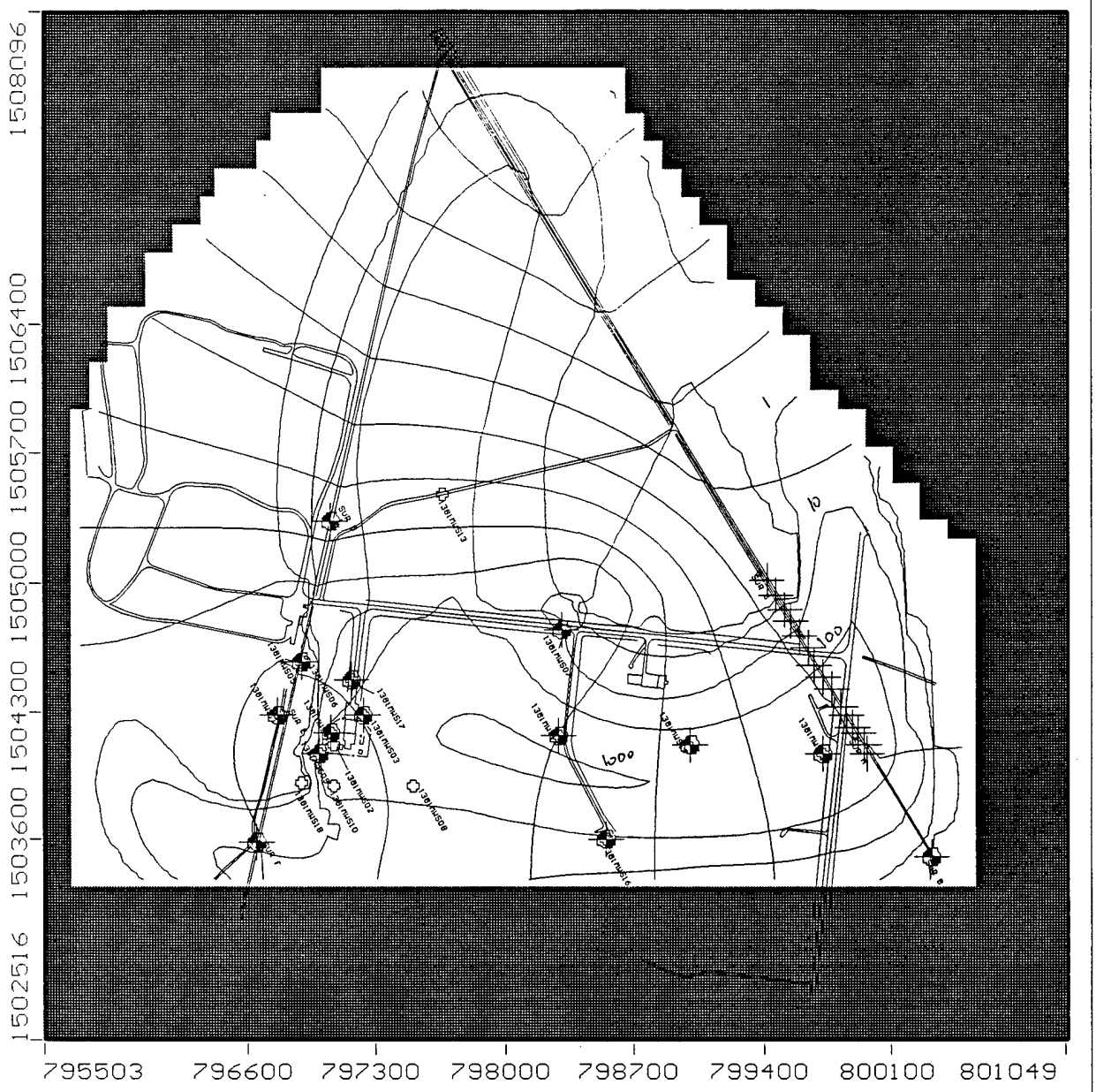


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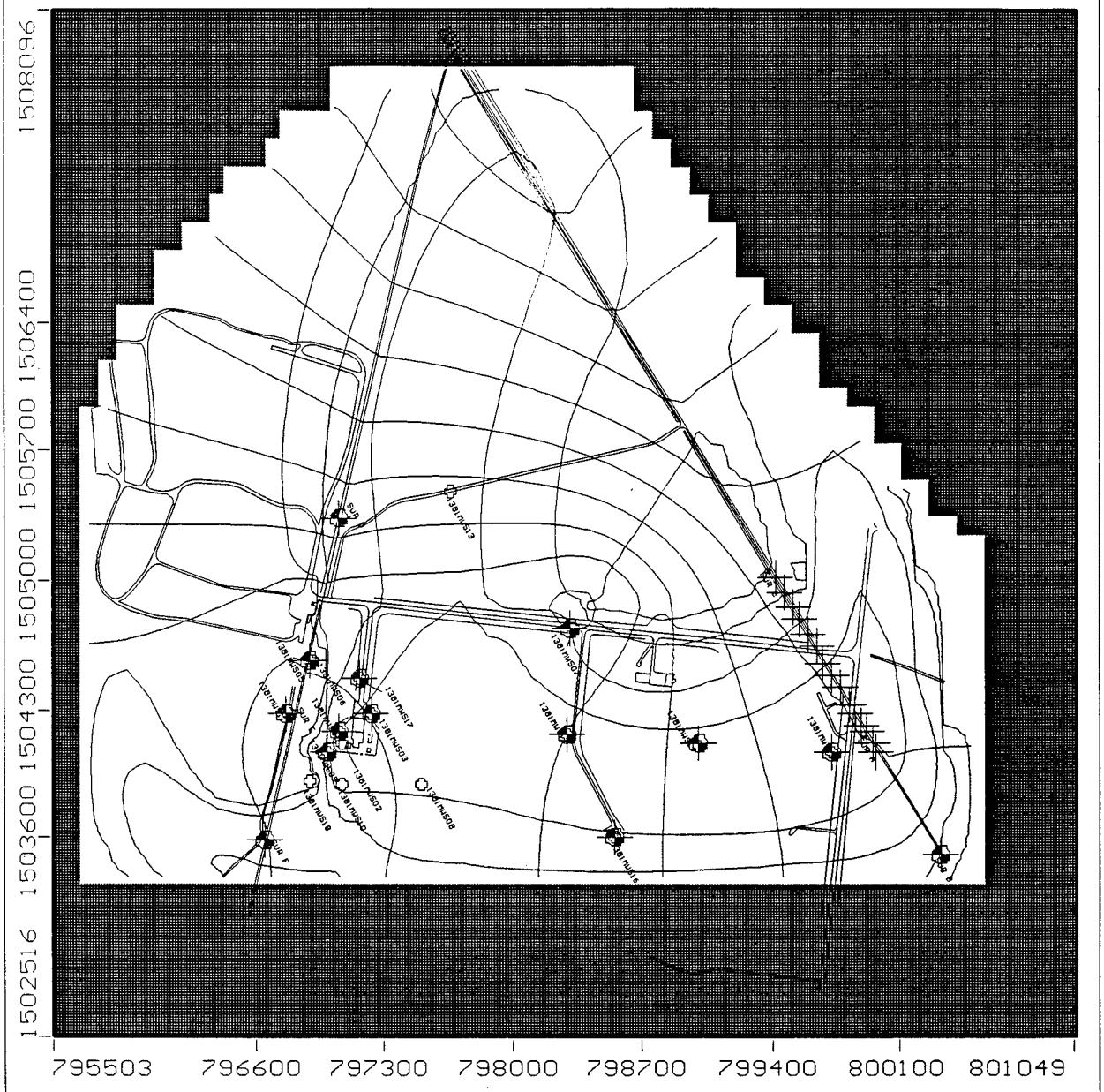


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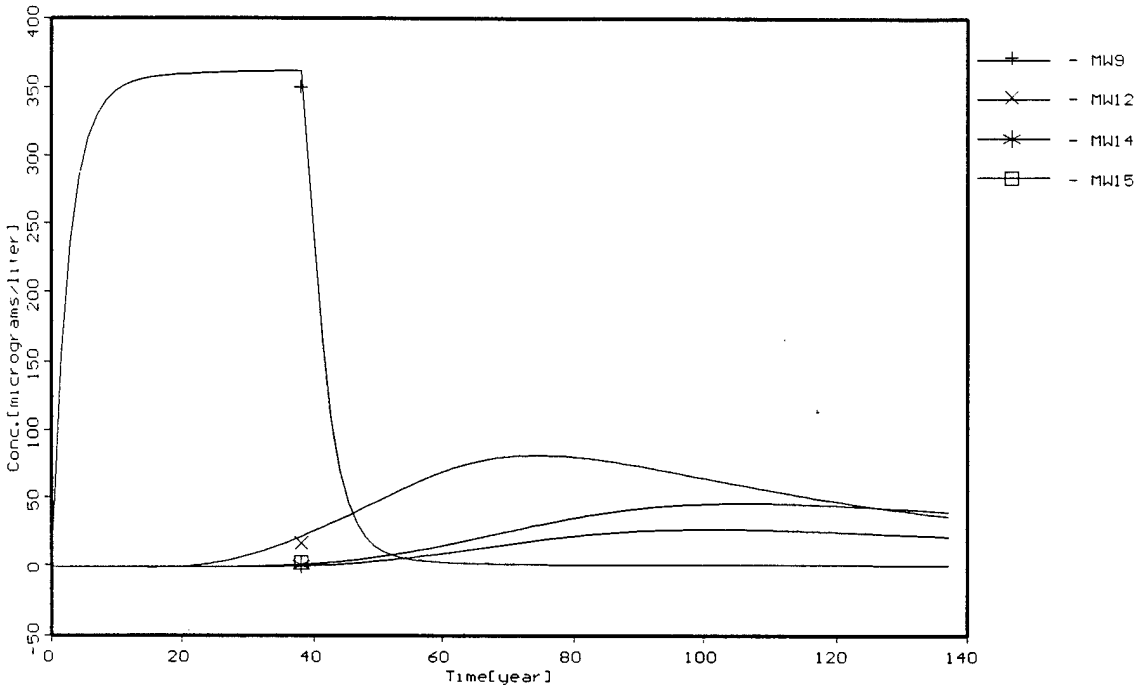

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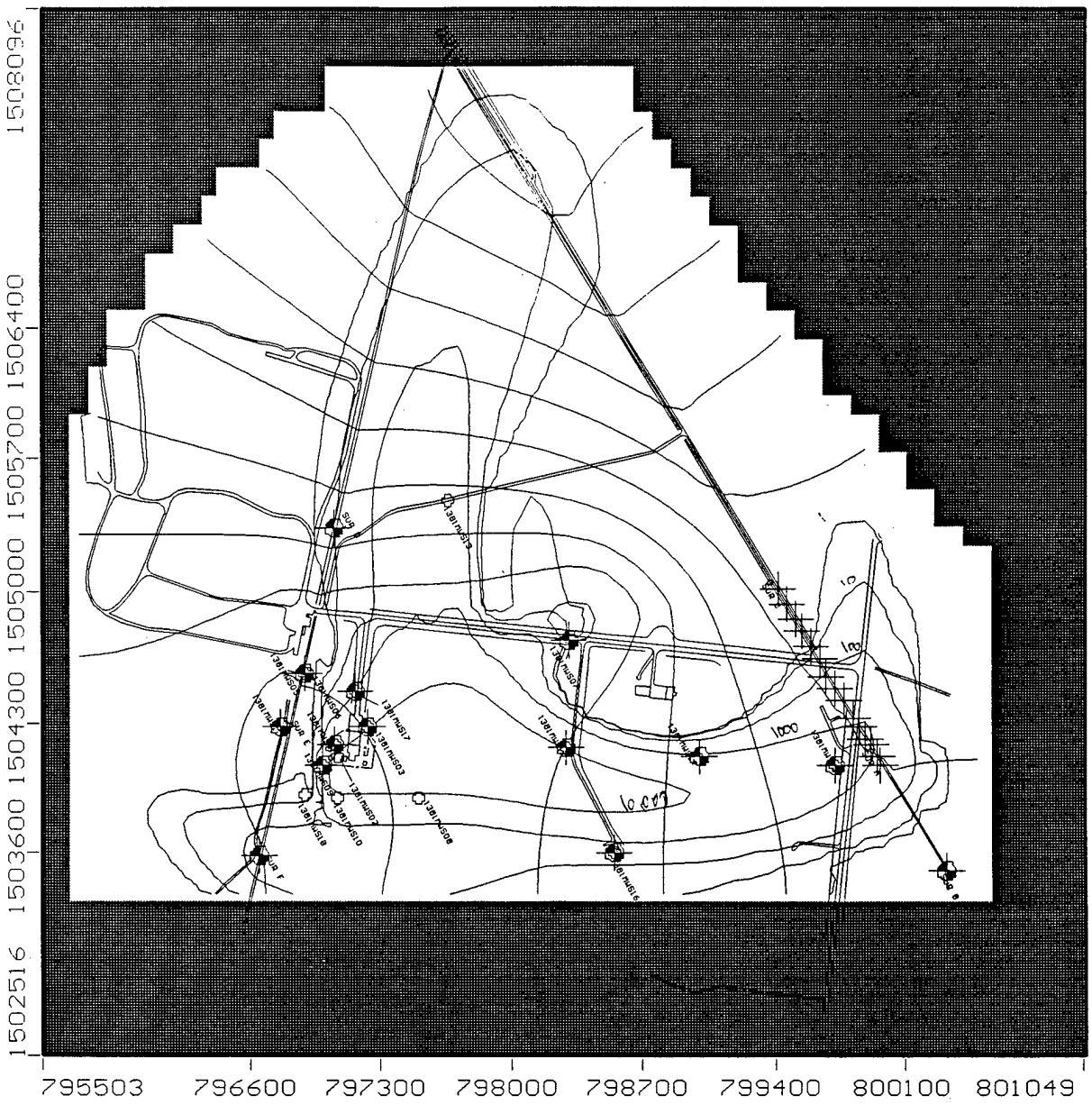
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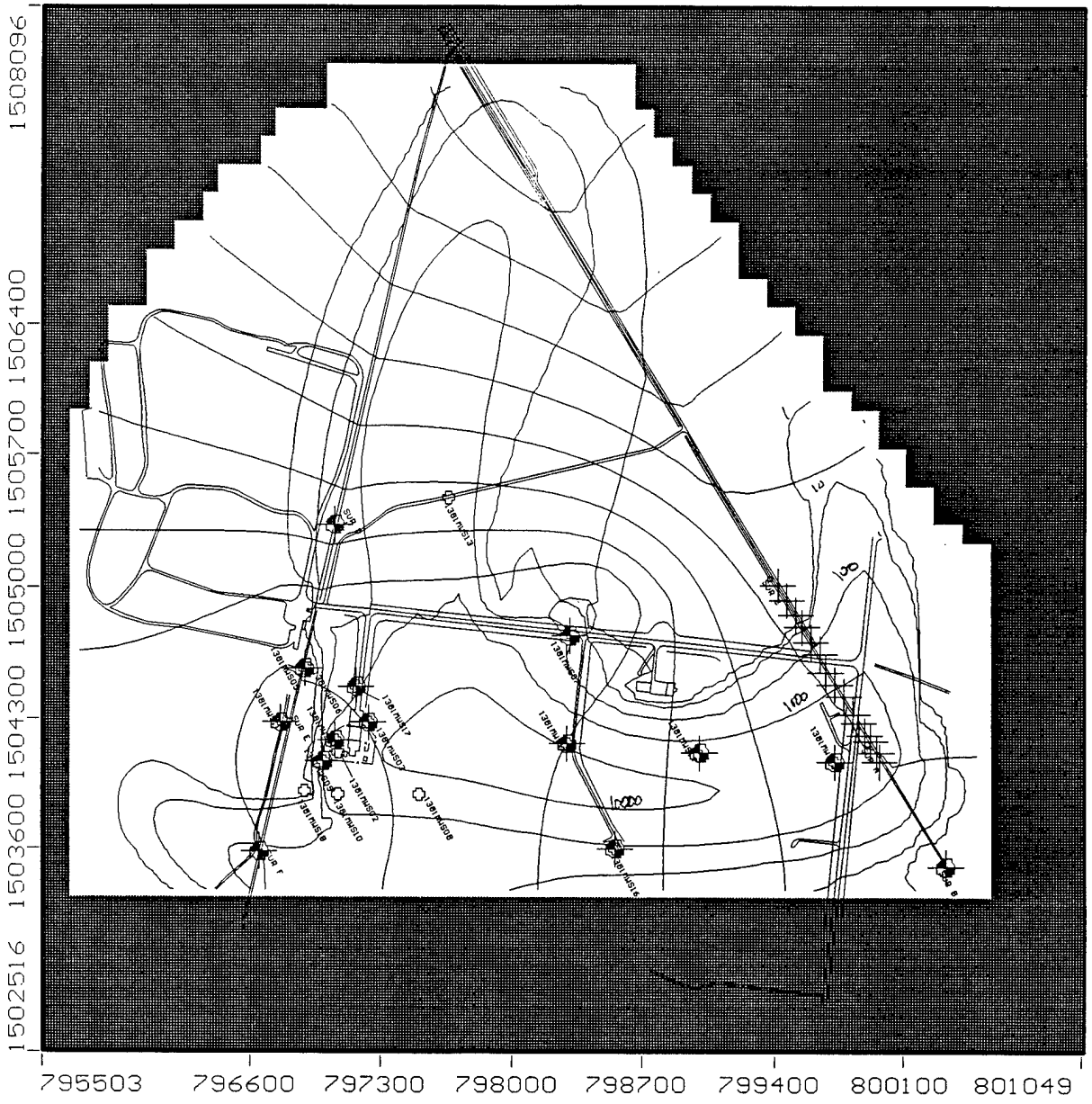
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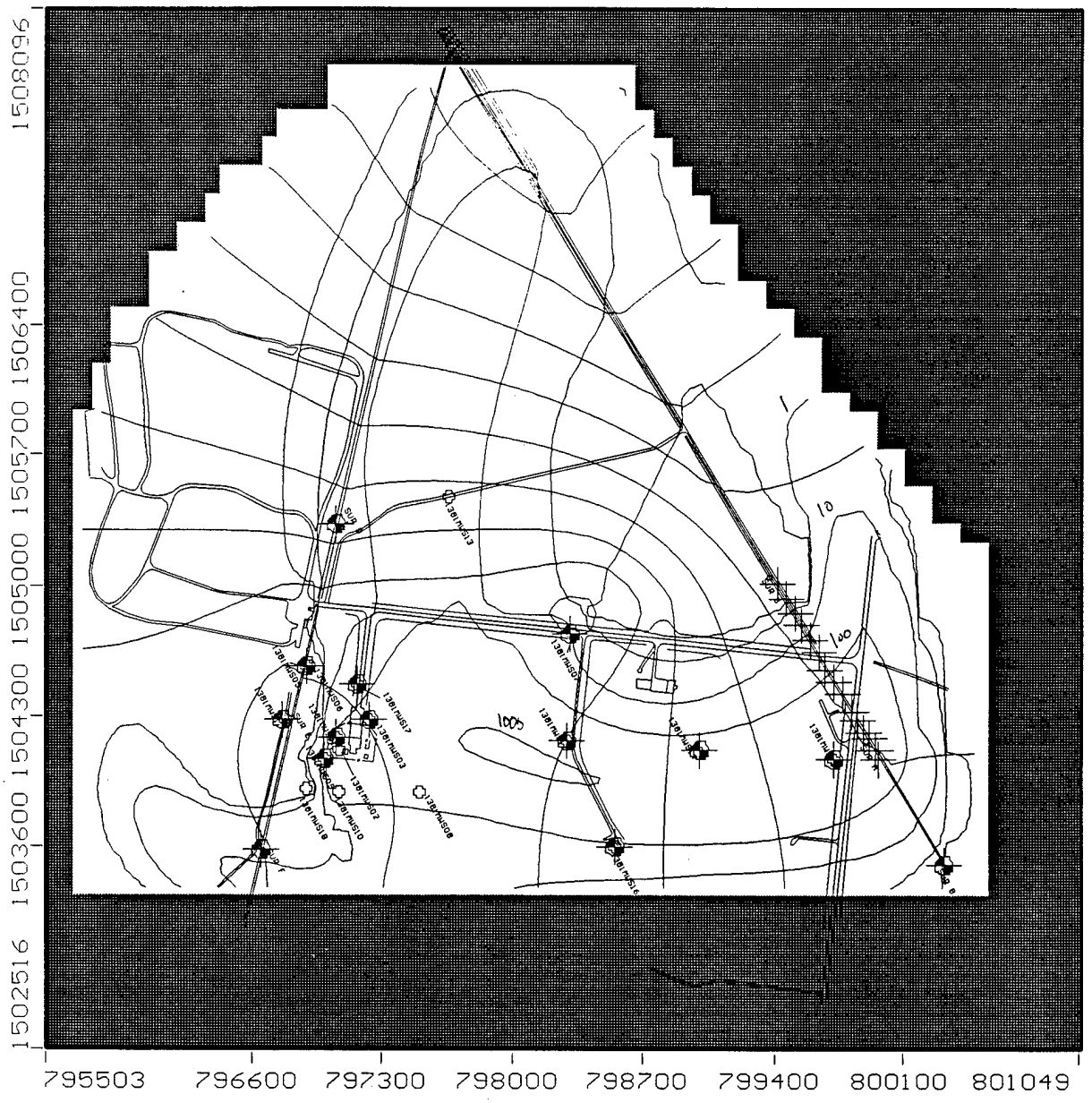
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Parsons Eng. Science, Inc. Project: FACILITY 1381 Description: 50% SOURCE DECAY--2021 Modeller: PARSONS ES 3 Sep 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 57 NR: 58 NL: 2 Current Layer: 1

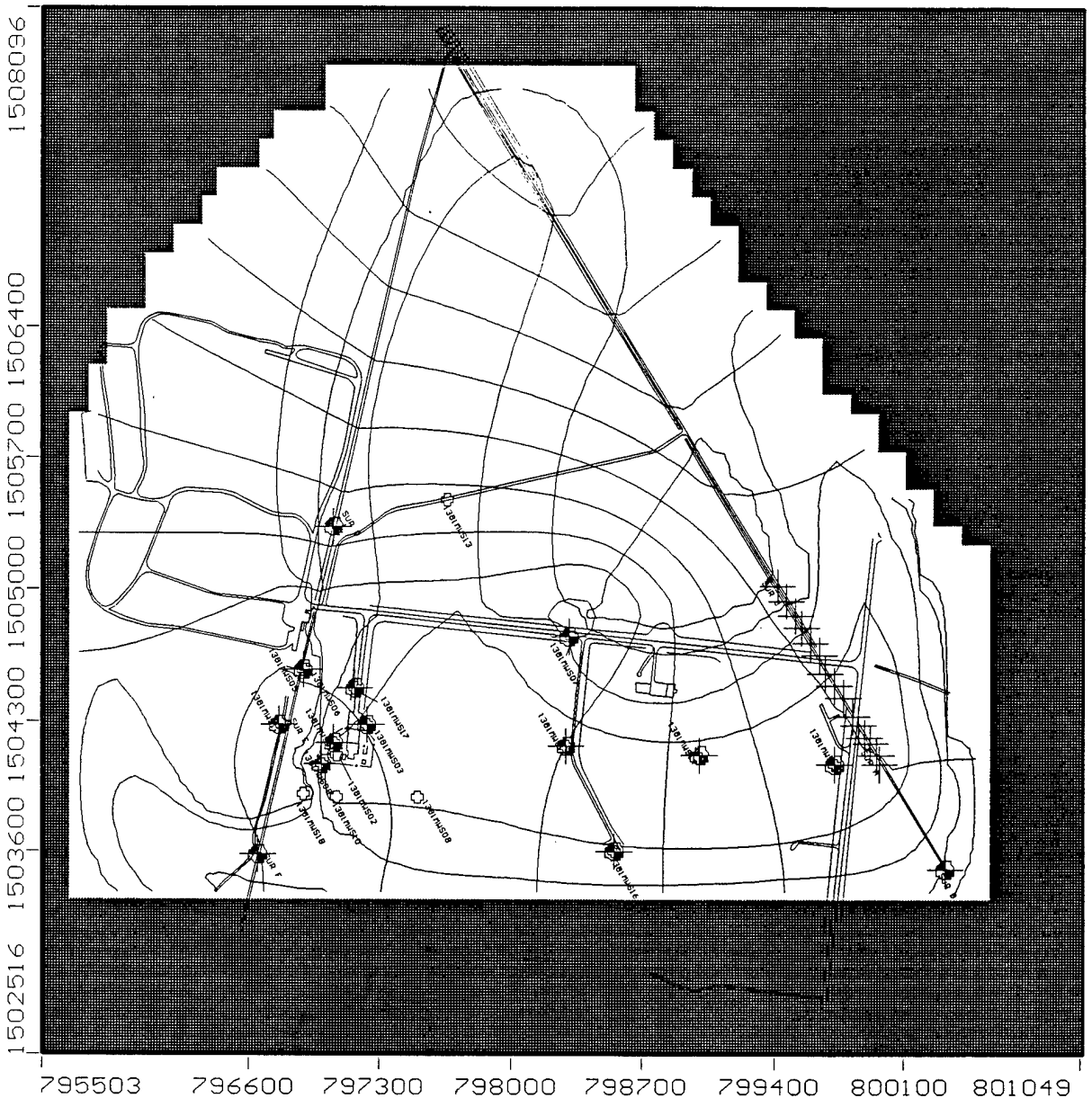


Parsons Eng. Science, Inc. Project: FACILITY 1381 Description: 50% SOURCE DECAY--2046 Modeller: PARSONS ES 3 Sep 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 57 NR: 58 NL: 2 Current Layer: 1



Parsons Eng. Science, Inc.
Project: FACILITY 1381
Description: 50% SOURCE DECAY--2071
Modeller: PARSONS ES
3 Sep 97

Visual MODFLOW v.2.20, (c) 1995
Waterloo Hydrogeologic Software
NC: 57 NR: 58 NL: 2
Current Layer: 1



Parsons Eng. Science, Inc. Project: FACILITY 1381 Description: 50% SOURCE DECAY--2096 Modeller: PARSONS ES 3 Sep 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 57 NR: 58 NL: 2 Current Layer: 1

APPENDIX D

MODEL INPUT AND OUTPUT FILES

APPENDIX E

COMPARISON OF *IN SITU* VS LABORATORY ANALYTICAL DATA FOR CHLORINATED ETHENE CONTAMINATION

PARSONS ENGINEERING SCIENCE, INC.

MEMORANDUM

2/21/97

To: Jerry Hansen

From: Todd Herrington T.H.

