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RISK-BASED REMEDIAL ACTION PLAN FOR THE PETROLEUM, OILS, AND LUBRICANTS (POL) FUEL FARM AREA (PFFA)

CASTLE AIRPORT, CALIFORNIA

Prepared for:

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

and

Air Force Base Conversion Agency
Castle Airport, California

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LIST OF ACRONYMS AND ABBREVIATIONS

°C	degrees centigrade (Celsius)
°F	degrees Fahrenheit
µg	micrograms
µg/L	microgram per liter
2-D	two-dimensional
AFB	Air Force Base
AFCEE	Air Force Center For Environmental Excellence
AMC	Air Mobility Command
AP	air permeability
ASTs	aboveground storage tanks
bgs	below ground surface
BRA	baseline risk assessment
BTEX	benzene, toluene, ethylbenzene, and total xylenes
$CaCO_3$	calcium carbonate
CAH	chlorinated aliphatic hydrocarbon
Cal/OSHA	State of California Occupational Safety and Health Administration
cfm	cubic feet per minute
COC	contaminant of concern
COPC	contaminant of potential concern
CPT	cone penetrometer testing
CSM	conceptual site model
DCA	dichloroethane
DCE	dichloroethene
DO	dissolved oxygen
DTSC	Department of Toxic Substances Control
EC	electrical conductivity
ES	Engineering-Science, Inc.
ET	exposure time
EW	extraction well
Fe^{+2}	ferrous iron
FS	Feasibility Study
ft	foot/feet
ft/day	feet per day

LIST OF ACRONYMS (continued)

ft/ft	foot per foot
ft/s	feet per second
ft^2	square feet
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HSA	hollow-stem auger
HSZ	hydrostratigraphic zone
ID	inside diameter
IDW	investigation-derived waste
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
ISR	*in situ* respiration
ITS	Inchcape Testing Services
kg	kilogram
L	liter
LLNL	Lawrence Livermore National Laboratories
LNAPL	light nonaqueous phase liquid
LTM	long-term monitoring
LUFT	leaking underground fuel tank
MCL	Maximum Contaminant Level
mg	milligrams
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mg/L	milligram per liter
msl	mean sea level
mV	millivolts
MW	monitoring well
N	nitrogen
NOAEL	no-observed-adverse-effect level
NRMRL	National Risk Management Research Laboratory
OD	outside diameter
ORD	Office of Research and Development
ORP	Oxidation/reduction potential

LIST OF ACRONYMS (continued)

OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
Parsons ES	Parsons Engineering Science, Inc.
PAH	polyaromatic hydrocarbon
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene
PEL	permissible exposure limit
PFFA	Petroleum, Oil, and Lubricants Fuel Farm Area
pH	negative logarithm of the hydrogen ion concentration
PID	photoionization detector
POA	point-of-action
POL	Petroleum, Oil, and Lubricants
ppbv	parts per billion, by volume
ppmv	parts per million, by volume
PRG	preliminary remedial goal
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
RAGS	Risk Assessment Guidance for Superfund
RAOs	remedial action objectives
RAP	Remedial Action Plan
RBCLs	risk-based cleanup levels
redox	reduction/oxidation potential
RfD_i	inhalation reference dose
RfD_o	oral reference dose
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RME	reasonable maximum exposure
RNA	remediation by natural attenuation
ROD	Record of Decision
RWQCB	Regional Water Quality Control Board (California)
s	second
scfm	standard cubic feet per minute
SAP	Sampling and Analysis Plan
SB	soil boring

LIST OF ACRONYMS (continued)

SF_i	inhalation slope factor
SF_o	oral carcinogenic slope factor
SOP	standard operating procedure
SVE	soil vapor extraction
SVOC	semivolatile organic compound
SWRCB	State Water Resources Control Board (California)
TCE	trichloroethene
TEMB	tetramethylbenzene
TKN	total Kjeldahl nitrogen
TMB	trimethylbenzene
TO	total organics
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TPH-d	TPH as diesel fuel
TPH-e	TPH, extractable
TPH-g	TPH as gasoline
TPH-jf	TPH as jet fuel
TS	treatability study
TVH	total volatile hydrocarbons
TVHA	total volatile hydrocarbon analyzer
TWA	time weighted average
UC	University of California
UCL	upper confidence level
US	United States
USAF	United States Air Force
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	underground storage tank
VC	vinyl chloride
VMP	vapor monitoring point
VOC	volatile organic compound
VW	vent well
WQSA	Water Quality Site Assessment

EXECUTIVE SUMMARY

General Overview

This report, which was prepared by Parsons Engineering Science, Inc. (Parsons ES) under contract with the United States Air Force Air Mobility Command (AMC) in cooperation with the Air Force Center for Environmental Excellence (AFCEE), describes the development of a risk-based remedial strategy for soil and groundwater contamination at the Petroleum, Oils, and Lubricants (POL) Fuel Farm Area (PFFA) at Castle Airport (formerly Castle Air Force Base [AFB]) in Merced County, California. The purpose of this report is to present evidence of natural attenuation processes in both soil and groundwater at the PFFA site, to evaluate potential risks to human and ecological receptors, and to make recommendations on how to appropriately close this site using a risk-based methodology.

Data collection activities also were designed to satisfy the requirements of the AFCEE-funded Department of Defense (DoD) Petroleum Hydrocarbon Demonstration Program (PHCDP), which has chosen the PFFA as one of its ten Leaking Underground Fuel Tank (LUFT) demonstration sites at California military facilities. This demonstration program is being conducted by the Lawrence Livermore National Laboratory (LLNL) and the University of California (UC). Recommendations of the LLNL/UC expert panel have been incorporated into this Remedial Action Plan (RAP) which is intended to gain final site closure. This RAP is intended to be supplemental to the ongoing Investigation Restoration Program (IRP) and Record of Decision (ROD) process at Castle Airport.

Castle Airport occupies approximately 3,000 acres of land, and is comprised of runway and airfield operations, industrial areas, and several non-contiguous parcels of land located near the former Base. Castle AFB was selected for closure under the Defense Base Closure and Realignment Act of 1990, and was officially closed in September 1995. Environmental investigations, UST removal, and soil and groundwater cleanup operations are ongoing. Some parts of the former Base have been leased to public and private entities.

The PFFA, built in the 1940s, is located in the southern portion of the Main Base Sector and was the bulk fuel storage and distribution facility. Approximately 18 USTs were formerly located at the site and 4 ASTs (3 million gallon total capacity) are currently located at the site. Fuel was originally transported to the PFFA, stored at the facility, then transported via underground pipeline to the flight line.

Extensive previous remedial investigations (RIs) have identified soil, soil vapor, and groundwater contamination at the PFFA. Groundwater monitoring is currently ongoing at the site. The contaminants of potential concern (COPCs) in soil at the PFFA are petroleum hydrocarbons (including the benzene, toluene, ethylbenzene, and xylenes [BTEX]); semivolatile organic compounds (SVOCs) (primarily polynuclear aromatic compounds [PAHs]); and, trichloroethene (TCE). The COPCs in groundwater at the PFFA are petroleum hydrocarbons (including BTEX); naphthalene; and TCE.

Overview of Project Activities

It is the intent of the Air Force to pursue a site-specific, risk-based remediation of the PFFA. The activities conducted pursuant to 1) classifying the release, 2) determining the need for and type of any remedial action, and 3) establishing the level of evaluation necessary to define risk-reduction requirements at this site included characterizing:

- The nature and extent of fuel hydrocarbon and CAH contamination at the site;
- The local geology, hydrogeology, and hydrology that may affect contaminant transport;
- The proximity of the site to drinking water aquifers, surface water, and other sensitive environmental resources;
- The expected persistence, mobility, chemical form, and environmental fate of contaminants in soils and groundwater under the influence of natural physical, chemical, and biological processes;
- The current and potential future uses of the site and its vicinity, including groundwater, and the likelihood of exposure of receptors to other potentially impacted environmental media over time;
- The potential risks associated with chemical contamination under current and foreseeable future conditions;
- The long-term target remedial objectives and chemical-specific concentration goals required to protect human health and the environment; and,
- The treatability of residual and dissolved fuel hydrocarbon contamination using cost effective source-reduction technologies such as soil vapor extraction (SVE) and bioventing.

Patterns observed in the distribution of hydrocarbons, electron acceptors, and biodegradation byproducts indicate that biodegradation is reducing dissolved BTEX concentrations in site groundwater. Geochemical data strongly suggest that biodegradation of fuel hydrocarbons in groundwater is occurring at the site via aerobic respiration and the anaerobic processes of denitrification, iron and manganese reduction, and methanogenesis. Groundwater extraction systems located downgradient from the PFFA, which are primarily designed to contain other sources of contamination, also appear to have the beneficial effect of reducing the potential for uncontrolled contaminant migration from the PFFA. Historical sampling results indicate that contaminants are biodegrading even before reaching these extraction systems.

The measured oxygen concentrations in soil vapor samples indicates that subsurface oxygen concentrations are limiting the rate of biological degradation of petroleum-hydrocarbon residuals in the vadose zone soil. Results from *in situ* respiration testing indicate there are active microorganism populations within the oxygen-depleted zones and that these populations can be stimulated by introducing oxygen-rich air into the subsurface. Therefore, bioventing for deep soils and SVE for shallow soils were determined to be feasible and economic remedial alternatives if engineered remediation is required to reduce long-term risks associated with exposure to contaminated media at this site.

Results of Risk-Based Analysis

To clearly identify remedial actions needed for the PFFA, a conceptual site model (CSM) was developed to analyze the source, potential pathways, and receptors which could be impacted by the contamination. An exposure pathways analysis was completed for the PFFA to determine the likelihood of human or ecological contact with site-related contamination. The exposure pathways analysis included both the present and future potential receptors based on present and future land use scenarios. Based on an evaluation of site data, volatilization from soil contamination and incidental dermal contact with and incidental ingestion of benzene-contaminated soil during excavation/construction activities appear to be the only potential migration pathways for exposure to contaminants of concern at the PFFA. Onsite intrusive workers are the only group of receptors that could come into contact with site-related contamination and only if/when deep excavation/construction activities are conducted. These exposure pathways will not be complete as long as appropriate exposure control measures, which are included as part of this RAP, are implemented at the site.

The CSM and risk analysis also show that although PFFA fuel contamination has impacted the groundwater, an exposure pathway is not likely to be completed onsite due to the depth of groundwater (i.e., 60 feet below ground surface [bgs] at the PFFA). Additionally, the potential for completion of an exposure pathway involving offsite receptors and groundwater is minimal so long as the BTEX plume remains commingled with the TCE plume, which is being remediated by the existing groundwater extraction and treatment system. Existing plans for groundwater treatment should be sufficient to ensure that all reasonable site groundwater exposure pathways remain incomplete in the future. In addition, the observed degree of natural attenuation of BTEX compounds should ensure that BTEX residuals will not remain in the groundwater after the TCE plume is remediated.

In summary, the conclusions of the risk-based site evaluation are:

- Strong evidence exists that natural attenuation of fuel hydrocarbons is occurring at the site;
- Subsurface oxygen concentrations are limiting the rate of biodegradation of fuel residuals in vadose zone soil;
- Active microorganism populations exist in the vadose zone soils, indicating that bioventing is a feasible remedial alternative for source reduction; and
- Based on a site-specific exposure pathways analysis, volatilization from soil contamination and incidental dermal contact with and incidental ingestion of soil contamination during excavation/construction activities appear to be the only potential reasonable pathways for exposure to contaminants of concern.

Based on an analysis of the data collected during this investigation and the results of the previous baseline risk assessment (BRA), a risk-based management strategy for the PFFA has been developed. This strategy consists of developing risk-based cleanup goals and using these goals to estimate the amount of additional source reduction required to minimize risks to potential receptors and to protect environmental resources. If institutional controls combined with proposed source reduction technologies and natural attenuation do not

provide adequate protection of human health or the environment, additional reduction of the contaminant source would be required as a contingency action.

Recommended Remedial Alternative

Although results from this investigation indicated that natural attenuation and institutional controls alone could be protective, without some form of active remediation land use controls and excavation restrictions in the shallow soils would be required. Although natural attenuation would be protective of downgradient groundwater receptors, without some form of active remediation contaminant concentrations in the vadose zone would remain above levels developed to protect groundwater quality immediately beneath the site. Based on a present worth cost analysis, which included reduced costs for long-term groundwater monitoring as a result of engineered remediation and site closure, and the expected public and regulatory preference for removing excavation restrictions and limiting the need for land use controls, engineered remediation is recommended for the site. Three remedial alternatives were developed to more rapidly achieve the desired contaminant reductions. The comparative remedial analysis presented in this RAP shows that the best combination of risk reduction and low cost remediation can be achieved by implementing focused SVE and *in situ* bioventing of residual contamination in the vadose zone source areas. In addition to the SVE/bioventing alternative, excavation and disposal of shallow, contaminated soils was also evaluated. Excavation and disposal of shallow contaminated soils would achieve the same degree of risk reduction as SVE of the shallow soils, but at a significantly higher cost.

Although the groundwater exposure pathway is not complete at this site, simulation of the SVE/bioventing alternative using the BIOSCREEN contaminant transport model suggeststhat this alternative has the significant added benefit of achieving drinking water MCLs for BTEX compounds for groundwater within 5 years. Based on this evaluation and the results of bioventing pilot tests, a full-scale SVE/bioventing design has been completed and is included in this RAP.

To confirm that the predicted degree of remediation is being attained and to ensure that no unacceptable receptor exposures to chemical contamination could occur at the site, a long-term monitoring (LTM) plan is included in this RAP. LTM data will be used to determine when engineered remediation is no longer required and when RBCLs have been attained.

SECTION 1
INTRODUCTION

1.1 PURPOSE AND SCOPE

Parsons Engineering Science, Inc. (Parsons ES), [formerly Engineering-Science, Inc. (ES)] was retained by the United States Air Force's (USAF) Air Mobility Command (AMC) and Air Force Center for Environmental Excellence (AFCEE) to prepare a remedial action plan (RAP) in support of a risk-based remediation decision for soil and groundwater contaminated with fuel hydrocarbons at the Petroleum, Oils, and Lubricants (POL) Fuel Farm Area (PFFA) at Castle Airport (formerly Castle Air Force Base [AFB]) in Merced County, California. Risk-based remediation is designed to combine natural physical, chemical, and biological processes with low-cost source removal technologies such as *in situ* bioventing, as necessary, to economically reduce potential risks posed by subsurface contamination.

This RAP develops and describes a recommended remedial action to be implemented at the PFFA that would protect human health and the environment from potentially unacceptable risks due to exposure to site-related contamination in soil and groundwater. The Source Control Operable Unit (SCOU) sites that are part of the PFFA, and therefore also addressed by this RAP, are described in detail in Section 1.4. Concentrations of individual volatile contaminants were detected in subsurface soil, soil vapor, and groundwater samples collected from the PFFA near fuel pump houses, truck filling stands, along the railroad tracks that were formerly used to transport fuel to the aboveground storage tanks (ASTs), along subsurface fuel piping, and near underground storage tanks (USTs).

Three remedial approaches that rely on natural contaminant attenuation processes alone or both natural contaminant attenuation processes and engineered solutions were evaluated for the site. The remedy proposed in this RAP would ensure that no hazardous substances would migrate at concentrations that may pose a risk to human health and the environment beyond an area that can be placed under reliable exposure controls [i.e., beyond the proposed point of action (POA)].

A site-specific exposure pathways analysis was completed for PFFA as part of this effort to ensure that existing and predicted future concentrations of hazardous substances would not pose a threat to current and foreseeable future onsite and offsite receptors. The site-specific analysis demonstrates that no exposure pathway involving groundwater would be complete for onsite human receptors given the depth to shallow groundwater (i.e., approximately 60 feet below ground surface [bgs]) and the future groundwater uses in the immediate area, and that site-related contamination will not migrate in groundwater beyond the proposed POA at concentrations in excess of promulgated groundwater quality standards. However, the site-specific analysis indicated that both current and future workers engaged in shallow (i.e., to 10 feet bgs) and deeper (i.e., to 20 feet bgs) excavation activities could come into contact with site-related contamination. Exposure routes considered reasonable included inhalation of chemicals volatilizing from disturbed soils, incidental dermal contact with soil contaminants, and incidental ingestion of contaminated soil particles. Consequently, the risk

analysis focused on the degree of soil remediation required to prevent unacceptable exposures via these pathways.

Although results from this investigation indicated that natural attenuation and institutional controls alone would be protective of downgradient groundwater receptors, without some form of active remediation in both the shallow and deep vadose zone soils, contaminant concentrations in the vadose zone would remain above levels developed to protect groundwater quality immediately beneath the site. If this contamination were not remediated, it is likely that groundwater use restrictions, groundwater monitoring, and institutional controls would be required for at least 30 years. Based on a present worth cost analysis, which included reduced costs for long-term groundwater monitoring as a result of engineered remediation and site closure, and the expected public and regulatory preference for removing excavation restrictions and limiting the need for land use controls, engineered remediation for both the shallow and deep vadose zone soils is recommended for the site.

The recommended remedy provides for the removal of hazardous substances from the soil and groundwater through the combined use of low-cost engineered source reduction activities and natural physical, chemical, and biological processes that are documented to be occurring at the site. The analysis included in this RAP demonstrates that supplementing these natural processes with engineered remedial activities will enhance and expedite site cleanup. This RAP is being submitted for regulatory review and approval.

The activities conducted pursuant to the preparation of this RAP included focused site investigation activities and data analysis to characterize:

- The nature and extent of fuel hydrocarbon contamination at the site;
- The local geology, hydrogeology, and hydrology that may affect contaminant transport;
- The current and potential future uses of groundwater and exposure of receptors to other potentially impacted environmental media;
- The proximity of the site to drinking water aquifers, surface water, and other sensitive environmental resources;
- The expected persistence, mobility, chemical form, and fate of hazardous substances in the soil, soil vapor, and groundwater under the influence of natural physical, chemical, and biological processes; and
- The treatability of residual and dissolved fuel contamination using low-cost source removal technologies such as bioventing and soil vapor extraction (SVE).

It is the intent of the Air Force to pursue a site-specific, risk-based remediation of the PFFA. Even though contaminants were detected in soil and soil vapor and measured in groundwater at concentrations above Water Quality Site Assessment (WQSA) thresholds and promulgated drinking water standards, a site-specific risk analysis demonstrates that existing site contamination does not pose a risk to current or future nonintrusive industrial workers on the basis of site-specific exposure assumptions. However, the existing site contamination could pose a risk to future intrusive workers (e.g., construction workers performing excavation work and exposed to deeper contaminated soil). Therefore, remedial alternatives for soil

were evaluated as part of this RAP. Contaminants in soil and soil vapor also were detected above the WQSA thresholds designed to protect groundwater quality.

While meeting WQSA thresholds is not an *a priori* goal of this RAP, the evaluated remedial alternatives for soil included technologies which could achieve WQSA thresholds. Achieving site closure in the most cost-effective manner is also a goal of this RAP. Since using a robust technology which could meet WQSA thresholds throughout the PFFA resulted in lower long-term monitoring, site investigation, and administrative costs, meeting WQSA thresholds was considered complementary to the stated goals of this RAP.

The risk analysis shows that no exposure pathway involving offsite receptors has been or will be completed due to the existing groundwater extraction and treatment system, which is remediating groundwater contaminated with trichloroethene (TCE) from sources outside the PFFA. Existing plans for groundwater extraction and treatment should be sufficient to ensure that the groundwater exposure pathway also remains incomplete in the future. In addition, the natural attenuation of fuel hydrocarbon compounds should ensure that dissolved fuel residuals will not remain in site groundwater after the TCE plume is remediated.

A quantitative assessment of the expected effectiveness of the recommended remedial action suggests that WQSA thresholds for soil and soil vapor and groundwater quality standards can be achieved at every point at the site by implementing the recommended remedial alternative. Although historically fuel hydrocarbon compounds, including benzene, toluene, ethylbenzene, and xylenes (BTEX), have been detected in samples from monitoring wells (MWs) at the PFFA, concentrations have been decreasing. As part of the recommended remedial alternative, annual monitoring will be conducted to ensure that site contaminants continue to decrease in mass and toxicity, and that no site-related contamination migrates offsite at concentrations above the proposed risk-based cleanup levels (RBCLs) or beyond the area under reliable exposure controls.

1.2 SUMMARY OF PROPOSED TYPE OF CLEANUP

The Air Force intends to implement a risk-based remedial action at the PFFA that is sufficient to minimize contaminant migration and eliminate potential risks to human health and the environment. The proposed remedial action will remove site-related contaminants that persist in site media above health-protective RBCLs and prevent site-related contaminants from migrating at concentrations above the RBCLs to areas beyond appropriate exposure controls. It also is likely that promulgated State of California groundwater quality standards (i.e., maximum contaminant level [MCLs]) will be fully achieved at the site over time. However, meeting these state standards at every point in the impacted area is not a goal of this RAP since it is not necessary to protect human health and the environment.

The site characterization data presented in this RAP show that individual volatile compounds are present in soil, soil vapor, and groundwater at concentrations above WQSA thresholds and state standards. No measurable light nonaqueous phase liquid (LNAPL) was found in any of the MWs. Data presented in this RAP suggest that the source of groundwater contamination is fuel residuals sorbed onto vadose zone soils, which partition to infiltrating water or directly to groundwater during times of higher groundwater elevation. The contaminants sorbed onto shallow vadose zone soils (the upper 20 feet bgs) probably resulted from vertical migration from surface fuel spills. A more extensive smear zone of residual

soil contaminants and soil vapor contaminants exists in the lower vadose zone due to the declining groundwater table. As groundwater levels declined, contaminants in groundwater partitioned to the remaining vadose zone as both vapors and as residuals remaining adsorbed onto soil particles.

Supplementing natural processes with source removal through excavation of soils, SVE, and *in situ* bioventing are options that were evaluated in this study and are discussed in Sections 7 and 8. The remedial alternative evaluation presented in this RAP indicates that the site could be a candidate for site closure within about 5 years provided adequate engineered actions are implemented to significantly reduce the soil contamination sources at the site. Once the site is closed, it would be unnecessary for the Air Force to undertake additional remedial actions or site investigations, including monitoring, at the PFFA. Long-term compliance monitoring is proposed to support efforts to close the site. Long-term compliance monitoring is a necessary element of the proposed remedial action to confirm that the predicted degree of remediation is attained.

1.3 REPORT ORGANIZATION

This RAP consists of 10 sections, including this introduction, and 7 appendices. Section 2 summarizes the site characterization activities performed by Parsons ES. Physical characteristics of the PFFA and the nature and extent of soil, soil vapor, and groundwater contamination are described in Sections 3 and 4, respectively. Section 5 presents the proposed RBCLs. Section 6 documents the effects of natural physical, chemical, and biological processes on site-related contaminants, and summarizes predictions of how these processes will affect soil, soil vapor, and groundwater contamination over time. Section 7 presents contaminant treatability pilot test results and evaluates source removal technologies. A comparative analysis of three candidate remedial alternatives is discussed in Section 8. Section 9 is a detailed implementation plan for the recommended remedial alternative. A site-specific long-term monitoring plan is presented in Section 10.

Appendix A presents soil, groundwater, and soil vapor analytical results from previous investigations. Appendix B contains the borehole logs, well construction data, and groundwater elevation data. Appendix C contains *in situ* respiration test and air permeability test data and calculations used for source removal feasibility testing. Appendix D contains RBCL calculations and chemical profiles for each chemical evaluated as part of this RAP. Appendix E summarizes the cost estimates of remedial alternatives considered in detail within this RAP. Appendix F presents a site-specific sampling and analysis plan (SAP) for use during long-term monitoring at the site.

1.4 SITE DESCRIPTION AND HISTORY

Castle Airport (formerly Castle AFB) is located in Merced County, California, approximately 5 miles northwest of the city of Merced (Figure 1.1). It occupies approximately 3,000 acres of land, and is comprised of runway and airfield operations, industrial areas, and several non-contiguous parcels of land located near the former Base. Castle AFB was selected for closure under the Defense Base Closure and Realignment Act of 1990, and was officially closed in September 1995. Environmental investigations, UST removal, and soil and groundwater cleanup operations are ongoing. Some parts of the former Base have been leased to public and private entities.

FIGURE 1.1

FACILITY LOCATION MAP

Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.

Oakland, California

The PFFA, built in the 1940s, is located in the southern portion of the Main Base Sector and was the bulk fuel storage and distribution facility (Figure 1.2). Approximately 18 USTs and 4 ASTs (3 million gallon total capacity) are located at the site. Fuel was originally transported to the PFFA by rail or truck, stored at the facility, then transported via underground pipeline to the flight line. Prior to Base closure, fuel was transferred to the ASTs via pipelines from off-Base refineries and then transported the flight line via tanker truck. Subsequent to Base closure, the existing pipelines have been out of service and properly cleaned and sealed. Of the 18 USTs, only 4 are currently in use (near Building 502). Most of the site is paved with asphalt or concrete, although there are also large areas with a gravel or grass/dirt cover.

In addition to general fueling operations within its boundaries, the PFFA includes 6 sites that have been investigated as potentially separate source areas of soil and groundwater contamination (Figure 1.3). These sites are:

- Building 917 (B917). Building 917 was the pumphouse for the wastewater treatment plant located south of the PFFA.
- Discharge Area 7 (DA7). DA7 is located north of Building 526 in the western portion of the PFFA. It is the site of the former Entomology Yard, where a pesticide equipment rinse area was located from the 1940s until 1979. Rinse water from cleaning operations was discharged at the site. Four abandoned USTs associated with fuel distribution operations until the 1950s are located at DA7.
- Building 508 (B508). Building 508 is the former fuels laboratory and the former location of an oil/water separator removed in 1996. Fuel contaminated with spent acids and solvents was discharged to the oil/water separator and then to the sanitary sewer from B508.
- Building 59 (B59). Building 59, located north of the ASTs, was used for vehicle refueling and maintenance operations. A 100-gallon oil/water separator was removed from the east side of B59 in 1996.
- Building 79 (B79). Building 79, also located north of the ASTs, was the location of a wash rack and oil/water separator.
- Sanitary Sewer System Segment 8 (SS8). A portion of the sanitary sewer system runs north-south approximately 80 feet west of B508 toward B917.

Because all six sites listed above are within the PFFA boundary, this RAP is intended to implement remedial action and closure at all 6 of these sites in addition to the PFFA.

1.5 SUMMARY OF PREVIOUS REMEDIAL INVESTIGATIONS

Extensive previous remedial investigations (RIs) have identified soil, soil vapor, and groundwater contamination at the PFFA (Jacobs, 1995a). Previous sampling activities included:

- Near surface and subsurface soil vapor surveys for volatile organic compounds (VOCs);

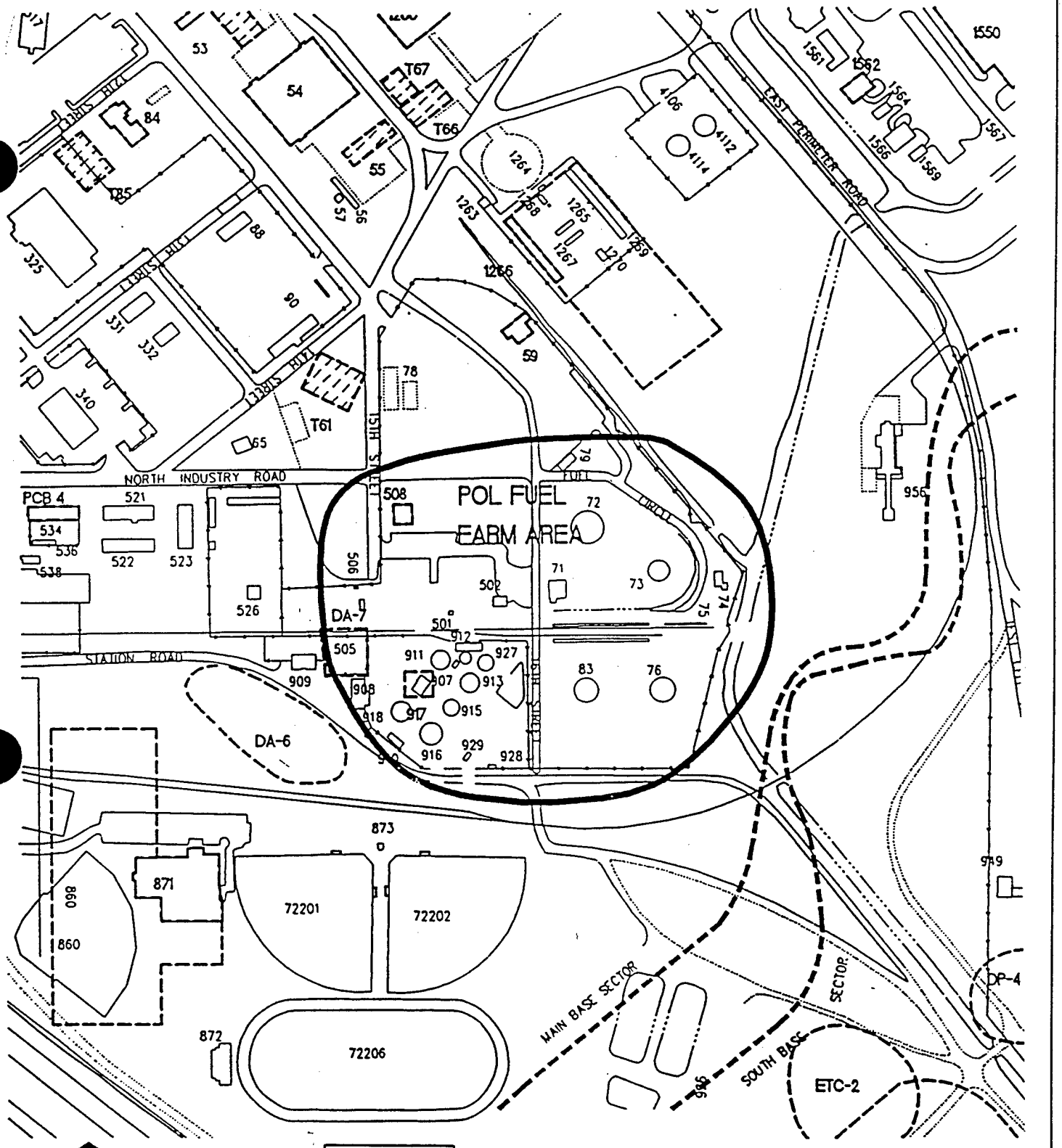

FIGURE 1.2

SITE LOCATION MAP

PFFA
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.

Oakland, California

SOURCE: Jacobs, 1995.

- Near surface and subsurface soil sampling for total petroleum hydrocarbons (TPH), VOCs, semivolatile organic compounds (SVOCs), metals, pesticides, polychlorinated biphenyls (PCBs), and selected physical characteristics, such as pH, grain-size distribution, and total organic carbon (TOC); and,
- Groundwater sampling for TPH, VOCs, and SVOCs from both discrete samples (Hydropunch®) and samples collected from MWs.

Groundwater monitoring is currently ongoing at the site.

1.5.1 Soil and Soil Vapor

The contaminants of potential concern (COPCs) in soil at the PFFA, based on a 1995 BRA and comparison of sampling results with the Preliminary Water Quality Site Assessment (PWQSA) values for Castle Airport, are petroleum hydrocarbons (including the BTEX compounds); SVOCs (primarily polynuclear aromatic compounds [PAHs]); and, TCE (Jacobs, 1995a). The PWQSA values used for the RI were: 100 milligrams per kilograms (mg/kg) TPH; 5 micrograms per kilogram (µg/kg) benzene, 5 µg/kg toluene, 5 µg/kg ethylbenzene, 5 µg/kg total xylenes, and 50 µg/kg TCE. Subsequent to the RI, the PWQSA values were replaced with the WQSA thresholds for both soil and soil vapor based on depth of contamination (Waste Policy Institute). The WQSA values and a comparison of COPC concentrations at the PFFA to WQSA thresholds are provided in Section 4.

Soil and soil vapor sampling locations are provided in Section 4 and Appendix A. Detected analytes and contaminant concentrations for VOCs in soil and soil vapor from all sampling activities are provided in Appendix A. The maximum concentrations for all contaminants detected in soil and soil vapor at the PFFA during the previous RIs are provided in Table 1.1. Based on the RI, the PAH contamination appears to be directly correlated with the distribution of fuel contamination. TCE was detected in only one soil sample at a concentration of 0.6 mg/kg at 44.5 feet bgs at PFFASB17. No significant sources of chlorinated compounds have been identified at the PFFA. Previous investigations identified four primary areas of vadose zone contamination: near the fuel pumping station (Building 71), near the east end of the railroad tracks north of AST 76, near Buildings 501 and 502, and north of the abandoned USTs at DA7.

Soil moisture, pH, and TOC content also were measured for selected soil samples collected during the previous RIs. For vadose zone soil samples, soil moisture content ranged from 1.5 to 26.7 percent by weight (% by wt.), with an average soil moisture content calculated at 11.1%. Soil pH values were measured between 4.8 and 8.6, with 85 percent of samples having pH concentrations between 6 and 8.

TOC concentrations were measured in soil samples collected from the vadose zone and the saturated zone. For vadose zone samples, except for one sample collected from PFFASB32 at 24 feet bgs in which a concentration of 3,400 mg/kg (0.34%) TOC was detected, all other TOC concentrations were either below the laboratory detection limit of 2,000 mg/kg (0.20%) or ranged from 60 mg/kg (0.006%) to 200 mg/kg (0.020%). For three saturated zone samples collected from MW969, MW970, and MW971, TOC concentrations were below laboratory detection limits, which varied from 2,300 mg/kg (0.23%) to 2,400 mg/kg (0.24%).

1.5.2 Groundwater

Based on the 1995 BRA, the COPCs in groundwater at the PFFA are petroleum hydrocarbons (including BTEX); naphthalene; and TCE. The maximum concentrations of COPCs historically detected in groundwater at the PFFA are: 2.5 milligrams per liter (mg/L) TPH; 1,500 micrograms per liter (µg/L) benzene, 640 µg/L toluene, 89 µg/L ethylbenzene, 370 µg/L total xylenes, 45 µg/L naphthalene and 26 µg/L TCE. The maximum concentrations for all contaminants detected in groundwater at the PFFA during previous RIs are provided in Table 1.2. Sampling locations are provided on Figure 1.3.

During the most recent sampling event conducted as part of this RAP and during regular groundwater monitoring in 1997, much lower concentrations have been measured than the historical maximums shown in Table 1.2. Groundwater extraction wells (EWs) are located north and northwest of the PFFA (Figure 1.3). Although these EWs are designed and operated to capture and treat a more extensive TCE plume north of the PFFA, the groundwater extraction and treatment systems have the added benefit of remediating groundwater migrating from the PFFA. The most recent sampling results and a discussion of historical reductions in COPC concentrations is provided in Sections 4 and 6. Detected analytes and contaminant concentrations for VOCs in groundwater from all sampling activities at the PFFA are provided in Appendix A. To date, the highest concentrations of groundwater COPCs have been detected in a grab sample collected from PFFASB38, located near one of the source areas at Building 71, and at monitoring wells MW531 (now dry), JM11, and JM12, which are the first MWs located downgradient from two of the source areas — Building 71 and near Buildings 501 and 502 (Figure 1.3). Based on these observations, four additional MWs (MW965, MW966, MW967, and MW968) were installed in March 1997 within these source areas and the previously installed MWs (Figure 1.3). Additional MWs also were installed downgradient from DA-7 (MW969) and downgradient from MW531, JM11, and JM12 (MW970 and MW971). After installation, these seven new MWs were sampled in preparation for this RAP. Results from the RAP sampling activities are discussed in Sections 4 and 6.

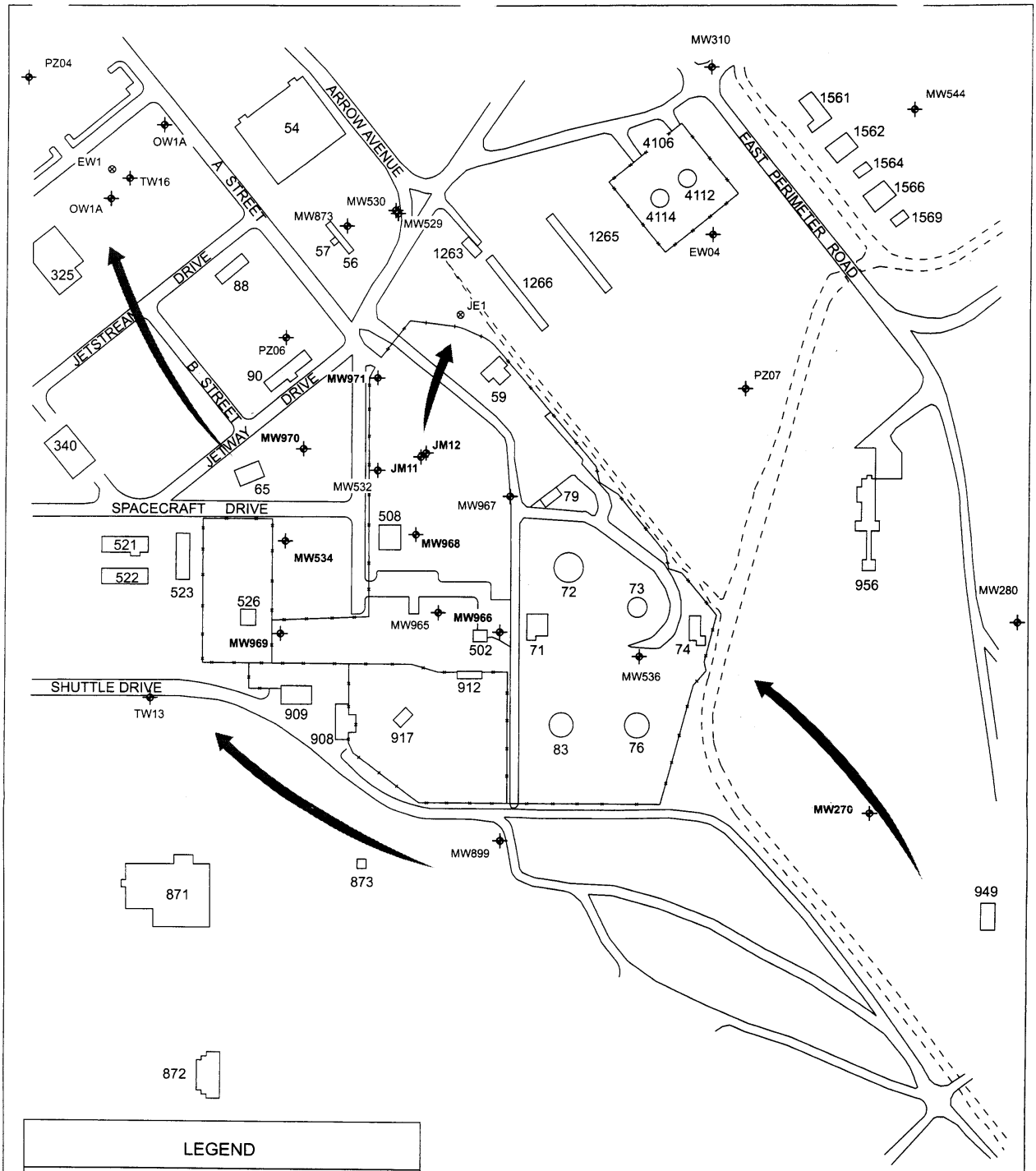

FIGURE 1.3

SITE MAP AND MONITORING WELL LOCATIONS

PFFA RAP
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.
Oakland, California

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TABLE 1.1
Maximum Detected Historical Contaminant Concentrations For Chemicals of Concern in Soil Vapor and Soil

PFFA RAP

Castle Airport, California

Analyte	Matrix	Concentration	Location
TPH-g	soil vapor	54,000 ppmv	PFFAVMP14
Benzene	soil vapor	1,200 ppmv	PFFAVMP14
Toluene	soil vapor	820 ppmv	PFFAVMP14
Ethylbenzene	soil vapor	196 ppmv	PFFASB39
Xylenes, Total	soil vapor	440 ppmv	PFFAVMP14
1,2,4-TMB	soil vapor	29 ppmv	PFFASG20
1,3,5-TMB	soil vapor	115 ppmv	PFFASG20
4-Ethyltoluene	soil vapor	30 ppmv	PFFASG20
Bromobenzene	soil vapor	0.34 ppmv	PFFASB02
PCE	soil vapor	11.2 ppmv	B917SG04
TCE	soil vapor	0.62 ppmv	PFFASB22
1,1-DCE	soil vapor	0.63 ppmv	PFFASB02
1,1,2-TCA	soil vapor	3.5 ppmv	DA7SB14
VC	soil vapor	7.4 ppmv	PFFASB02
TPH-g	soil	28,000 mg/kg	PFFAVMP14
TPH-d/JP4	soil	4,000 mg/kg	SB-529
Benzene	soil	12 mg/kg	PFFAVMP14
Toluene	soil	80 mg/kg	PFFAVMP14
Ethylbenzene	soil	61 mg/kg	SB-529
Xylenes, Total	soil	380 mg/kg	SB-529
1,2,4-TMB	soil	120 mg/kg	PFFASB15
1,3,5-TMB	soil	37 mg/kg	PFFASB15
Naphthalene	soil	18 mg/kg	PFFASB15
p-Isopropyltoluene	soil	9.6 mg/kg	PFFASB15
n-Propylbenzene	soil	24 mg/kg	PFFASB15
Isopropylbenzene	soil	15 mg/kg	PFFASB15
n-Butylbenzene	soil	16 mg/kg	PFFASB15
sec-Butylbenzene	soil	9.3 mg/kg	PFFASB06
tert-Butylbenzene	soil	0.71 mg/kg	DA7SB05
Anthracene	soil	0.23 mg/kg	PFFASB37
Acenaphthene	soil	0.09 mg/kg	PFFASB37
Benzo(a)anthracene	soil	0.49 mg/kg	PFFASB37
Benzo(a)pyrene	soil	0.13 mg/kg	PFFASB37
Benzo(b)fluoranthene	soil	0.32 mg/kg	PFFASB37
Benzo(g,h,i)perylene	soil	0.063 mg/kg	PFFASB37
Benzo(k)fluoranthene	soil	0.12 mg/kg	PFFASB37
bis-(2-ethylhexyl) phthalate	soil	0.36 mg/kg	PFFASB04
Chrysene	soil	0.44 mg/kg	PFFASB37
Dibenzofuran	soil	0.064 mg/kg	PFFASB37
di-n-Butyl-phthalate	soil	0.51 mg/kg	PFFASB10
Fluorene	soil	0.13 mg/kg	PFFASB37
Fluoranthene	soil	1.2 mg/kg	PFFASB37
Ideno(1,2,3-c,d)pyrene	soil	0.068 mg/kg	PFFASB37
2-Methylnaphthalene	soil	7.3 mg/kg	PFFASB17
Phenanthrene	soil	1.4 mg/kg	PFFASB37
Pyrene	soil	1.0 mg/kg	PFFASB37
Chlorobenzene	soil	0.4 mg/kg	DA7SB01
PCE	soil	0.0054 mg/kg	DA7SB11
TCE	soil	0.6 mg/kg	PFFASB17

DCE: dichlorethene DCB: dichlorobenzene TMB: trimethylbenzene

DCA: dichloroethane TCA: trichloroethane VC: vinyl chloride

TABLE 1.2
Maximum Detected Historical Contaminant Concentrations For Chemicals of Concern in Groundwater

PFFA RAP

Castle Airport, California

Analyte	Matrix	Concentration	Location
TPH-g	groundwater	2.5 mg/L	JM11
Benzene	groundwater	1,500 µg/L	JM11
Toluene	groundwater	640 µg/L	JM11
Ethylbenzene	groundwater	89 µg/L	JM11
Xylenes, Total	groundwater	370 µg/L	JM11
1,2,4-TMB	groundwater	110 µg/L	PFFASB38
1,3,5-TMB	groundwater	35 µg/L	PFFASB38
Naphthalene	groundwater	45 µg/L	PFFASB38
2-Methylnaphthalene	groundwater	28 µg/L	PFFASB38
sec-Butylbenzene	groundwater	1.7 µg/L	JM11
tert-Butylbenzene	groundwater	3.0 µg/L	JM11
Isopropylbenzene	groundwater	17 µg/L	PFFASB38
p-Isopropyltoluene	groundwater	6.2 µg/L	PFFASB38
n-Propylbenzene	groundwater	21 µg/L	PFFASB38
Acetone	groundwater	14 µg/L	MW970
Chlorobenzene	groundwater	0.60 µg/L	MW530
1,1-DCA	groundwater	1.0 µg/L	MW534
1,2-DCA	groundwater	2.0 µg/L	MW533
1,1-DCE	groundwater	1.8 µg/L	TW16
cis-1,2-DCE	groundwater	36 µg/L	MW536
Methylene Chloride	groundwater	1.2 µg/L	JM11
PCE	groundwater	3.7 µg/L	JM11
TCE	groundwater	26 µg/L	MW531

TPH-g: total petroleum hydrocarbons as gasoline
TPH-d: total petroleum hydrocarbons as diesel
TPH-jf: total petroleum hydrocarbons as jet fuel

DCE: dichlorethene
DCA: dichloroethane
TCB: trichlorobenzene
DCB: dichlorobenzene
PCE: tetrachloroethene
TCE: trichloroethene
TMB: trimethylbenzene

SECTION 2

SITE CHARACTERIZATION ACTIVITIES

To fully characterize the nature and extent of fuel hydrocarbon contamination at and downgradient from the PFFA and collect site-specific data documenting the effects of natural contaminant attenuation processes, various field investigation procedures were conducted by Parsons ES at the PFFA from May 1997 through March 1998 in support of this RAP. Sufficient data were collected to conduct a quantitative fate and transport analysis, perform an exposure pathways analysis, and evaluate the potential treatability of contaminated media using low-cost remedial technologies and approaches. Emphasis was placed on filling data gaps identified during previous RIs, collecting data relevant to documenting the biodegradation of fuel hydrocarbons in soil and groundwater, and collecting design information which would be needed for any potential remedial actions.

2.1 SCOPE OF DATA COLLECTION ACTIVITIES

The field investigation focused on collecting data on the specific chemical constituents that may drive potential risks and impact the remedial actions for the PFFA. The COPCs for the PFFA were identified based on a 1995 BRA conducted during the previous RI. These COPCs include TPH, BTEX, naphthalene, and TCE. Field and other fixed-base analytical data relevant to documenting biodegradation and assessing the effectiveness of low-cost source removal technologies also were collected.

The activities completed at the PFFA in preparation of this RAP were conducted using the approach and methodologies presented in both the *Work Plan for a Preliminary Evaluation of Intrinsic Remediation and Bioventing Feasibility at the Petroleum, Oils, and Lubricants Fuel Farm Area (PFFA)* (Parsons ES, 1997a) (hereafter referred to as the "natural attenuation work plan") and the *Bioventing Pilot Test Work Plan for the Petroleum, Oils, and Lubricants Fuel Farm Area (PFFA)* (Parsons ES, 1997c) (hereafter referred to as the "bioventing pilot test work plan"). A preliminary evaluation of data collected from activities described in the natural attenuation work plan were detailed in the *Draft Report To Lawrence Livermore National Laboratory On A Risk-Based Remediation of the Petroleum, Oils, and Lubricants Fuel Farm Area (PFFA)* (Parsons ES, 1997b) (hereafter referred to as the "LLNL report").

The following sampling and testing activities were performed by Parsons ES at the PFFA in preparation of this RAP:

- Collection of soil vapor samples at 8 vapor monitoring point (VMP) locations in March 1997 to evaluate bioventing feasibility;
- Collection of 19 groundwater samples for laboratory analysis of COPCs and geochemical parameters from site MWs in May 1997;
- Drilling and installation of 3 VMPs and one bioventing air injection vent well (VW), including soil and soil vapor sampling, in November 1997 in preparation for performing a bioventing pilot test used to collect full-scale design information;

- Conducting *in situ* respiration tests and air permeability tests in December 1997 as part of the bioventing pilot test; and,
- Collection of soil and soil vapor samples at 4 soil boring locations in March 1998 in the northern portion of the PFFA to identify the areal extent of vadose zone contamination in that area.

Sample locations and analytical results are provided in Section 4. Sampling procedures are discussed in the following sections. The program-specific analyte reporting limits for all analytical methods used to measure COPCs are listed in Table 2.1.

2.2 SOIL AND SOIL VAPOR SAMPLING

Soil and soil vapor sampling was performed to further define the extent of subsurface soil contamination and to determine the potential for lateral and upward diffusion of contaminated soil vapor at the site.

2.2.1 Vapor Monitoring Point/Vent Well Construction and Soil Vapor Sampling

To evaluate whether contaminated vadose zone soils at the PFFA were undergoing natural biodegradation, 11 soil VMPs, 1 vent well (VW), and 4 soil borings (SBs) were installed and sampled during this investigation in locations of previously-identified source areas or previously-identified areas of elevated contaminant concentrations in soil vapor (Jacobs, 1995a). Five (5) additional VMPs proposed for installation and sampling in the natural attenuation work plan (Parsons ES, 1997a) also were attempted. However, samples could not be collected from the 5 additional locations because of subsurface utilities, site access problems, perched groundwater conditions, or difficulty in extracting a sample because of tight soils. Sample locations and sampling results are discussed in Section 4. VW and VMP construction details are provided in Appendix B. Installation and sampling procedures are described below.

Eight (8) of the 11 VMPs were installed in March 1997 using the Geoprobe® system, as described in the natural attenuation work plan and LLNL report. The Geoprobe® is a direct-push sampling system which uses hydraulically-powered percussion to advance sampling tools through unconsolidated soils. The system provides for the rapid collection of soil vapor samples at shallow depths while minimizing the generation of investigation-derived waste (IDW) materials.

All soil vapor samples were screened for total volatile hydrocarbons (TVH), oxygen, and carbon dioxide using the test equipment and methods specified for field soil vapor surveys in the AFCEE protocol documents: *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Hinchee *et al.*, 1992) and *Addendum One to Test Plan and Technical Protocol for a Field Treatability Test for Bioventing: Using Soil Vapor Surveys to Determine Bioventing Feasibility and Natural Attenuation Potential* (Downey and Hall, 1994). The field instruments included a GasTech™ 3252OX for measuring oxygen and carbon dioxide and a GasTech™ TraceTechtor for measuring TVH. These field instruments and their calibration procedures are described in Section 2 and 6 of the Program SAP, respectively. Field screening results are provided in Section 4.

The soil vapor sampling system consists of a soil vapor probe, a vacuum pump and gauge, and dedicated tubing. The soil vapor probe consists of hollow rods attached to a perforated, stainless steel, retractable probe tip. The tubing runs from the tip to the ground surface within the hollow rods. After the probe is driven to the desired depth, it is retracted a minimum of 3 inches to expose the perforated probe tip and a vacuum pump is used to purge the tubing. Once the tubing was purged, the soil vapor sample is collected in a Tedlar bag within a vacuum chamber (Downey and Hall, 1994). The Geoprobe® system and soil vapor sample collection procedures followed those described in detail in the *Program Sampling and Analysis Plan (SAP) for Risk-Based Remediation Demonstrations* (Parsons ES, 1996a). Multi-depth profiling of soil vapor was conducted at each VMP location, at approximately 5- to 10-foot intervals, depending on site conditions and stratigraphy.

Soil vapor samples also were collected in March 1997 from MWs at the PFFA that had exposed screens above the water table and were near suspected or previously identified areas of vadose zone contamination (i.e., MW965, MW966, and MW967). Soil vapor samples also were collected from all three MWs which are now completely screened in the vadose zone due to the declining groundwater table (i.e., MW531, MW533, and MW535) and from the background MW (MW270).

Three (3) of the 8 VMPs installed in March 1997 were permanent completions, constructed using the Geoprobe® with a sacrificial drive point attached to a 6-inch length of 0.5-inch-diameter stainless steel mesh screen, which was in turn connected to 0.375-inch Teflon® tubing. A 1-foot thick sand filter pack was emplaced adjacent to the screen and a bentonite seal was emplaced above the filter pack to the ground surface. The remaining 5 VMPs installed in March 1997 were temporary completions, which consisted of a driving a retractable soil vapor probe to the desired depth and collecting the soil vapor sample, then removing the probe and grouting the borehole to the ground surface.

Subsequent to the installation of the 8 VMPs in March 1997, 3 additional permanent VMPs and 1 permanent VW were installed in November 1997 as part of a bioventing pilot test, as described in the bioventing pilot test work plan. The 3 permanent VMPs installed in November of 1997 were constructed of 0.50-inch inside diameter (ID), Schedule 80 polyvinyl chloride (PVC) casing and 1-inch ID slotted screen intervals (0.020-inch slot size). Flush threaded PVC casing and screen was used with no organic solvents or glues. Four screened intervals were used in each VMP at depths of approximately 10, 20, 35, and 50 feet bgs. The annular space between the vapor monitoring screen filter packs were sealed with a bentonite seal to isolate the monitoring intervals and allow for multi-depth monitoring in the same borehole. The purpose of using multi-depth monitoring points was to verify that air injected during the pilot test was able to provide oxygen across the entire vadose zone.

Borehole logs and well construction details for these 3 VMPs are provided in Appendix B. No soil logging was performed during installation of the 8 VMPs installed in March 1997, whose purpose was to collect soil vapor samples. Sampled depths and results from all VMPs are provided in Section 4.4. Additional details on VMP construction are found in Section 4 (Hinchee et al., 1992) and Volume II, Section 2.6 (USEPA ORD, 1995) of the protocol documents.

The VW was constructed of 4-inch ID Schedule 40 PVC casing, with an interval of 0.04-inch slotted screen. The screened interval was located between 6 and 21 feet bgs. The depth of the bottom of the screened interval for the VW was been selected to coincide with an observed change in lithology (Appendix B). Flush-threaded PVC casing and screen were used with no organic solvents or glues. The filter pack was a clean Lone Star sand with a #8/16 grain size and placed in the annular space of the screened interval. A 3-foot layer of bentonite was placed directly over the filter pack. The remainder of the annular space, except for a 2-foot open area directly below the ground surface, was filled with a bentonite/cement grout to provide a complete seal and minimize potential for short-circuiting of air to the surface during the pilot test. Additional details on VW construction are found in Section 4 (Hinchee *et al.*, 1992) and Volume II, Section 2.5 (USEPA ORD, 1995) of the protocol documents.

After completion of the VW and VMPs, soil vapor samples were collected for field screening analysis of oxygen, carbon dioxide, and TVH prior to the bioventing pilot test. Procedures for soil vapor sampling were similar to those described above. In addition, because these VMPs and the VW were located in an area of the site not extensively investigated during the previous RIs, selected soil vapor samples also were collected for laboratory analysis using the U.S. Environmental Protection Agency (USEPA) Method TO-3 for BTEX and TVH. Soil vapor samples collected for laboratory analysis were collected subsequent to purging and field screening by attaching an evacuated Summa™ canister directly to the VMP. A leak check was performed prior to sampling to ensure that no ambient air could leak into the sampling system and to verify that the canister had not leaked prior to its use.

Soil vapor samples sent at ambient temperature to prevent condensation of hydrocarbons. A completed chain-of-custody record accompanied the samples, which were shipped to Air Toxics, Ltd. of Folsom, California, under subcontract to Quanterra Labs of Denver, Colorado. Both labs meet all required U.S. Air Force and State of California certification requirements.

In March 1998, 4 additional soil borings were drilled to define the areal extent of vadose contamination in the northern portion of the PFFA. These soil borings were drilled using a cone penetrometer test (CPT) rig and equipment. Downhole soil vapor samples were collected during drilling of these 4 soil borings. Soil vapor samples using the CPT were collected using a sample collection system similar to that used with the Geoprobe® and described above. Soil vapor samples from these 4 soil borings were analyzed in the field for TVH, oxygen, and carbon dioxide and selected samples also were submitted for laboratory analysis using the methods and procedures described above. Analytical results for soil vapor samples collected in preparation of this RAP are summarized and presented in tabular form in Section 4.

2.2.2 Soil Sampling

Subsurface soil samples were collected in November 1997 during installation of the VW and 3 VMPs used for the bioventing pilot test. Boreholes were advanced using a hollow stem auger (HSA) drill rig equipped with 8-inch and 10-inch outside-diameter (OD) hollow-stem augers. The 10-inch augers were used to advance the pilot hole for the VW and the 8-inch augers were used for VMPs. Soil samples were collected approximately every 5 feet for

logging purposes; samples were collected continuously at significant lithologic changes or when evidence of contamination was noted. Soil samples were collected in a 2-inch ID split-barrel sampler. The split-barrel sampler was fitted with three pre-cleaned, 2-inch OD by 6-inch long, thin-walled, stainless steel or brass sleeves.

Selection of soil samples for laboratory analysis was based on an evaluation of physical and visual evidence of contamination (e.g. odors and staining), site lithology, as well as headspace or soil vapor screening using both a total volatile hydrocarbon analyzer (TVHA) and a photoionization detector (PID). The TVHA is a platinum catalyst combustion detector calibrated with hexane, which provides a conservative reading representative of TPH vapors present.

Soil samples collected in the sleeves were immediately trimmed and the ends sealed with Teflon® fabric held in place by plastic caps. The samples were labeled, wrapped in plastic, and placed in an ice chest for shipment. A completed chain-of-custody record form accompanied the ice chest.

In March 1998, 4 additional soil borings were drilled and sampled using CPT equipment to define the areal extent of vadose contamination in the northern portion of the PFFA. The CPT rig was equipped with an instrumented piezocone to provide an electronic borehole log for lithologic interpretation. CPT logs from these soil borings are provided in Appendix B.

Soil samples were collected during drilling of these 4 soil borings. Soil sampling with the CPT is accomplished using a piston-type sampler with stainless steel or brass collection tubes. The soil sampler is pushed in a closed position to the desired sampling depth. The inner portion of the sampler is retracted and locked, leaving a hollow sampler. The sampler is then pushed into the undisturbed soil and retrieved.

All soil samples were analyzed for TPH as gasoline and diesel (SW8015 Modified), BTEX (SW8020), and moisture content. All samples with TPH concentrations above the WQSA thresholds also were analyzed for soluble TPH using deionized water extraction (California Title 22, DI-WET Method). Selected samples from the most contaminated zones, based on field screening, also were analyzed for PAHs (SW8310) and ethylene dibromide (SW8260A). Selected samples from different lithologic zones or depths were analyzed for grain-size distribution (ASTM D422), total Kjeldahl nitrogen (TKN) (USEPA 351.2), and TOC (SW9060). Sample analysis was performed by Quanterra Labs of Denver, Colorado, which has been audited by the U.S. Air Force and which meets all quality assurance/quality control (QA/QC) and certification requirements for the State of California.

IDW materials generated during VW and VMP installation was containerized on site in labeled United States Department of Transportation approved 55-gallon drums. The drums were transported to the contaminated soils holding facility located at Castle Airport; no IDW was transported off the Castle Airport facility. Because the IDW consists only of petroleum-contaminated soils, Castle Airport personnel plan to landfarm the soils after enough volume is generated from other ongoing investigations.

2.3 GROUNDWATER SAMPLING

Groundwater samples were collected in May 1997 from existing groundwater MWs at the PFFA to further define the nature and extent of dissolved COPCs. Geochemical data

relevant to documenting the potential for biodegradation of dissolved COPCs and quantitatively investigating environmental fate and transport also were collected. Groundwater samples were collected using the procedures described in the natural attenuation work plan (Parsons ES, 1997a). Procedures also were in accordance with the standard operating procedures (SOPs) developed for the Castle Airport long-term groundwater monitoring program so that results could be compared. Investigation activities included well purging and sampling, water level measurements, and field and fixed-base analytical measurements performed in accordance with the Program SAP.

Groundwater sampling and analysis was performed at the PFFA to evaluate natural attenuation processes in accordance with the *Technical Protocol for Implementing the Intrinsic Remediation (Natural Attenuation) with Long-Term Monitoring Option for Dissolved Fuel Contamination in Groundwater* (Wiedemeier *et al.*, 1995), prepared by Parsons ES and the EPA's Subsurface Protection and Remediation Division. MWs were sampled and analyzed in the field for geochemical parameters relevant to documenting contaminant biodegradation. MWs also were sampled for chemical-specific analysis using fixed-base analytical methods. Each of these activities is described briefly in the following sections. Groundwater sampling locations are shown on Figure 1.3. Results are discussed in Section 4.

2.3.1 Sampling Procedures

Groundwater sampling forms were used to document the specific details of the sampling event for each MW. All equipment to be 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 groundwater and extracted samples. To prevent such contamination, downhole sampling equipment (e.g., sampling pump) and the water level probe and cable used to determine static water levels were thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented below:

- Washed with potable water and phosphate-free laboratory detergent;
- Rinsed with potable water;
- Rinsed with isopropyl alcohol; and
- Rinsed with distilled or deionized water.

When precleaned, disposable sampling equipment was used, the cleaning protocol specified above was not required. Laboratory-supplied sample containers were cleaned and sealed by the laboratory. Any deviations from these procedures were documented in the field scientist's field notebook and on the groundwater sampling record.

Prior to removing any water from the MWs, the static water level was measured. An electric water level probe was used to measure the depth to groundwater below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe was slowly lowered to the bottom of the monitoring well/point and the depth was measured to the nearest 0.01 foot. Based on these measurements, if a downhole pump was used for sampling, the volume of water to be purged from the MW was calculated.

For MWs sampled with non-dedicated downhole pumps (i.e., JM11, JM12, MW965, MW966, MW967, MW968, MW969, MW970, and MW971), MW purging consisted of the removal of at least three casing volumes of water prior to sample collection. Once three casing volumes of water were removed from the MW, purging continued until the temperature, oxidation/reduction potential (ORP), electrical conductivity, pH, and dissolved oxygen (DO) concentrations had stabilized, and if possible, until the purge water became clear. If a dedicated, low flow purge pump was installed in the MW, the SOPs developed under the Castle Airport groundwater sampling program for low-flow purging and sampling were followed.

When sufficient water was available, sample collection commenced immediately after completion of the purge. In all instances, groundwater samples were collected within 24 hours of the purge. For MWs sampled with non-dedicated downhole pumps, groundwater samples were collected with a dedicated bailer. If a dedicated, low flow purge pump was installed in the MW, sample containers were filled directly from the pump discharge tube. The groundwater was directed toward the bottle wall near the top and allowed to run down the inner walls of the sample bottle in order to minimize aeration of the sample. Sample containers were completely filled so that no air space remained in the container.

All purge water, decontamination rinseate, and other wastewaters were placed in a temporary holding tank located at the site. After sampling activities were completed, the water was discharged at the Castle Airport groundwater treatment system under the oversight of the treatment system contractor (Jacobs Engineering).

2.3.2 Field Sampling Methods

Table 2.1 summarizes the types of field measurements completed at the PFFA as part of the RAP sampling. Results of field sampling and screening are used in Section 4 to characterize the nature and extent of groundwater contamination at the PFFA and in Section 6 to assess the potential effects of natural physical, chemical, and biological processes on contaminant concentrations, mass, form, persistence, and mobility.

Because many geochemical parameters for groundwater will change during shipment to a fixed-base laboratory, field measurements were employed. Groundwater samples were analyzed by Parsons ES field scientists for DO, ORP, ferrous iron, soluble manganese, free carbon dioxide, temperature, pH and electrical conductivity. Field parameter values were determined from water samples collected by the same means as those submitted for fixed-base analysis.

As required, field analytical equipment was calibrated according to the manufacturers' specifications prior to field use. Calibration records for field analytical equipment were maintained by Parsons ES, and field calibrations were recorded in the field notebook. Calibration was required for equipment used for onsite measurements of DO, pH, electrical conductivity, temperature, ORP, and the Hach® equipment used for determining the field geochemical parameters listed in Table 2.1.

TABLE 2.1
Analytical Methods and Reporting Limits
PFFA
Castle Airport, California

Targeted Analyte by Matrix	Analytical Method	Field or Fixed-Base	Soil Vapor Reporting Limit	Soil Gas Units	Soil Reporting Limit	Soil Units	Water Reporting Limit	Water Units
SOIL VAPOR								
Benzene	EPA TO-3	Fixed-Base	2.7-3.1	ppmv	-	-	-	-
Ethylbenzene	EPA TO-3	Fixed-Base	2.7-3.1	ppmv	-	-	-	-
Toluene	EPA TO-3	Fixed-Base	2.7-3.1	ppmv	-	-	-	-
Total Xylenes	EPA TO-3	Fixed-Base	2.7-3.1	ppmv	-	-	-	-
TPH-g	EPA TO-4	Fixed-Base	27-31	ppmv	-	-	-	-
C2-C4 Hydrocarbons	EPA TO-3	Fixed-Base	27-31	ppmv	-	-	-	-
SOIL								
Acenaphthene	SW8310	Fixed-Base	-	-	0.2	mg/kg	-	-
Acenaphthylene	SW8310	Fixed-Base	-	-	0.2	mg/kg	-	-
Anthracene	SW8310	Fixed-Base	-	-	0.02	mg/kg	-	-
Benzene	SW8260A	Fixed-Base	-	-	0.62	mg/kg	-	-
	SW8020A	Fixed-Base	-	-	0.0052 to0.0071	mg/kg	-	-
Benzo(a)anthracene	SW8310	Fixed-Base	-	-	0.009	mg/kg	-	-
Benzo(a)pyrene	SW8310	Fixed-Base	-	-	0.015	mg/kg	-	-
Benzo(b)fluoranthene	SW8310	Fixed-Base	-	-	0.012	mg/kg	-	-
Benzo(g,h,i)perylene	SW8310	Fixed-Base	-	-	0.05	mg/kg	-	-
Benzo(k)fluoranthene	SW8310	Fixed-Base	-	-	0.011	mg/kg	-	-
tert-Butylmethylether	SW8260A	Fixed-Base	-	-	2.5	mg/kg	-	-
Chrysene	SW8310	Fixed-Base	-	-	0.04	mg/kg	-	-
Dibenz(a,h)anthracene	SW8310	Fixed-Base	-	-	0.02	mg/kg	-	-
1,2-Dibromomethane	SW8260A	Fixed-Base	-	-	0.62	mg/kg	-	-
1,2-DCA	SW8260A	Fixed-Base	-	-	0.62	mg/kg	-	-
Ethylbenzene	SW8260A	Fixed-Base	-	-	0.62	mg/kg	-	-
	SW8020A	Fixed-Base	-	-	0.0021 to 0.0028	mg/kg	-	-
Fluorene	SW8310	Fixed-Base	-	-	0.04	mg/kg	-	-
Fluoranthene	SW8310	Fixed-Base	-	-	0.04	mg/kg	-	-
Indeno(1,2,3-c,d)pyrene	SW8310	Fixed-Base	-	-	0.03	mg/kg	-	-
Naphthalene	SW8260A	Fixed-Base	-	-	0.88	mg/kg	-	-
	SW8310	Fixed-Base	-	-	0.2	mg/kg	-	-
Phenanthrene	SW8310	Fixed-Base	-	-	0.04	mg/kg	-	-
Pyrene	SW8310	Fixed-Base	-	-	0.04	mg/kg	-	-
Toluene	SW8260A	Fixed-Base	-	-	0.62	mg/kg	-	-
	SW8020A	Fixed-Base	-	-	0.0052 to 0.0071	mg/kg	-	-
TKN	SW9060	Fixed-Base	-	-	9.1	mg/kg	-	-
TOC	SW9060	Fixed-Base	-	-	550	mg/kg	-	-
m- and p-Xylenes	SW8260A	Fixed-Base	-	-	0.31	mg/kg	-	-
o-Xylene	SW8260A	Fixed-Base	-	-	0.31	mg/kg	-	-
Total-Xylene	SW8020A	Fixed-Base	-	-	0.0052 to 0.0071	mg/kg	-	-
TPH-d/JP4	SW8015(D)	Fixed-Base	-	-	1 to 4.4	mg/kg	-	-
TPH-g	SW8015(G)	Fixed-Base	-	-	1 to 4	mg/kg	-	-
GROUNDWATER								
Conductivity	Direct-reading meter	Field	-	-	-	-	0.1	umhos/cm
ORP	Direct-reading meter	Field	-	-	-	-	0.01	mV
Oxygen	Direct-reading meter	Field	-	-	-	-	0.5	mg/L
pH	Direct-reading meter	Field	-	-	-	-	0.1	pH units
Temperature	Direct-reading meter	Field	-	-	-	-	1	degrees C
Ferrous Iron	Hach 8146	Field	-	-	-	-	0.01	mg/L
Manganese	Hach 8034	Field	-	-	-	-	0.1	mg/L
Hydrogen Sulfide	Hach 8131	Field	-	-	-	-	0.01	mg/L
Carbon Dioxide	CHEMetrics 4500	Field	-	-	-	-	10	mg/L
Ammonia	350.1	Fixed-Base	-	-	-	-	0.1	mg/L
Alkalinity	310.2	Fixed-Base	-	-	-	-	10.0	mg/L

TABLE 2.1
Analytical Methods and Reporting Limits
PFFA
Castle Airport, California

Targeted Analyte by Matrix	Analytical Method	Field or Fixed-Base	Soil Vapor Reporting Limit	Soil Gas Units	Soil Reporting Limit	Soil Units	Water Reporting Limit	Water Units
GROUNDWATER (cont'd)								
Nitrate Nitrogen	353.2	Fixed-Base	-	-	-	-	0.05	mg/L
Nitrite Nitrogen	300.0	Fixed-Base	-	-	-	-	0.05	mg/L
Chloride	300.0	Fixed-Base	-	-	-	-	0.5	mg/L
Sulfate	300.0	Fixed-Base	-	-	-	-	0.5	mg/L
TOC	E415.1	Fixed-Base	-	-	-	-	1.0	mg/L
Methane	RSKSOP-175	Fixed-Base	-	-	-	-	0.5	ppbw
Ethane	RSKSOP-175	Fixed-Base	-	-	-	-	0.5	ppbw
Ethene	RSKSOP-175	Fixed-Base	-	-	-	-	0.5	ppbw
Acetone	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
Benzene	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
	SW8020A	Fixed-Base	-	-	-	-	4.0	µg/L
n-Butylbenzene	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
sec-Butylbenzene	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
tert-Butylbenzene	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
Chloroform	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
1,1-DCA	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
cis 1,2-DCE	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
Ethylbenzene	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
	SW8020A	Fixed-Base	-	-	-	-	4.0	µg/L
Isopropylbenzene	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
p-Isopropyltoluene	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
Naphthalene	SW8260A	Fixed-Base	-	-	-	-	5.0	µg/L
PCE	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
n-Propylbenzene	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
TCE	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
Toluene	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
	SW8020A	Fixed-Base	-	-	-	-	4.0	µg/L
1,3,5-TMB	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
	SW8020A	Fixed-Base	-	-	-	-	4.0	µg/L
1,2,4-TMB	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
	SW8020A	Fixed-Base	-	-	-	-	4.0	µg/L
total-Xylene	SW8260A	Fixed-Base	-	-	-	-	0.5	µg/L
	SW8020A	Fixed-Base	-	-	-	-	4.0	µg/L
TPH-g	SW8015M	Fixed-Base	-	-	-	-	50	µg/L

Notes:

ORP : Oxidation/Reduction Potential
mg/L : milligrams per liter
µg/L : micrograms per liter
ppmv : parts per million, by volume
TPH-g : total petroleum hydrocarbons as gasoline
TOC : total organic carbon
TMB : trimethylbenzene
DCA : dichloroethane
DCE : dichloroethene
PCE : tetrachloroethene
TCE : trichloroethene
TKN :total kjeldahl nitrogen

2.3.2.1 Dissolved Oxygen

DO measurements were made during purging and immediately prior to groundwater sample acquisition in a flow-through cell using a direct-reading meter (QED MicroPurge™ system). DO concentrations were recorded after each volume was purged. The stable value recorded at the end of the purge was assumed to represent the aquifer characteristics at each location.

2.3.2.2 pH, Temperature, and Specific Conductance

Because the pH, temperature, and specific conductance of a groundwater sample can change significantly within a short time following sample acquisition. Therefore, these parameters were measured in the field in a flow-through cell by the same technique used for DO measurements.

2.3.2.3 Oxidation-Reduction Potential

The ORP of groundwater is an indication of the relative tendency of a solution to accept or transfer electrons. Oxidation-reduction reactions in groundwater are usually biologically mediated; therefore, the ORP of a groundwater system depends upon and influences rates of biodegradation. ORP can be used to provide real-time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation. The ORP of a groundwater sample taken inside the contaminant plume should be somewhat less than that taken upgradient or crossgradient from the plume.

The ORP of a groundwater sample can change significantly within a short time following sample acquisition and exposure to atmospheric oxygen. Therefore, this parameter was measured in the field in a flow-through cell by the same technique used for DO measurements.

2.3.2.4 Carbon Dioxide

Because microbially-mediated reactions causing biodegradation of fuel hydrocarbons produce carbon dioxide and biologically generated acids, increases in carbon dioxide in groundwater can be used as evidence of biological activity. Carbon dioxide concentrations in groundwater were measured in the field by Parsons ES scientists via titrimetric analysis using CHEMetrics® Method 4500.

2.3.2.5 Ferrous Iron and Manganese

Iron is an important trace nutrient for bacterial growth, and different valence states of iron can affect the ORP of the groundwater and act as an electron acceptor for biological metabolism under anaerobic conditions. Manganese is also a potential electron acceptor under anaerobic conditions. Ferrous iron and manganese concentrations were measured in the field via colorimetric analysis with a Hach® DR/700 portable colorimeter. Hach® Method 8146 for ferrous iron (0 to 3.0 mg/L Fe^{2+}) and USEPA-approved Hach® Method 8034 for soluble manganese (0 to 20.0 mg/L Mn) were used to prepare and quantitate the samples.

2.3.2.6 Sulfide

Sulfate is a potential electron acceptor for fuel-hydrocarbon biodegradation in anaerobic environments, and sulfide is resultant after sulfate reduction. Sulfide concentrations were measured in the field using colorimetric analysis with a Hach® DR/700 portable colorimeter. USEPA-approved Hach® Method 8131 (0.60 mg/L S^{2-}) was used for quantitation of sulfide concentrations.

2.3.3 Analytical Sampling Methods

Groundwater samples were analyzed by fixed-base laboratory for the parameters listed in Table 2.1. Analytes included all of the COPCs (USEPA Method 8260) in addition to electron acceptors and indicators of contaminant biodegradation included in the AFCEE technical protocol for natural attenuation (e.g., nitrate, sulfate, methane/ethene/ethane, and alkalinity). QA/QC samples also were collected and analyzed in accordance with the Program SAP. Sample analysis was performed by Inchscape Testing Services (ITS) of San Jose, California, which has been audited by the U.S. Air Force and which meets all QA/QC and certification requirements for the State of California. Sample results are provided in Section 4.

Analytical data are used in Section 4 to characterize the nature and extent of groundwater contamination at the PFFA and in Section 6 to assess the potential effects of natural physical, chemical, and biological processes on contaminant concentrations, mass, form, persistence, and mobility.

2.4 *IN SITU* RESPIRATION TESTS

As part of source reduction feasibility testing at the PFFA, short-term *in situ* respiration (ISR) tests were conducted at two of the permanent VMPs installed in March 1997 (Section 2.2.1) and at the 3 VMPs installed in November 1997 as part of bioventing pilot test activities. ISR tests are used to quantify the biological uptake of oxygen by soil bacteria and quantify biodegradation rates of fuel hydrocarbons in soil. Procedures for ISR tests as outlined in the Air Force bioventing protocol documents (Hinchee *et al.*, 1992; Downey and Hall, 1994) and the USEPA bioventing manual (USEPA ORD, 1995) were followed.

Initial oxygen concentrations in soil vapor were measured using procedures described in Section 2.2.1 to evaluate whether oxygen conditions in the soil were limiting the rate of biological fuel degradation. ISR tests were performed at the VMPs where biodegradation was indicated by initially low oxygen levels and elevated carbon dioxide levels in the soil vapor. Air (20.8 percent oxygen) was injected into the VMPs for approximately 20 hours to oxygenate local contaminated soils. At the end of the 20-hour period, the air supply was cut off and oxygen, carbon dioxide, and TVH were monitored for the following 48 to 72 hours. The decline in oxygen concentrations over time were then used to estimate rates of bacterial degradation of fuel residuals. ISR test results are presented and discussed in Section 7.

2.5 AIR PERMEABILITY AND OXYGEN INFLUENCE TESTS

As part of bioventing pilot test activities conducted in December 1997, two air permeability (AP) and oxygen influence tests were performed at the PFFA. The objective of the AP and oxygen influence tests was to determine the air permeability of PFFA soils and to determine

extent of the subsurface which could be oxygenated from air injection at a single VW. The purpose of two AP tests was to determine the effect of depth and lithology on the radius of influence. As discussed in Section 3, the soils above 35 feet bgs are generally finer-grained and moister than soils below 35 feet bgs. Since contaminant source areas are generally within either of these two predominant lithologic zones, determination of the effect of depth on the radius of influence was an important design parameter for the full-scale bioventing system. Air permeability and radius of influence were calculated using the modified field drawdown method (Johnson *et al.*, 1990). Procedures for AP tests as outlined in Section 5.6 of the AFCEE bioventing protocol documents (Hinchee *et al.*, 1992) and Volume II, Section 1.5 (USEPA ORD, 1995) were followed.

Air was injected using a portable, 3.0-horsepower positive displacement blower powered by a 25-kilowatt portable diesel generator. The blower is capable of injecting air at approximately 40 standard cubic feet per minute (scfm) under a wide variety of field conditions. Air flow was measured using a thermal anemometer and a variable area air flow meter. Pressure response was measured at each VMP with differential pressure gauges (Dwyer Magnehelic™) to determine the region influenced by the blower. Oxygen response also was measured at each VMP using a portable field instrument (GasTech™ 3252OX).

Each AP test was run for several days to determine a more accurate radius of oxygen influence (treatment radius). Soils were allowed to reach pressure equilibrium between the two AP tests. During a portion of each of the AP tests, helium was mixed with the injected air at a concentration of approximately 1 percent. The helium was used as a tracer gas to verify subsurface air movement and provide additional verification of the expected treatment radius. AP test and oxygen influence test results are presented and discussed in Section 7. Data from the AP tests was used to design the full-scale SVE/bioventing system discussed in Section 9.

SECTION 3

PHYSICAL SETTING

3.1 SITE GEOLOGY AND HYDROGEOLOGY

3.1.1 Lithology and Stratigraphic Relationships

The shallow subsurface stratigraphy at Castle is characterized by Holocene to Pleistocene alluvial deposits consisting of interbedded sequences of sands, silts, and gravels. These deposits include the Riverbank and Modesto formations. Generally, the upper 20 feet of these deposits consist of Eolian and Holocene flood plain sediments, while the deeper deposits consist of sequences of silts, sands, and gravels that increase in coarseness with depth. Deposits are typically laterally discontinuous. Hardpan composed of iron- and silica-cemented sands and silts is often encountered between approximately 2.5 and 15 feet bgs.

At the PFFA site, the subsurface in the upper 20 feet is comprised predominantly of silty sand, overlying a laterally continuous silt layer between approximately 20 and 35 feet bgs. Below 30 to 35 feet bgs, sand with little to no fines predominates. An east-west trending cross-section through the central portion of the PFFA is shown in Figure 3.1.

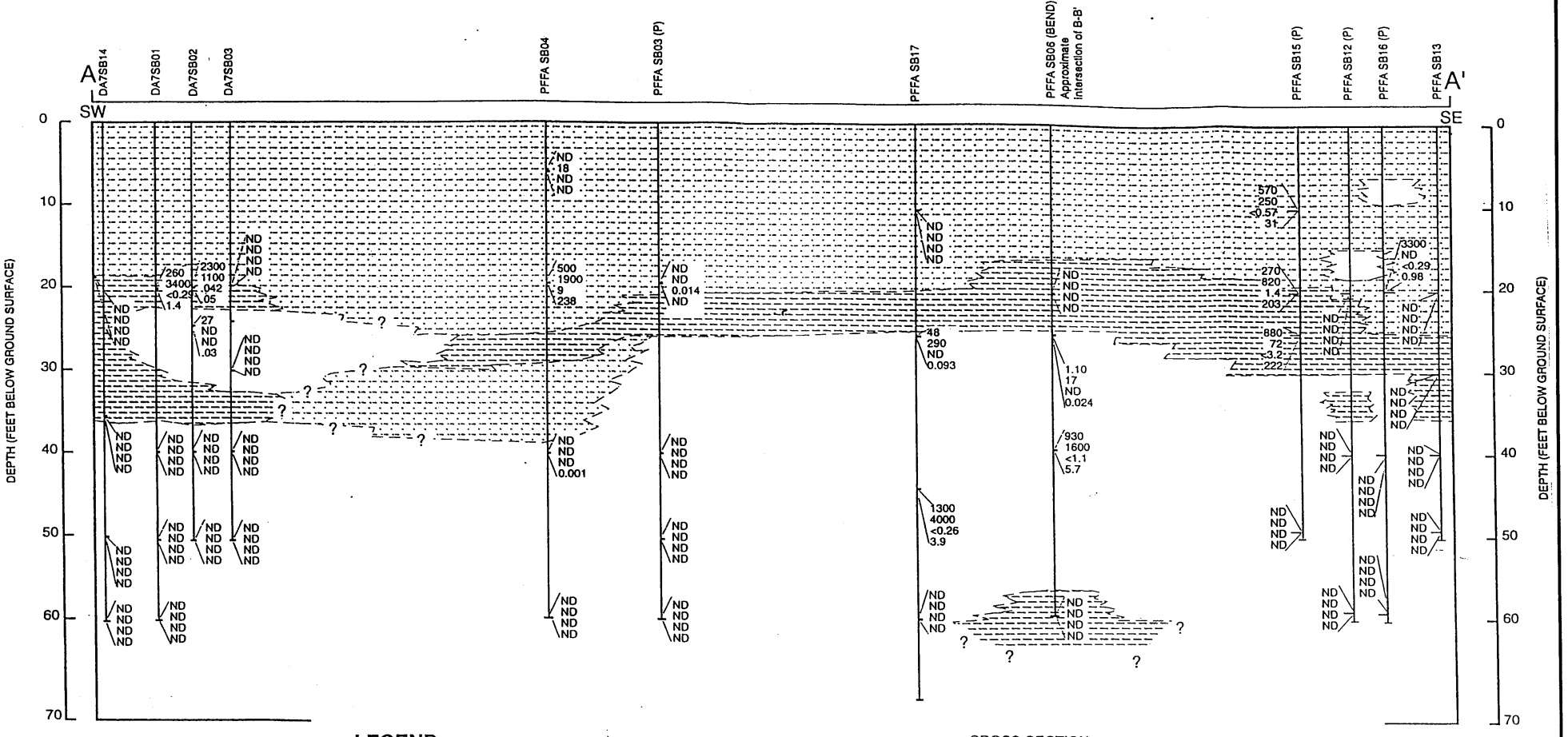
3.1.2 Groundwater Flow and Gradients

The Basewide RI defined 5 saturated hydrostratigraphic zones (HSZ) at Castle: shallow HSZ, upper subshallow HSZ, lower subshallow HSZ, confined HSZ, and the deep HSZ (Jacobs, 1995a). Currently, the shallow HSZ is generally encountered at approximately 60 feet bgs at the PFFA, although historically groundwater was as shallow as approximately 10 feet bgs in some areas of the Base. Groundwater pumping is extensive in the areas surrounding the Base. Private and municipal wells tap the shallow, upper subshallow, and lower subshallow HSZ.

Based on groundwater elevations measured in the shallow HSZ during the first quarter of 1998 (Figure 3.2), the shallow groundwater flow direction at the PFFA area is generally north to northwest toward groundwater extraction wells JE1 and EW1, located north and northwest of the site, respectively. The area of drawdown from JE1 exerts a local change in groundwater flow direction near wells JM11 and JM12. During the first quarter of 1998, the average gradient across the site was approximately 0.0025 foot/foot (ft/ft), with somewhat higher gradients measured near JM11 and JM12 due to groundwater extraction from JE1. Similar gradients were measured in the fourth quarter of 1996. Shallow groundwater elevations at the PFFA varied by no more than 2.5 feet seasonally between 1992 and 1998.

3.1.3 Hydraulic Conductivity

The average hydraulic conductivity for the upper subshallow HSZ was reported between 49 feet per day (ft/day) and 229 ft/day based on step-drawdown and short-term pumping tests at Operable Unit 2 (OU-2) (Jacobs, 1995a). The average hydraulic conductivity for the shallow HSZ was reported between 432 ft/day and 892 ft/day based on the same tests. The lower



LEGEND

- SAND
- SILTY SAND
- SILT

Results of soil sample analysis

- 550 TVPH (Gasoline)
- 190 TEPH (Diesel/JP4)
- ND Benzene
- 590 Xylenes

All concentrations are shown in mg/kg.

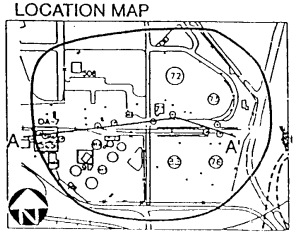
- ND Not Detected (below reporting limit shown on Data Table)
- (P) Projected into line of sedtion
- ⊙ Soil borings used in cross section

VERTICAL SCALE: 1" = 12'

HORIZONTAL SCALE: 1" = 60'

SOURCE: Jacobs, 1995.

CROSS-SECTION LOCATION MAP



(NOT TO SCALE)

FIGURE 3.1

CROSS SECTION A-A'

PFFA RAP

Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.

Oakland, California

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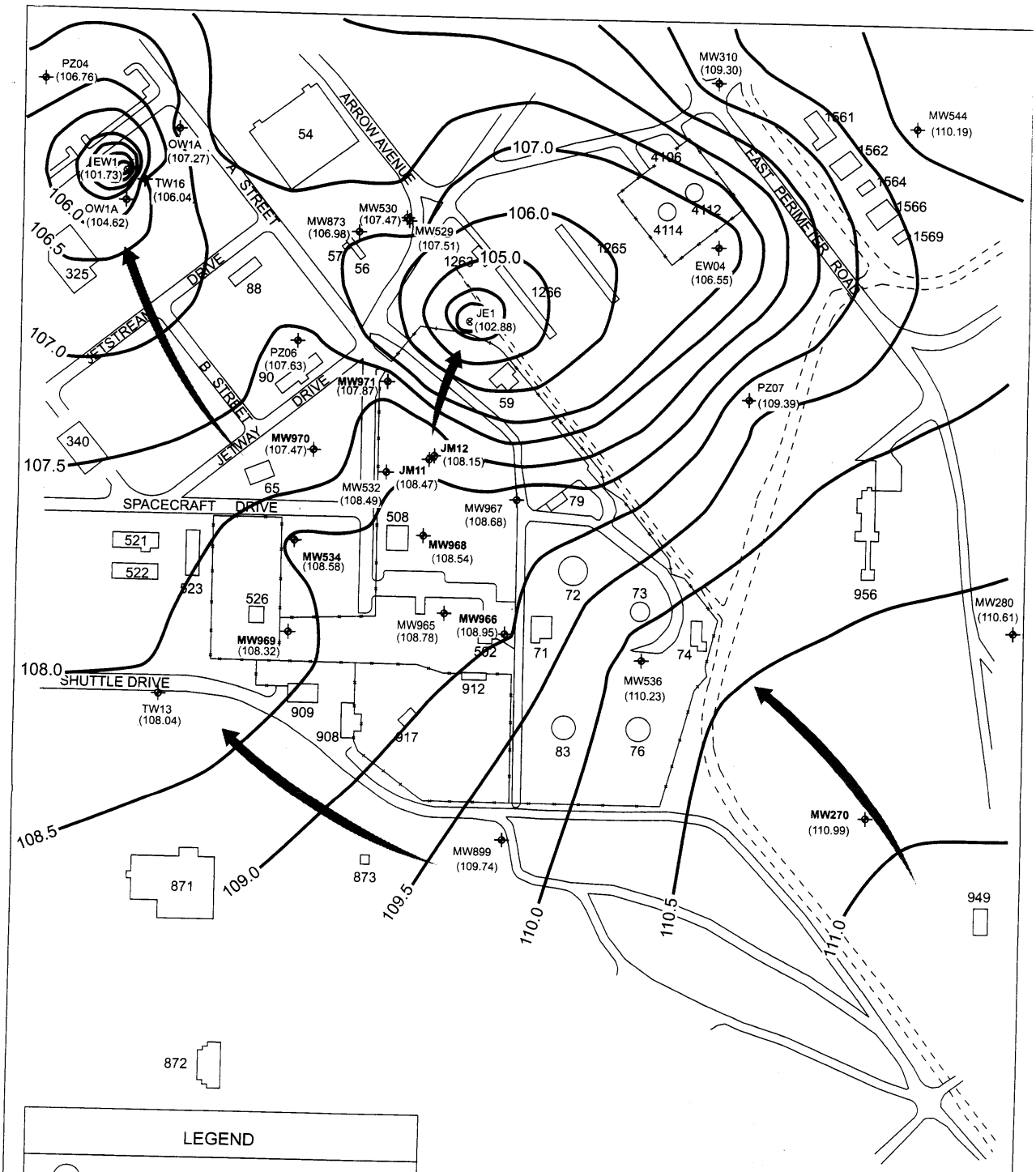

LEGEND

- ABOVE GROUND STORAGE TANK
- BUILDING
- FENCE
- DRAINAGE CHANNEL
- MW969 — GROUNDWATER MONITORING WELL OR PIEZOMETER
- JE1 — GROUNDWATER EXTRACTION WELL
- INFERRED DIRECTION OF GROUNDWATER MOVEMENT
- 110 — GROUNDWATER ELEVATION CONTOUR
- (108.78) GROUNDWATER ELEVATION

230' 115' 0 230'

SCALE: 1"=230'

FIGURE 3.2

GROUNDWATER ELEVATIONS FOR FIRST QUARTER 1998

PFFA RAP
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.

Oakland, California

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hydraulic conductivity values (i.e., 49 ft/day for the upper subshallow HSZ and 432 ft/day for the shallow HSZ) were measured during the step-drawdown tests, while the higher values were measured during the pumping tests. Jacobs (1995) reported that the results from the pumping tests may be biased high due to site conditions, local soil properties, aquifer leakance, and offsite pumping activities. Long-term aquifer pumping tests also were conducted at EW1, near the PFFA, and used to estimate aquifer properties of the shallow HSZ. The hydraulic conductivity calculated from these tests was between 322 and 362 ft/day.

3.1.4 Effective Porosity

Because of the difficulty involved in accurately determining effective porosity, accepted literature values for the type of soil comprising the shallow saturated zone were used. Walton (1988) give ranges of effective porosity for medium sand of 0.15 to 0.30 and for coarse sand of 0.20 to 0.35. Because lower effective porosities result in higher computed advective groundwater velocities, in order to be conservative an effective porosity of 0.25 was assumed for this project.

3.1.5 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)

K = hydraulic conductivity

dH/dL = gradient

n_e = effective porosity.

Using this relationship in conjunction with the site-specific range of hydraulic conductivities for the shallow HSZ discussed in Section 3.1.3 (between 322 and 362 ft/day), the measured average horizontal hydraulic gradient at the site (0.0025 ft/ft), and an effective porosity of 0.25, the advective groundwater velocity at the PFFA is estimated to be between 3.2 ft/day (1,200 ft/year) and 3.6 ft/day (1,300 ft/year).

3.2 CLIMATE

The climate of the Merced Area in central California, where Castle Airport is located, is semiarid, Mediterranean type and characterized by wet winters and long, dry summers with high temperatures often exceeding 100 degrees Fahrenheit (°F). Winters are very cool with high humidity. The mean annual temperature at Castle Airport is 62 °F; the mean monthly temperatures range from 45°F in January to 79°F in July (ISMSC, 1996). During the summer, the clear, dry air allows rapid radiation, leading to large differences between day and night temperatures (frequently 40°F or more).

The mean annual precipitation is 11.8 inches and the estimated mean annual evapotranspiration rate is 51.4 inches per year, leading to a net precipitation of minus 39.6 inches per year. This implies that precipitation has little chance to percolate to regional groundwater. However, approximately 85 percent of the total rainfall occurs during the winter and spring months when evapotranspiration rates are lowest. Net monthly precipitation is positive between November and February, so recharge probably occurs on a seasonal basis.

The average monthly relative humidity ranges from a high of approximately 75 percent during January to a low of approximately 30 percent in July. Winds from the northwest prevail throughout most the year. Although the strongest winds occur between January and March, daily peak wind speeds are typically between 10 and 20 knots throughout most of the year. Winter precipitation events are usually preceded by winds from the southeast.

3.3 LAND USE

3.3.1 Current Land Use and Site Access

Castle Airport is in the Base closure and realignment process. The PFFA is currently maintained as a deactivated fuel supply yard. The facilities within the PFFA are primarily used for vehicle maintenance and storage, vehicle refueling and fuel storage, and landscaping equipment storage. Most of the site is paved with asphalt or concrete, although there are also large areas with a gravel or grass/dirt cover.

Maintenance workers are present at the PFFA during normal business hours. Buildings within the PFFA are occupied only by these maintenance workers and only intermittently during normal business hours. Building 508 is currently used as office space for these workers.

Access to Castle Airport is currently unrestricted. However, access to the PFFA is restricted by a seven-foot security fence surrounding the entire area (Figure 1.3). Access to the PFFA is through gates that are left open during normal business hours but are locked at all other times. Only authorized personnel are permitted to enter the area. The nearest residential areas are located outside the Castle Airport boundary, approximately 1.5 miles west (downgradient) of the PFFA.

Groundwater pumping is extensive in the areas surrounding Castle Airport. Private and municipal wells located outside the Castle Airport boundary tap the shallow, upper subshallow, and lower subshallow HSZ. The water supply for Castle Airport facilities is currently derived from a production well (PW12) located approximately 2,700 feet upgradient from the PFFA.

3.3.2 Proposed Land Use

No changes in onsite land use or land use in areas immediately downgradient are planned. According to the Castle AFB Reuse Plan (AFBCA, 1995), the PFFA is in Parcel A, which is proposed for future use as aviation support or aviation-related industry. Therefore, land use is expected to remain light industrial or commercial and all receptor groups and their activities should remain similar to current conditions.

3.4 ECOLOGICAL RESOURCES

An screening ecological risk assessment was performed for Castle AFB which included evaluating ecological receptors at the PFFA (Jacobs, 1995b). The conclusion of the ecological risk assessment was that the industrial nature of the site, which includes concrete and asphalt driveways and parking areas, building structures, and chain link fencing, precludes the existence of suitable onsite wildlife habitat. The small sections of lawn present within the PFFA were determined to be too disturbed and isolated to be considered ecological habitat. The continuous industrial use of this site and the perimeter fencing prohibits free-ranging animals from becoming permanent inhabitants of the PFFA. The extent of impermeable, man-made surface cover over most of the site generally prohibits burrowing animals or phreatic plants from being exposed to contaminated environmental media. No rare or endangered plant or animal species are present at the PFFA.

Impacts to surface water are highly unlikely because groundwater is 60 feet bgs. The nearby and downgradient shallow drainage ditches are fed only from precipitation and runoff.

SECTION 4

NATURE AND EXTENT OF CONTAMINATION

4.1 OVERVIEW

This section summarizes the nature and extent of contamination in soil, soil vapor, and groundwater at the PFFA, emphasizing the results from the field activities conducted in support of this RAP. Data from the previous RIs are summarized in Section 1, but comparisons between data from the previous RI and the RAP investigation are included in this section. Discussion of the data is limited to COPCs in preparation for the risk analysis, which is presented in Section 5. Discussion of the geochemistry of site groundwater and an evaluation of natural attenuation is presented in Section 6.

4.2 SOURCES OF CONTAMINATION

As discussed in Section 1, the PFFA was historically used as a storage and handling area for fuels and oil. Potential sources of contamination include surface spills from fuel loading and off-loading operations, surface and subsurface leaks from fuel hydrants and distribution lines, and leaks from ASTs and/or USTs. As discussed in Section 1, the previous RI identified 6 sites within the PFFA that were investigated as potentially separate source areas of soil and groundwater contamination: Building 917 (B917), Discharge Area 7 (DA7), Building 508 (B508), Building 59 (B59), Building 79 (B79), and Sanitary Sewer System Segment 8 (SS8).

Extensive soil and soil vapor investigations have been made at the PFFA to identify contaminant source areas. Figure 4.1 shows all previous sampling locations (including those from the RI and those from the RAP sampling activities) in relation to potential primary sources of contamination (e.g., fuel lines, USTs, fuel/water separators). Four general areas of soil contamination were identified during the initial RI (Jacobs, 1995a):

1 Near Building 71, the former fuel pumphouse;

2 Near the locations of the former USTs within DA-7;

3 Near the locations of the former USTs west of Building 502; and,

4 Near the fuel hydrants along the railroad tracks in the eastern portion of the site.

Figures showing these previously-identified source areas are provided in Appendix A and Section 9. The vertical distribution of contamination within these source areas suggests that contamination near the USTs and along the eastern railroad tracks is predominantly in the upper 25 to 30 feet bgs, within the finer-grained materials at the site (Section 3.1.1), while contamination near Building 71 extends into the lower vadose zone within the coarser-grained materials.

In addition to the source areas identified during the RI, an additional fifth source area was identified by Parsons ES during soil and soil vapor sampling conducted as part of the bioventing pilot test:

5 North of Building 508 near JM11 and JM12.

LEGEND

- DRAINAGE DITCH
- ABOVE GROUND STORAGE TANK
- BUILDING
- FENCE
- RAILROAD TRACKS
- FUEL UNLOADING HYDRANTS
- BERM
- MW969 — GROUNDWATER MONITORING WELL
- PFFAVW01 — PERMANENT VENT WELL
- PFFAVMP01 — PERMANENT SOIL VAPOR MONITORING POINT
- PFFAVMP02 — TEMPORARY SHALLOW SOIL VAPOR SAMPLING LOCATION
- PFFASG32 — TEMPORARY SHALLOW SOIL VAPOR SAMPLING LOCATION
- PFFASB34 — SOIL BORING AND DEEP SOIL VAPOR SAMPLING LOCATION
- FUEL LINE INV. 161.63 — FUEL PIPING INVERT ELEVATIONS IN FEET (GROUND ELEVATION AT APPROX. 170' msl
- JE1 — GROUNDWATER EXTRACTION WELL

N

100 50 0 100

SCALE: 1"=100'

FIGURE 4.1

SAMPLING LOCATIONS AND PREVIOUS AND EXISTING FUEL LINES

PFFA RAP
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.
Oakland, California

Results supporting the identification of this new source area are provided in Section 4.4.1. For the purposes of identifying source areas, the initial screening criteria used was whether concentrations in soil or soil vapor exceeded the WQSA thresholds developed for Castle Airport to protect groundwater quality (Water Policy Institute, 1998). These WQSA threshold are provided in Table 4.1.

Table 4.1 provides WQSA thresholds based on the VLEACH model (Jacobs, 1995a; USEPA ORD, 1997) using two different sets of assumptions. The assumptions for the VLEACH1 model included contamination leaching to the water table and leachate mixing with groundwater in a 1 foot thick mixing zone. VLEACH1 used method detection limit (MDL) values as water quality protection criteria. VLEACH2, designed to be more conservative than VLEACH1, used RWQCB-recommended water quality limits (as opposed to MDLs) and ignored the mixing zone (i.e., leachate concentrations were compared directly against water quality limits). The PFFA exceeded VLEACH1 values for the following compounds and media: TPH (soil), toluene (soil vapor), ethylbenzene (soil and soil vapor), total xylenes (soil and soil vapor), and TCE (soil [at one location]). In addition to the above compounds and media, the PFFA exceeded the more conservative VLEACH2 values for benzene in soil and soil vapor.

4.3 CONTAMINANTS OF POTENTIAL CONCERN

The COPCs in soil at the PFFA based on the BRA and comparison of sampling results with the WQSA threshold values are petroleum hydrocarbons (including BTEX); several SVOCs (primarily PAHs); and, TCE (Jacobs, 1995a). Based on the BRA, the COPCs in groundwater at the PFFA are petroleum hydrocarbons (including BTEX), naphthalene, and TCE. Both soil and groundwater COPCs contributed to the cumulative carcinogenic and noncarcinogenic risk at the PFFA. Residential land use scenarios were incorporated into the BRA. Therefore, ingestion and dermal exposure to groundwater were considered as potentially completed pathways. It is the intention of the Air Force to obtain approval for a remedial action for the PFFA that will protect human health and the environment from exposure to site-related chemicals. However, appropriately health-protective RBCLs will be based upon potential human and ecological exposure scenarios that are more representative of current and planned future uses of the site (as discussed in Section 3.3.2), rather than overly conservative residential scenarios.

The maximum historical detections for all contaminants are provided in Tables 1.1 and 1.2. It should be noted that the groundwater COPCs have recently been detected at significantly lower concentrations than the historical detections shown in Table 1.2, probably as a result of the groundwater extraction and treatment system currently operating downgradient from the site and natural attenuation processes. Therefore, COPCs for groundwater only include a subset of those listed in Table 1.2, namely petroleum hydrocarbons, BTEX, naphthalene, and TCE.

Based on the findings and conclusions of the RI/BRA for the PFFA, these compounds were targeted for evaluation as part of additional data collection and analysis during the RAP sampling. TPH was included in the analytical protocol because TPH concentrations were used in the RI/FS as criteria for soil remediation and are included in the WQSA thresholds.. The most recent groundwater monitoring results are discussed below in Section 4.4. The remedial alternatives analysis completed in the previous FS focused on the soil COPCs due

TABLE 4.1
Water Quality Site Assessment Thresholds For Given Maximum Depths Of Contamination For Contaminants of Potential Concern

PFFA RAP

Castle Airport, California

		Soil									
		TPH-volatile	TPH-extractable	Benzene	Toluene	Ethyl-benzene	Total Xylenes	TMB	Naph-thalene	SVOCs [1]	TCE
Depth (ft bgs)	Model	all units in mg/kg									
0-10	VLEACH1	100	1500	88.6	215.8	220.4	293.4	293.4	82.91	82.91	2.7
	VLEACH2	----	----	0.292	315.2	220.3	293.4	293.4	82.90	82.90	0.048
10-20	VLEACH1	100	1500	19.6	44.7	88.8	102.2	102.2	82.91	82.91	1.0
	VLEACH2	----	----	0.068	75.4	220.3	195.1	195.1	82.90	82.90	0.018
20-30	VLEACH1	0.7	2.3	5.7	12.5	24.7	28.5	28.5	82.91	82.91	0.5
	VLEACH2	----	----	0.021	21.6	78.5	54.6	54.6	82.90	82.90	0.010
30-40	VLEACH1	0.7	2.3	1.7	3.7	7.4	8.6	8.6	82.91	82.91	0.3
	VLEACH2	----	----	0.003	6.1	22.6	15.4	15.4	82.90	82.90	0.007
40-50	VLEACH1	0.7	2.3	0.5	1.1	2.2	2.5	2.5	21.97	21.97	0.2
	VLEACH2	----	----	0.001	1.2	4.4	2.8	2.8	68.35	68.35	0.005
50-60	VLEACH1	0.7	2.3	0.1	0.2	0.4	0.5	0.5	1.71	1.71	0.1
	VLEACH2	----	----	0.00001	0.03	0.04	0.03	0.03	0.08	0.08	0.002

		Soil Vapor									
		Benzene	Toluene	Ethyl-benzene	Total Xylenes	TCE	Benzene	Toluene	Ethyl-benzene	Total Xylenes	TCE
Depth (ft bgs)	Model	units in ug/L					units in ppmv				
0-10	VLEACH1	85763.0	94872.0	48799.0	56439.0	2846.8	26938.4	25211.0	10816.8	13044.6	521.0
	VLEACH2	282.2	138540.0	48785.0	56439.0	49.6	88.6	36815.3	10813.6	13044.6	9.1
10-20	VLEACH1	18974.0	19662.0	19662.0	19962.0	1040.1	5959.8	5241.4	4549.1	4613.9	190.4
	VLEACH2	66.3	33150.0	48785.0	37525.0	19.0	20.8	8837.0	11287.2	8673.2	3.5
20-30	VLEACH1	5479.0	5479.0	5479.3	5479.3	559.1	1721.0	1459.1	1266.4	1266.4	120.6
	VLEACH2	20.1	9495.3	17391.0	10512.0	10.6	6.3	2528.6	4019.6	2429.7	2.3
30-40	VLEACH1	1645.2	1645.9	1646.3	1646.1	352.7	516.8	438.3	380.5	380.5	64.6
	VLEACH2	5.9	2703.0	5008.2	2962.3	6.9	1.9	719.8	1157.6	684.7	1.3
40-50	VLEACH1	485.2	489.2	492.1	490.2	235.0	152.4	130.3	113.7	113.3	43.0
	VLEACH2	1.4	528.3	970.6	547.8	4.8	0.4	140.7	224.3	126.6	0.9
50-60	VLEACH1	83.5	91.3	97.9	93.5	102.4	26.2	24.3	22.6	21.6	18.7
	VLEACH2	0.1	11.3	9.3	4.8	1.8	0.0	3.0	2.1	1.1	0.3

Source: Modified from SCOU ROD, Water Policy Institute, 1998.

[1] Semi-volatile thresholds refer to naphthalene VLEACH-modified thresholds and apply to any individual SVOC.

to the existing groundwater extraction and treatment system and because the sources of groundwater contamination were the contaminated vadose zone soils

4.4 SOIL VAPOR SAMPLING RESULTS

As part of the bioventing feasibility study conducted in March 1997, the bioventing pilot test conducted in November/December 1997, and an investigation to determine the areal extent of contamination in the northern portion of the PFFA in March 1998, soil vapor samples were collected from 11 VMP locations, 1 VW, 7 MWs with exposed screens, and downhole during the drilling of 4 SBs. Soil vapor sampling procedures and methods are described in Section 2. Sample results are provided in Table 4.2 and sampling locations are shown on Figure 4.1.

All samples were screened in the field for oxygen, carbon dioxide, and TVH concentration. Selected soil vapor samples were submitted for laboratory analysis for TVH and BTEX from the VMPs, VW, and SBs that were installed in an area of the site not previously investigated: the northern portion of the PFFA near JM11 and JM12, where the bioventing pilot test was conducted (Figure 4.1). This area was investigated during the RAP sampling because samples collected from JM11 and JM12 have historically had the maximum concentrations of TPH and BTEX at the PFFA.

The field screening results confirmed that contaminant source areas are oxygen depleted due to fuel biodegradation. There was a good correlation between low oxygen concentrations and high hydrocarbon concentrations, indicating that oxygen concentrations can be used as a screening indicator of contaminant concentrations in soil vapor and used to monitor remedial progress at the PFFA. Background oxygen concentrations, as measured at PFFAVMP01 and MW270, were near atmospheric concentrations indicating that the native soils do not exert a significant oxygen demand. The laboratory analytical results were consistent with the field screening results.

The laboratory analytical results clearly indicate that significant concentrations of TPH and BTEX are present in soil vapor in the northern portion of the PFFA. Concentrations of BTEX exceeded the WQSA thresholds for soil vapor at PFFAVMP14, PFFAVMP15, PFFAVMP16, PFFASB41, and PFFASB42. With the exception of the soil vapor sample collected from PFFAVMP14 at 51 feet bgs, concentrations of BTEX in soil vapor in the northern portion of the PFFA were generally of the same order of magnitude as previous maximum soil vapor concentrations at the other PFFA source areas. The analytical results for TPH, benzene, toluene, and total xylenes in the sample collected PFFAVMP14 at 51 feet bgs were significantly higher than previously measured at the PFFA: 54,000 part per million by volume (ppmv) TPH, 1,200 ppmv benzene, 820 ppmv toluene, and 440 ppmv total xylenes.

The soil vapor results indicate that higher contaminant concentrations and lower oxygen concentrations are present in the lower vadose zone (below approximately 25 feet bgs) compared to the upper vadose zone for the northern portion of the PFFA. Field screening results from VMPs installed in previously identified source areas within upper vadose zone contamination (Appendix A) indicated oxygen-depleted conditions corresponded with higher hydrocarbon concentrations.

TABLE 4.2
Soil Vapor Sampling Results
PFFA - Castle Airport, California

	Method:	EPA TO-3					Field Instruments		
	Analyte:	TPH-g	Benzene	Toluene	Ethyl-benzene	Total Xylenes	TVH	Oxygen	Carbon Dioxide
Location	Depth/Screen Interval (ft bgs)	units in ppmv						units in %	
PFFAVMP01	15	n.a.	n.a.	n.a.	n.a.	n.a.	66	19.4	1.5
	30	n.a.	n.a.	n.a.	n.a.	n.a.	36	19.0	1.8
MW270	48-89	n.a.	n.a.	n.a.	n.a.	n.a.	6	19.5	0.8
JM11	57-77	n.a.	n.a.	n.a.	n.a.	n.a.	>10,000	0.0	14.0
MW531	34-59	17,000	83	63	49	140 J	>10,000	0.0	14.0
MW533	33-58	n.a.	n.a.	n.a.	n.a.	n.a.	40	17.5	2.3
MW535	33-58	n.a.	n.a.	n.a.	n.a.	n.a.	2,900	3.5	10.0
MW965	53-73	n.a.	n.a.	n.a.	n.a.	n.a.	>10,000	1.3	10.5
MW966	53-73	n.a.	n.a.	n.a.	n.a.	n.a.	>10,000	1.0	10.0
MW967	53-73	n.a.	n.a.	n.a.	n.a.	n.a.	>10,000	0.0	10.4
MW968	53-73	n.a.	n.a.	n.a.	n.a.	n.a.	28	20.8	0.3
MW969	53-73	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6.5	5.5
MW970	53-73	n.a.	n.a.	n.a.	n.a.	n.a.	105	20.7	0.3
MW971	53-73	n.a.	n.a.	n.a.	n.a.	n.a.	>10,000	0.0	14.0
PFFAVW01	6-21	4,600	20	30	29	110 J	>10,000	1.5	12.5
PFFAVMP02	21	n.a.	n.a.	n.a.	n.a.	n.a.	4,200	0.0	7.9
PFFAVMP04	10	n.a.	n.a.	n.a.	n.a.	n.a.	>10,000	0.5	11.0
	19	n.a.	n.a.	n.a.	n.a.	n.a.	>10,000	0.0	12.1
PFFAVMP08	10	n.a.	n.a.	n.a.	n.a.	n.a.	60	12.3	4.5
	20	n.a.	n.a.	n.a.	n.a.	n.a.	200	8.8	6.8
PFFAVMP09	8	n.a.	n.a.	n.a.	n.a.	n.a.	62	3.3	11.5
	32	n.a.	n.a.	n.a.	n.a.	n.a.	>10,000	0.0	10.2
PFFAVMP11	9	n.a.	n.a.	n.a.	n.a.	n.a.	2,200	0.0	7.0
	19	n.a.	n.a.	n.a.	n.a.	n.a.	2,800	0.5	7.0
PFFAVMP12	19	n.a.	n.a.	n.a.	n.a.	n.a.	>10,000	0.0	8.5
PFFAVMP13	7.5	n.a.	n.a.	n.a.	n.a.	n.a.	58	18.0	2.9
	19	n.a.	n.a.	n.a.	n.a.	n.a.	100	10.1	7.3
	29	n.a.	n.a.	n.a.	n.a.	n.a.	360	4.8	9.2
PFFAVMP14	10	n.a.	n.a.	n.a.	n.a.	n.a.	200	1.5	12.5
	20	n.a.	n.a.	n.a.	n.a.	n.a.	1,500	0.3	8.0
	35	13,000 [12,000]	250 [250]	160 [160]	50 [42]	150 [110]	>10,000	0.0	12.7
	51	54,000 J	1,200 J	820 J	140 J	440 J	>10,000	1.0	12.3
PFFAVMP15	10	n.a.	n.a.	n.a.	n.a.	n.a.	260	12.8	2.5
	20	1,700	7.2	9.1	10	44 J	3,100	0.0	8.0
	42	n.a.	n.a.	n.a.	n.a.	n.a.	>10,000	0.4	13.2
	52	40,000	540	45	130	370	>10,000	0.0	13.0
PFFAVMP16	10	n.a.	n.a.	n.a.	n.a.	n.a.	1,100	18.3	2.1
	20	440	0.72	2.4	1.3	5.5 J	2,000	4.7	4.5
	35	n.a.	n.a.	n.a.	n.a.	n.a.	7,400	0.0	13.0
	51	22,000	230	47	48	110	>10,000	0.0	13.0
PFFASB40	11	80	0.019	0.070	0.80	1.5	160	18.0	2.6
	33	730	<0.12	5.0	3.6	8.7	1,600	3.8	7.9
PFFASB41	13	3,000	<0.58	7.7	3.7	11	3,800	8.1	6.7
	39	25,000	310	62	48	120	>10,000	0.6	11.0
PFFASB42	13	22	<0.012	0.036	0.38	0.68	36	20.5	0.4
	41	17,000	<3.1	49	41	150	>10,000	0.3	10.8
PFFASB43	12	61	0.45	0.14	0.84	1.5	78	20.4	0.7
	43	19,000 [15,000]	7.3 [4.7]	30 [28]	16 [11]	33 [27]	>10,000	0.4	12.2

Notes:

[15,000] : duplicate results shown in brackets

TPH-g : Total petroleum hydrocarbons quantitated as gasoline

>10,000 : Reading greater than indicated maximum limit of the instrument

TVH : Total volatile hydrocarbons

n.a. : not analyzed

2.1 J : "J" flag denotes estimated concentratio

4.5 SOIL SAMPLING RESULTS

As part of the bioventing pilot test conducted in November/December 1997, soil samples were collected from 3 VMP locations and 1 VW. Soil samples also were collected from 4 "step-out" SBs in March 1998 to identify the horizontal extent of contamination in the northern portion of the PFFA. Locations for the soil samples were a subset of the locations where soil vapor samples were collected. Soil sampling procedures and methods are described in Section 2. Soil sample results are provided in Table 4.3 and sampling locations are shown on Figure 4.1. All samples were collected in the northern portion if the PFFA, a source area not previously identified in earlier investigations.

The soil sampling results are generally consistent with the soil vapor results, with the maximum concentrations measured in the lower vadose zone at PFFAVMP14. The laboratory analytical results clearly indicate that significant concentrations of TPH and BTEX are present in soil in the northern portion of the PFFA. Concentrations of TPH exceeded the WQSA thresholds for TPH in soil at PFFAVW01, PFFASB41, PFFASB42, and PFFASB43. Concentrations of BTEX exceeded the WQSA thresholds for BTEX in soil only at PFFAVMP14. WQSA thresholds for soil were not exceeded at PFFASB40, located west of the PFFA fence boundary.

With the exception of the soil samples collected from PFFAVMP14 at 40.5 and 41 feet bgs, concentrations of TPH and BTEX in soil in the northern portion of the PFFA were generally of the same order of magnitude as previous maximum soil concentrations at the other PFFA source areas. The analytical results for TPH for the sample collected PFFAVMP14 at 41 feet bgs (28,000 mg/kg) was significantly higher than previously measured at the PFFFA. BTEX concentrations in this same location also were well above the WQSA threshold for BTEX: 12 mg/kg benzene, 80 mg/kg toluene, 37 mg/kg ethylbenzene, and 164 mg/kg total xylenes. Samples from the most contaminated locations based on field screening (PFFAVW01 at 33 feet bgs and PFFAVMP14 at 41 feet bgs) were also analyzed for ethylene dibromide (EDB) and methyl-tertiary-butyl ether (MTBE). EDB and MTBE were not detected in these samples.

4.6 GROUNDWATER SAMPLING RESULTS

MWs within and surrounding the PFFA were sampled as part of a natural attenuation evaluation by Parsons ES in May 1997; these analytical results were previously reported in the LLNL report. Seven (7) new MWs were installed at the site in March 1997 (Jacobs, 1997d). These new wells (MW965 through MW971) were installed and sampled to fill data gaps previously identified during the RI. The first comprehensive sampling event to include the previously installed MWs at the site and the 7 new MWs occurred during the May 1997 investigation. To evaluate the potential for biodegradation and natural attenuation of site contaminants, groundwater geochemical information also was collected. Groundwater geochemistry and the evaluation of natural attenuation of site contaminants are discussed in Section 6.

The locations of sampled MWs are shown on Figure 1.3. For groundwater samples collected during the May 1997 investigation, analytical results are shown in Tables 4.4 and 4.5. TPH and BTEX results are also shown on Figure 4.2. BTEX compounds were detected only at MW966 and JM11. The maximum measured concentrations were: 990 µg/L total petroleum

TABLE 4.3
Summary of Detected Analytes in Soil
PFFA - Castle Airport, California

		Total Petroleum Hydrocarbons		Volatile Organic Compounds					PAHs	Soluble Petroleum Hydrocarbons		Inorganics		Grain-Size Analysis					Moisture
	Method:	8015M/8015B		8020A/8260A					8310	DI WET		9060M	E351.2	ASTM D422					ASTM D2216
	Analyte:	TPH-g	TPH-d [1]	Benzene	Toluene	Ethyl-benzene	Total Xylenes	Naph-thalene	Naph-thalene	TPH-g	TPH-d [1]	TOC	TKN	Coarse sand	Med sand	Fine sand	Silt	Clay	Moisture Content
Location	Depth (ft bgs)	mg/kg								mg/L		mg/kg		% by weight					% by weight
PFFAVW01	20	1.4 J	2.9 J	0.044	<0.0067	0.0047	0.0075	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	25.5
	33	1,700 J	200 J	<0.062	<0.062	3.2	11.2	1.7	1.1	25 J	5.8 J	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.2
PFFAVMP14	15	0.84 J	2.6 J	<0.0055	<0.0055	<0.0022	<0.0055	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	8.7
	22	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	<2,000	n.a.	0.0	2.3	5.0	59.3	33.4	1.9
	40.5	2,200	1,000 J	9.9	65	49	219	6.2	18	7.7	n.a.	n.a.	<50	n.a.	n.a.	n.a.	n.a.	n.a.	18.0
	41	28,000	490 J	13	80	37	164	5.8	7.1	24	n.a.	n.a.	<50	n.a.	n.a.	n.a.	n.a.	n.a.	20.4
	51	2.9 J	130 J	0.021	0.034	0.014	0.054	<0.21	<0.21	0.94 J	0.27 J	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.5
PFFAVMP15	43	0.71 J	n.a.	<0.0051	<0.0051	<0.0020	<0.0051	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.0	17.9	73.3	8.8	0.0	2.4
	52	0.71 J	1.9 J	0.00062 J	<0.0052	<0.0021	<0.0052	n.a.	n.a.	n.a.	n.a.	<2,000	<50	n.a.	n.a.	n.a.	n.a.	n.a.	3.4
PFFAVMP16	15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	<2,000	58.8	0.6	24.8	44.3	19.9	10.4	0.9
	55	0.49 J	3.1 J	0.0019 J	<0.0052	<0.0021	<0.0052	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4.6
PFFASB40	35	<1.4	<5.7	<0.0071	<0.0028	<0.0071	<0.0071	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	29.5
PFFASB41	14	<1.1	<4.3	<0.0054	<0.0054	<0.0022	<0.0054	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7.3
	40	2,000	140	0.12	<0.12	0.33	1.1	n.a.	n.a.	<0.10	6.6 J	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	17.7
PFFASB42	14	<1.1	24	<0.0054	<0.0054	<0.0022	<0.0054	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7.8
	44	34	<5.1	<0.0064	<0.0064	<0.0026	<0.0064	n.a.	n.a.	<0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	22.0
PFFASB43	12	<1.1	<4.3	<0.0054	<0.0054	<0.0022	<0.0054	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6.7
	43	690	8.9	<0.54	<0.54	<0.22	<0.54	n.a.	<0.20	<0.10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	8.2

Notes:

[1] Chromatographic profile for all diesel results was inconsistent with the diesel reference fuel standard.

2.1 J	: Estimated concentration
n.a.	: not analyzed
<50	: Result was less than the indicated reporting limit

TPH-g : Total Petroleum Hydrocarbons in the gasoline range
TPH-d : Total Petroleum Hydrocarbons in the diesel range
PAHs : polycyclic aromatic hydrocarbons
DI-WET : Waste Extraction Test using deionized water (California Title 22)
TOC : Total Organic Carbon
TKN : Total Kjeldahl Nitrogen

TABLE 4.4
Summary of Detected Analytes in Groundwater
Petroleum-Related Hydrocarbons
PFFA RAP
Castle Airport, California

Method:	8015M	8260/8020												
Analyte:	TPH-g [1]	Benzene	Toluene	Ethyl-benzene	Xylenes, Total	1,2,4-TMB	1,3,5-TMB	Naph-thalene	n-Butyl-benzene	sec-Butyl-benzene	tert-Butyl-benzene	Isopropyl-benzene	n-Propyl-benzene	p-Isopropyl-toluene
Location	All concentrations in µg/L													
JM11	990	86	4	17	38	19	12	<25	<2	<2	3	3	3	<0.5
JM12	<50	0.3 (J)	0.4 (J)	<0.5	<0.5	<0.5	<0.5	<5.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MW270	<50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MW280	<50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<25	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MW530	60	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
MW532	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]
MW534	<50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MW536	<50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MW873	100	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MW899	<50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MW965	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]	<50 [<50]
MW966	670	7	<0.5	<0.5	2	8	1	2	<0.5	<0.5	0.5	<0.5	<0.5	<0.5
MW967	70	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MW968	110	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MW969	50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MW970	70	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5.0	<0.5	0.5	<0.5	<0.5	<0.5	<0.5
MW971	60 [60]	<0.5 [<0.5]	<0.5 [<0.5]	<0.5 [<0.5]	<0.5 [<0.5]	<0.5 [<0.5]	<0.5 [<0.5]	<0.5 [<0.5]	<0.5 [<0.5]	0.4 (J) [0.3 (J)]	<0.5 [<0.5]	<0.5 [<0.5]	<0.5 [<0.5]	<0.5 [<0.5]
TW13	<50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
TW16	80	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<5.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
PFFASB42 [2]	n.a.	61	<4.0	4.5	7.2	<4.0	<4.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Notes: Samples collected in May 1997, except for PFFASB42 which was collected in March 1998. Historical results are included in Appendix A

[1] TPH-g concentrations of 60 µg/L and 80 µg/L were detected in an ambient blank and a rinsate blank, respectively.

[60] : field duplicate results shown in brackets

(J) : estimated value

TPH-g : total petroleum hydrocarbons as gasoline

TMB : trimethylbenzene

n.a. : not analyzed

<0.5 : not detected at indicated detection limit

TABLE 4.5
Summary of Detected Analytes in Groundwater (2Q97)
Chlorinated Hydrocarbons and Other VOCs
PFFA RAP
Castle Airport, California

Method:	8260						
Analyte:	Acetone [1]	Chloroform	1,1-DCA	cis-1,2-DCE	trans-1,2-DCE	PCE	TCE
Location	All concentrations in µg/L						
JM11	<4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
JM12	<4	<0.5	<0.5	<0.5	<0.5	<0.5	0.3 (J)
MW270	<4	<0.5	<0.5	<0.5	<0.5	0.5	<0.5
MW280	<4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MW530	<4	<0.5	<0.5	9	<0.5	<0.5	160
MW532	<4 [<4]	<0.5 [<0.5]	<0.5 [<0.5]	<0.5 [<0.5]	<0.5 [<0.5]	<0.5 [<0.5]	0.2 (J) [<0.5]
MW534	<4	<0.5	<0.5	<0.5	<0.5	<0.5	0.2
MW536	<4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MW873	<4	<0.5	<0.5	10	<0.5	<0.5	350
MW899	<4	0.3 (J)	<0.5	<0.5	<0.5	<0.5	2
MW965	<4 [<4]	<0.5 [<0.5]	<0.5 [<0.5]	<0.5 [<0.5]	<0.5 [<0.5]	<0.5 [<0.5]	<0.5 [<0.5]
MW966	<4	<0.5	<0.5	0.6	<0.5	<0.5	<0.5
MW967	<4	<0.5	<0.5	0.3	<0.5	<0.5	1
MW968	<4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MW969	<4	<0.5	<0.5	<0.5	<0.5	<0.5	0.3 (J)
MW970	14	<0.5	0.3 (J)	2	<0.5	<0.5	6
MW971	<4 [<4]	<0.5 [<0.5]	<0.5 [<0.5]	0.6 [0.7]	<0.5 [<0.5]	<0.5 [<0.5]	2 [2]
TW13	<4	<0.5	<0.5	<0.5	<0.5	<0.5	1
TW16	<4	<0.5	<0.5	1	<0.5	0.4 (J)	22

Notes: Samples collected in May 1997, except for PFFASB42 which was collected in March 1998. Historical results are included in Appendix A

[1] Acetone was also detected in a trip blank sample shipped by the laboratory.

