95th Air Base Wing
Edwards Air Force Base, California

Environmental Restoration Program

Record of Decision
South Air Force Research Laboratory
Operable Units 4 and 9
Edwards Air Force Base
California

Final

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RECORD OF DECISION
SOUTH AIR FORCE RESEARCH LABORATORY

OPERABLE UNITS 4 AND 9
EDWARDS AIR FORCE BASE
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LIST OF ABBREVIATIONS AND ACRONYMS

%	percent
<	less than
95 ABW/CEV	95th Air Base Wing/Environmental Management
95 ABW/CEVR	95th Air Base Wing/Environmental Restoration Branch
95 ABW/EM	95th Air Base Wing/Environmental Management
μg/kg	micrograms per kilogram
μg/L	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter
AFB	Air Force Base
AFCEE/ERD	Air Force Center for Environmental Excellence, Environmental Restoration Division
AFCEE/ICE	Air Force Center for Engineering and the Environment, MAJCOM & Installation Support – CONUS (AFMC)
AFCEE/ISM	Air Force Center for Environmental Excellence, Installation Support, Materiel Command
AFFTC	Air Force Flight Test Center
AFFTC/EM	Air Force Flight Test Center, Environmental Management
AFFTC/EMR	Air Force Flight Test Center, Environmental Restoration Division
AFRL	Air Force Research Laboratory
AOC	area of concern
ARAR	applicable or relevant and appropriate requirement
ARB	Air Resources Board
ARD	anaerobic reductive dechlorination
AST	aboveground storage tank
AT&SF	Atchinson, Topeka and Santa Fe Railroad
ATSDR	Agency for Toxic Substances and Diseases Registry
AVEK	Antelope Valley-East Kern
BG	background
bgs	below ground surface
Bldg	Building
Blvd	boulevard
CA	California
Cal-EPA	California Environmental Protection Agency
CBr	competent bedrock
CCR	California Code of Regulations
CDHS	California Department of Health Services
CE	civil engineering
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation and Liability Information System
C_f	final concentration
CFC 113	chlorofluorocarbon 113
cfm	cubic feet per minute
CFR	Code of Federal Regulations

C_i	initial concentration
Co.	county
COC	chemical of concern
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
CRWQCB	California Regional Water Quality Control Board
CSM	conceptual site model
CZ	containment zone
DCE	dichloroethene
DERP	Defense Environmental Restoration Program
DHS	Department of Health Services
DNAPL	dense non-aqueous phase liquid
DoD	Department of Defense
DTSC	Department of Toxic Substances Control
DWEL	drinking water equivalent level
DWR	Department of Water Resources
EAFB	Edwards Air Force Base
EIAP	Environmental Impact Assessment Process
EMC	Environmental Management Compliance
EOD	explosive ordinance disposal
EOS®	Emulsified Oil Substrate
ERA	ecological risk assessment
ERP	Environmental Restoration Program
ESD	Explanation of Significant Differences
ESI/RFA	Expanded Source Investigation/RCRA Facility Assessment
FBZ	fractured bedrock zone
FFA	Federal Facility Agreement
FS	feasibility study
ft/day	feet per day
ft^2/day	square feet per day
ft/ft	vertical feet per horizontal foot
ft/yr	feet per year
GETS	groundwater extraction and treatment system
GIS	geographic information system
GP	General Plan
gpd	gallons per day
gpm	gallons per minute
GPS	global positioning system
GWVCL	groundwater vapor compliance level
HB&A	Higginbotham/Briggs & Associates
HDSC	hazardous distribution service center
HEAST	Health Effects Assessment Summary Table
HHRA	human health risk assessment
HI	hazard index
HQ	Hazard Quotient

HRC®	hydrogen release compound
HVAC	heating, ventilation and air conditioning
IAVML	indoor air vapor mitigation level
IC	institutional control
ind	industrial
INRMP	Integrated Natural Resources Management Plan
IRA	interim removal action
IRIS	integrated risk information system
IRP	installation restoration program
ISB	in-situ bioremediation
ISCO	in-situ chemical oxidation
ITIR	informal technical information report
J&E	Johnson and Ettinger
Jct.	junction
JP-4	jet propellant 4
K	hydraulic conductivity
K-12	kindergarten through 12th grade
KCEHSD	Kern County Environmental Health Services Department
km	kilometer
L/min	liters per minute
LNAPL	light non-aqueous phase liquid
LPGAC	liquid-phase granular activated carbon
LTM	long-term monitoring
LUC	land use control
MBAS	methylene blue active substances
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
mg/kg	milligrams per kilogram
mg/kg/day	milligrams per kilogram per day
mg/L	milligrams per liter
MSL	mean sea level
MTBE	methyl tertiary-butyl ether
NA	not applicable or not available
NAD	North American Datum
NASA	National Aeronautics and Space Administration
N	nitrogen
NCEA	National Center for Environmental Assessment
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
ND	not detected
NDMA	N-nitrosodimethylamine
NEPA	National Environmental Policy Act
NFI	no further investigation
NL	notification level
No.	number
NPL	National Priorities List

NS	not sampled
O&M	operation and maintenance
OEHHA	Office of Environmental Health Hazard Assessment
OU	operable unit
PAT	pump and treat
PCE	tetrachloroethene
PERA	predictive ecological risk assessment
PHG	public health goal
PIRA	Precision Impact Range Area
PLSS	Public Land Survey System
pMCL	primary maximum contaminant level
PP	proposed plan
ppb(v)	parts per billion (by volume)
PPE	personal protective equipment
PPRTV	provisional peer-reviewed toxicity values
PRB	permeable reactive barrier
PRG	preliminary remediation goal
PV	pore volume or present value
PVC	polyvinyl chloride
RA	remedial action
RAB	Restoration Advisory Board
RACER	remedial action cost engineering and requirements
RAO	remedial action objective
RAR	relevant and appropriate requirement
RBCG	risk-based cleanup goal
RBCL	risk-based cleanup level
RCRA	Resource Conservation and Recovery Act
res	residential
RfC	reference concentrations
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RISR	remedial investigation summary report
RL	reporting limit
ROD	record of decision
ROI	radius of influence
RP-1	rocket propellant 1 (a kerosene)
RPM	remedial project manager
S	aquifer storativity
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SERA	scoping ecological risk assessment
SI	site inspection
SP	South Pacific
SQ. FT.	square feet
sMCL	secondary maximum contaminant level

ST	street
STP	sewage treatment plant
SVE	soil vapor extraction
SWRCB	State Water Resources Control Board
T	transmissivity or time
TBC	to be considered
TCA	trichloroethane
TCE	trichloroethene
TDS	total dissolved solids
TEFA	technical and economic feasibility analysis that satisfies all requirements of SWRCB Resolution 92-49 Section III.G
TI	technical impracticability
TIA	Total Impacted Area
TIGV	Total Impacted Groundwater Volume
TOC	total organic carbon
TMB	trimethylbenzene
TS	treatability study
TSER	treatability study evaluation report
U.S.	United States
UCL	upper confidence limit
UIC	Underground Injection Control
URF	unit risk factor
USAF	United States Air Force
USACE	United States Army Corps of Engineers
USC	United States Code
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	underground storage tank
UTM	Universal Transverse Mercator
V	volume
VICB	vapor intrusion compliance boundary
VIP	vapor intrusion pathway
VOC	volatile organic compound
WBr	weathered bedrock
WQO	water quality objective

1.0 DECLARATION

1.1 SITE NAME AND LOCATION

Edwards Air Force Base (AFB), located in Kern, Los Angeles, and San Bernardino Counties, California (CA), United States Environmental Protection Agency (USEPA) Identification Number: CA1570024504. This decision document addresses the South Air Force Research Laboratory (AFRL) area of Operable Units (OUs) 4 and 9 at the Site. The South AFRL area includes Environmental Restoration Program (ERP) Sites 37, 120, 133, and 321.

1.2 STATEMENT OF BASIS AND PURPOSE

This decision document presents the selected remedy for the South AFRL in OUs 4 and 9 at Edwards AFB, CA, which was chosen to satisfy the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), and, to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). This decision is based on documents contained in the Administrative Record file for OU4 and OU9 found at Edwards AFB (95th Air Base Wing, Environmental Management Division, 5 East Popson Avenue, Building 2650A). The Air Force and the USEPA are selecting this remedy in concurrence with the California Department of Toxic Substances Control (DTSC) and the California Regional Water Quality Control Board (CRWQCB), Lahontan Region (Water Board).

1.3 ASSESSMENT OF THE SOUTH AFRL, OU4 AND OU9, EDWARDS AFB

This Record of Decision (ROD) documents the response action to prevent exposure to groundwater impacted by various chlorinated hydrocarbons and other chemicals at the South AFRL, OU4 and OU9, Edwards AFB; and to prevent exposure, via the vapor intrusion pathway (VIP), to chemicals in indoor air at concentrations exceeding an acceptable cancer risk level of 1×10^{-6}. The response action selected in this ROD is necessary to protect the public health and welfare and the environment from actual or threatened releases of hazardous substances into the environment.

The groundwater beneath the South AFRL, which is not currently used for drinking water purposes, exceeds the acceptable risk range under the hypothetical future residential use scenario. The groundwater beneath the South AFRL has been designated a potential drinking water source by the State of California, and there are applicable or relevant and appropriate requirements (ARARs) that provide protective cleanup standards, such as federal and state primary maximum contaminant levels (pMCLs). The specific chemicals of concern (COCs) that have been identified in groundwater at the South AFRL, and the pMCL (or other risk-based cleanup goal [RBCG] for those chemicals without pMCLs) for each, are provided in Table 2.5-1 in this ROD. Note that the remedy selected in this ROD includes a waiver of cleanup to pMCLs as ARARs, based on technical impracticability from an engineering perspective. Should the groundwater at the South AFRL ever be used for drinking, it would pose a potential risk to human health. Therefore, the remedy includes land use controls (LUCs) to prevent the use of groundwater for drinking or other human exposures, and long-term monitoring (LTM) to track contaminant migration within the South AFRL Containment Zone (CZ).

This ROD also documents the decision that No Action is necessary to protect public health or welfare or the environment from contact with soils; and the selection of LUCs and engineering controls to prevent exposure (under an unrestricted use and an industrial use scenario) to indoor air containing chemicals at concentrations that present an unacceptable carcinogenic risk.

1.4 DESCRIPTION OF THE SELECTED REMEDY

A decision of No Action is selected for soils at the South AFRL designated as ERP Sites 37, 120, 133, and 321. This decision is based on results of a human health risk assessment (HHRA) and an ecological risk assessment (ERA), which indicate that any risks associated with exposure to soil at the four sites (under all scenarios, including an unrestricted, residential land use) fall within an acceptable range, and do not require any response action.

The selected remedy for soil vapor includes LUCs to prevent exposure to indoor air under an unrestricted (residential) use scenario and LUCs/engineering controls to prevent exposure to indoor air under an industrial use scenario exceeding a cancer risk level of 1×10^{-6}. Groundwater vapor compliance levels (GWVCLs) and indoor air vapor mitigation levels (IAVMLs) to meet a 1×10^{-6}

"point of departure" risk level were selected as appropriate after evaluation of risk via the VIP (refer to Appendix B-1) indicated that soil concentrations of tetrachloroethene (PCE) (at Site 37) and groundwater concentrations of PCE (Sites 37, 120, 321) and trichloroethene (TCE) (Sites 120 and 133) exceeded a risk level of 10^{-4} for the residential exposure scenario. Figure 2.7-1 shows the vapor intrusion compliance boundary (VICB) inside which the LUCs and building controls must be applied.

The main components of the selected remedy for soil vapor (intrusion into indoor air) include:

- Implement, monitor, maintain, enforce, and report LUCs on soil vapor intrusion into indoor air within the VICB (refer to Figure 2.7-1) in accordance with the Base General Plan (GP). LUCs include maintaining the integrity of any current or future vapor mitigation or monitoring system. One specific component of these LUCs is maintaining the Edwards AFB geographic information system (GIS) as it relates to the extent of groundwater contaminant levels used for determining the VICB. GIS information is consulted and used in the approval process prior to issuance of work permits.

- Monitor and map groundwater plume migration for those plume contours that are at contaminant concentrations that present a potential cancer risk exceeding 1×10^{-6} in indoor air, via the modeled VIP for residential use (refer to Table 2.13-1) and industrial use (refer to Table 2.13-2) scenarios. These concentrations are termed GWVCLs-res and GWVCLs-ind, respectively, for the residential and industrial exposure scenarios. The initial VICB set by this ROD is based on the 30-year projected extent of groundwater that will be impacted by PCE or TCE at a 10^{-6} residential cancer risk level. When subsequent plume migration modeling during a future Five Year Review predicts that the residential risk contours will exceed the current VICB in less than 10 years, revise the appropriate maps and information in the Base GP to show an enlarged VICB with new boundaries based on an additional 30 years of predicted plume migration.

- Incorporate engineering controls to reduce risk via the VIP to less than 1×10^{-6} into all new construction within the VICB. These controls may include, but are not limited to, actions such as sub-slab depressurization; installation of vapor barriers; foundation ventilation systems; and heating, ventilation, and air-conditioning (HVAC) design.

- Initiate a sampling program (that may include soil vapor sampling adjacent to and/or beneath buildings) to assess whether the VIP is complete at existing buildings where groundwater contains chemical concentrations in excess of the GWVCLs-ind for Sites 37, 120, 133, and 321 (refer to Table 2.13-2). The areas currently exceeding GWVCLs-ind are shown on Figure 2.7-1. If a completed pathway is confirmed, periodically monitor indoor air for COCs in those existing buildings where groundwater contaminant concentrations exceed GWVCLs-ind. If measured indoor air COC concentrations exceed the risk-based IAVMLs for industrial use (IAVMLs-ind) listed in Table 2.13-3, activate appropriate mitigation measures (these may include, but are not limited to, actions such as

continued monitoring, soil vapor extraction [SVE], building controls such as sub-slab depressurization or HVAC modifications, or foundation repairs or ventilation).

The selected remedy for groundwater at the South AFRL includes a technical impracticability (TI) waiver from attaining ARARs, such as the drinking water pMCLs, within a 16.4-square-mile area (named the South AFRL CZ) shown on Figure 2.1-2 to a depth of 500 feet below ground surface (bgs); LUCs to prevent exposure to groundwater within this zone; and LTM to confirm that groundwater impacted by contaminant concentrations above these ARARs (the pMCL or RBCGs for those chemicals without pMCLs) does not migrate outside the South AFRL CZ (TI waiver zone). This remedy incorporating a TI waiver inside the South AFRL CZ meets the intent of California's Containment Zone Policy pursuant to State Water Resources Control Board (SWRCB) Resolution 92-49, Section III.H. The specific ARARs to be waived are the pMCLs (for those chemicals that have pMCLs) listed in Table 2.5-1. The ARARs waiver is invoked due to the technical impracticability, from an engineering perspective, of (1) achieving groundwater restoration for groundwater in fractured granitic bedrock impacted by dissolved-phase volatile organic compounds (VOCs) and other chemicals; and (2) removing dense non-aqueous phase liquid (DNAPL) solvents that are suspected to be present in the fractured granitic bedrock. DNAPL is suspected in localized source areas based on the site history, vertical distribution of the contaminant, and dissolved phase contaminant concentrations that exceed 1 percent (%) of the free-phase solubility for PCE at Site 37 and TCE at Site 133. The proposed dimensions of the CZ reflect the collective and best professional judgment of all the remedial project managers (RPMs) for Edwards AFB (Air Force, USEPA, Lahontan Water Board, and DTSC) based on existing data, necessary levels of protection, and engineering limitations.

The main components of the selected remedy in groundwater include:

- Implement, monitor, maintain, enforce, and report LUCs on groundwater within the South AFRL CZ in accordance with the Base GP (further details on LUC implementation and administration are provided in Section 2.13.2.1). LUCs will include maintaining the integrity of the current groundwater monitoring system or any future remedial or monitoring system within the groundwater CZ/LUC Compliance boundary shown on Figure 2.1-2. One specific component of these LUCs is maintaining the Edwards AFB GIS as it relates to the extent of contamination at the South AFRL (as part of a base-wide program). GIS information is consulted and used in the approval process prior to issuance of work permits.

- Contain impacted groundwater within the South AFRL CZ by natural processes (dilution, dispersion). The CZ boundary is drawn with the objective of preventing contaminants from impacting the alluvial aquifer to the west (Lancaster Sub-basin shown on Figure 2.5-3). The Air Force has adopted the United States Geological Survey (USGS) basin boundaries (as defined in USGS Water Resources Investigations Report 98-4022, Carlson et al 1998) and supported by borehole logs for wells installed by Earth Tech (2003a and 2003b) to define the location of the bedrock/alluvial aquifer interface. Post-ROD documents (i.e., remedial action [RA] work plans, including operation and maintenance [O&M] plans and schedules for the RA) will assess hydrogeologic conditions within the CZ. These documents may also specify additional field investigations to be conducted during the post-ROD period in order to provide greater confidence in the contaminant distribution and to evaluate the plumes' actual behavior against the site conceptual and computer groundwater models. Post-ROD investigations may include, but are not limited to, subsurface geophysics, aquifer pump tests, and/or discrete zone monitoring wells to assess contaminant transport in the fractured bedrock and nature and location of the alluvial aquifer/fractured bedrock interface (particularly in the southwest portion of the CZ where data gaps exist).

- Demonstrate containment of groundwater impacted by COCs at concentrations above the pMCL (or other RBCGs for chemicals without pMCLs) inside the South AFRL CZ by LTM of the groundwater to track contaminant migration. As appropriate, use monitoring data to update and refine groundwater flow and contaminant transport models, which currently project containment within the South AFRL CZ for at least 1,000 years.

- Conduct a technical and economic feasibility analysis (TEFA) (as defined in Section III.G, SWRCB Resolution 92-49) and institute active containment measures to ensure that COCs do not migrate outside the CZ. The trigger for both actions would be the projected arrival (based on contaminant transport modeling as validated using actual sampling results) of impacted groundwater at the CZ boundary within the next 10 years; or the detection of any COC in groundwater samples from sentinel wells outside the CZ. The active containment measures may include (but are not limited to) groundwater extraction and treatment systems (GETS) or in situ permeable reactive barriers (PRBs).

- Continue to review and evaluate technologies as part of the 5-year statutory review (described in Section 1.5) and report the results of this evaluation. If a promising technology is identified, which has been demonstrated to effectively treat the same types of chemicals at similar concentrations and in a similar hydrogeologic setting, conduct a field test of the technology, at a cost not to exceed $250,000 (inflation-adjusted from the date of the ROD), to be executed by the following 5-year review. The Air Force may, at its discretion, consider a field test costing greater than $250,000. Where a field test produces promising results, the Air Force will further evaluate the technology for potential scale-up. If no promising technologies that meet the criteria specified above are identified for field testing within the first 30 years of remedy implementation, the Air Force will select, with agency input at the following 5-year review, a suitable field-test or other RA, for the equivalent inflation-adjusted $250,000 at either the South AFRL or another area at Edwards AFB.

These actions for groundwater, soil, and soil vapor are intended to be the final actions for the South AFRL Sites 37, 120, 133, and 321 and are addressed independently of other OUs at Edwards AFB, and other areas of groundwater or soil contamination (e.g., AFRL Arroyos, Northeast AFRL, Mars Boulevard [Blvd]) within OU4 and OU9.

The NCP establishes an expectation that treatment will be used to address principal threats posed by the sites wherever practicable. As part of investigation activities, source materials (liquid waste sumps, waste discharge wells, VOCs in soil vapors) were removed from the South AFRL to the extent practicable, as described in Sections 2.2.3.2 and 2.2.3.3. Suspected DNAPL solvents remain on site and will not be treated under this action.

1.5 STATUTORY DETERMINATIONS

The Selected Remedy is protective of human health and the environment, complies with federal and state requirements that are applicable or relevant and appropriate to the RA (except that chemical-specific ARARs are waived within the South AFRL CZ due to technical impracticability, from an engineering perspective, of cleanup to pMCLs), and is cost effective. Even though compliance with chemical-specific ARARs is waived within the South AFRL CZ, the selected remedy is still protective of human health and the environment because exposure to contaminated groundwater and associated vapors is prevented by implementing LUCs, engineering controls, and an LTM program.

Because it is not practicable to conduct further treatment of groundwater at the South AFRL, the selected remedy does not utilize permanent solutions and alternative treatment (or resource recovery) technologies to the maximum extent practicable, nor satisfy the statutory preference for treatment as a principal element of the remedy. No technology considered will attain pMCLs at a reasonable cost or during a reasonable time frame. Therefore, a TI waiver from an engineering perspective is invoked. The protectiveness of the selected remedy must be ensured through LUCs and an LTM program designed to detect releases from the South AFRL CZ, migration of contaminants to water supply wells, or other releases that would indicate a possible failure of one of the remedy components.

Because this remedy will result in hazardous substances, pollutants, or contaminants remaining onsite above levels that allow for unrestricted use and unrestricted exposure (i.e., residential levels), a statutory review will be conducted within 5 years after initiation of the RA to satisfy NCP Section 300.430(f)(4)(ii), and at subsequent 5-year intervals thereafter, as long as hazardous substances remain at the site at levels that do not allow for unrestricted (residential) uses. Five-year reviews will be conducted in accordance with CERCLA Section 121(c) and are required to determine whether the remedy continues to be protective of human health and the environment. In addition, these 5-year reviews will include (as needed) validation of the groundwater flow and contaminant transport models. Finally, as listed in the final bullet of Section 1.4, the Air Force is committed to a continuing review of technologies and, if a promising technology is identified (that has been demonstrated to effectively treat the same types of chemicals at similar concentrations and in a similar hydrogeologic setting), will conduct a field test, at a cost not to exceed $250,000 (based on the average cost of treatability studies performed at Edwards AFB), to be executed by the following 5-year review.

The Air Force, as a federal entity and lead agency for this CERCLA action, is solely responsible for implementation of the remedy. The USEPA and the State will participate in the 5-year reviews to evaluate the continued protectiveness of the remedy.

Although the Air Force, the USEPA, and the State disagree on whether any portion, or all of California SWRCB Resolutions 68-16 and 92-49 are ARARs for the South AFRL action (refer to each entity's position as presented in Section 2.14.2.1), and on which Water Quality Objectives (WQOs) identified in the Basin Plan are applicable or relevant and appropriate, all parties agree to the selected remedy described in Section 1.4.

1.6 RECORD OF DECISION DATA REFERENCE LIST

The data reference list provided in Table 1.6-1 identifies the locations of certain key remedy selection information within the Decision Summary. Other relevant documents can be found in the Administrative Record.

TABLE 1.6-1. RECORD OF DECISION DATA REFERENCE LIST

Key Remedy Selection Information	Document Section/Table Number
Remedy Components	Section 1.4 and 2.13.2
Chemicals of Concern (COCs) in groundwater, their respective concentrations, and associated pMCL or other RBCGs.	Table 2.5-1
COCs for the vapor intrusion pathway (VIP), their associated groundwater vapor compliance levels (GWVCLs), and indoor air vapor mitigation levels (IAVMLs), and extent of the vapor intrusion compliance boundary (VICB).	Tables 2.13-1 through 2.13-3 and Figure 2.7-1
ARARs that are being waived and justification for the TI waiver.	Table 2.5-1 and Section 2.5.8
How source materials constituting principal threats are addressed.	Section 2.12
Current and reasonably anticipated future land use assumptions and current and potential future beneficial uses of groundwater used in the baseline risk assessment and record of decision.	Section 2.6
Potential land and groundwater use that will be available at the South AFRL as a result of the selected remedy.	Section 2.13.4
Estimated capital, annual operation and maintenance (O&M), and total present value (PV) costs, discount rate, and the number of years over which the remedy cost estimates are projected.	Table 2.13-4 and Section 2.13.3
Key factor(s) that led to selecting the remedy.	Section 2.13.1

Notes:

AFRL Air Force Research Laboratory
ARAR applicable or relevant and appropriate requirement
pMCL maximum contaminant level
RBCG risk-based cleanup goal
TI technical impracticability

1.7 AUTHORIZING SIGNATURES AND SUPPORT AGENCY ACCEPTANCE OF REMEDY

Bryan J. Gallagher, Col — Date 11 Sept 2007

BRYAN J. GALLAGHER, Colonel, USAF
Commander, 95th Air Base Wing
Edwards Air Force Base, California

Date 24 Sept. 2007

MICHAEL M. MONTGOMERY
Chief, Federal Facilities and Site Cleanup Branch
U.S. Environmental Protection Agency, Region 9

The State of California, Department of Toxic Substances Control and the California Regional Water Quality Control Board, Lahontan Region had an opportunity to review and comment on this Record of Decision, and our concerns were addressed.

Date 9-26-07

ANTHONY J. LANDIS, P.E.
Chief, Northern California Operations
Office of Military Facilities
California Department of Toxic Substances Control

Date 10/1/07

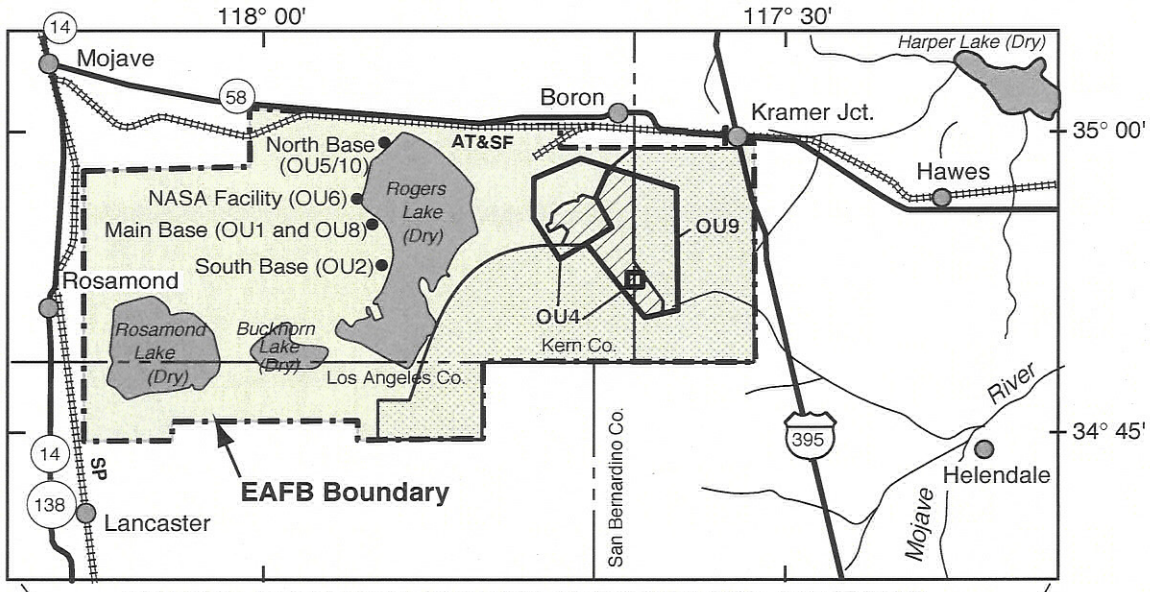
HAROLD J. SINGER, P.E.
Executive Officer
California Regional Water Quality Control Board
Lahontan Region

2.0 DECISION SUMMARY

2.1 SITE NAME, LOCATION, AND DESCRIPTION

Edwards AFB, a military facility, is located in the Southern California counties of Kern, Los Angeles, and San Bernardino, approximately 5 miles northeast of the city of Lancaster (Figure 2.1-1). The Edwards AFB Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) database USEPA Identification Number is CA1570024504. A geographic area in the eastern portion of Edwards AFB, including the AFRL (a tenant organization) and a portion of the Precision Impact Range Area (PIRA), is designated ERP OUs 4 and 9. The northernmost boundary of OUs 4 and 9 is less than 1/2-mile from the base boundary, with the nearest residential areas located to the north just outside the base boundary in the town of Boron. The South AFRL includes ERP Sites 37, 120, 133, and 321 (Figure 2.1-2) located wholly within Kern County. The responsible party and lead agency for OU4 and OU9 activities is the United States Air Force (USAF), which is also the funding entity. USEPA has a remedy selection and oversight role for the cleanup. Other regulatory agencies that support the cleanup action include the California DTSC and the Water Board.

The AFRL at Edwards AFB has been used as a rocket research and testing facility since the 1950s. During that time, workers involved in research, testing, evaluation, and maintenance activities used toxic and hazardous materials. Current use and disposal of these materials are strictly regulated under Resource Conservation and Recovery Act (RCRA) compliance regulations to prevent releases to the environment. Moreover, the USAF Pollution Prevention program strongly encourages the use of non-toxic or less toxic chemicals, where possible. However, in the past, materials were spilled or otherwise released to the ground surface or subsurface. Sites 37, 120, 133, and 321 are (or were) associated with rocket component maintenance, the AFRL wastewater treatment plant, civil engineering activities, and materials storage facilities located on the southwestern side of Leuhman Ridge (a topographic high where the geology is characterized by shallow granitic bedrock and groundwater located within bedrock fractures). The groundwater plumes associated with these sites, collectively identified as the South AFRL, share a regional groundwater flow direction toward the southwest. The primary contaminants at Sites 37, 120, 133, and 321 are PCE and TCE. Near



Base from U.S. Geological Survey State of California (South Half) 1:500,000

0 10 20 miles

0 10 20 30 km

Scale

North

Explanation:

AFB	Air Force Base
AFRL	Air Force Research Laboratory
AT&SF	Atchinson, Topeka & Santa Fe Railroad
Co.	County
EAFB	Edwards Air Force Base
km	Kilometers
Jct.	Junction
NASA	National Aeronautics and Space Administration
OU	Operable Units
SP	South Pacific
U.S.	United States

Air Force Research Laboratory Area

Precision Impact Range Area (PIRA)

Cities

Railroads

County Lines

Rivers

Note: OU3 and OU7, which are not shown, consist of base-wide water wells and miscellaneous/individual sites located outside other OUs, respectively.