Subject: Contract #: F4-1624-92-D-8036
Comparison of Laboratory versus Field Sampling of Chlorinated Ethenes at Facility 1381, Cape Canaveral Air Station, Florida.

A comparison of laboratory versus field analytical data for chlorinated ethenes has been completed for Facility 1381 at CCAS. Chlorinated ethene concentrations in groundwater were measured directly from existing monitoring wells with a direct sampling ion trap mass spectrometer. The unit was operated by Cyril Thompson of the Chemical and Analytical Science Division of Oakridge National Laboratory. Groundwater monitoring wells were sampled with the direct sampling spectrometer between September 19-21, 1996 and analyzed for trichloroethene (TCE), total dichloroethenes (DCE), and vinyl chloride (VC). Conventional groundwater sampling by pumping groundwater into 40 mL VOA bottles was also performed at Facility 1381 by Parsons ES and the USEPA as part of the AFCEE sponsored natural attenuation demonstration project for the site. Groundwater samples collected in VOA bottles were analyzed at the USEPA laboratory in Ada, Oklahoma.

Included with this memo is a table summarizing *in situ* (those collected directly from the monitoring well by the direct sampling spectrometer) and fixed-based laboratory groundwater sampling results for TCE, DCE, and VC. In particular, the table shows which *in situ* measurements were collected before or after purging the monitoring wells. Prepurge and postpurge groundwater samples were collected with the direct sampling spectrometer to evaluate any differences in chlorinated ethene concentrations as a result of flushing the wells with formation waters. All groundwater samples submitted to the USEPA laboratory were collected after the monitoring wells were purged. Comparison of *in situ* and laboratory analytical results suggests that *in situ* versus laboratory data have a poor correlation. Most *in situ* analytical results were higher than laboratory analytical results, which suggests that chlorinated ethenes in laboratory samples were lost by volatilization during collection, transport, and/or analysis. Furthermore, chlorinated ethene concentrations measured with the direct sampling spectrometer from prepurge and postpurge groundwater samples (e.g., at wells 1381MWS12 and 1381MWS14) showed no correlation.

Also included with this memo are tables describing the mean error, mean average error, and root-mean-square effort for *in situ* versus fixed-based laboratory analytical data for TCE, DCE, and VC. These tables numerically confirm that chlorinated ethene measurements tend to be relatively higher than measured by laboratory techniques. Scatter plots are also included with this memo to illustrate these trends.

Variability between sampling methods may be the result of sampling losses, sampling, technique, and/or laboratory technique. Parsons ES recommends that potential future studies incorporate split-laboratory sampling and matrix-spike addition to confirm the accuracy of the direct sampling spectrometer device and to determine the cause of potential discrepancies. The results summarized in this memo will be included, as appropriate, in the natural attenuation section of the corrective measures study (CMS) being written for CCAS by Parsons ES.

Please call Mr. Dave Moutoux or Mr. Todd Herrington at (303) 831-8100 if you have any further questions.

enclosure

cc: File 729691 29250
Dave Moutoux

COMPARISON OF *IN SITU* VS LABORATORY ANALYTICAL DATA FOR CHLORINATED ETHENE CONTAMINATION
FACILITY 1381
CORRECTIVE MEASURES STUDY
CAPE CANAVERAL AIR STATION, FLORIDA

	In Situ Sampling and Well Purging Schedule					*In Situ* Analytical Results			Laboratory Analytical Results		
Sample Location	*In Situ* Sampling Date	*In Situ* Sampling Time	Well Purge Date	Well Purge Time	*In Situ* Sampling Period[a/]	TCE (µg/L)[b/]	Total DCE (µg/L)	Vinyl Chloride (µg/L)	TCE (µg/L)	Total DCE (µg/L)	Vinyl Chloride (µg/L)
1381MWS01	20-Sep	2:00 PM	9/19/96	NA[c/]	post-purge	732	4490	1849	239	2423.7	210
1381MWS02	20-Sep	1:30 PM	NA	NA	pre-purge	563	204	193	NA	NA	NA
1381MWD02	20-Sep	1:30 PM	NA	NA	pre-purge	ND[d/]	ND	6	NA	NA	NA
1381MWS03	20-Sep	12:15 PM	9/19/96	2:10 PM	post-purge	4	6090	6909	ND	2617.7	836
1381MWD03	20-Sep	12:15 PM	9/20/96	3:50 PM	pre-purge	1	ND	ND	ND	ND	ND
1381MWD04	9/21/96	2:30 PM	9/20/96	NA	post-purge	ND	ND	ND	NA	NA	NA
1381MWS05	9/21/96	1:00 PM	9/19/96	4:00 PM	post-purge	ND	ND	ND	< 1.0	45.5	51.3
1381MWI05	9/21/96	1:00 PM	9/20/06	NA	post-purge	ND	ND	ND	ND	ND	ND
1381MWD05	9/21/96	1:00 PM	9/20/06	NA	post-purge	ND	ND	ND	NA	NA	NA
1381MWS07	9/19/96	4:15 PM	9/20/96	8:45 AM	pre-purge	ND	7	ND	ND	10.2	1.3
1381MWS08	9/19/96	1:45 PM	NA	NA	pre-purge	ND	26	198	NA	NA	NA
1381MWD08	9/19/96	1:45 PM	NA	NA	pre-purge	ND	ND	ND	NA	NA	NA
1381MWS09	20-Sep	1:00 PM	9/18/96	10:40 AM	post-purge	2812	1286	989	39400	4383.1	240
1381MWI09	20-Sep	1:00 PM	9/18/96	10:45 AM	post-purge	64	3026	5160	26.9	1361.1	795
1381MWD09	20-Sep	1:00 PM	9/18/96	10:55 AM	post-purge	1	38	5	6.6	3.6	1.6
1381MWS10	9/19/96	1:45 PM	NA	NA	pre-purge	ND	ND	4	NA	NA	NA
1381MWD10	9/19/96	1:45 PM	NA	NA	pre-purge	1	ND	9	NA	NA	NA
1381MWS11	9/19/96	12:30 PM	9/20/96	8:30 AM	pre-purge	ND	ND	5	ND	< 1.0	ND
1381MWD11	9/19/96	12:45 PM	NA	NA	pre-purge	ND	ND	ND	NA	NA	NA
1381MWS12	20-Sep	9:00 AM	NA	NA	pre-purge	ND	1259	10027	NA	NA	NA
1381MWS12	20-Sep	2:45 PM	9/20/96	10:30 AM	post-purge	ND	659	2546	ND	763.2	510
1381MWD12	20-Sep	9:45 AM	9/20/96	11:30 AM	pre-purge	ND	ND	ND	ND	ND	ND
1381MWS13	9/19/96	2:45 PM	9/20/96	NA	pre-purge	ND	ND	ND	ND	4.6	< 1.0
1381MWD13	9/19/96	2:45 PM	NA	NA	pre-purge	ND	ND	ND	NA	NA	NA
1381MWS14	9/19/96	4:00 PM	NA	NA	pre-purge	ND	15	ND	NA	NA	NA

COMPARISON OF *IN SITU* VS LABORATORY ANALYTICAL DATA FOR CHLORINATED ETHENE CONTAMINATION FACILITY 1381 CORRECTIVE MEASURES STUDY CAPE CANAVERAL AIR STATION, FLORIDA

	In Situ Sampling and Well Purging Schedule					*In Situ* Analytical Results			Laboratory Analytical Results		
Sample Location	*In Situ* Sampling Date	*In Situ* Sampling Time	Well Purge Date	Well Purge Time	*In Situ* Sampling Period[a/]	TCE (µg/L)[b/]	Total DCE (µg/L)	Vinyl Chloride (µg/L)	TCE (µg/L)	Total DCE (µg/L)	Vinyl Chloride (µg/L)
1381MWS14	20-Sep	11:15 AM	9/20/96	12:15 PM	pre-purge	ND	11	ND	NA	NA	NA
1381MWS14	20-Sep	3:15 PM	NA	NA	post-purge	1	488	ND	ND	65.6	2.3
1381MWS15	9/19/96	3:30 PM	9/20/96	2:20 PM	pre-purge	ND	212	160	ND	130	16.3
1381MWS16	NA	NA	9/21/96	8:10 AM	NA	NA	NA	NA	ND	2.1	1.2
1381MWS17	20-Sep	12:00 PM	9/19/96	3:30 PM	post-purge	1	2149	14496	ND	924.5	1040
1381MWD17	20-Sep	11:45 AM	NA	NA	pre-purge	ND	ND	ND	NA	NA	NA
1381MWS18	NA	NA	9/19/96	2:10 PM	NA	NA	NA	NA	< 1.0	ND	ND

[a/] All groundwater samples submitted for laboratory analysis were collected after the wells were purged (post-purged).

[b/] µg/L = micrograms per liter.

[c/] NA = Not Available.

[d/] ND = Not Detected.

MEAN ERROR, MEAN AVERAGE ERROR, AND ROOT-MEAN-SQUARE ERROR FOR *IN SITU* VERSUS ANALYTICAL TCE DATA

FACILITY 1381

CORRECTIVE MEASURES STUDY

CAPE CANAVERAL AIR STATION, FLORIDA

Monitoring Well	*In Situ* TCE Concentration (TCE_i)[a/]	Laboratory TCE Concentration (TCE_l)[a/]	TCE_i-TCE_l	abs(TCE_i-TCE_l)	(TCE_i-TCE_l)^2
1381MWS01	732	239	493.00	493.00	243049.00
1381MWS03	4	0	4.00	4.00	16.00
1381MWS05	0	1	-1.00	1.00	1.00
1381MWI05	0	0	0.00	0.00	0.00
1381MWS09	2812	39400	-36588.00	36588.00	1338681744.00
1381MWI09	64	26.9	37.10	37.10	1376.41
1381MWD09	1	6.6	-5.60	5.60	31.36
1381MWS12	0	0	0.00	0.00	0.00
1381MWS14	1	0	1.00	1.00	1.00
1381MWS17	1	0	1.00	1.00	1.00
Total:	3615.0	39673.5	-36058.50	37130.70	1338926219.77
			ME[b/] =	-3004.88	
			MAE[c/] =	3094.23	
			RMS[d/] =	10148.61	

[a/] Concentrations in µg/L.

[b/] ME = Mean Error =1/n x (TCE_i-TCE_l).

[c/] MAE = Mean Average Error = 1/n x |(TCE_i-TCE_l)|.

[d/] RMS = Root-Mean-Square (RMS) Error = (1/n x (TCE_i-TCE_l)^2)$^{0.5}$.

MEAN ERROR, MEAN AVERAGE ERROR, AND ROOT-MEAN-SQUARE ERROR FOR *IN SITU* VERSUS ANALYTICAL DCE DATA

FACILITY 1381

CORRECTIVE MEASURES STUDY

CAPE CANAVERAL AIR STATION, FLORIDA

Monitoring Well	*In Situ* DCE Concentration (DCE_i)[a/]	Laboratory DCE Concentration (DCE_l)[a/]	DCE_i-DCE_l	abs(DCE_i-DCE_l)	(DCE_i-DCE_l)^2
1381MWS01	4490	2423.7	2066.30	2066.30	4269595.69
1381MWS03	6090	2617.7	3472.30	3472.30	12056867.29
1381MWS05	0	45.5	-45.50	45.50	2070.25
1381MWI05	0	0	0.00	0.00	0.00
1381MWS09	1286	4383.1	-3097.10	3097.10	9592028.41
1381MWI09	3026	1361.1	1664.90	1664.90	2771892.01
1381MWD09	38	3.6	34.40	34.40	1183.36
1381MWS12	659	763.2	-104.20	104.20	10857.64
1381MWS14	488	65.6	422.40	422.40	178421.76
1381MWS17	2149	924.5	1224.50	1224.50	1499400.25
Total:	18226.0	12588.0	5638.00	12131.60	30382316.66
			ME[b/] =	469.83	
			MAE[c/] =	1010.97	
			RMS[d/] =	1528.76	

[a/] Concentrations in µg/L.

[b/] ME = Mean Error =1/n x (DCE_i-DCE_l).

[c/] MAE = Mean Average Error = 1/n x |(DCE_i-DCE_l)|.

[d/] RMS = Root-Mean-Square (RMS) Error = (1/n x (DCE_i-DCE_l)^2)$^{0.5}$.

MEAN ERROR, MEAN AVERAGE ERROR, AND ROOT-MEAN-SQUARE ERROR FOR *IN SITU* VERSUS ANALYTICAL VINYL CHLORIDE DATA

FACILITY 1381

CORRECTIVE MEASURES STUDY

CAPE CANAVERAL AIR STATION, FLORIDA

Monitoring Well	*In Situ* Vinyl Chloride Concentration (VC_i)[a/]	Laboratory Vinyl Chloride Concentration (VC_l)[a/]	VC_i-VC_l	abs(VC_i-VC_l)	(VC_i-VC_l)^2
1381MWS01	1849	210	1639.00	1639.00	2686321.00
1381MWS03	6909	836	6073.00	6073.00	36881329.00
1381MWS05	0	51.3	-51.30	51.30	2631.69
1381MWI05	0	0	0.00	0.00	0.00
1381MWS09	989	240	749.00	749.00	561001.00
1381MWI09	5160	795	4365.00	4365.00	19053225.00
1381MWD09	5	1.6	3.40	3.40	11.56
1381MWS12	2546	510	2036.00	2036.00	4145296.00
1381MWS14	0	2.3	-2.30	2.30	5.29
1381MWS17	14496	1040	13456.00	13456.00	181063936.00
Total:	31954.0	3686.2	28267.80	28375.00	244393756.54
			ME[b/] =	2355.65	
			MAE[c/] =	2364.58	
			RMS[d/] =	4335.84	

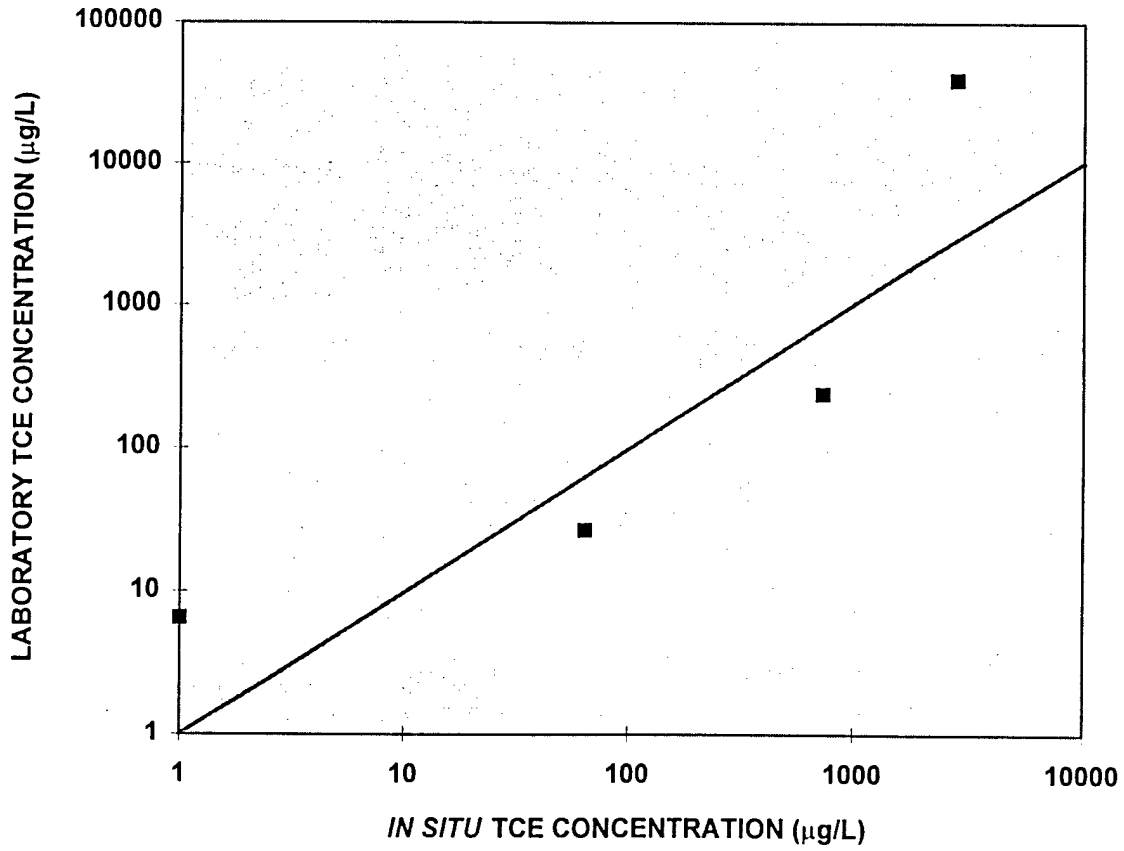
[a/] Concentrations in µg/L.

[b/] ME = Mean Error =1/n x (VC_i-VC_l).

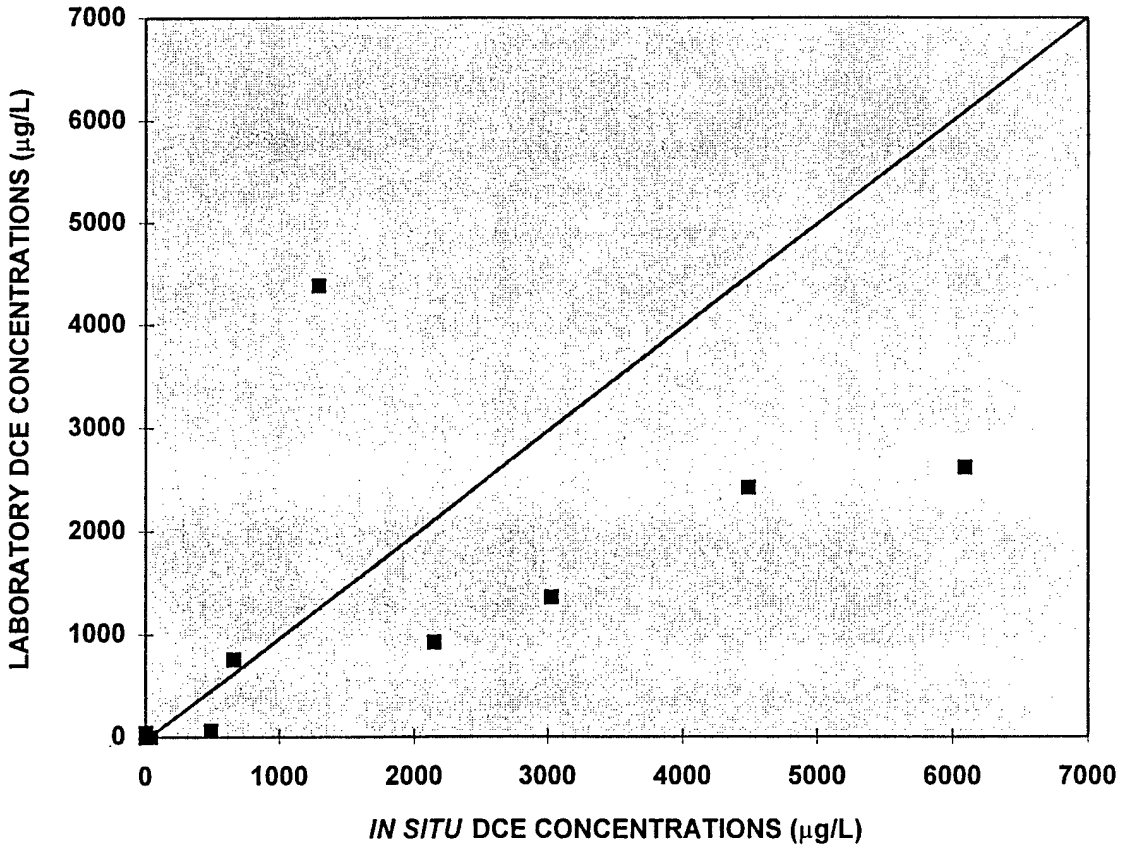
[c/] MAE = Mean Average Error = 1/n x |(VC_i-VC_l)|.

[d/] RMS = Root-Mean-Square (RMS) Error = (1/n x (VC_i-VC_l)^2)$^{0.5}$.

IN SITU VERSUS LABORATORY ANALYTICAL DATA FOR TCE
FACILITY 1381
CORRECTIVE MEASURES STUDY
CAPE CANAVERAL AIR STATION, FLORIDA

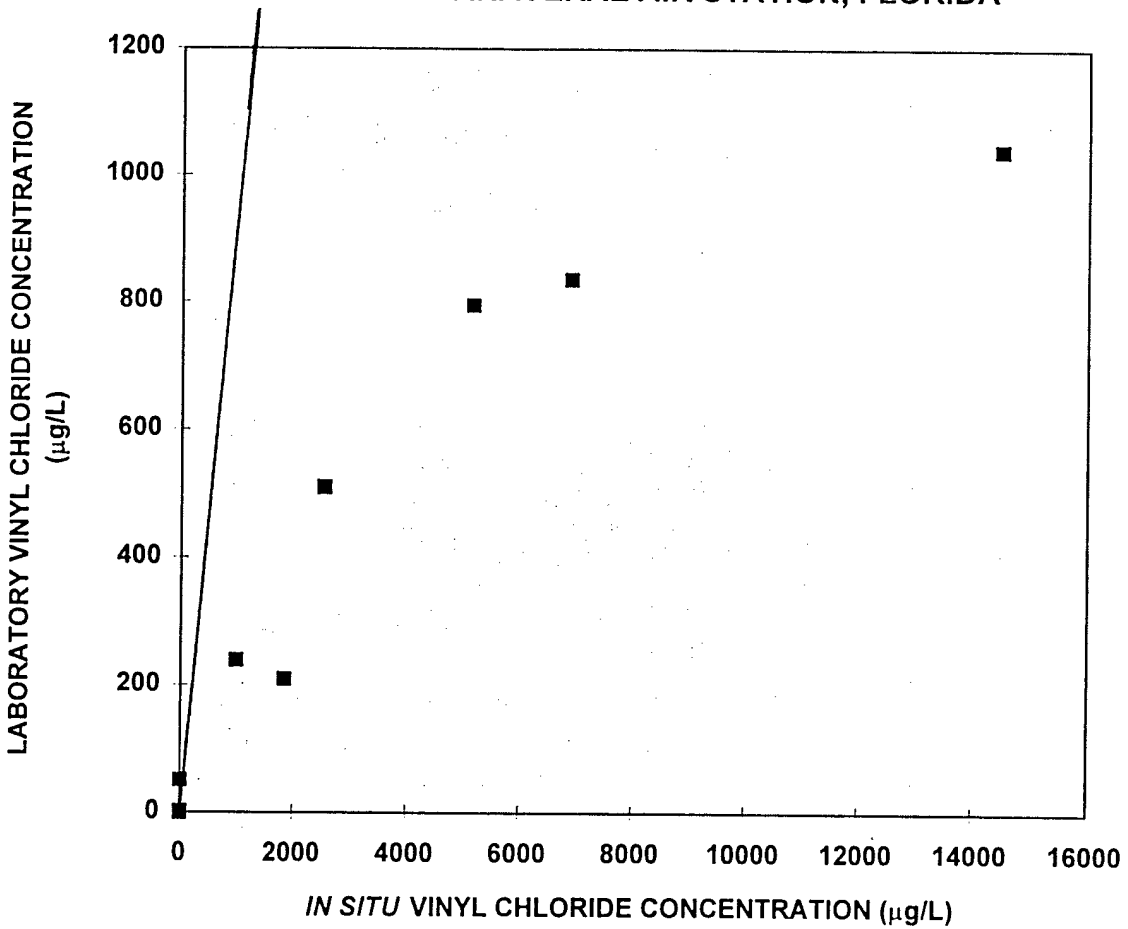


IN SITU VERSUS LABORATORY ANALYTICAL DATA FOR TOTAL DCE
FACILITY 1381
CORRECTIVE MEASURES STUDY
CAPE CANAVERAL AIR STATION, FLORIDA



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IN SITU VERSUS LABORATORY ANALYTICAL DATA FOR VINYL CHLORIDE
FACILITY 1381
CORRECTIVE MEASURES STUDY
CAPE CANAVERAL AIR STATION, FLORIDA



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APPENDIX F

RESPONSES TO COMMENTS

PARSONS

Parsons Engineering Science, Inc. • A Unit of Parsons Infrastructure & Technology Group Inc.
1700 Broadway, Suite 900 • Denver, Colorado 80290 • (303) 831-8100 • Fax: (303) 831-8208 • www.parsons.com

17 September, 1999

Mr. Jerry Hansen
AFCEE/ERT
3207 North Road, Bldg. 532
Brooks AFB, TX 78235-5363

Subject: Responses to AFCEE Comments on the Draft Remediation by Natural Attenuation Treatability Study for Facility 1381 (SWMU 21), Cape Canaveral Air Station, Florida (Contract F41624-92-D-8036)

Dear Mr. Hansen:

This letter provides responses to comments received on the Draft Remediation by Natural Attenuation (RNA) Treatability Study (TS) for Facility 1381 (SWMU 21), Cape Canaveral Air Station, Florida. The draft RNA TS was prepared by Parsons Engineering Science, Inc. (Parsons ES) for the Air Force Center for Environmental Excellence Technology Transfer Division (AFCEE/ERT) and Cape Canaveral Air Station. The intent of the RNA TS was to determine the role of natural attenuation in remediating chlorinated solvent and fuel contamination in soil and groundwater at Facility 1381 (SWMU 21). The draft RNA TS was submitted to AFCEE and Cape Canaveral Air Station in October 1997. Comments on the draft RNA TS were received from AFCEE as reviewed by Jon Atkinson dated April 27, 1999. Cape Canaveral Air Station did not comment on the report. Responses to these comments were prepared by Parsons ES and are presented herein.

Responses to AFCEE Comments: April 27, 1999

Comment 1) Page iv, Table of Contents: Suggest adding a list of appendices.

Parsons ES Response: A list of appendices will be added to the final RNA TS.

Comment 2) Page 1-7, Sec 1.3, Sent 5: Suggest depicting and labeling the CCAS landfill on a map similar to Figure 2.1.

Parsons ES Response: The landfill is identified on Figure 1.2. A new Figure 1.3 that is similar to Figure 2.1 and identifies the landfill also will be added to Section 1.

Comment 3) Page 1-12, Sec 1.4, Para 2, Line 9: Suggest clearly depicting and labeling the northern drainage canal on a map similar to Figure 2.1.

Parsons ES Response: A new Figure 1.3 that is similar to Figure 2.1 and identifies the drainage canals will be added to Section 1.

Comment 4) Page 2-15, Sec 2.4.1, Para 2: Manganese is not listed as an analytical parameter, but it appears in Table 2.3. This inconsistency should be corrected.

Parsons ES Response: Manganese was not analyzed for during the RNA TS site investigation. Therefore, the reference to manganese in Table 2.3 will be deleted from the final RNA TS.