<0.5 : not detected at indicated detection limit

[0.7] : field duplicate results shown in brackets

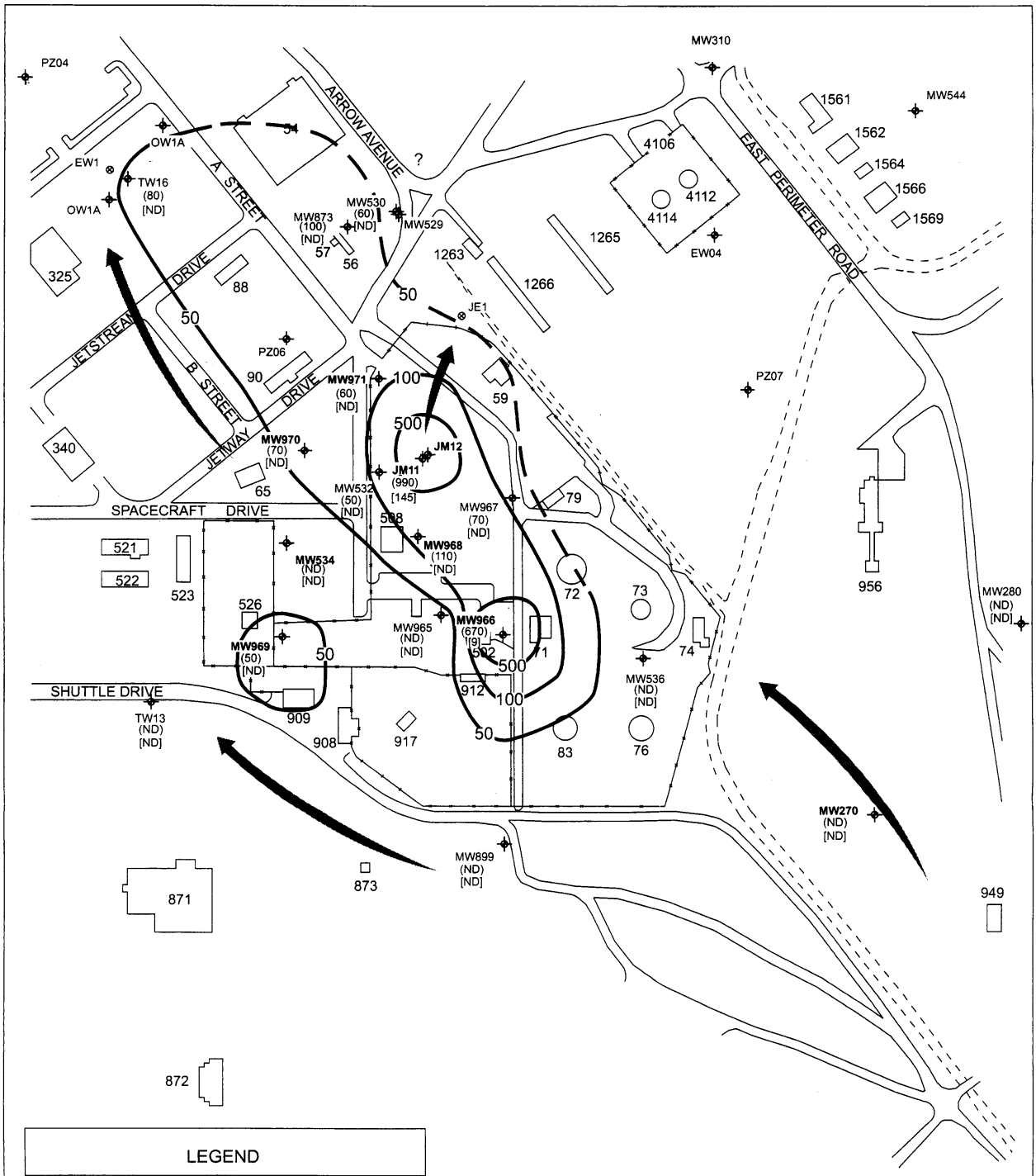
(J) : estimated value

DCA : dichloroethane

DCE : dichloroethene

PCE : tetrachloroethene

TCE : trichloroethene



LEGEND

- ABOVE GROUND STORAGE TANK
- BUILDING
- FENCE
- DRAINAGE CHANNEL
- MW969 — GROUNDWATER MONITORING WELL OR PIEZOMETER
- JE1 — GROUNDWATER EXTRACTION WELL
- INFERRED DIRECTION OF GROUNDWATER MOVEMENT
- 200 — LINE OF EQUAL TOTAL PETROLEUM HYDROCARBON AS GASOLINE (TPH-g) CONCENTRATION (µg/L) (DASHED WHERE INFERRED); CONTOUR INTERVAL VARIABLE
- (11) TPH-g CONCENTRATION (µg/L)
- [92.3] TOTAL BTEX CONCENTRATION (µg/L)

230' 115' 0 230'

SCALE: 1"=230'

FIGURE 4.2

TPH ISOPLETHS AND TOTAL BTEX CONCENTRATIONS FOR GROUNDWATER

PFFA RAP

Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.

Oakland, California

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hydrocarbons as gasoline (TPH-g), 86 µg/L benzene, 4.0 µg/L toluene, 17 µg/L ethylbenzene, and 38 µg/L total xylenes (all from the sample collected from JM11) and 2 µg/L naphthalene (from the sample collected from MW966).

During the drilling of 4 SBs in March 1998 (Section 2.2 and Section 4.5), a Hydropunch® groundwater sample was collected at PFFASB42 at 60 feet bgs and analyzed for BTEX by EPA Method 8020. Results from this sample are provided in Table 4.4. The BTEX concentrations measured in this sample were: 61 µg/L benzene, 4.5 µg/L ethylbenzene, and 7.2 µg/L total xylenes.

TPH-g was detected at a concentration of 60 µg/L and 80 µg/L from an ambient blank collected near MW-967 and a rinseate blank collected near MW-966, respectively. The rinseate blank was collected by pouring reagent-grade deionized water through an unused disposable bailer. Based on the detection of low levels of TPH-g in these quality control samples, it is possible that the widespread detections of low concentrations of TPH-g at the site are due to unavoidable contamination from ambient sources at the site during sampling activities or due to contamination of the reagent-grade water used for quality control samples. However, the relatively higher concentrations of TPH-g in JM11 (990 µg/L) and MW966 (670 µg/L) are consistent with the BTEX results for those MWs and are presumed to be representative of subsurface conditions.

For MWs within or immediately downgradient from the PFFA, the maximum concentrations for chlorinated compounds were: 6 µg/L TCE, 2 µg/L cis-1,2-dichloroethene (DCE), and 0.3 µg/L 1,1-dichloroethane (DCA) (all from the sample collected from MW970). TCE was only detected above its MCL at MW970 (and exceeded the MCL by only 1 µg/L). The occurrence and concentrations of these chlorinated hydrocarbons is consistent with historical results and the known chlorinated hydrocarbon plume whose source is north of the PFFA. Acetone also was detected in one sample. However, acetone is presumed to be a laboratory contaminant because acetone also was detected in one of the trip blanks sent by the laboratory which remained sealed during sampling activities. A historical summary of detected analytes and contaminant concentrations for groundwater are provided in Appendix A.

4.7 SUMMARY

The soil contamination at the site is located in previously-identified source areas and in the newly-identified source area in the northern portion of the PFFA. In each of the source areas, contaminant concentrations exceeded at least one of the WQSA values. However, the distribution of soil contamination in the source areas appears to be correlated with depth. In some source areas (e.g. Building 71), soil contamination extends from near surface to groundwater, while in other areas, soil contamination is only significant in the lower vadose zone (e.g., the northern portion of PFFA) or only in the shallow vadose zone (e.g., at DA-7).

The distribution of groundwater contamination suggests that the PFFA is the source of the petroleum-hydrocarbon contamination in groundwater, probably as a result of groundwater contact with contaminated vadose zone soils during previously shallower groundwater conditions, as discussed in Section 2, and through infiltration of water through residual contamination adsorbed onto vadose zone soils. Some chlorinated aliphatic hydrocarbons (CAHs), primarily TCE, also have been detected in groundwater at the PFFA at relatively

low concentrations (less than 10 µg/L total VOCs and 6 µg/L TCE during the May 1997 investigation). Based on the RI, the source of the CAH contamination in groundwater at the PFFA appears to be from sanitary sewer lines located near Building 917 and DA-7 and/or from the oil/water separator located at Building 508. The relatively higher concentrations of CAHs (up to 360 µg/L during the May 1997 investigation) detected in samples collected from MWs downgradient from the PFFA (MW530, MW873, and TW16) have been attributed to other sources.

To date, the maximum concentrations of groundwater COPCs have been detected at monitoring wells MW531 (now dry), JM11, JM12, and PFFASB42 which are located downgradient from two of the previously identified source areas — Building 71 (the former fuel pumping station) and near Buildings 501 and 502. These locations are also within or downgradient from the source area identified during this investigation — the northern portion of the PFFA where the bioventing pilot test was conducted (Figure 4.1). Analytical results from the seven new MWs installed downgradient from the PFFA source areas indicate that groundwater contamination is not extensive and appears to be restricted to the areas near Building 71 and the northern portion of the PFFA. Based on the analytical results from MW967 and MW971, there does not appear to be a significant source of groundwater contamination beneath ASTs 72 and 73.

SECTION 5

ESTABLISHING RISK-BASED CLEANUP LEVELS

5.1 OBJECTIVE

Fundamentally, the objective of risk-based remediation is to reduce the risk of specific chemicals to human health or ecological receptors. The purpose of this section is to develop risk-based cleanup levels (RBCLs) to be used to determine which COPCs at the PFFA site may warrant further investigation and/or drive remediation requirements. RBCLs are risk-based concentrations derived from standardized equations combining site-specific exposure information assumptions with USEPA and/or State of California EPA (Cal/EPA) toxicity data. Development of the RBCLs at this point in the RAP will serve to focus the evaluation of potential site remedial management strategies on those COPCs or exposure pathways that may present an unacceptable risk to human or ecological receptors. The proposed RBCLs should be considered supplemental to the 1995 BRA (Jacobs, 1995a), as these proposed target cleanup levels can be used to optimize remedial design and any long-term operational/monitoring plans.

With regard to groundwater, risk-based remediation and the establishment of RBCLs can be incorporated into existing California State Water Resources Control Board (SWRCB) policies. More specifically, in the case of SWRCB Resolution 68-16 ("Non-Degradation Policy") and Resolution 92-49 ("Policies and Procedures For Investigation and Cleanup and Abatement of Discharges"), flexibility is provided to local Regional Water Quality Control Boards (RWQCBs) in establishing goals for the cleanup of groundwater which has already been impacted by contamination. For stable or shrinking plumes (as a result of natural attenuation or limited source reduction), the beneficial uses of unimpacted groundwater are not affected. For shrinking plumes, if modeling or other means can be used to demonstrate that water quality limits (WQLs) (as determined by the local RWQCB) can be attained by the time groundwater will be used, then beneficial uses of the impacted groundwater also will not be affected. In practice, local RWQCBs are provided some flexibility in determining WQLs, although they are usually based on general water quality objectives established in the local Basin Plan (typically equivalent to MCLs) or other health-based criteria assuming use of the groundwater as a drinking water source. The local RWQCB also is given considerable flexibility in establishing what is considered a reasonable time period for achieving WQLs (based on the time from the present to when groundwater will be used for beneficial uses) and, in the case of in situ treatment of soils, may consider technological and economic feasibility

5.2 EXPOSURE PATHWAYS ANALYSIS

The objective of an exposure assessment is to estimate the type and magnitude of exposures to chemicals that are present or migrating from a site (USEPA, 1989). An exposure pathways analysis describes the migration paths a chemical takes from the source of contamination to a potentially exposed individual (USEPA, 1989). Site-related contamination can present a potential risk to receptors only if exposure pathways are completed. A completed exposure pathway must consist of a source, a release mechanism

(e.g., leaching or volatilization), a transport medium (e.g., groundwater or air), a potential receptor (e.g., current and future onsite workers), a potential exposure point (i.e., locations where receptors could come into contact with site-related contamination), and potential routes of exposure (i.e., ingestion, dermal contact, or inhalation). Each of these elements must be present before a particular exposure pathway can be considered completed. If any of these elements is missing, the exposure pathway is considered incomplete, and there is no risk (USEPA, 1992a). Thus, the overall objective of this analysis was to determine which, if any, exposure pathways are or may be completed at the PFFA site. Those exposure pathways that were considered potentially complete and significant were retained for use in developing the RBCLs.

5.2.1 Conceptual Site Model

A CSM is used to qualitatively define the type of potential exposures to contaminants at and migrating from a site (i.e., to systematically evaluate the impact of chemicals in relevant media to potential receptors). The CSM is essentially a three-dimensional "picture" of site conditions. The CSM developed as part of the 1995 BRA (Jacobs, 1995a), which was used to identify any potential data gaps and guide data collection activities, was included in the work plan for the RAP activities (Parsons ES, 1997a). Based on an understanding of existing and foreseeable site conditions (Section 3.3), the CSM has been updated to reflect the existing and proposed future non-residential uses of the site (Figure 5.1). This updated CSM, which will be used to guide the development of the RBCLs for this RAP, identifies only those exposure pathways that are realistic for the PFFA site and that may be involved in actual or hypothetical future exposure scenarios. The 1995 BRA presumed residential land use.

5.2.1.1 Sources of Chemical Contamination

As described in Sections 1 and 4, contamination at the PFFA site is likely the result of surface spills from fuel loading and off-loading operations, surface and subsurface leaks from fuel hydrants and distribution lines, and leaks from ASTs and/or USTs. The five general areas of soil vapor and soil contamination that have been identified at the site are described in Section 4.2 and are shown on figures included in Section 9, which discusses the recommended remedial action.

Based on the compound screening assessment included in the 1995 BRA (Jacobs, 1995a), soil vapor COPCs for the PFFA site include the BTEX compounds, the TMB isomers, bromobenzene, tetrachloroethene (PCE), TCE, 1,1-DCE, 1,1,2-TCA, and vinyl chloride. The 1995 BRA also identified the following 33 compounds as soil COPCs for the PFFA site:

Benzene	n-Butylbenzene	Dibenzofuran
Toluene	tert-Butylbenzene	di-n-butylphthalate
Ethylbenzene	Anthracene	Fluorene
Xylenes	Acenaphthene	Fluoranthene
1,2,4-TMB	Benzo(a)anthracene	Indeno(1,2,3-cd)pyrene
1,3,5-TMB	Benzo(a)pyrene	2-methylnaphthalene

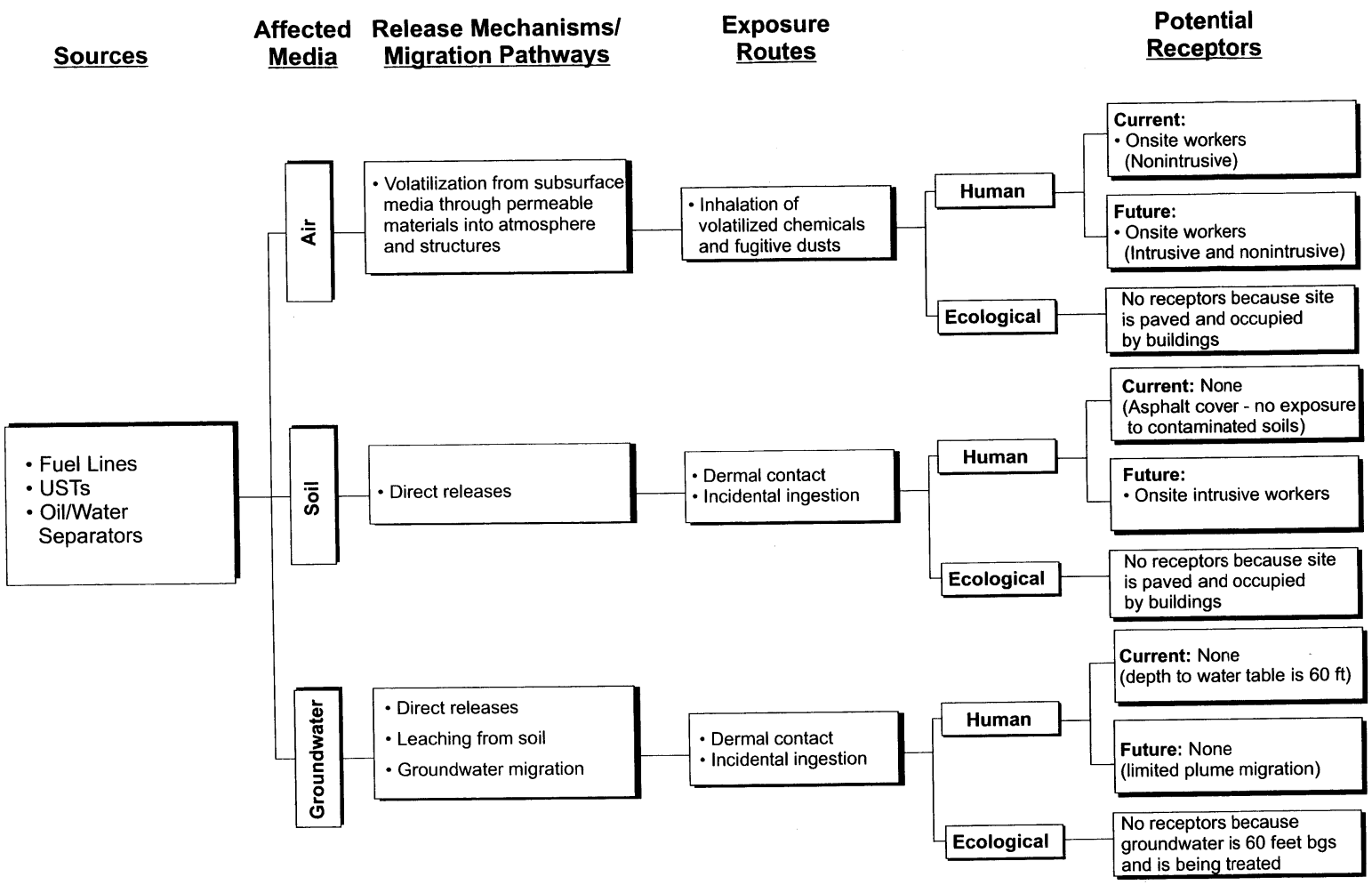


FIGURE 5.1

CONCEPTUAL SITE MODEL

PFFA RAP
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.
Oakland, California

Naphthalene	Benzo(b)fluoranthene	Phenanthrene
p-Isopropyltoluene	Benzo(g,h,i)perylene	Pyrene
n-Propylbenzene	Benzo(k)fluoranthene	Chlorobenzene
Isopropylbenzene	bis-(2-ethylhexyl)phthalate	PCE
sec-Butylbenzene	Chrysene	TCE

As anticipated, the groundwater COPCs are almost identical to the soil COPCs. The 1995 BRA (Jacobs, 1995a) identified 22 specific chemicals as the groundwater COPCs:

Benzene	p-Isopropyltoluene
Toluene	n-Propylbenzene
Ethylbenzene	Acetone
Xylenes	Chlorobenzene
1,2,4-TMB	1,1-DCA
1,3,5-TMB	1,2-DCA
Naphthalene	1,1-DCE
2-methylnaphthalene	cis-1,2-DCE
sec-Butylbenzene	Methylene chloride
tert-Butylbenzene	PCE
Isopropylbenzene	TCE

5.2.1.2 Release Mechanisms

Most of the PFFA site is paved with asphalt or concrete, although there are also some areas with a gravel or grass/dirt cover. Given these types of surface coverage and the depth of soil vapor and soil contamination at the site, direct exposure to COPCs in surface soil at the PFFA site is currently unlikely (i.e., through inhalation of fugitive dust, dermal contact, or incidental ingestion). Direct exposure to soil vapor and soil contamination is more likely to occur during future intrusive construction activities. Leaching of COPCs from soil into groundwater has and is still likely occurring at the PFFA. However, direct contact with COPCs in groundwater is not likely even during any future intrusive construction activities because groundwater is relatively deep (i.e., approximately 60 feet bgs).

Volatilization of organic vapors from soil is not considered to be a significant release mechanism for undisturbed surface media due to asphalt/concrete/gravel cover at the site. There also is little opportunity for fugitive dust generation within the PFFA for the same reason. However, if subsurface soils are exposed during future excavation activities, release mechanisms could include volatilization and fugitive dust generation.

5.2.1.3 Contaminant Transport and Fate

Contaminant transport, transformation, and fate in the environment following a release is important to consider when assessing the potential for exposure. Sampling activities completed in support of this RAP included evaluating the potential for *in situ* biodegradation of the petroleum hydrocarbon COPCs in soil (Section 7). These data indicate that biological degradation of petroleum-hydrocarbon residuals in the vadose zone soil has and is occurring, although the rate of degradation is limited by subsurface oxygen concentrations.

Available groundwater sampling results for the site suggest that the PFFA is the source of petroleum hydrocarbon compounds detected in groundwater at and immediately downgradient from the site. Several CAH compounds have been detected in site groundwater at relatively low concentrations (less than 10 µg/L total VOCs and 6 µg/L TCE during the May 1997 investigation. These compounds are believed to originate from the sanitary sewer lines located near Building 917 and DA-7 and/or from the oil/water separator located at Building 508. As discussed in Section 6, the extent of the fuel hydrocarbon and CAH contamination is expected to gradually decrease due to natural attenuation processes. Worst-case fate and transport model results (Section 6.6.3) suggest that the fuel-hydrocarbon groundwater plume will not migrate more than 750 feet downgradient from the source area. Consequently, the extent of downgradient transport is expected to be limited. These model results do not account for the effects of the operating groundwater extraction system, which also effectively interrupts uncontrolled downgradient migration. A more detailed evaluation of the transport, transformation, and fate of COPCs in groundwater is provided in Section 6.

5.2.1.4 Potentially Exposed Populations and Exposure Routes

Assumptions about land use form the basis for identifying reasonable potential receptors and potentially completed exposure pathways. Land use assumptions are critical to defining the types of receptors that are now present or may be reasonably expected to be present in the foreseeable future at the PFFA site, or in immediately adjacent areas that could potentially be impacted by site-related contamination in soils or groundwater.

USEPA (1991c) advises that the land use associated with the highest (most conservative) potential level of exposure and risk that can reasonably be expected to occur should be addressed in risk-based remedial decisions. Although hypothetical future residential land use provides the most conservative risk estimates, USEPA risk assessment guidance materials state that this conservative approach may not be justifiable if the site is surrounded by an operating industrial facility that can be reasonably assumed to remain as an industrialized area. In these cases, the USEPA recommends using other exposure scenarios, such as agricultural or light commercial/industrial, including a qualitative assessment of the likelihood that the assumed reasonable future land use will occur (55 Federal Register 710).

5.2.1.4.1 Current Conditions

Castle Airport occupies approximately 3,000 acres of land, and is comprised of runway and airfield operations, industrial areas, and several noncontiguous parcels of land located near the former Base. The Base was closed in September 1995. As described in Section 3.3, the PFFA site is currently maintained as a deactivated fuel supply yard. Maintenance workers are present at the PFFA during normal business hours. All buildings on the site are used by

these maintenance workers only intermittently. Public access to the PFFA is restricted by security fencing.

Groundwater pumping is extensive in the areas surrounding the Base. Private and municipal wells withdraw groundwater from at least the upper 3 of the 5 defined saturated hydrostratigraphic zones. However, no groundwater is withdrawn for potable uses within 1,000 feet of the PFFA. Consequently, current onsite human receptors are not at risk of ingesting contaminated groundwater. Additionally, the depth to the first saturated hydrostratographic zone at this site is approximately 60 feet bgs. No known industrial- or aviation-related utilities are installed at these depths. Thus, even highly intrusive construction activities would likely not involve incidental contact with groundwater.

5.2.1.4.2 Future Conditions

No changes in onsite land use or land use in areas immediately downgradient from the PFFA site are planned for the foreseeable future. According to the Castle AFB Reuse Plan (AFBCA, 1995), this area is proposed for future use as aviation support or aviation-related industry. Residential/commercial development is not reasonable and representative of the likely future uses of the PFFA and environs immediately downgradient from the PFFA. Because the immediate future use of the site is not expected to change and because restrictions or institutional controls could be applied to the site, RBCLs for the PFFA will be based only on those completed exposure pathways involving industrial and intrusive (construction/remedial) workers.

5.2.2 Summary of Potentially Completed Exposure Pathways

Current and future human receptors for contamination from the PFFA are assumed to include individuals working at the site or in nearby areas (Figure 5.1). Those persons most likely to be onsite are those workers carrying out the daily operations associated with vehicle maintenance and storage, vehicle refueling and fuel storage, and landscaping. Occasional, localized intrusive work, such as excavating to install utility lines, landscaping, or building foundations, may occur at the site in the future. Thus, both current and potential future human receptors are limited to maintenance (non-intrusive) and construction (intrusive) workers at the PFFA source areas and the immediate environs (Figure 5.1).

Persons performing either of these types of activities would have the highest potential for exposure to contaminants in soil vapor and soil. However, their exposure would be expected to be relatively infrequent and of short duration (i.e., about 250 days for maintenance workers and less than 90 days for construction workers). No exposure pathways involving groundwater are expected to be complete for onsite human receptors, given the depth of the most shallow saturated zone. Additionally, based on the contaminant transport modeling presented in Section 6, groundwater contamination from the PFFA is not likely to migrate more than a few hundred feet beyond its current downgradient extent.

Probable existing and future exposure pathways are dependent upon which receptors come into contact with what contaminated media. Given the depth of soil contamination at this site, the only completed exposure pathway identified for the maintenance workers involves inhalation of chemicals that have volatilized from deep soil into indoor and outdoor ambient air. However, potentially completed exposure pathways for the construction workers could

include inhalation of chemicals volatilizing from disturbed soils, incidental ingestion of contaminated soil/fugitive dusts, and incidental dermal contact with disturbed contaminated soil. No exposure pathways involving groundwater were determined to be complete, given the depth to groundwater and the expected limited extent of downgradient migration.

5.3 CALCULATION OF RISK-BASED CLEANUP LEVELS

Exposure scenarios that describe the duration and frequency of exposure for a maintenance (nonintrusive) worker and a construction (intrusive) worker were used to calculate site-specific RBCLs. Major assumptions, scientific judgments, and, to the extent possible, estimates of the uncertainties embodied in the assessment also were considered in the analysis and are discussed in the following sections.

5.3.1 Quantification of Exposure

Once the exposure pathways are described qualitatively, the amount of any one chemical to which a receptor may be exposed during a specified time is estimated. Calculating chemical intake hinges on reasonable, yet conservative, assumptions about how each group of potential receptors at a particular site may be exposed to site-related contamination. This step in the RBCL development process is called quantification of exposure. The health-protective RBCL for a particular receptor group exposed to site-related contamination is then estimated by coupling target risk levels with both toxicity and quantified exposure data.

Intake estimates are normally expressed as the amount of chemical at the exchange boundary in milligrams of contaminant per kilogram of body weight per day (mg/kg-day), which represents an intake normalized for body weight over time. The total exposure is then divided by the time period of interest to obtain an average exposure over time. The time used to average exposure is a function of the toxicity endpoint: for noncarcinogenic effects it is the exposure duration, and for carcinogenic effects it is a lifetime (70 years).

The RBCLs developed herein presume chronic exposures to measured COPC concentrations. Short-term (i.e., subchronic) and acute exposures are not considered. As required by the USEPA (1992b), a reasonable maximum exposure (RME) scenario was used to derive the RBCLs. When coupled with the appropriate toxicity information, intakes calculated using the RME parameters result in RME RBCLs. RME intakes use a target hazard quotient of 1 and a target cancer risk of one-in-a-million (1.0×10^{-6}).

In general, standard default intake variables as defined by USEPA (1991d) were used in quantifying exposure for both the nonintrusive maintenance workers and the intrusive construction workers (i.e., body weight, breathing rate, lifetime). Some intake variables were based on best professional judgment. For example, the nonintrusive worker was assumed to be assigned to the PFFA for a total of 10 years; in comparison, the intrusive construction worker was assumed to remain at the job for an equivalent of only 90 days (3 months). This assumption is based on best professional judgment, as most construction-related/remediation activities at the site would likely not last more than the equivalent of 90 days of continuous exposure. Any necessary remediation activities at the site will not require workers to be constantly present after initial installation activities are complete. Likewise, construction-related activities, such as the excavation and placement of a concrete slab foundation or the installation of utility lines for a new building at the site, would require only

a few weeks of intrusive work. Workers involved in excavation activities would not remain at the site once the foundation or pavement has been poured and the aboveground construction activities have been initiated.

Calculation of dermal exposure to soil also required development of one intake variable. An exposed surface area of 5,000 cm^2 was used based on the assumption that an individual's hands and arms would not be covered by clothing and therefore were exposed to contaminated soil. The intake variables, resulting exposure factors, and the formulas used to calculate intake for both the nonintrusive and intrusive workers are shown in Appendix D. The RBCLs based on these assumptions are derived and discussed in subsequent sections.

5.3.2 Toxicity Assessment

The objective of the toxicity assessment is to weigh available evidence regarding the potential for particular contaminants to cause adverse effects in exposed individuals and to provide, where possible, an estimate of the relationship between the extent of exposure to a contaminant and the increased likelihood and/or severity of adverse effects. For humans, USEPA and Cal/EPA have conducted numerous toxicity assessments that have undergone extensive review within the scientific community.

The types of toxicity values used in this risk analysis include oral reference doses (RfD_o), inhalation reference doses (RfD_i), oral carcinogenic slope factors (SF_o), and inhalation slope factors (SF_i). RfD_os and RfD_is are used to evaluate noncarcinogenic effects. SF_os and SF_is are used to evaluate carcinogenic effects. Toxicity values for the noncarcinogens and carcinogens evaluated in this risk analysis are presented in Appendix D. The primary source of oral and inhalation RfDs was the USEPA's *Integrated Risk Information System* (IRIS) (USEPA, 1997a). The primary source of oral and inhalation SFs was Cal/EPA's *Criteria for Carcinogens* (Cal/EPA, 1994). In cases where the USEPA and Cal/EPA toxicity values differed, the more conservative (health-protective) values were used. If values were not available from IRIS or Cal/EPA, the *Health Effects Assessment Summary Tables* (HEAST) or USEPA Region III values were used (USEPA, 1995 and 1997b). Although the intrusive construction workers are assumed to have subchronic exposure, they were evaluated with chronic toxicity values to be more conservative (health-protective).

USEPA and Cal/EPA have not derived toxicity values for all routes of exposure. Most of the available toxicity values are for oral exposure, although many inhalation values are available. No values are currently available for dermal exposure. As per Cal/EPA and DTSC (1994) guidance, oral toxicity values were used as surrogate values to estimate systemic toxicity as a result of dermal absorption. For those chemicals for which toxicity values are not available for any route of exposure, no RBCL was developed.

5.3.3 Risk-Based Cleanup Levels

The objective of developing RBCLs is to define the concentration for each COPC that can persist at the site and not result in a risk greater than 1×10^{-6} for each carcinogenic chemical or a hazard index (HI) of 1 for each noncarcinogenic chemical. RBCLs have been developed herein to address only those completed exposure pathways for involving nonintrusive and intrusive site workers. Consequently, the RBCLs for nonintrusive workers are based on a single route of exposure: inhalation of volatilizing chemicals and fugitive dusts; the RBCLs

for the intrusive workers incorporate potential exposure from three routes: inhalation, incidental ingestion, and incidental dermal contact.

RBCLs were only developed for those COPCs potentially involved in completed exposure pathways (i.e., the soil vapor and soil COPCs). Although RBCLs were not developed for any of the groundwater COPCs, the potential for natural attenuation processes to interrupt exposure pathways involving groundwater and eventually reduce COPC mass and toxicity is quantitatively explored in Section 6 of this RAP. The outcome of that evaluation should be factored into the remedial decision-making process for the entire PFFA site to ensure that all reasonable requirements are satisfied. This section highlights only those cleanup requirements that are necessary to protect human and ecological receptors, given the nature of potential exposures at the site.

5.3.3.1 Maintenance Worker RBCLs

Table 5.1 presents the RBCLs for soil vapor/soil COPCs that are protective of onsite maintenance (nonintrusive) workers and compares these concentrations to the most recently measured maximum site concentration. Detailed calculations of these RBCLs are shown in Appendix D. Soil vapor was not treated as an environmental medium of concern itself; rather, it was considered to be representative of *in situ* soil conditions. Consequently, the soil vapor RBCLs are "backcalculated" from the soil RBCLs developed to protect potential workers from adverse health impacts associated with inhaling volatile chemicals and/or contaminated fugitive dust. A simple equilibrium phase relationship was used to define the concentration of a chemical that may be measured in soil vapor that correlates to a concentration in soil that may trigger the need for further evaluation and/or action.

Table 5.1 indicates that benzene in soil is the only compound that may present an unacceptable health risk to onsite nonintrusive workers. The soil RBCL for benzene incorporates both volatilization and fugitive dust as potential release mechanisms. This is a highly conservative exposure assumption, given the type of ground cover encountered at the PFFA site. Additionally, the depth of elevated benzene concentrations in soil will serve to minimize the amount of chemical that can migrate to a receptor exposure point. The "backcalculated" soil vapor RBCL confirms the finding that benzene may persist in site soils at concentrations that may be associated with adverse health impacts for maintenance workers. In summary, this analysis suggests that additional evaluation and/or action may be necessary to address benzene-contaminated soils at the PFFA.

In addition to benzene, the "backcalculated" soil vapor RBCLs for PCE, 1,1,2-TCA, and vinyl chloride were exceeded by at least one soil vapor sampling result. Neither 1,1,2-TCA or vinyl chloride were identified as soil COPCs during the 1995 BRA (Jacobs, 1995a). The detections for all 3 compounds were isolated detections and concentrations above the RBCL were detected only in one soil vapor sample. As a secondary check, the measured soil vapor concentrations for these three compounds can be compared to workplace environmental standards adopted by the Occupational Safety and Health Administration (OSHA). OSHA permissible exposure limits (PELs) are time-weighted average (TWA) concentrations that should not be exceeded during any 8-hour work shift of a 40-hour work week. Comparing measured soil vapor concentrations to these types of standards is a conservative (i.e., health-protective) approach, because it assumes that *in situ* soil vapor concentrations are

TABLE 5.1
Comparison of Maintenance Worker RBCLs to Maximum Detected Soil Vapor and Soil COPC Concentrations
PFFA RAP
Castle Airport, California

Chemical	Units	Maximum Detected Concentration	Calculated Inhalation RBCL	Inhalation RBCL Exceeded?
Soil Vapor COPCs				
Benzene	ppmv	**1.20E+03**	**3.77E+00**	**Yes**
Toluene	ppmv	8.20E+02	1.46E+03	No
Ethylbenzene	ppmv	1.96E+02	4.90E+03	No
Xylenes, Total	ppmv	4.40E+02	2.55E+04	No
1,2,4-TMB	ppmv	2.90E+01	--	--
1,3,5-TMB	ppmv	1.15E+02	--	--
4-Ethyltoluene	ppmv	3.00E+01	--	--
Bromobenzene	ppmv	3.40E-01	--	--
PCE	ppmv	1.12E+01	9.85E+01	No
TCE	ppmv	6.20E-01	2.64E+01	No
1,1-DCE	ppmv	6.30E-01	2.38E+02	No
1,1,2-TCA	ppmv	**3.50E+00**	**1.83E+00**	**Yes**
Vinyl chloride	ppmv	**7.40E+00**	**1.10E-01**	**Yes**
Soil COPCs				
Benzene	mg/kg	**1.20E+01**	**2.46E+00**	**Yes**
Toluene	mg/kg	8.00E+01	2.33E+03	No
Ethylbenzene	mg/kg	6.10E+01	4.96E+03	No
Xylenes, Total	mg/kg	3.80E+02	4.14E+04	No
1,2,4-TMB	mg/kg	1.20E+02	--	--
1,3,5-TMB	mg/kg	3.70E+01	--	--
Naphthalene	mg/kg	1.80E+01	4.42E+03	No
p-Isopropyltoluene	mg/kg	9.60E+00	--	--
n-Propylbenzene	mg/kg	2.40E+01	--	--
Isopropylbenzene	mg/kg	1.50E+01	2.55E+06	No
n-Butylbenzene	mg/kg	1.60E+01	--	--
sec-Butylbenzene	mg/kg	9.30E+00	--	--
tert-Butylbenzene	mg/kg	7.10E-01	--	--
Anthracene	mg/kg	2.30E-01	7.07E+05	No
Acenaphthene	mg/kg	9.00E-02	1.35E+04	No
Benzo(a)anthracene	mg/kg	4.90E-01	6.31E+04	No
Benzo(a)pyrene	mg/kg	1.30E-01	3.32E+03	No
Benzo(b)fluoranthene	mg/kg	3.20E-01	3.32E+03	No
Benzo(g,h,i)perylene	mg/kg	6.30E-02	--	--
Benzo(k)fluoranthene	mg/kg	1.20E-01	3.32E+03	No
bis-(2-ethylhexyl) phthalate	mg/kg	3.60E-01	1.73E+06	No
Chrysene	mg/kg	4.40E-01	6.31E+05	No
Dibenzofuran	mg/kg	6.40E-02	--	--
di-n-Butyl-phthalate	mg/kg	5.10E-01	3.47E+08	No
Fluorene	mg/kg	1.30E-01	5.22E+04	No
Fluoranthene	mg/kg	1.20E+00	1.39E+08	No
Ideno(1,2,3-c,d)pyrene	mg/kg	6.80E-02	3.32E+03	No
2-Methylnaphthalene	mg/kg	7.30E+00	1.39E+08	No
Phenanthrene	mg/kg	1.40E+00	--	--
Pyrene	mg/kg	1.00E+00	1.04E+08	No
Chlorobenzene	mg/kg	4.00E-01	1.31E+02	No
PCE	mg/kg	5.40E-03	6.32E+01	No
TCE	mg/kg	6.00E-01	1.19E+01	No

representative of ambient air conditions. The maximum measured soil vapor result for 1,1,2-TCA (3.5 ppmv) and PCE (11.2 ppmv) were less than their OSHA PELs of 10 ppmv and 25 ppmv, respectively. The maximum measured soil vapor result for vinyl chloride (7.3 ppmv) is slightly above its OSHA PEL of 1 ppmv; however, vinyl chloride was only detected in one sample during the RI at a depth of 23.5 feet bgs. The nature of ground cover at the PFFA site will significantly impede chemical migration from deeper soils to ambient air.

5.3.3.2 Construction Worker RBCLs

Table 5.2 presents the RBCLs for soil vapor/soil COPCs that are protective of onsite construction (intrusive) workers and compares these concentrations to the most recently measured maximum site concentration. Detailed calculations of these RBCLs are shown in Appendix D. As before, soil vapor was not treated as an environmental medium of concern itself; rather, it was considered to be representative of *in situ* soil conditions. Consequently, the soil vapor RBCLs are "backcalculated" from the soil RBCLs developed to protect potential workers from adverse health impacts associated with: inhaling volatile chemicals and/or contaminated fugitive dust, incidentally ingesting contaminated soil particulates, and incidentally coming into direct contact with contaminated soil. A simple equilibrium phase relationship was used to define the concentration of a chemical that may be measured in soil vapor that correlates to a concentration in soil that may trigger the need for further evaluation and/or action.

Table 5.2 indicates that benzene in soil is the only compound that may present an unacceptable health risk to onsite intrusive workers. The soil RBCL for benzene is an integrated cleanup level that incorporates several exposure pathways, including inhalation of chemicals volatilizing from the subsurface and/or released in fugitive dusts; incidental ingestion of contaminated soils during excavation activities; and incidental direct contact with contaminated soil. Benzene is the only compound measured in either soil vapor or soil to exceed these industrial RBCLs. In summary, this analysis suggests that additional evaluation and/or action may be necessary to address benzene-contaminated soils at the PFFA.

In addition to benzene, the "backcalculated" soil vapor RBCLs for PCE, 1,1,2-TCA, and vinyl chloride were exceeded by at least one soil vapor sampling result. These results are similar to the results obtained with the maintenance worker RBCLs, as discussed in Section 5.3.3.1. Neither PCE or 1,1,2-TCA exceeded their respective OSHA PELs. Vinyl chloride was only detected in one sample during the RI at a depth of 23.5 feet bgs. The isolated detections of these compounds and the nature of ground cover at the PFFA site will significantly impede chemical migration from deeper soils to ambient air.

5.4 CONCLUSIONS AND RECOMMENDATIONS

The development of the site-specific RBCLs indicates that benzene-contaminated soils may warrant additional evaluation and/or remediation to protect both current and potential future onsite workers. Soil vapor data for 1,1,2-TCA and vinyl chloride also suggest these compounds may be present in very isolated areas at the PFFA site at concentrations that may warrant evaluation and/or remediation. Neither of these compounds were identified as soil COPCs as a result of screening earlier soil sampling results (Jacobs, 1995a). Future remedial

TABLE 5.2
Comparison of Construction Worker Integrated RBCLs to Maximum Detected Soil Vapor and Soil COPC Concentrations
PFFA RAP
Castle Airport, California

Chemical	Units	Maximum Detected Concentration	Calculated Integrated RBCL	Integrated RBCL Exceeded?
Soil Vapor COPCs				
Benzene	ppmv	**1.20E+03**	**3.31E+01**	**Yes**
Toluene	ppmv	8.20E+02	3.75E+03	No
Ethylbenzene	ppmv	1.96E+02	1.04E+04	No
Xylenes, Total	ppmv	4.40E+02	5.77E+05	No
1,2,4-TMB	ppmv	2.90E+01	--	--
1,3,5-TMB	ppmv	1.15E+02	--	--
4-Ethyltoluene	ppmv	3.00E+01	--	--
Bromobenzene	ppmv	3.40E-01	--	--
PCE	ppmv	1.12E+01	2.41E+02	No
TCE	ppmv	6.20E-01	2.54E+02	No
1,1-DCE	ppmv	6.30E-01	2.38E+02	No
1,1,2-TCA	ppmv	3.50E+00	1.60E+01	No
Vinyl chloride	ppmv	7.40E+00	1.01E+00	No
Soil COPCs				
Benzene	mg/kg	**1.20E+01**	**2.46E+00**	**Yes**
Toluene	mg/kg	8.00E+01	2.33E+03	No
Ethylbenzene	mg/kg	6.10E+01	4.96E+03	No
Xylenes, Total	mg/kg	3.80E+02	4.14E+04	No
1,2,4-TMB	mg/kg	1.20E+02	--	--
1,3,5-TMB	mg/kg	3.70E+01	--	--
Naphthalene	mg/kg	1.80E+01	4.42E+03	No
p-Isopropyltoluene	mg/kg	9.60E+00	--	--
n-Propylbenzene	mg/kg	2.40E+01	--	--
Isopropylbenzene	mg/kg	1.50E+01	2.55E+06	No
n-Butylbenzene	mg/kg	1.60E+01	--	--
sec-Butylbenzene	mg/kg	9.30E+00	--	--
tert-Butylbenzene	mg/kg	7.10E-01	--	--
Anthracene	mg/kg	2.30E-01	7.07E+05	No
Acenaphthene	mg/kg	9.00E-02	1.35E+04	No
Benzo(a)anthracene	mg/kg	4.90E-01	6.31E+04	No
Benzo(a)pyrene	mg/kg	1.30E-01	3.32E+03	No
Benzo(b)fluoranthene	mg/kg	3.20E-01	3.32E+03	No
Benzo(g,h,i)perylene	mg/kg	6.30E-02	--	--
Benzo(k)fluoranthene	mg/kg	1.20E-01	3.32E+03	No
bis-(2-ethylhexyl) phthalate	mg/kg	3.60E-01	1.73E+06	No
Chrysene	mg/kg	4.40E-01	6.31E+05	No
Dibenzofuran	mg/kg	6.40E-02	--	--
di-n-Butyl-phthalate	mg/kg	5.10E-01	3.47E+08	No
Fluorene	mg/kg	1.30E-01	5.22E+04	No
Fluoranthene	mg/kg	1.20E+00	1.39E+08	No
Ideno(1,2,3-c,d)pyrene	mg/kg	6.80E-02	3.32E+03	No
2-Methylnaphthalene	mg/kg	7.30E+00	1.39E+08	No
Phenanthrene	mg/kg	1.40E+00	--	--
Pyrene	mg/kg	1.00E+00	1.04E+08	No
Chlorobenzene	mg/kg	4.00E-01	1.31E+02	No
PCE	mg/kg	5.40E-03	6.32E+01	No
TCE	mg/kg	6.00E-01	1.19E+01	No

decision-making activities for the PFFA site should focus on addressing benzene-contaminated soils.

No potentially completed exposure pathways involving groundwater were identified. Consequently, no RBCLs for the groundwater COPCs were developed. However, a more detailed evaluation of the potential for chemical migration in groundwater is recommended to assure that all exposure pathways remain incomplete/interrupted. This evaluation can be found in Section 6 of this RAP.

SECTION 6

EVALUATION OF NATURAL ATTENUATION

6.1 OVERVIEW

As discussed in Section 1, the primary objective of this RAP is to develop and describe a risk-based remedial action for the PFFA that meets the requirements of local regulatory agencies. The interim remedial strategy for the PFFA based on the RI/FS process is SVE and bioventing, primarily to reduce soil contamination and reduce to potential for soil contaminant sources to impact groundwater. This section specifically documents the potential for natural chemical attenuation processes (alone and possibly in combination with source reduction technologies) to reduce the persistence, mobility, mass, and toxicity of COPCs in groundwater at the PFFA. The quantitative chemical fate assessment presented in this section was completed to support compliance with the risk-based remediation requirements discussed in Section 5. An evaluation of bioventing and SVE as source removal technologies for contaminants in the vadose zone is provided in Section 7.

The screening exposure pathway analysis completed in Section 5 indicated that exposure pathways to offsite receptors may be completed if the groundwater extraction system that is now being operated north of the PFFA were to be turned off and site-related contaminants migrated at hazardous concentrations to potential offsite exposure points. The objective of this natural attenuation evaluation was to quantitatively determine whether any exposure pathways involving offsite receptors could reasonably be completed when the effects of natural chemical attenuation processes were considered.

6.2 OPERATIVE MECHANISMS OF CONTAMINANT ATTENUATION

Understanding the fate of each of the BTEX compounds and naphthalene in environmental media is critical to evaluating and predicting contaminant distribution patterns. There are several physical, chemical, and biological processes that influence how a chemical behaves in soil and groundwater. The following sections present a brief overview of the major chemical characteristics that define the fate of the contaminants in soils and groundwater at the PFFA. These chemical characteristics ultimately determine if the mass of contaminants in the environment can be eliminated or rendered immobile by natural processes. The positive effects of these natural processes on reducing the actual mass of naphthalene and BTEX and/or minimizing the extent of migration in groundwater and soil is termed natural attenuation (sometimes also referred to as intrinsic remediation).

6.2.1 Contaminant Properties and Mass Transport Mechanisms

The relative solubility, sorptive nature, and volatility of a chemical can govern the effectiveness of nondestructive chemical attenuation processes at the PFFA. Nondestructive attenuation processes can be described as those physical and chemical processes that may prohibit significant contaminant migration but may not result in a permanent reduction in contaminant mass. Examples of nondestructive attenuation processes include volatilization, sorption, advection, and dispersion. These processes must be evaluated when determining

whether a compound poses an actual risk to human health and the environment. If the contaminant is not likely to reach a potential receptor, the contaminant poses no risk.

6.2.1.1 Solubility

The water solubility of a chemical species defines how that particular chemical could partition (leach) from a contaminant source and dissolve into and migrate with groundwater. In general, lighter hydrocarbon chains tend to be more water soluble than heavier hydrocarbon chains. For example, the water solubilities of benzene, toluene, ethylbenzene, the various xylene isomers, and naphthalene are approximately 1,700 mg/L, 500 mg/L, 160 mg/L, 145 to 175 mg/L, and 30 mg/L respectively (Bohon and Claussen, 1951; Mackay and Shiu, 1981; Verschueren, 1983; Isnard and Lambert, 1988; Howard, 1990). Consequently, even though naphthalene and the BTEX compounds may comprise a low mass fraction (i.e., approximately 4 percent) of the initial source of contamination, these compounds preferentially leach from contaminated soil or dissolve from light, nonaqueous phase liquid (LNAPL) (also termed free product) into groundwater and migrate as dissolved contamination (Lyman *et al.*, 1992).

Dissolution of soluble contaminants from residual soil contamination and LNAPL can be significant sources of groundwater contamination. Since there was no LNAPL found at the site, only residual soil contamination was retained for more detailed evaluation as part of the screening exposure pathway analysis completed in Section 5. The potential impacts of contaminants leaching from soils and impacting groundwater quality are quantitatively evaluated in Section 6.6.

6.2.1.2 Sorption

Another chemical characteristic that can govern how a compound is attenuated in soil and groundwater is its sorptive properties. If a contaminant can be strongly sorbed to the aquifer matrix, the compound will be less mobile and less likely to be transported great distances from the source area. The BTEX compounds are less sorptive than other petroleum hydrocarbons. Naphthalene and other PAHs tend to sorb more strongly than the BTEX compounds. Benzene does not sorb readily to soil and is considered the most mobile of the BTEX compounds. Toluene sorbs more readily to soil than benzene, but is still very mobile. Ethylbenzene sorbs more strongly to soil than benzene but less strongly than toluene. Of all the BTEX compounds, xylenes sorb most strongly to soil, but can still leach from unsaturated soil and dissolve and migrate slowly in groundwater (Abdul *et al.*, 1987). In comparison, heavier hydrocarbons such as naphthalene and the other PAH compounds sorb more strongly to the soil matrix and migration is limited in both soil and groundwater (Verschueren, 1983).

The effects of sorption tend to be more pronounced with increases in molecular weight and complexity. Thus, sorptive effects should be most pronounced for heavier-weight PAHs, somewhat less for naphthalene, toluene, and xylenes, and least pronounced for benzene. Hydrocarbons, including naphthalene and the BTEX compounds, sorb primarily to that portion of the soil matrix that is composed of organic carbon.

The TOC content of both unsaturated and saturated soils was measured as part of previous sampling (Section 1.5). TOC contents were generally below 0.10%. This level of organic carbon is not likely to significantly retard the solute transport in groundwater for the less

sorptive and soluble compounds such as BTEX and naphthalene, but is probably significant enough to retard heavier-weight PAHs to some degree in the vadose zone.

6.2.1.3 Volatility

The volatility of PAHs, naphthalene, and each of the BTEX compounds also affects how the contaminants behave in the environment. All of the BTEX compounds are classified as volatile chemicals because they have vapor pressures in excess of 0.1 millimeter of mercury (mm Hg). Benzene is the most volatile of the BTEX compounds, with a vapor pressure of about 95 mm Hg, and xylenes are the least volatile with vapor pressures between 6 and 9 mm Hg. PAH compounds, including naphthalene, are not considered volatile chemicals. Naphthalene has a vapor pressure below 0.1 mm Hg and the heavier-weight PAHs have vapor pressures several orders of magnitude below that of naphthalene.

Volatilization from contaminated media was investigated as a mass transport mechanism at the PFFA (Section 5). The risk-based remediation criteria for soils were calculated to protect onsite workers from health risks associated with exposure to soils during both normal and deep excavation activities. The soil concentration goals include volatilization of contaminants from exposed soils. Because concentrations of volatile contaminants are above the health-protective criteria developed using reasonable, site-specific exposure assumptions, the volatilization pathway is a risk element and is involved in chemical fate at the site.

6.2.1.4 Discussion

The preceding discussion shows that solubility, sorptive characteristics, and volatility are important chemical characteristics to consider when assessing whether hydrocarbon contamination in soil and groundwater at the PFFA may present an unacceptable risk to human health and the environment. Site contaminants characterized by relatively high water solubility, low sorptive properties, and high volatility, such as the BTEX compounds and to a lesser extent naphthalene, can be rapidly introduced into and transported with groundwater. Consequently, because naphthalene and the BTEX compounds are relatively mobile, they may drive the type and magnitude of remediation necessary to isolate the contamination and protect downgradient and onsite receptors from potential risks due to exposure to these chemicals. PAHs, including naphthalene, are less soluble than the BTEX compounds and more effectively sorbed to the soil matrix. Thus, they are less mobile than the BTEX compounds and are more likely to be isolated in and near the initial source of contamination.

6.2.2 Biodegradation of Petroleum Compounds in Soil and Groundwater

Biodegradation may also act as a chemical attenuation process. In comparison to nondestructive chemical attenuation processes, destructive chemical attenuation processes result in the permanent removal of contaminant mass from the environment and may reduce the length of time required to attain cleanup goals. Documenting and distinguishing the effects of destructive attenuation processes, such as biodegradation, from nondestructive attenuation processes is important in evaluating the potential for natural attenuation to bring about a reduction in contaminant mass over time. The effectiveness of destructive attenuation processes at reducing contaminant mass at a site depends on how amenable the chemical is to biodegradation and whether the site is characterized by physical, chemical, and biological conditions favorable to such processes.

Numerous laboratory and field studies have shown that hydrocarbon-degrading bacteria can participate in the degradation of many of the chemical components of gasoline, jet fuel, and diesel fuel including BTEX, naphthalene, and to some extent other PAH compounds, under both aerobic and anaerobic conditions (e.g., Jobson *et al.*, 1972; Perry, 1977; Atlas, 1981, 1984, 1988; Gibson, 1984; Reinhard *et al.*, 1984; Young, 1984; Bartha, 1986; Wilson *et al.*, 1986, 1987, 1990; Baedecker *et al.*, 1988; Lee, 1988; Chiang *et al.*, 1989; Grbic-Galic, 1989, 1990; Leahy and Colwell, 1990; Parker *et al.*, 1990; Stieber *et al.*, 1990, 1994; Altenschmidt and Fuchs, 1991; Alvarez and Vogel, 1991; Baedecker and Cozzarelli, 1991; Bauman, 1991; Borden, 1991; Brown and McFarland, 1991; Haag *et al.*, 1991; Hutchins and Wilson, 1991; Beller *et al.*, 1992; Bouwer, 1992; Edwards and Grbic-Galic, 1992; Thierrin *et al.*, 1992; Malone *et al.*, 1993; Davis *et al.*, 1994; Aronson and Howard, 1997). Biodegradation of fuel hydrocarbons will occur when an indigenous population of hydrocarbon-degrading microorganisms is present in the soil and groundwater, and sufficient concentrations of electron acceptors and nutrients, including fuel hydrocarbons, are available to these organisms. Soils and groundwater with a history of exposure to BTEX and PAH compounds generally contain microbial populations competent to facilitate biodegradation reactions (Zobell, 1946; Litchfield and Clark, 1973; Borden, 1994; Seech *et al.*, 1994; Simpkin and Giesbrecht, 1994). The chemical basis for the biodegradation of BTEX compounds is described in more detail in Section 6.4, where geochemical data relevant to documenting biodegradation at the field scale at the PFFA are presented.

6.3 EVIDENCE OF FIELD-SCALE CONTAMINANT MASS LOSS

The first step in determining whether site data indicate that TPH, BTEX compounds, and naphthalene are biodegrading at the PFFA is to evaluate the analytical data presented in Section 4 and Appendix A. Comparison of analytical data collected over time can be a valuable indicator that contaminants are being destructively attenuated in soil and groundwater.

6.3.1 Observed Contaminant Loss from Groundwater

At the PFFA, groundwater sampling has been conducted since July 1989, although regular quarterly monitoring has only been conducted since February 1993 and many of the MWs first installed and sampled in 1989 went dry between well installation and the start of quarterly monitoring activities. Therefore, only a limited data set exists for evaluating historical contaminant reductions.

The largest data set of historical results from contaminated MWs exists for JM11 and JM12. These MWs were installed in the Summer of 1993 and were first sampled in November of 1993. Figure 6.1 and 6.2 show the results for total BTEX and TCE for sampling conducted between November 1993 and August 1997 at JM11 and JM12, including the results collected during this investigation in May 1997. Results from samples collected during the first quarter of 1996 from JM11 and the first and third quarters of 1996 for JM12 have not been included in the data set because of the change in sampling protocol from conventional purging to low flow purging during these events (Jacobs, 1997a). Conventional purging was recommenced for JM11 and JM12 in the third quarter of 1996 and the first quarter of 1997, respectively.

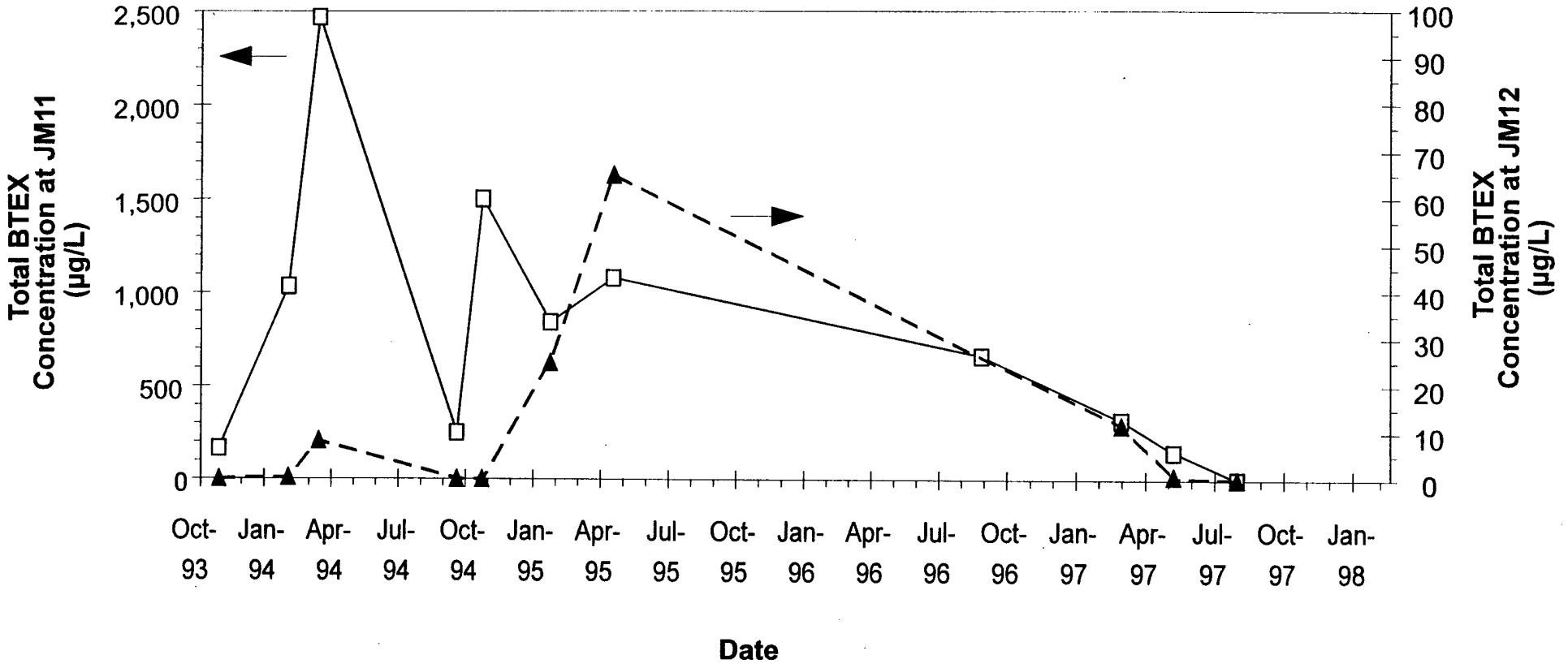


FIGURE 6.1

HISTORICAL TOTAL BTEX CONCENTRATIONS AT JM11 AND JM12

PFFA RAP
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.

Oakland, California

\731297\REPORT\RISKRPT\FIGS_L8.CDR 4/30/98

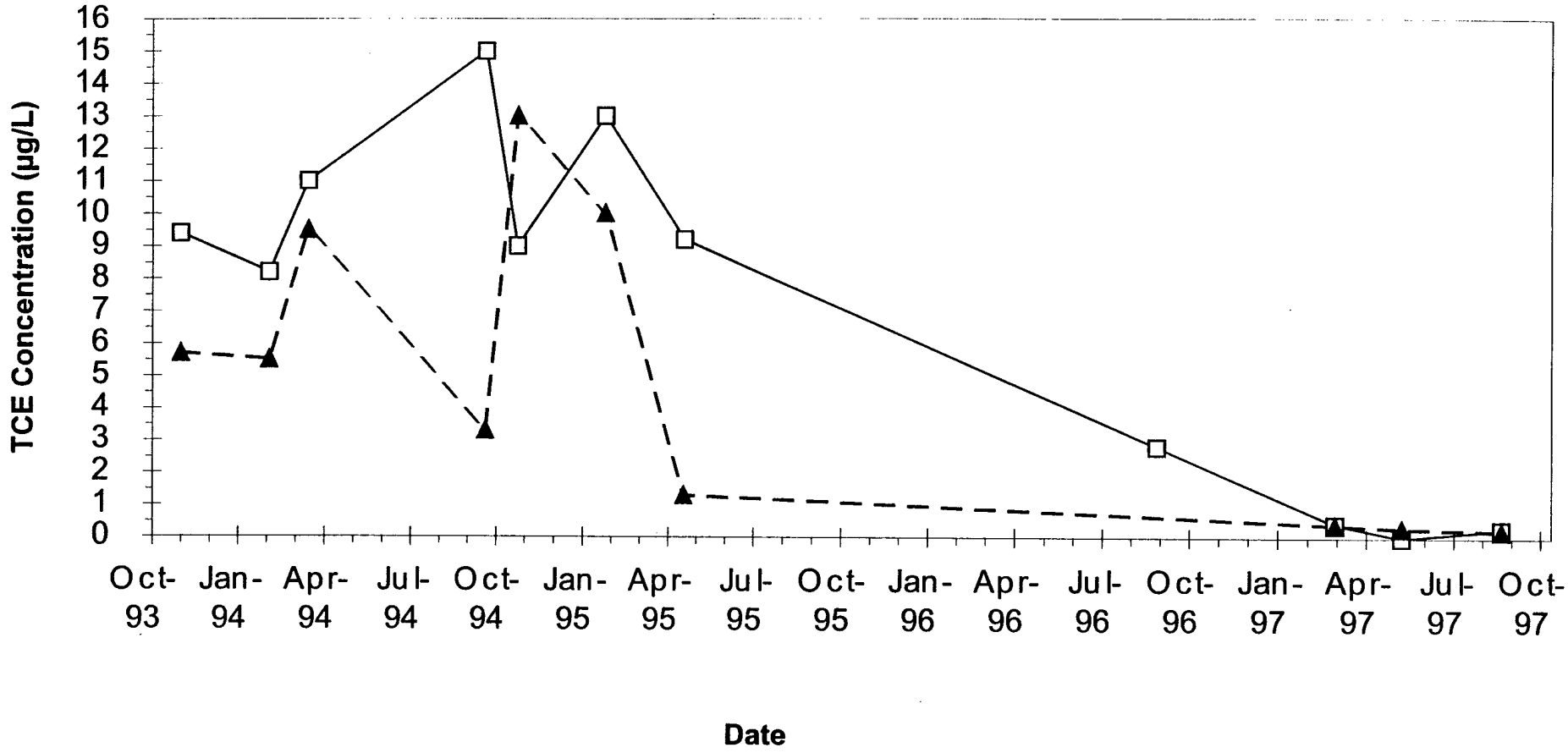


FIGURE 6.2

HISTORICAL TCE CONCENTRATIONS AT JM11 AND JM12

PFFA RAP
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.

Oakland, California

\731297\REPORT\RISKRPT\FIGS_L8.CDR 4/30/98

There is considerable variability in the sampling results, which may be due to seasonal groundwater elevation fluctuations, seasonal changes in infiltration rates, a heterogeneous distribution of contamination, influences of the groundwater extraction well (JE1) north of JM11 and JM12, or removal of contaminant sources at the PFFA due to changes in site operations and Base closure activities. Increases in BTEX concentrations at JM12 appear to be correlated with the initiation of groundwater extraction at JE1 in the third quarter of 1994, with a noticeable upward trend in the following 2 sampling events. JE1 is screened between 64 and 84 feet bgs, across the screened intervals of both JM11 and JM12, and groundwater extraction and drawdown of the water table may have drawn some contamination from the upper part of the aquifer into the lower part of the aquifer.

Despite the variability in sampling results at JM11 and increases in BTEX concentrations at JM12 after initiation of the groundwater extraction system, there is a noticeable downward trend in benzene, total BTEX, and TCE concentrations for both JM11 and JM12 since April 1995. Samples collected at JM11 in August 1997 (the most recent sampling event) detected a total BTEX concentration of 0.53 µg/L, all of which was total xylenes. TCE was detected in both JM11 and JM12 at concentrations of 0.27 µg/L and 0.21 µg/L, respectively. Benzene, TPH, and naphthalene were not detected in either MW.

BTEX was not detected in May 1997 at MW970 or MW971, installed downgradient/crossgradient of JM11 and MW531, where the highest concentrations of BTEX have historically been detected. BTEX compounds have also not been detected in extracted groundwater from either of the two extraction wells (EW1 or JE1) since the extraction systems began operation, suggesting that BTEX compounds are being degraded before they reach the extraction wells. The limited extent of the BTEX plume downgradient from JM11 and MW531, despite the relatively high historical BTEX concentrations at JM11 and MW531, the relatively high advective groundwater velocity (Section 2.2), and relatively low TOC content of the aquifer (Section 2.3.1), provides strong evidence that BTEX mass loss is occurring at the site. The groundwater geochemical results (presented in Section 6.4) provide evidence that at least some of the mass loss is due to biodegradation. Therefore, the observed BTEX loss in groundwater and limited extent of the BTEX plume is probably a combination of biodegradation and weathering losses from the vadose zone soils in the source areas, biodegradation in the groundwater, and flushing of the aquifer by the groundwater extraction and treatment system.

Because there are no significant sources of TCE at the PFFA, the observed TCE loss in groundwater is probably mainly due to flushing of the aquifer by the groundwater extraction and treatment system. TCE concentrations began decreasing in JM11 soon after the system was brought online in the third quarter of 1994. Some degree of TCE biodegradation may also be occurring in groundwater through reductive dechlorination. Evidence for reductive dechlorination is provided by the detection of *cis*-1,2-DCE coincident with the TCE in site MWs (Table 4.5 and Appendix A). Groundwater conditions in some areas of the PFFA appear to have the necessary conditions to support reductive dechlorination (Section 6.4), namely, sulfate and methane reducing conditions.

6.3.2 Estimating Site-Specific Contaminant Biodegradation Rates

Estimation of biodegradation rate constants is necessary to accurately simulate the fate and transport of contaminants dissolved in groundwater. 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. Use of this method for an expanding plume can result in an overestimation of the rate of biodegradation 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.

The Bushchek and Alcantar method is useful for estimating total biodegradation rates which includes both aerobic and anaerobic biodegradation. Because both processes appear to be occurring at the PFFA (Section 6.4), the Buscheck and Alcantar method is an appropriate method for calculating a first-order biodegradation rate at the PFFA. Although one of the assumptions in the method is a steady-state plume and the data presented in Section 6.3.1 indicates the plume at the PFFA is probably shrinking, a biodegradation rate calculated for shrinking plumes using this method will underestimate the true biodegradation rate, so the estimate is conservative.

The biodegradation rate calculations are summarized in Appendix E. The biodegradation rate was estimated using groundwater analytical data from the May 1997 sampling event, the most recent sampling event for all PFFA MWs. The groundwater flow pathway between MW966 (near Building 71, one of the source areas) and MW971 was used. This flow pathway was chosen based on the groundwater elevation contours (Figure 3.2) and the geometry of the electron acceptor plumes (Section 6.4). Although higher concentrations of BTEX and TPH were measured in JM11, there were no downgradient MWs between JM11 and JE1 which could be used to calculate a biodegradation rate. Contaminant sources contributing to BTEX or TPH from sources within the northern portion of the PFFA near JM11, which is along the chosen groundwater flow pathway, would tend to decrease the calculated biodegradation rate; therefore, the estimate is conservative.

Because BTEX was only detected at MW966, only two data points were available along the groundwater flow pathway (i.e., at MW966 and MW968). At MW968, one half of the detection limit was used in the calculation since BTEX was not detected. Since only two data points were available for the BTEX biodegradation rate estimate, for comparison purposes, TPH concentrations also were used along the flow pathway to calculate a biodegradation rate (TPH was detected at 3 MWs along the flow pathway, the minimum number of data points required). The biodegradation rates calculated for BTEX and TPH were estimated at 3.2×10^{-2} day^{-1} (12 year^{-1} or a half-life of 0.059 years) and 1.4×10^{-2} day^{-1} (5.1 year^{-1} or a half-life of 0.14 years), respectively. Because these rates are based on site data and are also at the lower end of the ranges reported in the literature (Howard *et al.*,

1991; Aronson and Howard, 1997), the rates were considered to be reasonable and conservative.

6.4 EVIDENCE OF CONTAMINANT BIODEGRADATION VIA MICROBIALLY CATALYZED REDOX REACTIONS

Evidence of field-scale contaminant mass losses presented in preceding section suggests that TPH, BTEX, naphthalene, and, potentially, TCE are biodegrading in groundwater at the PFFA. Another line of evidence that can be used to show that these contaminants are biodegrading in saturated soil and groundwater at the PFFA involves geochemical indicators. Analytical data on potential electron acceptors can be used as geochemical indicators of biodegradation (Salanitro, 1993; McCallister and Chiang, 1994; Wiedemeier *et al.*, 1995; Borden *et al.*, 1995).

Reductions in the concentrations of oxidized chemical species that are used by microorganisms to facilitate the oxidation of naphthalene and the BTEX compounds is another indication that contaminants are biodegrading. The amount of potential electron acceptors available to participate in contaminant biodegradation reactions can be used to estimate the total contaminant mass that can be biodegraded over time at this site. Coupled with the biodegradation rates described earlier, this information can be used to predict how much and how quickly contaminant mass can be permanently removed from saturated soils and groundwater at the PFFA by natural processes. These data can also be used to assess whether potentially significant exposure pathways involving offsite receptors could be completed over time.

Electron acceptors and other geochemical indicators were measured in site groundwater samples collected during the sampling conducted to evaluate natural attenuation by Parsons ES in May 1997. Sampling procedures and methods were described in Section 2.3. Results from the May 1997 sampling event are provided in Table 6.1 and discussed in this section.

6.4.1 Relevance of Redox Couples in Biodegradation

Microorganisms obtain energy to replenish enzymatic systems and to reproduce by oxidizing organic matter. Biodegradation of TPH, naphthalene and the BTEX compounds is the result of a series of reduction-oxidation (redox) reactions which maintain the charge balance within the natural environment. Microorganisms facilitate the degradation of TPH, naphthalene and the BTEX compounds by transferring electrons from the contaminants (electron donor) to available electron acceptors. Electron acceptors are elements or compounds that occur in relatively oxidized states and can participate in redox reactions involving TPH, naphthalene and the BTEX compounds. Electron acceptors that may be present in saturated soil and groundwater at the PFFA are oxygen, nitrate, manganese, sulfate, ferric iron, and carbon dioxide. Results from site-specific electron acceptor analysis at the PFFA are discussed later in this section. The principal electron acceptors operating at the PFFA are discussed in Section 6.5.

Microorganisms facilitate TPH, naphthalene and BTEX biodegradation to produce energy for their use. 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; Berg *et*

al., 1994). Microorganisms will facilitate only those redox reactions that will yield energy. Microorganisms are able to utilize electron transport systems and chemiosmosis to combine energetically favorable and unfavorable reactions to produce energy for life processes. By coupling the oxidation of TPH, naphthalene and the BTEX compounds, which requires energy, to the reduction of other compounds (e.g., oxygen, nitrate, manganese, ferric iron, sulfate, and carbon dioxide), which yield energy, the overall reaction will yield energy.

Figure 6.3 illustrates the sequence of microbially mediated redox processes based on the amount of free energy released for microbial use. 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 6.3 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, manganese, ferric iron, sulfate, and finally carbon dioxide. Each successive redox reaction provides less energy to the system, 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.

The expected sequence of redox processes is also a function of the oxidizing potential (Eh) of the groundwater. The oxidizing potential measures the relative tendency of a solution or chemical reaction to accept or transfer electrons. The oxidizing potential of the groundwater can be measured in the field. This measurement can be used as an indicator of which redox reactions may be operating at a site. This field measurement can then be expressed as pe, which is the hypothetical measure of the electron activity associated with a specific Eh. High pe means that the solution or redox couple has a relatively high oxidizing potential.

Microorganisms can only facilitate the biodegradation (oxidation) of TPH, naphthalene and BTEX compounds using redox couples that have a higher oxidizing potential than the contaminants. Appendix E includes tables that show that redox couples including nitrate, oxygen, manganese, ferric iron, sulfate, and carbon dioxide all have higher oxidizing potentials than the redox couples including TPH, naphthalene and BTEX compounds. This is why these electron acceptors can be used to oxidize TPH, naphthalene and BTEX compounds. The reduction of highly oxidized species results in an overall decrease in the oxidizing potential of the groundwater. As shown in Figure 6.3, the reduction of oxygen and nitrate will reduce the oxidizing potential to levels at which manganese and ferric iron (Fe^{3+}) reduction can occur. As each chemical species that can be used to oxidize the contaminants is exhausted, the microorganisms are forced to use other available electron acceptors with lower oxidizing capacity. When sufficiently negative pe levels have been developed as a result of these redox reactions, sulfate reduction and methanogenesis can occur almost simultaneously (Stumm and Morgan, 1981).

6.4.2 Dissolved Oxygen

DO concentrations at the PFFA ranged from 0.20 to 7.50 mg/L (Table 6.1). Figure 6.4 is an isopleth map showing the distribution of DO concentrations in groundwater and shows graphically that areas with detectable TPH and total BTEX concentrations generally correlate

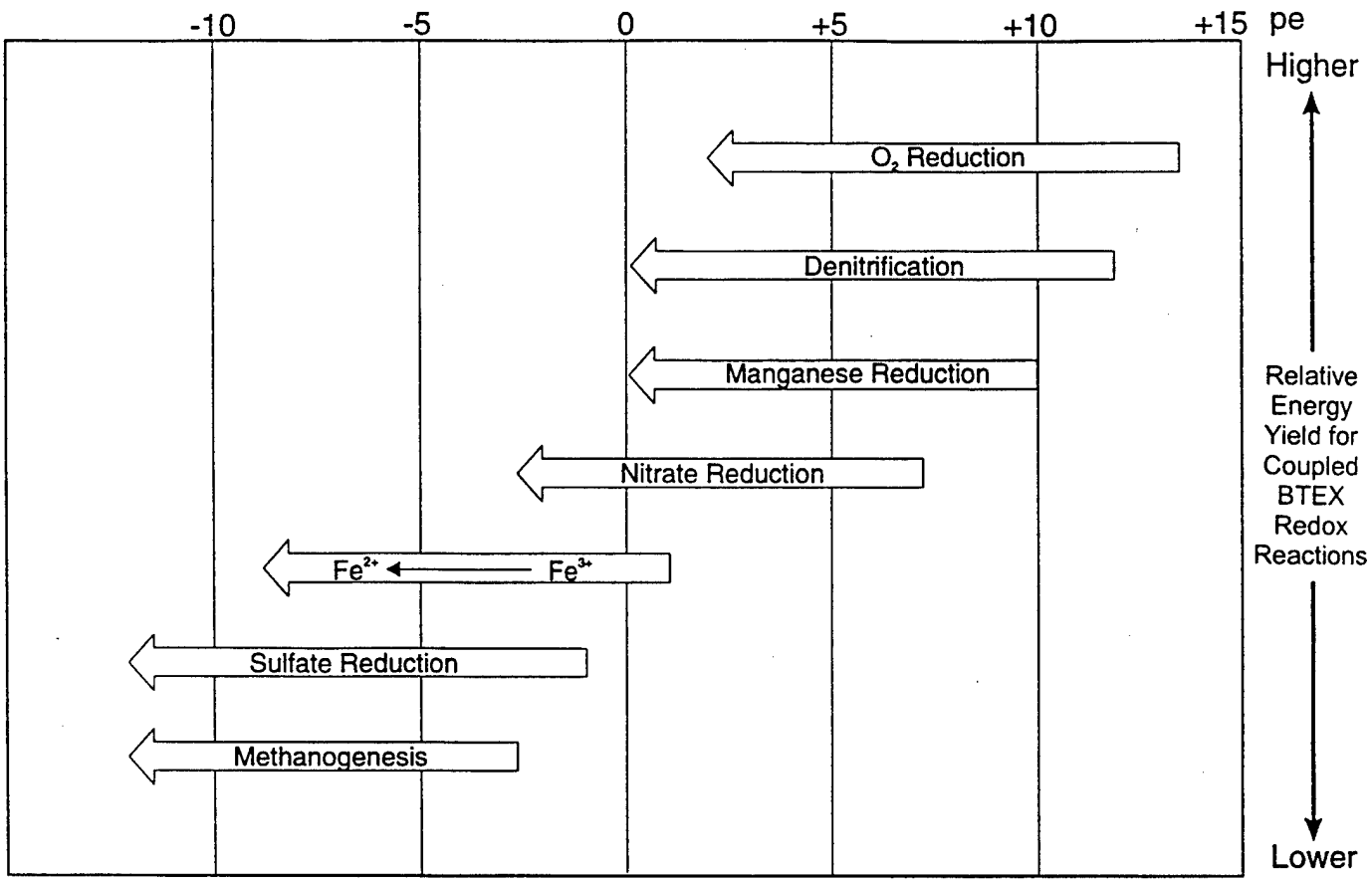
TABLE 6.1
Groundwater Analytical Results
Geochemical Indicator Parameters
PFFA RAP
Castle Airport, California

Method:	A2580B	E150.1	E170.1	E120.1	E360.1	E353.2	E300.0	H8034	H8146	E300.0	H8131	RSK175	C4500	E310.2	E350.1	E300.0	E415.1
Analyte:	ORP (E_h)	pH	Temp	EC	DO	Nitrate (as N)	Nitrite (as N)	Mn	Fe (II)	Sulfate	Sulfide	Methane	CO_2	Alkalinity (as $CaCO_3$)	Ammonia	Chloride	TOC
Location	(mv)	(-)	(°C)	µS/cm	All concentrations in mg/L												
JM11	143	6.55	23.1	577	1.4	2.1	<0.05	2.6	0.37	16.5	0.058	0.05	85	268	<0.10	25.8	<1.0
JM12	228	6.91	22.1	571	2.8	5.3	<0.05	0.5	<0.014	25.5	<0.010	0.0008	33	201	<0.10	28.9	<1.0
MW270	352	6.52	20.1	579	3.1	7.3	<0.05	0.5	<0.014	33.3	0.017	<0.0005	18	186	<0.10	38.4	n.a.
MW280	340	7.00	21.1	408	7.2	4.1	<0.05	0.3	<0.014	13.3	0.029	0.0006	16	161	0.2	17.0	n.a.
MW530	254	7.08	24.0	447	7.5	7.1	<0.05	0.1	0.04	16.7	<0.010	0.0009	26	175	<0.10	20.2	n.a.
MW532	354	7.06	21.5	538	2.9	6.3 [6.5]	<0.05 [<0.05]	0.7	<0.014	26.1 [26.9]	0.012	<0.0005 [<0.0005]	13	107 [189]	0.28 [0.32]	32.2 [32.6]	n.a.
MW534	336	6.64	23.2	548	3.3	6.5	<0.05	<0.1	0.02	27.1	<0.010	<0.0005	20	182	<0.10	34.0	n.a.
MW536	321	6.55	22.9	554	1.8	6.5	<0.05	0.7	<0.014	32.4	<0.010	0.0007	23	184	0.20	37.5	n.a.
MW873	348	6.92	22.3	481	6.2	6.2	<0.05	0.4	<0.014	16.7	<0.010	<0.0005	23	190	<0.10	19.5	1.99
MW899	304	6.94	22.6	590	2.8	10.5	<0.05	0.6	<0.014	34.4	<0.010	0.0006	20	165	0.50	44.9	n.a.
MW965	338	6.41	21.4	554	2.5	5.0 [4.9]	<0.05 [<0.05]	0.2 [0.3]	0.10 [0.09]	26.0 [24.6]	0.083 [0.106]	0.0025 [0.0019]	38 [44]	206 [219]	<0.10 [<0.10]	30.6 [29.4]	<1.0 [<1.0]
MW966	195	6.51	22.2	641	0.2	0.31	<0.05	3.5	0.35	7.7	0.018	0.34	80	355	<0.10	19.5	<1.0
MW967	5	5.20	22.3	471	2.6	1.9	<0.05	0.8	0.10	12.9	0.016	0.0179	65	220	<0.10	20.0	<1.0
MW968	252	6.55	22.5	610	1.2	2.5	<0.05	2.5	0.02	12.8	0.030	0.057	80	303	0.25	24.4	<1.0
MW969	221	6.60	22.6	622	2.2	5.0	<0.05	0.4	0.05	28.3	0.047	0.0037	37	255	0.25	36.0	<1.0
MW970	312	6.60	22.7	656	2.0	2.0	<0.05	1.3	0.34	15.2	0.174	0.0039	35	349	<0.10	25.1	4.32
MW971	11	6.80	23.7	542	1.7	3.2 [3.0]	<0.05 [<0.05]	0.8 [1.1]	0.06 [0.04]	19.6 [20.8]	0.072 [0.073]	0.0078 [0.0083]	60 [55]	272 [266]	<0.10 [<0.10]	24.5 [24.7]	<1.0 [<1.0]
TW13	336	6.77	24.1	600	3.2	10.5	<0.05	0.2	0.07	37.9	0.018	0.0008	22	158	<0.10	41.8	n.a.
TW16	297	7.08	25.4	331	5.6	5.8	<0.05	0.4	0.03	10.3	<0.010	0.0008	10	111	<0.10	17.1	<1.0

Notes:

A2580B : Standard Method reference (18th Edition, 1992)
E300.0 : USEPA Method reference (USEPA, 1983)
H8034 : Hach Method reference (Hach Company, 1997)
C4500 : CHEMetrics Method reference (CHEMetrics, 1997)
RSK175 : Robert S. Kerr Lab Method reference (Kampbell et al., 1989)
ORP (E_h) : oxidation-reduction potential relative to hydrogen

n.a. : not analyzed
[4.9] : field duplicate results shown in brackets
EC : electrical conductivity
Mn : manganese
Fe (II) : ferrous iron
TOC : total organic carbon



Notes

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 pe of the system.

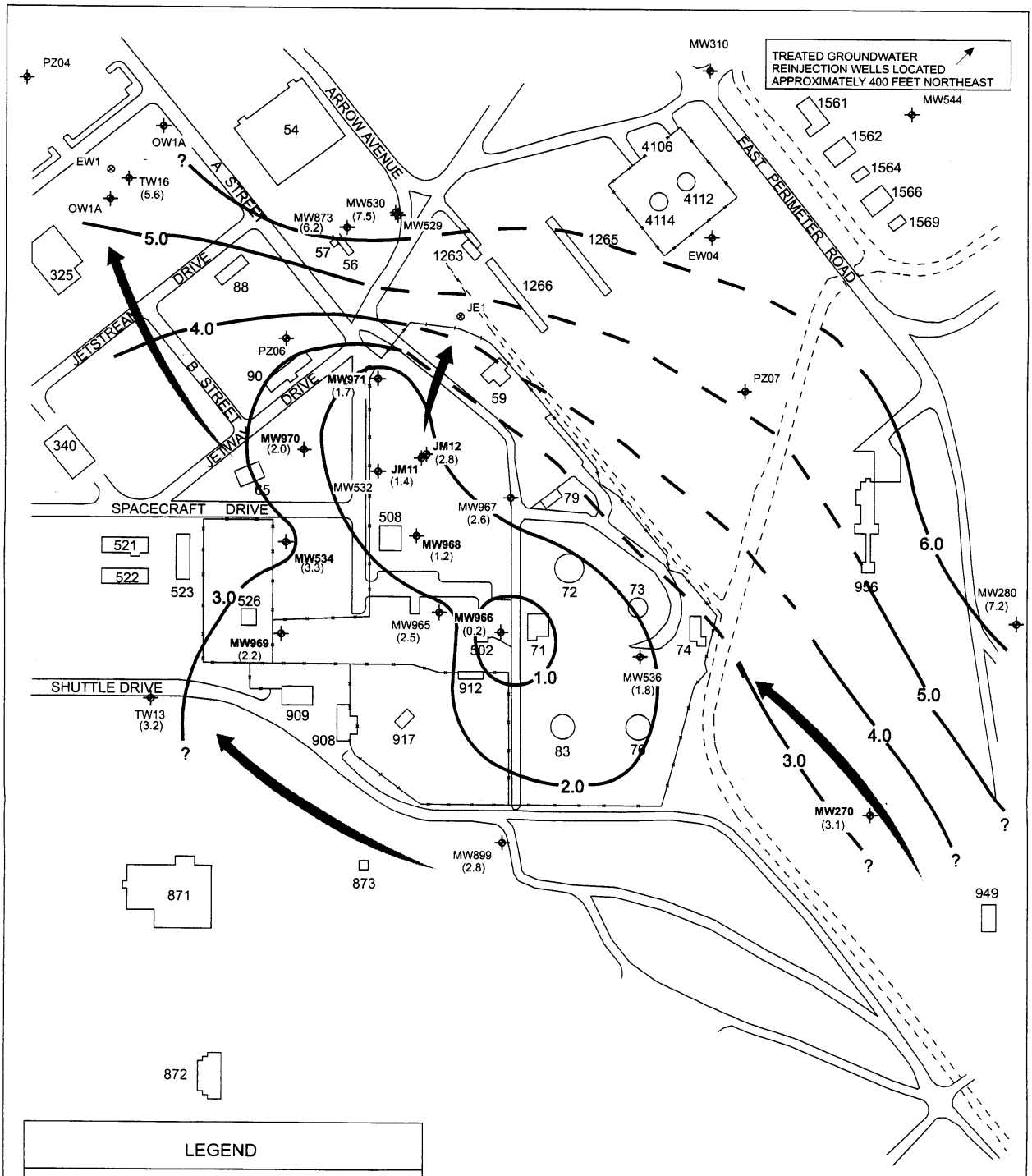
3. The pe of the system determines which electron acceptors are available for COC oxidation.

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

Adapted from Stumm and Morgan, 1981.

FIGURE 6.3
SEQUENCE OF MICROBIALLY MEDIATED REDOX PROCESSES
PFFA RAP
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.
Oakland, California



LEGEND

- ABOVE GROUND STORAGE TANK
- BUILDING
- FENCE
- DRAINAGE CHANNEL
- MW969 — GROUNDWATER MONITORING WELL OR PIEZOMETER
- JE1 — GROUNDWATER EXTRACTION WELL
- INFERRED DIRECTION OF GROUNDWATER MOVEMENT
- 4.0 — LINE OF EQUAL DISSOLVED OXYGEN CONCENTRATION (mg/L) (DASHED WHERE INFERRED); CONTOUR INTERVAL VARIABLE
- (2.5) DISSOLVED OXYGEN CONCENTRATION (mg/L)

FIGURE 6.4

DISSOLVED OXYGEN ISOPLETHS FOR GROUNDWATER

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with areas with depleted DO concentrations. DO concentrations below 0.5 mg/L are generally considered to represent anaerobic conditions. Although DO concentrations were not below 0.5 mg/L at some expected locations (notably JM11, where the maximum BTEX concentrations were detected), the very long screened intervals at most MWs and/or the heterogeneous distribution of contaminants may be causing mixing of aerobic and anaerobic groundwater during purging and sampling activities. More importantly, other geochemical indicators (discussed in the following sections) and the DO result from MW966 indicate that anaerobic conditions can occur at the site and groundwater conditions can be sufficiently reducing for other electron acceptors to be utilized by native microorganisms.

The relatively high DO concentrations to the north and northeast of the PFFA (e.g., as measured in MW280 and MW530) are likely due to the reinjection of treated groundwater in several injection wells located northeast of the site (approximately 400 feet north of Building 1561; not shown on Figure 6.4). MW532 was not used in developing the DO isopleth figure or other electron acceptor figures because it is screened significantly deeper than the other MWs at the site (Appendix B). Although geochemical data from MW532 followed the same general trends noted for other MWs, the trends were not as pronounced (i.e., less DO depletion, lower increases in alkalinity).

6.4.3 Nitrate and Nitrite

Concentrations of nitrate at the site ranged from 0.30 mg/L to 10.5 mg/L (measured as nitrogen [N]). Nitrite was not detected in any sample. Nitrate depletion in groundwater showed the same general trends as that observed for DO depletion. This relationship provides evidence that anaerobic biodegradation of the BTEX compounds is currently occurring at the site through the microbially mediated process of denitrification.

6.4.4 Manganese

Detected soluble manganese concentrations measured at the site ranged from 0.1 mg/L to 3.5 mg/L. Figure 6.5 is an isopleth map showing the distribution of manganese concentrations in groundwater and shows graphically that areas with depleted DO and detectable TPH and total BTEX concentrations generally correlate with areas with increases in manganese concentrations. Background concentrations of manganese were generally below the detection limit or at concentrations less than 0.5 mg/L. The spatial distribution of reduced forms of manganese indicates that manganese is currently being used as an electron acceptor in anaerobic biodegradation reactions.

6.4.5 Ferrous Iron

Detected ferrous iron (Fe^{2+}) concentrations measured at the site ranged from 0.02 mg/L to 0.37 mg/L. Ferrous iron concentrations above 0.10 mg/L were measured only at three MWs located near or downgradient from the source areas (JM11, MW966, MW970), indicating that anaerobic biodegradation through ferric iron reduction is currently limited in extent compared to aerobic respiration, denitrification, and manganese reduction processes. Background concentrations of ferrous iron were generally below the detection limit or at concentrations less than 0.05 mg/L. These relationships provide strong evidence that ferric iron hydroxide is currently being reduced to ferrous iron through anaerobic biodegradation of the BTEX compounds.

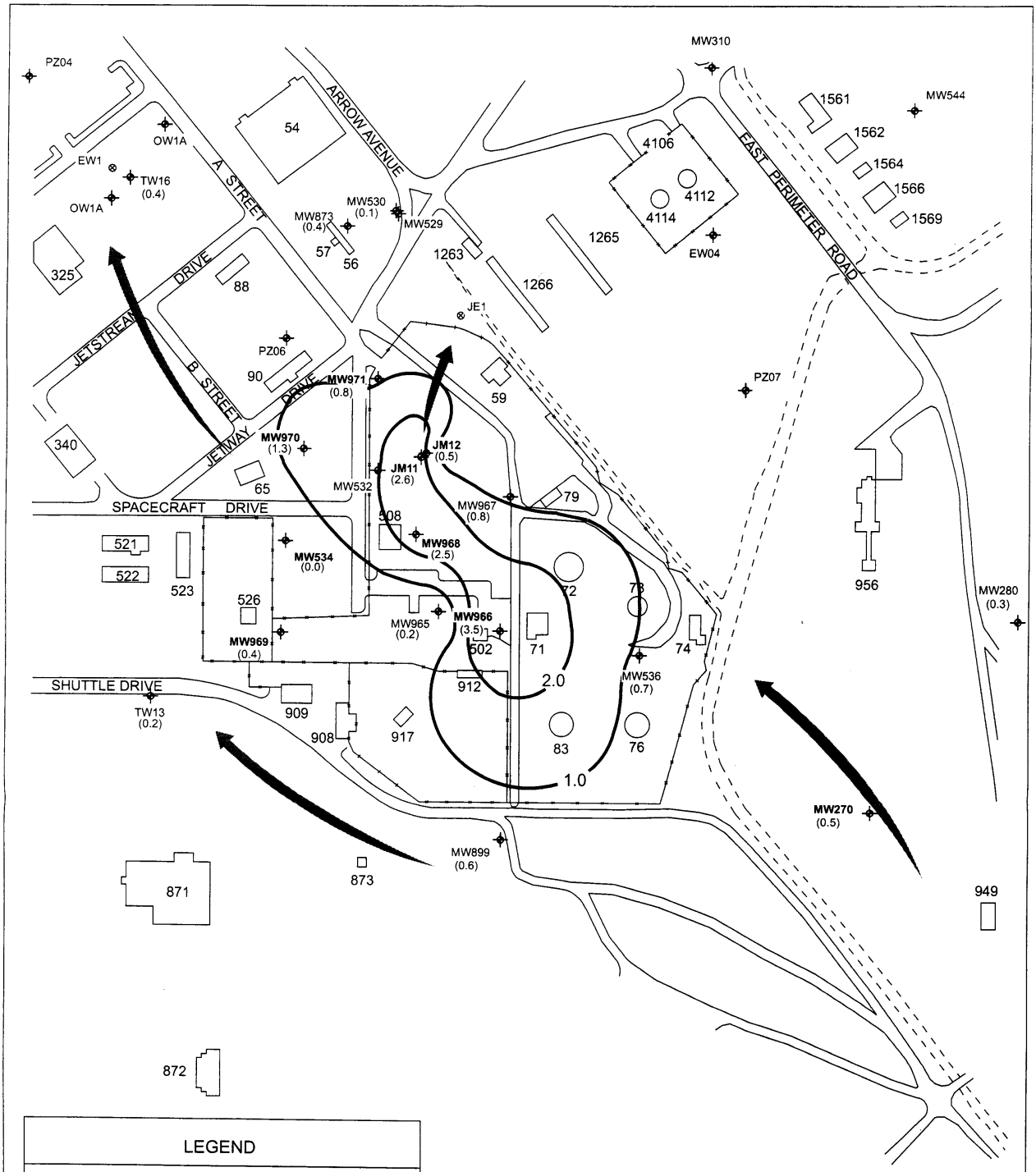

FIGURE 6.5

MANGANESE ISOPLETHS FOR GROUNDWATER

PFFA RAP
Castle Airport, California

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Oakland, California

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6.4.6 Sulfate and Sulfide

Sulfate concentrations in groundwater at the site ranged from 7.7 mg/L to 37.9 mg/L. Sulfate reduction generally will only occur after all available DO and nitrate are depleted and reducing conditions are below the range where ferrous iron reduction occurs. However, sulfate-reducing microorganisms typically are more sensitive to environmental conditions (e.g., temperature, nutrients, and pH) than other reducing processes. Although the lowest sulfate concentration was measured in MW966, where the lowest DO concentration and highest methane concentration also was measured, a comparison of sulfate concentrations relative to the TPH, BTEX, and other electron acceptor concentrations did not show a definite pattern of sulfate depleted below background concentrations. Therefore, to be conservative, sulfate reduction was not considered an important process contributing to the natural attenuation of petroleum hydrocarbons at this site.

Hydrogen sulfide is produced when sulfate is reduced to oxidize naphthalene and BTEX compounds. The production of hydrogen sulfide in areas with elevated fuel hydrocarbon concentration would be a strong indicator that sulfate is being utilized as an electron acceptor at the PFFA. However, elevated concentrations of hydrogen sulfide were not detected in groundwater samples collected form the suspected source area.

6.4.7 Methane

On the basis of free energy yield and oxidizing potential, the carbon dioxide-methane (CO_2-CH_4) redox couple also could be used to oxidize fuel hydrocarbon compounds to carbon dioxide and water once the groundwater is sufficiently reducing. To attain these reducing levels, other highly oxidizing chemical species such as oxygen, nitrate, and manganese must be reduced. This redox reaction is called methanogenesis or methane fermentation. Methanogenesis yields the least free energy to the system in comparison to other chemical species (Figure 6.3). The presence of methane in groundwater at elevated concentrations relative to background concentrations is a good indicator of methane fermentation.

Detected methane concentrations measured at the site ranged from 0.0006 mg/L to 0.34 mg/L. Methane concentrations greater than or equal to 0.05 mg/L were measured only at the two MWs with detectable BTEX and the highest concentrations of ferrous iron (JM11 and MW966), indicating that methanogenesis is currently limited in extent compared to other processes. Background concentrations of methane were generally near or below the detection limit. The methane results are consistent with other electron acceptor data for this site, with the two MWs with the highest methane concentrations corresponding with lowest DO and nitrate concentrations and highest manganese and ferrous iron concentrations. Background levels of methane were near or below the detection limit (0.0005 mg/L). These relationships provide strong evidence that anaerobic biodegradation is occurring at the site and that strongly reducing conditions are possible in some of the contaminated areas.

6.4.8 Alkalinity and Carbon Dioxide

Because microbially-mediated reactions causing biodegradation of fuel hydrocarbons produce carbon dioxide and biologically generated acids, increases in groundwater alkalinity is further evidence of biological activity. In aquifers that have carbonate materials as part of

the matrix, carbon dioxide forms carbonic acid, which dissolves these minerals, increasing the alkalinity of the groundwater. An increase in alkalinity above background conditions in an area with elevated BTEX concentrations can be used to infer the amount of petroleum hydrocarbon destroyed through aerobic respiration, denitrification, manganese reduction, ferric iron reduction, and sulfate reduction. In addition, carbon dioxide produced in these aerobic and anaerobic reactions can be cycled in the methanogenic reactions to continue BTEX biodegradation through methanogenesis.

The total alkalinity (as calcium carbonate [CaCO3]) measured at the site ranged from 111 mg/L to 355 mg/L. The carbon dioxide concentrations measured at the site ranged from 10 mg/L to 85 mg/L. Figure 6.6 is an isopleth map showing the distribution of alkalinity concentrations in groundwater and shows graphically that areas with depleted DO and other geochemical indicators of biodegradation generally correlate with increases in groundwater alkalinity. Although not shown on the figure, a similar correlation was observed for dissolved carbon dioxide.

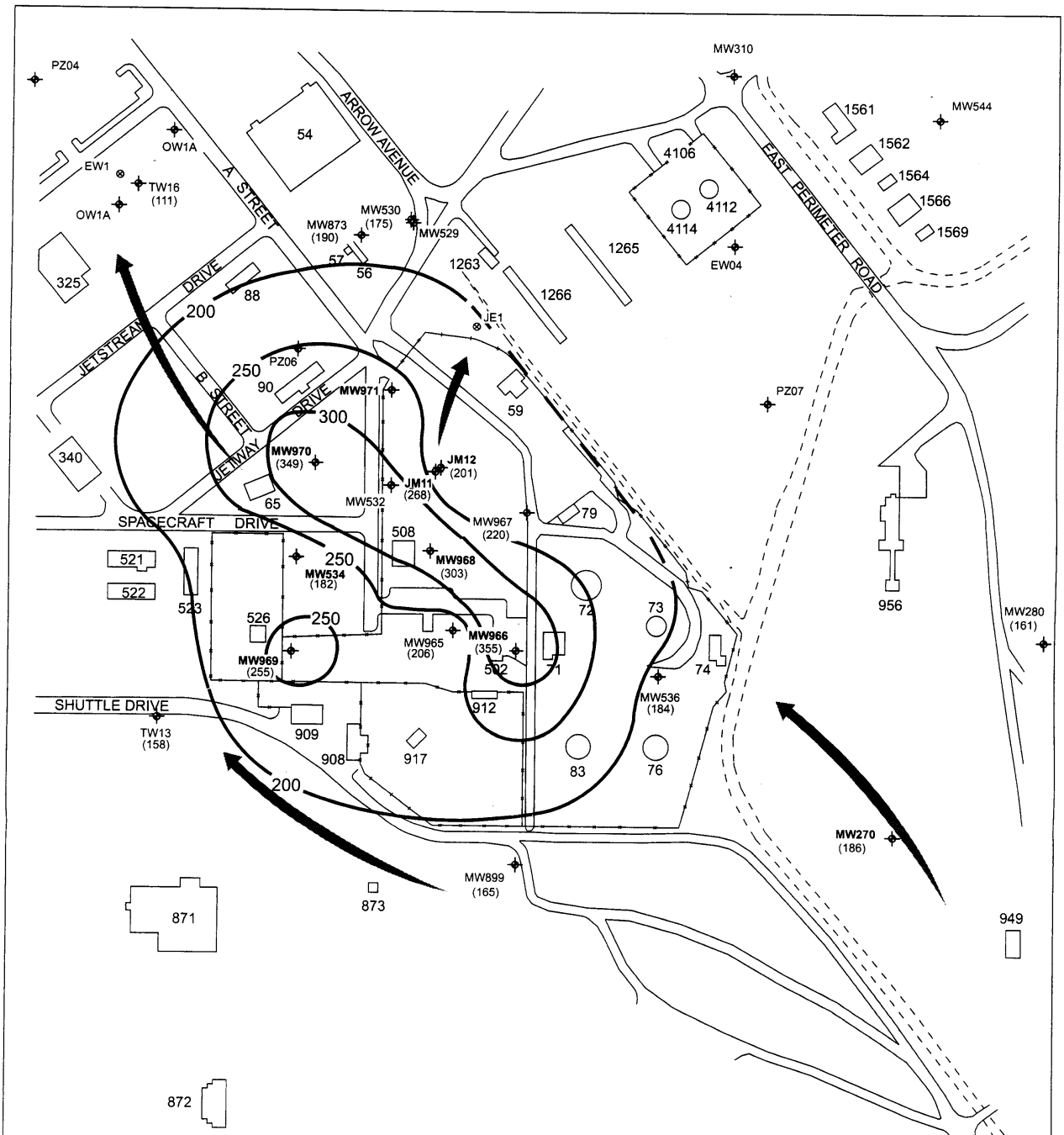
6.4.9 Oxidation Reduction Potential

Oxidation-reduction potential (ORP) is a measure of the relative tendency of a solution to accept or transfer electrons. The ORP of a groundwater system depends on which electron acceptors are being reduced by microbes during BTEX oxidation. The ORP measured at the site ranged from 5 millivolts (mV) to 354 mV, measured relative to hydrogen (Eh). The ORP measurements at the site are illustrated graphically on Figure 6.7. As expected, areas at the site with lower ORP coincide with areas of BTEX contamination, low DO and nitrate concentrations, and elevated manganese, ferrous iron, and methane concentrations.

The ORP measured at the site are higher than the theoretical optimum ORP for ferric iron reduction, sulfate reduction, and methanogenesis (Norris *et al.*, 1994). This discrepancy is a common problem associated with measuring oxidizing potential using field instruments. Many redox species are not electroactive on the platinum electrode surfaces used in such instruments, including hydrogen sulfide and methane (Stumm and Morgan, 1981). Many authors have noted that field measured ORP data alone cannot be used to reliably predict the electron acceptors that may be operating at a site (Godsey, 1994; Lovley *et al.*, 1994). Integrating ORP measurements with analytical data on reduced and oxidized chemical species allows a more thorough and reasonable interpretation of which electron acceptors are being used to biodegrade site contaminants.

6.5 THEORETICAL ASSIMILATIVE CAPACITY ESTIMATES

The preceding discussions have been devoted to determining if naphthalene and BTEX compounds are biodegrading at the PFFA. Comparison of petroleum-hydrocarbon concentrations and electron acceptor and biodegradation byproduct isopleth maps for the PFFA site provides strong qualitative evidence of biodegradation of petroleum hydrocarbons compounds and BTEX. The results indicate that the following electron acceptors are active in at least some areas of the PFFA site: DO, nitrate, manganese and ferric iron (indicated by the presence of soluble manganese and ferrous iron), and carbon dioxide (indicated by the presence of methane).



LEGEND

- ABOVE GROUND STORAGE TANK
- BUILDING
- FENCE
- DRAINAGE CHANNEL
- MW969 — GROUNDWATER MONITORING WELL OR PIEZOMETER
- JE1 — GROUNDWATER EXTRACTION WELL
- INFERRED DIRECTION OF GROUNDWATER MOVEMENT
- 200 — LINE OF EQUAL ALKALINITY CONCENTRATION (mg/L) (DASHED WHERE INFERRED); CONTOUR INTERVAL VARIABLE
- (111) ALKALINITY CONCENTRATION (mg/L)

230' 115' 0 230'

SCALE: 1"=230'

FIGURE 6.6

ALKALINITY ISOPLETHS FOR GROUNDWATER

PFFA RAP
Castle Airport, California

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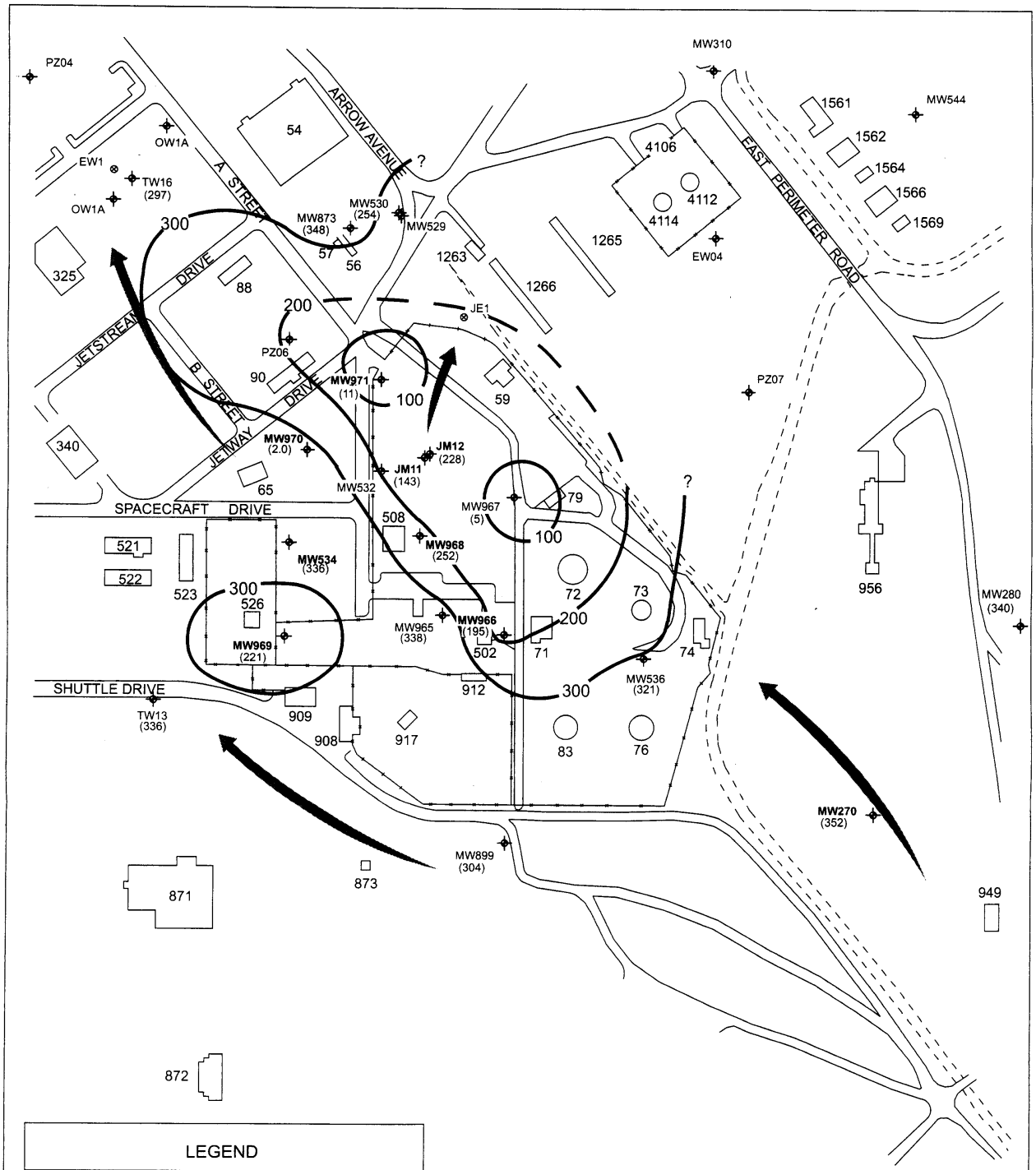

LEGEND

- ABOVE GROUND STORAGE TANK
- BUILDING
- FENCE
- DRAINAGE CHANNEL
- MW969 — GROUNDWATER MONITORING WELL OR PIEZOMETER
- JE1 — GROUNDWATER EXTRACTION WELL
- INFERRED DIRECTION OF GROUNDWATER MOVEMENT
- 200 — LINE OF EQUAL OXIDATION REDUCTION POTENTIAL (mg/L) (DASHED WHERE INFERRED); CONTOUR INTERVAL VARIABLE
- (11) — OXIDATION REDUCTION POTENTIAL, RELATIVE TO HYDROGEN (E_h)

N

230' 115' 0 230'

SCALE: 1"=230'

FIGURE 6.7

OXIDATION REDUCTION POTENTIAL FOR GROUNDWATER

PFFA RAP

Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.

Oakland, California

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Analytical data on reduced and oxidized chemical species indicate that indigenous microorganisms are facilitating the oxidation of naphthalene and BTEX compounds by reducing certain electron acceptors to generate free energy for cell maintenance and production. Typically, zones of depleted oxygen, depleted nitrate, elevated soluble manganese and ferrous iron concentrations, and elevated methane concentrations coincide with areas of detectable petroleum hydrocarbons compounds and BTEX. At the PFFA site, the sequence of electron acceptor use can be interpreted from the isopleth maps presented on Figures 6.4 through 6.7 and from the fact that significant increases in ferrous iron and methane concentrations only occurred in MWs with detectable BTEX concentrations (i.e., JM11 and MW966).

The question of how much contaminant mass can be biodegraded must be addressed to assess the full potential for long-term natural attenuation at the site. Mass-balance relationships can be used to determine how much contaminant mass can be degraded by each of the redox reactions that the microorganisms might use to make free energy available for cell maintenance and production. The stoichiometric relationship between the contaminant and the electron acceptor can be used to estimate the assimilative capacity of the groundwater. Now that the redox reactions that are operating at the PFFA have been defined, it is possible to estimate how much contaminant mass can be assimilated or oxidized by available electron acceptors. This analysis, when coupled with the biodegradation rate information discussed earlier (Section 6.3.2), will provide the basis for determining the potential for continued natural attenuation of groundwater contamination at the site.

Appendix E presents the coupled redox reactions that represent the biodegradation of naphthalene and each of the BTEX compounds. These tables also present the stoichiometric mass ratio of electron acceptors needed to oxidize naphthalene and each of the BTEX compounds. These stoichiometric mass ratios can be used to estimate the assimilative capacity of the groundwater at the PFFA. This is accomplished by first determining the initial mass of each electron acceptor available in the groundwater. Data on these chemical species were collected at sample locations upgradient of the site (MW270 and MW280) and downgradient from the site outside the area of contamination (MW530, MW873, and TW16). As groundwater migrates from background areas into the source area, electron acceptors are brought into contact with hydrocarbon-degrading microorganisms and site contamination. This influent mass is divided by the mass of electron acceptors required to mineralize each of the fuel hydrocarbon compounds to estimate the intrinsic capacity of the groundwater to biodegrade each of the fuel hydrocarbon compounds.

Conservative estimates of the background concentrations of all of the electron acceptors that may be involved in the biodegradation of naphthalene and BTEX compounds are listed in Table 6.2. These concentrations are used to calculate the available or expressed assimilative capacity of each electron acceptor for naphthalene and BTEX based on the mass stoichiometric relationships presented in detail in Appendix E. Table 6.2 also presents the highest concentration of ferrous iron and soluble manganese measured at the site. These concentrations are used to "back-calculate" the expressed assimilative capacity that is attributable to ferric iron and manganese reduction, respectively.

On the basis of these calculations, the groundwater at the PFFA has the intrinsic capacity to oxidize a concentration of approximately 6,500 µg/L of total BTEX per pore volume

TABLE 6.2
Expressed Assimilative Capacity
PFFA RAP
Castle Airport, California

Electron Accepting Process	Measured Geochemical Indicator	Average Source Area Concentration [1] (mg/L)	Average Background Concentration [2] (mg/L)	Calculated BTEX Assimilative Capacity (µg/L)
Aerobic Respiration	Dissolved Oxygen	0.80	5.9	1,600
Denitrification	Nitrate	1.2	6.1	4,500
Manganese Reduction	Soluble Manganese	3.1	0.34	150
Iron Reduction	Ferrous Iron	0.36	0.0	17
Methanogenesis	Methane	0.20	0.0	250

Total Assimilative Capacity (µg/L)	6,500
Maximum Observed Total BTEX Concentration (µg/L)	145

Notes:

[1] Results from monitoring wells JM11 and MW966.

[2] Results from monitoring wells MW270, MW280, MW530, MW873, and TW16.

exchange of groundwater. The primary mechanism is nitrate reduction, which accounts for approximately 4,500 µg/L of expressed BTEX assimilative capacity. However, aerobic degradation is an effective secondary mechanism, accounting for 1,600 µg/L of expressed BTEX assimilative capacity. Manganese and ferric iron reduction and methanogenesis also contribute to the system's assimilative capacity. Sulfate reduction may be occurring; however, the data was not conclusive and to be conservative, it was not included in the assimilative capacity calculation.

This expressed assimilative capacity is conservative because of the likelihood that mixing of anaerobic and aerobic groundwater occurred during sampling and purging. The shallower groundwater is probably more anaerobic than deeper groundwater since contamination and biodegradation are greater in the shallower groundwater, leading to a reduction in oxygen concentrations. Purging and sampling from wells with long screened intervals which cross zones of varying contaminant concentrations, as at the PFFA, would tend to mix groundwater from the formation within the well, producing samples that are a combination of both anaerobic and aerobic groundwater. This in-well mixing would tend to mask the true magnitude of the difference in geochemistry between anaerobic and aerobic groundwater.

The groundwater beneath a site is an open system, which continually receives additional electron receptors from through the flow of the aquifer. This means that the assimilative capacity is not fixed as it is in a closed system, and therefore cannot be compared directly to contaminant concentration in the groundwater. Rather, the expressed assimilative capacity of groundwater is intended to serve as a qualitative tool. Although the expressed assimilative capacity at this site is greater than the highest measured total BTEX concentration (145 µg/L during the May 1997 sampling event), the fate of BTEX in groundwater and the potential impact to receptors is dependent on the relationship between the kinetics of biodegradation (Section 6.3.2) and the groundwater and solute transport velocity, which is approximately the same as the advective groundwater velocity due to the limited potential for sorption (Section 3.1.4 and Section 6.2.1.2). However, this significant expressed assimilative capacity is a strong indicator that an environment conducive to biodegradation of BTEX is present, and that the groundwater appears to have sufficient assimilative capacity to degrade the observed dissolved BTEX as well as other petroleum hydrocarbons and limit plume migration.

Each year at the PFFA, the entire pore volume of groundwater is replaced (the length of the PFFA — 1,200 feet — is approximately same magnitude as the advective groundwater velocity estimated in Section 3.2 [1,200 feet per year]). This means that dissolved contaminant mass in the source areas is being brought into contact with more than sufficient electron acceptor mass to facilitate not only BTEX degradation reactions, but also other petroleum hydrocarbons such as naphthalene.

6.6 PREDICTING THE COMBINED EFFECTS OF CONTAMINANT MIGRATION AND BIODEGRADATION

Understanding the effects of natural physical, chemical, and biological processes on chemicals is an important step in determining potential long-term risks associated with chemical migration in the environment. The behavior of BTEX compounds and naphthalene under the influence of these processes must be quantified to estimate the likelihood and nature of any future releases, to predict the extent that any chemical could migrate, and to

assess the effects on chemical persistence, mass, concentration, and toxicity over time at the site. If destructive and nondestructive attenuation processes can minimize or eliminate the concentration of contaminants to which a receptor could be exposed, remedial action may not be warranted because no reasonable exposure pathway exists or the exposure pathway would result in insignificant risks. The focus of this section is to predict how BTEX compounds and naphthalene will be transported and transformed in soils and groundwater based on site data and site-specific chemical release and transport models.

6.6.1 Model Overview and Approach

Simulations of groundwater flow and contaminant fate and transport were performed to evaluate the dissolved BTEX and petroleum hydrocarbons in groundwater at the PFFA. The primary objective of the modeling effort was to predict the potential extent and concentration of a dissolved contaminant plume in support of the risk analysis and the evaluation of remedial alternatives.

The model code used to evaluate the potential for dissolved BTEX and petroleum hydrocarbons migration and degradation was BIOSCREEN, developed for AFCEE for use in evaluating natural attenuation (USEPA ORD, 1996). BIOSCREEN is a screening model based on the Domenico (1987) analytical solute transport model and has the ability to simulate advection, dispersion, adsorption, and biodegradation processes. BIOSCREEN can simulate biodegradation processes using either a first-order decay or an instantaneous reaction model. BIOSCREEN is relatively easy to use, yet powerful enough to incorporate site-specific input data and provide site-specific results when used appropriately.

The objective of the BIOSCREEN modeling effort for the PFFA was to determine if natural attenuation processes occurring at the PFFA, as described in Section 6.4, are sufficient to limit potential migration of contaminants to downgradient receptors. Conservative input parameters and a conservative model scenario were used, as is appropriate for a screening model.

Two model scenarios were evaluated. For the first model scenario, the maximum historical BTEX concentrations measured at the PFFA were assumed to be emanating from a source area within the PFFA. The source was assumed to remain in place with no engineered remediation. For the second model scenario, the source was assumed to undergo engineered remediation, leading to a reduction in mass over time. Both model scenarios assumed that natural attenuation of dissolved contaminants proceeded at the site-specific biodegradation rate calculated from site data, as discussed in Section 6.3.2. To be conservative in the estimates of downgradient plume extent, both model scenarios assumed the existing groundwater extraction and treatment systems north of the PFFA were no longer in operation. Predictions of the maximum downgradient extent of the plume were then evaluated.

6.6.2 Conceptual Model and Model Development

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. Data presented in Sections 3 and 4

were synthesized into a conceptual model that was used as the basis for the flow and transport modeling.

6.6.2.1 Source Contribution - Leaching from Contaminated Vadose Zone Soils

The climate of the Merced Area near Castle Airport is classified as semiarid, Mediterranean type and characterized by wet winters and long, dry summers (Section 3.3). Net monthly precipitation is positive between November and February, so recharge to groundwater and infiltration through the vadose zone probably occurs on a seasonal basis.

The analytical results for soil presented in Section 4.5 indicate that contaminant concentrations in the vadose zone exceeded WQSA values developed to protect groundwater. Although some areas of the PFFA are covered with asphalt, which would minimize infiltration and recharge, many areas of the site, including some of the source areas, are covered with grass or gravel. Thus, unsaturated soils could represent a long-term source of contamination to groundwater through infiltration of rainwater through contaminated vadose zone soils.

6.6.2.2 Model Hydraulics

The groundwater flow patterns and plume data do not clearly indicate any influence of heterogeneities in the aquifer system. As a result, the conceptual model does not incorporate significant heterogeneities (e.g., a constant hydraulic conductivity was used based on the pump test data discussed in Section 3.1.3). A homogeneous, two-dimensional (2D) solution was considered sufficient for screening purposes since the site was being modeled on the assumption that the groundwater extraction and treatment system was not in place and, therefore, no significant vertical flow gradients would be expected. In addition, groundwater does not discharge to surface water at the PFFA.

Where available, initial input parameters were based on site-specific data (e.g., hydraulic conductivity and gradient). In the absence of usable, site-specific data, reasonable assumptions were made on the basis of accepted literature values or were derived from methodologies described in literature. The input parameters used in the model and their sources are provided in Appendix E and are briefly discussed below.

The saturated soils consists of medium- to coarse-grained sands and gravels (Section 3.1 and Appendix B). A hydraulic conductivity value of 342 ft/day (0.12 centimeters/second) was used in the model, based on the mean of the estimated values reported in Section 3.1.3. As discussed in Section 3.1.4, an effective porosity of 0.25 was estimated based on literature values for the medium- to coarse-grained materials at the site. Since the screening approach was to evaluate contaminant migration if the existing groundwater extraction and treatment system were turned off, a measured groundwater gradient in an area of the site which does not appear to be significantly influenced by the system was used (0.0020 ft/ft).

A value of 26 feet was used for longitudinal dispersivity, using a relationship between dispersivity and plume length developed by Xu and Eckstein (1995). The ratio of transverse to longitudinal dispersivity was 0.10 and vertical dispersivity was conservatively assumed to be zero. Because of the relatively low TOC content in site soils (less than 0.1%) (Section 1.5), no retardation factor was used during the model simulation.

6.6.2.3 Source Term Estimate

In transport models, boundary conditions are used to specify contaminant sources such as NAPL bodies or dissolved mass entering through recharge through contaminated soil. Sources 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 (i.e., definition of plume geometry or groundwater concentrations), while actual source characteristics and strength are generally not known with any degree of certainty. Therefore, it is common modeling practice to estimate source terms using the approach described by Spitz and Moreno (1996). The source is represented as a "black box" that produces appropriate concentrations at selected points in the model domain. Under this approach, the effects of a "black box" source on plume geometry are evaluated rather than directly deriving source characteristics from site data.

At the PFFA, contaminant mass is assumed to enter groundwater due to migration of recharge (precipitation) through soil containing residual contamination above the water table and/or through seasonal groundwater contact with residual contamination. In BIOSCREEN, the partitioning of BTEX and petroleum hydrocarbon compounds into groundwater is simulated by entering the width of the source zone perpendicular to the direction of groundwater flow and the contaminant concentration in groundwater along the width. The source zone width used as input to the model for the PFFA was 100 feet, the approximate width of the source areas near Building 71 and JM11. Based on the soil and groundwater contaminant concentrations discussed in Section 4 and the electron acceptor maps presented in Section 6.4, sources in these two source areas control the plume geometry.

The contaminant source term used by BIOSCREEN can either be an infinite, continuous source or a source with a declining concentration. For the first model scenario (Scenario #1: No Source Removal), an infinite, continuous source was used as a screening mechanism to evaluate the potential downgradient plume length. As discussed above, the objective of Scenario #1 was to evaluate a "worst-case" in which contaminant sources do not undergo engineered remediation or weathering and continue to impact groundwater at the maximum concentrations measured historically at the site. The groundwater concentration used as input for the source was 2,500 µg/L, the maximum historical BTEX concentration (measured at the site in 1994).

For the second model scenario (Scenario #2: Source Reduction with SVE/Bioventing), the initial source strength was assumed to be equal to the mass required to produce the maximum dissolved BTEX concentration measured in March 1997 (145 µg/L at JM11 [Table 4.4]). The strength of the source was assumed to be reduced by 95% within the first 2 years of engineered remediation, based on experience with contaminant source reductions obtained during the AFCEE Bioventing Initiative (Miller *et al.*, 1993; Downey et al., 1994). As discussed in Section 7, bioventing is the technology which was evaluated for potential engineered remediation at the site.

6.6.2.4 Biodegradation Rate

A site-specific, first-order biodegradation rate for BTEX was developed for PFFA, as described in Section 6.3.2. This rate, 12 $year^{-1}$,was used for the model simulation.

6.6.3 Model Predictions

Detailed input data and output results of the two BIOSCREEN model scenarios developed for the PFFA are provided in Appendix E. Plots of predicted groundwater concentrations along the center line of the plume parallel to the direction of groundwater flow for each of the two scenarios are provided in Figures 6.8 and 6.9 and discussed below. The three different biodegradation models calculated by BIOSCREEN are shown: 1) first-order decay; 2) instantaneous reaction; and, 3) no biodegradation (for comparison purposes). Both the first-order decay model and the instantaneous reaction model are based on site-specific input parameters for the PFFA. For the first-order decay model, the biodegradation rate developed for the PFFA in Section 6.3.2 was used. For the instantaneous reaction model, the difference between background and plume concentrations of DO, nitrate, ferrous iron, and methane (Table 6.2) were used to determine the availability of electron acceptors for aerobic and anaerobic degradation. Although the site data clearly indicate biodegradation is occurring, they do not indicate conclusively which of the two biodegradation reaction models is more appropriate for the PFFA. Therefore, comparing the results from both reaction models helps to provide a predicted range within which a potential contaminant plume will likely behave.