South AFRL ROD

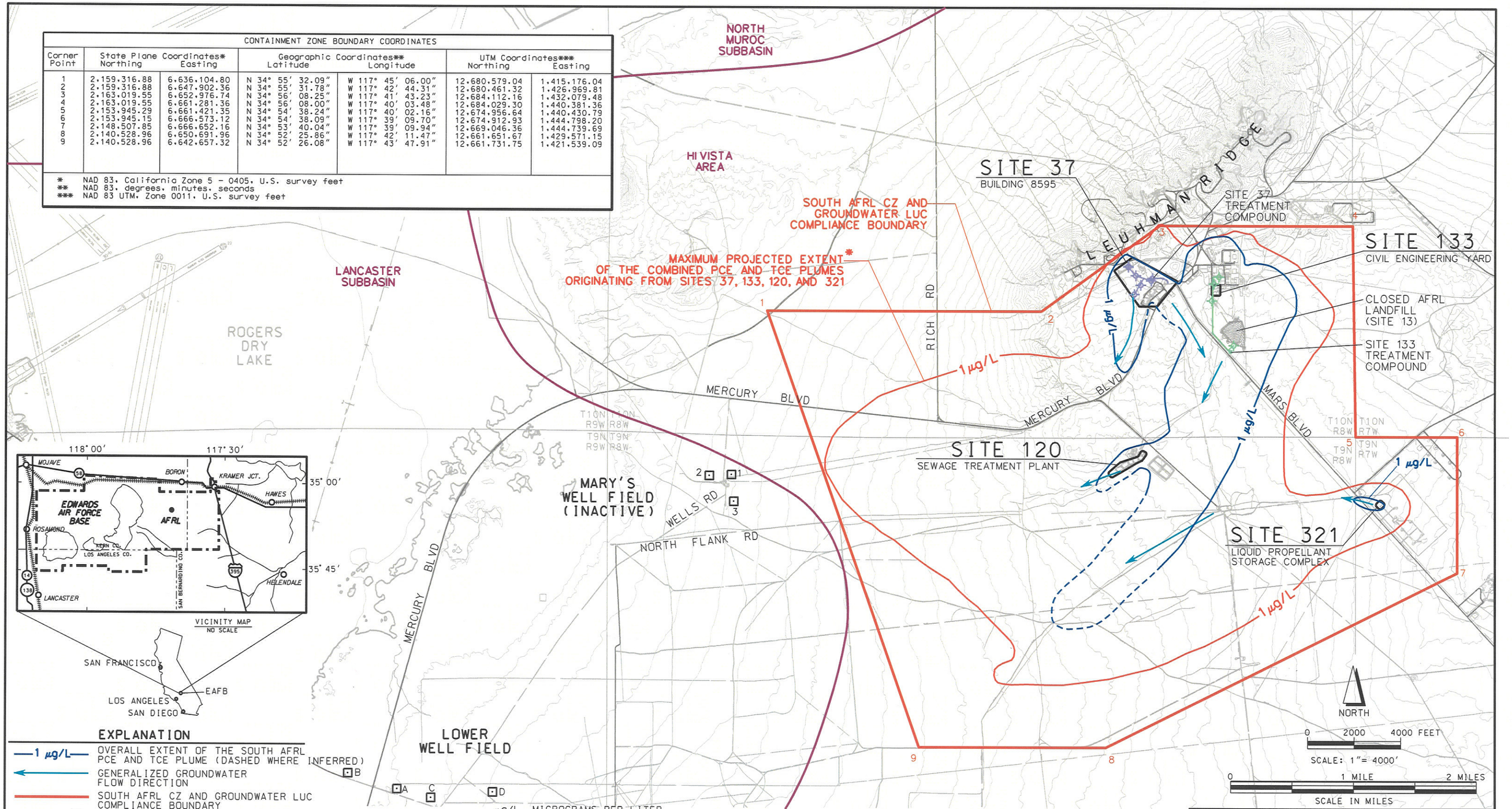
Edwards AFB Location Map

Date 09-07	Air Force Research Laboratory Edwards AFB	Figure 2.1-1
Project No. 67861		

67861.17.03

CONTAINMENT ZONE BOUNDARY COORDINATES						
Corner Point	State Plane Coordinates* Northing	Easting	Geographic Coordinates** Latitude	Longitude	UTM Coordinates*** Northing	Easting
1	2,159,316.88	6,636,104.80	N 34° 55′ 32.09″	W 117° 45′ 06.00″	12,680,579.04	1,415,176.04
2	2,159,316.88	6,647,902.36	N 34° 55′ 31.78″	W 117° 42′ 44.31″	12,680,461.32	1,426,969.81
3	2,163,019.55	6,652,976.74	N 34° 56′ 08.25″	W 117° 41′ 43.23″	12,684,112.16	1,432,079.48
4	2,163,019.55	6,661,281.36	N 34° 56′ 08.00″	W 117° 40′ 03.48″	12,684,029.30	1,440,381.36
5	2,153,945.29	6,661,421.35	N 34° 54′ 38.24″	W 117° 40′ 02.16″	12,674,956.64	1,440,430.79
6	2,153,945.15	6,666,573.12	N 34° 54′ 38.09″	W 117° 39′ 09.70″	12,674,912.93	1,444,798.20
7	2,148,507.85	6,666,652.16	N 34° 53′ 40.04″	W 117° 39′ 09.94″	12,669,046.36	1,444,739.69
8	2,140,528.96	6,650,691.96	N 34° 52′ 25.86″	W 117° 42′ 11.47″	12,661,651.67	1,429,571.15
9	2,140,528.96	6,642,657.32	N 34° 52′ 26.08″	W 117° 43′ 47.91″	12,661,731.75	1,421,539.09

* NAD 83, California Zone 5 - 0405, U.S. survey feet
** NAD 83, degrees, minutes, seconds
*** NAD 83 UTM, Zone 0011, U.S. survey feet



EXPLANATION

- 1 µg/L — OVERALL EXTENT OF THE SOUTH AFRL PCE AND TCE PLUME (DASHED WHERE INFERRED)
- GENERALIZED GROUNDWATER FLOW DIRECTION
- SOUTH AFRL CZ AND GROUNDWATER LUC COMPLIANCE BOUNDARY
- SITE BOUNDARY
- GROUNDWATER PRODUCTION WELL (ACTIVE OR INACTIVE)
- SITE 37 EXTRACTION WELLS, SYSTEM, AND CONNECTING UNDERGROUND COMPRESSED AIR AND GROUNDWATER PIPING
- SITE 133 EXTRACTION WELLS, SYSTEM, AND CONNECTING UNDERGROUND COMPRESSED AIR AND GROUNDWATER PIPING
- * GENERATED USING TRANSPORT MODELS FOR PCE (SITES 37 AND 321) AND TCE (SITES 120 AND 133). SIMULATION RUN FOR 1,000 YEARS, BUT MAXIMUM PLUME EXTENT IS PROJECTED AT APPROXIMATELY 800 YEARS.

µg/L	MICROGRAMS PER LITER
AFRL	AIR FORCE RESEARCH LABORATORY
BLVD	BOULEVARD
CO.	COUNTY
CZ	CONTAINMENT ZONE
EAFB	EDWARDS AIR FORCE BASE
JCT.	JUNCTION
LUCs	LAND USE CONTROLS
NAD	NORTH AMERICAN DATUM
PCE	TETRACHLOROETHENE
RD	ROAD
TCE	TRICHLOROETHENE
U.S.	UNITED STATES
UTM	UNIVERSAL TRANSVERSE MERCATOR

NOTE:

BOUNDARIES OF NORTH MUROC AND LANCASTER SUBBASINS AND HI VISTA RECHARGE AREA FROM USGS 2005 FACT SHEET (SNEED ET AL 2006) AS ADOPTED FROM CARLSON ET AL (1998) BASED ON GEOPHYSICAL EVIDENCE.

South AFRL ROD

Sites 37, 120, 133, and 321
Reference Map and South AFRL CZ and Groundwater LUC Compliance Boundary

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		2.1-2

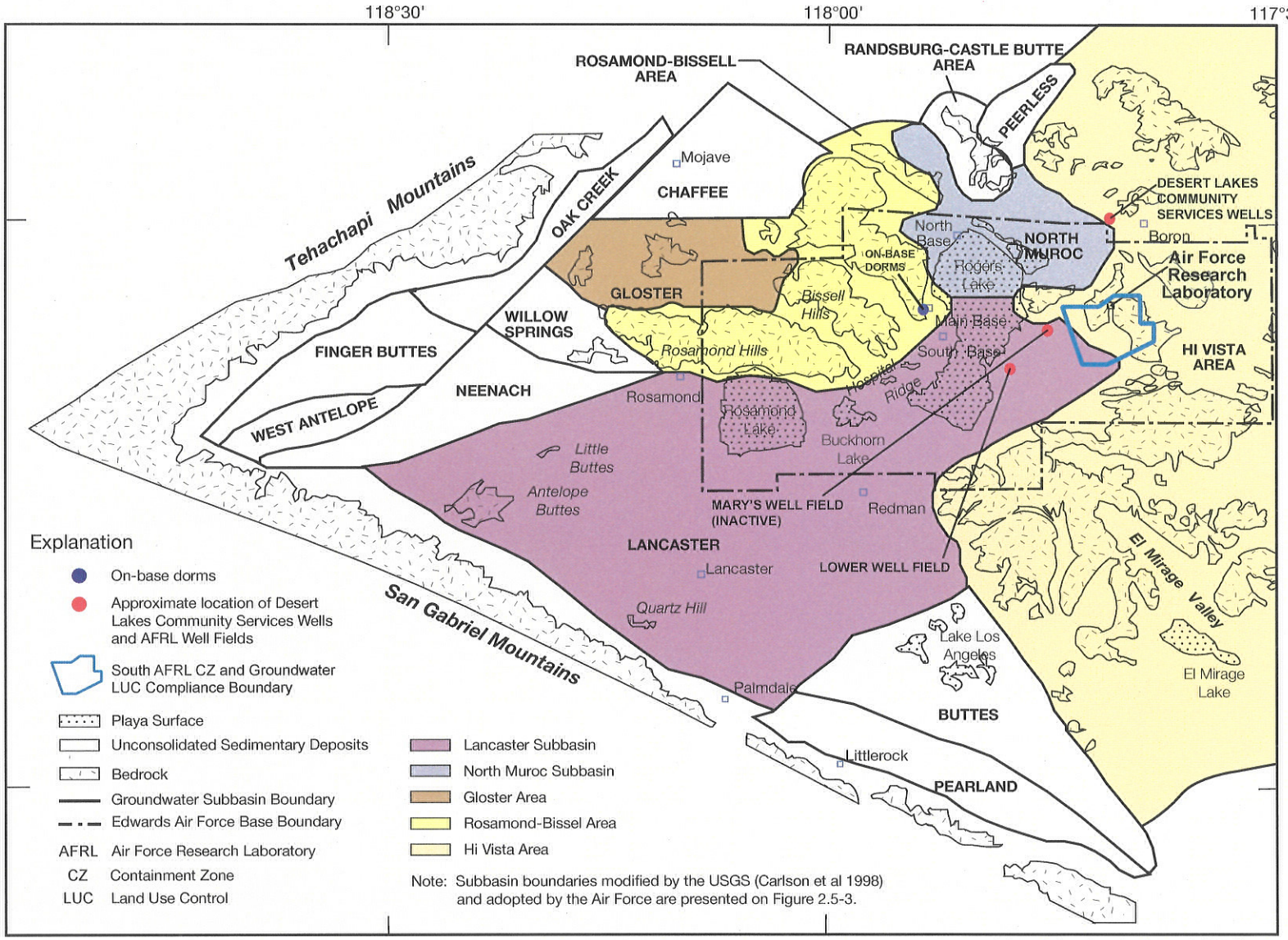
EDWARDS\ 67861\B5896FGA.A02

the source areas for Sites 37 and 133, these solvents are suspected to be present as DNAPLs, based upon 1) historic practices at these sites (as described in Section 2.2.2); 2) vertical distribution of PCE just south of Building 8595 (Site 37) and of TCE adjacent to Dry Wells E and F (Site 133); and 3) dissolved phase concentrations that persist at greater than 1% (1,500 micrograms per liter [μg/L] for PCE and 11,000 μg/L for TCE) of their free-phase solubility, cited by the USEPA (1994) as presumptive evidence for the presence of a DNAPL.

The groundwater beneath the South AFRL, which occurs in fractured granitic bedrock in the Hi Vista area (Figure 2.1-3), is not considered an aquifer and is not part of a groundwater basin as defined by the USGS (refer to Sections 2.5.2.2 and 2.6.1). Rather this area of shallow bedrock and low groundwater yield provides recharge to the surrounding Lancaster and North Muroc Sub-basins. The nearest on-base drinking water wells are located in the Lancaster Sub-basin approximately 6.8 miles southwest of the AFRL cantonment area and approximately 5.1 miles from the outer limits of groundwater contamination at the South AFRL. The on-base water supply is supplemented by Sacramento Delta water from the State Water project, which is piped to the AFRL by the Antelope Valley-East Kern (AVEK) Water Agency. The nearest off-base drinking water wells (currently off-line due to naturally-occurring arsenic concentrations exceeding the federal pMCL) are located approximately 650 feet northeast of the Base boundary, which is approximately 3.4 miles north of the South AFRL CZ. The nearest residential areas are located approximately 4.3 miles to the north of the CZ just outside the base boundary in the town of Boron. There are also dormitories and Base housing located approximately 8.6 miles and 10.1 miles, respectively, west of the South AFRL CZ at the Main Base, across Rogers Dry Lake bed. The nearest surface water courses are numerous intermittent streams that drain the South AFRL following heavy rains.

2.2 SITE ENFORCEMENT ACTIVITIES AND HISTORY

The United States (U.S.) Congress passed CERCLA in 1980. In that same year, the Department of Defense (DoD) issued guidelines to investigate and clean up wastes from past operations at military installations worldwide. Shortly afterward, the Air Force began investigating its bases under the DoD ERP, with the goal of protecting human health and the environment. The ERP at Edwards AFB is a



Adapted from Londquist et al. (1993).

North

0 10 20 Miles

0 10 20 Kilometers

S. AFRL ROD

Groundwater Subbasins and Shallow Bedrock Areas in the Antelope Valley

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure 2.1-3
Project No. 67861		

67861.17.03 South AFRL ROD : Fig. 2.1-3

localized version of the DoD program with active participation from the USEPA and the State of California. The ERP is managed and implemented by the Environmental Restoration Branch, under the 95th Air Base Wing, Environmental Management Division (95 ABW/CEV). In 1981, a preliminary assessment was performed for Edwards AFB that included a limited identification of ERP sites at the AFRL. Most of the early ERP studies at Edwards AFB were focused on sites identified at the Main Base and South Base.

Following Edwards AFB's formal listing on the National Priorities List (NPL) on 30 August 1990, the USAF entered into a Federal Facility Agreement (FFA) with the USEPA, California DTSC, and the Water Board. The FFA establishes the process for involving USEPA and the State and the public in the Edwards AFB remedial response process. It provides a procedural framework for developing, implementing, and monitoring response actions at Edwards AFB in accordance with CERCLA, SARA, the NCP, pertinent provisions of RCRA, and applicable or relevant and appropriate state laws.

In response to Edwards AFB's listing on the NPL, and to facilitate the investigation of wastes from past military and/or tenant agency use and implement response actions, the Base was divided into 10 OUs. The OUs are defined by lease boundaries, if applicable; geographic location; similarities in contaminant types and distribution; and/or hydrologic setting. OUs 1, 6, and 8 are located in the Main Base area; OU2 is located in the South Base area; OU3 consists of abandoned or no longer required water wells located throughout the Base; OUs 4 and 9 are located in the AFRL area east of Rogers Dry Lake; OU5/10 is located in the North Base area (formerly OUs 5 and 10); and OU7 includes miscellaneous/individual sites located outside of the other OUs. OUs 4 and 9, while encompassing all of the AFRL lease boundary, also extend into the PIRA that borders the AFRL to the northeast, east and south.

2.2.1 IDENTIFICATION AND STATUS OF ERP SITES IN OU4 AND OU9

From 1991 to 1993, a comprehensive Expanded Source Investigation/RCRA Facility Assessment (ESI/RFA, The Earth Technology Corporation 1993) was performed that covered the entire Base, including the AFRL facilities. The ESI/RFA involved the assessment and inspection of over 1,000 features, from small hazardous waste storage facilities to large, multiple-story aircraft hangar/maintenance facilities and rocket test stands. Based on 1) results of the ESI/RFA,

2) a subsequent site inspection (SI) conducted between 1993 and 1995, and 3) development of remedial investigation/feasibility study (RI/FS) field sampling plans for OU4 (Earth Tech 1996a) and OU9 (Earth Tech 1996b), a total of 88 sites and areas of concern (AOCs) were identified as contaminated or potentially contaminated in OU4 (one site was identified in 1999 bringing the total to 89) and 46 sites and AOCs were identified as contaminated or potentially contaminated in OU9.

2.2.1.1 Sites Removed from the CERCLA Process

Of the 89 OU4 sites or AOCs, 38 were eliminated after the SI study phase because "no significant contamination" was identified through investigative activities such as soil and soil gas sampling, generally by screening sampling results (where chemicals were detected) against residential Preliminary Remediation Goals (PRGs published by USEPA Region 9); consistent with the CERCLA petroleum exclusion, another 29 were removed from the CERCLA process because they involved petroleum only. The majority (24) of the petroleum-only sites correspond to the locations of removed underground storage tanks (USTs), which generally were used to contain heating oil; two sites (184, 186) included USTs associated with a former and active gas station; the other three sites (32, 40, 169) involved the aboveground storage and/or rail transport of large volumes of rocket propellant (RP-1) fuel. Based on results of soil samples collected at the time of tank removal, during further site characterization, or following interim removal actions (IRAs) including bioventing (Sites 143 and 144) and excavation (Sites 32, 137, 151, 169), these sites were all approved for no further investigation (NFI) by the RPMs and (with the possible exception of continued groundwater monitoring at Site 32) require no further action by the local enforcement agency (Kern County Environmental Health Services Department [KCEHSD]).

Of the 46 OU9 sites or AOCs, 29 were eliminated after the SI study phase because "no significant contamination" was identified, generally by screening soil sampling results (where chemicals were detected) against residential PRGs; six were removed because they involved petroleum only (and were approved for NFI on the basis of soil sampling results); and one (Site 39) was removed from the CERCLA process because it remains an active waste management site. The remaining 22 sites and AOCs in OU4 were investigated during the remedial investigation (RI) phase between 1996 and 2004 while the remaining 10 sites in OU9 were investigated in the RI phase between 2001 and 2005. Detailed information for these 32 sites and AOCs is available in the OU4 Remedial Investigation Summary Report (OU4 RISR) (Earth Tech 2005a) or the OU9 Remedial Investigation Summary Report

(OU9 RISR) (Earth Tech 2006a) and in previously issued Site/AOC reports referenced in the RISRs. These documents are included in the publicly available Administrative Record files for OU4 and OU9 maintained at the 95th Air Base Wing, Environmental Management Division, 5 East Popson Avenue, Building 2650A, Edwards AFB, California, 93524.

2.2.1.2 Sites Remaining in the CERCLA Process

For the feasibility study (FS) and subsequent phases, the 32 sites in OU4 and OU9 remaining in the CERCLA process were organized by contaminated medium (groundwater or soil) as shown below (note that Sites 115 and 318 appear in both lists):

- Impacted groundwater (further categorized by geographic location and direction of groundwater flow):
  - South AFRL - Sites 37, 120, and 133 in OU4 and Site 321 in OU9.
  - AFRL Arroyos - Sites 162 and 461 in OU4.
  - Northeast AFRL - Sites 177 and 318 in OU4 and Sites 115, 116, 178, and 325 in OU9.
  - Mars Blvd - Site 333 in OU4 and Sites 27, 125, and 127 in OU9.
- Impacted soil and/or debris: Sites 7, 13, 26, 36, 150, 153, 166, 167, 170/171, 172, 312, 318, 329, and 396 in OU4; and Sites 6, 113, and 115 in OU9.

Locations of the 32 sites remaining in the CERCLA process are shown on Plate 1. Descriptions of the soil and debris sites are provided in Table A-1 (for sites located within the South AFRL CZ) and Table A-2 (for all other soil and debris sites). Descriptions of sites having impacted groundwater are provided in Table A-3.

2.2.2 SITES ADDRESSED IN THIS ROD

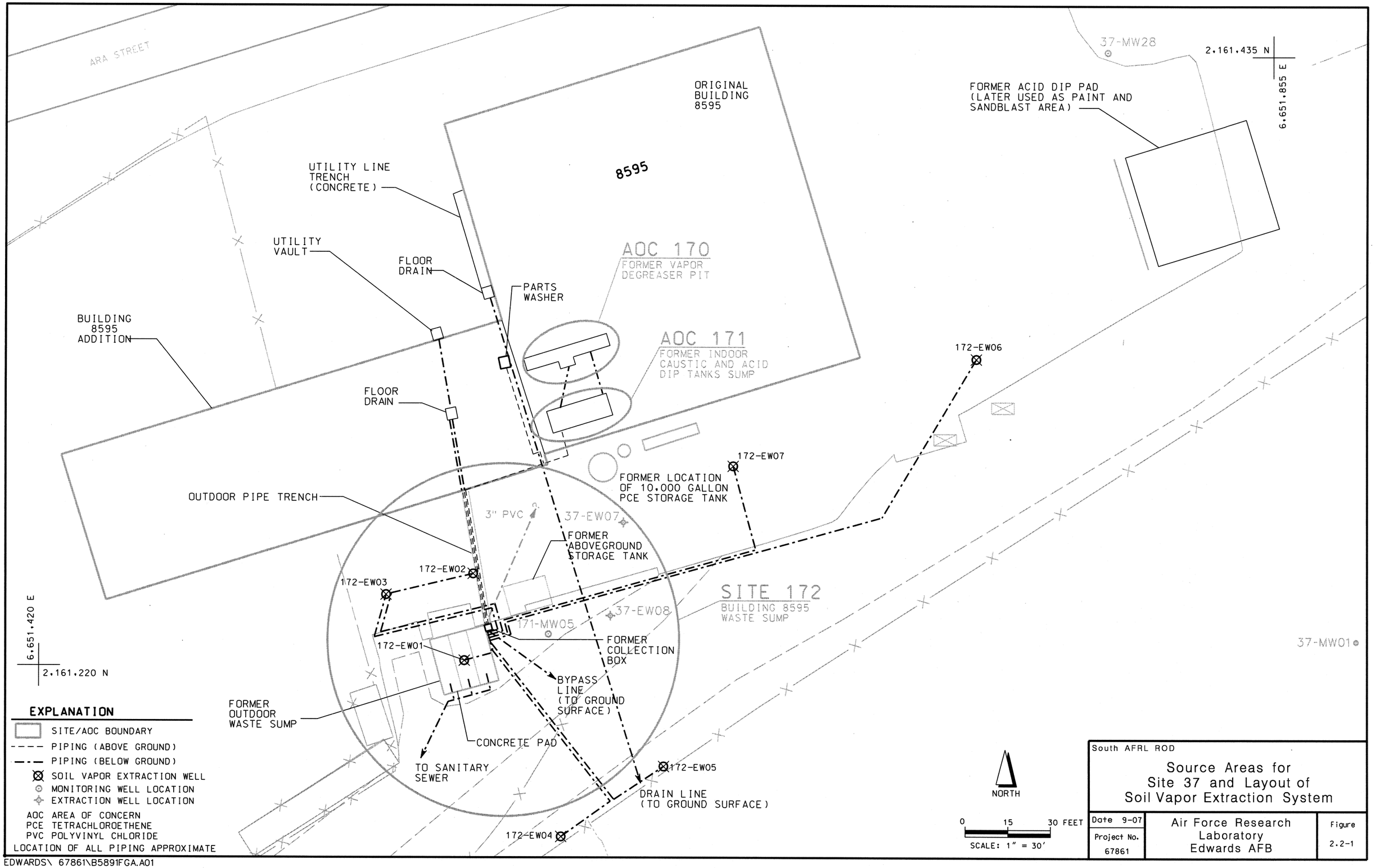
This decision document addresses groundwater and suspected DNAPL solvent contamination at Sites 37, 120, 133, and 321 in the South AFRL area of OUs 4 and 9. Soil vapors originating from the impacted groundwater (at Sites 37, 120, 133, and 321) and from soil (at Sites 37 and 321) are also addressed. The soils at Sites 37, 120, 133, and 321 have been recommended for No Action, and the selection of No Action is explained and justified in Section 2.7 of this ROD.

2.2.2.1 Site 37 – Building 8595 PCE Plume

Site 37 originates at Building 8595 on the southwestern flank of Leuhman Ridge. This building was used from 1960 to 1997 for maintenance and repair of rocket components. These processes involved the use of chemicals, primarily PCE, which were inadvertently spilled or otherwise released to the ground surface, creating a large plume of contaminated groundwater. Past sources at Building 8595 that contributed to groundwater contamination include a removed indoor vapor degreaser and its associated concrete pit (identified as AOC 170) and removed indoor caustic and acid dip tanks and an associated indoor sump (AOC 171). Liquids that collected in the indoor sump were discharged via pipeline to an outdoor waste sump (Site 172). A major source of PCE contamination to groundwater underlying Site 37 is attributed to a release from a 10,000-gallon aboveground storage tank (AST) that supplied PCE to the vapor degreaser. The release occurred when a valve was inadvertently left open sometime in the early 1980s allowing the tank contents to spill onto the ground surface. Assuming the tank was filled to its capacity, one can estimate a maximum release of 136,000 pounds from this spill. Figure 2.2-1 identifies these Site 37 groundwater contaminant source areas; AOCs 170, 171, and 172, as listed in Table A-1, are addressed in the AFRL Soil and Debris Sites Proposed Plan (PP). Source control actions completed at Site 37 are listed in Section 2.2.3.2; further details are provided in Table A-4 in Appendix A. Since 1998, the building has been used as an electronic propulsion research laboratory; the work performed does not include the use or release of chlorinated solvents or other hazardous materials.

2.2.2.2 Site 120 - AFRL Sewage Treatment Plant

Site 120, the former AFRL sewage treatment plant (STP), is located outside the AFRL security gate along the entry road to the PIRA. The STP was constructed in the early 1950s and included an Imhoff tank for sedimentation of suspended solids, two unlined sludge-drying beds, seven unlined evaporation/percolation ponds, and three unlined overflow ponds. The locations of these features are shown on Figure 2.2-2. Before the plant was renovated in 1995, the partially-treated wastewater was discharged from the Imhoff tank to the evaporation/percolation ponds and allowed to evaporate or seep into the soil. Based on results for groundwater samples, the water discharged to these ponds in the past may have contained dissolved solvents (primarily PCE) and other chemicals that were disposed of



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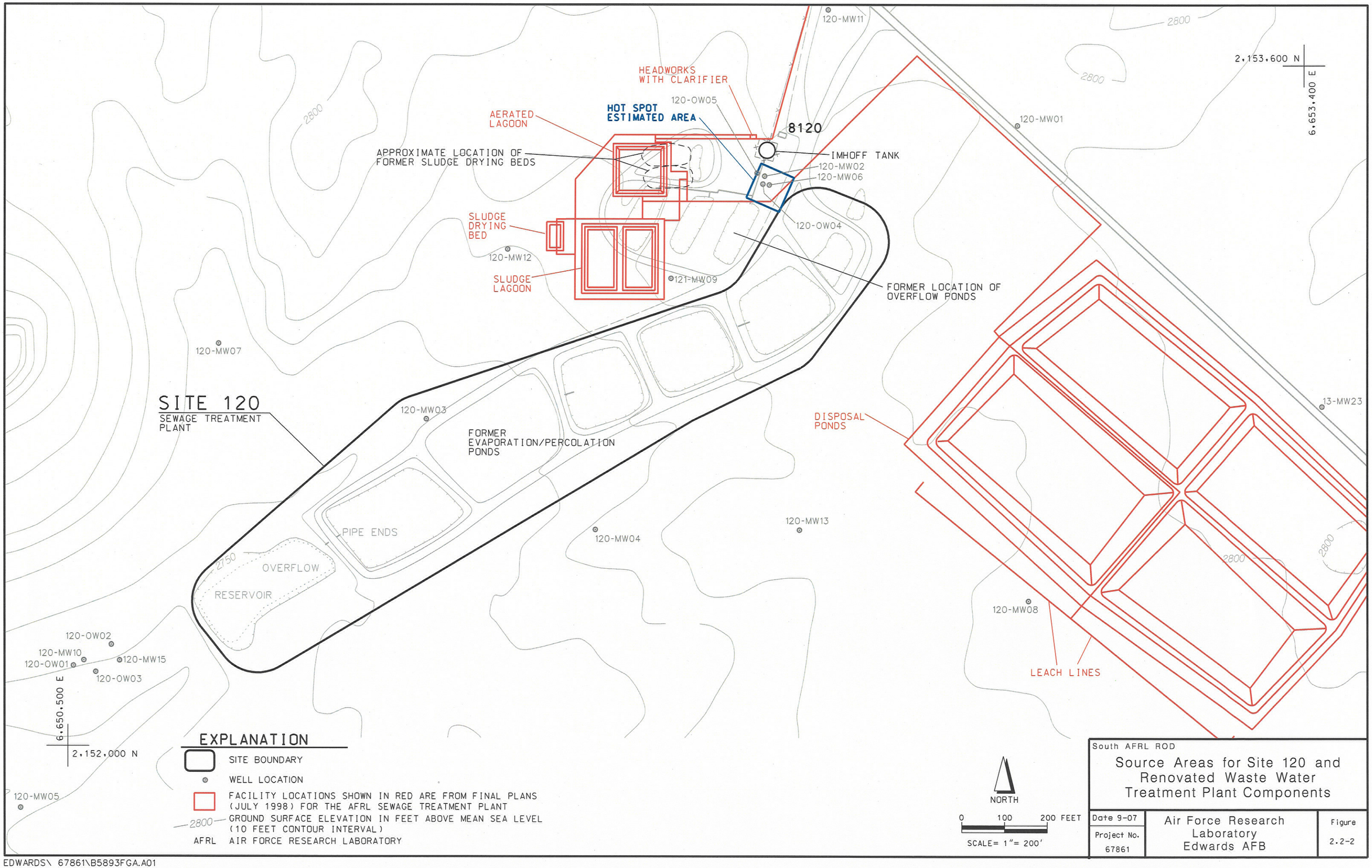

South AFRL ROD

Source Areas for Site 120 and Renovated Waste Water Treatment Plant Components

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure 2.2-2
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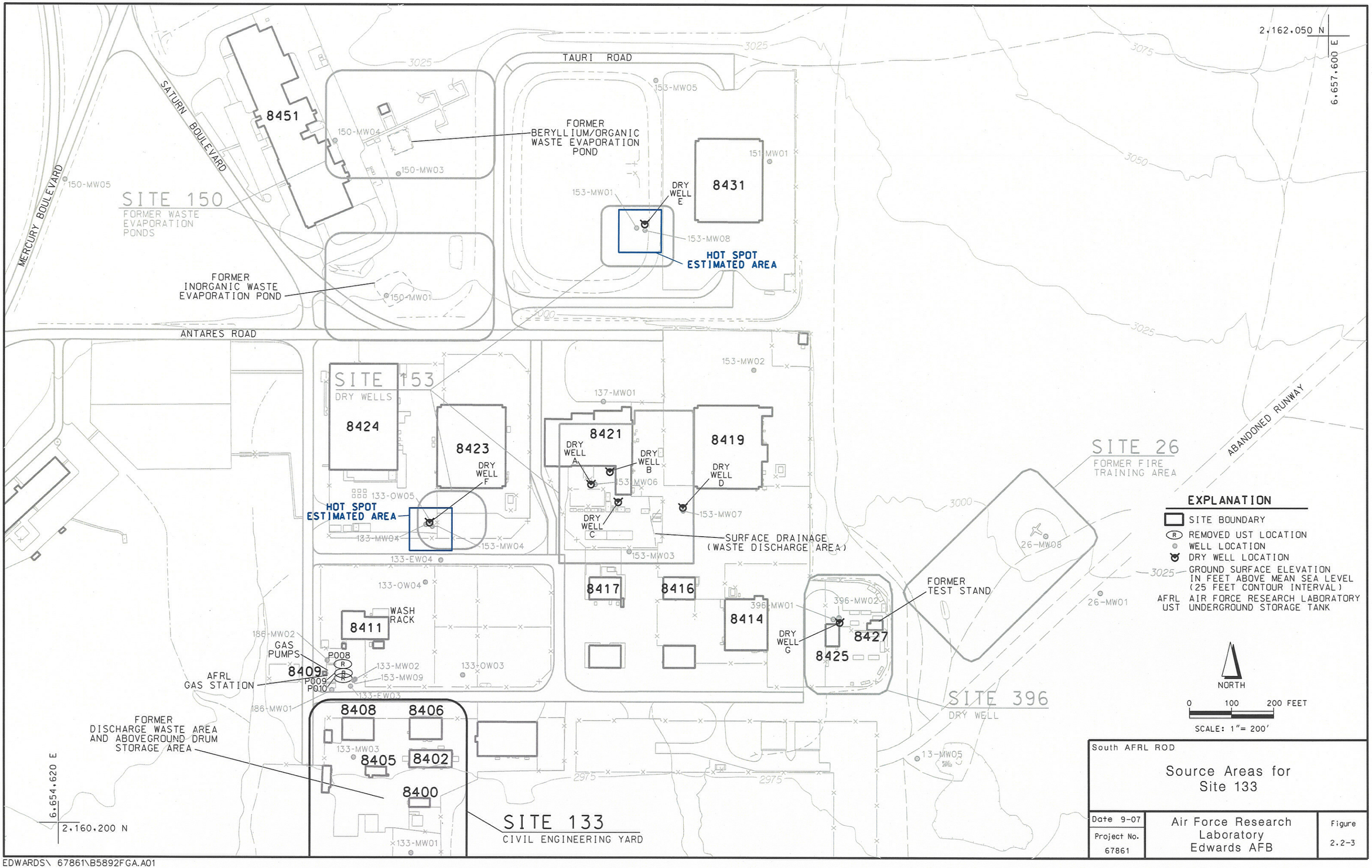
in sinks and storm drains throughout the AFRL. The renovated STP facilities (shown in red on Figure 2.2-2), which include secondary treatment, went on line in May 1999. The original STP had a reported treatment capacity of 137,000 gallons per day (gpd) but, prior to renovation of the facility, was treating approximately 85,000 gpd. The renovated STP facility is permitted to treat 125,000 gpd. However, the actual treatment volume ranges from 50,000 gpd to 80,000 gpd.