Comment 5) Page 2-21, Table 2.4: Northings and eastings should be reported to one decimal place (e.g., 798904.6 ft) to be consistent with the reported surveying accuracy on page 2-24, Sec 2.9—0.1 ft.

Parsons ES Response: Northings and eastings were surveyed to two decimal places. Therefore, the reported surveying accuracy on page 2-24, Section 2.9 will be changed to 0.01 foot in the final RNA TS.

Comment 6) Page 3-2, 3.1, Para 3, Last Sent: Suggest giving the approximate distance in miles from the study site to Patrick AFB.

Parsons ES Response: An approximate distance of 15 miles from the study site to Patrick AFB will be added to Section 3.1 in the final RNA TS.

Comment 7) Page 3-13, Sec 3.3.2.1, Para 1, Last Sent: Contrary to the statement here, groundwater beneath the landfill flows to the southwest away from the drainage canal, not to the northeast and into the drainage canal. These apparent errors need to be corrected.

Parsons ES Response: The June 1996 water table elevation data presented in the RNA TS Work Plan (see attached Figure 2.8) indicates flow toward the drainage canal. However, the flow direction may vary seasonally depending on water levels in the canal. Based on the data presented in the attached Figure 2.8, no changes to the text in question are proposed.

Comment 8) Page 4-30, Sec 4.4, Sent 4: Recommend clearly depicting and labeling the northern drainage canal on Figures 4.4 and 4.5.

Parsons ES Response: The northern drainage canal will be depicted and labeled on Figures 4.4 and 4.5 in the final RNA TS.

Comment 9) Page 4-43, Sec 4.4.5.1, Line 3: "drive to" should be "to drive."

Parsons ES Response: The text will be changed as indicated in the final RNA TS.

Comment 10) Page 4-44, Sec 4.4.5.2: This page should be filled with text.

Parsons ES Response: The page will be filled with text in the final RNA TS.

Comment 11) Page 4-48, Sec 4.4.5.2, Para 1, Sent 1: "1.92 mg/L should be "192 mg/L" to be consistent with sentence two.

Parsons ES Response: The text will be changed as indicated in the final RNA TS.

Comment 12) Page 4-58, Sec 4.4.6.6, Para 2, Line 7: Recommend inserting "at" between "detected" and "low."

Parsons ES Response: The text will be changed as indicated in the final RNA TS.

Comment 13) Page 4-64, Sec 4.5, Para 1, Line 3: Appendix C, not D, should be referenced here.

Parsons ES Response: Appendix C will be referenced in the final RNA TS.

Comment 14) Page 4-65, Table 4-8: To better reflect accuracy and reliability of the calculated values, suggest reporting decay rates and half lives to two significant figures

Parsons ES Response: Decay rates and half lives will be reported to two significant figures in the final RNA TS.

Comment 15) Page 4-68, Sec 4.6, Para 2, Sent 1: To better reflect accuracy and reliability of the calculated values, suggest reporting decay rates and half lives to two significant figures.

Parsons ES Response: Decay rates and half lives will be reported to two significant figures in the final RNA TS.

Comment 16) Pages 5-3 and 5-4, Sec 5.2, Last Sent: To correct terminology, recommend changing "groundwater table" to "water table."

Parsons ES Response: The text will be changed as indicated in the final RNA report.

Comment 17) Page 5-5, Sec 5.3.1: Recommend stating that the model grid is oriented about 50 degrees east of north. Additionally, suggest stating the rationale for this grid orientation.

Parsons ES Response: A statement will added stating that the model grid is oriented approximately 50 degrees east of north. The rationale for this grid orientation is to align the grid axes with directions of maximum hydraulic gradient (Figure 3.4 and 3.5) and the longitudinal axis of the contaminant plume (Figure 4.4). This rationale will be added to the final RNA TS.

Comment 18) Page 5-8, Sec 5.3.2.1, Sent 2: Suggest adding that the MODFLOW river package was used to simulate the northern and southern drainage canals.

Parsons ES Response: The MODFLOW river package will be referenced in the final RNA TS as suggested.

Comment 19) Page 5-9, Sec 5.3.2.2, Para 2, Last Sent: The shallow aquifer is unconfined and relatively permeable; consequently, a reasonable specific yield for layer one of the model is 0.2. Freeze and Cherry (1979) state that the usual range in specific yield is 0.01 to 0.30. For layer two, suggest assigning a specific yield of 0.01.

Parsons ES Response: Based on lithologic information presented in Section 3.3.1 and Figure 3.2, relatively clean sands can be found to nearly 35 feet below ground surface. Layer 1 of the model is 15 feet thick, and layer 2 is 35 feet thick According to Section 3.3.2.3, an effective porosity of 0.25 was assumed to be representative of all depth intervals in the surficial aquifer because coarse to medium sands may represent a preferred migration pathway at the site. Therefore, Parsons ES would prefer to not make the recommended changes.

Comment 20) Page 5-12, Sec 5.3.3.4, Last Line: Appendix C, not D, should be referenced.

Parsons ES Response: Appendix C will be referenced in the final RNA TS.

Comment 21) Page 5-12, Sec 5.4.1, Para 1:

a. Recommend depicting on Figure 5.2 calibration target wells with a unique well symbol.

b. Suggest adding to the text or Appendix C a table (with appropriate title) tabulating observed, simulated and residual (obs. – sim.) head values for the calibration target wells.

Parsons ES Response:

a. Calibration target wells will be indicated on Figure 5.2 in the final RNA TS using a unique well symbol or box around the well name.

b. A table will be added to Appendix C tabulating observed, simulated, and residual head values for the calibration target wells.

Comment 22) Page 5-15, Sec 5.4.2, Para 1, Last Sent: Assuming that the total simulated CAH molar concentrations were converted to a mass concentration of DCE as stated on page 6-7, paragraph three, recommend revising the end of the sentence as follows: ". . . molarity to an equivalent mass concentration of DCE."

Parsons ES Response: The text will be changed as recommended in the final RNA TS.

Comment 23) Page 6-8, Fig 6.1: Suggest adding to the title that the simulated CAH concentrations represent a mass concentration of DCE.

Parsons ES Response: The requested information will be added as a note to the figure: Note: The simulated CAH concentrations were converted to a DCE mass equivalent."

Comment 24) Page 6-16, Sec 6.4, Para 2, Last Line: Suggest correcting as follows: ". . . pump-and-treat system, reactive wall, . . ."

Parsons ES Response: The text will be changed as indicated in the final RNA TS.

If you have any questions, have additional comments, or require additional information, please call me at (303) 831-8100.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC.

Bruce M Henry

Bruce M. Henry, P.G.
Project Manager

cc: Mr. Mark Kershner, Cape Canaveral Air Station
Mr. John Hicks, Parsons ES
File 722450.16000

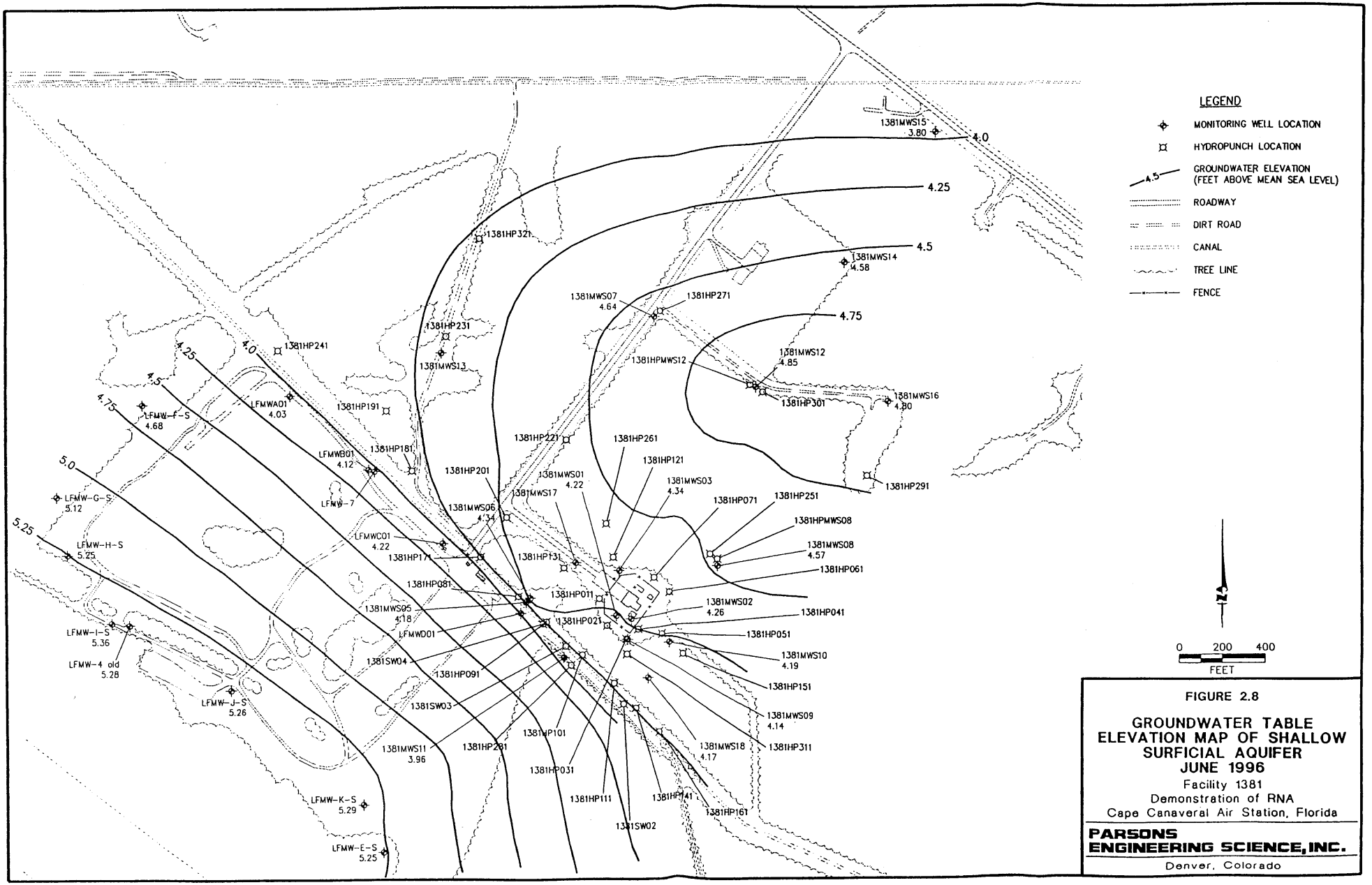


FIGURE 2.8

GROUNDWATER TABLE ELEVATION MAP OF SHALLOW SURFICIAL AQUIFER JUNE 1996

Facility 1381
Demonstration of RNA
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

K:\AFCEE\729691\96DN0675, 08/22/96 at 11:26

APPENDIX G

FINAL REMEDIATION BY NATURAL ATTENUATION TREATABILITY STUDY ADDENDUM

FOR

FACILITY 1381 (SWMU 21)
CAPE CANAVERAL AIR STATION, FLORIDA

FINAL

REMEDIATION BY NATURAL ATTENUATION TREATABILITY STUDY ADDENDUM FOR FACILITY 1381 (SWMU 21) CAPE CANAVERAL AIR STATION FLORIDA

December 1999

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE
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45th SPACE WING FACILITIES
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LIST OF ACRONYMS AND ABBREVIATIONS

AFCEE	Air Force Center for Environmental Excellence
AOC	area of concern
BTEX	benzene, toluene, ethylbenzene, and xylenes
$CaCO_3$	calcium carbonate
CAH	chlorinated aliphatic hydrocarbon
CCAS	Cape Canaveral Air Station
CENTRAL OU	Central Area Operable Unit
DCA	dichloroethane
DCE	dichloroethene
DO	dissolved oxygen
ESE	Environmental Science and Engineering, Inc.
gal/yr	gallons per year
GAT	Guidance Azimuth Transfer
LTM	long-term monitoring
MCL	maximum contaminant level
µg/L	micrograms per liter
mg/L	milligrams per liter
MTBE	methyl tertiary-butyl ether
mV	millivolts
N	nitrogen
nM/L	nanomoles per liter
NRMRL	National Risk Management Research Laboratory
ORP	oxidation reduction potential
Parsons ES	Parsons Engineering Science, Inc.
PCE	tetrachloroethene
POL	petroleum, oil, and lubricants
redox	oxidation-reduction
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RNA	remediation by natural attenuation
SI	site investigation
TCA	trichloroethane
TCE	trichloroethene
TMB	trimethylbenzene
TOC	total organic carbon
TS	treatability study
USEPA	US Environmental Protection Agency
VC	vinyl chloride
VOC	volatile organic compound

1.0 INTRODUCTION

This Treatability Study (TS) addendum was prepared for the Air Force Center for Environmental Excellence (AFCEE) and the 45th Space Wing Facilities by Parsons Engineering Science, Inc. (Parsons ES) as an update to the Draft Treatability Study in Support of Remediation by Natural Attenuation for Facility 1381, Cape Canaveral Air Station, Florida (Parsons ES, 1997a). The initial TS sampling event was conducted in September 1996 to evaluate the use of natural attenuation with long-term monitoring (LTM) for remediation of groundwater contaminated with chlorinated aliphatic hydrocarbons (CAHs) at the site.

This addendum summarizes the results of a second sampling event conducted as part of the evaluation of natural attenuation at the site. The main emphasis of this summary is to evaluate changes in dissolved concentrations of tetrachloroethene (PCE), trichloroethene (TCE), dichloroethene (DCE), and vinyl chloride (VC); plume extent; and natural attenuation mechanisms between September 1996 and March 1998. Results and predictions presented in the remediation by natural attenuation treatability study (RNA TS) report are used as the basis for comparison.

In the RNA TS report, comparison of CAH, electron acceptor, and biodegradation byproduct isopleth maps for Facility 1381 provided strong qualitative evidence of the biodegradation of dissolved CAHs. Chemical and geochemical data strongly suggested that reductive dehalogenation of dissolved CAHs was occurring at the site as microbes utilize organic carbon as a substrate.

While the results of the RNA TS indicated that natural attenuation of CAHs was occurring at the site, numerical models constructed for the site predicted that, without source removal, state maximum contaminant levels (MCLs) would not be achieved within the next two centuries. With engineered source removal at the site, state MCLs still would not be achieved within the next century. In both scenarios, the CAH plume was expected to achieve the same areal extent; however, with engineered source reduction the concentrations in the source area were expected to be much less than without any engineered source removal.

Several conservative assumptions were used in modeling CAH migration. Specifically, relatively low CAH biodegradation rates were used, which may have underestimated the overall effectiveness of biodegradation at the site. In recognition of the potentially conservative nature of the model predictions, the RNA TS report recommended LTM to allow assessment of site conditions over time. If LTM data indicate that the selected remedial actions are not sufficient to reduce groundwater CAH concentrations or surface water impact to levels considered protective of human health and the environment, additional corrective actions may be required to remediate groundwater at the site. If data indicate that the effects of RNA were underestimated and plume stabilization has occurred, the frequency or location of LTM may be reduced or modified, as necessary.

1.1 Scope and Objectives

The primary objective of this addendum is to evaluate changes in the concentration and extent of dissolved CAHs, and natural attenuation mechanisms between September 1996 and March 1998. Data collected in September 1996 for the RNA TS are used as a baseline for comparison. In March 1998, groundwater samples were collected from 19 existing monitoring wells/points by researchers from the United States Environmental Protection Agency (USEPA) National Risk Management Research Laboratory (NRMRL), Subsurface Protection and Remediation Division.

1.2 Site History and Previous Investigations

Cape Canaveral Air Station (CCAS) is located on the east coast of Florida on a barrier island in Brevard County. The main complex occupies about 25 square miles of assembly and launch facilities for missiles and space vehicles. The property is bounded by the Atlantic Ocean on the east and the Banana River on the west. The southern boundary is a man-made shipping channel, and the John F. Kennedy Space Center adjoins the CCAS to the north. Since 1950, CCAS has been a proving ground for US Department of Defense military missile programs, including the Bomarc, Matador, Redstone, Atlas, Titan, and Navy Trident programs.

The Ordnance Support Facility (Facility 1381), formerly the Guidance Azimuth Transfer (GAT) building and the In-Place Cleaning Facility, is located along the landfill access road in Area 5 of CCAS. The site is part of the CCAS Central Area Operable Unit (CENTRAL OU). The site is enclosed within a chain-link fence, and access is controlled. South of the facility, across the drainage canal, is the CCAS landfill. There are no other facilities adjacent to the site. The following facilities are located within the chain-link fence: Ordnance Support Facility (1381), Petroleum, Oils, and Lubricants (POL) / Hazardous Storage Base (1400), Sewage Septic Tank and Drain Field (20295), Electrical Substation (20296), and the Equipment Shed (AOC-517). Areas of concern (AOCs) at Facility 1381 include the support Facility Equipment Shed (AOC-517), the former Acid Neutralization Pit (AOC-518), and the Drainfield/Septic Tank (AOC-519).

Over its 39-year history that began in 1958, ownership of and operations performed at Facility 1381 have changed several times. Facility 1381 originally may have been used for research, testing, and/or instruction of missile/space technology, although historic information about the site between 1958 and 1968 is limited. During the operation of an In-Place Precision Cleaning Lab (1968-1977), the building housed acid and solvent dip tanks for cleaning metal components. According to Environmental Science and Engineering (ESE, 1984), waste TCE was generated at a rate of approximately 3,300 gallons per year (gal/yr) from a parts dip tank. Through 1972, the waste TCE was drummed, taken to Launch Complex 15, and incinerated. Beginning in 1972, TCE was incinerated in a boiler at CCAS (ESE, 1984). Waste nitric and hydrochloric cleaning acids also were used within the facility. A 4-foot by 40-foot by 2.5-foot lined, stainless steel acid dip tank was used to clean pipe. The waste acids were disposed of by discharging them into a neutralization pit filled with crushed limestone, located southwest of the building.

The US Coast Guard has operated the site as the Ordnance Support Facility since 1977. According to site personnel, the only change that has occurred at the facility since

the Coast Guard assumed ownership in 1977 was the addition of three dip tanks and electrical hardwiring (Parsons ES, 1997b). According to an interviewee, the dip tanks contained acid (Fozdip), oil, and water (May 2-6, 1992).

The acid neutralization pit has not been clearly identified from site reconnaissance, nor clearly located in previous reports and construction blueprints. Previous descriptions of likely pit locations have placed it within the confines of the septic field or 30 to 40 feet southwest of Facility 1381 (ESE, 1984). The pit was reportedly filled with crushed limestone during operation, but was later filled with soil.

Blueprints and records describing the design of Facility 1381 noted that the septic field consisted of a 500-gallon septic tank and a 30-foot by 20-inch distribution box. The septic drain field has been in place since 1958, and no notable features, such as a limestone-filled pit, appear to have been incorporated into its design. Therefore, the septic drain field is not suspected to coincide with the former location of the acid neutralization pit.

Aerial photographs, blueprints, and a site reconnaissance have confirmed the presence of a concrete pit covered with a metal grate located approximately 45 to 50 feet southwest of Facility 1381. The construction of the pit is not consistent with the reported design and function of the acid neutralization pit because the metal grate and concrete walls would be corroded by acid. Furthermore, the concrete pit was filled with water instead of soil (as previously described). Therefore, the observed concrete pit does not appear to be the acid neutralization pit, although it is in the general suspected location of the latter structure. To date, the exact location of the acid neutralization pit remains uncertain.

In June 1994, the concrete pit located at the southwestern corner of the concrete pad was drained in order to investigate the structural integrity of the concrete. The pit is approximately 4 feet deep, and no cracks or leaks were observed in the concrete sides and bottom. The pit was subsequently decontaminated and sealed. The contents of the pit were disposed of at a hazardous waste disposal facility.

Chlorinated solvent contamination at the site is suspected to have resulted from accidental releases from past metal cleaning operations. In the earliest available photograph of the site, taken in 1967, several drums were visible resting on the ground surface at various locations across the site. During the site reconnaissance conducted as part of the 1989 RCRA Facility Assessment (RFA), several drums were discovered outside the fenced area southwest of Facility 1381 (USEPA, 1989). It is suspected that drums containing chlorinated volatile organic compounds (VOCs) were periodically stored at this location and contributed to soil and groundwater contamination. Solvents also were released at the site during the dumping of solvents from tanker trucks in the woods around the site. The length of practice of these disposal methods is unknown.

Facility 1381 was first investigated for environmental concerns during a Phase I study (ESE, 1984). In 1989, a Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA) Report (Mitchell, 1989) was issued for the site by the USEPA. Parsons ES performed field reconnaissance in 1992, and issued a preliminary Assessment and Field Sampling Strategy Report (Parsons ES, 1993). This was followed by a site investigation (SI) that included sample collection and analysis, performed by Parsons ES

(1995). A brief summary of the findings of each of the previous investigations is presented in the RCRA Facility Investigation (RFI) report (Parsons ES, 1997b).

Site characterization results obtained during the RFI at Ordnance Support Facility 1381 revealed that hydrogeologic conditions at the site create both northward and southward contaminant migration as the result of a groundwater divide. Contaminated groundwater that discharges to the geographically closer southern drainage canal contains elevated concentrations of TCE and DCE, creating a more urgent groundwater scenario that must be addressed by active treatment technologies. The current consensus between CCAS, AFCEE, and Parsons ES is that groundwater contamination migrating north from Facility 1381 poses a lesser risk to potential receptors because the migration pathway to the northern drainage canal is longer, allowing the beneficial effects of natural attenuation to reduce dissolved contaminant concentrations prior to discharge to this canal. For this reason, the evaluation of RNA with LTM in both the RNA TS report (Parsons ES, 1997a) and this addendum is limited to that portion of the groundwater plume emanating from Facility 1381 and migrating north toward the northern drainage canal.

1.3 Engineered Remedial Actions

An air sparging pilot test was performed at Facility 1381 by Parsons ES (1998) between October 1996 and February 1997. The pilot test area encompassed approximately 6,400 square feet (80 feet by 80 feet) in the source area immediately west of well 1381MWS09 and immediately south of 1381MWS01. Three sparge well clusters consisting of 3 wells apiece were installed; each cluster consisted of one well installed in the shallow, intermediate, and deep zones of the surficial aquifer.

Deep zone sparging was conducted between 14 October 1996 and 7 November 1996. Sparging of the intermediate and shallow zones was conducted from 7 November 1996 to 20 November 1996 and 20 November 1996 to 11 December 1996, respectively. Subsequently, continuous sparging of all three zones was conducted from 11 December 1996 to 23 December 1996, and pulsed sparging tests were conducted from 13 January 1997 to 04 February 1997.

Substantial reductions in CAH concentrations in the intermediate zone were measured during deep zone sparging. These reductions were attributed to upward migration of the injected air through the intermediate zone. Results from sparging of the intermediate zone were inconclusive due to possible rebound effects from the previous deep zone sparging test. During intermediate zone sparging, the CAH concentrations remained relatively constant, and actually increased in several of the sparge monitoring wells.

During shallow zone sparging, CAH concentrations remained relatively stable in most wells, but concentrations decreased significantly in the wells closest to the sparge wells. Only slight increases in DO concentrations were measured, and the radius of influence of each sparging well appeared to be limited to 10 to 15 feet. Given that the March 1998 sampling event occurred 13 months after the conclusion of the sparging tests, it is likely that any residual DO introduced during sparging would have dissipated prior to this sampling event.

2.0 RESULTS

In March 1998, researchers from the US Environmental Protection Agency National Risk Management Research Laboratory (USEPA NRMRL) measured groundwater levels and collected groundwater samples from 19 monitoring wells/points at Facility 1381. Samples were analyzed in the field for oxidation/reduction (redox) potential (ORP), dissolved oxygen (DO), conductivity, temperature, pH, ferrous iron, hydrogen sulfide, carbon dioxide, alkalinity, and dissolved hydrogen. Additional sample volumes were analyzed at the USEPA NRMRL in Ada, Oklahoma for benzene, toluene, etheylbenzene, and xylenes (BTEX), trimethylbenzenes (TMBs), methyl tertiary-butyl ether (MTBE), total fuel carbon, CAHs, chlorobenzenes, ammonia, nitrate + nitrite, sulfate, chloride, methane, ethane, ethene, and total organic carbon (TOC). Analytical methods for March 1998 are summarized in Table 1.

2.1 Groundwater Flow Direction and Gradient

Groundwater elevation data are summarized in Table 2, and groundwater elevations measured at shallow monitoring wells/points in September 1996 and March 1998 are plotted on Figure 1. On the basis of these groundwater elevation maps, the drainage canal system has a major influence on groundwater flow in the vicinity of Facility 1381. One drainage canal is located approximately 300 feet south-southwest of the facility, and the other is located approximately 2,500 feet north of the facility. Both canals flow westward toward the Banana River, and merge into a single canal approximately 0.65 mile northwest of the facility. Groundwater flow directions and gradients in the surficial aquifer at CCAS are variable and dependent on surface water depths in the drainage canals.

Based on Figure 1, it can be inferred that groundwater flow directions in the shallow portion of the surficial aquifer beneath the site are influenced by surface water elevations in the drainage canals. In September 1996, it appears that water levels in the canals were lower than groundwater elevations in the adjacent aquifer, causing groundwater to discharge into the canals from the aquifer. Conversely, in March 1998, water levels in at least the northern canal appeared to be higher than adjacent groundwater elevations, and surface water from this canal was recharging the aquifer. During both measurement events, a southeast/northwest-trending groundwater divide was present that caused groundwater migration toward both the southern and northern drainage canals. In March 1998, the available data indicate that a second divide was present nearer the northern drainage canal, that was due to recharge from the northern canal.

Vertical gradients in September 1996 were variable in magnitude and direction. The vertical gradients at source area well cluster 1381MWS09/I09/D09 were 0.021 foot per foot (ft/ft) (upward) between the shallow and intermediate wells and 0.028 ft/ft (downward) between the intermediate and deep wells. The vertical gradients between the shallow and intermediate and intermediate and deep wells in March 1998 were 0.016 ft/ft (downward) and 0.019 ft/ft (upward). Therefore, the vertical gradients are temporally as well as spatially variable.