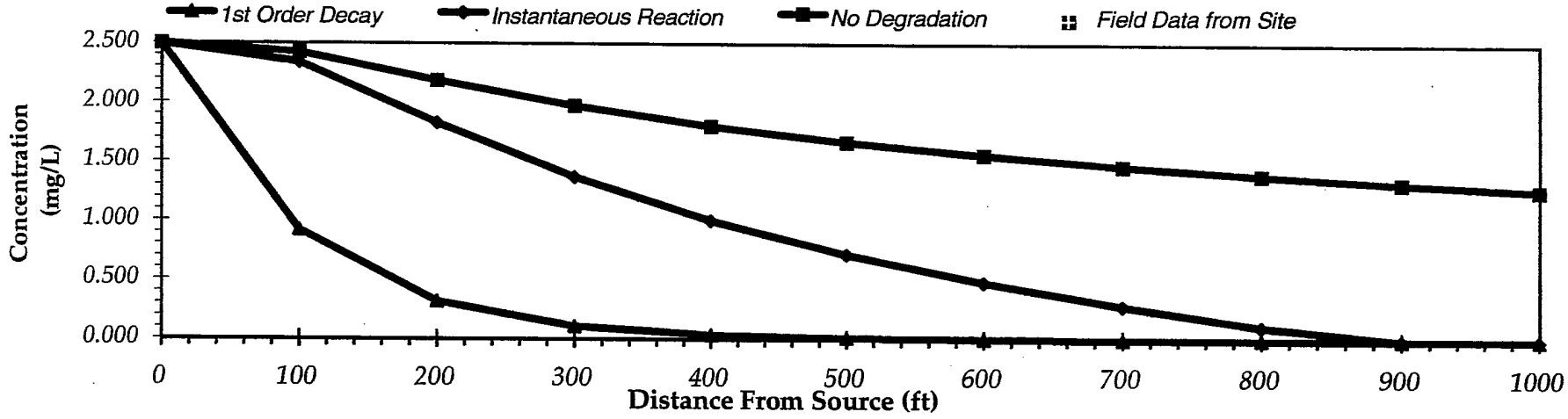
Scenario #1: No Source Removal

The results from Scenario #1 are presented on Figure 6.8. The plot shows predicted dissolved BTEX concentrations along the center line of the plume parallel to the direction of groundwater flow. The results of the model for Scenario #1 indicate that, even under the worst-case scenario (highest historical concentrations from a constant, non-degrading source), the downgradient migration of the dissolved BTEX plume (defined as a total BTEX concentration less than 1 µg/L) is limited to 800 feet from the source area if first-order decay is assumed and limited to 900 feet from the source area if an instantaneous reaction model is assumed. Therefore, even under the most conservative scenario, contaminants from the PFFA would not reach offsite receptors outside the Castle Airport boundary, located approximately 1.5 miles (8,000 feet) west (downgradient) of the PFFA. Comparison of the two biodegradation models with the "no biodegradation model" results clearly illustrates that the biodegradation of BTEX and petroleum hydrocarbons occurring at the PFFA, as documented in the previous sections, is currently responsible (along with the groundwater extraction system) and in the future would continue to be responsible for limiting the potential migration of contaminants originating from the PFFA. These model results are also supported by the fact that BTEX was not detected in MW970 and MW971, which are located approximately 250 feet downgradient of the source area near JM11 and JM12.

It is important to reemphasize that the predictions presented in Figure 6.8 are based on a worst-case scenario in which the groundwater extraction and treatment systems are turned off and in which contaminant sources at the PFFA do not decrease in strength. Data presented in Section 6.3 indicate that the contaminant source are in fact declining in strength. It is also highly unlikely that the groundwater extraction systems would be turned off before remediating the hydrocarbon plume since the TCE plume north of the PFFA, for which the systems were designed, is expected to persist much longer than the hydrocarbon plume.

PREDICTED MAXIMUM CONCENTRATIONS WITH NO SOURCE REMOVAL
DISSOLVED BTEX CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	2.500	2.426	2.190	1.977	1.808	1.674	1.564	1.473	1.395	1.329	1.271
1st Order Decay	2.500	0.921	0.316	0.108	0.038	0.013	0.0047	0.0017	0.0006	0.000	0.000
Inst. Reaction	2.500	2.340	1.831	1.371	1.007	0.716	0.479	0.282	0.116	0.000	0.000
Field Data from Site											



Time:
5.0 Years

FIGURE 6.8

PREDICTED STEADY-STATE BTEX CONCENTRATIONS WITH NO SOURCE REMOVAL

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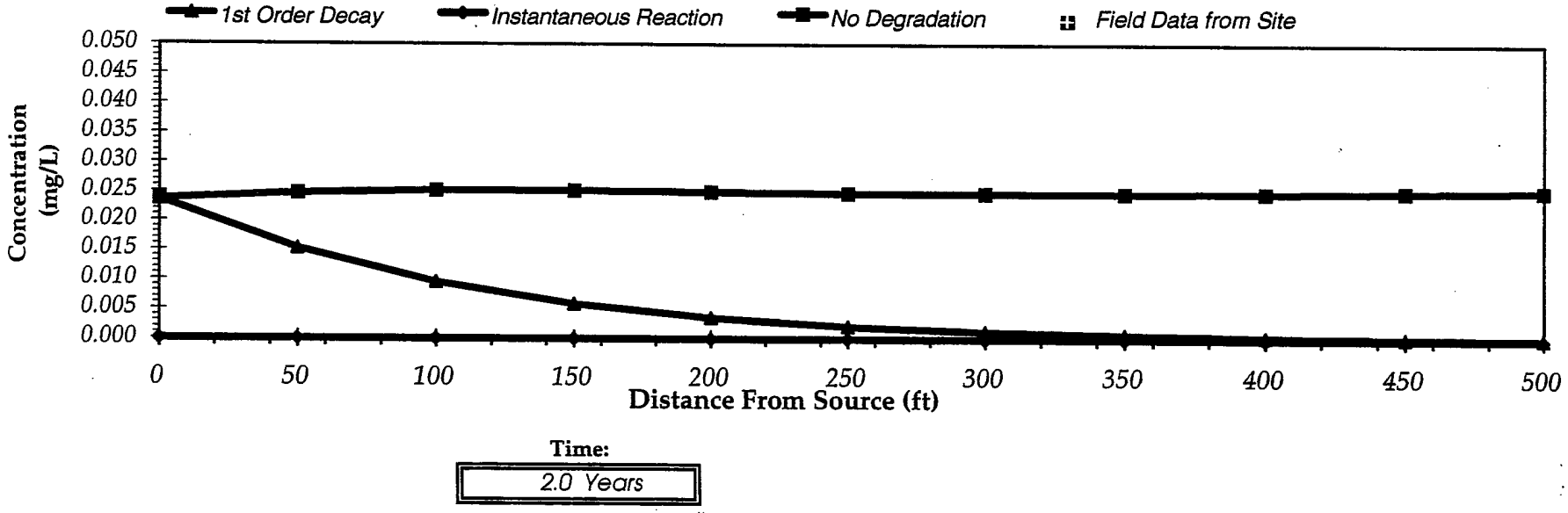
\731297\REPORT\FIGS_L8.CDR 4/30/98

PREDICTED CONCENTRATIONS WITH SVE/BIOVENTING
DISSOLVED BTEX CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.024	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
1st Order Decay	0.024	0.015	0.010	0.006	0.004	0.002	0.0014	0.0008	0.0005	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Time:
2.0 Years

FIGURE 6.9

PREDICTED BTEX CONCENTRATIONS AFTER 2 YEARS OF SOURCE REDUCTION

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\731297\REPORT\FIGS_L8.CDR 4/30/98

Scenario #2: Source Reduction With SVE/Bioventing

While Scenario #1 represents a worst-case scenario, Scenario 2 represents a more realistic scenario for the PFFA. As discussed in Section 6.6.2.3, for Scenario #2 the most recently measured groundwater concentrations at the site, a reasonable estimate of natural attenuation based on site-specific data, and a reasonable estimate of the reduction in source concentrations due to SVE/bioventing were used to predict dissolved concentrations in groundwater within the next 5 years. Figure 6.9 shows predicted dissolved BTEX concentrations along the center line of the plume parallel to the direction of groundwater flow after 2 years of engineered source reduction (model inputs and results for additional years are provided in Appendix E). For the first-order decay model, the extent of the dissolved BTEX plume (defined as BTEX concentration greater than 1 µg/L) is much smaller under Scenario #2 after only 2 years (350 feet) compared to the extent of the steady-state plume predicted by Scenario #1 (800 feet). The first-order decay model predicted that dissolved BTEX concentrations were below 1 µg/L at all locations after 5 years. Because of the relatively low BTEX concentrations compared to the significant assimilative capacity of the groundwater (Section 6.5), the instantaneous reaction model for Scenario #2 predicted that dissolved BTEX concentration were never greater than 1 µg/L at any location at any point in time.

Scenario #2 represents the most likely conditions expected at the site in the future if engineered source removal is implemented. Results from Scenario #2 indicate that dissolved BTEX concentrations would rapidly decrease to concentrations below MCLs within 5 years after implementation of source reduction.

6.7 CONCLUSIONS

This section has focused on explaining how and why TPH and BTEX compounds in saturated soil and groundwater at the PFFA can be effectively attenuated by natural nondestructive and destructive processes. The important findings of this section are summarized as follows:

- TPH and BTEX compounds are biodegrading in groundwater at the PFFA via oxygen reduction, denitrification, ferric iron reduction, manganese reduction, and methanogenesis at rates within the range of values found in the technical literature;
- Site-specific biodegradation rate estimates and site-specific theoretical assimilative capacity estimates confirm that measured concentrations of contaminants in groundwater can be biodegraded by natural processes;
- Quantitative, site-specific chemical fate assessment modeling indicates that natural processes should be sufficient to interrupt potentially significant exposure pathways to offsite receptors even if the existing groundwater extraction and treatment system were turned off, even without engineered source reduction; and,
- With engineered source reduction, quantitative, site-specific chemical fate assessment modeling indicates that natural processes in combination with source reduction could achieve drinking water MCLs within 5 years.

Although biological processes are expected to limit plume migration and interrupt groundwater contaminant exposure pathways to offsite receptors, removal of contamination in vadose zone soils would help to eliminate soil exposure pathways to onsite receptors and reduce potential long-term sources of groundwater contamination. Alternatives such as bioventing, which promotes in situ biodegradation of vadose zone contamination, and soil vapor extraction (SVE), which volatilizes and removes vadose zone contamination as well as promoting biodegradation, would be effective in reducing risk to human health and reducing the costs of extended groundwater monitoring at the PFFA. Section 7 documents the expected effectiveness of these cost-effective source reduction technologies that could be used to remediate contaminated soils at the site. A comparative analysis of remedial alternatives, including source reduction and natural attenuation, is provided in Section 8.

SECTION 7

EVALUATION OF SOURCE REMOVAL TECHNOLOGIES

7.1 OVERVIEW

Section 6 of this RAP shows that both destructive and nondestructive attenuation processes should be effective at minimizing groundwater contaminant migration and reducing groundwater contaminant mass at the PFFA at Castle Airport. The interim remedial strategy for the PFFA based on the RI/FS process (Jacobs, 1995a) is SVE and bioventing, primarily to eliminate any future risks from excavation activities in fuel contaminated soils and in reducing the long-term leaching of BTEX compounds into groundwater. Therefore, a detailed evaluation of bioventing was conducted at the PFFA as part of field activities in the event that engineered source removal is required to protect human health and the environment or to reduce the total time and cost of remediation. Although the focus of the field effort was an evaluation of bioventing, because the two technologies have similar engineering requirements, many of the bioventing tests and results also can be used to evaluate SVE.

7.2 *IN SITU* BIOVENTING PILOT TEST PROCEDURES

Bioventing is an innovative technology which uses low rates of air injection to supply oxygen to soil bacteria employed in the biodegradation of fuel hydrocarbons. The USAF has successfully used bioventing for remediation at hundreds of fuel spill sites (Miller *et al.*, 1993).

As part of source reduction feasibility testing at the PFFA in March 1997, soil vapor sampling and measurement of oxygen and carbon dioxide concentrations were conducted in contaminated vadose zone soils at the PFFA (Parsons ES, 1997b). These results were summarized in Section 4.4. The measured oxygen concentrations in soil vapor samples indicated that subsurface oxygen concentrations are limiting the rate of biological degradation of petroleum-hydrocarbon residuals in the vadose zone soil.

A bioventing pilot test was conducted at the PFFA by Parsons ES in November and December 1997. In preparation for the pilot test, 1 vent well (VW), PFFAVW01, and 3 vapor monitoring points (VMPs), PFFAVMP14, PFFAVMP15, and PFFAVMP16 were installed in November 1997. The VW and VMPs were located in the northern portion of the PFFA near JM11 (Figure 4.1). The locations for the VW and VMPs were chosen near an area of the site not previously investigated and also near MW531, a former groundwater MW currently screened entirely within the vadose zone due to a declining water table. By locating the VW and VMPs in an area of the site not previously investigated, additional soil and soil vapor samples could be collected to fill a site investigation data gap and evaluate the need for remediation in that area. By locating the VW and VMPs near MW531, drilling costs were saved because MW531 could be used for air permeability and oxygen influence testing in the deep vadose zone, as discussed in Sections 7.4 and 7.5.

VW and VMP construction methods are discussed in Section 2. Construction details and boring logs are provided in Appendix B. Soil and soil vapor sampling methods and analytical results are provided in Section 2 and Section 4, respectively.

The bioventing pilot test consisted of three types of tests: *in situ* respiration (ISR) tests, air permeability (AP) tests, and oxygen influence tests. Detailed procedures for each of these tests are described in Sections 2.5 and 2.6 and results are discussed in the following sections.

7.3 *In Situ* Respiration Test Results

ISR testing was performed at the PFFA to quantify the biological uptake of oxygen by soil bacteria and quantify biodegradation rates of fuel hydrocarbons in soil. ISR tests were initially conducted in June 1997 as part of bioventing feasibility testing (Parsons ES, 1997b). Additional ISR testing was conducted in February 1998 at the 3 VMPs installed near JM11 for the bioventing pilot test. Procedures and equipment used to conduct the ISR tests are described in Section 2.4.

The initial ISR tests were conducted between 25 and 27 June 1997 at two locations: PFFAVMP04 and PFFAVMP09 (Figure 4.1). Testing was conducted at the two discrete depth screens at VMP4 (10 feet and 20 feet bgs) and the one discrete depth screen at PFFAVMP09 (30.5 feet bgs). The follow-up ISR tests were conducted between 16 and 19 February 1998 at PFFAVMP14, PFFAVMP15, and PFFAVMP16. Testing was conducted at two discrete depth screens at PFFAVMP14 (35 feet and 51 feet bgs), one discrete depth screen at PFFAVMP15 (42 feet bgs), and one discrete depth screen at PFFAVMP16 (35 feet bgs). The purpose of using multi-depth monitoring points was to verify that soil bacteria and oxygen demand were present within the entire vadose zone. Based on soil and soil vapor sampling, vadose zone soils in all of these areas were initially oxygen-depleted (Table 4.2) and residual soil contamination also was present near these areas.

The biological uptake of oxygen by soil bacteria over time for each of the VMPs are shown on figures provided in Appendix C. Oxygen utilization at PFFAVMP15-42 and PFFAVMP04-20, the locations where the minimum and maximum rates occurred, are shown for comparison on Figure 7.1. Results from the ISR tests indicate there are active microorganism populations within the oxygen-depleted zones that were tested. The oxygen-utilization rates measured at the site were low to moderate, ranging from 0.087% oxygen per hour (% O_2/hr) at PFFAVMP15 at 42 feet bgs to 0.53% O_2/hr at PFFAVMP04 at 20 feet bgs, with a mean rate at all tested locations of 0.27% O_2/hr (6.5% O_2/day).

7.4 Estimate of Soil Contamination Biodegradation Rate

Based on the measured oxygen-utilization rates from the ISR tests, the soil moisture contents measured during analytical testing (Table 4.3), and estimated total soil porosities based on soil type, it is estimated that approximately 510 to 1,500 mg of fuel hydrocarbons per kg of soil can be biodegraded each year at the site. The biodegradation rate estimates are based on calculated air-filled porosities, which ranged from 9.4% to 31 % by volume, and a ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. Methods of calculation followed procedures outlined in the Air Force bioventing protocol document (Hinchee *et al.*, 1992) and the USEPA bioventing manual (USEPA ORD, 1995). Detailed calculations and the assumptions used are provided in Appendix C.

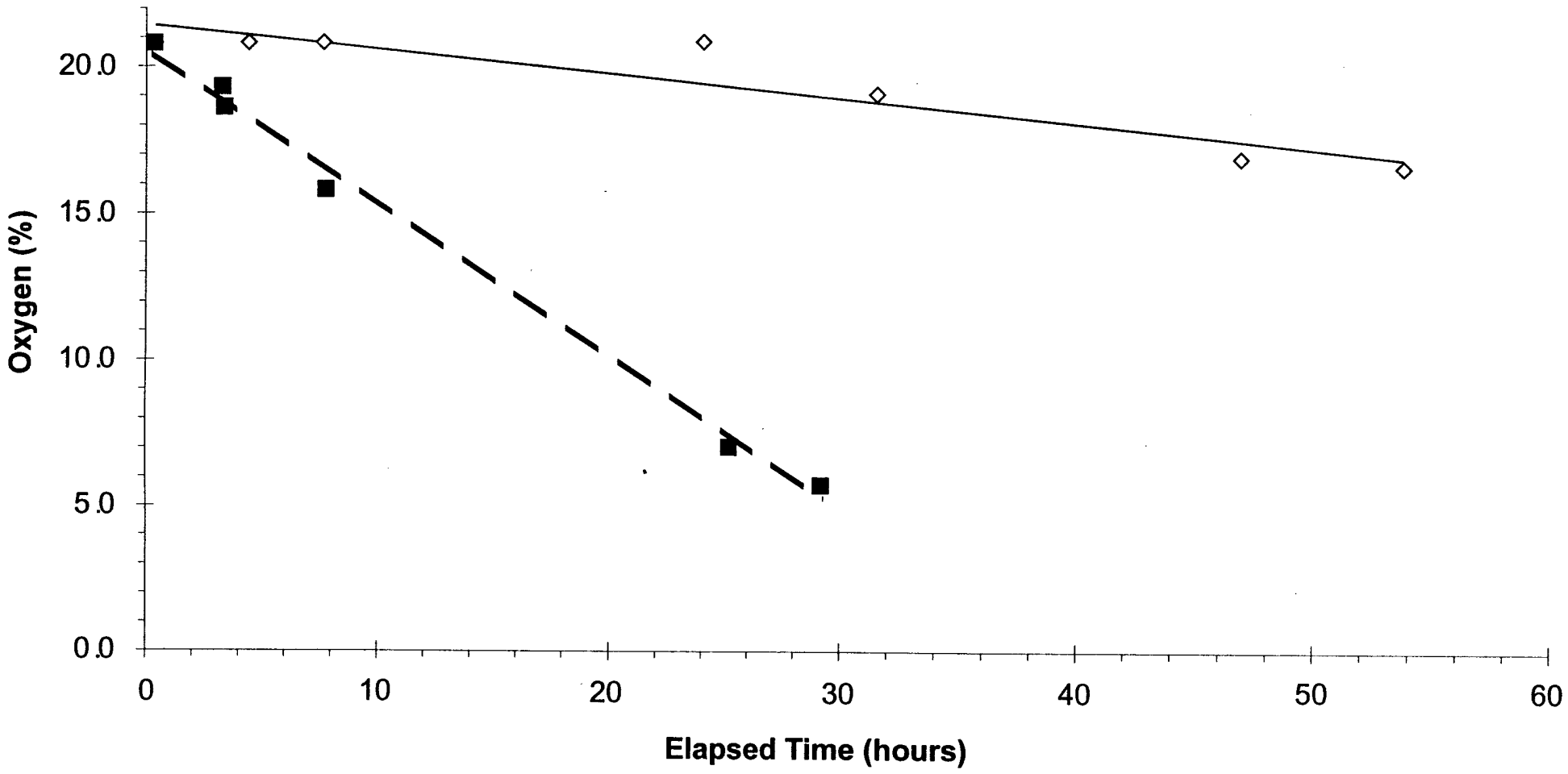

FIGURE 7.1

IN SITU RESPIRATION TEST RESULTS

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The estimates of soil contamination biodegradation are potential rates and assume that sufficient oxygen is provided to the microorganisms through either an engineered system (i.e., bioventing or SVE) or natural air exchange. The oxygen-depleted conditions measured throughout most of the PFFA (Section 4.4) indicate that a lack of oxygen is currently limiting biodegradation of contaminant residuals in soil.

7.5 Air Permeability Test Results

Two AP tests were conducted at the PFFA between 19 December 1997 and 03 January 1998. The objective of the AP test was to determine the air permeability of PFFA soils and to determine extent of the subsurface which could be oxygenated from air injection at a single VW. The purpose of two AP tests was to determine the effect of depth and lithology on the radius of influence. Procedures and equipment used to conduct the AP tests are described in Section 2.5.

During the first AP test, air was injected into PFFAVW01 for approximately 5 days at a flow rate of approximately 40 standard cubic feet per minute (scfm) and an average wellhead pressure of 2.5 pounds per square inch (psi). Because PFFAVW01 is screened between 6 and 21 feet bgs, air injection into PFFAVW01 was designed to evaluate permeability of the finer-grained materials in the shallow vadose zone. During the first few hours, and then periodically over the following 4 days, pressure in the 3 VMPs and surrounding MWs was measured to evaluate dynamic and steady-state pressure response. Air permeability and radius of influence were calculated using the modified field drawdown method (Johnson *et al.*, 1990).

The pressure response in the VMPs to air injection in PFFAVW01 are shown on figures provided in Appendix C. The pressure response measured at the VMPs increased rapidly during the first 10 minutes of air injection and reached near steady-state conditions within the first 20 minutes. This relatively fast response is typical of less permeable, finer-grained soils as are present in the shallow vadose zone at the PFFA. Therefore, air permeability of the shallow vadose zone was calculated using the steady-state calculation method. The calculated air permeability for the shallow soils was approximately 3.9 darcys, within the range typical of silty sands that are present in the shallow vadose zone. A radius of pressure influence of approximately 70 feet was inferred from the pressure response in the VMPs. Steady-state pressure response in the VMPs is shown on Figure 7.2. Calculation procedures are described in the bioventing protocol documents (Hinchee *et al.*, 1992; USEPA ORD, 1995).

During the second AP test, air was injected into MW531 for approximately 5 days at a flow rate of approximately 40 scfm and an average wellhead pressure of 0.17 psi. Because MW531 is screened between 34 and 59 feet bgs, air injection into MW531 was designed to evaluate permeability of the coarser-grained materials in the deep vadose zone.

The pressure response in the VMPs to air injection in MW531 are shown on figures provided in Appendix C. The pressure response measured at the VMPs increased steadily during the few hours of air injection and reached near steady-state conditions after approximately 2.5 hours. Air permeability of the deep vadose zone was calculated using both the dynamic and steady-state calculation methods. The calculated air permeability for the deep vadose ranged between approximately 38 and 200 darcys, within the range typical of medium- to coarse-grained sands that are present in the deep vadose zone.. A radius of pressure influence of approximately 110 feet was inferred from the pressure response in the VMPs.

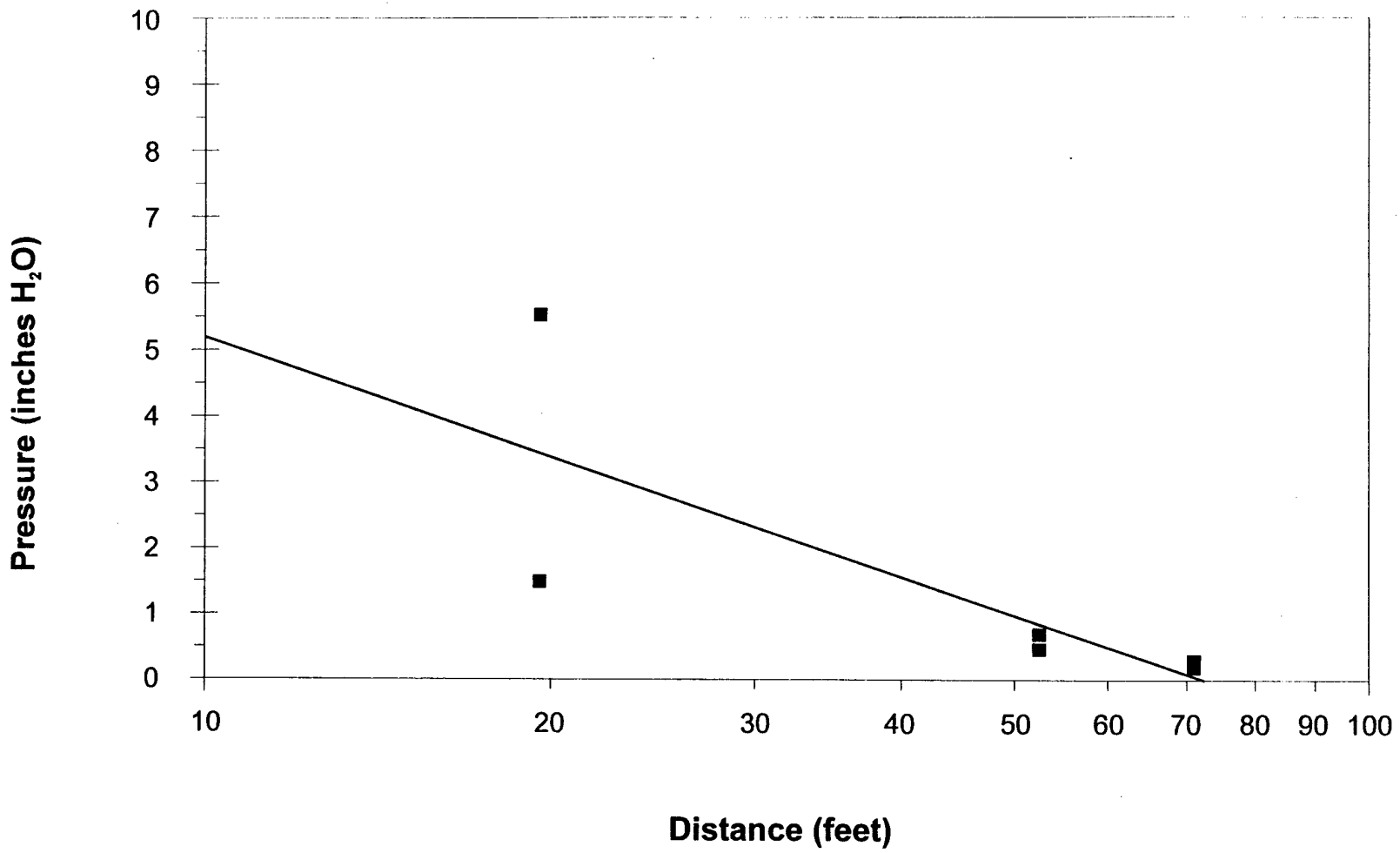

FIGURE 7.2

STEADY-STATE PRESSURE RESPONSE FROM AIR INJECTION IN PFFAVW01

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Dynamic response at PFFAVMP15, which is representative of the response at all 3 VMPs, is shown on Figure 7.3.

7.6 Oxygen Influence Test Results and Design Radius of Influence

The depth and radius of oxygen increase in the subsurface resulting from air injection during pilot testing is the primary design parameter for full-scale bioventing systems. Optimization of full-scale and multiple VW systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Figures 7.4 and 7.5 present the changes in soil vapor oxygen concentrations that occurred during the 5-day air injection periods in PFFAVW01 and MW531, respectively. During the AP test at PFFAVW01, oxygen concentrations increased significantly in all VMPs at the 10-foot depth, with smaller, though appreciable, increases at the 20-foot depth in PFFAVMP14 and PFFAVMP15. The smaller increases at the 20-foot depths are consistent with the smaller pressure changes measured at these depths during the AP test and are probably due to the fact that the VW screen terminated at 21 feet bgs and some components of vertical air flow were present. In addition, a very low permeability layer of silt and clay is present between 20 and 25 feet bgs in the area near PFFAVW01 and this layer may be restricting air flow between these depths.

During the AP test at MW531, oxygen concentrations increased significantly in all VMPs and at all depths. Oxygen concentrations also increased in monitoring well JM11, located approximately 100 feet from MW531, although time constraints required termination of AP test prior to oxygen concentrations reaching a steady-state concentration at JM11. Therefore, the radius of oxygen influence in the deep vadose zone is potentially larger than 100 feet.

During a portion of each of the AP tests, helium was mixed with the injected air at a concentration of approximately 1 percent. The helium was used as a tracer gas to verify subsurface air movement and to provide additional verification of the treatment radius in case utilization of oxygen in the injected air was significant. Helium injection was started approximately 70 hours into the AP test at PFFAVW01 and during the first 24 hours of the test at MW531. Significant increases in helium were measured at all locations where significant increases in oxygen were measured. Helium measurements are shown on figures provided in Appendix C. During the AP test at MW531, when helium and air injection were started simultaneously, breakthrough of helium and oxygen occurred at approximately the same time. These results confirmed that changes in soil vapor oxygen concentrations with distance were due to advective air flow from the injection point.

Based on the measured changes in oxygen concentrations with distance from the air injection locations and the radius of pressure influence calculated from the AP test results, it is anticipated that the radius of oxygen influence for a long-term bioventing system will be approximately 70 feet in the shallow vadose zone and at least 100 feet in the deep vadose zone at the PFFA. These estimated treatment radii were used to design the full-scale SVE/bioventing system described in Section 9.

7.7 Evaluation of Soil Vapor Extraction

Although the bioventing pilot test focused on identifying design criteria for a full-scale bioventing system, the same tests can also be used to evaluate SVE feasibility and design full-scale SVE systems. Adequate soil air permeability must exist for both SVE and bioventing technologies to be feasible and cost-effective because both technologies rely upon

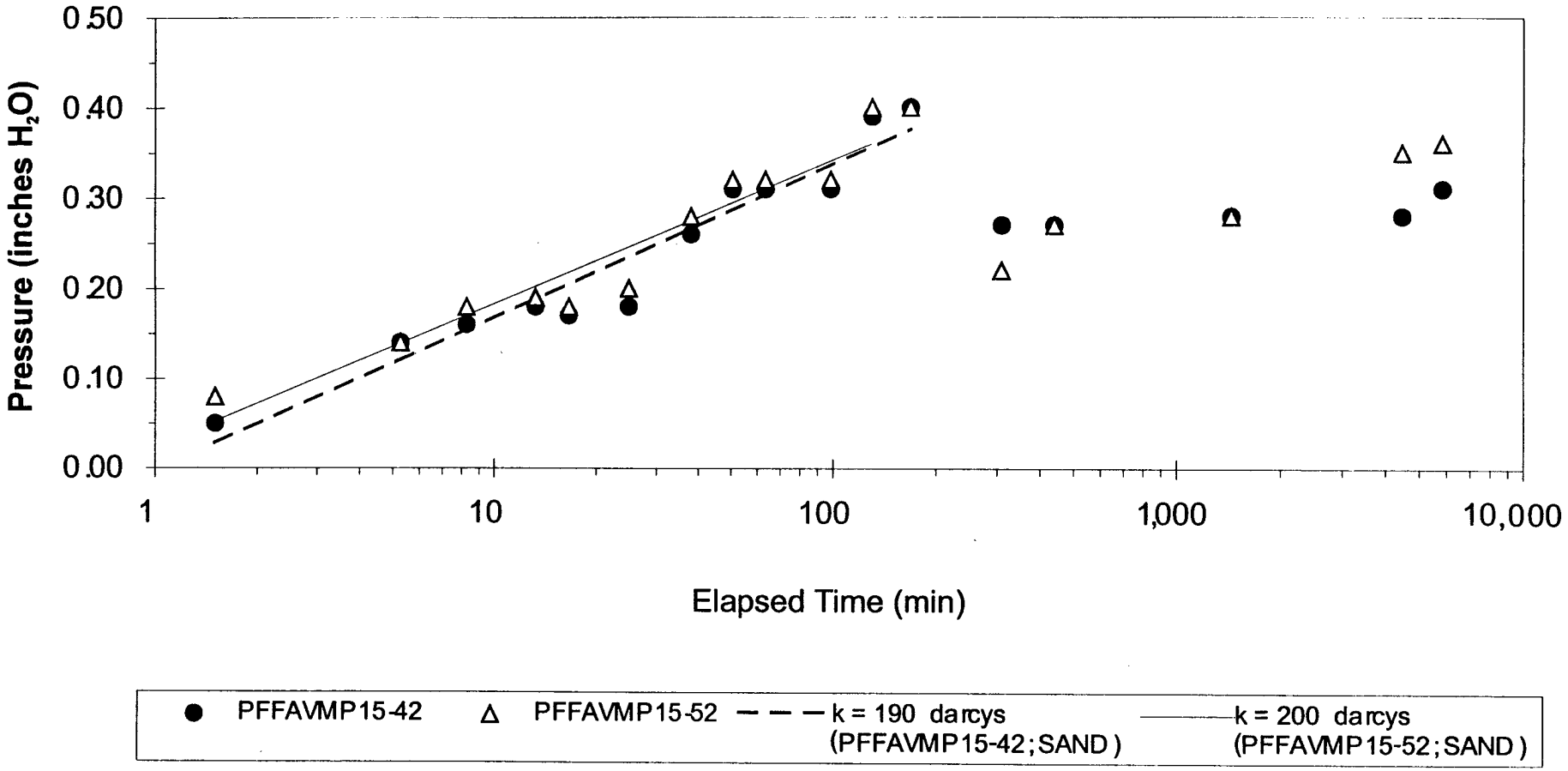

FIGURE 7.3

DYNAMIC PRESSURE RESPONSE FROM AIR INJECTION IN MW531

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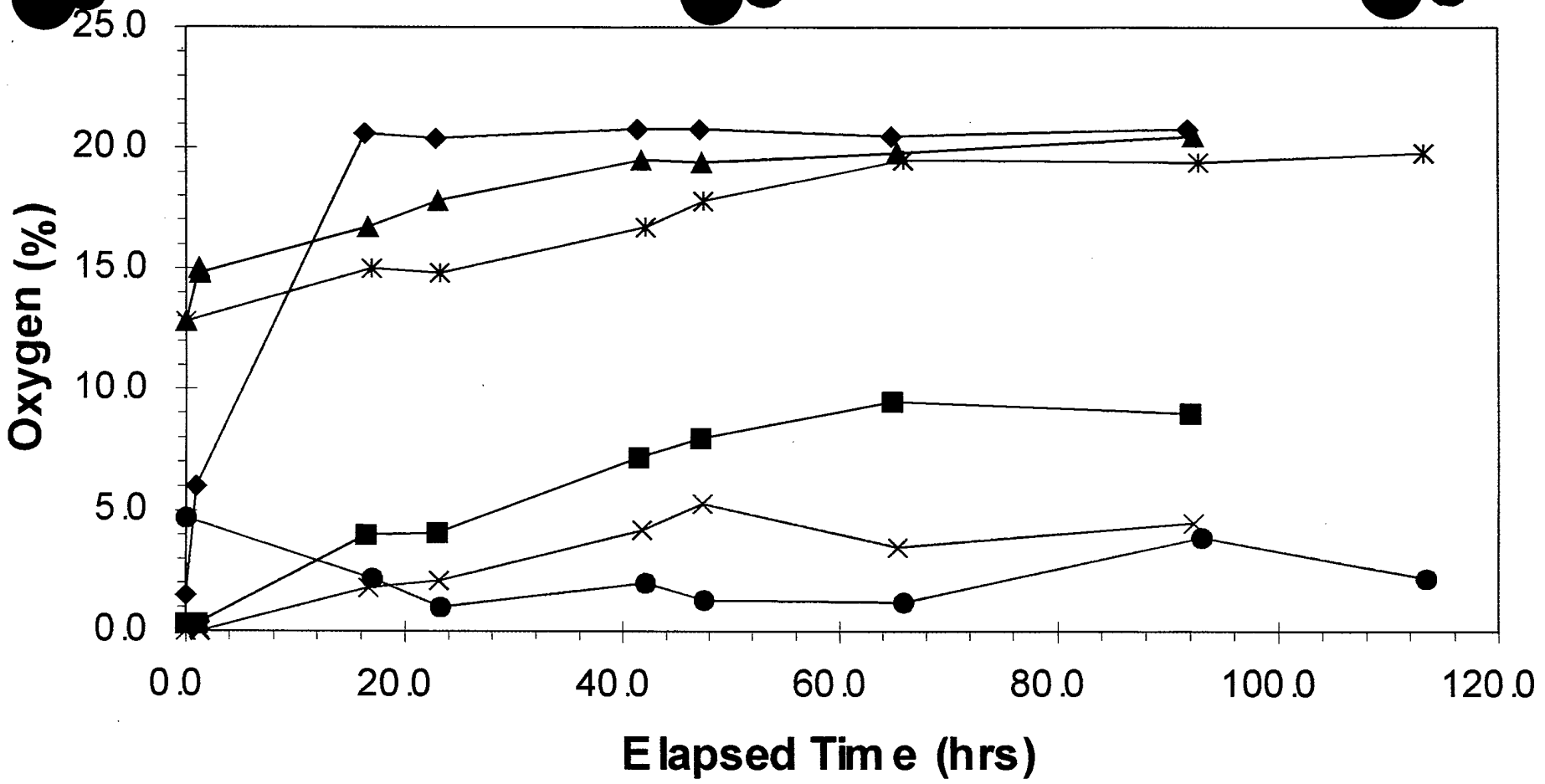

FIGURE 7.4

OXYGEN RESPONSE DUE TO AIR INJECTION IN PFFAVW01

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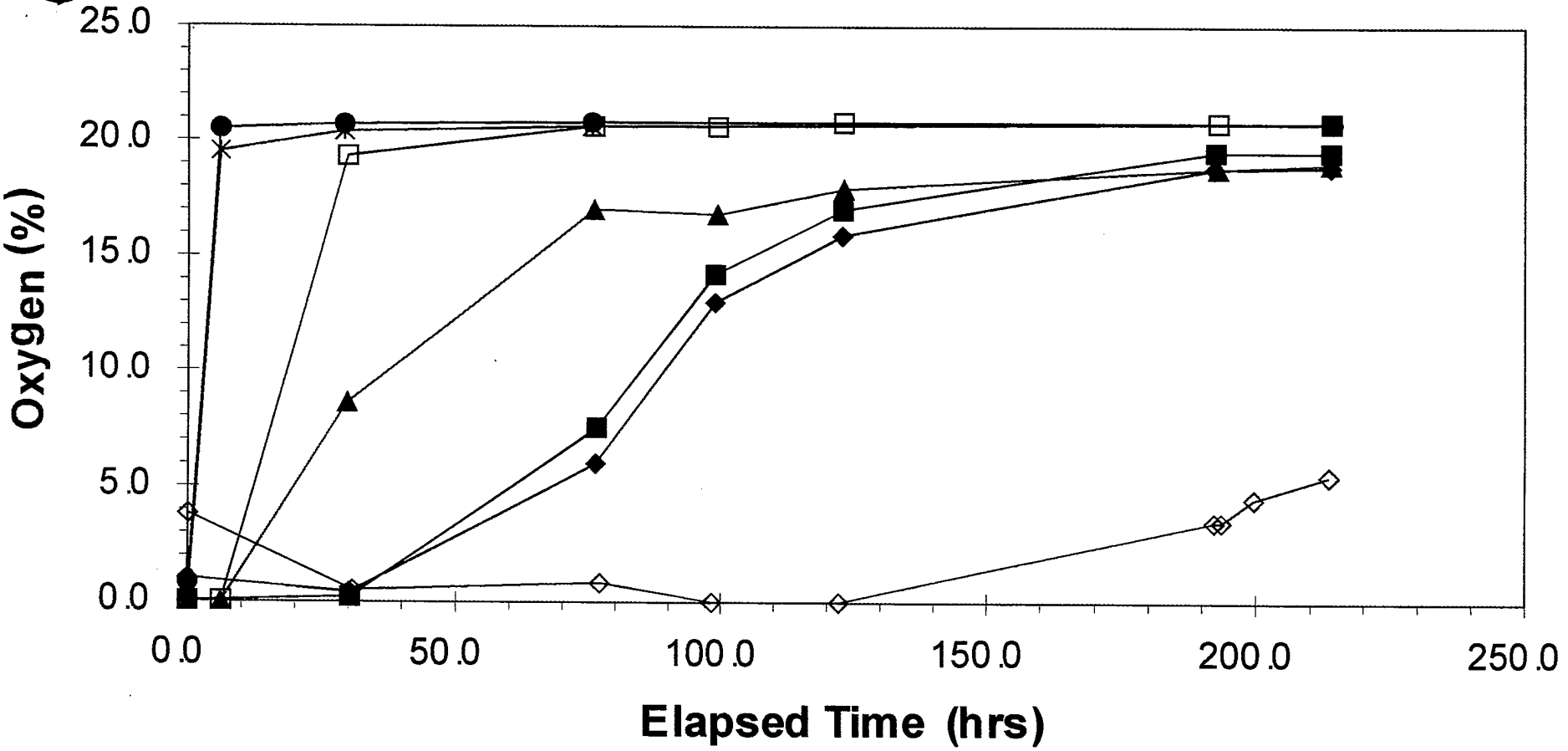

FIGURE 7.5

OXYGEN RESPONSE DUE TO AIR INJECTION IN Mw531

PFFA RAP
Castle Airport, California

PARSONS
ENGINEERING SCIENCE, INC.

Oakland, California

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air flow in the subsurface for remediation. A reasonable radius of influence must also be achievable for both technologies to be cost effective and so that an excessive number of VWs is not required. The major difference in the evaluation of the two technologies is that higher vacuums must be achievable with distance with SVE compared to bioventing because SVE relies upon volatilization rather than biodegradation to reduce contaminant mass.

The air permeabilities measured at the PFFA for the shallow and deep vadose zones, 3.9 darcys and between 38 and 200 darcys, respectively, are high enough for both technologies to be technically effective. Although the radius of influence at the PFFA was measured using an air injection AP test, the modified field-drawdown method of Johnson *et al.* (1990) predicts that at the same flow rate, air permeability, and wellhead pressure/vacuum, the radius of vacuum influence during air extraction will not be significantly different than the radius of pressure influence during air injection. Field data from sites where both air extraction and air injection AP tests were conducted (Phelps *et al.*, 1995; Parsons ES, 1996b) are consistent with this interpretation.

Although higher flow rates are typically used for SVE systems and the radius of vacuum influence is expected to be larger with higher SVE flow rates, the effectiveness of SVE is also more sensitive to the magnitude of the induced vacuum, which decreases with distance from the extraction well. Since the magnitude of the induced vacuum during SVE decreases exponentially with distance, the radii of influence measured during the air injection AP tests at the PFFA (i.e., 70 feet for the shallow vadose zone and 100 feet for the deep vadose zone) were considered reasonable and conservative for the design of either a low air flow air injection bioventing system or a high flow air extraction SVE system. In addition, by designing the well spacing for bioventing operations, an SVE system could be easily converted to an air injection bioventing system without the need for additional VWs. A conversion from SVE to bioventing might be more cost-effective as contaminant concentrations decrease over time and the efficiency of the SVE system is reduced.

SECTION 8

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

8.1 OVERVIEW

As described in Section 5, benzene was detected in soil at concentrations that exceeded site-specific risk-based cleanup levels (RBCLs). Sections 6 provided scientific documentation that natural attenuation processes, with or without the existing groundwater extraction and treatment system, will prevent migration of groundwater contamination to off-site receptors above the RBCLs for groundwater. Consequently, it is not necessary to implement additional engineered groundwater remediation to protect human receptors.

However, it may be necessary to implement soil remediation to protect human receptors, given the types of exposure likely to occur at the PFFA. Section 7 provided an evaluation of the potential benefits of bioventing and/or SVE in accelerating the remediation of the source areas at the PFFA, which will reduce soil concentrations below RBCLs. In addition, because soil COPCs may continue to leach from source area soils into groundwater, contaminant source removal from soils may be more cost-effective than the long-term monitoring that may be needed to ensure natural attenuation continues to prevent groundwater contaminants from reaching off-site receptors.

Preliminary screening of various remedial approaches and technologies that may be appropriate to attain risk-based remediation requirements for protection of human health was conducted. In addition to land and groundwater use controls, natural chemical attenuation, public education, and long-term groundwater monitoring, two additional candidate source reduction alternatives (forming a total of three alternatives) were retained from this screening step as technically feasible and cost-effective approaches to attain risk-based cleanup objectives for the PFFA in a reasonable time frame. The three remedial alternatives were developed using various combinations of natural attenuation, land and groundwater use controls, long-term monitoring, active source removal, and contaminated soil excavation and treatment.

The three retained alternatives are:

1 Natural attenuation alone;

2 Natural attenuation combined with SVE in the contaminated areas of the shallow vadose zone and air injection bioventing in the contaminated areas of the deep vadose zone; and,

3 Natural attenuation combined with excavation and on-site treatment by landfarming for the contaminated areas of the shallow vadose zone and air injection bioventing in the contaminated areas of the deep vadose zone.

All three alternatives also include land and groundwater use controls, public education, and long-term groundwater and surface water monitoring. The benefits (and potential disadvantages) of using engineered remediation to supplement exposure controls and natural chemical attenuation to comply with RBCLs are described in this section.

The objectives of Section 8 are to summarize the alternatives, to review the primary evaluation criteria used to compare these alternatives, and to complete a more detailed comparative analysis of each alternative in an effort to identify the most logical approach for remediating the PFFA. Each alternative is more fully explained in terms of its effectiveness, technical and administrative implementability, and cost. Following this evaluation, an implementation plan for the recommended alternative is summarized in Section 9.

8.2 SUMMARY OF CANDIDATE REMEDIAL ALTERNATIVES

Based on the remedial screening process (described in Section 8.3), several remedial approaches and technologies were retained for the development of remedial alternatives. These technologies were selected to provide a range of passive to more active response actions, all of which will minimize contaminant migration, minimize increases in contaminant concentrations, and prevent receptor exposures. The primary goal of all the proposed alternatives is to demonstrate that unrestricted industrial use is appropriate for the PFFA and allow the Air Force to close the PFFA after RBCLs based on an industrial use are achieved, either through natural attenuation alone or natural attenuation in combination with limited source removal actions.

The following remedial approaches and technologies were retained for evaluation:

- Limited administrative land use controls;
- Groundwater use controls;
- Natural chemical attenuation of groundwater COPCs;
- Long-term groundwater and surface water monitoring;
- Public education;
- Air injection bioventing for treatment of soil COPCs in source area;
- SVE for treatment of soil COPCs in source area; and,
- Excavation and onsite treatment of contaminated soils in source areas.

The engineered remedial approaches and technologies listed above can be grouped into two categories:

1 Exposure controls to minimize the potential for human receptors to come into contact with site-related contamination (this grouping includes land and groundwater use controls and public education).

2 Source reduction technologies to accelerate removal of COPCs from vadose zone soils in the source areas (this grouping includes air injection bioventing, SVE, and excavation and treatment of contaminated soil).

Although not explicitly included in each of the three alternatives, the existing groundwater extraction and treatment systems operating north of the PFFA are also assumed to continue to operate under each of the three alternatives. Although designed to remediate a separate TCE plume, these systems are also effectively providing plume control for the PFFA and preventing migration of groundwater contaminants to downgradient receptors. Because

natural attenuation and the groundwater extraction systems have been effectively reducing dissolved BTEX compounds and naphthalene in the groundwater and limiting downgradient migration (Section 6), these ongoing remediation process can best be enhanced through a reduction of the vadose zone sources of contamination at the PFFA.

The three candidate remedial alternatives that were developed are described in the following sections.

8.2.1 Alternative 1 - Natural Attenuation, Long-Term Monitoring, and Land and Groundwater Use Controls

Goal of Alternative 1: Attainment of RBCLs in soil and groundwater and unrestricted industrial use within a reasonable time frame without the need for engineered remediation.

Section 6 presents evidence that groundwater contaminants are being remediated by natural physical, chemical, and biological processes. Natural chemical attenuation processes have been removing, and should continue to remove, contaminant mass dissolved in groundwater and limit plume migration (Section 6). Alternative 1 assumes that these processes will be allowed to continue with no engineered source removal.

On the basis of previous soil sampling results presented in Section 4 and evaluated in Section 5, contaminant concentrations in shallow soils are above levels that are protective of human health for future intrusive workers. Because site subsurface soil contaminants are present at concentrations that pose a risk to human health, this site will require further treatment before it is suitable for unrestricted industrial use.

Land and groundwater use restrictions also are considered necessary components of any remedial alternative at this site to ensure that the exposure assumptions used to develop the RBCLs are representative of site exposure conditions. Current and proposed land use plans indicate that site access will be restricted to industrial activities. The other restrictions are that excavations in the contaminated source areas will only be allowed with proper health and safety precautions, and any excavation/activities in the contaminated source areas must not disturb remediation progress and monitoring systems.

In addition, installation of potable water wells in the surficial aquifer will be forbidden until it can be demonstrated that any remaining groundwater contamination poses no risk when used as a drinking water source. Maintaining the light industrial land use at this site is consistent with the planned near-term use of this site. Limitations on groundwater use (i.e., groundwater cannot be used as a potable drinking water source) will not impose additional restrictions on the current or planned near-term future use in this industrial area. Groundwater monitoring also should be implemented to track the progress of both natural and engineered remediation and to verify that no unacceptable receptor exposures could occur while remediation is in progress.

The expected effectiveness of Alternative 1 is detailed in Section 8.3.1.1 and estimated costs are detailed in Section 8.3.1.3. In summary, based on contaminant transport modeling presented in Section 6, migration of contaminants to off-site receptors is unlikely. However, due to the expected persistence of residual contaminants in soil due to the asphalt cover across most of the site and lack of aerobic biodegradation, Alternative 1 is not expected to achieve RBCLs for shallow soil at the site within a reasonable time frame (less than 30

years). Therefore, this alternative is not expected to meet the goal of achieving RBCLs for shallow soil and unrestricted industrial use within a reasonable time frame. However, this alternative would be still protective of human health with appropriate long-term land use and excavation restrictions (i.e., excavation and handling of contaminated soils would require special health and safety considerations for the construction contractor and fugitive dust and vapor would require monitoring or engineering controls).

This alternative would include annual monitoring of groundwater for at least 30 years to verify that natural attenuation processes are proceeding as expected and that remaining soil residuals do not impact groundwater at concentrations which would migrate to downgradient receptors above concentrations protective of human health. Land use restrictions and groundwater use controls would also need to remain in place for at least 30 years. Additional details on the MW locations and the frequency and types of groundwater analysis recommended to confirm the effectiveness of ongoing natural processes are presented in the long-term monitoring (LTM) plan included in Section 10.

8.2.2 Alternative 2 - Soil Vapor Extraction in Shallow Soils and Air-Injection Bioventing in Deep Soils, Natural Attenuation, Long-Term Monitoring, and Land and Groundwater Use Controls

Goal of Alternative 2 - Attainment of unrestricted industrial use within approximately 1 year and elimination of long-term groundwater monitoring costs within 5 years.

Under Alternative 2, several SVE and bioventing air injection wells would be installed within the source areas present at the PFFA. SVE and bioventing in the source areas would be employed to lower residual contaminant concentrations in unsaturated soils. SVE would be implemented in the shallow soils to rapidly remove residual contaminant concentrations at depths where intrusive activities could potentially occur (less than 15 feet bgs). Because benzene is above its RBCL (Section 5) and benzene is the most volatile of the BTEX compounds, SVE is a very effective way to reduce benzene concentrations in soil and soil vapor and allow unrestricted industrial uses of the PFFA in a relatively short time period (within 1 year). Bioventing would be implemented in the deeper soils to rapidly reduce residual BTEX concentrations in soil, provide long-term protection of groundwater, and gain site closure in a relatively short time period (within 5 years based on modeling presented in Section 6). Bioventing is not required to protect human health and the environment under the current and most reasonable future land use assumptions for the PFFA. It is included primarily to reduce the time frame needed for groundwater monitoring (i.e., from at least 30 years to approximately 5 years). While SVE of the deeper soils would achieve similar reductions in residual BTEX concentrations in soil in a slightly shorter time frame than bioventing, the significant increase in capital and O&M costs in order to reduce the long term monitoring costs by only a few years would not be cost effective.

Several new vent wells would be installed as part of the SVE/bioventing remediation system. A detailed SVE/bioventing remediation system design is provided in Section 9, which includes figures identifying showing source areas planned for treatment. The SVE system would consist of an internal combustion engine (ICE) used to withdraw and treat soil vapors from the shallow soils. One ICE would be used and moved sequentially to each source area well. While SVE operations continued at subsequent source areas, soil vapor in previously

treated source areas would be allowed to rest and reach equilibrium. After the resting period, if necessary, source areas would be treated repeatedly until RBCLs could be demonstrated or longer-term treatment with bioventing was deemed more appropriate. SVE operations are estimated to be completed within 1 year.

The bioventing system would consist of several new air injection VWs screened within the deep vadose zone source areas. Where both the shallow and deep vadose zones are planned for treatment, one VW with isolated screened intervals would be used for both SVE and bioventing in order to save drilling and well construction costs. Two existing dry MWs will also be used as air injection VWs. It is expected that the bioventing system will be operated for approximately 2 years.

Land use and groundwater use controls for Alternative 2 would be identical to those described for Alternative 1, but would be needed for a shorter time period. Site access would be required to maintain the SVE/bioventing systems. Periodic monitoring of the SVE/bioventing system would be required to monitor system performance, comply with any permit requirements, and evaluate cleanup progress. Long-term groundwater monitoring would be the same as that under Alternative 1, but for a shorter time period.

8.2.3 Alternative 3 - Excavation of Shallow Contaminated Soils Followed by Landfarming, Air-Injection Bioventing in Deep Soils, Natural Attenuation, Long-Term Monitoring, and Land and Groundwater Use Controls

Goal of Alternative 3 - Attainment of unrestricted industrial use within approximately 6 months and elimination of long-term groundwater monitoring costs within 5 years.

Alternative 3 is similar to Alternative 2 except that SVE in the shallow soils is replaced by excavation followed by on-site treatment by landfarming. By replacing SVE with excavation, a slightly shorter time frame for achieving RBCLs is achieved. This alternative might be preferable to the *in situ* techniques of Alternative 2 if replacement of utilities or significant construction work was planned for the PFFA as part of Base reuse plans.

Soil excavation would be used to remove contaminants from the shallow unsaturated soils at the PFFA (soil less than 15 feet bgs). Soils shallower than 15 feet bgs would most likely be exposed and provide an exposure pathway during future construction work. Potential construction work would include foundation or trenching work. The soil would be removed from the site to a location within the Castle Airport boundary where the soil would undergo treatment by landfarming (i.e., aboveground treatment of soil by volatilization and natural bioremediation). It is estimated that this operation would take up to 6 months to ensure that all contaminated areas in the shallow soils have been excavated, the soil has been treated, and the soil is returned in place.

As with Alternative 2, bioventing would be used to remediate fuel-related contamination in the deeper unsaturated soils at the PFFA because excavation of soil deeper than 15 feet bgs would likely be cost-prohibitive. As under Alternative 2, bioventing is not required to protect human health and the environment under the current and most reasonable future land use assumptions for the PFFA. It is included primarily to reduce the need for additional site investigation sampling and lower long-term groundwater monitoring costs. The

implementation, construction and operation of the bioventing system would be identical to that under Alternative 2.

Land use and groundwater use controls for Alternative 3 would be identical to those described for Alternative 2. Site access would be required to conduct excavation and landfarming activities and maintain the bioventing systems. Long-term groundwater monitoring would be the same as Alternative 2.

8.3 REVIEW OF SCREENING AND EVALUATION CRITERIA

The evaluation criteria used to identify appropriate remedial alternatives for soil and groundwater contamination at the PFFA were based on conclusions from the FS for the PFFA (Jacobs, 1995a) and the evaluation of natural attenuation presented in Section 6. As stated in Section 1.1, this RAP is intended to be supplemental to the ongoing IRP and ROD process; therefore, a detailed reevaluation of remedial alternatives was not necessary. The process alternatives ranked highest in the FS for COPCs in soil were SVE and bioventing; therefore, these alternatives were retained. Soil excavation and treatment also was included as an additional remedy for shallow contaminated soils because it was expected to achieve a risk-based cleanup in the shortest possible time frame. Some combination of these alternatives, along with natural attenuation and administrative controls, were used to develop the three reasonable and cost-effective alternatives for the PFFA described in Section 8.1.

Criteria used to develop the three selected alternatives for the PFFA include (1) anticipated effectiveness in meeting target cleanup criteria, (2) technical and administrative implementability, and (3) relative cost. The following sections briefly describe the scope and purpose of each criterion.

8.3.1 Effectiveness

Each remedial technology or remedial alternative (which can be a combination of remedial technologies) was evaluated to determine how effectively it can attain the desired degree of cleanup. Remedial technologies that could not cost-effectively attain the desired level of remediation were not considered. The remedial actions proposed for this site under Alternatives 2 and 3 are designed to provide eligibility for unrestricted industrial use status for the PFFA. Although Alternative 1 does not achieve unrestricted industrial use status for the PFFA, through land use and excavation controls, it does provide protection of human health without the need for engineered remediation and serves as a useful comparison to Alternatives 2 and 3.

All 3 alternatives proposed for the PFFA would ensure that dissolved contamination in groundwater would not migrate to off-site receptors at concentrations above drinking water standards. Section 5 provides the rationale for determining that industrial use status is appropriate for the site, given the current and planned future land uses and the potential for receptor exposures to site-related contamination.

Remedial technologies retained for detailed evaluation are compared in terms of the expected effectiveness of each technology to attain the desired degree of risk reduction at the PFFA, based on site-specific data supplemented with treatability test data collected for the site. The ability to minimize potentially adverse impacts on surrounding facilities and operations and other environmental resources is considered. Time to implementation and time until

protection is achieved are described. Potentially adverse impacts that could be realized during implementation, the cost of necessary mitigation measures, and the potential for residual risks remaining following remedial action also were qualitatively considered. Long-term reliability for providing continued protection, including an assessment of potential for failure of the technology and the potential threats resulting from such a failure, is also evaluated.

8.3.2 Implementability

The technical feasibility, applicability, and reliability of each remedial technology identified in the FS conclusions were used to develop remedial approaches for the site. Technologies retained for detailed evaluation were evaluated in terms of engineering implementation, reliability, constructability, and technical/logistical feasibility. Potential effects due to unanticipated site conditions or significant changes in site conditions were considered. The ability to monitor performance and public perception are discussed. Any prohibition of onsite activities that would be required to ensure successful implementation is described.

8.3.3 Cost

Relative cost of various remedial technologies was used as an initial screening tool in the FS. More detailed cost estimates were prepared for each remedial alternative retained for comparative analysis. The cost includes operation and maintenance costs, over the time required for implementation. Present-worth cost estimates were prepared in accordance with OSWER Directive 9355.3-01.

8.4 DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

In this section, each of the candidate alternatives is evaluated using the more detailed criteria described in the previous section. Each alternative is more fully described in terms of its effectiveness, technical and administrative implementability, and cost.

8.4.1 Alternative 1- Natural Attenuation, Long-Term Monitoring, and Land and Groundwater Use Controls

8.4.1.1 Effectiveness

Soil, soil vapor, and groundwater sampling performed at the PFFA in 1997 indicates that concentrations of COPCs in soil vapor are above levels that would cause a risk to human health and the environment under an industrial land use scenario. COPC concentrations are expected to decrease slowly over time through both destructive and nondestructive attenuation processes. However, the asphalt cover throughout much of the site will probably minimize the rate of these attenuation processes. It is anticipated that RBCLs for soil vapor would not be achieved for at least 30 years, during which time land use controls and excavation controls would need to be in place. There is a significant amount of uncertainty in estimating the length of time required to achieve RBCLs under this alternative because of the uncertainly in estimating natural weathering rates for soil contamination. However, it is likely that the contaminants have been in the vadose zone for at least 30 years (the PFFA has been in operation since the 1940's) and that they will persist into the future without some form of active remediation. For example, even with a liberal first-order attenuation (decay)

rate of 10% for vadose zone soil contamination, after 30 years the concentration of benzene at 40 feet bgs in the vadose zone near JM11/JM12 (detected at 13 mg/kg; see Table 4.3) would still be above VLEACH1 values after 30 years ($13e^{-.10(30)}=0.6$). For the present worth analysis, the time frame was limited to 30 years using published CERCLA guidance (USEPA, 1988).

Nevertheless, based on the evaluation of natural attenuation and the modeling presented in Section 6, the assimilative capacity of the groundwater and the site-specific biodegradation rates will be sufficient to eventually transform COPCs into carbon dioxide and water and to limit unchecked migration of any groundwater contamination. It should be noted, however, that the groundwater extraction and treatment systems and the hydrogeology of the site are also significant factors responsible for the containment of the plume.

Land use controls, excavation controls, and groundwater use controls are important components of this alternative. The current restrictions of site access (PFFA perimeter fencing and only authorized personnel are permitted to enter the area) provide an effective measure of protection against unauthorized site access and contaminated media contact. The present (uninhabited) land use and existing groundwater extraction and treatment systems have effectively eliminated potential current exposure pathways involving groundwater at this site.

As a part of this RAP, the Air Force proposes well permit restrictions to prevent withdrawal of groundwater from the shallow aquifer for drinking water applications within 1,000 feet of the leading edge of the current contamination until such time as the COPCs in soil and soil vapor stabilize at levels below WQSA thresholds and COPCs in groundwater are below drinking water standards. These groundwater use restrictions should be a component of any future land use change or property exchange. This strategy will not interfere with the current and intended industrial use of the PFFA for aviation support or aviation-related industry. In the unlikely event that the site is rezoned for unrestricted residential use, groundwater use restrictions must be kept in place and enforced until such time as COPCs have been stabilized at concentrations equal to or below WQSA thresholds and drinking water standards at every point.

Long-term groundwater monitoring is recommended under Alternative 1 as a method of measuring the effectiveness of natural attenuation and to eventually demonstrate the eligibility of the site for inactive status. The groundwater monitoring network would consist of nine existing groundwater MWs. These wells would be sampled annually for BTEX and naphthalene. Sampling details can be found in Section 10, which contains a LTM plan. Based on sampling results, the migration of the contaminant plume will be monitored.

It is estimated that inactive status would not be achieved at the PFFA under this alternative in less than 30 years, primarily because contaminant residuals in soil are expected to persist for a long period of time due to the low natural weathering rates. Although migration of groundwater contaminants to downgradient receptors is unlikely based on modeling presented in Section 6, the potential for groundwater contamination at the PFFA will remain for as long as the soil residuals remain above WQSA thresholds.

A complete LTM plan is provided in Section 10 to assist Castle Airport in implementing long-term groundwater monitoring. Every year, groundwater data will be compared to

predictions to ensure that natural attenuation, the groundwater extraction and treatment systems, and site hydrogeology are preventing the contaminant plume from spreading further than expected. In the event that remediation is not progressing as expected and/or the dissolved plume is migrating further or faster than expected, the following contingency actions are recommended:

- Resample all MWs to confirm initial results;
- Evaluate the results of the most recent groundwater sampling event to determine if there is a trend indicating that natural chemical attenuation processes have significantly changed (e.g., change in biodegradation rate or geochemical conditions) or if the site hydrogeology has been misinterpreted;
- Reevaluate the CSM and complete a risk analysis to determine if the levels of groundwater contamination present a risk given actual site and downgradient land use at the time of sampling; and,
- If there is a significant potential for unacceptable exposure and this alternative is deemed insufficient to reduce that potential, reevaluate implementing active methods of remediation (e.g., Alternatives 2 or 3).

8.4.1.2 Technical and Administrative Implementability

Alternative 1 is technically simple and easy to implement. Existing MWs within and upgradient and downgradient from the PFFA are already in place to monitor groundwater contamination. Several MWs are far enough downgradient from the source areas and existing groundwater contamination to serve as sentry wells should the plume move to the west outside the influence of the groundwater extraction and treatment systems. Long-term groundwater sampling is a standard procedure involving minimal worker exposure to contaminated media. Equipment reliability and maintainability are not issues under Alternative 1 because no remediation equipment will be used at the site. The ability of natural attenuation, the existing groundwater extraction and treatment systems, and site hydrogeology to reduce contaminant concentrations and limit plume migration would be reevaluated every year.

Administrative implementation of this alternative would require that Castle Airport personnel communicate plans regarding the future use of the PFFA to the public and regulatory agencies. Any proposed change in land use that differs from industrial use, or any proposed groundwater use within 1,000 feet of the leading edge of the current plume, should be carefully evaluated. The existing site perimeter fence and controlled-access status also should be maintained to prevent unauthorized access. Any future construction or maintenance activities in this area should be planned to minimize deep excavations (i.e., greater than 5 feet bgs in locations near the shallow source zone areas) and should protect the network of groundwater MWs. Wells should remain locked and protected against tampering or vandalism.

The length of time required to achieve risk-based remedial goals under Alternative 1 might not be considered a reasonable time frame by either regulatory agencies or the public; however, it could still be protective of human health with the proper institutional controls in place. Although this alternative would be protective of human health and the environment,

contaminants that exceed the RBCLs would remain onsite for a lengthy period of time. Therefore, it is anticipated that public reaction to allowing contaminants to persist onsite would not be positive. To counteract potentially negative public opinion, public education would need to be a prominent part of this alternative and would need to focus on the site-specific risk analysis and cost savings. Consistent long-term monitoring would provide verification of natural attenuation effectiveness and land use controls to ensure that site conditions do not change over time.

8.4.1.3 Cost

The costs associated with Alternative 1 are presented in Table 8.1. Detailed cost calculations are presented in Appendix F. There would be no remediation equipment operated or maintained under this alternative. Annual costs would include site management and groundwater monitoring, which would include evaluation of annual monitoring data, continued liaison with state regulatory agencies and the public, and participation in future land use planning. Based on the assumption that at least 30 years of natural attenuation and long-term monitoring would be required to pursue and achieve an inactive status classification, the present-worth cost of Alternative 1 is estimated to be at least $316,300. There is a significant amount of uncertainty in estimating the length of time required to achieve RBCLs under this alternative because of the uncertainty in estimating natural weathering rates for soil contamination. Higher costs would be incurred if RBCLs could not be achieved even after 30 years.

8.4.2 Alternative 2 - Soil Vapor Extraction in Shallow Soils and Air-Injection Bioventing in Deep Soils, Natural Attenuation, Long-Term Monitoring, and Land and Groundwater Use Controls

8.4.2.1 Effectiveness

The effectiveness of Alternative 2 in minimizing plume migration and reducing contaminant residuals in soil and soil vapor at the PFFA would rely primarily on the mass removal effects of bioventing processes and contaminant volatilization. SVE and bioventing would initially reduce contaminant mass in the source area, but would have little immediate impact on the dissolved contamination originating from the PFFA. Natural attenuation in combination with the existing groundwater extraction and treatment systems would be the remedial approaches prescribed for the remediation of dissolved contamination in groundwater at the PFFA under this alternative. The major benefit derived from implementing source removal activities at the PFFA would be achieving RBCLs for soil and soil vapor, which would allow unrestricted industrial use of the PFFA, in a much shorter time period than that predicted for Alternative 1.

SVE would be employed at the PFFA under this alternative to remediate contaminated soils in the several known "hot spots" within the shallow vadose zone. An ICE would be used to withdraw and treat soil vapors. Rates for contaminant removal would be determined after SVE operations begin. These rates would be then be used to determine how long SVE operations will be technically effective and cost-effective in removing significant quantities of contaminants. Based upon current contaminant concentrations in soil and soil vapor and prior field experience with SVE under similar hydrogeologic conditions, it is anticipated that

TABLE 8.1
Cost Estimate for Alternative 1
PFFA RAP
Castle Airport, California

Site Management and Monitoring Tasks	Present Worth Costs
Annual groundwater sampling at 8 groundwater MWs in accordance with the Long-Term Monitoring Plan (30 years)	$254,200
Site management and maintenance of institutional controls (30 years)	$62,000
Proposed Present Worth of Alternative 1	**$316,300**

Present worth costs based on annual adjustment rate of 7 percent (USEPA, 1993).
Cost details provided in Appendix F.

short-term SVE operations (less than 2 months at each source area) would be sufficient to reduce concentrations below the RBCLs for soil and soil vapor presented in Section 5.

Bioventing would be employed under this alternative to remediate contaminated soils in the deep vadose zone. This remedial action is not required to protect human health because no exposure pathway for deep soils or groundwater exists at the site. It is included primarily to reduce the need for additional site investigation sampling and lower long-term groundwater monitoring costs. Based on the results of the bioventing pilot test presented in Section 7, bioventing will be effective in efficiently and cost effectively remediating fuel-related contamination in unsaturated soils. Based on results from the U.S. Air Force Bioventing Initiative, the bioventing pilot test, and prior field experience with bioventing under similar hydrogeologic conditions, achievement of WQSA thresholds for soil and soil vapor in the deep vadose zone is anticipated to take approximately 2 years with bioventing. Depending upon the short-term technical effectiveness and cost-effectiveness of SVE, treatment of the shallow vadose zone could also be continued with bioventing as needed to achieve RBCLs and/or WQSA thresholds and site closure.

The land use and groundwater use controls for this alternative would be identical to those described for Alternative 1, except for a much shorter period of time. The long-term groundwater monitoring proposed for Alternative 2 would also be identical to Alternative 1, except for a much shorter period of time. The installation and operation of the SVE and bioventing systems would require additional site access. The SVE system would require weekly system maintenance checks and more frequent monitoring to determine the effectiveness of contaminant removal. The bioventing system would require respiration testing and soil vapor monitoring of BTEX concentrations every six months to verify system effectiveness and to track remedial progress. Long-term monitoring and post-remedial sampling would be required to provide verification of source removal and natural attenuation effectiveness prior to receiving closure status.

8.4.2.2 Technical and Administrative Implementability

Alternative 2 would be somewhat more difficult to implement than Alternative 1. Additional vadose zone extraction and air injection wells would need to be installed in the source areas for the SVE and bioventing systems. Underground distribution piping and 208-volt electrical service would need to be installed for the bioventing system. However, no underground piping or electrical service is required for the SVE system since the ICE is portable and generates its own power through the burning of the withdrawn contaminant vapors (when required, supplemental fuel is provided by portable propane tanks).

In order to complete the full-scale design, 3 new bioventing VWs, 3 new SVE extraction wells, and 2 new combination SVE/bioventing wells would be installed at the PFFA under this alternative. Two existing dry MWs would also be used for air injection as part of the bioventing system. In order to minimize electrical installation costs, two air injection blowers would be installed at the site, one adjacent to Building 508 and one adjacent to Building 71. In order to minimize trenching costs and site disruption, a combination of aboveground and subsurface distribution lines would be installed to each VW. All equipment required for SVE and bioventing can be installed at the PFFA with a minimal

degree of difficulty and all components for SVE and bioventing are readily available. Further details are provided in Section 9.

The general reliability and maintainability of SVE and bioventing systems is high. Bioventing blower motors are sealed and do not require lubrication. Air filters provide blower protection and the filters generally require replacement only every 90 to 180 days. No special training is required for maintenance personnel. The SVE system proposed for use at the PFFA is simple and reliable, consisting of an ICE and catalytic converter and does not require electrical power. The ICE requires more specialized maintenance personnel and more frequent maintenance (weekly) than the bioventing system. Weekly maintenance consists of checking system operation, fluid and fuel levels, proper fuel/air mixture, and extraction flow rates. System effectiveness and mass removal measurements would be performed on a monthly basis.

Administrative implementation of Alternative 2 would be similar to that described for Alternative 1. Castle Airport personnel would need to communicate plans regarding the future use of the PFFA to the public and regulatory agencies. Any proposed change in land use that differs from industrial use, or any proposed groundwater use within 1,000 feet of the leading edge of the current plume, should be carefully evaluated. The existing site perimeter fence and controlled-access status also should be maintained to prevent unauthorized access. Any future construction or maintenance activities in this area should be planned to minimize deep excavations while remediation was in progress and should protect the network of groundwater MWs, distribution piping, and SVE/bioventing equipment. One additional administrative requirement for this alternative is the probable need for an air permit and associated reporting requirements for the SVE system. However, it is generally not difficult to receive permits for SVE systems which use ICE treatment technology.

The public perception of Alternative 2 is expected to be significantly more positive compared to Alternative 1 because it includes some form of engineered remediation to supplement natural processes. In addition, public perception is expected to be positive because of the short time frame required to reach RBCLs. The primary advantage of Alternative 2 over Alternative 1 is that it would achieve unrestricted industrial use status in a shorter, more predictable amount of time.

8.4.2.3 Cost

The costs associated with Alternative 2 are presented in Table 8.2. Detailed cost calculations are presented in Appendix F. Capital costs include the cost of drilling and installing additional wells, the bioventing blowers and associated piping, electrical service, and the SVE system. One year of SVE and two years of bioventing operations and monitoring have been included as annual costs. Annual costs also would include groundwater monitoring and site management, which would include public education, continued liaison with state regulatory agencies, and participation in future land use planning. Closure sampling and well maintenance costs associated with any annual monitoring after inactive status has been achieved are not included in the cost estimate. Using these assumptions, the present-worth cost of Alternative 2 is $341,300.

TABLE 8.2
Cost Estimate for Alternative 2
PFFA RAP
Castle Airport, California

Initial Tasks	First Year Capital Costs
SVE/Bioventing System Installation	$170,600
SVE System O&M (within the first year)	$30,000
Site Management and Monitoring Tasks	**Present Worth Costs**
Annual groundwater sampling at 8 groundwater MWs in accordance with the Long-Term Monitoring Plan (5 years)	$62,900
Bioventing system O&M and reporting (2 years)	$49,400
Reporting of groundwater sampling results (5 years)	$21,100
Site management and maintenance of institutional controls (5 years)	$20,500
Proposed Present Worth of Alternative 2	**$341,300**

Present worth costs based on annual adjustment rate of 7 percent (USEPA, 1993).
Cost details provided in Appendix F.

8.4.3 Alternative 3 - Excavation of Shallow Contaminated Soils Followed by Landfarming, Air-Injection Bioventing in Deep Soils, Natural Attenuation, Long-Term Monitoring, and Land and Groundwater Use Controls

8.4.3.1 Effectiveness

Excavation and treatment of the contaminated soils in the shallow vadose zone would decrease the amount of contaminated soil at the PFFA and reach RBCLs in the shortest time frame. However, excavation would have little effect in remediating the deeper vadose zone contamination primarily responsible for groundwater contamination. Therefore, bioventing of contaminated soils in the deep vadose zone has been combined with excavation of the contaminated soils in the shallow vadose zone and natural attenuation for the dissolved contamination in groundwater at the PFFA under this alternative. The major benefit derived from implementing Alternative 3 over Alternative 2 is that unrestricted industrial use of the PFFA would be achieved in a slightly shorter time period than that predicted for Alternative 2.

Soil excavation would be employed at the PFFA under this alternative to remediate contaminated soils in the shallow vadose zone. Soil would be transported to a holding area within the Castle Airport facility where it would undergo treatment by landfarming. Landfarming of fuel-contaminated soils is a well-developed treatment technology and would probably be very effective in reducing concentrations to levels that would protect human health without the need for off-site disposal. Only the areas with shallow contamination (less than 15 feet bgs) would be excavated since it is not expected to be practical or cost-effective to excavate significant quantities of soil deeper than 15 feet. A estimated total volume of 17,000 cubic yards would be removed, treated, and replaced. Bioventing would be employed under this alternative to remediate contaminated soils in the deep vadose zone in an identical manner to that described under Alternative 2.

The effectiveness of Alternative 3 is significantly improved from Alternative 1 because the contaminants in the shallow vadose zone soils, which are driving risk at the site, are immediately removed by excavation. The effectiveness is slightly improved over Alternative 2 because of the shorter time period anticipated for excavation and treatment compared to SVE operations (6 months versus 1 year). However, it may not be possible to remove all contaminated soil surrounding subsurface utilities. Small, isolated pockets of contamination might remain undetected or might need to be left in place, which could reduce the improved effectiveness of Alternative 3 over Alternative 2. Because of the depth limitations of excavation and the expected need to remediate the deeper vadose zone soils to achieve site closure, the total time frame required to achieve site closure does not change under Alternative 3 compared to Alternative 2.

8.4.3.2 Technical and Administrative Implementability

Alternative 3 would be moderately difficult to implement compared to Alternatives 1 and 2. Although by eliminating the SVE system, less wells will need to be installed, significant site disruption would occur during excavation operations. Proper oversight of the remedial contractor handling contaminated soils would be required. Fugitive dust and emissions would need to be monitored and controlled.

In addition, it is likely to be extremely difficult to excavate around the many subsurface utilities which run throughout the PFFA and under the asphalt pavement which covers much of the site. The locations of many of the subsurface utilities are not known with any degree of certainty; therefore, extensive geophysical mapping of utilities and/or very slow and careful excavation would be required. Excavation in some of the contaminated areas might require the destruction of some of the MWs that have been installed at the site. Additional MWs might have to be installed to replace any destroyed during the excavation process.

Landfarming of fuel-contaminated soils may require a permit, but it is generally not difficult to receive permits for landfarming. Implementation of the bioventing system and long-term groundwater monitoring would be identical to that described in Section 8.4.2.2 for Alternative 2.

The general reliability of removal of the contaminants is fairly high with this alternative. Areas that have been clearly identified as being contaminated can be excavated with a fairly high degree of certainty. However, there would be some uncertainty in the identification process. Since past sources of contamination at the PFFA are likely to have included subsurface fuel lines, it may not be possible to remove all contaminated soil surrounding them without incurring the trouble and expense of replacing the fuel lines themselves, which would be time-consuming and expensive. Small, isolated pockets of contamination might remain undetected or might need to be left in place.

Administrative implementation of this alternative would be similar to that described in Section 8.4.2.2 for Alternative 2, except that significant site disruption during excavation operations would require additional coordination with personnel who use the area. Equipment currently staged in the area would need to be temporarily relocated.

The public perception of Alternative 3 is expected to be positive compared to Alternative 1 and about the same as that for Alternative 2 because it includes some form of engineered remediation to supplement natural processes. Public perception is expected to be positive because of the short time frame required to reach RBCLs. The primary advantage of Alternative 3 over Alternative 1 is that it would achieve unrestricted industrial use status in a shorter, more predictable amount of time. With the exception that RBCLs are achieved for shallow vadose zone soils in a slightly shorter time frame, there do not appear to be any significant advantages of Alternative 3 over Alternative 2. Excavation would have minimal impact on deeper vadose zone contamination which is responsible for the groundwater contamination nor would it reduce the amount of time that dissolved groundwater contamination persists at the site.

8.4.3.3 Cost

The costs associated with Alternative 3 are presented in Table 8.3. Detailed cost calculations are presented in Appendix F. Capital costs include the cost of drilling and installing additional wells (including those destroyed during excavation), the bioventing blowers and associated piping, electrical service, and excavation and treatment of contaminated soil. Two years of bioventing operations and monitoring have been included as annual costs. Annual costs also would include groundwater monitoring and site management, which would include public education, continued liaison with state regulatory agencies, and participation in future land use planning. One post-remedial sampling event in support of site closure is also

TABLE 8.3
Cost Estimate for Alternative 3
PFFA RAP
Castle Airport, California

Initial Tasks	First Year Capital Costs
Excavation, Characterization, and Landfarming of Shallow Soils	$906,700
Bioventing System Installation For Deep Soils	$81,200
Site Management and Monitoring Tasks	**Present Worth Costs**
Annual groundwater sampling at 8 groundwater MWs in accordance with the Long-Term Monitoring Plan (5 years)	$62,900
Bioventing system O&M and reporting (2 years)	$49,400
Reporting of groundwater sampling results (5 years)	$21,100
Site management and maintenance of institutional controls (5 years)	$20,500
Proposed Present Worth of Alternative 3	**$1,075,900**

Present worth costs based on annual adjustment rate of 7 percent (USEPA, 1993).
Cost details provided in Appendix F.

included. Sampling and well maintenance costs associated with any annual monitoring after inactive status has been achieved are not included in the cost estimate. Using these assumptions, the present-worth cost of Alternative 3 is $1,075,900.

8.5 RECOMMENDED ALTERNATIVE

Alternative 2 (SVE in Shallow Soils and Air Injection Bioventing in Deep Soils, Natural Attenuation, Long-Term Monitoring, and Land and Groundwater Use Controls) is recommended for remediation of the PFFA based on its expected effectiveness in attaining RBCLs and inactive status in a relatively short period of time, its relative simplicity with respect to technical and administrative implementation, and its relatively low overall cost.

As discussed in Section 7 and in this section, there is considerable evidence that SVE and bioventing will effectively reduce fuel-related contamination in unsaturated soils in the vicinity of the source area at the PFFA to concentrations that meet the RBCLs developed for the site in Section 5. Along with the existing groundwater extraction and treatment systems north of the PFFA, significant evidence exists that natural physical, chemical, and biological conditions at the PFFA are currently and will continue in the future to limit the migration of the dissolved groundwater contamination to downgradient receptors.

Given the current and projected industrial land use at the PFFA and in surrounding areas, some form of active remediation contaminated soils in the shallow vadose zone is required to achieve unrestricted industrial use of the site. Although no active remediation of contaminated soils in the deep vadose zone is required at this site to protect human health, bioventing is proposed to achieve WQSA thresholds developed for Castle Airport to protect groundwater quality and to accelerate attainment of unrestricted industrial use status for the site. Long-term groundwater monitoring will be used to verify the effectiveness of natural attenuation and to assure that COPCs in groundwater do not migrate beyond the area under reliable exposure controls. Limitations on groundwater use at the site should not affect future land use or operations.

Although Alternative 3 could also achieve RBCLs and attain unrestricted industrial use of the site, Alternative 3 is somewhat more expensive and more difficult to implement when compared with Alternative 2. Alternative 3 could be implemented in the future if it is found that SVE has been ineffective in reducing the contaminant concentration to RBCLs in the shallow soils. The proposed remedial action is relatively simple with respect to technical and administrative implementation concerns, and relies on relatively low-cost, *in situ* techniques. The capital costs of the proposed action are justified by the expected decrease in remediation time resulting from the implementation of source reduction activities when compared against natural attenuation alone (Alternative 1). Alternative 2 also provides the best combination of risk reduction and relatively low cost without imposing additional long-term land use or excavation restrictions that are unlikely to be acceptable to the public or the regulatory agencies.

Section 9 provides additional details on the recommended implementation of this alternative.

SECTION 9

IMPLEMENTATION OF RECOMMENDED REMEDIAL ACTION

This section provides an implementation plan for the recommended remedial action alternative: SVE in shallow soils and air injection bioventing in deep soils, natural attenuation, long-term groundwater monitoring, and land and groundwater use controls. This section reviews the scope and schedule of remediation activities, discusses possible contingencies if this remedial approach does not prevent offsite migration of COPCs, and summarizes costs by fiscal year.

9.1 SCOPE OF REMEDIAL ACTIVITIES

The recommended remedial action alternative will be implemented over a 5 year period to ensure that the PFFA is eligible for unrestricted industrial use status. The following sequence of events is proposed to fully implement this remedial action.

9.1.1 Review and Approval of Remedial Action Plan

Approval of this draft RAP is within the authority of Castle Airport/AFBCA environmental staff, AFCEE, and the regulatory agencies responsible for oversight of petroleum-only sites at Castle Airport: the California Regional Water Quality Control Board (Sacramento Region) and the Department of Toxics Substances Control. This group of environmental professionals is responsible for final approval of this RAP and implementation of the approved remedial action. Copies of this document will be distributed to each of the above organizations for review and comment. Approximately 30 days has been designated in the implementation schedule for review of the document.

Following the 30-day review period, a project presentation will be provided by Parsons ES and AFCEE at a location selected by Castle Airport/AFBCA, Sacramento RWQCB, and USEPA personnel. The purpose of this presentation will be to describe the major findings of this risk-based remediation project and to receive feedback and discuss any unresolved issues that may surface during document review. This direct interface between the document preparers and the group charged with RAP implementation is essential for final RAP preparation and a smooth transition into remedial actions.

Following the presentation, any unresolved issues or concerns can be provided in writing to AFCEE and/or AFBCA for additional discussion and formal incorporation into the final RAP. Parsons ES will have approximately 30 days to produce a final RAP and forward it to AFCEE and Castle Airport personnel, who will gain final approval from the regulatory agencies prior to implementation.

9.1.2 Design, Installation, and Operation of Soil Vapor Extraction System in Shallow Soils

Parsons ES has been contracted by AFCEE to construct a full-scale remediation system at the PFFA, and as part of this remedial action, Parsons ES is responsible for system construction, start-up, and the first year of operations. The first component of the remediation system is

operation of an SVE system to remediate the shallow soil contamination. The proposed SVE system has been designed to remediate petroleum-contaminated soils while maintaining strict California air emission standards. Such systems have been permitted within the State of California at similar sites. Although a site-specific air permit is not required due to CERCLA status, requirements of the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD) will be followed.

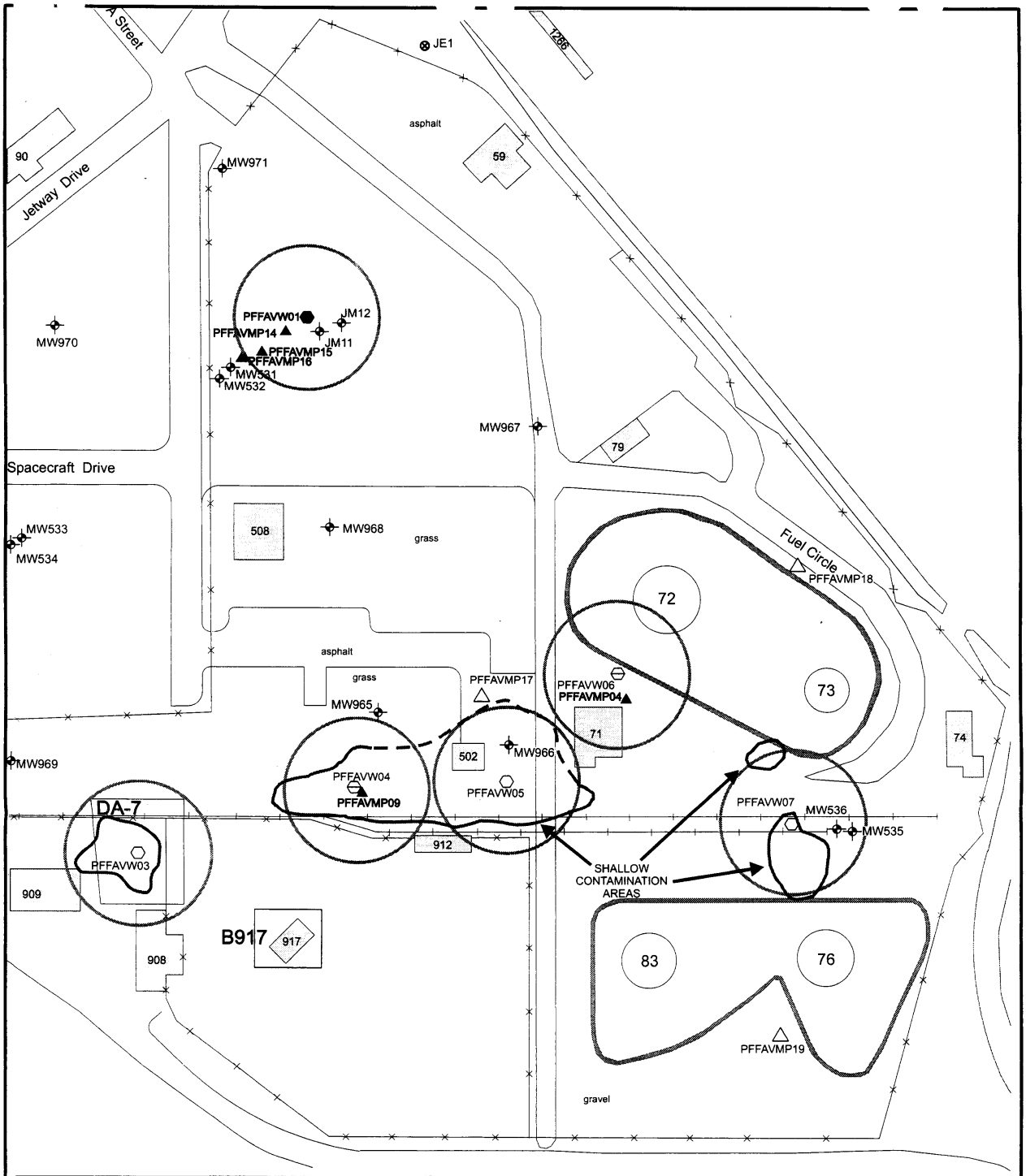
As part of the SVE system, 5 new extraction wells will be installed in the shallow vadose zone (screened between approximately 5 and 25 feet bgs) in previously identified source areas. In addition to the 5 new extraction wells, SVE operations will also be conducted at PFFAVW01, an existing VW installed for the bioventing pilot test. Locations for the extraction wells are shown on Figure 9.1. Two (2) of the 5 new wells will be constructed as combination SVE/bioventing wells and will have isolated, dual screen completions. The dual screen completions will allow for separate SVE/air injection from the shallow and deep vadose zones within one well completion. Construction details for the new wells are provided in Figure 9.2. The locations for the wells were chosen based on the design radius of influence for the shallow vadose zone (70 feet), as discussed in Section 7.7, and the previously identified source areas from the RI that were above WQSA thresholds and/or RBCLs.

The proposed SVE system (RSI Modular six-cylinder system) uses an ICE as a source of vacuum to draw soil vapor from the extraction wells into the intake manifold of the engine. The soil vapor is then combusted within the engine, with propane or natural gas used as a supplemental fuel during startup or when hydrocarbon levels in the soil vapor are insufficient to keep the engine operating efficiently. The exhaust gas is then passed through a catalytic converter to ensure maximum reduction of hydrocarbons. An automatic air/fuel controller (Phoenix 1000) maintains an optimal air/fuel ratio to minimize supplemental fuel use and maximize efficiency. No external power source is required. A process flow and instrumentation diagram for the ICE is shown in Figure 9.3.

The system requires regular maintenance, consisting primarily of resupplying the supplemental fuel tanks, monitoring engine performance, and performing routine mechanical maintenance (e.g., changing the engine oil). It is trailer-mounted for ease of transportation and setup.

The SVE system is sized to deliver a flow rate of up to 80 scfm at the expected wellhead pressure of the extraction wells. A system of this size will remove up to approximately 30 pounds/hour of hydrocarbons at a destruction efficiency exceeding 95%, based on performance at similar sites. Actual operating parameters at the PFFA will be dependent on soil conditions, hydrocarbon concentrations in the extracted soil vapor, air emissions requirements, and engine performance.

SVE operations are anticipated to last less than one year. A single, portable SVE system will mobilized to the site and sequentially moved to each extraction well planned for remediation. Although results for the PFFA will have to be evaluated based on actual operating performance and site response, based on experience at other sites treated with SVE/ICE with similar vapor concentrations and geology, it is expected that an influent concentration of between 1,000 and 2,000 ppmv total VOCs could be achieved within approximately six weeks of operation. After six weeks of operation (or longer if contaminant concentrations



LEGEND

- DRAINAGE DITCH
- ABOVE GROUND STORAGE TANK
- BUILDING
- FENCE
- RAILROAD TRACKS
- BERM
- MW969 — GROUNDWATER MONITORING WELL
- PFFAVW04 — PROPOSED COMBINATION AIR INJECTION AND SOIL VAPOR EXTRACTION WELL
- PFFAVW01 — EXISTING VENT WELL
- PFFAVW03 — PROPOSED SOIL VAPOR EXTRACTION WELL SCREENED IN SHALLOW SOILS
- PFFAVMP17 — PROPOSED VAPOR MONITORING POINT
- PFFAVMP14 — EXISTING VAPOR MONITORING POINT
- DESIGN RADIUS OF INFLUENCE IN SHALLOW SOILS
- AREAS OF CONTAMINATION IN SHALLOW SOILS WITH SOIL OR SOIL VAPOR ABOVE WQSA VLEACH1 THRESHOLDS OR SOIL OR SOIL VAPOR ABOVE RBCLs (DASHED WHERE INFERRED)

N

100 50 0 100

SCALE: 1"=100'

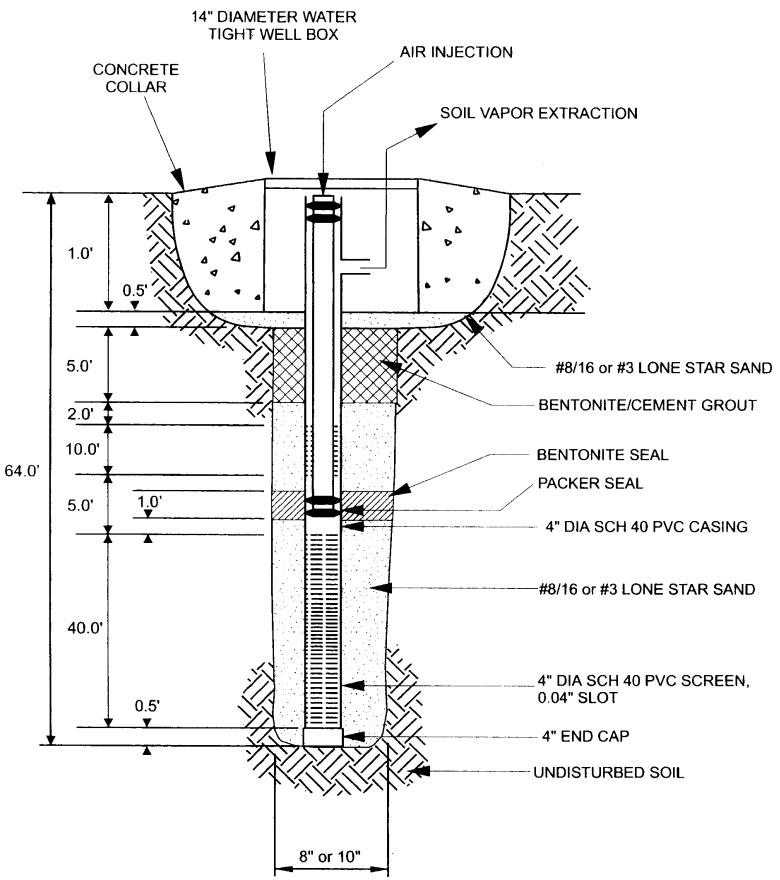
FIGURE 9.1

PROPOSED LOCATIONS FOR SOIL VAPOR EXTRACTION WELLS

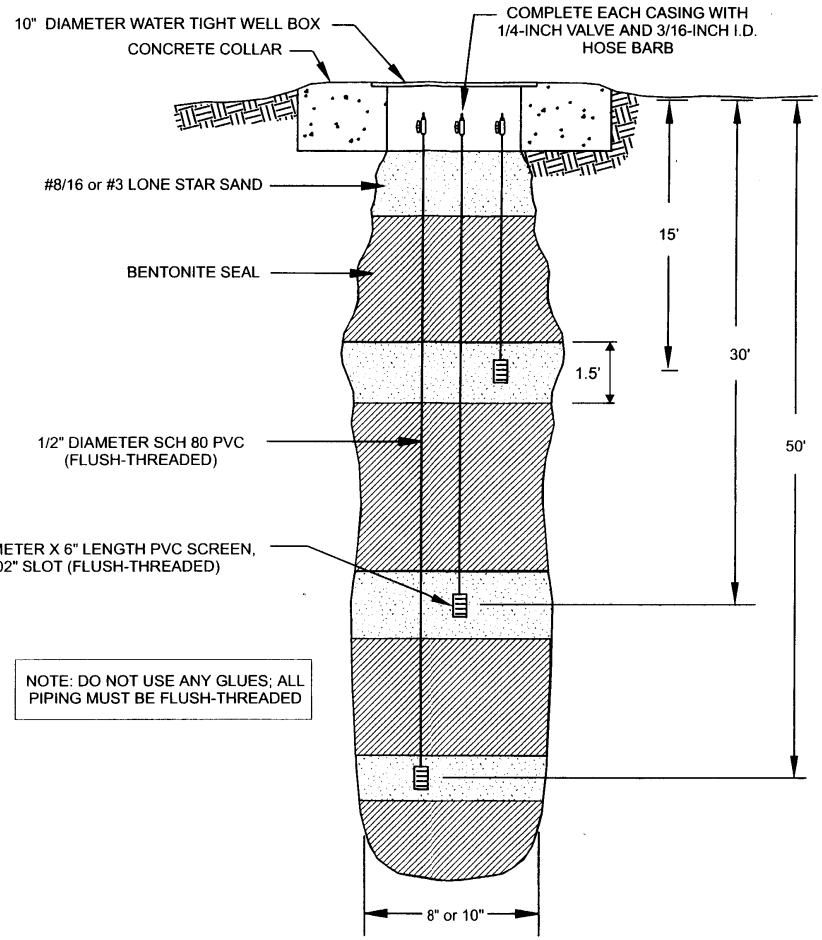
PFFA RAP
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.

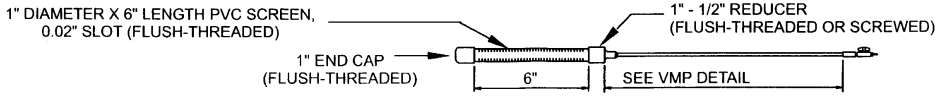
Oakland, California



VENT WELL DETAIL
NOT TO SCALE



VAPOR MONITORING POINT DETAIL
NOT TO SCALE



VMP SCREEN DETAIL
NOT TO SCALE

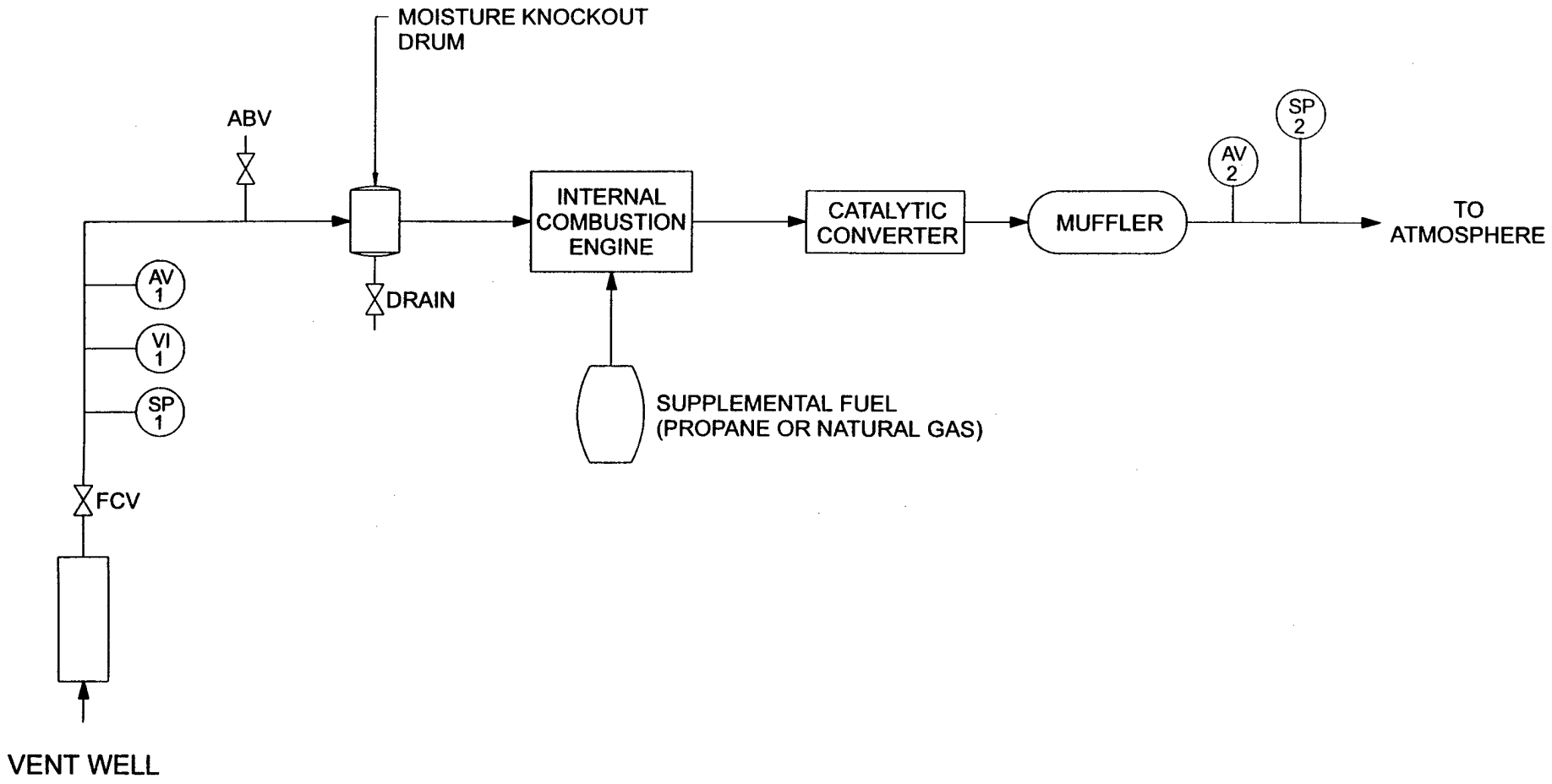
FIGURE 9.2

VENT WELL AND VAPOR MONITORING POINT CONSTRUCTION

PFFA
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.
Oakland, California

\731272\WORKPLAN\SSTDP\FIGS_L11.CDR 1/17/98



EXPLANATION

SP 1	SAMPLE POINT
AV 2	AIR VELOCITY INDICATOR
VI 1	VACUUM INDICATOR
ABV	AIR BLEED VALVE
FCV	FLOW CONTROL VALVE

FIGURE 9.3

PROCESS FLOW AND INSTRUMENTATION DIAGRAM FOR SOIL VAPOR EXTRACTION USING INTERNAL COMBUSTION ENGINE

PFFA RAP
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.

Oakland, California

\731297\REPORT\RISKRPT\FIGS_L8.CDR 4/30/98

decrease at a slower rate than expected), the SVE system will be mobilized to the next extraction well scheduled for treatment. Previously treated areas will be allowed to reach equilibrium ("resting period") while operations continued at the next well. SVE may be conducted at multiple extraction wells located in close proximity to each other if the aboveground piping between the ICE and the extraction wells would not adversely affect site operations at the PFFA. Additional details on the schedule and operations of the SVE system are provided in Section 10.2.

Simultaneous SVE in the shallow vadose zone and air injection bioventing in the deep vadose zone may occur for wells completed with dual screens (PFFAVW04 and PFFAVW06). To prevent preferential flow from the more permeable deeper vadose zone, a downhole well packer and riser pipe will be positioned between the dual screens at approximately 20 feet bgs, coinciding with the intervening bentonite seal (Figure 9.2). The well packer, riser pipe, and separate control valves will allow for air flow from each screen to be individually controlled. If SVE and bioventing are conducted simultaneously in the same well, system monitoring (i.e., pressure/vacuum response, influent contaminant concentrations) would be also conducted to ensure that significant short circuiting between air flow in the deep vadose zone and the shallow zone does not occur.

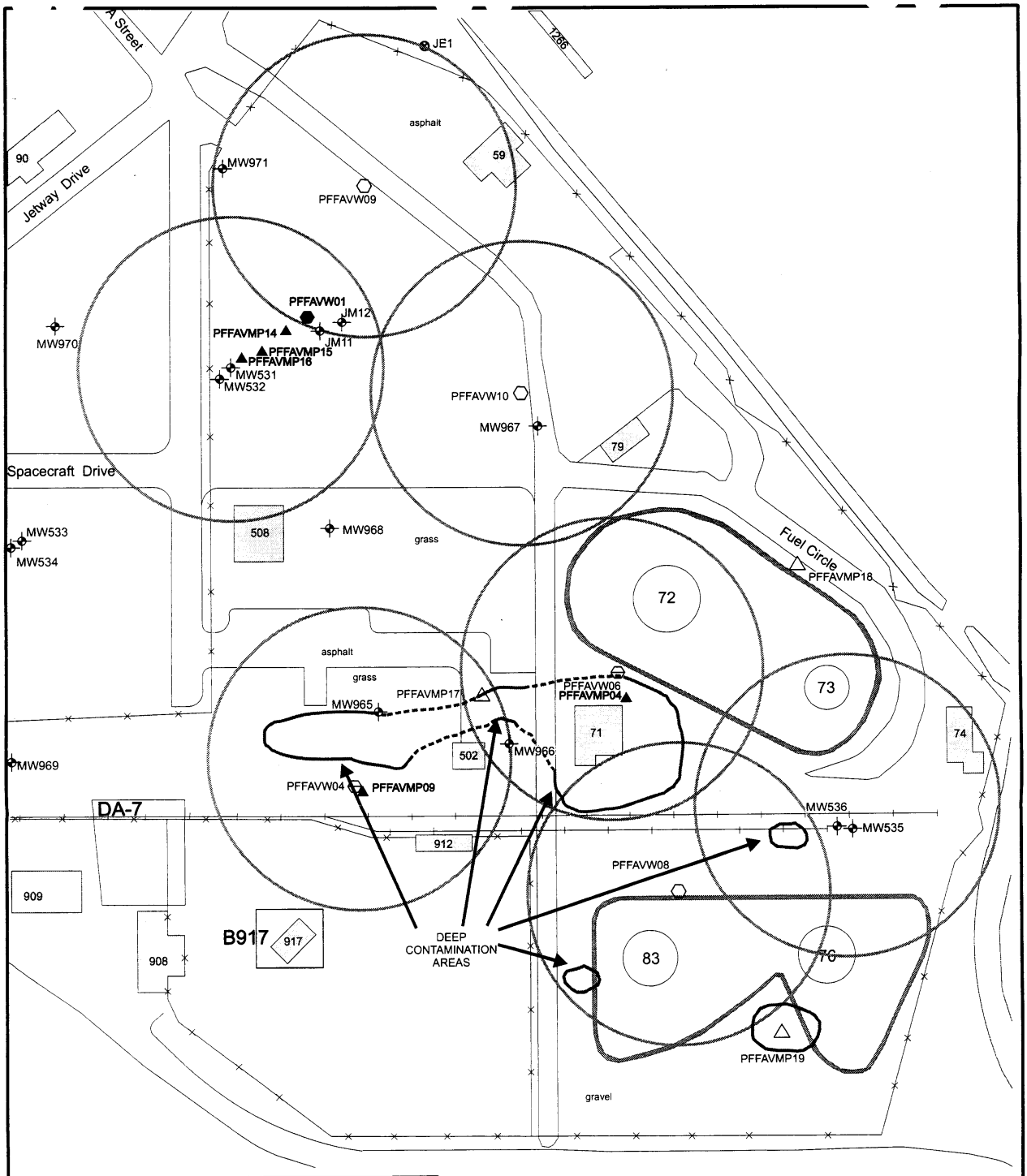
The SVE system will be operated and maintained by Parsons ES or its subcontractor; however, Castle Airport personnel will be requested to check weekly that the system is in operation and notify Parsons ES supplemental fuel use rates, system shutdowns, adverse site impacts, and any unanticipated problems. Additional details on sampling and system operation and maintenance requirements are provided in Section 10, the LTM plan for the PFFA, and in Appendix F, the Sampling and Analysis Plan (SAP). Section 10 also describes the criteria that will be used to determine when SVE operations will be to terminated.

9.1.3 Design, Installation, and Operation of Full-Scale Bioventing System in Deep Soils

The second component of the remediation system is a full-scale air injection bioventing system that will focus on remediation of contaminated soils in the deep vadose zone. Because no ambient air emissions are produced, the bioventing system does not require permitting.

As part of the bioventing system, 5 new VWs will be installed in the deep vadose zone (screened between approximately 25 and 65 feet bgs) in previously identified source areas. In addition to the 5 new VWs wells, bioventing operations will also be conducted at MW531 and MW535, two groundwater monitoring wells currently screened only in the deep vadose zone due to the declining water table. Locations for these new VWs are shown on Figure 9.4. As discussed in Section 9.1.2, 2 of the 5 new wells will be constructed as combination SVE/bioventing wells with isolated, dual screen completions. Construction details for the new wells are provided in Figure 9.2.

The locations for the wells were chosen based on a design radius of influence of 150 feet and the previously identified source areas that were above WQSA thresholds and/or RBCLs. The bioventing protocol documents recommend using a design radius of influence for a multiple well bioventing system that is 1 to 1.5 times larger than that measured during single-well pilot tests (USEPA ORD, 1995). A factor of 1.5 was used for the design of the bioventing



LEGEND

- DRAINAGE DITCH
- ABOVE GROUND STORAGE TANK
- BUILDING
- FENCE
- RAILROAD TRACKS
- BERM
- MW969 — GROUNDWATER MONITORING WELL
- PFFAVW03 — PROPOSED DEEP AIR INJECTION VENT WELL
- PFFAVW01 — PROPOSED COMBINATION AIR INJECTION AND SOIL VAPOR EXTRACTION WELL
- PFFAVMP17 — PROPOSED VAPOR MONITORING POINT
- PFFAVMP14 — EXISTING VAPOR MONITORING POINT
- DESIGN RADIUS OF INFLUENCE IN DEEP SOILS
- AREAS OF CONTAMINATION IN DEEP SOILS WITH SOIL OR SOIL VAPOR ABOVE WQSA VLEACH1 THRESHOLDS OR SOIL OR SOIL VAPOR ABOVE RBCLs (DASHED WHERE INFERRED)

N

100 50 0 100

SCALE: 1"=100'

FIGURE 9.4

PROPOSED LOCATIONS FOR DEEP AIR INJECTION WELLS

PFFA RAP
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.
Oakland, California

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system for the PFFA because the measured radius of oxygen influence from the pilot test of 100 feet was considered conservative since oxygen increases greater than 5% were still occurring at JM11 when the test was terminated (Section 7.6). In addition, the radius of oxygen influence at the PFFA is expected to expand with extended operations due to the relatively low oxygen-utilization rates measured at the site and because higher air flow rates and higher air injection pressures could be used to expand the treatment radius after the first year of operation.

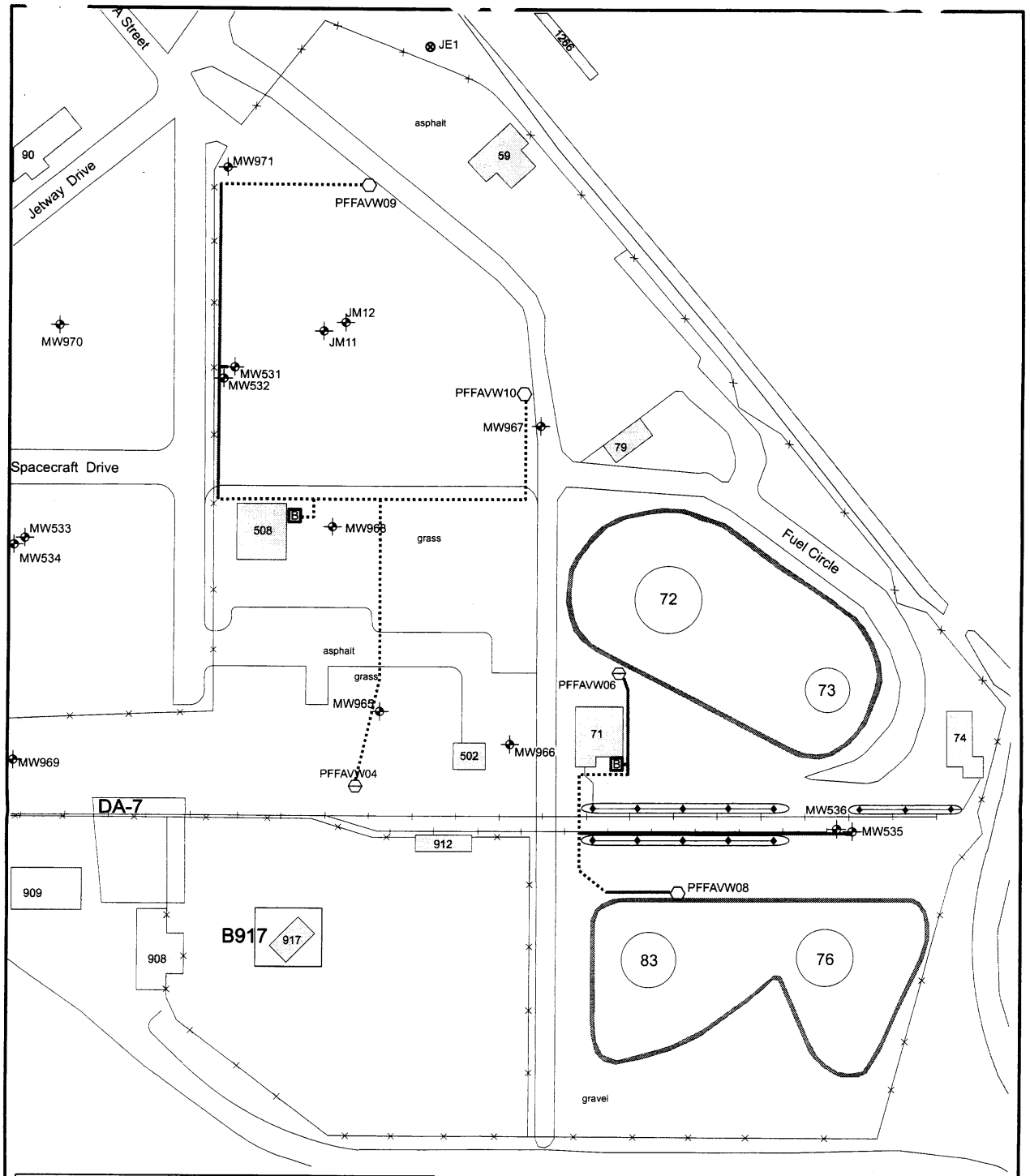
Wells used for air injection will be plumbed and connected to two regenerative blowers (Gast® Model R6) each capable of injecting air at approximately 200 scfm total flow at a pressure of 20 inches of water. Proposed blower locations and distribution piping are shown on Figure 9.5. Each well will be individually piped and valved to control individual air flows into each well. Injection rates may be modified over time to maximize oxygen distribution and minimize contaminant volatilization and vapor migration.

Three VMPs will be installed at the site to supplement existing VMPs and groundwater MWs (which can also be used for vapor monitoring). Proposed locations for the 3 new VMPs are shown on Figure 9.4 and well construction details are provided on Figure 9.2. Each VMP will be screened at 15, 30 and 50 feet bgs to monitor both the shallow and vadose zones. The VMPs will also be used to monitor SVE operations.

The locations for the new VMPs (PFFAVMP17, PFFAVMP18, and PFFAVMP19) were chosen to monitor the radius of influence of the system and, therefore, were placed near or just outside the design radius of influence. Two of the new VMPs (PFFAVMP18 and PFFAVMP19) were located on the opposite side of the ASTs from the VWs to monitor vapor migration from any contaminated soil and soil vapor beneath the ASTs. In addition, these VMPs will be used to determine if the bioventing system is adequately aerating soils beneath the ASTs (i.e., increases in oxygen at these VMPs will be used to infer increases in oxygen beneath the ASTs).

Groundwater MWs with exposed screen lengths (i.e., a portion of the screened length is within the vadose zone) will also be used for vapor monitoring. Based on historic groundwater elevations at the PFFA, MW965, MW966, MW968, MW969, MW970, and MW971 are expected to have exposed screen lengths. MW966, MW968, MW970, and MW971 are located near or just outside the design radius of influence and are well positioned for vapor monitoring.

After system startup and optimization, periodic monitoring of the system will be performed. Castle Airport personnel will be requested on a weekly basis to verify that the blowers are operating and on a monthly basis to record blower temperature, injection pressure, and check and replace the inlet air filters as necessary. During the first year of operation, Parsons ES will complete semiannual *in situ* respiration testing and soil vapor sampling to assess biodegradation rates and remediation progress. Confirmatory soil samples will be collected to determine contaminant reductions at the conclusion of approximately 1 to 2 years of operation (when equilibrium soil vapor results indicate that it is appropriate). If soil contaminant levels have been reduced below RBCLs and WQSA thresholds, a request for site closure and deactivation of the bioventing system will be made. Additional details on sampling and system operation and maintenance requirements are provided in Section 10, the LTM plan for the PFFA, and in Appendix F, the SAP.



LEGEND

- DRAINAGE DITCH
- ABOVE GROUND STORAGE TANK
- BUILDING
- FENCE
- RAILROAD TRACKS
- BERM
- MW969 — GROUNDWATER MONITORING WELL
- B — BLOWER LOCATION
- AIR DISTRIBUTION PIPING (DASHED FOR UNDERGROUND)
- PFFAVW03 — PROPOSED DEEP AIR INJECTION VENT WELL
- PFFAVW01 — PROPOSED COMBINATION AIR INJECTION AND SOIL VAPOR EXTRACTION WELL
- FUEL UNLOADING HYDRANTS (ON CONCRETE PAD)

N

100 50 0 100

SCALE: 1"=100'

FIGURE 9.5

BIOVENTING BLOWERS AND AIR DISTRIBUTION PIPING LOCATIONS

PFFA RAP
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.
Oakland, California

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9.1.4 Implementation of Long-Term Groundwater Monitoring

Section 10 of this RAP provides a complete LTM plan for the PFFA. Long-term groundwater monitoring is being proposed to verify that engineered source reduction technologies and natural chemical attenuation processes are sufficient to achieve the desired degree of remediation (i.e., protect potential receptors). Careful implementation of the LTM plan is a key component of this RAP. The proposed remedial action for this site calls for annual sampling of groundwater for the next 5 years or until 2 years after attainment of RBCLs (the additional 2 years would be used for verification sampling as discussed below).

Annual sampling is recommended to track reductions in contaminant mass due to engineered source reduction activities. Additionally, 2 years of verification sampling conducted on an annual basis should be performed after RBCLs in soil and soil vapor are reached, to confirm uniform attainment of groundwater RBCLs.

Sampling activities pursuant to this RAP are recommended to begin in 1998 upon approval of the final RAP. Results of each groundwater sampling event would be provided to Castle Airport/AFBCA staff, AFCEE, and the regulatory agencies to update all parties involved on remediation progress and to provide new information for pending land use decisions, as necessary. Castle Airport/AFBCA staff will also forward the results to contractors performing groundwater sampling activities at other areas at Castle Airport to avoid duplication of effort.

9.1.5 Verification of Current and Future Land and Groundwater Use Controls

An important element of the recommended remedial action at the PFFA is groundwater use control. On the basis of 1997 groundwater data and the exposure pathways analysis in Section 5, the site is immediately acceptable for continued industrial use provided that future land use does not require extraction of site groundwater for potable use. Excavation in the contaminated area also should be limited to depths of less than 5 feet bgs. If excavation deeper than 5 feet bgs is anticipated, excavation and handling of contaminated soils would require special health and safety considerations for the construction contractor and fugitive dust and vapor would require monitoring or engineering controls. These restrictions on excavation could be lifted within one year if SVE was successful in reducing soil and soil vapor contamination below RBCLs in the shallow soils.

It is recommended that the current restricted access be maintained at the site, and that any future land use plans for the PFFA and impacted environs stipulate that shallow groundwater will not be extracted for potable use within 1,000 feet of the leading edge of the current dissolved contamination until COPC concentrations have stabilized below drinking water standards. This restriction is already being followed due to the existing groundwater extraction and treatment system. It is expected that within 2 years following completion of both SVE and bioventing operations, restrictions on groundwater use due to sources within the PFFA could also be removed. However, restrictions on groundwater use downgradient from the PFFA may need to be kept in place due to other groundwater contaminant sources within the Castle Airport facility.

9.2 IMPLEMENTATION SCHEDULE

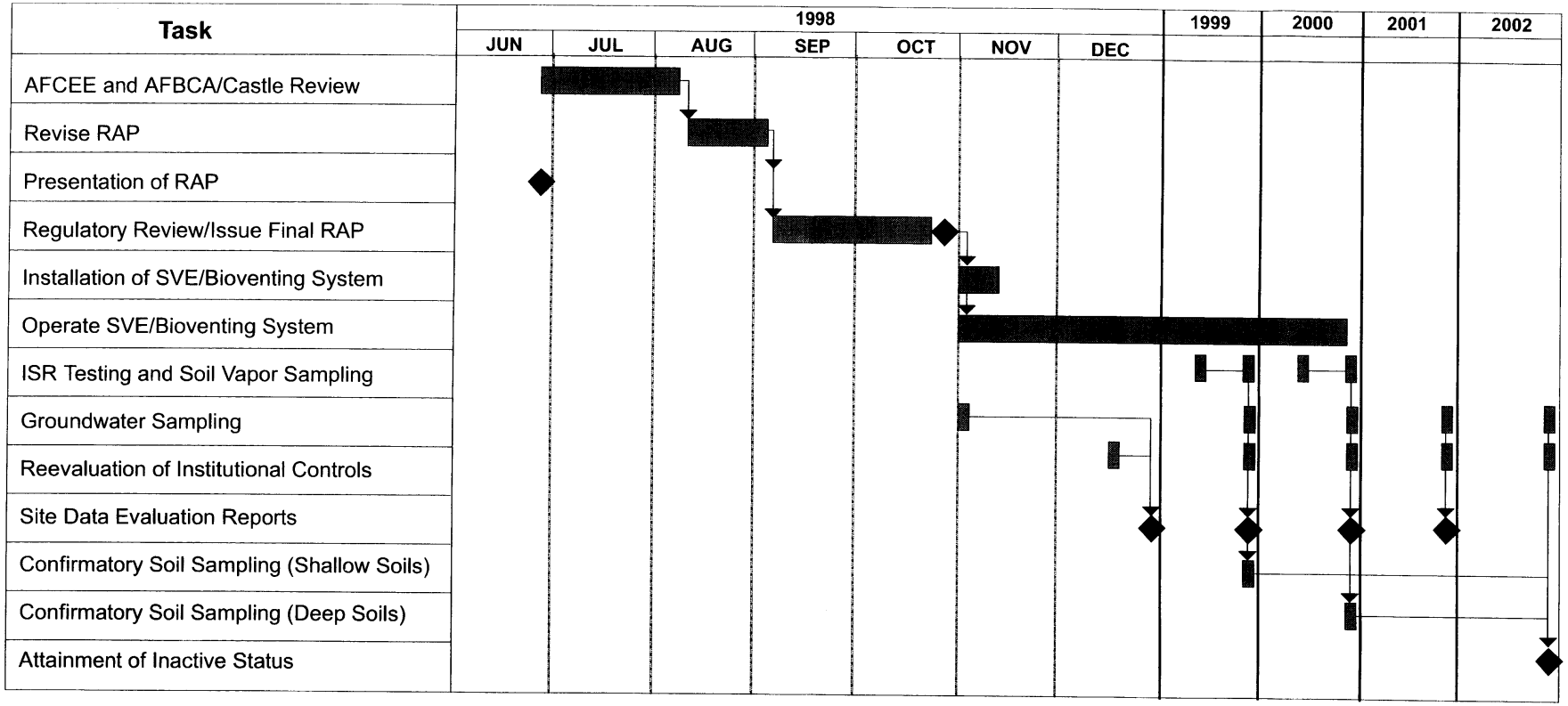
Figure 9.6 is a proposed schedule for implementation of the RAP at the PFFA. The schedule is provided for planning purposes only, and is subject to timely approval of the RAP by all interested parties. Parsons ES has already been contracted and funded for the design and installation of the full-scale SVE/bioventing system plus one-year of system operation, maintenance, and monitoring.

9.3 PERMITTING REQUIREMENTS

Although a site-specific air permit for the SVE system is not required due to CERCLA status, requirements and emissions limits of the SJVUAPCD will be met. The monitoring and sampling program provided in Section 10.2 is designed to satisfy SJVUAPCD requirements. As required, short letter reports will be issued to the SJVUAPCD which summarize SVE system sampling results and demonstration of compliance with emissions limits and treatment system efficiencies.

9.4 COST OF IMPLEMENTATION

A summary of the estimated present worth cost of implementing the recommended remedial alternative is provided in Section 8.4.2.3. Table 9.1 provides a cost estimate, based on expenditures in the next 5 fiscal years, to assist the Air Force in budgeting for the PFFA remedial actions. Closure sampling, bioventing system decommissioning, and well abandonment are not included in the cost estimate.



LEGEND

- Task Duration
- Dependency
- Milestone

FIGURE 9.6

IMPLEMENTATION SCHEDULE

PFFA RAP

Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.

Oakland, California

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TABLE 9.1
PROPOSED REMEDIAL ALTERNATIVE
ESTIMATED COSTS BY FISCAL YEAR
PFFA RAP
Castle Airport, California

Task	FY98	FY99	FY00	FY01	FY02
Iinstallation of new wells and SVE/Bioventing Systems [1]	$159,400	--	--	--	--
Operate SVE system (one year) [1]	$28,000	--	--	--	--
Annual groundwater sampling [2]	$15,300	$15,300	$15,300	$15,300	$15,300
Semi-annual bioventing system testing and sampling [2]	--	$21,300	$21,300	--	--
Annual reporting of groundwater/bioventing sampling [2]	$5,100	$5,100	$5,100	$5,100	$5,100
Site management/Maintenance of institutional controls [2]	$5,000	$5,000	$5,000	$5,000	$5,000
Fiscal Year Totals	**$ 212,800**	**$ 46,700**	**$ 46,700**	**$ 25,400**	**$ 25,400**

[1] Currently funded and to be performed by Parsons ES.

[2] First year is currently funded and to be performed by Parsons ES.