2.2.2.3 Site 133 – AFRL Civil Engineering Yard

The Site 133 groundwater plume encompasses a large area south of Leuhman Ridge. Site 133 was first identified as the AFRL civil engineering (CE) yard, but was expanded to include groundwater under: two former waste evaporation/percolation ponds (Site 150) associated with the chemistry laboratory (Building 8451); the AFRL gas station; several former waste disposal (dry) wells identified as Sites 153 and 396, including dry wells E and F associated with Buildings 8431 and 8423 (former missile assembly buildings); and a former fire training area (Site 26). Site records are incomplete and do not allow confidence in any approximation of the mass released at Site 133. However, groundwater sampling results indicate that the highest concentrations of TCE are found at depth in monitoring wells installed down gradient from dry wells E and F. To provide some indication of the mass that may have been released, it was assumed that the equivalent of 10 55-gallon drums of TCE were disposed to each of the two dry wells during the 30-plus years over which these releases may have occurred. This assumption leads to an estimated release approaching 15,000 pounds of TCE. Figure 2.2-3 identifies the Site 133 groundwater contaminant source areas; as listed in Table A-1, Sites 26, 150, 153, and 396 are addressed in the AFRL Soil and Debris Sites PP.

Potential release locations identified at the CE yard included a former waste discharge area located south of Building 8405 and an aboveground drum storage area located approximately 50 feet further south, where materials including waste oils and spent solvents were discharged to the ground surface. Three removed USTs associated with the AFRL gas station (Building 8409) were used to store leaded and unleaded gasoline and released constituents including benzene and methyl tertiary-butyl ether (MTBE); waste oil and spent solvents may have also been discharged. Prior to the ponds being backfilled with soil in the mid 1970s, a wide variety of chemicals may have been released from the chemistry laboratory to the waste evaporation/percolation ponds including TCE, PCE, 1,4-dioxane



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and N-nitrosodimethylamine (NDMA). The waste disposal wells associated with former missile assembly buildings are suspected to have been used in the past to dispose of spent and/or pure phase TCE; when decommissioned in 2001, these wells were receiving only condensation (clean water) drainage from the buildings' air conditioning systems. Exercises conducted at the former fire training area involved the use of jet propellant 4 (JP-4) fuel; based on sampling results, spent PCE was apparently also discharged to the ground surface in this area.

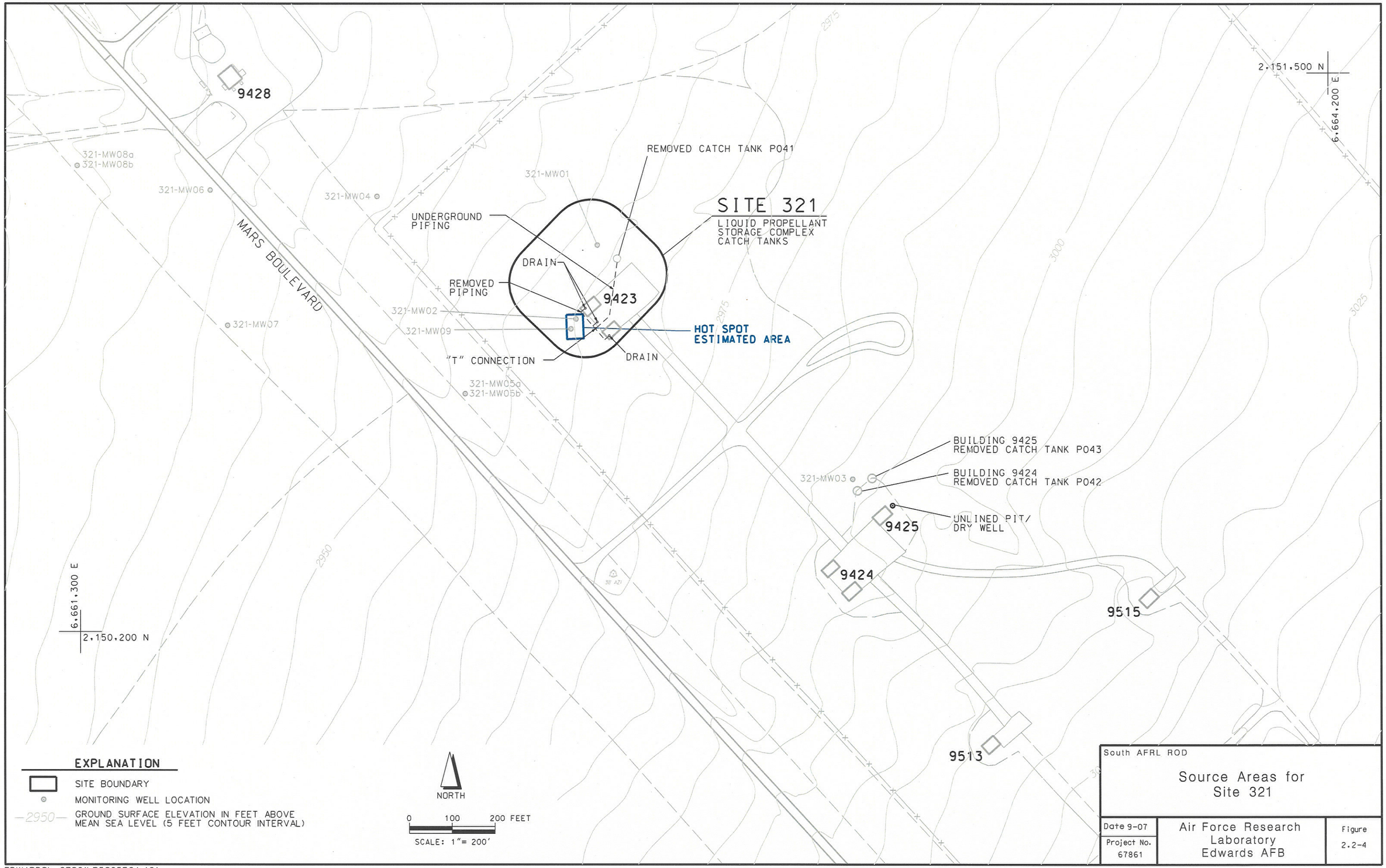
Source control actions completed at Site 133 are listed in Section 2.2.3.2; further details are provided in Table A-4 in Appendix A. The Site 133 groundwater plume extends underneath the closed AFRL landfill identified as Site 13 (addressed in the AFRL Soil and Debris Sites PP), and merges into Site 120 at its southern extent (refer to Figure 2.1-2).

2.2.2.4 Site 321 – Liquid Propellant Storage Complex Catch Tanks

Site 321, located at the Liquid Propellant Storage Complex along Mars Blvd. (Figure 2.2-4) in OU9, was used as a storage area for liquid rocket propellants (hydrazine and nitrogen tetroxide). Sampling results show that PCE and TCE were released here as well. Three catch tanks, formerly used to contain runoff of excess chemicals and rainwater from three associated buildings (9423, 9424, and 9425), were removed in 1995. Rinse water released to the catch tanks during the 1960s and 1970s may have contained diluted spent solvents. Leakage from the 8,000- to 18,000-gallon tanks (before they were removed) is the source of the groundwater contamination at this site.

2.2.3 PREVIOUS SITE ACTIVITIES

An overview of the types of site investigation, completed source control actions, and ongoing treatability studies is presented below, with results summarized in Section 2.5. Investigation procedures and results are presented in much greater detail in technical reports including the RISRs for OU4 and OU9 and the *Focused Feasibility Study to Support a Technical Impracticability Evaluation/Containment Zone Application for the South AFRL (Sites 37, 133, 120 and 321)* (South AFRL Focused FS, Earth Tech 2005b) available in the Administrative Record.



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2.2.3.1 Remedial Investigations and Monitoring

SI and RI activities were performed at Sites 37, 120, 133, and 321 from 1993 through 2005. These activities included soil gas sampling, soil borehole logging, soil sampling, monitoring well installation, quarterly groundwater level measurements, groundwater sampling, a test of vacuum extraction in the bedrock at Site 37, groundwater pump testing to derive aquifer parameters, surface fracture mapping, and a three-dimensional seismic reflection survey at Site 37. Groundwater monitoring was performed approximately semiannually at Sites 37, 120, and 133 in OU4 from 1998 through 2001 and annually beginning in 2002; annual samples have been collected at Site 321 since 2003. In 2004, an LTM program (Earth Tech 2004a revised 2005) began that included sampling of selected wells on either a semiannual, annual, or biennial basis and a discontinuation of sampling in some wells.

2.2.3.2 Source Control Actions

The following source control actions to prevent ongoing or future releases have been completed at Sites 37, 120, 133, and 321:

- Decommissioned, cleaned, and backfilled the leaking sumps (AOCs 170/171 and Site 172) at Building 8595 in 1997. Replaced the flooring inside the building now used as an electronic propulsion laboratory (Earth Tech 1998);
- Renovated and upgraded the STP (Site 120) between 1995 and 1999, including taking the former Imhoff tank, sludge drying beds, and waste evaporation/percolation ponds out of service (as described in Earth Tech 1999a);
- Removed USTs from the AFRL gas station (petroleum-only Site 186) in 1995 (Earth Tech 2000a);
- Removed an AST from the former fire training area (Site 26) (Earth Tech 2000b) and excavated petroleum-contaminated soil in 2000 and 2001 (Earth Tech 2001a);
- Excavated petroleum-impacted soil associated with removed USTs in the CE Yard in 2001 and at Building 8431 in 1995 (petroleum-only Sites 137 and 151) (Earth Tech 2002 and 1996c, respectively);
- Destroyed waste discharge wells (Sites 153 and 396) by redirecting active inlet lines; cleaning out contaminated soil, sludge and water; and backfilling with cement/sand slurry in 2001 (Earth Tech 2001b);
- Installed a final cover system at the AFRL Landfill (Site 13) in 2001 to 2002 (Earth Tech 1999b revised 2000 and Earth Tech 2003c); and

- Removed below-grade catch tanks associated with Site 321 in 1995 (Aman Environmental Construction, 1996).

These actions, and supporting references, are summarized in Table A-4 in Appendix A.

2.2.3.3 Treatability Studies and Interim Removal Actions

In addition to source control actions listed above, the following TSs and IRAs are ongoing at Sites 37 and 133 (however, the Air Force does not plan to continue operation of these systems as part of the RA for the South AFRL):

- Operation of a GETS as a TS at Site 37 since 1999. The system began operation with two extraction wells in January 1999 and was later expanded to include seven extraction wells (including three inside the suspected DNAPL zone). Extraction well locations are shown in purple on Figure 2.1-2. A treatability study evaluation report (TSER) (Earth Tech 2000c) concluded that the system demonstrated success in slowing the lateral spread of near-surface dissolved contaminants above a targeted PCE concentration of 10,000 μg/L. In 8 years of operation (through 2006), the system removed an estimated 566 pounds of PCE at an estimated cost (for annual O&M including monitoring) of approximately $2,917 per pound (refer to Table A-5 in Appendix A). Due to the continual slow dissolving of PCE from DNAPL into the overlying groundwater, however, it is estimated that the system would be required to operate indefinitely (well over 100 years) to continue to contain the lateral spread of contaminants near the surface.

- Operation of a small-scale GETS as a TS at Site 133 since 2001. This system, like the one at Site 37, was designed to slow the lateral spread of near-surface groundwater contamination, and was shown to be effective within its area of influence. The system includes four groundwater extraction wells (shown in green on Figure 2.1-2), but operation of the wells is limited by the volume of treated water that can be discharged (treated water is piped to the AFRL STP). In 6 years of operation (through 2006), the system removed an estimated 303 pounds of TCE at an estimated cost (for annual O&M) of $4,062 per pound (refer to Table A-5 in Appendix A). One reason the cost is so much higher than at Site 37 is because perchlorate was also treated between 2004 and 2006. As at Site 37, due to the continual slow dissolving of DNAPL (TCE at Site 133) into the overlying groundwater, system operation would be required indefinitely (well over 100 years) to continue to contain the lateral spread of contaminants near the surface.

- Operation of an SVE and treatment system as an IRA beneath and surrounding the former waste sump (Site 172) south of Building 8595 (refer to Figure 2.2-1) since 2000. Although the initial estimate of contaminant mass in the sandy fill material underlying the sump was relatively low (on the order of 100 pounds), in 7 years of operation (through 2006) the SVE system removed an estimated 7,379 pounds of PCE at a cost (for annual O&M) of approximately $123 per pound (refer to Table A-5 in Appendix A). In July 2006, the system was taken off line to allow monitoring for rebound in VOC concentrations in the

soil vapor. The results of this rebound monitoring led to a revised conceptual site model (CSM) for the unconsolidated soils south of Building 8595 (as presented in Section 2.5.4).

Because a primary difficulty in implementing RAs at the South AFRL is effective distribution of material to, or extraction of groundwater from, the fractured granitic bedrock, a pilot study involving the creation of two engineered fractured bedrock zones (FBZs) was conducted at Site 37 beginning in late 2004. The objectives of the pilot study were to:

- Evaluate the ability of an FBZ to increase aquifer yield in the low permeability water-producing zone(s) at Site 37;
- Assess the long-term sustainability of increased extraction yield; and
- Evaluate the practicality and ability to use blast fracturing in a larger scale design and/or at other sites to increase groundwater yields and/or the ability to enhance delivery of treatment components to the aquifer.

Based on observations made prior to and during fieldwork to create the two small FBZs (Earth Tech 2006b), and results obtained during subsequent long-term pumping tests, the pilot study performance in meeting these objectives is summarized below:

- Aquifer yield was not increased in the low permeability water-producing zone(s) at Site 37.
- The extraction yields in pumping wells installed inside each of the FBZs were not substantially increased. Over a 4-month pumping period, a pumping rate of 0.02 gallons per minute (gpm) was sustained in Well 37-EW09 (in the northern FBZ) and 0.13 gpm in Well 37-EW10 (in the southern FBZ).
- Due to limitations (for safety reasons and potential damage to utilities) on the amount of explosives that can be used to create the fractures, and the depth of dissolved phase and suspected DNAPL at South AFRL sites, FBZ is considered impractical in a large-scale design to increase groundwater yields and/or the ability to enhance delivery of treatment components to the aquifer.

2.3 COMMUNITY PARTICIPATION

The OU4 RISR was finalized in March 2005 and the OU9 RISR was finalized in February 2006. Both reports, as well as the South AFRL Focused FS (final dated June 2005) and the *Proposed Plan for Cleanup of Groundwater at the South Air Force Research Laboratory* (South AFRL PP) dated

April 2006 were added to the Administrative Record file maintained at the 95th Air Base Wing, Environmental Management Division, 5 East Popson Avenue, Building 2650A, Edwards AFB, California 93524.

The Edwards AFB Restoration Advisory Board (RAB) is a voluntary group that meets quarterly to facilitate the exchange of information and concerns between on-base and off-base communities, federal and state regulators, and Edwards AFB ERP managers. An overview of the South AFRL PP was presented at the RAB meeting held on 16 February 2006 in North Edwards, California.

A 2-page fact sheet about the South AFRL PP was distributed with the March 2006 mailing of Report to Stakeholders, a monthly publication prepared by the Community Relations department of 95 ABW/CEV with a mailing list of approximately 2,000. A notice of availability of the South AFRL PP was published in local newspapers (the *Antelope Valley Press*, *Desert Wings*, and *Mojave Desert News)* in April 2006. A public comment period was held from 7 April 2006 to 13 May 2006. Public meetings were held on 12 April 2006 and 25 April 2006 to present the South AFRL PP to a broader community audience than those that had already been involved. At the 12 April 2006 meeting held at the AFRL lunchroom, approximately 13 workers attended two separate sessions where a PowerPoint presentation was delivered followed by a question-and-answer session (summarized in Section 3, Responsiveness Summary). Posters explaining the site hydrogeology and presenting the remedial alternatives were also made available. Prior to the 25 April 2006 meeting held in Boron, CA, advertisements were published in the same three newspapers cited above. Representatives from Edwards AFB, the California DTSC, and the Water Board were available to answer questions from the community about problems at the South AFRL and the proposed remedial alternatives. The same posters and PowerPoint presentation (revised to incorporate clarifications based on the AFRL meeting) were presented. However, only one community member (the North Edwards representative on the RAB) attended the Boron meeting. Transcripts from both meetings are available in the Administrative Record for OU4 and OU9. One letter dated 2 June 2006 was received in response to the fact sheet placed in the Edwards AFB Report to Stakeholders newsletter; a discussion of the letter and USAF response are included in the Responsiveness Summary (Section 3 of this ROD).

2.4 SCOPE AND ROLE OF OPERABLE UNIT OR RESPONSE ACTION

OU4 and OU9 at the AFRL are two of the 10 OUs at Edwards AFB (refer to Figure 2.1-1) designated to group sites with similar site operations, or conditions and contaminants. OU4 and OU9 are the only OUs located east of Rogers Dry Lake and as such, receive no hydrogeologic influence from the other OUs at Edwards AFB. As presented in Section 2.2.1.2, the 32 sites and AOCs in OU4 and OU9 remaining in the CERCLA process through the RI/FS have been subcategorized into soil and debris sites and four groundwater areas. These sites and groundwater areas are shown on Plate 1 and are listed in Tables A-1 through A-3 in Appendix A. Table A-1 lists the soil and debris sites located within the South AFRL CZ while Table A-2 lists the other soil and debris sites (those not in the South AFRL CZ) in OU4 and OU9 remaining in the CERCLA process. The subject of this ROD is groundwater contamination at the South AFRL, which includes Sites 37, 120, and 133 in OU4 and Site 321 in OU9. Table A-3 lists these sites and the other groundwater sites (not in the South AFRL CZ) in OU4 and OU9 remaining in the CERCLA process. The RA at the South AFRL is not dependent on the implementation of response actions at any other OU at Edwards AFB, or on the implementation of response actions at any other groundwater area in OU4 and OU9.

CERCLA remedial activities at the South AFRL, the subject of this ROD, focus on groundwater and indoor air at Sites 37, 120, 133, and 321. The results of RI activities and groundwater monitoring indicated that contaminants were detected in groundwater. Ingestion of extracted groundwater poses a potential risk to human health because USEPA's acceptable risk range (between 10^{-4} and 10^{-6}) is exceeded and concentrations of contaminants are greater than pMCLs. Inhalation of indoor air overlying impacted soil (at Site 37) and impacted groundwater (at all four sites) poses a potential risk to human health under a hypothetical residential (unrestricted) use and the current industrial exposure setting, based on results of a modeling simulation (Johnson and Ettinger [J&E] version 3.1), that predicts indoor air concentrations at levels exceeding 10^{-4} in localized areas. Groundwater at the South AFRL is not currently used for drinking water nor does the land use include residential uses; thus, potential risks associated with ingestion of COCs in groundwater are reduced by the lack of complete exposure pathways; however, the potential for inhalation of COCs in indoor air by workers must be addressed by disrupting currently complete exposure pathways. The Air Force will implement the

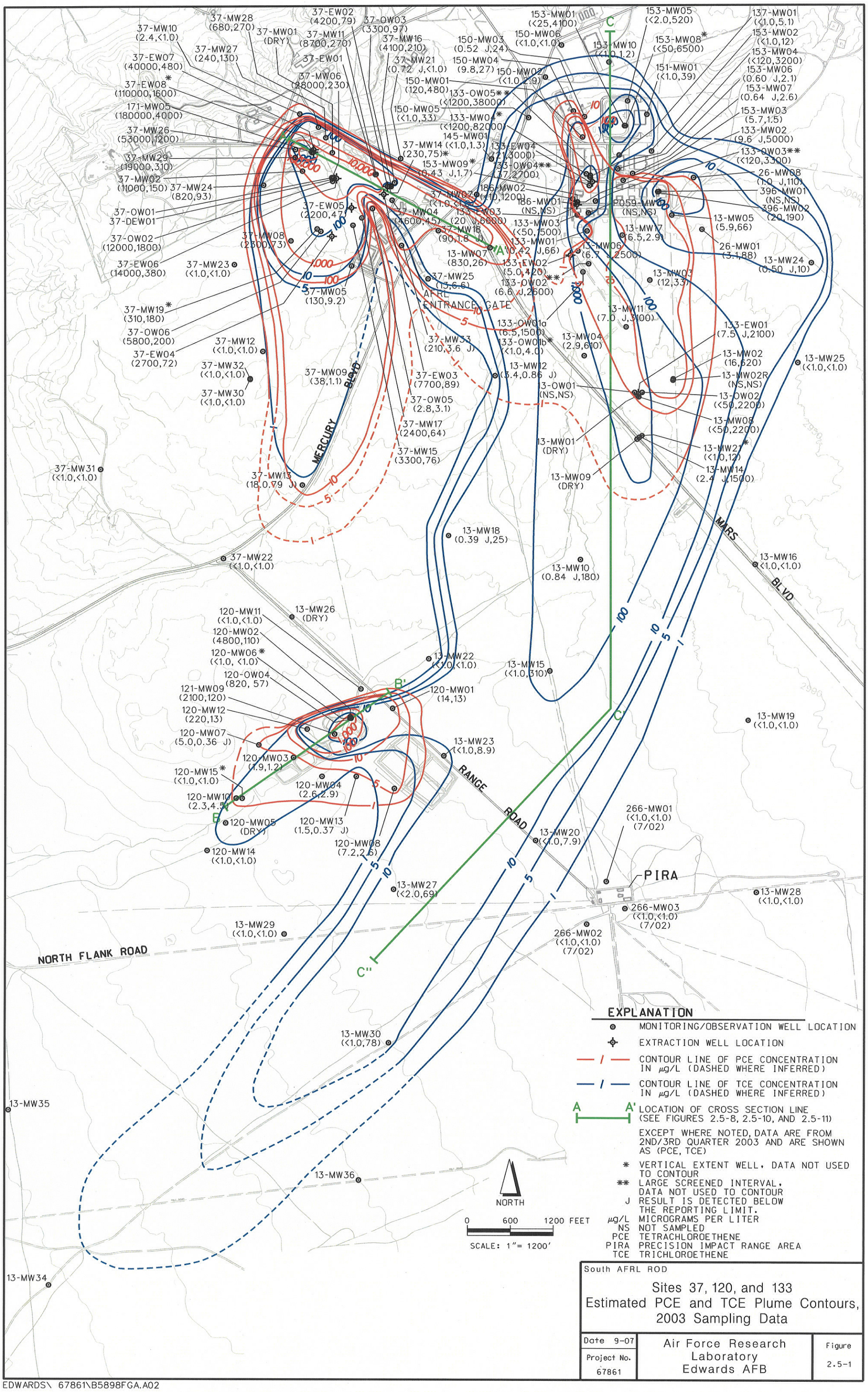
selected remedy using CERCLA remedial authorities. This ROD is a final remedy decision for groundwater at the South AFRL.

2.5 SOUTH AFRL CHARACTERISTICS

The current extent of the South AFRL groundwater plume encompasses 1,842 acres (refer to blue outlines on Figure 2.1-2; by comparison, the CZ established in this ROD is approximately 10,500 acres or 16.4 square miles). The estimated lateral distribution (based on 2003 sampling data) of the dissolved phase PCE and TCE plumes originating at Sites 37, 120, and 133 is shown on Figure 2.5-1. Figure 2.5-2 shows the estimated lateral distribution (based on 2003 sampling data) of the dissolved phase TCE and PCE plumes originating at Site 321.

Due to the reduced number of wells sampled during LTM events in 2004 through 2006, plume contours have not been updated since 2003; however, Table A-6 in Appendix A provides comparisons of the 2003 and 2006 concentrations of TCE and PCE measured in the wells that are sampled annually under the LTM. This comparison indicates that, despite fluctuations in individual wells, based on the aggregate data set, plume concentration contours have remained similar from 2003 through 2006. Figures and a statistical analysis of the concentration trends in individual wells are included in each annual groundwater monitoring report; a larger number of monitoring wells will be sampled in 2008 (and at subsequent 5-year intervals) to allow plume contours to be updated every 5 years.

The following sections provide a listing of COCs (Section 2.5.1), an overview of the regional environmental setting (Section 2.5.2), and a discussion of man-made features (Section 2.5.3), followed by, for each site, a summary of the sampling strategy and contaminant nature and extent (Section 2.5.4). The exposure pathways evaluated for each site in the HHRA and ERA are then presented (Section 2.5.5), followed by a CSM (Section 2.5.6) for the South AFRL, and computer-based modeling simulations of groundwater flow and contaminant transport (Section 2.5.7). Finally, in Section 2.5.8, an evaluation of the potential for groundwater restoration (justification for the TI waiver of ARARs) at the South AFRL is presented.