TABLE 1
SUMMARY OF GROUNDWATER ANALYTICAL METHODS
MARCH 1998
FACILITY 1381 RNA TS ADDENDUM
CAPE CANAVERAL AIR STATION, FLORIDA

Analyte	Method	Field (F) or Fixed-Base Laboratory (L)
Oxidation\Reduction Potential	Direct Reading Meter	F
Dissolved Oxygen	Direct Reading Meter	F
Conductivity	Direct Reading Meter	F
Temperature	Direct Reading Meter	F
pH	Direct Reading Meter	F
Ferrous Iron (Fe^{2+})	Colorimetric, Hach Method 8146	F
Hydrogen Sulfide	Colorimetric, Hach Method 8131	F
Carbon Dioxide	Titrimetric, Hach Method 1436-01	F
Alkalinity (Carbonate [CO_3^{2-}] and Biocarbonate [HCO_3^-])	Titrimetric, Hach Method 8221	F
Manganese	Colorimetric, Hach Method 8034	F
Nitrate + Nitrite	Lachat FIA Method 10-107-04-2-A	L
Ammonia	Lachat FIA Method 10-107-06-1-A	L
Chlorides	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane, Ethene, Ethane	RSKSOP-175[a/] and RSKSOP-194	L
BTEX[b/], MTBE[c/], TMBs[d/], and Total Fuel Carbon	RSKSOP-122	L
CAHs[e/] and Chlorobenzenes	RSKSOP-148	L
TOC[f/]	RSKSOP-102	L
Dissolved Hydrogen	RSKSOP-196	F

[a/] RSKSOP = Robert S. Kerr Laboratory (now known as NRMRL) standard operating procedure.

[b/] BTEX = Benzene, toluene, ethylbenzene and xylenes.

[c/] MTBE = Methyl tertiary-butyl ether.

[d/] TMB = Trimethylbenzene.

[e/] CAHs = chlorinated aliphatic hydrocarbons.

[f/] TOC = Total organic carbon.

TABLE 2
GROUNDWATER ELEVATIONS
FACILITY 1381 RNA TS ADDENDUM
CAPE CANAVERAL AIR STATION, FLORIDA

Well Location	Sample Collection Date	Datum Elevation (ft msl)[a]	Ground Elevation (ft msl)	Groundwater Depth (ft btoc)[b]	Groundwater Elevation (ft msl)
1381[c]-MWS[d]01	9/26/1996	9.08	9.17	6.93	2.15
1381-MWS01	3/19/1998	9.08	9.17	5.6	3.48
1381-MWS02	9/26/1996	9.14	9.30	NS[e]	NS
1381-MWS02	3/19/1998	9.14	9.30	5.70	3.44
1381-MWS03	9/26/1996	8.38	8.24	6.25	2.13
1381-MWS03	3/19/1998	8.38	8.24	4.10	4.28
1381-MWS05	9/26/1996	11.18	7.68	8.71	2.47
1381-MWS05	3/19/1998	11.18	7.68	7.90	3.28
1381-MWS06	9/26/1996	10.69	7.68	NS	NS
1381-MWS07	9/26/1996	10.20	NA[f]	8.01	2.19
1381-MWS07	3/19/1998	10.20	NA	6.30	3.90
1381-MWS08	9/26/1996	9.76	7.17	NS	NS
1381-MWS08	3/19/1998	9.76	7.17	3.10	6.66
1381-MWS09	9/26/1996	7.14	7.45	5.02	2.12
1381-MWS09	3/19/1998	7.14	7.45	3.80	3.34
1381-MWS10	9/26/1996	10.55	7.97	NS	NS
1381-MWS10	3/19/1998	10.55	7.97	6.30	4.25
1381-MWS11	9/26/1996	10.86	8.08	8.68	2.18
1381-MWS12	9/26/1996	9.62	6.88	7.60	2.02
1381-MWS12	3/19/1998	9.62	6.88	5.70	3.92
1381-MWS13	9/26/1996	10.91	8.24	9.09	1.82
1381-MWS13	3/19/1998	10.91	8.24	dry	dry
1381-MWS14	9/26/1996	8.24	8.23	6.30	1.94
1381-MWS14	3/19/1998	8.24	8.23	3.70	4.54
1381-MWS15	9/26/1996	10.44	7.79	8.77	1.67
1381-MWS15	3/19/1998	10.44	7.79	4.80	5.64
1381-MWS16	9/26/1996	10.08	7.81	8.19	1.89
1381-MWS16	3/19/1998	10.08	7.81	6.10	3.98
1381-MWS17	9/26/1996	8.51	8.70	6.41	2.10
1381-MWS17	3/19/1998	8.51	8.70	4.70	3.81
1381-MWS18	9/19/1996	9.16	6.65	6.85	2.31
1381-MWS18	3/19/1998	9.16	6.65	5.90	3.26
1381MPI[g]01	9/26/1996	8.60	8.78	6.85	1.75
1381MPI01	3/19/1998	8.60	8.78	5.6	3.00
1381-MWI05	9/26/1996	11.28	7.68	8.79	2.49
1381-MWI09	9/26/1996	6.77	7.22	4.17	2.60
1381-MWI09	3/19/1998	6.77	7.22	3.80	2.97
1381-MWD[h]01	9/26/1996	9.04	9.17	6.89	2.15
1381-MWD01	3/19/1998	9.04	9.17	5.5	3.54
1381-MWD02	9/26/1996	9.15	9.30	NS	NS

TABLE 2 (Continued)
GROUNDWATER ELEVATIONS
FACILITY 1381 RNA TS ADDENDUM
CAPE CANAVERAL AIR STATION, FLORIDA

Well Location	Sample Collection Date	Datum Elevation (ft msl)[a/]	Ground Elevation (ft msl)	Groundwater Depth (ft btoc)[b/]	Groundwater Elevation (ft msl)
1381-MWD03	9/26/1996	8.30	8.24	6.25	2.05
1381-MWD04	9/26/1996	12.23	9.52	NS	NS
1381-MWD05	9/26/1996	10.32	7.68	8.19	2.13
1381-MWD08	9/26/1996	10.08	7.38	NS	NS
1381-MWD09	9/26/1996	7.05	7.14	4.87	2.18
1381-MWD09	3/19/1998	7.05	7.14	3.80	3.25
1381-MWD10	9/26/1996	10.84	7.97	NS	NS
1381-MWD11	9/26/1996	10.96	8.33	8.82	2.14
1381-MWD12	9/26/1996	9.60	6.96	7.55	2.05
1381-MWD13	9/26/1996	10.85	8.62	8.85	2.00
1381-MWD17	9/26/1996	8.48	8.72	6.35	2.13
1381-MWD19	9/26/1996	7.86	5.29	NS	NS
1381MPS01	9/26/1996	8.53	8.78	6.91	1.62
1381MPS07	9/26/1996	8.44	8.62	6.51	1.93
1381MPS08	9/26/1996	7.99	8.00	6.06	1.93
1381MPS10	9/26/1996	7.91	8.01	5.85	2.06
1381MPI02	9/26/1996	7.71	8.02	5.82	1.89
1381MPI03	9/26/1996	7.93	8.15	5.95	1.98
1381MPI05	9/26/1996	7.64	7.27	5.81	1.83
1381MPI06	9/26/1996	8.86	9.05	6.77	2.09
1381MPI07	9/26/1996	8.47	8.62	6.49	1.98
1381MPI08	9/26/1996	7.85	8.00	5.91	1.94
1381MPI10	9/26/1996	7.86	8.01	5.89	1.97
1381MPI11	9/26/1996	8.10	8.05	6.37	1.73
1381MPI13	9/26/1996	7.06	7.15	5.31	1.75
1381MPI17	9/26/1996	8.40	8.60	6.42	1.98
1381MPI18	9/26/1996	6.12	6.44	4.73	1.39
1381MPI18	3/19/1998	6.12	6.44	2.6	3.52
1381MPI19	9/26/1996	8.26	8.38	NA	NA
1381MPI20	9/26/1996	6.01	6.01	NA	NA
1381MPI21	9/26/1996	6.97	7.25	5.12	1.85

[a/] ft msl = Feet above mean sea level.

[b/] ft btoc = Feet below top of casing.

[c/] The number 1381 identifies wells/piezometers located within the perimeter of Facility 1381.

[d/] The letter S identifies wells/piezometers within the shallow portion of the surficial aquifer.

[e/] NS = Data not collected.

[f/] NA = Not available.

[g/] The letter I identifies wells/piezometers within the intermediate-depth portion of the surficial aquifer.

[h/] The letter D identifies wells/piezometers within the deep portion of the surficial aquifer.

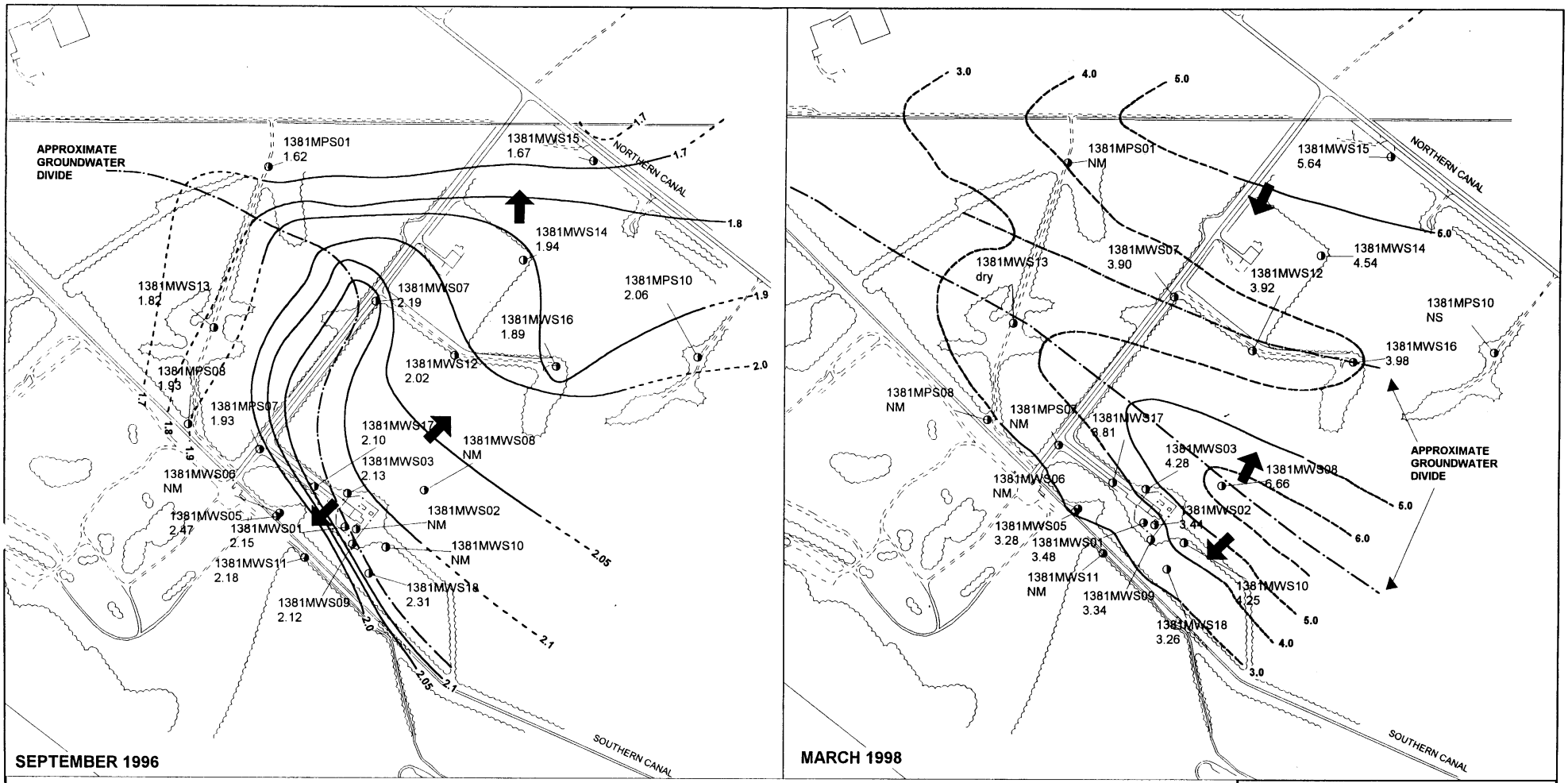


FIGURE 1

GROUNDWATER ELEVATIONS MEASURED AT SHALLOW MONITORING WELLS/ POINTS

Facility 1381 RNA TS Update
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.

Denver, Colorado

DATE: 7/28/99

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2.2 Dissolved BTEX Contamination

As shown in Table 3, BTEX compounds were detected in 17 of 43 groundwater samples collected in September 1996 and in 3 of 8 samples collected in March 1998. None of the BTEX compounds detected in the samples were present in sufficient concentrations to be considered contaminants of concern for this site.

2.3 Dissolved Chlorinated Solvent Contamination

The CAHs PCE, TCE, *cis*-1,2-DCE, *trans*-1,2-DCE, 1,1-DCE, 1,1-dichloroethane (1,1-DCA), 1,1,1-trichloroethane (1,1,1-TCA), and VC were detected in groundwater samples collected during both sampling events. 1,2-DCA was only detected at one location during September 1996 at a concentration of less than 1.0 micrograms per liter (µg/L), and was not detected in any of the samples collected in March 1998. Concentrations of individual CAHs detected in groundwater samples collected during the September 1996 and March 1998 sampling events are presented in Table 4.

2.3.1 PCE and TCE

PCE and TCE concentrations for shallow wells/points are posted, and TCE concentration isopleths are presented on Figure 2. PCE was detected in 2 of 19 shallow wells/points sampled during the March 1998 sampling event and in 1 of 39 shallow wells/points sampled in September 1996 (Table 4). PCE was not detected in any of the intermediate or deep wells/points sampled during September 1996 and March 1998. The maximum PCE concentrations detected during the September 1996 and March 1998 sampling events were 3.3 µg/L and 17.2 µg/L, respectively. Both of these concentrations were detected at source area well 1381MWS09. The 1998 sampling results confirm that PCE is not a compound of major concern at Facility 1381.

TCE was detected in samples from 8 of 14 shallow wells/points in March 1998 (Table 4). Of the 11 shallow wells sampled during both events, 3 had increased concentrations (1381MWS01, 1381MWS03, and 1381MWS09), and the remaining 8 wells exhibited similar results for both events. In the only two intermediate-depth wells/points sampled during both events (1381MWI09 and 1381MPI18), the TCE concentration increased from 26.9 to 251 µg/L at 1381MWI09 and was not detected during both events at 1381MPI18. In the only deep well sampled during both events (1381MWD09), the detected TCE concentrations were similar (6.6 µg/L and 4.4 µg/L).

The highest detected TCE concentration at the site was 210,000 µg/L in well 1381MWS09, detected in March 1998. This well also had the highest TCE concentration for September 1996 (39,400 µg/L). Wells 1381MWS09, 1381MWI09, and 1381MWD09 form a cluster that is located in the suspected source area. Overall, TCE concentrations increased near the source area; however, the TCE plume still appears to be restricted to the vicinity of the source area. The substantial increase in TCE concentrations near the source area indicates that a significant TCE source remains in the soils at Facility 1381, and that seasonally variable precipitation rates and groundwater levels affect the leaching rate of TCE from this source. The groundwater elevation data in Table 2 show that the water table in March 1998 was higher than in September 1996.

TABLE 3
FUEL HYDROCARBONS DETECTED IN GROUNDWATER AND SURFACE WATER
FACILITY 1381 RNA TS ADDENDUM
CAPE CANAVERAL AIR STATION, FLORIDA

Sample Location	Sample Collection Date	Benzene (µg/L)[c]	Toluene (µg/L)	Ethyl-benzene (µg/L)	Xylenes (µg/L)	Total BTEX[a] (µg/L)	1,3,5-TMB[b] (µg/L)	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	Fuel Carbon (µg/L)
1381MWS01	9/19/1996	ND[d]	ND	ND	2	2	ND	ND	ND	34.1
1381MWS01	3/19/1998	ND	ND	ND	ND	ND	ND	ND	ND	NA[e]
1381MWS03	9/20/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWS05	9/20/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWS07	9/20/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWS09	9/19/1996	ND	2.4	1	2.9	6.3	ND	1.6	ND	1450
1381MWS09	3/19/1998	ND	16.2	5.4	22.2	43.8	3.9	10.1	3.5	NA
1381MWS11	9/20/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWS12	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWS13	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWS14	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWS14	3/19/1998	ND	ND	ND	4.6	4.6	ND	ND	ND	NA
1381MWS15	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWS16	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWS17	9/20/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWS18	9/19/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWI01	3/19/1998	ND	BLQ[f]	ND	ND	ND	ND	ND	ND	NA
1381MWI05	9/20/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWI09	9/19/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWI09	3/19/1998	ND	BLQ	ND	ND	ND	ND	ND	ND	NA
1381MWD01	3/19/1998	ND	ND	BLQ	1.3	1.3	ND	ND	ND	NA
1381MWD03	9/23/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWD09	9/19/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWD09	3/19/1998	ND	ND	ND	ND	ND	ND	ND	ND	NA
1381MWD12	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPS01	9/19/1996	ND	< 1.0	ND	ND	< 1.0	ND	ND	ND	< 1.0
1381MPS07	9/23/1996	ND	5.6	ND	ND	5.6	ND	ND	ND	12.5
1381MPS08	9/23/1996	ND	1.5	ND	ND	1.5	ND	ND	ND	8
1381MPS10	9/24/1996	ND	4.0	ND	ND	4.0	ND	ND	ND	3.4
1381MPI02	9/21/1996	ND	3.3	ND	ND	3.3	ND	ND	ND	4.2
1381MPI03	9/23/1996	ND	1.9	ND	ND	1.9	ND	ND	ND	5.5
1381MPI05	9/24/1996	ND	< 1.0	ND	ND	< 1.0	ND	ND	ND	< 1.0
1381MPI06	9/24/1996	ND	3.8	ND	ND	3.8	ND	ND	ND	9.2

TABLE 3 (Continued)
FUEL HYDROCARBONS DETECTED IN GROUNDWATER AND SURFACE WATER
FACILITY 1381 RNA TS ADDENDUM
CAPE CANAVERAL AIR STATION, FLORIDA

Sample Location	Sample Collection Date	Benzene (µg/L)[c/]	Toluene (µg/L)	Ethyl-benzene (µg/L)	Xylenes (µg/L)	Total BTEX[a/] (µg/L)	1,3,5-TMB[b/] (µg/L)	1,2,4-TMB (µg/L)	1,2,3-TMB (µg/L)	Fuel Carbon (µg/L)
1381MPI07	9/23/1996	ND	3.8	ND	ND	3.8	ND	ND	ND	4.5
1381MPI08	9/24/1996	ND	5.7	ND	ND	5.7	ND	ND	ND	6.4
1381MPI10	9/24/1996	ND	1.8	ND	ND	1.8	ND	ND	ND	1.6
1381MPI11	9/24/1996	ND	1.8	ND	ND	1.8	ND	ND	ND	1.8
1381MPI13	9/24/1996	ND	2.8	ND	ND	2.8	ND	ND	ND	4.6
1381MPI17	9/23/1996	ND	3.5	ND	ND	3.5	ND	ND	ND	3.6
1381MPI18	9/24/1996	ND	6.4	ND	ND	6.4	ND	ND	ND	5.4
1381MPI18	3/19/1998	ND	ND	ND	ND	ND	ND	ND	ND	NA
1381MPI19	9/23/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI20	9/25/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURA	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURB	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURC	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURD	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURE	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURF	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
PRMP01	9/25/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
PRMP02	9/25/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND

[a/] BTEX = Benzene, toluene, ethylbenzene, and xylenes.

[b/] TMB = Trimethylbenzene.

[c/] µg/L = Micrograms per liter.

[d/] ND = Not detected.

[e/] NA=Not analyzed.

[f/] BLQ = Below level of quantitation

TABLE 4
CHLORINATED ALIPHATIC HYDROCARBONS DETECTED IN GROUNDWATER AND SURFACE WATER
FACILITY 1381 RNA TS ADDENDUM
CAPE CANAVERAL AIR STATION, FLORIDA

Sample Location	Sample Collection Date	PCE[a] (µg/L)[f]	TCE[b] (µg/L)	cis-1,2-DCE[c] (µg/L)	trans-1,2-DCE (µg/L)	1,1-DCE (µg/L)	1,1-DCA[d] (µg/L)	1,2-DCA (µg/L)	1,1,1-TCA[e] (µg/L)	Vinyl Chloride (µg/L)
1381MWS01	9/19/1996	ND[g]	239	2400	9.1	14.6	4.1	ND	ND	210
1381MWS01	3/19/1998	ND	819	2620	14.4	25.1	5.7	ND	ND	470
1381MWS02	3/19/1998	1.3	30500	6670	32.2	384	40.1	ND	80.5	206
1381MWS03	9/20/1996	ND	ND	2590	15.1	12.6	4.6	ND	ND	836
1381MWS03	3/19/1998	ND	1.1	1010	6.6	3.9	2.4	ND	ND	559
1381MWS05	9/20/1996	ND	< 1.0	43.7	1.8	ND	< 1.0	ND	ND	51.3
1381MWS05	3/19/1998	ND	ND	166	2.4	ND	< 1.0	ND	ND	118
1381MWS07	9/20/1996	ND	ND	10.2	ND	ND	ND	ND	ND	1.3
1381MWS07	3/19/1998	ND	ND	< 1.0	ND	ND	ND	ND	ND	ND
1381MWS08	3/19/1998	ND	< 1.0	122	< 1.0	< 1.0	ND	ND	ND	37.3
1381MWS09	9/19/1996	3.3	39400	4120	25.1	238	26.4	< 1.0	130	240
1381MWS09	3/19/1998	17.2	210000	7110	34.9	1150	71.7	ND	351	166
1381MWS10	3/19/1998	ND	< 1.0	33.0	< 1.0	ND	ND	ND	ND	24.0
1381MWS11	9/20/1996	ND	ND	< 1.0	ND	ND	< 1.0	ND	ND	ND
1381MWS12	9/21/1996	ND	ND	751	10.8	1.4	1.4	ND	ND	510
1381MWS12	3/19/1998	ND	< 1.0	111	1.1	ND	< 1.0	ND	ND	42.2
1381MWS13	9/21/1996	ND	ND	4.6	ND	ND	ND	ND	ND	< 1.0
1381MWS14	9/21/1996	ND	ND	65.6	< 1.0	ND	ND	ND	ND	2.3
1381MWS14	3/19/1998	ND	ND	82.6	< 1.0	ND	ND	ND	ND	2.7
1381MWS15	9/21/1996	ND	ND	130	< 1.0	ND	ND	ND	ND	16.3
1381MWS15	3/19/1998	ND	ND	88.8	< 1.0	ND	ND	ND	ND	8.9
1381MWS16	9/21/1996	ND	ND	2.1	ND	ND	ND	ND	ND	1.2
1381MWS16	3/19/1998	ND	ND	2.7	ND	ND	ND	ND	ND	2.0
1381MWS17	9/20/1996	ND	ND	901	21.2	2.3	2.6	ND	ND	1040
1381MWS17	3/19/1998	ND	< 1.0	612	10.3	2.3	3.9	ND	ND	931
1381MWS18	9/19/1996	ND	< 1.0	ND	ND	ND	ND	ND	ND	ND
1381MWS18	3/19/1998	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWI01	3/19/1998	ND	ND	< 1.0	ND	ND	ND	ND	ND	ND
1381MWI05	9/20/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWI09	9/19/1996	ND	26.9	1210	145	6.1	< 1.0	ND	ND	795
1381MWI09	3/19/1998	ND	251	2.6	21.6	ND	ND	ND	< 1.0	11.6
1381MWD01	3/19/1998	ND	ND	< 1.0	ND	ND	ND	ND	ND	ND
1381MWD03	9/23/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MWD09	9/19/1996	ND	6.6	3.6	ND	ND	ND	ND	ND	1.6
1381MWD09	3/19/1998	ND	4.4	1.6	ND	ND	ND	ND	ND	1.5
1381MWD12	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPS01	9/19/1996	ND	ND	3.6	ND	ND	ND	ND	ND	ND
1381MPS07	9/23/1996	ND	ND	78.3	2.3	ND	ND	ND	ND	39.5
1381MPS08	9/23/1996	ND	ND	26.6	< 1.0	ND	< 1.0	ND	ND	13.8
1381MPS10	9/24/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 4 (Continued)
CHLORINATED ALIPHATIC HYDROCARBONS DETECTED IN GROUNDWATER AND SURFACE WATER
FACILITY 1381 RNA TS ADDENDUM
CAPE CANAVERAL AIR STATION, FLORIDA

Sample Location	Sample Collection Date	PCE[a] (µg/L)[f]	TCE[b] (µg/L)	cis-1,2-DCE[c] (µg/L)	trans-1,2-DCE (µg/L)	1,1-DCE (µg/L)	1,1-DCA[d] (µg/L)	1,2-DCA (µg/L)	1,1,1-TCA[e] (µg/L)	Vinyl Chloride (µg/L)
1381MPI01	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI02	9/21/1996	ND	ND	< 1.0	ND	ND	ND	ND	ND	ND
1381MPI03	9/23/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI05	9/24/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI06	9/24/1996	ND	< 1.0	4.7	ND	ND	ND	ND	ND	1.6
1381MPI07	9/23/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI08	9/24/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI10	9/24/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI11	9/24/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI13	9/24/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI17	9/23/1996	ND	ND	< 1.0	ND	ND	ND	ND	ND	ND
1381MPI18	9/24/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI18	3/19/1998	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI19	9/23/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
1381MPI20	9/25/1996	ND	ND	4.4	ND	ND	ND	ND	ND	1.6
1381MPI21	9/24/1996	NA[h]	NA	NA	NA	NA	NA	NA	NA	NA
SURA	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURB	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURC	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURD	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURE	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
SURF	9/21/1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
PRMP01	9/25/1996	ND	< 1.0	1210	11	4.6	2.4	ND	ND	767
PRMP02	9/25/1996	ND	< 1.0	1760	17.6	5.5	ND	ND	ND	1350

[a] PCE = Tetrachloroethene.

[b] TCE = Trichloroethene.

[c] DCE = Dichloroethene.