SECTION 10

LONG-TERM MONITORING PLAN AND CONTINGENCY PLAN

10.1 OVERVIEW

In keeping with the requirements of the recommended remedial action for the PFFA (SVE and bioventing in the source areas, natural attenuation, long-term monitoring, and land and groundwater use controls), a LTM Plan has been developed. This LTM Plan includes operations and maintenance (O&M) and sampling requirements for the proposed SVE and bioventing systems, a proposed groundwater monitoring network, sampling and analysis strategies for groundwater, and an evaluation of land use controls. A schedule for implementation of the actions described in the plan is presented on Figure 9.1. The purpose of LTM plan is to confirm the effectiveness of engineered source removal technologies and natural processes at reducing contaminant concentration, mass, mobility, and toxicity in affected media. This plan also will assess site conditions over time and the need for additional remediation.

As part of LTM, contaminant behavior in groundwater over time will be monitored to verify that the proposed remedial action is sufficient to protect human health and the environment. The areal extent of contamination will be monitored for increases in concentration and spatial distribution of the COPCs during the course of the proposed remediation. In the event that data collected under this LTM program indicate that engineered source removal technologies and natural physical, chemical, and biological processes are insufficient to achieve unrestricted industrial use status for the PFFA, contingency actions will be implemented to augment the effects of the proposed remedial action.

10.2 SOIL VAPOR EXTRACTION SYSTEM OPERATION AND MAINTENANCE

The SVE system will need to be checked weekly by Castle Airport personnel to ensure that the system is operating and adequate supplemental fuel is available. System shutdowns, adverse site impacts, and any unanticipated problems should be reported to Parsons ES.

Parsons ES personnel or their subcontractor will maintain and monitor the ICE monthly to ensure smooth operation and adequate treatment efficiency. The following parameters will be monitored and recorded on a monthly basis:

- engine speed;
- vacuum at the extraction well;
- vacuum at surrounding VMPs/extraction wells;
- air flow rate from extraction well(s);
- influent contaminant concentrations (lab analysis);
- influent oxygen and carbon dioxide concentrations (field analysis);

- contaminant and oxygen and carbon dioxide concentrations at surrounding VMPs/extraction wells; and,
- effluent contaminant concentrations and exhaust air flow rate and temperature (as needed to meet SJVUAPCD requirements).

Oxygen, carbon dioxide, and TVH (using field instruments) will be used to screen soil vapor samples for laboratory analysis and verify that oxygen levels in soil vapor increase as a result of SVE operations. Field meters will also be used initially within surrounding buildings and along any accessible subsurface utilities to verify that hazardous levels of vapors are not migrating and to establish baseline conditions.

In order monitor remediation progress, each month influent soil vapor samples will be collected and air flow will be measured in order to determine the mass removed by the system. If required by the SJVUAPCD to demonstrate treatment system efficiency, effluent soil vapor samples will also be collected to measure the offgas treatment efficiency of the ICE. Soil vapor samples will be submitted for BTEX and TPH analysis by EPA Method TO-3. Oxygen and carbon dioxide measurements will be collected in order to estimate the quantity of mass removed by biodegradation. Biodegradation is predicted to be responsible for a significant portion of the mass removed during extended SVE operations oxygen from uncontaminated soils enters the contaminated soil volume.

Each month, the mass removal rates, supplemental fuel use rates, and influent concentrations will be evaluated to determine the cost effectiveness of continued SVE operations within the area being remediated. If it is determined that continued SVE from the current extraction well is no longer cost-effective using SVE or if contaminant concentrations in the influent have been reduced to asymptotic levels, SVE operations cease at that extraction well and the SVE system will be mobilized to the next extraction well. Soil vapor will be allowed to reach equilibrium for at least one month while remediation is progressing at the next extraction well. Because a rebound in equilibrium contaminant concentrations is more likely to occur in more contaminated soils, SVE operations will proceed from more contaminated areas to less contaminated areas (PFFAVW01, PFFAVW07, PFFAVW04, PFFAVW06, PFFAVW03, and PFFAVW05).

After SVE operations have been conducted at least once in each extraction well and equilibrium concentrations have been measured, the ICE will be remobilized to previously treated areas where soil vapor concentrations have rebounded above levels indicative of RBCLs. The criteria for no longer using SVE in an area will include an evaluation of whether RBCLs and WQSA thresholds have already been reached and whether continued treatment through bioventing in the shallow vadose zone is more appropriate than continued treatment with SVE.

Although results for the PFFA will have to be evaluated based on actual operating performance and site response, based on experience at other sites treated with SVE/ICE with similar vapor concentrations and geology, it is expected that an influent concentration of between 1,000 and 2,000 ppmv total VOCs will result in a request for cessation of SVE operations. Based on past experience at jet fuel contaminated sites, at these concentrations the rate of mass removed by biodegradation is approximately equal to the rate of mass removed by volatilization and air injection operations are possible without causing

significant vapor migration. In addition, this concentration range is lower than the WQSA threshold values for total BTEX in soil vapor (Table 4.1). Concurrence from Castle Airport/AFBCA personnel, regulatory agencies, and AFCEE will be required prior to cessation of SVE operations.

Confirmatory soil and soil vapor samples will be collected after the completion of SVE operations to demonstrate the RBCLs for the shallow vadose zone have been achieved. A separate work plan will be issued for approval prior to confirmatory sampling activities. Sample collection and analysis procedures will follow the SAP included as Appendix F. Soil and soil vapor samples will be collected from source area locations and analytical results will be compared to results from samples collected during pre-remedial investigation activities in order to determine reductions in contaminant concentrations.

10.3 BIOVENTING SYSTEM OPERATION AND MAINTENANCE

After installation of the blowers, distribution piping, and electrical service, the bioventing system will be started for a system check. Following the system check, air flow injection rates will be optimized for each VW to maximize biodegradation and minimize contaminant volatilization and vapor migration. Once the system has been optimized, long-term operations will begin.

Castle Airport personnel will be requested to perform a simple system checkup biweekly (every other week). The following activities will typically be performed during a bioventing system check:

- Record air injection pressures at the blowers;
- Record blower operating temperature and inlet vacuum;
- Assess the condition of the air inlet filter element and replace as necessary; and,
- Note any unusual operating characteristics (e.g., clogged lines or tripped breakers).

All maintenance activities will be recorded on an O&M checklist and will become part of the site record. An bioventing system O&M manual will be prepared and provided to Castle Airport personnel prior to the beginning of long-term operations. Parsons ES will provide a short training session for Castle Airport personnel on the collection of biweekly system readings for the blowers and procedures for changing air filters. As-built system drawings, vendor specifications, schematic drawings, maintenance checklists, replacement parts and suppliers, and a list of emergency contacts will be included in the O&M manual.

In addition to the monitoring described above, ISR tests will be performed semi-annually at selected injection VWs, MWs with exposed screens, and VMPs. ISR testing procedures will follow those outlined in the bioventing protocol documents and described in Section 2. Soil vapor samples will also be collected from all locations and analyzed for oxygen, carbon dioxide, and TVH concentrations with field meters. Selected soil vapor samples will be submitted for laboratory analysis of BTEX and TVH concentrations by EPA Method TO-3. Sample collection and analysis procedures will follow the SAP included as Appendix F.

Testing and sampling will be used to assess remedial progress and to determine the appropriateness of confirmatory soil sampling activities to demonstrate achievement of

RBCLs and WQSA thresholds. A separate work plan will be issued for approval prior to confirmatory soil and soil vapor sampling activities used to gain site closure. Soil samples will be collected from source area locations and analytical results will be compared to results from samples collected during pre-remedial investigation activities in order to determine reductions in contaminant concentrations. Concurrence from Castle Airport/AFBCA personnel, regulatory agencies, and AFCEE will be required prior to cessation of bioventing operations.

10.4 GROUNDWATER MONITORING NETWORKS

A total of 9 existing MWs will be used to monitor dissolved contaminant concentrations at the site over time. The MWs are located within, upgradient from, downgradient from, and at the leading edge of the dissolved contamination to ensure that natural attenuation processes are occurring at rates sufficient to remove COPC mass and minimize contaminant transport in groundwater. The locations of all wells to be used for long-term monitoring are illustrated on Figure 10.1.

10.4.1 Upgradient and Plume Wells

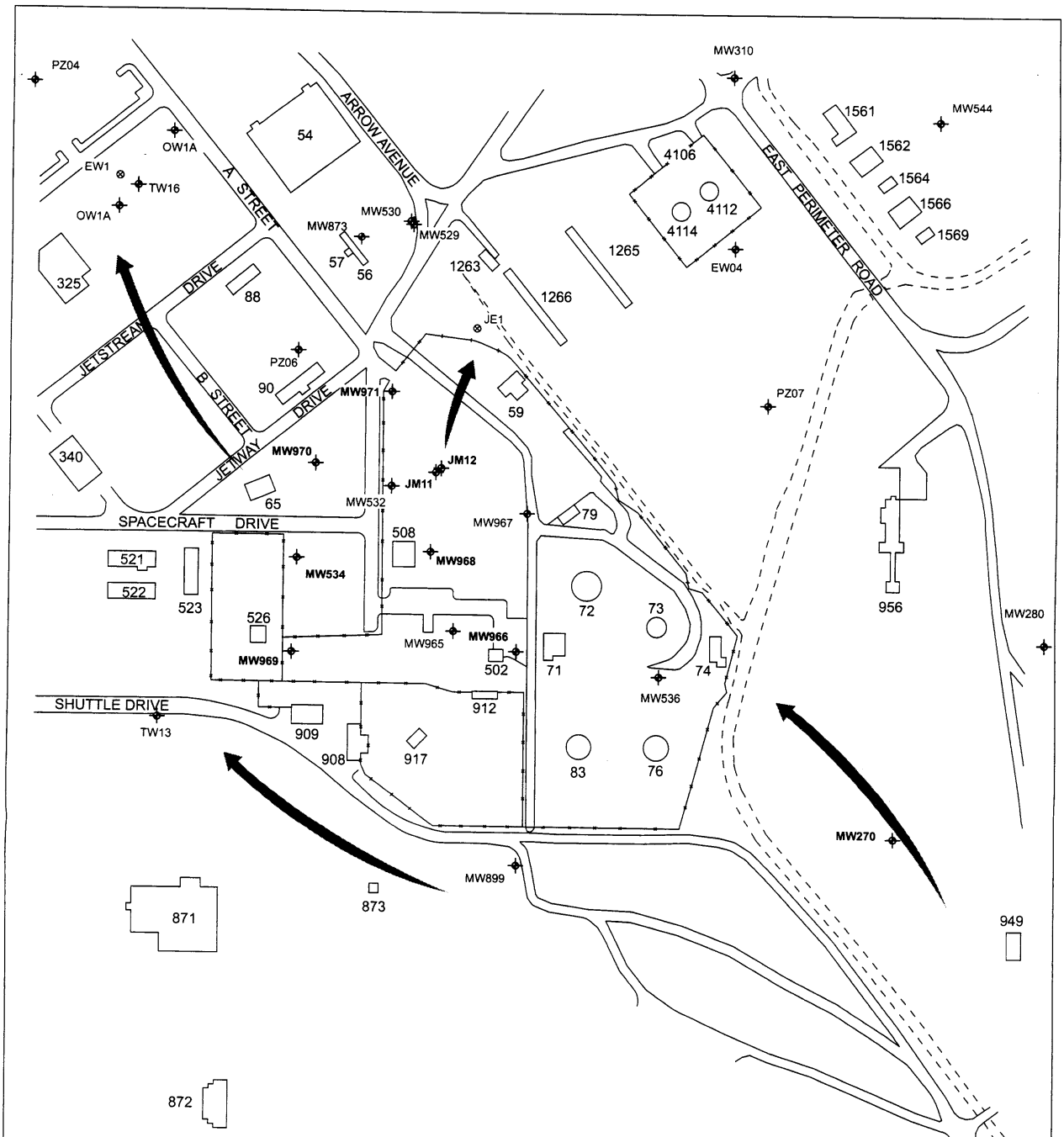
One existing MW (MW-270), which is upgradient from and outside the influence of the contaminant sources, will be monitored to evaluate background conditions. Four existing MWs (MW966, MW968, JM11, and JM12) located within or at the lateral edge of the dissolved contamination area and source areas will be monitored to evaluate the rates of contaminant removal as a result of source removal activities and natural attenuation. These 4 MWs will also be used to assure that any future plume migration or changes in plume geometry follow the same patterns that have caused the current contaminant distribution at the site. These MWs will also be used to evaluate future biodegradation rates. Upgradient and plume wells will be sampled and analyzed for the parameters listed in Table 10.1 to verify the effectiveness of the proposed remedial action.

10.4.2 Sentry Wells

Sentry wells are located directly in front of the leading edge of the contamination and used to evaluate any migration of the leading edge of the dissolved contamination. Four existing MWs (MW534, MW969, MW970, and MW971) will serve as sentry wells. BTEX was not detected in these MWs during sampling conducted in 1997 and is not predicted to migrate to these MWs. Therefore, these MWs will be used to verify that the plume is at steady-state conditions or shrinking. All of the sentry wells will be monitored for parameters listed in Table 10.1.

10.4.3 Point-of-Action Wells

Point-of-Action (POA) wells are typically located to delineate the maximum possible downgradient extent of groundwater contamination. They are placed at locations which, according to model predictions, site-related contaminants should never be measured. POA MWs are used to demonstrate plume containment and stability. The detection of site-related contaminants at POA wells would trigger the need to evaluate possible contingency actions. Based on modeling presented in Section 6.6, location for POA wells should be located approximately 350 feet downgradient from the source areas.



LEGEND

- ABOVE GROUND STORAGE TANK
- BUILDING
- FENCE
- DRAINAGE CHANNEL
- MW969 — GROUNDWATER MONITORING WELL OR PIEZOMETER
- JE1 — GROUNDWATER EXTRACTION WELL
- INFERRED DIRECTION OF GROUNDWATER MOVEMENT
- **MW970** — WELLS TO BE USED IN LONG TERM MONITORING PLAN

230' 115' 0 230'

SCALE: 1"=230'

FIGURE 10.1

WELLS TO BE USED IN LONG TERM MONITORING PLAN

PFFA RAP
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.
Oakland, California

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TABLE 10.1

ANALYTICAL PROTOCOL FOR LONG-TERM MONITORING OF GROUNDWATER
PFFA RAP
CASTLE AIRPORT, CALIFORNIA

Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Aromatic hydrocarbons (BTEX)	SW8020A (Gas Chromatography/ Mass Spectrometry method)	As described in latest version of *Test Methods for Evaluating Solid Waste* (EPA SW-846)	BTEX compounds (benzene, toluene, ethylbenzene, and total xylenes) have been identified as groundwater COPCs	Annually	Collect water samples in a 40 ml volatile organic analysis vial with zero headspace; cool to 4°C; add hydrochloric acid to pH≤2	Fixed-base
Total Petroleum Hydrocarbons as gasoline (volatile)	SW8015M (Gas Chromatography/ Mass Spectrometry method)	As described in latest version of *Test Methods for Evaluating Solid Waste* (EPA SW-846) and California LUFT manual	Used to monitor the reductions in TPH concentrations. TPH is also a source of anthropogenic carbon for reductive dechlorination.	Annually	Collect water samples in a 40 ml volatile organic analysis vial with zero headspace; cool to 4°C; add hydrochloric acid to pH≤2	Fixed-base
Methane, Ethene, and Ethane	RSKSOP-175 (headspace with dual thermal conductivity and flame ionization detection	Method published by the USEPA National Risk Management Research Laboratory	The presence of methane indicates reducing conditions and anaerobic biodegradation.	Annually	Collect water samples in a 40 ml volatile organic analysis vial with zero headspace; cool to 4°C	Fixed-base
Nitrate (NO_3^{-1})	IC Method E300	Handbook Method	Substrate for microbial respiration if oxygen is depleted.	Annually	Collect 100 ml of water in a glass or plastic container;; cool to 4°C	Fixed-base
Sulfate (SO_4^{-2})	IC Method E300	Handbook Method	Reduced concentrations of sulfate indicate that microorganisms are facilitating sulfate reduction.	Annually	Collect 100 ml of water in a glass or plastic container;; cool to 4°C	Fixed-base
Dissolved Oxygen	Direct-reading meter	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	Concentrations less than 1 mg/L indicate anaerobic conditions. Reduced concentrations of dissolved oxygen indicate that microorganisms are facilitating oxygen reduction.	Annually	Measure directly using a flow-through cell with probe portals. Probe should be calibrated with zero dissolved oxygen solution	Field

ANALYTICAL PROTOCOL FOR LONG-TERM MONITORING OF GROUNDWATER
PFFA RAP
CASTLE AIRPORT, CALIFORNIA

Redox potential	Direct-reading meter (A2580B)	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 the nature of the biologically mediated reactions: can be used as an indicator of the terminal electron acceptor process involved in COC biodegradation	Annually	Measure directly using a flow-through cell with probe portals. Probe should be standardized against Zobel solution	Field
pH	Direct-reading meter (E150.1)	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	Purging adequacy. Aerobic and anaerobic processes are pH-sensitive.	Annually	Measure directly using a contained flow-through cell with probe portals. Probe should be calibrated using at least three pH standards	Field
Temperature	Direct-reading meter (E170.1)	Field only	Purging adequacy. Metabolism rates for microorganisms depend on temperature	Annually	Measure directly using a contained flow-through cell with probe portals.	Field
Conductivity	Direct-reading meter (E120.1)	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	Purging adequacy. General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Annually	Measure directly using a contained flow-through cell with probe portals. Probe is factory calibrated	Field
Ferrous iron (Fe^{+2})	Colorimetric HACH 8146	Field only	Elevated ferrous iron concentrations indicate that microorganisms are facilitating ferric reduction. VC may be oxidized under nitrate-reducing conditions.	Annually	Collect 100 ml of water in a glass or plastic container; filter and use 10 ml aliquot for analysis	Field
Manganese (Mn^{+2})	Colorimetric HACH 8034	Field only	Elevated concentrations of reduced forms of manganese indicate that microorganisms are facilitating manganese reduction.	Annually	Collect 100 ml of water in a glass or plastic container; filter and use 10 ml aliquot for analysis	Field

TABLE 10.1 (continued)

ANALYTICAL PROTOCOL FOR LONG-TERM MONITORING OF GROUNDWATER
PFFA RAP
CASTLE AIRPORT, CALIFORNIA

NOTES:

1. "HACH" refers to the HACH Company catalog, 1990.
2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, U.S. Environmental Protection Agency, March 1979.
4. "Protocols" refers to the AFCEE *Environmental Chemistry Function Installation Restoration Program Analytical Protocols*, 11 June 1992.
5. "Handbook" refers to the AFCEE *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)*, September 1993.
6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, U.S. Environmental Protection Agency, 3rd edition, 1986.
7. "ASTM" refers to the *American Society for Testing and Materials*, current edition.
8. "RSKSOP" refers to *Robert S. Kerr (Environmental Protection Agency Laboratory) Standard Operating Procedure.*
9. "LUFT" refers to the state of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.

The location of POA wells for the PFFA is complicated by the presence of the groundwater extraction wells, JE1 and EW1 (Figure 3.2 and Figure 10.1). Any POA wells located near these two wells would be affected by the local flow patterns created by steep drawdown of the water table in the vicinity of the extraction wells. Therefore, in lieu of POA wells, the sentry wells described in Section 10.4.2 will be used to monitor unexpected plume migration or unexpected increases in contaminant concentrations attributable to sources within the PFFA. Since the PFFA plume appears to be shrinking or to have reached steady-state conditions, unexpected increases in contaminant concentrations at the sentry wells will be used to trigger contingency actions (Section 10.5).

The scope of contingency actions will be establish when concentrations of site-related contaminants exceeding groundwater standards appear in collected samples from any of the POA wells. These actions could include, but may not be limited to, the following:

- Additional investigation efforts to reevaluate results obtained during initial investigation activities;
- Reevaluation of model results to determine if concentrations of contaminants that may pose a risk to human health or the environment have the potential to migrate beyond Base boundaries (approximately 2 miles downgradient from the leading edge current plume); and
- Additional engineering evaluations to determine if more aggressive remedial efforts are necessary and/or feasible.

10.5 GROUNDWATER SAMPLING

This LTM plan includes a comprehensive groundwater SAP. The LTM plan, when implemented in accordance with the SAP, will verify that COPCs do not increase unexpectedly and are not migrating downgradient from any of the sentry wells. The SAP for all sampling is provided in Appendix F. LTM wells and sentry wells will be sampled and analyzed annually as described in Section 10.5.2 to verify that source removal technologies and natural processes are effectively reducing contaminant concentrations, mass, mobility, and toxicity. Reductions in COPC toxicity will be implied by concentration and mass reduction (e.g., as COPCs are biodegraded to less toxic compounds such as carbon dioxide and water).

10.5.1 Implementation Requirements

All LTM wells will be sampled and analyzed in accordance with Table 10.1 and the SAP to determine progress toward and compliance with the proposed RBCLs for the PFFA. Additionally, QA/QC samples and procedures will be implemented as described in the SAP.

10.5.2 Sampling Frequency

Each of the MWs included in the LTM plan will be sampled annually until RBCLs are achieved, and then annually for another 2 years to confirm that RBCLs have been uniformly achieved. If the sampling results contradict the model predictions (i.e., the plume is migrating faster or at greater concentration than suggested by the conservative model), annual monitoring of all MWs in the LTM network will continue until RBCLs are

demonstrated or until contingency remedial actions are considered. Based on the expected remediation time frame for the SVE/bioventing system (2 years) and the results of the model of the site (Section 6), sampling will be required for a total of 5 years (including 1998) to achieve RBCLs and perform verification sampling.

10.6 CONTINGENCY PLAN

Should the engineered source control activities in combination with natural attenuation prove to be an ineffective means to reduce contaminant concentration, mass, and mobility in soil, soil vapor, and groundwater at the PFFA, there should be no immediate risk or impact on the land use plans for this area. No new land use has been proposed for the PFFA. For the foreseeable future, the PFFA will continue to operate as either a general industrial storage area and fueling area for vehicles or for aviation-related industry.

The restrictions on groundwater use and deep excavations are not overly burdensome. Groundwater extraction in this area is not anticipated so long as the groundwater extraction and treatment system remains in operations and alternate water supplies exist. In the event that shallow groundwater near this site must be extracted for potable uses and drinking water standards have not yet been achieved or unrestricted deep excavations are required and RBCLs for soil have not yet been achieved, the following contingency actions are available:

- The results of the most recent groundwater sampling event will be evaluated to determine if there is a trend indicating that natural attenuation is not proceeding at the rates predicted in Section 6.
- A risk analysis will be completed to determine if levels of groundwater contamination present an actual risk based on the intended use of the groundwater.
- If significant risk from soil or groundwater exists, more active methods of remediation will be evaluated. More active methods could include:
  - a simultaneous use of multiple ICEs within all source areas instead of moving one ICE sequentially to each source area;
  - b initiation of SVE in the deep vadose zone instead of bioventing to speed source removal;
  - c excavation and disposal of contaminated soil as described for Alternative 2 (Section 8);

Contingency plans also would be required if the contamination migrates at concentrations exceeding model predictions. The sentry wells downgradient from the site will be monitored to assure that contaminants do not migrate farther than expected. If COPCs are detected at concentrations significantly exceeding expectations in any of the long-term monitoring wells or if annual groundwater sampling indicates a significant change in the direction of contaminant migration, the following contingency actions are available:

- A second round of samples will be collected to confirm the analytical results.
- All MWs within the PFFA will be sampled to determine the extent of contaminant migration and to locate the centerline of the leading edge of the plume.

- The results of the most recent groundwater sampling event will be evaluated to determine if there is a trend indicating that natural attenuation is not proceeding at the rates predicted in Section 6.
- A risk analysis will be completed to determine if concentrations present a risk based on the actual intended use of the groundwater.

If significant risk exists, or if COPC could migrate beyond the area of exposure control, use of more active methods of remediation will be evaluated, as described above. In addition, augmentation of the existing groundwater extraction system would be evaluated to achieve plume containment.

10.7 LAND USE CONTROLS VERIFICATION

Long-term site management responsibilities will include verification that any future land uses are consistent with assumptions used to derive RBCLs (i.e., industrial land use and groundwater is not used as a potable source). The monitoring program specified herein is designed to document plume stability and eventual contaminant mass removal. These data will be used to confirm that there is no need for additional exposure controls at or downgradient from the PFFA to minimize potential human health risks and unacceptable environmental impacts. Any changes in activities conducted in areas impacted by the PFFA contamination will be documented.

Any future uses of the site should preclude use of impacted groundwater as a source of potable water until such time that state groundwater standards have been attained at every monitoring point. In addition to future site use reviews, interim confirmation of land and groundwater use controls are proposed to include documenting the land zoning, types of potential onsite receptors, and the kinds of activities in which these potential receptors may engage at the site. For example, this RAP recommends that extensive soil excavation at the PFFA should be minimized to the extent practicable to prevent worker contact with contaminated soil and soil vapor. This administrative confirmation step will be formally documented when the results of site analytical sampling events are prepared for review and assessment. Any significant changes in land use will be identified, and any modification of the recommended remedial alternative that may be required to protect human health and the environment will be identified and proposed for review and implementation, as necessary.

SECTION 11

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APPENDIX A

ANALYTICAL DATA FROM PREVIOUS INVESTIGATIONS

TABLE A.1
Historical Summary of Detected Analytes in Soil
Total Petroleum Hydrocarbons and BTEX Compounds
PFFA RAP

Castle Airport, California

			Total Petroleum Hydrocarbons				BTEX			
		Method:	8015 (Mod.)				8020/8260			
		Analyte:	TPH-g	TPH-jf	TPH-d	TPH-oil	Benzene	Toluene	Ethyl-benzene	Total Xylenes
Location	Date	Depth (bgs)	Concentrations in mg/kg							
SB-518	May-90	15.0	ND	1,140	1,800	ND	ND	ND	18	79
		20.0	ND	ND	ND	ND	ND	ND	21	93
SB-523	May-90	35.0	ND	ND	ND	ND	ND	ND	0.0040	0.0030
SB-524	May-90	15.0	ND	ND	ND	ND	ND	ND	0.031	0.20
		20.0	ND	ND	ND	ND	ND	ND	0.0020	0.0020
		25.0	ND	ND	ND	ND	ND	ND	0.072	0.15
SB-525	May-90	10.0	ND	ND	150	ND	ND	ND	ND	ND
		15.0	ND	ND	60	ND	ND	ND	ND	ND
		20.0	ND	ND	57	ND	ND	ND	ND	ND
SB-526	May-90	20.0	ND	ND	ND	ND	ND	ND	ND	5.2
SB-528	May-90	15.0	ND	160	ND	400	ND	ND	ND	ND
		20.0	ND	760	ND	ND	ND	ND	20	29
		30.0	ND	ND	ND	ND	ND	ND	0.24	1.6
SB-529	May-90	10.0	ND	2,700	ND	ND	ND	ND	1.3	4.9
		15.0	ND	980	ND	ND	ND	ND	7.5	33
		20.0	ND	150	ND	ND	ND	ND	ND	ND
		25.0	ND	3,200	ND	ND	ND	ND	24	150
		30.0	ND	3,100	ND	ND	ND	ND	61	380
		35.0	ND	2,900	ND	300	ND	ND	4	22
		40.0	ND	72	ND	ND	ND	ND	0.014	0.079
		50.0	ND	4,000	ND	ND	ND	ND	18	110
SB-532	May-90	30.0	ND	ND	ND	ND	ND	ND	ND	0.78
SB-534	May-90	10.0	ND	1,000	ND	ND	ND	ND	9.1	37
		25.0	ND	59	ND	ND	ND	ND	0.39	2.2
		30.0	ND	130	ND	ND	ND	ND	0.80	4.9
		35.0	ND	150	ND	ND	ND	ND	0.72	3.8
		40.0	ND	100	ND	ND	ND	ND	0.049	0.36
		45.0	ND	ND	ND	ND	ND	ND	9.3	34
		50.0	ND	2,270	ND	ND	ND	ND	5.7	29
SB-535	May-90	5.0	ND	ND	290	ND	ND	ND	ND	0.55
		10.0	ND	ND	270	ND	ND	ND	ND	0.46
		15.0	ND	ND	320	ND	ND	ND	0.70	0.97
		20.0	ND	ND	200	ND	ND	ND	0.15	ND
		30.0	ND	ND	64	ND	ND	ND	ND	ND
		35.0	ND	ND	360	ND	ND	ND	ND	ND
		50.0	ND	ND	1,180	ND	ND	ND	ND	ND
SB-536	May-90	10.0	ND	2,500	ND	ND	ND	ND	0.016	0.14
SB-540	May-90	10.0	ND	ND	120	ND	ND	ND	ND	0.41
SB-573	May-90	25.0	ND	150	ND	ND	ND	ND	ND	ND

TABLE A.1 (continued)
Historical Summary of Detected Analytes in Soil
Total Petroleum Hydrocarbons and BTEX Compounds

PFFA RAP

Castle Airport, California

			Total Petroleum Hydrocarbons				BTEX			
		Method:	8015 (Mod.)				8020/8260			
		Analyte:	TPH-g	TPH-jf	TPH-d	TPH-oil	Benzene	Toluene	Ethyl-benzene	Total Xylenes
Location	Date	Depth (bgs)	Concentrations in mg/kg							
B917SB01	Oct-93	4.0	ND	ND	ND	ND	ND	ND	ND	0.0013
B917SB01A	Oct-93	20.0	2.8	ND	ND	ND	ND	ND	ND	ND
		30.0	ND	10	ND	ND	ND	ND	ND	ND
B917SB02	Oct-93	24.0	45	ND	ND	ND	ND	ND	ND	ND
B917SB03	Oct-93	29.5	29	ND	ND	ND	ND	ND	ND	ND
DA7SB01	Oct-93	19.5	260	3,400	ND	ND	ND	ND	0.40	1.4
DA7SB02	Oct-93	19.0	2,300	1,100	ND	ND	0.042	ND	0.017	0.049
		24.0	27	ND	ND	ND	ND	ND	0.014	0.028
DA7SB04	Oct-93	14.0	ND	ND	ND	ND	0.015	ND	ND	ND
		34.0	ND	ND	ND	ND	ND	0.0042	ND	ND
DA7SB05	Oct-93	19.0	ND	110	ND	ND	0.0041	ND	0.0052	0.010
		39.0	ND	ND	ND	ND	ND	ND	1.5	6.9
DA7SB11	Oct-93	19.0	3	ND	ND	ND	ND	ND	ND	ND
		24.0	43	ND	4.2	ND	ND	ND	ND	ND
DA7SB14	Oct-93	49.5	ND	ND	ND	ND	ND	0.00046	ND	ND
		59.5	ND	ND	ND	ND	ND	0.00049	ND	ND
PFFASB03	Sep-93	19.5	ND	ND	ND	ND	0.014	ND	0.025	NI
PFFASB04	Sep-93	4.5	ND	ND	18	ND	ND	ND	ND	ND
		19.5	500	ND	1,900	ND	9.0	7.7	44	24
		39.5	ND	ND	ND	ND	ND	ND	0.00075	0.0009
PFFASB05	Sep-93	14.0	76	ND	ND	ND	ND	ND	ND	ND
PFFASB06	Sep-93	19.5	ND	ND	ND	ND	ND	ND	0.012	ND
		24.5	1.1	ND	17	ND	ND	ND	0.010	0.024
		39.5	930	ND	1,600	ND	ND	ND	3.0	5.7
PFFASB07	Sep-93	24.5	ND	ND	ND	ND	ND	ND	ND	0.0016
		39.5	19	ND	2,300	ND	ND	ND	0.26	0.80
PFFASB08	Sep-93	4.5	130	ND	680	ND	ND	ND	ND	ND
PFFASB09	Sep-93	9.5	ND	ND	ND	ND	ND	ND	ND	0.002
PFFASB10	Sep-93	20.5	ND	ND	ND	ND	ND	ND	0.00073	0.00020
PFFASB15	Sep-93	9.5	570	ND	250	ND	ND	ND	8.7	31
		19.5	270	ND	820	ND	1.4	10	45	200
		24.5	880	ND	72	ND	ND	ND	45	220
PFFASB16	Sep-93	19.5	3,300	ND	ND	ND	ND	ND	0.88	0.98
PFFASB17	Sep-93	24.5	48	ND	290	ND	ND	ND	0.074	0.093
		44.5	1,300	4,000	37	ND	ND	ND	4.6	3.9
PFFASB18	Sep-93	14.5	760	ND	ND	ND	ND	ND	0.012	0.0075
PFFASB18A	Dec-93	20.5	230	ND	ND	ND	ND	ND	1.8	6.1
		30.5	510	ND	360	ND	ND	ND	2.8	11.0
		40.0	350	ND	ND	ND	ND	ND	ND	0.43
PFFASB19	Sep-93	14.0	4.3	ND	ND	ND	ND	ND	0.00091	ND
		29.5	140	ND	2.9	ND	ND	ND	0.011	NI
PFFASB25	Jan-94	9.0	ND	ND	ND	ND	ND	ND	0.0072	0.02

TABLE A.1 (continued)
Historical Summary of Detected Analytes in Soil
Total Petroleum Hydrocarbons and BTEX Compounds
PFFA RAP
Castle Airport, California

			Total Petroleum Hydrocarbons				BTEX			
		Method:	8015 (Mod.)				8020/8260			
		Analyte:	TPH-g	TPH-jf	TPH-d	TPH-oil	Benzene	Toluene	Ethyl-benzene	Total Xylenes
Location	Date	Depth (bgs)	Concentrations in mg/kg							
PFFASB27	Jan-94	24.5	33	ND	ND	ND	ND	ND	ND	0.23
PFFASB31	Jan-94	29.0	11	ND	ND	ND	ND	ND	ND	ND
PFFASB32	Jan-94	4.0	1,300	ND	ND	ND	ND	ND	ND	8.1
PFFASB33	Jan-94	14.0	2.4	ND	ND	ND	ND	ND	ND	ND
PFFASB36	Mar-94	14.0	80	ND	ND	ND	ND	ND	0.032	0.030
		29.0	240	ND	ND	ND	ND	ND	0.070	0.020
PFFASB37	Mar-94	9.0	4.4	ND	7.4	ND	ND	ND	0.92	3.1
		19.0	1,100	ND	ND	ND	ND	ND	3.6	15
		39.0	ND	ND	ND	ND	ND	ND	0.00079	0.0017
PFFASB38	Mar-94	24.0	ND	2,000	ND	ND	ND	ND	ND	0.57
		39.0	910	ND	65	ND	ND	ND	1.7	2.6
		54.0	ND	ND	ND	ND	ND	ND	0.0010	0.0043
PFFASB39	Mar-94	9.0	ND	ND	ND	ND	0.0033	ND	ND	ND
		14.0	570	ND	160	ND	ND	ND	0.39	1.7
		39.0	ND	ND	ND	ND	ND	ND	0.0020	0.0087
MW965	Mar-97	30.5	4.3(N)	ND	ND	n.a.	ND	0.0086	0.0093(J)	0.0031(J)
		40.5	0.39	ND	ND	n.a.	ND	ND	ND	ND
MW966	Mar-97	25.0	ND	ND	ND	n.a.	ND	ND	0.0017(NJ)	0.0035(NJ)
		40.0	ND	ND	ND	n.a.	0.0012(J)	ND	0.0014(J)	0.0048(J)
MW967	Mar-97	45.5	ND	ND	ND	n.a.	ND	ND	ND	ND
		55.5	ND	ND	ND	n.a.	ND	ND	ND	ND
PFFASB40	Mar-98	35.0	ND		ND	n.a.	ND	ND	ND	ND
PFFASB41	Mar-98	14.0	ND		ND	n.a.	ND	ND	ND	ND
		40.0	2,000		140	n.a.	0.12	ND	0.33	1.1
PFFASB42	Mar-98	14.0	ND		24	n.a.	ND	ND	ND	ND
		44.0	34		ND	n.a.	ND	ND	ND	ND
PFFASB43	Mar-98	12.0	ND		ND	n.a.	ND	ND	ND	ND
		43.0	690		8.9	n.a.	ND	ND	ND	0.37

ND : Not detected at or above the reporting limit
(J) : estimated value
(N) : presumptive identification
TPH-g : Total Petroleum Hydrocarbons as gasoline
TPH-jf : Total Petroleum Hydrocarbons as jet fuel
TPH-d : Total Petroleum Hydrocarbons as diesel
TPH-oil : Total Petroleum Hydrocarbons as oil

TABLE A.2
Historical Summary of Detected Analytes in Soil
Other Petroleum-Related Compounds

PFFA RAP

Castle Airport, California

		Method:	Volatile Organic Compounds 8260								
		Analyte:	1,2,4-TMB	1,3,5-TMB	Naph-thalene	p-isopropyl-toluene	n-propyl-benzene	isopropyl-benzene	n-butyl-benzene	sec-butyl-benzene	tert-butyl-benzene
Location	Date	Depth (bgs)	Concentrations in mg/kg								
DA7SB01	Oct-93	19.5	3.5	1.4	0.32	0.40	0.42	ND	ND	ND	ND
DA7SB02	Oct-93	24.0	0.12	<TDL	0.10	0.018	<TDL	<TDL	<TDL	<TDL	ND
DA7SB04	Oct-93	14.0	<TDL	<TDL	<TDL	0.0092	ND	ND	ND	ND	ND
DA7SB05	Oct-93	19.0	<TDL	<TDL	<TDL	0.0078	<TDL	<TDL	<TDL	<TDL	ND
		39.0	5.9	2.1	2.0	ND	0.78	ND	0.83	ND	0.71
DA7SB11	Oct-93	19.0	0.062	<TDL	<TDL	0.014	<TDL	<TDL	ND	<TDL	ND
		24.0	0.20	0.066	0.12	0.045	<TDL	<TDL	0.061	<TDL	ND
PFFASB04	Sep-93	19.5	34	13	7.7	ND	6.2	9.1	3.0	ND	ND
PFFASB06	Sep-93	24.5	<TDL	<TDL	<TDL	0.0042	<TDL	<TDL	ND	<TDL	ND
		39.5	24	8.7	2.6	2.4	4.6	2.7	3.7	1.9	ND
PFFASB07	Sep-93	39.5	1.8	0.81	0.33	0.33	0.39	ND	0.65	0.33	ND
PFFASB15	Sep-93	9.5	36	14	5.8	5.9	9.3	5.9	8.3	5.0	ND
		19.5	99	32	11	9.6	23	15	16	9.3	ND
		24.5	120	37	17	7.4	24	15	14	8.5	ND
PFFASB16	Sep-93	19.5	8.0	ND	0.66	1.1	1.7	0.90	1.3	1.3	ND
PFFASB17	Sep-93	24.5	0.18	0.061	<TDL	<TDL	<TDL	<TDL	<TDL	<TDL	ND
		44.5	10	3.4	1.5	1.1	2.2	1.5	ND	0.86	ND
PFFASB36	Mar-94	13.5	0.060	ND	<TDL	<TDL	<TDL	<TDL	ND	1.0	ND
PFFASB37	Mar-94	9.0	1.2	0.48	ND	ND	ND	0.45	ND	ND	ND
		19.0	2.8	ND	ND	ND	0.49	0.61	ND	ND	ND
PFFASB38	Mar-94	24.0	0.78	ND	0.44	ND	ND	ND	ND	ND	ND
		39.0	7.6	2.9	2.2	1.4	2.0	1.2	ND	1.0	ND
PFFASB39	Mar-94	14.0	2.1	ND	0.65	ND	0.40	ND	ND	ND	ND
PFFASB43	Mar-98	43.0	ND	ND	ND	ND	ND	ND	ND	ND	ND

<TDL: less than Total Designated Level (Castle AFB Basewide Waste Management Plan)
ND: Not detected at or above the reporting limit

TABLE A.3
Historical Summary of Detected Analytes in Groundwater
Petroleum-Related Hydrocarbons
PFFA RAP
Castle Airport, California

	Method:	8015 (Mod.)	8260 or 8010/8020													
	Analyte:	TPH-g	Benzene	Toluene	Ethyl-benzene	Xylenes, Total	1,2,4-TMB	1,3,5-TMB	Naph-thalene	n-Butyl-benzene	sec-Butyl-benzene	tert-Butyl-benzene	Isopropyl-benzene	n-Propyl-benzene	p-Isopropyl toluene	1-Methyl-ethyl-benzene
Location	Date	Concentrations in µg/L														
B917SB02 [1]	Oct-93	280	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DA7SB07 [1]	Oct-93	58	ND	0.08	ND	ND	0.12	ND	ND	ND	ND	ND	ND	ND	ND	ND
PFFASB33 [1]	Jan-94	110	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PFFASB34 [1]	Mar-94	40	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PFFASB38 [1]	Mar-94	2400	8.1	ND	81	232	110	35	45	ND	5.3	ND	17	21	6.2	ND
PFFASB42 [1]	Mar-98	n.a.	61	ND	4.5	7.4	ND	ND	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
JM11	4Q93	270	140	10	ND	14	2.7	0.27	ND	ND	ND	ND	n.r.	ND	ND	ND
	1Q94	1900	780	110	35	110	14	ND	ND	ND	ND	ND	2.1	2.8	ND	ND
	1Q94	n.a.	1400	640	59	370	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	3Q94	n.a.	250	ND	ND	ND	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	4Q94	n.a.	1500	ND	ND	ND	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	1Q95	n.a.	840	ND	ND	ND	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	2Q95	2500	680	90	89	220	49	21	5.6	ND	1.4	ND	7.8	9.4	1.4	ND
	1Q96 [3]	150	3.3	2.6	ND	8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	3Q96 [3]	ND	0.49	ND	ND	ND	ND	ND	0.58	ND	ND	ND	ND	ND	ND	ND
	3Q96	1000	450	9.6	71	130	27	13	ND	ND	1.7	ND	7.4	8.1	1.6	ND
	1Q97 [2]	2100	190	2.1	32	93	59	27	4.4	ND	2.4	ND	n.a.	8.1	7.0	7.0
	2Q97	990	86	4.0	17	38	19	12	ND	ND	ND	3.0	3.0	3.0	ND	n.a.
JM12	1Q94	n.a.	0.24	0.11	ND	8.2	ND	ND	ND	ND	ND	ND	n.r.	ND	ND	ND
	1Q95	n.a.	25	ND	ND	ND	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	2Q95	n.a.	36	20	0.98	8.1	0.22	0.15	ND	ND	ND	ND	n.r.	ND	ND	ND
	1Q96 [3]	n.a.	0.19	0.16	ND	ND	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	3Q96 [3]	n.a.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	n.a.	ND	ND	ND
	1Q97 [2]	ND	7.0	3.9	ND	0.72(J)	ND	ND	ND	ND	ND	ND	n.a.	ND	ND	ND
	2Q97	ND	0.3 (J)	0.4 (J)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	n.a.
MW531	Jul-89	n.r.	660	17	10	43	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
	Oct-89	n.r.	380	ND	12	9.2	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.

TABLE A.3 (continued)
Historical Summary of Detected Analytes in Groundwater
Petroleum-Related Hydrocarbons
PFFA RAP
Castle Airport, California

	Method:	8015 (Mod.)	8260 or 8010/8020													
	Analyte:	TPH-g	Benzene	Toluene	Ethyl-benzene	Xylenes, Total	1,2,4-TMB	1,3,5-TMB	Naph-thalene	n-Butyl-benzene	sec-Butyl-benzene	tert-Butyl-benzene	Isopropyl-benzene	n-Propyl-benzene	p-Isopropyl toluene	1-Methyl-ethyl-benzene
Location	Date	Concentrations in µg/L														
MW532	1Q94	n.a.	ND	ND	ND	2.6	ND	ND	ND	ND	ND	ND	n.r.	ND	ND	ND
	2Q95	n.a.	ND	0.35	ND	ND	ND	ND	ND	ND	ND	ND	n.r.	ND	ND	ND
MW533	Oct-89	n.r.	1.9	2.0	0.5	2.5	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
MW534	Oct-89	n.r.	0.40	0.40	ND	ND	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
	3Q94	n.a.	0.093	0.10	ND	ND	ND	ND	ND	ND	ND	ND	n.r.	ND	ND	ND
MW536	Oct-89	n.r.	ND	0.70	ND	1.5	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
MW873	1Q94	n.a.	ND	0.27	0.079	0.21	0.13	ND	ND	ND	ND	ND	n.r.	ND	ND	ND
	2Q94	n.a.	ND	ND	ND	ND	ND	0.08	1.1	0.12	ND	0.069	n.r.	ND	0.10	ND
	2Q97	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	n.a.
MW965	1Q97 [1]	n.a.	1.5(J)	0.47(J)	27	46	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	2Q97	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	n.a.
MW966	1Q97 [1]	n.a.	0.97(J)	0.79(J)	4.2	1.6(J)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	2Q97	670	7.0	ND	ND	2.0	8.0	1.0	2.0	ND	ND	ND	ND	ND	ND	n.a.
MW967	1Q97 [1]	n.a.	0.32(J)	ND	0.15(J)	ND	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	2Q97	70	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	n.a.
MW968	1Q97 [1]	n.a.	ND	ND	1.3(J)	2.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	2Q97	110	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	n.a.
MW969	2Q97	50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	n.a.
MW970	2Q97	70	ND	ND	ND	ND	ND	ND	ND	ND	0.5	ND	ND	ND	ND	n.a.
MW971	2Q97	60	ND	ND	ND	ND	ND	ND	ND	ND	0.4 (J)	ND	ND	ND	ND	n.a.
TW16	2Q95	n.a.	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.19	ND	ND	ND
	2Q97	80	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	n.a.

[1] PFFASB42 was a hydropunch sample collected from 66 feet bgs. All other hydropunch samples were collected at 66 feet bgs.

[2] Preliminary results.

[3] Sampling protocol change occurred during this event (see Section 2.3).

Source: Jacobs, 1995 and 1997a.

ND : Not detected
n.a. : Not analyzed
n.r. : Not reported

(J) : estimated value

TABLE A.4
Historical Summary of Detected Analytes in Groundwater
Chlorinated Hydrocarbons
PFFA RAP
Castle Airport, California

	Method:	8260 or 8010/8020																	
	Analyte:	Chloro-benzene	Chloro-form	2-Chloro-toluene	1,1-DCA	1,2-DCA	1,3-DCB	1,4-DCB	1,1-DCE	cis-1,2-DCE	trans-1,2-DCE	Hexa-Chloro-butadiene	Methyl-ene chloride	PCE	TCE	1,1,1-TCA	1,2,3-TCB	1,2,4-TCB	Trichloro-fluoro-methane
Location	Date	Concentrations in µg/L																	
B917SB02 [1]	Oct-93	0.14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DA7SB07 [1]	Oct-93	ND	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.37	ND	ND	ND	ND
PFFASB17 [1]	Sep-93	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.25	ND	ND	ND	ND
PFFASB38 [1]	Mar-94	ND	ND	ND	ND	ND	ND	ND	ND	1.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
JM11	4Q93	ND	ND	ND	ND	ND	ND	ND	ND	3.2	ND	ND	1.2	ND	9.4	ND	ND	ND	ND
	1Q94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.7	8.2	ND	ND	ND	ND
	1Q94	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	ND	11	ND	n.r.	n.r.	ND
	3Q94	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	ND	15	ND	n.r.	n.r.	ND
	4Q94	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	ND	9	ND	n.r.	n.r.	ND
	1Q95	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	ND	13	ND	n.r.	n.r.	ND
	2Q95	ND	ND	ND	ND	ND	ND	ND	ND	6.6	ND	ND	ND	ND	9.2	ND	ND	ND	ND
	1Q96	ND	ND	n.r.	ND	ND	ND	ND	ND	3.7	ND	n.r.	0.75	0.18	6.6	ND	n.r.	n.r.	ND
	3Q96	ND	ND	ND	ND	ND	ND	ND	ND	2.1	ND	ND	ND	ND	2.8	ND	ND	ND	ND
	1Q97 [2]	ND	ND	ND	ND	5.7	ND	ND	ND	ND	ND	ND	ND	ND	0.42	ND	ND	ND	ND
	2Q97	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
JM12	4Q93	ND	ND	ND	ND	ND	ND	ND	ND	1.1	ND	ND	ND	0.33	5.7	ND	ND	ND	ND
	1Q94	ND	ND	ND	ND	ND	ND	ND	ND	1.5	ND	ND	ND	0.28	5.5	ND	ND	ND	ND
	3Q94	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	ND	9.5	ND	n.r.	n.r.	ND
	4Q94	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	ND	3.3	ND	n.r.	n.r.	ND
	1Q95	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	ND	13	ND	n.r.	n.r.	ND
	2Q95	ND	ND	ND	ND	ND	ND	ND	ND	4.8	ND	ND	ND	0.24	10	ND	ND	ND	ND
	1Q96	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	ND	0.62	ND	n.r.	n.r.	ND
	3Q96	ND	ND	ND	ND	ND	ND	ND	ND	0.43	ND	ND	ND	ND	1.3	ND	ND	ND	ND
	1Q97 [2]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.39	ND	ND	ND	ND
	2Q97	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.30	ND	ND	ND	ND
MW270	1Q94	ND	0.24	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1Q96	ND	0.13	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	0.18	ND	ND	n.r.	n.r.	ND
	1Q97 [2]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.39	ND	ND	ND	ND	ND
	2Q97	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.50	ND	ND	ND	ND	ND

TABLE A.4 (continued)
Historical Summary of Detected Analytes in Groundwater
Chlorinated Hydrocarbons
PFFA RAP
Castle Airport, California

	Method:	8260 or 8010/8020																	
	Analyte:	Chloro-benzene	Chloro-form	2-Chloro-toluene	1,1-DCA	1,2-DCA	1,3-DCB	1,4-DCB	1,1-DCE	cis-1,2-DCE	trans-1,2-DCE	Hexa-Chloro-butadiene	Methyl-ene chloride	PCE	TCE	1,1,1-TCA	1,2,3-TCB	1,2,4-TCB	Trichloro-fluoro-methane
Location	Date	Concentrations in µg/L																	
MW280	1Q94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.46	0.16	ND	ND	ND	ND	ND
	1Q96	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	0.15	ND	ND	n.r.	n.r.	ND
	2Q97	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW530	1Q93	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	ND	60	ND	n.r.	n.r.	ND
	1Q94	0.6	ND	ND	ND	ND	ND	ND	ND	6.5	ND	ND	ND	ND	140	ND	ND	ND	ND
	3Q94	ND	ND	ND	ND	ND	ND	ND	ND	11	ND	ND	ND	ND	160	ND	ND	ND	ND
	4Q94	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	ND	140	ND	n.r.	n.r.	ND
	1Q95	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	ND	100	ND	n.r.	n.r.	ND
	2Q95	ND	ND	ND	ND	ND	ND	ND	1.2	20	ND	ND	ND	ND	380	ND	ND	ND	ND
	1Q96	ND	ND	n.r.	ND	ND	ND	ND	ND	14	ND	n.r.	ND	ND	260	ND	n.r.	n.r.	ND
	3Q96	ND	ND	n.r.	ND	ND	ND	ND	ND	16	ND	n.r.	ND	ND	240	ND	n.r.	n.r.	ND
	1Q97 [2]	ND	0.17	ND	ND	ND	ND	ND	0.42	4.2	ND	ND	ND	ND	71	ND	ND	ND	ND
	2Q97	ND	ND	ND	ND	ND	ND	ND	ND	9.0	ND	ND	ND	ND	160	ND	ND	ND	ND
MW531	Jul-89	ND	ND	n.r.	ND	ND	ND	ND	ND	25	0.6	n.r.	ND	ND	18	ND	n.r.	n.r.	ND
	Oct-89	ND	ND	n.r.	ND	ND	ND	ND	0.3	36	0.5	n.r.	ND	ND	26	ND	n.r.	n.r.	ND
MW532	1Q93	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	ND	2.4	ND	n.r.	n.r.	ND
	3Q93	ND	ND	ND	ND	ND	ND	ND	ND	3.1	ND	ND	0.83	0.2	4.8	ND	ND	ND	ND
	1Q94	ND	ND	ND	ND	ND	ND	ND	ND	1.8	ND	ND	0.64	0.19	3.8	ND	ND	ND	ND
	3Q94	ND	ND	ND	ND	ND	ND	ND	ND	3	ND	ND	ND	0.25	5.9	ND	ND	ND	ND
	4Q94	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	ND	22	ND	n.r.	n.r.	ND
	1Q95	ND	ND	ND	ND	ND	ND	ND	ND	1.2	ND	ND	ND	0.22	3.8	ND	ND	ND	ND
	2Q95	ND	ND	ND	ND	ND	ND	ND	0.5	0.44	ND	ND	ND	0.17	0.58	0.29	ND	ND	ND
	1Q96	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	1.3	0.11	0.40	ND	n.r.	n.r.	ND
	3Q96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.26	ND	ND	ND	ND
	1Q97 [2]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.35	ND	ND	ND	ND
	2Q97	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.20	ND	ND	ND	ND
MW533	Jul-89	ND	ND	n.r.	2.3	2.0	ND	ND	ND	ND	ND	n.r.	ND	ND	ND	ND	n.r.	n.r.	ND
	Oct-89	ND	ND	n.r.	1.0	ND	ND	ND	ND	ND	ND	n.r.	ND	ND	ND	ND	n.r.	n.r.	ND

TABLE A.4 (continued)
Historical Summary of Detected Analytes in Groundwater
Chlorinated Hydrocarbons
PFFA RAP
Castle Airport, California

	Method:	8260 or 8010/8020																	
	Analyte:	Chloro-benzene	Chloro-form	2-Chloro-toluene	1,1-DCA	1,2-DCA	1,3-DCB	1,4-DCB	1,1-DCE	cis-1,2-DCE	trans-1,2-DCE	Hexa-Chloro-butadiene	Methyl-ene chloride	PCE	TCE	1,1,1-TCA	1,2,3-TCB	1,2,4-TCB	Trichloro-fluoro-methane
Location	Date	Concentrations in µg/L																	
MW534	Jul-89	ND	ND	n.r.	1.0	ND	ND	ND	ND	ND	ND	n.r.	ND	ND	ND	ND	n.r.	n.r.	ND
	Oct-89	ND	ND	n.r.	ND	ND	ND	ND	ND	ND	ND	n.r.	ND	ND	0.40	ND	n.r.	n.r.	ND
	1Q93	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	7.8	ND	ND	ND	ND
	3Q93	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.45	ND	ND	ND	ND	ND	ND
	1Q94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.2	ND	0.43	ND	ND	ND	ND
	3Q94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.45	ND	ND	ND	ND
	1Q95	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.26	ND	ND	ND	ND
	2Q97	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.20	ND	ND	ND	ND
MW536	Jul-89	ND	ND	n.r.	ND	ND	ND	ND	ND	ND	ND	n.r.	ND	0.30	0.30	ND	n.r.	n.r.	ND
	Oct-89	ND	ND	n.r.	ND	ND	ND	ND	ND	ND	ND	n.r.	ND	0.30	0.30	ND	n.r.	n.r.	ND
	1Q96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.28	ND	ND	ND	ND
MW873	1Q94	ND	0.098	ND	ND	ND	ND	ND	0.22	1.9	ND	ND	0.41	0.11	34	ND	ND	ND	0.34
	2Q94	ND	0.11	0.1	ND	ND	0.12	0.15	0.26	2.8	ND	0.35	ND	0.27	52	ND	1.6	0.7	0.3
	3Q94	ND	ND	ND	ND	ND	ND	ND	0.53	4.1	ND	ND	ND	0.16	86	ND	ND	ND	0.58
	4Q94	ND	0.11	ND	ND	ND	ND	ND	0.53	4.5	ND	ND	ND	0.12	93	ND	ND	ND	0.57
	1Q95	ND	ND	ND	ND	ND	ND	ND	ND	8.4	ND	ND	ND	ND	180	ND	ND	ND	ND
	3Q95	ND	ND	n.r.	ND	ND	ND	ND	ND	5	ND	n.r.	ND	ND	110	ND	n.r.	n.r.	ND
	1Q96	ND	ND	n.r.	ND	ND	ND	ND	ND	8.6	ND	n.r.	ND	3.1	280	ND	n.r.	n.r.	ND
	3Q96	ND	ND	n.r.	ND	ND	ND	ND	ND	9.8	ND	n.r.	ND	ND	250	ND	n.r.	n.r.	ND
	1Q97 [2]	ND	ND	ND	ND	ND	ND	ND	0.24	2.1	ND	ND	ND	ND	57	ND	ND	ND	ND
	2Q97	ND	ND	ND	ND	ND	ND	ND	ND	10	ND	ND	ND	ND	350	ND	ND	ND	ND
MW899	2Q94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4	ND	ND	ND	ND	ND	ND
	1Q96	ND	0.21	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	ND	ND	2.8	ND	n.r.	n.r.	ND
	1Q97 [2]	ND	0.17	ND	ND	ND	ND	ND	ND	n.r.	ND	ND	ND	ND	1.5	ND	ND	ND	ND
	2Q97	ND	0.30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.0	ND	ND	ND	ND
MW966	2Q97	ND	ND	ND	ND	ND	ND	ND	ND	0.60	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW967	2Q97	ND	ND	ND	ND	ND	ND	ND	ND	0.30	ND	ND	ND	ND	1.0	ND	ND	ND	ND
MW969	2Q97	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.30	ND	ND	ND	ND
MW970	2Q97	ND	ND	ND	0.30	ND	ND	ND	ND	2.0	ND	ND	ND	ND	6.0	ND	ND	ND	ND
MW971	2Q97	ND	ND	ND	ND	ND	ND	ND	ND	0.60	ND	ND	ND	ND	2.0	ND	ND	ND	ND

TABLE A.4 (continued)
Historical Summary of Detected Analytes in Groundwater
Chlorinated Hydrocarbons
PFFA RAP
Castle Airport, California

	Method:	8260 or 8010/8020																	
	Analyte:	Chloro-benzene	Chloro-form	2-Chloro-toluene	1,1-DCA	1,2-DCA	1,3-DCB	1,4-DCB	1,1-DCE	cis-1,2-DCE	trans-1,2-DCE	Hexa-Chloro-butadiene	Methyl-ene chloride	PCE	TCE	1,1,1-TCA	1,2,3-TCB	1,2,4-TCB	Trichloro-fluoro-methane
Location	Date	Concentrations in µg/L																	
TW13	1Q95	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	ND	ND	ND	1.6	ND	n.r.	n.r.	ND
	1Q96	ND	ND	n.r.	ND	ND	ND	ND	ND	n.r.	ND	n.r.	0.86	0.25	1.5	ND	n.r.	n.r.	ND
	3Q96	ND	0.12	n.r.	ND	ND	ND	ND	ND	ND	ND	n.r.	ND	ND	1.4	ND	n.r.	n.r.	ND
	1Q97[2]	ND	0.12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.4	ND	ND	ND	ND
	2Q97	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.0	ND	ND	ND	ND
TW16	1Q94	ND	0.17	ND	ND	ND	ND	ND	ND	1.7	ND	ND	ND	0.97	56	ND	ND	ND	ND
	3Q94	ND	ND	ND	ND	ND	ND	ND	ND	n.r.	ND	ND	ND	2.0	65	ND	ND	ND	ND
	4Q94	ND	ND	ND	ND	ND	ND	ND	ND	n.r.	ND	ND	ND	3.2	42	ND	ND	ND	ND
	1Q95	ND	ND	ND	ND	ND	ND	ND	1.8	n.r.	ND	ND	ND	2.5	51	ND	ND	ND	ND
	2Q95	ND	ND	ND	ND	ND	ND	ND	0.38	1.8	ND	ND	ND	1.3	55	ND	ND	ND	ND
	1Q96	ND	ND	ND	ND	ND	ND	ND	ND	1.6	ND	ND	ND	0.48	47	ND	ND	ND	ND
	3Q96	ND	0.16	ND	ND	ND	ND	ND	ND	1.3	ND	ND	ND	ND	35	ND	ND	ND	ND
	1Q97[2]	ND	0.16	ND	ND	ND	ND	ND	0.33	1.1	ND	ND	ND	1.3	31	ND	ND	ND	ND
	2Q97	ND	ND	ND	ND	ND	ND	ND	ND	1.0	ND	ND	ND	0.40	22	ND	ND	ND	ND

[1] Hydropunch sample collected from approximately 60 to 70 feet bgs.

[2] Results are preliminary.

Source: Jacobs, 1995 and 1997a.

ND	Not detected
n.a.	Not analyzed
n.r.	Not reported

TA' FFA.SG

VOLATILE ORGA ON ATIONS IN SOIL GAS SAMPLES

BORING/SOIL GAS LOCATION	DEPTH (ft bgs)	SAMPLING DATE	BZ (µg/L)	BZME (µg/L)	EBZ (µg/L)	XYLMP (µg/L)	XYLO (µg/L)	XYLENES (µg/L)	LAB METHOD	OTHER: (µg/L)
B917SB01A	10	15-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
B917SB01A	20	15-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
B917SB01A	40	15-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
B917SB01A	50	15-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
B917SB02	41.5	14-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
B917SB03	20	15-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
B917SG01	5	19-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
B917SG01	10	19-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
B917SG02	10	19-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
B917SG03	5	19-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	PCE = 1.91 JN
B917SG03	10	19-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	PCE = 75.8 JN
B917SG04	5	19-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
B917SG04*	10	19-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
B917SG05	5	19-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
B917SG05	10	19-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB01	20	13-Oct-93	< 1.0 UJ	< 1.0 UJ	78.4 JN	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB01	40	13-Oct-93	< 1.0 UJ	< 1.0 UJ	6.4 JN	5.6 JN	< 1.0 UJ	---	SGVOCS	
DA7SB01	50	13-Oct-93	< 1.0 UJ	641.3 JN	114.8 JN	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB02	20	07-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB02	40	07-Oct-93	< 1.0 UJ	< 1.0 UJ	74.3 JN	< 1.0 UJ	28.8 JN	---	SGVOCS	
DA7SB02	50	07-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB03	40	07-Oct-93	362.8 JN	< 1.0 UJ	13.8 JN	< 1.0 UJ	5.0 JN	---	SGVOCS	
DA7SB03	50	07-Oct-93	< 1.0 UJ	< 1.0 UJ	82.1 JN	< 1.0 UJ	31.3 JN	---	SGVOCS	
DA7SB04	40	11-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB04	50	11-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB05	50	07-Oct-93	57.8 JN	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	1.9 JN	---	SGVOCS	
DA7SB06	20	06-Oct-93	< 1.9 UJ	< 2.3 UJ	---	---	---	2.5 JB	E18	TCE = 2.04 JB
DA7SB06	40	06-Oct-93	< 4.8 UJ	< 5.6 UJ	---	---	---	< 10.8 UJ	E18	
DA7SB06	50	06-Oct-93	< 4.8 UJ	< 5.6 UJ	---	---	---	< 10.8 UJ	E18	
DA7SB07	40	12-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB07	60	12-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	

TABLE [illegible]

VOLATILE ORGANIC CONCEN[illegible]TIONS IN SOIL GAS SAMPLES

BORING/SOIL GAS LOCATION	DEPTH (ft bgs)	SAMPLING DATE	BZ (µg/L)	BZME (µg/L)	EBZ (µg/L)	XYLMP (µg/L)	XYLO (µg/L)	XYLENES (µg/L)	LAB METHOD	OTHER: (µg/L)
DA7SB08	40	11-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB08	50	11-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB09	20	08-Oct-93	< 0.96 U	< 1.1 U	---	---	---	< 2.2 U	E18	PCE=11.5 TCE=0.11 J
DA7SB09	40	08-Oct-93	< 0.96 U	< 16.9 UR	---	---	---	< 2.2 U	E18	PCE=8.1
DA7SB09	50	08-Oct-93	< 4.8 UJ	< 56.4 UJ	---	---	---	< 10.8 UJ	E18	
DA7SB10	20	06-Oct-93	0.02 J	0.19 JB	---	---	---	0.23 JB	E18	TCA111=0.004 J TCLME=0.08 J TCE=0.41 JB PCE=0.18 J
DA7SB10	40	06-Oct-93	0.0048 J	0.0064 JB	---	---	---	0.0026 JB	E18	
DA7SB10	50	06-Oct-93	0.0029 J	0.006 JB	---	---	---	< 0.043 UJ	E18	
DA7SB11	20	11-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB11	40	11-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB11	50	11-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB13	10	12-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB13	20	12-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB13	40	12-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB13	60	12-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB14	20	13-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB14	40	13-Oct-93	< 1.0 UJ	< 1.0 UJ	88.2 JN	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB14	50	13-Oct-93	< 1.0 UJ	< 1.0 UJ	94.0 JN	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
DA7SB14	60	13-Oct-93	< 1.0 UJ	599.6 JN	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	TC1112=18.8 JN
PFFASB02	23.5	21-Jun-93	< 1.0 UJ	23.7 JN	3.0 JN	1.9 JN	< 1.0 UJ	---	SGVOCS	BRBZ=2.2 JN DCE11=2.5 JN VC=19.0 JN
PFFASB03	20	28-Sep-93	< 1.0 UJ	< 1.0 UJ	8.2 JN	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASB03	40	28-Sep-93	< 1.0 UJ	< 1.0 UJ	57.51 JN	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASB03	50	28-Sep-93	< 1.0 UJ	< 1.0 UJ	13.8 JN	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASB04	20	28-Sep-93	< 1.0 UJ	< 1.0 UJ	120.1 JN	94.7 JN	< 1.0 UJ	---	SGVOCS	
PFFASB04	40	28-Sep-93	< 1.0 UJ	< 1.0 UJ	57.3 JN	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASB04	50	28-Sep-93	< 1.0 UJ	< 1.0 UJ	84.4 JN	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASB06	20	24-Sep-93	< 1.0 UJ	< 1.0 UJ	8.7 JN	6.2 JN	< 1.0 UJ	---	SGVOCS	
PFFASB06	40	24-Sep-93	< 1.0 UJ	< 1.0 UJ	184.7 JN	176.1 JN	< 1.0 UJ	---	SGVOCS	
PFFASB06	50	24-Sep-93	< 1.0 UJ	< 1.0 UJ	90.9 J	108.2 JN	20.1 JN	---	SGVOCS	
PFFASB07	20	23-Sep-93	< 1.0 UJ	< 1.0 UJ	9.0 JN	9.7 JN	< 1.0 UJ	---	SGVOCS	
PFFASB07	40	23-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASB07	50	23-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASB08	20	22-Sep-93	< 1.0 UJ	27.2 JN	< 1.0 UJ	< 1.0 UJ	16.0 JN	---	SGVOCS	

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VOLATILE ORGA NCE TIONS IN SOIL GAS SAMPLES

BORING/SOIL GAS LOCATION	DEPTH (ft bgs)	SAMPLING DATE	BZ (µg/L)	BZME (µg/L)	EBZ (µg/L)	XYLMP (µg/L)	XYLO (µg/L)	XYLENES (µg/L)	LAB METHOD	OTHER: (µg/L)
PFFASB08	40	22-Sep-93	< 1.0 UJ	77.5 JN	< 1.0 UJ	< 1.0 UJ	15.7	---	SGVOCS	
PFFASB08	50	22-Sep-93	< 1.0 UJ	75.8 JN	< 1.0 UJ	62.3 JN	16.1 JN	---	SGVOCS	
PFFASB09	20	23-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	42.0 JN	< 1.0 UJ	---	SGVOCS	
PFFASB09	40	23-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	42.6 JN	< 1.0 UJ	---	SGVOCS	
PFFASB09	50	23-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	75.2 JN	< 1.0 UJ	---	SGVOCS	
PFFASB10	21.5	22-Jun-93	31.7 JN	6.9 JN	< 1.0 UJ	22.3 JN	< 1.0 UJ	---	SGVOCS	DCE11 = 1.6 JN
PFFASB11	21.5	23-Jun-93	0.0035 J	1.1 B	---	---	---	0.043	E18	
PFFASB12	20	29-Sep-93	< 1.0 UJ	< 1.0 UJ	5.2 JN	3.1 JN	< 1.0 UJ	---	SGVOCS	
PFFASB12	40	29-Sep-93	< 1.0 UJ	< 1.0 UJ	34.4 JN	11.1 JN	< 1.0 UJ	---	SGVOCS	
PFFASB12	55	29-Sep-93	< 1.0 UJ	< 1.0 UJ	1.0 JN	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASB13	20	24-Sep-93	< 1.0 UJ	< 1.0 UJ	78.4 JN	88.1 JN	< 1.0 UJ	---	SGVOCS	
PFFASB13	40	24-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASB13	50	24-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASB14	20	27-Sep-93	< 1.0 UJ	< 1.0 UJ	3.2 JN	< 1.0 UJ	2.7 JN	---	SGVOCS	
PFFASB14	40	27-Sep-93	< 1.0 UJ	< 1.0 UJ	89.5 JN	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASB14	50	27-Sep-93	< 1.0 UJ	< 1.0 UJ	57.8 JN	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASB15	20	27-Sep-93	130.2 JN	< 1.0 UJ	149.4 JN	138.2 JN	48.4 JN	---	SGVOCS	
PFFASB15	40	27-Sep-93	< 1.0 UJ	< 1.0 UJ	41.0 JN	49.8 JN	20.1 JN	---	SGVOCS	
PFFASB15	50	27-Sep-93	< 1.0 UJ	< 1.0 UJ	8.9 JN	10.0 JN	< 1.0 UJ	---	SGVOCS	
PFFASB16	20	27-Sep-93	< 1.0 UJ	4.3 JN	< 1.0 UJ	5.0 JN	< 1.0 UJ	---	SGVOCS	
PFFASB16	40	27-Sep-93	< 1.0 UJ	18.8 JN	< 1.0 UJ	21.0 JN	< 1.0 UJ	---	SGVOCS	
PFFASB16	50	27-Sep-93	< 1.0 UJ	15.8 JN	< 1.0 UJ	10.3 JN	< 1.0 UJ	---	SGVOCS	
PFFASB17	40	30-Sep-93	< 1.0 UJ	< 1.0 UJ	442.3 JN	307.2 JN	< 1.0 UJ	---	SGVOCS	
PFFASB17	55	30-Sep-93	< 1.0 UJ	< 1.0 UJ	175.2 JN	105.5 JN	< 1.0 UJ	---	SGVOCS	
PFFASB18A	20	15-Dec-93	0.073 J	0.14 JB	---	---	---	0.52 JB	E18	
PFFASB18A	40	15-Dec-93	10.8	< 5.6 U	---	---	---	117.0 B	E18	
PFFASB19	20	29-Sep-93	< 1.0 UJ	1078.3 JN	196.0 JN	48.1 JN	< 1.0 UJ	---	SGVOCS	
PFFASB19	40	29-Sep-93	< 1.0 UJ	1582.9 JN	183.1 JN	35.3 JN	< 1.0 UJ	---	SGVOCS	
PFFASB19	55	29-Sep-93	< 1.0 UJ	< 1.0 UJ	6.3 JN	2.4 JN	< 1.0 UJ	---	SGVOCS	
PFFASB19A	20	14-Dec-93	0.35	0.86	---	---	---	1.9	E18	
PFFASB19A	40	14-Dec-93	1.7 J	0.75 JB	---	---	---	4.8 JB	E18	
PFFASB19A	60	14-Dec-93	< 12.1 UJ	< 14.3 UJ	---	---	---	< 28.9 UJ	E18	
PFFASB21	20	20-Dec-93	0.16	0.53 B	---	---	---	1.2 B	E18	TCE = 0.012 J

TABLE PFFA.SG
VOLATILE ORGANIC CONCENTRATIONS IN SOIL GAS SAMPLES

BORING/SOIL GAS LOCATION	DEPTH (ft bgs)	SAMPLING DATE	BZ (µg/L)	BZME (µg/L)	EBZ (µg/L)	XYLMP (µg/L)	XYLO (µg/L)	XYLENES (µg/L)	LAB METHOD	OTHER: (µg/L)
PFFASB21	40	20-Dec-93	0.016	0.068 JB	---	---	---	0.1 B	E18	TCE=0.005 J
PFFASB21	50	20-Dec-93	0.017	0.068 JB	---	---	---	0.13 B	E18	
PFFASB22	40	20-Dec-93	0.011 J	0.056 JB	---	---	---	0.13 B	E18	DCE12C=0.048 TCE=0.44
PFFASB22*	50	20-Dec-93	0.007 J	0.033 JB	---	---	---	0.048 JB	E18	DCE12C=0.2 J TCE=1.5 J TCLME=0.002 J
PFFASB23	40	21-Dec-93	0.012 J	0.06 JB	---	---	---	0.14 JB	E18	TCE=0.051 J
PFFASB23	50	21-Dec-93	0.018	0.06 JB	---	---	---	0.095 B	E18	FC12=0.0025 J TCE=0.004 J
PFFASB24	40	22-Dec-93	0.024 B	0.098 JB	---	---	---	0.19 B	E18	CTCL=0.001 J FC12=0.0025 J
PFFASB24	60	22-Dec-93	0.005 JB	0.034 JB	---	---	---	0.036 B	E18	
PFFASB25	20	03-Jan-94	0.7 JB	< 2.6 UJ	---	---	---	36.0 B	E18	
PFFASB25	40	03-Jan-94	1.5 JB	< 4.5 UJ	---	---	---	1.5 JB	E18	
PFFASB25	50	03-Jan-94	0.76 JB	< 1.9 UJ	---	---	---	< 3.6 UJ	E18	
PFFASB26	20	04-Jan-94	0.008 JB	0.028 JB	---	---	---	0.056 JB	E18	
PFFASB26	40	04-Jan-94	0.010 JB	0.02 JB	---	---	---	0.82 B	E18	
PFFASB26	55	04-Jan-94	0.020 JB	0.06 JB	---	---	---	0.23 B	E18	
PFFASB27	20	04-Jan-94	0.018 B	0.038 JB	---	---	---	0.06 JB	E18	
PFFASB27	40	04-Jan-94	< 4.8 UJ	< 5.6 UJ	---	---	---	< 10.8 UJ	E18	
PFFASB27	55	04-Jan-94	< 4.8 UJ	< 5.6 UJ	---	---	---	< 10.8 UJ	E18	
PFFASB28	20	05-Jan-94	0.073 J	< 0.23 UJ	---	---	---	0.25 JB	E18	
PFFASB28	40	05-Jan-94	0.002 J	0.014 JB	---	---	---	0.017 JB	E18	
PFFASB28	55	05-Jan-94	0.2 J	< 1.1 UJ	---	---	---	< 2.2 UJ	E18	
PFFASB30	20	05-Jan-94	0.015	0.03 JB	---	---	---	0.038 JB	E18	
PFFASB30	40	05-Jan-94	< 0.016 UJ	< 0.019 UJ	---	---	---	< 0.036 UJ	E18	
PFFASB30	50	05-Jan-94	< 0.018 UJ	0.011 JB	---	---	---	0.009 JB	E18	
PFFASB31	20	06-Jan-94	0.006 J	0.013 JB	---	---	---	0.015 J	E18	
PFFASB31	40	06-Jan-94	0.003 J	0.009 JB	---	---	---	0.013 J	E18	FC12=0.0015 J
PFFASB31	50	06-Jan-94	0.004 J	0.009 JB	---	---	---	0.01 J	E18	
PFFASB32	20	06-Jan-94	< 3.2 UJ	< 3.8 UJ	---	---	---	2.3 J	E18	
PFFASB32	40	06-Jan-94	0.035 J	0.026 JB	---	---	---	< 0.52 UJ	E18	
PFFASB32	55	06-Jan-94	< 2.4 UJ	< 2.8 UJ	---	---	---	< 5.2 UJ	E18	
PFFASB33	20	07-Jan-94	0.009 J	0.038 JB	---	---	---	0.069 B	E18	TCA111=0.005 J
PFFASB33	40	07-Jan-94	0.004 J	0.049 JB	---	---	---	0.006 JB	E18	
PFFASB33	55	07-Jan-94	0.004 J	0.023 JB	---	---	---	0.034 B	E18	
PFFASB34	20	14-Mar-94	< 4.0 UJ	< 4.0 UJ	< 4.0 UJ	< 4.0 UJ	< 4.0 UJ	---	SGVOCS	

VOLATILE ORGANIC CO[illegible] ATIONS IN SOIL GAS SAMPLES

G/SOIL GAS LOCATION	DEPTH (ft bgs)	SAMPLING DATE	BZ (µg/L)	BZME (µg/L)	Z (µg/L)	XYLMP (µg/L)	XYLO (µg/L)	XYLENES (µg/L)	LAB METHOD	OT[illegible]: (µg/L)
PFFASB34	40	14-Mar-94	< 4.0 UJ	96.0 JN	26.0 JN	13.0 JN	70.0 JN	---	SGVOCS	
PFFASB35	20	15-Mar-94	< 4.0 UJ	< 4.0 UJ	< 4.0 UJ	< 4.0 UJ	< 4.0 UJ	---	SGVOCS	
PFFASB35*	40	15-Mar-94	< 4.0 UJ	150.0 JN	20.0 JN	9.0 JN	1.6 JNB	---	SGVOCS	TCE = 1.3 JNB
PFFASB36	20	16-Mar-94	640.0 JN	160.0 JN	4.1 JN	43.0 JN	4.7 JNB	---	SGVOCS	
PFFASB36	40	16-Mar-94	< 4.0 UJ	< 4.0 UJ	< 4.0 UJ	< 4.0 UJ	< 4.0 UJ	---	SGVOCS	
PFFASB37	20	16-Mar-94	290.0 JN	27.0 JN	< 4.0 UJ	71.0 JN	26.0 JNB	---	SGVOCS	
PFFASB37	40	16-Mar-94	200.0 JN	45.0 JN	17.0 JN	200.0 JN	7.1 JNB	---	SGVOCS	
PFFASB38	20	18-Mar-94	< 4.0 UJ	< 4.0 UJ	< 4.0 UJ	< 4.0 UJ	< 4.0 UJ	---	SGVOCS	
PFFASB38	40	18-Mar-94	52.0 JN	18.0 JN	83.0 JN	230.0 JN	77.0 JN	---	SGVOCS	
PFFASB39	20	17-Mar-94	340.0 JN	120.0 JN	850.0 JN	75.0 JN	25.0 JNB	---	SGVOCS	
PFFASB39	40	17-Mar-94	460.0 JN	190.0 JN	50.0 JN	120.0 JN	44.0 JN	---	SGVOCS	
PFFASG01	5	13-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG01	10	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG02	5	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG02	10	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG03	5	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG03*	10	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG04	5	13-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG04	10	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG05	5	13-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG05	10	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG06	5	13-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG06	10	15-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG07	5	13-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG07	10	15-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG08	5	15-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG08	10	15-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG09	5	13-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG09	10	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG10	5	13-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG10	10	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	

TABLE FFA.SG
VOLATILE ORGANIC CONCE ATIONS IN SOIL GAS SAMPLES

BORING/SOIL GAS LOCATION	DEPTH (ft bgs)	SAMPLING DATE	BZ (µg/L)	BZME (µg/L)	EBZ (µg/L)	XYLMP (µg/L)	XYLO (µg/L)	XYLENES (µg/L)	LAB METHOD	OTHER: (µg/L)
PFFASG11	5	13-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG11	10	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG12	5	13-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG12	10	15-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG13	5	13-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG13	10	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG14	5	13-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG14	10	15-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG16	5	13-Sep-93	265.8 JN	242.9 JN	86.1 JN	175.7 JN	144.2 JN	---	SGVOCS	
PFFASG16	10	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG17	5	13-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG17	10	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG18	5	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG18	10	15-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	6.5 JN	---	SGVOCS	
PFFASG19	5	13-Sep-93	< 1.0 UJ	3.1 JN	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG19	10	14-Sep-93	< 1.0 UJ	87.5 JN	< 1.0 UJ	< 1.0 UJ	38.2 JN	---	SGVOCS	
PFFASG20	5	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG20	10	15-Sep-93	< 1.0 UJ	< 1.0 UJ	267.8 J	328.4 J	< 1.0 UJ	---	SGVOCS	
PFFASG20-D*	10	15-Sep-93	< 1.0 UJ	< 1.0 UJ	235.6 J	286.4 J	79.3 JN	---	SGVOCS	
PFFASG21	5	21-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG21	10	23-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG22	5	21-Sep-93	< 1.0 UJ	< 1.0 UJ	4.2 JN	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG22	10	23-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG23	5	21-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG23	10	23-Sep-93	222.4 JN	< 1.0 UJ	34.6 JN	32.6 JN	< 1.0 UJ	---	SGVOCS	
PFFASG24	5	21-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG24	10	21-Sep-93	< 1.0 UJ	5.7 JN	3.8 JN	2.1 JN	< 1.0 UJ	---	SGVOCS	
PFFASG25	5	21-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG25	10	21-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG26	5	20-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG26	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	

T. FFA.SG

VOLATILE ORG[illegible]ON[illegible] ATIONS IN SOIL GAS SAMPLES

BORING/SOIL GAS LOCATION	DEPTH (ft bgs)	SAMPLING DATE	BZ (µg/L)	BZME (µg/L)	EBZ (µg/L)	XYLMP (µg/L)	XYLO (µg/L)	XYLENES (µg/L)	LAB METHOD	OTHER: (µg/L)
PFFASG27	5	20-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG27	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG28	5	20-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG28	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG29	5	21-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG29	10	21-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG30	5	21-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG30	10	23-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG31	5	20-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG31	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG32	5	20-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG32 •	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG33	5	20-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG33	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG35 •	5	21-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG35	10	21-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG36	5	21-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG36 •	10	23-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG37	5	21-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG37	10	23-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	TCE = 1.5 JN
PFFASG38	5	20-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG38	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG39	5	20-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG39	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG40 •	5	20-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG40	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG41	5	20-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG41	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG42	5	20-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG42	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	

TABLE PFFA.SG
VOLATILE ORGANIC CONCENTRATIONS IN SOIL GAS SAMPLES

BORING/SOIL GAS LOCATION	DEPTH (ft bgs)	SAMPLING DATE	BZ (µg/L)	BZME (µg/L)	EBZ (µg/L)	XYLMP (µg/L)	XYLO (µg/L)	XYLENES (µg/L)	LAB METHOD	OTHER: (µg/L)
PFFASG43	5	20-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG43 *	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG44	5	20-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG44	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG45	5	21-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG45	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG46	5	20-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG46	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG47	5	21-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG47	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG48	5	21-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG48	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG49	5	20-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG49	10	22-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG50	5	13-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG50	10	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG51	5	13-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG51	10	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG52	5	13-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG52 *	10	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG53	5	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
PFFASG53	10	14-Sep-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
SS8SB01	10	04-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
SS8SB01	20	04-Oct-93	< 1.0 UJ	51.3 JN	21.4 JN	6.4 JN	6.4 JN	---	SGVOCS	
SS8SB02	10	30-Sep-93	< 1.0 UJ	1.3 JN	7.0 JN	6.2 JN	< 1.0 UJ	---	SGVOCS	
SS8SB02	20	30-Sep-93	< 1.0 UJ	< 1.0 UJ	3.7 JN	2.7 JN	< 1.0 UJ	---	SGVOCS	
SS8SB03	10	30-Sep-93	< 1.0 UJ	< 1.0 UJ	3.6 JN	2.6 JN	< 1.0 UJ	---	SGVOCS	
SS8SB03	20	30-Sep-93	< 1.0 UJ	3.0 JN	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
SS8SB04	10	30-Sep-93	< 1.0 UJ	< 1.0 UJ	1.7 JN	1.6 JN	< 1.0 UJ	---	SGVOCS	
SS8SB04	20	30-Sep-93	< 1.0 UJ	1.0 JN	3.2 JN	1.5 JN	< 1.0 UJ	---	SGVOCS	
SS8SB05	10	01-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	

TA PFFA.SG

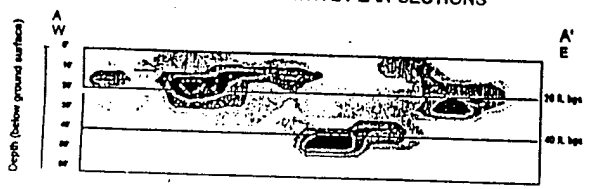
VOLATILE ORG ONC. ATIONS IN SOIL GAS SAMPLES

BORING/SOIL GAS LOCATION	DEPTH (ft bgs)	SAMPLING DATE	BZ (µg/L)	BZME (µg/L)	EBZ (µg/L)	XYLMP (µg/L)	XYLO (µg/L)	XYLENES (µg/L)	LAB METHOD	OTHER: (µg/L)
SS8SB05	20	01-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
SS8SB06	10	01-Oct-93	< 1.0 UJ	2.3 JN	1.9 JN	2.1 JN	< 1.0 UJ	---	SGVOCS	
SS8SB06	20	01-Oct-93	< 1.0 UJ	< 1.0 UJ	9.7 JN	3.9 JN	< 1.0 UJ	---	SGVOCS	
SS8SB06	40	01-Oct-93	< 1.0 UJ	< 1.0 UJ	54.7 JN	38.5 JN	< 1.0 UJ	---	SGVOCS	
SS8SB07	10	01-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
SS8SB07	20	01-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
SS8SB08	20	05-Oct-93	< 1.0 UJ	256.6 JN	54.1 JN	17.0 JN	< 1.0 UJ	---	SGVOCS	
SS8SB08	40	05-Oct-93	< 1.0 UJ	2.9 JN	1.3 JN	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	
SS8SB08	55	05-Oct-93	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	< 1.0 UJ	---	SGVOCS	

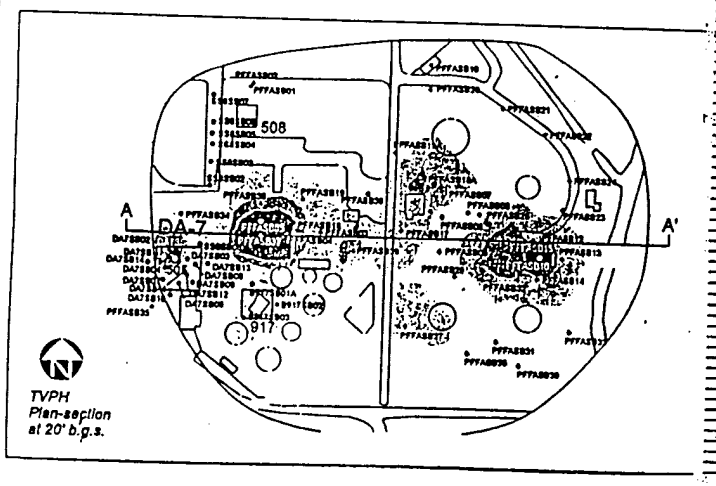
NOTES:

<, U	Analyte was not detected. Analyte concentration is below the Reporting Quantitation Limit.
---	Not Analyzed
J	Analyte concentration is an estimated value.
B	Analyte was detected in field blank.
N	Tentatively identified
R	Rejected
(µg/L)	Micrograms per Liter
ft bgs	Feet Below Ground Surface
BZ	Benzene
BZME	Toluene
DCE11	1,1-Dichloroethene
DCE12C	cis-1,2-Dichloroethene
EBZ	Ethylbenzene
FC11	Trichlorofluoromethane
-D	Duplicate Sample
FC12	Dichlorodifluoromethane
PCE	Tetrachloroethene
TCE	Trichloroethene
VC	Vinyl Chloride
XYLMP	m- and p-Xylenes
XYLO	o-xylene
•	See TO14 table for regulatory duplicate results associated with this sample.

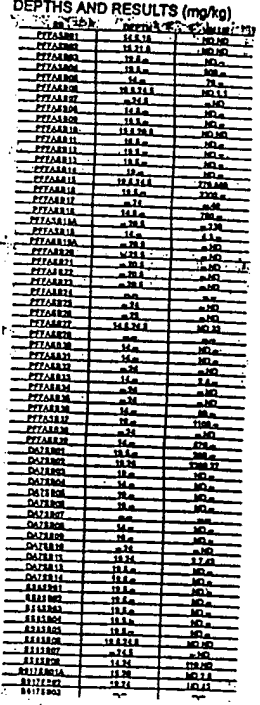
CROSS-SECTION WITH 2 PLAN-SECTIONS

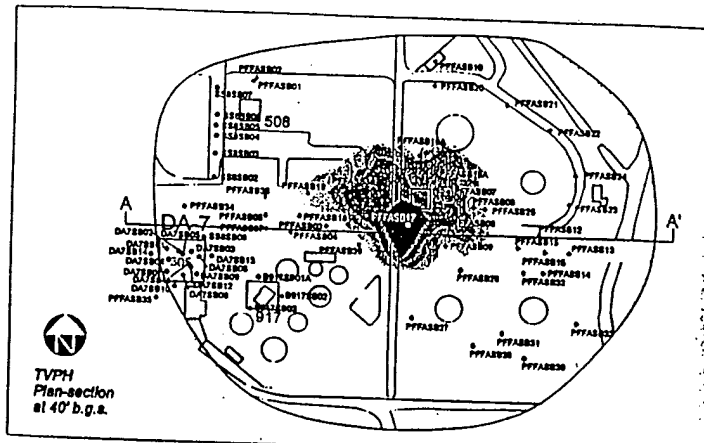


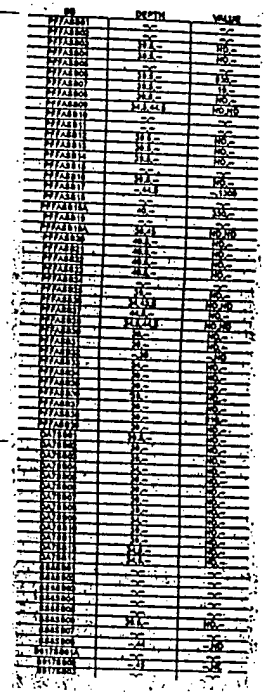
Cross-section A-A' showing TVPH (Gasoline) Above 0.68 mg/kg



ANALYTICAL DATA
NEAREST SAMPLED
DEPTHS AND RESULTS (mg/kg)







LEGEND

- PFFASSOO SOIL BORING (JEG, 1993)
- >0.68 mg/kg
- >100 mg/kg
- >500 mg/kg
- >1000 mg/kg
- A — A' LINE OF SECTION

0 300 600
SCALE (IN FEET)

ND - Not detected (below reporting limit shown on Data Table)

NOTE: The tables provide only those data proximal to the slice elevations. Refer to summary data table for complete listing.

NOTE: The Cross-section and Plan-sections represent one foot thick slices of a three-dimensional isosurface interpreted by an inverse distance algorithm.

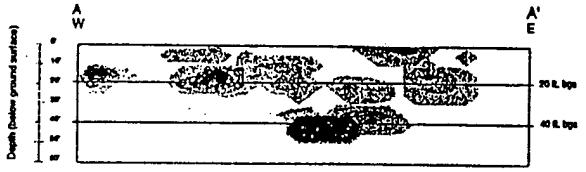
SOURCE: Jacobs, 1995.

ESTIMATED EXTENT OF TVPH CONTAMINATION IN SOIL
PFFA
Castle Airport, California

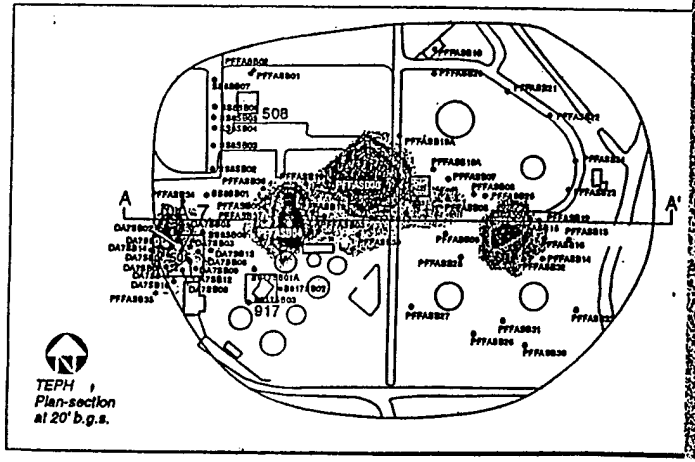
PARSONS ENGINEERING SCIENCE, INC.
Oakland, California

\731297\WORKPLAN\BIOVFIGS_L11.CDR 11/26/97

CROSS-SECTION WITH 2 PLAN-SECTIONS

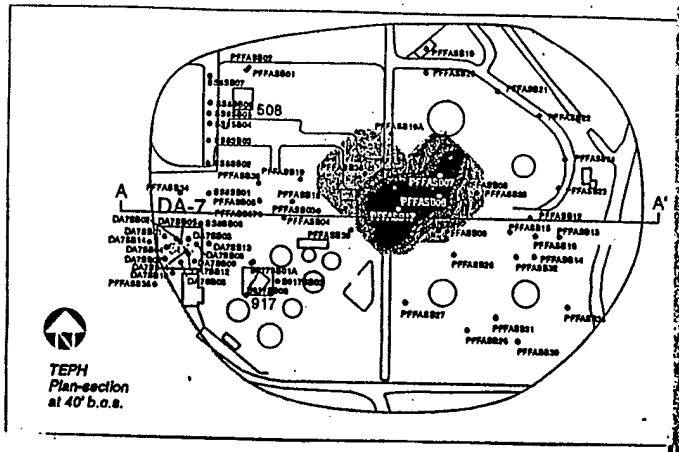


Cross-section A-A' showing TEPH (Diesel) Above 2.3 mg/kg



TEPH Plan-section at 20' b.g.s.

ANALYTICAL DATA
NEAREST SAMPLED
DEPTHS AND RESULTS (mg/kg)



TEPH Plan-section at 40' b.o.s.

LEGEND

- PFFASB06 SOIL BORING (JEQ, 1993)
- >2.3 mg/kg
- >100 mg/kg
- >500 mg/kg
- >1000 mg/kg
- A — A' LINE OF SECTION

0 300 600
SCALE (IN FEET)

ND - Not detected (below reporting limit shown on Data Table)

NOTE: The tables provide only those data proximal to the slice elevations. Refer to summary data table for complete listing.

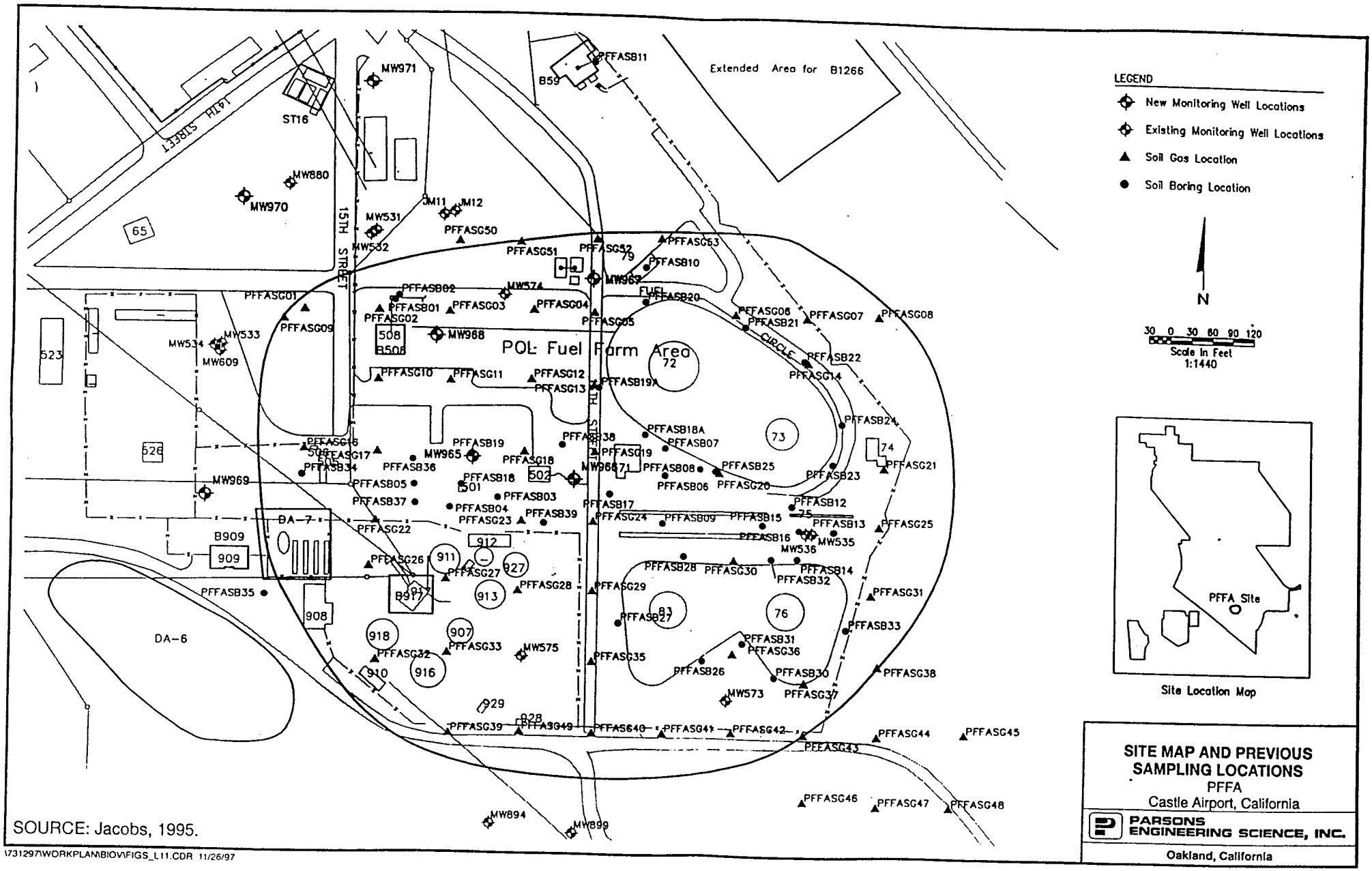
NOTE: The Cross-section and Plan-sections represent one foot thick slices of a three-dimensional isosurface interpreted by an inverse distance algorithm.

ESTIMATED EXTENT OF TEPH CONTAMINATION IN SOIL
PFFA
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.
Oakland, California

SOURCE: Jacobs, 1995.

\731297\WORKPLAN\BIOV\FIGS_L11.CDR 11/26/97



SITE MAP AND PREVIOUS SAMPLING LOCATIONS
PFFA
Castle Airport, California

PARSONS ENGINEERING SCIENCE, INC.
Oakland, California

\731297\WORKPLAN\BIOV\FIGS_L11.CDR 11/26/97

APPENDIX B

GEOLOGIC BORING LOGS, CPT ELECTRONIC LOGS, AND WELL CONSTRUCTION DATA

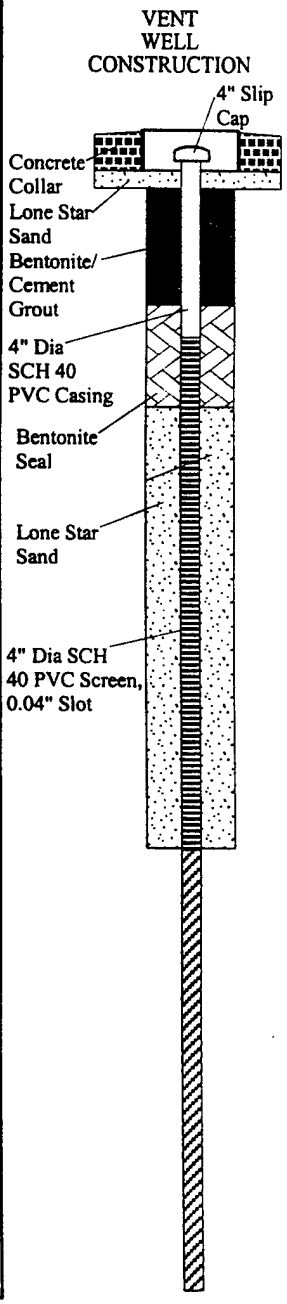
PARSONS ENGINEERING SCIENCE, INC.

BORING NUMBER: PFFA VW 01

PROJECT NUMBER: 731297.03000	**PROJECT NAME:** Castle AFB Risk-Based Remediation
CLIENT: AFCEE	
LOCATION: PFFA	**DRILLER:** West Hazmat
Castle Air Force Base, California	**DRILLING METHOD:** HSA
GEOLOGIST: JFH/MLP	**HOLE DIAMETER:** 10"
COMPLETION DATE: 12/16/97	**TOTAL DEPTH:** 34'

DEPTH (feet)	GW ELEVATION	SAMPLE NUMBER	SAMPLE LOCATION	Headspace Screening: Background/ Breathing Zone (PID)	Headspace Screening: Sample (PID)	BLOW COUNT	USCS SOIL CLASS	GEOLOGIC DESCRIPTION
0								6" Asphalt, road base
				0/2	0/2	32 23 19		Sand, f-md, md brn, v. moist, tr. clay, silt no odor
				0/0	0/0		SP	Sand, v.f.-md, md brn, moist, tr. silt, no odor
5				0/0	0/0	35 50 60		SAA no odor, grey & brn
								SAA abundant micas
					3/10	18 30 42	ML	SILT, moist, clay (<10%), micas, f. sand (<10%), olive green to grey
						18	SM	Silty SAND (SM), fine sand, moist, olive grey green to grey, abundant micas
10					0/10	27 32 60		SAA, v. hard
				0/0	0/4			SAA, brn, more sand (v.f.) @ 13'
					0/0		SP	Sand, vf-coarse, md brn, moist, no odor
15					129/120	28 50 - 50	SM	Silty SAND, f sand, moist, sl. Hc odor, partially cemented grey-brown
					10.6/7	37 50-2"		SAA, f-md., <10% coarse, fuel odor
20					1027/ 1100			SAA, 6" vf sand & silt @ 20, fuel odor
					1300/ 1600	29 55	ML	SILT, sm clay, tr coarse sand (cemented), olive-grey, Hc odor, v. moist
					1450/ 1700			SAA, Fe stain, some drk grey stain, strong Hc odor, moist
25					2500/ 4000			SAA
					2550/ 4800	26 28 -	SP	SAND, f-md, grey, strg Hc odor, v. moist, mica, mostly f. grained
					2930/ 4800	9 11 13 17		SAA, fine, grey stg Hc odor, moist, mica
30					2910/ 6100	11 19 20 27		SAA, fine ~10% md., strg Hc odor, moist, lt. grey-tan
				0.7/0.7	2990/ 7400			SAA stg Hc odor

(see next page)



▽ - First encountered groundwater. — - Contact location. ■ - Shading indicates percent recovery in sampler.

▼ - Equilibrated groundwater level. ---- - Approximate contact location. NR - Not Recorded □ - Drive sample.

*Sample submitted for laboratory analysis

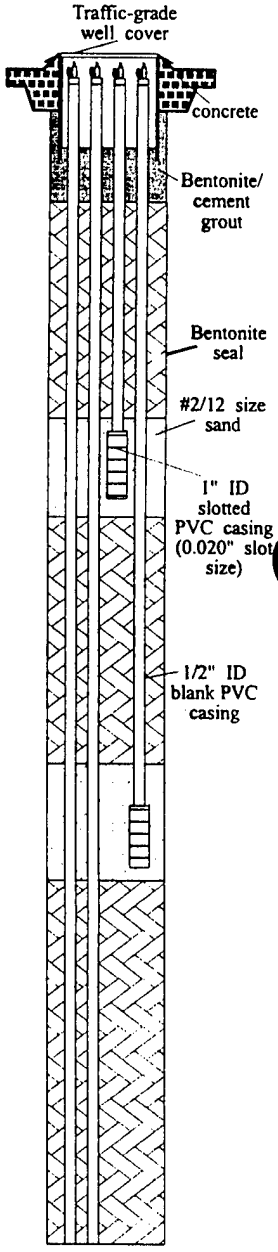
PARSONS ENGINEERING SCIENCE, INC.

BORING NUMBER: PFFA VMP14

PROJECT NUMBER: 731297.03000	**PROJECT NAME:** Castle AFB Risk-Based Remediation
CLIENT: Castle Air Force Base	
LOCATION: PFFA	**DRILLER:** West Hazmat
Castle Air Force Base, California	**DRILLING METHOD:**
GEOLOGIST: JFH	**HOLE DIAMETER:** 8"
COMPLETION DATE: 12/16/97	**TOTAL DEPTH:** 61'

DEPTH (feet)	GW ELEVATION	SAMPLE NUMBER	SAMPLE LOCATION	Headspace Screening: Background/ Breathing Zone (PID)	Headspace Screening: Sample (PID)	BLOW COUNT	USCS SOIL CLASS	GEOLOGIC DESCRIPTION
0								6" Asphalt / road base SAND, f-m, orange-brn, moist, no odor, tr silt
5					12.9/6			SAA
10					11.7/10			SAND, f, tr silt & clay, md. brn, moist no odor
15					9.4/26			SAND, fine, tr silt, md. brn, v. moist - wet, no odor
20					14/12	35 50		SAND, vf.-f., silty, clayey, grey-brn, moist no odor
					12.2/22	34 38		SILT, tr clay, olive-blue-grey, moist no odor
25					29.8/32	19 21 37		SAA SAND fine, some med. grey, Fe stain, sl. Hc odor, sl. cemented
30				0.0/0.2	144/120			SAND, f-md, grey, moist, Hc odor, dk grey stain (see next page)

VAPOR MONITORING POINT CONSTRUCTION



▽ - First encountered groundwater. — - Contact location. ■ - Shading indicates percent recovery in sampler.

▼ - Equilibrated groundwater level. ---- - Approximate contact location. NR - Not Recorded ▯ - Drive sample.

*Sample submitted for laboratory analysis

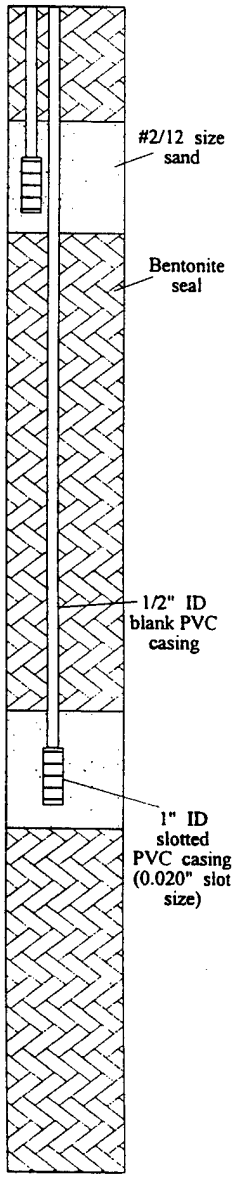
BORING NUMBER: PFFA VMP14

PROJECT NUMBER: 731297.03000	**PROJECT NAME:** Castle AFB Risk-Based Remediation
CLIENT: Castle Air Force Base	
LOCATION: PFFA	**DRILLER:** West Hazmat
Castle Air Force Base, California	**DRILLING METHOD:**
GEOLOGIST: JFH	**HOLE DIAMETER:** 8 inches
COMPLETION DATE: 12/16/97	**TOTAL DEPTH:** 61'

DEPTH (feet)	GW ELEVATION	SAMPLE NUMBER	SAMPLE LOCATION	Headspace Screening: Background/ Breathing Zone (PID)	Headspace Screening: Sample (PID)	BLOW COUNT	USCS SOIL CLASS	GEOLOGIC DESCRIPTION
30				0.0/0.2	144/120			SAND, f-med, grey, moist, Hc odor, dk grey stain
35					1430/ 1600	28 50		SAA SILT, olive grey, Fe stain, moist, Hc odor, ~30% vf sand
40					2100/ 710K	37 50		SILT, & f-vf SAND, Fe stain, stg. HC odor, moist
					2050/ 710K			SAND, f. some md, grey, stg Hc odor moist
45					2100/ 710K			SAA, stg Hc odor
50					585/1100			SAA, stg odor @ 49, sl. odor @ 51.5, Fe stain
55					250/280			SAND, s-m, grey, moist, no odor
60					565/980			SAA, SI odor

(see next page)

VAPOR MONITORING POINT CONSTRUCTION



▽ - First encountered groundwater. — - Contact location. ■ - Shading indicates percent recovery in sampler.

▼ - Equilibrated groundwater level. ---- - Approximate contact location. NR - Not Recorded □ - Drive sample.

*Sample submitted for laboratory analysis

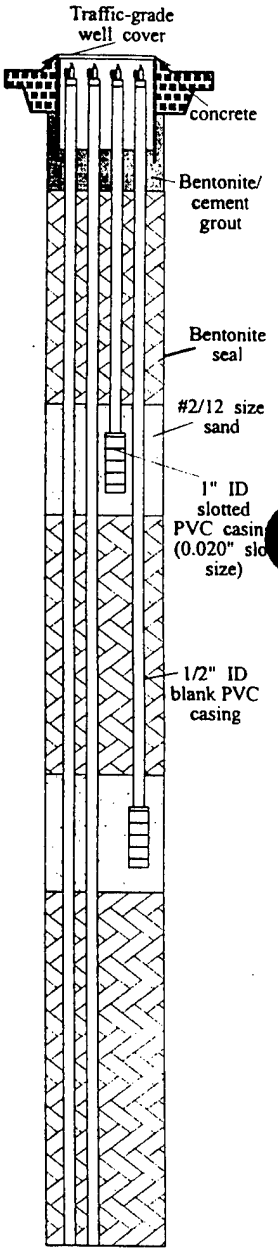
PARSONS ENGINEERING SCIENCE, INC.

BORING NUMBER: PFFA VMP15

PROJECT NUMBER: 731297.03000	**PROJECT NAME:** Castle AFB Risk-Based Remediation
CLIENT: AFCEE	
LOCATION: PFFA	**DRILLER:** West Hazmat
Castle Air Force Base, California	**DRILLING METHOD:** HSA CME75
GEOLOGIST: JFH	**HOLE DIAMETER:** 8"
COMPLETION DATE: 12/16/97	**TOTAL DEPTH:** 59'

DEPTH (feet)	GW ELEVATION	SAMPLE NUMBER	SAMPLE LOCATION	Headspace Screening: Background/ Breathing Zone (PID)	Headspace Screening: Sample (PID)	BLOW COUNT	USCS SOIL CLASS	GEOLOGIC DESCRIPTION
0								6" Asphalt / road base SAND, f-m, md brn, moist (cuttings)
5					16/8	20 26 42		SAND, fine, md brn, moist, tr silt, moist, no odor
10					19.4/16	17 22 37		Silty SAND, fine, sm silt, lt-md brn, moist, no odor
					19.4/12	18 22 50		SAND, fine, tr silt, v. moist, md red-brn, no odor
15					4.9/10			SAND, fine-md, silty, orange-brn, moist, no odor
				0.0	5.4/22			SAA, grey silt (4") at 17.5
20					2.9/22			SAA, no silt
					21/32			SILT, grey, v. moist-wet, mica, Fe stain, no odor
25					113/78			SAND, fine, tr md grained, grey, moist, stg Hc odor
					111/110			SAA, Hc odor f-md grained
30				0.0/0.0	61.4/40			(see next page)

VAPOR MONITORING POINT CONSTRUCTION



▽ - First encountered groundwater. — - Contact location. ■ - Shading indicates percent recovery in sampler.

▼ - Equilibrated groundwater level. ---- - Approximate contact location. NR - Not Recorded ▯ - Drive sample.

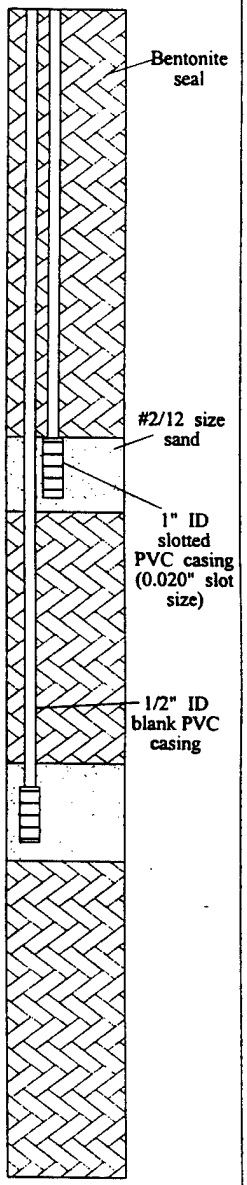
*Sample submitted for laboratory analysis

BORING NUMBER: PFFA VMP15

PROJECT NUMBER: 731297.03000	**PROJECT NAME:** Castle AFB Risk-Based Remediation
CLIENT: Castle Air Force Base	
LOCATION: PFFA	**DRILLER:** West Hazmat
Castle Air Force Base, California	**DRILLING METHOD:**
GEOLOGIST: JFH	**HOLE DIAMETER:** 8 inches
COMPLETION DATE: 12/16/97	**TOTAL DEPTH:** 59'

DEPTH (feet)	GW ELEVATION	SAMPLE NUMBER	SAMPLE LOCATION	Headspace Screening: Background/ Breathing Zone (PID)	Headspace Screening: Sample (PID)	BLOW COUNT	USCS SOIL CLASS	GEOLOGIC DESCRIPTION
30				0.0/0.0	61.4/40			SAND, f-m, ~5% coarse, grey, moist Hc odor
35					3.3/280			SAA Silty Sand, fine, grey-brn, moist Hc odor
40					690/640			2" - SAA SILT, and fine-gr SAND, grey-olive grey, Fe stain, sl odor, moist
					1801/ 4700			SAA to 42.2 SAND f-md, lt grey, moist, stg Hc odor
45						10 20 16 26		
				0.0/0.1	41/58			SAA, tr. coarse gr. sl odor Fe stain
50						10 16 43 40		
					23/18			SAA, no odor
55				0.0/0.0	10.7/6			SAA, less med. grained, sl. Hc odor
					24/18			SAA
60								(see next page)

VAPOR MONITORING POINT CONSTRUCTION



▽ - First encountered groundwater. — - Contact location. ■ - Shading indicates percent recovery in sampler.

▼ - Equilibrated groundwater level. ---- - Approximate contact location. NR - Not Recorded □ - Drive sample.

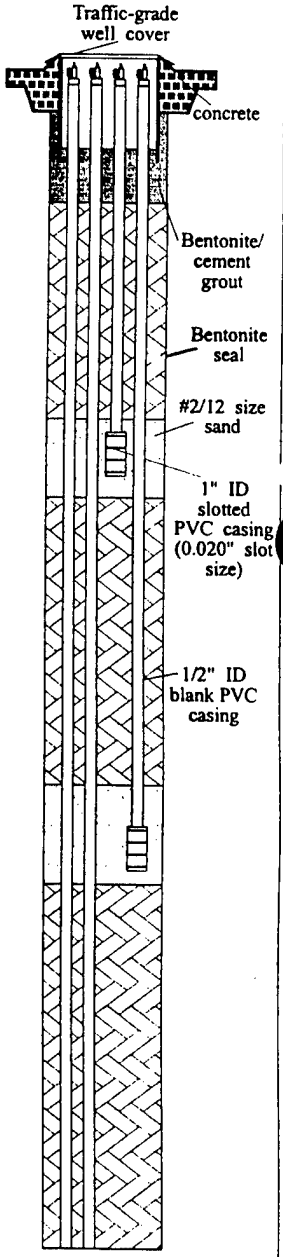
*Sample submitted for laboratory analysis

BORING NUMBER: PFFA VMP16

PROJECT NUMBER: 731297.03000	**PROJECT NAME:** Castle AFB Risk-Based Remediation
CLIENT: AFCEE	
LOCATION: PFFA	**DRILLER:** West Hazmat
Castle Air Force Base, California	**DRILLING METHOD:**
GEOLOGIST: JFH	**HOLE DIAMETER:** 8"
COMPLETION DATE: 12/17/97	**TOTAL DEPTH:** 61'

DEPTH (feet)	GW ELEVATION	SAMPLE NUMBER	SAMPLE LOCATION	Headspace Screening: Background/ Breathing Zone (PID)	Headspace Screening: Sample (PID)	BLOW COUNT	USCS SOIL CLASS	GEOLOGIC DESCRIPTION
0								6" Asphalt / road base
5					5.8/4			SAND, f., moist, tr. silt, 10YR4/4 no order
10					5.9/7			SAND, v.f., & SILT, tr. clay, moist, no odor 5Y6/2 SAND, m-c, silty, moist 10YR4/4
15				0.0/0.0	8.6/7			Interbedded SAND, f & sand f-c., moist, silty, sl. cemented 7.5YR5/6 no odor
20						50 50		SAND, f-m, tr. silt, moist, no odor 2.5Y5/3
				0.0/0.0	1.3/8	58 70		SAND, v.f, silty, moist Fe stain, no odor, 5/5BG
					1.6/8	37 50		SILT, Fe stain on fractions, 5/10BG
25					18.3/30	21 32 48		SAND, f, moist, sl Hc odor, 5Y7/1 silty 24.5-25
30				0.0/0.0	7.8/10	11 19 33		SAND, f-m, some coarse, moist, no odor, 5Y7/1 (see next page)

VAPOR MONITORING POINT CONSTRUCTION



▽ - First encountered groundwater. — - Contact location. ■ - Shading indicates percent recovery in sampler.

▼ - Equilibrated groundwater level. ---- - Approximate contact location. NR - Not Recorded ▯ - Drive sample.

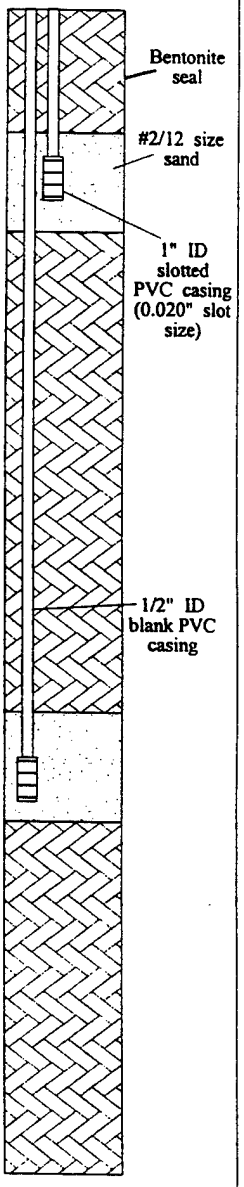
*Sample submitted for laboratory analysis

BORING NUMBER: PFFA VMP16

PROJECT NUMBER: 731297.03000	**PROJECT NAME:** Castle AFB Risk-Based Remediation
CLIENT: Castle Air Force Base	
LOCATION: PFFA	**DRILLER:** West Hazmat
Castle Air Force Base, California	**DRILLING METHOD:**
GEOLOGIST: JFH	**HOLE DIAMETER:** 8 inches
COMPLETION DATE: 12/17/97	**TOTAL DEPTH:** 61'

DEPTH (feet)	GW ELEVATION	SAMPLE NUMBER	SAMPLE LOCATION	Headspace Screening: Background/ Breathing Zone (PID)	Headspace Screening: Sample (PID)	BLOW COUNT	USCS SOIL CLASS	GEOLOGIC DESCRIPTION
30				0.0/0.0	1.8/10	11 19 33		SAND, f-m,some coarse, moist, no odor 5Y7/1
35					210/140			SAND, f-m, moist, sl Hc odor, Fe stain 5Y7/1
40				0.0/0.0	1239/ 1400			SILT, tr. v. f. sand, moist, sl Hc odor, 4/5G SAND, v. f. moist, sl Hc odor 2.5Y6/3
45					277/410	12 14 32		SAND, f-m, some coarse, moist, Fe stain, sl Hc odor 5Y7/3
50					262/280			SAA no odor
55				0.0/0.0	93.1/100	15 25 46		SAA, v. sl. odor
60					438/4N			SAA, sl. Hc odor (see next page)

VAPOR MONITORING POINT CONSTRUCTION



▽ - First encountered groundwater. — - Contact location. ■ - Shading indicates percent recovery in sampler.

▼ - Equilibrated groundwater level. ---- - Approximate contact location. NR - Not Recorded ☐ - Drive sample.