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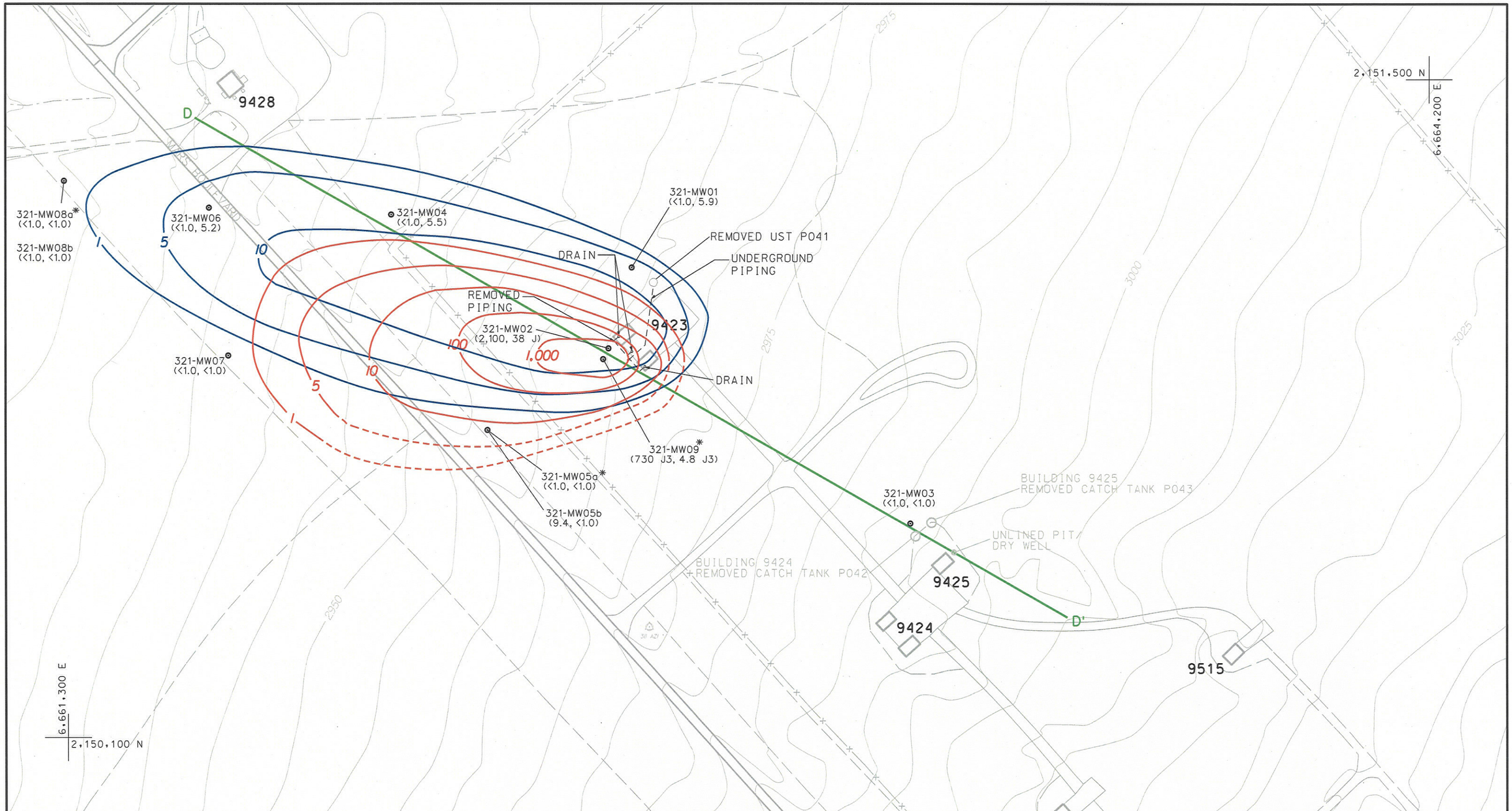

EXPLANATION

- ⊙ MONITORING WELL LOCATION
- —10— CONTOUR LINE OF PCE CONCENTRATION IN µg/L. (DASHED WHERE INFERRED)
- —10— CONTOUR LINE OF TCE CONCENTRATION IN µg/L.
- D——D' LOCATION OF CROSS SECTION LINE (SEE FIGURE 2.5-12)

DATA ARE FROM 2ND QUARTER 2003 AND ARE SHOWN AS (PCE, TCE).

*	VERTICAL EXTENT WELL, DATA NOT USED TO CONTOUR.
J	RESULT IS DETECTED BELOW THE REPORTING LIMIT.
J3	ESTIMATED VALUE. EXTRACTION OR ANALYSIS OUT OF HOLD TIME. MAY INDICATE LOW BIAS.
µg/L	MICROGRAMS PER LITER
PCE	TETRACHLOROETHENE
TCE	TRICHLOROETHENE
UST	UNDERGROUND STORAGE TANK

NORTH

0 100 200 FEET

SCALE: 1"= 200'

South AFRL ROD

Site 321
Estimated PCE and TCE Plume Contours, 2003 Sampling Data

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure 2.5-2
Project No. 67861		

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Complete site descriptions and results of previous investigations for Sites 37, 120, and 133 can be found in the OU4 RISR (Earth Tech 2005a) and references cited therein. A complete site description and previous sampling results for Site 321 are presented in the OU9 RISR (Earth Tech 2006a) and references cited therein.

2.5.1 SOUTH AFRL CHEMICALS OF CONCERN

COCs at the South AFRL were selected by the following process:

1. During the RI, groundwater at each site was analyzed for a standard suite of analytes (by the listed analytical methods) that included VOCs (SW5030/SW8260), semivolatile organic compounds (SW3510/SW8270), 22 metals (SW3005/SW6010), mercury (SW7470), and general water quality parameters (alkalinity [A2320], chloride, nitrate, and sulfate [E300], fluoride [E340.2], total dissolved solids [TDS, E160.1], hardness [A2340B], methylene blue active substances [MBAS, E425.1], and total organic carbon [TOC, SW9060]). Additional analyses (for chemicals such as 1,4-dioxane, NDMA, perchlorate, hydrazine and/or other exotic chemicals) were included where the site history indicated a potential release. Soil samples from each site were similarly analyzed by a standard suite of methods to which additional analyses were added where specific chemicals were considered to be potentially present based on the site history.

2. Of the validated data collected through August 2001 (for OU4 Sites 37, 120, and 133) and through January 2003 (for OU9 Site 321), all detected chemicals above upper limits on background (BG) concentrations established for the AFRL (Earth Tech 1999c revised 2000) were evaluated in the HHRA and ERA as described in Section 2.7.

3. Chemicals identified as posing a potential risk to human or ecological receptors were evaluated for consideration as COCs during risk management meetings held with the RPMs in 2004 and 2005. Among the factors considered during these meetings were the distribution of the chemical site-wide, its consistency of detection, whether there was an identified site source, and the concentration range relative to a given "target" concentration (e.g., pMCL and/or PRG) representing an acceptable risk level.

4. In response to a comment received from the Water Board on the draft ROD (dated November 2006), the previously determined BG value (18.2 milligrams per liter [mg/L] for nitrate as nitrogen [N]) and risk management decisions for nitrate were revisited. As a result, the Air Force has determined that the methodology used to calculate the BG level was invalid for nitrate, and has withdrawn this BG value. Furthermore, because nitrate (as N) values consistently exceed the pMCL (10 mg/L) in groundwater samples collected from one or more wells at each of the South AFRL sites, and the site histories indicate the potential for mission-related releases at each site, nitrate is now identified as a COC at each of Sites 37, 120, 133, and 321.

As the outcome of the process described above, the chemicals retained as COCs in groundwater at Sites 37, 120, 133, and 321 are listed in Table 2.5-1, which also includes the highest concentrations detected in 2003, the maximum detected concentrations (in any sampling event), and a comparison of these concentrations to the promulgated pMCLs or other RBCGs for each chemical. The COCs include VOCs (primarily PCE and TCE), chemicals identified as emergent contaminants of concern (1,4-dioxane, NDMA, and perchlorate), and nitrate.

No state or federal pMCL has been established for the emergent contaminants 1,4-dioxane, NDMA, and perchlorate. For drinking water systems, the State of California has established non-promulgated notification levels (NLs) of 3 μg/L for 1,4-dioxane, 0.01 μg/L for NDMA, and 6 μg/L for perchlorate (this latter is also a public health goal [PHG] for perchlorate as established by the California Department of Health Services). In January 2006, the DoD adopted a "level of concern" of 24 μg/L for perchlorate based on a USEPA drinking water equivalent level (DWEL); the DoD policy explicitly precludes action for perchlorate levels less than the DWEL. Therefore, concentrations of 3 μg/L for 1,4-dioxane, 0.01 μg/L for NDMA, and 24 μg/L for perchlorate have been adopted as the RBCGs in groundwater to be contained inside the South AFRL CZ.

2.5.2 SOUTH AFRL ENVIRONMENTAL SETTING

The climate at Edwards AFB including the South AFRL is characteristic of the high desert regions of California, with hot, dry summers and cool, slightly moist, mild winters. Temperatures in summer commonly exceed 100 degrees Fahrenheit, while winter temperatures may drop to below freezing. The mean annual rainfall is approximately 5 inches per year, with approximately 80% of precipitation falling between November and March.

The topography of the AFRL is greatly influenced by Leuhman Ridge, a prominent northeast-southwest trending topographic high on which the earliest AFRL test areas were located. The South AFRL begins on, and extends down gradient from, the southeast facing flank of Leuhman Ridge (refer to Figure 2.1-2). Surface flow from both sides of the ridge ultimately drains to Rogers Dry Lake, located to the west of the AFRL. Throughout the AFRL, and particularly along Leuhman Ridge and its southeastern flank, weathered and competent fractured granitic bedrock crops out at the ground surface.

TABLE 2.5-1. CHEMICALS OF CONCERN IN GROUNDWATER AT SOUTH AFRL

Contaminant	COC at Site(s)	Highest 2003 Level (μg/L)	Maximum Detected Concentration (μg/L)	Federal MCLGs[a] (μg/L)	Federal pMCL[a] (μg/L)	State of California pMCL[b] (μg/L)	TBC (μg/L)	Cancer Causing?
1,1,1-trichloroethane	37	1,100	8,800	200	**200**	200	-	No
1,1-dichloroethane	37	120	200	-	-	**5**	-	Possible
1,2-dichloroethane	133	9.1	37	0	5	**0.5**	-	Probable
1,1-dichloroethene	37	1,900	2,400	7	7	**6**	-	No
1,4-dioxane	37, 120, 133	391	470	-	-	-	*3* [c]	Probable
benzene	37,133	38[d]	38	0	5	**1**	-	Yes
cis-1,2-dichloroethene	37, 120, 133, 321	5,100	23,000	70	70	**6**	-	No
trichlorofluoroethane (CFC 113)	37	16,000	16,000	-	-	**1,200**	-	No
methylene chloride (dichloromethane)	37	650	1,200	0	**5**	5	-	Probable
methyl tert butyl ether (MTBE)	133	290	7,000	-	-	**13**	-	Probable
N-nitrosodimethylamine (NDMA)	37, 133	0.0798	0.415	-	-	-	*0.01*[c]	Probable
naphthalene	37	ND[e]	2000[f]	-	**-**	17	-	
tetrachloroethene (PCE)	37, 120, 133, 321	180,000	180,000	0	**5**	5	-	Probable
trans-1,2-dichloroethene	120, 133	46	160	100	100	**10**	-	No
trichloroethene (TCE)	37, 120, 133, 321	82,000	120,000	0	**5**	5	-	Probable
vinyl chloride	37, 120, 133, 321	5.5	5.5	0	2	**0.5**	-	Probable
perchlorate	37, 120, 133	104	160	-	-	-	*24* [g]	No
nitrate (as Nitrogen)	37, 120, 133, 321	903 mg/L[h]	903	10 mg/L	**10** mg/L	10 mg/L	-	No

Notes:

This table shows the chemicals of concern in the groundwater at the South AFRL.
Values in bold indicate ARARs to be waived within the South AFRL CZ. Values in italics indicate risk based cleanup goals adopted for chemicals without MCLs. These chemicals will also be contained.
The State does not agree that this table is a comprehensive list of all ARARs that pertain to the remedial action at the South AFRL. See Section 2.14.2.1 for a discussion of the State's position concerning ARARs.

[a] Source: USEPA 2006.
[b] Source: California DHS 2007.
[c] NL; Source: California DHS 2007.
[d] Not detected in 2003. Concentration shown is historic maximum.
[e] Not detected above the reporting limit which ranged from 1 μg/L to 5,000 μg/L
[f] Estimated value; result is below the reporting limit of 2,500 μg/L
[g] Although there is no federal or state MCL for perchlorate, a drinking water equivalent level of 24 μg/L has been derived as the DoD level of concern from an oral reference dose of 0.0007 mg/kg/day listed in the USEPA's IRIS database.
[h] Not analyzed in 2003. Concentration shown is historic maximum.

-	none promulgated
μg/L	micrograms per liter
AFRL	Air Force Research Laboratory
ARAR	applicable or relevant and appropriate requirement
CFC	chlorofluorocarbon
COC	chemical of concern
CZ	containment zone
DHS	Department of Health Services
DoD	Department of Defense
IRIS	Integrated Risk Information System
pMCL	primary maximum contaminant level
MCLG	maximum contaminant level goal
mg/kg/day	milligrams per kilogram per day
mg/L	milligrams per liter
ND	not detected above reporting limits
NL	notification level
TBC	to-be-considered
USEPA	United States Environmental Protection Agency

Topographic relief ranges from moderate at Building 8595 in Site 37 to low at the former evaporation/percolation ponds in Site 120, and the land surface dips generally to the south and west. Localized surface drainage from Sites 37 and 133 is initially toward the south on the flank of the ridge, trending toward the southwest near Site 120. Surface drainage from Site 321 is to the west.

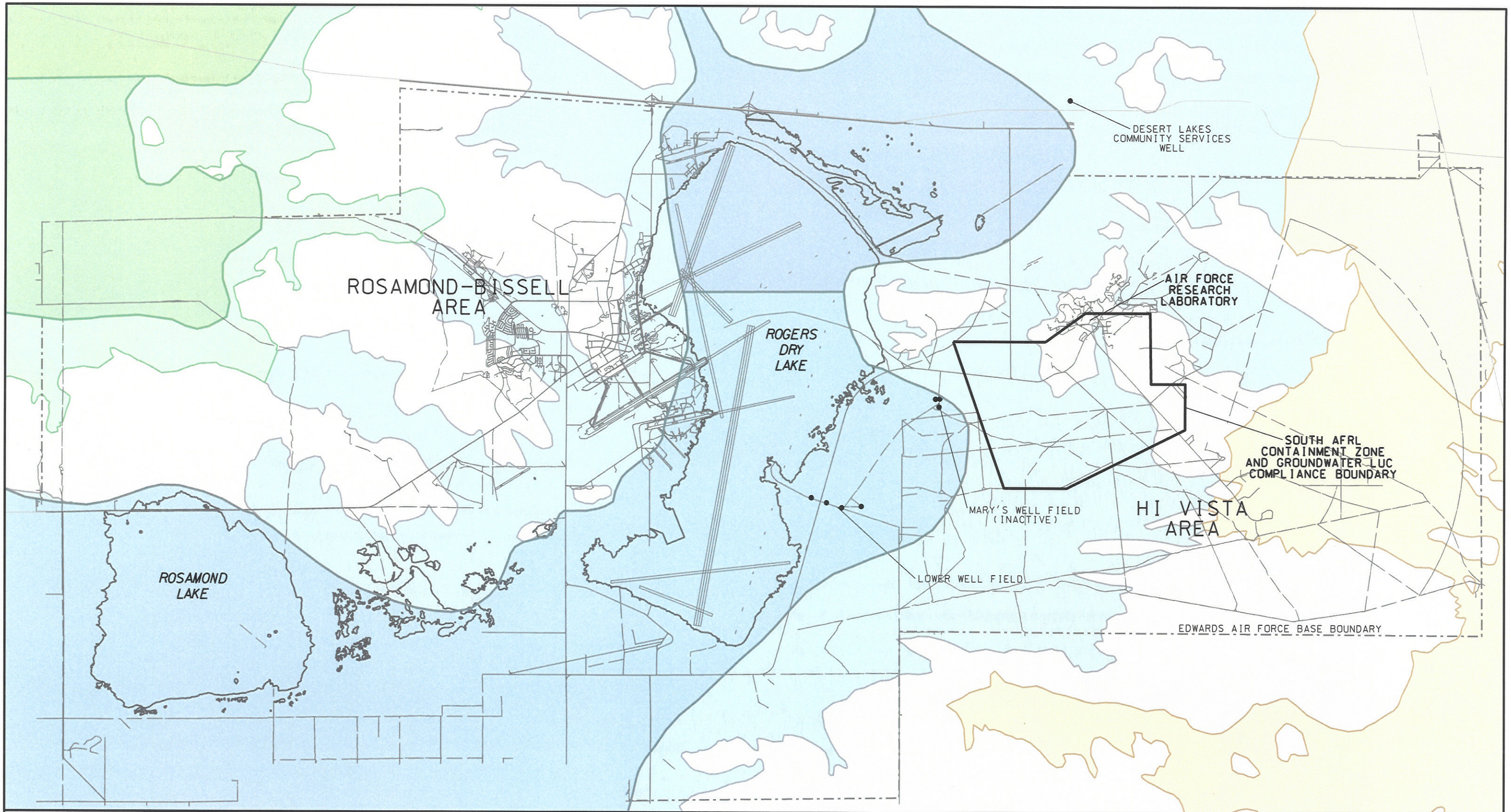
2.5.2.1 Geology

The regional subsurface geology at the AFRL is characterized as a crystalline granitic bedrock complex overlain in areas by a thin veneer of unconsolidated material increasing in thickness down slope from the crest of the ridge. The unconsolidated material grades into fractured, weathered bedrock (WBr) below which fractured, competent bedrock (CBr) is encountered. Depth to CBr varies from 2 feet to 65 feet bgs at Site 37, 5 feet to 110 feet bgs at Site 120, 3 feet to greater than 250 feet bgs at Site 133, and 13 feet to 52 feet bgs at Site 321. The bedrock consists of three types of pre-Tertiary crystalline rock: predominantly quartz monzonite; intruded granite that forms Leuhman Ridge; and a Tertiary volcanic rock (dacite) that forms Haystack Butte. A complete description of the geology at the AFRL is included in the South AFRL Focused FS.

2.5.2.2 Hydrogeology

Edwards AFB overlies portions of three sub-basins of the Antelope Valley groundwater basin: the North Muroc Sub-basin, the Lancaster Sub-basin, and the Gloster Sub-basin (Figure 2.1-3). In addition, the base encompasses two areas of shallow bedrock and low groundwater yield, known as the Rosamond-Bissell and Hi Vista areas. The AFRL (OUs 4 and 9) is located within the Hi Vista Area, which provides groundwater recharge to both the North Muroc and Lancaster sub-basins. The AFRL has not been designated as a critical recharge area.

Bedrock at the AFRL is not an aquifer (i.e., it does not yield useable quantities of groundwater), and is not within a basin as delineated by the USGS (Figure 2.5-3) based on geophysical evidence (Sneed et al [2006] adopted from Carlson et al [1998] as modified from Bloyd [1967] and Durbin [1978] and supported by borehole logs for wells installed by Earth Tech [2003a and 2003b]). However, the Water Board considers the AFRL to fall within the Antelope Valley hydrologic Basin 6-44 (refer to blue-shaded areas on Figure 2.5-3 adapted from the California Department of Water Resources



EXPLANATION

AFB AIR FORCE BASE
DWR DEPARTMENT OF WATER RESOURCES
LUC LAND USE CONTROL
USGS UNITED STATES GEOLOGICAL SURVEY

6-44 ANTELOPE VALLEY BASIN
- RECHARGE AREA
- LANCASTER SUBBASIN (USGS)
- NORTH MUROC SUBBASIN (USGS)

6-46 FREMONT VALLEY BASIN
- RECHARGE AREA
- GLOSTER SUBBASIN (USGS)
- CHAFFE SUBBASIN (USGS)

6-41 MIDDLE MOJAVE RIVER VALLEY BASIN
- RECHARGE AREA

6-47 HARPER VALLEY BASIN
- RECHARGE AREA

NOTES:
1. HYDROLOGIC UNITS BASED ON DWR BULLETIN 118.
2. USGS SUBBASIN BOUNDARIES FROM USGS 2005 FACT SHEET (SNEED ET AL 2006) AS ADOPTED FROM CARLSON ET AL (1998) BASED ON GEOPHYSICAL EVIDENCE.

NORTH

0 6000 12000 FEET

SCALE: 1"= 12000'

South AFRL ROD

Antelope Valley 6-44 DWR Hydrologic Basin with USGS Subbasins

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure 2.5-3
Project No. 67861		

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[California DWR] Bulletin 118 [California DWR 2003]), for which Table 2-2 of the *Water Quality Control Plan for the Lahontan Region* (Basin Plan, CRWQCB 1995) designates the following beneficial uses: municipal, agricultural, industrial, and freshwater replenishment. The maximum concentrations of COCs in the groundwater at the South AFRL are listed in Table 2.5-1. Groundwater in the alluvial aquifer (Lancaster Sub-basin as defined by the USGS) down gradient from the South AFRL site is not impacted by these COCs.

In Section 5.2 of the *South AFRL Focused FS* (Earth Tech 2005b), the potential suitability of South AFRL groundwater for municipal or domestic water supply was evaluated against criteria in the California SWRCB Resolution Number (No.) 88-63 (Sources of Drinking Water) and *Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy* (USEPA 1986). Results are summarized in Table 2.5-2 and referenced further below.

Historically, potable water for the AFRL was supplied by two production well fields tapping alluvial aquifers: Mary's Well Field (including Wells 1, 2, and 3 that have been inactive since at least 1994) and the Lower Well Field (including Wells A, B, C, and D), located approximately 1,655 feet (0.3 miles) west and 14,918 feet (2.8 miles) southwest, respectively, of the South AFRL CZ boundary. Both well fields are located to the southeast of Rogers Dry Lake (refer to Figure 2.1-2), in the eastern portion of the Lancaster Sub-basin. Both draw groundwater from the middle aquifer in that sub-basin. Since late 1997, AFRL has purchased a portion of its potable water supply from AVEK, which runs a pipeline to AFRL from Boron. Well production records for 2002 show that AVEK supplied approximately 39 million gallons, or 64% of the water supply, in that year (Antelope Valley-Eastern Kern Water Agency 2007). On average, AVEK supplied approximately 80% of the AFRL water supply from 2001 to 2005.

The nearest off-base groundwater production wells (tapping the unconfined aquifer of the North Muroc Sub-basin, and operated by Boron and Desert Lakes Community Services but currently off-line indefinitely due to naturally-occurring arsenic concentrations exceeding the federal pMCL) are located approximately 650 feet northeast of the Base boundary, and approximately 4.6 miles north of the South AFRL CZ boundary. As shown in Table 2.5-2, naturally-occurring arsenic concentrations also exceed the federal pMCL in approximately 60% of groundwater monitoring wells at the South AFRL.

Groundwater at the AFRL occurs under hydrostatic pressure within fractures in both weathered and competent granitic bedrock. Depth to first groundwater contact varies from 24 feet to 266 feet bgs

TABLE 2.5-2. EVALUATION OF GROUNDWATER AS A POTENTIAL DRINKING WATER SOURCE AT THE SOUTH AFRL

Condition that precludes use as a source of drinking water	State Guideline based on Resolution 88-63 "Sources of Drinking Water"	Federal Guidelines based on Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy, Final Draft (1986)	Groundwater at South AFRL
Total dissolved solids (TDS) concentration	Exceeds 3,000 mg/L	Exceeds 10,000 mg/L	Range from 78 to 8,310 mg/L; TDS in 26 of 143 wells exceed 3,000 mg/L.
Contamination (natural or due to broad-scale human activity unrelated to specific pollution incident)	Cannot reasonably be treated for domestic use	Cleanup is not practicable	Arsenic (naturally occurring) exceeds the current MCL (0.01 mg/L) in 63% of wells at Site 37, 63% of wells at Site 133, 69% of wells at Site 120, and 45% of wells at Site 321.
Single well yield	Not capable of producing an average sustained yield of 200 gallons per day	Not capable of producing an average sustained yield of 150 gallons per day	Number of wells not capable of sustaining a minimum pumping rate of 0.4 gpm during well development (and thus developed by bailing): 28 of 45 (63%) at Site 37; 45 of 84 (54%) at Site 133; 11 of 18 (60% at Site 120); and 7 of 9 (80%) at Site 321. Average sustained yield over at least 6 months of pumping for the seven extraction wells at Site 37: a range between 0.03 gpm (43 gpd) and 0.53 gpm (763 gpd) and an average yield around 0.27 gpm (390 gpd). Average sustained yield over approximately 9 months of pumping from three extraction wells at Site 133: a range from 2 gpm (3,000 gpd) to 8 gpm (11,500 gpd).

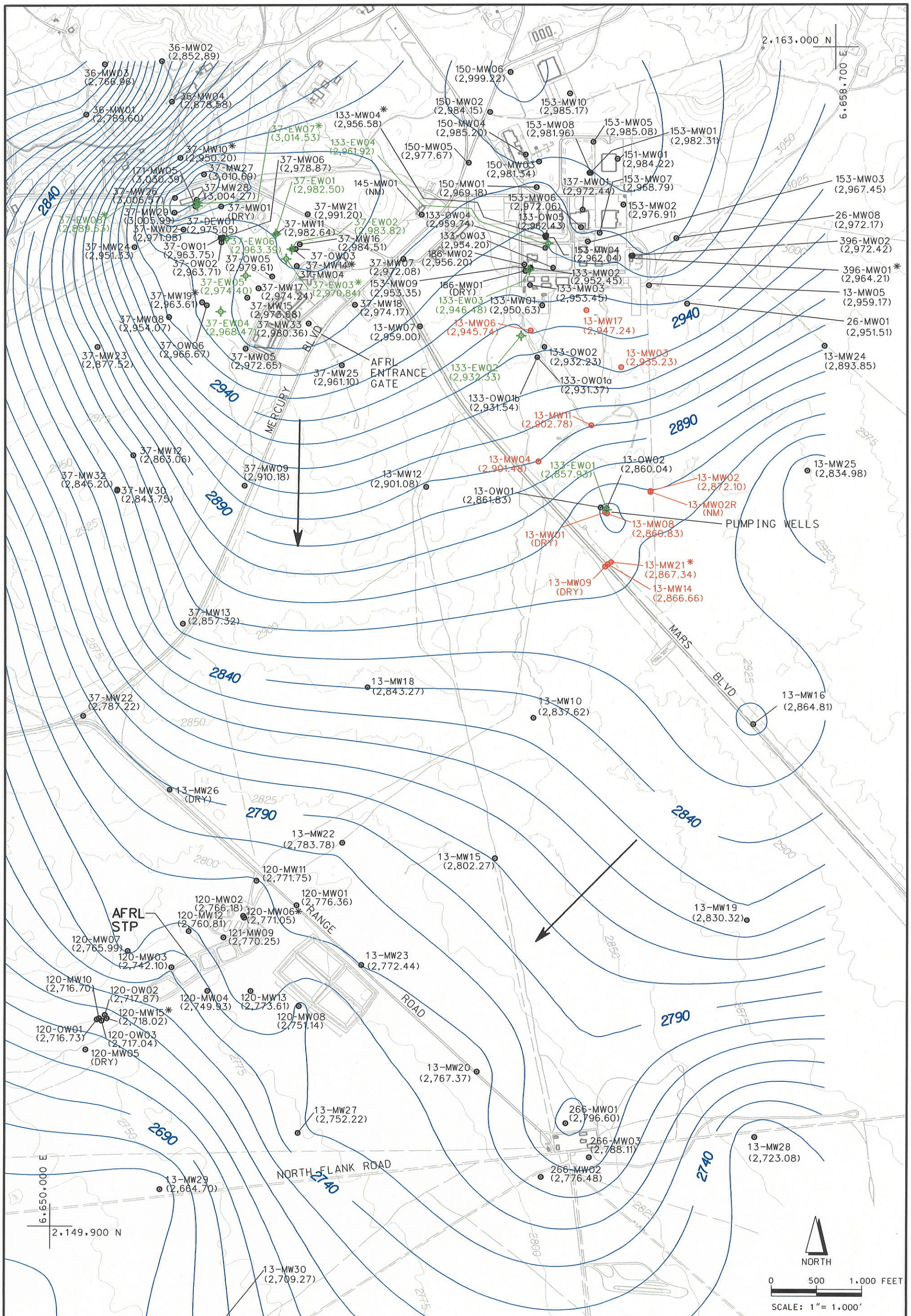
Notes:

%	percent
AFRL	Air Force Research Laboratory
ARAR	applicable or relevant and appropriate requirement
EPA	Environmental Protection Agency
gpd	gallons per day
gpm	gallons per minute
MCL	maximum contaminant level
mg/L	milligrams per liter

at Site 37, 15 feet to 142 feet bgs at Site 120, 12 feet to 420 feet bgs at Site 133, and 45 feet to 235 feet bgs at Site 321. Groundwater flow rates in monitoring wells screened across first water contact are generally low. At the South AFRL individual well yields were estimated based on pumping rates achievable during monitoring well development. The 60% of wells that had to be bailed because they were not able to be pumped at the estimated minimum rate of 0.4 gpm are categorized as not meeting state (200 gpd or 0.14 gpm) or federal (150 gpd or 0.10 gpm) yield criteria for a potential drinking water source (refer to Table 2.5-2). Not counted in these percentages are the boreholes where water production was so low that no well was installed (27% of wells attempted based on results of a 3-D high resolution seismic reflection survey at Site 37). Of the 40% of wells that could be pumped, well yields ranged from 0.5 gpm to 17.5 gpm. As another estimate of sustainable yield, the pumping rates exhibited by extraction wells at Sites 37 and 133 were estimated following at least 6 months of operation. The sustained yield for the seven wells at Site 37 ranged from 0.03 gpm (43 gpd) to 0.53 gpm (763 gpd) for an average yield around 0.27 gpm (390 gpd). The sustained yield for three wells at Site 133 ranged from 2 gpm (3,000 gpd) to 8 gpm (11,500 gpd).

Regional groundwater flow directions generally mimic surface drainage. In the South AFRL area, groundwater flows ultimately into the Lancaster Sub-basin, recharging the aquifer. Groundwater does not discharge into surface water.

Groundwater contours based on water levels measured in July 2003 are presented on Figures 2.5-4 and 2.5-5. The average hydraulic gradient along the southern flank of Leuhman Ridge within the commingled Sites 37, 120, and 133 plumes is estimated at 0.033 vertical feet per horizontal foot (ft/ft), as measured from Well 171-MW05 (located near the source area for the Site 37 plume) to Well 13-MW29 (located southwest of the Site 120 STP). Groundwater near the AFRL CE Yard flows to the south, ultimately flowing to the southwest to west near the AFRL STP. The average horizontal hydraulic gradient is 0.03 ft/ft near the AFRL CE Yard, 0.04 ft/ft near the landfill and the AFRL STP, and 0.02 ft/ft in the area between the landfill and the STP. Groundwater flow at Site 321 is directed to the west at an average hydraulic gradient of 0.08 ft/ft as measured from Well 321-MW21 to Well 321-MW07.