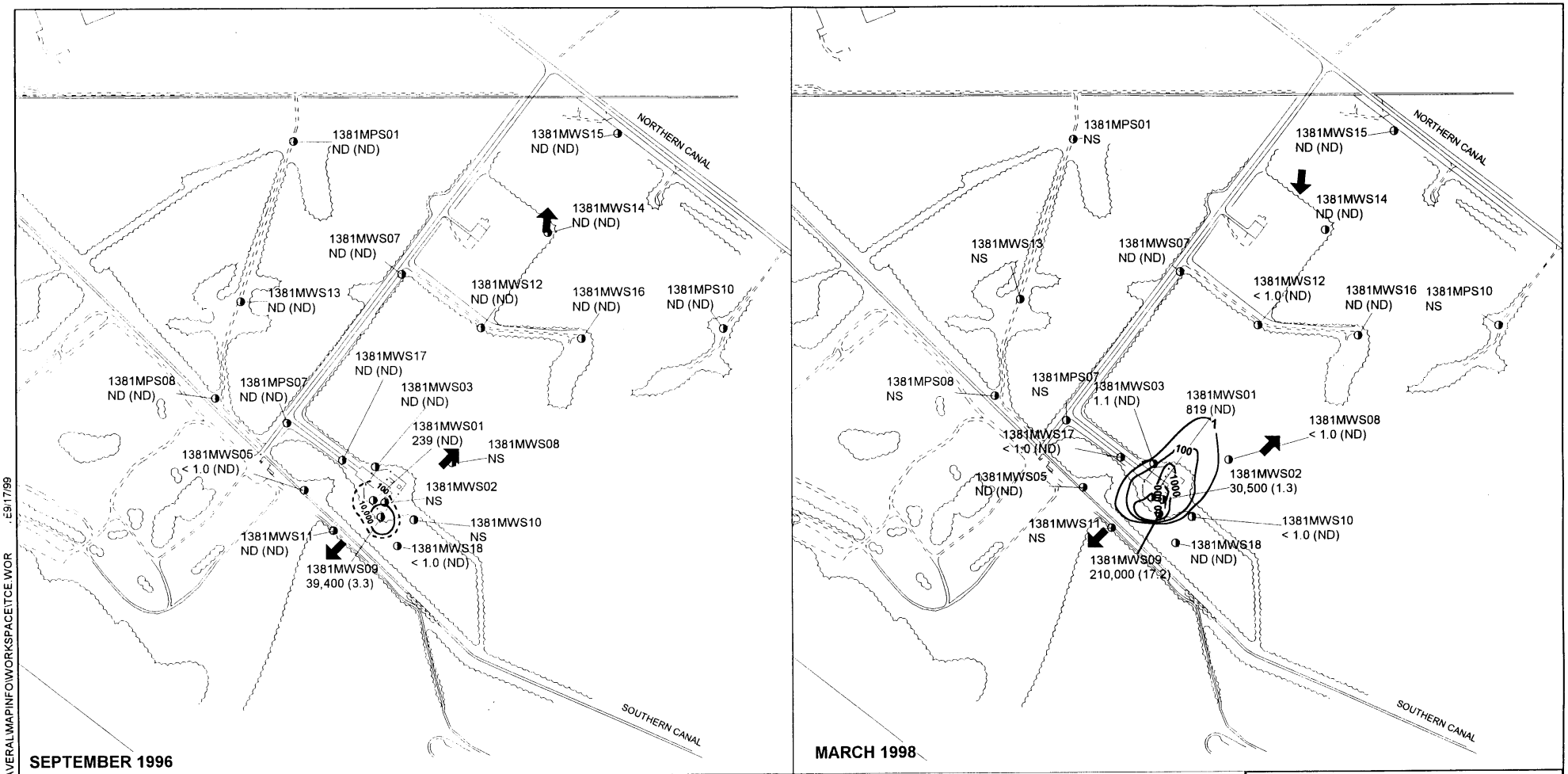
[d] DCA = Dichloroethane.

[e] TCA = Trichloroethane.

[f] µg/L = Micrograms per liter.

[g] ND = Not detected.

[h] NA = Not analyzed.



LEGEND

1381MWS09 39,400 (3.3)	Groundwater Monitoring Well/ Point TCE Concentration (µg/L) PCE Concentration (µg/L) in Parentheses	ND	Not Detected
		NS	Not Sampled
10,000	Line of Equal TCE Concentration (µg/L) (Dashed where Inferred)		
	Approximate Direction of Groundwater Flow		

N

0 300 600
Feet

FIGURE 2

PCE AND TCE CONCENTRATIONS MEASURED AT SHALLOW MONITORING WELL/ POINT LOCATIONS

Facility 1381 RNA TS Update
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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2.3.2 DCE

Total DCE (*cis*-1,2-DCE; *trans*-1,2-DCE; and 1,1-DCE) was detected in 17 of the 19 wells/points sampled in March 1998 (Table 4), indicating that it continues to be the most widespread CAH detected in site groundwater. Of the three DCE isomers targeted for analysis, the *cis* isomer was present at the highest concentrations. Concentration isopleths for total DCE in groundwater samples from shallow monitoring wells/points sampled in September 1996 and March 1998 are presented on Figure 3. The maximum concentrations of each DCE component detected in shallow groundwater in March 1998 occurred in the sample from well 1381MWS09, which is where the maximum TCE concentrations also were detected. Of the 11 shallow wells/points sampled in both 1996 and 1998, total DCE concentrations increased in 4 wells (1381MWS01, 1381MWS05, 1381MWS09, and 1381MWS14), decreased in five wells (1381MWS03, 1381MWS07, 1381MWS12, 1381MWS15, and 1381MWS17), and similar results were obtained for the remaining two wells (1381MWS16 and 1381MWS18). The most substantial concentration increase occurred at 1381MWS09, paralleling the substantial increase in the TCE concentration at this location.

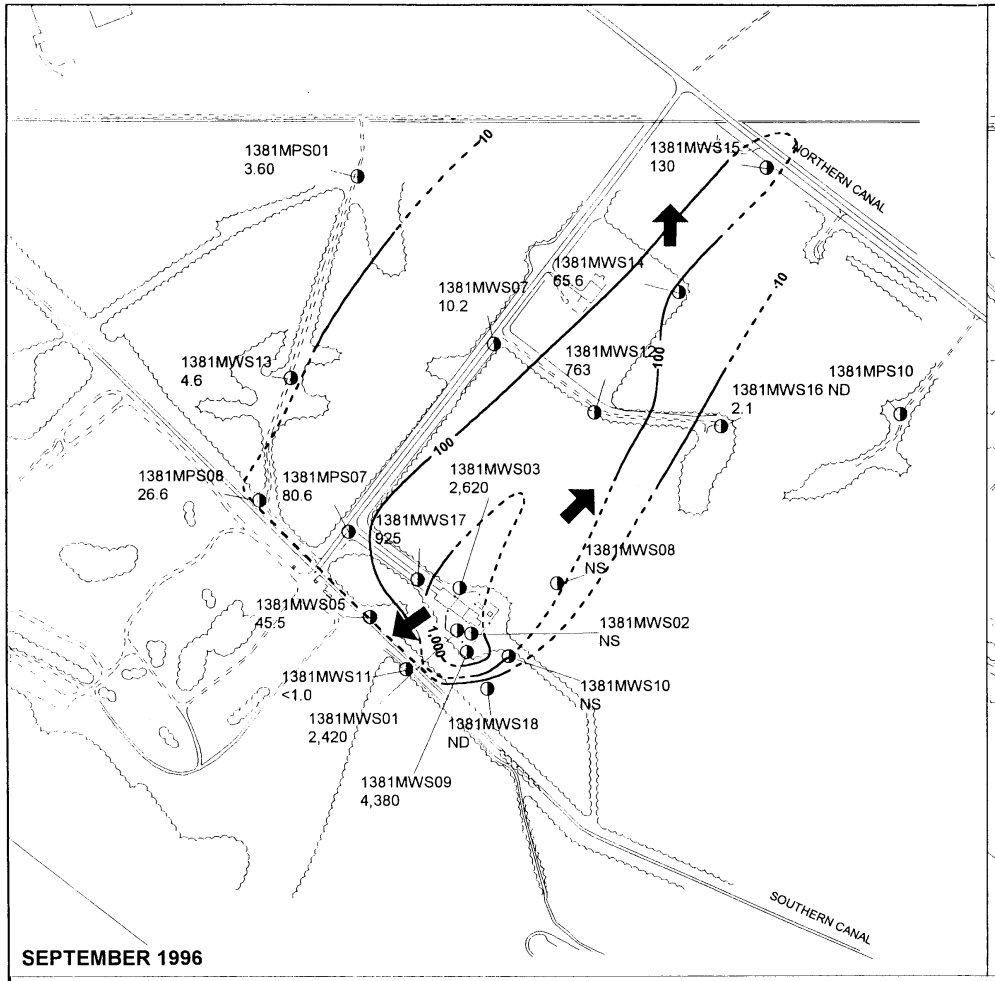
In contrast, DCE concentrations in the clustered intermediate-depth and deep wells 1381MWI09 and 1381MWD09 were lower in 1998 than in 1996. The total DCE concentration at downgradient well 1381MWS15 decreased from 1996 to 1998; however, the DCE plume still appears to extend to the northern drainage canal.

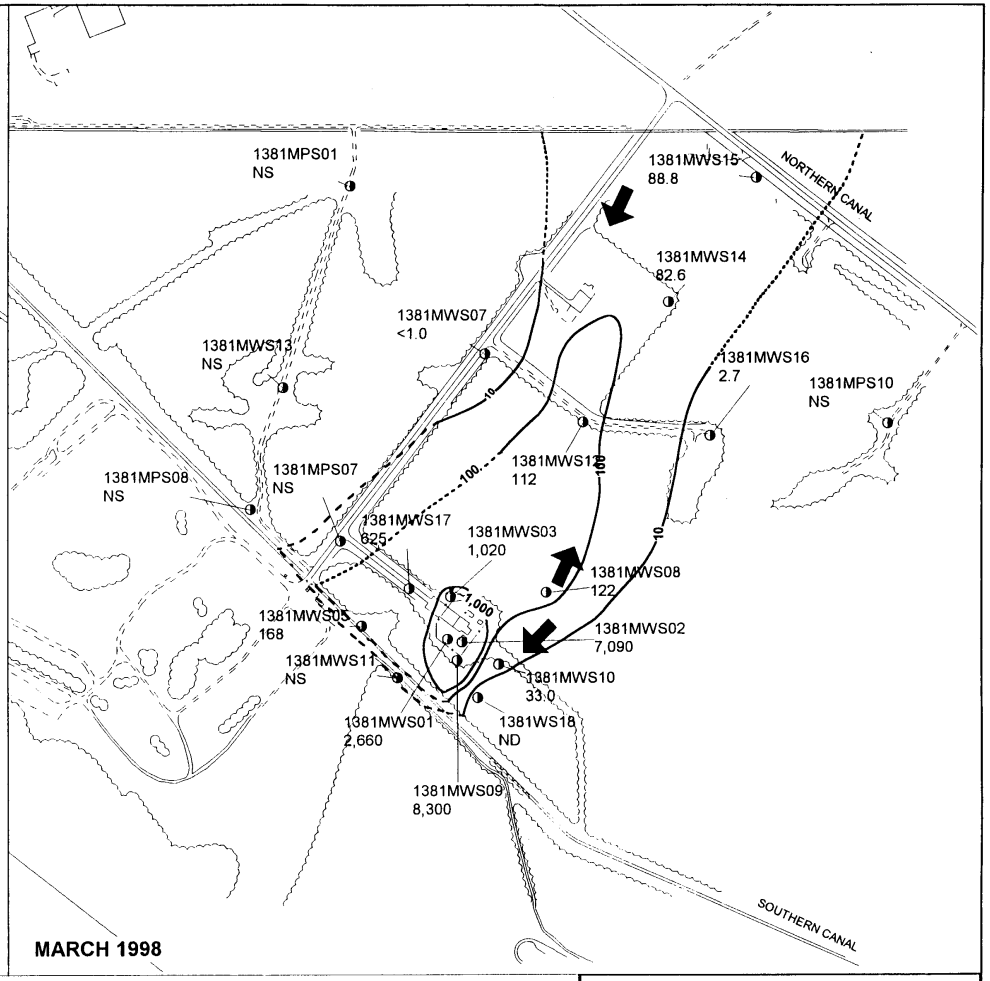
2.3.3 VC

VC was detected at 14 of the 19 shallow wells/points sampled in March 1998 (Table 4), indicating continuing reductive dehalogenation of DCE. Concentration contour maps for shallow wells/points in September 1996 and March 1998 are presented in Figure 4. The maximum VC concentration measured in March 1998 was 931 µg/L at well 1381MWS17, located northwest of well 1381MWS09 where the maximum TCE and DCE concentrations were detected. The offset in the location of the VC "hotspot" indicates that DCE is being reductively dehalogenated as it migrates downgradient from the source area. Of the 10 wells that had detectable VC concentrations in both September 1996 and March 1998, significantly increased concentrations were evidenced at only two wells (1381MWS01 and 1381MWS05). These wells are located at or southwest of the suspected source area. In contrast, VC concentrations at six wells were lower in 1998 than in 1996 (1381MWS03, 1381MWS07, 1381MWS09, 1381MWS12, 1381MWS15, and 1381MWS17). The largest decrease (510 µg/L to 42 µg/L) occurred at 1381MWS12, located approximately midway between the source area and the northern drainage canal. Decreased VC concentrations were evidenced at each of the three wells in the MW09 cluster (MWS09, MWI09 and MWD09). The continued detection of VC in downgradient well 1381MWS15 indicates that the VC plume still extends to or near the northern drainage canal.

2.3.4 Ethene

Ethene is the final end product in the series of chlorinated ethene reductive dehalogenation reactions that begins with PCE. Ethene was detected in 7 of the 19 wells sampled in March 1998, and in 16 of the 37 wells sampled in September 1996. The





LEGEND

1381MWS01 2,420 — Groundwater Monitoring Well/ Point; Total DCE Concentration (µg/L)

100 — Line of Equal DCE Concentration (µg/L) (Dashed where Inferred)

Approximate Direction of Groundwater Flow

ND Not Detected

NS Not Sampled

0 300 600 Feet

N

FIGURE 3

TOTAL DCE CONCENTRATIONS MEASURED AT SHALLOW MONITORING WELLS/ POINTS

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Cape Canaveral Air Station, Florida

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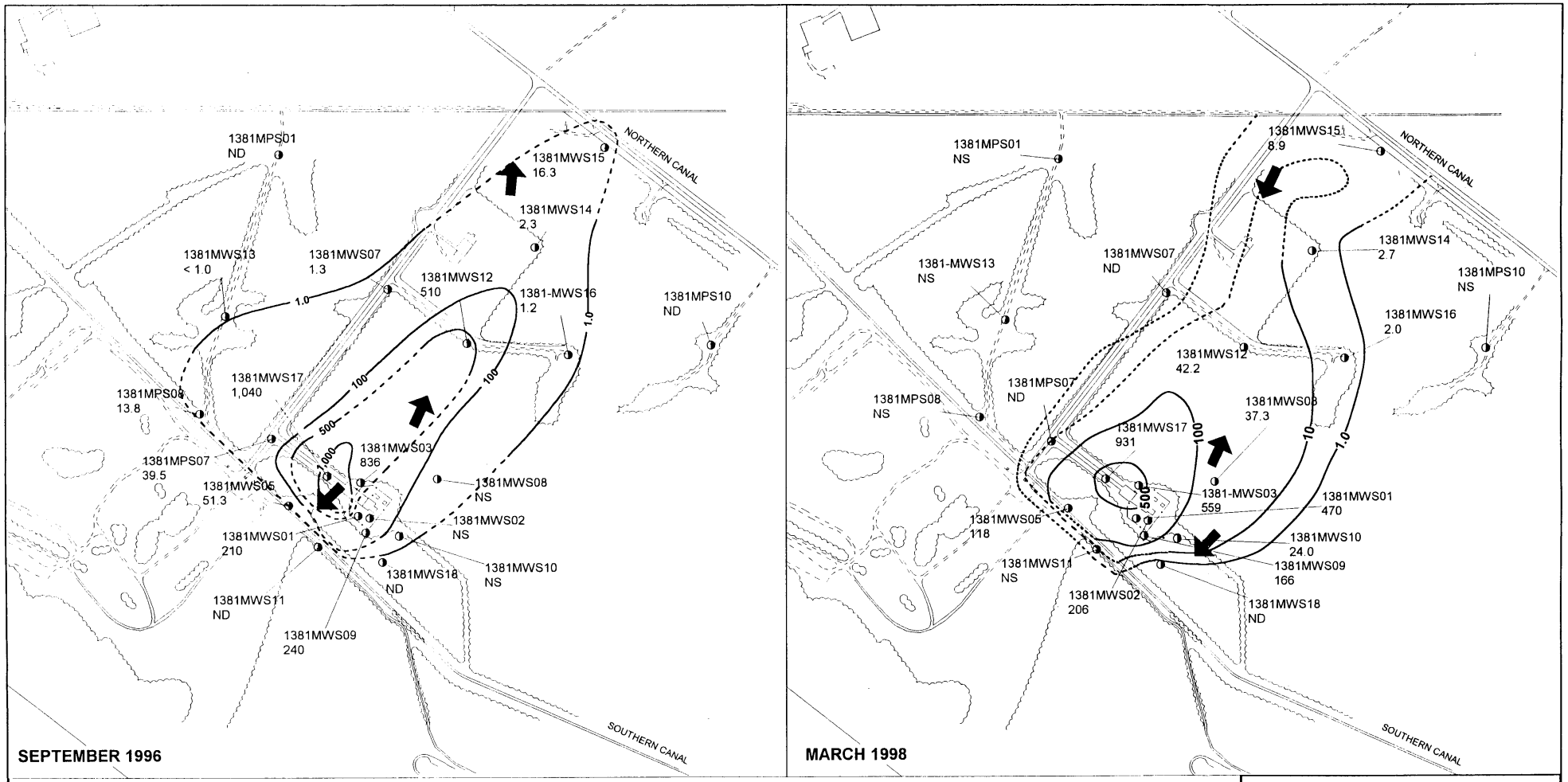


FIGURE 4

VINYL CHLORIDE CONCENTRATIONS MEASURED AT SHALLOW MONITORING WELLS/ POINTS

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Cape Canaveral Air Station, Florida

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Denver, Colorado

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continued presence of an ethene plume at the site indicates that the groundwater ORP near the source area is still sufficiently reducing to promote reductive dehalogenation of VC. Historic ethene concentrations for the site are summarized in Table 5. Concentration contour maps for ethene measured at shallow wells/points are presented for September 1996 and March 1998 on Figure 5. Detected concentrations of this analyte in shallow groundwater in 1996 and 1998 ranged from <3.0 to 18 µg/L and 6 to 16 µg/L, respectively. Ethene concentrations increased in only 1 of the 11 shallow wells that were sampled in both September 1996 and March 1998 (1381MWS01, located in the source area). In contrast, concentrations decreased in 3 wells (1381MWS03, 1381MWS12, and 1381MWS15), and 1998 concentrations in the remaining 4 wells were similar to the 1996 values. The ethene concentration increased from 64 to 87 µg/L at 1381MWI09, an intermediate-depth well located in the source area. As described above, the VC concentration in this well decreased from 1996 to 1998, indicating that active dehalogenation of VC has been occurring at this location. Ethene was not detected in the paired deep well (1381MWD09) in 1996 or 1998.

2.3.5 Chlorinated Ethanes

Chlorinated ethanes detected in March 1998 include 1,1-DCA, and 1,1,1-TCA. While 1,2-DCA was detected below 1 µg/L at well 1381MWS09 in September 1996, it was not detected at any location during the March 1998 sampling event. Detections of 1,1,1-TCA in March 1998 were primarily limited to source area wells 1381MWS09 and 1381MWS02. As with TCE and DCE, the 1,1,1-TCA concentration detected at MWS09 in 1998 was higher than the 1996 value; well 1381MWS02 was not sampled in 1996. The absence of TCA detections downgradient from the source area indicates that, similar to TCE, this compound is readily degraded as it migrates from the source area. The RNA TS report (Parsons ES, 1997a) concluded that the overall impact of TCA contamination relative to other CAHs is minor and limited to the approximate vicinity of the source area. The 1998 sampling results support this observation.

1,1-DCA was detected in 7 wells sampled in March 1998 at concentrations ranging from <1.0 to 71.7 µg/L. The maximum 1,1-DCA concentration was detected at well 1381MWS09 in the suspected source area. Similar to TCE, DCE, and TCA, concentrations of 1,1-DCA detected in this well were higher in March 1998 than in September 1996. The second-highest 1,1-DCA concentration (40.1 µg/L) was detected at well 1381MWS02, where the second-highest concentration of 1,1,1-TCA was detected. The concurrent presence of elevated concentrations of 1,1,1-TCA and 1,1-DCA indicate that the DCA results from the reductive dehalogenation of TCA. March 1998 concentrations of 1,1-DCA in the other nine wells sampled during both events were similar to the 1996 values.

2.3.6 Other CAHs Detected in Groundwater

Analytical results for other CAHs detected in site groundwater at low concentrations and in a small number of samples are listed in Appendix A. Chloroform was detected in groundwater samples from wells 1381MWS01 (<1.0 µg/L), 1381MWS02 (3.7 µg/L), and 1381MWS09 (15.1 µg/L). The only detection of this compound in 1996 was at 1381MWS09 at a concentration of 2.5 µg/L. Chloroform can result from the aerobic oxidation of TCE or TCE daughter products (e.g., 2,2,2-trichloracetaldehyde or

TABLE 5
GROUNDWATER GEOCHEMICAL DATA
FACILITY 1381 RNA TS ADDENDUM
CAPE CANAVERAL AIR STATION, FLORIDA

Sample Location	Date Sampled	Temp. (°C)[a]	pH	Conductivity (µs/cm²)[b]	Alkalinity (mg/L)[c]	Redox Potential (mV)[d]	Carbon Dioxide (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Nitrate + Nitrite (mg/L)	Ferrous Iron (mg/L)	Methane (mg/L)	Ethene (µg/L)[e]	Ammonia (mg/L)	Hydrogen Sulfide (mg/L)	Dissolved Oxygen (mg/L)	Dissolved Hydrogen (nM/L)[f]	Total Organic Carbon (mg/L)
1381MWS01	9/19/1996	26.1	7.3	1020	239	15	60	NA[g]	NA	NA	< .05	0.637	6	NA	NA	3.2	2.2	6.47
1381MWS01	3/19/1998	21.5	7.9	1040	260	-34	50	105	55.4	6.18	0.1	1.37	16	0.47	<0.1	0.1	4.05	4.05
1381MWS02	9/19/1996	NA	NA	NA	NA	NA	NA	121	47.3	1.85	NA	NA	NA	0.34	NA	NA	NA	NA
1381MWS02	3/19/1998	22.5	7	1160	760	NA	95	130	54.7	0.49	0.3	1.19	6	0.78	<0.1	1	1.24	5.57
1381MWS03	9/20/1996	26.3	7.2	1100	301	-136	140	106	44.6	< .05	2.0	1.040	18	0.38	< .1	0.1	1.3	6.2
1381MWS03	3/19/1998	21.5	7.8	940	300	-87	40	88.7	44.5	< 0.1	1.4	0.649	11	0.27	<0.1	0.3	2.18	4.99
1381MWS05	9/20/1996	21.2	7.4	2540	326	-179	208	151	24.3	< .05	0.2	2.600	<3.0	2.86	0.1	0.6	2.0	5.2
1381MWS05	3/19/1998	21.4	7.8	1418	360	-90	60	ND[h]	ND	<0.1	2.9	2.44	ND	2.81	<0.1	0.4	NA	8.9
1381MWS07	9/20/1996	26.1	7.3	609	271	-109	120	33.9	8.77	< .05	0.5	0.215	ND	0.27	< .1	<0.1	4.1	3.0
1381MWS07	3/19/1998	20.8	7.5	656	200	-7	50	50.6	15.7	< 0.1	0.1	0.022	ND	<0.1	<0.1	1.2	2.46	4.61
1381MWS08	3/19/1998	19.9	7.8	1641	280	-123	70	250	72.5	< 0.1	1.0	0.333	ND	0.16	0.1	0.2	7.24	10.9
1381MWS09	9/19/1996	27.8	7.2	1393	354	-50	160	207	55.10	< .05	1.3	4.000	6	0.91	NA	0.1	NA	9.0
1381MWS09	3/19/1998	22.1	8	1388	300	-87	70	170	79.7	< 0.1	3	2.09	6	1.28	0.1	<0.1	NA	8.97
1381MWS10	3/19/1998	NA	7.8	1370	300	-104	40	180	33	< 0.1	2.8	0.4	ND	0.31	0.1	0.3	NA	6.75
1381MWS11	9/20/1996	26.5	7.0	1260	NA	-159	360	64.8	138	< .05	8.7	0.484	ND	1.52	< .1	0.2	5.1	12.2
1381MWS12	9/21/1996	24.6	7.3	3560	328	-340	182	227	67.7	< .05	8.5	1.230	13	0.46	< .1	<0.1	1.8	7.8
1381MWS12	3/19/1998	20.5	7.6	676	220	-52	70	53.6	19.7	< 0.1	0.6	0.569	ND	0.17	<0.1	1.3	4.21	3.48
1381MWS13	9/21/1996	27.9	7.7	326	178	184	100	17.8	25.2	0.15	< .05	0.074	ND	< .05	NA	4.8	1.4	NA
1381MWS13	3/19/1998	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.0	0.6
1381MWS14	9/21/1996	27.8	7.2	660	270	172	120	37.6	31.3	0.13	0.18	0.098	ND	< .05	NA	1.0	1.4	2.3
1381MWS14	3/19/1998	19.0	7.8	ND	240	NA	35	51.1	14.6	< 0.1	0.1	0.002	ND	<0.1	<0.1	7.2	NA	3.21
1381MWS15	9/21/1996	25.1	7.2	1430	315	-154	188	242	38.6	< .05	2.3	0.793	<3.0	0.33	< .1	0.1	1.2	12.3
1381MWS15	3/19/1998	20.4	8.0	2340	240	-75	50	480	38.9	< 0.1	2.4	0.536	ND	0.55	<0.1	0.8	NA	9.81
1381MWS16	9/21/1996	26.1	7.4	500	223	120	60	13.3	17.8	< .05	< .05	0.078	ND	< .05	NA	0.2	1.6	1.2
1381MWS16	3/19/1998	20.7	7.9	795	340	-43	60	89.65	12.7	< 0.1	0.6	0.584	ND	0.21	<0.1	2.7	NA	5.2
1381MWS17	9/20/1996	27.7	7.3	1360	342	-102	158	171	71.4	< .05	1.6	1.520	13	0.76	< .1	0.1	6.0	6.6
1381MWS17	3/19/1998	22.3	7.9	1278	320	-72	70	130	73.9	< 0.1	2.8	2.21	8	0.96	<0.1	6.7	NA	6.37
1381MWS18	9/19/1996	24.8	7.3	1170	311	277	172	195	22	< .05	1.8	0.228	ND	0.35	NA	0.2	1.4	5.0
1381MWS18	3/19/1998	20.2	8.0	1289	260	-101	45	180	12.8	< 0.1	2.6	0.056	ND	0.54	<0.1	0.2	NA	6.28
1381MWI01	3/19/1998	22.5	7.8	5500	720	-103	65	1410	< 1.0	< 0.1	0.3	25.3	10	15.8	0.3	0.2	10.13	12.1
1381MWI05	9/20/1996	26	7.4	3680	668	-270	208	859	< 1	0.15	0.2	15.210	ND	14.7	0.1	0.1	2.5	10.9
1381MWI09	9/19/1996	25	7.7	6480	960	-296	308	1790	< 1	0.19	0.3	15.420	64	19.1	NA	0.1	NA	18.8
1381MWI09	3/19/1998	24.9	7.9	7100	840	-169	120	1640	< 1.0	< 0.1	0.3	16.4	87	18.2	2	0.2	NA	17.9
1381MWD01	9/19/1996	25.0	7.5	4090	457	-50	120	989	< 1	< .05	< .05	19.090	ND	9.37	NA	<0.1	5.3	NA
1381MWD01	3/19/1998	23.2	7.9	4100	440	-172	45	1020	< 1.0	< 0.1	0.2	15.3	ND	10.0	0.4	<0.1	NA	4.74
1381MWD03	9/23/1996	NA	8.1	4300	458	-176	102	1110	< 1	< .05	< .05	16.810	114	9.63	< .1	NA	7.1	NA
1381MWD09	NA	NA	NA	NA	NA	NA	NA	1050	< 1	<0.05	NA	17.500	ND	8.73	NA	NA	NA	6.3
1381MWD09	3/19/1998	23.1	7.9	3520	300	-122	55	930	< 1.0	< 0.1	0.4	23.9	ND	7.20	0.2	<0.1	NA	5.5
1381MWD12	9/21/1996	25.5	8.3	1360	487	-186	196	919	< 1	0.07	0.2	18.930	<3.0	8.64	0.3	0.1	6.4	NA
1381MPS01	9/21/1996	27.3	7.5	600	195	-172	130	28.2	16.3	< .05	0.6	0.134	ND	< .05	< .1	0.3	NA	1.2
1381MPS07	9/23/1996	29.2	7.4	618	225	-138	92	39	28.5	< .05	0.04	0.463	<3.0	0.48	< .1	0.2	NA	2.6