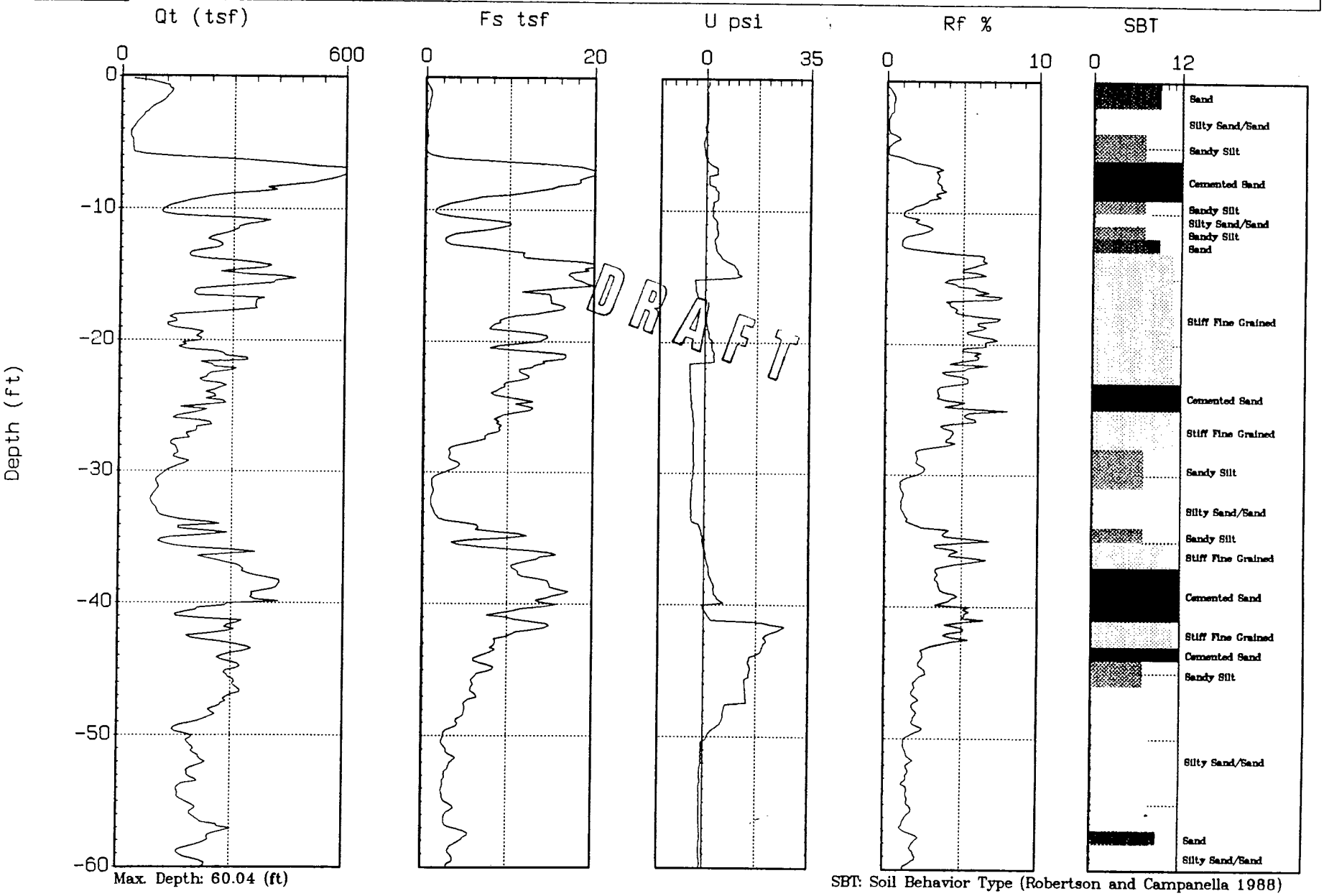
*Sample submitted for laboratory analysis

GREGG

PARSONS ENGINEERING

Site : PFFA
Location : SB-40

Geologist : M. PIERCE
Date : 03:04:98 12:34



Max. Depth: 60.04 (ft)

Depth Inc.: 0.164 (ft)

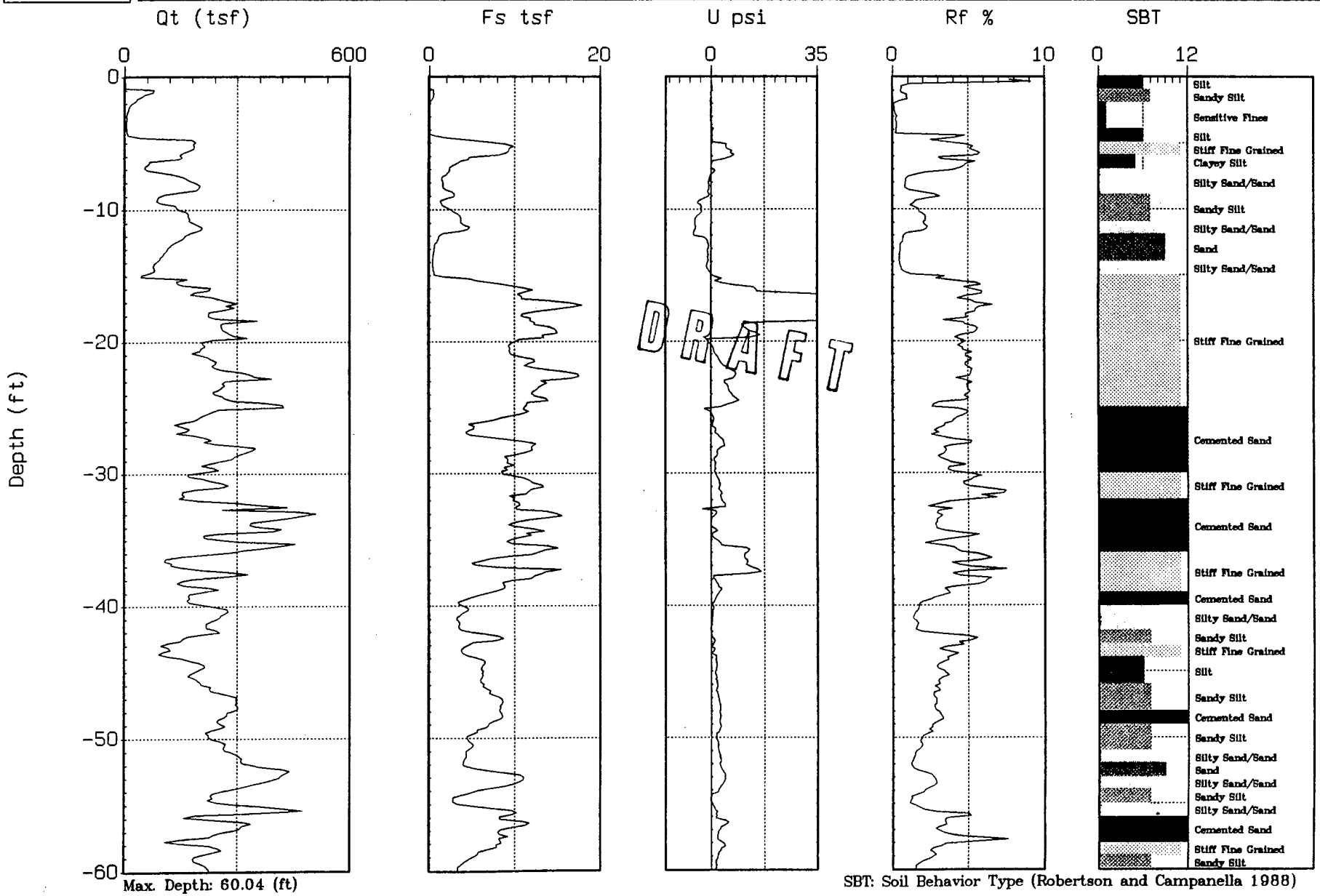
SBT: Soil Behavior Type (Robertson and Campanella 1988)

GREGG

PARSONS ENGINEERING

Site : PFFA
Location : SB-41

Geologist : M. PIERCE
Date : 03:04:98 09:03



Max. Depth: 60.04 (ft)

Depth Inc.: 0.164 (ft)

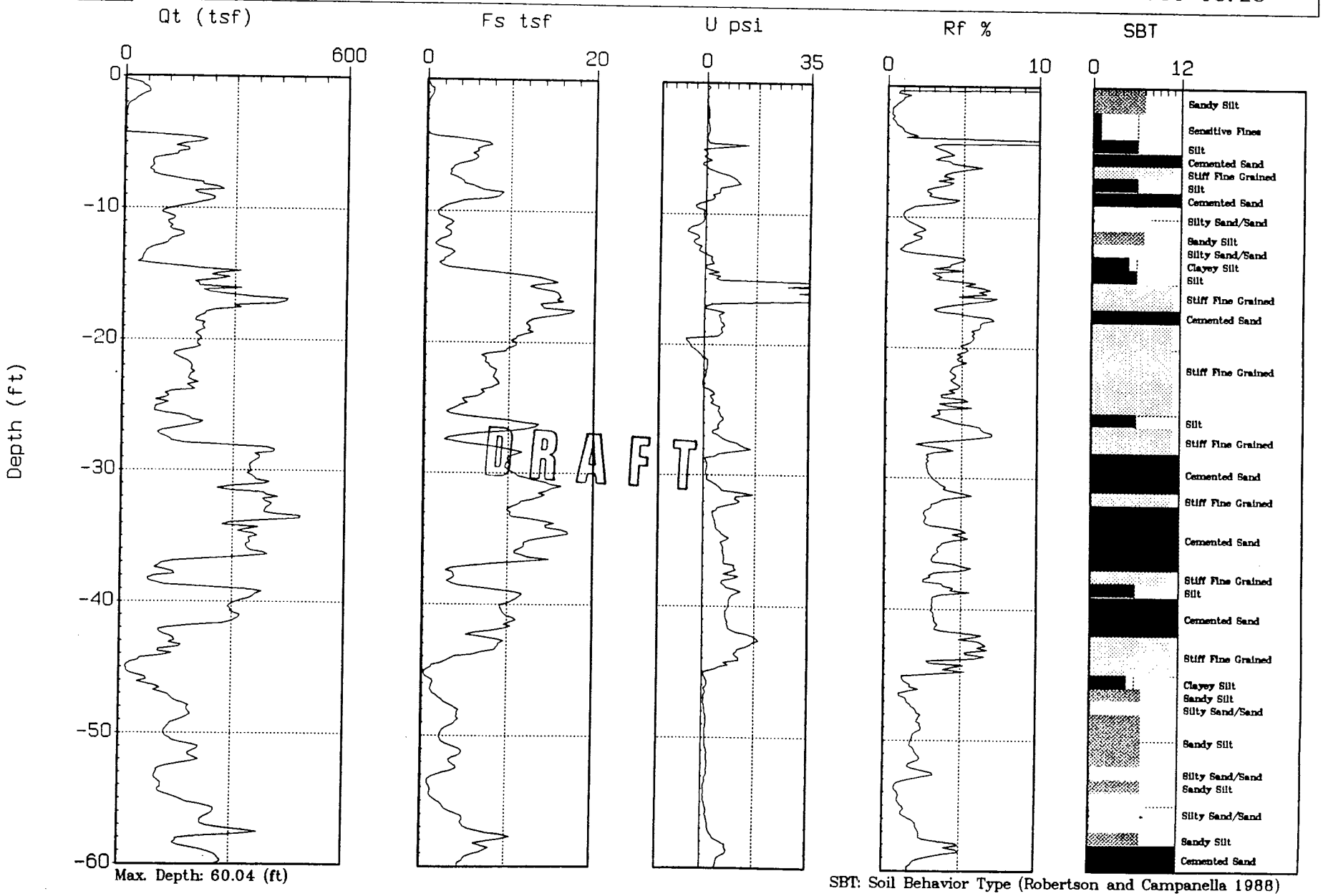
SBT: Soil Behavior Type (Robertson and Campanella 1988)

GREGG

PARSONS ENGINEERING

Site : PFFA
Location : SB-42

Geologist : M. PIERCE
Date : 03:04:98 10:29



Max. Depth: 60.04 (ft)

Depth Inc.: 0.164 (ft)

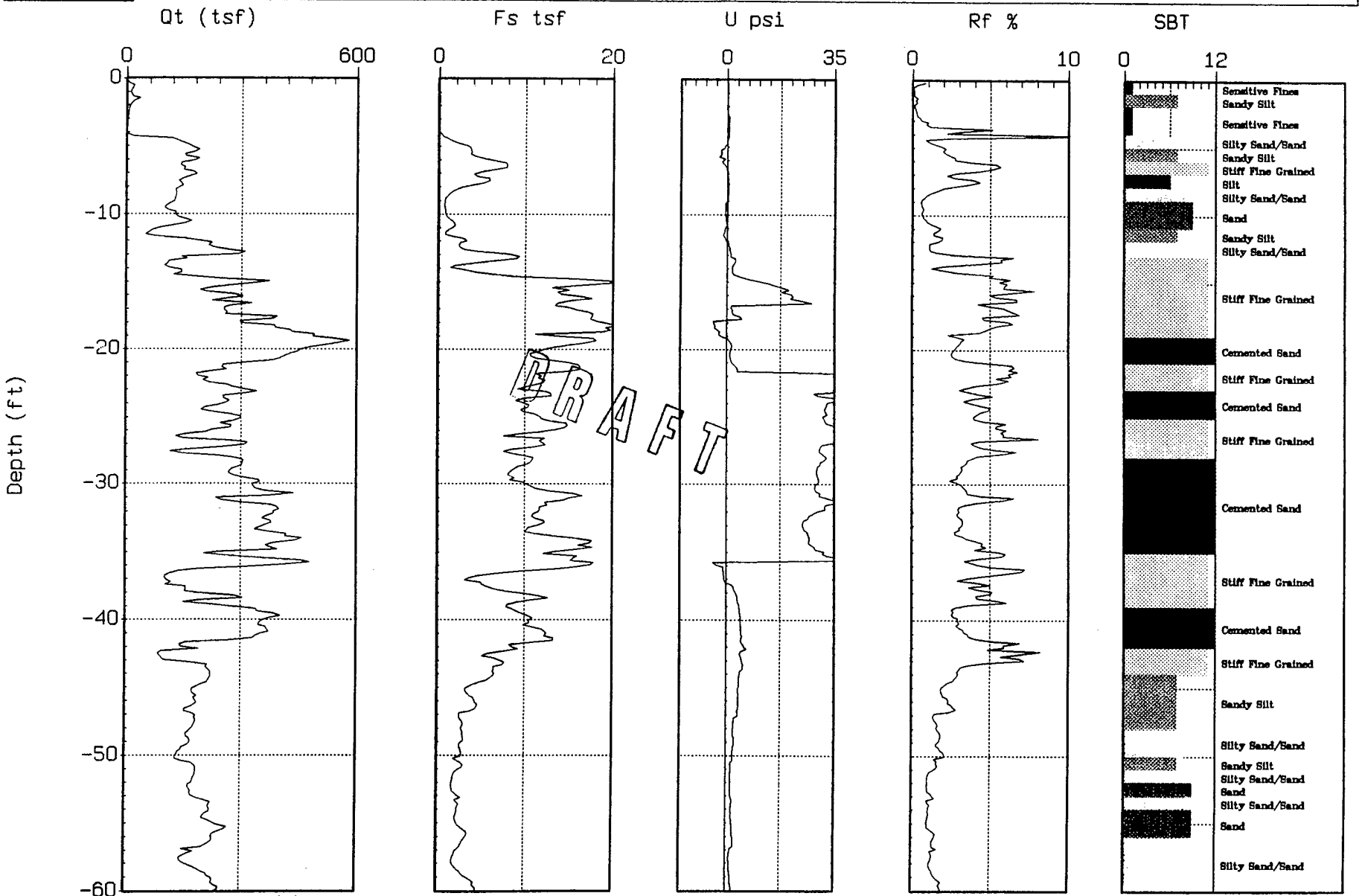
SBT: Soil Behavior Type (Robertson and Campanella 1988)

GREGG

PARSONS ENGINEERING

Site : PFFA
Location : SB-43

Geologist : M. PIERCE
Date : 03:04:98 11:26



Max. Depth: 60.04 (ft)

Depth Inc.: 0.164 (ft)

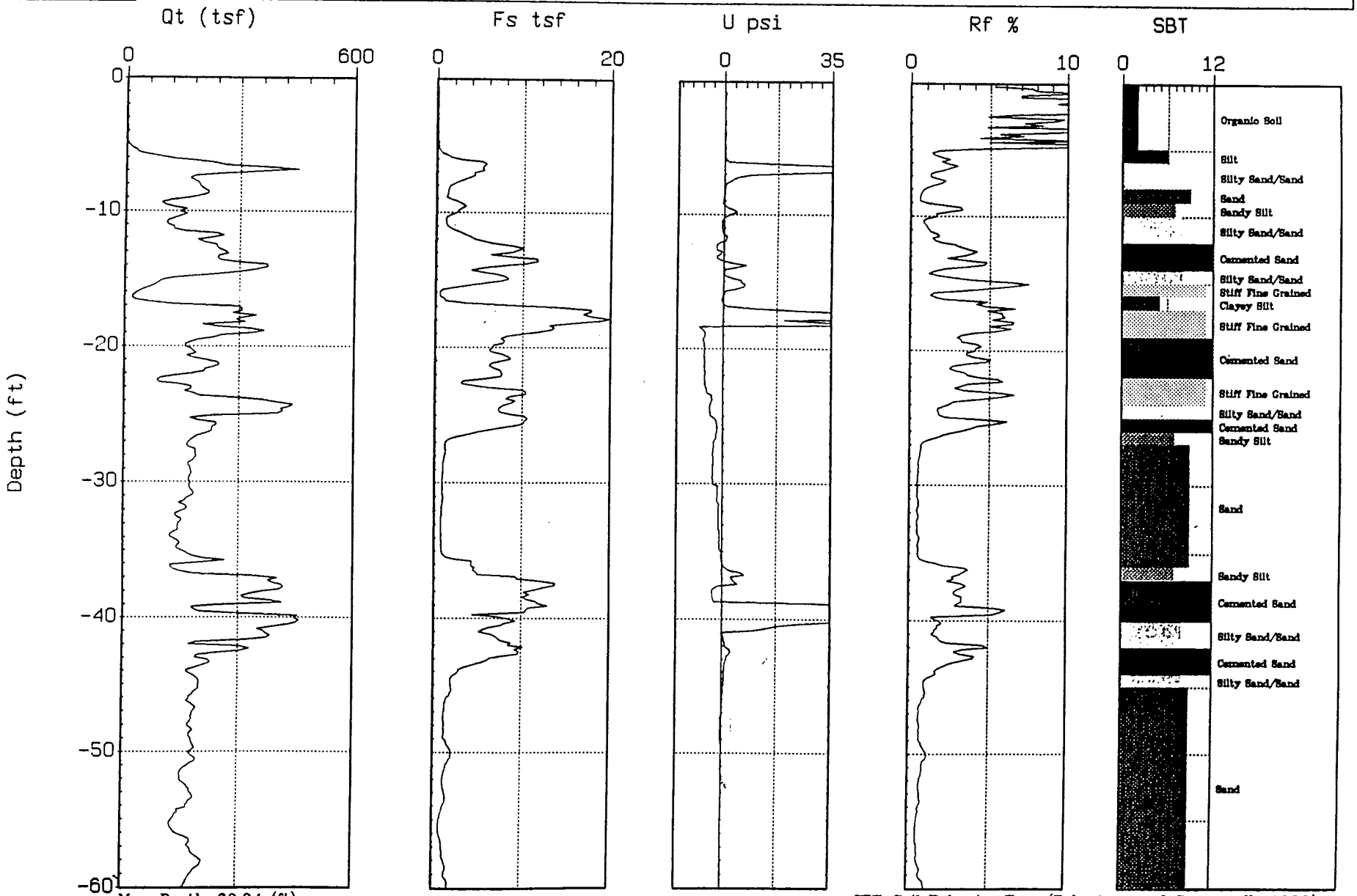
SBT: Soil Behavior Type (Robertson and Campanella 1988)

GREGG

PARSONS ENGINEERING

Site : PFFA
Location : VW02

Geologist : M. PIERCE
Date : 03:03:98 14:07



Max. Depth: 60.04 (ft)

Depth Inc.: 0.164 (ft)

SBT: Soil Behavior Type (Robertson and Campanella 1988)

WESTON

DRILLING LOG

WELL NUMBER: MW 270 OWNER: USAF
LOCATION: SLFZ - LF 2 Bldg 949 ADDRESS: Castle AFB
TOTAL DEPTH 105'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: Stang DRILLING METHOD: Mud Rotary DATE DRILLED: 11/05/1984
DRILLER: T.R. HELPER:
LOG BY: BWB/WWB

SKETCH MAP

NOTES:

DEPTH (FEET)	OVA/HNU	INTERVAL (FEET)	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0	0	0 - 10	Orange-brown SILTY fine SAND SC
	0		
10		10 - 15	Brown SILTY fine SAND w/some CLAYEY SILT lenses SC
		15 - 23	Light gray-brown CLAY (laminated) CL
20	0		
		23 - 28	Brown fine to medium SAND with some trace coarse quartz SAND SP
	0		
		28 - 43	Brown SILTY CLAY with trace coarse SAND CL
30	0		
	0		
40			

* A.S.T.M. D1586

WESTON

DRILLING LOG

WELL NUMBER: MW 270 OWNER: _____
LOCATION: _____ ADDRESS: _____
_____ _____
_____ TOTAL DEPTH _____
SURFACE ELEVATION: _____ WATER LEVEL: _____
DRILLING COMPANY: _____ DRILLING METHOD: _____ DATE DRILLED: _____
DRILLER: _____ HELPER: _____

LOG BY: BWB/WWB

SKETCH MAP

NOTES:

DEPTH (FEET)	OVA/HNU	INTERVAL (FEET)			DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
40					
	0	43	-	60	Brown CLAY with some medium to coarse SAND CL
50	0				
	0				
60					
	0	60	-	73	Variegated fine to coarse SAND micaceous SP
	0				
70					
	0	73	-	88	Variegated fine to coarse SAND and variegated fine to medium GRAVEL (sub-angular) (hard drilling) GP
80	0				

* A.S.T.M. D1586

WESTON

DRILLING LOG

WELL NUMBER: MW 280 OWNER: USAF
LOCATION: SLFZ-LF 2 ADDRESS: Castle AFB
TOTAL DEPTH 100'
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: Stang DRILLING METHOD: Mud Rotary DATE DRILLED: 11/02/84
DRILLER: T.R. HELPER:
LOG BY: BWB/WWB

SKETCH MAP

NOTES:

DEPTH (FEET)	OVA/HNU	INTERVAL (FEET)	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0	0	0 - 4	Reddish-brown SILTY fine SAND (friable)
		4 - 10	Brown SILTY fine SAND
10	0	10 - 28	Brown fine to medium SAND
	0		
20	0		
	0		
30		28 - 56	Brown fine to medium SAND w/some coarse variegated SAND
	0		
	0		
40			

* A.S.T.M. D1586

WESTON

DRILLING LOG

WELL NUMBER: MW 280 OWNER: _____

LOCATION: _____ ADDRESS: _____

_____ _____

_____ TOTAL DEPTH _____

SURFACE ELEVATION: _____ WATER LEVEL: _____

DRILLING COMPANY: _____ DRILLING METHOD: _____ DATE DRILLED: _____

DRILLER: _____ HELPER: _____

LOG BY: BWB/WWB

SKETCH MAP

NOTES:

DEPTH (FEET)	OVA/HNU	INTERVAL (FEET)			DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
40					
	0				
50	0				
	0	56	-	60	Reddish-brown CLAY (plastic)
60					
	0	60	-	68	Light gray fine to medium SAND with some mica
	0	68	-	71	Variegated fine to coarse GRAVEL with some medium SAND (hard drilling)
70					
		71	-	83	Light gray fine to medium SAND with trace fine GRAVEL and fine mica
	0				
80	0				

* A.S.T.M. D1586

WESTON

DRILLING LOG

WELL NUMBER: MW 280 OWNER:
LOCATION: ADDRESS:
TOTAL DEPTH
SURFACE ELEVATION: WATER LEVEL:
DRILLING COMPANY: DRILLING METHOD: DATE DRILLED:
DRILLER: HELPER:

LOG BY: BWB/WWB

SKETCH MAP

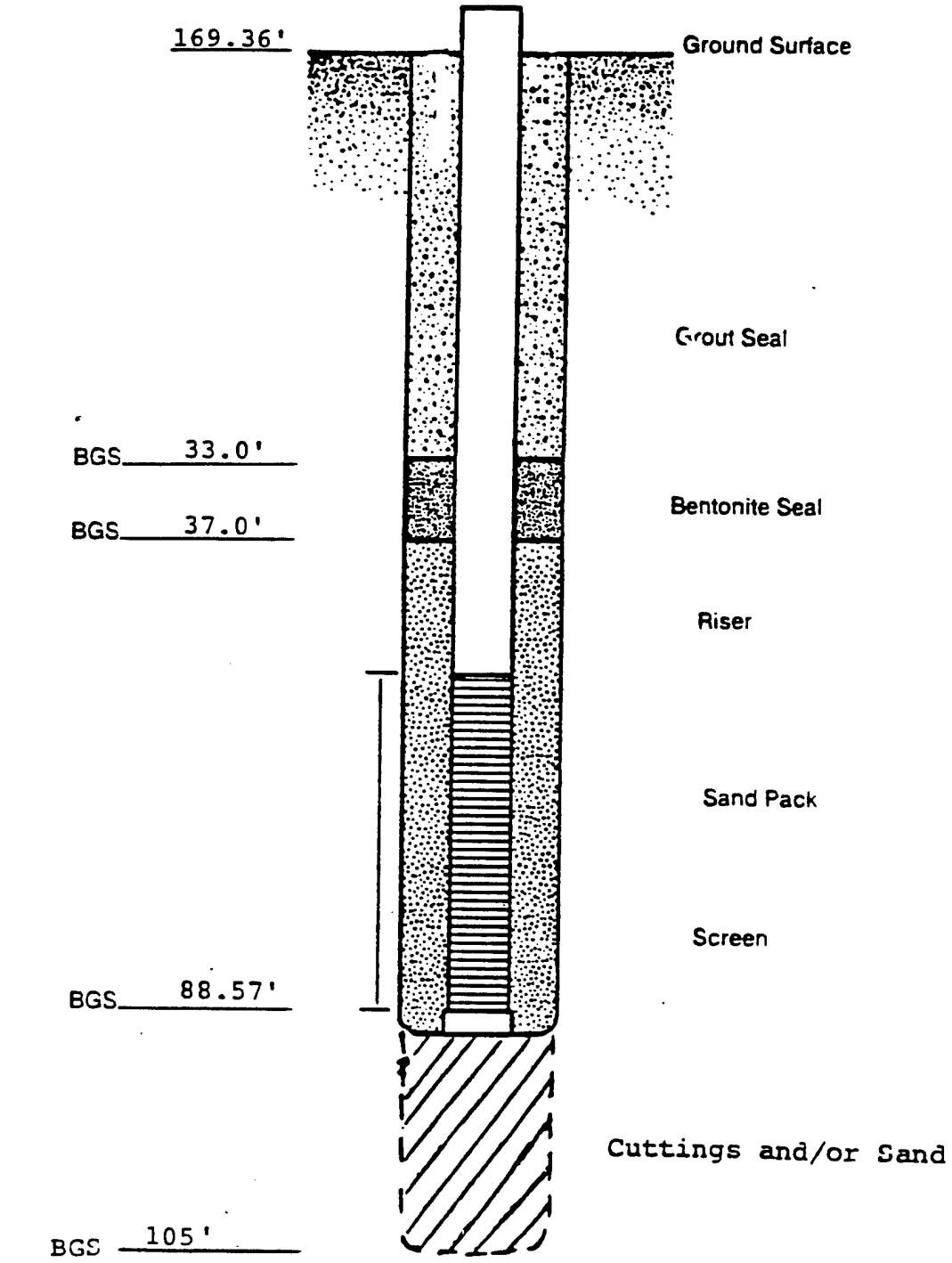
NOTES:

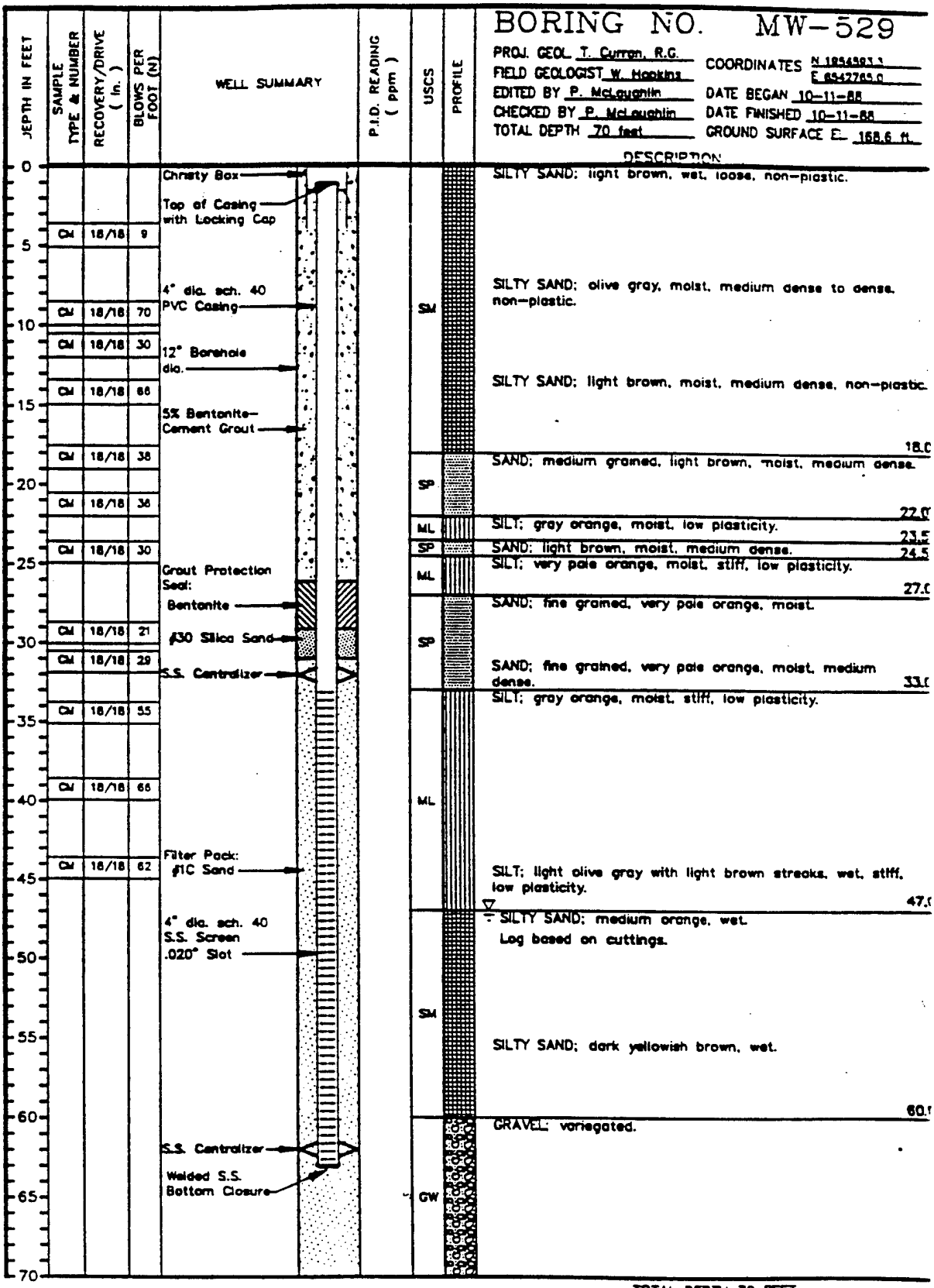
DEPTH (FEET)	OVA/HNU	INTERVAL (FEET)	DESCRIPTION / SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
80			
	0	83 - 88	Variegated fine to coarse GRAVEL with some fine to coarse SAND (hard drilling)
90		88 - 91	Brown CLAY with some fine SAND (low plastic)
		91 - 100	Light brown-green fine SANDY CLAY
100			END OF DRILLING

* A.S.T.M. D1586

WESTON

MW-280





TOTAL DEPTH 70 FEET

DRILLING CO.: Beylik Drilling Inc.
DRILL METHOD: Hollow Stem Auger (Rig MD-3)

PAGE 1 OF

SEE LEGEND FOR LOGS AND TEST PITS FOR EXPLANATION OF SYMBOLS AND TERMS

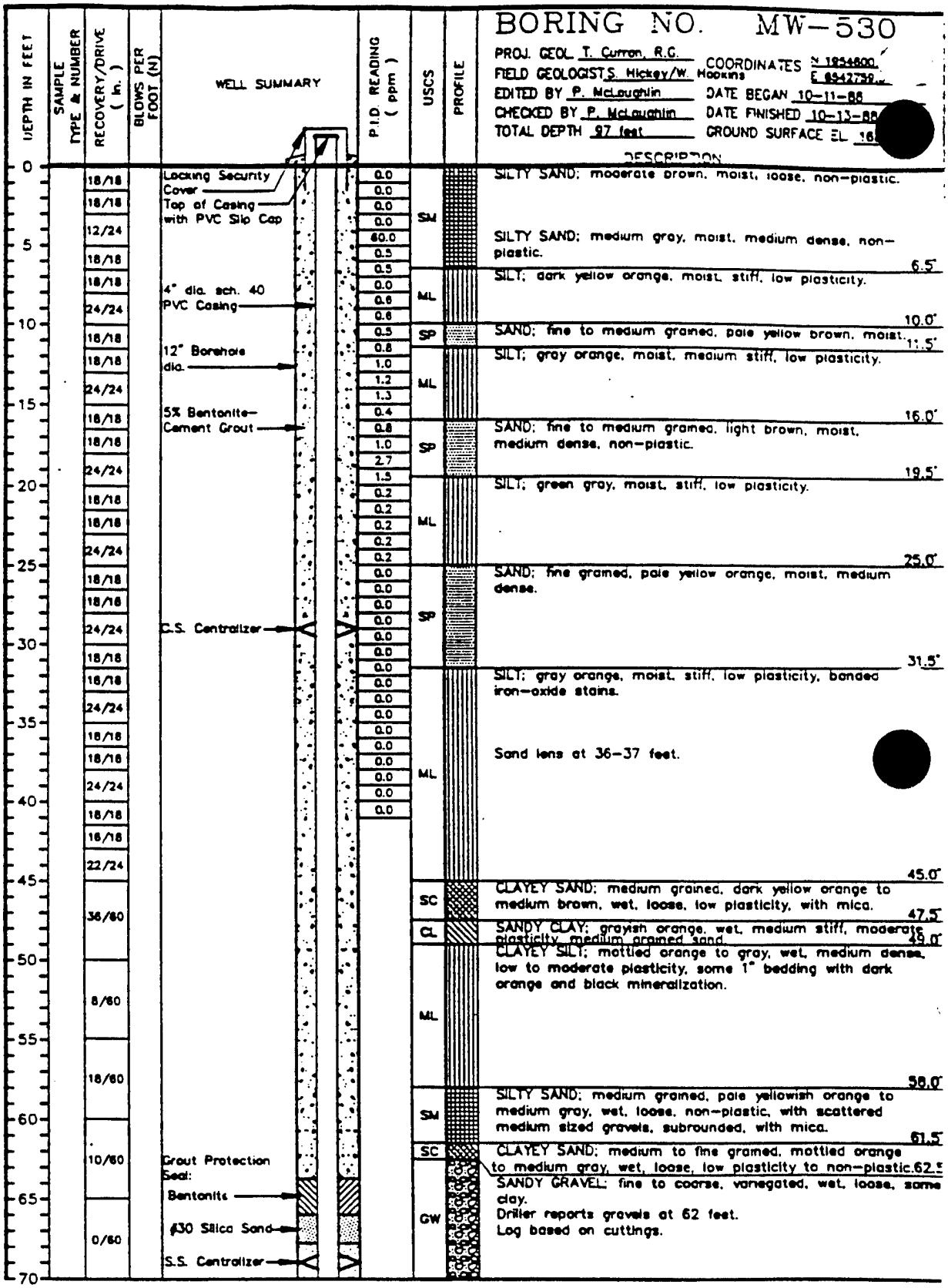
PROJECT NO.: 409642
CLIENT: Castle Air Force Base
LOCATION: Castle Air Force Base, California

INTERNATIONAL TECHNOLOGY CORPORATION

MW-529(•CA10)

BORING NO. MW-530

PROJ. GEOL. T. Curran, R.G. — COORDINATES N 1954600, E 8542759
FIELD GEOLOGIST S. Hickey/W. Hopkins
EDITED BY P. McLaughlin — DATE BEGAN 10-11-88
CHECKED BY P. McLaughlin — DATE FINISHED 10-13-88
TOTAL DEPTH 97 feet — GROUND SURFACE EL. 16[redacted]



DRILLING CO.: Beylik Drilling Inc. .
DRILL METHOD: Hollow Stem Auger 0-45' (Rig MD-3)
Mud Rotary 45'-T.D. (Rig TH-10)
PROJECT NO.: 409642
CLIENT: Castle Air Force Base
LOCATION: Castle Air Force Base, California

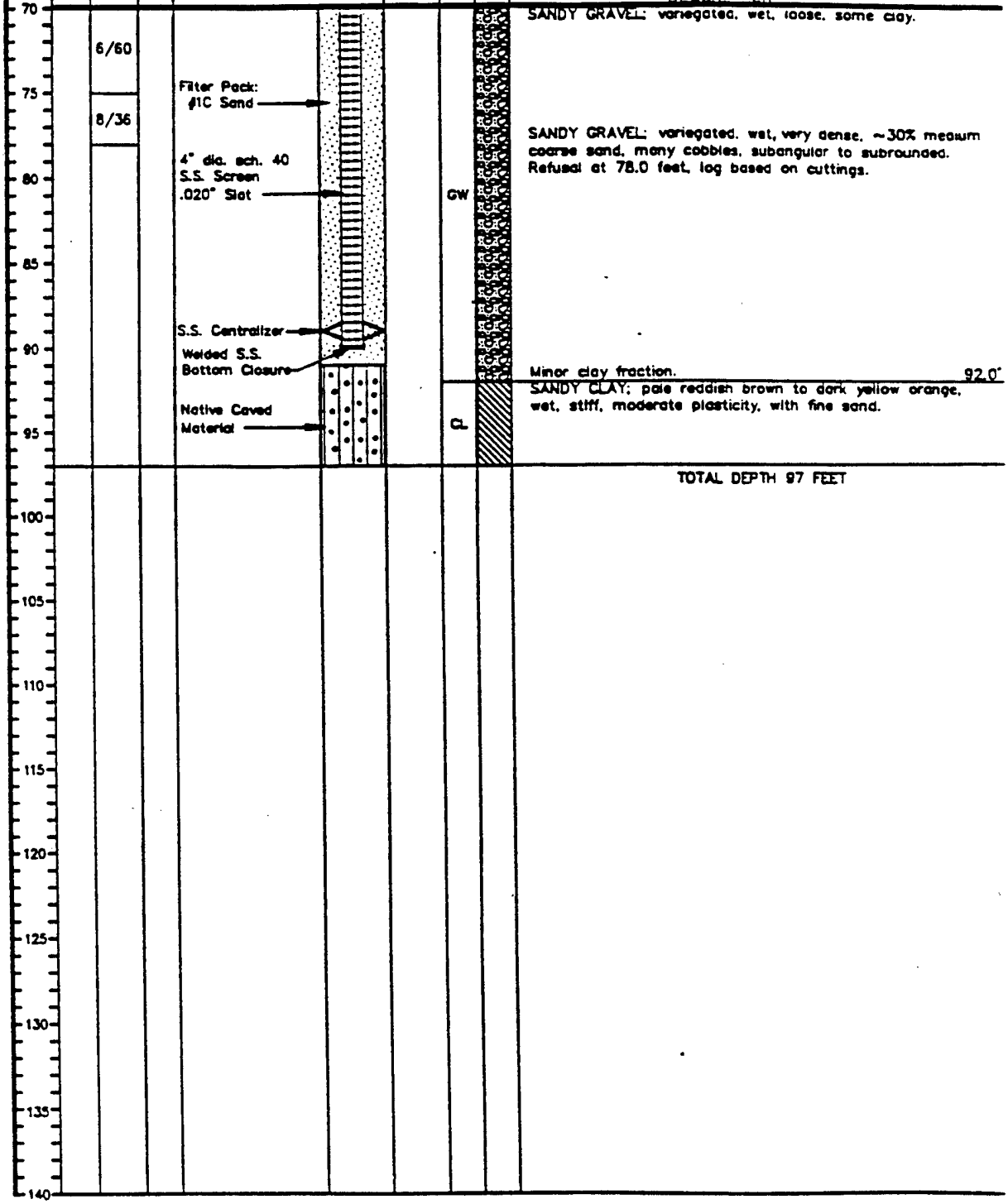
SEE LEGEND FOR LOGS AND TEST
FOR EXPLANATION OF SYMBOLS A[redacted]N

INTERNATIONAL TECHNOLOGY CORPORATION

MW-530(*CA10)

BORING NO. MW-530

PROJ. GEOL. T. Curran, R.G. COORDINATES N 1954800.2
FIELD GEOLOGIST S. Hickey/W. Hopkins E 6542756.1
EDITED BY P. McLaughlin DATE BEGAN 10-11-88
CHECKED BY P. McLaughlin DATE FINISHED 10-13-88
TOTAL DEPTH 97 feet GROUND SURFACE EL. 168.4 ft.



DESCRIPTION	
SANDY GRAVEL: variegated, wet, loose, some clay.	
SANDY GRAVEL: variegated, wet, very dense, ~30% medium coarse sand, many cobbles, subangular to subrounded. Refusal at 78.0 feet, log based on cuttings.	
Minor clay fraction.	92.0'
SANDY CLAY: pale reddish brown to dark yellow orange, wet, stiff, moderate plasticity, with fine sand.	
TOTAL DEPTH 97 FEET	

DRILLING CO.: Beylik Drilling Inc.
DRILL METHOD: Hollow Stem Auger 0-45' (Rig MD-3)
Mud Rotary 45'-T.D. (Rig TH-10)
PROJECT NO.: 409642
CLIENT: Castle Air Force Base
LOCATION: Castle Air Force Base, California

SEE LEGEND FOR LOGS AND TEST PITS FOR EXPLANATION OF SYMBOLS AND TERI

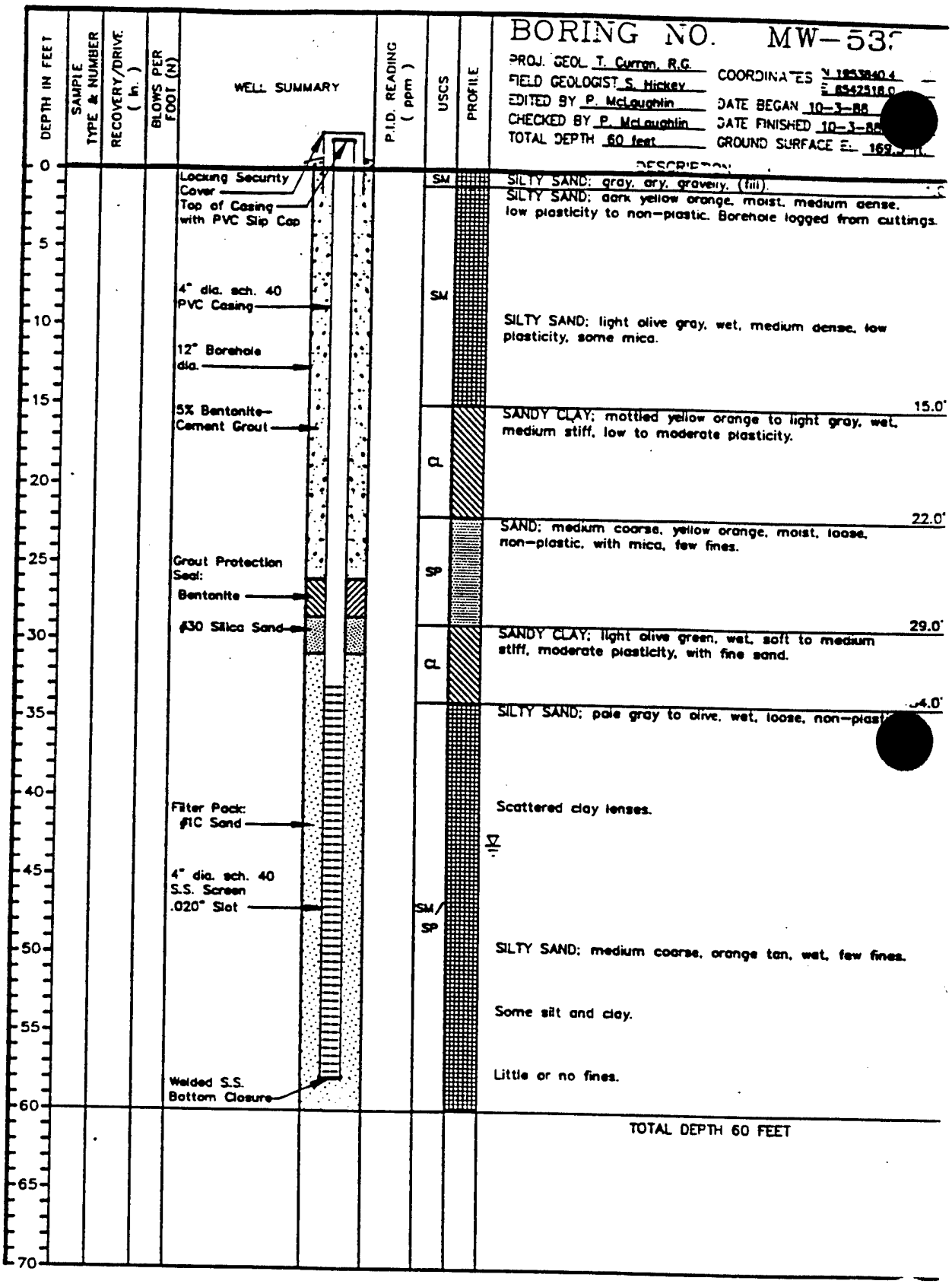
INTERNATIONAL TECHNOLOGY CORPORATION

MW-530(eCA10)

BORING NO. MW-533

PROJ. GEOL. T. Curran, R.G.
FIELD GEOLOGIST S. Hickey
EDITED BY P. McLaughlin
CHECKED BY P. McLaughlin
TOTAL DEPTH 60 feet

COORDINATES N 1853840.4 E 6542518.0
DATE BEGAN 10-3-88
DATE FINISHED 10-3-88
GROUND SURFACE EL. 169.[illegible] ft.



DRILLING CO.: Beylik Drilling Inc.
DRILL METHOD: Hollow Stem Auger (Rig MD-3)

PAGE

SEE LEGEND FOR LOGS AND TEST [illegible]
FOR EXPLANATION OF SYMBOLS AND [illegible]M

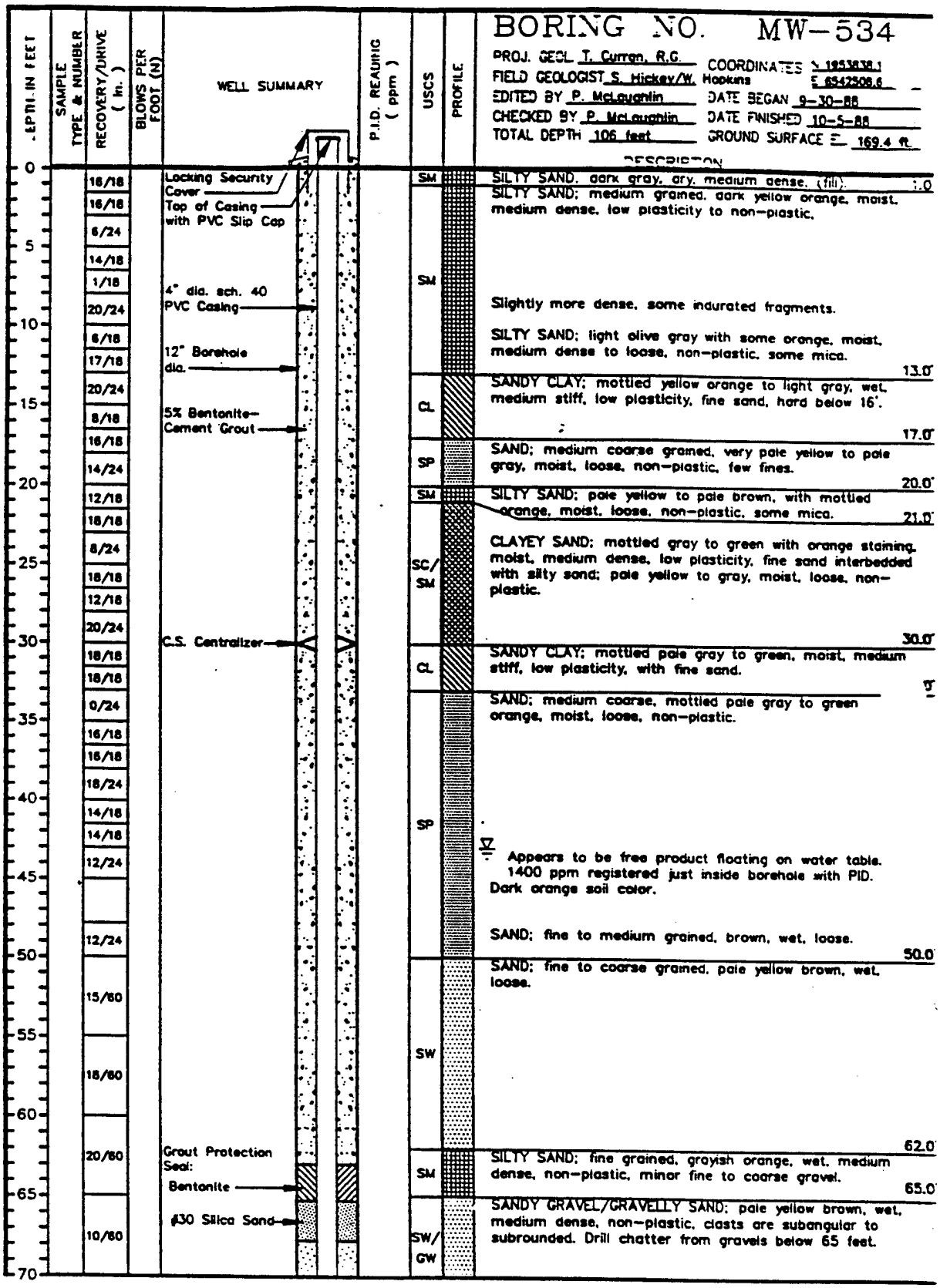
PROJECT NO.: 409642
CLIENT: Castle Air Force Base
LOCATION: Castle Air Force Base, California

MW-533(•CA11)

INTERNATIONAL TECHNOLOGY CORPORATION

BORING NO. MW-534

PROJ. GEOL. T. Curran, R.G. COORDINATES N 1953838.1
FIELD GEOLOGIST S. Hickey/W. Hopkins E 6542508.6
EDITED BY P. McLaughlin DATE BEGAN 9-30-88
CHECKED BY P. McLaughlin DATE FINISHED 10-5-88
TOTAL DEPTH 106 feet GROUND SURFACE E 169.4 ft



DRILLING CO.: Beylik Drilling Inc.
DRILL METHOD: Hollow Stem Auger 0-45' (Rig MD-3)
Mud Rotary 45'-T.D. (Rig TH-10)
PROJECT NO.: 409642
CLIENT: Castle Air Force Base
LOCATION: Castle Air Force Base, California

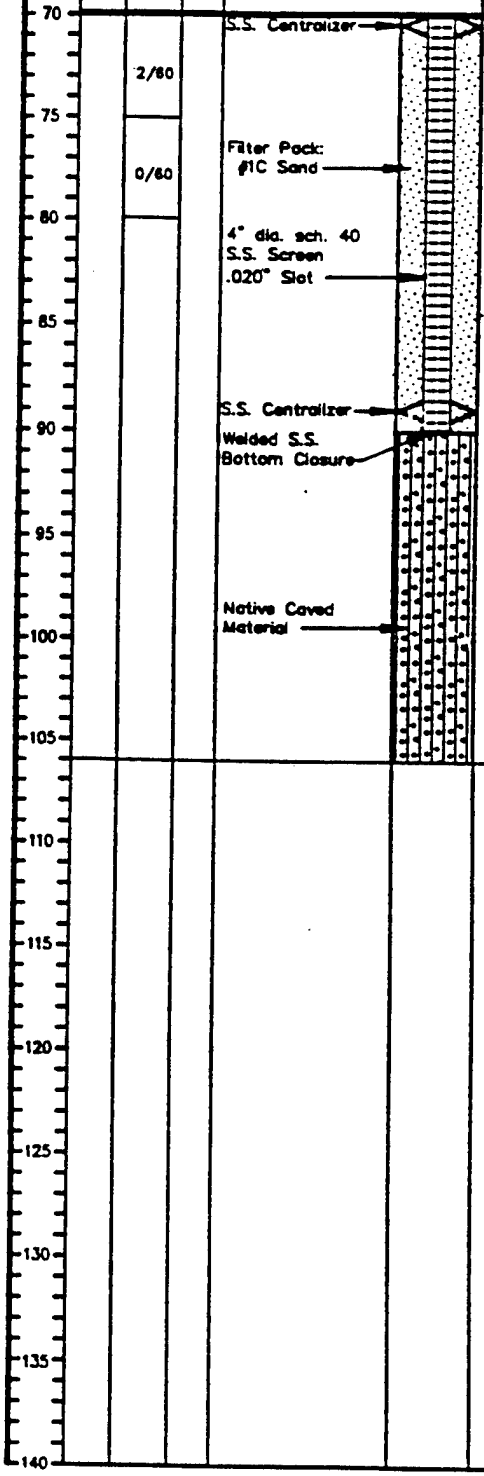
SEE LEGEND FOR LOGS AND TEST PITS
FOR EXPLANATION OF SYMBOLS AND TERMS

MW-534(eCA11)

INTERNATIONAL TECHNOLOGY CORPORATION

BORING NO. MW-53

PROJ. GEOL. T. Curran, R.G.
FIELD GEOLOGIST S. Hickey/W. Hopkins
EDITED BY P. McLaughlin
CHECKED BY P. McLaughlin
TOTAL DEPTH 106 feet
COORDINATES N 1953834 E 6542508.6
DATE BEGAN 9-30-88
DATE FINISHED 10-5-88
GROUND SURFACE EL. 169'



DESCRIPTION

GRAVEL: subrounded to subangular. Drill rig chatter from gravels. Logged primarily from cuttings.

Coring refusal at 82 feet.

99.0'

SANDY CLAY: gray orange, wet, stiff, low to moderate plasticity. Rig drilling rate changes abruptly at 99 feet also rig chatter ceases. Logged from cuttings.

TOTAL DEPTH 106 FEET

DRILLING CO.: Beylik Drilling Inc.
DRILL METHOD: Hollow Stem Auger 0-45' (Rig MD-3)
Mud Rotary 45'-T.D. (Rig TH-10)
PROJECT NO.: 409642
CLIENT: Castle Air Force Base
LOCATION: Castle Air Force Base, California

PAGE

SEE LEGEND FOR LOGS AND TEST P
FOR EXPLANATION OF SYMBOLS AND

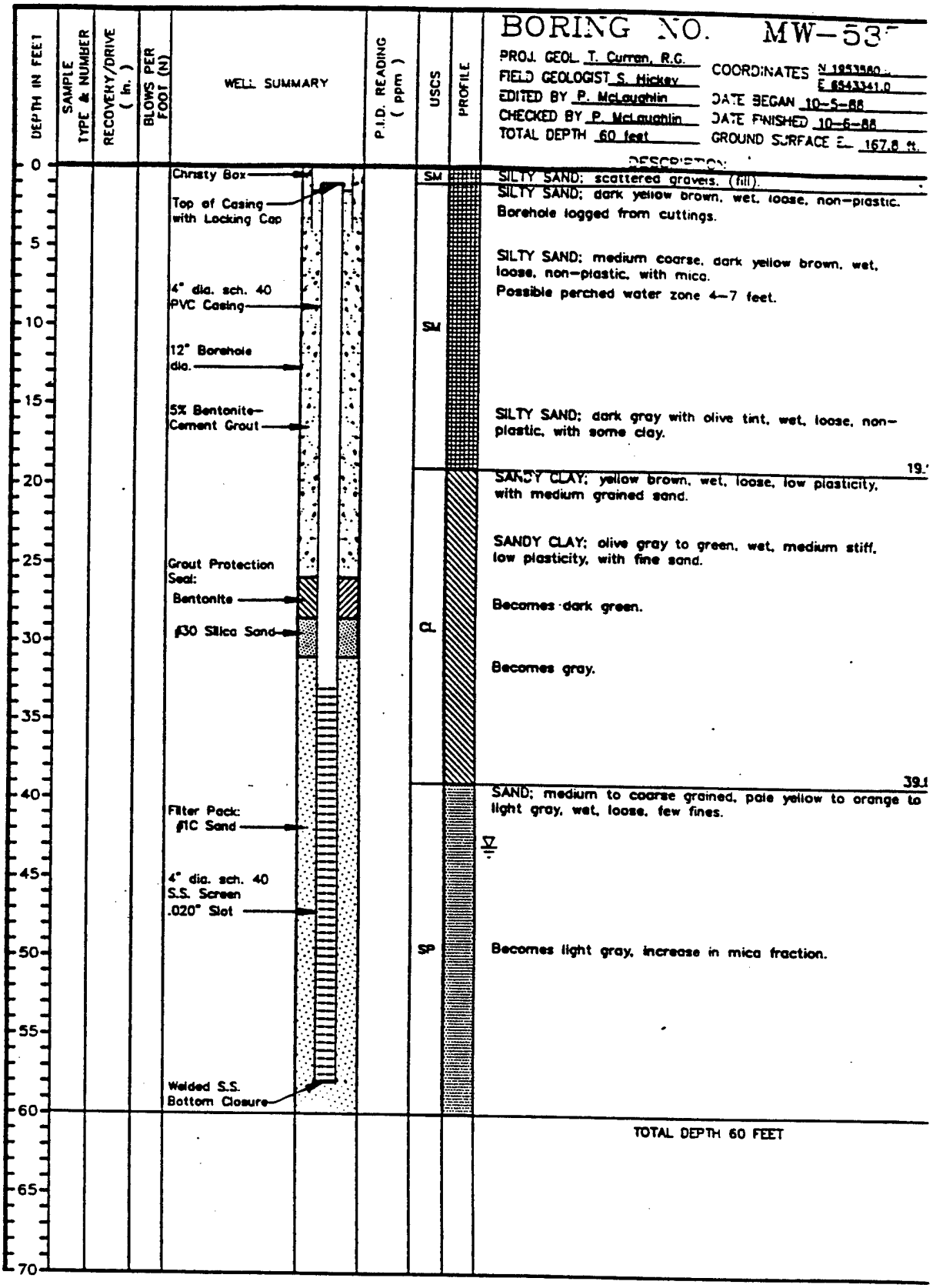
MW-534(•CA11)

INTERNATIONA
TECHNOLOGY
CORPORATION

BORING NO. MW-53

PROJ. GEOL. T. Curran, R.G.
FIELD GEOLOGIST S. Hickey
EDITED BY P. McLaughlin
CHECKED BY P. McLaughlin
TOTAL DEPTH 60 feet

COORDINATES N 1953580.
E 6543341.0
DATE BEGAN 10-5-88
DATE FINISHED 10-6-88
GROUND SURFACE E. 167.8 ft.



DESCRIPTION:

SILTY SAND; scattered gravels. (fill).

SILTY SAND; dark yellow brown, wet, loose, non-plastic. Borehole logged from cuttings.

SILTY SAND; medium coarse, dark yellow brown, wet, loose, non-plastic, with mica. Possible perched water zone 4-7 feet.

SILTY SAND; dark gray with olive tint, wet, loose, non-plastic, with some clay.

19.

SANDY CLAY; yellow brown, wet, loose, low plasticity, with medium grained sand.

SANDY CLAY; olive gray to green, wet, medium stiff, low plasticity, with fine sand.

Becomes dark green.

Becomes gray.

39.

SAND; medium to coarse grained, pale yellow to orange to light gray, wet, loose, few fines.

▽

Becomes light gray, increase in mica fraction.

TOTAL DEPTH 60 FEET

DRILLING CO.: Beylik Drilling Inc.
DRILL METHOD: Hollow Stem Auger (Rig MD-3)

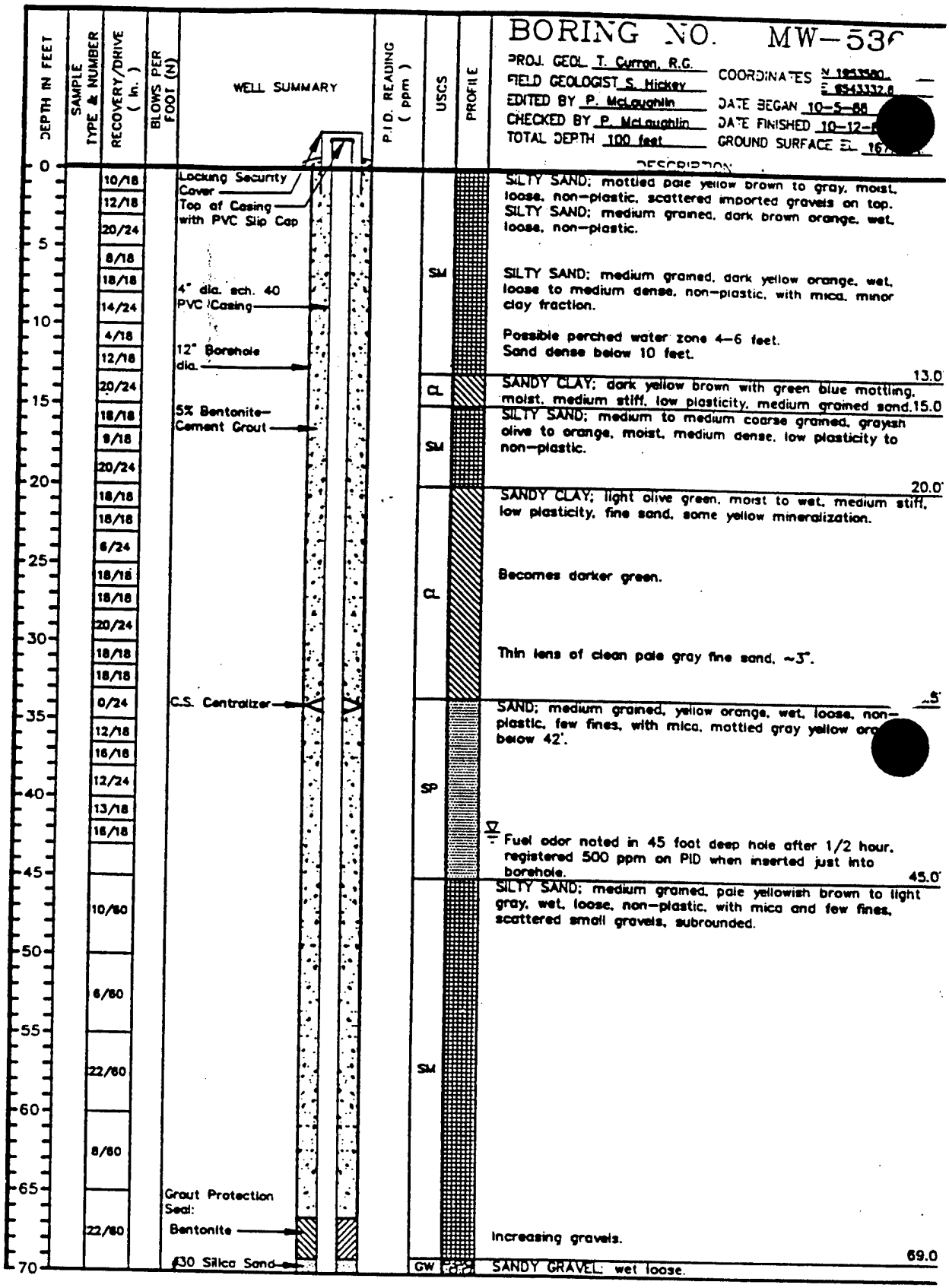
PAGE

PROJECT NO.: 409642
CLIENT: Castle Air Force Base
LOCATION: Castle Air Force Base, California

SEE LEGEND FOR LOGS AND TEST PITS FOR EXPLANATION OF SYMBOLS AND TERM

MW-535(•CA11)

INTERNATIONAL TECHNOLOGY CORPORATION



DRILLING CO.: Beylik Drilling Inc.
DRILL METHOD: Hollow Stem Auger 0-45' (Rig MD-3)
Mud Rotary 45'-T.D. (Rig TH-10)
PROJECT NO.: 409642
CLIENT: Castle Air Force Base
LOCATION: Castle Air Force Base, California

PAGE

SEE LEGEND FOR LOGS AND TEST
FOR EXPLANATION OF SYMBOLS AN M:

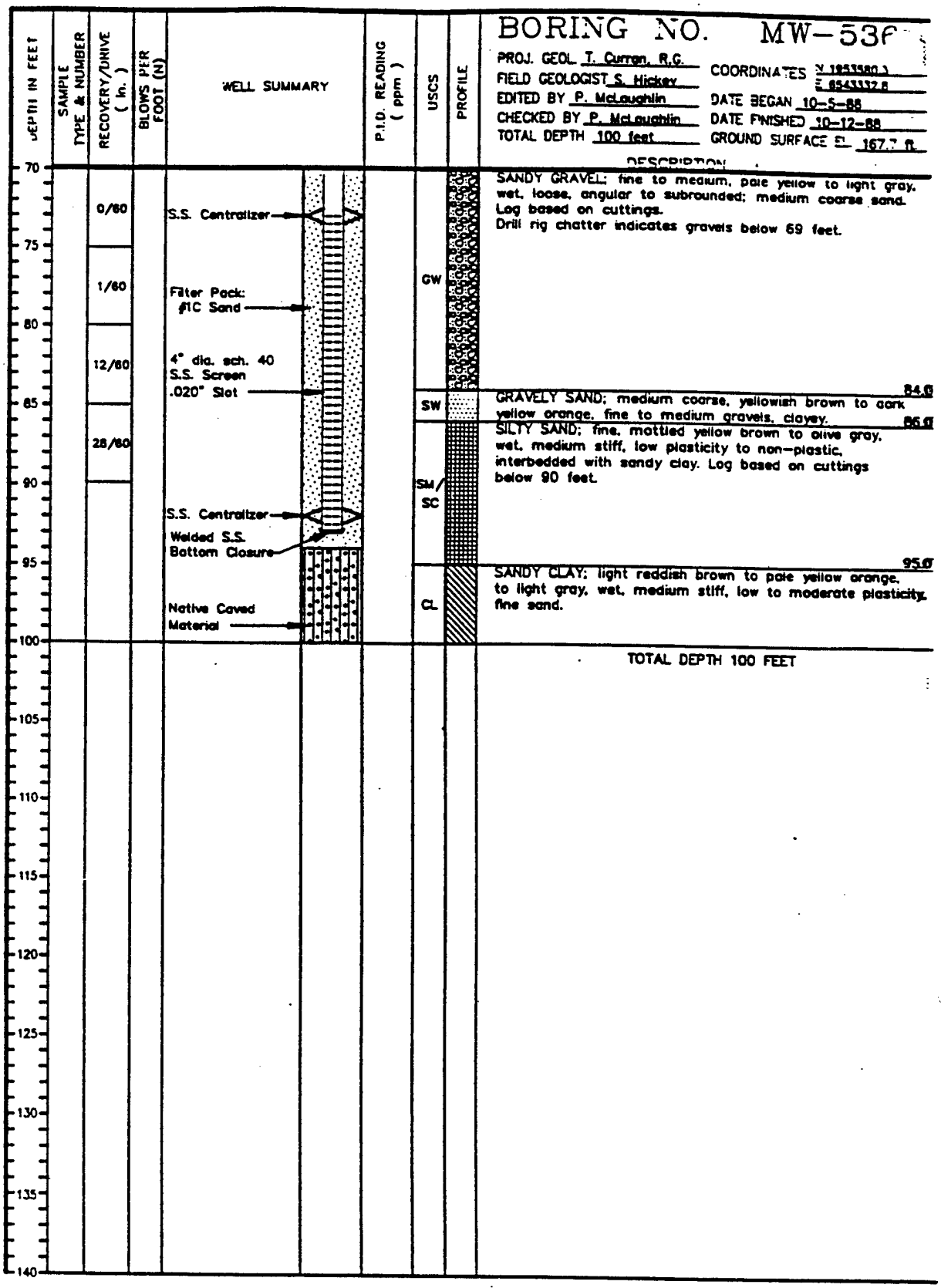
MW-536(•CA12)

INTERNATIONAL TECHNOLOGY CORPORATION

BORING NO. MW-536

PROJ. GEOL. T. Curran, R.G.
FIELD GEOLOGIST S. Hickey
EDITED BY P. McLaughlin
CHECKED BY P. McLaughlin
TOTAL DEPTH 100 feet

COORDINATES N 1953580.1 E 8543332.8
DATE BEGAN 10-5-88
DATE FINISHED 10-12-88
GROUND SURFACE EL 167.7 ft.



DESCRIPTION

SANDY GRAVEL: fine to medium, pale yellow to light gray, wet, loose, angular to subrounded; medium coarse sand. Log based on cuttings.
Drill rig chatter indicates gravels below 69 feet.

84.0

GRAVELY SAND: medium coarse, yellowish brown to dark yellow orange, fine to medium gravels, clayey.

86.0

SILTY SAND: fine, mottled yellow brown to olive gray, wet, medium stiff, low plasticity to non-plastic, interbedded with sandy clay. Log based on cuttings below 90 feet.

95.0

SANDY CLAY: light reddish brown to pale yellow orange, to light gray, wet, medium stiff, low to moderate plasticity, fine sand.

TOTAL DEPTH 100 FEET

DRILLING CO.: Beylik Drilling Inc.
DRILL METHOD: Hollow Stem Auger 0-45' (Rig MD-3)
Mud Rotary 45'-T.D. (Rig TH-10)
PROJECT NO.: 409642
CLIENT: Castle Air Force Base
LOCATION: Castle Air Force Base, California

SEE LEGEND FOR LOGS AND TEST PITS FOR EXPLANATION OF SYMBOLS AND TERM

MW-536(•CA12)

INTERNATIONAL TECHNOLOGY CORPORATION

LOG OF BORING MW873

PROJECT NAME: CASTLE AIR FORCE BASE -CB/ORIGINALLY LOGGED AS B55HP01		AIR FORCE BASE CASTLE AFB	
PROJECT NUMBER: 21611400	LOCATION IDENTIFIER: MW873		1 of 5
rthing: 314162.55 Easting: 1981274.59		Elevation and Datum: 169.20 ft above mean sea level(	
Health and Safety: Level D with Tyvek		Date Started: 10/15/93	Date Finished: 10/15/93
Drilling Equipment: Speedstar 15		Total Depth(feet): 130.00	Depth to Groundwater(feet):
Drilling Method: Air-Rotary/Casing Hammer		Borehole Diameter: 10.00 inches	
Sampling Method: Cuttings		Monitoring Well Total Depth (feet): 90.50	As-Built In Appendix D
Hammer Information 0 lb with 0 in drop		Logged by: TZ	Checked by: WFW WFW

Depth (feet)	Blow Counts	Percent Recovery	Sample Interval	Sample ID	OVM Reading	USCS Code	Graphic Log	Lithologic Description	Remarks
0 00									
	0 0 0	0 00			115 00	ML		SANDY SILT Silt w/ app 40% fn to md sand, sl moist, bluish-gray, strg diesel-like odor (strg diesel vapors in disclosed soil)	
5 00									
10 00	0 0 0	0 00			2 00	ML		SANDY SILT 10YR5/2 gry brown, silt w/ app 20% sand, sl moist, sl discoloration to bluish gray w/ no odor	
	0 0 0	0 00			0 00	ML		SILT 7 5YR5/4 brown, silt w/ app 5% fn sand, sl moist, non pl (md Drilling Resistance=DR)	
15 00									
20 00	0 0 0	0 00			0 00	ML		SILT 7 5YR4/4 dk brown, silt, sl moist, micaceous	
	0 0 0	0 00			0 00	ML		SILT 10YR5/6 yllw brown, silt w/ app 5% fn sand, sl moist, micaceous (md DR)	
25 00									

LOG OF BORING MW873

PROJECT NAME: CASTLE AIR FORCE BASE - CB\ORIGINALLY LOGGED AS B55HP01 | AIR FORCE BASE CASTLE AFB

PROJECT NUMBER: 21611400 | LOCATION IDENTIFIER: MW873 | SHEET: 2 of: 5

Depth (feet)	Blow Counts	Percent Recovery	Sample Interval	Sample ID	OVM Reading	USCS Code	Graphic Log	Lithologic Description	Remarks
						SM		SILTY SAND: fn sand w/ app 40% silt, sl moist, micaceous (low DR)	
30.00	0 0 0	0.00			0.00				
35.00	0 0 0	0.00			0.00	SM		SILTY SAND: Sand w/ app 15% silt, sl moist, poorly graded, micaceous (low DR)	
						SP		SAND: 10YR5/8 yllw brown, sand w/ app 5% silt, sl moist (low DR)	
	0 0 0	0 00			0 00				
						ML		SANDY SILT: Silt w/ app 25% fn sand, sl moist, micaceous (Low DR)	
45.00	0 0 0	0 00			0.00				
						CL		CLAY: 10YR5/6 yllw brown, sl moist, stiff (low DR)	
50.00	0 0 0	0 00			0 00				
						ML		SANDY SILT: Silt w/ app 30% fn sand, sl moist, micaceous. (low DR)	
55.00	0 0	0 00			0 00				

LOG OF BORING MW873

PROJECT NAME: CASTLE AIR FORCE BASE - CB\ORIGINALLY LOGGED AS B55HP01 | AIR FORCE BASE CASTLE AFB

PROJECT NUMBER: 21611400 | LOCATION IDENTIFIER: MW873 | SHEET: 3 of 5

Dep. (feet)	Blow Counts	Percent Recovery	Sample Interval	Sample ID	OVM Reading	USCS Code	Graphic Log	Lithologic Description	Remarks
55 00									
						SM			
	0 0 0	0.00			0.00			SILTY SAND fn sand w/ app 50% silt, sl moist, micaceous (low DR)	
60 00									
						SW			
	0 0 0	0.00			0.00			SAND Sand w/ app 10% silt and app 10% fn subrnd to rnd gravel, sl moist to moist (low DR)	
65 00									
						GPGM			
	0 0 0	0.00			0.00			GRAVEL fn subrnd to rnd gravel w/ app 10% sand and app 10% silt, poorly graded (low DR)	
70 00									
	0 0 0	0 00			0 00	GPGM		GRAVEL Same as above (md DR)	
75 00									
	0 0 0	0 00			0 00	GP			
80 00	0 0 0	0 00		CA-B269401	0 00			SANDY GRAVEL fn to crs subang to rnd gravel w/ app 25% fn to crs sand (mostly crs) w/ app 5% silt, wet. (quartzite, slate) Hydropunch sample interval from 80' to 83' BGS (Good recovery, turbid water)	
	0 0 0	0 00			0 00	SP		GRAVELLY SAND fn to crs (60% crs, 30% md, 10% fn)	
85 00									

LOG OF BORING MW873

PROJECT NAME: CASTLE AIR FORCE BASE - CB\ORIGINALLY LOGGED AS B55HP01 | AIR FORCE BASE CASTLE AFB

PROJECT NUMBER: 21611400 | LOCATION IDENTIFIER: MW873 | SHEET: 4 of: 5

Depth (feet)	Blow Counts	Percent Recovery	Sample Interval	Sample ID	OVM Reading	USCS Code	Graphic Log	Lithologic Description	Remarks
								subang to rnd sand w/ app 25% fn to crs (mostly fn) ang to rnd gravel w/ app 10% silt, wet.	
						SP		SAND: Fn to crs subrnd to rnd qtz sand w/ app 5% silt, wet, md dense, app 5% mfx	
90 00	0 0 0	0.00			0.00				
	0 0 0	0 00		CA-B269501	0.00	SPSM		Hydropunch sample interval from 94' to 95' BGS SAND: Fn to md subang to subrnd qtz sand w/ app 10% silt w/ tr clay, wet to saturated, md dense	
95 00									
	0 0	0 00			0 00	SM		SILTY SAND: Fn to md sand w/ app 30% silt w/ tr clay, wet to saturated, non pl, md dense, some siltstone nuggets	
						CL		SANDY CLAY: Clay w/ app 10% fn sand w/ some silt, wet, low pl, soft to firm, slow dilatancy, low toughness, low dry strength, semi-cemented siltstone nuggets	
105 00	0 0 0	0.00			0 00				
						SM			
110 00	0 0 0	0.00			0.00			SILTY SAND: Fn to md qtz sand w/ app 30% silt, wet to saturated, non pl, loose, "chocolate shake" consistency	
	0 0	0.00		CA-B217101	0 00			Hydropunch sample interval from 114' to 115' BGS	
115 00						SM		SILTY SAND: Fn to md sand w/ app 35% silt w/ some clay, wet to saturated, loose siltstone nuggets, md	

LOG OF BORING MW873

PROJECT NAME: CASTLE AIR FORCE BASE - CB/ORIGINALLY LOGGED AS B55HP01 | AIR FORCE BASE CASTLE AFB

PROJECT NUMBER: 21611400 | LOCATION IDENTIFIER: MW873 | 5 of 5

Depth (feet)	Blow Counts	Percent Recovery	Sample Interval	Sample ID	OVM Reading	USCS Code	Graphic Log	Lithologic Description	Remarks
115 00	0 0 0	0.00			0.00			cemented, FeOx stain	
120 00	0 0 0	0 00			0.00	SPSM		SAND Md subang to subrnd qtz sand w/ app 20% fn sand w/ app 10% crs sand w/ app 10% silt, wet to saturated, md dense, micaceous	
						SM		SILTY SAND Fn to md subang to subrnd qtz sand w/ app 20% silt, saturated, md dense, micaceous	
125 00	0 0 0	0 00			0.00				
130 00	0 0 0	0 00			0 00	SM		SILTY SAND Fn to md subang to subrnd sand w/ app 35% silt w/ some clay, wet to saturated, md dense, some nodules of semi-cemented siltstone	
								TD=130' BGS Although depicted as continuous, lithology is based on grab samples taken approximately every five feet and shown as 6" bars Contacts are arbitrarily placed midway between samples unless specifically noted on field log and based on continuous observation of cuttings and rig performance	
135 00									
140 00									
145 00									

LOG OF BORING MW899

PROJECT NAME: CASTLE AIR FORCE BASE - CB/ORIGINALLY LOGGED AS MBSHP05A		AIR FORCE BASE CASTLE AFB	
PROJECT NUMBER: 21611400	LOCATION IDENTIFIER: MW899	SHEET: 1 of 4	
thing: 312759.43 Easting: 1981523.60		Elevation and Datum: 165.44 ft above mean sea level(app)	
ealth and Safety: Level D w/ Tyvek (minimum)		Date Started: 11/18/93	Date Finished: 11/18/93
ling Equipment: Dresser (*104)		Total Depth(feet): 100.00	Depth to Groundwater(Feet): 60'
lling Method: Air-Rotary/Casing Hammer		Borehole Diameter: 10.00 inches	
Sampling Method: Cuttings		Monitoring Well Total Depth (feet): 87	As-Built In Appendix D
Hammer Information: 0 lb with 0 in drop		Logged by: DM	Checked by: WFW WFW

Depth (feet)	Blow Counts	Percent Recovery	Sample Interval	Sample ID	OVM Reading	USCS Code	Graphic Log	Lithologic Description	Remarks
0 00									
	0 0 0	0 00			0 00	SM		SILTY SAND 2.5Y3/3 dk olv brown, fn sand w/ app 30% silt w/ tr clay, moist, loose	
5 00									
	0 0	0 00			0 00	SM		SILTY SAND 7.5YR3/2 dk brown, fn sand w/ app 40% silt, sl moist, loose	
						ML		SANDY SILT 7.5YR3/2 dk brown, silt w/ app 35% vry fn to fn sand, moist, non pl, rapid dilatancy	
	0 0 0	0 00			0 00				
15 00						ML		SILT 7.5YR3/2 dk brown, silt w/ app 20% vry fn to fn sand, moist, non pl, rapid dilatancy	
	0 0 0	0 00			0 00				
20 00									
	0 0	0 00			0 00	ML		SILT 10YR6/4 lt yllw brown, silt w/ app 25% sand, moist, non pl, md dense, rapid dilatancy, w/	
25 00									

LOG OF BORING MW899

PROJECT NAME: CASTLE AIR FORCE BASE - CB/ORIGINALLY LOGGED AS MBSHP05A | AIR FORCE BASE CASTLE AFB

PROJECT NUMBER: 21611400 | LOCATION IDENTIFIER: MW899 | SHEET: 2 of: 4

Depth (feet)	Blow Counts	Percent Recovery	Sample Interval	Sample ID	OVM Reading	USCS Code	Graphic Log	Lithologic Description	Remarks
25 00								semi-consolidated silt, w/ rootlets	
30 00	0 0 0	0 00			0.00	ML		SILT 10YR6/4 lt yllw brown, silt, moist, non pl, md density, rapid dilatancy, w/ semi-consolidated silt w/ rootlets	
35 00	0 0 0	0 00			0 00	ML		SILT 10YR4/4 dk yllw brown, w/ app 15% vry fn to fn sand, moist, non pl, hard, w/ semiconsolidated silt (remnant from 30')	
40 00	0 0 0	0 00			0 00	SM		SILTY SAND 10YR4/4 dk yllw brown, fn subang to subrnd sand w/ app 40% silt w/ tr clay, moist, non pl	
45 00	0 0 0	0 00			0 00	SPSM		SAND 2.5Y6/3 lt olv brown, fn subang to subrnd qtz sand w/ app 30% vry fn sand w/ app 10% silt, sl moist	
50 00	0 0 0	0 00			0 00	SPSM		SAND 2 5YR5/3 lt olv brown, fn subang to subrnd qtz sand w/ app 10% silt, moist	
55 00						SM		SILTY SAND 10YR5/6 yllw brown, fn subang to subrnd sand w/ app 30% silt, w/ tr clay, moist, md dense	

LOG OF BORING MW899

PROJECT NAME: CASTLE AIR FORCE BASE - CB/ORIGINALLY LOGGED AS MBSHP05A | AIR FORCE BASE CASTLE AFB

PROJECT NUMBER: 21611400 | LOCATION IDENTIFIER: MW899 | SHEET: 3 of 4

Depth (feet)	Blow Counts	Percent Recovery	Sample Interval	Sample ID	OVM Reading	USCS Code	Graphic Log	Lithologic Description	Remarks
	0 0 0	0 00			0.00				
						ML		SILT 10YR4/3 brown, silt w/ app 5% vry fn to fn sand w/ clay, moist, non pl, vry stiff, rapid dilatancy	
60 00	0 0 0	0 00			0.00				
65 00	0 0 0	0 00			0.00	ML		SILT 10YR4/3 brown, silt w/ app 5% sand w/ clay balls, moist, non pl, md density, non dilatancy, nodules of semi-consolidated silt	
	0 0 0	0 00			0 00	ML		SILT 10YR4/4 dk yllw brown, silt w/ app 20% fn sand, wet, non pl, md dense, non dilatancy	
						SP		SAND 2.5Y lt olv brown, md sand w/ app 20% fn w/ app 15% crs subang to subrnd qtz sand (w/ app 7% mafics) w/ app 5% silt w/ tr gravel, wet.	
75 00	0 0 0	0 00			0 00				
						SPSM		GRAVELLY SAND 2 5Y lt olv brown, md subang to subrnd sand w/ app 20% crs sand w/ app 15% fn sand w/ app 30% fn to md subrnd to rnd gravel (to 3.5 cm).	
80 00	0 0 0	0 00			0 00				
						GP		GRAVEL Md subrnd to rnd gravel (to 4 5 cm) w/ app 12% md 4% crs 4% fn subang to subrnd sand & w/ app 10% silt, wet (saturated), non pl, no dilatancy.	
85 00	0 0	0 00			0 00				

LOG OF BORING MW899

PROJECT NAME: CASTLE AIR FORCE BASE - CB/ORIGINALLY LOGGED AS MBSHP05A | AIR FORCE BASE CASTLE AFB

PROJECT NUMBER: 21611400 | LOCATION IDENTIFIER: MW899 | SHEET: 4 of: 4

Depth (Feet)	Blow Counts	Percent Recovery	Sample Interval	Sample ID	OVM Reading	USCS Code	Graphic Log	Lithologic Description	Remar
85 00						SM		SILTY SAND 10YR4/4 dk yllw brown, fn sand w/ app 30% silt w/ app 10% subang to subrnd gravel (up to 3 cm), wet, md dense, thick "soupy"	
90 00	0 0 0	0 00			0.00	GC		CLAYEY GRAVEL 10YR4/4 dk yllw brown, subrnd to rnd gravel (to 6 cm, average 4 cm), w/ app 25% clay & w/ app 15% fn to crs subang to subrnd sand, wet (saturated), non pl, dense, no dilatancy, vry qtz-rich	
95 00	0 0 0	0 00			0 00	SP		SAND 10YR4/4 dk yllw brown, fn sand w/ app 10% md sand w/ app 10% silt, wet (saturated), dense, vry qtz-rich	
100 00	0 0 0	0 00			0 00			TD = 100' BGS Although depicted as continuous, lithology is based on grab samples taken approximately every five feet and shown as 6" bars Contacts are arbitrarily placed midway between samples unless specifically noted on field log and based on continuous observation of cuttings and rig performance	
105 00									
110 00									
115 00									

BORING NO. MW-965

DATE DRILLED	3/11/97 - 3/12/97	LOGGED BY	R. Hedegaard
NORTHING	313280.74	DRILLING CONTRACTOR	
EASTING	1981495.24	C-57 LICENSE NUMBER	
ELEVATION	169.44 MSLD feet	DRILLING METHOD	
TOC ELEVATION	171.823 MSLD feet	DRILLING EQUIPMENT	
TOTAL DEPTH	75 feet bgs	SAMPLING METHOD	
		COMPLETION	

REVIEWED BY L. Phillips

Beylik Drilling
306291
Hollow Stem Auger
Ingersoll Rand A-400
Split Spoon
Monitoring Well

SAMPLES					FIELD ANALYSIS UNITS AND OBSERVATIONS	LOG	WELL CONSTRUCTION DETAILS
BLOW COUNT	PERCENT RECOVERY	TYPE LOG	TYPE LAB	I.D. NUMBER		LITHOLOGIC DESCRIPTION AND ASSOCIATED USCS SYMBOL	
					PID = 0.0 FID = 0.0	Grass, native soil.	Concrete
6 20 21	100				PID = 20.0 FID = 0.0	SAND WITH SILT (SP-SM): reddish-brown (5YR4/3), fine-to medium-grained, poorly graded, angular to subangular, moist, no cementation, slight hydrocarbon odor.	
21 27 22	100				PID = 15.0 FID = 0.0	SILTY SAND (SM): brown (7.5YR4/4), fine-to medium-grained, poorly graded, angular to subangular, moist, no cementation, slight hydrocarbon odor.	
20 50 50	75				PID = 50.0 FID = 125.0	SANDY SILT (ML): dark grayish-brown (2.5Y4/2), non-plastic, slight dilatancy, low toughness, damp, firm.	
						SAND WITH SILT (SP-SM): dark greyish brown (2.5Y4/2), fine-to medium-grained, poorly graded, subangular to angular, damp, no cementation, mottled with green and purple hydrocarbon stains, slight hydrocarbon odor.	
25 50 50	100				PID = 20.0 FID = 4.0	SILTY SAND (SM): light olive brown (2.5Y5/4), fine-to medium-grained, poorly graded, subangular to angular, damp, no cementation, with interbedded silts, pronounced hydrocarbon odor.	
26 40 50	100				PID = 400.0 FID = 4900.0	SILTY SAND (SM): olive brown (2.5Y4/3), fine-to medium-grained, poorly graded, subangular, damp, weak cementation, pronounced hydrocarbon odor.	
18 35 50	100			CA-D730501	PID = 450.0 FID = 14%	SANDY SILT (ML): light olive brown (2.5Y5/3), fine-grained sand, slow dilatancy, low toughness, damp, iron oxide staining, interbeds of silty sand, firm, moderate hydrocarbon odor, blebs of iron oxide staining.	Cement/4% Bentonite Grout
6	100						

DEPTH Feet BGS

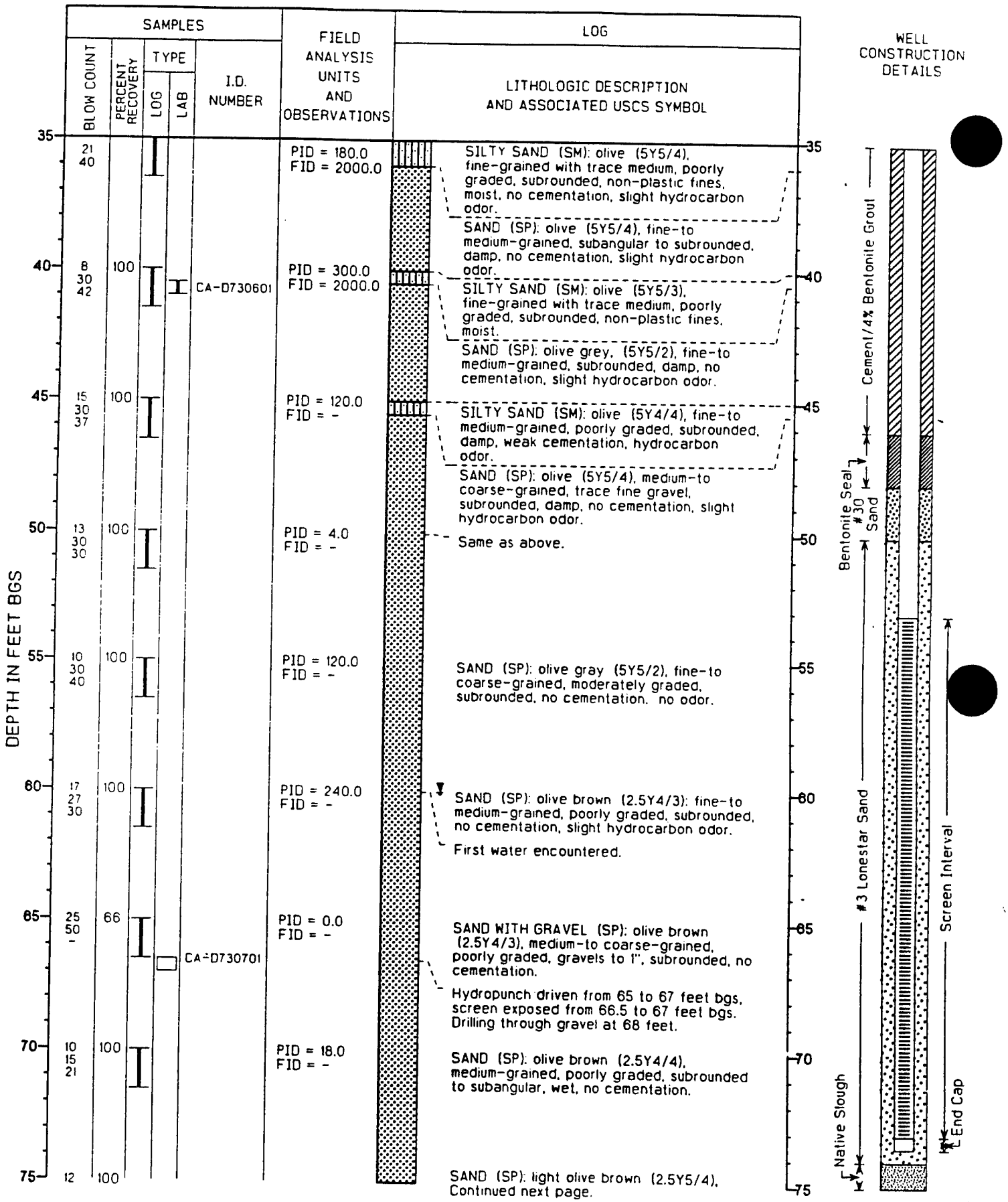
0 5 10 15 20 25 30 35

JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-965

PFFA-LTGSP
Castle Airport

BORING NO. MW-965



JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-965

PFFA-LTGSP
Castle Airport

BORING NO. MW-965

SAMPLES					FIELD ANALYSIS UNITS AND OBSERVATIONS	LOG	WELL CONSTRUCTION DETAILS
BLOW COUNT	PERCENT RECOVERY	TYPE: LOG	TYPE: LAB	I.D. NUMBER		LITHOLOGIC DESCRIPTION AND ASSOCIATED USCS SYMBOL	
16 27					PID = 24.0 FID = -	medium-to coarse-grained, moderately graded, subrounded to rounded, wet, no cementation, minor lenses of fine sand/silt.	

NOTES:
1. Hand augered to 5 feet.
2. Total depth 75 feet bgs.
3. 4 inch diameter sch 40 PVC blank.
4. 4 inch diameter sch 40 PVC screen .020 slot size.

DEPTH FEET BGS

75 80 85 90 95 100 105 110 115

Log of Boring MW-965

PFFA-LTGSP
Castle Airport
Page 3 of 3

JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

3-18-97 ig
4-9-97 ig

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27K72501

BORING NO. MW-966

DATE DRILLED	3/13/97 - 3/14/97
NORTHING	313250.16
EASTING	1981637.44
ELEVATION	168.40 MSLD feet
TOC ELEVATION	167.951 MSLD feet
TOTAL DEPTH	75 feet bgs

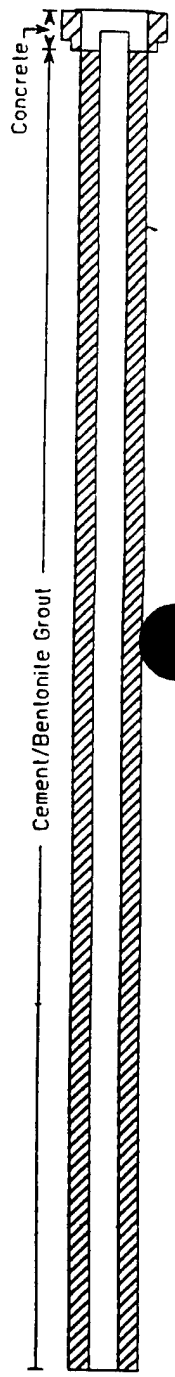
LOGGED BY	R. Hedegaard
DRILLING CONTRACTOR	
C-57 LICENSE NUMBER	
DRILLING METHOD	
DRILLING EQUIPMENT	
SAMPLING METHOD	
COMPLETION	

REVIEWED BY	L. Phillips
	Beylik Drilling
	306291
	Hollow Stem Auger
	Ingersoll Rand A-400
	Split Spoon
	Monitoring Well

JE Phillips

DEPTH IN FEET BGS	SAMPLES: BLOW COUNT	SAMPLES: PERCENT RECOVERY	SAMPLES: TYPE LOG	SAMPLES: TYPE LAB	SAMPLES: I.D. NUMBER	FIELD ANALYSIS UNITS AND OBSERVATIONS	LOG: LITHOLOGIC DESCRIPTION AND ASSOCIATED USCS SYMBOL
0							4 inches asphalt, native soil.
5	12 27 45	100	I			PID = 100.0 FID = 75.0	SILTY SAND (SM): brown (7.5YR4/4), fine-to medium-grained, poorly graded, damp, no cementation, minor hydrocarbon odor.
10	12 16 25	100	I			PID = 40.0 FID = 50.0	Same as above.
15	40 45 50	100	I			PID = 40.0 FID = 25.0	SILTY SAND (SM): dark reddish-brown (5YR3/3), fine-to medium-grained, poorly graded, subrounded, moist, no cementation.
20	6 28 50	100	I			PID = 16.0 FID = 0.0	SILT (ML): light brown (7.5YR6/4), fine-grained sand, no dilatancy, dry, very hard. SILTY SAND (SM): brown (10YR5/3), fine-to medium-grained, poorly graded, subangular to subrounded, low plasticity, no dilatancy, medium stiffness, moist, soft.
25	7 12 19	100	I	I	CA-D731701 CA-D731702	PID = 250.0 FID = 1.4%	SANDY SILT (ML): brownish yellow (10YR6/6), medium plasticity, rapid dilatancy, low toughness, moist, somewhat hard, pronounced hydrocarbon odor.
30	7 15 21	100	I			PID = 500.0 FID = 13%	SAND WITH SILT (SP-SM): yellowish red (5YR5/6), fine-to medium-grained, subangular to subrounded, nonplastic fines, moist, no cementation, hydrocarbon odor. SAND (SP): pink (7.5YR7/3), fine-to medium-grained, subangular to subrounded, non-plastic fines, damp, pronounced hydrocarbon odor.
35	15	100					

WELL CONSTRUCTION DETAILS

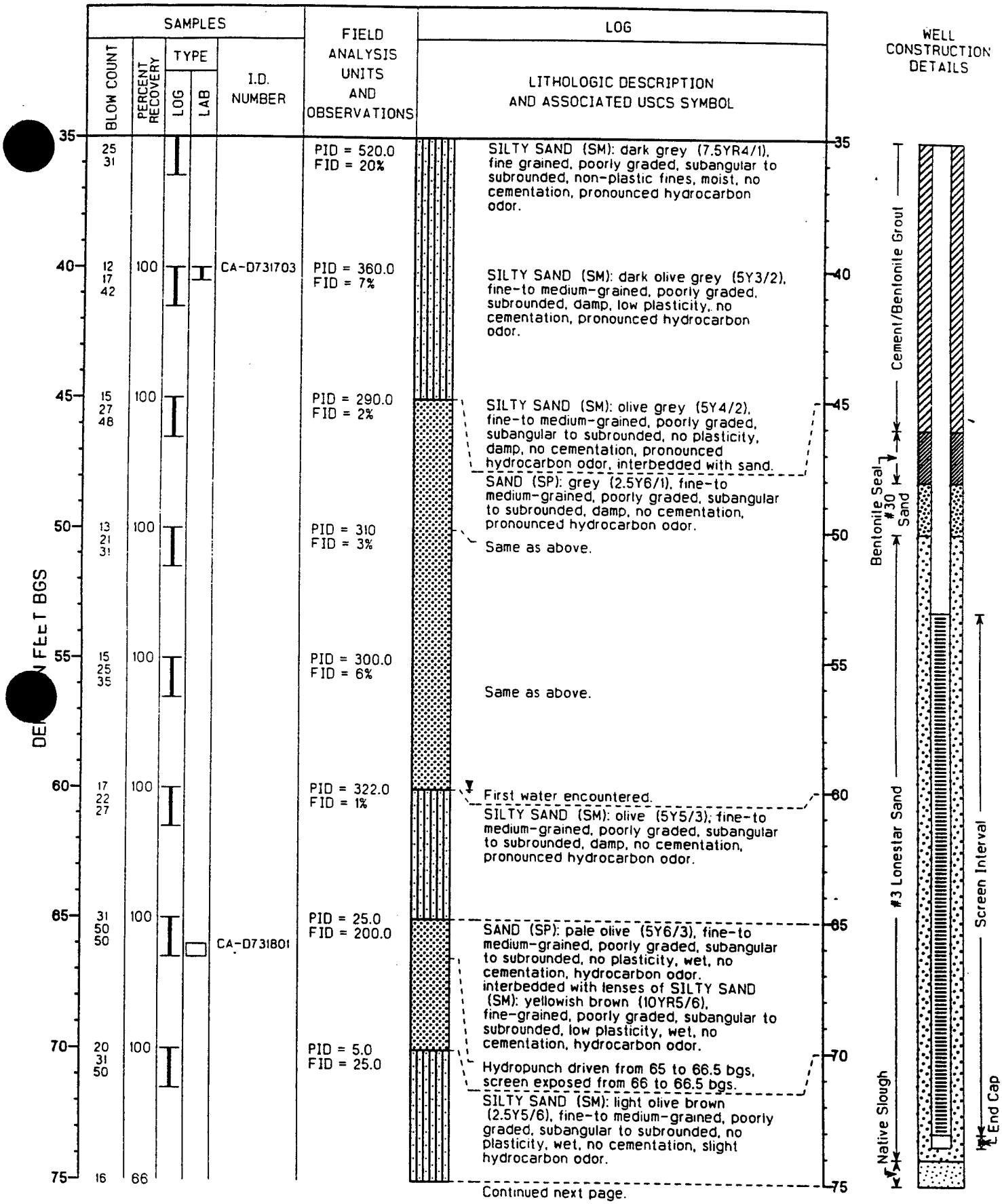


JE JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-96

PFFA-LT
Castle Airport

BORING NO. MW-966



JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-966

PFFA-LTGSP
Castle Airport

3-19-97 ig
4-2-97 ig

g:/gtgs/castle/ltgsp/mw-966.log/hsamw1.gpo

27K72501

BORING NO. MW-966

SAMPLES					FIELD ANALYSIS UNITS AND OBSERVATIONS	LOG	WELL CONSTRUCTION DETAILS
BLOW COUNT	PERCENT RECOVERY	TYPE: LOG	TYPE: LAB	I.D. NUMBER		LITHOLOGIC DESCRIPTION AND ASSOCIATED USCS SYMBOL	
27 50		I			PID = 50.0 FID = 250.0	SAND (SP): light yellowish brown (2.5Y6/4), fine-to medium-grained, poorly graded, subangular to subrounded, wet, no cementation, slight hydrocarbon odor.	

DEPTH IN FEET BGS

75 80 85 90 95 100 105 110 115

NOTES.
1. Hand augered to 5 feet.
2. Total depth 75 feet bgs.
3. 4 inch diameter sch 40 PVC blank.
4. 4 inch diameter sch 40 PVC screen .020 slot size.

JE JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-966

PFFA-LTGS
Castle Airport

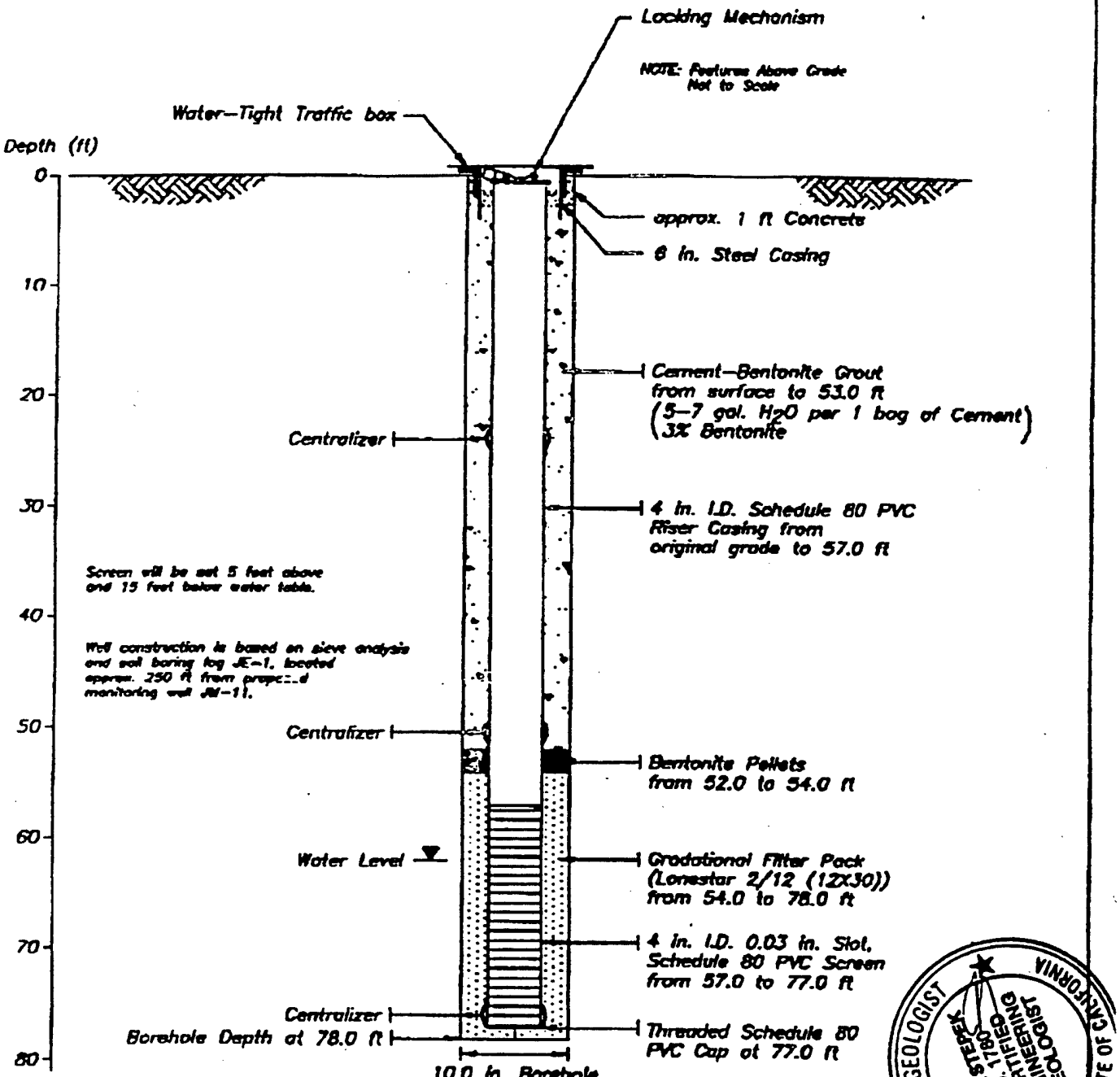
3-19-97 ig
4-2-97 ig

g:/gtgs/castle/ltgsp/mw-966.log/hsamwl.gpo

27K72501

WELL NO: JM-11

WELL COMPLETION DIAGRAM



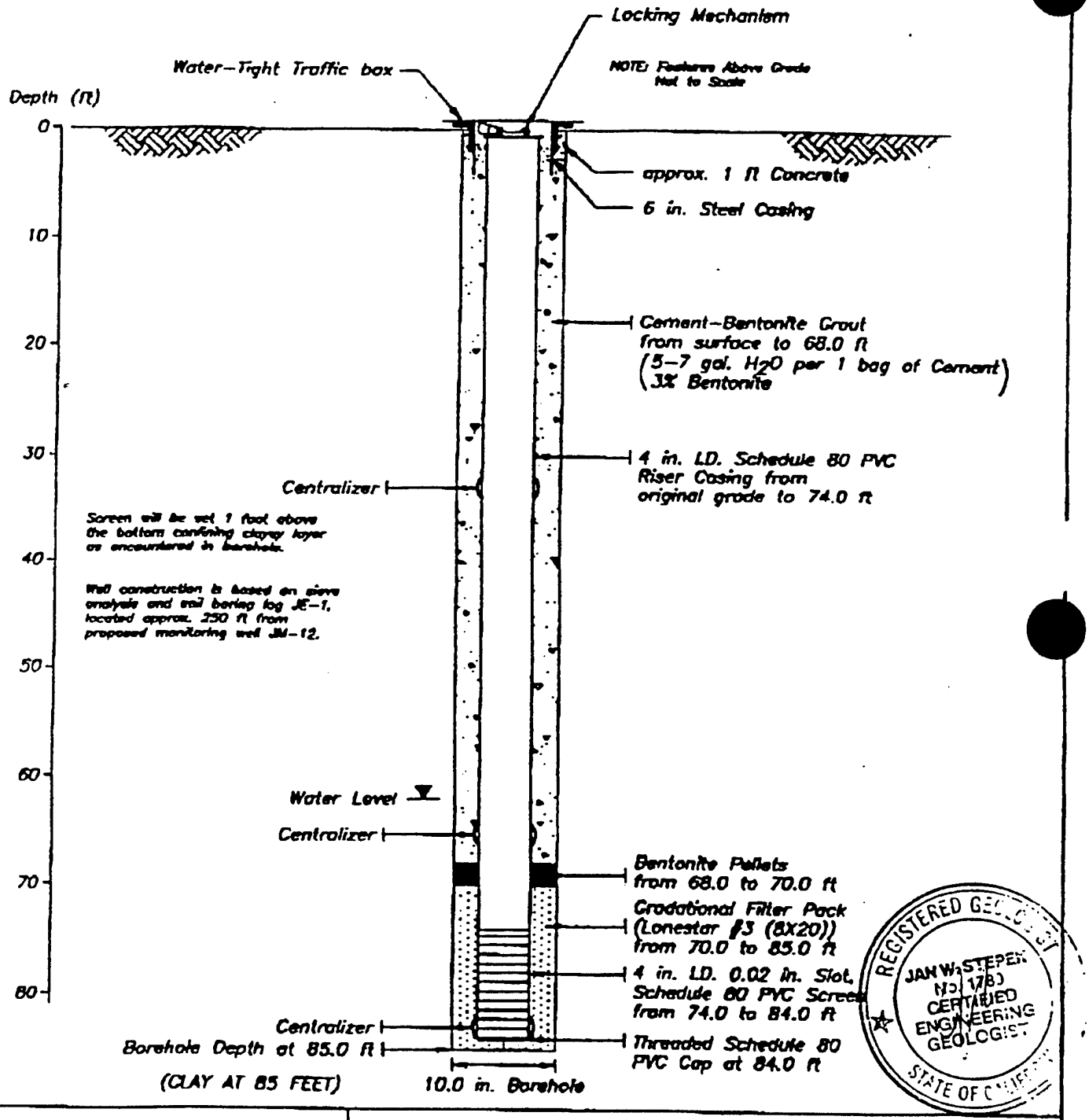
REGISTERED GEOLOGIST
DAN W. STEEK
No. 1780
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

EA®
ENGINEERING, SCIENCE, AND TECHNOLOGY

CASTLE AIR FORCE BASE
ATWATER, CA

WELL NO: JM-12

WELL COMPLETION DIAGRAM



REGISTERED GEOLOGIST
JAN W. STEPEK
NO. 1780
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

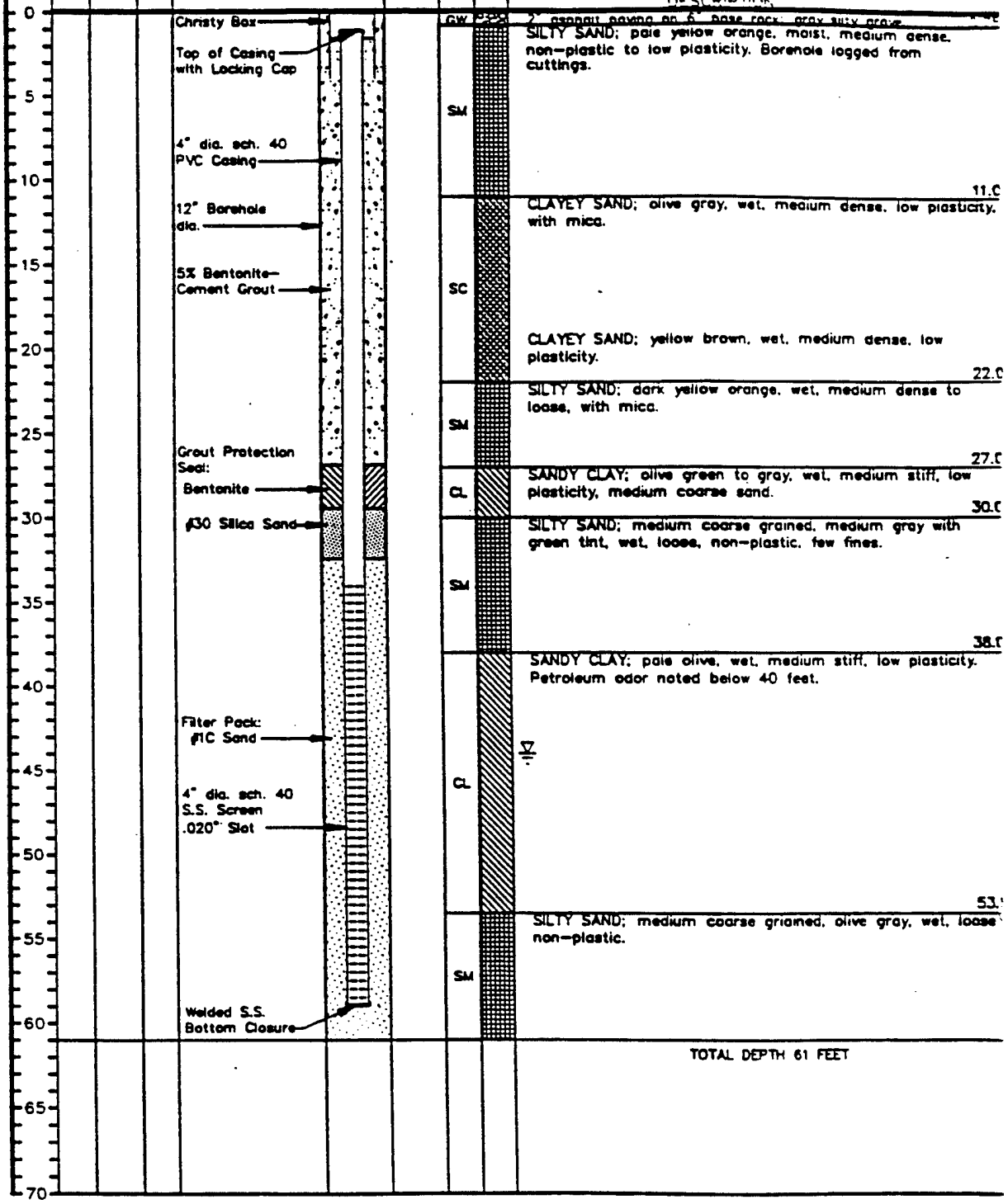
EA®
ENGINEERING, SCIENCE, AND TECHNOLOGY

CASTLE AIR FORCE BASE
ATWATER, CA

BORING NO. MW-531

PROJ. GEOL. T. Curran, R.G.
FIELD GEOLOGIST S. Hickey
EDITED BY P. McLaughlin
CHECKED BY P. McLaughlin
TOTAL DEPTH 61 feet

COORDINATES N 1854004.8 E 6542727.4
DATE BEGAN 10-4-88
DATE FINISHED 10-4-88
GROUND SURFACE EL. 169.7 ft.



DRILLING CO.: Beylik Drilling Inc.
DRILL METHOD: Hollow Stem Auger (Rig MD-3)

PAGE 1 OF

SEE LEGEND FOR LOGS AND TEST PITS FOR EXPLANATION OF SYMBOLS AND TERMS

PROJECT NO.: 409642
CLIENT: Castle Air Force Base
LOCATION: Castle Air Force Base, California

INTERNATIONAL TECHNOLOGY CORPORATION

MW-531(*CA10)

BORING NO. MW-532

PROJ. GEOL T. Curran, R.G.
FIELD GEOLOGIST S. Hickey
EDITED BY P. McLaughlin
CHECKED BY P. McLaughlin
TOTAL DEPTH 111 feet

COORDINATES N 1853999 E 8542720.2
DATE BEGAN 10-4-88
DATE FINISHED 10-10-88
GROUND SURFACE = 16[redacted]

DEPTH IN FEET	SAMPLE TYPE & NUMBER	RECOVERY/DRIVE (in.)	BLOWS PER FOOT (N)	WELL SUMMARY	P.I.D. READING (ppm)	USCS	PROFILE	DESCRIPTION
0		12/18		Locking Security Cover; Top of Casing with PVC Slip Cap; C.S. Centralizer; 4" dia. sch. 40 PVC Casing; 12" Borehole dia.; 5% Bentonite-Cement Grout		GW		2" asphalt on 6" base rock; dark gray silty gravel; [illegible]
		18/18				SM		SILTY SAND: coarse, dark orange brown, moist, dense, non-plastic, with mica below 3 feet.
5		16/24						
		16/18						
		14/18						
		12/24						9.0'
10		14/18				SC		CLAYEY SAND: grayish olive, moist, medium dense, non-plastic to low plasticity, with indurated fragments and mica.
		18/18						12.0'
		20/24				SM		SILTY SAND: medium to coarse grained, yellow brown to dark yellow orange, moist, medium dense, with clay filled, mineralized fracture surfaces.
15		16/18						15.0'
		16/18				CL		SANDY CLAY: mottled blue green to olive gray, moist, stiff, low plasticity, with ~3" sand lens at 19.5'.
		16/24						
20		16/18						
		18/18						
		12/24						24.5'
25		12/18				SP		SAND: medium coarse, medium gray, wet, loose, non-plastic.
		12/18						
		12/24						Greenish yellow tint.
30		14/18						
		12/18						
		18/24						
35		0/18						[redacted]'
		17/18				CL		SANDY CLAY: pale olive to yellowish gray, moist, stiff, low plasticity, fine sand. Fuel odor noted at about 43 feet, approximately at water table.
		15/24						
40		1/18						
		18/18		C.S. Centralizer				42.5'
		18/24				SM		SILTY SAND: medium to fine grained, mottled pale gray to green yellow, wet, loose, non-plastic, few fines.
45		12/60						
								49.0'
50						CL		SANDY CLAY: reddish brown, wet, medium stiff, low to moderate plasticity, with scattered large rounded gravels. 51.0'
		40/60				SM		SILTY SAND: fine grained, light gray to pale yellow, wet, loose, non-plastic, with little silt, with mica.
55								Increased silt fraction 55-60 feet.
		20/60						
60								Scattered medium gravels, subangular.
		27/60						
								64.0'
65		0/60				GW		SANDY GRAVEL: up to 1" diameter, light gray, loose, non-plastic, subrounded to subangular, coarse sand.
								68.0'
70						GP		GRAVEL: dark gray, coarse gravels and cobbles. Driller reports coarse gravels below 67 feet.

DRILLING CO.: Beylik Drilling Inc.
DRILL METHOD: Hollow Stem Auger 0-45' (Rig MD-3)
Mud Rotary 45'-T.D. (Rig TH-10)
PROJECT NO.: 409642
CLIENT: Castle Air Force Base
LOCATION: Castle Air Force Base, California

SEE LEGEND FOR LOGS AND TEST P[redacted]
FOR EXPLANATION OF SYMBOLS AN[redacted]S

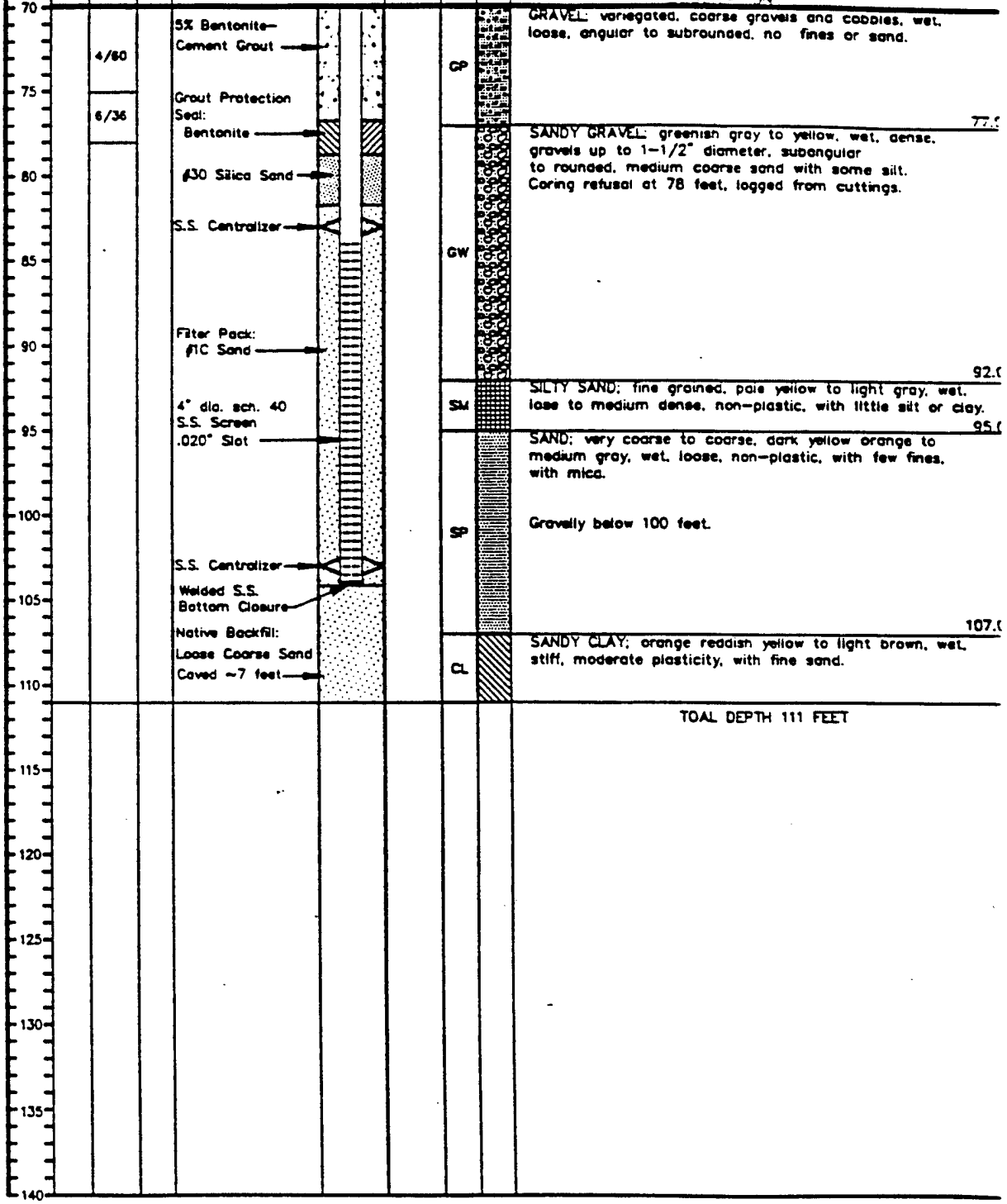
MW-532(•CA11)

INTERNATIONAL TECHNOLOGY CORPORATION

BORING NO. MW-532

PROJ. GEOL. T. Curran, R.G.
FIELD GEOLOGIST S. Hickey
EDITED BY P. McLaughlin
CHECKED BY P. McLaughlin
TOTAL DEPTH 111 feet

COORDINATES N 1853988.1 E 8542720.3
DATE BEGAN 10-4-88
DATE FINISHED 10-10-88
GROUND SURFACE E. 169.7 ft.



DRILLING CO.: Beylik Drilling Inc.
DRILL METHOD: Hollow Stem Auger 0-45' (Rig MD-3)
Mud Rotary 45'-T.D. (Rig TH-10)
PROJECT NO.: 409642
CLIENT: Castle Air Force Base
LOCATION: Castle Air Force Base, California

SEE LEGEND FOR LOGS AND TEST PITS FOR EXPLANATION OF SYMBOLS AND TER

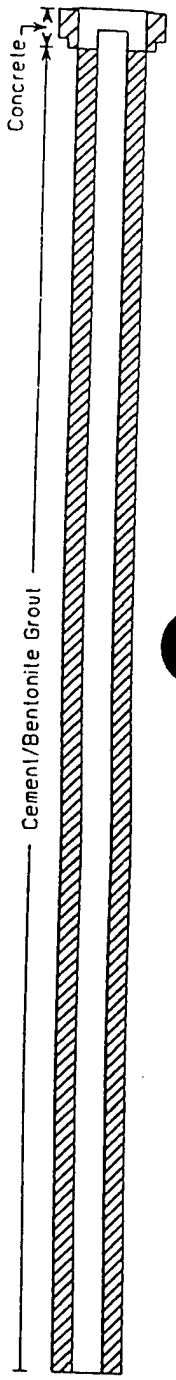
INTERNATIONAL TECHNOLOGY CORPORATION

BORING NO. MW-967

DATE DRILLED	3/17/97 - 3/18/97	LOGGED BY	R. Hedegaard
NORTHING	313538.51	REVIEWED BY	L. Phillips
EASTING	1981661.85	DRILLING CONTRACTOR	Beylik Drilling
ELEVATION	168.83 MSLD feet	C-57 LICENSE NUMBER	306291
TOC ELEVATION	168.400 MSLD feet	DRILLING METHOD	Hollow Stem Auger
TOTAL DEPTH	75 feet bgs	DRILLING EQUIPMENT	Ingersoll Rand A-400
		SAMPLING METHOD	Split Spoon
		COMPLETION	Monitoring Well

DEPTH IN FEET BGS	SAMPLES: BLOW COUNT	SAMPLES: PERCENT RECOVERY	SAMPLES: TYPE LOG	SAMPLES: TYPE LAB	SAMPLES: I.D. NUMBER	FIELD ANALYSIS UNITS AND OBSERVATIONS	LOG: LITHOLOGIC DESCRIPTION AND ASSOCIATED USCS SYMBOL
0						PID = 0.0 FID = 0.0	3 inches asphalt, native soil.
5	10 33 50	100				PID = 12.0 FID = 8.0	SILTY SAND (SM): olive yellow (2.5Y6/6), fine-to medium-grained, poorly graded, angular to subangular, damp, no cementation.
10	10 22 70	100				PID = 4.0 FID = 6.0	Same as above.
15	25 50 50	100				PID = 3.0 FID = 3.0	SILTY SAND (SM): yellowish brown (10YR5/4), medium-grained, poorly graded, subangular to subrounded, low plasticity, moist, no cementation, slight hydrocarbon odor, trace coarse sand and trace gravel.
20	20 50 -	50				PID = 2.0 FID = 2.0	SILTY SAND (SM): yellowish-brown (10YR5/8), medium-to coarse-grained, poorly graded, subangular to subrounded, low plasticity, moist, moderate cementation, slight hydrocarbon odor. SILT (ML): dark yellowish brown (10YR4/6), no plasticity, moist, soft, trace fine-grained sand.
25	15 30 50	100				PID = 2.0 FID = 8.0	SILTY SAND (SM): light yellowish brown (10YR6/4), fine-to medium-grained, poorly graded, angular to subangular, low plasticity, damp, weak cementation, slight hydrocarbon odor. SILT (ML): light yellowish brown (10YR6/4), trace fine-grained sand, low plasticity, no dilatancy, low toughness, soft, iron oxide staining in blebs.
30	17 40 49	100				PID = 3.0 FID = 3.0	SILTY SAND (SM): strong brown (7.5YR5/6), fine-grained, poorly graded, subangular to subrounded, damp. SILT (ML): pale brown (10YR6/3), trace fine-grained sand, no dilatancy, moist.
35	10	100					

WELL CONSTRUCTION DETAILS

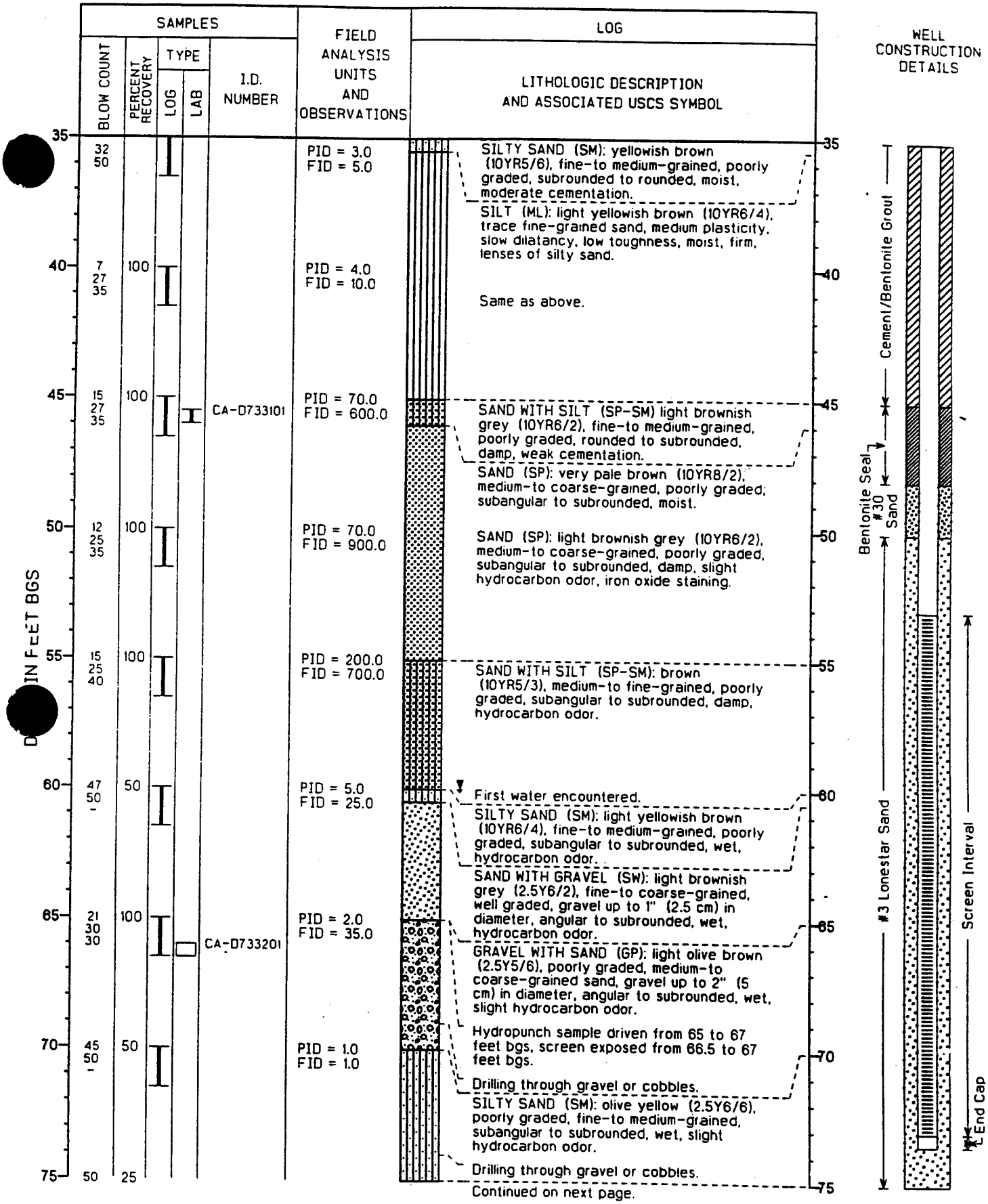


JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-967

PFFA-LTGSP
Castle Airport

BORING NO. MW-967



JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-967

PFFA-LTGSP
Castle Airport

BORING NO. MW-967

SAMPLES					FIELD ANALYSIS UNITS AND OBSERVATIONS	LOG	WELL CONSTRUCTION DETAILS
BLOW COUNT	PERCENT RECOVERY	TYPE: LOG	TYPE: LAB	I.D. NUMBER		LITHOLOGIC DESCRIPTION AND ASSOCIATED USCS SYMBOL	
					PID = 1.0 FID = 0.0	SAND WITH GRAVEL AND SILT (SW-SM): light yellowish brown (2.5Y6/4), 80% sand, 10% silt, 10% gravel, subangular to subrounded, well graded, wet, gravel up to 0.75" (2 cm) in diameter.	