EXPLANATION

- MONITORING WELLS IN POST-CLOSURE MONITORING PROGRAM FOR AFRL LANDFILL (SITE 13)
- MONITORING/OBSERVATION WELL LOCATION
- EXTRACTION WELL LOCATION
- 2880 — GROUNDWATER ELEVATION IN FEET ABOVE MEAN SEA LEVEL MEASURED JULY 2003 (10 FEET CONTOUR INTERVAL)
- 2750 — GROUND SURFACE ELEVATION IN FEET ABOVE MEAN SEA LEVEL (25 FEET CONTOUR INTERVAL)
- → APPROXIMATE GROUNDWATER FLOW DIRECTION
- * GROUNDWATER DATA NOT USED TO CONTOUR GROUNDWATER ELEVATION

AFRL AIR FORCE RESEARCH LABORATORY
BLVD BOULEVARD
NM NOT MEASURED
STP SEWAGE TREATMENT PLANT

South AFRL ROD

Sites 37, 120, and 133 Groundwater Contour Map, July 2003

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		2.5-4

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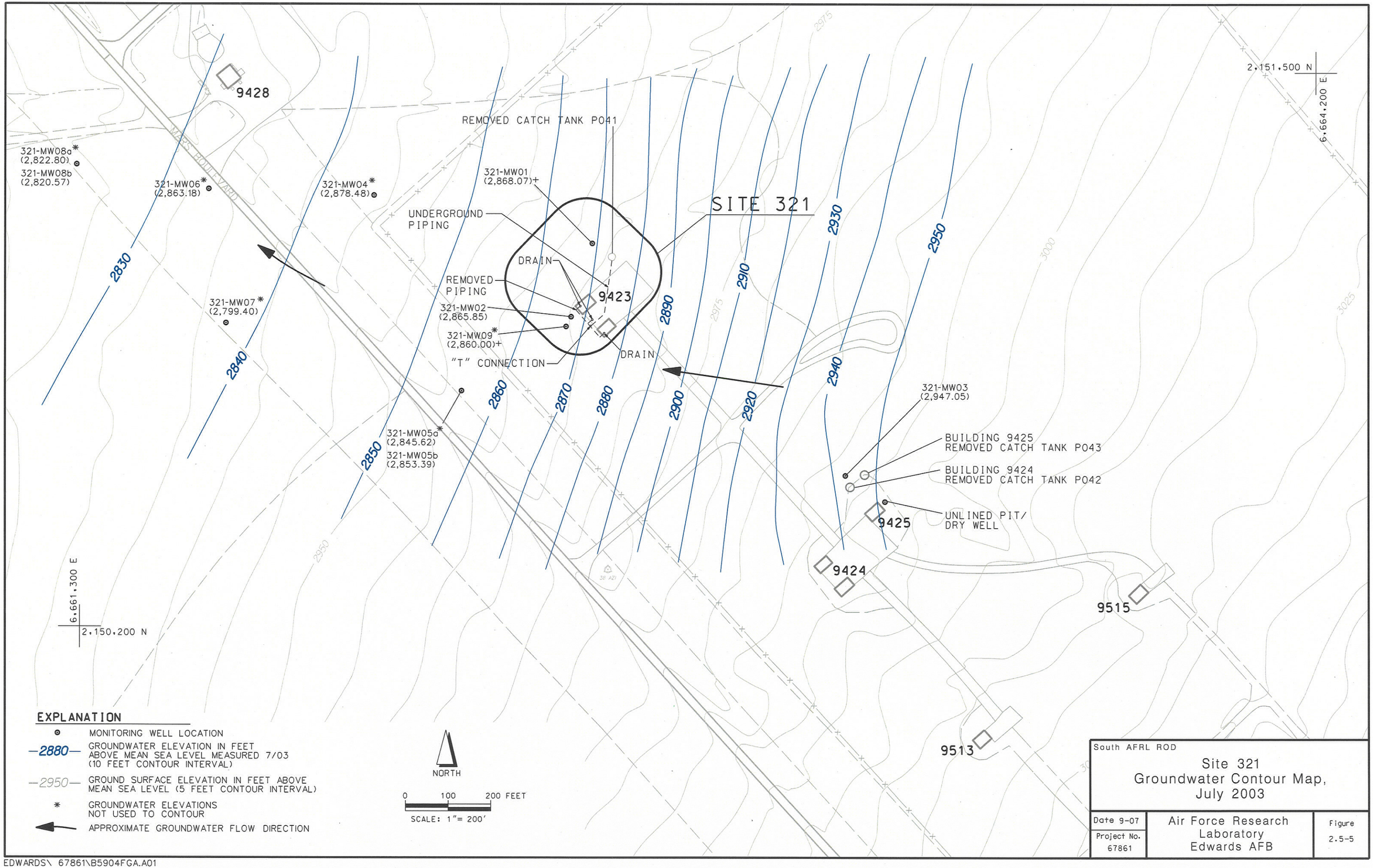

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Hydraulic conductivity (K) values calculated from aquifer pump test results at Site 37 and/or drawdown in response to extraction from Wells 37-EW02 and 37-EW03 ranged from 0.008 feet per day (ft/day) to 0.73 ft/day, a range characteristic of fractured igneous rock. Using average K values from pump tests (0.24 ft/day) and sustained extraction (0.016 ft/day), an assumed porosity of 1%, and the hydraulic gradient (0.03 ft/ft) at Site 37 cited above, groundwater velocity at the site was estimated to range from 0.05 ft/day to 0.7 ft/day (18 feet per year [ft/year] to 256 ft/year). By comparison, the contaminant transport velocity was estimated at 0.4 ft/day (140 ft/year) by dividing the length of the PCE contaminant plume (6,000 feet from source at Building 8595 to the southern extent of the 1 μg/L contour; refer to Figure 2.5-1) by 43 years (estimated travel time through 2003 assuming releases began around 1960).

K values calculated from pumping test results at Site 133 ranged from 0.23 ft/day to 8.5 ft/day, within the upper range characteristic of fractured igneous rock. Using this K range, an assumed porosity of 1% to 10%, and the average hydraulic gradient (0.035 ft/ft) at Site 133, groundwater velocity was estimated to range from 0.8 ft/day to 3 ft/day (296 feet per year [ft/yr] to 1,095 ft/yr). This compares to a rough (conservative) approximation of contaminant migration velocity of 1.1 ft/day (415 ft/yr), based on the distance (17,880 feet) the TCE contaminant had moved (in 2003) from an assumed starting point around monitoring Well 150-MW01 just south of Dry Well E (refer to Figure 2.2-3) to the southern extent of the 1 μg/L contour, and a travel time of 43 years (assuming release began in 1960).

K values derived from an aquifer pump test at Site 120 range from 0.41 ft/day to 1.56 ft/day. No pumping test was conducted at Site 321.

Transmissivity (T) ranged between 0.3 square feet per day (ft^2/day) at Site 37 to 763 ft^2/day at Site 133. Aquifer storativity (S) ranged from 10^{-7} at Site 37 to 10^{-2} at Site 133, indicating confined conditions at Site 37 and confined to low-yield unconfined conditions at Sites 120 and 133.

2.5.3 SOUTH AFRL FEATURES

The South AFRL area includes a complex of administrative, laboratory, research, shop and storage buildings that support the AFRL mission, which emphasizes rocket propulsion concepts, propellants, components, and systems for both missile and space applications; and hosts sea level static and altitude

test cells for full-scale rocket engine and motor testing. The significant man-made features at the source areas for the South AFRL are depicted on Figures 2.2-1 through 2.2-4. These include: ASTs for chemical and waste storage; a closed landfill with final cover (shown on Figure 2.1-2); stormwater drains, electrical substations, drainage ditches, sanitary sewer lines and the renovated wastewater treatment plant, and former waste evaporation/percolation ponds at the STP. The AFRL in cooperation with 95 ABW/CEV has instituted measures to ensure that these features are no longer sources of soil and groundwater contamination. All known USTs have been removed and hazardous materials and wastes are now managed by a pharmacy chemical management system in which hazardous materials are stored and distributed from authorized hazardous distribution service centers (HDSC). Unused chemicals and empty containers are returned to each HDSC for storage, re-issue, disposal and/or recycling.

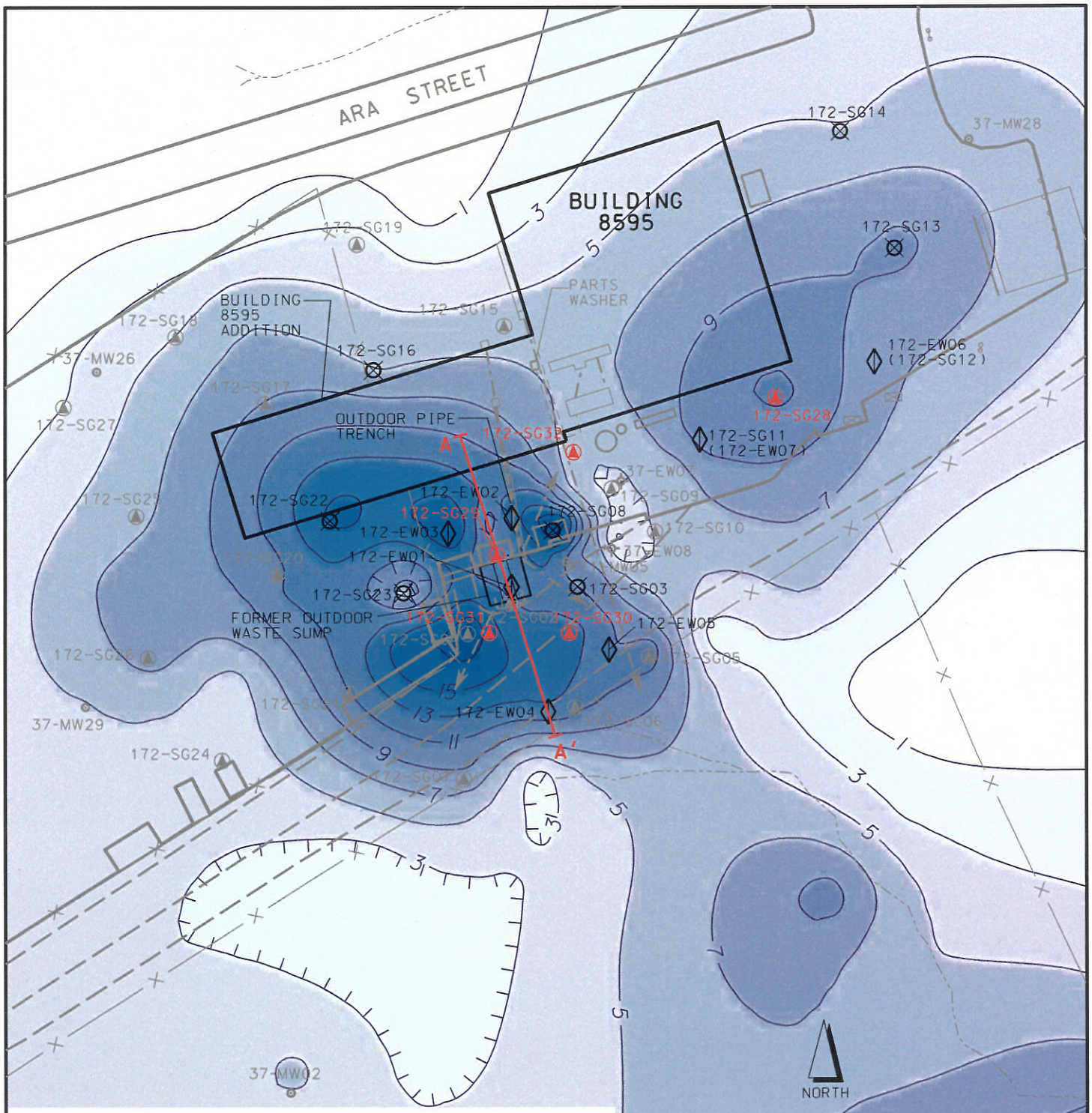
Areas of archaeological interest have been identified within the South AFRL CZ. Buildings designated as potentially eligible for nomination to the National Register of Historic Places are present.

2.5.4 SUMMARY OF SAMPLING STRATEGY AND CONTAMINANT NATURE AND EXTENT

2.5.4.1 Site 37

Due to the shallow bedrock at this site, limited soil samples were collected during the SI phase. PCE was the only VOC detected, and was found in just three of 17 soil sampling locations, with the maximum concentration (0.24 milligrams per kilogram [mg/kg]) detected at 30 feet bgs in a borehole located 650 feet south of Building 8595. Soil sampling results collected through 2005 are further discussed in the presentation of site risks (Section 2.7). In July 2006, soil samples were collected from five vapor monitoring wells installed as part of a study to evaluate rebound in VOC concentrations following shutdown of the SVE system south of Building 8595 on 28 July 2006 (Earth Tech 2007a). PCE was detected in the soil sample from one location (Well 172-SG30) at a concentration of 0.940 mg/kg. No other VOCs were detected above the reporting limit in any sample.

Soil gas samples collected in the vicinity of the building during the SI were used to aid in selecting locations of groundwater monitoring wells. In 2001, a seismic refraction study (to assess the extent of unconsolidated materials by delineation of depth to bedrock as shown on Figure 2.5-6) and soil gas survey were conducted to aid in selection of locations to expand the SVE well field. During the SI and



NOTES:
1. LOCATION OF ALL PIPING APPROXIMATE.
2. CROSS SECTION LINE A-A' IS SHOWN AS FIGURE 2.5-6.

EXPLANATION

- PIPING (ABOVEGROUND)
- PIPING (BELOWGROUND)
- A—A' CROSS SECTION LINE
- SOIL VAPOR MONITORING WELLS INSTALLED ON 5 JULY 2006
- AUGUST 2001 SOIL GAS LOCATION
- EXISTING SOIL VAPOR MONITORING WELL
- SOIL VAPOR EXTRACTION WELL
- GROUNDWATER MONITORING WELL
- GROUNDWATER EXTRACTION WELL

BEDROCK DEPTH (FEET BELOW GROUND SURFACE)

1 3 5 7 9 11 13 15 17 21

South AFRL ROD

Site 37 – Building 8595 Vapor Monitoring Well Locations and Depth to Bedrock Contours

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure 2.5-6
Project No. 67861		

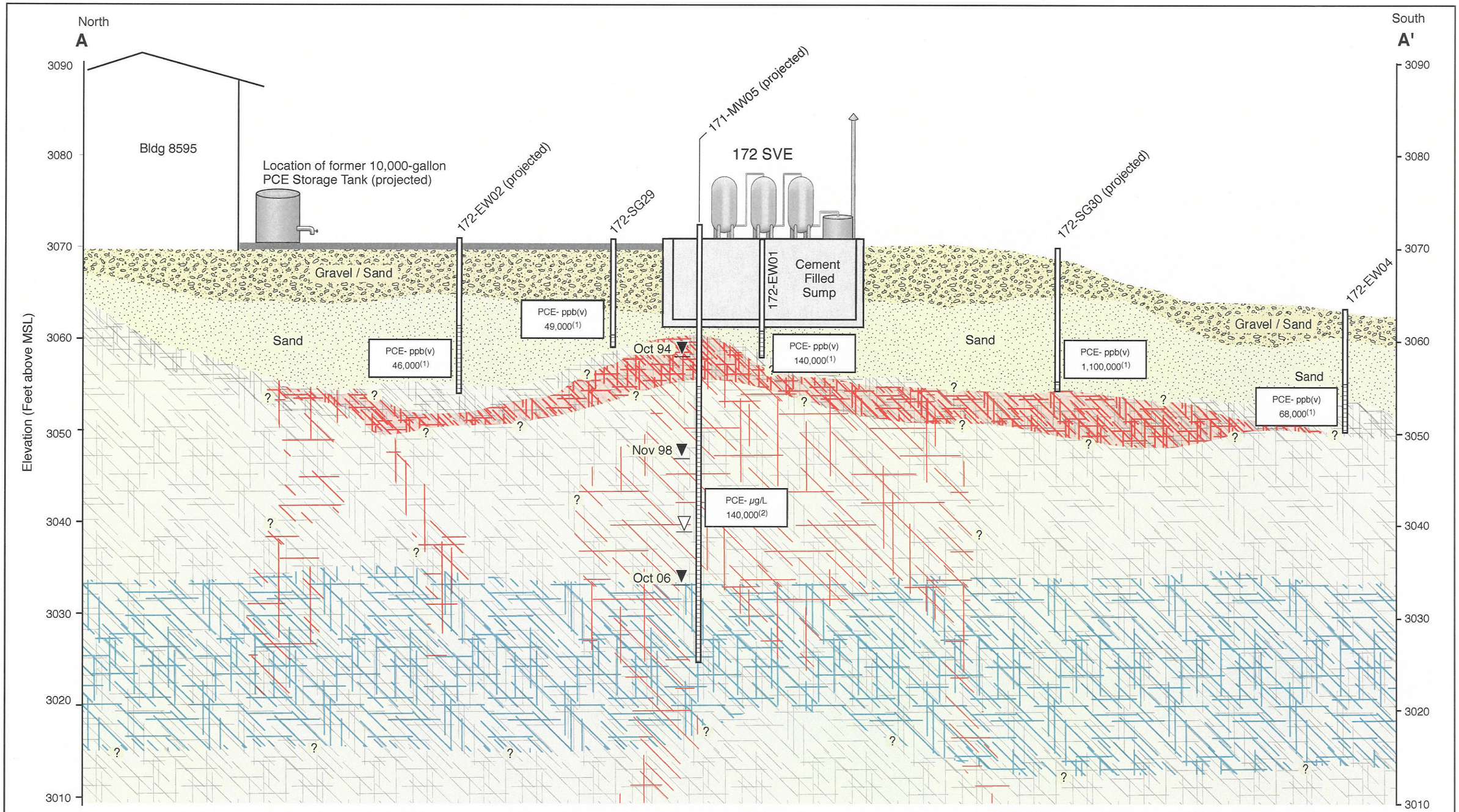
EDWARDS\ 67861\B6418FGA.A01

RI, soil gas samples were collected and analyzed as field screening data and were not used to derive an estimate of site risks.

However, as part of the evaluation of vapor-phase rebound in VOC concentrations following shutdown of the SVE system, soil gas samples were collected for definitive-level analysis (by Method TO14A) from 15 monitoring well locations (including the seven offline vapor extraction wells) just prior to, 6 weeks after, and 3 months after shutdown. Based on drilling observations (made during installation of vapor monitoring wells in July 2006) and results of the rebound monitoring (an increase in total VOC concentrations by 130% or greater in all wells after 3 months), the CSM for the source area just south of Building 8595 was refined (Earth Tech 2007a) as presented on Figure 2.5-7 (Figure 2.5-6 shows the cross-section line). The subsurface geology south of Building 8595 includes a zone of loose sands underlain by highly degraded and clayey WBr above the competent granitic bedrock. The high concentrations of PCE detected in the soil vapor during rebound monitoring, particularly in Well 172-SG30, indicate a continuing source of solvent in close proximity to that vapor well. As presented on the CSM, it is suspected that residual PCE (that leaked from the 10,000-gallon AST and outdoor waste sump between 40 and 20 years ago) remains saturated on top of and within the WBr south of Building 8595, in addition to a large portion having infiltrated through fractures and into the competent granitic bedrock.

In 1994, the first groundwater monitoring wells were installed at Site 37: Well 171-MW05 located approximately 50 feet south of Building 8595 and Well 37-MW06 located approximately 500 feet down slope. In groundwater samples collected in July 1994, PCE was detected at 130,000 μg/L in Well 171-MW05 and at 48,000 μg/L in Well 37-MW06. Based on these concentrations, which are a significant fraction of the solubility of PCE in water (150,000 μg/L), the presence of DNAPL is strongly inferred (detection of dissolved phase contaminant concentrations in excess of 1% of their solubility indicates the probable presence of a DNAPL source zone [Pankow and Cherry, 1996]).

Between 1996 and 2002, more than 40 additional monitoring wells were installed to delineate the groundwater plume's lateral and vertical extent. A majority of these wells were sampled in 2003. Based on these results, the estimated lateral extents of PCE and TCE as shown on Figure 2.5-1 were developed. Besides PCE and TCE, a number of other VOCs are detected in groundwater at Site 37



Explanation

- Sorbed DNAPL PCE
- Dissolved PCE in groundwater
- Fractured bedrock
- Weathered bedrock with clay
- Sand
- Gravel / Sand
- Asphalt
- 1st water encountered
- Static water level

?	extent inferred or unknown	MSL	mean sea level	(1)	October 2006 vapor concentration
µg/L	mircrogram per liter	PCE	tetrachloroethene	(2)	October 2006 groundwater concentration
CSM	conceptual site model	ppb(v)	parts per billion (by volume)		
DNAPL	dense non-aqueous phase liquid	SVE	soil vapor extraction		

Vertical Scale: 0, 5, 10 ft

Horizontal Scale: 0, 5, 10 ft

South AFRL ROD

Revised CSM for Site 37 Source Area South of Building 8595

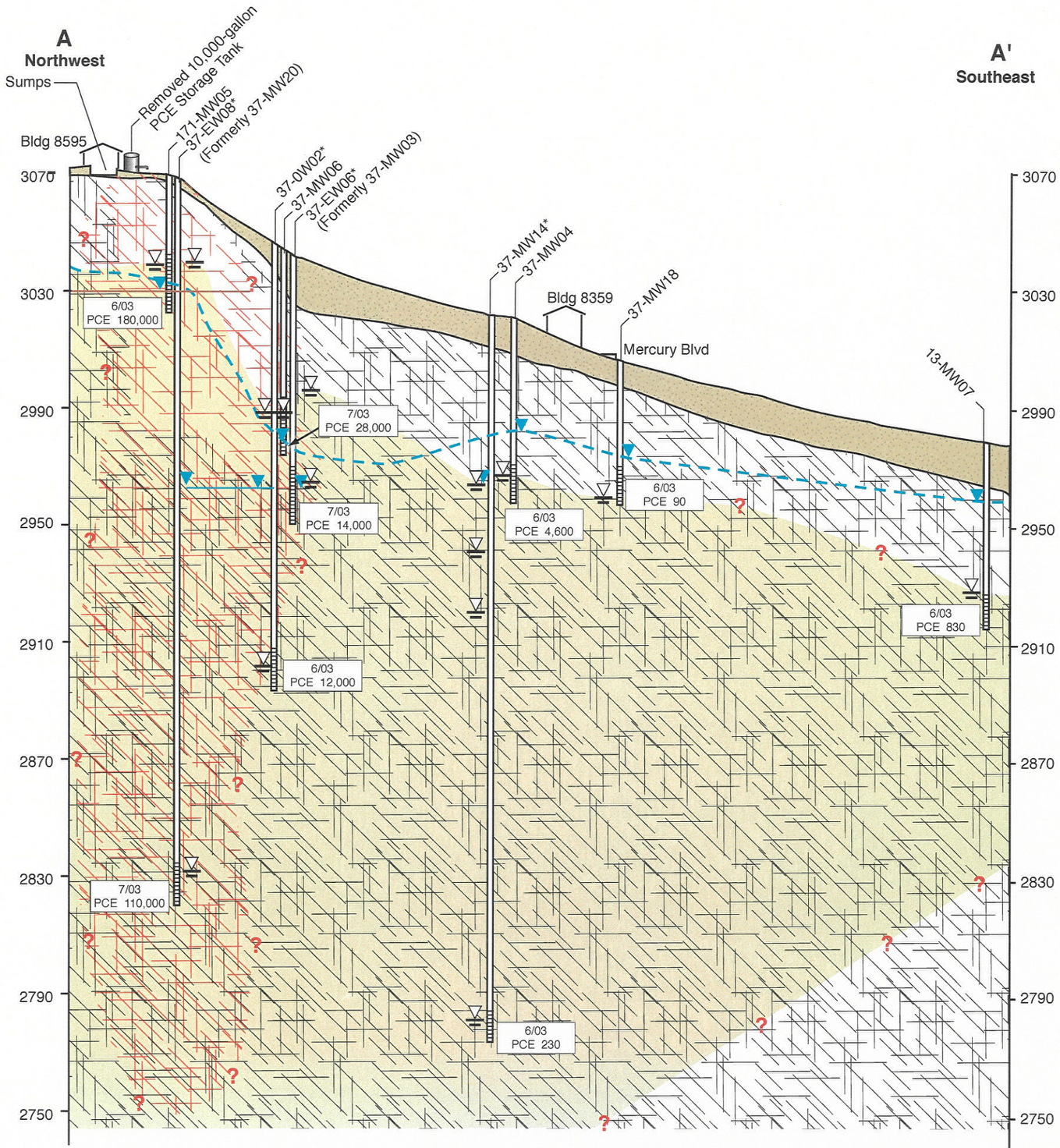
Date 9-07	Air Force Research Laboratory Edwards AFB	Figure 2.5-7
Project No. 67861		

67861.17.03

(in at least one sampling point) at concentrations exceeding their respective pMCLs. The most widespread of these include 1,1-dichloroethene (1,1-DCE), cis-1,2-DCE, and 1,1,1-trichloroethane (1,1,1-TCA). TCE and 1,1,1-TCA are solvents known to have been used at Building 8595; cis-1,2-DCE (and a portion of the TCE) is believed to be a biodegradation product from the reductive dechlorination of PCE; 1,1-DCE is believed to be a breakdown product (due to abiotic chemical transformation) of 1,1,1-TCA (Earth Tech 2001c). The distributions of the TCE and 1,1-DCE concentrations indicate that these contaminant plumes extend down gradient approximately 4,800 feet and 2,000 feet, respectively. The emergent contaminant 1,4-dioxane (a semivolatile organic compound used as a stabilizer additive to solvents) extends down gradient approximately 2,100 feet.

Site 37 has been characterized by borehole drilling (using air rotary) and visual logging of drill cuttings to a maximum depth of 290 feet bgs in Well 37-MW14. Zones of fracturing and weathering of the CBr were observed in the borehole for this well to its total depth as depicted on Figure 2.5-8 (Figure 2.5-1 shows the location of the cross-section line). Deep water-bearing zones ranging from 230 feet to 266 feet bgs in fractured crystalline bedrock, separated vertically by non-water producing fractured intervals in competent crystalline bedrock, were encountered during drilling of two other so-called "deep" wells (Wells 37-MW19 and 37-EW08) installed as part of well clusters to assess the vertical extent of contamination. As summarized in Table 2.5-3, the PCE concentration at 250 feet bgs in Well 37-EW08 within 30 feet of Building 8595 is of the same order of magnitude as the concentration in shallow Well 171-MW05. By contrast, the PCE concentration at 250 feet bgs in Well 37-MW14 located approximately 1,250 feet down slope from Building 8595 is less than 7% that in adjacent Wells 37-EW02 and 37-OW03 screened over the first water-bearing interval. Similarly, the PCE concentration at 250 feet bgs in Well 37-MW19, located approximately 1,100 feet down slope from Building 8595, was less than 12% that in nearby Wells 37-EW04 and 37-OW06 screened over the first water-bearing interval.

DNAPL has not been directly observed at Site 37. However, based on the site history and the distribution of dissolved- and vapor-phase contaminants, a "source area" (or inferred DNAPL zone) was conceptually defined for the site as a 270,000-square foot area that includes the pure phase contaminant represented by groundwater concentrations of chlorinated hydrocarbons that exceed



Eluvium

Fractured bedrock

Potentiometric surface elevation 7/03

Groundwater encountered

DNAPL

Dissolved chlorinated hydrocarbons

? Extent either inferred or unknown

Concentrations are in micrograms per liter (µg/L).

µg/L	micrograms per liter
Bldg	building
Blvd	boulevard
DNAPL	dense non-aqueous phase liquid
MSL	mean sea level
PCE	tetrachloroethene

Location of cross section line is shown on Figure 2.5-1.

0 10 20 40 feet
Vertical Scale

0 100 200 400 feet
Horizontal Scale

Vertical Exaggeration = 10:1

*Monitoring well screened for deeper aquifer and not included in generating potentiometric surface elevation.

South AFRL ROD	Site 37 Conceptual Site Model Cross Section	
Date 9-07	Air Force Research Laboratory Edwards AFB	Figure 2.5-8
Project No. 67861		

67861.17.03 Fig 2.5-8 Conc Xsec

TABLE 2.5-3. COMPARISON OF CONTAMINANT CONCENTRATIONS IN WELL CLUSTERS INSTALLED TO MONITOR VERTICAL EXTENT – SITES 37, 120, 133, AND 321
(Page 1 of 2)

Well Cluster Location	Well Number	Screen interval (feet bgs)	PCE (μg/L)	TCE (μg/L)	cis-1,2-DCE (μg/L)
Site 37					
Within 30 feet of Building 8595	171-MW05	30-45	180,000	4,000	<1,000
	37-EW07	37.4-57.4	40,000	480	<100
	37-EW08	235-250	110,000	1,600	<250
600 feet down slope of Building 8595	37-MW06	47.5-67.5	28,000	230	<100
	37-EW06	75-90	14,000	380	1,900
	37-OW02	140-155	12,000	1,800	1,300
1,250 feet down slope of Building 8595 to southeast	37-EW02	56-76	4,200	79	6.4 J
	37-OW03	66-86	3,300	97	70
	37-MW14	242-252	230	75	18
1,100 feet down slope of Building 8595 to south	37-OW06	53-73	5,800	200	170
	37-EW04	73-93	2,700	72	410
	37-MW19	230-250	310	180	26
Site 120					
Just downgradient of Imhoff Tank	120-MW02	52-62	4,800	110	2,400
	120-OW04	52.4-62.4	820	57	5,100
	120-MW06	239-249	<1.0	<1.0	<1.0
2,000 feet southwest of Imhoff Tank	120-MW10	56-66	2.3	4.5	1.4
	120-MW15	328-338	<1.0	<1.0	<1.0
Site 133					
Down gradient of landfill	13-MW09	17-27	7.0[a]	2,700[a]	8.9[a]
	13-MW14	100-115	2.4	1,500	4.3
	13-MW21	178-198	<1.0	12	1.5
1,050 feet down gradient of Gas Station	133-OW01a	18-38	6.5	1,500	3.3 J
	133-OW01b	120-150	<1.0	4.0	310
Just down gradient of removed USTs at Gas Station	186-MW01	18-28	<50[b]	2,400[b]	330[b]
	186-MW02	18-28	<10	1,200	26
	133-MW02	23.5-33.5	9.6 J	5,000	150
	133-EW03	33-153	20 J	6,600	<50
	153-MW09	250.5-260.5	0.43 J	1.7	0.60 J

TABLE 2.5-3. COMPARISON OF CONTAMINANT CONCENTRATIONS IN WELL CLUSTERS INSTALLED TO MONITOR VERTICAL EXTENT – SITES 37, 120, 133, AND 321
(Page 2 of 2)

Well Cluster Location	Well Number	Screen interval (feet bgs)	PCE (μg/L)	TCE (μg/L)	cis-1,2-DCE (μg/L)
Site 133 (Continued)					
Next to Dry Well F	153-MW04	29-39	< 120	3,200	< 120
	133-OW05	127-147	< 1,200	38,000	< 1,200
	133-MW04	316.8-326.8	< 1,200	82,000	< 1,200
Next to Dry Well E	153-MW01	34-49	< 25	4,100	< 25
	153-MW08	157.5-167.5	< 50	6,500	< 50
Site 321					
50 feet southwest of Building 9423	321-MW02	163.5-173.5	2,100	38 J	700
	321-MW09	303.3-313.3	730 J3	4.8 J3	< 1.0 UJ3
300 feet southwest of Building 9423	321-MW05b	205.7-225.7	9.4	< 1.0	< 1.0
	321-MW05a	243.8-263.8	< 1.0	< 1.0	< 1.0
1,200 feet down slope and northwest of Building 9423	321-MW08b	162.8-172.8	< 1.0	< 1.0	< 1.0
	321-MW08a	247.7-267.7	< 1.0	< 1.0	< 1.0

Notes:

2003 sampling results, unless otherwise noted.
[a] Well dry and could not be sampled in 2003. TCE concentration measured in November 2001.
[b] Well not sampled in 2003. TCE concentration measured in August 2002.