TABLE 5 (Continued)
GROUNDWATER GEOCHEMICAL DATA
FACILITY 1381 RNA TS ADDENDUM
CAPE CANAVERAL AIR STATION, FLORIDA

Sample Location	Date Sampled	Temp. (°C)[a/]	pH	Conductivity (µs/cm²)[b/]	Alkalinity (mg/L)[c/]	Redox Potential (mV)[d/]	Carbon Dioxide (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Nitrate + Nitrite (mg/L)	Ferrous Iron (mg/L)	Methane (mg/L)	Ethene (µg/L)[e/]	Ammonia (mg/L)	Hydrogen Sulfide (mg/L)	Dissolved Oxygen (mg/L)	Dissolved Hydrogen (nM/L)[f/]	Total Organic Carbon (mg/L)
1381MPS08	9/23/1996	24.9	7.2	1458	386	-96	204	221	9.12	0.06	1.50	3.360	ND	6.01	< .1	0.1	NA	5.7
1381MPS10	9/24/1996	26.4	7.8	7520	834	-109	386	18	2.76	< .05	< .05	0.228	ND	0.56	0.1	0.3	NA	7.0
1381MPI01	9/21/1996	27	7.8	2130	554	-250	170	486	< 1	0.1	< .05	NA	NA	11.2	< .1	0.1	NA	NA
1381MPI02	9/21/1996	27	7.8	2380	537	-238	252	451	< 1	0.19	< .05	18.490	ND	18.3	NA	0.2	NA	8.3
1381MPI03	9/23/1996	24.6	7.7	5420	863	-86	416	1260	< 1	0.13	< .05	30.100	ND	16.5	< .1	0.1	NA	57.3
1381MPI05	9/24/1996	24.3	7.7	6620	955	-185	388	295	< 0.1	< .05	< .05	32.550	ND	18.6	< .1	<0.1	NA	15.2
1381MPI06	9/24/1996	25.4	7.7	5710	789	-98	294	250	< 0.1	< .05	< .05	27.960	51	16.2	< .1	0.1	NA	11.4
1381MPI07	9/23/1996	27.2	7.7	2330	485	-212	210	445	< 1	0.06	< .05	21.630	159	11.3	< .1	<0.1	NA	8.2
1381MPI08	9/24/1996	21.4	8.3	3760	524	-290	232	161	< 0.1	< .05	< .05	0.103	ND	9.04	0.1	0.1	NA	83.2
1381MPI10	9/24/1996	26.6	7.3	972	321	-118	196	17.8	< 0.1	< .05	0.80	0.212	ND	0.55	< .1	0.1	NA	2.6
1381MPI11	9/24/1996	24.4	7.7	7910	905	-225	358	365	< 0.1	< .05	< .05	27.130	ND	15.3	0.1	<0.1	NA	192.0
1381MPI13	9/24/1996	24.6	7.8	4370	744	-190	332	171	< 0.1	< .05	0.20	26.270	ND	14.5	0.1	0.1	NA	13.0
1381MPI17	9/23/1996	26.3	7.8	4730	770	-206	296	1050	< 1	0.16	< .05	27.260	<3.0	15.5	< .1	0.2	NA	14.9
1381MPI18	9/24/1996	23.9	7.8	4770	801	-211	306	189	< 0.1	< .05	NA	29.980	ND	14.7	0.1	0.2	NA	13.8
1381MPI18	3/19/1998	20.8	7.5	453	800	-105	70	1050	< 1.0	< 0.1	0.10	32.900	ND	14.0	<0.1	0.1	NA	19.6
1381MPI19	9/23/1996	25.4	7.8	5440	755	-40	438	NA	NA	NA	< .05	NA	NA	NA	< .1	0.1	NA	NA
1381MPI20	9/25/1996	24.1	7.7	5870	877	-60	347	261	< .1	< .05	< .05	25.510	ND	15.8	0.1	0.2	NA	11.7
1381MPI21	9/24/1996	23.8	7.8	5110	670	-243	258	227	< 0.1	< .05	0.3	20.270	ND	14.7	0.3	0.3	NA	9.9
1381PRMP01	9/25/1996	25.2	7.3	1129	337	NA	112	NA	9.46	< .05	2.00	1.290	12	0.49	< .1	0.4	NA	6.2
1381PRMP02	9/25/1996	24.9	7.2	1270	345	NA	345	NA	12.5	< .05	1.60	1.820	18	0.74	< .1	<0.1	NA	5.9

[a/] °C = Degrees Celsius.

[b/] µs/cm² = Microsiemens per square centimeter.

[c/] mg/L = Milligrams per liter.

[d/] mV = Millivolts.

[e/] µg/L = Micrograms per liter.

[f/] nM/L = Nanomoles per liter.

[g/] NA = Not available.

[h/] ND = Not detected.

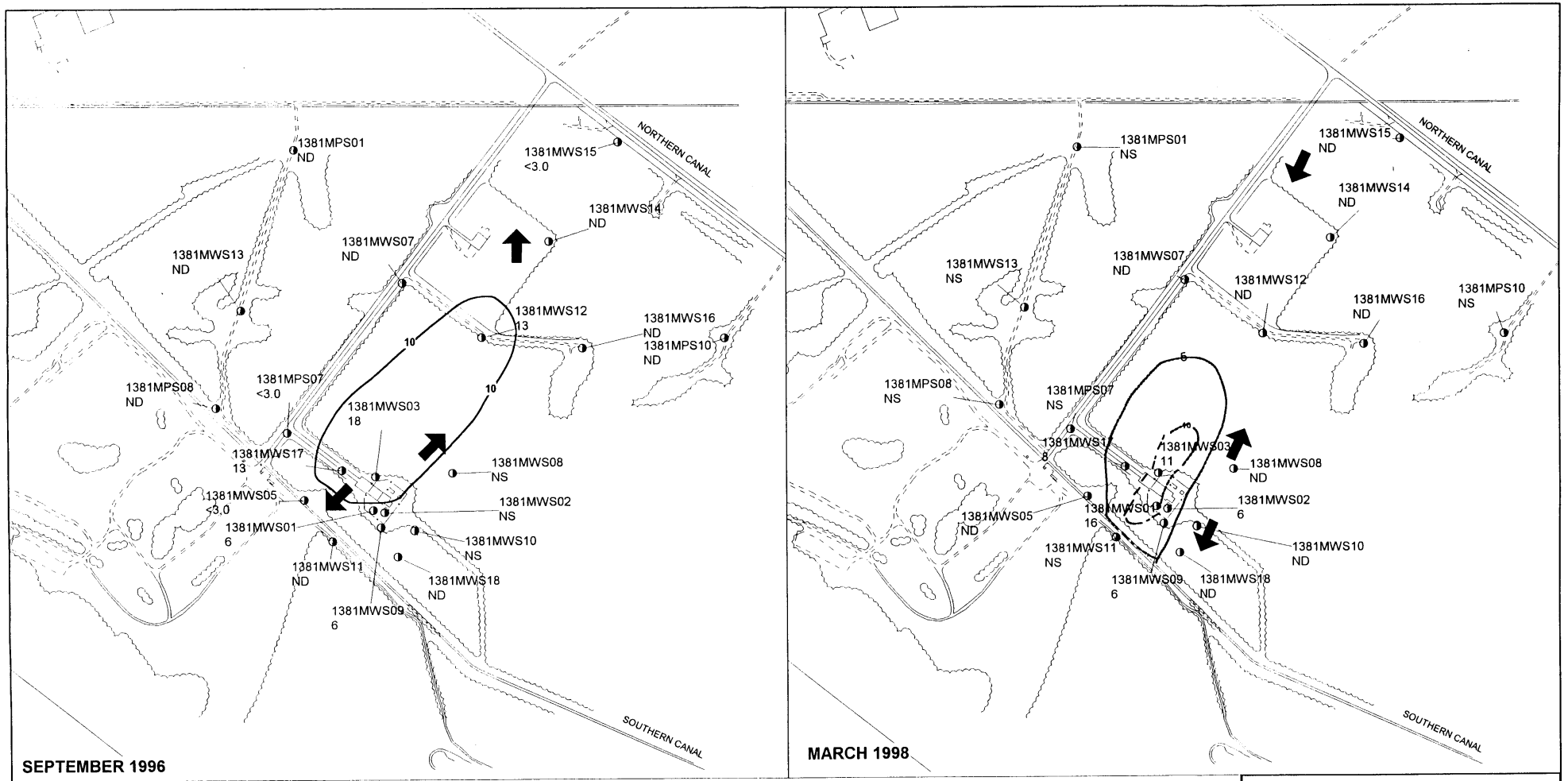


FIGURE 5

ETHENE CONCENTRATIONS MEASURED AT SHALLOW MONITORING WELLS/ POINTS

Facility 1381 RNA TS Update
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

FILE Name: S:\ES\REMED\BIOPLUME\CANAVERAL\MAPINFO\WORKSPACE\ETHENE.WOR Date: 7/29/99

2,2,2-tricyloroethanol) produced during aerobic oxidation. Chloroform was detected in source area monitoring wells that were susceptible to oxygen enrichment from precipitation or from adjacent air sparging testing. Therefore, the aerobic production of chloroform is plausible.

Carbon tetrachloride was also detected in samples from source area wells 1381MWS02 (8.9 µg/L) and 1381MWS09 (38.4 µg/L). This compound is not a byproduct of CAH biodegradation, and its presence suggests that carbon tetrachloride was released at the site, possibly cosolvenated with other CAH compounds. In 1996, this compound was present only in a single deep well (1381MWD12) at a concentration of 15.9 µg/L

Chlorobenzene was detected at a trace concentration of less than 1.0 µg/L in groundwater from 1381MWS05, located adjacent to the southern drainage canal. In 1996, this compound also was detected in a single sample (1381MPS08) collected near the canal (<1.0 µg/L).

2.4 Natural Attenuation Analysis

Biodegradation of chlorinated ethenes in Facility 1381 groundwater appears to be occurring primarily by reductive dehalogenation. The continued presence of (1) anaerobic conditions throughout much of the plume area, and (2) substantial TOC concentrations, and the continued absence of significant anthropogenic carbon (e.g., BTEX compounds or other fuel hydrocarbons), indicate that type 2 behavior (where a natural carbon source drives reductive dehalogenation) continues to be prevalent. The TCE plume does not appear to have migrated more than several hundred feet from the source area, suggesting relatively rapid degradation to DCE. However, DCE and VC contamination extends from the source area to the northern canal, indicating that dehalogenation of DCE and VC are occurring at a slower rate. The presence of ethene indicates dehalogenation of VC continues to occur.

2.4.1 Presence of Daughter Products and Molar Fractions

Transformation of chlorinated ethenes (PCE, TCE, DCE, VC, and ethene) as contamination migrates away from the source area can be evaluated using the molar fraction of individual compounds to total molar chlorinated ethenes (Figures 6 and 7). The molar fraction of TCE decreases dramatically from source area well 1381MWS09 to wells 1381MWS01 and 1381MWS03 in both 1996 and 1998, indicating rapid degradation to DCE by reductive dehalogenation. This results in a significant increase in the molar fraction of DCE from well 1381MWS09 to 1381MWS01. From well 1381MWS01 to 1381MWS012 in 1996, and from well 1381MWS01 to 1381MWS03 in 1998, the molar fraction of DCE decreases while the molar fraction of VC increases, indicating further degradation of DCE to VC.

With further downgradient migration, the molar fraction of DCE increases, perhaps due to less reducing conditions and a lack of reductive dehalogenation of DCE. The molar fraction of VC continues to decline, indicating some oxidation of VC (this also can occur under ferric iron reducing conditions). The molar fraction of VC relative to the

FIGURE 6
MOLAR FRACTION OF CHLORINATED ALIPHATIC HYDROCARBONS VERSUS DISTANCE
MARCH 1998
FACILITY 1381 RNA TS ADDENDUM
CAPE CANAVERAL AIR STATION, FLORIDA

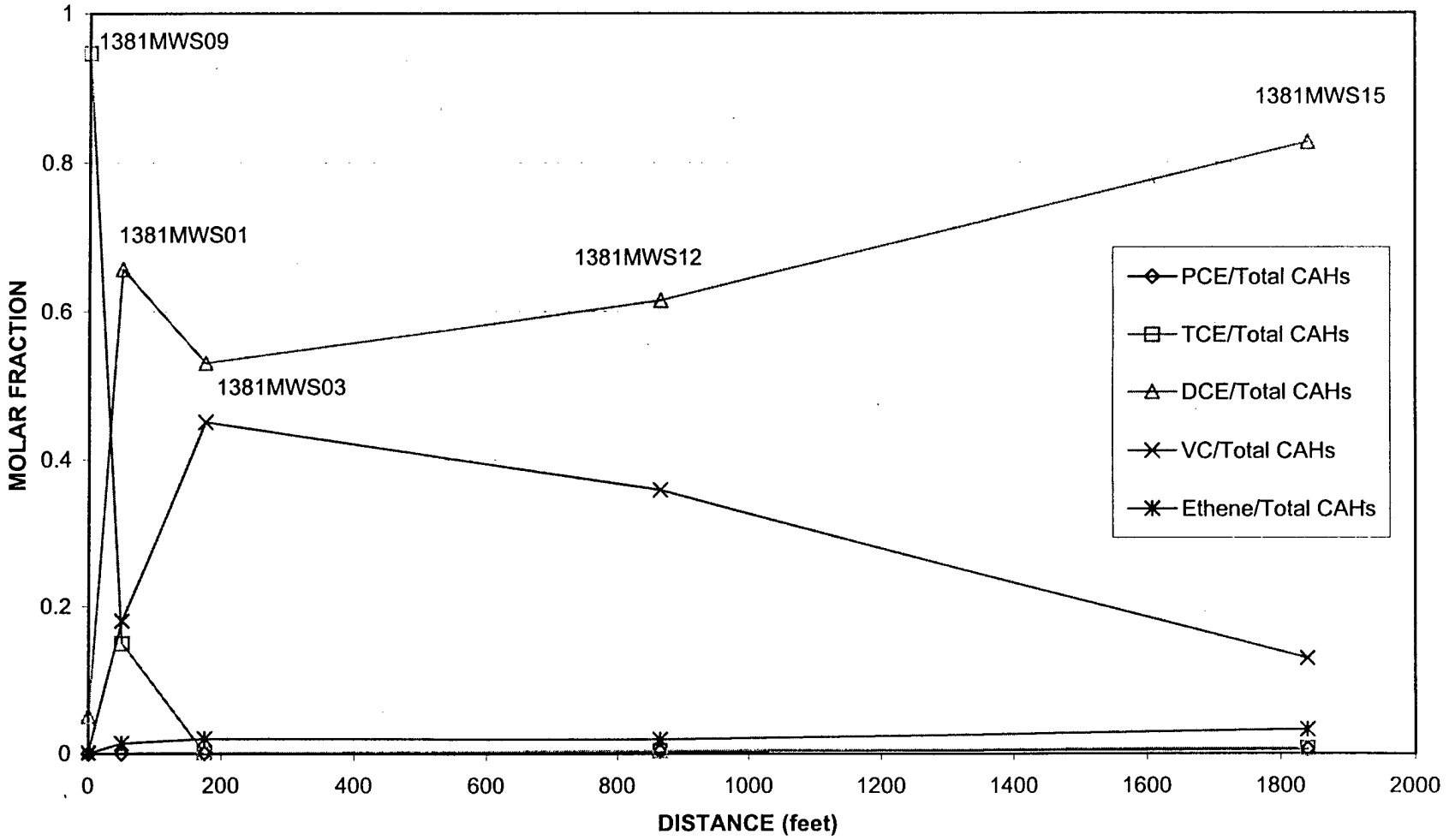
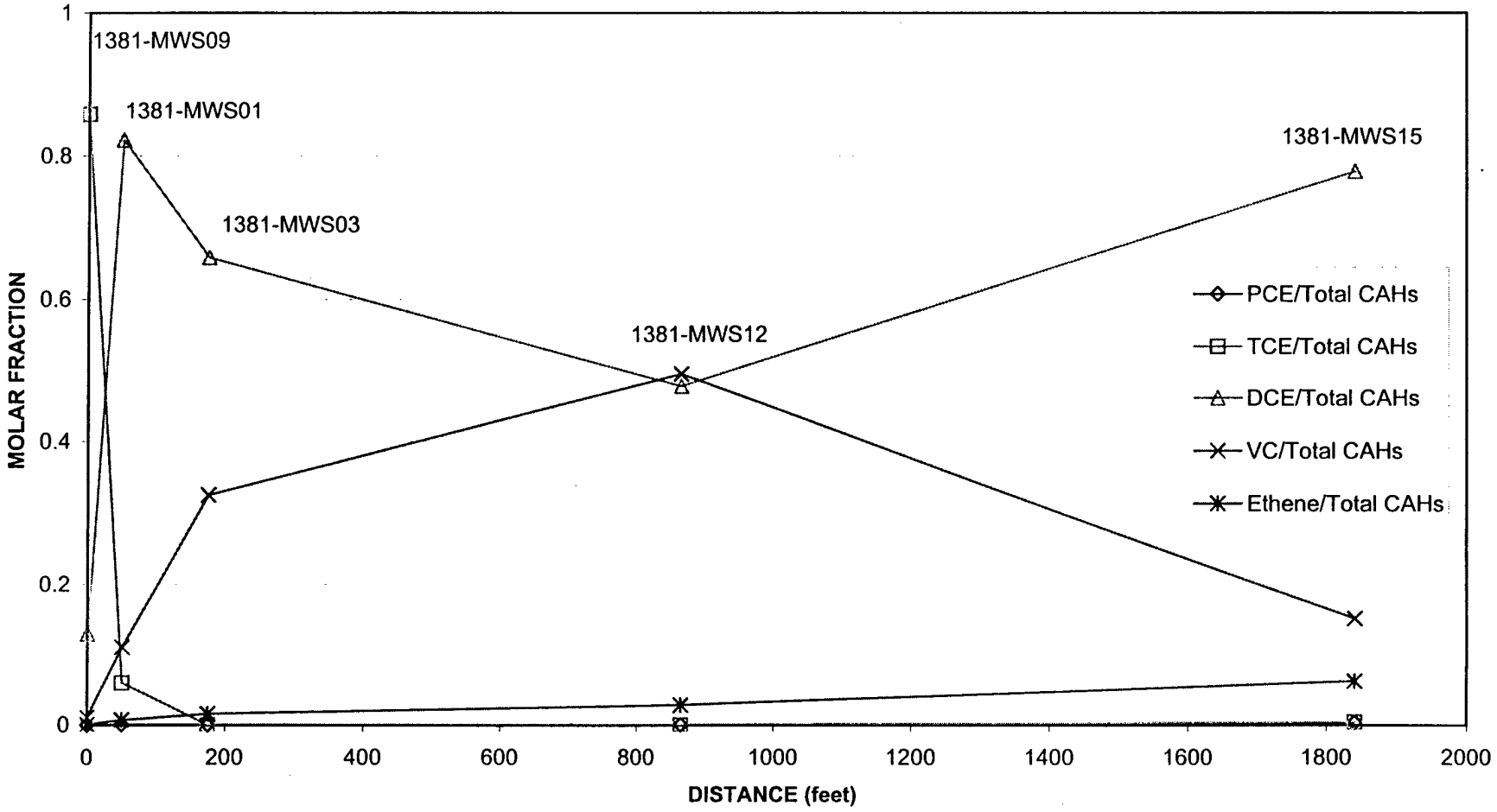


FIGURE 7
MOLAR FRACTION OF CHLORINATED ALIPHATIC HYDROCARBONS VERSUS DISTANCE
SEPTEMBER 1996
FACILITY 1381 RNA TS ADDENDUM
CAPE CANAVERAL AIR STATION, FLORIDA



molar fraction of ethene also decreased downgradient from well 1381MWS03 during both sampling events, suggesting progressive transformation of VC to ethene.

In summary, molar fractions of the individual chlorinated ethene compounds indicates significant degradation of TCE to DCE and DCE to VC by reductive dehalogenation from the source area (well 1381MWS09) to downgradient wells 1381MWS01 and 1381MWS03. Downgradient of well 1381MWS03, the degradation of DCE slows due to a lack of sufficiently reducing conditions for reductive dehalogenation, while the rate of degradation of VC relative to DCE increases, due to some aerobic oxidation of VC.

2.4.2 Field-Scale Contaminant Mass Losses

A comparison of TCE, DCE, and VC concentrations between the September 1996 and March 1998 sampling events does not reveal consistent mass loss over time, despite the performance of the air sparging pilot tests described in Section 1.3. Concentrations of chlorinated ethenes increased in portions of the suspected source area, most likely due to increased precipitation, groundwater elevations, and leaching of CAHs sorbed to source area soils. Conversely, concentrations of DCE and VC decreased in other portions of the source area and in selected wells downgradient from the source area. It is possible that increased precipitation rates caused DO concentrations to increase (see the discussion of DO results below) and reductive dehalogenation rates to decrease, and promoted some aerobic biodegradation of DCE and VC. These data indicate that CAH reductive dehalogenation rates are temporally variable at this site, and that biodegradation mechanisms for the less-chlorinated compounds (i.e., DCE and VC) also vary temporally.

2.4.3 Chloride as an Indicator of Dehalogenation

Chloride concentrations were measured in groundwater samples collected in March 1998 (Table 5). Chloride is removed from CAHs during reductive dehalogenation and enters solution. Therefore, chloride concentrations in groundwater should increase above background in areas where reductive dehalogenation occurs. The RNA TS report concluded that reductive dehalogenation along the length of the CAH plume was causing elevated chloride concentrations in the shallow aquifer along a narrow corridor extending from the source area to the northern drainage canal. In addition, elevated chloride concentrations at the intermediate depth in the source area suggested that significant reductive dehalogenation was occurring at depth.

With a few exceptions, chloride concentrations in March 1998 were similar to those detected in September 1996, suggesting that significant long-term changes in reductive dehalogenation rates did not occur during the intervening time period. The exceptions include wells 1381MWS05, 1381MWS12, 1381MWS15, and 1381MWS16. Substantial decreases in chloride concentrations were measured at 1381MWS05 and 1381MWS12, located southwest and northeast of the suspected source area, respectively. These decreases may reflect seasonal recharge of the shallow aquifer by surface water in the southern drainage canal (1381MWS05) and dilution of chloride concentrations due to increased precipitation recharge (both wells). The March 1998 DO concentration at 1381MWS12 was higher than measured in 1996, supporting the observation that precipitation-induced oxygenation of the shallow aquifer in this area was diluting chloride concentrations and limiting the occurrence of reductive dehalogenation.

Substantial increases in chloride concentrations occurred at 1381MWS15 and 1381MWS16, located along the plume axis adjacent to the northern drainage canal and along the eastern edge of the CAH plume, respectively. These increases occurred despite the fact that March 1998 DO concentrations at these locations were higher than in September 1996. If the surface water in the northern drainage ditch was more saline than the adjacent shallow groundwater at 1381MWS15, then the increase at this location could be explained by surface water recharge. The cause of the increase at 1381MWS16 is not known.