DEPTH IN FEET BGS

75 80 85 90 95 100 105 110 115

NOTES:
1. Hand augered to 6 feet.
2. Total depth 75 feet bgs.
3. 4 inch diameter sch 40 PVC blank.
4. 4 inch diameter sch 40 PVC screen .020 slot size.

JE JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-96

PFFA-LTG
Castle Airp

3-19-97 ig
4-2-97 ig

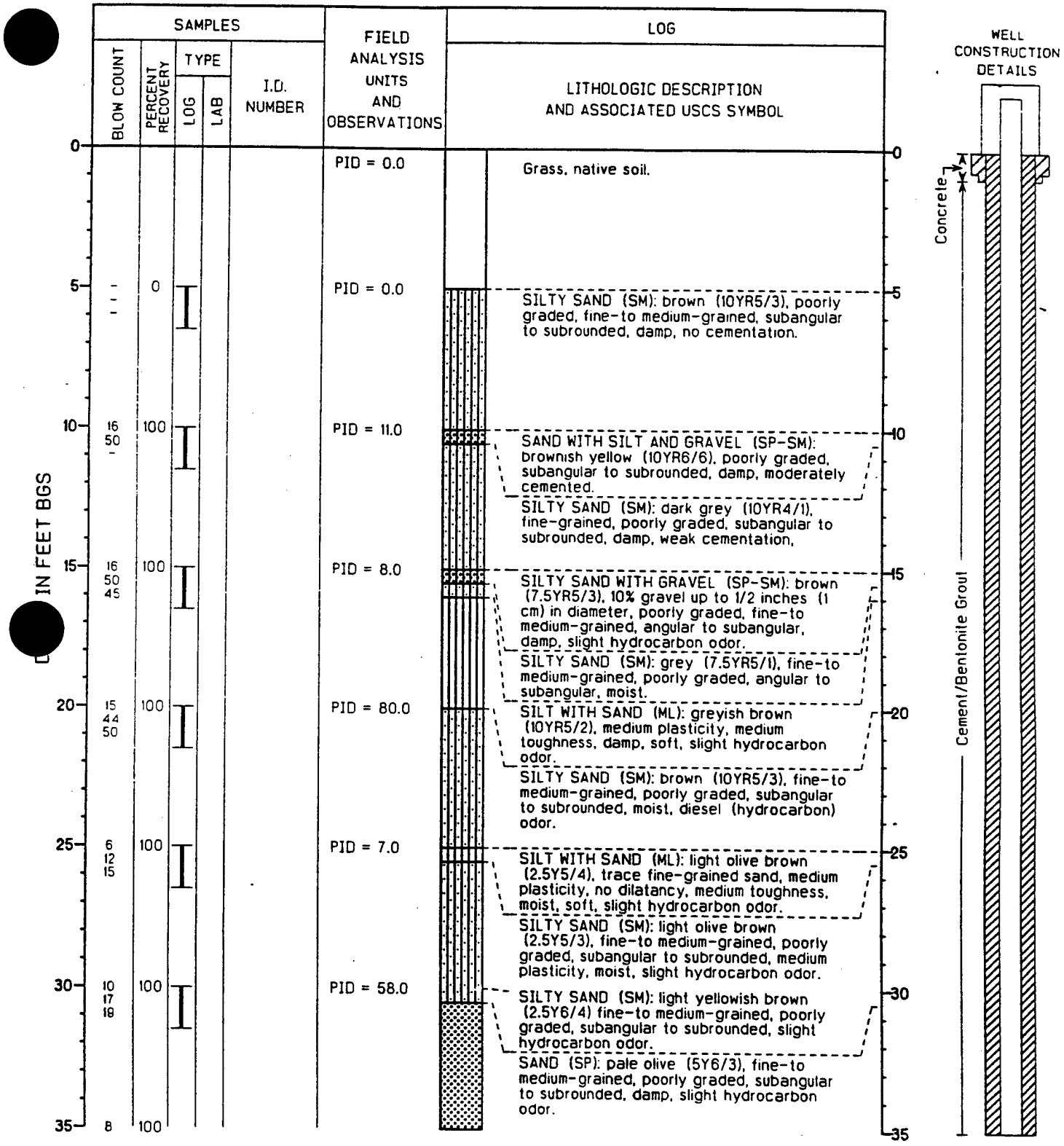
g:/gtgs/castle/ltgsp/mw-967.log/hsamwl.gpo

27K72501

BORING NO. MW-968

DATE DRILLED	3/19/97 - 3/20/97	LOGGED BY	E. Gavric
NORTHING	313454.00	DRILLING CONTRACTOR	Beylik Drilling
EASTING	1981444.08	C-57 LICENSE NUMBER	306291
ELEVATION	169.82 MSLD feet	DRILLING METHOD	Hollow Stem Auger
TOC ELEVATION	171.645 MSLD feet	DRILLING EQUIPMENT	Ingersoll Rand A-400
TOTAL DEPTH	75 feet bgs	SAMPLING METHOD	Split Spoon
		COMPLETION	Monitoring Well

REVIEWED BY L. Phillips



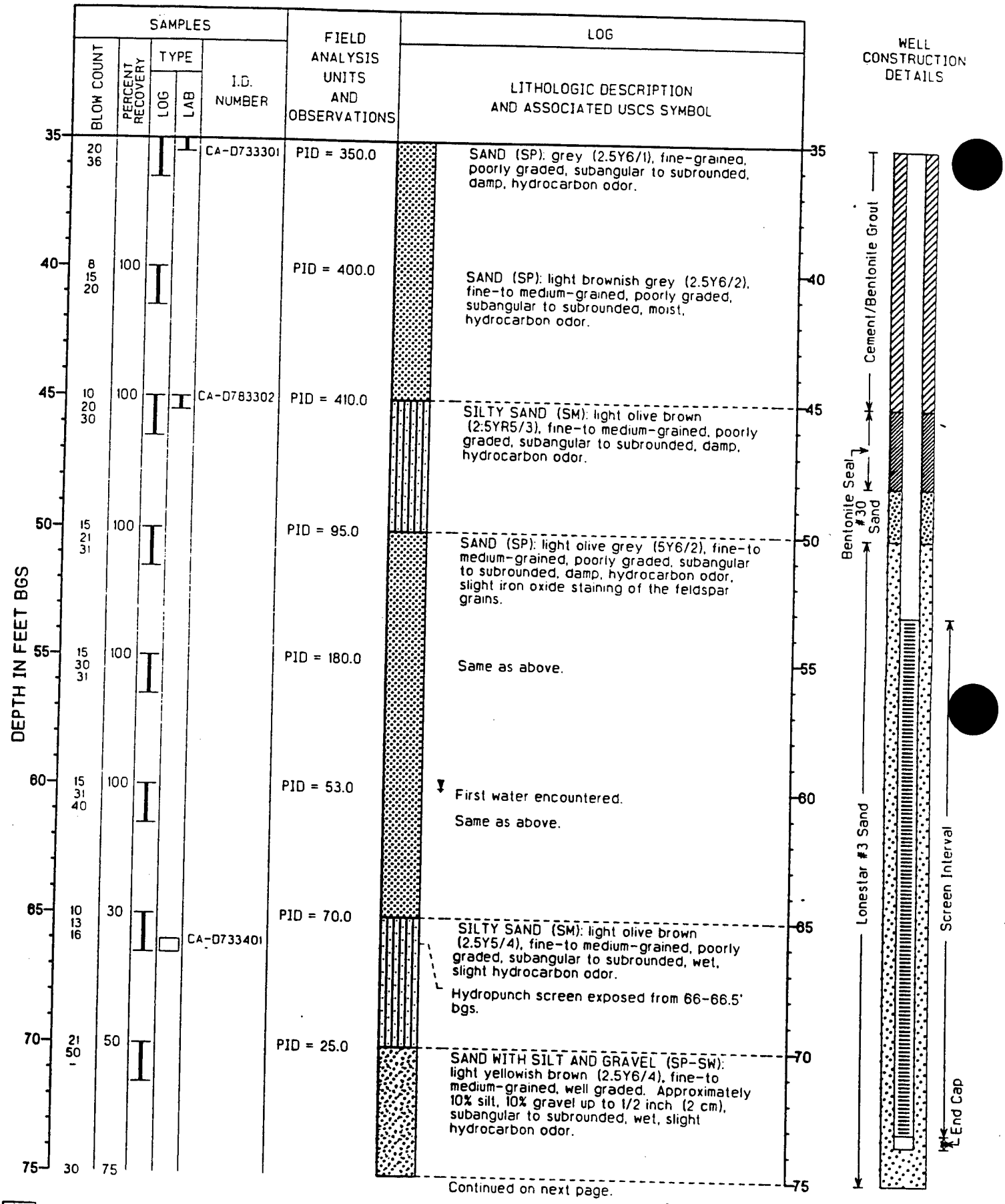
BLOW COUNT	PERCENT RECOVERY	I.D. NUMBER
- - -	0	
16 50 -	100	
16 50 45	100	
15 44 50	100	
6 12 15	100	
10 17 18	100	
8	100	

JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-968

PFFA-LTGSP
Castle Airport

BORING NO. MW-968



JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-968

PFFA-LTGS
Castle Airport

3-24-97 jg
4-2-97 jg
g:/gtgs/castle/ltgsp/mw-968.log/hsamwl.gpo
27K72501

BORING NO. MW-968

SAMPLES					FIELD ANALYSIS UNITS AND OBSERVATIONS	LOG	WELL CONSTRUCTION DETAILS
BLOW COUNT	PERCENT RECOVERY	TYPE: LOG	TYPE: LAB	I.D. NUMBER		LITHOLOGIC DESCRIPTION AND ASSOCIATED USCS SYMBOL	
50 / 1					PID = 1.5	GRAVEL WITH SILT AND SAND (GP-GM): light olive brown (2.5Y5/6), gravel up to 5 inches (12.5 cm), subangular to subrounded, wet, slight hydrocarbon odor.	

NOTES:
1. Hand augered to 5 feet.
2. Total depth 75 feet bgs.
3. 4 inch diameter sch 40 PVC blank.
4. 4 inch diameter sch 40 PVC screen .020 slot size.

DEPTH IN FEET BGS: 75, 80, 85, 90, 95, 100, 105, 110, 115

JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-968

PFFA-LTGSP
Castle Airport

4-24-97 jg
4-2-97 jg
g:/gtgs/castle/ltgsp/mw-968.log/hsamwl.gpo
27K72501

BORING NO. MW-969

DATE DRILLED	3/24/97 - 3/25/97
NORTHING	313222.00
EASTING	1981129.40
ELEVATION	168.59 MSLD feet
TOC ELEVATION	170.334 MSLD feet
TOTAL DEPTH	75 feet bgs

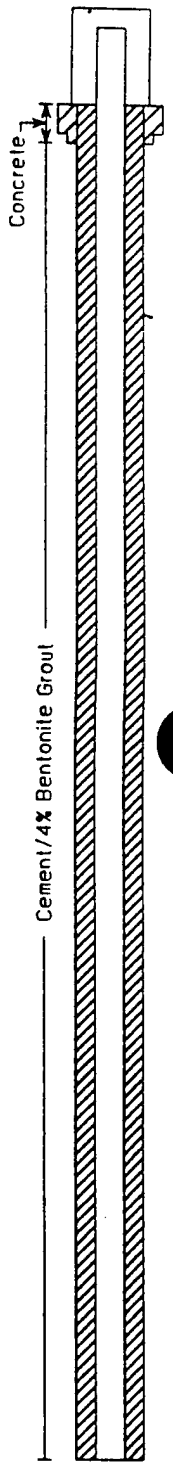
LOGGED BY	R. Hedegaard
DRILLING CONTRACTOR	
C-57 LICENSE NUMBER	
DRILLING METHOD	
DRILLING EQUIPMENT	
SAMPLING METHOD	
COMPLETION	

REVIEWED BY L. Phillips

Beylik Drilling
306291
Hollow Stem Auger
Ingersoll Rand A-400
Split Spoon
Monitoring Well

DEPTH IN FEET BGS	SAMPLES: BLOW COUNT	SAMPLES: PERCENT RECOVERY	SAMPLES: TYPE LOG	SAMPLES: TYPE LAB	SAMPLES: I.D. NUMBER	FIELD ANALYSIS UNITS AND OBSERVATIONS	LOG: LITHOLOGIC DESCRIPTION AND ASSOCIATED USCS SYMBOL
0						PID = 0.0 FID = 0.0	8 inches gravel roadbase.
							SAND WITH SILT (SP-SM): strong brown (7.5YR5/6), fine-to medium-grained, poorly graded, subrounded to subangular, dry (from cuttings).
5	17 41 35	100				PID = 0.0 FID = 0.0	Same as above.
10	21 25 30	100				PID = 0.0 FID = 0.0	SILTY SAND (SM): brown (7.5YR4/4), fine-to coarse-grained, moderately graded, subangular, damp.
15	12 21 50	100				PID = 50.0 FID = 0.0	SILTY SAND (SM): brown (10YR5/3), fine-to coarse-grained, moderately graded, subangular, damp, slight hydrocarbon odor. CLAY (CL): reddish brown (5YR5/4), medium to high plasticity, no dilatancy, medium toughness, moist, hard.
20	7 15 21	100				PID = 55.0 FID = 0.0	SILTY SAND (SM): dark yellowish brown (10YR5/6), fine-to medium-grained, poorly graded, subrounded to subangular, damp, slight hydrocarbon odor.
25	7 10 20	100				PID = 75.0 FID = 0.0	SILTY SAND (SM): yellowish red (10YR5/6), fine-to medium-grained, poorly graded, subrounded, damp, slight hydrocarbon odor. SANDY SILT (ML): grayish brown (2.5YR5/2), non-plastic, slow dilatancy, low toughness, damp, firm, slight hydrocarbon odor, iron oxide stringers.
30	11 50 -	75				PID = 600.0 FID = 50.0	Same as above. SILTY SAND (SM): yellowish red (10R5/6), fine-to medium-grained, poorly graded, subrounded, damp, slight hydrocarbon odor, silt lenses throughout.
35	9	100					

WELL CONSTRUCTION DETAILS



JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

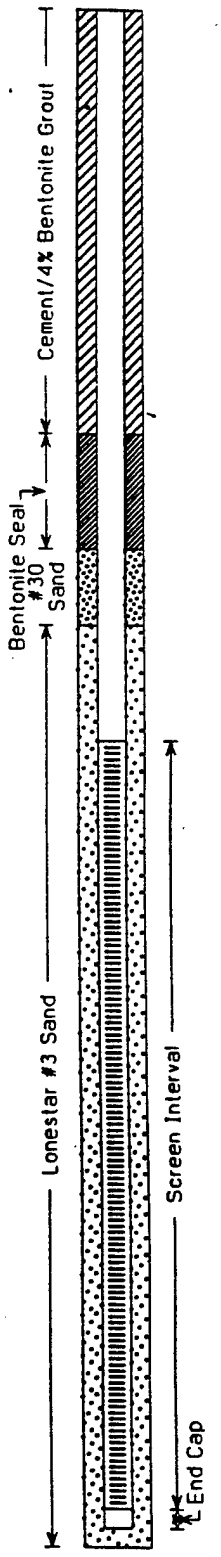
Log of Boring MW-96

PFFA-LTG
Castle Airp

BORING NO. MW-969

DEPTH IN FEET BGS	SAMPLES: BLOW COUNT	SAMPLES: PERCENT RECOVERY	SAMPLES: TYPE LOG	SAMPLES: TYPE LAB	SAMPLES: I.D. NUMBER	FIELD ANALYSIS UNITS AND OBSERVATIONS	LITHOLOGIC DESCRIPTION AND ASSOCIATED USCS SYMBOL
35	15 25					PID = 1500.0 FID = 200.0	Same as above. SAND (SP): yellowish brown (10YR5/4), medium-grained, poorly graded, subrounded, damp, light hydrocarbon odor.
40	11 20 30	100				PID = 700.0 FID = 23.0	Same as above, with iron oxide staining.
45	19 25 35	100				PID = 400.0 FID = 13.0	Same as above, without iron oxide staining, trace mica.
50	15 25 35	100				PID = 500.0 FID = 13.0	Color change to light olive brown (2.5Y5/3).
55	15 25 40	100				PID = 180.0 FID = 5.0	SAND (SP): olive brown (2.5Y4/3), medium-to coarse-grained, poorly graded, subrounded to subangular, damp, mica flakes to 1/8".
60	11 27 40	100				PID = 115.0 FID = 10.0	First water encountered. Same as above, damp. Encounter gravel at 64 feet bgs.
65	15 50	50			CA-D738101	PID = 110.0 FID = 5.0	GRAVEL WITH SAND (GP): yellowish brown (10YR5/6), fine-to coarse gravel, medium-to coarse-grained sand, poorly graded, subrounded to rounded, wet, predominately quartzite and chert.
70	22 50	75				PID = 107.0 FID = 3.0	GRAVEL WITH SILT AND SAND (GP-GM): yellowish brown (10YR5/6), fine to coarse gravel, fine to coarse-grained sand, moderately graded, subrounded, wet.
75	8	100					Same as above.

WELL CONSTRUCTION DETAILS



JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-969

PFFA-LTGSP
Castle Airport

BORING NO. MW-969

SAMPLES					FIELD ANALYSIS UNITS AND OBSERVATIONS	LOG	WELL CONSTRUCTION DETAILS
BLOW COUNT	PERCENT RECOVERY	TYPE: LOG	TYPE: LAB	I.D. NUMBER		LITHOLOGIC DESCRIPTION AND ASSOCIATED USCS SYMBOL	
10 15		I			PID = 70.0 FID = 1.0		

DEPTH IN FEET BGS

75 80 85 90 95 100 105 110 115

NOTES:
1. Hand augered to 6 feet.
2. Total depth 75 feet bgs.
3. 4 inch diameter sch 40 PVC blank.
4. 4 inch diameter sch 40 PVC screen .020 slot size.

JE JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-969

PFFA-LTGS
Castle Airpor

3-26-97 jag
4-2-97 jg

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27K72501

BORING NO. MW-970

DATE DRILLED	3/25/97 - 3/26/97	LOGGED BY	R. Hedegaard	REVIEWED BY	L. Phillips
NORTHING	313647.35	DRILLING CONTRACTOR			Beylik Drilling
EASTING	1981178.61	C-57 LICENSE NUMBER			306291
ELEVATION	170.65 MSLD feet	DRILLING METHOD			Hollow Stem Auger
TOC ELEVATION	172.831 MSLD feet	DRILLING EQUIPMENT			Ingersoll Rand A-400
TOTAL DEPTH	76 feet bgs	SAMPLING METHOD			Split Spoon Hydropunch
		COMPLETION			Monitoring Well

SAMPLES					FIELD ANALYSIS UNITS AND OBSERVATIONS	LOG
BLOW COUNT	PERCENT RECOVERY	TYPE: LOG	TYPE: LAB	I.D. NUMBER		LITHOLOGIC DESCRIPTION AND ASSOCIATED USCS SYMBOL
						Grass, native soil.
10 15 21	100				PID = 0.0 FID = 0.0	SAND WITH SILT (SP-SM): brown (7.5YR4/3), fine-to medium-grained, poorly graded, subrounded, damp.
15 26 30	100				PID = 40.0 FID = 0.0	SAND WITH SILT (SP-SM): yellowish brown (10YR5/6), fine-to medium-grained, poorly graded, subrounded, damp.
						SILTY SAND (SM): light olive brown (2.5Y5/4), fine-grained, trace medium-grained, poorly graded, subangular, moist.
20 50 -	75				PID = 45.0 FID = 0.0	SILTY SAND (SM): brown (10YR4/3), fine-to medium-grained, poorly graded, subangular to subrounded, damp.
						SILTY SAND (SM): reddish brown (5YR4/4), fine-grained, trace medium grained, poorly graded, subangular, damp.
12 50 -	75				PID = 8.0 FID = 0.0	SAND WITH SILT (SP-SM): strong brown (7.5YR4/6), fine-to medium-grained, trace coarse-grained, poorly graded, damp.
12 50 -	75				PID = 12.0 FID = 0.0	Color change to brown (10YR4/3).
						SILT WITH SAND (ML): light yellowish brown (10YR6/4), non plastic, slow dilatancy, low toughness, moist, hard, iron oxide and carbonaceous stringers.
13 40 50	100				PID = 10.0 FID = 0.0	Same as above.
						SAND (SP): dark yellowish brown (10YR4/4), fine-grained, poorly graded, angular to subangular, damp, iron oxide staining.

DEPTH IN FEET BGS

0 5 10 15 20 25 30 35

WELL CONSTRUCTION DETAILS

Concrete

Cement/4% Bentonite Grout

Log of Boring MW-970

PFFA-LTGSP
Castle Airport

JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

7-97 jg
4-1-97 jg

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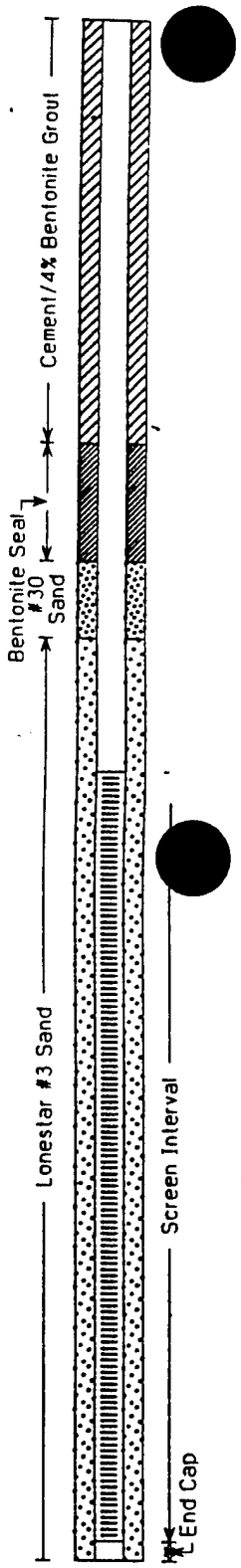
27K72501

BORING NO. MW-970

DEPTH IN FEET BGS	BLOW COUNT	PERCENT RECOVERY	SAMPLES TYPE LOG	SAMPLES TYPE LAB	I.D. NUMBER	FIELD ANALYSIS UNITS AND OBSERVATIONS	LITHOLOGIC DESCRIPTION AND ASSOCIATED USCS SYMBOL
35	12 15 27	100				PID = 30.0 FID = 0.0	SILT (ML): pale brown (10YR6/3), low plasticity, slow dilatancy, no toughness, damp, iron oxide staining.
							Same as above.
40	12 21 37	100				PID = 25.0 FID = 0.0	SILTY SAND (SM): dark greyish brown (10YR4/2), fine-grained, poorly graded, subangular, damp, thin iron oxide laminations throughout.
45	16 30 40	100				PID = 235.0 FID = 0.0	SAND WITH SILT (SP-SM): light olive brown (2.5Y5/4), fine-grained, poorly graded, subangular, damp, slight hydrocarbon odor.
50	14 30 50	100				PID = 150.0 FID = 0.0	SAND (SP): yellowish brown (10YR5/4), fine-grained, trace medium-grained, poorly graded, subangular to subrounded, damp, mica, slight hydrocarbon odor, slight iron oxide stains.
55	13 40 50	100				PID = 450.0 FID = 0.0	Same as above, fine-to medium-grained.
60	20 35 50	100				PID = 100.0 FID = 0.0	SAND (SP): grey (2.5Y5/1), fine-to medium-grained, poorly graded, subrounded, damp, micaceous. ▼ First water encountered.
65	40 50 –	75			CA-D738501	PID = 15.0 FID = 0.0	Same as above. GRAVEL WITH SAND (GP): brown (10YR4/3), fine-to coarse-grained, moderately graded, subrounded, wet, predominately chert, hydrocarbon odor.
70	25 35 50	100				PID = 10.0 FID = 3.0	SAND WITH SILT AND GRAVEL (SP-SM): dark greyish brown (2.5Y4/2), fine-to coarse-grained, moderately graded, gravel to 3/4", subrounded, wet, hydrocarbon odor. GRAVEL (GP) olive brown (2.5Y4/3), fine-to coarse-grained, poorly graded, rounded to subrounded, wet.
75							

WELL CONSTRUCTION DETAILS



JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-97

PFFA-LTG
Castle Airp

BORING NO. MW-970

SAMPLES					FIELD ANALYSIS UNITS AND OBSERVATIONS	LOG	WELL CONSTRUCTION DETAILS
BLOW COUNT	PERCENT RECOVERY	TYPE: LOG	TYPE: LAB	I.D. NUMBER		LITHOLOGIC DESCRIPTION AND ASSOCIATED USCS SYMBOL	
15 50	50				PID = 4.0 FID = 0.0	GRAVEL (GP) olive brown (2.5Y4/3), fine-to coarse-grained, poorly graded, rounded to subrounded, wet.	Lonestar #3-Sand

DEPTH IN FEET BGS

75
80
85
90
95
100
105
110
115

NOTES.
1. Hand augered to 6 feet.
2. Total depth 76 feet bgs.
3. 4 inch diameter sch 40 PVC blank.
4. 4 inch diameter sch 40 PVC screen .020 slot size.

Log of Boring MW-970

PFFA-LTGSP
Castle Airport

JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

3-27-97 jg
4-1-97 jg

g:/gtgs/castle/ltgsp/mw-970.log/hsamwl.gpo

27K72501

BORING NO. MW-971

DATE DRILLED	3/26/97 - 3/27/97	LOGGED BY	R. Hedegaard
NORTHING	313814.01	DRILLING CONTRACTOR	
EASTING	1981351.29	C-57 LICENSE NUMBER	
ELEVATION	169.52 MSLD feet	DRILLING METHOD	
TOC ELEVATION	169.120 MSLD feet	DRILLING EQUIPMENT	
TOTAL DEPTH	76 feet bgs	SAMPLING METHOD	
		COMPLETION	

REVIEWED BY L. Phillips

Beylik Drilling
306291
Hollow Stem Auger
Ingersoll Rand A-400
Split Spoon
Monitoring Well

SAMPLES					FIELD ANALYSIS UNITS AND OBSERVATIONS	LOG	WELL CONSTRUCTION DETAILS
BLOW COUNT	PERCENT RECOVERY	TYPE LOG	TYPE LAB	I.D. NUMBER		LITHOLOGIC DESCRIPTION AND ASSOCIATED USCS SYMBOL	
						Asphalt, native soil.	Concrete
10 12 21	100				PID = 0.0 FID = 0.0	SILTY SAND (SM): strong brown (7.5YR4/6), fine-to medium-grained, poorly graded, subangular, damp.	
6 14 15	75				PID = 12.0 FID = 0.0	SILTY SAND (SM): brown (10YR5/3), fine-to medium-grained, poorly graded, subangular to subrounded, damp, silty interbeds.	
18 50 -	75				PID = 41.0 FID = 0.0	Same as above. SAND WITH SILT (SP-SM): strong brown (7.5YR5/6), fine-to medium-grained, poorly graded, subrounded, damp.	
14 50 -	75				PID = 45.0 FID = 0.0	SILTY SAND (SM): strong brown (7.5YR5/6), fine-to medium-grained, poorly graded, subangular to subrounded, damp.	
15 50 50	100				PID = 14.0 FID = 0.0	SILTY SAND (SM): brown (10YR4/3), fine-to medium-grained, poorly graded, subangular, moist. SILT WITH SAND (ML): yellowish brown (10YR5/4), low plasticity, slow dilatancy, low toughness, damp, firm, iron oxide and black carbonaceous stringers.	Cement/4% Bentonite Grout
19 45 50	100				PID = 11.0 FID = 0.0	SAND WITH SILT (SP-SM): brown (7.5YR4/4), fine-grained, trace medium-grained, subangular, damp, trace iron oxide staining. SILT (ML): yellowish brown (10YR5/4), low plasticity, slow dilatancy, low toughness, moist, firm, iron oxide lenses.	
15	100						

DEPTH IN FEET BGS

0 5 10 15 20 25 30 35

JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-97
PFFA-LTG
Castle Airpo

4-2-97 jg
4-3-97 jg
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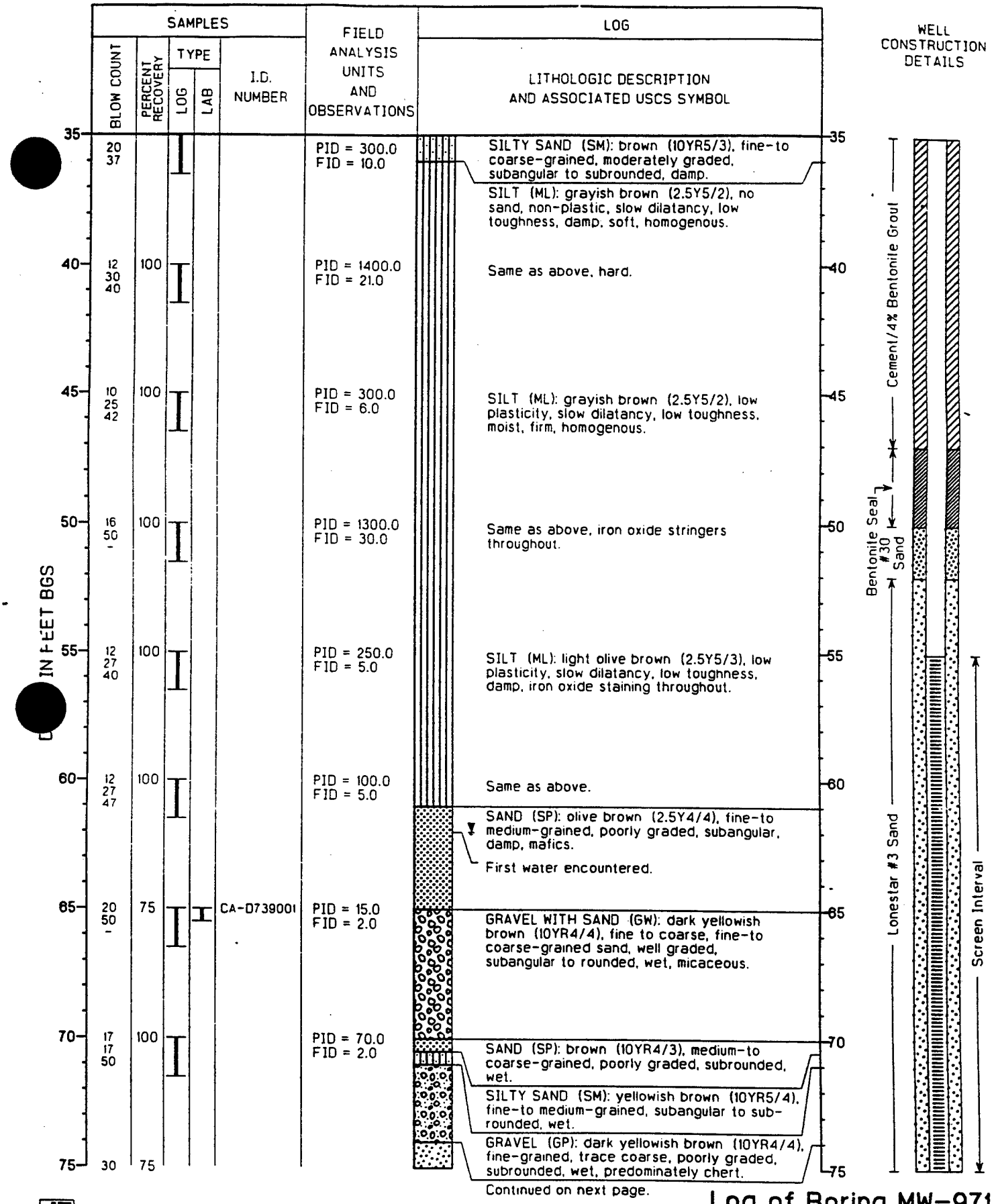
27K72501

BORING NO. MW-971



Log of Boring MW-971

JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

PFFA-LTGSP
Castle Airport

BORING NO. MW-971

SAMPLES					FIELD ANALYSIS UNITS AND OBSERVATIONS	LOG	WELL CONSTRUCTION DETAILS
BLOW COUNT	PERCENT RECOVERY	TYPE: LOG	TYPE: LAB	I.D. NUMBER		LITHOLOGIC DESCRIPTION AND ASSOCIATED USCS SYMBOL	
50 / 1					PID = 10.0 FID = 0.0	SAND (SW): brown (10YR4/3), fine-to coarse-grained, well-graded, subrounded, wet, silty laminations (1/8" thick).	Lonestar #3 Sand End

DEPTH IN FEET BGS

75 80 85 90 95 100 105 110 115

NOTES:
1. Hand augered to 6 feet.
2. Total depth 76 feet bgs.
3. 4 inch diameter sch 40 PVC blank.
4. 4 inch diameter sch 40 PVC screen .020 slot size.

JACOBS ENGINEERING GROUP INC.
NORTHERN CALIFORNIA ENVIRONMENTAL OPERATIONS

Log of Boring MW-97

PFFA-LTGS
Castle Airpo

4-2-97 ig
4-3-97 ig

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27K72501

TW13

J. H. KLEINFELDER & ASSOCIATES
GEOTECHNICAL CONSULTANTS — MATERIALS TESTING

BORING LOG

HOLE NO.	PROJECT NO.	PROJECT	SHEET 2 OF 7
Well 13	81-0623	Water Sampling Wells	
MFR. DESIGNATION OF DRILL		LOCATION	
Acker AD-II		Castle AFB	
TYPE OF BIT	HAMMER DATA: WT. LBS. DROP INCHES	ELEV.	TOTAL DEPTH OF HOLE
DATE STARTED	DRILLING AGENCY J. H. Kleinfelder & Assoc.		95'
DATE COMPLETED	INSPECTOR	GROUNDWATER DEPTH	TIME
DATE BACKFILLED	CREW		
SURFACE CONDITIONS			

DIST. FROM SURF.	LEGEND	SAMPLE TYPE	SAMPLE NO.	RECOVERY	BLOWS PER 6 IN.	USCS	LOG OF MATERIAL
0							SM Silty Sand
55							CL Clay.
65							SM Silty Sand.
70							GM Gravel.
80							SP Sand.
85							Well Screen
90							CL Clay.
95							Pump at Bottom of Well Screen.

SHEET OF JOB NO.

TW 16

J. H. KLEINFELDER & ASSOCIATES
GEOTECHNICAL CONSULTANTS — MATERIALS TESTING

BORING LOG

HOLE NO.	PROJECT NO.	PROJECT	SHEET
Well 16 / Add-I	81-0623	Water Sampling Wells	1 of 7

MFR. DESIGNATION OF DRILL	LOCATION
Acker AD-II	Castle AFB

TYPE OF BIT	HAMMER DATA: WT.	LBS. DROP	INCHES	ELEV.	TOTAL DEPTH OF HOLE
					102'

DATE		
STARTED	DRILLING AGENCY	J. H. Kleinfelder & Assoc.
COMPLETED	INSPECTOR	
BACKFILLED	CREW	

GROUNDWATER DEPTH _____ TIME _____

SURFACE CONDITIONS

DIST. FROM SURF.	LEGEND	SAMPLE TYPE	SAMPLE NO.	RECOVERY	BLOWS PER 6 IN.	USCS	LOG OF MATERIAL
5							SM Silty Sand.
10							
15							
20							
25							
30							
35							
40							
45							
50							
55							
60							
65							GM Gravel
70							
75							
80							
85							
90							SP Fine to Medium Sand.
95							Well Screen
100							CL Sandy Clay.
105							Pump at Bottom of Well Screen.

SHEET OF

Table 4-1
Well Inventory and Construction Information

WELL NUMBER	BASE SECTOR	DATE INSTALLED	SCREENED HSZ	NORTHING (ft) 316,062.45 NAD83	EASTING (ft) 1,981,207.44 NAD83	GRID	TOTAL DEPTH OF BORING (ft, bgs)	FILTER PACK INTERVAL (ft, bgs)		WELL SCREEN INTERVAL (ft, bgs)		CURRENT STATUS	COMMENTS
								TOP	BOTTOM	TOP	BOTTOM		
AM11	OBS	11/6/61	MHZ	313,119.67	1,974,085.46	S 5	NA	NA	NA	88	278	ABD	Abandoned in 1991 (as per B. Swalley, City of Atwater)
AM12	OBS	NA	LSS,CF	309,530.61	1,973,393.89	W 4	NA	NA	NA	192	266	ABD	Abandoned in 1992 (as per B. Swalley, City of Atwater)
AM16	OBS	10/88?	CF,DP	312,730.12	1,975,186.49	T 6	653	NA	NA	330	600		Pumping (rate: 1600 - 2400 gpm)
AM17	OBS	NA	CF,DP	313,230.00	1,971,150.00	S 2	620	NA	NA	305	515		Pumping (rate: 500 - 2300 gpm)
AM18	OBS	3/10/92	DP	309,550.00	1,974,850.00	W 5	620	NA	NA	380	600		Pumping (rate: 1400 gpm)
AM19	OBS	3/10/92	DP	315,612.95	1,972,729.99	Q 3	720	NA	NA	485	660		Pumping (rate unknown)
AM20	OBS	5/15/92	CF,DP	308,000.00	1,978,430.00	Y 7	992	NA	NA	340	640		Pumping (rate: 500 - 2300 gpm)
AS1-6	OBS	NA	NA	313,141.42	1,975,226.76	S 6	NA	NA	NA	NA	NA		
BE1	OBS	02/02/88	LSS	313,829.45	1,975,331.55	S 6	NA	NA	NA	210	250		
BE2	OBS	02/02/88	S	313,790.93	1,975,330.68	S 6	NA	NA	NA	65	85		
BE3	OBS	02/02/88	LSS	312,164.61	1,975,941.37	T 6	NA	NA	NA	220	240		
BE4	OBS	02/02/88	S	312,117.83	1,975,945.12	T 6	NA	NA	NA	75	95		
CMHP1	OBS	NA	S	313,903.40	1,977,888.87	S 8	NA	NA	NA	NA	NA	ABD	Reported as TD=135'
CMHP2	OBS	NA	S	313,611.94	1,977,839.73	S 8	NA	NA	NA	NA	NA	ABD	
CMHP3	OBS	03/29/72	S, USS	314,226.68	1,977,566.15	R 8	NA	NA	NA	120	140	ABD	
D150	OBS	5/14/63	S	NA	NA	N A	90	NA	NA	NA	NA		
D1161	OBS	NA	NA	313,493.30	1,975,702.99	S 6	NA	NA	NA	NA	NA		
D1233	OBS	5/16/05	S	313,359.13	1,976,030.69	S 7	NA	NA	NA	NA	NA		
D1246	OBS	NA	NA	NA	NA	N A	NA	NA	NA	NA	NA		Location uncertain. May be UNKNOWN location (Grid S/7) on well map
D2679	OBS	NA	NA	313,166.66	1,977,886.84	S 8	NA	NA	NA	NA	NA		
D2689	OBS	NA	S	313,264.62	1,977,890.02	S 8	NA	NA	NA	NA	NA	ABD	Location uncertain. May be UNKNOWN location (Grid S/7) on well map
D2689BR	OBS	NA	S	313,264.62	1,977,890.02	S 8	NA	NA	NA	NA	NA	ABD	
D2889	OBS	8/20/76	S, USS	NA	NA	N A	140	85	115	85	115		2889 Buhach Rd. Ann. seal to 20'
D4002	OBS	5/9/61	USS	NA	NA	N A	138	NA	138	118	138		4002 N. Buhach Rd.
D4115	OBS	NA	NA	308,407.80	1,982,971.71	X 13	NA	NA	NA	NA	NA		No data available from City of Atwater
D4193	OBS	NA	NA	308,860.76	1,982,036.59	X 13	NA	NA	NA	NA	NA		No data available from City of Atwater
D4246	OBS	NA	NA	309,037.26	1,981,918.16	W 12	NA	NA	NA	NA	NA		No data available from City of Atwater
D4263	OBS	NA	NA	309,090.76	1,983,030.80	W 14	NA	NA	NA	NA	NA		No data available from City of Atwater
D4310	OBS	6/7/1985	S, USS, LSS	309,442.06	1,978,340.01	W 9	180	NA	NA	165	180		Annular seal @ 110'
D4316	OBS	06/05/85	S, USS, LSS	309,510.87	1,978,326.36	W 9	165	NA	NA	155	165		Annular seal @ 110'
D4320	OBS	6/5/05	S, USS, LSS	309,487.53	1,977,957.90	W 8	NA	NA	NA	NA	NA		Annular seal @ 100'
D4331	OBS	5/10/61	S	NA	NA	W 9	73	NA	NA	50.5	73		4331 West Avenue

Table 4-1
Well Inventory and Construction Information

WELL NUMBER	BASE SECTOR	DATE INSTALLED	SCREENED HSZ	NORTHING (ft) 316,062.45 NAD83	EASTING (ft) 1,981,207.44 NAD83	GRID	TOTAL DEPTH OF BORING (ft, bgs)	FILTER PACK INTERVAL (ft, bgs) TOP	FILTER PACK INTERVAL (ft, bgs) BOTTOM	WELL SCREEN INTERVAL (ft, bgs) TOP	WELL SCREEN INTERVAL (ft, bgs) BOTTOM	CURRENT STATUS	COMMENTS
D4338	OBS	6/8/84	S	309,714.16	1,978,346.07	W 9	110	NA	NA	95	110		Annular seal @ 65'
D4358	OBS	01/10/84	LSS	309,866.23	1,978,364.48	W 9	NA	NA	NA	215	235		
D4366BL	OBS	06/09/80	NA	310,022.51	1,978,727.59	V 9	NA	NA	NA	NA	NA		No data available from City of Atwater
D4366BR	OBS	6/2/05	S	309,715.74	1,977,960.33	W 8	NA	NA	NA	NA	NA		Annular seal 50'
D4382	OBS	6/23/78	S	NA	NA	N A	NA	NA	NA	97	107		4382 Avenue 1; Annular seal to 20'
D4394	OBS	6/2/05	S, USS	309,879.55	1,977,970.31	W 8	NA	NA	NA	NA	NA		
D4398	OBS	5/3/85	LSS	310,072.84	1,978,263.06	V 9	175	NA	NA	160	175		
D4407	OBS	NA	NA	308,963.73	1,980,946.17	X 11	NA	NA	NA	NA	NA		
D4426	OBS	6/7/05	S, USS	310,023.54	1,978,174.27	V 9	NA	NA	NA	NA	NA		
D4431	OBS	NA	S	310,802.45	1,981,811.33	V 12	NA	NA	NA	NA	NA		
D4432	OBS	12/15/84	S, USS	310,802.45	1,981,811.33	V 12	145	NA	NA	130	145		Annular seal @ 70'
D4440	OBS	NA	S	310,041.89	1,977,981.70	V 8	NA	NA	NA	NA	NA		
D4445	OBS	NA	S, USS	310,236.71	1,982,463.55	W 13	NA	NA	NA	70	110		Santa Fe Road
D4450	OBS	NA	S	310,052.00	1,983,492.71	V 14	NA	NA	NA	70	100		Santa Fe Road
D4460	OBS	06/01/84	S, USS, LSS	309,704.53	1,978,196.20	W 9	175	NA	NA	160	175		Annular seal @ 110'
D4472	OBS	1984-86	S	309,524.66	1,978,178.76	W 9	NA	NA	NA	NA	NA		
D4480	OBS	NA	S	310,240.80	1,977,993.72	V 8	NA	NA	NA	NA	NA		
D4504-1	OBS	01/01/79	USS	310,575.51	1,978,068.49	V 9	NA	NA	NA	120	145		
D4504-2	OBS	NA	S, USS	310,637.19	1,978,010.52	V 9	NA	NA	NA	113	117		
D4517	OBS	3/13/86	S	NA	NA	N A	120	NA	NA	98	108		4517 Longview; Annular Seal to 80'
D4531	OBS	08/25/72	S, USS	310,536.00	1,981,963.55	V 12	114.5	NA	NA	100	114.5		Santa Fe Road (no Annular seal)
D4570	OBS	09/13/77	S, USS	310,953.06	1,978,040.35	V 9	122	NA	NA	105	122		Annular seal 20'
D4591	OBS	6/9/05	USS, LSS	309,005.45	1,979,930.33	W 10	NA	NA	NA	170	200		
D4614	OBS	5/29/05	S, USS	311,389.93	1,978,110.57	U 9	NA	NA	NA	113	117		Buhach Rd. (casing to 113'; ann seal 30')
D4740	OBS	NA	S	311,770.74	1,978,065.75	U 9	NA	NA	NA	NA	NA	ABD	
D4781	OBS	5/30/05	S	311,815.42	1,980,171.99	U 11	NA	NA	NA	83	103		Santa Fe Road
D4851	OBS	5/31/05	USS	309,058.56	1,978,395.39	W 9	NA	NA	NA	NA	NA		
D4920-1	OBS	8/20/76	S, USS	309,324.01	1,978,591.34	W 9	140	NA	NA	105	115		
D4920-2	OBS	9/29/76	S, USS	NA	NA	W 9	120	NA	NA	77	117		4920 West Avenue 2; Annular Seal to 50'
D4926	OBS	5/20/05	NA	309,314.70	1,978,365.19	W 9	140(?)	NA	NA	NA	140(?)		
D4930	OBS	8/27/76	USS	309,322.78	1,978,178.21	W 9	156	NA	NA	127	137		
D4970	OBS	1/10/77	USS	309,319.23	1,977,973.75	W 8	122	NA	NA	102	122		

Table 4-1
Well Inventory and Construction Information

WELL NUMBER	BASE SECTOR	DATE INSTALLED	SCREENED HSZ	NORTHING (ft) 316,062.45 NAD83	EASTING (ft) 1,981,207.44 NAD83	GRID	TOTAL DEPTH OF BORING (ft, bgs)	FILTER PACK INTERVAL (ft, bgs)		WELL SCREEN INTERVAL (ft, bgs)		CURRENT STATUS	COMMENTS
								TOP	BOTTOM	TOP	BOTTOM		
D5112	OBS	NA	NA	313,875.68	1,972,612.41	S 3	NA	NA	NA	NA	NA		No data available from City of Atwater
D5144-1	OBS	8/15/61	S, USS	317,390.70	1,977,211.70	N 8	NA	NA	NA	102	109		Old well at this residence
D5144-2	OBS	6/6/78	S, USS	317,390.77	1,977,213.09	N 8	NA	NA	NA	115	135		New well at this residence
D5161	OBS	NA	S, USS	317,091.02	1,977,102.42	N 8	NA	NA	NA	NA	NA		
D5220	OBS	NA	NA	314,351.12	1,972,667.02	R 3	NA	NA	NA	NA	NA		No data available from City of Atwater
D5248	OBS	NA	NA	314,583.80	1,972,620.98	R 3	NA	NA	NA	NA	NA		No data available from City of Atwater
D5266(A)	OBS	NA	S, USS	NA	NA	N 7	NA	NA	NA	NA	NA		
D5266(B)	OBS	01/01/76	S, USS	317,360.01	1,976,528.58	N 7	150	NA	NA	130	150		Wallace Rd. (Annular seal @ 20')
D5451	OBS	NA	S, USS, LSS	315,360.95	1,975,458.83	Q 6	NA	NA	NA	NA	NA		No data available from City of Atwater
D5472	OBS	NA	S, USS, LSS	315,817.78	1,976,132.42	Q 7	NA	NA	NA	NA	NA		Santa Fe Road (no data available from the City Atwater)
D5480	OBS	NA	S, USS, LSS	315,954.28	1,976,033.90	Q 7	NA	NA	NA	NA	NA		Santa Fe Road
D5482	OBS	NA	S	315,993.84	1,975,882.90	P 6	NA	NA	NA	NA	NA		Santa Fe Road (no data available inCity Atwater document), Inoperative
D5486	OBS	01/01/76	USS	317,337.40	1,975,428.65	N 6	NA	NA	NA	130	150		Wallace Rd. (before filtration) Annular seal @20'; casing to 150'
D5489(69)	OBS	5/16/61	S	316,945.50	1,975,487.83	P 6	72	NA	NA	0	72		Inoperative
D5489(79)	OBS	11/17/69	USS	316,945.50	1,975,487.83	P 6	80	NA	NA	0	80		
D5502(A)	OBS	6/7/05	LSS	318,260.00	1,975,240.00	M 6	NA	NA	NA	175	190		Annular seal at 125 ft.
D5502(B)	OSB	NA	LSS	NA	NA	M 6	NA	NA	NA	NA	NA		
D5511	OBS	NA	S	317,050.03	1,975,325.51	N 6	NA	NA	NA	NA	NA		Wallace Rd.
D5630	OBS	01/01/76	NA	315,753.40	1,972,721.84	Q 3	NA	NA	NA	NA	NA	ABD	No data available from City of Atwater
D5682	OBS	01/01/85	S	317,463.44	1,974,401.24	N 5	NA	NA	NA	NA	NA		Wallace Rd.
D5766	OBS	NA	NA	317,541.59	1,973,894.46	N 4	NA	NA	NA	NA	NA		Santa Fe Road (no data available from City of Atwater)
D5886	OBS	NA	NA	317,910.88	1,972,671.48	N 3	NA	NA	NA	NA	NA		No data available from City of Atwater
D6357-1	OBS	NA	S	320,474.90	1,972,441.52	K 3	NA	NA	NA	NA	NA		
D6357-2	OBS	NA	LSS	320,360.96	1,972,042.31	K 3	NA	NA	NA	200	220		
D6441	OBS	2/23/91	LSS, CF	NA	NA	N A	NA	NA	NA	195	255		6441 N. Shaffer Road; Annular Seal to 50'
D6506-1	OBS	NA	S	321,721.35	1,973,504.80	J 4	NA	NA	NA	NA	NA		
D6506-2	OBS	01/01/85	CF	321,591.08	1,973,521.30	J 4	NA	NA	NA	NA	NA		
Buhach - Strawberry	OBS	NA	NA	NA	NA	U 9	NA	NA	NA	NA	NA		
DA4-1	WBS	01/?/91	S	319,949.00	1,977,466.00	L 8	NA	NA	NA	76?	91?		Not used. Production too low (mud infiltration). Replaced by DA4-2; Not surveyed.
DA4-2	WBS	02/04/91	S	319,978.44	1,977,367.37	L 8	NA	NA	NA	76	91		Extraction well, DA4 system. Out of service 5/95
DA4-3	WBS	10/21/91	S	320,219.74	1,977,664.77	K 8	NA	NA	NA	83	93		Monitor well for DA4 system.

Table 4-1
Well Inventory and Construction Information

WELL NUMBER	BASE SECTOR	DATE INSTALLED	SCREENED HSZ	NORTHING (ft) 316,062.45 NAD83	EASTING (ft) 1,981,207.44 NAD83	GRID	TOTAL DEPTH OF BORING (ft, bgs)	FILTER PACK INTERVAL (ft, bgs)		WELL SCREEN INTERVAL (ft, bgs)		CURRENT STATUS	COMMENTS
								TOP	BOTTOM	TOP	BOTTOM		
DA4-4	WBS	10/22/91	S	319,647.54	1,977,640.67	L 8	NA	NA	NA	73	93		
DA4-5	WBS	10/18/91	S	320,357.64	1,977,049.07	K 8	NA	NA	NA	80	90		Monitor well for DA4 system.
EW1	MBS	12/21/90	S	314,292.80	1,980,736.13	R 11	NA	NA	NA	67	92		Extraction at OU-1.
EW2	MBS	12/28/90	S	315,524.30	1,979,434.23	Q 10	NA	NA	NA	68	88		Extraction at OU-1.
EW3	MBS	NA	S	NA	NA	S 10	NA	NA	NA	61	86		Extraction at OU-1.
I1	OBS	2/7/73	LSS	NA	NA	N A	NA	NA	NA	190	214		0.5 mile N. of Buhach Rd., 30' S. of Bellevue Rd.
I2	OBS	2/2/73	LSS, CF	NA	NA	N A	NA	NA	NA	190	260		0.4 mile N. of Juniper Ave., 3/8 mile W. of Buhach Rd.
I3	OBS	2/12/73	LSS, CF	NA	NA	N A	NA	NA	NA	160	259		20' S. of Juniper Ave., 0.6 mile W. of Buhach Rd.
I4	OBS	2/12/73	LSS, CF	NA	NA	N A	NA	NA	NA	170	256		50' W. of Buhach Rd., 700' N. of Green Sands Ave.
I5	OBS	2/17/73	LSS	NA	NA	N A	NA	NA	NA	160	198		660' S. of Juniper Ave., 774' W. of Buhach Rd.
I1-19	OBS	NA	NA	327,174.03	1,972,799.34	C 3	NA	NA	NA	NA	NA		
I1-30	OBS	NA	SS?	323,333.24	1,974,906.12	G 5	NA	NA	NA	NA	NA		Produces 1600 gpm and influences subshallow wells; may be screened in the Subshallow.
I6285	OBS	4/13/90	USS, LSS	NA	NA	N A	NA	NA	NA	125	225		6285 Shaffer Rd; Annular Seal to 50'
JE1	MBS	7/2/93	S	313,965.34	1,981,532.47	S 12	90	54	85	64	84		Extraction at OU-1. Screen interval 64-88. Shallow Zone
JE2	MBS	7/1/93	S	315,910.04	1,979,855.87	Q 10	92	55	87	61	86		Extraction at OU-1. Screen interval 61-86. Shallow Zone
JI1	MBS	NA	S	314,840.34	1,982,592.97	R 13	NA	NA	NA	NA	NA		Injection at OU-1.
JI2	MBS	6/9/93	S	315,029.84	1,982,364.27	Q 13	86	50	82	60	80		Injection at OU-1.
JI3	MBS	6/15/93	S	315,167.84	1,982,167.67	Q 13	93	51	87	61	86		Injection at OU-1.
JI4	MBS	6/24/93	S	315,030.24	1,980,359.37	Q 11	90	54	90	64	89		Injection at OU-1.
JI5	MBS	6/23/93	S	315,218.54	1,980,547.37	Q 11	93	53	89	63	88		Injection at OU-1.
JI6	MBS	6/28/93	S	315,405.44	1,980,751.37	Q 11	103	52	103	62	102		Injection at OU-1.
JI7	MBS	6/17/93	S	316,261.94	1,980,837.17	P 11	97	53	89	63	88		Injection at OU-1.
JI8	MBS	6/30/93	S	316,544.34	1,980,615.67	P 11	91	51	87	61	86		Injection at OU-1.
JI9	MBS	6/18/93	S	316,729.74	1,980,318.57	P 11	98.5	53	89	63	88		Injection at OU-1.
JM1	MBS	NA	S	316,656.74	1,980,432.07	P 11	81	55	81	60	80		Proposed screen interval
JM2	MBS	NA	S	NA	NA	S 10	NA	NA	NA	60	80		Piezometer installed for EW-3 pump test
JM3	MBS	NA	S	314,964.44	1,982,499.57	R 13	76	50	76	55	75		Proposed screen interval
JM4	MBS	NA	S	NA	NA	S 9	NA	NA	NA	60	80		Piezometer installed for EW-3 pump test
JM5	MBS	NA	S	315,536.34	1,981,033.27	Q 12	81	55	81	60	80		Proposed screen interval
JM6	MBS	NA	S	315,577.14	1,981,072.07	Q 12	91	70	91	75	90		Proposed screen interval
JM7	MBS	NA	S	315,225.24	1,982,565.57	Q 13	76	50	76	55	75		Proposed screen interval
JM8	MBS	NA	S	315,243.54	1,982,517.87	Q 13	91	70	91	75	90		Proposed screen interval

Table 4-1
Well Inventory and Construction Information

WELL NUMBER	BASE SECTOR	DATE INSTALLED	SCREENED HSZ	NORTHING (ft) 316,062.45 NAD83	EASTING (ft) 1,981,207.44 NAD83	GRID	TOTAL DEPTH OF BORING (ft, bgs)	FILTER PACK INTERVAL (ft, bgs)		WELL SCREEN INTERVAL (ft, bgs)		CURRENT STATUS	COMMENTS
								TOP	BOTTOM	TOP	BOTTOM		
JM9	MBS	NA	S	316,812.54	1,980,795.17	P 11	81	55	81	60	80		Proposed screen interval
JM10	MBS	NA	S	316,818.14	1,980,739.87	P 11	91	70	91	75	90		Proposed screen interval
JM11	MBS	NA	S	313,688.94	1,981,438.87	S 12	78	54	78	57	77		Proposed screen interval
JM12	MBS	NA	S	313,654.84	1,981,492.37	S 12	85	70	85	74	84		Proposed screen interval
JM13	MBS	NA	S	315,987.04	1,979,637.37	Q 10	81	55	81	60	80		Proposed screen interval
JM14	MBS	NA	S	315,992.64	1,979,687.27	Q 10	87	71	87	76	86		Proposed screen interval
JM15	MBS	NA	S	315,161.54	1,980,385.57	Q 11	81	55	81	60	80		Proposed screen interval
JM16	MBS	NA	S	314,272.44	1,983,215.47	R 14	85	67	85	69	84		Proposed screen interval
JM19	MBS	NA	S	314,168.74	1,983,209.59	R 14	78	55	78	57	77		Proposed screen interval
MID6	OBS	9/8/23	S	316,200.00	1,969,000.00	P 1	110	NA	NA	0	102		Perforated zone
MID6B	OBS	12/27/68	S, LSS	NA	NA	N A	251	NA	NA	104/187	109/194		Mutiple casings
MID7	OBS	09/22/23	S	310,503.17	1,977,491.15	V 8	85	NA	NA	74	85		No perforations; casing to 73.5'; no ann. seal
MID7B	OBS	02/01/67	S,USS, LSS,CF	309,224.04	1,976,842.64	W 7	240	NA	NA	68	236		No Annular seal
MID7C	OBS	4/30/54	S,USS, LSS	NA	NA	N A	NA	NA	NA	90	228		In Castle Gardens
MID8	OBS	11/15/23	S	309,148.02	1,981,867.18	W 12	84	NA	NA	50	84		No Annular seal; casing to 50'; no screen
MID9	OBS	NA	S,USS,LSS, CF	306,040.00	1,966,160.00	X 16	302	NA	NA	130	250		Perforated zone
MID34	OBS	09/01/22	S	314,067.89	1,973,755.23	R 4	84	NA	NA	51	84		No Annular. seal; casing to 51'; no screen
MID34A	OBS	12/01/40	S	312,236.06	1,973,001.65	T 4	96	NA	NA	0	54		Perforated zone
MID66	OBS	3/15/28	S	325,740.00	1,969,200.00		86	NA	NA	0	86		No perforations; casing to 73.5'; no ann. seal
MID70	OBS	03/17/28	S	316,136.12	1,975,054.52	P 6	NA	NA	NA	81	93		Perforated zone
MID130	OBS	05/01/50	S,USS	317,130.04	1,972,453.03	N 3	NA	NA	NA	76	135		Second loc. N=317,106.37 E=1,975,073.50
MID155	OBS	6/1/57	S, USS	320,150.00	1,970,330.00	K 1	157	NA	NA	49	157		No perforations; casing to 73.5'; no ann. seal
MID226P	OBS	4/27/65	S, USS, LSS	313,450.00	1,984,700.00	S 15	206	NA	NA	62	206		No perforations; casing to 73.5'; no ann. seal
MID227	OBS	12/13/65	LSS,USS	309,765.06	1,983,056.62	W 14	NA	NA	NA	144	188		
MID228	OBS	12/17/65	LSS	311,717.31	1,979,627.13	U 10	292	NA	NA	174	182		
MID237	OBS	5/27/66	MHZ	328,540.00	1,976,660.00	B 6	608	NA	NA	NA	NA		No perforations; casing to 73.5; no ann. seal
MW001	OBS	09/19/90	S	312,140.61	1,973,689.33	T 4	NA	NA	71	46	71		
MW002	OBS	09/06/90	S	311,120.20	1,973,679.41	U 4	NA	NA	71	46	71		
MW003	OBS	09/11/90	S	311,851.92	1,973,401.29	U 4	NA	NA	71.5	46.5	71.5		
MW004	OBS	09/20/90	S	309,679.54	1,974,567.70	W 5	NA	NA	68.5	43.5	68.5		
MW005	OBS	09/24/90	S	309,526.64	1,974,270.56	W 5	NA	NA	67.0	42	67		
MW006	OBS	09/27/90	S	309,533.66	1,974,513.58	W 5	NA	NA	67.0	42	67		

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Well Inventory and Construction Information

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								TOP	BOTTOM	TOP	BOTTOM		
MW115	MBS	01/14/87	S	314,734.73	1,978,976.82	R 9	55	36.5	55.0	37.5	54.5	ABD	Abandoned 4Q-95, Dry
MW120	MBS	02/01/87	S	314,963.89	1,981,258.19	R 12	55	33.5	55.0	37	53	DRY	Dry, 4Q-89
MW121	MBS	1/6/87	S	316,239.90	1,980,987.20	P 11	21.5	7.5	21.5	9	20	DRY	Dry
MW124	MBS	01/28/87	S	316,214.20	1,980,871.29	P 11	101.0	33.5	50	38	48.5	DRY	Dry, 3Q-89
MW125	MBS	01/30/87	S	316,211.27	1,980,867.91	P 11	101.0	61	79.5	63.5	79		
MW130	MBS	01/29/87	S	317,204.45	1,980,231.23	N 11	54	34	54	38	54	ABD	Abandoned 4Q-95, Dry 4Q-89
MW210	MBS	10/25/84	S	314,196.93	1,978,466.64	R 9	120.0	41	89	48	89		
MW220	MBS	10/24/84	S	313,584.60	1,979,346.87	S 10	100	43	89	48	89		
MW225	MBS	01/13/87	S	312,563.96	1,980,374.87	T 11	71	30	50.5	33.5	50	DRY	Dry, 3Q-89
MW230	SBS	10/31/84	S	310,406.87	1,983,056.53	V 14	105	48	94	53	94		
MW235	MBS	01/15/87	S	312,906.70	1,980,034.15	T 11	47	24	47.0	29	44.5	ABD	Abandoned 4Q-95, Dry 3Q-89
MW240	SBS	11/01/84	S	312,102.98	1,983,272.54	T 14	112	49	95	59	95		
MW245	MBS	01/14/87	S	312,697.84	1,980,116.57	T 11	53	30	53.0	35	50	DRY	Dry, 2Q-89
MW250	SBS	10/29/84	S	311,839.10	1,982,338.05	U 13	105	47	92	52	92		
MW260	SBS	10/27/84	S	312,085.17	1,982,649.79	T 13	110	46	92	51	92		
MW270	MBS	11/05/84	S	312,810.57	1,982,492.03	T 13	105	42	89	48	89		
MW280	MBS	11/02/84	S	313,251.94	1,982,830.10	S 13	105	37	89	48	89		
MW290	MBS	11/05/84	S	314,166.24	1,982,942.18	R 13	95	35	80	59	80		
MW300	MBS	12/03/84	S	315,136.21	1,982,415.08	Q 13	100	46	91	51	91		
MW310	MBS	11/14/84	S	314,526.06	1,982,120.50	R 13	105	42	87	47	87		
MW320	EBS	11/18/84	S	318,758.37	1,984,566.18	M 15	105	41	105	48	78		
MW321	EBS	09/14/88	S	318,715.07	1,983,845.91	M 14	60	31	60.0	33	58	ABD	Abandoned 4Q_95, Dry 4Q-90
MW322	EBS	09/13/88	S	318,714.33	1,983,834.63	M 14	111	81	111.0	86	106		
MW330	EBS	11/10/84	S	318,991.42	1,983,770.63	M 14	100	32	100.0	40	81		
MW335	EBS	01/16/87	S	318,829.28	1,984,102.14	M 15	58.5	37.5	58.5	42	57	DRY	Dry, 4Q-90
MW340	EBS	11/10/84	S	319,193.68	1,983,919.26	L 14	105	32	105.0	41	81		
MW345	EBS	01/29/87	S	319,218.84	1,984,205.36	L 15	63.5	41	63.5	44	62	DRY	Dry, 4Q-90
MW350	NBS	11/15/84	S	324,194.53	1,980,895.85	F 12	120	35	120.0	49	90		
MW351	NBS	09/16/88	S	324,348.36	1,979,857.41	F 10	75	42.5	75.0	45.8	70.8	DRY	Dry, 4Q-90
MW352	NBS	09/21/88	S	324,347.30	1,979,849.17	F 10	110	81.5	110.0	84	104		
MW355	NBS	01/26/87	S	324,375.29	1,979,230.85	F 10	80	54.5	75	59.5	75	DRY	
MW360	NBS	11/13/84	S	325,215.14	1,980,909.14	E 11	105	42	105.0	59	90		
MW365	NBS	01/17/87	S	324,245.01	1,980,635.86	F 11	70	45	65	48	63.5	DRY	Dry, 2Q-90

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Well Inventory and Construction Information

WELL NUMBER	BASE SECTOR	DATE INSTALLED	SCREENED HSZ	NORTHING (ft) 316,062.45 NAD83	EASTING (ft) 1,981,207.44 NAD83	GRID	TOTAL DEPTH OF BORING (ft, bgs)	FILTER PACK INTERVAL (ft, bgs) TOP	FILTER PACK INTERVAL (ft, bgs) BOTTOM	WELL SCREEN INTERVAL (ft, bgs) TOP	WELL SCREEN INTERVAL (ft, bgs) BOTTOM	CURRENT STATUS	COMMENTS
MW370	NBS	11/14/84	S	325,200.89	1,979,956.24	E 10	105	41	105.0	55	95		
MW380	NBS	11/15/84	S	325,134.23	1,978,914.05	E 9	110	46	110.0	52	92		
MW390	WBS	11/30/84	S	324,338.63	1,975,112.40	F 6	120	74	120.0	81	102		
MW395	WBS	01/27/87	S	322,615.23	1,975,243.54	H 6	78.5	55	78.5	60	76	DRY	Dry, 4Q-93
MW397	WBS	11/10/89	S	324,321.62	1,975,432.74	F 6	NA	50	NA	NA	NA	DRY	Dry, 4Q-90
MW400	WBS	11/29/84	S	323,668.72	1,975,025.29	G 6	120	50	120.0	57	97		
MW405	WBS	01/26/87	S	322,210.89	1,975,589.91	H 6	73.5	50	73.5	55	70.5	ABD	Abandoned 4Q-95, Dry 1Q-93
MW407	WBS	10/24/89	S	322,666.07	1,975,809.25	H 6	NA	NA	NA	NA	NA	ABD	Abandoned 4Q-95, Dry 4Q-90, Damaged
MW410	WBS	11/19/84	S	322,895.23	1,975,021.37	H 6	110	49	110.0	54	95		
MW415	WBS	01/16/87	S	321,754.52	1,975,929.66	J 6	75	51	69.5	53.5	69.5	DRY	Dry, 4Q-92
MW416	WBS	01/26/87	S	321,678.60	1,976,224.11	J 7	73	50	73.0	54	70.5	ABD	Abandoned 4Q-95, Dry 4Q-92
MW420	WBS	11/16/84	S	321,932.66	1,976,376.09	J 7	120	50	120.0	57	97		
MW424	WFLS	12/21/86	S	319,219.40	1,980,205.98	L 11	33	17	31	20	33	DRY	Dry
MW425	WFLS	01/17/87	S	319,230.85	1,979,999.81	L 10	81	40	61	45.5	61	DRY	Dry, 2Q-90
MW426	WFLS	01/17/87	S	319,277.81	1,980,176.64	L 11	64	44	63	47	63	DRY	Dry, 2Q-90
MW427	WFLS	12/26/86	S	320,152.86	1,979,416.24	K 10	36	17.5	29.5	19	29.5	ABD	Abandoned 4Q-95, Dry
MW430	WFLS	11/12/84	S	322,186.47	1,977,656.41	H 8	95	28	79	38	78		
MW432	WFLS	01/18/87	S	319,869.11	1,979,699.65	L 10	63	38.5	58.5	43.5	58.5	DRY	Dry, 3Q-90
MW433	WFLS	01/19/87	S	320,067.01	1,979,462.25	K 10	81	36	55.5	40	55.5	ABD	Abandoned 4Q-95, Dry 3Q-89
MW435	WFLS	01/17/87	S	320,791.02	1,978,968.22	K 9	62.5	40.5	62.5	43.5	59	DRY	Dry, 2Q-90
MW436	WFLS	01/20/87	S	320,757.88	1,978,826.86	K 9	58	34.5	55	39	55	DRY	Dry, 3Q-89
MW440	WBS	11/17/84	S	318,932.79	1,978,954.79	M 9	120	72	120.0	77	97		
MW443	WFLS	1/7/87	S	322,066.04	1,977,824.91	H 8	24.5	10.5	24	13.5	24	DRY	Dry
MW445	WFLS	01/20/87	S	322,238.91	1,977,784.00	H 8	86.5	40.5	60	43.5	59	DRY	Dry, 2Q-90
MW446	WFLS	01/20/87	S	322,059.89	1,977,704.23	H 8	63	43	61	45	61	DRY	Dry, 2Q-90
MW450	WBS	11/06/84	S	320,675.44	1,976,782.35	K 7	105	49	95	54	95		
MW454	WBS	12/19/86	S	320,353.64	1,977,228.93	K 8	41	16	29.5	19	29.5	ABD	Abandoned 4Q-95, Dry
MW455	WBS	01/13/87	S	320,505.04	1,976,923.43	K 7	98.5	65	85	70	85		
MW456	WBS	01/15/87	S	320,803.57	1,977,220.52	K 8	84	60	80	68	80	DRY	
MW460	EBS	11/28/84	S	321,099.95	1,985,883.99	J 16	110	50	96	56	96		
MW461	EBS	09/22/88	S	319,816.45	1,985,554.52	L 16	73	37	66	39	64	DRY	Dry, 3Q-93
MW462	EBS	09/23/88	S	319,805.76	1,985,554.61	L 16	105	72	96	74	94		
MW465	EBS	01/16/87	S	320,750.69	1,985,375.75	K 16	76	41	62.5	44.5	60	ABD	Abandoned 4Q-95, Dry 3Q-90

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WELL NUMBER	BASE SECTOR	DATE INSTALLED	SCREENED HSZ	NORTHING (ft) 316,062.45 NAD83	EASTING (ft) 1,981,207.44 NAD83	GRID	TOTAL DEPTH OF BORING (ft, bgs)	FILTER PACK INTERVAL (ft, bgs) TOP	FILTER PACK INTERVAL (ft, bgs) BOTTOM	WELL SCREEN INTERVAL (ft, bgs) TOP	WELL SCREEN INTERVAL (ft, bgs) BOTTOM	CURRENT STATUS	COMMENTS
MW470	EBS	11/27/84	S	320,304.66	1,985,254.31	K 16	120	50	120.0	56	97		
MW477	EBS	NA	S	320,090.38	1,985,938.66	K 16	NA	NA	NA	NA	NA	DRY	Dry, 4Q-90
MW501	WBS	09/06/88	S	319,987.99	1,977,404.73	L 8	68	42	68	44.5	64.5	DRY	Dry, 4Q-90
MW502	WBS	09/02/88	S	319,978.42	1,977,410.35	L 8	96.5	69	96.5	71	91		
MW503	WBS	09/29/88	S	318,723.70	1,979,279.01	M 10	69	39	69.0	42	67	DRY	Dry, 4Q-91
MW504	WBS	09/28/88	S	318,710.22	1,979,284.21	M 10	111	81	107	83	103		
MW505	WBS	09/14/88	S	318,335.93	1,978,341.51	M 9	67	32	62	34	59	ABD	Abandoned 4Q-95, Dry 3Q-91
MW506	WBS	09/13/88	S	318,327.78	1,978,342.95	M 9	88	59	88.0	61.5	81.5		
MW507	WBS	10/13/88	S	317,394.29	1,977,872.99	N 8	66	36	66.0	48.5	63.5	DRY	Dry, 4Q-92
MW508	WBS	12/12/88	S	317,403.42	1,977,887.88	N 8	93	63.5	90	69	89		
MW509	MBS	10/07/88	S	316,191.94	1,977,204.95	P 8	65	36	65.0	38	63	ABD	Abandoned 4Q-95, Dry, 4Q-92
MW510	MBS	10/20/88	S	316,182.75	1,977,200.89	P 8	116	87.5	111	90	110		
MW511	MBS	09/25/88	S	315,260.17	1,976,852.95	Q 7	70	41.5	70.0	43	68	DRY	Dry, 4Q-91
MW512	MBS	09/28/88	S	315,255.37	1,976,860.55	Q 7	120	89	112	91	111		
MW513	MBS	10/14/88	S	316,352.22	1,978,701.50	P 9	63	33	63.0	35.5	60.5	DRY	Dry, 4Q-92
MW514	MBS	11/21/88	S	316,344.88	1,978,692.31	P 9	106	65	101	71	91		
MW515	MBS	11/16/88	S	315,406.39	1,978,115.13	Q 9	63	32	59	34	59	DRY	Dry, 2Q-91
MW516	MBS	12/13/88	S	315,405.73	1,978,128.89	Q 9	102	62.5	99	70	90		
MW517	MBS	09/27/88	S	314,446.97	1,977,932.74	R 8	60	30	60.0	32	57	DRY	Dry, 4Q-90
MW518	MBS	10/03/88	S	314,435.12	1,977,929.27	R 8	115	61.5	84	62.5	82.5		
MW519	MBS	10/27/88	S	316,194.84	1,980,318.81	P 11	64	34.5	64.0	37	62	DRY	Dry, 2Q-93
MW520	MBS	11/22/88	S	316,186.96	1,980,325.23	P 11	95	66	95.0	70	90		
MW521	MBS	09/20/88	S	315,664.26	1,979,385.65	Q 10	66	35.5	66.0	38	63	DRY	Dry, 4Q-92
MW522	MBS	10/14/88	S	315,656.26	1,979,379.37	Q 10	96	63	85	65	85		
MW523	MBS	10/20/88	S	314,519.14	1,979,816.57	R 10	64	34.5	64.0	36	61	DRY	Dry, 4Q-92
MW524	MBS	11/23/88	S	314,510.74	1,979,806.07	R 10	96	66	90	68	86		
MW525	MBS	11/14/88	S	314,304.50	1,980,729.69	R 11	62	31	62.0	35	60	DRY	Dry, 1Q-93
MW527	MBS	10/25/88	S	315,259.96	1,981,943.05	Q 12	64	31.5	62	34	59	DRY	Dry, 4Q-92
MW528	MBS	11/04/88	S	315,267.70	1,981,948.23	Q 12	95	67	94	70	90		
MW529	MBS	10/11/88	S	314,191.02	1,981,396.81	R 12	70	31	70.0	31	63	DRY	Dry
MW530	MBS	10/13/88	S	314,197.90	1,981,391.07	R 12	97	62.5	91	70	90		
MW531	MBS	10/04/88	S	313,602.52	1,981,359.19	S 12	61	32.5	59	34	59	DRY	Dry, 4Q-92
MW532	MBS	10/10/88	S	313,597.52	1,981,352.05	S 12	111	62	104	84	104		

Table 4-1
Well Inventory and Construction Information

WELL NUMBER	BASE SECTOR	DATE INSTALLED	SCREENED HSZ	NORTHING (ft) 316,062.45 NAD83	EASTING (ft) 1,981,207.44 NAD83	GRID	TOTAL DEPTH OF BORING (ft, bgs)	FILTER PACK INTERVAL (ft, bgs) TOP	FILTER PACK INTERVAL (ft, bgs) BOTTOM	WELL SCREEN INTERVAL (ft, bgs) TOP	WELL SCREEN INTERVAL (ft, bgs) BOTTOM	CURRENT STATUS	COMMENTS
MW533	MBS	10/03/88	S	313,438.10	1,981,149.81	S 12	60	31	60.0	33	58	DRY	Dry, 4Q-90
MW534	MBS	10/05/88	S	313,435.88	1,981,140.39	S 12	106	67.5	90	70	90		
MW535	MBS	10/06/88	S	313,178.22	1,981,972.77	S 12	60	31	60.0	33	58	DRY	Dry, 2Q-91
MW536	MBS	10/12/88	S	313,178.04	1,981,964.53	S 12	100	70	94	73	93		
MW537	SBS	10/17/88	S	311,414.22	1,981,813.79	U 12	58	28	58.0	30	55	DRY	Dry, 3Q-93
MW538	SBS	10/24/88	S	311,406.59	1,981,822.37	U 12	95	62	86	64	84		
MW539	SBS	12/02/88	S	311,262.70	1,982,926.39	U 13	59	31	59.0	33	58	DRY	Dry, 2Q-90
MW540	SBS	12/07/88	S	311,253.14	1,982,921.91	U 13	96	62	87	65.5	85.5		
MW541	SBS	10/18/88	S	310,635.62	1,982,944.21	V 13	58	28.5	58	30.5	55.5	DRY	Dry, 2Q-91
MW542	SBS	10/25/88	S	310,628.56	1,982,948.37	V 13	105	73	95	75	95		
MW543	MBS	10/12/88	S	314,441.14	1,982,579.43	R 13	58	28	58.0	30	55	DRY	Dry,4Q-90
MW544	MBS	10/19/88	S	314,433.64	1,982,585.31	R 13	90	57	79	59	79		
MW551	MBS	10/28/88	S	313,566.48	1,979,271.23	S 10	62	32	62.0	33	58	DRY	Dry, 1Q-93
MW552	MBS	10/27/88	S	316,217.52	1,980,860.07	P 11	110	78	102	80	100		
MW554	MBS	11/08/88	S	314,975.76	1,981,250.89	R 12	103	60	83	62	82		
MW556	MBS	10/18/88	S	314,670.49	1,979,004.16	R 10	100.5	74	100.5	75	95		
MW557	MBS	11/17/88	S	315,114.76	1,980,076.25	Q 11	63	34	63.0	35	61	DRY	Dry, 4Q-92
MW559	WFLS	09/13/89	S	319,788.35	1,979,491.55	L 10	68	40	68	43	68	ABD	Abandoned 4Q-95, Dry 1Q-93
MW576A	MBS	06/14/90	USS	316,656.52	1,977,396.72	P 8	NA	NA	140.0	119	139		
MW601	WBS	10/27/88	CF	317,405.20	1,977,865.53	N 8	309	266	309.0	285	304		
MW602	MBS	10/27/88	CF	315,266.33	1,976,866.69	Q 7	324	257	296	273	292		
MW603	MBS	10/20/88	CF	314,445.08	1,977,923.11	R 8	343.5	240	343.5	259.7	269		
MW604	MBS	11/28/88	CF	315,425.44	1,978,130.48	Q 9	304	264	304	279	300		
MW605	MBS	10/03/88	CF	315,667.86	1,979,375.47	Q 10	310	277	310.0	289	309		
MW606	MBS	11/09/88	CF	313,555.00	1,979,271.19	S 10	328	294	328.0	305	324		
MW607	MBS	11/21/88	CF	314,248.26	1,980,700.01	R 11	310	265	295	272	292		
MW608	MBS	12/07/88	LSS	315,266.62	1,981,938.31	Q 12	383	205	243	222	243		
MW609	MBS	11/14/88	CF	313,427.64	1,981,147.95	S 12	327	272	327.0	286	305		
MW701	OBS	11/03/88	S	318,803.42	1,976,950.66	M 7	69	40	69.0	42	67	DRY	Dry
MW702	OBS	12/09/88	S	318,795.34	1,976,958.67	M 7	97	63	88	66	86	DMG	Pump damaged
MW702A	OBS	06/26/90	USS	318,735.86	1,976,892.14	M 7	145	115	145.0	118	138		Second location, N=318795.384, E=1,976,958.70
MW703	OBS	11/02/88	S	317,303.35	1,976,461.32	N 7	70	37	70.0	40	65	DRY	Dry
MW704	OBS	11/10/89	S	317,303.37	1,976,478.10	N 7	98	69	98.0	72	92		

Table 4-1
Well Inventory and Construction Information

WELL NUMBER	BASE SECTOR	DATE INSTALLED	SCREENED HSZ	NORTHING (ft) 316,062.45 NAD83	EASTING (ft) 1,981,207.44 NAD83	GRID	TOTAL DEPTH OF BORING (ft, bgs)	FILTER PACK INTERVAL (ft, bgs) TOP	FILTER PACK INTERVAL (ft, bgs) BOTTOM	WELL SCREEN INTERVAL (ft, bgs) TOP	WELL SCREEN INTERVAL (ft, bgs) BOTTOM	CURRENT STATUS	COMMENTS
MW709	OBS	11/10/88	S	312,933.20	1,977,957.27	T 8	60	30	58	32.5	57.5	DRY	Dry
MW710	OBS	11/30/88	S	312,941.94	1,977,957.21	T 8	107	77	103	80	100		
MW711	OBS	11/08/88	S	312,402.96	1,978,726.55	T 9	58	27.5	58	30.5	55.5	ABD	Abandoned 4Q-95
MW712	OBS	11/28/89	S	312,411.30	1,978,726.73	T 9	105	72.5	105.0	75	95		
MW752	OBS	12/02/88	S	311,632.70	1,979,868.91	U 10	107.5	73	103	79	99		
MW754	OBS	12/05/88	S	309,874.91	1,983,062.56	W 14	103.5	74	103.5	76.5	96.5		
MW802A	WBS	05/22/93	USS	320,232.30	1,977,697.87	K 8	224	131	151.5	133.7	148.4		
MW803	OBS	06/21/93	S	319,940.79	1,976,985.36	L 7	95	67	91	70	89.7		
MW804A	OBS	06/18/93	USS	319,939.77	1,976,967.41	L 7	160	140	155	143.5	153		
MW805	OBS	06/07/93	S	319,105.26	1,977,391.16	L 8	144	59.5	94.5	83	93		
MW806A	OBS	06/02/93	USS	319,125.36	1,977,388.87	L 8	170	140.5	156	147.5	152		
MW807	OBS	06/09/93	S	319,657.08	1,975,150.04	L 6	96	59	92	67.5	89.9		
MW808A	WBS	6/5/93	USS	319,773.97	1,976,155.49	L 9	152	132.5	152	137	147		
MW811	OBS	05/20/93	S	316,447.10	1,975,374.46	M 6	95	67	95	70.5	89.7		
MW812A	OBS	06/11/93	USS	316,229.00	1,974,445.68	M 5	159	125	140	130	135		
MW813	OBS	06/01/93	S	316,945.42	1,976,359.73	P 7	93	65.8	93	69.7	89.9		
MW815	OBS	06/15/93	S	316,263.47	1,975,472.50	P 6	122	53	82	57.7	77.9		
MW816	OBS	8/13/93	S	316,123.68	1,972,741.88	M 3	157	53	85	57	81.7		
MW817	OBS	8-24/25-93	S	314,478.97	1,976,384.48	R 7	107	85	106	88	103		
MW818	OBS	8-23/24-93	LSS	310,188.39	1,980,896.05	V 11	228	205	226	210.5	225		
MW819	OBS	8-19/20-93	S	309,594.71	1,981,747.58	W 12	127	59	84	61.8	82.2		
MW820	MBS	8/30/93	USS	313,917.89	1,981,462.85	S 12	221	125.5	143	130	140		
MW821	BKGD	8/26/93	S	323,298.39	1,984,282.05	G 15	117	89	100	92	97		Duplicate location, N.1,984,282.044+Z383, E.323,298.39
MW822	BKGD	9/10/93	USS	322,808.51	1,984,681.51	H 15	177	140	152	144	149		
MW823	BKGD	9/13/93	LSS	322,327.46	1,985,072.20	H 16	247	221	238	226	236		
MW824	WFLS	9/10/93	S	319,835.11	1,979,596.21	L 10	142	64	89	66	86		
MW825	OBS	8-16/17-93	S	316,120.23	1,972,758.78	M 3	87	53	87	57	82		
MW826	OBS	9/8/93	S	311,693.95	1,977,564.42	U 8	136	59	87	62.25	82.25		
MW827	BKGD	8/31/93	S	323,273.40	1,984,297.80	G 15	102	71	92	75	90		
MW828	SBS	9/9/93	USS	311,186.26	1,982,054.57	U 13	175	113.5	128.5	115.5	125.5		
MW829	OBS	9/10/93	S	311,682.16	1,977,568.04	U 8	105	90	105	92	102		
MW830	MBS	9/13/93	LSS	315,985.45	1,980,122.43	Q 11	321	203.5	219	206.5	216.5		
MW831	WBS	9/13/93	S	323,982.17	1,976,239.99	G 7	130	70	90	73	88		

Table 4-1
Well Inventory and Construction Information

WELL NUMBER	BASE SECTOR	DATE INSTALLED	SCREENED HSZ	NORTHING (ft) 316,062.45 NAD83	EASTING (ft) 1,981,207.44 NAD83	GRID	TOTAL DEPTH OF BORING (ft, bgs)	FILTER PACK INTERVAL (ft, bgs)		WELL SCREEN INTERVAL (ft, bgs)		CURRENT STATUS	COMMENTS
								TOP	BOTTOM	TOP	BOTTOM		
MW832	OBS	4/29/94	DP	311,957.09	1,979,018.77	U 10	520	496	520	505	515		
MW833	MBS	9/13/93	LSS	315,047.22	1,979,503.05	Q 10	310	162	180	165	175		
MW834	OBS	9/16/93	S	310,045.05	1,979,372.87	V 10	317	79.5	94	82.6	92.6		
MW835	EBS	9/16/93	S	319,857.12	1,983,141.15	L 14	145	75	98	80	95	ABD	PVC casing damaged. Not developed; Abandoned 4Q-95
MW835R	EBS	11/23/93	S	319,895.82	1,983,101.31	L 14	102	83	100	86.5	96.5		
MW836	EBS	9-20/21-93	S	316,690.64	1,984,117.35	M 15	121	90	104	92	101.5		
MW837	NBS	9/22/93	S	323,913.38	1,980,146.64	G 11	130	68	84.5	72	82		
MW838	EBS	9-21/22-93	S	319,577.65	1,984,235.39	L 15	120	84	100	87	97		
MW839	WBS	9/22/93	S	324,897.20	1,975,480.81	F 6	137	91	107	95	105		
MW840	EBS	9/21/93	S	316,898.94	1,983,220.69	M 14	130	76	97.5	79	94	ABD	PVC casing damaged. Not developed; Abandoned 4Q-95
MW840R	EBS	11/10/93	S	316,943.60	1,983,187.21	M 14	100	61	80	64	79		
MW841	EBS	9/22/93	S	320,717.08	1,984,623.28	K 15	131	82	82.5	85	80		
MW842	WBS	9/23/93	S	321,448.99	1,976,182.69	J 7	137	97	112	100	110		
MW843	NBS	9/23/93	S	325,031.37	1,981,605.69	E 12	130.5	70	95	73	93		
MW844	OBS	9/23/93	S	313,191.77	1,975,224.39	S 6	130	70.5	85	74.5	84.5		
MW845	NBS	9/28/93	S	323,880.12	1,978,949.14	G 9	134	80	95.5	83	93		
MW846	WBS	9/29/93	S	322,237.83	1,975,545.96	H 6	140.5	101.6	117	105	115		
MW847	WBS	9/29/93	S	323,376.54	1,975,030.10	G 6	127	78	102	85	100		
MW848	NBS	9/30/93	S	323,419.80	1,979,421.66	G 10	130.5	85	104.5	88	102.5		
MW849	EBS	9/29/93	S	316,208.69	1,983,984.32	M 14	120	57	73	60	70		
MW850	OBS	9/23/93	S	317,336.04	1,972,045.39	N 3	130	76	91.5	79	89		
MW851	EBS	10/1/93	S	321,431.66	1,985,600.14	J 16	131	62	82.5	65	80		
MW852	MBS	10/7/93	S	317,661.13	1,979,276.94	N 10	120	77	97	80	95	ABD	PVC casing damaged. Not developed; Abandoned 4Q-95
MW852R	MBS	11/17/93	S	317,620.95	1,979,310.98	N 10	101	69	84	72	82		
MW853	EBS	10/1/93	S	317,756.21	1,983,653.93	N 14	131	57	77	60	75		
MW854	NBS	10/8/93	S	323,458.16	1,981,018.36	G 12	132	77	98	80.5	95.5		
MW855	NBS	10/12/93	S	324,600.11	1,979,595.10	F 10	133	77	97	80	95		
MW856	EBS	10/13/93	S	319,457.84	1,983,408.80	L 14	130	92	107	95	105		
MW857	OBS	10/13/93	LSS	312,565.95	1,976,513.53	T 7	228	208.5	228	211.5	226.5		
MW858	EBS	10/14/93	S	319,476.36	1,983,416.23	L 14	90	62	78	65	75		
MW859	EBS	10/14/93	S	320,149.79	1,983,946.91	K 14	130	62	82	65	80		
MW860	EBS	10/15/93	S	316,554.38	1,982,911.98	M 13	138	65	84	68	83		
MW861	NBS	10/14/93	S	324,556.75	1,980,616.22	F 11	132	77	98	80	95		

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Well Inventory and Construction Information

WELL NUMBER	BASE SECTOR	DATE INSTALLED	SCREENED HSZ	NORTHING (ft) 316,062.45 NAD83	EASTING (ft) 1,981,207.44 NAD83	GRID	TOTAL DEPTH OF BORING (ft, bgs)	FILTER PACK INTERVAL (ft, bgs) TOP	FILTER PACK INTERVAL (ft, bgs) BOTTOM	WELL SCREEN INTERVAL (ft, bgs) TOP	WELL SCREEN INTERVAL (ft, bgs) BOTTOM	CURRENT STATUS	COMMENTS
MW862	NBS	10/14/93	S	324,499.17	1,980,238.87	F 11	133	82	102	85	100	ABD	PVC casing damaged. Not developed; Abandoned 4Q-95
MW862R	NBS	11/17/93	S	324,498.19	1,980,185.78	F 11	103	75	95	78	93		
MW863	MBS	10-19/20-93	LSS	314,366.16	1,981,364.04	R 12	210	172	187	175	185		
MW864	EBS	10/19/93	S	319,214.68	1,982,900.84	L 13	130	58	77	61	76		
MW865	NBS	10/20/93	S	325,160.04	1,980,707.00	E 11	132	77	97	80	95		
MW866	EBS	10/21/93	S	319,763.07	1,984,768.10	L 15	130	59	79.5	62	77		
MW867	OBS	10/22/93	LSS	312,620.24	1,978,115.80	T 9	220	200	213	200	210		
MW868	MBS	10/25/93	LSS	313,639.30	1,980,458.94	S 11	220	192	207	195	205		
MW869	EBS	10/25/93	S	319,242.02	1,984,787.78	L 15	140	85	100	88	98		
MW870	NBS	10/26/93	S	323,545.21	1,981,881.51	G 12	133	92	107	95	105	ABD	PVC casing damaged. Not developed; Abandoned 4Q-95
MW870R	NBS	11-18/19-93	S	323,550.06	1,981,941.13	G 12	107	75	95	78	93		
MW871	EBS	10/27/93	S	321,077.95	1,983,215.90	J 14	110	72	86.5	75	85		
MW872	EBS	10/28/93	S	320,450.94	1,982,996.56	K 13	130	62	81.75	65	80		
MW873	MBS	10/27/93	S	314,162.55	1,981,274.59	R 12	130	72	92	75	90		
MW874	NBS	10/27/93	S	322,908.90	1,979,824.39	H 10	133	81	102	85	100		
MW875	EBS	10/29/93	S	317,564.71	1,983,366.80	N 14	133	69	90	72	87		
MW876	EBS	10/29/93	S	317,909.24	1,982,908.88	N 13	130	61.5	81.5	65	80		
MW877	EBS	10/30/93	S	318,697.23	1,982,482.70	M 13	130	62	83	65	80		
MW878	NBS	11/2/93	S	322,866.81	1,979,257.15	H 10	128	87	107	90	105		
MW879	NBS	11/3/93	S	322,772.98	1,980,483.91	H 11	136	84	104	87	102		
MW880	MBS	11/9/93	LSS	313,666.90	1,981,240.73	S 12	230	205	220	208	218		
MW881	OBS	11/9/93	LSS	311,189.36	1,978,305.73	U 9	240	225	240	228	238		
MW882	WBS	11/9/93	S	323,745.26	1,975,529.19	G 6	133	74	89	77	87		
MW883	EBS	11/3/93	S	320,232.46	1,981,938.33	K 12	130	65	84	68	83		
MW884	EBS	11/5/93	S	319,774.36	1,982,321.39	L 13	130	63.5	84	67	82		
MW885	WBS	11/5/93	S	322,978.80	1,975,469.51	H 6	133	79	99	82	97		
MW886	EBS	11/9/93	S	318,873.82	1,983,678.87	M 14	120	72.5	85	74	84		
MW887	WBS	11/10/93	S	324,493.14	1,975,819.61	F 6	133	69	90	72	87		Pumped dry 3Q-94. No recovery in 2 weeks
MW888	WBS	11/12/93	S	323,317.65	1,975,939.61	G 6	133	77	97	80	95		
MW889	EBS	11/12/93	S	318,953.02	1,983,221.06	M 14	106	86	99	88	98		
MW890	OBS	11/12/93	USS	314,336.84	1,975,150.53	R 6	130	112	127	115	125		
MW891	WBS	11/15/93	S	322,636.44	1,976,328.80	H 7	133	68.1	89	72	87		
MW892	EBS	11/16/93	S	321,389.51	1,985,222.92	J 16	130	63	77	65	75		

Table 4-1
Well Inventory and Construction Information

WELL NUMBER	BASE SECTOR	DATE INSTALLED	SCREENED HSZ	NORTHING (ft) 316,062.45 NAD83	EASTING (ft) 1,981,207.44 NAD83	GRID	TOTAL DEPTH OF BORING (ft, bgs)	FILTER PACK INTERVAL (ft, bgs)		WELL SCREEN INTERVAL (ft, bgs)		CURRENT STATUS	COMMENTS
								TOP	BOTTOM	TOP	BOTTOM		
MW893	OBS	11/17/93	S	309,298.74	1,980,227.40	W 11	180	95	112	98	108		
MW894	MBS	11/17/93	LSS	312,747.72	1,981,640.00	T 12	221	195	210	198	208		
MW895	EBS	11/17/93	S	320,557.88	1,983,532.54	K 14	135	65.5	84.5	68	83		
MW896	EBS	11-19/22-93	S	321,027.74	1,982,731.97	J 13	120	64	78.5	67	77		
MW897	OBS	11/22/93	USS	316,976.42	1,973,892.86	P 4	145	125	140	128.5	138.5		
MW898	MBS	11/23/93	USS	312,509.75	1,982,091.28	T 13	147	137	147	140	145		
MW899	MBS	11/19/93	S	312,759.43	1,981,523.60	T 12	100	72	87	75	85		
MW900	WBS	11/22/93	S	320,630.25	1,977,461.05	K 8	133	77	92	80	90		
MW901	WBS	11/24/93	USS	319,125.25	1,978,135.53	L 9	142	126	136	129	134		
MW902	MBS	2/7/94	USS	317,315.30	1,975,996.96	N 6	150.5	125	140	128	138		
MW903	MBS	1/5/94	USS	313,600.91	1,978,982.23	S 9	150.5	127	148	130	140		
MW904	MBS	1/12/94	USS	314,902.00	1,979,233.59	R 10	178	152	164	155	160		
MW905	MBS	1/14/94	USS	316,590.52	1,979,046.87	P 10	150	117	135	124	134		
MW906	MBS	1/14/94	USS	314,892.80	1,977,881.09	R 8	150	121	132	120	130		
MW907	MBS	1/27/94	LSS	312,539.55	1,980,454.54	T 11	218	174	189	177	187		
MW908	MBS	1/20/94	LSS	316,724.89	1,977,404.29	P 8	218	192	207	195	205		
MW909	SWS	1/28/94	USS	312,620.61	1,978,165.48	T 9	150	115	130	118	128		
MW910	WFLS	2/2/94	USS	317,959.62	1,976,782.45	N 9	150	117	132	120	130		
MW911	MBS	2/2/94	USS	316,579.43	1,976,379.26	P 7	150	125	139	128	138		
MW912	MBS	3/4/94	USS	311,717.92	1,979,912.46	U 10	150	120	138	123.5	133.5		
MW913	SWS	2/22/94	USS	314,478.63	1,976,398.99	R 7	148	117	127.5	120	125		
MW914	MBS	2/17/94	LSS	315,867.10	1,981,025.09	Q 12	220	177	192	180	190		
MW915	MBS	2/14/94	LSS	313,696.81	1,982,957.78	S 13	210	184	201	188	198		
MW916	SWS	2/18/94	LSS	309,304.95	1,981,477.38	W 12	240	221.3	240	225	235		
MW917	MBS	2/18/94	USS	315,908.90	1,980,998.52	Q 11	150	124.8	140	128	138		
MW918	MBS	2/22/94	LSS	314,986.96	1,978,211.46	R 9	220	201.5	218.5	205.8	215.8		
MW919	MBS	2/24/94	LSS	313,387.13	1,979,412.80	S 10	220	184	200	188	198		
MW920	MBS	3/2/94	LSS	314,919.88	1,980,368.68	R 11	220	188	202	190.5	200.5		
MW921	MBS	2/25/94	LSS	316,569.38	1,979,020.28	P 10	220	203.5	218	206	216		
MW922	MBS	2/28/94	USS	316,259.11	1,978,369.03	P 9	150	115	130	120	130		
MW923	SWS	3/2/94	USS	309,300.55	1,981,531.93	W 12	140	114.5	140	118	128		
MW924	MBS	3/18/94	LSS	314,919.50	1,979,258.54	R 10	240	222.5	236	225.3	235		
MW925	SWS	3/11/94	LSS	311,712.28	1,979,974.02	U 10	210	190.5	205	193.5	203.5		

Table 4-1
Well Inventory and Construction Information

WELL NUMBER	BASE SECTOR	DATE INSTALLED	SCREENED HSZ	NORTHING (ft) 316,062.45 NAD83	EASTING (ft) 1,981,207.44 NAD83	GRID	TOTAL DEPTH OF BORING (ft, bgs)	FILTER PACK INTERVAL (ft, bgs)		WELL SCREEN INTERVAL (ft, bgs)		CURRENT STATUS	COMMENTS
								TOP	BOTTOM	TOP	BOTTOM		
MW926	SWS	3/8/94	USS	311,261.57	1,978,328.11	U 9	150	134	148	136.8	146.8		
MW927	SWS	4/6/94	CF	312,007.14	1,979,031.13	T 10	600	332	358	336	346		
MW928	MBS	4/18/94	CF	314,371.76	1,979,262.09	R 10	600	297.5	337	320	330		
MW929	SWS	5/6/94	CF	313,133.94	1,977,823.85	S 8	610	353	375	358	368		
MW930	SWS	4/15/94	CF	311,230.00	1,978,312.00	U 9	605	332	360	340	350	ABD	Not surveyed, well sealed and abandoned
MW930R	SWS	4/15/94	CF	311,230.18	1,978,312.64	U 9	605	332	358	340	350		
MW932	SWS	4/24/94	CF	311,780.02	1,979,922.76	U 10	603	321.8	345	325.75	333.8		
OW1A	MBS	11/29/90	S	314,221.18	1,980,735.10	R 11	99	NA	NA	46	96		
OW1B	MBS	12/04/90	S	314,393.28	1,980,856.26	R 11	NA	NA	NA	49	99		
OW2A	MBS	11/30/90	S	315,533.82	1,979,446.00	Q 10	NA	NA	NA	45	95		
OW2B	MBS	12/03/90	S	315,649.86	1,979,591.32	Q 10	NA	NA	NA	NA	NA		
PW1	MBS	01/01/39	CF	314,398.06	1,979,058.08	R 10	305	NA	NA	273	305	ABD	Main production well for main base till 1985, backup 1985 - 1991, ABD. in 1991
PW2	MBS	01/01/39	CF	314,210.61	1,979,210.82	R 10	320	NA	NA	299	319.5	ABD	Main production well for main base till 1985, backup 1985 - 1991, ABD. In 1991
PW3	MBS	01/01/39	CF	314,005.86	1,979,401.63	R 10	290	NA	NA	267	290	ABD	Main production well for main base till 1985, backup 1985 - 1991, ABD. In 1991
PW4	MBS	01/01/39	CF	313,832.53	1,979,552.86	S 10	290	NA	NA	270	290	ABD	Main production well for main base till 1985, backup 1985 - 1991, ABD. In 1991
PW5	EBS	01/01/56	S, USS	319,804.63	1,983,195.24	L 14	126	NA	NA	76	120	ABD	Abandoned 4Q-95. Out of service 1991 - high colliform bacteria count
PW5A	EBS	NA		319,784.77	1,983,187.03	L 14	NA	NA	NA	NA	NA		
PW6	EBS	NA	S, USS	320,101.79	1,983,266.20	K 14	120	NA	NA	76	120		Used on demand. Supplies WSA, dog kennels (75 gpm)
PW07 (CAFB 7)	MBS	01/01/51	LSS	313,207.93	1,977,669.54	S 8	NA	NA	NA	NA	NA	ABD	Abandoned 4Q-95. Serviced Castle Gardens. (500 gpm)
PW08 (CAFB 8)	MBS	01/01/51	CF	313,021.79	1,977,650.85	S 8	NA	NA	NA	NA	NA	ABD	Abandoned 4Q-95. Serviced Castle Gardens. (1200 gpm)
PW09 (CAFB 9)	MBS	01/01/51	CF	311,487.98	1,976,010.90	U 7	NA	NA	NA	NA	NA	ABD	Abandoned 4Q-95. Serviced Castle Gardens. (900 gpm)
PW10	MBS	08/09/84	CF,DP	315,320.88	1,978,125.53	Q 9	804	NA	NA	261	734		Used Apr-Oct. Backup to PW-12, serves main base area (2400 gpm)
PW11	EBS	01/01/54	S	319,493.16	1,985,202.45	L 16	NA	NA	NA	NA	NA		Used on demand. Serves rifle range and skeet range (25 gpm)
PW12	MBS	05/01/88	CF,DP	314,019.12	1,984,262.66	R 15	900	NA	NA	360	875		Continual usage. Serves main base area (2400 gpm)
RP1	OBS	2/7/73	LSS	313,194.41	1,975,100.35	S 6	232	NA	NA	190	214		
RP2	OBS	02/02/73	LSS, CF	311,149.53	1,974,889.06	U 5	301	NA	NA	190	260		
RP3	OBS	02/12/73	USS, LSS, CF	309,268.78	1,974,715.50	W 5	312	NA	NA	160	259		
RP5	OBS	02/17/73	USS, LSS	308,600.00	1,977,075.00	X 8	NA	NA	NA	160	198		
STRAWBERRY	OBS	NA	S(?)	317,727.79	1,973,477.81	N 4	NA	NA	NA	NA	NA		
TW12	SBS	01/01/81	S	310,876.51	1,982,462.06	V 13	100	NA	NA	87	97		
TW13	MBS	11/01/81	S	313,091.35	1,980,832.06	S 11	95	NA	NA	80	90		

Table 4-1
Well Inventory and Construction Information

WELL NUMBER	BASE SECTOR	DATE INSTALLED	SCREENED HSZ	NORTHING (ft) 316,062.45 NAD83	EASTING (ft) 1,981,207.44 NAD83	GRID	TOTAL DEPTH OF BORING (ft, bgs)	FILTER PACK INTERVAL (ft, bgs) TOP	FILTER PACK INTERVAL (ft, bgs) BOTTOM	WELL SCREEN INTERVAL (ft, bgs) TOP	WELL SCREEN INTERVAL (ft, bgs) BOTTOM	CURRENT STATUS	COMMENTS
TW14	MBS	01/01/81	S	313,988.38	1,979,492.42	S 10	95	NA	NA	82	97	DMG	Well cannot be located, field area is paved over.
TW15	MBS	01/01/81	S	312,521.59	1,980,919.65	T 11	90	NA	NA	72	82		Also reported as N. 310,784.08 ;E. 1,981,544.72
TW16	MBS	01/01/81	S	314,270.97	1,980,776.16	R 11	102	NA	NA	92	102		Also reported as N. 314,230.46; E. 1,980,746.59
TW17	MBS	01/01/81	S	312,866.66	1,980,035.80	T 11	100	NA	NA	90	100		
TW18	MBS	01/01/81	S	315,136.38	1,980,073.20	Q 11	NA	NA	NA	79	89		
TW19	EBS	NA	NA	320,374.88	1,983,440.46	K 14	NA	NA	NA	NA	NA	ABD	Abandoned
WR1	MBS	10/1/91	S,USS	317,515.04	1,977,394.12	N 8	NA	NA	NA	80&110	95&140		Continual use. Wallace Rd. extraction system. Screen in both S and USS HSZs (150 gpm)
WR2	MBS	10/2/91	S,USS	317,223.68	1,977,439.67	N 8	NA	NA	NA	80&111	95&141		Continual use. Wallace Rd. extraction system. Screen in both S and USS HSZs (150 gpm)
WR3	MBS	10/3/91	S,USS	316,917.97	1,977,397.93	P 8	NA	NA	NA	80&112	95&142		Continual use. Wallace Rd. extraction system. Screen in both S and USS HSZs (150 gpm)
WR4	MBS	6/15/95	S	NA	NA	M 8	96	61	93	68	93		Continual use. Wallace Rd. extraction system. Screened in Shallow HSZ.