<	less than
μg/L	micrograms per liter
bgs	below ground surface
DCE	dichloroethene
PCE	tetrachloroethene
TCE	trichloroethene
UST	underground storage tank

Laboratory-Assigned Data Qualifiers:

J	Estimated result. Result is detected below the reporting limit.

Data Validation Qualifiers:

J3, UJ3	Extraction or analysis out of holding time; indicates low bias for most analytes.

50,000 μg/L and soil vapor concentrations that exceed 100 μg/L (Figure 2.5-9). The DNAPL zone is estimated to affect an area of approximately 6.4 acres and extend to a depth of 250 feet bgs. The volume of soil and rock in the DNAPL zone is estimated at 7.0 x 10^7 cubic feet and the volume of water is estimated at 5.24 x 10^6 gallons (assuming an effective porosity of 1%).

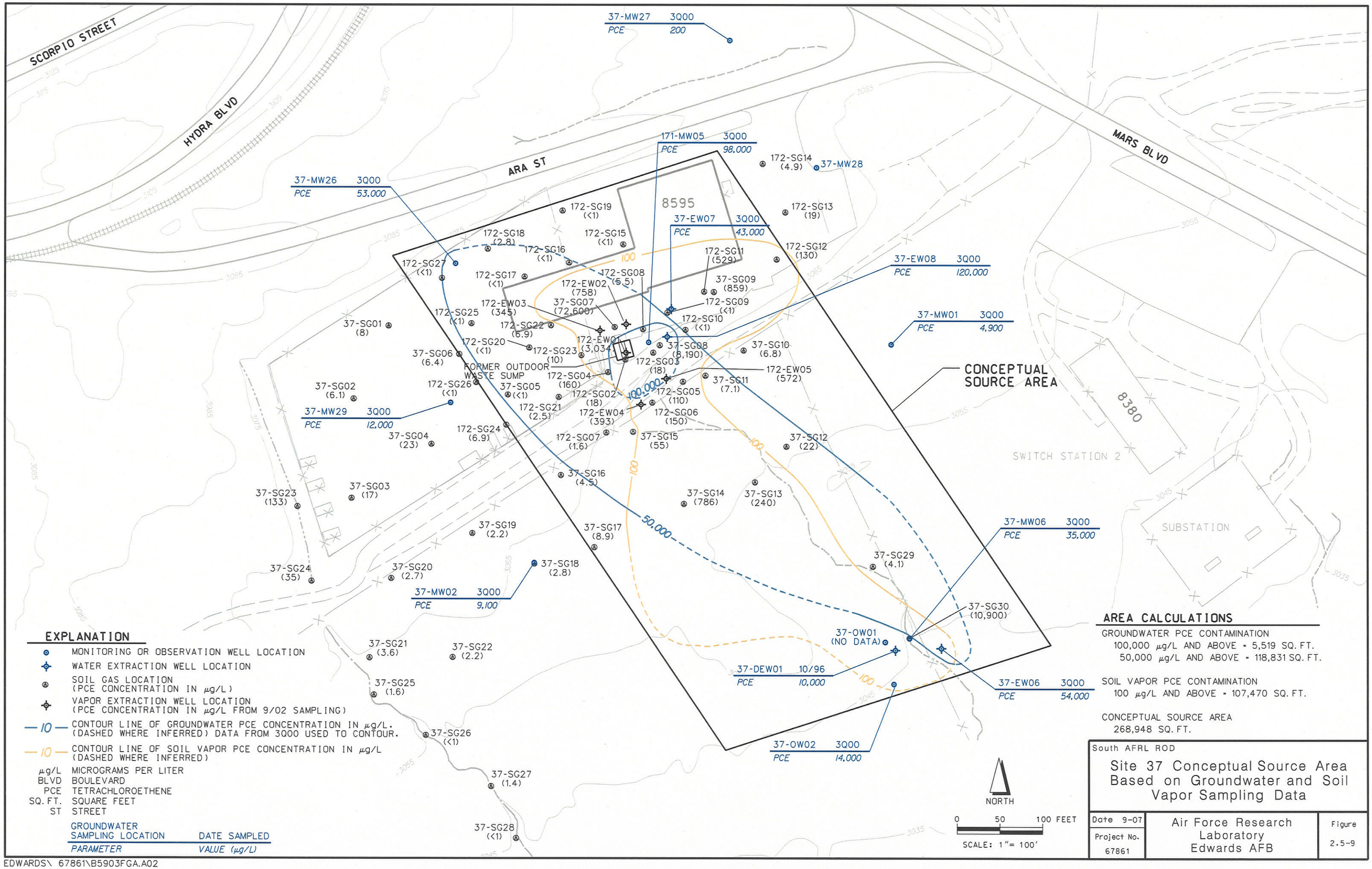
The dissolved phase plume based on the maximum distribution of PCE and TCE is estimated to extend approximately 6,000 feet south of Building 8595 and to cover a surface area of approximately 390 acres.

2.5.4.2 Site 120

During the SI phase, surface water and sediment samples were collected from the two northernmost evaporation/percolation ponds at the STP (refer to Figure 2.2-2). Low concentrations of oil and grease, cis-1,2-DCE, methylene chloride, and dichlorobenzene were identified in the surface water or sediment samples; these data were evaluated in the HHRA and ERA. Surface water and soil sampling results are further discussed in the presentation of site risks (Section 2.7).

Between 1994 and 2003, a total of 15 monitoring wells and five observation wells were installed to assess the presence and extent of groundwater contamination associated with the former STP facilities. A majority of these wells were sampled in 2003. Based on these results, the estimated lateral extents of PCE and TCE as shown on Figure 2.5-1 were developed. The dissolved phase plume at Site 120 commingles with the Site 133 TCE plume. The source areas at the STP appear to contribute PCE, cis-1,2-DCE, 1,4-dioxane, and perchlorate to the larger TCE plume. Sampling results suggest that reductive dechlorination via intrinsic biodegradation of PCE, probably enhanced by organics in the wastewater formerly treated in the Imhoff Tank, is occurring in a localized area at Site 120.

Well clusters screened over different depth intervals were installed to evaluate the vertical distribution of groundwater contamination. The site has been characterized by borehole drilling to a maximum depth of 338 feet bgs in Well 120-MW15 as depicted on Figure 2.5-10 (Figure 2.5-1 shows the location of the cross-section line). As summarized in Table 2.5-3, in deep Well 120-MW06 installed adjacent to wells 120-MW02 and 120-OW04 near the Imhoff Tank, no contaminants were detected at 249 feet bgs. Likewise, in deep Well 120-MW15 installed adjacent to Well 120-MW10 near the downgradient extent of the STP source-area plumes, no contaminants were detected at 338 feet bgs.



EXPLANATION

- MONITORING OR OBSERVATION WELL LOCATION
- WATER EXTRACTION WELL LOCATION
- SOIL GAS LOCATION (PCE CONCENTRATION IN µg/L)
- VAPOR EXTRACTION WELL LOCATION (PCE CONCENTRATION IN µg/L FROM 9/02 SAMPLING)
- — 10 — CONTOUR LINE OF GROUNDWATER PCE CONCENTRATION IN µg/L. (DASHED WHERE INFERRED) DATA FROM 3Q00 USED TO CONTOUR.
- — 10 — CONTOUR LINE OF SOIL VAPOR PCE CONCENTRATION IN µg/L (DASHED WHERE INFERRED)

µg/L MICROGRAMS PER LITER
BLVD BOULEVARD
PCE TETRACHLOROETHENE
SQ. FT. SQUARE FEET
ST STREET

GROUNDWATER SAMPLING LOCATION	DATE SAMPLED
PARAMETER	*VALUE (µg/L)*

AREA CALCULATIONS

GROUNDWATER PCE CONTAMINATION
100,000 µg/L AND ABOVE = 5,519 SQ. FT.
50,000 µg/L AND ABOVE = 118,831 SQ. FT.

SOIL VAPOR PCE CONTAMINATION
100 µg/L AND ABOVE = 107,470 SQ. FT.

CONCEPTUAL SOURCE AREA
268,948 SQ. FT.

South AFRL ROD

Site 37 Conceptual Source Area Based on Groundwater and Soil Vapor Sampling Data

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure 2.5-9
Project No. 67861		

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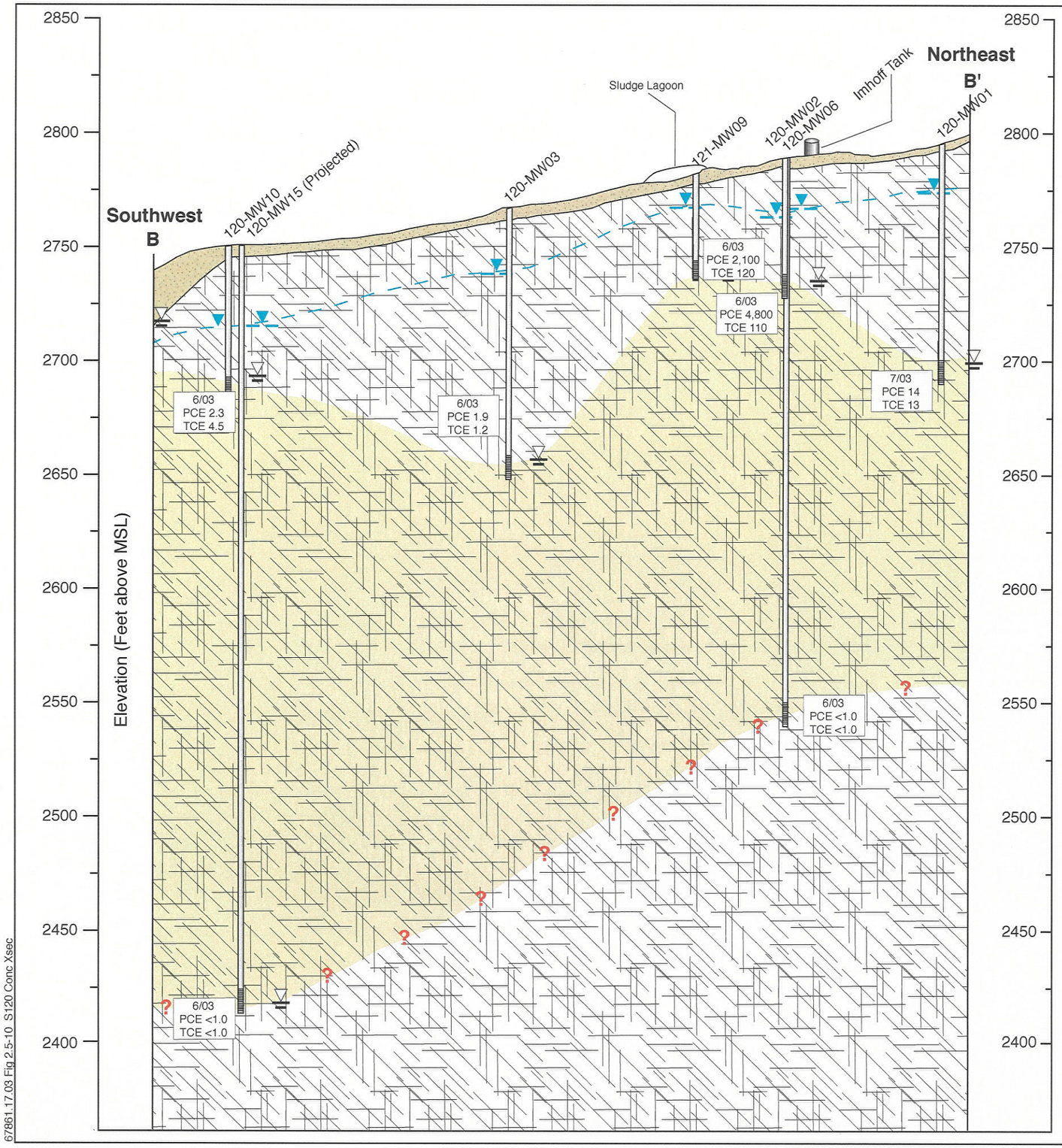


Explanation:

- Unconsolidated sediments
- Fractured granitic bedrock
- Potentiometric surface elevation 7/03
- Groundwater encountered
- Dissolved chlorinated hydrocarbons
- ? Extent either inferred or unknown

Concentrations are in micrograms per liter (µg/L).

µg/L	micrograms per liter
MSL	mean sea level
PCE	tetrachloroethene
TCE	trichloroethene

Location of cross section line is shown on Figure 2.5-1.

0 200 400 FEET

HORIZONTAL SCALE: 1"=400' VERTICAL SCALE: 1"=50'

South AFRL ROD

Site 120 Conceptual Site Model Cross Section

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		2.5-10

67861.17.03 Fig 2.5-10 S120 Conc Xsec

The dissolved-phase, commingled Sites 133 and 120 TCE plume extends an estimated 3.2 miles from Well 153-MW10 north of Building 8431 to south of the STP and is estimated to cover a surface area of approximately 1,500 acres (Figure 2.5-1). Although the concentration and distribution of dissolved contaminants do not suggest the presence of DNAPL at Site 120, a "hot spot" area was conceptually defined as shown on Figure 2.2-2. This approximately 80- by 80- square foot area includes PCE concentrations in excess of 4,000 μg/L in the immediate vicinity of the Imhoff Tank.

2.5.4.3 Site 133

Soil gas and limited soil samples were collected inside the CE yard during the SI phase. Solvents including TCE, PCE, and 1,1-DCE were detected in the soil gas samples, which were used to select a location for installation of monitoring Well 133-MW01 in 1994. Soil gas samples were collected and analyzed as field screening data and were not used to derive an estimate of site risks. TCE was detected at a concentration (0.011 mg/kg) well below its residential PRG in a single soil sample collected at a depth of 6 feet bgs. Soil sampling results are further discussed in the presentation of site risks (Section 2.7).

In a groundwater sample collected from Well 133-MW01 in April 1996, TCE was detected at 1,600 μg/L and PCE was detected at 43 μg/L. Meanwhile, TCE had also been detected in monitoring wells that were installed around the Site 13 former AFRL landfill to the south and at the former Fire Training Area to the east. These results indicated that the solvent contamination extended beneath, up gradient, and down gradient of the CE Yard.

Between 1992 and 2003, more than 60 monitoring wells and 10 observation wells were installed to assess the presence and extent of groundwater contamination associated with the CE Yard and surrounding ERP Sites 13, 26, 150, and 153. A majority of these wells were sampled in 2003. Based on these results, the estimated lateral extents of PCE and TCE as shown on Figure 2.5-1 were developed. Besides TCE and PCE, a number of other VOCs are detected in the groundwater at Site 133 at concentrations exceeding their respective pMCLs. The most widespread of these are cis-1,2-DCE and MTBE. Sampling results indicating the presence of cis-1,2-DCE suggest that limited reductive dechlorination of TCE has occurred in localized areas within the Site 133 groundwater plume, near the AFRL gas station, down gradient of the former landfill, and down gradient of

Building 8451. In all of these locations, a possible anthropogenic source of carbon may have been present due to past releases of petroleum hydrocarbons. Other COCs, which occur at concentrations exceeding their respective NLs or DWEL, include 1,4-dioxane, NDMA, and perchlorate.

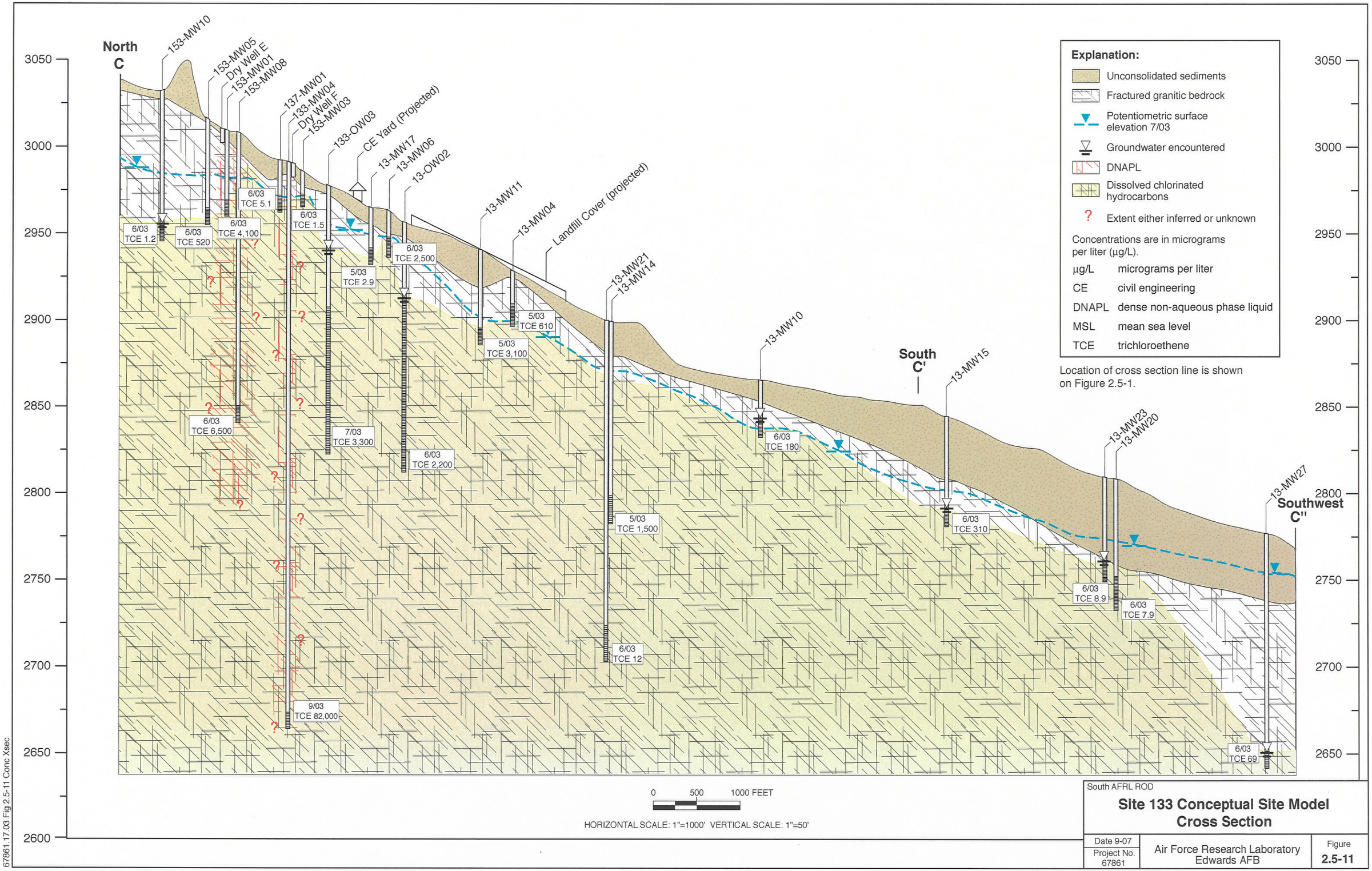
Well clusters screened over different depth intervals were installed to evaluate the vertical distribution of groundwater contamination. The site has been characterized by borehole drilling to a maximum depth of 327 feet bgs in Well 133-MW04. Zones of fracturing and weathering of the CBr were observed in the borehole for this well to its total depth as depicted on Figure 2.5-11 (Figure 2.5-1 shows the location of the cross-section line).

In general, the deeper water bearing zones (e.g., in the landfill and gas station areas) are far less contaminated than the comparable shallow zones. However, this pattern of contaminant concentrations decreasing with depth is reversed adjacent to former waste discharge (dry) Wells E and F, where the presence of DNAPL is suspected although not directly observed. Based on the site history and the distribution of dissolved-phase TCE at depth, two 100- by 100-square foot "source areas" (or inferred DNAPL zones) were conceptually defined for the site (refer to Figure 2.2-3). These are "hot spots" of contamination surrounding former Dry Wells E and F, represented by TCE concentrations in excess of 5,000 μg/L. The vertical extent of this hot spot contamination has not been well defined but is known to exceed 170 feet bgs near Dry Well E and 325 feet bgs near Dry Well F (Figure 2.5-11).

As already noted in Section 2.5.4.2, the dissolved-phase, commingled Sites 133 and 120 TCE plume (exceeding 1 μg/L) is estimated to extend from Well 153-MW10 north of Building 8431 approximately 3.2 miles to the south (1.6 miles southwest of Mars Blvd) and to cover a surface area of approximately 1,500 acres (refer to Figure 2.5-1).

2.5.4.4 Site 321

Soil samples were collected at Site 321 during the SI phase and following excavation of the catch tanks in 1995. Soil sampling results are further discussed in the presentation of site risks (Section 2.7). Soil gas samples collected during the SI detected low concentrations of TCE and PCE. Soil gas samples were collected and analyzed as field screening data and were not used to derive an estimate of site risks.

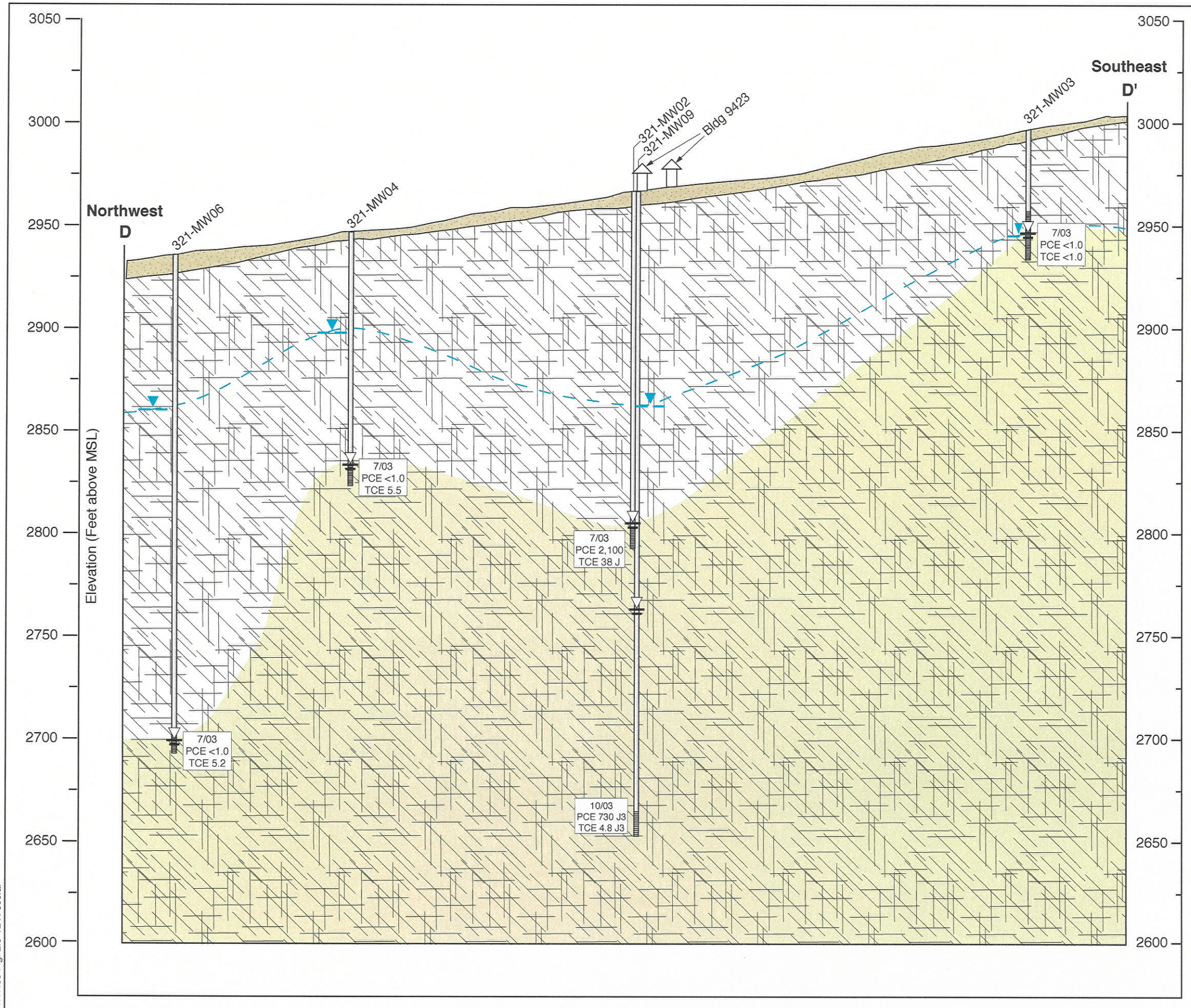

North C
South C'
Southwest C"
153-MW10
153-MW05
Dry Well E
153-MW01
153-MW08
137-MW01
133-MW04
Dry Well F
153-MW03
133-OW03
CE Yard (Projected)
13-MW17
13-MW06
13-OW02
13-MW11
13-MW04
Landfill Cover (projected)
13-MW21
13-MW14
13-MW10
13-MW15
13-MW23
13-MW20
13-MW27
6/03 TCE 1.2
6/03 TCE 520
6/03 TCE 4,100
6/03 TCE 5.1
6/03 TCE 1.5
5/03 TCE 2.9
6/03 TCE 2,500
5/03 TCE 610
5/03 TCE 3,100
6/03 TCE 180
6/03 TCE 310
6/03 TCE 8.9
6/03 TCE 7.9
6/03 TCE 69
6/03 TCE 6,500
7/03 TCE 3,300
6/03 TCE 2,200
5/03 TCE 1,500
6/03 TCE 12
9/03 TCE 82,000
3050
3000
2950
2900
2850
2800
2750
2700
2650
2600
0 500 1000 FEET
HORIZONTAL SCALE: 1"=1000' VERTICAL SCALE: 1"=50'
Explanation:
Unconsolidated sediments
Fractured granitic bedrock
Potentiometric surface elevation 7/03
Groundwater encountered
DNAPL
Dissolved chlorinated hydrocarbons
Extent either inferred or unknown
Concentrations are in micrograms per liter (µg/L).
µg/L micrograms per liter
CE civil engineering
DNAPL dense non-aqueous phase liquid
MSL mean sea level
TCE trichloroethene
Location of cross section line is shown on Figure 2.5-1.
South AFRL ROD
Site 133 Conceptual Site Model Cross Section
Date 9-07
Project No. 67861
Air Force Research Laboratory Edwards AFB
Figure 2.5-11
67861.17.03 Fig 2.5-11 Conc Xsec

In 1994, Well 321-MW01 was installed and sampled: TCE was detected at 18 μg/L and PCE was detected at 2.2 μg/L. Between 2001 and 2003, 10 additional monitoring wells were installed to evaluate the lateral and vertical extent of groundwater contamination at Site 321. A majority of these wells were sampled in 2003. Based on these results, the estimated lateral extents of PCE and TCE as shown on Figure 2.5-2 were developed.

Based on results of the 2003 sampling event, PCE is the primary contaminant at Site 321 with concentrations as high as 2,100 μg/L; the plume extends approximately 800 feet down gradient of Building 9423. Although much lower concentrations of TCE were detected (maximum of 38 μg/L), the TCE plume extends over 1,100 feet down gradient of Building 9423 and covers a surface area estimated at 11 acres. Cis-1,2-DCE was detected only in Well 321-MW02, at a concentration of 700 μg/L. This result indicates the potential for reductive dechlorination in a localized area.

Well clusters screened over different depth intervals were installed to evaluate the vertical distribution of groundwater contamination. Well 321-MW09 is screened over a deep water-bearing zone (in fractured crystalline bedrock) to a depth of 313 feet bgs, separated vertically from the first-encountered water zone by non-water producing fractured intervals in competent crystalline bedrock (Figure 2.5-12). Figure 2.5-2 shows the location of the cross-section line. As summarized in Table 2.5-3, PCE was detected at 730 μg/L in deep Well 321-MW09, located 20 feet southwest of Well 321-MW02. By contrast, deep Well 321-MW05a (approximately 250 feet bgs), which is cross gradient to the source area, exhibits no site contaminants above reporting limits. No VOCs were detected in either the first water-bearing zone or the deeper water-bearing zone in downgradient Wells 321-MW08a and 321-MW08b.

DNAPL has not been directly observed but may potentially be present in a localized area southwest of Building 9423. As shown on Figure 2.2-4, a “source area” or “hot spot” was conceptually defined as an approximately 80- by 50-square foot area south of Building 9423 where PCE concentrations exceed 1,000 μg/L. Sampling results from deep Well 321-MW09 indicate that contamination in the source area extends to least 300 feet bgs.



Explanation:

- Unconsolidated sediments
- Fractured granitic bedrock
- Potentiometric surface elevation 7/03
- Groundwater encountered
- Dissolved chlorinated hydrocarbons

Concentrations are in micrograms per liter (µg/L).

J	Result is detected below the reporting limit and is an estimated concentration.
J3	Extraction or analysis out of hold time; indicated low bias for most analytes.
µg/L	micrograms per liter
Bldg	building
MSL	mean sea level
PCE	tetrachloroethene
TCE	trichloroethene

Location of cross section line is shown on Figure 2.5-2.

0 500 1000 FEET

HORIZONTAL SCALE: 1"=1000' VERTICAL SCALE: 1"=50'

South AFRL ROD

Site 321 Conceptual Site Model Cross Section

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		2.5-12

67861.17.03 Fig. 2.5-12 X-sec.ai

2.5.5 EXPOSURE PATHWAYS EVALUATED IN HUMAN HEALTH RISK ASSESSMENT (HHRA) AND ECOLOGICAL RISK ASSESSMENT (ERA)

Figure 2.5-13 summarizes the potentially complete exposure pathways identified for the HHRA at Sites 37, 120, 133, and 321. Exposure pathways were evaluated for soil and groundwater media at Sites 37, 120, 133, and 321.