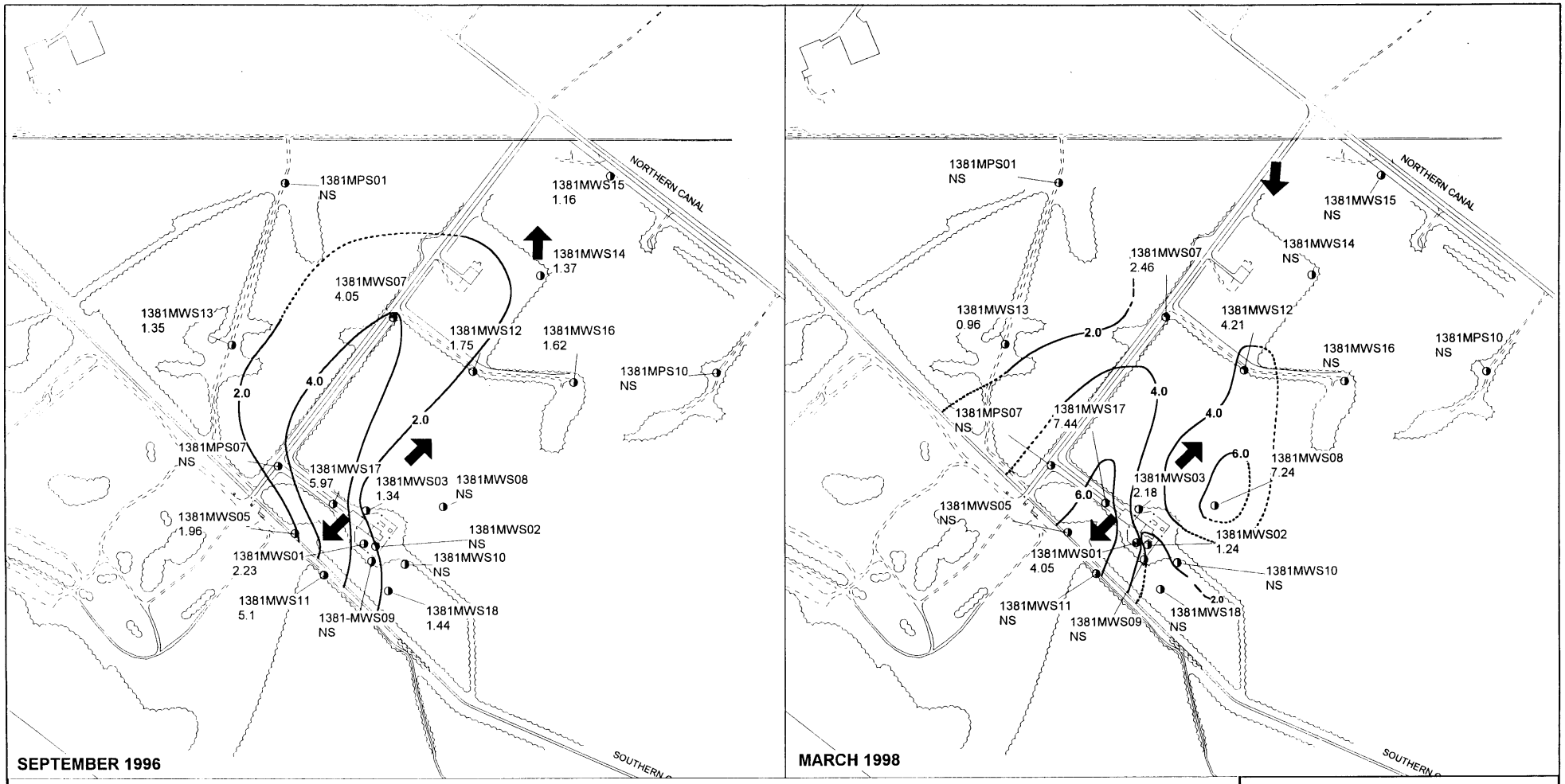
2.4.4 Redox Potential and Dissolved Hydrogen as Indicators of Redox Processes

Redox potentials measured in shallow, intermediate, and deep groundwater at Facility 1381 in September 1996 ranged from 277 to –340 millivolts (mV), –40 to –296 mV, and -50 to –176 mV, respectively (Table 5). Redox potentials in shallow groundwater in the source area and along the plume centerline, measured in September 1996, were mostly less than –100 mV. The RNA TS report (Parsons ES, 1997a) states that the groundwater at the two shallow wells that exhibited higher redox potentials (1381MWS01 and 1381MWS09) may have been aerated by a former air sparging system. There were no noticeable areal trends in redox potentials in the intermediate and deep intervals.

Redox potentials measured in shallow, intermediate, and deep groundwater in March 1998 ranged from -7 mV to -172 mV, -105 to –169 mV, and –172 mV (1 well only), respectively. The shallow wells that exhibited lower (more negative) redox potentials in 1998 were mostly near the periphery of the CAH plume. The redox potentials at most of the wells in the plume area were higher (more positive) than in 1996, which is consistent with the occasionally higher DO levels and indications that the shallow aquifer had been influenced by oxygenated recharge water. Given that the observed increases were not limited to the source area, and the substantial length of time between the conclusion of the air sparging pilot test (Section 1.3) and the March 1998 sampling event (13 months), it is likely that the increases were not substantially related to the air sparging pilot test described in Section 1.3. It should be noted that the redox potentials measured at shallow, intermediate, and deep wells still indicate the presence of a reducing environment that is capable of supporting the reductive dehalogenation of CAHs.

Dissolved hydrogen concentrations measured at eight locations in March 1998 are summarized in Table 5. Concentration contours are provided on Figure 8 for September 1996 and March 1998. Dissolved hydrogen concentrations measured in September 1996 ranged from 1.34 nanomoles per liter (nM/L) to 5.97 nM/L. Based on the magnitude of these values, the RNA TS report concluded that sulfate reduction should be the dominant electron accepting process in the plume area at shallow wells/points. Dissolved hydrogen concentrations for the shallow aquifer, measured in March 1998, ranged from 0.96 nM/L to 7.24 nM/L. These data support the observation that sulfate reduction should be the dominant electron accepting process throughout much of the CAH plume area, and indicate that methanogenesis is prevalent in localized areas. The only dissolved hydrogen concentration measured at an intermediate-depth well (1381MWI01) was 10.13 nM/L, indicating the presence of methanogenic conditions.

The relatively low redox potentials and moderate to high dissolved hydrogen concentrations measured in site groundwater continue to indicate that reductive dehalogenation, primarily under sulfate reducing or methanogenic conditions, is possible



LEGEND

1381MWS01
2.23 — Groundwater Monitoring Well/ Point
Dissolved Hydrogen Concentration
(in nanomoles per Liter)

NS Not Sampled

2.0 — Line of Equal Dissolved Hydrogen Concentration (nM/L)
(Dashed where Inferred)

Approximate Direction of Groundwater Flow

N

0 300 600
Feet

FIGURE 8

DISSOLVED HYDROGEN IN GROUNDWATER MEASURED AT SHALLOW MONITORING WELLS/ POINTS

Facility 1381 RNA TS Update
Cape Canaveral Air Station, Florida

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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at most locations within the aquifer. The most rapid dehalogenation rates, affecting the widest range of CAHs occurs under increasingly reduced environments (Bouwer, 1994).

2.4.5 Alternate Electron Acceptors and Metabolic Byproducts

Results of alternate electron acceptor and metabolic byproduct analyses are presented in Table 5. The following paragraphs discuss those parameters most useful in evaluating site biodegradation processes.

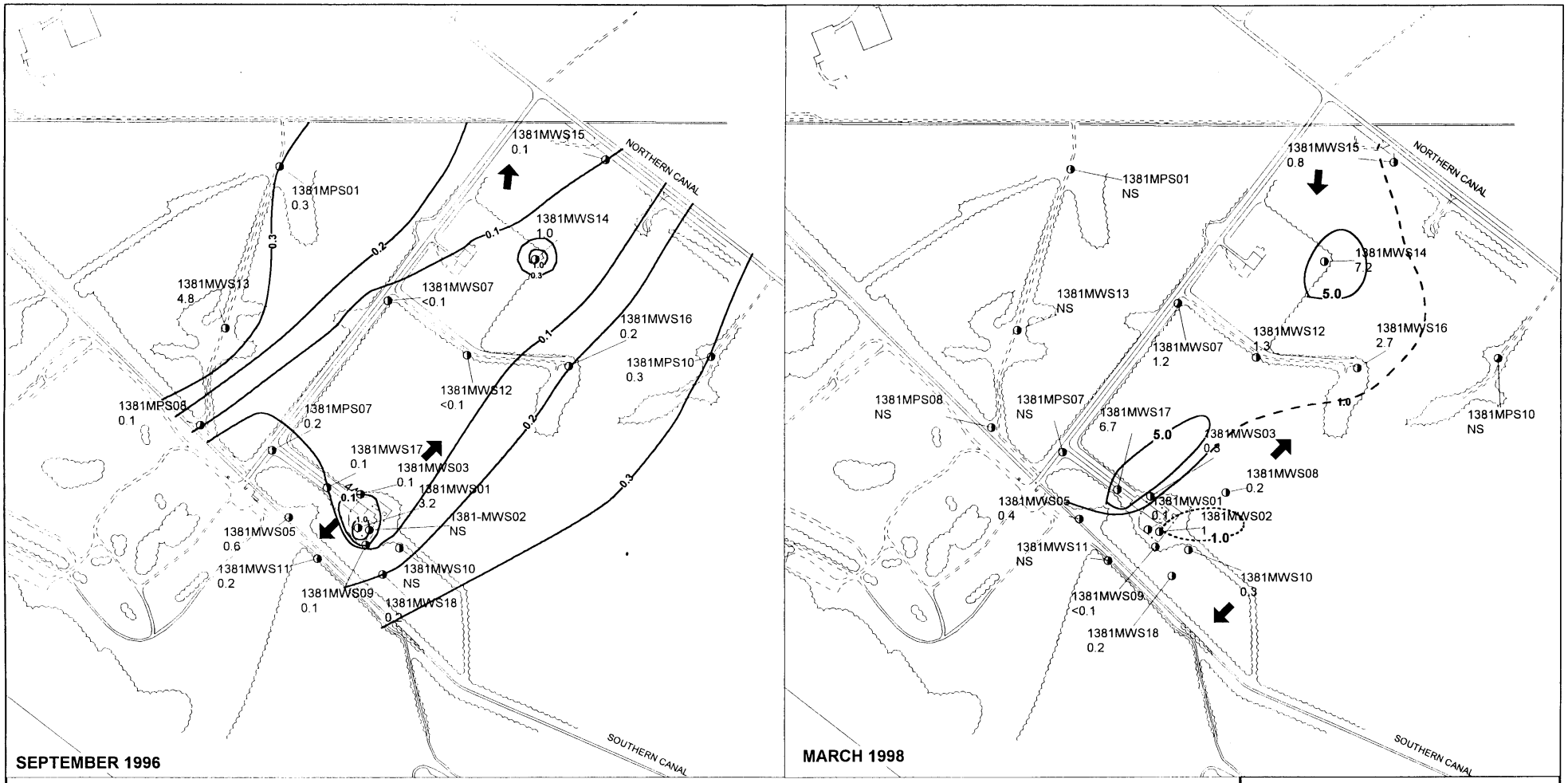
2.4.5.1 Dissolved Oxygen

Reductive dehalogenation is an anaerobic process, and DO concentrations in excess of 0.5 milligrams per liter (mg/L) may cause the reductive transformation pathway to be suppressed (Wiedemeier *et al.*, 1999). Therefore, highly chlorinated compounds such as PCE, TCE, and TCA are biologically recalcitrant under aerobic conditions. However, less chlorinated compounds such as DCE and VC can be aerobically biodegraded. DO concentrations were measured at monitoring wells/points during the March 1998 sampling event. These concentrations are summarized in Table 5, and DO concentrations measured at shallow monitoring wells/points in 1996 and 1998 are displayed on Figure 9.

September 1996 DO concentrations were mostly less than 0.5 mg/L. March 1998 DO concentrations ranged from <0.1 mg/L at well 1381MWS09 in the source area to 7.2 mg/L at well 1381MWS14, located about 800 feet southwest of the northern drainage canal. DO concentrations in shallow groundwater in the source area averaged 0.4 mg/L (average of wells 1381MWS01, 1381MWS02, 1381MWS03, and 1381MWS09), indicating the continued presence of anaerobic conditions that are conducive to the occurrence of reductive dehalogenation of CAHs. However, comparison of Figures 3 and 9 indicate that DO concentrations in other portions of the CAH plume were elevated, possibly due to increased recharge rates. Therefore, the occurrence of reductive dehalogenation may be temporarily suppressed in these areas. DO concentrations measured at intermediate and deep wells/points were less than 0.2 mg/L, which is consistent with the September 1996 data.

2.4.5.2 Nitrate + Nitrite

As shown in Table 5, concentrations of nitrate + nitrite (as nitrogen [N]) were detected at all of the 19 locations sampled in March 1998. The highest nitrate + nitrite (as N) concentration was 6.18 mg/L, measured at 1381MWS01 in the source area. This well is located near where the highest nitrate concentration was detected in September 1996 (1381MWS02, 1.85 mg/L). The RNA TS report observed that nitrate may have entered the groundwater at this location as a result of nitrate compounds disposed of near the former leachfield or possibly as a result of lawn fertilizer applied to the grass around Facility 1381. With the exception of 1381MWS01, the concentrations of nitrate + nitrite in shallow wells/points ranged from <0.1 to 0.49 mg/L. Nitrate concentrations measured at intermediate and deep monitoring wells/points were all <0.1 mg/L. Both the 1996 and 1998 data indicate that reductive dehalogenation of CAHs in groundwater at the site at any depth interval should not be inhibited by preferential use of nitrate as an electron acceptor.



LEGEND

1381MWS01 3.2 — Groundwater Monitoring Well/ Point; Dissolved Oxygen Concentration (milligrmas per liter)

0.1 — Line of Equal Dissolved Oxygen Concentration (mg/L) (Dashed where Inferred)

Approximate Direction of Groundwater Flow

ND Not Detected

NS Not Sampled

0 300 600
Feet

N

FIGURE 9

DISSOLVED OXYGEN CONCENTRATIONS MEASURED AT SHALLOW WELLS/POINTS

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Cape Canaveral Air Station, Florida

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2.4.5.3 Ferrous Iron

The presence of redox conditions that are favorable to the production of ferrous iron via ferric iron reduction suggests that reductive dehalogenation of the more highly chlorinated CAHs (e.g., PCE and TCE) is likely. Conversely, conditions are less than optimal for the reductive dehalogenation of DCE or VC, although these processes may still occur. Ferrous iron was detected at all of the 19 locations sampled in March 1998. Table 5 lists ferrous iron concentrations measured in site groundwater, and Figure 10 presents isopleth maps showing the September 1996 and March 1998 distributions of ferrous iron in shallow groundwater. Concentrations of ferrous iron measured at shallow monitoring wells/points in March 1998 ranged from 0.1 to 3 mg/L. The highest concentrations of ferrous iron were located near the source area (1381MWS09, 1381MWS05, 1381MWS18, and 1381MWS10). Another area exhibiting elevated ferrous iron concentrations was at well 1381MWS15 adjacent to the northern drainage canal. Lower concentrations were detected between the source area and the northern canal. The most dramatic change in ferrous iron concentrations between 1996 and 1998 occurred at 1381MWS12, located approximately midway between the source area and the northern canal, where the concentration decreased from 8.5 mg/L in 1996 to 0.6 mg/L in 1998 (Figure 10). Ferrous iron concentrations measured in intermediate and deep monitoring wells were below 0.4 mg/L, which is consistent with the September 1996 data.

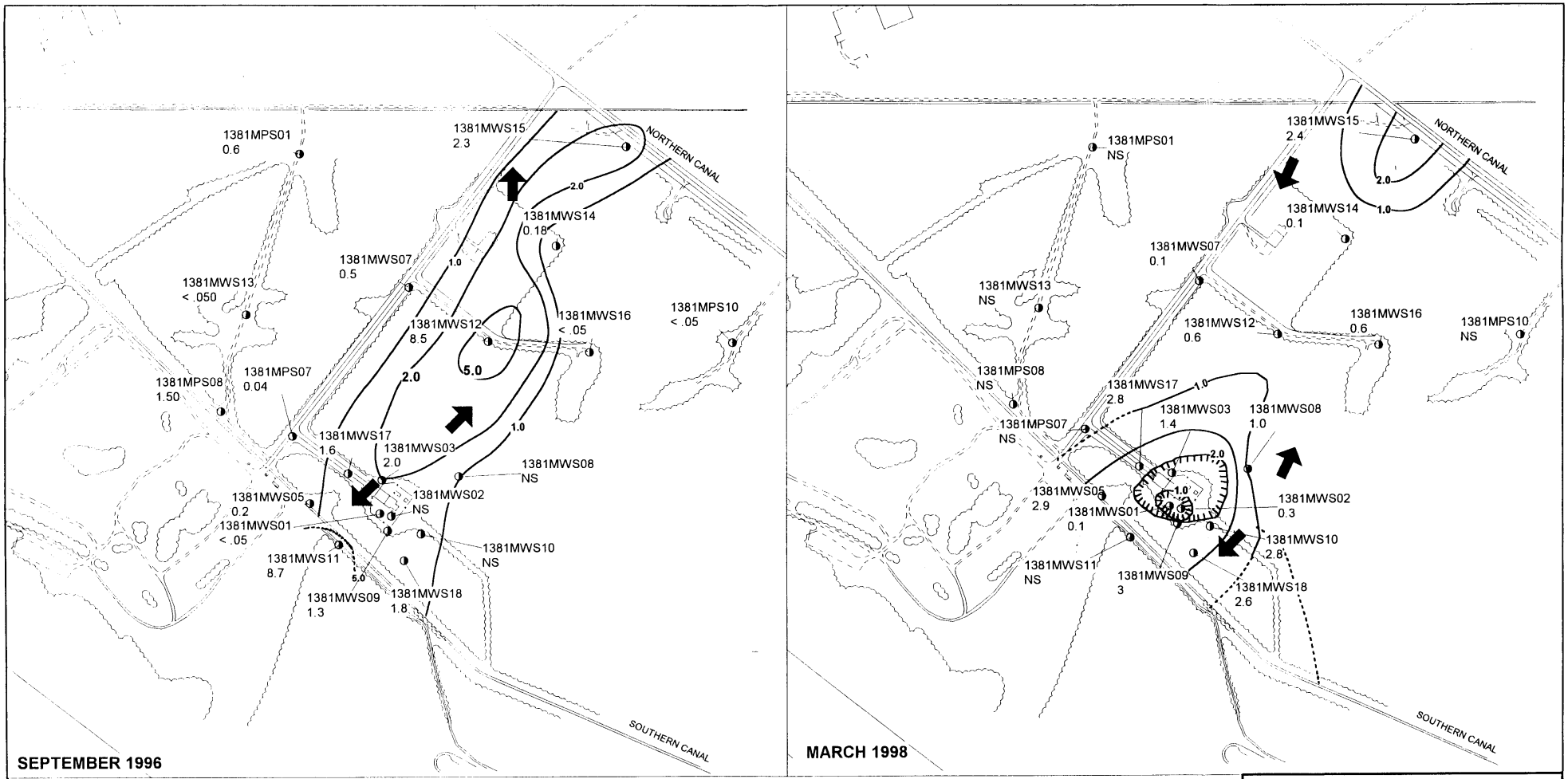
The widespread occurrence of ferrous iron in shallow groundwater is not consistent with the redox conditions indicated by the dissolved hydrogen results discussed above. The contradictory conclusions regarding the redox conditions in the shallow aquifer derived from review of the dissolved hydrogen and ferrous iron data suggest that redox conditions vary spatially and/or temporally within the sampled interval of the aquifer, and that "microenvironments" characterized by differing redox conditions (e.g., ferric iron reducing versus sulfate reducing) may exist.

2.4.5.4 Sulfate

Sulfate concentrations in shallow monitoring wells/points at the site ranged from 12.7 mg/L to 79.7 mg/L (Table 5). Measured shallow background sulfate concentrations at the site were 12.7 and 15.7 mg/L (1381MWS16 and 1381MWS07, respectively). Sulfate concentrations at source area wells 1381MWS01, 1381MWS02, and 1381MWS09 ranged from 54.7 to 79.7 mg/L, and averaged 63.3 mg/L. Therefore, similar to September 1996, sulfate concentrations in the source area in March 1998 were typically increased relative to background concentrations. Sulfate concentrations in intermediate and deep monitoring points/wells were below 1 mg/L at all sampled locations. The March 1998 data continue to indicate that sulfate in shallow groundwater could be expected to compete with CAHs for use as electron acceptors in the source area, and might therefore limit reductive dehalogenation. Competition between CAHs and sulfate should not be a factor at depth in the aquifer because of the low sulfate concentrations.

2.4.5.5 Methane

Methane was detected in groundwater from all 19 wells/points sampled in March 1998, and analytical results are summarized in Table 5. Methane concentration contours



LEGEND

1381MWS09 1.3	Groundwater Monitoring Well/ Point Iron Concentration (mg/L)	ND	Not Detected
		NS	Not Sampled
1.0	Line of Equal Ferrous Iron Concentration (mg/L) (Dashes where Inferred)		
	Approximate Direction of Groundwater Flow		

N

0 300 600
Feet

FIGURE 10

FERROUS IRON CONCENTRATIONS MEASURED AT SHALLOW MONITORING WELL/ POINT LOCATIONS

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for September 1996 and March 1998 are presented on Figure 11. March 1998 methane concentrations at 8 of the 11 shallow wells sampled during both events were lower than the September 1996 concentrations. These decreases are consistent with the generally higher redox potentials measured in March 1998. However, the magnitudes of the decreases are typically small, and the data do not indicate substantial, widespread changes in redox processes. The most substantial decrease in methane concentrations occurred at source area well 1381MWS09 (4.0 to 2.09 mg/L).

The continued presence of methane within and downgradient from the TCE source area and at background locations indicates that petroleum hydrocarbons and/or native organic matter are being used to support methanogenesis. Elevated methane concentrations continue to occur in the source area, supporting the continued presence of highly reducing conditions that are favorable for the reductive dehalogenation of CAHs. Similar to September 1996, 1998 methane concentrations in the intermediate and deep monitoring wells sampled were substantially higher than in shallow groundwater. The fact that methanogenesis continues to occur at Facility 1381, particularly at intermediate and deep intervals, indicates the continued presence of redox conditions that are favorable for the reductive dehalogenation of CAHs.

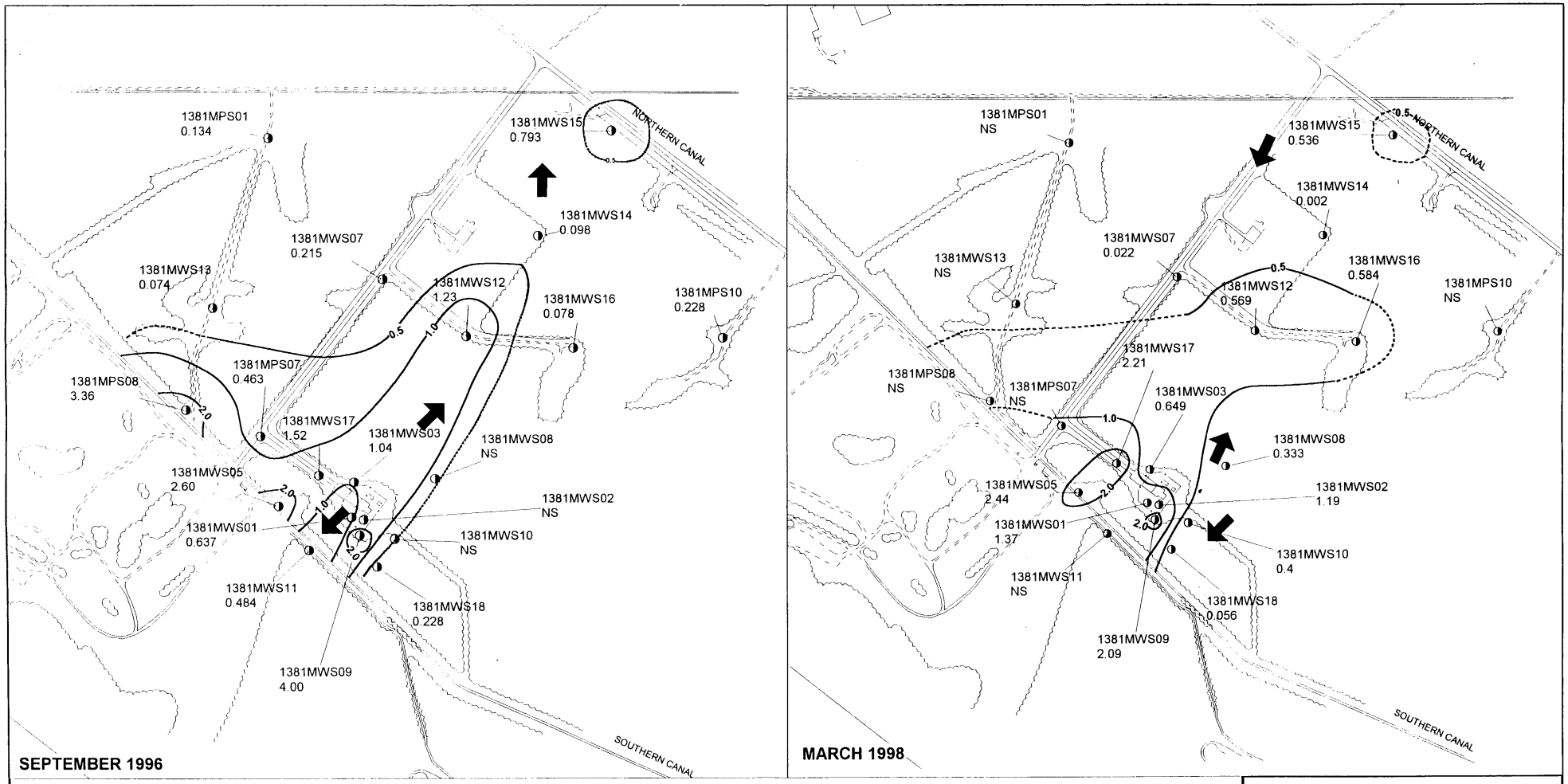
2.4.6 Additional Geochemical Indicators

2.4.6.1 Alkalinity and Carbon Dioxide

The RNA TS report (Parsons ES, 1997a) concluded that the September 1996 alkalinity data suggested the presence of increased alkalinity along the CAH plume centerline (generally greater than 300 mg/L as calcium carbonate ($CaCO_3$), indicating the occurrence of microbially-mediated redox reactions. The March 1998 alkalinities measured at the five plume centerline wells shown on Figures 6 and 7 ranged from 220 to 300 mg/L as $CaCO_3$ and averaged 260 mg/L. Background alkalinities in March 1998 were 200 mg/L (1381MWS07) and 340 mg/L (1381MWS16). Comparison of plume centerline and background alkalinities measured in March 1998 do not indicate a significant difference, suggesting a general lessening in the rate at which microbially-mediated redox reactions were occurring and/or the temporal effects of increased recharge. However, the range of alkalinity measured at the site should still have been sufficient to buffer potential changes in pH caused by biologically mediated reactions, and suggests that aerobic and/or anaerobic biodegradation processes should not have caused detrimental shifts in pH. This conclusion is supported by the pH data described below. Similar to the 1996 results, alkalinities measured in intermediate-depth and deep wells in 1998 were higher than in shallow groundwater.

The RNA TS report concluded that carbon dioxide concentrations in the shallow portion of the surficial aquifer did not provide direct evidence of the occurrence of methanogenesis or of the complete mineralization of VC. However, elevated carbon dioxide concentrations in contaminated groundwater at intermediate depths suggested that complete mineralization of contaminants under methanogeneic conditions with subsequent generation of carbon dioxide was occurring.

Carbon dioxide concentrations measured in 1998 were lower than the 1996 values in nearly all of the wells sampled for this parameter during both events. Shallow carbon



LEGEND

1381MWS09 4.00	Groundwater Monitoring Well/ Point Methane Concentration (mg/L)	ND	Not Detected
		NS	Not Sampled
1.0	Line of Equal Methane Concentration (mg/L) (Dashed Where Inferred)		
	Approximate Direction of Groundwater Flow		

0 300 600
Feet

N

FIGURE 11

METHANE CONCENTRATIONS MEASURED AT SHALLOW MONITORING WELL/ POINT LOCATIONS

Facility 1381 RNA TS
Cape Canaveral Air Station, Florida

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dioxide concentrations measured along the plume centerline in March 1998 ranged from 40 mg/L to 70 mg/L and averaged 56 mg/L. Shallow background concentrations averaged 55 mg/L. Therefore, similar to 1996, the carbon dioxide data for shallow groundwater do not support the occurrence of biodegradation. The carbon dioxide concentration measured in groundwater from intermediate well 1381MWI09 (120 mg/L), located in the source area, was higher than at 1381MWI18 (70 mg/L), located adjacent to the CAH plume, suggesting the continued occurrence of biodegradation under methanogenic conditions.