NOTES:

HSZ = Hydrostratigraphic Zone
S = Shallow
USS = Upper Subshallow
LSS = Lower Subshallow
CF = Confined
DP = Deep
MHZ = Multiple screened zones

bgs = Below ground surface
TD = Total depth
? = Uncertain
R = Redrill
NA = Not available
DRY = Well dry
DMG = Well damaged
ABD = Well abandoned/destroyed

EBS = East base sector
WBS = West base sector
MBS = Main base sector
OBS = Off base sector
SBS = South base sector
NBS = North base sector
WFLS = West flight line sector
BKGD = Background location

3Q-89 = Third quarter of 1989 calander year (typical)

APPENDIX C

RESPIRATION TEST RESULTS, AIR PERMEABILITY TEST RESULTS, AND SOIL CONTAMINATION BIODEGRADATION RATE CALCULATIONS

Respiration Test Calculations

Site: PFFA
Location: Castle Airport

initial
stop date: 02/17/98
stop time: 09:25

VMP14-35

Respiration Test at VMP14-35 PFFA - Castle Airport

Date	Time	Elapsed Time (hrs) T_1	Injection 35, O2 (%), [initial] O_1
02/17/98	9:40	0.3	20.8
02/17/98	13:38	4.2	20.5
02/17/98	17:23	8.0	20.5
02/18/98	9:15	23.8	16.0
02/18/98	16:45	31.3	13.0
02/19/98	8:31	47.1	10.2
02/19/98	15:20	53.9	4.2

initial O2 = 0.1
slope= -0.291
ko=0.29 %/hr

trend time/O2:
0.3 22.0
53.9 6.4

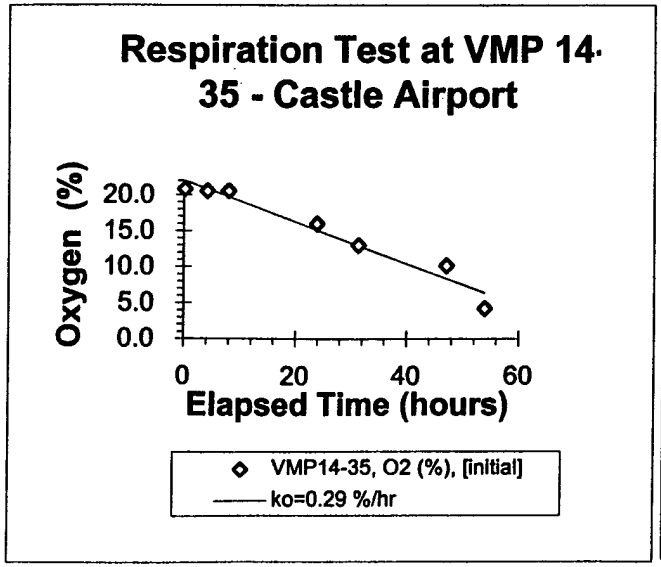
VMP14-51

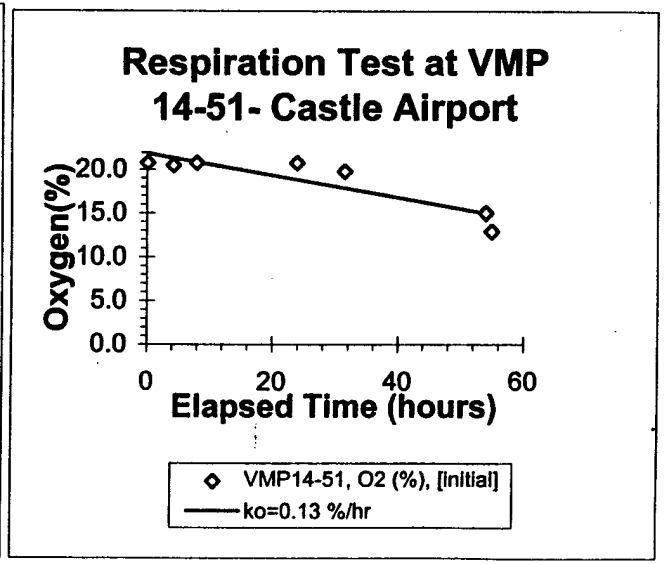
Respiration Test at VMP14-51 PFFA - Castle Airport

Date	Time	Elapsed Time (hrs) T_2	Injection 51, O2 (%), [initial] O_2
02/17/98	9:30	0.1	20.8
02/17/98	13:40	4.3	20.5
02/17/98	17:21	7.9	20.8
02/18/98	9:18	23.9	20.8
02/18/98	16:51	31.4	19.8
02/19/98	15:27	54.0	15.0
02/19/98	16:23	55.0	12.9

initial O2 = 5.8
slope= -0.129
ko=0.13 %/hr

trend time/O2:
0.1 21.9
55.0 14.8

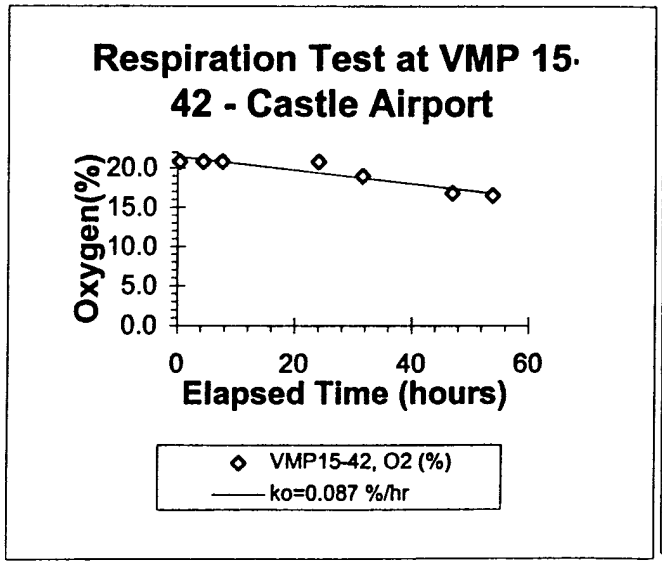




VMP15-42 Injection

Respiration Test at VMP15-42 PFFA - Castle Airport

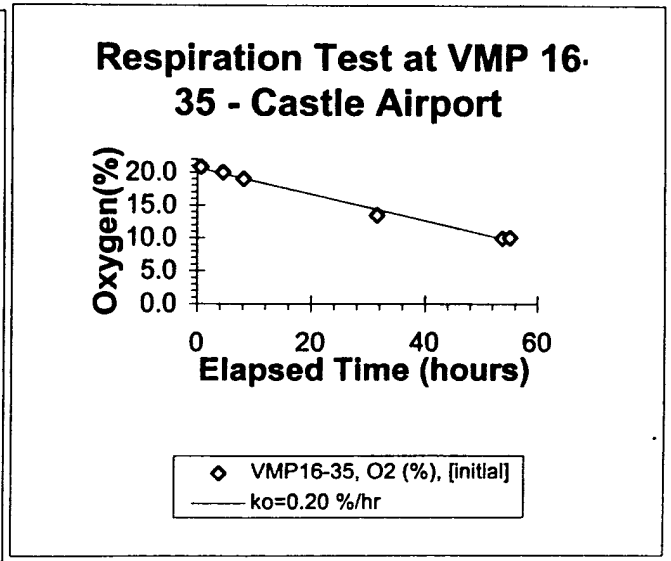
Date	Time	Elapsed Time (hrs) T_3	VMP15-42, O2 (%) O_3
02/17/98	9:48	0.4	20.8
02/17/98	13:47	4.4	20.8
02/17/98	17:00	7.6	20.8
02/18/98	9:24	24.0	20.8
02/18/98	16:56	31.5	19.0
02/19/98	8:20	46.9	16.8
02/19/98	15:15	53.8	16.5
		initial O2	11.2
		slope=	-0.087
			ko=0.087 %/hr
trend time/O2:		0.4	21.4
		53.8	16.8



VMP16-35 Injection

Respiration Test at VMP16-35 PFFA - Castle Airport

Date	Time	Elapsed Time (hrs) T_4	VMP16-35, O2 (%), [initial] O_4
02/17/98	10:04	0.7	20.8
02/17/98	13:55	4.5	20.0
02/17/98	17:33	8.1	19.0
02/18/98	17:01	31.6	13.5
02/19/98	15:11	53.8	10.0
02/19/98	16:30	55.1	10.1
		initial O2	0.0
		slope=	-0.200
			ko=0.20 %/hr
trend time/O2:		0.7	20.6
		55.1	9.7

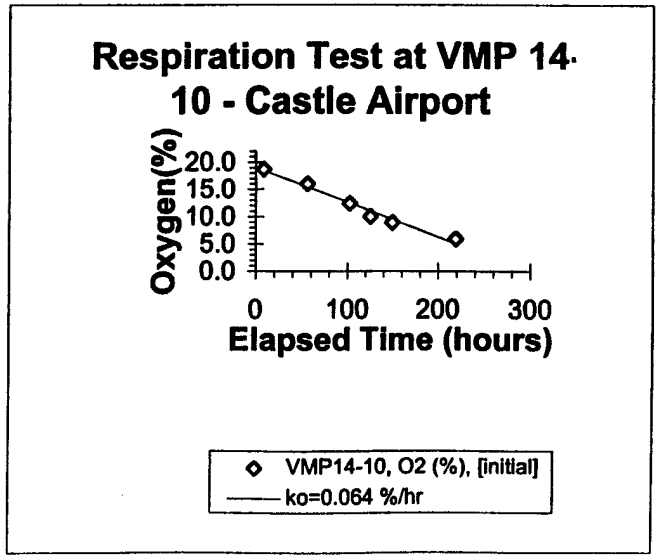


O2 Influence Test
stop date: 12/29/97
stop time: 07:00

VMP14-10 Areal Injection
Respiration Test at VMP14-10 PFFA - Castle Airport

Date	Time	Elapsed Time (hrs) T_5	10, O2 (%), [initial] O_5
12/29/97	15:46	8.8	18.7
12/31/97	15:28	56.5	16.0
01/02/98	13:33	102.6	12.4
01/03/98	12:34	125.6	10.0
01/04/98	12:30	149.5	8.9
01/07/98	10:03	219.0	5.9

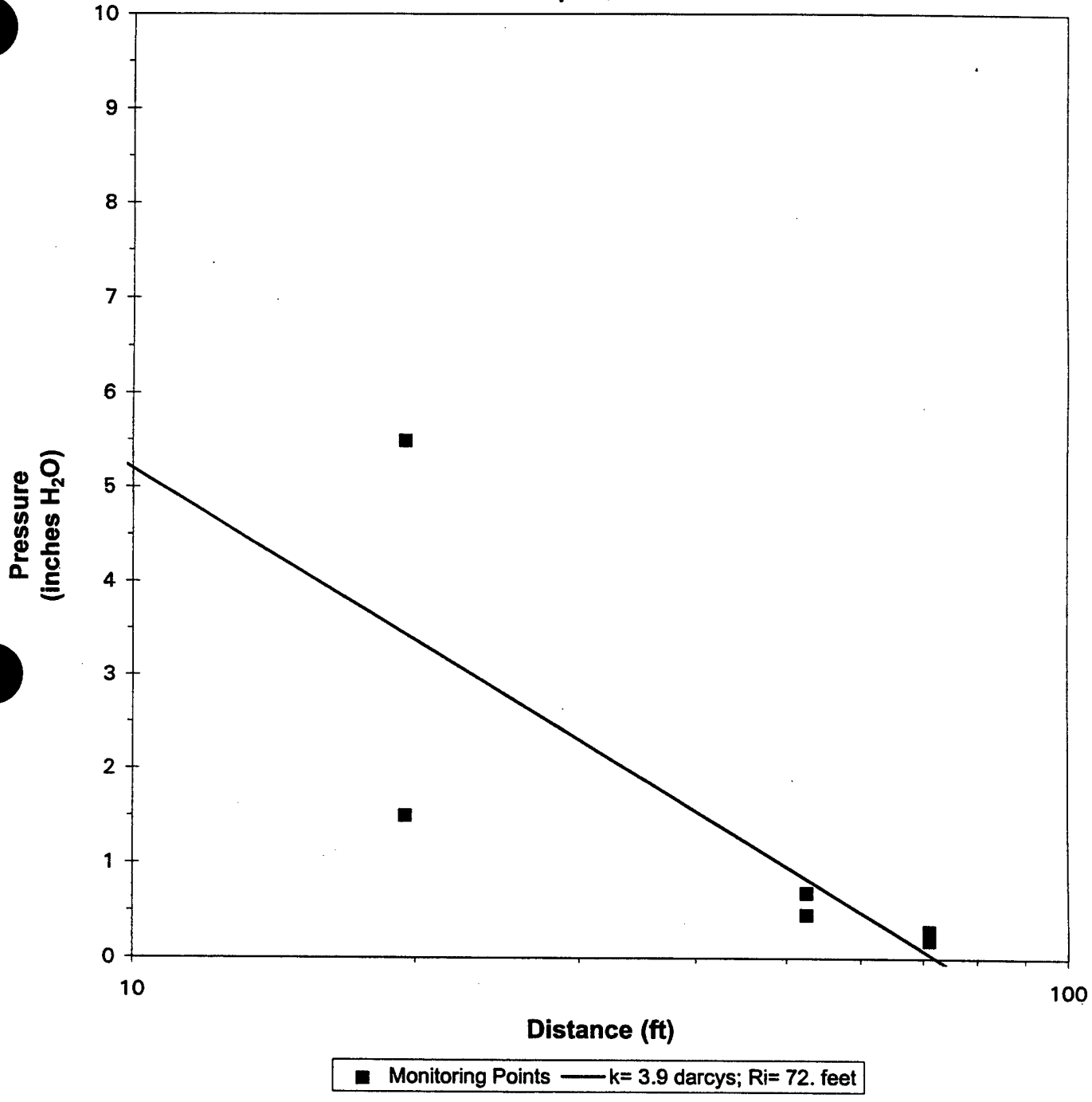
	initial O2	0.0
	slope=	-0.064
		ko=0.064 %/hr
trend time/O2:	8.8	18.5
	219.0	5.0

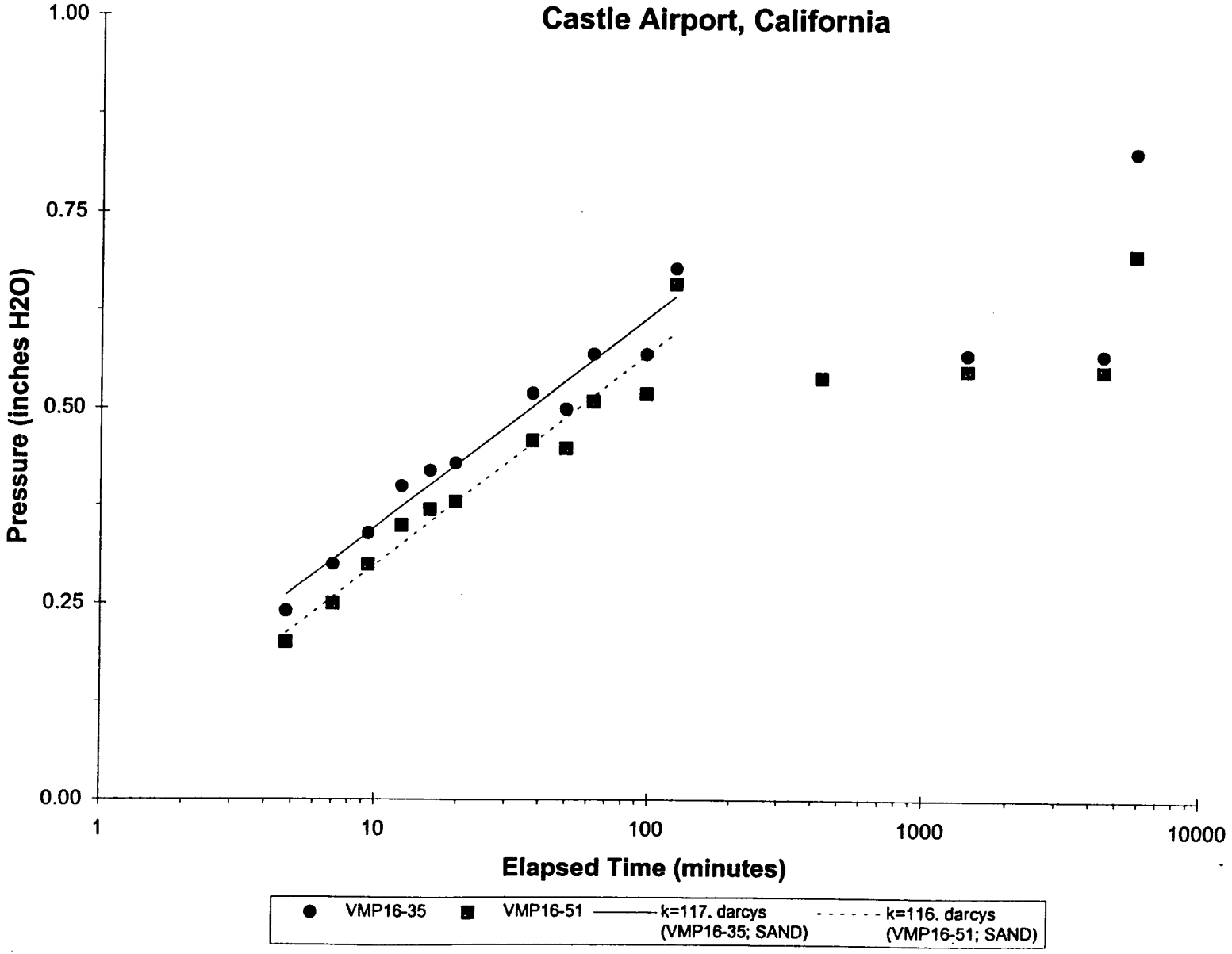


Biodegradation Rate Calculations
Site: PFFA
Location: Castle AFB, CA

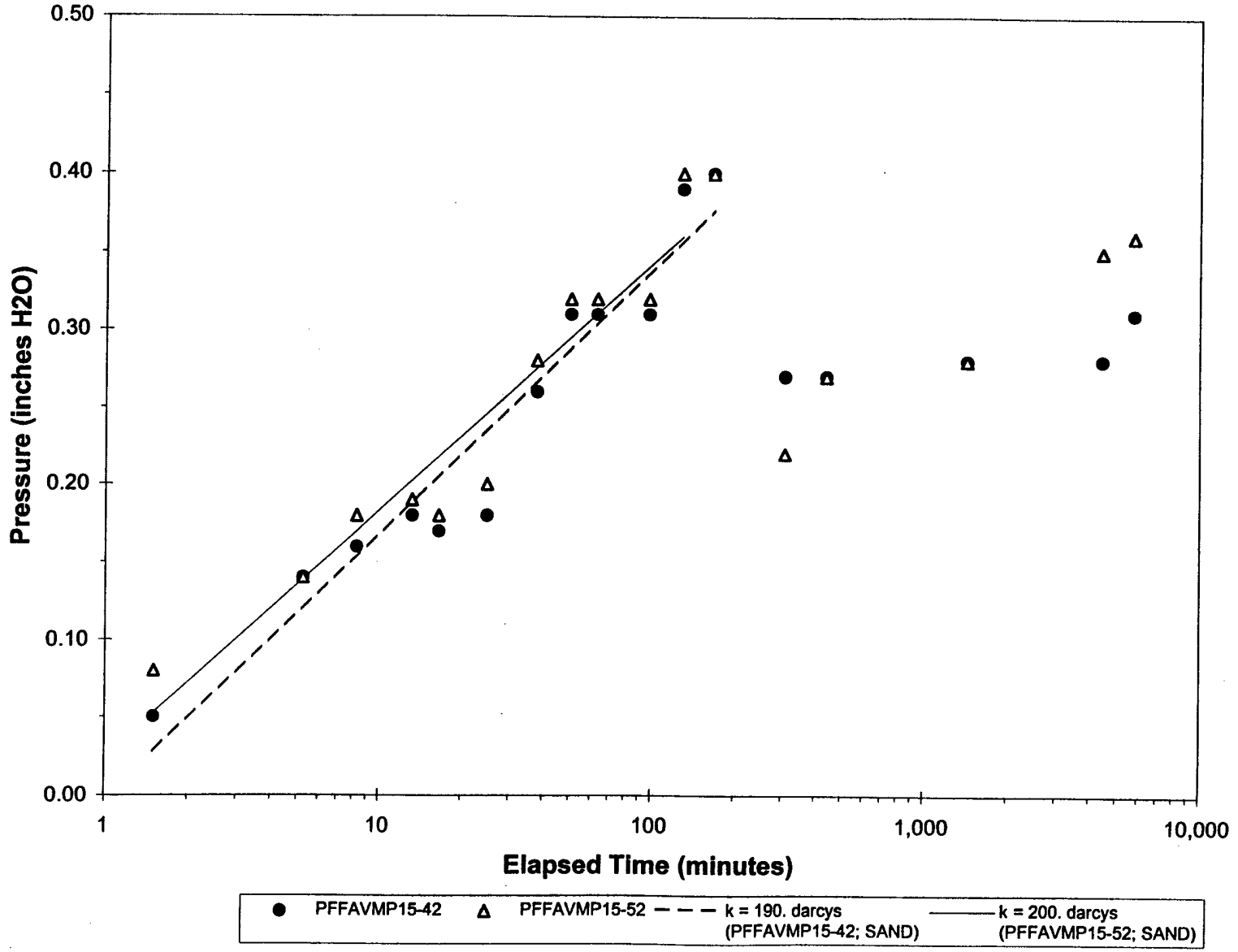
	VMP4-10	VMP4-20	VMP9-30.5	VMP14-35	VMP14-51	VMP15-42	VMP16-35
user entered data							
Ko, oxygen utilization rate (%/hr)	0.23	0.53	0.44	0.29	0.13	0.087	0.2
w, moisture content (% by wt)	9.6%	14.9%	13.7%	3.2%	2.5%	2.4%	3.2%
Soil type [from boring logs]	silty SAND	silty SAND	silty SAND	fine-med SAND	fine SAND	silty SAND	fine-med SAND
Gravel fraction (% by wt.)	-	-	-	-	-	0.0%	-
Sand fraction (% by wt.)	-	-	-	-	-	91.2%	-
Silt and Clay fraction (% by wt.)	-	-	-	-	-	8.8%	-
n, porosity (-) [est. from soil descriptions]	0.35	0.35	0.35	0.33	0.30	0.35	0.33
TPH contamination in soil (mg/kg)	-	-	-	-	130	0.71	-
BTEX contamination in soil (mg/kg)	-	-	-	-	0.12	ND	-
TVH contamination in soil vapor (ppmv)	-	-	-	-	54,000	-	-
BTEX contamination in soil vapor (ppmv)	-	-	-	-	2,600	-	-
Oxygen Concentration (%)	0.5	0.0	0.0	0.0	1.0	0.4	0.0
constants							
unit weight of water (g/cm3)	1.0	1.0	1.0	1.0	1.0	1.0	1.0
G, spec. gravity of solids (- or g/cm3)	2.65	2.65	2.65	2.65	2.65	2.65	2.65
Do, density of oxygen (mg/L)	1340	1340	1340	1340	1340	1340	1340
C, carbon/oxygen ratio	0.29	0.29	0.29	0.29	0.29	0.29	0.29
calculated data							
volume of solids, in 1 cm3 of soil (cm3)	0.65	0.65	0.65	0.67	0.70	0.65	0.67
volume of voids, in 1 cm3 of soil (cm3)	0.35	0.35	0.35	0.33	0.30	0.35	0.3
Dry unit weight/Bulk density (g/cm3)	1.72	1.72	1.72	1.78	1.86	1.72	1.7
e, void ratio (-)	0.54	0.54	0.54	0.49	0.43	0.54	0.4
Sr, degree of saturation	0.47	0.73	0.67	0.17	0.15	0.12	0.
volume of water, in 1 cm3 of soil (cm3)	0.165	0.256	0.236	0.057	0.046	0.041	0.05
volume of air, in 1 cm3 of soil (cm3)	0.185	0.094	0.114	0.273	0.254	0.309	0.273
A, air filled porosity (cm3 air/cm3 soil) (-)	0.185	0.094	0.114	0.273	0.254	0.309	0.273
wet density of soil (kg/L)	1.89	1.98	1.96	1.83	1.90	1.76	1.83
A, air filled porosity (liter air/kg wet soil)	0.098	0.048	0.058	0.149	0.133	0.175	0.149
Kb, biodegradation rate (mg TPH/kg soil per year)	**750**	**850**	**860**	**1,450**	**580**	**510**	**1,000**

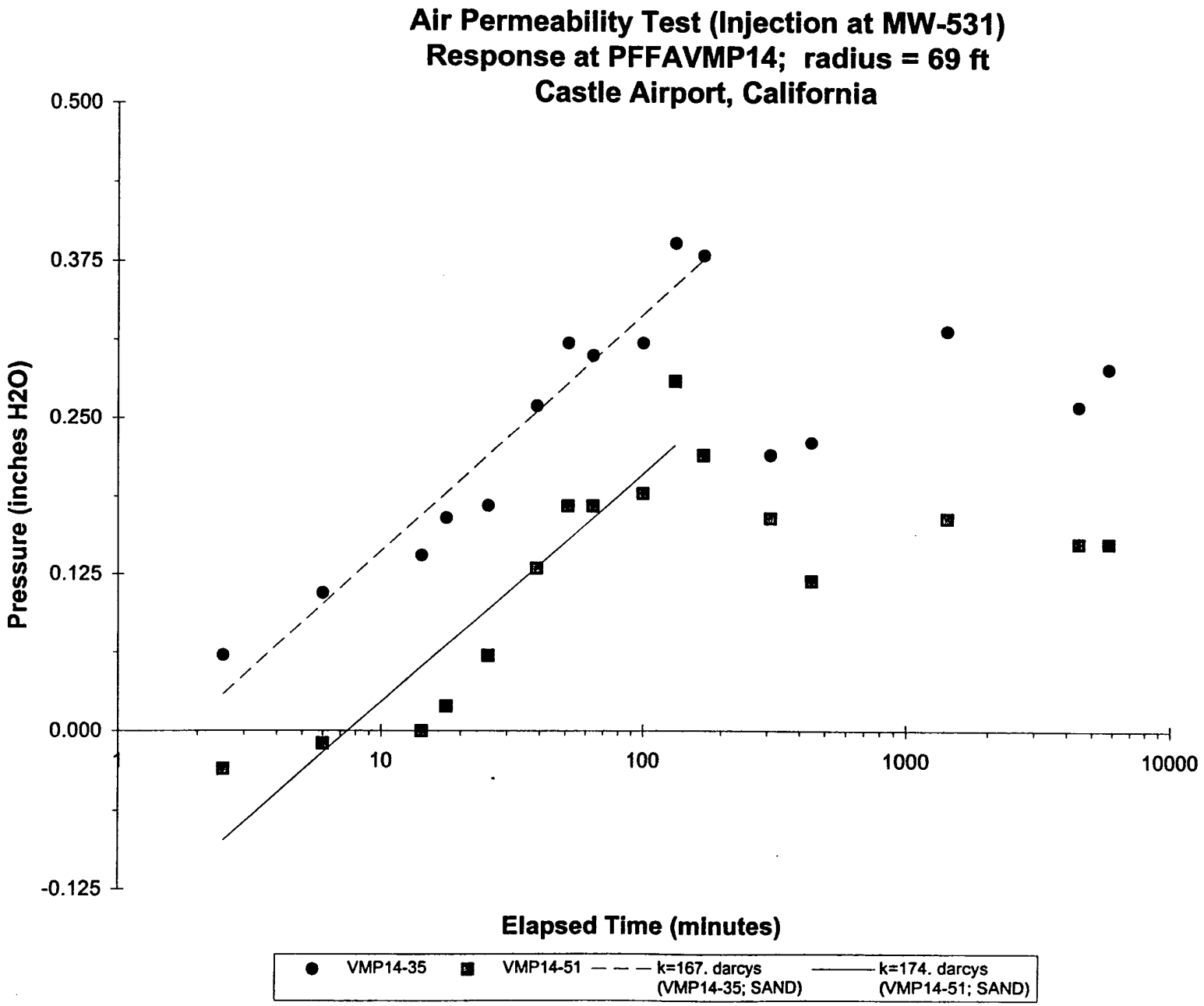
Air Permeability (Injection at PFFAVW01)
Steady-State Calculation Method
PFFA - Castle Airport, California



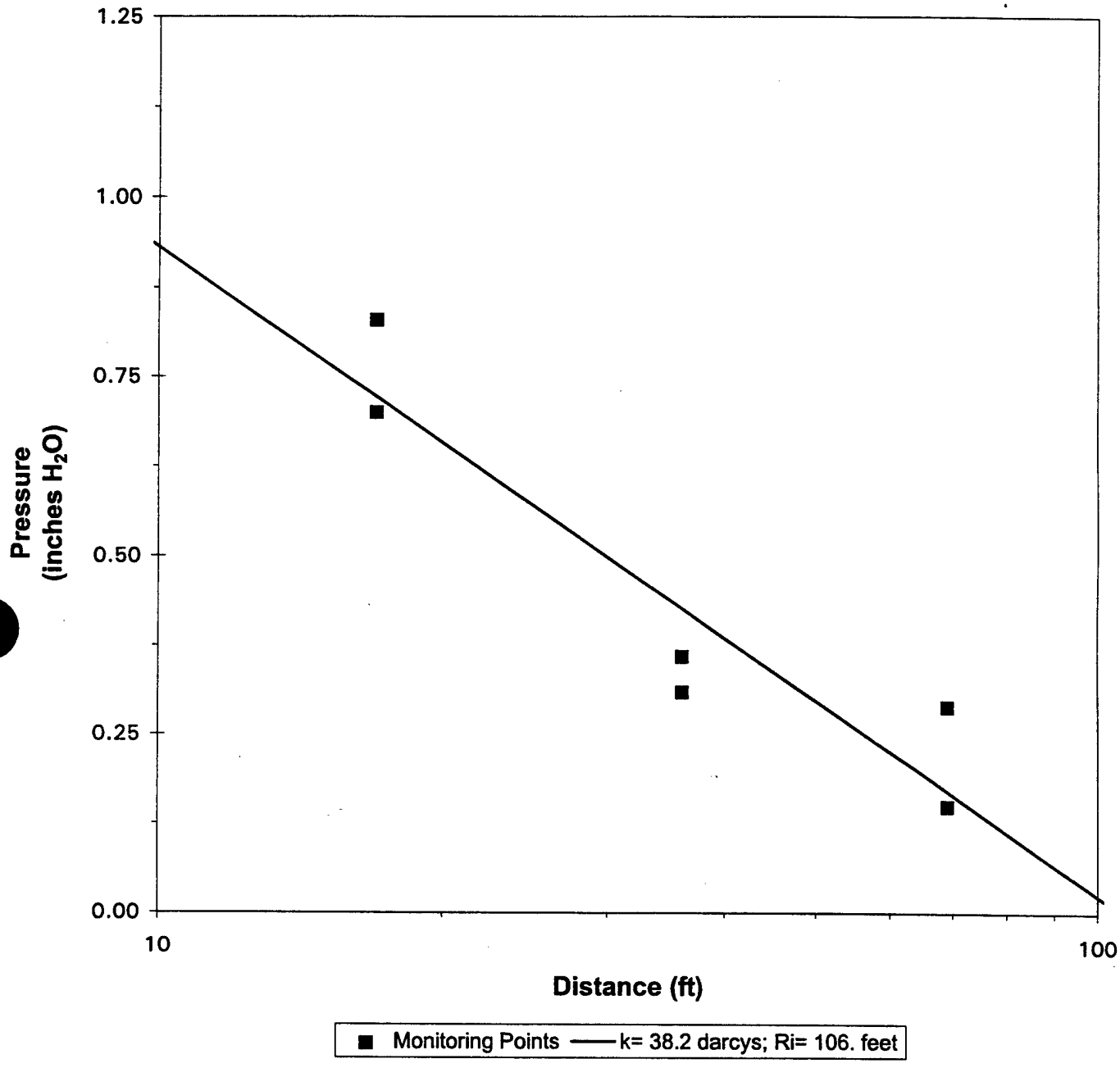

Air Permeability Test (Injection at MW-531)
Response at PFFAVMP16; radius = 17 ft
Castle Airport, California
Pressure (inches H2O)
1.00
0.75
0.50
0.25
0.00
1
10
100
1000
10000
Elapsed Time (minutes)
VMP16-35
VMP16-51
k=117. darcys
(VMP16-35; SAND)
k=116. darcys
(VMP16-51; SAND)

Air Permeability Test (Injection at MW-531)
Response at PFFAVMP15; radius = 36 ft
Castle Airport, California




Air Permeability Test (Injection at MW-531)
Response at PFFAVMP14; radius = 69 ft
Castle Airport, California
0.500
0.375
0.250
0.125
0.000
-0.125
Pressure (inches H2O)
1
10
100
1000
10000
Elapsed Time (minutes)
VMP14-35
VMP14-51
k=167. darcys
(VMP14-35; SAND)
k=174. darcys
(VMP14-51; SAND)

Air Permeability (Injection at MW531)
Steady-State Calculation Method
PFFA - Castle Airport, California



APPENDIX D

RISK ANALYSIS CALCULATIONS

APPENDIX D
MAINTENANCE WORKER - RME
CALCULATION OF SOIL RBCLS FOR INHALATION
REMEDIAL ACTION PLAN
Petroleum, Oils, Lubricants Fuel Farm Area (PFFA)
CASTLE AIRPORT, CALIFORNIA

Exposure Assumptions					Volatilization Factor Derivation		
Body Weight (BW)	70	kg	**Carcinogenic Chemicals:**		Q/C (inverse conc)	35.1	$g/m^2/kg/m^3$
Exposure Frequency (EF)	250	days/yr	RBCL (mg/kg) = TR*AT*BW/(IUR*1000*EF*ED*(1/VF+1/PEF))		T (exp interval)	1.80E+08	seconds
Exposure Duration (ED)	10	yrs			Dei (effective diffusivity)	chem-spec	cm^2/sec
Volatilization Factor (VFs)	chem-spec	m^3/kg	**Noncarcinogenic Chemicals:**		a (air filled porosity)	0.28	
Particulate Emission Factors (PEFs)	6.79E+08	m^3/kg	RBCL (mg/kg) = THI*AT*BW/(1/RfC*EF*ED*(1/VF+1/PEF))		Di (diffusivity in air)	chem-spec	cm^2/sec
Avging Time, Noncar (ATn)	3,650	days	.		n (total porosity)	0.43	
Avging Time, Carcin (ATc)	25,550	days	**Volatilization Factor:**		pb (dry soil density)	1.5	
			VF (mg^3/kg) = Q/C*(3.14*A*T)^0.5*10e-4/(2*Dei*a*Kas)		ps (soil particulate density)	2.65	
			where		Kas (soil-air partition coefficien	chem-spec	g/cm^3
			A = (Dei*a)/(a+(ps*(1-a)/Kas))		H (Henry's Law constant)	chem-spec	$atm\text{-}m^3/mol$
					Kd (soil-water partition coeff)	chem-spec	cm^3/g
			Target Risk	1.0E-06	foc (organic soil fraction)	0.02	
			Target Hazard Index	1.0	Koc (organic carbon part coeff)	chem-spec	cm^3/g

MAINTENANCE WORKER - RME
CALCULATION OF SOIL RBCLS FOR INHALATION
REMEDIAL ACTION PLAN
Petroleum, Oils, Lubricants Fuel Farm Area (PFFA)
CASTLE AIRPORT, CALIFORNIA

Chemical	CAS No.	Dei (cm^2/sec)	Di (cm^2/sec)	H ($atm\text{-}m^3/mol$)	Koc (cm^3/g)	Kd (cm^3/g)	Kas (g/cm^3)	Inhalation RfC (mg/m^3)	IUR $(ug/m^3)^{-1}$	VEF (m^3/kg)	RBCL (mg/kg)
Benzene	71-43-2	6.86E-03	0.088	0.0055	65	0.39	5.78E-01	--	8.30E-06	2.00E+03	2.46E+00
Toluene	108-88-3	6.08E-03	0.078	0.0066	260	1.56	1.73E-01	4.00E-01	--	3.99E+03	2.33E+03
Ethylbenzene	100-41-4	5.85E-03	0.075	0.0079	220	1.32	2.45E-01	1.00E+00	--	3.40E+03	4.96E+03
Xylenes, Total	1330-20-7	6.79E-03	0.087	0.0053	240	1.44	1.51E-01	7.00E+00	--	4.05E+03	4.14E+04
1,2,4-TMB	108-67-8	--	--	--	--	--	--	--	--	--	--
1,3,5-TMB	75-01-4	--	--	--	--	--	--	--	2.00E-03	--	--
4-Ethyltoluene		--	--	--	--	--	--	--	--	--	--
Bromobenzene		--	--	--	--	--	--	--	--	--	--
Chlorobenzene	108-90-7	5.62E-03	0.072	0.0035	160	0.96	1.49E-01	2.00E-02	--	4.48E+03	1.31E+02
Naphthalene	91-20-3	5.38E-03	0.069	0.0013	1300	7.8	6.83E-03	1.40E-01	--	2.16E+04	4.42E+03
p-Isopropyltoluene	25155-15-1	--	--	--	--	--	--	--	--	--	--
n-Propylbenzene		--	--	--	--	--	--	--	--	--	--
Isopropylbenzene		--	--	--	--	--	--	2.57E-03	--	--	2.55E+06
n-Butylbenzene	104-51-8	--	--	--	--	--	--	--	--	--	--
sec-Butylbenzene		--	--	--	--	--	--	--	--	--	--
tert-Butylbenzene		--	--	--	--	--	--	--	--	--	--
Anthracene	120-12-7	4.52E-03	0.058	0.000034	13000	78	1.79E-05	1.05	--	4.61E+05	7.07E+05
Acenaphthene	83-32-9	4.99E-03	0.064	0.0012	4600	27.6	1.78E-03	2.10E-01	--	4.40E+04	1.35E+04
Benzo(a)anthracene	56-55-3	--	--	1.16E-06	1380000	8280	5.74E-09	--	1.10E-04	--	6.31E+04
Benzo(a)pyrene	50-32-8	--	--	1.55E-06	5500000	33000	1.93E-09	--	2.09E-03	--	3.32E+03
Benzo(b)fluoranthene	205-99-2	--	--	1.19E-05	550000	3300	1.48E-07	--	2.09E-03	--	3.32E+03
Benzo(g,h,I)perylene	191-24-2	--	--	5.34E-08	1600000	9600	2.28E-10	--	--	--	--
Benzo(k)fluoranthene	207-08-9	--	--	3.94E-05	550000	3300	4.90E-07	--	2.09E-03	--	3.32E+03
bis-(2-ethylhexyl)phthalate	117-81-7	--	--	--	--	--	--	7.00E-02	4.00E-06	--	1.73E+06
Chrysene	218-01-9	--	--	1.05E-06	200000	1200	3.59E-08	--	1.10E-05	--	6.31E+05
Dibenzofuran	132-64-9	--	--	--	--	--	--	--	--	--	--
di-n-butylphthalate	84-74-2	--	--	2.82E-07	170000	1020	1.13E-08	3.50E-01	--	--	3.47E+08
Fluorene	86-73-7	4.76E-03	0.061	0.000064	7900	47.4	5.54E-05	1.40E-01	--	2.56E+05	5.22E+04
Fluoranthene	206-44-0	--	--	6.46E-06	38000	228	1.16E-06	1.40E-01	--	--	1.39E+08
Indeno(1,2,3-cd)pyrene	193-39-5	--	--	6.86E-08	1600000	9600	2.93E-10	--	2.09E-03	--	3.32E+03
2-methylnaphthalene	91-57-6	--	--	--	--	--	--	1.40E-01	--	--	1.39E+08
Phenanthrene	85-01-8	4.52E-03	0.058	0.00004	14000	84	1.95E-05	--	--	4.41E+05	--
Pyrene	129-00-0	--	--	5.04E-06	38000	228	9.06E-07	1.05E-01	--	--	1.04E+08
1,1-Dichloroethene (DCE)	75-35-4	6.16E-03	0.079	0.15	65	0.39	1.58E+01	3.15E-02	--	2.31E+02	1.06E+01
1,1,2-Trichloroethane (TCA)	79-00-5	6.24E-03	0.08	0.0012	56	0.336	1.46E-01	1.40E-02	1.60E-05	4.29E+03	2.74E+00
Tetrachloroethene (PCE)	127-18-4	5.62E-03	0.072	0.023	660	3.96	2.38E-01	3.50E-02	5.70E-07	3.52E+03	6.32E+01
Trichloroethene (TCE)	79-01-6	6.32E-03	0.081	0.00892	130	0.78	4.69E-01	--	2.00E-06	2.33E+03	1.19E+01
Vinyl chloride	75-01-4	8.58E-03	0.11	0.7	57	0.342	8.39E+01	--	8.57E-05	4.24E+01	5.05E-03

APPENDIX D
MAINTENANCE WORKER - RME
CALCULATION OF SOIL VAPOR RBCLS FOR INHALATION
REMEDIAL ACTION PLAN
Petroleum, Oils, Lubricants Fuel Farm Area (PFFA)
CASTLE AIRPORT, CALIFORNIA

Equilibrium Partitioning: Vapor Phase in Contaminated Soils

$C_{v,eq} = (H*C_{soil}*p_s)/(\phi_w+Kd*p_s+H*\phi_a)$

where

$C_{v,eq}$	Equilibrium vapor concentration (g/cm^3)	chemical-specific
H	Henry's law constant (dimensionless)	chemical-specific
C_{soil}	Soil RBCL (g/g-soil)	chemical-specific
p_s	Soil bulk density (g-soil/cm^3-soil)	2.65
ϕ_w	Volumetric content of pore water (dimensionless)	0.15
Kd	Sorption coefficient (cm^3-H_2O/g-soil)	chemical-specific
ϕ_a	Volumetric content of pore vapor (dimensionless)	0.28

Chemical	H (atm-m^3/mol)	H (dimensionless)	RBCL (mg/kg)	RBCL (g/g)	Kd (cm3/g)	Vapor RBCL (mg/L)
Benzene	5.50E-03	2.26E-01	2.46E+00	2.46E-03	3.90E-01	1.18E-03
Toluene	6.60E-03	2.71E-01	2.33E+03	2.33E+00	1.56E+00	3.83E-01
Ethylbenzene	7.90E-03	3.24E-01	4.96E+03	4.96E+00	1.32E+00	1.14E+00
Xylenes, Total	5.30E-03	2.17E-01	4.14E+04	4.14E+01	1.44E+00	5.92E+00
1,2,4-TMB	--	--	--	--	--	--
1,3,5-TMB	--	--	--	--	--	--
4-Ethyltoluene	--	--	--	--	--	--
Bromobenzene	--	--	--	--	--	--
Chlorobenzene	3.50E-03	1.44E-01	1.31E+02	1.31E-01	9.60E-01	1.82E-02
Naphthalene	1.30E-03	5.33E-02	4.42E+03	4.42E+00	7.80E+00	2.99E-02
p-Isopropyltoluene	--	--	--	--	--	--
n-Propylbenzene	--	--	--	--	--	--
Isopropylbenzene	--	--	2.55E+06	2.55E+03	--	--
n-Butylbenzene	--	--	--	--	--	--
sec-Butylbenzene	--	--	--	--	--	--
tert-Butylbenzene	--	--	--	--	--	--
Anthracene	3.40E-05	1.39E-03	7.07E+05	7.07E+02	7.80E+01	1.26E-02
Acenaphthene	1.20E-03	4.92E-02	1.35E+04	1.35E+01	2.76E+01	2.40E-02
Benzo(a)anthracene	1.16E-06	4.76E-05	6.31E+04	6.31E+01	8.28E+03	3.62E-07
Benzo(a)pyrene	1.55E-06	6.36E-05	3.32E+03	3.32E+00	3.30E+04	6.39E-09
Benzo(b)fluoranthene	1.19E-05	4.88E-04	3.32E+03	3.32E+00	3.30E+03	4.91E-07
Benzo(g,h,I)perylene	5.34E-08	2.19E-06	--	--	9.60E+03	--
Benzo(k)fluoranthene	3.94E-05	1.62E-03	3.32E+03	3.32E+00	3.30E+03	1.63E-06
bis-(2-ethylhexyl)phthalate	--	--	1.73E+06	1.73E+03	--	--
Chrysene	1.05E-06	4.31E-05	6.31E+05	6.31E+02	1.20E+03	2.26E-05
Dibenzofuran	--	--	--	--	--	--
di-n-butylphthalate	2.82E-07	1.16E-05	3.47E+08	3.47E+05	1.02E+03	3.93E-03
Fluorene	6.40E-05	2.62E-03	5.22E+04	5.22E+01	4.74E+01	2.89E-03
Fluoranthene	6.46E-06	2.65E-04	1.39E+08	1.39E+05	2.28E+02	1.61E-01
Indeno(1,2,3-cd)pyrene	6.86E-08	2.81E-06	3.32E+03	3.32E+00	9.60E+03	9.73E-10
2-methylnaphthalene	--	--	1.39E+08	1.39E+05	--	--
Phenanthrene	4.00E-05	1.64E-03	--	--	8.40E+01	--
Pyrene	5.04E-06	2.07E-04	1.04E+08	1.04E+05	2.28E+02	9.43E-02
1,1-Dichloroethene (DCE)	1.50E-01	6.15E+00	1.06E+01	1.06E-02	3.90E-01	5.96E-02
1,1,2-Trichloroethane (TCA)	1.20E-03	4.92E-02	2.74E+00	2.74E-03	3.36E-01	3.39E-04
Tetrachloroethene (PCE)	2.30E-02	9.43E-01	6.32E+01	6.32E-02	3.96E+00	1.45E-02
Trichloroethene (TCE)	8.92E-03	3.66E-01	1.19E+01	1.19E-02	7.80E-01	4.98E-03
Vinyl chloride	7.00E-01	2.87E+01	5.05E-03	5.05E-06	3.42E-01	4.22E-05

APPENDIX D
CONSTRUCTION WORKER - RME
CALCULATION OF SOIL RBCLS FOR MULTIPLE PATHWAYS
REMEDIAL ACTION PLAN
Petroleum, Oils, Lubricants Fuel Farm Area (PFFA)
CASTLE AIRPORT, CALIFORNIA

Exposure Assumptions			Toxicity Value Definitions	
Body Weight (adult) (BWA)	70	kg	RfDo = Reference Dose (Oral)[a]	mg/kg-day
Exposure Frequency (EF)	90	days/yr	RfDd = Reference Dose (Dermal)[b]	mg/kg-day
Exposure Duration (adult) (EDA)	3	yr	RfC = Reference Concentration (Inhalation)[a]	mg/m3
Fraction Ingested (FI)	1	unitless	SFo = Oral Slope Factor[a]	kg-day/mg
Ingestion Rate (adult) (IRA)	50	mg/day	SFd = Dermal Slope Factor[c]	kg-day/mg
Surface Area (SA)	5000	cm^2	IUR = Inhalation Unit Risk[a]	m3/ug
Adherence Factor (AF)	1	mg/cm^2-day	RBCL-non = Noncarcinogenic RBCL	mg/kg
Dermal Absorption Factor (DABS)[d]	chem-specific	unitless	RBCL-car = Carcinogenic RBCL	mg/kg
Oral Absorption Factor (OABS)[e]	chem-specific	unitless		
Volatilization Factor (VF)[f]	chem-specific	m^3/kg		
Particulate Emission Factor (PEF)[f]	6.79E+08	m^3/kg	**RBCL Calculations**	
Averaging Time (AT)			Noncarcinogens	
Noncarcinogens	1095	days	RBCL (mg/kg) = (THQ*BWA*ATadult)/	
Carcinogens	25550	days	((1/RfDo*1E-6*EF*EDA*IRA*FI)+	
			(1/RfDd*1E-6*SA*AF*DABS*EF*EDA)+	
Target Risk Level (TR)	1.00E-06	unitless	(1/RfC*EF*EDA*(1/VF+1/PEF)*BWA))	
Target Hazard Quotient (THQ)	1	unitless	Carcinogens	
			RBCL (mg/kg) = ((TR)*(ATadult)*BWA)/	
			((SFo*1E-6*EF*IRA*FI*EDA)+	
			(SFd*1E-6*SA*AF*DABS*EF*ED)+	
			(IUR*1000*EF*ED*(1/VF+1/PEF)*BWA))	

Compounds	Classification	VF	RfDo	OABS	RfDd	RfC	SFo	SFd	IUR	DABS	RBCL-non	RBCL-car
Acenaphthene	NR	4.40E+04	6.00E-02	5.00E-01	3.00E-02	--	--	--	--	1.50E-01	1.10E+04	--
Anthracene	D	4.61E+05	3.00E-01	5.00E-01	1.50E-01	--	--	--	--	1.50E-01	5.49E+04	--
Benzo(a) Pyrene[i]	B2	--	--	2.00E-01	--	--	7.30E+00	3.65E+01	1.74E-03	1.50E-01	--	2.39E-01
Benzo(a)Anthracene[i]	B2	--	--	5.00E-01	--	--	7.30E-01	1.46E+00	1.74E-04	1.50E-01	--	5.85E+00
Benzene	A	2.00E+03	--	9.50E-01	--	--	2.90E-02	3.05E-02	8.30E-06	1.00E-01	--	2.15E+01
Benzo(b)Fluoranthene[i]	B2	--	--	5.00E-01	--	--	7.30E-01	1.46E+00	1.74E-04	1.50E-01	--	5.85E+00
Benzo(g,h,i)perylene	D	--	--	5.00E-01	--	--	--	--	--	1.50E-01	--	--
Benzo(k)Fluoranthene[i]	B2	--	--	5.00E-01	--	--	7.30E-02	1.46E-01	1.74E-05	1.50E-01	--	5.85E+01
Bis(2-ethylhexyl)Phthalate	B2	--	2.00E-02	5.00E-01	1.00E-02	--	1.40E-02	2.80E-02	--	1.00E-01	5.41E+03	4.51E+02
n-Butylbenzene	NR	--	--	8.00E-01	--	--	--	--	--	1.00E-01	--	--
sec-Butylbenzene	NR	--	--	8.00E-01	--	--	--	--	--	1.00E-01	--	--
Chlorobenzene		4.48E+03	2.00E-02	8.50E-01	1.70E-02	1.99E-02				1.00E-01	8.90E+03	--
Chrysene[i]	B2	--	--	6.00E-01	--	--	7.30E-03	1.22E-02	1.74E-06	1.50E-01	--	6.98E+02
Di-n-Butylphthalate	D	--	1.00E-01	9.00E-01	9.00E-02	--	--	--	--	1.00E-01	4.69E+04	--
Ethylbenzene	D	3.40E+03	1.00E-01	8.50E-01	8.50E-02	1.00E+00	--	--	--	1.00E-01	1.05E+04	--
Fluoranthene	D	--	4.00E-02	5.00E-01	2.00E-02	--	--	--	--	1.50E-01	7.33E+03	--
Fluorene	D	2.56E+05	4.00E-02	5.00E-01	2.00E-02	--	--	--	--	1.00E-01	1.08E+04	--
Indeno(1,2,3-cd)Pyrene[i]	B2	--	--	5.00E-01	--	--	7.30E-01	1.46E+00	1.74E-04	1.50E-01	--	5.85E+00
Isopropylbenzene (Cumene)	NR	--	4.00E-02	5.00E-01	2.00E-02	2.57E-03	--	--	--	1.50E-01	7.33E+03	--
2-Methylnaphthalene	NR	--	--	5.00E-01	--	--	--	--	--	1.50E-01	--	--
Naphthalene	D	2.16E+04	4.00E-02	5.00E-01	2.00E-02	--	--	--	--	1.50E-01	7.33E+03	--
Phenanthrene	D	4.41E+05	--	5.00E-01	--	--	--	--	--	2.50E-01	--	--
n-Propylbenzene	NR	--	--	5.00E-01	--	--	--	--	--	1.50E-01	--	--
Pyrene	D	--	3.00E-02	5.00E-01	1.50E-02	--	--	--	--	1.50E-01	5.49E+03	--
Toluene	D	3.99E+03	2.00E-01	8.00E-01	1.60E-01	4.00E-01	--	--	--	1.00E-01	6.01E+03	--
Tetrachloroethene		3.52E+03	1.00E-02	9.00E-01	9.00E-03	3.50E-02	5.20E-02	5.78E-02	5.70E-07	1.00E-01	4.69E+03	1.55E+02
Trichloroethene	NR	2.33E+03	6.00E-03	9.00E-01	5.40E-03	--	1.10E-02	1.22E-02	1.70E-06	1.00E-01	2.81E+03	1.15E+02
1,2,4-Trimethylbenzene	NR	--	--	8.00E-01	--	--	--	--	--	1.00E-01	--	--
1,3,5-Trimethylbenzene	NR	--	--	8.00E-01	--	--	--	--	--	1.00E-01	--	--
Vinyl Chloride	A	4.24E+01	--	9.00E-01	--	--	1.90E+00	2.11E+00	8.57E-05	1.00E-01	--	4.64E-02
Xylenes	D	4.05E+03	2.00E+00	9.00E-01	1.80E+00	--	--	--	--	1.00E-01	9.38E+05	--

[a] RfDo, RfC, SFo, and IUR from IRIS (Micromedex, 1997). When IRIS values were unavailable, HEAST (USEPA, 1995) was used. In some cases, withdrawn or provisional values were used.

[b] RfDd (Dermal RfD) = Oral RfD x oral absorption factor.

[c] SFd (Dermal-SF) = Oral-SF/oral absorption factor.

[d] DABS (USEPA, 1992e; CalEPA, 1994).

[e] Oral absorption values obtained from chemical specific Agency for Toxic Substances Disease Registry (ATSDR) profiles. If ATSDR profiles were unavailable, default values of 0.2 for inorganics, 0.8 for volatiles, and 0.5 for semivolatiles were used.

[f] VF and PEF (USEPA, 1996c).

[g] NR = not reported.

[h] "--" indicates that item is not applicable, or that there is no entry in either IRIS or HEAST.

[i] The slope factors for the carcinogenic PAHs were derived by multiplying the slope factor for benzo(a)pyrene by the following toxicity equivalency factors: 0.1 for benzo(a)anthracene, benzo(b)fluoranthene, and indeno(1,2,3-cd)perylene, 0.01 for benzo(k)fluoranthene, 0.001 for chrysene and 1.0 for dibenz(a,h)anthracene. (USEPA, 1993).

APPENDIX D
CONSTRUCTION WORKER - RME
CALCULATION OF SOIL VAPOR RBCLS FOR INHALATION
REMEDIAL ACTION PLAN
Petroleum, Oils, Lubricants Fuel Farm Area (PFFA)
CASTLE AIRPORT, CALIFORNIA

Equilibrium Partitioning: Vapor Phase in Contaminated Soils

$C_{v,eq} = (H*C_{soil}*p_s)/(\phi_w+Kd*p_s+H*\phi_a)$

where

$C_{v,eq}$	Equilibrium vapor concentration (g/cm^3)	chemical-specific
H	Henry's law constant (dimensionless)	chemical-specific
C_{soil}	Soil RBCL (g/g-soil)	chemical-specific
p_s	Soil bulk density (g-soil/cm^3-soil)	2.65
ϕ_w	Volumetric content of pore water (dimensionless)	0.15
Kd	Sorption coefficient (cm^3-H_2O/g-soil)	chemical-specific
ϕ_a	Volumetric content of pore vapor (dimensionless)	0.28

Chemical	H (atm-m^3/mol)	H (dimensionless)	RBCL (mg/kg)	RBCL (g/g)	Kd (cm3/g)	Vapor RBCL (mg/L)
Benzene	5.50E-03	2.26E-01	2.15E+01	2.15E-02	3.90E-01	1.03E-02
Toluene	6.60E-03	2.71E-01	6.01E+03	6.01E+00	1.56E+00	9.88E-01
Ethylbenzene	7.90E-03	3.24E-01	1.05E+04	1.05E+01	1.32E+00	2.42E+00
Xylenes, Total	5.30E-03	2.17E-01	9.38E+05	9.38E+02	1.44E+00	1.34E+02
1,2,4-TMB	--	--	--	--	--	--
1,3,5-TMB	--	--	--	--	--	--
4-Ethyltoluene	--	--	--	--	--	--
Bromobenzene	--	--	--	--	--	--
Chlorobenzene	3.50E-03	1.44E-01	8.90E+03	8.90E+00	9.60E-01	1.24E+00
Naphthalene	1.30E-03	5.33E-02	7.33E+03	7.33E+00	7.80E+00	4.97E-02
p-Isopropyltoluene	--	--	--	--	--	--
n-Propylbenzene	--	--	--	--	--	--
Isopropylbenzene	--	--	7.33E+03	7.33E+00	--	--
n-Butylbenzene	--	--	--	--	--	--
sec-Butylbenzene	--	--	--	--	--	--
tert-Butylbenzene	--	--	--	--	--	--
Anthracene	3.40E-05	1.39E-03	5.49E+04	5.49E+01	7.80E+01	9.81E-04
Acenaphthene	1.20E-03	4.92E-02	1.10E+04	1.10E+01	2.76E+01	1.95E-02
Benzo(a)anthracene	1.16E-06	4.76E-05	5.85E+00	5.85E-03	8.28E+03	3.36E-11
Benzo(a)pyrene	1.55E-06	6.36E-05	2.39E-01	2.39E-04	3.30E+04	4.60E-13
Benzo(b)fluoranthene	1.19E-05	4.88E-04	5.85E+00	5.85E-03	3.30E+03	8.66E-10
Benzo(g,h,I)perylene	5.34E-08	2.19E-06	--	--	9.60E+03	--
Benzo(k)fluoranthene	3.94E-05	1.62E-03	5.85E+01	5.85E-02	3.30E+03	2.87E-08
bis-(2-ethylhexyl)phthalate	--	--	4.51E+02	4.51E-01	--	--
Chrysene	1.05E-06	4.31E-05	6.98E+02	6.98E-01	1.20E+03	2.50E-08
Dibenzofuran	--	--	--	--	--	--
di-n-butylphthalate	2.82E-07	1.16E-05	4.69E+04	4.69E+01	1.02E+03	5.31E-07
Fluorene	6.40E-05	2.62E-03	1.08E+04	1.08E+01	4.74E+01	5.98E-04
Fluoranthene	6.46E-06	2.65E-04	7.33E+03	7.33E+00	2.28E+02	8.51E-06
Indeno(1,2,3-cd)pyrene	6.86E-08	2.81E-06	5.85E+00	5.85E-03	9.60E+03	1.72E-12
2-methylnaphthalene	--	--	--	--	--	--
Phenanthrene	4.00E-05	1.64E-03	--	--	8.40E+01	--
Pyrene	5.04E-06	2.07E-04	5.49E+03	5.49E+00	2.28E+02	4.98E-06
Tetrachloroethene (PCE)	2.30E-02	9.43E-01	1.55E+02	1.55E-01	3.96E+00	3.54E-02
Trichloroethene (TCE)	8.92E-03	3.66E-01	1.15E+02	1.15E-01	7.80E-01	4.80E-02
Vinyl chloride	7.00E-01	2.87E+01	4.64E-02	4.64E-05	3.42E-01	3.88E-04

APPENDIX E

REDOX REACTIONS, BIODEGRADATION RATE ESTIMATE, AND CONTAMINANT FATE AND TRANSPORT MODEL

Electron Donor and Electron Acceptor Half Cell Reactions

HALF-CELL REACTIONS	ΔG°_r (kcal/equiv)*	ΔG°_r (kJ/equiv)*	E° (mV)	Eh (mV)	pe	Conditions for Eh and pe §
ELECTRON-ACCEPTOR (REDUCTION) HALF CELL REACTIONS						
$5e^- + 6H^+ + NO_3^- \Rightarrow 0.5N_2 + 3H_2O$ *Denitrification*	-28.7	-120.	+1.24	+0.712	+12.0	pH = 7 $\Sigma[N]=10^{-3}$
$4e^- + 4H^+ + O_2 \Rightarrow 2H_2O$ *Aerobic Respiration*	-28.3	-119.	+1.23	+0.805	+13.6	pH = 7 $P_{O_2}=0.21$ atm
$2e^- + 4H^+ + MnO_2 \Rightarrow Mn^{2+} + 2H_2O$ *Pyrolusite Dissolution/Reduction*	-28.3	-119	+1.23	+0.550	+9.27	pH = 7 $\Sigma[Mn]=10^{-5}$
$e^- + H^+ + CO_2 + \underline{MnOOH} \Rightarrow \underline{MnCO_3} + H_2O$ *a Manganite Carbonation/Reduction*	-23.1	-96.8	+1.00	+0.412	+6.96	pH = 8 $P_{CO_2}=10^{-2}$
$e^- + H^+ + \underline{MnO_2} \Rightarrow \underline{MnOOH}$ *Pyrolusite Hydrolysis/Reduction*	-22.1	-92.5	+0.959	+0.545	+9.21	pH = 7
$e^- + 3H^+ + \underline{Fe(OH)_{3,amph.}} \Rightarrow Fe^{2+} + 3H_2O$ *Amorphous "Goethite" Dissolution/Reduction*	-21.5	-89.9	+0.932	+0.163	+2.75	pH = 6
$8e^- + 10H^+ + NO_3^- \Rightarrow NH_4^+ + 3H_2O$ *Nitrate Reduction*	-20.3	-84.9	+0.879	+0.362	+6.12	pH = 6 $\Sigma[Fe]=10^{-5}$
$2e^- + 2H^+ + NO_3^- \Rightarrow NO_2^- + H_2O$ *Nitrate Reduction*	-18.9	-78.9	+0.819	+0.404	+6.82	pH = 7
$1e^- + 3H^+ + \underline{FeOOH} \Rightarrow Fe^{2+} + 2H_2O$ *"Ferric oxyhydroxide" Dissolution/Reduction*	-15.0	-62.9	+0.652	-0.118	-1.99	pH = 6 Σ [Fe]$=10^{-5}$
$e^- + 3H^+ + \underline{Fe(OH)_{3,xline.}} \Rightarrow Fe^{2+} + 3H_2O$ *Crystallized "Goethite" Dissolution/Reduction*	-11.8	-49.2	+0.51 0	-0.259	-4.38	pH = 6 Σ [Fe]$=10^{-5}$
$e^- + H^+ + CO_{2,g} + \underline{Fe(OH)_{3,amph.}} \Rightarrow \underline{FeCO_3} + 2H_2O$ *Amorphous "Goethite" Carbonation/Reduction*	-11.0	-46.2	+0.479	-0.113	-1.90	pH = 8 $P_{CO_2}=10^{-2}$ atm
$8e^- + 9H^+ + SO_4^{2-} \Rightarrow HS^- + 4H_2O$ *Sulfate Reduction*	-5.81	-24.3	+0.252	-0.281	-4.74	pH = 8
$8e^- + 10H^+ + SO_4^{2-} \Rightarrow H_2S^\circ + 4H_2O$ *Sulfate Reduction*	-6.93	-28.9	+0.301	-0.143	-2.42	pH = 6
$8e^- + 8H^+ + CO_{2,g} \Rightarrow CH_{4,g} + 2H_2O$ *Methanogenesis*	-3.91	-16.4	+0.169	-0.259	-4.39	pH = 7 $P_{CO_2}=10^{-2}$ $P_{CH_4}=10^{0}$

HALF-CELL REACTIONS	ΔG°_r (kcal/equiv)*	ΔG°_r (kJ/equiv)*	E° (mV)	Eh (mV)	pe	Conditions for Eh and pe §
ELECTRON-DONOR (OXIDATION) HALF CELL REACTIONS						
$12H_2O + C_6H_6 \Rightarrow 6CO_2 + 30H^+ + 30e^-$ *Benzene Oxidation*	+2.83	+11.8	+0.122	-0.316	-5.34	pH = 7 $P_{CO_2}=10^{-2}$
$14H_2O + C_6H_5CH_3 \Rightarrow 7CO_2 + 36H^+ + 36e^-$ *Toluene Oxidation*	+2.96	+12.4	+0.128	-0.309	-5.22	pH = 7 $P_{CO_2}=10^{-2}$
$16H_2O + C_6H_5C_2H_5 \Rightarrow 8CO_2 + 42H^+ + 42e^-$ *Ethylbenzene Oxidation*	+2.95	+12.4	+0.128	-0.308	-5.21	pH = 7 $P_{CO_2}=10^{-2}$
$16H_2O + C_6H_4(CH_3)_2 \Rightarrow 8CO_2 + 42H^+ + 42e^-$ *m-Xylene Oxidation*	+3.02	+12.7	+0.131	-0.305	-5.88	pH = 7 $P_{CO_2}=10^{-2}$
$20H_2O + C_{10}H_8 \Rightarrow 10CO_2 + 48H^+ + 48e^-$ *Napthalene Oxidation*	+3.02	+12.6	+0.131	-0.308	-5.20	pH = 7 $P_{CO_2}=10^{-2}$
$28H_2O + C_{14}H_{10} \Rightarrow 14CO_2 + 66H^+ + 66e^-$ *Phenanthrene Oxidation*	+3.08	+12.9	+0.134	-0.305	-5.16	pH = 7 $P_{CO_2}=10^{-2}$

NOTES:

* = ΔG°_r for half cell reaction as shown divided by the number of electrons involved in reaction.

§ = Conditions assumed for the calculation of Eh and pe (pe = Eh/0.05916). Where two dissolved species are involved, other than those mentioned in this column, their activities are taken as equal. Note, this does not affect the free energy values listed.

Coupled Oxidation Reactions for BTEX and PNA Compounds

Coupled Benzene Oxidation Reactions	ΔG°_r (kcal/mole Benzene)	ΔG°_r (kJ/mole Benzene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$7.5O_2 + C_6H_6 \Rightarrow 6CO_{2,g} + 3H_2O$ *Benzene oxidation /aerobic respiration*	-765.34	-3202	3.07:1
$6NO_3^- + 6H^+ + C_6H_6 \Rightarrow 6CO_{2,g} + 6H_2O + 3N_{2,g}$ *Benzene oxidation / denitrification*	-775.75	-3245	4.77:1
$30H^+ + 15MnO_2 + C_6H_6 \Rightarrow 6CO_{2,g} + 15Mn^{2+} + 18H_2O$ *Benzene oxidation / manganese reduction*	-765.45	-3202	10.56:1
$3.75\,NO_3^- + C_6H_6 + 7.5\,H^+ + 0.75\,H_2O \Rightarrow 6\,CO_2 + 3.75\,NH_4^+$ *Benzene oxidation / nitrate reduction*	-524.1	-2193	2.98:1
$60H^+ + 30Fe(OH)_{3,a} + C_6H_6 \Rightarrow 6CO_2 + 30Fe^{2+} + 78H_2O$ *Benzene oxidation / iron reduction*	-560.10	-2343	21.5:1
$7.5H^+ + 3.75SO_4^{2-} + C_6H_6 \Rightarrow 6CO_{2,g} + 3.75H_2S^{\circ} + 3H_2O$ *Benzene oxidation / sulfate reduction*	-122.93	-514.3	4.61:1
$4.5H_2O + C_6H_6 \Rightarrow 2.25CO_{2,g} + 3.75CH_4$ *Benzene oxidation / methanogenesis*	-32.40	-135.6	0.77:1 [b]

Coupled Toluene Oxidation Reactions	ΔG°_r (kcal/mole Toluene)	ΔG°_r (kJ/mole Toluene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$9O_2 + C_6H_5CH_3 \Rightarrow 7CO_{2,g} + 4H_2O$ *Toluene oxidation /aerobic respiration*	-913.76	-3823	3.13:1
$7.2NO_3^- + 7.2H^+ + C_6H_5CH_3 \Rightarrow 7CO_{2,g} + 7.6H_2O + 3.6N_{2,g}$ *Toluene oxidation / denitrification*	-926.31	-3875	4.85:1
$36H^+ + 18MnO_2 + C_6H_5CH_3 \Rightarrow 7CO_{2,g} + 18Mn^{2+} + 22H_2O$ *Toluene oxidation / manganese reduction*	-913.89	-3824	10.74:1
$72H^+ + 36Fe(OH)_{3,a} + C_6H_5CH_3 \Rightarrow 7CO_2 + 36Fe^{2+} + 94H_2O$ *Toluene oxidation / iron reduction*	-667.21	-2792	21.86:1
$9H^+ + 4.5SO_4^{2-} + C_6H_5CH_3 \Rightarrow 7CO_{2,g} + 4.5H_2S^{\circ} + 4H_2O$ *Toluene oxidation / sulfate reduction*	-142.86	-597.7	4.7:1
$5H_2O + C_6H_5CH_3 \Rightarrow 2.5CO_{2,g} + 4.5CH_4$ *Toluene oxidation / methanogenesis*	-34.08	-142.6	0.78:1 [b]

Coupled Ethylbenzene Oxidation reactions	ΔG°_r (kcal/mole Ethylbenzene)	ΔG°_r (kJ/mole Ethylbenzene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$10.5O_2 + C_6H_5C_2H_5 \Rightarrow 8CO_{2,g} + 5H_2O$ *Ethylbenzene oxidation /aerobic respiration*	-1066.13	-4461	3.17:1
$8.4NO_3^- + 8.4H^+ + C_6H_5C_2H_5 \Rightarrow 8CO_{2,g} + 9.2H_2O + 4.2N_{2,g}$ *Ethylbenzene oxidation / denitrification*	-1080.76	-4522	4.92:1
$46H^+ + 22MnO_2 + C_6H_5C_2H_5 \Rightarrow 8CO_{2,g} + 22Mn^{2+} + 28H_2O$ *Ethylbenzene oxidation / manganese reduction*	-1066.27	-4461	11.39:1
$84H^+ + 42Fe(OH)_{3,a} + C_6H_5C_2H_5 \Rightarrow 8CO_2 + 42Fe^{2+} + 110H_2O$ *Ethylbenzene oxidation / iron reduction*	-778.48	-3257	22:1
$10.5H^+ + 5.25SO_4^{2-} + C_6H_5C_2H_5 \Rightarrow 8CO_{2,g} + 5.25H_2S^{\circ} + 5H_2O$ Eth *ylbenzene oxidation / sulfate reduction*	-166.75	-697.7	4.75:1
$5.5H_2O + C_6H_5C_2H_5 \Rightarrow 2.75CO_{2,g} + 5.25CH_4$ *Ethylbenzene oxidation / methanogenesis*	-39.83	-166.7	0.79:1 [b]

Coupled m-Xylene Oxidation Reactions	ΔG°_r (kcal/mole *m*-xylene)	ΔG°_r (kJ/mole *m*-xylene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$10.5O_2 + C_6H_4(CH_3)_2 \Rightarrow 8CO_{2,g} + 5H_2O$ *m-Xylene oxidation /aerobic respiration*	-1063.25	-4448	3.17:1
$8.4NO_3^- + 8.4H^+ + C_6H_4(CH_3)_2 \Rightarrow 8CO_{2,g} + 9.2H_2O + 4.2N_{2,g}$ *m-Xylene oxidation / denitrification*	-1077.81	-4509	4.92:1
$46H^+ + 22\underline{MnO_2} + C_6H_4(CH_3)_2 \Rightarrow 8CO_{2,g} + 22Mn^{2+} + 28H_2O$ *m-Xylene oxidation / manganese reduction*	-1063.39	-4449	11.39:1
$84H^+ + 42\underline{Fe(OH)_{3,a}} + C_6H_4(CH_3)_2 \Rightarrow 8CO_2 + 42Fe^{2+} + 110H_2O$ *m-Xylene oxidation / iron reduction*	-775.61	-3245	22:1
$10.5H^+ + 5.25SO_4^{2-} + C_6H_4(CH_3)_2 \Rightarrow 8CO_{2,g} + 5.25H_2S^{\circ} + 5H_2O$ *m-Xylene oxidation / sulfate reduction*	-163.87	-685.6	4.75:1
$5.5H_2O + C_6H_4(CH_3)_2 \Rightarrow 2.75CO_{2,g} + 5.25CH_4$ *m-Xylene oxidation / methanogenesis*	-36.95	-154.6	0.79:1 [a/]

Coupled Napthalene Oxidation reactions	ΔG°_r (kcal/mole Napthalene)	ΔG°_r (kJ/mole Napthalene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$12O_2 + C_{10}H_8 \Rightarrow 10CO_{2,g} + 4H_2O$ *Napthalene oxidation / aerobic respiration*	-1215.38	-5085.63	3.0:1
$9.6NO_3^- + 9.6H^+ + C_{10}H_8 \Rightarrow 10CO_{2,g} + 8.8H_2O + 4.8N_2$ *Napthalene oxidation / denitrification*	-1230.02	-5155	4.65:1
$13.7MnO_2 + 6.8H^+ + C_{10}H_8 \Rightarrow 10CO_{2,g} + 7.4H_2O + 13.7Mn^{2+}$ *Napthalene oxidation / manganese reduction*	-631.6	-2642.73	12.87:1
$48Fe(OH)_{3,a} + 96H^+ + C_{10}H_8 \Rightarrow 10CO_{2,g} + 124H_2O + 48Fe^{2+}$ *Napthalene oxidation / iron reduction*	-886.65	-3709.9	20.94:1
$6SO_4^{2-} + 12H^+ + C_{10}H_8 \Rightarrow 10CO_{2,g} + 4H_2O + 6H_2S$ *Napthalene oxidation / sulfate reduction*	-187.52	-783.83	4.5:1
$8H_2O + C_{10}H_8 \Rightarrow 4CO_{2,g} + 6CH_4$ *Napthalene oxidation / methanogenesis*	-42.57	-178.15	0.75:1 [a/]

Coupled Phenanthrene Oxidation Reactions	ΔG°_r (kcal/mole Phenanthrene)	ΔG°_r (kJ/mole Phenanthrene)	Stoichiometric Mass Ratio of Electron Acceptor to Compound
$16.5O_2 + C_{14}H_{10} \Rightarrow 14CO_{2,g} + 5H_2O$ *Phenanthrene oxidation / aerobic respiration*	-1667.2	-6975.87	2.97:1
$13.2NO_3^- + 13.2H^+ + C_{14}H_{10} \Rightarrow 14CO_{2,g} + 11.6H_2O + 6.6N_2$ *Phenanthrene oxidation / denitrification*	-1690	-7071.62	4.60:1
$33MnO_2 + 66H^+ + C_{14}H_{10} \Rightarrow 14CO_{2,g} + 38H_2O + 33Mn^{2+}$ *Phenanthrene oxidation / manganese reduction*	-1667.43	-6976.84	10.19:1
$66Fe(OH)_{3,a} + 132H^+ + C_{14}H_{10} \Rightarrow 14CO_{2,g} + 170H_2O + 66Fe^{2+}$ *Phenanthrene oxidation / iron reduction*	-1215.19	-5084.61	20.71:1
$8.25SO_4^{2-} + 16.5H^+ + C_{14}H_{10} \Rightarrow 14CO_{2,g} + 5H_2O + 8.25H_2S$ *Phenanthrene oxidation / sulfate reduction*	-253.89	-1062.07	4.45:1
$11.5H_2O + C_{14}H_{10} \Rightarrow 5.75CO_{2,g} + 8.25CH_4$ *Phenanthrene oxidation / methanogenesis*	-54.45	-227.83	0.74:1 [a/]

([a/] mass of methane produced during microbial respiration.)

Gibbs Free Energy of Formation forSpecies used in Half Cell reactions and Coupled Oxidation-Reduction Reactions

Species	State	$\Delta G^{\circ}_{f,298.15}$ (kcal/mole)	Source
e^-	i	0	std
H^+	i	0	std
O_2	g	0	std
H_2O	l	-56.687	Dean (1972)
Carbon Species			
CO_2	g	-94.26	Dean (1972)
CH_2O, formalydehyde	aq	-31.02	Dean (1972)
C_6H_6, benzene	l	+29.72	Dean (1972)
CH_4, methane	g	-12.15	Dean (1972)
$C_6H_5CH_3$, toluene	l	+27.19	Dean (1972)
$C_6H_5C_2H_5$, Napthalene	l	+28.61	Dean (1972)
$C_6H_4(CH_3)_2$, o-xylene	l	+26.37	Dean (1972)
$C_6H_4(CH_3)_2$, m-xylene	l	+25.73	Dean (1972)
$C_{10}H_8$, napthalene	l	+46.03	Dean (1972)
$C_{14}H_{10}$, phenanthrene	l	+64.12	Dean (1972)
$C_6H_4(CH_3)_2$, p-xylene	l	+26.31	Dean (1972)
Nitrogen Species			
NO_3^-	i	-26.61	Dean (1972)
N_2	g	0	std
NO_2^-	i	-7.7	Dean (1972)
NH_4^+	i	-18.82	Dean (1972)
Sulfur Species			
SO_4^{2-}	i	-177.97	Dean (1972)
H_2S	aq	-6.66	Dean (1972)
H_2S	g	-7.9	Dean (1972)
HS^-	i	+2.88	Dean (1972)
Iron Species			
Fe^{2+}	i	-18.85	Dean (1972)
Fe^{3+}	i	-1.1	Dean (1972)
αFe_2O_3, hematite	c	-177.4	Dean (1972)
αFeOOH, ferric oxyhydroxide	c	-117.2	Naumov *et al.* (1974)
$Fe(OH)_3$, goethite	a	-167.416	Langmuir and Whittemore (1971)
$Fe(OH)_3$, goethite	c	-177.148	Langmuir and Whittemore (1971)
$FeCO_3$, siderite	c	-159.35	Dean (1972)
Manganese Species			
Mn^{2+}	i	-54.5	Dean (1972)
MnO_2, pyrolusite	c	-111.18	Stumm and Morgan (1981)
MnOOH, manganite	c	-133.29	Stumm and Morgan (1981)
$MnCO_3$, rhodochrosite	p	-194	Dean (1972)

NOTES:

c = crystallized solid

a = amorphous solid (may be partially crystallized - dependant on methods of preparation)

p = freshly precipitated solid

i = dissociated, aqueous ionic species (concentration = 1 m)

aq = undissociated aqueous species

g = gaseous

l = liquid

std = accepted by convention

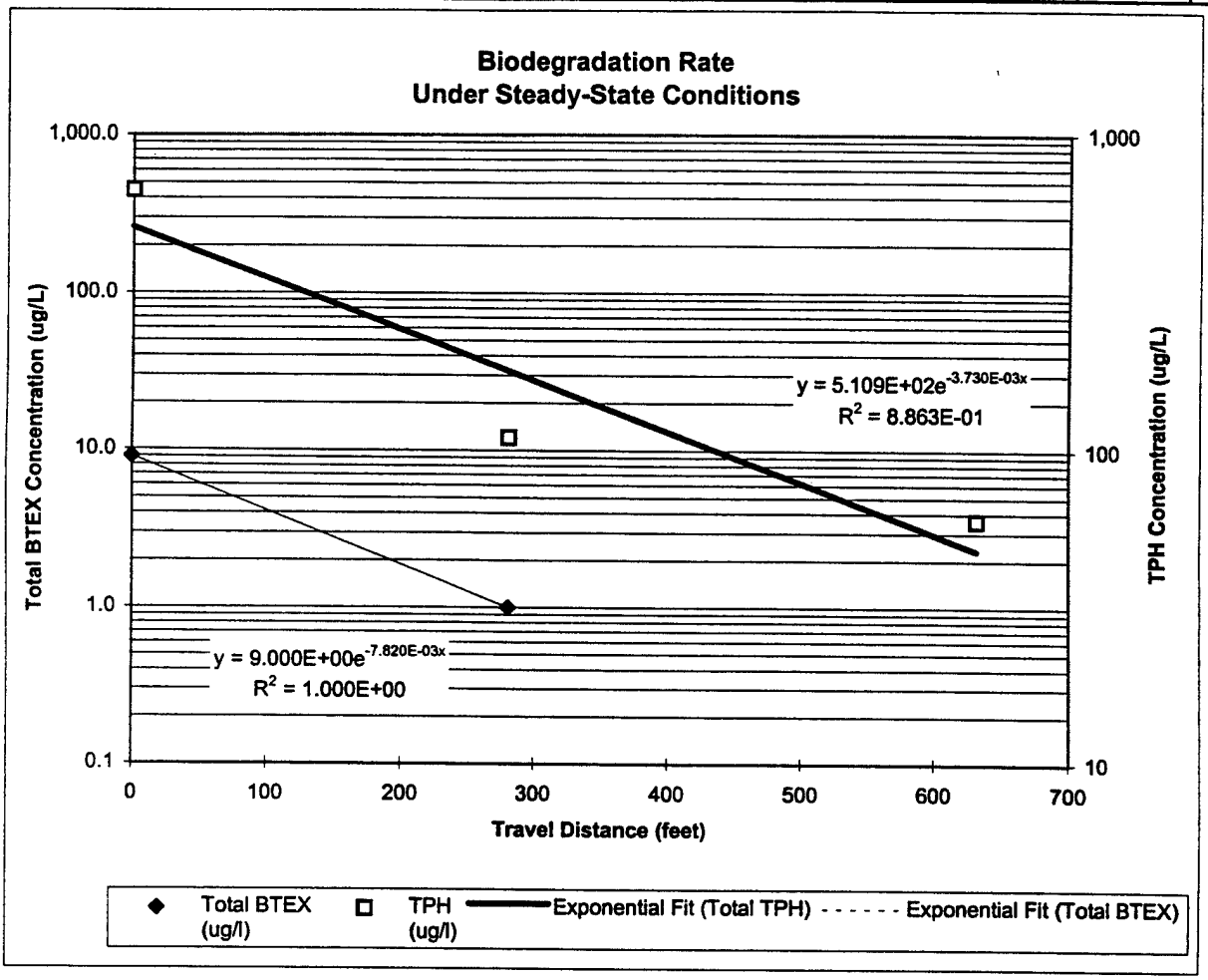
Wherever possible multiple sources were consulted to eliminate the possibility of typographical error.

Calculation of Biodegradation Rate

PFFA RAP

McClellan AFB, California

Location	Travel Distance (ft)	K (ft/day)	gradient (ft/ft)	n_e (-)	v (ft/day)	Travel Time (days)	Benzene (ug/L)	Toluene (ug/L)	Ethyl-benzene (ug/L)	Xylenes (ug/L)	Total BTEX (ug/l)	TPH (ug/l)
MW966	0	342	0.0025	0.25	3.42	0	7	0	0	2	9.0	670
MW968	281	342	0.0025	0.25	3.42	82	0.25	0.25	0.25	0.25	1.0	110
MW971	632	342	0.0025	0.25	3.42	185						60



BTEX

$\lambda = (v_x/4\alpha_x)([1+2\alpha_x(k/v_x)]^2-1)$

where v_c = 3.42 ft/day (from slug tests & retardation)

L_p = 1200 feet (length of plume)

α_x = 26 feet (Xu and Eckstein, 1995 formula)

k/v = 0.00782 (enter manually off graph)

refore λ = 0.0323 $days^{-1}$

or λ = 11.8 $years^{-1}$

$t_{1/2}$ = 0.059 years

TPH

$\lambda = (v_x/4\alpha_x)([1+2\alpha_x(k/v_x)]^2-1)$

where v_c = 3.42 ft/day (from slug tests & retard

L_p = 1200 feet (length of plume)

α_x = 26 feet (Xu and Eckstein, 1995

k/v = 0.00373 (enter manually off grap

therefore λ = 0.0140 $days^{-1}$

or λ = 5.1 $years^{-1}$

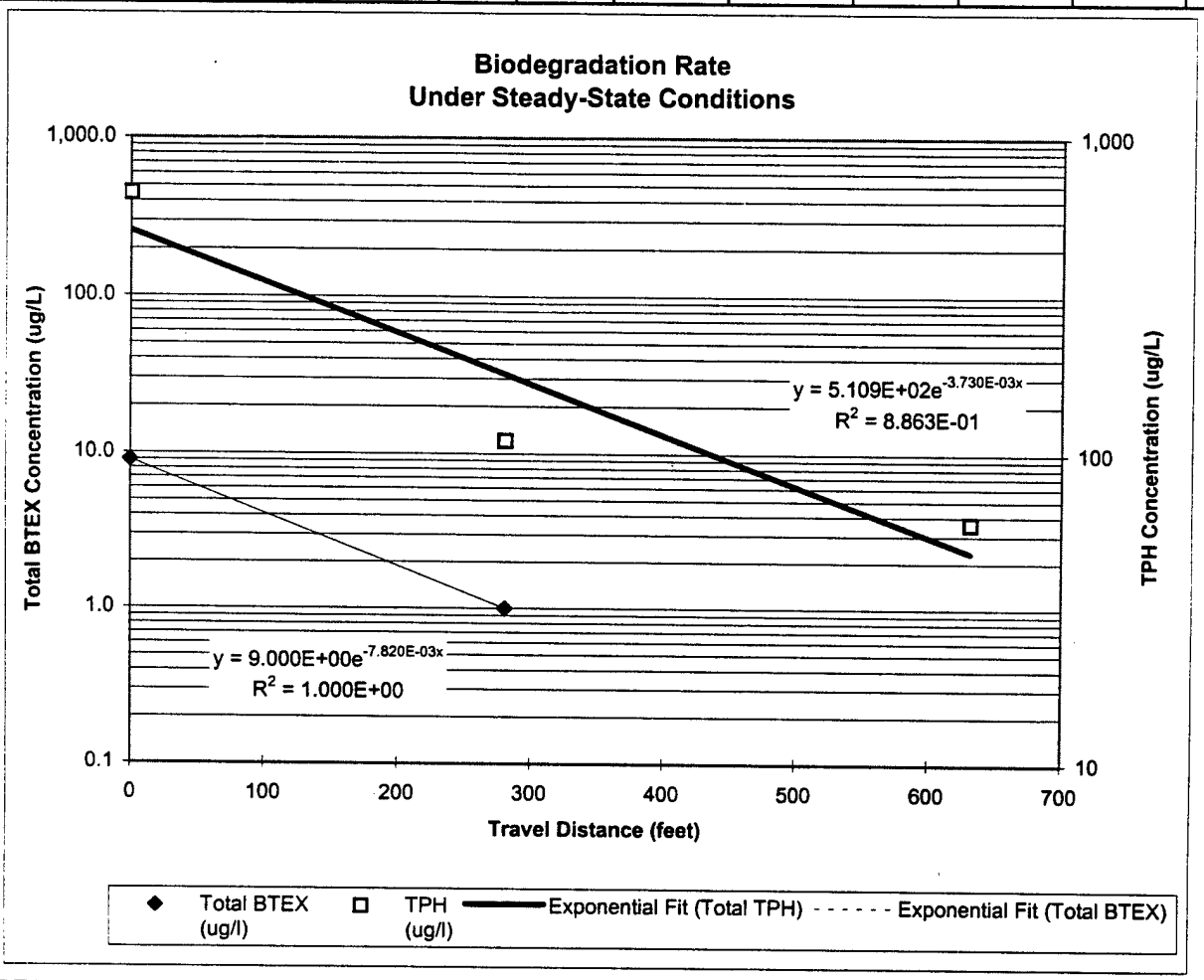
$t_{1/2}$ = 0.14 years

Calculation of Biodegradation Rate

PFFA RAP

Castle Airport, California

Location	Travel Distance (ft)	K (ft/day)	gradient (ft/ft)	n_e (-)	v (ft/day)	Travel Time (days)	Benzene (ug/L)	Toluene (ug/L)	Ethyl-benzene (ug/L)	Xylenes (ug/L)	Total BTEX (ug/l)	TPH (ug/l)
MW966	0	342	0.0025	0.25	3.42	0	7	0	0	2	9.0	670
MW968	281	342	0.0025	0.25	3.42	82	0.25	0.25	0.25	0.25	1.0	110
MW971	632	342	0.0025	0.25	3.42	185						60



BTEX

$\lambda = (v_x/4\alpha_x)([1+2\alpha_x(k/v_x)]^2-1)$

where v_c = 3.42 ft/day (from slug tests & retardation)

L_p = 1200 feet (length of plume)

α_x = 26 feet (Xu and Eckstein, 1995 formula)

k/v = 0.00782 (enter manually off graph)

refore λ = 0.0323 $days^{-1}$

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TPH

$\lambda = (v_x/4\alpha_x)([1+2\alpha_x(k/v_x)]^2-1)$

where v_c = 3.42 ft/day (from slug tests & retard

L_p = 1200 feet (length of plume)

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k/v = 0.00373 (enter manually off grap

therefore λ = 0.0140 $days^{-1}$

or λ = 5.1 $years^{-1}$

$t_{1/2}$ = 0.14 years

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.4*

PFFA - Castle
BTEX - Scenario #1
Run Name

Data Input Instructions:

115 or 0.02
1. Enter value directly....or
2. Calculate by filling in grey cells below. (To restore formulas, hit button below)

Variable* — Data used directly in model.
20 — Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	998.6	(ft/yr)
or		or	
Hydraulic Conductivity	K	1.2E-01	(cm/sec)
Hydraulic Gradient	i	0.002	(ft/ft)
Porosity	n	0.25	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	26.4	(ft)
Transverse Dispersivity*	alpha y	2.6	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	1200	(ft)

3. ADSORPTION

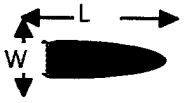
Retardation Factor*	R	1.0	(-)
or		or	
Soil Bulk Density	rho	1.7	(kg/l)
Partition Coefficient	Koc	38	(L/kg)
FractionOrganicCarbon	foc	1.3E-4	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	1.2E+1	(per yr)
or		or	
Solute Half-Life	t-half	0.059	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO	5.1	(mg/L)
Delta Nitrate*	NO3	4.9	(mg/L)
Observed Ferrous Iron*	Fe2+	0.36	(mg/L)
Delta Sulfate*	SO4	0	(mg/L)
Observed Methane*	CH4	0.2	(mg/L)

5. GENERAL

Modeled Area Length*	1000	(ft)
Modeled Area Width*	500	(ft)
Simulation Time*	5	(yr)



6. SOURCE DATA

Source Thickness in Sat.Zone* 10 (ft)

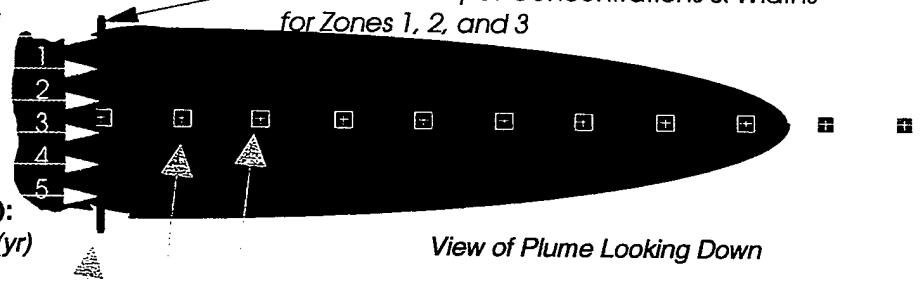
Source Zones:

Width* (ft)	Conc. (mg/L)*
100	2.5
0	0
0	0

Source Halflife (see Help):

Infinite	Infinite	(yr)
Inst. React.	1st Order	
Soluble Mass	Infinite	(Kg)
In Source NAPL, Soil		

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	0	100	200	300	400	500	600	700	800	900	1000
Concentration (mg/L)											

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — **View Output**

RUN ARRAY — **View Output**

Help

Recalculate This Sheet

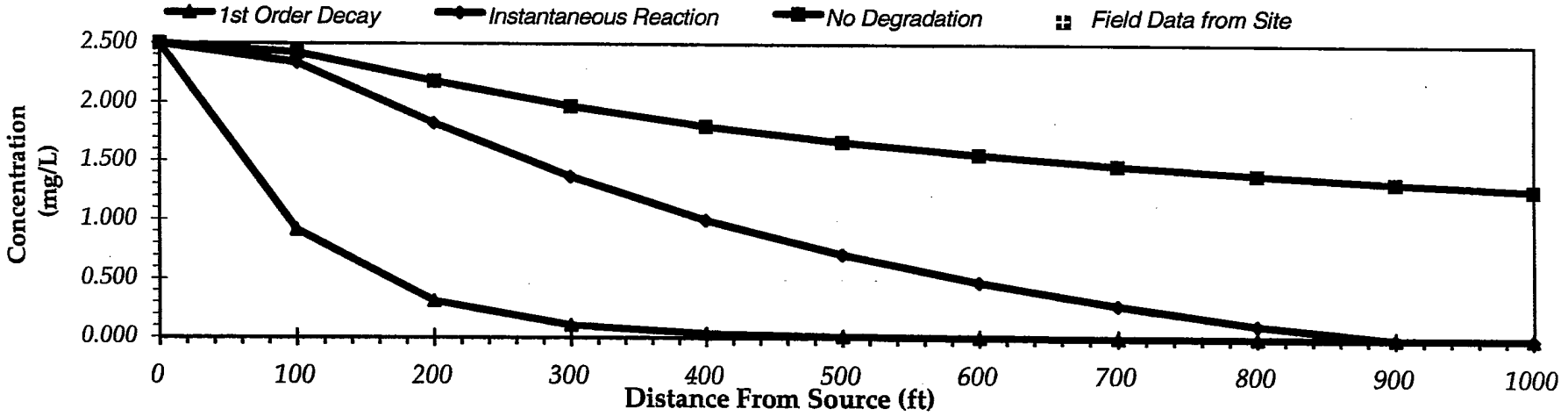
Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

PREDICTED MAXIMUM CONCENTRATIONS WITH NO SOURCE REMOVAL
DISSOLVED BTEX CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

Distance from Source (ft)

TYPE OF MODEL	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	2.500	2.426	2.190	1.977	1.808	1.674	1.564	1.473	1.395	1.329	1.271
1st Order Decay	2.500	0.921	0.316	0.108	0.038	0.013	0.0047	0.0017	0.0006	0.000	0.000
Inst. Reaction	2.500	2.340	1.831	1.371	1.007	0.716	0.479	0.282	0.116	0.000	0.000
Field Data from Site											



Replay Animation

Prev Timestep

Time:
5.0 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence

Version 1.4

PFFA - Castle
BTEX - Scenario #2
Run Name

Data Input Instructions:

115 or 0.02 — *1. Enter value directly....or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below)*

Variable* — *Data used directly in model.*

20 — *Value calculated by model. (Don't enter any data).*

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	998.6	*(ft/yr)*
or		*or*	
Hydraulic Conductivity	*K*	1.2E-01	*(cm/sec)*
Hydraulic Gradient	*i*	0.002	*(ft/ft)*
Porosity	*n*	0.25	*(-)*

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	26.4	*(ft)*
Transverse Dispersivity*	*alpha y*	2.6	*(ft)*
Vertical Dispersivity*	*alpha z*	0.0	*(ft)*
or		*or*	
Estimated Plume Length	*Lp*	1200	*(ft)*

3. ADSORPTION

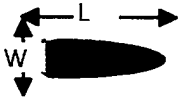
Retardation Factor*	*R*	1.0	*(-)*
or		*or*	
Soil Bulk Density	*rho*	1.7	*(kg/l)*
Partition Coefficient	*Koc*	38	*(L/kg)*
FractionOrganicCarbon	*foc*	1.3E-4	*(-)*

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	1.2E+1	*(per yr)*
or		*or*	
Solute Half-Life	*t-half*	0.059	*(year)*
or Instantaneous Reaction Model			
Delta Oxygen*	*DO*	5.1	*(mg/L)*
Delta Nitrate*	*NO3*	4.9	*(mg/L)*
Observed Ferrous Iron*	*Fe2+*	0.36	*(mg/L)*
Delta Sulfate*	*SO4*	0	*(mg/L)*
Observed Methane*	*CH4*	0.2	*(mg/L)*

5. GENERAL

Modeled Area Length*	500	*(ft)*
Modeled Area Width*	500	*(ft)*
Simulation Time*	5	*(yr)*



6. SOURCE DATA

Source Thickness in Sat.Zone* 10 *(ft)*

Source Zones:

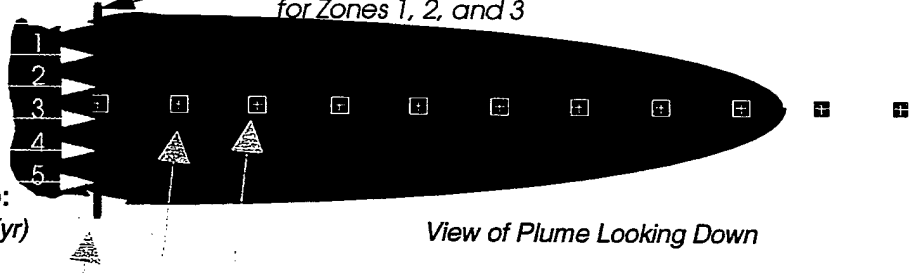
Width* (ft)	Conc. (mg/L)*
100	0.145
0	0
0	0

Source Halflife (see Help):

<0.25	0.76	*(yr)*
Inst. React.	1st Order	
Soluble Mass	1.13	*(Kg)*

In Source NAPL, Soil

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
50	
100	
150	
200	
250	
300	
350	
400	
450	
500	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — **View Output**

RUN ARRAY — **View Output**

Help

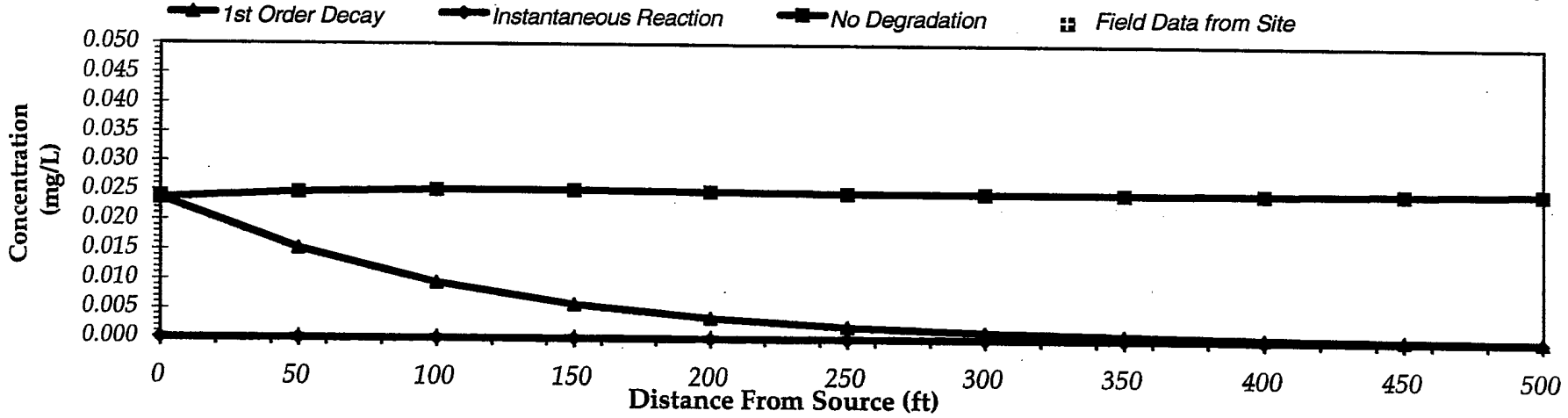
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

PREDICTED CONCENTRATIONS WITH SVE/BIOVENTING
DISSOLVED BTEX CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.024	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
1st Order Decay	0.024	0.015	0.010	0.006	0.004	0.002	0.0014	0.0008	0.0005	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



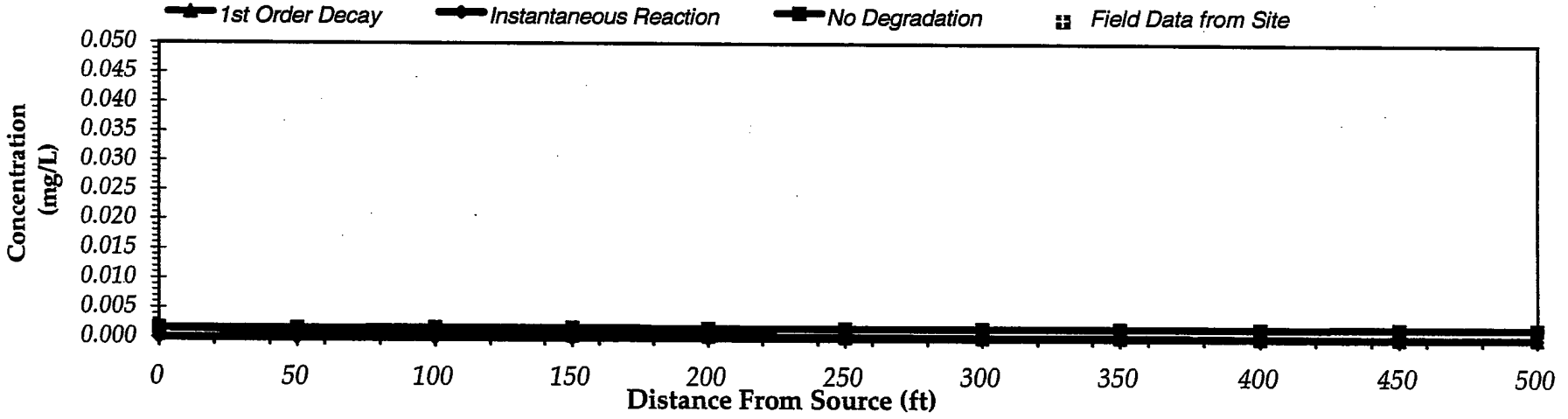
Replay Animation | Next Timestep | Prev Timestep

Time: 2.0 Years

Return to Input | Recalculate This Sheet

PREDICTED CONCENTRATIONS WITH SVE/BIOVENTING
DISSOLVED BTEX CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	50	100	150	200	250	300	350	400	450	500
No Degradation	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
1st Order Decay	0.0016	0.0010	0.0006	0.000	0.000	0.000	0.0001	0.0001	0.0000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Replay Animation

Prev Timestep

Time:
5.0 Years

Return to Input

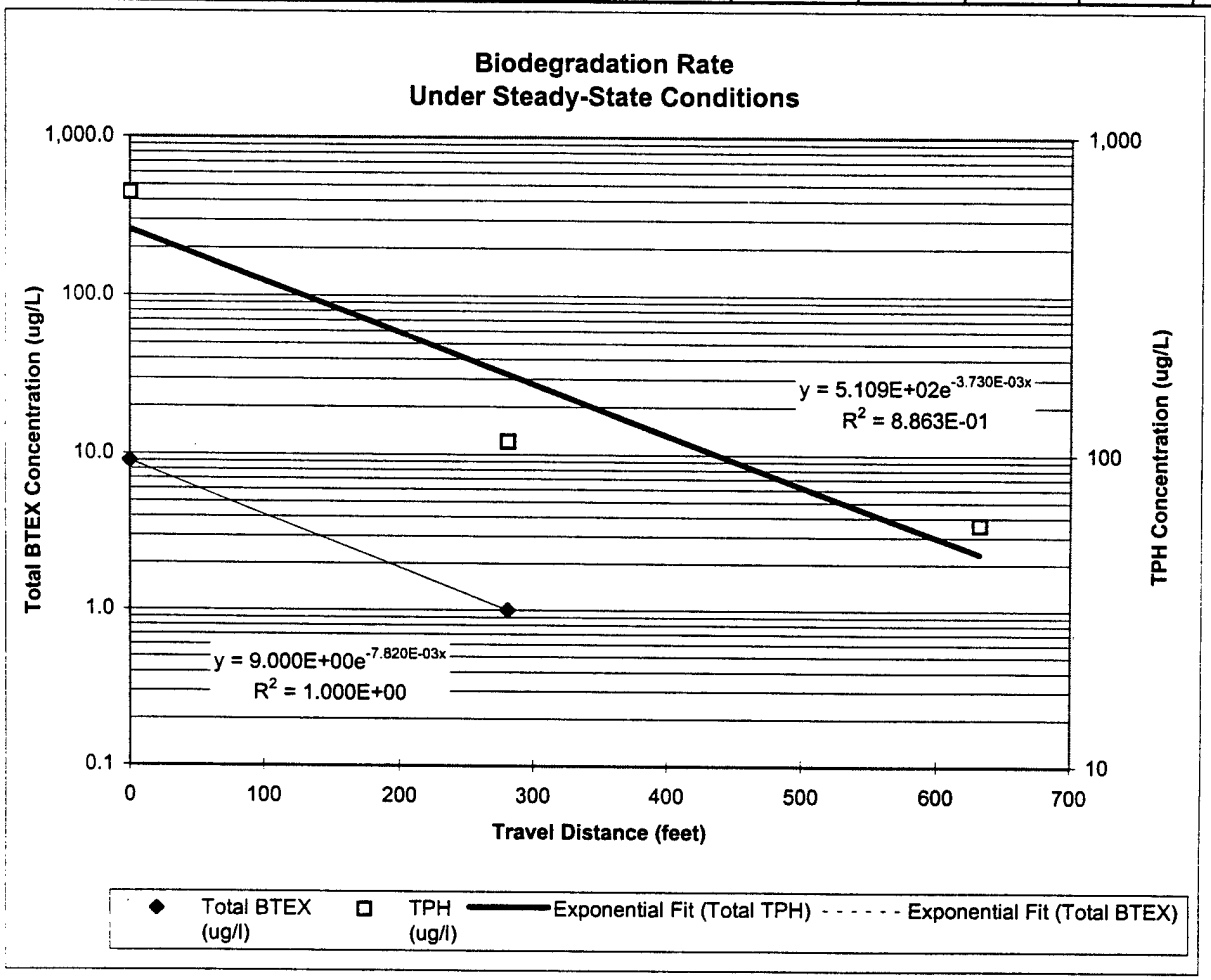
Recalculate This Sheet

Calculation of Biodegradation Rate

PFFA RAP

Castle Airport, California

Location	Travel Distance (ft)	K (ft/day)	gradient (ft/ft)	n_e (-)	v (ft/day)	Travel Time (days)	Benzene (ug/L)	Toluene (ug/L)	Ethyl-benzene (ug/L)	Xylenes (ug/L)	Total BTEX (ug/l)	TPH (ug/l)
MW966	0	342	0.0025	0.25	3.42	0	7	0	0	2	9.0	670
MW968	281	342	0.0025	0.25	3.42	82	0.25	0.25	0.25	0.25	1.0	110
MW971	632	342	0.0025	0.25	3.42	185						60



BTEX

$\lambda = (v_x/4\alpha_x)([1+2\alpha_x(k/v_x)]^2-1)$

where v_c = 3.42 ft/day (from slug tests & retardation)

L_p = 1200 feet (length of plume)

α_x = 26 feet (Xu and Eckstein, 1995 formula)

k/v = 0.00782 (enter manually off graph)

refore λ = 0.0323 $days^{-1}$

or λ = 11.8 $years^{-1}$

$t_{1/2}$ = 0.059 years

TPH

$\lambda = (v_x/4\alpha_x)([1+2\alpha_x(k/v_x)]^2-1)$

where v_c = 3.42 ft/day (from slug tests & retard

L_p = 1200 feet (length of plume)

α_x = 26 feet (Xu and Eckstein, 1995

k/v = 0.00373 (enter manually off grap

therefore λ = 0.0140 $days^{-1}$

or λ = 5.1 $years^{-1}$

$t_{1/2}$ = 0.14 years

APPENDIX F

REMEDIAL ALTERNATIVE COST CALCULATIONS

Remedial Action Plan (RAP)
Present Worth Analysis
PFFA - Castle Airport, California

Annual Adjustment Factor = 7%

Alternative 1: Natural Attenuation, Long-Term Monitoring and Land/Groundwater Use Controls		Present Worth	Cost ($) at Year Indicated					
	years	($)	Year: 1	2	3	4	5	30
Institutional Controls (annual)	30	$62,045	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
Long-term Monitoring								
Install New Wells	0	$0	$0	$0	$0	$0	$0	$0
GW Sampling (annual)	30	$190,461	$15,349	$15,349	$15,349	$15,349	$15,349	$15,349
Reporting/Mgmt (annual)	30	$63,765	$5,139	$5,139	$5,139	$5,139	$5,139	$5,139
Subtotal Present Worth ($)		$316,272						

Total Present Worth Cost ($): $316,272

Remedial Action Plan (RAP)
Present Worth Analysis
PFFA - Castle Airport, California

Annual Adjustment Factor = 7%

Alternative 2: SVE and Bioventing, Long-Term Monitoring, and Land/Groundwater Use Controls		Present Worth	Cost ($) at Year Indicated					
	years	($)	Year: 1	2	3	4	5	30
SVE/Bioventing System								
System Installation	1	$159,420	$170,579	$0	$0	$0	$0	$0
SVE System O&M	1	$27,996	$29,955	$0	$0	$0	$0	$0
Bioventing System O&M	2	$38,575	$21,336	$21,336	$0	$0	$0	$0
Report	2	$10,855	$6,004	$6,004	$0	$0	$0	$0
Subtotal Present Worth ($)		$236,846						
Institutional Controls (annual)	5	$20,501	$5,000	$5,000	$5,000	$5,000	$5,000	$0
Long-term Monitoring								
Install New Wells	0	$0	$0	$0	$0	$0	$0	$0
GW Sampling (annual)	5	$62,932	$15,349	$15,349	$15,349	$15,349	$15,349	$0
Reporting/Mgmt (annual)	5	$21,069	$5,139	$5,139	$5,139	$5,139	$5,139	$0
Subtotal Present Worth ($)		$104,503						

Total Present Worth Cost ($): $341,348

Remedial Action Plan (RAP)
Present Worth Analysis
PFFA - Castle Airport, California

Annual Adjustment Factor = 7%

Alternative 3: Excavation/Bioventing, Natural Attenuation, Long-Term Monitoring, and Land Groundwater Use Controls		Present Worth	Cost ($) at Year Indicated					
	years	($)	Year: 1	2	3	4	5	30
Excavation and Landfarm Soil (17,000 cubic yards)	1	$847,392	$906,710	$0	$0	$0	$0	$0
Bioventing								
System Installation	1	$75,879	$81,191	$0	$0	$0	$0	$0
System O&M	2	$38,575	$21,336	$21,336	$0	$0	$0	$0
Report	2	$9,578	$5,298	$5,298	$0	$0	$0	$0
Subtotal Present Worth ($)		$124,033						
Institutional Controls (annual)	5	$20,501	$5,000	$5,000	$5,000	$5,000	$5,000	$0
Long-term Monitoring								
Install New Wells	0	$0	$0	$0	$0	$0	$0	$0
GW Sampling (annual)	5	$62,932	$15,349	$15,349	$15,349	$15,349	$15,349	$0
Reporting/Mgmt (annual)	5	$21,069	$5,139	$5,139	$5,139	$5,139	$5,139	$0
Subtotal Present Worth ($)		$104,503						

Total Present Worth Cost ($): **$1,075,928**

Remedial Action Plan (RAP) Cost Summary Sheet
PFFA - Castle Airport, California
Alternatives 1, 2, and 3: Long-Term Monitoring and Institutional Controls

Standard Rate Schedule

Billing Category Cost Code/(Billing Category)	Billing Rate	Task 1 (hrs)	Install New LTM Wells ($)	Task 2 (hrs)	GW Sampling ($)	Task 3 (hrs)	GW Reporting & PM ($)
Word Processor 88/(15)	$39	0	$0	20	$780	8	$312
CADD Operator 58/(25)	$48	0	$0	0	$0	8	$384
Technician 42/(50)	$48	0	$0	60	$2,880	25	$1,200
Staff Level 16/(65)	$64	0	$0	60	$3,840	30	$1,920
Project Level 12/(70)	$73	0	$0	10	$730	8	$584
Senior Level 10/(80)	$96	0	$0	5	$480	2	$192
Principal 02/(85)	$140	0	$0	2	$280	1	$140
Total Labor (hrs|$)		0	$0	157	$8,990	82	$4,732
ODCs							
Phone			$0		$30		$25
Photocopy			$0		$10		$25
Mail/Overnight			$0		$156		$8
Computer			$0		$0		$0
CAD			$0		$0		$80
WP			$0		$0		$0
Travel			$0		$184		$184
Per Diem			$0		$648		$70
Eqpt. & Supplies			$0		$1,091		$15
Total ODCs			$0		$2,119		$407
Outside Services							
LTM Well Installation Costs			$0		$0		$
Laboratory Fees [1]			$0		$4,240		$0
Other: Maintain Institutional Controls			$0		$0		$5,000
Total Outside Services			$0		$4,240		$5,000

Proposal Estimate	Task 1	Task 2	Task 3
Labor	$0	$8,990	$4,732
ODC's	$0	$2,119	$407
Outside Services	$0	$4,240	$5,000
Total by Task	$0	$15,349	$10,139

Total Labor	$13,722
Total ODCs	$2,525
Total Outside Services	$9,240
Total Project	$25,487

[1] BTEX/TPH-g/Methane @ $115ea; All electron acceptors @ $75 ea; QA/QC: 10% duplicates, 10% field blanks

Remedial Action Plan (RAP) Cost Summary Sheet
PFFA - Castle Airport, California
Alternative 2: SVE/Bioventing

Standard Rate Schedule

Billing Category Cost Code/(Billing Category)	Billing Rate	Task 1 (hrs)	Install & Permit SVE/ Bioventing System ($)	Task 2 (hrs)	SVE System O&M [1] (First Year $)	Task 3 (hrs)	Bioventing System O&M & Testing [2] (Annual $)	Task 4 (hrs)	Annual Report (Annual $)
Word Processor 88/(15)	$39	40	$1,560	15	$585	15	$585	5	$195
CADD Operator 58/(25)	$48	50	$2,400	0	$0	0	$0	5	$240
Technician 42/(50)	$48	150	$7,200	192	$9,216	96	$4,608	20	$960
Staff Level 16/(65)	$64	150	$9,600	96	$6,144	56	$3,584	35	$2,240
Project Level 12/(70)	$73	100	$7,300	30	$2,190	25	$1,825	10	$730
Senior Level 10/(80)	$96	15	$1,440	6	$576	5	$480	3	$288
Principal 02/(85)	$140	4	$560	0	$0	0	$0	0	$0
Total Labor (hrs|$)		509	$30,060	339	$18,711	197	$11,082	78	$4,653
ODCs									
Phone			$50		$180		$75		$150
Photocopy			$100		$10		$10		$200
Mail/Overnight			$95		$211		$107		$263
Computer			$0		$0		$0		$0
CAD			$475		$0		$0		$48
WP			$0		$0		$0		$0
Travel			$918		$2,203		$367		$120
Per Diem			$3,240		$420		$1,080		$70
Eqpt. & Supplies			$1,500		$5,100		$1,825		$500
Total ODCs			$6,378		$8,124		$3,464		$1,351
Outside Services									
Well Installation/Site Investigation			$39,986		$0		$0		$0
SVE/Bioventing System Installation			$11,715		$0		$0		$0
Equipment Costs			$79,440		$0		$0		$0
Electrical Costs			$3,000		$0		$5,489		$0
Laboratory Fees (influent/effluent & VWs/VMPs)			$0		$3,120		$1,300		$0
Other			$0		$0		$0		$0
Total Outside Services			$134,141		$3,120		$6,789		$0
Estimate		Task 1		Task 2		Task 3		Task 4	
Labor			$30,060		$18,711		$11,082		$4,653
ODC's			$6,378		$8,124		$3,464		$1,351
Outside Services			$134,141		$3,120		$6,789		$0
Total by Task			$170,579		$29,955		$21,336		$6,004

Total Labor (First Year)	$48,771
Total ODCs (First Year)	$14,503
Total Outside Services (First Year)	$137,261
Total First Year Costs	$200,534
Total Annual Costs	$27,339

[1] The SVE system is maintained once a month for one year.

[2] The bioventing system is maintained twice a year and ISR tests are performed once a year.

Remedial Action Plan (RAP) Cost Summary Sheet
PFFA - Castle Airport, California
Alternative 3: Excavation/Bioventing

Standard Rate Schedule

Billing Category Cost Code/(Billing Category)	Billing Rate	Task 1 (hrs)	Excavate and Landfarm Soil ($)	Task 2 (hrs)	Install Bioventing System ($)	Task 3 (hrs)	Bioventing System O&M & Testing [2] (Annual $)	Task 4 (hrs)	Annual Report (Annual $)
Word Processor 88/(15)	$39	30	$1,170	10	$390	15	$585	5	$195
CADD Operator 58/(25)	$48	30	$1,440	20	$960	0	$0	5	$240
Technician 42/(50)	$48	248	$11,904	120	$5,760	96	$4,608	15	$720
Staff Level 16/(65)	$64	100	$6,400	120	$7,680	56	$3,584	30	$1,920
Project Level 12/(70)	$73	80	$5,840	60	$4,380	25	$1,825	8	$584
Senior Level 10/(80)	$96	8	$768	8	$768	5	$480	3	$288
Principal 02/(85)	$140	2	$280	2	$280	0	$0	0	$0
Total Labor (hrs/$)		498	$27,802	340	$20,218	197	$11,082	66	$3,947
ODCs									
Phone			$50		$75		$75		$150
Photocopy			$100		$10		$10		$200
Mail/Overnight			$95		$107		$107		$263
Computer			$0		$0		$0		$0
CAD			$285		$190		$0		$48
WP			$0		$0		$0		$0
Travel			$551		$367		$367		$120
Per Diem			$2,160		$432		$1,080		$70
Eqpt. & Supplies			$4,000		$2,125		$1,825		$500
Total ODCs			$7,241		$3,306		$3,464		$1,351
Outside Services									
Excavation, Characterize, Landfarm Soils			$871,667		$0		$0		
Well Installation/Site Investigation			$0		$37,562		$0		$0
Bioventing System Installation			$0		$11,715		$0		$0
Equipment Costs			$0		$4,090		$0		$0
Electrical Costs			$0		$3,000		$5,489		$0
Laboratory Fees (influent/effluent & VWs/VMPs)			$0		$1,300		$1,300		$
Other			$0		$0		$0		$
Total Outside Services			$871,667		$57,666		$6,789		$0
Estimate		Task 1		Task 2		Task 3		Task 4	
Labor			$27,802		$20,218		$11,082		$3,947
ODC's			$7,241		$3,306		$3,464		$1,351
Outside Services			$871,667		$57,666		$6,789		$0
Total by Task			$906,710		$81,191		$21,336		$5,298

Total Labor (First Year)	$48,020
Total ODCs (First Year)	$10,547
Total Outside Services (First Year)	$929,333
Total First Year Costs	$987,901
Total Annual Costs	$26,633

[1] The SVE system is maintained once a month for one year.

[2] The bioventing system is maintained twice a year and ISR tests are performed once a year.

Remedial Action Plan (RAP) Subcontractor Costs
PFFA - Castle Airport, California

Alternatives 1, 2 and 3: Long-term Monitoring							
Misc calculations		Cost calculations					
		Description	Unit	Qty.	Unit Price	Subtotal	Total	Source (If applicable)
Number of new LTM wells:		Well Installation					$ -	Gregg Drilling & Testing
Number of wells:	-	Mobilization	ea	-	$ 1,200	$ -		
Depth each:	75 ft	Well Installation	ln ft	-	$ 61	$ -		
		Soil Disposal	drum	-	$ 120	$ -		

Remedial Action Plan (RAP) Subcontractor Costs
PFFA - Castle Airport, California

Alternative 2: SVE/Bioventing System

Misc calculations		
Number of SVE wells:	3	
Depth each:	25	ft
Number of Bioventing wells:	5	
Depth each:	65	ft
Number of VMPs:	3	
Depth each:	65	ft
Piping Trench Volume/Area		
Width:	12	in
Depth:	3	ft
Length:	1,500	ft
Volume:	4,500	cf
	167	cy
Surface Area:	1,500	sf
	167	sy

Cost calculations

Description	Unit	Qty.	Unit Price	Subtotal	Total	Source (If applicable)
Well Installation					$ 39,986	
Mobilization	ea	1	$ 2,000	$ 2,000		Gregg Drilling & Testing
Well Installation	ln ft	595	$ 59	$ 35,105		Gregg Drilling & Testing
Soil Disposal	yd3	12	$ 93	$ 1,116		Gregg Drilling & Testing
Site clearance (wells)	well	11	$ 95	$ 1,045		Norcal Geophysics
Site clearance (trench)	each	6	$ 120	$ 720		Norcal Geophysics
Equipment & Treatment Costs					$ 79,440	
SVE/ICE mob/demob/access.	lump	1	$ 2,150	$ 2,150		RSI
SVE/ICE rental/maintenance	month	12	$ 4,700	$ 56,400		RSI
Supplemental Fuel for ICE	week	40	$ 300	$ 12,000		RSI
SVE manifolding	ea	1	$ 400	$ 400		RSI
Bioventing blowers/access.	ea	2	$ 3,000	$ 6,000		Gast
Bioventing manifolding/sheds	ea	2	$ 650	$ 1,300		
Blower shipping/freight	ea	2	$ 595	$ 1,190		
System Installation					$ 14,715	
Mob/Demob	ea	1	$ 800	$ 800		
Trenching	ln ft	1,500	$ 0.51	$ 765		Means 16th Edition
Pipe laying	ln ft	1,500	$ 3.64	$ 5,460		Means 16th Edition
Backfill	cy	12	$ 18.35	$ 227		Means 16th Edition
Compaction	ln ft	750	$ 0.48	$ 360		Means 16th Edition
Piping	ln ft	1,650	$ 1.30	$ 2,145		Means 16th Edition
Asphalt Repair	sy	83	$ 23.50	$ 1,958		Means 16th Edition
Electrical	ls	2	$ 1,500	$ 3,000		S&C Electric
					$ 134,141	

Remedial Action Plan (RAP) Subcontractor Costs
PFFA - Castle Airport, California

Alternative 3: Excavate Shallow Soils; Biovent Deep soils

Misc calculations

Number of Bioventing wells:	5	
Depth each:	70	ft
Number of VMPs:	3	
Depth each:	70	ft
Area:	30,000	ft2
Depth:	15	ft
Volume (contaminated):	450,000	cf
	16,667	cy
Surface Area:	30,000	sf
	3333	sy

Cost calculations

Description	Unit	Qty.	Unit Price	Subtotal	Total	Source (If applicable)
Well Installation					$ 37,562	
Mobilization	ea	1	$ 2,000	$ 2,000		Gregg Drilling & Testing
Well Installation	ln ft	560	$ 59	$ 33,040		Gregg Drilling & Testing
Soil Disposal	yd3	11	$ 93	$ 1,042		Gregg Drilling & Testing
Site clearance (wells)	well	8	$ 95	$ 760		Norcal Geophysics
Site clearance (trench)	each	6	$ 120	$ 720		Norcal Geophysics
Excavate, transport, and treat soil					$ 871,667	
Excavate, store, & transport soil	cy	16,667	$ 30	$500,000		Downey et al., 1994
Landfarm nonhazardous soil	cy	16,667	$ 20	$333,333		Downey et al., 1994
Characterize source area soil	sample	333	$ 115	$ 38,333		Curtis & Tompkins
Bioventing Equipment					$ 4,090	
Bioventing blowers	ea	2	$ 800	$ 1,600		Gast
Bioventing manifolding/sheds	ea	2	$ 650	$ 1,300		
Blower shipping/freight	ea	2	$ 595	$ 1,190		
System Installation					$ 14,715	
Mob/Demob	ea	1	$ 800	$ 800		
Trenching	ln ft	1,500	$ 0.51	$ 765		Means 16th Edition
Pipe laying	ln ft	1,500	$ 3.64	$ 5,460		Means 16th Edition
Backfill	cy	12	$ 18.35	$ 227		Means 16th Edition
Compaction	ln ft	750	$ 0.48	$ 360		Means 16th Edition
Piping	ln ft	1,650	$ 1.30	$ 2,145		Means 16th Edition
Asphalt Repair	sy	83	$ 23.50	$ 1,958		Means 16th Edition
Electrical	ls	2	$ 1,500	$ 3,000		S&C Electric
					$928,033	

APPENDIX G

SAMPLING AND ANALYSIS PLAN (SAP) FOR LONG-TERM MONITORING

PROGRAM
SAMPLING AND ANALYSIS PLAN/QUALITY ASSURANCE PLAN

FOR

RISK-BASED REMEDIATION DEMONSTRATIONS

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)
TECHNOLOGY TRANSFER DIVISION
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SECTION 1

INTRODUCTION AND DATA QUALITY OBJECTIVES

1.1 INTRODUCTION

The purpose of this program sampling and analysis plan (SAP) is to describe the procedures to be followed when collecting data in support of site characterization and the long-term monitoring plan (LTMP) which will be completed as a part of the nationwide risk-based remediation demonstrations for the U. S. Air Force Center for Environmental Excellence (AFCEE). Details on analytical requirements, desired quantitation (detection) limits, and specific quality assurance (QA) sampling requirements are summarized herein as part of the program sampling procedures. QA samples will be used to determine the precision, accuracy, completeness, and representativeness of the final data set.

The remainder of Section 1 discusses data quality objectives. Soil gas sampling is described in Section 2; procedures for soil and sediment sampling are presented in Section 3; groundwater/surface water sampling procedures are described in Section 4; and field quality assurance/quality control (QA/QC) samples are described in Section 5. Section 6 describes field data reduction, validation, and reporting; Section 7 presents analytical procedures for groundwater/surface water and soil/sediment sampling. References used in this SAP are listed in Section 8.

1.2 DATA QUALITY OBJECTIVES

The objectives of collecting and analyzing environmental samples are 1) to determine the three-dimensional distribution of hydrocarbon and heavy metal contamination at the site; 2) to obtain the data needed to evaluate the effectiveness of specific remedial approaches, including natural attenuation of groundwater; 3) to establish site-specific remediation goals that minimize or eliminate risk potential to receptors and limit offsite migration of site-related contamination; and 4) to prepare a remedial action plan and remedial implementation plan to progress toward a final site remedy. This section has been developed for use in conjunction with sampling activities and describes the QA/QC procedures and protocols that will be used during sample analysis. This section will serve as a controlling mechanism during this investigation to ensure that a sufficient quantity of data is collected and that all data collected are valid, reliable, and defensible.

1.3 ANALYTICAL DATA QUALITY LEVELS

Data quality objectives (DQOs) for the analyses described herein are defined in the interim final guidance, *Data Quality Objectives Process for Superfund* (USEPA, 1993). The analytical levels for this project's DQOs will conform to the two USEPA-defined categories of data. These data categories are defined below (USEPA, 1993):

Screening Data with Definitive Confirmation - Screening data are generated by rapid, less precise methods of analysis with less rigorous sample preparation. Sample preparation steps may be restricted to simple procedures such as dilution with a solvent, instead of elaborate extraction/digestion and cleanup. Screening data provide analyte identification and quantification, although the quantification may be relatively imprecise. At least 10 percent of the screening data are confirmed using analytical methods, QA/QC procedures, and QC criteria associated with definitive data. Screening data without associated confirmation data are not considered to be data of known quality. Results of field laboratory analyses conducted at the site will be considered screening-category data.

Definitive Data - Definitive data are generated using rigorous analytical methods, such as approved USEPA reference methods. Data are analyte-specific, with confirmation of analyte identity and concentration. Methods produce tangible raw data (e.g., chromatograms, spectra, digital values) in the form of hard-copy printouts or computer-generated electronic files. Data may be generated at the site or at an off-site location, as long as the QA/QC requirements are satisfied. For the data to be definitive, either analytical or total measurement error must be determined. Results of fixed-based laboratory analyses of samples collected at the site will be considered definitive data.

During the AFCEE risk-based remediation program, the following data quality levels will be used as indicated:

- Screening analyses with definitive confirmation will be used for the air screening in worker breathing zones for health and safety purposes. This category may also be used to screen samples to select portions for further analysis. For example, soil gas or sample headspace may be screened to determine if laboratory analyses are required. In addition, this data category will be used to determine the presence of geochemical parameters that support natural attenuation of chlorinated hydrocarbon contaminants in groundwater. Resulting data will be used to evaluate the effectiveness of natural attenuation at the site.
- Definitive analyses will be used to satisfy the requirements for site characterization, risk analysis, decision document preparation, and site cleanup prioritization. USEPA Level III data from previous site investigations will be combined with newly acquired definitive data to evaluate the magnitude and extent of contamination at the site. Definitive data acquired during the investigation will be used to evaluate potential receptor risks and to develop remedial alternatives.

An effective QA program addresses DQOs for both field sampling and laboratory methodologies. The contractor's field QA efforts will focus on assuring that samples are representative of the conditions in the various environmental media at the time of sampling. Fixed-based laboratory QA efforts will be aimed primarily at assuring that

analytical procedures provide sufficient accuracy and precision to reliably quantify contaminant levels in environmental samples. The contract laboratory also will ensure that analyzed portions are representative of each sample, and that the results obtained from analysis of each sample are comparable to those obtained from analysis of other similar samples.

1.4 DATA QUALITY ASSESSMENT CRITERIA

Data assessment criteria will be used to evaluate the quality of both the field sampling and screening methods and laboratory performance for the project, and are expressed in terms of analytical precision, accuracy, representativeness, completeness, and comparability. Procedures used to assess data accuracy and precision are in accordance with *Guidelines Establishing Test Procedures for the Analyses of Pollutants,* Appendix III, "Example Quality Assurance and Quality Control Procedures for Organic Priority Pollutants" (40 CFR 136), and the respective analytical methods from the USEPA (1995) *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, SW-846.*

1.4.1 Precision

Precision is the measure of variability among individual sample measurements under prescribed conditions. The results of laboratory control samples (LCS) demonstrate the precision of the methods. When the LCS results meet the accuracy criteria, (USEPA, 1995) results are believed to be precise. This is based on the LCS being within control limits in comparison to LCS results from previous analytical batches of similar methods and matrices. The relative percent difference (RPD) of field duplicate, laboratory sample duplicate, and matrix spike/matrix spike duplicates (MS/MSD) results demonstrate the precision of the sample matrix. Precision will be expressed in terms of RPD between the values resulting from duplicate analyses. RPD is calculated as follows:

$$RPD = [(x1 - x2)/X][100]$$

where:

x1	=	analyte concentration in the primary sample
x2	=	analyte concentration in the duplicate sample
X	=	average analyte concentration in the primary and the duplicate sample.

Acceptable levels of precision will vary according to the sample matrix, the specific analytical method, and the analytical concentration relative to the method detection limit (MDL). For field duplicate samples, the target RPDs are ≤ 35 percent for soil and water samples. Precision criteria for the laboratory QC samples are defined by limits listed in Table 1.1. An RPD within the control limit indicates satisfactory precision in a measurement system.

TABLE 1.1
QC[a] ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Water (% R)[b]	Precision Water (RPD)[c]	Accuracy Soil (% R)	Precision Soil (RPD)
Aromatic Volatile Organic Compounds SW5030A/SW8020A (W[d], S[e])	1,2-Dichlorobenzene	61–134	≤ 20	51–144	≤ 30
	1,3-Dichlorobenzene	70–131	≤ 20	60–141	≤ 30
	1,4-Dichlorobenzene	75–126	≤ 20	66–136	≤ 30
	Benzene	75–125	≤ 20	66–135	≤ 30
	Chlorobenzene	75–129	≤ 20	66–139	≤ 30
	Ethylbenzene	71–129	≤ 20	61–139	≤ 30
	Toluene	70–125	≤ 20	60–135	≤ 30
	Xylenes, total	71–133	≤ 20	61–143	≤ 30
	Surrogates:				
	Bromochlorobenzene	46–136	NA[f]	36–146	NA
	Bromofluorobenzene	48–138	NA	38–148	NA
	Difluorobenzene	48–138	NA	38–148	NA
	Fluorobenzene	44–165	NA	34–175	NA
	1,1,1-Trifluorotoluene	44–165	NA	34–175	NA
Methane SW3810 Modified (W)	Methane	70-130	≤ 20	NA	NA
	Ethane	70–130	≤ 20	NA	NA
	Ethene	70–130	≤ 20	NA	NA
Volatile Organics SW5030A/SW8260A (W, S)	1,1,1,2-Tetrachloroethane	72–125	≤ 20	62–108	≤ 30
	1,1,1-Trichloroethane	75–125	≤ 20	65–135	≤ 30
	1,1,2,2-Tetrachloroethane	74–125	≤ 20	64–135	≤ 30
	1,1,2-Trichloroethane	75–127	≤ 20	65–135	≤ 30
	1,1-Dichloroethane	72–125	≤ 20	62–135	≤ 30
	1,1-Dichloroethene	75–125	≤ 20	65–135	≤ 30
	1,1-Dichloropropene	75–125	≤ 20	65–135	≤ 30
	1,2,3-Trichlorobenzene	75–137	≤ 20	65–147	≤ 30
	1,2,3-Trichloropropane	75–125	≤ 20	65–135	≤ 30
	1,2,4-Trichlorobenzene	75–135	≤ 20	65–145	≤ 30
	1,2,4-Trimethyl Benzene	75-125	≤ 20	65–135	≤ 30
	1,2-Dichloroethane	68–127	≤ 20	58–137	≤ 30
	1,2-Dichlorobenzene	75-125	≤ 20	65–135	≤ 30
	1,2-Dibromo-3-chloropropane	59–125	≤ 20	49–135	≤ 30
	1,2-Dichloropropane	70–125	≤ 20	60–135	≤ 30
	1,2-Dibromoethane	75-125	≤ 20	65–135	≤ 30
	1,3,5-Trimethylbenzene	72–112	≤ 20	62–135	≤ 30
	1,3-Dichlorobenzene	75-125	≤ 20	65–135	≤ 30
	1,4-Dichlorobenzene	75-125	≤ 20	65–135	≤ 30
	1-Chlorohexane	75-125	≤ 20	65–135	≤ 30
	2,2-Dichloropropane	75-125	≤ 20	65–135	≤ 30
	2-Chlorotoluene	73–125	≤ 20	63–135	≤ 30
	4-Chlorotoluene	74–125	≤ 20	64–135	≤ 30
	Benzene	75–125	≤ 20	65–135	≤ 30
	Bromobenzene	75–125	≤ 20	65–135	≤ 30

TABLE 1.1 (Continued)
QC[a] ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Water (% R)[b]	Precision Water (RPD)[c]	Accuracy Soil (% R)	Precision Soil (RPD)
Volatile Organics (Cont)	Bromochloromethane	73–125	≤ 20	63–135	≤ 30
SW5030A/SW8260A	Bromodichloromethane	75–125	≤ 20	65–135	≤ 30
(W, S)	Bromoform	75–125	≤ 20	65–135	≤ 30
	Bromomethane	72–125	≤ 20	62–135	≤ 30
	Carbon Tetrachloride	62–125	≤ 20	52–135	≤ 30
	Chlorobenzene	75–125	≤ 20	65–135	≤ 30
	Chlorodibromomethane	75–125	≤ 20	65–135	≤ 30
	Chloroethane	65–125	≤ 20	55–135	≤ 30
	Chloroform	74–125	≤ 20	64–135	≤ 30
	Chloromethane	75-125	≤ 20	65–135	≤ 30
	Cis-1,2-Dichloroethene	75–125	≤ 20	65–135	≤ 30
	Cis-1,3-Dichloropropene	74–125	≤ 20	64–135	≤ 30
	Dibromochloromethane	73–125	≤ 20	63–135	≤ 30
	Dibromomethane	69–127	≤ 20	59–137	≤ 30
	Dichlorodifluoromethane	75-125	≤ 20	65–135	≤ 30
	Dichloropropene	75–125	≤ 20	65–135	≤ 30
	Ethylbenzene	75–125	≤ 20	65–135	≤ 30
	Hexachlorobutadiene	75–125	≤ 20	65–135	≤ 30
	Isopropylbenzene	75–125	≤ 20	65–135	≤ 30
	m-Xylene	75–125	≤ 20	65–135	≤ 30
	Methylene Chloride	75–125	≤ 20	65–135	≤ 30
	n-Butylbenzene	75–125	≤ 20	65–135	≤ 30
	n-Propylbenzene	75–125	≤ 20	65–135	≤ 30
	Naphthalene	75–125	≤ 20	65–135	≤ 30
	o-Xylene	75–125	≤ 20	65–135	≤ 30
	p-Isopropyltoluene	75–125	≤ 20	65–135	≤ 30
	p-Xylene	75–125	≤ 20	65–135	≤ 30
	Sec-Butylbenzene	75–125	≤ 20	65–135	≤ 30
	Styrene	75–125	≤ 20	65–135	≤ 30
	Trichloroethene	71–125	≤ 20	61–135	≤ 30
	Tetrachloroethylene	71–125	≤ 20	61–135	≤ 30
	Toluene	74–125	≤ 20	64–135	≤ 30
	Trans-1,2-Dichloroethene	75–125	≤ 20	65–135	≤ 30
	Trans-1,3-Dichloropropene	66–125	≤ 20	56–135	≤ 30
	Trichlorofluoromethane	67–125	≤ 20	57–135	≤ 30
	Vinyl Chloride	46–134	≤ 20	36–144	≤ 30
	Xylenes, Total	75–125	≤ 20	65–135	≤ 30
	Surrogates:				
	Dibromofluoromethane	75–125	NA	65–135	NA
	Toluene-D8	75–125	NA	65–135	NA
	4-Bromofluorobenzene	75–125	NA	65–135	NA
	1,2-Dichloroethane-D4	62–139	NA	52–149	NA

TABLE 1.1 (Continued)
QC[a] ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Water (% R)[b]	Precision Water (RPD)[c]	Accuracy Soil (% R)	Precision Soil (RPD)
Semivolatile Organics	1,2,4-Trichlorobenzene	44–142	≤ 20	34–152	≤ 30
Base/Neutral	1,2-Dichlorobenzene	42–155	≤ 20	32–135	≤ 30
Extractables	1,3-Dichlorobenzene	36–125	≤ 20	26–135	≤ 30
SW3510B/SW8270B (W)	1,4-Dichlorobenzene	30–125	≤ 20	25–135	≤ 30
SW3550A/SW8270B (S)	2,4-Dinitrotoluene	39–139	≤ 20	29–149	≤ 30
	2,6-Dinitrotoluene	51–125	≤ 20	41–135	≤ 30
	2-Chloronaphthalene	60–125	≤ 20	50–135	≤ 30
	2-Methylnaphthalene	41–125	≤ 20	31–135	≤ 30
	2-Nitroaniline	50–125	≤ 20	40–135	≤ 30
	3,3'-Dichlorobenzidine	29–175	≤ 20	25–175	≤ 30
	3-Methylphenol	41–144	≤ 20	31–154	≤ 30
	3-Nitroaniline	51–125	≤ 20	41–135	≤ 30
	4-Bromophenyl Phenyl Ether	53–127	≤ 20	43–137	≤ 30
	4-Chloroaniline	45-136	≤ 20	35-146	≤ 30
	4-Chlorophenyl Phenyl Ether	51–132	≤ 20	41–142	≤ 30
	4-Nitroaniline	40–143	≤ 20	30–153	≤ 30
	Acenaphthalene	47–125	≤ 20	37–135	≤ 30
	Acenaphthene	49–125	≤ 20	39–135	≤ 30
	Anthracene	45–165	≤ 20	35–175	≤ 30
	Benz (a) Anthracene	51–133	≤ 20	41–143	≤ 30
	Benzo (a) Pyrene	41–125	≤ 20	31–135	≤ 30
	Benzo (b) Fluoranthene	37–125	≤ 20	27–1 35	≤ 30
	Benzo (g,h,i) Perylene	34–149	≤ 20	25–159	≤ 30
	Benzo (k) Fluoranthene	37–125	≤ 20	27–135	≤ 30
	Benzyl Alcohol	35–125	≤ 20	25–135	≤ 30
	Bis (2-chloroethoxy) Methane	49–125	≤ 20	39–135	≤ 30
	Bis (2-chloroethyl) Ether	44–125	≤ 20	34–135	≤ 30
	Bis (2-chloroisopropyl) Ether	36–166	≤ 20	26–175	≤ 30
	Bis (2-ethylhexyl) Phthalate	33–129	≤ 20	25–139	≤ 30
	Butyl Benzyl Phthalate	26–125	≤ 20	25–135	≤ 30
	Carbazole	34–132	≤ 20	25–142	≤ 30
	Chrysene	55–133	≤ 20	45–143	≤ 30
	Di-n-Butyl Phthalate	34–126	≤ 20	25–136	≤ 30
	Di-n-Octyl Phthalate	38–127	≤ 20	28–137	≤ 30
	Dibenzo (a,h) Anthracene	50–125	≤ 20	40–135	≤ 30
	Dibenzofuran	52–125	≤ 20	42–135	≤ 30
	Diethyl Phthalate	37–125	≤ 20	27–135	≤ 30
	Dimethyl Phthalate	25–175	≤ 20	25–175	≤ 30
	Fluoranthene	47–125	≤ 20	37–135	≤ 30
	Fluorene	48–139	≤ 20	38–149	≤ 30
	Hexachlorobenzene	46–133	≤ 20	36–143	≤ 30
	Hexachlorobutadiene	25–125	≤ 20	25–135	≤ 30

TABLE 1.1 (Continued)
QC[a] ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Water (% R)[b]	Precision Water (RPD)[c]	Accuracy Soil (% R)	Precision Soil (RPD)
Semivolatile Organics Base/Neutral Extractables SW3510B/SW8270B (W) SW3550A/SW8270B (S) (Cont)	Hexachlorocyclopentadiene	41–125	≤ 20	31–135	≤ 30
	Hexachloroethane	25–153	≤ 20	25–163	≤ 30
	Indeno (1,2,3-c,d) Pyrene	27–160	≤ 20	25–170	≤ 30
	Isophorone	26–175	≤ 20	25–175	≤ 30
	N-Nitrosodi-n-propylamine	37–125	≤ 20	27–135	≤ 30
	N-Nitrosodiphenylamine	27–125	≤ 20	25–135	≤ 30
	Naphthalene	50–125	≤ 20	40–135	≤ 30
	Nitrobenzene	46–133	≤ 20	36–143	≤ 30
	p-Chloroaniline	56–125	≤ 20	46–135	≤ 30
	Phenanthrene	54–125	≤ 20	44–135	≤ 30
	Pyrene	47–136	≤ 20	37–146	≤ 30
Semivolatile Organics Acid Extractables SW3510B/SW8270B (W) SW3550A/SW8270B (S)	2,4,5-Trichlorophenol	25–175	≤ 20	25–175	≤ 30
	2,4,6-Trichlorophenol	39–128	≤ 20	29–138	≤ 30
	2,4-Dichlorophenol	46–125	≤ 20	36–135	≤ 30
	2,4-Dimethylphenol	45–139	≤ 20	35–149	≤ 30
	2,4-Dinitrophenol	30–151	≤ 20	25–161	≤ 30
	2-Chlorophenol	41–125	≤ 20	31–135	≤ 30
	2-Methylphenol	25–125	≤ 20	25–135	≤ 30
	2-Nitrophenol	44–125	≤ 20	34–135	≤ 30
	4,6-Dinitro-2-Methyl Phenol	26–134	≤ 20	25–144	≤ 30
	4-Chloro-3-Methyl Phenol	44–125	≤ 20	34–135	≤ 30
	4-Methylphenol	33–125	≤ 20	25–135	≤ 30
	4-Nitrophenol	25–131	≤ 20	25–141	≤ 30
	Benzoic Acid	25–162	≤ 20	25–172	≤ 30
	Pentachlorophenol	28–136	≤ 20	38–146	≤ 30
	Phenol	25–125	≤ 20	25–135	≤ 30
	Surrogates:				
	2,4,6-Tribromophenol	25–134	NA	25–144	NA
	2-Fluorobiphenyl	43–125	NA	34–135	NA
	2-Fluorophenol	25–125	NA	25–135	NA
	Nitrobenzene-D5	32–125	NA	25–135	NA
	Phenol-D5	25–125	NA	25–135	NA
	Terphenyl-D14	42–126	NA	32–136	NA
Polynuclear Aromatic Hydrocarbons SW3510B/SW8310 (W) SW2550A/SW8310 (S)	1-Methylnaphthalene	25–150	≤ 30	25–160	≤ 50
	2-Methylnaphthalene	25–150	≤ 30	25–160	≤ 50
	Acenaphthalene	49–125	≤ 30	39–135	≤ 50
	Acenaphthene	43–130	≤ 30	33–140	≤ 50
	Anthracene	54–125	≤ 30	44–135	≤ 50
	Benzo (a) Anthracene	39–135	≤ 30	29–145	≤ 50
	Benzo (a) Pyrene	52–125	≤ 30	42–135	≤ 50
	Benzo (b) Fluoranthene	31–137	≤ 30	25–147	≤ 50
	Benzo (g,h,i) Perylene	53–125	≤ 30	43–135	≤ 50
	Benzo (k) Fluoranthene	60–129	≤ 30	50–139	≤ 50

TABLE 1.1 (Continued)
QC[a] ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Water (% R)[b]	Precision Water (RPD)[c]	Accuracy Soil (% R)	Precision Soil (RPD)
	Chrysene	59–134	≤ 30	49–144	≤ 50
	Dibenzo (a,h) Anthracene	51–125	≤ 30	41–135	≤ 50
	Fluoranthene	42–125	≤ 30	32–135	≤ 50
	Fluorene	53–125	≤ 30	43–135	≤ 50
	Indeno (1,2,3-c,d) Pyrene	55–125	≤ 30	45–135	≤ 50
	Naphthalene	43–125	≤ 30	33–135	≤ 50
	Phenanthrene	52–129	≤ 30	42–139	≤ 50
	Pyrene	55–125	≤ 30	45–135	≤ 50
	Surrogates:				
	Terphenyl-D14	25–157	NA	22–167	NA
ICP Screen for Metals SW3005A/SW6010A (W) SW3050A/SW6010A (S)	Aluminum	80–120	≤ 15	80–120	≤ 25
	Antimony	80–120	≤ 15	80–120	≤ 25
	Arsenic	80–120	≤ 15	80–120	≤ 25
	Barium	80–120	≤ 15	80–120	≤ 25
	Beryllium	80–120	≤ 15	80–120	≤ 25
	Cadmium	80–120	≤ 15	80–120	≤ 25
	Calcium	80–120	≤ 15	80–120	≤ 25
	Chromium	80–120	≤ 15	80–120	≤ 25
	Cobalt	80–120	≤ 15	80–120	≤ 25
	Copper	80–120	≤ 15	80–120	≤ 25
	Iron	80–120	≤ 15	80–120	≤ 25
	Lead	80–120	≤ 15	80–120	≤ 25
	Magnesium	80–120	≤ 15	80–120	≤ 25
	Manganese	80–120	≤ 15	80–120	≤ 25
	Molybdenum	80–120	≤ 15	80–120	≤ 25
	Nickel	80–120	≤ 15	80–120	≤ 25
	Potassium	80–120	≤ 15	80–120	≤ 25
	Selenium	80–120	≤ 15	80–120	≤ 25
	Silver	80–120	≤ 15	80–120	≤ 25
	Sodium	80–120	≤ 15	80–120	≤ 25
	Thallium	80–120	≤ 15	80–120	≤ 25
	Vanadium	80–120	≤ 15	80–120	≤ 25
	Zinc	80–120	≤ 15	80–120	≤ 25
SW3020A/SW7421 (W) SW3050A/SW7421 (S)	Lead	74-124	≤ 15	74-124	≤ 25
SW3020A/SW7131A (W) SW3050A/SW7131A (S)	Cadmium	80-122	≤ 15	80-122	≤ 15
Common Anions SW9060	Bromide	86–112	≤ 20	86–112	≤ 30
	Chloride	91–111	≤ 20	91–111	≤ 30
	Fluoride	86–114	≤ 20	86–114	≤ 30
	Nitrate	90–110	≤ 20	90–110	≤ 30
	Nitrite	88–116	≤ 20	88–116	≤ 30

TABLE 1.1 (Continued)
QC[a] ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Water (% R)[b]	Precision Water (RPD)[c]	Accuracy Soil (% R)	Precision Soil (RPD)
Common Anions SW9060 (Cont)	Phosphate	87–110	≤ 20	87–110	≤ 30
	Sulfate	88–115	≤ 20	88–115	≤ 30
E160.1	Total Dissolved Solids	NA	≤ 20	NA	NA
E160.2	Total Suspended Solids	NA	≤ 20	NA	NA
E310.1	Alkalinity	80-120	≤ 20	80-120	NA
E353.1	Nitrogen, nitrate/nitrite	80-120	≤ 20	80-120	NA
SW9050	Conductance	NA	≤ 20	NA	NA
SW9040	pH	NA	NA	NA	NA

SOURCE: AFCEE QAPP, Version 1.1, February 1996
[a] QC = Quality Control
[b] %R = Percent Recovery
[c] RPD = Relative percent difference
[d] W = Water
[e] S = Soil [f] NA=Not Applicable

TABLE 1.1 (cont)
QC ACCEPTANCE CRITERIA
SITE SAMPLING AND ANALYSIS PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Gas (%R)	Precision Gas (RDP)
EPA Method TO-14 for Soil Gas Volatile Organics	Freon 12	70-130	±30
	Chloromethane	70-130	±30
	Freon 114	70-130	±30
	Vinyl Chloride	70-130	±30
	Bromomethane	70-130	±30
	Chloroethane	70-130	±30
	Freon 11	70-130	±30
	1,1-Dichloroethene	70-130	±30
	Dichloromethane (Methylene Chloride)	70-130	±30
	Trichlorotrifluoroethane (Freon 113)	70-130	±30
	1,1-Dichloroethane	70-130	±30
	cis-1,2-Dichloroethene	70-130	±30
	Chloroform	70-130	±30
	1,2-Dichloroethane	70-130	±30
	Methyl Chloroform (1,1,1-Trichloroethane)	70-130	±30
	Benzene	70-130	±30
	Carbon Tetrachloride	70-130	±30

TABLE 1.1 (Continued)
QC[a] ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Gas (%R)	Precision Gas (RDP)
EPA Method TO-14 for Soil Gas Volatle Organics (Cont)	1,2-Dichloropropane	70-130	±30
	Trichloroethene	70-130	±30
	cis-1,3-Dichloropropene	70-130	±30
	trans-1,3-Dichloropropene	70-130	±30
	1,1,2-Trichloroethane	70-130	±30
	Toluene	70-130	±30
	1,2-Dibromethane (EDB)	70-130	±30
	Tetrachloroethene	70-130	±30
	Chlorobenzene	70-130	±30
	Ethylbenzene	70-130	±30
	m,p-Xylene	70-130	±30
	0-Xylene	70-130	±30
	Styrene	70-130	±30
	1,1,2,2-Tetrachloroethane	70-130	±30
	1,3,5-Trimethylbenzene	70-130	±30
	1,2,4-Trimethylbenzene	70-130	±30
	1,2-Dichlorobenzene	70-130	±30
	Chlorotoluene (Benzyl Chloride)	70-130	±30
	1,4-Dichlorobenzene	70-130	±30
	1,3-Dichlorobenzene	70-130	±30
	1,2,4-Trichlorobenzene	70-130	±30
	Hexachlorobutadiene	70-130	±30
	Propylene	60-140	±40
	1,3-Buradiene	60-140	±40
	Acetone	60-140	±40
	Carbon Disulfide	60-140	±40
	Isopropanol	60-140	±40
	trans-1,2-Dichloroethene	60-140	±40
	Vinyl Acetate	60-140	±40
	Chloroprene	60-140	±40
	2-Butanone (Methyl Ethyl Ketone)	60-140	±40
	Hexane	60-140	±40
	Tetrahydrofuran	60-140	±40
	Cyclohexane	60-140	±40
	1,4-Dioxane	60-140	±40
	Bromodichloromethane	60-140	±40
	4-Methyl-2-Pentanone (MIBK)	60-140	±40
	2-Hexanone	60-140	±40
	Dibromochloromethane	60-140	±40
	Bromoform	60-140	±40
	4-Ethyltoluene	60-140	±40
	Ethanol	60-140	±40
	Methyl-Butyl Ether (MTBE)	60-140	±40
	Heptane	60-140	±40

TABLE 1.1 (Continued)
QC ACCEPTANCE CRITERIA
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Accuracy Gas (%R)	Precision Gas (RDP)
EPA Method TO-14 for Soil Gas Volatile Organics (Cont)	Surrogates		
	Octafluorotoluene	70-130	±30
	Toluene-d8	70-130	±30
	4-Bromofluorobenzene	70-130	±30
	Internal Standards (I.S.)		
	Bromochloromethane		
	1,4-Difluorobenzene		
	Chlorobenzene-d5		
ASTM Method D3416 for Methane in Soil Gas	Methane	75-125	±25

Criteria: Sample, QC sample and blank I.S. area must be within ±40% of the calibration checks I.S. area. Retention Time (R.T.) must be within ±0.5 minutes of the calibration check's R.T.