Figure 2.5-14 summarizes the potentially complete exposure pathways identified for the predictive ecological risk assessment (PERA) at Sites 37, 120, and 133. A scoping ecological risk assessment (SERA) was performed that did not identify any potentially complete exposure pathways to ecological receptors at Site 321: therefore, no PERA was performed for that site. Exposure pathways were evaluated for soil and groundwater media at Sites 37 and 133; and for soil (sediment), surface water, and groundwater media at Site 120.

HHRA and PERA results are presented in Section 2.7.

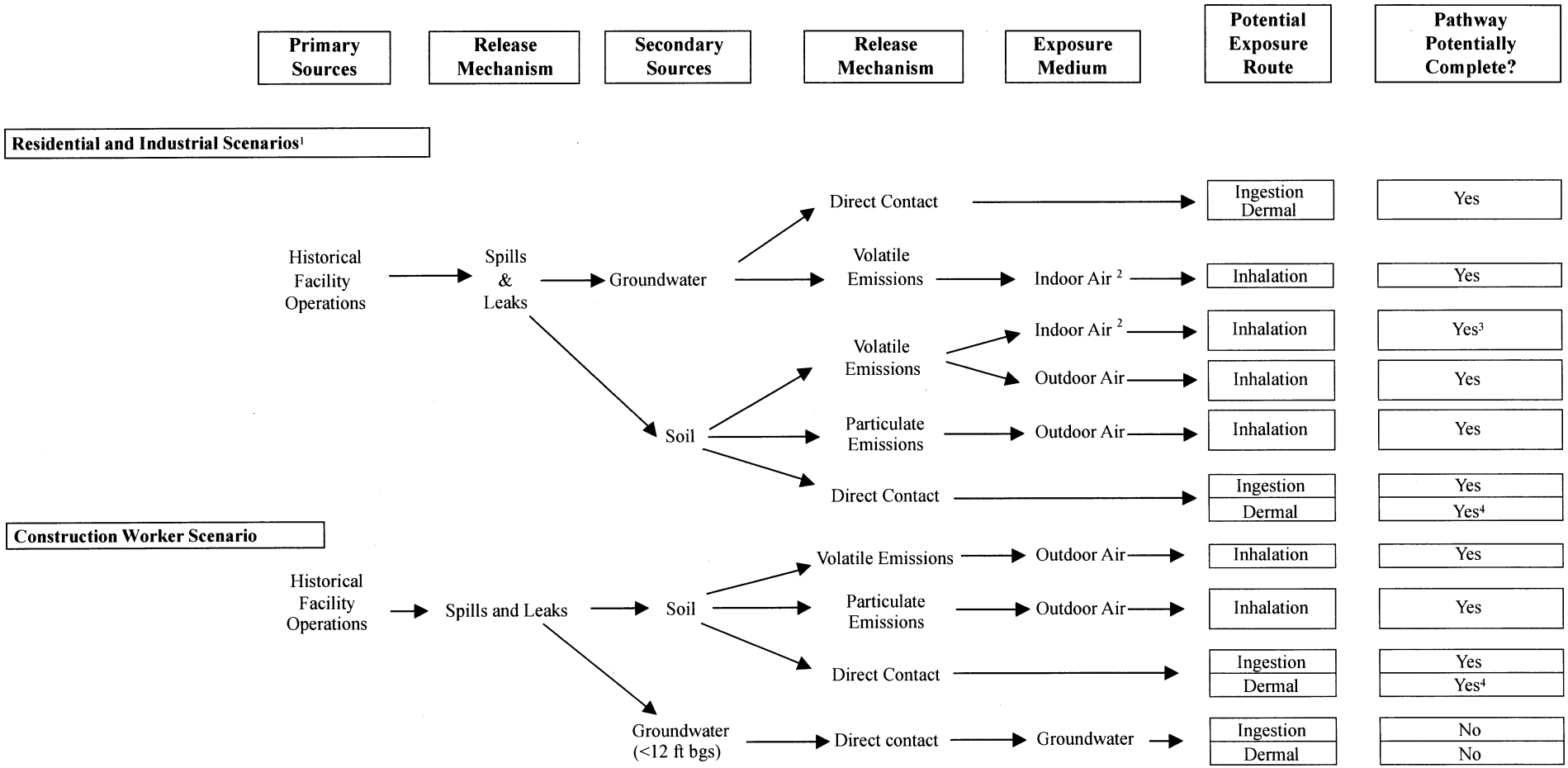
2.5.6 CONCEPTUAL SITE MODEL

Based on the summary of information presented in Sections 2.5-1 through 2.5-5, a CSM for the South AFRL was developed that includes the following major findings/assumptions:

- The geology of the South AFRL area is characterized by a thin veneer of eluvium (silty sand) overlying weathered and competent granitic bedrock. The bedrock is highly fractured. At many locations throughout the South AFRL, fractured granitic bedrock is exposed at the surface.

- Groundwater occurs under hydrostatic pressure within the fractured granitic bedrock, generally under conditions of very low K (such that groundwater flows at a very low rate and significant quantities of contaminated groundwater cannot be readily removed). Likewise, the amount of groundwater that could be withdrawn for drinking is also very low. The contoured, undisturbed potentiometric surface (i.e., prior to groundwater extraction) generally mimics the slope of the overlying topography.

- On a localized (well) scale, the movement of groundwater and contaminants is fracture controlled. However at the regional scale evaluated for groundwater flow and contaminant transport modeling, groundwater flow emulates that of a porous media aquifer. Fracture spacing (based on fracture mapping conducted in 1997) ranges from ½-inch to 6.6 feet, averaging approximately 1.5 feet. Therefore, the fracture density is very high relative to the modeled area (over 146 square miles).



Notes:

[1] Residential exposure scenario is hypothetical, and constitutes only those pathways addressed by the residential preliminary remediation goals.
[2] Indoor air is considered a complete pathway for the industrial receptor only if buildings are present.
[3] Not a potentially complete pathway for Site 321.
[4] Pathway was not evaluated for Site 37.

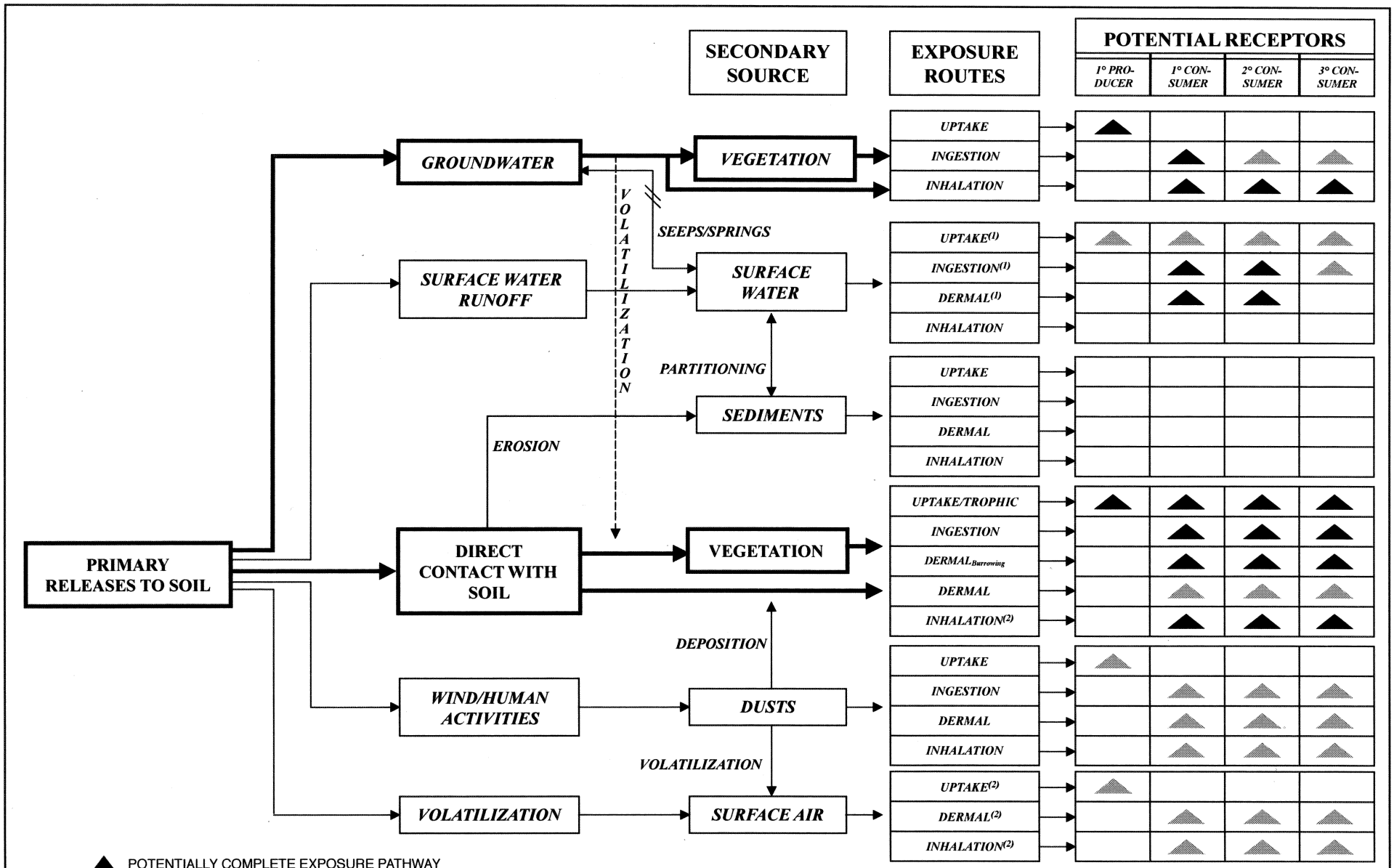
ft bgs feet below ground surface
HHRA human health risk assessment

South AFRL ROD

Summary of Exposure Pathways Evaluated in Sites 37, 120, 133, and 321 HHRAs

Date 9-07	Air Force Research Laboratory Ewards AFB	Figure 2.5-13
Project No. 67861		

67861.17.03 Fig 2.5-13



▲ POTENTIALLY COMPLETE EXPOSURE PATHWAY

▲ POSSIBLY COMPLETE EXPOSURE PATHWAY; CLEAR = INCOMPLETE EXPOSURE PATHWAY

ERA Ecological Risk Assessment

USGS United States Geological Survey

- - - Evaluated in Validation Study

Note: Adapted from USGS 2004c

(1) Incomplete exposure pathway for Producers and Consumers at Sites 37 and 133.

(2) Incomplete exposure pathway for Producers and Consumers at Site 120.

South AFRL ROD

Summary of Exposure Pathways Evaluated in Sites 37, 120, and 133 ERAs

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		2.5-14

- PCE and TCE are the primary groundwater contaminants, occurring as DNAPL in the Site 37 and 133 source areas. PCE, TCE, and other solvents (mixed with wastewaters) were discharged for perhaps 25 years (from the late 1950s through the early 1980s) and have had the opportunity to migrate for more than 40 years. Various source areas are located throughout the Site 133 plume. Sources at Sites 37, 120, and 321 are more localized. Long-term releases from the former sumps at Building 8595 (Site 37); the former waste disposal (dry) wells at Buildings 8431 and 8423 (Site 133), the Imhoff Tank, former sludge drying beds, and former evaporation/percolation ponds at the STP (Site 120); and former Catch Tanks at Site 321 are thought to be the primary contributors to groundwater contamination. Additionally, a one-time release of pure-phase PCE to the surface reportedly occurred at Site 37 in the early 1980s, creating significant groundwater contamination originating at Building 8595 and extending approximately 200 feet down gradient.

Factors affecting the potential for (i.e., difficulty of) restoring groundwater are summarized on Figure 2.5-15. As shown on this figure and supported by the information presented in the CSM, hydrogeology and contaminant-related factors put the South AFRL area on the right-hand side (i.e., demonstrating greatest difficulty) of the "generalized remediation difficulty scale."

The inferred presence of DNAPL in groundwater within the fractured granitic bedrock is a major factor driving selection of a TI waiver as a component of the selected remedy.

2.5.7 GROUNDWATER FLOW AND CONTAMINANT TRANSPORT MODEL

As part of the FS process, a comprehensive groundwater flow and contaminant transport model (Earth Tech 2005c) was developed for the South AFRL. Groundwater flow and contaminant transport were simulated using MODFLOW and MT3D, respectively. Because the site hydrogeologic setting is complex, reasonable yet conservative input parameters and assumptions were used to develop simulations that are conservative in their projections (i.e., inputs would tend to overestimate rather than underestimate the projected maximum rate and size of contaminant migration). Furthermore, the intended use of the contaminant transport simulations is to allow a comparison among remedial alternatives (including a no action alternative) and simulations cannot be used with a high degree of confidence to predict future contaminant distributions; thus continued monitoring is required to allow testing of model predictions and refinement of input assumptions. The groundwater modeling report and South AFRL Focused FS present the modeling assumptions and limitations in detail.

Site/Contaminant Characteristics	Generalized Remediation Difficulty Scale Increasing Difficulty	
Site Use		
Nature of Release	Small Volume Short Duration Slug Release ✓	Large Volume ✓ Long Duration ✓ Continual Release ✓
Chemical Properties		
Biotic/Abiotic Decay Potential	High	Low ✓
Volatility	✓ High	Low
Contaminant Retardation (Sorption) Potential	✓ Low	High
Contaminant Distribution		
Contaminant Phase	✓ Aqueous, ✓ Gaseous → Sorbed → LNAPLs	✓ DNAPLs
Volume of Contaminated Media	Small	Large ✓
Contaminant Depth	Shallow	Deep ✓
Hydrogeologic Characteristics		
Geology		
Stratigraphy	Simple Geology, e.g., Planar Bedding Strata	Complex Geology, ✓ e.g., Interbedded and Discontinuous
Texture of Unconsolidated Deposits*	Sand	Clay
Degree of Heterogeneity	Homogeneous e.g., well-sorted sand	✓ Heterogeneous, e.g., interbedded sand and silts, clays, fractured media, karst
Hydraulics/Flow		
Hydraulic Conductivity of Aquifer	High (>10^{-2} cm/sec)	Low (<10^{-4} cm/sec) ✓
Temporal Variation of Flow Regime	✓ Little/None	High
Vertical Flow	✓ Little Component	Large Downward Flow

✓ Conditions characterizing South AFRL are checked.
* Unconsolidated aquifers are not present.

AFRL Air Force Research Laboratory
LNAPL Light non-aqueous phase liquid
DNAPL Dense non-aqueous phase liquid
cm/sec Centimeters per second
USEPA United States Environmental Protection Agency

Certain site characteristics may limit the effectiveness of subsurface remediation. The examples listed above are highly generalized. The particular factor or combination of factors that may critically limit restoration potential will be site specific. (Figure is taken from USEPA, 1993 as amended in USEPA 1995).

South AFRL ROD

Examples of Factors Affecting Groundwater Restoration Potential

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		2.5-15

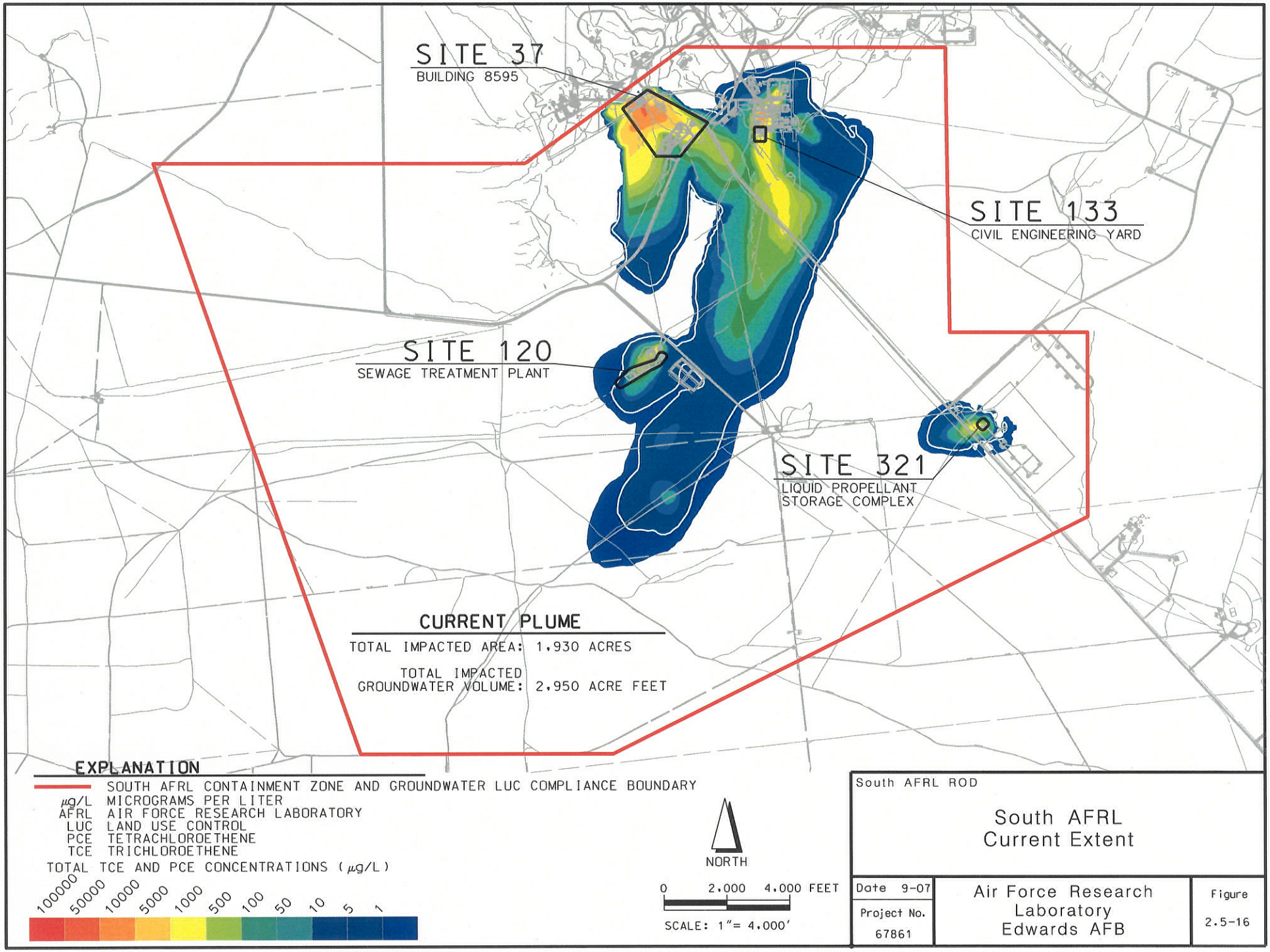
67861.17.03

The groundwater flow model incorporates groundwater elevation data collected between 1998 and 2003 and results of aquifer testing conducted between 1997 and 2002. Inputs to the groundwater flow model include K, recharge, aquifer thickness, and constant hydraulic head elevations. The contaminant transport model, which assumes a continuing contaminant source (localized pockets of DNAPL) at each site, incorporates contaminant distribution data collected between 1999 and early 2004, and inputs for effective porosity, dispersion, and contaminant flux. Steady-state and transient calibrations were performed for the groundwater flow model to a 2.3% relative error. A transient calibration was performed for the contaminant transport model to within an order of magnitude of actual PCE concentrations.

The calibrated groundwater flow and contaminant transport models were used to simulate several remedial alternatives for the South AFRL, including:

- No action;
- Hydraulic containment by expansion and continued operation of the existing Site 37 and Site 133 GETS to contain PCE and TCE concentrations greater than 1,000 μg/L (source control);
- Hydraulic containment to contain PCE and TCE concentrations greater than 5 μg/L (plume control); and
- Contaminant source removal within 10 years or 100 years (source treatment). For purposes of modeling, the technology for source removal was unspecified.

The last scenario is considered hypothetical because no current remedial technologies have been proven effective for 100% removal of DNAPL in fractured bedrock. For each of these scenarios, the model was used to generate simulations at 1, 30, 100, 200, 600, and 1,000 years. The current extent of the South AFRL plume is shown on Figure 2.5-16 and the simulated outcomes of each of the above scenarios at 100 years and 1,000 years are compared on Figure 2.5-17. Note that, although successful application of either of the two active containment scenarios is projected to result in a significantly lower volume of impacted groundwater than no active containment after 1,000 years, these scenarios do not have an endpoint so long as DNAPL continues to be present. As expected, the successful removal of DNAPL would have the best long-term outcome.



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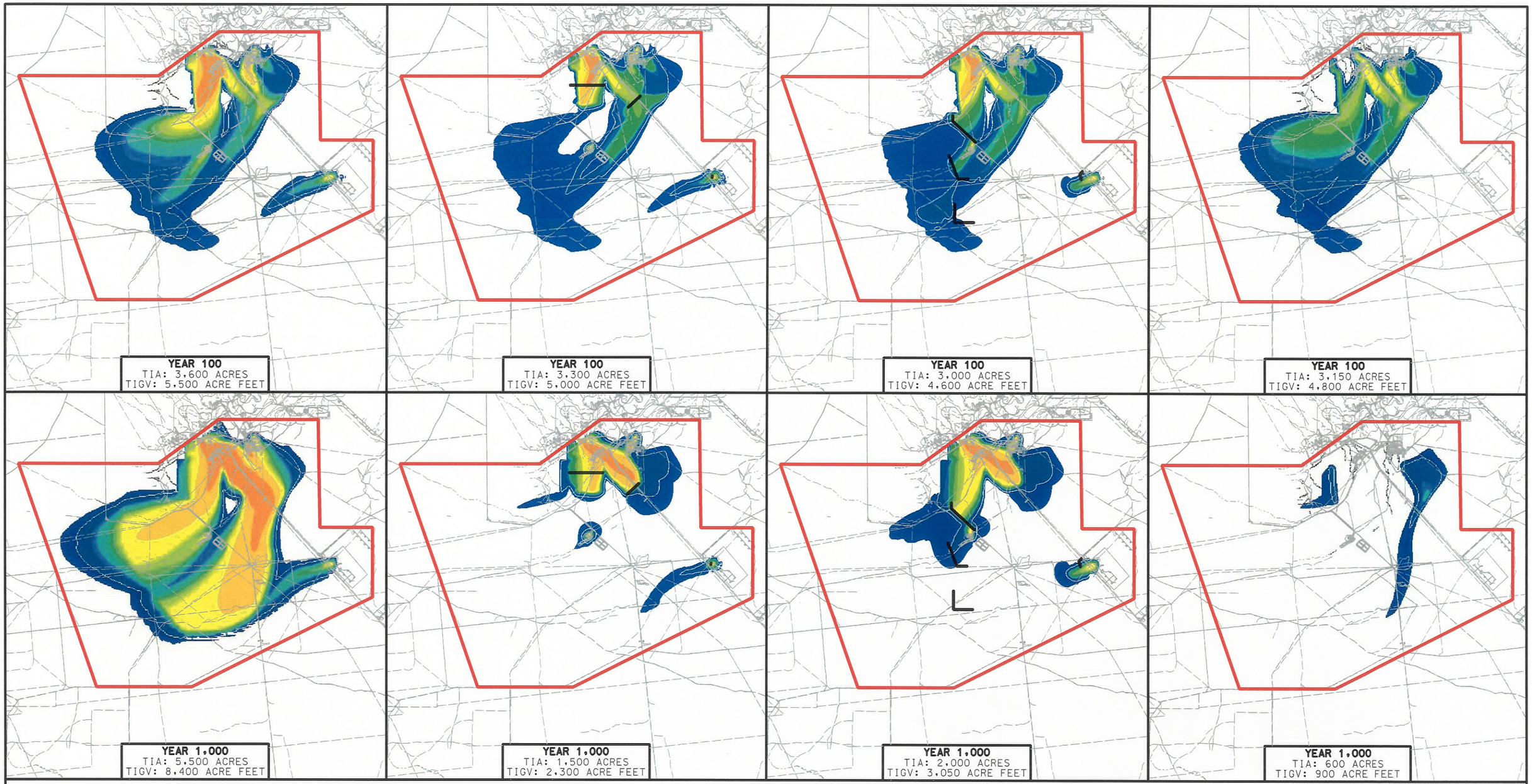


A. NO ACTIVE CONTAINMENT SCENARIO

B. HOT SPOT CONTAINMENT (CONTAMINANT CONCENTRATIONS > 1,000 µg/L)

C. PLUME CONTAINMENT (CONTAMINANT CONCENTRATIONS > 5 µg/L)

D. REMOVAL OF DNAPL IN 10 YEARS

EXPLANATION

SOUTH AFRL CONTAINMENT ZONE AND GROUNDWATER LUC COMPLIANCE BOUNDARY

POTENTIAL EXTRACTION WELL FIELDS TO CONTAIN THE PLUMES

µg/L MICROGRAMS PER LITER
AFRL AIR FORCE RESEARCH LABORATORY
LUC LAND USE CONTROL
PCE TETRACHLOROETHENE
TCE TRICHLOROETHENE
TIA TOTAL IMPACTED AREA
TIGV TOTAL IMPACTED GROUNDWATER VOLUME

TOTAL TCE AND PCE CONCENTRATIONS (µg/L)

100000 50000 10000 5000 1000 500 100 50 10 5 1

NORTH

0 4000 8000 FEET

SCALE: 1"= 8000'

South AFRL ROD

South AFRL
Remedial Scenario Comparison

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		2.5-17

EDWARDS\ 67861\B6256FGA.A02

Under the no action (no active containment) scenario, the model projects that the plume will persist at levels above regulatory limits to the end of the 1,000-year simulation. However, although the combined PCE and TCE plumes are initially expected to advance, after approximately 300 years, the western lobe of the plume (Site 37) would reach a steady-state condition, wherein the combined effects of dispersion and dilution would balance the continuous source release. After approximately 800 years, the leading edge of the eastern lobe of the plume (Sites 120/133) would also reach equilibrium, although higher concentrations within the interior of the plume would continue to advance. The modeling simulation, in conjunction with groundwater monitoring results, projects that contaminants in the groundwater at the South AFRL would not advance beyond the South AFRL CZ boundary within 1,000 years and therefore, these contaminants do not represent an immediate or long-term threat to the potable water supply, or to human exposure through ingestion of contaminated water.

2.5.8 EVALUATION OF THE TECHNICAL IMPRACTICABILITY OF GROUNDWATER RESTORATION AT THE SOUTH AFRL

This section summarizes the evaluation (presented in the South AFRL Focused FS) of the technical impracticability of restoring the groundwater within the South AFRL to drinking water standards. The evaluation was based on procedures set forth in the USEPA September 1993 "Guidance for Evaluating Technical Impracticability of Ground-Water Restoration" (TI Guidance), which includes the following required components:

1. Specific ARARs or media cleanup standards for which TI waivers are sought.
2. The spatial area over which the TI waiver will apply.
3. A CSM that describes the site geology; hydrogeology; and contaminant sources, transport, and fate (presented in Sections 2.5.2 through 2.5.7).
4. An evaluation of the restoration potential of the site, including data and analyses that support the assertion that attainment of ARARs or media cleanup standards is technically impracticable from an engineering perspective.
5. Estimates of the hypothetical costs to a) implement source area (DNAPL zone) removal and b) construct, operate, and maintain (over the first 30 years) a groundwater pump-and-treat (PAT) system designed to achieve groundwater restoration to the pMCL for PCE and TCE.

2.5.8.1 Specific ARARs for Which TI Waivers are Sought

Because of the impracticability of groundwater restoration, none of the COCs within the South AFRL CZ will be cleaned up to their respective pMCLs or RBCGs as listed in Table 2.5-1. For those COCs that have pMCLs, a TI waiver is sought for these chemical-specific ARARs. A TI waiver is not necessary for those COCs (perchlorate, NDMA, and 1,4-dioxane) for which there is no chemical-specific ARAR (i.e., pMCL) at present. The State's position concerning State ARARs is discussed in Section 2.14.2.1.

2.5.8.2 Spatial Area Over Which TI Decision Would Apply

Figure 2.1-2 shows the limits of the South AFRL CZ. This boundary covers an area of approximately 16.4 square miles, and where convenient, coincides with the U.S. Public Land Survey System (PLSS) of township, range, and section. The TI Guidance states that "the limits of the TI zone should be delineated clearly on site maps and geologic cross sections. While concentration data may be appropriate to consider when determining the size of a containment area or the extent of a TI zone, the limits of that TI zone should be fixed in space, both horizontally and vertically."

To satisfy this directive, in addition to showing PLSS coordinates, Figure 2.1-2 displays the boundary corner points in state plane, geographic (latitude and longitude), and Universal Transverse Mercator (UTM) coordinates, all referenced to the North American Datum of 1983 (NAD 83). This approach has the advantage of tying the boundary to a familiar, established coordinate system. Due to its size, fences are not practical for delineating the South AFRL CZ boundary, and ground markers at the boundary corners would be ineffective because no two markers would be visible at any one time. Placement of a sufficient number of markers to allow sighting along the boundary between them would likely result in undesirable impacts to the surrounding desert habitat and/or ongoing military mission during marker installation and subsequent maintenance. Therefore, global positioning system (GPS) receivers, used in conjunction with the Edwards AFB GIS database, will be employed to identify the zone boundaries in the field.

The boundary of the South AFRL CZ was designed with the objective of preventing contaminants from impacting the alluvial aquifer to the west (Lancaster Sub-basin shown on Figure 2.5-3); to exclude the inactive and active production wells at Mary's Well Field and the Lower Well Field, respectively; and

to encompass the maximum projected extent of the PCE and TCE contaminant plumes originating at Sites 37, 120, 133, and 321 under a no action scenario (refer to Figure 2.5-17A). The perimeter of the South AFRL CZ is located 3.6 miles from the nearest on-base active drinking water wells, 4.6 miles from the nearest off-base active drinking water wells, 8.9 miles from the nearest on-base residential area (across Rogers Dry Lake bed at Main Base), 4.3 miles from the nearest off-base residential area (to the north in Boron), and 3.4 miles from the northern Base boundary. As discussed in Section 2.5.7, under the "no action" scenario, results of the contaminant transport modeling developed for the South AFRL indicate that the combined PCE and TCE plumes would advance for approximately 300 years before the western lobe would reach equilibrium and another 800 years before the eastern lobe would reach equilibrium. The maximum extent of the plume shown on Figure 2.1-2 corresponds to the plume distributions between 300 and 800 years.