2.4.6.2 pH and Temperature

The March 1998 pH values were generally slightly more alkaline than the 1996 values; however, they were still within the optimal range for most microbial populations that degrade organic matter. Groundwater temperatures measured in 1998 were typically lower than in 1996, but were still relatively warm (greater than or equal to 20 degrees Celsius), suggesting that the rate at which biochemical processes such as reductive dehalogenation occur should be enhanced.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The overall extent of the CAH plume and distribution of parent and daughter compounds in March 1998 were similar to that delineated in September 1996. However, migration of dissolved contaminants to the northern drainage canal appears to have been inhibited in March 1998 by a temporary reversal of groundwater flow directions near the canal, most likely caused by increased flow and higher surface water levels in the canal.

Overall, TCE concentrations dissolved in groundwater increased in the source area, indicating the continuing presence of a significant TCE source remaining in the soils at Facility 1381. Temporal variations in TCE concentrations in the source area are probably due to seasonally variable precipitation rates and groundwater levels that affect the leaching rate of TCE. Despite increased concentrations, the March 1998 TCE plume was still restricted to the vicinity of the source area due to the effects of reductive dehalogenation under type 2 conditions (where a natural carbon source drives reductive dehalogenation).

cis-1,2-DCE continues to be the most widespread contaminant in site groundwater, and the March 1998 DCE plume still appeared to extend to the northern drainage canal. The continued presence of VC and ethene plumes supports the conclusion that DCE and VC also continue to be reductively transformed to less-chlorinated daughter products. Available data suggest that some oxidation of VC also may be occurring in the plume area, at least seasonally.

Geochemical results from the March 1998 sampling event indicate the continued presence of a generally anaerobic, reducing environment, especially in deeper zones of the surficial aquifer that are not influenced by precipitation recharge. Therefore, the redox environment continues to support the occurrence of reductive dehalogenation of CAHs. However, measured increases in redox potentials and DO concentrations and decreases in methane concentrations in some shallow monitoring wells/points suggest that increased precipitation rates had caused a more oxidizing environment to be present,

at least in some portions of the plume area, in March 1998. As a result, it is likely that reductive dehalogenation rates in the shallow zone are temporally variable, and that the significance of aerobic degradation of less-chlorinated CAHs (e.g., DCE and VC) also varies.

Insufficient LTM data have been collected to date to support comparison of LTM results to numerical model predictions. The numerical model developed for the site predicted that rapid changes in the magnitude and extent of CAH concentrations would not occur, especially in the absence of a full-scale engineered source reduction system.

It is recommended that the two new LTM wells described in the LTM plan developed for the site (see Section 7 of the RNA TS report [Parsons ES, 1997a]) be installed and included in future LTM events. In addition, future sampling events at the site should include, at a minimum, the following sampling stations:

- The seven existing wells listed in the LTM plan;
- Intermediate-depth well 1381MWI09; and
- The three surface water stations in the northern canal described in the LTM plan.

In the draft TS, Parsons ES recommended annual LTM for 20 years to assess if RNA (and other potential remedial actions) are removing dissolved contaminants and controlling plume expansion. The LTM plan should be periodically reviewed and revised as appropriate on the basis of available groundwater quality data. At the conclusion of the LTM period, the site should be reevaluated to decide upon an appropriate course of action.

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ATTACHMENT A

1998 ANALYTICAL DATA

MANTECH

Ref: 98/JAD24

March 31, 1998

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Don:

As requested in Service Request # SF-4-312, headspace GC/MS analysis of 20 water samples for chlorinated volatile organics from Cape Canaveral site 1381 was completed. The samples were received on March 17, 1998 and analyzed on March 17-21, 1998. RSKSOP-148 (Determination of Volatile Organic Compounds in Water by Automated Headspace Gas Chromatography/Mass Spectrometry (Saturn II Ion Trap Detector) was used for this analysis.

An internal standard calibration method was established for the 15 compounds. The standard curves were prepared from 1.0 to 4000 ppb. The lower calibration limits were 1.0 ppb.

If you should have any questions, please feel free to contact me.

Sincerely,

John Allen Daniel

John Allen Daniel

xc: R.L. Cosby
G.B. Smith
D.D. Fine
J.L. Seeley SV for
J.T. Wilson

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

Table 1. Quantitation Report for SDG SF-4-312 from Cape Canaveral 1381.

Concentration = ppb

Compound	18-1381 -MPI	1381 MW-S01	1381 MW01	MW-D01	MWS02	MWSO2 1/100 Dil Field Dup	MWS03	MWS05	MWS07	MWS08
VINYL CHLORIDE	ND	470	ND	ND	206	193	559	118	ND	37.3
1,1-DICHLOROETHENE DCE	ND	25.1	ND	ND	384	364	3.9	ND	ND	---
T-1,2-DICHLOROETHENE DCE	ND	14.4	ND	ND	32.2	---	6.6	2.4	ND	---
1,1-DICHLOROETHANE DCA	ND	5.7	ND	ND	40.1	---	2.4	---	ND	ND
C-1,2-DICHLOROETHENE DCE	ND	2620	---	---	*****	6670	1010	166	---	122
CHLOROFORM	ND	---	ND	ND	3.7	ND	ND	ND	ND	ND
1,1,1-TRICHLOROETHANE TCA	ND	ND	ND	ND	80.5	---	ND	ND	ND	ND
CARBON TETRACHLORIDE	ND	ND	ND	ND	8.9	ND	ND	ND	ND	ND
1,2-DICHLOROETHANE DCA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRICHLOROETHENE TCE	ND	819	ND	ND	*****	30,500	1.1	ND	ND	---
TETRACHLOROETHENE PCE	ND	ND	ND	ND	1.3	ND	ND	ND	ND	ND
CHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	---	ND	ND
1,3-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

	MWSO9	MWSO9 1/100 Dil Field Dup	MWIO9	MWDO9	MWS10	MWS10 Lab Dup	MWS12	MWS14	MWS15	MWS16
VINYL CHLORIDE	166	176	11.6	1.5	24.0	22.4	42.2	2.7	8.9	2.0
1,1-DICHLOROETHENE	1150	1300	ND	ND	ND	ND	ND	ND	ND	ND
T-1,2-DICHLOROETHENE	34.9	---	21.6	ND	---	---	1.1	---	---	ND
1,1-DICHLOROETHANE	71.7	---	ND	ND	ND	ND	---	ND	ND	ND
C-1,2-DICHLOROETHENE	*****	7110	2.6	1.6	33.0	29.8	111	82.6	88.8	2.7
CHLOROFORM	15.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-TRICHLOROETHANE	351	714	---	ND	ND	ND	ND	ND	ND	ND
CARBON TETRACHLORIDE	38.4	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROETHANE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TRICHLOROETHENE	*****	210,000	251	4.4	---	---	---	ND	ND	ND
TETRACHLOROETHENE	17.2	ND	ND	ND	ND	ND	ND.	ND	ND	ND
CHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DICHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND = None Detected ***** = Above Calibration Limit(4000 ppb) Dil = Dilution --- = Below Calibration Limit(1.0 ppb)

Table 2. Quantitation Report for S[redacted]# SF-4-312 from Cape Canav[redacted]al 1381.

Concentration = ppb

	MWS17	MWS18	MWS18 Field Dup	MW-13S	MW13S Lab Dup	QC0317C 20 ppb	QC0317D 200 ppb	QC0317E 20 ppb	QC0317F 200 ppb	QC0317G 20 ppb
VINYL CHLORIDE	931	ND	ND	ND	ND	21.8	220	22.3	221	23.0
1,1-DICHLOROETHENE	2.3	ND	ND	ND	ND	22.2	236	23.1	235	23.6
T-1,2-DICHLOROETHENE	10.3	ND	ND	ND	ND	18.4	178	17.6	183	18.8
1,1-DICHLOROETHANE	3.9	ND	ND	ND	ND	22.5	228	23.3	236	24.1
C-1,2-DICHLOROETHENE	612	ND	ND	2.4	2.6	22.5	220	22.0	226	21.4
CHLOROFORM	ND	ND	ND	ND	ND	20.7	205	20.4	201	20.9
1,1,1-TRICHLOROETHANE	ND	ND	ND	---	---	21.4	221	22.0	223	21.9
CARBON TETRACHLORIDE	ND	ND	ND	ND	ND	19.8	217	20.6	214	20.3
1,2-DICHLOROETHANE	ND	ND	ND	ND	ND	21.4	206	22.0	209	19.8
TRICHLOROETHENE	---	ND	ND	ND	ND	17.8	188	17.9	188	18.7
TETRACHLOROETHENE	ND	ND	ND	ND	ND	19.2	206	19.3	202	19.5
CHLOROBENZENE	ND	ND	ND	ND	ND	21.9	215	21.9	219	21.8
1,3-DICHLOROBENZENE	ND	ND	ND	ND	ND	20.1	208	21.1	209	20.9
1,4-DICHLOROBENZENE	ND	ND	ND	ND	ND	20.4	208	21.9	217	20.3
1,2-DICHLOROBENZENE	ND	ND	ND	ND	ND	21.5	213	22.8	217	21.3

	BL0317A
VINYL CHLORIDE	ND
1,1-DICHLOROETHENE	ND
T-1,2-DICHLOROETHENE	ND
1,1-DICHLOROETHANE	ND
C-1,2-DICHLOROETHENE	ND
CHLOROFORM	ND
1,1,1-TRICHLOROETHANE	ND
CARBON TETRACHLORIDE	ND
1,2-DICHLOROETHANE	ND
TRICHLOROETHENE	ND
TETRACHLOROETHENE	ND
CHLOROBENZENE	ND
1,3-DICHLOROBENZENE	ND
1,4-DICHLOROBENZENE	ND
1,2-DICHLOROBENZENE	ND

ND = None Detected --- = Below Calibration Limit(1.0 ppb) QC = Quality Control Std BL = Blank

MANTECH

Ref: 98-LH27

April 06, 1998

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Don:

As requested in Service Request #SF-4-312, gas analysis was performed for methane, ethylene, and ethane on samples from Cape Canaveral at site 1381. The samples were received on March 17, 1998. The analyses were performed on March 19, 1998. These analyses were performed as per RSKSOP-194, and the calculations were done as per RSKSOP-175.

If you should have any questions, please feel free to contact me.

Sincerely,

Lisa C Hopkins

Lisa Hopkins

xc: R.L. Cosby
J.T. Wilson
K. Hurt
G.B. Smith
J.L. Seeley JS

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

SF-4-312 03/19/98
Cape Canaveral 1381

Sample	Methane	Ethene Ethylene	Ethane
100ppm CH4	95.6	**	**
100ppm C2H4	**	100.5	**
100ppm C2H6	**	**	105.4
HPHe	**	**	**
Lab Blank	**	**	**
18-1381-MPI	32.9	**	**
MW-S01	1.37	0.016	**
MW-D01	15.3	**	**
MW-S02	1.19	0.006	**
MW-S05	2.44	**	0.002
MW-S05	2.41	**	0.004
Lab Dup			
MW-S03	0.649	0.011	**
MW-S07	0.022	**	**
MW-S08	0.333	**	**
MW-S09	2.09	0.006	**
MW-D09	23.9	**	**
MW-D09	23.4	**	**
Field Dup		**	**
10ppm CH4	10.5	**	**
MW-S10	0.400	**	**
MW-S12	0.569	**	**
MW-S14	0.002	**	**
MW-S15	0.536	**	**
MW-S16	0.584	**	**
MW-S16	0.580	**	**
Lab Dup			
MW-S17	2.21	0.008	**
MW-S18	0.056	**	**
MW-I01	25.3	0.010	0.024
MW-I09	16.4	0.087	**
MW-I09	15.9	0.088	**
Field Dup			
1000ppm CH4	1070.3	**	**
100ppm CH4	94.5	**	**
100ppm C2H4	**	99.9	**
100ppm C2H6	**	**	100.2
Lower Limit of Quantitation			
	0.001	0.003	0.002

Units for the samples are mg/L dissolved in water.
Units for the standards are parts per million.

** denotes None Detected.
* denotes Below Limit of Quantitation.

MANTECH

Ref: 98-MB21
March 20, 1998

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: Steve Vandegrift SV

Dear Don:

Please find attached the analytical results for Service Request SF-4-312 requesting the analysis of aqueous samples from Cape Canaveral NAS, FL to be analyzed for MTBE, BTEXXX and TMBs. The 10 samples were received in capped, 40 mL VOA vials on March 17, 1998. The samples were analyzed on March 19, 1998. All samples were acquired using the Millennium data system. A 6 point (1-1200 ppb) external calibration curve was used to determine the concentration for all compounds.

RSKSOP-122 "Analysis of Volatile Aromatic Hydrocarbons with Separation of Xylene Isomers by Purge & Trap Gas Chromatography" was used for these analyses. Auto-sampling was performed using a Dynatech Precision autosampler system in line with a Tekmar LSC 2000 concentrator.

Sincerely,

Mark Blankenship

xc: R.L. Cosby
J.L. Seeley
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

[redacted]ted 03/20/98 SF-4-312 [redacted]yses for Dr. Kampbell Units = ng/[redacted]yst M. Blankenship

SAMPLE NAME	MTBE	BENZENE	TOLUENE	ETHYLBENZENE	p-XYLENE	m-XYLENE	o-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB
1 GC LAB BLANK	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2 QC, OBSERVED, 20 PPB	22.8	20.8	20.9	22.2	22.9	21.9	21.5	23.9	23.3	18.8
3 QC, TRUE VALUE, 20 PPB	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
4 MP-2 FT17	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	ND	BLQ	BLQ
5 MP-3S FT17	2.2	1.9	2.1	1.9	1.2	BLQ	4.1	BLQ	BLQ	2.2
6 13-1381-MPI	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7 MW-D01	ND	ND	ND	BLQ	BLQ	BLQ	1.3	ND	ND	ND
8 MW-S01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9 MW-D09	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
10 MW-I09	ND	ND	BLQ	ND	ND	ND	ND	ND	ND	ND
11 MW-S09	ND	ND	16.2	5.4	4.6	9.1	8.5	3.9	10.1	3.5
12 MW-S14	ND	ND	ND	ND	ND	4.6	ND	ND	ND	ND
13 MW-I01	ND	ND	BLQ	ND	ND	ND	ND	ND	ND	ND
14 MW-I01 DUPLICATE	ND	ND	BLQ	ND	ND	ND	ND	ND	ND	ND
15 1000 PPB STD	934.7	1156	1172	1107	1132	1126	1167	1101	1100	1189

ND = None Detected; BLQ = Below Limit of Quantitation, 1 ppb

MANTECH

Ref: 98-SH24

March 23, 1998

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection & Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74820

THRU: S.A. Vandegrift SV

Dear Don:

Attached are TOC results for 19 Cape Canaveral Site 1381 liquids submitted March 19, 1998 under Service Request #SF-4-312. Sample analysis was begun March 19, 1998 and completed March 19, 1998 using RSKSOP-102.

Blanks, duplicates, and AQC samples were analyzed along with your samples, as appropriate, for quality control. If you have any questions concerning this data, please feel free to ask me.

Sincerely,

Sharon Hightower

Sharon Hightower

xc: R.L. Cosby
G.B. Smith
J.L. Seeley JS

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

KAMPBELL CAPE CANAVERAL SITE 1381 SF-4-312

SAMPLE	MG/L TOC
MWD01	4.74
MWD09	5.48
MWI01	12.1
MWI09	17.9
MWS01	4.05
MWS02	5.57
MWS03	4.99
MWS05	8.90
DUP	8.71
MWS07	4.61
MWS08	10.9
MWS09	8.97
MWS10	6.75
MWS12	3.48
MWS14	3.21
MWS15	9.81
MWS16	5.20
MWS17	6.37
MWS18	6.28
18-1381-MPI	19.6
WS38	4.61

WS38 std. t.v.=4.92

MANTECH

Ref: MAB19
March 17, 1998

Dr. Don Kampbell
Natinoal Risk Management Research Laboratory
Subsurface Protection & Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, Ok 74820

THRU: S. A. Vandegrift

Dear Don:

As per Service Request #SFTA-4-144, hydrogen analysis was performed onsite at Cape Canaveral NAS, FL, using a RGA3 Reduction Gas Analyzer (Trace Analytical). The analysis began on March 10, 1998 and was concluded on March 13, 1998. The method used for this analysis was "RSKSOP-196" (modification 1). A 6 place (0.5 to 20.0 PPM) external standard curve was used to quantitate the samples. The flowrate was 500 ml\minute. The following data represents the concentration in the dissolved phase.

Cape Canaveral, FL

WELL	H_2 CONCENTRATION (nM)
MW-S13	0.96
1.25 Check Standard	1.23
MW-S07	2.46
18-1381MPI	1.52
MW-S12	4.21
MW-S17	7.44
MW-S03	2.18
MW-S03 (Duplicate)	2.33
MW-S08	7.24
MW-S01	4.05
MW-I01	10.13
MW-S02	1.24
CPT-8-FT17	0.34
5.0 Check Standard	5.21
MW-D7-FT17	8.09
MW-S3-FT17	0.72
MP-2-FT17	2.70

If you have any questions, please see me.

Sincerely,

Mark Blankenship

xc: R. Cosby
J. Seeley
J. Wilson
K. Hurt

MANAGEMENT TECHNOLOGY

Ref: 98-MW27/ck
98-BS25/ck

March 31, 1998

Dr. Don Kampbell
National Risk Management Research Laboratory
Subsurface Protection & Remediation Division
U.S. Environmental Protection Agency
P.O. Box 1198
Ada, OK 74821-1198

THRU: S.A. Vandegrift SV

Dear Don:

Attached are the results of 19 field samples from Cape Canaveral Site 1381 submitted to MERSC as part of S.R. #SF-4-312. The samples were received 3/18/98 and analyzed 3/19/98. The methods used for analysis were Lachat FIA methods 10-107-06-1-A for NH_3, 10-107-04-2-A for $NO_2 + NO_3$, and Waters capillary electrophoresis method N-601 for Cl and SO_4.

Quality assurance measures performed on this set of samples included spikes, duplicates, known AQC samples, and blanks.

If you have any questions concerning these results, please feel free to contact us.

Sincerely,

Mark White

Brad Scroggins

xc: R.L. Cosby
J.L. Seeley
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

CAPE CANAVERAL SITE 1381

Sample	mg/L Cl^-	mg/L SO_4^{-2}	mg/L $NO_2^-+NO_3^-(N)$	mg/L $NH_3(N)$
18-1381-MPI	1050	<1.00	<.1	14.0
MW-S01	105	55.4	(6.18)(6.18)	(.46)(.47)
MW-D01	1020	<1.00	<.1	10.0
MW-S02	(130)(130)	(53.8)(54.7)	.49	.78
MW-S03	88.7	44.5	<.1	.27
MW-S05	-----	------	<.1	2.81
MW-S07	50.6	15.7	<.1	<.1
MW-S08	250	72.5	<.1	.16
MW-S09	170	79.7	<.1	1.28
MW-D09	930	<1.00	<.1	7.20
MW-S10	180	33.0	<.1	.31
MW-S12	53.6	19.7	(<.1)(<.1)	(.16)(.17)
MW-S14	51.1	14.6	<.1	<.1
MW-S15	480	38.9	<.1	.55
MW-S16	(92.4)(86.9)	(12.7)(12.0)	<.1	.21
MW-S17	130	73.9	<.1	.96
MW-S18	180	12.8	<.1	.54
MW-I01	1410	<1.00	<.1	15.8
MW-I09	1640	<1.00	<.1	18.2
BLANK	<1.00	<1.00	<.1	<.1
AQC	33.8	40.8	.60	.26
TRUE VALUE	34.8	44.0	.62	.26
SPIKE REC.	96%	99%	104%	101%

WATER QUALITY ANALYSES
CAPE CANAVERAL - 1381

Sample	Date	D.O.	Redox	Conductivity	Fe#	CO_2	Alkalinity	Sulfide	Manganese	pH	Temp
MW-S05	3-10-98	0.4	-90	1418	2.9	60	360	<.1	<.1	7.8	21.4
MW-S07	3-10-98	1.2	-7	656	0.1	50	200	<.1	<.1	7.5	20.8
MW-S12	3-10-98	1.3	-52	676	0.6	70	220	<.1	<.1	7.6	20.5
MPI-18	3-10-98	0.1	-105	453	0.1	70	800	<.1	<.1	7.5	20.8
MW-S16	3-10-98	2.7	-43	795	0.6	60	340	<.1	<.1	7.9	20.7
MW-S13				CL-VOA only							
MW-S14	3-10-98	7.2	N.D.	N.D.	0.1	35	240	<.1	<.1	7.8	19.
MW-S17	3-10-98	6.7	-72	1278	2.8	70	320	<.1	<.1	7.9	22.3
MW-S15	3-10-98	0.8	-75	2340	2.4	50	240	<.1	<.1	8.0	20.4
MW-S03	3-10-98	0.3	-87	940	1.4	40	300	<.1	<.1	7.8	21.5
MW-S10	3-11-98	0.3	-104	1370	2.8	40	300	0.1	0.1	7.8	
MW-S18	3-11-98	0.2	-101	1289	2.6	45	260	<.1	<.1	8.0	20.2
MW-S08	3-11-98	0.2	-123	1641	1.0	70	280	0.1	<.1	7.8	19.9
MW-D09	3-11-98	0.0	-122	3520	0.4	55	300	0.2	<.1	7.9	23.1
MW-I09	3-11-98	0.2	-169	7100	0.3	120	840	2.0	<.1	7.9	24.9
MW-S09	3-11-98	0.0	-87	1388	3.0	70	300	0.1	0.1	8.0	22.1
MW-IO1	3-11-98	0.2	-103	5500	0.3	65	720	0.3	<.1	7.8	22.5
MW-D01	3-11-98	0.0	-172	4100	0.2	45	440	0.4	<.1	7.9	23.2
MW-S01	3-11-98	0.1	-34	1040	0.1	50	260	<.1	<.1	7.9	21.5
MW-S0[redacted]	3-11-98	1.0	N.D.	1160	[redacted]	95	760	<.1	<.1	7.0	22.5

Cape Canaveral - 1381 Site - March 1998

Sample	$\nabla\delta^{13}C$-TOC
MW-505	7.9
MW-507	6.3
MW-512	5.7
MPI-18	2.6
MW-516	6.1
MW-513	N.D. (dry)
MW-514	3.7
MW-517	4.7
MW-515	4.8
MW-503	4.1
MW-510	6.3
MW-518	5.9
MW-508	3.1
MW-D09	3.8
MW-I09	3.8
MW-509	3.8
MW-I01	5.6
MW-D01	5.5
MW-501	5.6
MW-502	5.7

ATTACHMENT B

RESPONSES TO COMMENTS

PARSONS

Parsons Engineering Science, Inc. • A Unit of Parsons Infrastructure & Technology Group Inc.
1700 Broadway Suite 900 • Denver, Colorado 80290 • (303) 831-8100 • Fax: (303) 831-8208 • www.parsons.com

13 December 1999

Mr. Jerry Hansen
Technical Program Manager
AFCEE/ERT
3207 North Road, Bldg. 532
Brooks AFB, TX 78235-5363

Subject: Responses to AFCEE Comments on the Draft Remediation by Natural Attenuation Treatability Study Addendum for Facility 1381(SWMU 21), Cape Canaveral Air Station, Florida

Dear Mr. Hansen:

This letter provides responses to comments received on the Draft Remediation by Natural Attenuation Treatability Study Addendum for Facility 1381(SWMU 21), Cape Canaveral Air Station, Florida. This draft addendum was prepared by Parsons Engineering Science, Inc. (Parsons ES) for the Air Force Center for Environmental Excellence Technology Transfer Division (AFCEE/ERT) and the 45th Space Wing Facilities at Cape Canaveral Air Station, Florida. The intent of the report was to summarize the results long-term monitoring and to evaluate the effectiveness of remediation by natural attenuation of groundwater contaminated with chlorinated aliphatic hydrocarbons (CAHs) at Facility 1381. The draft addendum was submitted to AFCEE in September 1999. Comments on the draft report were received from AFCEE as reviewed by Mr. Jon Atkinson of AFCEE dated September 27, 1999. Responses to these comments were prepared by Parsons ES and are presented herein.

COMMENTS

Comment 1) Page 7, Sec 2.0, Line 10: The phrase "dissolved total organic carbon (TOC)" is contradictory. If the samples were not filtered in the field or in the lab to remove suspended/colloidal material possibly containing organic matter, suggest using TOC as in Table 1. If the samples were filtered, the correct terminology would be dissolved organic carbon (DOC).

Parsons ES Response: *The groundwater samples were not filtered in the field. Therefore, the correct terminology is "total organic carbon (TOC)." The text will be corrected as such.*

Comment 2) Pages 24 and 25, Table 5: Sample-collection dates need to be added.

Parsons ES Response: *Sample collection dates will be added to Table 5.*

Comment 3) Page 28, Sec 2.4, Sent 2: See comment 1.

Parsons ES Response: *See response to comment 1.*

Comment 4) Page 28, Sec 2.4.1 and Pages 29 and 30, Figs 6 and 7: The text and y-axis labels should state whether these ratios are simple mass ratios or molar ratios. When evaluating natural attenuation, molar ratios are more meaningful than weight ratios.

Parsons ES Response: *Parsons ES will change Figures 6 and 7 to show the molar fraction (ratios) of chlorinated ethenes (PCE, TCE, DCE, VC, and ethene) with distance from the source area. Molar fractions are useful to analyze changes in the molar fraction of individual chlorinated ethene compounds that result from degradation.*

Comment 5) Page 37, Sec 2.4.5.2, Sent 4: Recommend stating the known or plausible source(s) (e.g., explosives, fertilizer) of nitrogen compounds disposed of at the site.

Parsons ES Response: *The source of nitrogen compounds in groundwater is not known. The addendum states the lack of knowledge of possible sources of nitrogen compounds that may have been disposed at the site.*

Comment 6) Page 44, Sec 3.0, Para 3: Recommend stating the recommended frequency of groundwater and surface-water sampling.

Parsons ES Response: *The recommended frequency of groundwater and surface-water sampling will be stated in the text.*

If you have any questions, have additional comments, or require additional information, please call me at (303) 831-8100.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC.

Bruce M. Henry

Bruce M. Henry, P.G.
Project Manager

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