1.4.2 Accuracy

Accuracy is a measure of the closeness of a reported concentration to the true value. Accuracy is expressed as a bias (high or low) and is determined by calculating percent recovery (%R) from MS/MSDs, LCSs, and surrogate spikes. MS/MSD and surrogate spike %Rs indicate accuracy relevant to a unique sample matrix. LCS %Rs indicate accuracy relevant to an analytical batch lot, and are strictly a measure of analytical accuracy conditions independent of samples and matrices. The %R of an analyte, and the resulting degree of accuracy expected for the analysis of QC spiked samples, are dependent upon the sample matrix, method of analysis, and the compound or element being measured. The concentration of the analyte relative to the detection limit of the method also is a major factor in determining the accuracy of the measurement.

Accuracy is expressed as %R and is calculated as follows:

$$\%R = [(A-B)/C] \times 100$$

where:

A	=	spiked sample concentration
B	=	measured sample concentration (without spike)
C	=	concentration of spike added.

Accuracy criteria for the laboratory are defined by control limits listed in Table 1.1.

1.4.3 Completeness

Completeness is defined as the percentage of laboratory measurements judged to be valid on a method-by-method basis. Valid data are defined as all data and/or qualified data considered to meet the DQOs for this project. Data completeness is expressed as percent complete (PC) and should be ≥ 90 percent. The goal for meeting analytical holding times is 100 percent. At the end of each sampling event, the completeness of the data will be assessed. If any data omissions are apparent, the parameter in question will be resampled and/or reanalyzed, if feasible. The laboratory results will be monitored as they become available to assess laboratory performance and its effect on data completeness requirements. When appropriate, additional samples will be collected to ensure that laboratory performance meets PC requirements.

PC is calculated as follows:

$$PC = \frac{N_A}{N_I} X100$$

Where:

N_A = Actual number of valid analytical results obtained

N_I = Theoretical number of results obtainable under ideal conditions.

1.4.4 Comparability

Comparability expresses the confidence with which data from one sample, sampling round, site, laboratory, or project can be compared to those from another. Comparability during sampling is dependent upon sampling program design and time periods. Comparability during analysis is dependent upon analytical methods, detection limits, laboratories, units of measure, and sample preparation procedures.

Comparability is determined on a qualitative rather than quantitative basis. For this project, comparability of all data collected will be ensured by adherence to standard sample collection procedures, standard field measurement procedures, and standard reporting methods, including consistent units. For example, concentrations will be reported in a manner consistent with general industry practice (e.g., soil data will be reported on a dry-weight basis).

In addition, to support the comparability of fixed-base laboratory analytical results with those obtained in previous or future testing, all samples will be analyzed by USEPA-approved methods, where available. The USEPA-recommended maximum permissible holding times for organic and inorganic parameters will not be exceeded. All analytical standards will be traceable to standard reference materials. Instrument calibrations will be performed in accordance with USEPA method specifications, and will be checked at the frequency specified for the methods. The results of these analyses can then be compared with analyses by other laboratories and/or with analyses for other sites addressed by this site investigation.

1.4.5 Representativeness

Representativeness expresses the extent to which collected data define site contamination. Where appropriate, sample results will be statistically characterized to determine the degree to which the data accurately and precisely represent a characteristic of a population, parameter variation at a sampling point, a process, or an environmental condition.

Sample collection, handling, and analytical procedures will strive to obtain the most representative sample possible. Representative samples will be achieved by the following:

- Collection of samples from locations fully representing site conditions;
- Use of appropriate sampling procedures, including equipment and equipment decontamination;
- Use of appropriate analytical methods for the required parameters and project reporting limits; and
- Analysis of samples within the required holding times.

Sample representativeness also is affected by the portion of each collected sample that is chosen for analysis. The laboratory will adequately homogenize all samples prior to taking aliquots for analysis to ensure that the reported results are representative of the sample received. Because many homogenization techniques may cause loss of contaminants through volatilization, homogenization for all volatile organic compound (VOC) method analyses will be performed with extreme care to minimize these risks.

SECTION 2

SOIL GAS SAMPLING

2.1 INTRODUCTION

Soil gas will be used as an indicator of subsurface contamination. The use of shallow soil gas probes to delineate potential subsurface contamination has several economic and technical advantages over more traditional drilling and soil sampling techniques. The labor and equipment cost can be significantly less than a conventional drilling and sampling team. Many new hydraulically driven, multi-purpose probes can be used for soil gas sampling. These probes can be advanced as quickly as conventional augers and do not produce drill cuttings which can require expensive analysis and disposal. Further, soil gas sampling can represent the average chemistry of several cubic feet of soil as compared to a discrete soil sample, which can only describe a few cubic inches of the subsurface. This is of particular importance in risk-based remediation projects where the extent of contamination and the degree of contaminant removal can most accurately be determined by using multiple soil gas sampling locations.

2.2 SOIL GAS SAMPLING FREQUENCY AND LOCATIONS

The primary purpose of soil gas screening will be to locate "hot spots" which exhibit high levels of volatile organics. A hand-held Gas Tech multi-gas meter and photoionization detector (PID) will be used to provide a semi-quantitative screening to determine total volatile hydrocarbons and ionizable volatile organic compounds (VOCs) in the soil gas. If significant TVH or VOC levels are detected, the "hot spots" will be resampled using a Summa™ Canister and analyzed in a certified laboratory using EPA Method TO-3 or EPA Method TO-14. These results will be used to provide some correlation between field screening estimates and laboratory results. Sampling frequency and locations will be specified in site-specific work plans.

2.3 SOIL GAS SAMPLING PROCEDURES

The test equipment and methods that will be required to conduct field soil gas sampling at this site are generally described in *Addendum One to Test Plan and Technical Protocol for a Field Treatability Test for Bioventing - Using Soil Gas Surveys to Determine Bioventing Feasibility and Natural Attenuation Potential* (Downey and Hall, 1994). During soil gas screening, soil gas will be collected using a stainless-steel soil gas probe (5/8 or 3/4 inch O.D.). Probes will be pushed by a Geoprobe® or hand-driven to a

depth of approximately 4 feet at each location. The probe will be retracted approximately 6 inches to expose the soil gas screen to the soil.

A 1-cfm vacuum pump will be operated for an appropriate length of time at each location (dependent upon depth) to purge soil gas in the sampling apparatus and collect a representative sample. A Gas Tech multi-gas meter and/or PID will continuously sample the purge stream to insure that concentrations have stabilized. Once stabilized, oxygen, carbon dioxide, TVH, and PID levels will be recorded. The multi-gas meter has range settings of 0 to 25 percent for both O_2 and CO_2. Before analyzing samples, the analyzer must be calibrated and the battery charge checked. The analyzer will be calibrated daily using atmospheric conditions of O_2 (20.9 percent) and CO_2 (0.05 percent) and a gas standard containing 0.0 percent O_2 and 5.0 percent CO_2.

The TVH analyzer will be capable of measuring hydrocarbon concentrations in the range of 1 to 20,000 parts per million, volume per volume (ppmv). The TVH analyzer will be calibrated daily using a 3,000 ppmv hexane calibration gas.

Sample locations identified for laboratory analytical, compound-specific analysis will be resampled using 3-liter Tedlar® bags and a vacuum chamber. The samples will then be transferred to 1-liter SUMMA® canisters and shipped to Air Toxics, Inc. in Folsom, California for compound-specific analysis using US Environmental Protection Agency (USEPA) analytical Method TO-14 or Method TO-3. The chosen analytical method will be site-specific and provided in the site-specific work plan.

Field quality assurance/quality control (QA/QC) procedures for soil gas will include collection of one field duplicate for every 10 samples collected (e.g., frequency of 10 percent), use of analyte-appropriate containers, and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the analytical laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., soil gas), and analyses requested. Samples will be preserved in accordance with the analytical method to be used.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature.

The analytical laboratory will conduct one matrix spike analysis, one laboratory control sample, and one laboratory blank test for each specific analysis requested for soil gas (i.e., required only once for soil gas since only one analytical method will be used).

SECTION 3

SOIL/SEDIMENT SAMPLING

3.1 INTRODUCTION

Soil and sediment sampling will typically be performed as part of the site characterization. Soil samples will be collected from the vadose zone in source areas or from saturated soils which exhibit elevated volatile organics in groundwater screening samples. Sediment samples may be collected at sites where past sampling has indicated contaminants of potential concern exist. The following sections describe the soil and sediment sampling procedures, borehole installation, soil sampling, procedures for equipment decontamination, and datum surveying procedures to be used as part of the soil/sediment sampling field effort.

3.2 SAMPLING LOCATIONS

Subsurface soil sampling will take place at source areas and/or at locations where groundwater screening indicates higher concentrations of VOCs may exist. The exact number of samples will be determined in the field and a preliminary estimate will be made in the site-specific work plan. Saturated zone soil samples typically will be collected from a depth of approximately 2-4 feet below the water table. Sediment samples typically will be collected from the upper 6-inches of the sediment at each location.

3.3 SOIL AND SEDIMENT SAMPLING PROCEDURES

3.3.1 Soil Sampling

Soil sampling in unconsolidated soils will be accomplished using a Geoprobe® hydraulic sampling rig. The Geoprobe® will be used to advance a 2-inch-diameter sampler containing a butylene liner to the desired sampling depth. Once the desired sampling depth is attained, the end point of the sampler will be retracted and the sampler will be advanced approximately 4 feet until filled with soil. The sampler will be returned to the surface, the liner removed, and its ends capped with Teflon® squares and plastic caps. All sampling equipment will be decontaminated prior to use and between uses, as described in Section 3.8. If subsurface conditions are such that the planned installation technique does not produce acceptable results another technique deemed more appropriate to the type of soils present will be used.

The Parsons ES field geologist will be responsible for observing all borehole installation and sampling activities, maintaining a detailed log of the target sample interval, and properly labeling and storing samples. An example of the proposed geologic boring log form is presented in Figure 3.1. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination (e.g., staining, odor or elevated headspace screening readings);
- Soil or rock description of the target sampling interval, including relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and
- The depth of lithologic contacts and/or significant textural changes, measured and recorded to the nearest 0.1 foot (1 inch) if present within the target interval.

3.3.2 Sediment Sampling

Sediment samples will be collected from the upper six inches of the sediment layer using a metal hand trowel, placed in a 500 ml glass jar with minimum headspace, and sealed using a teflon sheet and screw on lid.

3.4 SAMPLE HANDLING

This section describes the handling of soil and sediment samples from the time of sampling until the samples arrive at the laboratory.

3.4.1 Sample Containers and Labels

New, factory cleaned butylene sample sleeves and end caps (or glass jars for sediments) will be provided by Parsons ES or the laboratory. The sample label will be firmly attached to the sample sleeve immediately after sample collection, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample depth;
- Sampling date;
- Sampling time; and
- Sample collector's initials.

GEOLOGIC BORING LOG

BORING NO. _____ CONTRACTOR: _____ DATE SPUD: _____
CLIENT: _____ RIG TYPE: _____ DATE CMPL: _____
JOB NO.: _____ DRLG METHOD: _____ ELEVATION: _____
LOCATION: _____ BORING DIA.: _____ TEMP.: _____
GEOLOGIST: _____ DRLG FLUID _____ WEATHER: _____
COMMENTS: _____

Elev. (ft.)	Depth (ft.)	Pro-file	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Blkgnd/Reading (ppm)
	1								
	5								
	10								
	15								
	20								
	25								
	30								

sl – slight
tr – trace
sm – some
& – and
@ – at
w – with

v – very
lt – light
dk – dark
bf – buff
brn – brown
blk – black

f – fine
m – medium
c – coarse
BH – Bore Hole
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

C Core recovery
. Core lost

Water level drilled

Figure 3-1

3.4.2 Sample Preservation

Samples will be properly prepared for transportation to the laboratory by placing the samples in an adequately padded cooler containing ice to maintain an approximate shipping temperature of 4 degrees centigrade (°C).

3.4.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the analytical laboratory. The analytical laboratory and location will be specified in the site-specific work plan. Samples will be shipped priority overnight via Federal Express®. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Label shipping container with:
  - Sample collector's name, address, and telephone number;
  - Laboratory's name, address, and telephone number;
  - Description of sample;
  - Quantity of sample; and
  - Date of shipment.

The packaged samples will be delivered to the laboratory as soon as possible after sample acquisition, and in accordance with analytical method-specific holding times.

3.4.4 Chain-of-Custody Control

After the samples have been collected, chain-of-custody procedures will be followed to establish a written record of sample handling and movement between the sampling site and the laboratory. Each shipping container will have a chain-of-custody form completed in triplicate by the sampling personnel. One copy of this form will be kept by the sampling team and the other two copies will be sent to the laboratory. One of the laboratory copies will become a part of the permanent record for the sample and will be returned with the sample analytical results. The chain-of-custody will contain the following information:

- Sample identification number;
- Sample collector's printed name and signature;
- Date and time of collection;
- Place and address of collection;
- Sample matrix;
- Analyses requested;
- Signatures of individuals involved in the chain of possession; and

- Inclusive dates of possession.

The chain-of-custody documentation will be placed inside the shipping container so that it will be immediately apparent to the laboratory personnel receiving the container, but will not be damaged or lost during transport. The shipping container will be sealed so that it will be obvious if the seal has been tampered with or broken.

3.4.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the Parsons ES field scientist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
  - Sample appearance,
  - Sample odor;
- Weather conditions;
- Sampler's identification;
- Any other relevant information.

3.5 LABORATORY ANALYSES

Laboratory analyses will be performed on all soil samples and the required QA/QC samples (see Section 3.6 and Section 5). Analytical methods for soil and sediment samples will be specified in the site-specific work plan. All containers, preservatives, and shipping requirements will be consistent with the laboratory protocol. Laboratory personnel will specify any additional QC samples required and provide all containers and preservatives which are required. Shipping containers, ice chests with adequate padding, and cooling media will be sent by the laboratory or provided by Parsons ES.

3.6 QUALITY ASSURANCE/QUALITY CONTROL SAMPLES

As a check on the quality of field sampling activities (sampling, containerization, shipment, and handling) QA/QC trip blanks, field blanks, equipment rinseate samples, and field replicates will be sent to the laboratory. QA/QC sampling will include one replicate for soil samples (i.e., frequency of 10 percent), one rinseate sample (i.e., frequency of 10 percent), one field blank, and a trip blank for each individual shipping

cooler sent to the analytical laboratory containing samples for volatile organic compound (VOC) analysis. The procedures for the collection of field QA/QC samples are discussed in Section 5 of this SAP. Laboratory QA/QC procedures will include one matrix spike analysis, one laboratory control sample, and one laboratory blank sample test for each specific analysis requested.

3.7 MINIMIZATION AND MANAGEMENT OF SOIL RESIDUALS

Borehole installation and soil sampling activities using the Geoprobe® typically generate no soil cuttings.

3.8 EQUIPMENT DECONTAMINATION PROCEDURES

Water to be used in equipment cleaning will be obtained from one of the Base's onsite water supplies. Base personnel will assist Parsons ES field personnel in locating a suitable source. Water use approval will be verified by contacting the appropriate facility personnel. Only potable water will be used for decontamination. A decontamination water blank will be collected from the potable water source. The procedures for the collection of the decontamination water blank are described in Section 5. The Parsons ES field scientist will make the final determination as to the suitability of site water for these activities.

Prior to arriving at the site, the Geoprobe® rods, samplers, tools and other downhole equipment will be decontaminated using a hot-water wash. During borehole installation operations, the rig, samplers, and any other downhole equipment will be decontaminated at a temporary decontamination pad that will be set up adjacent to each borehole location. The decontamination fluids will be stored in a temporary holding tank or, if transported off-Base, in 55-gallon Department of Transportation (DOT) approved drums for proper treatment and disposal.

Prior to arriving at the site and between borehole locations, all sampling tools will be cleaned with a clean water/phosphate-free detergent mix, a clean water rinse, isopropyl alcohol rinse, and a final distilled water rinse. Materials that cannot be cleaned to the satisfaction of the Parsons ES field scientist will not be used. All decontamination activities will be conducted in a manner so that the excess water will be controlled and not allowed to flow into any open borehole.

Fuel, lubricants, and other similar substances will be handled in a manner consistent with accepted safety procedures and standard operating practices. The Geoprobe® rig will not be allowed onsite unless it is free from leaks in all hydraulic and fuel lines, and is free of any exterior oil and grease.

Surface runoff such as miscellaneous spills and leaks, precipitation, and spilled decontamination fluids will not be allowed to enter any boring. Berms around the borehole and surficial bentonite packs, as appropriate, will be used to prevent cross-contamination.

3.9 SURVEY OF BOREHOLE LOCATIONS

The horizontal location of the new boreholes will be located by Parsons ES field personnel after completion of sampling procedures. Horizontal locations will be measured relative to previously installed groundwater wells that have established coordinates (i.e., previously surveyed by a register surveyor). Horizontal distances will be recorded to the nearest 0.1 foot by measuring the distance from each borehole to three established locations (monitoring wells or other previously surveyed locations deemed more appropriate by field personnel). These distances will be used to locate each borehole on any additional maps generated as part of the risk-based investigation.

3.10 BOREHOLE ABANDONMENT

Geoprobe® sampling operations will produce boreholes that are approximately 2.5 inches in diameter. These holes will be abandoned by filling with pelletized bentonite. The bentonite will be hydrated in place with potable water at 2-foot intervals to ensure proper hydration and subsequent sealing of the borehole. The concrete or asphalt at the site will be patched with ready-mix concrete or asphalt patch troweled to match the existing grade.

SECTION 4

GROUNDWATER AND SURFACE WATER SAMPLING

4.1 INTRODUCTION

This section describes the scope of work required for collecting groundwater samples from any existing and/or newly-installed monitoring wells (MWs), temporary or permanent monitoring points (MPs), and surface water samples from surface water sampling stations. In order to maintain a high degree of QC during sampling events, the procedures described in the following sections will be followed.

Two levels of sampling may be performed, depending on site-specific conditions. The level of sampling required at each site will be specified in the site-specific work plan. Sampling of MWs will be completed using either dedicated bladder pumps or handbailing after purging with a downhole electric pump. At some sites, initial groundwater screening may be completed at temporary or permanently-installed MPs using a direct push groundwater sampling probe and a peristaltic pump to purge and collect samples. Any historical sampling and purging procedures will be followed to the extent practicable to maintain consistency with historical data. Any required deviations from historical sampling procedures will be detailed in the site-specific work plan.

Groundwater/surface water sampling will be conducted by qualified Parsons ES scientists and technicians trained in the conduct of well sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this Program SAP and the site-specific work plan prior to sample acquisition and will have a copy of both available onsite for reference.

Activities that will occur during groundwater/surface water sampling are summarized below:

- Assembly and preparation of equipment and supplies;
- Inspection of existing wells, including:
  - Protective cover, cap and lock,
  - External surface seal and pad,
  - Well stick-up, cap, and datum reference,
  - Internal surface seal,
  - Condition of any dedicated equipment, if present;

- Groundwater sampling, including:
  - Water level measurements,
  - Visual inspection of borehole water,
  - Well purging,
  - Sampling;
- Surface water sampling, including:
  - Inspection of permanent location marker (i.e., visibility, integrity),
  - Visual inspection of surface water,
  - Sampling;
- Sample preservation and shipment, including:
  - Sample preparation and preservation, as appropriate,
  - Onsite measurement of physical parameters,
  - Sample labeling,
  - Sample packaging in appropriate shipping containers;
- Completion of sampling records;
- Completion of chain-of-custody records; and
- Sample shipment via overnight courier.

Detailed groundwater/surface water sampling and sample handling procedures are presented in following sections.

4.2 GROUNDWATER/SURFACE WATER SAMPLING LOCATIONS

4.2.1 Groundwater Screening from Monitoring Points

To define the possible sources of dissolved VOC contamination emanating from source areas and assist in the placement of permanent MW installation, a screening of shallow groundwater samples from permanent or temporary MPs may be completed at sites with shallow groundwater contamination (less than 30 feet bgs). Samples will be collected using a temporary stainless steel probe advanced using push technologies (i.e., Geoprobe® or CPT) at each location. Sampling will proceed from the outer, less contaminated areas to the inner, more contaminated areas to minimize the potential for cross-contamination. Locations for any MPs will be detailed in the site-specific work plan.

4.2.2 Groundwater Sampling from Permanent Monitoring Wells

Groundwater samples may be collected from new or existing MWs at some sites. The site-specific work plan will detail the specific locations of new or existing MWs which will be sampled.

4.2.3 Surface Water Sampling

If required, surface water sampling will take place at both upgradient and downgradient locations to determine the potential impact of site-related contamination to surface water. If possible, sampling will be completed during a low-flow period to minimize the impact of dilution on surface water contaminant concentrations. The site-specific work plan will detail the specific locations of any required surface water sampling.

4.3 MONITORING POINT CONSTRUCTION AND PREPARATION FOR SAMPLING

4.3.1 Temporary Monitoring Point Probes

The Geoprobe® unit or CPT will be used to advance a 1-inch O.D. stainless-steel probe which has a 2-foot section of 0.01-inch slotted steel for collecting groundwater samples. The probe will be advanced to at least 4 feet below the groundwater table. A section of dedicated high-density polyethylene (HDPE) tubing will be lowered inside the probe and connected to a pressure gauge to determine the approximate depth that groundwater is first encountered. The approximate groundwater depth below ground surface will be recorded to the nearest 0.1 foot. The tubing will then be inserted to within 1 foot of the bottom of the probe and connected to a peristaltic pump for purging. Each temporary MP will be purged until dissolved oxygen and temperature readings have stabilized. Once stable readings are obtained, samples will collected from the peristaltic pump discharge for laboratory and/or field analysis. Water from the peristaltic pump can be directly discharged into the sample container. The water should be carefully poured down the inner walls of a 40-ml sample bottle to minimize aeration of the sample. Sample containers for VOC analysis will be filled at approximately 200 ml/min and should fill the entire container to eliminated any headspace. Samples will be labeled and analyzed using procedures described in Section 4.7.

4.3.2 Permanent Monitoring Point Installation

Permanent groundwater MPs may be installed at some locations instead of temporary MPs. The permanent groundwater MPs will be constructed through 2-inch-outside-diameter Geoprobe® or CPT drive rods using 0.75-inch OD/0.5-inch ID, flush-threaded, Schedule 40 polyvinyl chloride (PVC) casing and screen. The screens will consist of 5-foot-long sections of 0.010-inch factory-slotted screen with threaded bottom caps. The borehole will be backfilled with No. 10-20 silica sand pack to 1-foot above the top of the screen. Bentonite pellets will placed from the top of the sand pack to 6 inches below

ground surface. The top of the casing will be sealed with a 1/2 PVC slip cap. At some locations, two MPs may be completed to collect groundwater samples from just below the groundwater surface and from a deeper depth, near the bottom of the aquifer or a significant lithologic change (e.g., bedrock interface).

The surface completion will consist of an 8-inch-diameter, flush-mounted well box set in a concrete collar sloping away from the well box and matching the site grade. The field scientist will verify and record the total depth of the monitoring point, the lengths of all casing sections, and the depth to the top of all monitoring point completion materials. All lengths and depths will be measured to the nearest 0.1 foot.

4.3.3 Preparation for Sampling Monitoring Points and Existing Wells

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to the beginning of the sampling event. In addition, all record keeping materials will be gathered prior to leaving the office. A brief organizational meeting will be held to ensure proper communication between project management staff and field personnel.

4.4 EQUIPMENT DECONTAMINATION

All portions of sampling and test equipment that will contact the sample will be thoroughly cleaned before each use. This equipment may include water-level probe and cable, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Based on the expected chemical contaminants expected to be encountered under this program, the following decontamination protocol will be used (any deviations from this decontamination protocol must be stated in the site-specific work plan):

- Clean with potable water and phosphate-free laboratory detergent (Liquinox® or equivalent);
- Rinse with potable water;
- Rinse with distilled or deionized water;
- Rinse with reagent-grade isopropanol;
- Rinse with distilled or deionized water; and
- Air dry the equipment prior to use.

All decontamination fluids will be temporarily placed in 55-gallon DOT approved containers for proper disposal.

Any deviations from proscribed decontamination procedures will be documented in the field scientist's field notebook and on the groundwater sampling form. If pre-cleaned dedicated sampling equipment is used, the decontamination protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory and, therefore, will not need to be cleaned in the field. Equipment field blanks

and equipment rinseate samples will be collected to assure that all containers and field equipment are free of contamination.

4.5 EQUIPMENT CALIBRATION

As required, field analytical equipment will be calibrated according to the manufacturer's specifications prior to field use. This applies to equipment used for onsite chemical measurements such as dissolved oxygen, pH, electrical conductivity, and temperature. Additional details on the calibration of field equipment are presented in Section 6 of this SAP.

4.6 SAMPLING PROCEDURES

Special care will be taken to prevent contamination of the groundwater/surface water and extracted samples. The two primary ways in which sample contamination can occur are through contact with improperly cleaned equipment and by cross-contamination through insufficient decontamination of equipment between sampling locations. To prevent such contamination, the peristaltic pump and water level probe and cable used to determine static water levels and total well depth will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 4.4. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile gloves will be worn each time a different MW or MP is sampled. New, clean tubing will be used for the peristaltic pump for each of the temporary "screening" wells sampled. Properly decontaminated or disposable bailers will be used to sample for VOCs in MWs. MWs and MPs will be sampled sequentially from areas suspected to be least contaminated to areas suspected to be more contaminated. Plastic will be placed around each of the wells to be sampled and sampling equipment will not be allowed to come in contact with the ground surface at any time during the sampling event.

The following paragraphs present the procedures for groundwater/surface water sample acquisition from all groundwater/surface water sampling locations. These activities will be performed in the same order as presented below. Exceptions to this procedure will be noted in the Parsons ES field scientist's field notebook.

4.6.1 Preparation of Location

Prior to starting the sampling procedure, the area around the MW or sampling location will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the location. New, clean plastic (4 to 6 mil) will be placed around the location well to prevent the contamination of both the ground surface and any equipment that may come into contact with the ground surface.

4.6.2 Water Level and Total Depth Measurements

Prior to removing any water from MPs or MWs, the static water level will be measured. An electrical water level probe will be used to measure the depth to groundwater below the datum to the nearest 0.01 foot. If the total depth of the MW or MP is not known or is suspected to be inaccurate, the total depth will be measured by slowly lowering the water level probe to the bottom of the MW or MP. Total depth will be measured to the nearest 0.01 foot. Total depth will only be measured when absolutely necessary to minimize the amount of sediment disturbance in the well. Based on water level and total depth information, the volume of water to be purged will be calculated.

4.6.3 Monitoring Point and Monitoring Well Purging

The static groundwater inside each MP will be purged using a peristaltic pump. The well will be purged at a low flow rate [10 milliliters per minute (ml/min) to 1,000 ml/min]. The objective of the low flow purging is to remove a small volume of water at a low flow rate from a discrete portion of the screened interval of the well without significantly disturbing, aerating, or agitating the water within the casing or causing a significant amount of drawdown in the formation.

MWs will be purged using either dedicated bladder pumps or downhole electric pumps. Purging techniques for existing MWs should follow the historical procedures used for each MW. Unless specifically stated otherwise is the site-specific work plan, the volume of water contained within the MW or MP casing at the time of sampling will be calculated, and a minimum of three times the calculated volume will be removed. The actual purged volume will be determined by stabilization of measurements for temperature, conductivity, dissolved oxygen (DO), and pH.

During both MP and MW purging, the pH, temperature, dissolved oxygen, and specific conductivity will be continuously monitored during purging using a flow-through cell. If a peristaltic pump is used for purging and sample collection, the flow-through cell will be attached directly to the discharge tubing of the peristaltic pump using new, dedicated polyethylene tubing. Purging will continue until the parameters have stabilized (less than 0.2 standard pH units or a 10-percent change for the other parameters over a 5-minute period) and the water is clear and free of fines.

Research conducted on low-flow micropurging has found that dissolved oxygen and specific conductance readings are the most useful field indicator parameters for stabilization of background water chemistry during purging (Barcelona, *et. al.*, 1994). The research also concluded that stabilization of dissolved oxygen and specific conductance shows some correlation to stabilization of VOC concentrations in "formation" waters.

If required, Parsons ES will be responsible for sampling, laboratory analysis, and arranging for the offsite disposal of any contaminated or potentially contaminated purge and development water. It is anticipated that at most facilities, purge water will be clean enough to be disposed of at Base wastewater or groundwater treatment facilities in accordance with local waste handling procedures for investigation-derived waste (IDW).

If off-Base disposal is required, all purge water will be placed in DOT-approved 55-gallon containers and transported and disposed of properly. Any drums or temporary holding tanks will be staged and temporarily stored onsite until analytical results are received to confirm disposal requirements. Disposal procedures will be detailed in the site-specific work plan.

4.6.4 Sample Extraction and Collection

For each MP, a peristaltic pump with new, dedicated tubing will be used to extract groundwater samples for all analyses. For MWs purged using downhole electric pumps, bailers will be used for collecting samples. Sample extraction equipment will be gently lowered into the water to prevent splashing and extracted gently to prevent creation of an excessive vacuum in the well. The sample will be transferred directly to the appropriate sample container. Where bailers are used, the water sample will be transferred from the bottom of the bailer using a bottom emptying device to allow a controlled flow into the sample container. Water from the peristaltic pump will be directly discharged into the sample container. The water should be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample. Sample containers for VOC analysis will be filled at approximately 200 ml/min and all other sample collection rates will not exceed 400 ml/min.

Surface water samples will be collected using a peristaltic pump following the same procedures used for MPs, except that purging will only be required for the tubing itself. Alternatively, surface water samples will be collected directly into the sample bottle by submerging the sample bottle beneath the surface of the water and allowing the water to slowly fill the bottle without exposure to the atmosphere. The sample bottle will be capped while submerged to prevent capture of air bubbles in the sample vial.

Unless other instructions are given by the analytical laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be placed into the containers used for well purge waters and disposed of in accordance with procedures detailed Section 4.6.3 and in the site-specific work plan.

4.7 ONSITE CHEMICAL PARAMETER MEASUREMENT

Because many chemical parameters of a groundwater sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field using Hach® or CHEMetrics® test kits. The following discussion describes the field procedures for obtaining the onsite chemical parameter measurements. The manufacturer's published calibration procedure, if any, for the instruments used for onsite parameter measurement will be followed.

Groundwater quality measurements such as temperature, pH, specific conductivity, dissolved oxygen, and reduction/oxidation (redox) potential will be continuously monitored during well purging using a flow-through cell. The flow-through cell will be attached directly to the discharge tubing of the peristaltic pump using new, dedicated

polyethylene tubing. All groundwater quality measuring equipment which could potentially contact the water sample will be decontaminated following the procedures described in Section 4.4. The groundwater quality measuring equipment will be calibrated daily, or more often if required by the manufacturer, following the manufacturer's recommended calibration procedures. The measurements observed immediately before groundwater sampling begins will be considered the final measurements for the sample and will be recorded in the field notebook and/or on the groundwater sampling form.

Groundwater quality measurements such as nitrate, nitrite, manganese, ferrous iron, sulfate, sulfide, and alkalinity may be measured in the field using HACH® or CHEMetrics® field analysis methods. All appropriate equipment and glassware associated with the field analysis of groundwater samples will be decontaminated following the procedures described in Section 4.4. Groundwater samples for these measurements will be collected after all sample containers for laboratory analyses have been collected. Two 250-ml bottles of groundwater will be collected and capped for field analysis. The field analysis of groundwater samples will begin immediately after collection. Direct sunlight, contact with air, and high temperatures may greatly affect the concentrations of the analytes in question. If possible, analyses will be run indoors, and groundwater samples will be capped and stored in a cooler with a temperature maintained at 4°C when not in use. Duplicate analyses will be run at a frequency of 10 percent, or one duplicate sample for every ten field analyses. One blank (distilled water) analysis will be performed for each sampling round.

4.8 LABORATORY SAMPLE HANDLING

This section describes the handling of samples to be analyzed by the fixed-based laboratory from the time of sampling until the samples arrive at the laboratory.

4.8.1 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the laboratory. The sample containers will be filled as described in Section 4.6.4, and the container lids will be tightly closed. Container lids will not be removed at any time prior to sample collection. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (groundwater, surface water, etc.);
- Sampling date;
- Sampling time;
- Preservatives added; and
- Sample collector's initials.

4.8.2 Sample Preservation

The laboratory will add any necessary chemical preservatives prior to shipping the containers to the site. Samples will be properly prepared for transportation to the laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of 4°C.

4.8.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to an analytical laboratory certified to perform the requested analysis. The analytical laboratory to be used at each site will be specified in the site-specific work plan. Samples will be shipped priority overnight via Federal Express®. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Label shipping container with:
  - Sample collector's name, address, and telephone number;
  - Laboratory's name, address, and telephone number;
  - Description of sample;
  - Quantity of sample; and
  - Date of shipment.

The packaged samples will be delivered to the laboratory as soon as possible after sample acquisition, and within method-specific holding times.

4.8.4 Chain-of-Custody Control

After the samples have been collected, chain-of-custody procedures will be followed as described in Section 3.4.4.

4.8.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the Parsons ES field scientist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of

- Sample appearance,
- Sample odor;

- Weather conditions;
- Water level prior to purging;
- Total well depth;
- Approx Purge volume;
- Water level after purging;
- Well condition;
- Sampler's identification;
- Field measurements of pH, temperature, and specific conductivity; and
- Any other relevant information.

Groundwater/surface water sampling activities will be recorded on a groundwater sampling form or in the field scientist's field notebook. Figure 4.1 shows an example of the groundwater sampling record.

4.9 LABORATORY ANALYSES

Laboratory analyses will be performed on all groundwater/surface water samples and the required QA/QC samples (see Section 4.10). The analytical methods and detection limit requirements for sampling events will be detailed in the site-specific work plan. Prior to sampling, arrangements will be made with the laboratory to provide a sufficient number of appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with laboratory protocol.

Laboratory personnel will specify any additional QC samples and prepare bottles for all samples. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory prior to shipping. Shipping containers with adequate padding will be sent by the laboratory to the site. Sampling personnel will fill the sample containers and return the samples to the laboratory.

4.10 QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES AND SAMPLING

Field QA/QC samples for groundwater/surface water sampling will include collection of field duplicates; equipment rinseate samples; and field and trip blanks. Analyte-appropriate containers and chain-of-custody procedures for sample handling and tracking will be used. All samples to be transferred to the analytical laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., groundwater/surface water), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packaged in coolers with ice to maintain an approximate temperature of 4°C.

SAMPLING LOCATION _____
SAMPLING DATE(S)_____

GROUND WATER SAMPLING RECORD - MONITORING WELL _____
(number)

REASON FOR SAMPLING: [ ] Regular Sampling; [ ] Special Sampling;
DATE AND TIME OF SAMPLING: _____, 19___ _____ a.m./p.m.
SAMPLE COLLECTED BY: _____ of _____
WEATHER: _____
DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____
_____
_____
_____

MONITORING WELL CONDITION:

[ ] LOCKED: [ ] UNLOCKED
WELL NUMBER (IS - IS NOT) APPARENT
STEEL CASING CONDITION IS: _____
INNER PVC CASING CONDITION IS: _____
WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT
[ ] DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR
[ ] MONITORING WELL REQUIRED REPAIR (describe): _____
_____
_____

Check-off

1 [ ] EQUIPMENT CLEANED BEFORE USE WITH _____
Items Cleaned (List): _____
_____
_____

2 [ ] WATER DEPTH _____ FT. BELOW DATUM
Measured with: _____

3 [ ] WATER-CONDITION BEFORE WELL EVACUATION (Describe):
Appearance: _____
Odor: _____
Other Comments: _____

4 [ ] WELL EVACUATION:
Method: _____
Volume Removed: _____
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: _____
Other comments: _____

Figure 4.1

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature.

Groundwater/surface water QA/QC sampling frequency will be 10 percent or one sample for every ten locations sampled. This ten percent frequency applies to both equipment rinseate samples and field duplicates. In the event that less than ten locations will be sampled in an event, a minimum of one QA/QC sample will be collected. At least one ambient blank (field blank) and decontamination water blank will be collected per sampling event. One trip blank will be sent with each sample shipment. The procedures for the collection of field QA/QC samples are described in Section 5. The laboratory will conduct one matrix spike analysis, one laboratory control sample, and one laboratory blank test for each specific analysis requested.

SECTION 5

FIELD QUALITY ASSURANCE/QUALITY CONTROL SAMPLES

As a check on field sampling, QA/QC samples will be collected during each sampling event. Definitions for field QA/QC samples are presented below.

5.1 FIELD DUPLICATES

A field duplicate is defined as two or more samples collected independently at the same sampling location during a single act of sampling. Soil and sediment samples are divided into two equal parts (replicates) for analysis. Field duplicates will be indistinguishable from other samples by the laboratory. Each of the field duplicates will be uniquely identified with a coded identifier, which will be in the same format as other sample identifiers. Duplicate sample results are used to assess the precision of the sample collection process. During the collection of VOC samples, compositing should not be performed due to the potential for target compound loss. Ten percent of all field samples will be field duplicates.

5.2 TRIP BLANKS

The trip blank is used to indicate potential contamination by VOCs or SVOCs during sample shipping and handling. A trip blank consists of analyte-free laboratory reagent water in a 40-milliliter (ml) glass vial sealed with a Teflon® septum. The blank accompanies the empty sample bottles to the field and is placed in each cooler containing water or soil matrix VOC/SVOC samples returning to the laboratory for analysis. The trip blank is not opened until analysis in the laboratory with the corresponding site samples.

5.3 EQUIPMENT RINSEATE BLANKS

Equipment rinseate blanks consist of reagent grade water poured into or pumped through the sampling device following decontamination. The rinseate is transferred to an appropriate sample bottle for the analysis and transported to the laboratory. The equipment rinseate samples are analyzed for the same laboratory parameters as the site samples. Equipment blanks are used to measure to contamination introduced to a sample set from improperly decontaminated sampling equipment.

5.4 DECONTAMINATION WATER BLANK

A decontamination water blank is designed to check the purity of potable water used for equipment decontamination during the field operation. One decontamination water blank will be collected for each water source used during the field work. Decontamination water blanks are collected by filling the appropriate sample container directly from the potable water source. Decontamination water blanks are labeled, preserved, handled, and shipped in the same manner as an environmental water sample. The blank will be analyzed for the same analytes and parameters as the environmental samples.

5.5 FIELD BLANKS

A field blank is designed to assess the effects of ambient field conditions on sample results. A field blank will consist of a sample of reagent grade water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for the same analytes and parameters as the environmental samples.

SECTION 6

FIELD DATA REDUCTION, VALIDATION, AND REPORTING

The following sections describe field analytical instrumentation calibration, and field data reporting, validation, reduction, and review.

6.1 CALIBRATION PROCEDURES AND FREQUENCY FOR FIELD TEST EQUIPMENT

Instruments and equipment used to gather, generate, or measure environmental data in the field will be calibrated with sufficient frequency and in such a manner that accuracy and reproducibility of results are consistent with the manufacturer's specifications. Field instruments may include a soil gas GasTech™ multi-gas or Trace-Techtor® meter, pH meter, digital thermometer, O_2/CO_2 meter, specific conductivity meter, DO meter, oxidation/reduction potential meter, and Hach® colorimeter. A summary of calibration frequency and acceptance criteria is presented in Table 6.1.

6.2 FIELD DATA REDUCTION

During processing of field data, validation checks will be performed by individuals designated by the project manager. The purpose of these checks is to identify outliers; that is, data which do not conform within two standard deviations to the pattern established by other observations. The Students "t" test will be used to identify outliers when the total number of samples is less than 31, and the normal distribution will be used to identify others when the total number of samples is greater than 31. Although outliers may be the result of transcription errors or instrument breakdowns, they may also be manifestations of a greater degree of spatial or temporal variability than expected. Therefore, after an outlier has been identified, a decision must be made concerning its further use. Obvious mistakes in data will be corrected when possible, and the corrected values will be inserted. If the correct value cannot be obtained, the datum may be excluded. An attempt will be made to explain the existence of the outlier. If no plausible explanation can be found for the outlier, it may be excluded, and a note to that effect will be included in the report. Also, an attempt will be made to determine the effect of the outlier both when included in and when excluded from the data set, and the results will be discussed in the report. In addition, the data will be compared against those obtained in previous investigations (where available) and against applicable standards and guidelines.

6.3 REVIEW OF FIELD RECORDS

All field records are evaluated for the following:

TABLE 6.1
FIELD SCREENING METHODS ANALYTICAL PROTOCOL
SUMMARY OF QC [a] PROCEDURES
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO REMEDIATION

Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]	Reporting Limit
SW9050	Conductance	Calibration with potassium chloride standard	Once per day at beginning of testing	± 5%	If calibration is not achieved, check meter, standards, and probe; recalibrate	0.02 µmhos/cm
		Field duplicate	10% of field samples	± 5%	Correct problem, repeat measurement	
SW9040	pH (water)	2-point calibration with pH buffers	Once per day at beginning of testing	± 0.05 pH units for every buffer	If calibration is not achieved, check meter, buffer solutions, and probe; replace if necessary; repeat calibration	pH units
		pH 7 buffer	At each sample location	± 0.1 pH units	Correct problem, recalibrate	
		Field duplicate	10% of field samples	± 0.1 pH units	Correct problem, repeat measurement	
E170.1	Temperature	Field duplicate	10% of field samples	± 1.0°C[c]	Correct problem, repeat measurement	°C
ASTM[d] D1498	Oxidation-reduction potential	Calibration with one standard	Once per day at beginning of testing	Two successive readings ± 10 millivolts	Correct problem, recalibrate	pe[e] units
		Field duplicate	10% of field samples	± 10 millivolts	Correct problem, repeat measurement	
Hach™ 8221	Alkalinity	Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by standard solutions, and optical cell; replace if necessary; repeat calibration check	20.0 mg/L[f]
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	

TABLE 6.1 (Continued)
FIELD SCREENING METHODS ANALYTICAL PROTOCOL
SUMMARY OF QC PROCEDURES
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO REMEDIATION

Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]	Reporting Limit
E360.1	Dissolved oxygen	Calibration check with one standard, and zero meter with sodium sulfate solution	Once per day at beginning of testing	± 5 %	Correct problem by checking meter, standard solutions, replace if necessary; repeat calibration check	0.5 mg/L
		Field duplicate	10% of field samples	RPD[a/] < 20%	Correct problem, repeat measurement	
HACH™ 8039	Nitrate (NO_3)	Calibration check with one standard, and zero meter w/sodium sulfate solution	Once per day at beginning of testing	± 5 %	Correct problem by checking meter, standard solutions, replace if necessary; repeat calibration check	0.07 mg/L
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	
HACH™ 8040	Nitrite (NO_2)	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	0.01 mg/L
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	

TABLE 6.1 (Continued)
FIELD SCREENING METHODS ANALYTICAL PROTOCOL
SUMMARY OF QC PROCEDURES
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO REMEDIATION

Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]	Reporting Limit
Hach™ 8146	Ferrous Iron (Fe^{2+})	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	0.024 mg/L
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	
Hach™ 8034	Manganese	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	0.024 mg/L
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	
Hach™ 8131	Hydrogen Sulfide (H_2S)	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	0.024 mg/L

TABLE 6.1 (Continued)
FIELD SCREENING METHODS ANALYTICAL PROTOCOL
SUMMARY OF QC PROCEDURES
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO REMEDIATION

Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]	Reporting Limit
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	
HACH™ 8051	Sulfate (SO_4^{-2})	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	0.01 mg/L
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	
HACH™ 8131	Sulfide (S^{-2})	Calibration check with one standard	Once per day at beginning of testing	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	NA [b/]
		Accuracy check, (3 concentration points)	Once per day	± 50 %	Correct problem by checking meter, standard solutions, and optical cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	

TABLE 6.1 (Continued)
FIELD SCREENING METHODS ANALYTICAL PROTOCOL
SUMMARY OF QC PROCEDURES
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO REMEDIATION

Method	Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b/]	Reporting Limit
Gas Tech Multi-gas Meter	TVH and Methane	Accuracy check, (2 concentration points)	Once per day	± 20 %	Correct problem by checking meter, chech gas standards, correlate with lab analysis	20 ppmv
		Field duplicate	10% of field samples	± 20 %	Correct problem, repeat measurement	
Gas Tech Multi-gas Meter	Oxygen, Carbon Dioxide	Calibration check with ambient air and one standard	Once per day at beginning of testing	± 10 %	Correct problem by checking meter, gas standards, and reaction cell; replace if necessary; repeat calibration check	0.5 %
		Accuracy check, (2 concentration points)	Once per day	± 10 %	Correct problem by checking meter, gas standard , and reaction cell; replace if necessary; repeat calibration check	
		Field duplicate	10% of field samples	± 10 %	Correct problem, repeat measurement	

a/ QC = quality control.
b/ All corrective actions will be documented, and the records will be maintained by the prime contractor.
c/ °C = degrees Celsius.
d/ ASTM = American Society for Testing and Materials.
e/ pe = potential platinum electrode.
f/ mg/L = milligrams per liter.
g/ RPD = relative percent difference.
h/ NA = not applicable.

Completeness of field records. The check of field record completeness will ensure that all requirements for field activities have been fulfilled, complete records exist for each field activity, and that the procedures specified in the SAP (or approved as field change requests) were implemented. Field documentation will ensure sample integrity and provide sufficient technical information to recreate each field event. The results of the completeness check will be documented, and environmental data affected by incomplete records will be identified in the technical report.

Identification of valid samples. The identification of valid samples involves interpretation and evaluation of the field records to detect problems affecting the representativeness of environmental samples. For example, field records can indicate whether a well is properly constructed or if unanticipated environmental conditions were encountered during construction. The lithologic and geophysical logs may be consulted to determine if a well is screened only in the water-bearing zone of concern. Records also should note sample properties such as clarity, color, odor, etc. Photographs may show the presence or absence of obvious sources of potential contamination, such as operating combustion engines near a well during sampling. Judgments of sample validity will be documented in the technical report, and environmental data associated with poor or incorrect field work will be identified.

Correlation of data. The results of field tests obtained from similar areas will be correlated. For example, soil gas TVH readings and VOC analysis results may be correlated. The findings of these correlations will be documented, and the significance of anomalous data will be discussed in the technical report.

Identification of anomalous field test data. Anomalous field data will be identified and explained to the extent possible. For example, a water temperature for one well that is significantly higher than any other well temperature in the same aquifer will be explained in the technical report.

Accuracy and precision of field data and measurements. The assessment of the quality of field measurements will be based on instrument calibration records and a review of any field corrective actions. The accuracy and precision of field measurements will be discussed.

Field record review is an ongoing process. Field team leaders will be responsible for ensuring that proper documentation is recorded during each site's sampling activities.

6.4 FIELD DATA VALIDATION AND REPORTING

The contractor analyst will review 100 percent of all screening data prior to reporting. Screening data will constitute all analytical method results from analyses performed in the field laboratory environment. The contractor will determine if their data quality objectives (DQOs) for field data have been met, and also will calculate the percent complete (PC) for field data results.

At a minimum, the review of screening data will focus on the following topics:

- Holding times;

- Method blanks;
- Field instrumentation detection limits;
- Analytical batch control records including calibrations, and spike recoveries;
- Completeness of data; and
- Flag all results with an "S" to denote sample results from field screening versus fixed laboratory results.

Field data will be validated using four different procedures, as described below:

- Routine checks (e.g., looking for errors in identification codes) will be made during the processing of data.
- Internal consistency of a data set will be evaluated. This step will involve plotting the data and testing for outliers.
- Checks for consistency of the data set over time will be performed. This can be accomplished by comparing data sets against gross upper limits obtained from historical data sets, or by testing for historical consistency. Anomalous data will be identified.
- Checks may be made for consistency with parallel data sets. An example of such a check would be comparing data from the same region of the aquifer or volume of soil.

SECTION 7

FIXED-BASE LABORATORY ANALYTICAL PROCEDURES

Application of a specific analytical method depends on the sample matrix and the analytes to be identified. Methods for each of the parameters likely to be included in the analytical program, as well as detection limits, are discussed in the following subsections. All analytical methods are USEPA approved.

7.1 ANALYTICAL METHODS

Analytical procedures will follow the established USEPA and/or American Society for Testing and Materials (ASTM) methods as recommended by AFCEE wherever such methods exist for a specified analyte. All approved methods are presented in Table 7.1. The referenced methods are defined in the following documents:

- USEPA (1983) *Methods for Chemical Analysis of Water and Wastes*, EPA 600/4-79-020.
- USEPA (1995) *Test Methods for Evaluating Solid Waste, Physical and Chemical Methods*, SW846, 3rd Edition , Update IIB.
- *American Society for Testing and Materials Methods* (ASTM, 1995).

7.1.2 Detection and Quantitation Limits

This section describes the terms, definitions, and formulas that will be used for detection and quantitation limits.

7.1.3 Instrument Detection Limit

The instrument detection limit (IDL) reflects the instrument operating efficiency, not sample preparation or concentration/dilution factors. The IDL is operationally defined as three times the standard deviation of seven replicate analyses of the lowest concentration that is statistically different from a blank. This represents 99-percent confidence that the signal identified is the result of the presence of the analyte, and not random noise.

7.1.4 Method Detection Limit

The method detection limit (MDL) is the lowest concentration at which a specific analyte in a matrix can be measured and reported with 99-percent confidence that the analyte concentration is greater than zero. MDLs are experimentally determined and

TABLE 7.1
PRACTICAL QUANTITATION LIMITS
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Water		Soil	
		PQL[a]	Unit	PQL	Unit
Aromatic Volatile Organics Compounds SW5030A/SW8020A (W[d], S[c])	1,2-Dichlorobenzene	4.0	µg/L[b]	0.004	mg/kg[c]
	1,3-Dichlorobenzene	4.0	µg/L	0.004	mg/kg
	1,4-Dichlorobenzene	3.0	µg/L	0.003	mg/kg
	Benzene	2.0	µg/L	0.002	mg/kg
	Chlorobenzene	2.0	µg/L	0.002	mg/kg
	Ethylbenzene	2.0	µg/L	0.002	mg/kg
	Toluene	2.0	µg/L	0.002	mg/kg
	Xylenes, Total	2.0	µg/L	0.002	mg/kg
Methane SW3810 Modified (W)	Methane	2.0	µg/L	NA[d]	NA
	Ethane	4.0	µg/L	NA	NA
	Ethene	2.0	µg/L	NA	NA
Volatile Organics SW5030A/SW8260A (W, S)	1,1,1,2-Tetrachloroethane	0.5	µg/L	0.003	mg/kg
	1,1,1-Trichloroethane	0.8	µg/L	0.004	mg/kg
	1,1,2,2-Tetrachloroethane	0.4	µg/L	0.002	mg/kg
	1,1,2-Trichloroethane	1.0	µg/L	0.005	mg/kg
	1,1-Dichloroethane	0.4	µg/L	0.002	mg/kg
	1,1-Dichloroethene	1.2	µg/L	0.006	mg/kg
	1,1-Dichloropropene	1.0	µg/L	0.005	mg/kg
	1,2,3-Trichlorobenzene	0.3	µg/L	0.002	mg/kg
	1,2,3-Trichloropropane	3.2	µg/L	0.02	mg/kg
	1,2,4-Trichlorobenzene	0.4	µg/L	0.002	mg/kg
	1,2,4-Trimethylbenzene	1.3	µg/L	0.007	mg/kg
	1,2-Dichloroethane	0.6	µg/L	0.003	mg/kg
	1,2-Dichlorobenzene	0.3	µg/L	0.002	mg/kg
	1,2-Dibromo-3-Chloropropane	2.6	µg/L	0.01	mg/kg
	1,2-Dichloropropane	0.4	µg/L	0.002	mg/kg
	1,2-Dibromoethane	0.6	µg/L	0.003	mg/kg
	1,3,5-Trimethylbenzene	0.5	µg/L	0.003	mg/kg
	1,3-Dichlorobenzene	1.2	µg/L	0.006	mg/kg
	1,3-Dichloropropane	0.4	µg/L	0.002	mg/kg
	1,4-Dichlorobenzene	0.3	µg/L	0.002	mg/kg
	1-Chlorohexane	0.5	µg/L	0.003	mg/kg
	2,2-Dichloropropane	3.5	µg/L	0.02	mg/kg
	2-Chlorotoluene	0.4	µg/L	0.002	mg/kg
	4-Chlorotoluene	0.6	µg/L	0.003	mg/kg
	Benzene	0.4	µg/L	0.002	mg/kg
	Bromobenzene	0.3	µg/L	0.002	mg/kg
	Bromochloromethane	0.4	µg/L	0.002	mg/kg
	Bromodichloromethane	0.8	µg/L	0.004	mg/kg
	Bromoform	1.2	µg/L	0.006	mg/kg
	Bromomethane	1.1	µg/L	0.005	mg/kg
	Carbon Tetrachloride	2.1	µg/L	0.01	mg/kg
	Chlorobenzene	0.4	µg/L	0.002	mg/kg
	Chloroethane	1.0	µg/L	0.005	mg/kg

TABLE 7.1 (Continued)
PRACTICAL QUANTITATION LIMITS
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Water		Soil	
		PQL[a]	Unit	PQL	Unit
Volatile Organics (Cont)	Chloroform	0.3	µg/L	0.002	mg/kg
SW5030A/SW8260A	Chloromethane	1.3	µg/L	0.007	mg/kg
(W, S)	Cis-1,2-Dichloroethene	1.2	µg/L	0.006	mg/kg
	Cis-1,3-Dichloropropene	1.0	µg/L	0.005	mg/kg
	Dibromochloromethane	0.5	µg/L	0.003	mg/kg
	Dibromomethane	2.4	µg/L	0.01	mg/kg
	Dichlorodifluoromethane	1.0	µg/L	0.005	mg/kg
	Ethylbenzene	0.6	µg/L	0.003	mg/kg
	Hexachlorobutadiene	1.1	µg/L	0.005	mg/kg
	Isopropylbenzene	0.5	µg/L	0.008	mg/kg
	m-Xylene	0.5	µg/L	0.003	mg/kg
	Methylene Chloride	0.3	µg/L	0.002	mg/kg
	n-Butylbenzene	1.1	µg/L	0.005	mg/kg
	n-Propylbenzene	0.4	µg/L	0.002	mg/kg
	Naphthalene	0.4	µg/L	0.002	mg/kg
	o-Xylene	1.1	µg/L	0.005	mg/kg
	p-Isopropyltoluene	1.2	µg/L	0.006	mg/kg
	p-Xylene	1.3	µg/L	0.007	mg/kg
	Sec-Butylbenzene	1.3	µg/L	0.007	mg/kg
	Styrene	0.4	µg/L	0.002	mg/kg
	Tricholoroethene	1.0	µg/L	0.01	mg/kg
	Tert-Butylbenzene	1.4	µg/L	0.007	mg/kg
	Tetrachloroethylene	1.4	µg/L	0.007	mg/kg
	Toluene	1.1	µg/L	0.005	mg/kg
	Trans-1,2-Dichloroethene	0.6	µg/L	0.003	mg/kg
	Trans-1,3-Dichloropropene	1.0	µg/L	0.005	mg/kg
	Trichlorofluoromethane	0.8	µg/L	0.004	mg/kg
	Vinyl Chloride	1.1	µg/L	0.009	mg/kg
Semivolatile Organics	1,2,4-Trichlorobenzene	10.0	µg/L	0.7	mg/kg
Base/Neutral	1,2-Dichlorobenzene	10.0	µg/L	0.7	mg/kg
Extractables					
SW3510B/SW8270B (W)	1,3-Dichlorobenzene	10.0	µg/L	0.7	mg/kg
SW3550A/SW8270B (S)	1,4-Dichlorobenzene	10.0	µg/L	0.7	mg/kg
	2,4-Dinitrotoluene	10.0	µg/L	0.7	mg/kg
	2,6-Dinitrotoluene	10.0	µg/L	0.7	mg/kg
	2-Chloronaphthalene	10.0	µg/L	0.7	mg/kg
	2-Methylnaphthalene	10.0	µg/L	0.7	mg/kg
	2-Nitroaniline	50.0	µg/L	3.3	mg/kg
	3-Nitroaniline	50.0	µg/L	3.3	mg/kg
	3.3'-Dichlorobenzidine	20.0	µg/L	1.3	mg/kg
	4-Bromophenyl Phenyl Ether	10.0	µg/L	0.7	mg/kg
	4-Chloroaniline	20.0	µg/L	1.3	mg/kg
	4-Chlorophenyl Phenyl Ether	10.0	µg/L	0.7	mg/kg
	4-Nitroaniline	50.0	µg/L	3.3	mg/kg
	Acenaphthylene	10.0	µg/L	0.7	mg/kg

TABLE 7.1 (Continued)
PRACTICAL QUANTITATION LIMITS
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Water		Soil	
		PQL[a]	Unit	PQL	Unit
Semivolatile Organics	Acenapthene	10.0	µg/L	0.7	mg/kg
Base/Neutral	Anthracene	10.0	µg/L	0.7	mg/kg
Extractables					
SW3510B/SW8270B (W)	Benz (a) Anthracene	10.0	µg/L	0.7	mg/kg
SW3550A/SW8270B (S)	Benzo (a) Pyrene	10.0	µg/L	0.7	mg/kg
(Cont)	Benzo (b) Fluoranthene	10.0	µg/L	0.7	mg/kg
	Benzo (g,h,i) Perylene	10.0	µg/L	0.7	mg/kg
	Benzyl Alcohol	20.0	µg/L	1.3	mg/kg
	Bis (2-Chlorethyl) Ether	10.0	µg/L	0.7	mg/kg
	Bis (2-Chloroethoxy) Methane	10.0	µg/L	0.7	mg/kg
	Bis (2-Chloroisopropyl) Ether	10.0	µg/L	0.7	mg/kg
	Bis (2-Ethylhexyl) Phthalate	10.0	µg/L	0.7	mg/kg
	Butyl Benzylphthalate	10.0	µg/L	0.7	mg/kg
	Chrysene	10.0	µg/L	0.7	mg/kg
	Di-n-Butylphthalate	10.0	µg/L	0.7	mg/kg
	Di-n-Octylphthalate	10.0	µg/L	0.7	mg/kg
	Dibenz (a,h) Anthracene	10.0	µg/L	0.7	mg/kg
	Dibenzofuran	10.0	µg/L	0.7	mg/kg
	Diethyl Phthalate	10.0	µg/L	0.7	mg/kg
	Dimethly Phthalate	10.0	µg/L	0.7	mg/kg
	Fluoranthene	10.0	µg/L	0.7	mg/kg
	Fluorene	10.0	µg/L	0.7	mg/kg
	Hexachlorobenzene	10.0	µg/L	0.7	mg/kg
	Hexachlorobutadiene	10.0	µg/L	0.7	mg/kg
	Hexachlorocyclopentadiene	10.0	µg/L	0.7	mg/kg
	Hexachloroethane	10.0	µg/L	0.7	mg/kg
	Indeno (1,2,3-cd) Pyrene	10.0	µg/L	0.7	mg/kg
	Isophorone	10.0	µg/L	0.7	mg/kg
	n-Nitrosodiphenylamine	10.0	µg/L	0.7	mg/kg
	n-Nitrosodi-n-Propylamine	10.0	µg/L	0.7	mg/kg
	Naphthalene	10.0	µg/L	0.7	mg/kg
	Nitrobenzene	10.0	µg/L	0.7	mg/kg
	Phenanthrene	10.0	µg/L	0.7	mg/kg
	Pyrene	10.0	µg/L	0.7	mg/kg
Semivolatile Organics	2,4,5-Trichlorophenol	50.0	µg/L	3.3	mg/kg
Acid Extractables	2,4,6-Trichlorophenol	10.0	µg/L	0.3	mg/kg
SW3510B/SW8270B (W)	2,4-Dichlorophenol	10.0	µg/L	0.3	mg/kg
SW3550A/SW8270B (S)	2,4-Dimethylphenol	10.0	µg/L	0.3	mg/kg
	2,4-Dinitrophenol	50.0	µg/L	3.3	mg/kg
	2-Chlorophenol	10.0	µg/L	0.3	mg/kg
	2-Methylphenol	10.0	µg/L	0.3	mg/kg
	2-Nitrophenol	10.0	µg/L	0.3	mg/kg
	4,6-Dinitro-2-Methylphenol	50.0	µg/L	3.3	mg/kg
	4-Chloro-3-Methylphenol	20.0	µg/L	1.3	mg/kg
	4-Methylphenol	10.0	µg/L	0.3	mg/kg

TABLE 7.1 (Continued)
PRACTICAL QUANTITATION LIMITS
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Water		Soil	
		PQL[a]	Unit	PQL	Unit
	4-Nitrophenol	50.0	µg/L	1.6	mg/kg
Semivolatile Organics Acid Extractables SW3510B/SW8270B (W) SW3550A/SW8270B (S) (Cont)	Benzoic Acid	50.0	µg/L	1.6	mg/kg
	Pentachlorophenol	50.0	µg/L	3.3	mg/kg
	Phenol	10.0	µg/L	0.3	mg/kg
Polynuclear Aromatic Hydrocarbons SW3510B/SW8310 (W) SW3550A/SW8310 (S)	Acenaphthene	18.0	µg/L	1.2	mg/kg
	Acenaphthylene	23.0	µg/L	1.54	mg/kg
	Anthracene	6.6	µg/L	0.44	mg/kg
	Benz (a) Anthracene	0.13	µg/L	0.009	mg/kg
	Benzo (a) Pyrene	0.23	µg/L	0.015	mg/kg
	Benzo (b) Fluoranthene	0.18	µg/L	0.012	mg/kg
	Benzo (g,h,i) Perylene	0.76	µg/L	0.05	mg/kg
	Benzo (k) Fluoranthene	0.17	µg/L	0.011	mg/kg
	Chrysene	1.5	µg/L	0.1	mg/kg
	Dibenzo (a,h) Anthracene	0.3	µg/L	0.02	mg/kg
	Fluoranthrene	2.1	µg/L	0.14	mg/kg
	Fluorene	2.1	µg/L	0.14	mg/kg
	Indeno (1,2,3-c,d) Pyrene	0.43	µg/L	0.03	mg/kg
	Naphthalene	18.0	µg/L	1.2	mg/kg
	Phenanthrene	6.4	µg/L	0.42	mg/kg
	Pyrene	2.7	µg/L	0.18	mg/kg
ICP Screen for Metals SW3005A/SW6010A (W) SW3050A/SW6010A (S)	Aluminum	0.5	mg/L[a]	50.0	mg/kg
	Antimony	0.4	mg/L	40.0	mg/kg
	Arsenic	0.6	mg/L	60.0	mg/kg
	Barium	0.02	mg/L	2.0	mg/kg
	Beryllium	0.003	mg/L	0.3	mg/kg
	Cadmium	0.04	mg/L	4.0	mg/kg
ICP Screen for Metals SW3005A/SW6010A (W) SW3050A/SW6010A (S) (Cont)	Calcium	0.1	mg/L	10.0	mg/kg
	Chromium	0.07	mg/L	7.0	mg/kg
	Cobalt	0.07	mg/L	7.0	mg/kg
	Copper	0.06	mg/L	6.0	mg/kg
	Iron	0.07	mg/L	7.0	mg/kg
	Lead	0.5	mg/L	50.0	mg/kg
	Magnesium	0.3	mg/L	30.0	mg/kg
	Manganese	0.02	mg/L	2.0	mg/kg
	Molybdenum	0.08	mg/L	8.0	mg/kg
	Nickel	0.15	mg/L	15.0	mg/kg
	Potassium	5.0	mg/L	500.0	mg/kg
	Selenium	0.8	mg/L	80.0	mg/kg
	Silver	0.07	mg/L	7.0	mg/kg
	Sodium	0.3	mg/L	30.0	mg/kg
	Thallium	0.4	mg/L	40.0	mg/kg
	Vanadium	0.08	mg/L	8.0	mg/kg
	Zinc	0.02	mg/L	2.0	mg/kg

7.1(cont)

Table ~~7.2.8-1~~. PQLs for Method SW8081

Parameter/Method	Analyte	Water		Soil	
		PQL	Unit	PQL	Unit
Organochlorine Pesticides and PCBs SW3510B/SW8081 (W) SW3550A/SW8081 (S)	α-BHC	0.35	µg/L	0.019	mg/kg
	β-BHC	0.23	µg/L	0.033	mg/kg
	δ-BHC	0.24	µg/L	0.011	mg/kg
	γ-BHC (Lindane)	0.25	µg/L	0.020	mg/kg
	α-Chlordane	0.80	µg/L	0.015	mg/kg
	γ-Chlordane	0.37	µg/L	0.015	mg/kg
	4,4'-DDD	0.50	µg/L	0.042	mg/kg
	4,4'-DDE	0.58	µg/L	0.025	mg/kg
	4,4'-DDT	0.81	µg/L	0.036	mg/kg
	Aldrin	0.34	µg/L	0.022	mg/kg
	Dieldrin	0.44	µg/L	0.035	mg/kg
	Endosulfan I	0.30	µg/L	0.021	mg/kg
	Endosulfan II	0.40	µg/L	0.024	mg/kg
	Endosulfan Sulfate	0.35	µg/L	0.036	mg/kg
	Endrin	0.39	µg/L	0.036	mg/kg
	Endrin Aldehyde	0.50	µg/L	0.016	mg/kg
	Heptachlor	0.40	µg/L	0.020	mg/kg
	Heptachlor Epoxide	0.32	µg/L	0.021	mg/kg
	Methoxychlor	0.86	µg/L	0.057	mg/kg
	PCB-1016	1.00	µg/L	0.70	mg/kg
	PCB-1221	1.00	µg/L	0.70	mg/kg
	PCB-1232	1.00	µg/L	0.70	mg/kg
	PCB-1242	1.00	µg/L	0.70	mg/kg
	PCB-1248	1.00	µg/L	0.70	mg/kg
	PCB-1254	1.00	µg/L	0.70	mg/kg
	PCB-1260	1.00	µg/L	0.70	mg/kg
	Toxaphene	0.50	µg/L	0.57	mg/kg

TABLE 7.1 (Continued)
PRACTICAL QUANTITATION LIMITS
QUALITY ASSURANCE PROJECT PLAN
RISK-BASED APPROACH TO FUEL SPILL REMEDIATION

Parameter/Method	Analyte	Water		Soil	
		PQL[a]	Unit	PQL	Unit
SW3020A/SW7421 (W) SW3050A/SW7421 (S)	Lead	0.005	mg/L	0.5	mg/kg
SW3020A/SW7131 (W) SW3050A/SW7131 (S)	Cadmium	0.001	mg/L	0.1	mg/kg
Common Anions SW9056	Bromide	0.1	mg/L	0.1	mg/kg
	Chloride	0.2	mg/L	0.2	mg/kg
	Fluoride	0.2	mg/L	0.2	mg/kg
	Nitrate	0.1	mg/L	0.1	mg/kg
	Nitrite	0.4	mg/L	0.1	mg/kg
	Phosphate	0.1	mg/L	0.1	mg/kg
	Sulfate	0.2	mg/L	0.2	mg/kg
E160.1	Total Dissolved Solids	10.0	mg/L	NA	NA
E160.2	Total Suspended Solids	5.0	mg/L	NA	NA
E310.1	Alkalinity	10.0	mg/L	NA	NA
E353.1	Nitrogen, Nitrate/Nitrite	0.1	mg/L	NA	NA
SW9050	Conductance	NA	NA	NA	NA
SW9040	pH	NA	NA	NA	NA

SOURCE: AFCEE QAPP, Version 1.1, February 1996

[a] PQLs = practical quantitation limits. PQLs are equal to the project reporting limits.
µg/L = micrograms per liter.
mg/kg = milligrams per kilogram.
W = water.
S = soil.
NA = not applicable.
mg/L = milligrams per liter.

7.1 (cont)

Table ~~7.2.8-2~~. QC Acceptance Criteria for Method SW8081

Method	Analyte	Accuracy Water (% R)	Precision Water (% RPD)	Accuracy Soil (% R)	Precision Soil (% RPD)
SW8081	α-BHC	75–125	≤30	65–135	≤50
	β-BHC	51–125	≤30	41–133	≤50
	δ-BHC	75–126	≤30	65–136	≤50
	γ-BHC (Lindane)	73–125	≤30	63–130	≤50
	α-Chlordane	41–125	≤30	31–135	≤50
	γ-Chlordane	41–125	≤30	31–133	≤50
	4,4-DDD	48–136	≤30	38–146	≤50
	4,4-DDE	45–139	≤30	35–149	≤50
	4,4-DDT	34–143	≤30	25–153	≤50
	Aldrin	47–125	≤30	37–126	≤50
	Dieldrin	42–132	≤30	32–142	≤50
	Endosulfan I	49–143	≤30	39–153	≤50
	Endosulfan II	75–159	≤30	65–169	≤50
	Endosulfan Sulfate	46–141	≤30	36–151	≤50
	Endrin	43–134	≤30	33–144	≤50
	Endrin Aldehyde	75–150	≤30	65–160	≤50
	Heptachlor	45–128	≤30	35–138	≤50
	Heptachlor Epoxide	53–134	≤30	43–144	≤50
	Methoxychlor	73–142	≤30	63–152	≤50
	PCB-1016	54–125	≤30	44–127	≤50
	PCB-1221	41–126	≤30	31–136	≤50
	PCB-1232	41–126	≤30	31–136	≤50
	PCB-1242	39–150	≤30	29–160	≤50
	PCB-1248	41–126	≤30	31–136	≤50
	PCB-1254	29–131	≤30	25–141	≤50
	PCB-1260	41–126	≤30	31–136	≤50
	Toxaphene	41–126	≤30	31–136	≤50
	Surrogates:				
	DCBP	34–133		25–143	
	TCMX	45–125		35–135	

verified for each target analyte of the methods in the sampling program. The laboratory will determine MDLs for each analyte and matrix type prior to analysis of project samples. MDLs are based on the results of seven matrix spikes at the estimated MDL, and are statistically calculated in accordance with the Title 40, Code of Federal Regulations Part 136 (40 CFR 136). The standard deviation of the seven replicates is determined and multiplied by 3.14 (i.e., the 99-percent confidence interval from the one-sided Students T-test). MDLs must be determined annually as a minimum. The MDLs to be used are intended to allow that both nondetects and detects will be usable to the fullest extent possible for the project.

7.1.5 Project Reporting Limit

To define analytical data reporting limits that meet project DQOs, potential risk-based screening criteria were identified. State-specified "clean closure" concentrations, risk-based preliminary remediation goals (PRGs), regulatory concentrations, or other relevant soil, groundwater, and surface water action levels will be reviewed to identify the most stringent comparison criteria for each matrix likely to be applicable. The project reporting limits (PRLs), listed as the practical quantitation limits (PQL) in Table 7.1, will be reviewed in comparison to the risk-based screening criteria.

The PRL is equivalent to the current PQL guidance listed in the AFCEE (1996) QAPP. Because the project remediation goals are developed for risk-based site closure, all sample results will be the reported at or above the MDL for each analyte. All results above the MDL but below the PQL will be qualified in the data deliverable from the laboratory with a "FJ" flag. The "FJ" flag will denote the sample result as below the PQL (see Section 7.6.2). Where practical, MDLs must be lower than the risk-based criterion determined for the project. Laboratories must verify the PRLs by analyzing a standard at or below the PRL within the calibration curve.

All analytical results for soils (both nondetected and detected) will be reported on a dry-weight basis (i.e., corrected for moisture content). The moisture content for each soil sample will be reported. The equation for moisture content given for the SW-846 Method SW3550 is as follows:

$$\frac{\text{Initial Weight - Dried Weight}}{\text{Initial Weight}} \times 100 = \% \text{ moisture}$$

The result of the sample on a dry-weight basis is as follows:

$$\text{Result of analysis on wet weight basis} = \text{Result of analysis on a dry-weight basis} \quad \frac{}{100 - \% \text{ Moisture}}$$

7.1.6 Sample Quantitation Limit

Sample quantitation limits (SQLs) are defined as the MDL multiplied by the dilution factor (DF) required to analyze the sample, and corrected for moisture or sample size. These adjustments may be due to matrix effects or to the high concentrations of some analytes. For example, if an analyte is present at a concentration that is greater than the

linear range of the analytical method, the sample must be diluted for accurate quantitation. The DF raises the reporting limit, which then becomes the SQL. Because the reported SQLs take into account sample characteristics and analytical adjustments, they are the most relevant quantitation limits for evaluating nondetected chemicals.

7.1.7 Reporting Units

The following are the prescribed reporting units for all analytical methods:

Soil and sediment samples - organics: micrograms per kilogram (µg/kg), dry-weight basis;

Soil and sediment samples - inorganics/metals: milligrams per kilogram (mg/kg), dry-weight basis;

Water samples - inorganics/metals: milligrams per liter (mg/L); and

Water samples - organics: micrograms per liter (µg/L).

7.2 LABORATORY QUALITY CONTROL DATA

Laboratory QC data are necessary to determine the precision and accuracy of the analyses, confirm matrix interferences, and demonstrate target compound contamination of sample results. QC samples will be analyzed routinely by the analytical laboratory as part of the laboratory QC procedures. Contract laboratories performing definitive data quality analyses require a more stringent QC program than those performing screening-level data quality analyses. Definitions for QC samples are presented below. Frequency and acceptance requirements are defined in Table 7.2. All precision and accuracy control limit criteria are defined in Table 1.1.

7.2.1 Holding Time

Holding times for sample extraction and/or analysis as required by the methods will be met for all samples. The holding time is calculated from the date and time of sample collection to the time of sample preparation and/or analysis. All sample analyses to include dilutions and second-column confirmation will meet the required holding times. Results for samples exceeding holding time will be qualified as unusable (flagged "R"). Table 7.3 defines applicable method-specific analytical holding times.

7.2.3 Method Blanks

Method blanks are designed to detect contamination of the field samples in the laboratory environment. Method blanks verify that interferences caused by contaminants in solvents, reagents, glassware, or in other sample processing hardware are known and minimized. The method blank will be ASTM Type II water (or equivalent) for water samples, and a purified solid matrix (Ottawa sand or equivalent) for soil samples. The concentration of target compounds in the blanks must be less than

TABLE 7.2
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Aromatic Volatile Organic Compounds SW8020A and Alcohols SW8015B	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	RSD[c] < 20% for CFs[d] or Rfs[e] or >0.995 correlation coefficeint	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verification	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Initial calibration verification	Daily, before sample analysis	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within ±15% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL[f]	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS[g] for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Aromatic Volatile Organic Compounds SW8020A and Alcohols SW8015B (cont)	MDL[b] study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample
	MS/MSD[c]	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	Results reported between MDL and PRL	None	None	None
Volatile Organics SW8260A	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	SPCCs[d] average RF ≥ 0.30[b]; and RSD for all calibration analytes ≤ 30%	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±25% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Calibration verification	Daily, before sample analysis, every 12 hours of analysis time, and at end of analysis sequence	SPCCs average RF ≥ 0.30, and CCCs[d] < 20% drift; and all calibration analytes within ±25% of expected value	Correct problem then repeat initial calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria

LE . (Continued)

SUMMARY OF CALIBRATION AND QC[a] PROCEDURES

QUALITY ASSURANCE PROGRAM PLAN

RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Volatile Organics SW8260A (cont)	Check of mass spectral ion intensities using BFB[m]	Prior to initial calibration and calibration verification	Refer to criteria listed in the method description	Retune instrument and verify
	IS[n]	Every sample, spiked sample, standard, and method blank	Retention time ±30 seconds: EICP[o] area within -50% to +100% of last calibration verification (12 hours) for each	Inspect mass spectrometer or GC[p] for malfunctions; mandatory reanalysis of samples analyzed while system was malfunctioning
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then reextract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Semi-volatile Organics SW8270B	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	SPCCs average RF ≥ 0.05; and RSD for all calibration analytes ≤ 30%	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±25% of expected value	Correct problem then repeat initial calibration

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b]
Semi-volatile Organics SW8270B (cont)	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Calibration verification	Daily, before sample analysis, every 12 hours of analysis time, and at end of analysis sequence	SPCCs average RF ≥ 0.05; and CCCs < 20% drift; and all calibration analytes within ±25% of expected value	Correct problem then repeat initial calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Check of mass spectral ion intensities using DFTPP	Prior to initial calibration and calibration verification	Refer to criteria listed in the method description	Retune instrument and verify
	IS	Every sample, spiked sample, standard, and method blank	Retention time ±30 seconds: EICP area within -50% to +100% of last calibration verification (12 hours) for each	Inspect mass spectrometry or GC for malfunctions; mandatory reanalysis of samples analyzed while system was malfunctioning
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Semi-volatile Organics SW8270B (cont)	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Polynuclear Aromatic Hydrocarbons SW8310, Formaldehyde SW8315, Ethylene Glycol SW8315 modified, and Methyl Carbamate Pesticides SW8318	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	RSD[c] < 20% for CFs[d] or Rfs[e] or >0.995 correlation coefficeint	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Polynuclear Aromatic Hydrocarbons SW8310, Formaldehyde SW8315, Ethylene Glycol SW8315 modified, and Methyl Carbamate Pesticides SW8318 (cont)	Initial calibration verification	Daily, before sample analysis	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within ±15% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	Confirmation[d]	100% for all positive results	Same as for initial or primary analysis	Same as for initial or primary analysis
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
ICP Metals SW6010A and SW6010 Trace analyses	Initial multipoint calibration (minimum 3 standards and a blank)	Daily initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration check standard	Once per initial daily multipoint calibration	Analyte within ±10% of expected value	Correct problem then repeat initial calibration
	Highest calibration standard	Before beginning a sample run	All analytes within ±5% of expected value	Correct problem then repeat initial calibration
	Calibration blank	After every 10 samples and at end of the analysis sequence	No analyte detected >PQL.	Repeat twice, and average results; if average is not within ±3 standard deviations of background mean, terminate analysis; locate and correct problem; reanalyze previous 10 samples
	Continuing calibration verification (Instrument Check Standard)	After every 10 samples and at the end of the analysis sequence	All analyte(s) within ±10% of expected value	Repeat calibration and reanalyze all samples since last successful calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
ICP Metals SW6010A and SW6010 Trace analyses (cont)	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	Interference check solution (ICS)	At the beginning and end of an analytical run or twice during an 8 hour period, whichever is more frequent	Within ±20% of expected value	Terminate analysis; correct problem; reanalyze ICS, reanalyze all affected samples
	LCS for the analyte	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Dilution test	Each new sample matrix	1:4 dilution must agree within ±10% of the original determination	Perform post-digestion spike addition
	Post-digestion spike addition	When dilution test fails	Recovery within 75-125% of expected results	Correct problem then reanalyze post-digestion spike addition
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Lead and Lead-Based Paint SW7421, Selenium SW7740, Arsenic SW7060A, and Cadmium SW7131A	Initial multipoint calibration (minimum 3 standards and a blank)	Daily initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration check standard	Once per initial daily multipoint calibration	Analyte within ±10% of expected value	Correct problem then repeat initial calibration
	Calibration blank	Once per initial daily multipoint calibration	No analyte detected > PRL	Correct problem then reanalyze calibration blank and all samples associated with blank
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	The analyte within ±20% of expected value	Correct problem then repeat calibration and reanalyze all samples since last successful calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for the analyte	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Lead and Lead-Based Paint SW7421, Selenium SW7740, Arsenic SW7060A, and Cadmium SW7131A (cont)	New matrix check; five-fold dilution test	Each new sample matrix	Five times dilution sample result must be ±10% of the undiluted sample result	Perform recovery test
	Recovery test	When new matrix check fails	Recovery within 85-115% of expected results	Run all samples by the method of standard addition
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Organo-phosphorus Pesticides SW8141A	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	RSD[c] < 20% for CFs[d] or Rfs[e] or >0.995 correlation coefficeint	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Initial calibration verification	Daily, before sample analysis	All analytes within ±15% of expected value	Correct problem then repeat initial calibration

TABLE _ (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action [b]
Organo-phosphorus Pesticides SW8141A (cont)	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within ±15% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Chlorinated Herbicides SW8151	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	RSD[c] < 20% for CFs[d] or Rfs[e] or >0.995 correlation coefficeint	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Chlorinated Herbicides SW8151 (cont)	Initial calibration verification	Daily, before sample analysis	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within ±15% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Organo-chlorine Pesticides and PCBs SW80	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	RSD[c] < 20% for CFs[d] or Rfs[e] or >0.995 correlation coefficeint	Correct problem then repeat initial calibration

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Organo-chlorine Pesticides and PCBs SW8081 (cont)	Second-source calibration verification	Once per five-point initial calibration	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Initial calibration verification	Daily, before sample analysis	All analytes within ±15% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All analytes within ±15% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Breakdown check (Endrin and DDT)	Daily prior to analysis of samples	Degradation ≤20%	Repeat breakdown check
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria	Correct problem then re-extract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	Second-column confirmation	100% for all positive results	Same as for initial or primary column analysis	Same as for initial or primary column analysis

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL.
	Results reported between MDL and PRL	None	None	None
Volatile and Extractable Total Petroleum Hydrocarbons SW8015 modified	Five-point initial calibration for all analytes	Initial calibration prior to sample analysis	%RSD < 20% or >0.995 correlation coefficeint	Correct problem then repeat initial calibration
	Initial calibration verification	Daily, before sample analysis	All concentration levels of gasoline-range organics within ±15% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	All concentration levels within ±15% of initial calibration	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No TPH detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	Surrogate spike	Every sample, spiked sample, standard, and method blank	QC acceptance criteria,	Correct problem then re-extract and analyze sample
	MS/MSD	One MS/MSD per every 20 project samples per matri	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Volatile and Extractable Total Petroleum Hydrocarbons SW8015 modified (cont)	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Mercury SW7470 and SW7471	Initial multipoint calibration (minimum 5 standards and a blank)	Daily initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration check standard	Once per initial daily multipoint calibration	Analyte within ±10% of expected value	Correct problem then repeat initial calibration
	Calibration blank	Once per initial daily multipoint calibration, every 10 samples, and ending	No analyte detected > PRL	Correct problem then reanalyze calibration blank,and all samples associated with blank
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	The analyte within ±20% of expected value	Correct problem then repeat calibration and reanalyze all samples since last successful calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for the analyte	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Mercury SW7470 and SW7471 (cont)	New matrix check; five-fold dilution test	Each new sample matrix	Five times dilution sample result must be ±10% of the undiluted sample result	Perform recovery test
	Recovery test	When new matrix check fails	Recovery within 85-115% of expected results	Run all samples by the method of standard addition
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Common Anions E300.0	Multipoint calibration for all analytes (minimum 3 standards and one calibration blank)	Initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per multipoint calibration	All analytes within ±10% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Initial calibration verification	Daily, before sample analysis or when elutent is changed	All analytes within ±10% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	Instrument response within ±10% of expected response	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
		After every analytical batch	All analytes within ±10% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Common Anions E300.0 (cont)	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyses of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None
Hexavalent Chromium SW7196	Multipoint calibration curve (minimum three standards and a blank)	Initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration verification	After each new stock standard preparation	Chromium within ±10% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 15 samples and at the end of the analysis sequence	Chromium within ±20% of expected value	Correct problem then repeat initial calibration and reanalyze all samples since last successful calibration
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration
	Verification check to ensure lack of reducing condition and/or interference	Once for every sample matrix analyzed	Spike recovery between 85-115%	If check indicates interference, dilute and reanalyze sample persistent interference indicates the need to use and alternate method

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b]
Hexavalent Chromium SW7196 (Cont)	MDL study	Once per year	Detection limits established shall be < the PQLs	None
	Method blank	One per analytical batch	No analyte detected > PQL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PQL	None	None	None
Total Petroleum Hydrocarbons E418.1	Multipoint calibration for all analytes (minimum 3 standards and one calibration blank)	Initial calibration prior to sample analysis	Correlation coefficient ≥0.995 for linear regression	Correct problem then repeat initial calibration
	Second-source calibration verification	Once per multipoint calibration	All analytes within ±10% of expected value	Correct problem then repeat initial calibration
	Retention time window calculated for each analyte	Each initial calibration and calibration verifications	± 3 times standard deviation for each analyte retention time from 72-hour study	Correct problem then reanalyze all samples analyzed since the last retention time check
	Initial calibration verification	Daily, before sample analysis or when elutent is changed	All analytes within ±10% of expected value	Correct problem then repeat initial calibration
	Continuing calibration verification	After every 10 samples and at the end of the analysis sequence	Instrument response within ±5% of expected response	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification

TABLE 7.2 (Continued)
SUMMARY OF CALIBRATION AND QC[a/] PROCEDURES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIATION

Applicable Parameter	QC Check	Minimum Frequency	Acceptance Criteria	Corrective Action[b/]
Total Petroleum Hydrocarbons E418.1 (Cont)		After every analytical batch	All analytes within ±10% of expected value	Correct problem then repeat initial calibration verification and reanalyze all samples since last successful calibration verification
	Demonstrate ability to generate acceptable accuracy and precision using four replicate analyzes of a QC check sample	Once per analyst	QC acceptance criteria	Recalculate results; locate and fix problem with system and then rerun demonstration for those analytes that did not meet criteria
	Method blank	One per analytical batch	No analytes detected > PRL	Correct problem then reprep and analyze method blank and all samples processed with the contaminated blank
	LCS for all analytes	One LCS per analytical batch	QC acceptance criteria	Correct problem then reprep and analyze the LCS and all samples in the affected analytical batch
	MS/MSD	One MS/MSD per every 20 project samples per matrix	QC acceptance criteria	Re-extract and re-analyze the MS and MSD sample within holding time
	MDL study	Once per year	Detection limits established shall meet QAPP-established criteria	Re-establish MDL
	Results reported between MDL and PRL	None	None	None

a/ QC = quality control.
b/ All corrective actions associated with project work will be documented, and all records will be maintained by the laboratory.
c/ RSD = relative standard deviation.
d/ CF = control factor.
e/ RF = response factor.
f/ PRL = project reporting limit.
n/ IS = internal standard.
o/ EICP = extracted ion current profile.
p/ GC = gas chromatograph.
g/ LCS = laboratory control sample.
h/ MDL = method detection limit.
i/ MS/MSD = matrix spike/matrix spike duplicate.
j/ SPCC = system performance check compound.
k/ ≤30% = except for >0.10 for bromoform and >0.01 for chloromethane and 1,1-dichloroethane.
l/ CCC = continuing calibration check.
m/ BFB = 4-bromofluorobenzene.

TABLE 7.3
REQUIREMENTS FOR CONTAINERS, PRESERVATION TECHNIQUES, SAMPLE VOLUMES, AND HOLDING TIMES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIDAITON

Name	Analytical Methods	Container[a/]	Preservation[b/c/]	Minimum Sample Volume or Weight	Maximum Holding Time
Alkalinity	E310.2	P, G	4°C	50 ml	14 days
Common Anions	E300.0	P, G	4°C	50 ml	28 days for Br^-, F^-, Cl^-, and SO_4^{-2}; 48 hours for NO_3^-, NO_2^- and PO_4^{-3}
Filterable Residue	E160.1	P, G	4°C	100 ml	7 days
Nonfilterable Residue	E160.2	P, G	4°C	100 ml	7 days
Hydrogen Ion (pH)	SW9040/ SW9045	P, G	4°C	50 ml or 4 ounces	Analyze immediately
Ammonia, Nitrogen	E350.1	P, G	4°C, H_2SO_4 to pH < 2	500 ml	28 days
Nitrogen, Nitrate/Nitrite	E353.2	P, G	4°C, H_2SO_4 to pH < 2	500 ml	28 days
Cadmium	SW7131A	P, G, T	HNO_3 to pH < 2, 4°C	500 ml or 8 ounces	180 days (water and soil)
Mercury	SW7470/ SW7471	P, G, T	HNO_3 to pH < 2, 4°C	500 ml or 8 ounces	28 days (water and soil)
Metals[d/] (except Cadmium and Mercury)	SW6010A and SW7XXX[e/]	P, G, T	HNO_3 to pH < 2, 4°C	500 ml or 8 ounces	180 days (water and soil)
Total Petroleum Hydrocarbons (TVH)-Gasoline	SW8015 (modified)	G, Teflon®-lined septum, T	4°C, HCl to pH < 2	3 x 40 ml or 4 ounces	14 days (water and soil); 7 days if unpreserved by acid

TABLE 7.3 (Continued)
REQUIREMENTS FOR CONTAINERS, PRESERVATION TECHNIQUES, SAMPLE VOLUMES, AND HOLDING TIMES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIDAITON

Name	Analytical Methods	Container[a/]	Preservation[b/c/]	Minimum Sample Volume or Weight	Maximum Holding Time
Total Petroleum Hydrocarbons (TEH)-Diesel	SW8015 (modified)	G, amber, T	4°C	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Volatile Aromatics	SW8020A	G, Teflon®-lined septum, T	4°C, HCl to pH < 2, 0.008% $Na_2S_2O_3$	3 x 40 ml or 4 ounces	14 days (water and soil)
Volatile Halocarbons	SW8010A	G, Teflon®-lined septum, T	4°C, HCl to pH < 2, 0.008% $Na_2S_2O_3$	3 x 40 ml or 4 ounces	14 days (water and soil)
Formaldehyde	SW8315	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Ethylene Glycol	SW8315 modified	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Alcohol Scan	SW8015B	G, Teflon®-lined septum, T	4°C, HCl to pH < 2, 0.008% $Na_2S_2O_3$	3 x 40 ml or 4 ounces	14 days (water and soil); 7 days if unpreserved by acid

TABLE 7.3 (Continued)
REQUIREMENTS FOR CONTAINERS, PRESERVATION TECHNIQUES,
SAMPLE VOLUMES, AND HOLDING TIMES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIDAITON

Name	Analytical Methods	Container[a/]	Preservation[b/c/]	Minimum Sample Volume or Weight	Maximum Holding Time
Total Petroleum Hydrocarbons (TPH)	E418.1	G, amber, T	4°C	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Chlorinated Herbicides	SW8151	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Organochlorine Pesticides and Polychlorinated Biphenyls (PCBs)	SW8081	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Organophosphorus Pesticides	SW8141A	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Semivolatile Organics	SW8270B	G, Teflon®-lined cap, T	4°C, 0.008% $Na_2S_2O_3$	1 liter or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)

TABLE 7.3 (Continued)
REQUIREMENTS FOR CONTAINERS, PRESERVATION TECHNIQUES, SAMPLE VOLUMES, AND HOLDING TIMES
QUALITY ASSURANCE PROGRAM PLAN
RISK-BASED APPROACH TO FUEL AND CHLORINATED SOLVENT REMEDIDAITON

Name	Analytical Methods	Container[a/]	Preservation[b/c/]	Minimum Sample Volume or Weight	Maximum Holding Time
Volatile organics	SW8260A/8240	G, Teflon®-lined septum, T	4°C, 0.008% $Na_2S_2O_3$ (HCl to pH < 2 for volatile aromatics by SW8240 and SW8260)[b]	3 x 40 ml or 4 ounces	14 days (water and soil)
Polynuclear Aromatic Hydrocarbons (PAHs)	SW8310	G, Teflon®-lined cap, T	4°C, store in dark, 0.008% $Na_2S_2O_3$	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Methyl Carbamate Herbicides	SW8318	G, Teflon®-lined cap, T	4°C, pH 5–9	2 liters or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Lead (paint)	SW7421	P, G	4°C	2 ounces	180 days
Asbestos	NIOSH 7400	P, G	4°C	2 ounces	NA[f/]

a/ Polyethylene (P); glass (G); brass sleeves in the sample barrel (T).
b/ No pH adjustment for soil.
c/ Preservation with 0.008 percent $Na_2S_2O_3$ is only required when residual chlorine is present.
d/ All metals collected for a dissolved portion analysis will be filtered in the field prior to preservation.
e/ SW7XXX is all graphite furnace atomic absorption methods, SW7421, 7060, 7131, and 7740.
f/ Not applicable.

or equal to the PRL (Table 7.1). Exceptions are not made for common laboratory contaminants. If the blank contaminant concentration is not less than the specified limit, then the source of contamination will be identified, and corrective action will be taken. SQLs and detection limits will not be raised because of blank contamination. Analytical data will not be corrected for presence of analytes in blanks.

7.2.4 Laboratory Control Samples

Laboratory control samples (LCSs) are blank spikes made from clean laboratory-simulated matrices (reference method blank matrices) spiked with known concentrations of all target analytes of interest at levels approximately 10 times the MDLs. The LCS is carried through the complete sample preparation and analysis procedures. LCSs are designed to check the instrument and method accuracy. An LCS will be analyzed with every analytical batch. Failure of the LCS to meet %R criteria listed in Table 1.1 requires corrective action before any further analyses can continue. All sample results associated with the out-of-control LCS must be reanalyzed after control has been reestablished.

7.2.5 Surrogate Spike Analyses

Surrogate spike analyses are used to determine the efficiency of analyte recovery in sample preparation and analysis in relation to sample matrix. Calculated %R of the spike is used to measure the accuracy of the analytical method for an individual sample. A surrogate spike is prepared by adding to an environmental sample (before extraction) a known concentration of a compound similar in type to the target analytes (i.e., a surrogate compound) to be analyzed for organic target compounds. Surrogate compounds as specified in the methods will be added to all samples analyzed, including method blanks, MS/MSDs, LCSs, field samples, and duplicate samples.

7.2.6 Matrix Spike/Matrix Spike Duplicate

Matrix spike (MS) samples are designed to check the accuracy of the analytical procedures for the sample matrix by analyzing a field sample spiked in the laboratory with a known standard solution containing all the target analytes. A matrix spike duplicate (MSD) is the second of a pair of laboratory MS samples. The MSDs are designed to check the precision and accuracy of analytical procedures by sample matrix.

One MS/MSD pair will be collected for every group of 20 project samples of similar matrix. Field blanks or duplicates are not to be used as MS/MSDs. If surrogate and target analyte compounds concentrations are out of control in the MS/MSD, but the associated accuracy and precision are in control in the LCS, then the out-of-control situation will be attributed to a matrix interference. If the laboratory system is shown to be out-of-control (i.e., if the LCS is out-of-control), then re-extraction and reanalysis will be required. The laboratory will report the data from any reanalysis that is performed.

7.2.7 Analytical Batches

Analytical batches will be designated in the laboratory at a minimum of one batch per sample delivery group (SDG). Each SDG will be comprised of a maximum of 20 project samples of similar matrix collected within a 7-day period. Included in each SDG of 20 (or fewer) samples per analytical method will be an analytical batch identification number. This identification number will clearly allow a reviewer to determine the association between field samples and QC samples. Analytical batches also will be inclusive of preparation lots and calibration periods.

7.2.8 Retention Times

Retention time (RT) is the amount of time required for a target compound to elute from the chromatographic column, and the instrument detector to record a signal response. The RT window is the allowable deviation from the true expected RT for any one compound. A peak response within this RT window will constitute a positive detection for that compound. RT windows are QC criteria for all gas chromatograph (GC) and high-performance liquid chromatography (HPLC) methods. RT windows are determined through replicate analyses of a standard over multiple days. The calculation of RT windows is described in USEPA (1995) Method SW8000A. Corrective action is required when the RT windows are out of control.

7.2.9 Internal Standards

Internal standards (ISs) are compounds of known concentrations used to quantitate the concentrations of target detections in field and QC samples. ISs are added to all samples after sample extraction or preparation. Because of this, ISs provide for the accurate quantitation of target detections by allowing for the effects of sample loss through extraction, purging, and/or matrix effects. ISs are used for any method requiring an IS calibration. Corrective action is required when ISs are out of control.

7.2.10 Interference Check Standard

The interference check standard (ICS) is used to verify the background and interelement correction factors for metals in method SW6010A. The ICS is analyzed at the beginning and end of each analytical sequence. Method-specific acceptance limits listed in Table 1.1 will apply.

7.2.11 Second Column Confirmation

Quantitative confirmation of results at or above the PQL for samples analyzed by GC or HPLC will be required and will be completed within the method-required holding times. For GC methods, a second column is used for confirmation. For HPLC methods, a second column or a different detector is used. The result of the first column/detector will be the result reported.

7.2.12 Control Limits

The control limits associated with all method QC will follow guidance established in the AFCEE (1996) QAPP. For methods not defined in the AFCEE (1996) QAPP (e.g., SW3810 modified for methane), the acceptance criterion in Table 1.1 is listed as suggested guidance.

7.2.13 Calibration Requirements

Analytical instruments will be calibrated in accordance with the analytical methods. All analytes reported will be present in the initial and continuing calibrations, and these calibrations must meet the acceptance criteria specified in Table 1.1. Records of standard preparation and instrument calibration will be maintained by the contract laboratory. Records will unambiguously trace the preparation of standards and their use in calibration and quantitation of sample results. Calibration standards will be traceable to standard materials.

Analyte concentrations are determined with either calibration curves or response factors (RFs). For GC and GC/mass spectroscopy (MS) methods, when using RFs to determine analyte concentrations, the average RF from the initial five-point calibration will be used. The continuing calibration will not be used to update the RFs from the initial five-point calibration.

7.2.14 Standard Materials

Standard materials used in calibration and to prepare samples will be traceable to National Institute of Standards and Technology (NIST), USEPA, American Association of Laboratory Accreditation (A2LA) or other equivalent approved source, if available. The standard materials will be current, in accordance with the following expiration policy: The expiration dates for ampulated solutions will not exceed the manufacturer's expiration date or one year from the date of receipt, whichever occurs first. Expiration dates for laboratory-prepared stock and diluted standards will be no later than the expiration date of the stock solution or material, or the date calculated from the holding time allowed by the applicable analytical method, whichever occurs first. The laboratory will label standard and QC materials with expiration dates.

7.3 SAMPLE CUSTODY REQUIREMENTS

Sample custody begins in the field at the time of collection and continues throughout the laboratory analytical process. COC forms will be prepared at the time sample collection and will accompany the samples through the laboratory sample processing. To facilitate the documentation of sample custody, the laboratory will track the progress of sample preparation, analysis, and report preparation. Samples received by the laboratory will be checked carefully for label identification, COC forms, and any discrepancies. The laboratory will also note physical damage, incomplete sample labels, incomplete paperwork, discrepancies between sample labels and paperwork, broken or leaking containers, and inappropriate caps or bottles. On the day of receipt of samples from the

contractor, the laboratory will send signed facsimile copies of all COCs and sample log-in receipt forms to the contractor. All discrepancies and/or potential problems (e.g., lack of sample volume) will be discussed immediately with the contractor's project task manager.

The laboratory sample custodian will be required to provide a report to the contractor of any problems observed with any of the samples received. This report will also document the condition of samples, sample numbers received, corresponding laboratory numbers, and the estimated date for completion of analysis. The laboratory must receive written permission from the contractor before sending any samples (originally scheduled to be analyzed at their facility) to another laboratory. Analyses will not be performed on samples whose integrity has been compromised or is suspect.

7.4 SAMPLE HANDLING

Laboratory sample custody will be maintained by the following procedures:

1. The laboratory will designate a sample custodian responsible for maintaining custody of the samples and all associated paperwork documenting that custody.
2. Upon receipt of the samples, the sample custodian will sign the original COC form and compare the analyses requested thereon with the label on each sample container.
3. A qualitative assessment of each sample container will be performed to note any anomalies such as broken or leaking bottles or lack of preservation (e.g., ice melted enroute). This assessment will be recorded as part of the incoming COC procedure.
4. If the COC and samples correlate, and there has been no tampering with the custody seals, the "received by laboratory" box on the COC form will be signed and dated.
5. Care will be exercised to document any labeling or descriptive errors. In the event of discrepancies, breakage, or conditions that could compromise the validity of analyses, the laboratory project coordinator will immediately contact the task manager as part of the corrective action process.
6. Samples will be logged into the laboratory management computer system, which includes a tracking system for extraction and analysis dates. The laboratory will assign a laboratory work number to each sample for identification purposes. The sample custodian will log the laboratory work number and the field sample identification into a laboratory sample custody log. The laboratory sample custody log may either be hard copy or computerized, depending on the laboratory's system.
7. The samples will be stored in a secured area at a temperature of approximately 4 ± 2 degrees Celsius (°C) or cooler (as applicable) until analyses commence. The laboratory log should also contain the laboratory storage cooler number (if applicable) that the sample will be stored in while on the laboratory's premises.

Samples will be logged when they are removed and returned from storage for analysis. Samples must be stored in separate coolers from those used to store analytical standards, reagents, and/or QC samples.

8. The samples will be distributed to the appropriate analysts, with names of individuals who receive samples recorded in internal laboratory records.
9. The original COC form will accompany the laboratory report submittal and will become a permanent part of the project records.
10. Data generated from the analysis of samples also must be kept under proper custody by the laboratory.

Upon analysis, a laboratory lot control number will be assigned to the sample. All samples within a given laboratory analysis group (e.g., samples sharing the same laboratory QC measurement samples) will have identical laboratory lot control numbers.

Disposal of sample containers and remaining sample material will be the responsibility of the laboratory. Samples should be disposed of appropriately when all analyses and related QA/QC work are completed.

7.5 SAMPLE IDENTIFICATION AND SAMPLE CUSTODY RECORDS

The laboratory conducting the analysis of the samples will provide the data user with information on the laboratory sample identification system. With knowledge of this laboratory sample identification system, data generated at the laboratory can be tracked by both the laboratory and field sample identification systems.

Each sample will be logged into the laboratory system by assigning it a unique sample number. This laboratory number and the field sample identification number will be recorded on the laboratory report.

7.6 LABORATORY DATA REDUCTION, VALIDATION, AND REPORTING

7.6.1 Review Procedures for Definitive Data

The fixed-base laboratory will review 100 percent of all definitive data prior to reporting. The establishment of detection and control limits will be verified. Any control limits outside of the acceptable ranges specified in the analytical methods will be identified. Any trends or problems with the data will be evaluated. Any laboratory-established detection limits that exceed the established method-specified limits will be identified. The absence of records supporting the establishment of control criteria or detection limits will be noted. Analytical batch QC, calibration check samples, method calibrations, continuing calibration verifications, corrective action reports, the results of reanalysis, sample holding times, sample preservations, and any resampling and analysis all will be evaluated.

Samples associated with out-of-control QC data will be identified in the data package case narrative, and an assessment of the utility of such analytical results will be made. The check of laboratory data completeness will ensure that:

- All samples and analyses specified in the SAP have been processed;
- Complete records exist for each analysis and the associated QC samples; and
- Procedures specified in this SAP have been implemented.

The results of the completeness check will be documented.

An analyst other than the original data processor, will be responsible for reviewing all steps of the data processing. All input parameters, calibrations, and transcriptions will be checked. All manually input, computer-processed data will be checked. Each page of checked data will be signed and dated by the verifier.

QC sample results (LCSs, MS/MSDs, surrogates, initial calibration standards, and continuing calibration standards) are compared against stated criteria for accuracy and precision (Table 7.2). QC data must meet acceptance levels prior to processing the analytical data. If QC standards are not met, the cause will be determined. If the cause can be corrected without affecting the integrity of the analytical data, processing of the data will proceed. If the resolution jeopardizes the integrity of the data, reanalysis will occur.

Decisions to repeat sample collection and analyses may be made by the contractor project manager based on the extent of the deficiencies and their importance in the overall context of the project.

7.6.2 Laboratory Data Reporting Flags

The following qualifiers must be used by the laboratory when reporting sample results.

Qualifier	Description
J	The analyte was positively identified, the quantitation is an estimation.
U	The analyte was analyzed for, but not detected. The associated numerical value is at or below the MDL.
F	The analyte was positively identified but the associated numerical value is below the PQL.
R	The data are unusable due to deficiencies in the ability to analyze the sample and meet QC criteria.
B	The analyte was found in an associated blank, as well as in the sample.
M	A matrix effect was present.
T	Tentatively identified compound (using GC/MS)

7.6.3 Contractor Data Reporting Flags

The following define the contractor organic and inorganic data validation qualifiers:

- U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is the PRL (e.g., the nondetect level).
- J - The associated value is an estimated quantity.
- R - The data are unusable (Note: analyte may or may not be present).
- UJ - The material was analyzed for but was not detected. The associated value is an estimate and may be inaccurate or imprecise.

7.6.4 Data Validation and Assessment of Usability

Data from QC samples will be assessed by the contractor using the procedures and criteria presented earlier in this section. This assessment will be a continuous process in which QA problems are identified immediately, and the appropriate corrective action is implemented. Additionally, the contractor will assess the usability of analytical data. Any limitations on data use will be expressed quantitatively to the extent practicable and will be documented in any reporting of the data.

This data usability review will include a review of the analytical methods, quantitation limits, and other factors important in determining the precision, accuracy, completeness, and representativeness of the final data set. The outcome of this data review will be a data set appropriate to support quantitative fate and transport analyses and risk analysis. The data evaluation methods defined in *Risk Assessment Guidance for Superfund (RAGS), Volume 1: Human Health Evaluation Manual* (USEPA, 1989) and the *Guidance for Data Useability in Risk Assessment* (USEPA, 1992) will be used as appropriate.

7.6.5 Hard-Copy Data Deliverables

Data deliverables required for the analytical results include both a hard copy and an electronic copy. Hard-copy reporting of analytical results will include analytical results summaries for all field samples, and their associated QA/QC samples. The laboratory will be required to provide two copies of each hard copy data reporting package. Data reporting requirements for hard-copy analytical reports are in Table 7.4 as those items listed with an asterisk.

7.6.6 Electronic Data Deliverables

To facilitate data handling and management, both field and laboratory data will be entered into a computerized format. All data will be delivered to the contractor from the laboratory in the database format specified in the *Installation Restoration Program Information Management System (IRPIMS) Data Loading Handbook*, Version 2.2, AFCEE, 1991. The laboratory will be responsible for running QC Tools on the analytical data files prior to delivery to the contractor.

TABLE 7.4
REQUIRED LABORATORY DELIVERABLES

Method Requirements	Laboratory Deliverables (Definitive Data)
Requirements for all methods:	
- Case narrative	Project identification Analytical method description and reference citation. Discussion of unusual circumstances, problems, and nonconformances.
Monthly QA report	Any format to discuss issues which may affect data quality *
- Chain of Custody (COC)	Signed and dated when samples were* received at laboratory
- Dates of sample preparation and analysis (including first run and subsequent runs).	Specific deliverable depends upon* type of analysis
- Quantitation limits achieved.	Specific deliverable depends upon type* of analysis
- Dilution or concentration factors.	Specific deliverable depends upon* type of analysis
- Summary analytical batch report including analytical batch samples, method of analysis, matrix description, date of sample collection and receipt, laboratory identification number of each environmental sample plus identification number of each batch quality control (QC) sample (including Matrix Spike/Matrix Spike Duplicate (MS/MSD), calibration check, etc.).	Any format*
- Method reporting limits.	QC summary report*
- QC limits.	QC summary report*
- Practical Quantitation Limit (PQL) verification standard (weekly).	Any format
- Corrective action reports.	Any format *
- A copy of all raw laboratory analytical data.	Any format (chromatograms, mass spectra and data system printouts)
- Example sample calculation	Any format
- A copy of the sample preparation data form for each method indicating sample identification number, batch identification number, and date of preparation.	Any format (preparation, extraction, or digestion data)
Percent moisture for all soil samples	Any format *

TABLE 7.4 (Concluded)
REQUIRED LABORATORY DELIVERABLES

Method Requirements	Laboratory Deliverables (Definitive Data)
Requirements for organic analytical methods:	
- Sample data sheets.	Summary information only a/*
- Surrogate recoveries.	Summary information only *
- MS/MSD.	Summary information only *
- Method blank analysis.	Summary information only *
- Laboratory control spike (LCS)	Summary information only*
- Instrument performance check (Tuning).	Summary information only
- Degradation/breakdown (SW8080).	Summary information only
- Initial calibration data	Summary information only
- Continuing calibration data.	Summary information only
- Calibration blank data	Summary information only
- Internal standard area and retention time summary data.	Summary information only
- Retention time windows	Summary information only*
- Second-column confirmation. To be done for all compounds that are detected above reporting limit	Summary information only*
- Analysis run log.	No format
Requirements for inorganic analytical methods Metals:	
- Sample data sheets.	Summary information only *
- Initial and continuing calibration.	Summary information only
- Method blank, taken through sample preparation.	Summary information only *
- Calibration blank data.	Summary information only
- Interference check sample.	Summary information only
- Laboratory control spike/laboratory control spike duplicate.	Summary information only*
- Matrix spike/matrix spike duplicate.	Summary information only *
- Post-digestion spike sample recovery	Summary information only
- Method of standard additions	Summary information only
- Serial dilutions	Summary information only
- Analysis run logs	No format

* Indicates hard-copy deliverables required for QC summary package of Option 3 and 4.

a\ Summarized results can be in any format that provides the necessary data to completely validate that QC parameter. Example formats are the form equivalents to those defined for the USEPA Contract Laboratory Program (CLP) or SW-846 programs.

The laboratory reporting system will be implemented and tested prior to beginning the sampling. Any problems detected in format will be corrected by laboratory prior to providing any electronic deliverables to the contractor. All data entered into the electronic data files will correspond to the data contained in the original laboratory reports and other documents associated with sampling and the laboratory hard copy data deliverable packages.

7.6.7 Quality Assurance Reports

At monthly intervals beginning with the initiation of sampling activities, the laboratory will submit to the contractor's project task manager an internal QA report that documents laboratory-related QA/QC issues. These reports will include discussions of any conditions adverse or potentially adverse to quality, such as:

- Responses to the findings of any internal or external systems or performance laboratory audits;
- Any laboratory or sample conditions which necessitate a departure from the methods or procedures specified in this SAP;
- Any missed holding times or problems with laboratory QC acceptance criteria; and
- The associated corrective actions taken.

Submittal of QA reports will not preclude earlier contractor notification of such problems when timely notice can reduce the loss or potential loss of quality, time, effort, or expense. Appropriate steps will be taken to correct any QA/QC concerns as they are identified. The QA reports and a summary of the laboratory QA/QC program and results will be included in the final project report.

7.7 CORRECTIVE ACTION

The following procedures have been established to assure that conditions adverse to data quality are promptly investigated, evaluated, and corrected. Adverse conditions may include malfunctions, deficiencies, deviations, and errors.

When a significant condition adverse to data quality is noted at the laboratory, the cause of the condition will be determined, and corrective action will be taken to prevent repetition. Condition identification, cause, reference documents, and corrective action planned will be documented and reported to the contractor QA officer by the laboratory QC coordinator. Following implementation of corrective action, the laboratory QC coordinator will report the actions taken and their results to the contractor project manager and QA officer. A record of the action taken and results will be attached to the data report package. If samples are reanalyzed, the assessment procedures will be repeated, and the control limits will be reevaluated to ascertain if corrective actions have been successful.

Implementation of corrective action is verified by documented follow-up action. All project personnel have the responsibility, as part of the normal work duties, to identify, report, and solicit approval of corrective actions for conditions adverse to data quality.

Corrective actions will be initiated in the following instances:

- When predetermined acceptance criteria are not attained (Tables 7.1, 7.2, and 7.3) (objectives for precision, accuracy, and completeness);
- When the prescribed procedure or any data compiled are faulty;
- When equipment or instrumentation is determined to be faulty;
- When the traceability of samples, standards, or analysis results is questionable;
- When QA requirements have been violated;
- When designated approvals have been circumvented;
- As a result of systems or performance audits;
- As a result of regular management assessments;
- As a result of intralaboratory or interlaboratory comparison studies; and
- At any other instance of conditions significantly adverse to quality.

Laboratory project management and staff, such as QA auditors, document and sample control personnel, and laboratory groups, will monitor work performance in the normal course of daily responsibilities.

The laboratory QC coordinator or designated alternate will audit work at the laboratory. Items, activities, or documents ascertained to be compliant with QA requirements will be documented, and corrective actions will be mandated in the audit report. The contractor QA officer and laboratory QC coordinator will log, maintain, and control the audit findings.

The contractor QA officer and laboratory QC coordinators are responsible for documenting all out-of-control events or non-conformance with QA protocols. The QC checks, their frequency, acceptance criteria, and corrective actions for out-of-control data are summarized in Table 1.1 for each analytical method. A nonconformance report will summarize each nonconformance condition. The laboratory will notify the contractor project manager or QA officer of any laboratory QA/QC nonconformances upon their discovery. Copies of all field change requests and corrective action forms will be maintained in the project files. A stop-work order may be initiated by the contractor if corrective actions are insufficient.

7.7 AUDITS

This section describes participation in external and internal systems audits for AFCEE contractors and laboratories.

7.7.1 System Audits

System audits review laboratory operations and the resulting documentation. An onsite audit ensures that the laboratory has all the personnel, equipment, and internal standard operating procedures (SOPs) needed for performance of contract requirements in place and operating. The system audits ensure that proper analysis documentation procedures are followed, that routine laboratory QC samples are analyzed, and that any nonconformances are identified and resolved.

7.7.2 Internal Audits

The laboratory must conduct internal system audits on a periodic basis. The results of these audits will be documented by the laboratory QC coordinator, and the laboratory will provide the contractor with the results of these internal audits.

7.7.3 External Audits

The contractor project QA officer or designee may conduct an external system audit of the laboratory during the performance project samples. This audit would evaluate the capabilities and performance of laboratory personnel, items, and activities. It also documents the measurement systems and identifies and corrects any deficiencies. The contractor QA manager acts on audit results by documenting deficiencies and informing the contractor project manager of the need for corrective action. The contractor project manager may suspend operations until problems are resolved. If conditions adverse to quality are detected, or if the contractor project manager requests additional audits, additional unscheduled audits may be performed.

In addition to the contractor audit of the laboratory, various state and/or federal agencies may conduct an audit prior to the commencement of the project, and may conduct additional audits as deemed necessary. The frequency and schedule of any such audits will be established by the auditing agency and coordinated directly with the laboratory.

7.7.4 Performance Audits

Laboratory performance audits may be conducted to determine the accuracy and implementation of the SAP by the contractor QA manager or designee prior to initiation of field sampling. Unplanned audits may be implemented if requested by the contractor project manager. In addition to in-house performance audits, the laboratory may also participate in interlaboratory performance evaluation studies for different state or federal agencies. The contractor project QA manager will act to correct any laboratory performance problems.

7.8 PREVENTIVE MAINTENANCE

7.8.1 Procedures

Equipment, instruments, tools, gauges, and other items requiring preventive maintenance will be serviced in accordance with the manufacturers' specified recommendations or written procedures developed by the operators.

7.8.2 Schedules

Manufacturers' procedures identify the schedule for servicing critical items in order to minimize the downtime of the measurement system. It will be the responsibility of the individual operator assigned to a specific instrument to adhere to the instrument maintenance schedule and to promptly arrange any necessary service. Servicing of the equipment, instruments, tools, gauges, and other items will be performed by qualified personnel.

The laboratory will establish logs to record maintenance and service procedures and schedules. All maintenance records will be documented and will be traceable to the specific equipment, instruments, tools, and gauges. Records produced for laboratory instruments will be reviewed, maintained, and filed by the operators at the laboratories.

7.8.3 Spare Parts

A list of critical spare parts will be requested from manufacturers and identified by the operator. These spare parts will be stored for availability and use in order to reduce downtime due to equipment failure and repair.

7.9 SUBCONTRACT LABORATORY SERVICES

The laboratory will assume responsibility for providing all analytical services specified in the laboratory agreement. Should it be agreed in writing that the laboratory may use an additional subcontract laboratory facility, the primary laboratory will supply to the contractor the SOPs, MDL studies, and QA plans for the other laboratories that are used. The laboratory will be responsible for communicating all analytical guidelines and QC requirements of the project to these laboratories. The QA officers from both the primary laboratory and the contractor will monitor the data from subcontract laboratories and correct any QC nonconformances.

SECTION 8

REFERENCES

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