Setting the vertical limit of the South AFRL CZ is complex because the total depth of contamination in the source areas is physically difficult and costly to determine with any certainty. However, the TI Guidance specifies that the limits of the TI zone should be fixed in space vertically as well as horizontally (the State Containment Zone Policy has a similar requirement). To comply with this requirement, a depth of 500 feet bgs (at least 175 feet below the maximum depth of contamination identified - adjacent to Dry Well F, a source area for Site 133) was selected as the vertical limit of the TI Zone. The 500 feet bgs vertical extent of the CZ was deemed reasonable because (1) no water-bearing units exist below the competent, crystalline bedrock (i.e., there is no deeper aquifer); and (2) the size and density of fractures decrease with increasing depth. Because fractures become smaller and less frequent and do not effectively transport water at greater depth, installation of monitoring wells becomes increasingly difficult and expensive, especially if care is taken not to carry contamination further downward. In addition, it becomes highly unlikely that contaminants in groundwater below 500 feet bgs could be intercepted and effectively remediated or their migration could be controlled.

2.5.8.3 Evaluation of Restoration Potential for Groundwater at the South AFRL

Based on the CSM and groundwater modeling simulations presented in Sections 2.5.6 and 2.5.7, and the evaluation of remediation difficulty in terms of site hydrogeology and contaminant characteristics

presented on Figure 2.5-15, an assessment of the restoration potential for the South AFRL was conducted as presented below.

Source Identification and Removal

Source control actions and treatability studies that have been completed or are ongoing at the South AFRL Sites 37, 120, 133, and 321 were listed in Sections 2.2.3.2 and 2.2.3.3 and summarized in Table A-4 (included in Appendix A).

None of the source control actions implemented to date have addressed DNAPL in the fractured granitic bedrock at the South AFRL. However, as summarized in Table 2.5-4 (adapted from Table 4.3-1 in the South AFRL Focused FS but updated for use in this ROD), potential source area remediation technologies were screened for use at the South AFRL based on their implementability, effectiveness to achieve source reduction, and relative cost. Of the treatment technologies listed in Table 2.5-4, the following (as summarized in Table E-2 in Appendix E) have been tested at Edwards AFB: in-situ chemical oxidation (ISCO) using permanganate, persulfate, or Fenton's reagent; in-situ bioremediation (ISB) either by injection of electron donor (whey powder, edible oil substrate, or hydrogen-release compound) to stimulate anaerobic reductive dechlorination (ARD) or by injection of toluene as a carbon substrate to stimulate the cometabolic degradation of TCE (by bacterial oxygenase), with or without air sparging to maintain aerobic conditions; steam injection to enhance removal by SVE; and hydraulic fracturing or blast fracturing as a way to increase extraction yield. In general, each of these technologies has demonstrated low to moderate success in reducing source area concentrations, generally within a very localized area (radius of influence [ROI] on the order of 10 feet to 15 feet) and over a relatively narrow vertical extent (targeting shallow depth zones); none has been demonstrated at full scale in fractured granitic bedrock (at Edwards AFB or elsewhere) although ISCO using sodium permanganate was selected as the final remedy for treatment of chlorinated solvents in groundwater at OU6 and has been proposed as a final remedy (already initiated) for groundwater at OU2.

The source removal technology that has shown the greatest efficiency in removing contaminant mass at Edwards AFB is SVE, either by itself or operated as a dual extraction system with de-watering. The

TABLE 2.5-4. SCREENING OF IN-SITU SOURCE AREA REMEDIATION TECHNOLOGIES FOR USE AT THE SOUTH AFRL

Technology	Implementability in Fractured Crystalline Bedrock	Effectiveness to Achieve Source Reduction	Relative Cost	Comments
Enhanced Recovery				
Hydraulic Fracturing	Low	Low	Moderate	Demonstrated at Site 25 in OU8. Limited to shallow depths
Pneumatic Fracturing	Low	Low	Moderate	Like hydraulic, limited to shallow depths
Blast Fracturing	Moderate	Low to Moderate	Moderate	Pilot study at Site 37 not effective in increasing well yield
In Situ Thermal Technologies	Low to Moderate	Low to Moderate	High	Steam injection demonstrated at Site 61 in OU8.
Flushing with Clean Water	Low to Moderate	Low to Moderate	Moderate	Limited by ability to inject water (low permeability of aquifer)
Surfactants/Cosolvents	Low	Low to Moderate	High	Additional site characterization would be required prior to implementation
In Situ Treatment				
Chemical Oxidation	Low	Low	Moderate	Selected as final remedy for shallow groundwater sites in OU6, however, depth to groundwater at South AFRL is a deterrent to effective implementability Ongoing pilot study at shallow groundwater Site 5/14 in OU2
Bioremediation	Low to Moderate	Low to Moderate	Moderate	Evaluation of natural attenuation suggests biodegradation is limited by availability of carbon substrate/hydrogen donor Pilot studies ongoing at two sites in OU4/OU9
Permeable Reactive Barrier	Very Low	Low	High	Impractical for the depths required and not recommended because it is a passive technology
Ex-Situ Treatment				
Dual extraction or SVE	Moderate to High	Moderate to High	Low	Dual extraction used for hot spot treatment in OU1; SVE used in source area at Site 37. However, use of SVE is limited to the unconsolidated soils above the fractured, competent bedrock and is not a feasible alternative for remediation of groundwater at the South AFRL

Notes:

AFRL Air Force Research Laboratory
OU operable unit
SVE soil vapor extraction

use of SVE, however, is limited to the unconsolidated soils above the fractured, competent granitic bedrock at the South AFRL. On the Main Base at Edwards AFB, dual extraction has been effective in a highly weathered bedrock zone not encountered at the South AFRL.

On the basis of the CSM, and the screening of source area treatment technologies available including their performance at Edwards AFB, the evidence indicates that removal of the whole DNAPL mass at the site is not technically practicable.

Analysis of Performance of Ongoing Remedial Actions

A summary of the capital costs, costs for O&M, and contaminant mass removal for the GETS at Sites 37 and 133 and the SVE system at Site 172 is presented in Table A-5 in Appendix A. The locations of the SVE extraction wells are presented on Figure 2.2-1; locations of the GETS extraction wells and treatment compounds are shown on Figure 2.9-1. The effectiveness and limitations of SVE for use at the South AFRL were discussed above. Although the Air Force could continue to operate the groundwater PAT systems, the transport model simulation (refer to Figure 2.5-17B) projects that these systems would not contain the plume for at least 100 years because a continuing DNAPL source is present.

Predictive Analysis of the Timeframe to Attain the Drinking Water Standard for PCE and TCE Using Available Technologies

The potential for restoration of the groundwater aquifer within the South AFRL CZ was evaluated based on the estimated time to reduce the dissolved-phase PCE concentrations at Site 37 to below the pMCL using groundwater extraction and treatment, assuming effective source control (i.e., no continuing source due to DNAPL dissolution). Given that conditions are similar at Sites 120, 133, and 321, it is assumed that timeframes to remediate the TCE and PCE plumes at these sites would also be similar.

An estimated 150 PAT extraction wells, distributed throughout the Site 37 groundwater plume and operating concurrently, would be required to achieve a site-wide reduction in PCE concentrations to the pMCL (5 μg/L). However, because each well can only effect treatment within its ROI, the time required to achieve the pMCL at each well is independent of the number of wells in operation. Therefore, to demonstrate a range of treatment time frames, each of the following scenarios assess the number of years required for one of these hypothetical extraction wells to reduce the PCE

concentrations to the pMCL within its ROI. Each scenario assumes the hypothetical well in question is located along a PCE concentration contour, representing initial concentrations of 50,000 μg/L, 10,000 μg/L, 1,000 μg/L, and 100 μg/L, respectively (Table 2.5-5). Also presented is an estimate of the additional number of years a hypothetical well would need to be pumped to further reduce the PCE concentration from the pMCL to BG (1 μg/L or less).

The hypothetical well is assumed to exhibit the following characteristics:

- The well can sustain a pump rate of 0.3 gpm (the average pump rate sustained by Wells 37-EW02 through 37-EW08 over at least 6 months of pumping).
- The well can affect an area of influence of 71,000 square feet based on an assumed ROI of 150 feet (estimated from pump tests conducted at Site 37).
- The total depth of contamination is 250 feet bgs (maximum depth to which contamination has been detected at Site 37).
- The effective porosity is 1% (consistent with the value used to derive aquifer parameters).

Thus, the only variable driving differences in the time estimate is the number of pore volumes (PVs) required to flush the initial concentration (C_i) to the final concentration (C_f). The assumptions used to derive the pore volume estimates are detailed in Appendix G of the South AFRL Focused FS.

The conclusion that can be drawn from Table 2.5-5 is that even under the unlikely condition that the DNAPL source can be successfully removed (or, a more probable assumption, fully controlled) so that no additional discharge occurs, the estimated timeframe to flush the remaining contaminants from the aquifer (either to pMCLs or to BG) by means of groundwater PAT is well over 100 years at each of the concentrations considered. By comparison, the TI Guidance states, "…very long restoration timeframes (e.g., longer than 100 years) may be indicative of hydrogeologic or contaminant-related constraints to remediation." In this case, the hydrogeologic and contaminant-related constraints to remediation by PAT prevent effective treatment of the contaminant plume to levels that meet WQOs and protect beneficial uses.

TABLE 2.5-5. ESTIMATED TIME TO ACHIEVE REDUCTION IN PCE CONCENTRATIONS USING GROUNDWATER PUMP AND TREAT

Initial Concentration (C_i) in μg/L	Final Concentration (C_f) in μg/L	Number of Pore Volumes (PV) (Unitless)	Total Volume (V) of Water to Be Treated (gallons)	Time (T) to Achieve Final Concentration (Years)
50,000	5	143	189,400,000	1,200
10,000	5	118	156,300,000	990
1,000	5	82	109,000,000	690
100	5	46	61,610,000	390
5	1	25	33,100,000	210

Notes:

Volume and time estimates have been rounded to 4 and 2 significant figures, respectively.

T (years) = V (gallons) x 1 year/(0.3 gpm x 1,440 minutes x 365 days). Details on these calculations and assumptions can be found in Appendix G of the South AFRL Focused FS (Earth Tech 2005b).

μg/L micrograms per liter
AFRL Air Force Research Laboratory
FS feasibility study
gpm gallons per minute
PCE tetrachloroethene

Demonstration that No Other Remedial Technologies Could Attain the Drinking Water Standard for PCE and TCE in a Reasonable Timeframe

An additional component suggested for evaluating the restoration potential of a site is a demonstration that no other remedial technologies (conventional or innovative) could reliably, logically or feasibly attain the cleanup levels at the site within a reasonable timeframe. A screening of innovative technologies including recent advances in enhanced recovery and in-situ remediation of groundwater at DNAPL sites was presented in Table 2.5-4. As part of the evaluation of remedial alternatives for the South AFRL, costs (presented in Section 2.9) were developed for a source removal action in the relatively small (270,000-square-foot) source area at Site 37 (refer to Figure 2.5-9). Considering (1) the limited full scale testing of these technologies, (2) the limited number of vendors offering these services, and particularly (3) the lack of data on these approaches in fractured crystalline bedrock, initial assessment of the effectiveness of these techniques in a limited area is the most logical approach to identify the combination of techniques most likely to show a significant reduction in contaminant mass. This phased approach is also in line with the presumptive response strategy for groundwater sites.

At this time, no remedial technology (conventional or innovative) has been demonstrated that could feasibly attain pMCLs at the South AFRL within a reasonable timeframe.

2.5.8.4 Estimated Cost to Construct and Operate Groundwater Pump and Treat (PAT) Systems to Meet the Primary MCLs

As a final component of the evaluation of TI for groundwater restoration at the South AFRL, this section presents estimated costs to achieve the drinking water pMCLs for PCE and/or TCE at all four South AFRL plumes. This would be accomplished by aggressively removing the DNAPL sources at Sites 37 and 133 within 10 years (e.g., by fracture blasting/clean water flushing/and ISB or ISCO), and by constructing, operating, and maintaining groundwater PAT systems throughout the plumes. The source area treatment is further developed in Section 2.9 and is not the focus of this discussion. Costs are derived from Table H-6 in Appendix H of the South AFRL Focused FS.

The PAT evaluation is based on the same assumptions listed in Section 2.5.8.3 and used to develop the estimated timeframe for remediation presented in Table 2.5-5. Note that, based on performance of the

existing GETS at Site 37, the long-term probability of sustaining an average flow rate of 0.3 gpm is questionable (although more plausible at Site 133). To treat the combined current extent of the groundwater plumes (estimated to cover a surface area of 1,900 acres), an estimated 600 extraction wells would be needed. Based on experience in drilling at these sites, the cost assumption includes provisions to drill five pilot boreholes per extraction well to be installed.

The purpose of the pilot boreholes is to aid in locating a well that encounters productive water-bearing zones. Once the extraction wells are installed (to an average depth of 100 feet bgs), they would be tied in via underground piping (up to 180,000 feet) to the existing Sites 37 and 133 GETS, which would require modifications to increase the current maximum flow rates. It is anticipated that the increased flow rate from the new extraction wells (total flow estimated to average 180 gpm) would exceed the current discharge limit for the Sites 37 and 133 systems to the AFRL STP, which is set at a combined 20 gpm. Therefore, it is assumed that additional evaporation/percolation ponds would be needed to handle the excess wastewater generated by the upgraded system. The cost estimate includes provisions to install new evaporation/percolation ponds and to tie treated water discharge from the Sites 37 and 133 GETS to the ponds via underground piping.

The estimated capital costs to drill, install, and connect the wells to the existing GETS and to modify the systems for expansion of flow capacity are presented in Table 2.5-6, which also includes the estimated total costs to: perform O&M of the systems and evaporation/percolation ponds for 30 years; conduct LTM; and implement LUCs.

The total cost for this hypothetical action would be approximately $221 million over 30 years, a cost that could be reduced to $195 million using present value (PV) discounts (see Section 2.13.3 for a discussion of how costs were derived). The projected outcome of this action would be the dewatering of portions of the groundwater plumes and a gradual reduction in overall concentrations, but not the achievement of drinking water standards within 30 years (as shown in Table 2.5-5, the predicted timeframe to achieve contaminant reduction to the pMCL is close to 1,000 years).

For the sake of completeness, Table 2.5-7 presents a preliminary cost estimate to achieve aquifer restoration using PAT for 990 years. However, it should be noted that due to the extremely long

TABLE 2.5-6. COST ESTIMATE TO CONSTRUCT AND OPERATE (FIRST 30 YEARS) A PUMP AND TREAT SYSTEM TO MEET THE pMCLs FOR PCE AND TCE AT THE SOUTH AFRL AREA

Phase Element	Escalated Cost	Present Value Cost
Source Area Treatment		
Capital Costs	$18,750,000	$18,050,000
Supplemental LTM (10 years)	$4,070,000	$2,740,000
Supplemental Sites 37 and 133 GETS O&M (10 years)	$560,000	$380,000
Subtotal	$23,380,000	$21,170,000
Plume Treatment		
Capital Costs	$172,140,000	$165,720,000
LTM (30 years)	$9,230,000	$3,150,000
O&M Sites 37 and 133 GETS (30 years)	$11,380,000	$3,580,000
O&M Site 172 SVE System (30 years)	$3,160,000	$980,000
O&M Evaporation Ponds	$1,450,000	$480,000
Land Use Controls	$230,000	$70,000
5-Year Reviews (Reports)	$300,000	$90,000
Subtotal	$197,890,000	$174,074,000
TOTAL	**$221,270,000**	**$195,244,000**

Notes:

Cost estimates used a 7% discount rate instead of 3.1% as recommended by USEPA (2000b) Guidance, which would have increased the PV Costs by 8 to 50%.

%	percent
AFRL	Air Force Research Laboratory
GETS	groundwater extraction and treatment system
LTM	long term monitoring
MCL	maximum contaminant level
O&M	operation and maintenance
PCE	tetrachloroethene
PV	present value
SVE	soil vapor extraction
TCE	trichloroethene
USEPA	United States Environmental Protection Agency

TABLE 2.5-7. PRELIMINARY COST ESTIMATES TO TREAT ENTIRE SOUTH AFRL AREA GROUNDWATER PLUME TO pMCL LEVELS (990 YEAR TREATMENT TIMEFRAME)

Task	Cost Per Event	Number of Events	Extended Cost
Capital Costs for Source Area Treatment			
Blast Fracture Trenches	$9,090,000	1	$9,090,000
Update Sites 37 and 133 GETS	$200,000	1	$200,000
Install Wells and GETS Tie-in	$8,760,000	1	$8,760,000
Annual Costs for Source Area Treatment			
Incremental O&M to GETS	$50,000	10	$500,000
Incremental LTM	$370,000	10	$3,700,000
Recurring Capital Costs for Plume Treatment (every 50 years)			
Install/Replace Extraction Wells	$161,890,000	20	$3,237,800,000
Construct/Replace Evaporation Ponds	$2,800,000	20	$56,000,000
Tie Evaporation Ponds into GETS	$1,040,000	20	$20,800,000
Replace GETS	$1,780,000	19	$33,820,000
Annual Costs for Plume Treatment			
Land Use Controls	$10,000	990	$9,900,000
Plume LTM	$230,000	990	$227,700,000
GETS O&M	$290,000	990	$287,100,000
O&M of Evaporation Ponds	$36,000	990	$35,640,000
5-Year Reviews (Reports)	$45,000	198	$8,910,000
Total			**$3,939,920,000**

Notes:
All costs are rounded to the nearest $10,000
It is assumed that all equipment will need to be completely replaced every 50 years on average.
It is assumed that aggressive source area remediation will remove the inferred DNAPL mass within 10 years.
Due to uncertainty in economic conditions over the next 990 years, values do not factor inflation or present value discounts
As preliminary estimates, these costs are greatly simplified and should not be considered definitive level.

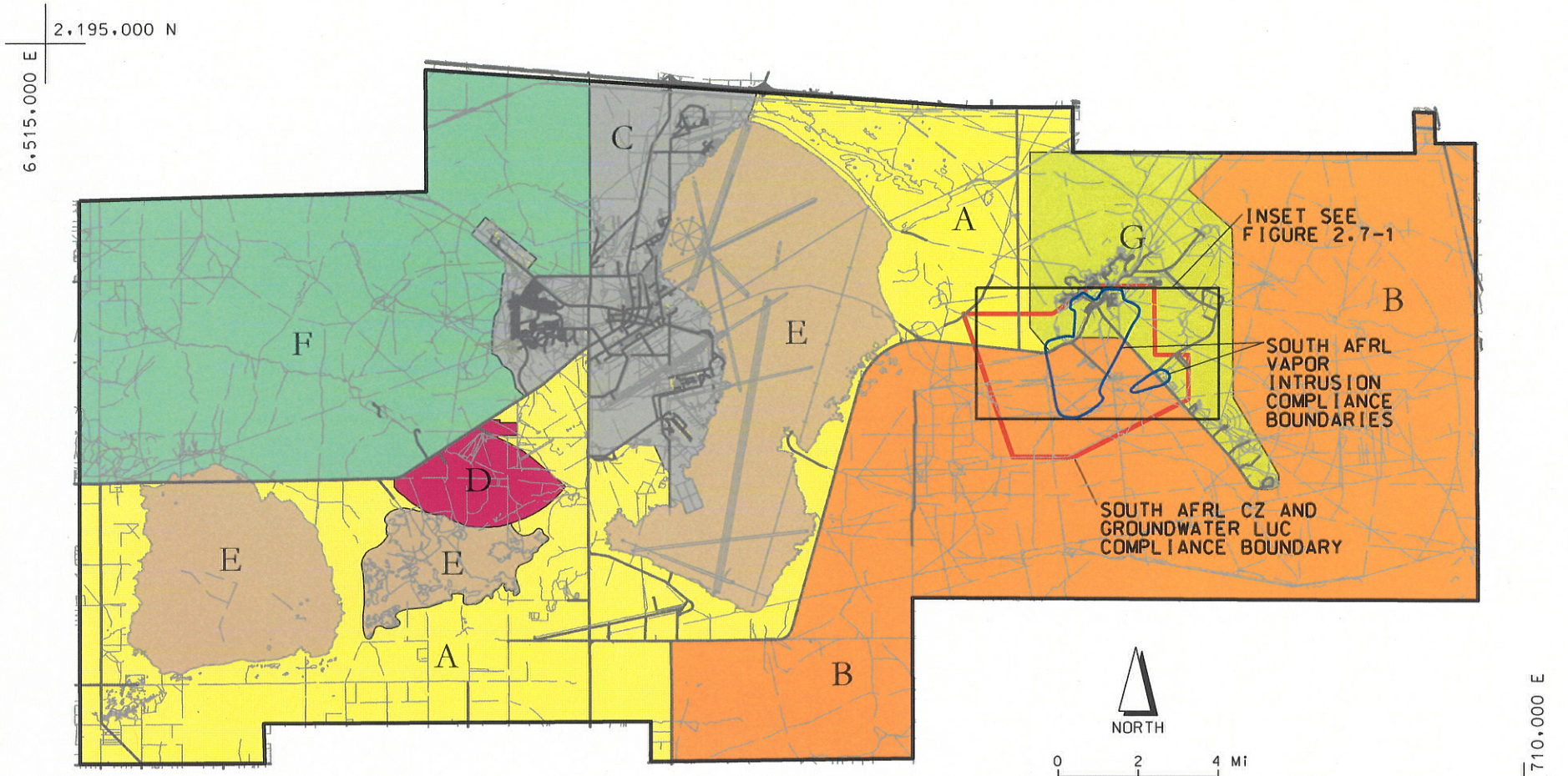
AFRL Air Force Research Laboratory
DNAPL dense non-aqueous phase liquid
GETS groundwater extraction and treatment system
LTM long term monitoring
MCL maximum contaminant level
O&M operation and maintenance

timeframe, the $3.9 billion total cost estimate represents only a very approximate estimate of true costs. Together with the information presented in Section 2.5.8.3, the results of these cost estimates support a finding of TI from an engineering perspective for groundwater restoration at this site.

2.6 CURRENT AND POTENTIAL FUTURE LAND AND RESOURCE USES

The limits of the South AFRL CZ include an area located partially within the AFRL and partially within the PIRA, both entirely within Edwards AFB. According to the Base GP (Higginbotham/Briggs & Associates [HB&A] 2001), current and long-term land uses at the AFRL (Management Area G, refer to Figure 2.6-1) include the testing of rocket engines, extensive safety zones surrounding the test cells, and industrial, research, development and administrative uses. The current and designated long-term land use for the PIRA (Management Area B) is aircraft flight testing, explosive ordnance disposal (EOD), and placement of communication equipment. The South AFRL CZ also extends (on the west) into Management Area A, designated as an Aircraft Overflight Test Area, which is generally undeveloped and supports aircraft test activity. Land uses within the AFRL, PIRA, and Aircraft Overflight Test Area are industrial in nature, and no residential uses (including day care facilities or other uses that would result in higher exposure amounts beyond worker exposures) of any portion of these Management Areas are anticipated, as the Air Force will continue to occupy the Base indefinitely.

As shown on Figure 2.1-2, the nearest active drinking water well field (Lower Well Field) is located outside the South AFRL CZ boundary, more than 5 miles southwest of the outer limit of the commingled South AFRL groundwater plumes. The Lower Well Field extracts groundwater from the alluvial Lancaster Sub-basin shown on Figure 2.5-3; no production wells tap the water-bearing fractured bedrock of the Hi Vista area in which the South AFRL CZ is located. It should be noted that groundwater occurring within fractured, granitic bedrock does not meet the definition of a groundwater basin as defined by the California DWR Bulletin 118, titled *California's Groundwater* (DWR 2003), i.e., "A groundwater basin is defined as an alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and a definable bottom." Further, Table 8 of the Bulletin, titled "Types and boundary characteristics of groundwater basins," describes groundwater



EXPLANATION

- EDWARDS AFB BOUNDARY
- SOUTH AFRL CZ AND GROUNDWATER LUC COMPLIANCE BOUNDARY
- SOUTH AFRL VAPOR INTRUSION COMPLIANCE BOUNDARIES
- PAVED ROAD
- UNPAVED ROAD
- MANAGEMENT AREA A (AIRCRAFT OVERFLIGHT TEST AREA)
- MANAGEMENT AREA B (PRECISION IMPACT RANGE AREA)
- MANAGEMENT AREA C (DEVELOPED AREA [HOUSING/COMMERCIAL/INDUSTRIAL])
- MANAGEMENT AREA D (COMBAT ARMS RANGE)
- MANAGEMENT AREA E (DRY LAKEBEDS [FLIGHT TEST/RUNWAYS])
- MANAGEMENT AREA F (MILITARY EXERCISE/ TEST AREA)
- MANAGEMENT AREA G (AIR FORCE RESEARCH LABORATORY)

AFB AIR FORCE BASE
AFRL AIR FORCE RESEARCH LABORATORY
CZ CONTAINMENT ZONE
LUC LAND USE CONTROL
U.S. UNITED STATES
USAF UNITED STATES AIR FORCE

NOTES:
1. FIGURE WAS MODIFIED FROM THE USAF'S INTEGRATED NATURAL RESOURCES MANAGEMENT PLAN FOR EDWARDS AIR FORCE BASE, CALIFORNIA, FIGURE 3-3 (2002 REVISED 2004).
2. VIP COMPLIANCE BOUNDARIES ARE SHOWN AT A LARGER SCALE ON FIGURE 2.7-1.

MAP COORDINATES: NORTH AMERICAN DATUM 1983 (U.S. FEET).

South AFRL ROD

Land Use Management Areas and Groundwater and Vapor Intrusion Compliance Boundaries, Edwards AFB

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		2.6-1

EDWARDS\ 67861\B6472FGA.A01

in weathered crystalline rocks (fractured hard rock) as "not considered a basin" and provides the following characteristics (consistent with that of groundwater within the South AFRL CZ): "small quantities of groundwater; low-yielding wells; most wells are completed in the crystalline rock and rely on fractures to obtain groundwater."

Nevertheless, the Basin Plan (CRWQCB 1995) identifies the Antelope Valley Basin (6-44) as including both the Lancaster Sub-basin and the Hi Vista area (see Figure 2.5-3), and Table 2-2 of the Basin Plan designates the following beneficial uses for groundwater within this basin: municipal, agricultural, industrial, and freshwater replenishment.

The total groundwater storage capacity of the sedimentary aquifers comprising the Antelope Valley Basin is estimated at 68-70 million acre-feet (*Bulletin 118*, California DWR, 2003); the available capacity is estimated to be 30,000 - 60,000 acre-feet annually (*2005 Integrated Urban Water Management Plan for the Antelope Valley*, Kennedy/Jenks Consultants, 2005) because not all the water can be withdrawn economically or without serious physical effects such as subsidence. The South AFRL contaminant plume occurs entirely within fractured rock in upland areas that are not part of the basin, so the quantity of impacted water in the plume cannot be stated as a percentage of total basin capacity. However, the following assumptions were made to provide an estimate of fracture storage for the sake of comparison.

Area and Volume of Groundwater in the South AFRL CZ

Total area of CZ = 16.35 square miles = 10,460 acres
Aquifer thickness = total depth of CZ (500 feet) – average depth of wells (120 feet) = 380 feet
Average fracture porosity =0.4% (0.004) (assumed)
Total volume = 10,460 acres x 380 feet x 0.004 = 15,900 acre-feet.
Percent of Total Capacity in the Antelope Valley Basin = 15,900 acre-feet/68 million acre-feet = 0.02%.

Area and Volume of Impacted Groundwater (projected after 30 years)

Area of plumes at modeled 30-year projection = 2,700 acres
Average water column thickness = 380 feet
Fracture porosity =0.4%
Total capacity under the modeled 30-year projection = **4,100 acre-feet**.

This is very likely an overestimate, and produces a volume equal to 0.006% of the storage capacity of the basin.

Annual yield is not normally calculated and predicted for fractured rock source areas because of the unpredictability of groundwater occurrence in hard-to-map fracture systems and uncertainties regarding sustainability. However, given that one-quarter of AFRL drill holes have been dry and 60% of successful wells have yielded less than 0.4 gpm, we conservatively assume that the available capacity of groundwater in the bedrock fractures is 50% of the total capacity or **2,050 acre-feet**.

There are no current or long-term uses of groundwater for drinking water supply or any other purpose at the South AFRL. Those WQOs identified in Table D-1 as relevant and appropriate requirements (RARs) for the selected remedy at the South AFRL will be waived within the South AFRL CZ.

No permanent surface water bodies exist at the South AFRL other than man-made retention ponds at the STP. Engineered drainages and stormwater runoff ultimately drain to Rogers Dry Lake bed where standing water collects during most winters.

2.7 SUMMARY OF SITE RISKS

The RA selected in this ROD is necessary to prevent exposure to COC concentrations in groundwater that exceed pMCLs. As part of RI/FS activities for OU4 and OU9, human health and ERAs were performed for those sites where complete or potentially complete exposure pathways to human or ecological receptors were identified. The HHRA and PERA documents are included in the Administrative Record and summarized in the OU4 and OU9 RISRs. This section presents a summary of the findings of the HHRA as amended by Appendix B-1 to this ROD (Section 2.7.1), and a summary of findings of the ERA (Section 2.7.2), followed by a determination of the risk basis (Section 2.7.3) for taking a response action at the South AFRL.

2.7.1 SUMMARY OF HUMAN HEALTH RISK ASSESSMENTS

An HHRA for each site at the South AFRL was performed to estimate the potential risks to human health posed by chemicals that were released into the environment. The assessments were conducted using the procedures described in the *Basewide Human Health Risk Assessment Work Plan* (Earth Tech 2001d). Details of the assessment are presented in the *Human Health Risk Assessment, Air Force Research Laboratory, Operable Unit 4* (OU4 HHRA, Earth Tech 2004b) and the *Human*

Health Risk Assessment, Air Force Research Laboratory, Operable Unit 9 (OU9 HHRA, Earth Tech 2004c). The data set for the OU4 HHRA includes SI and RI sampling results collected through August 2001. The data set for the OU9 HHRA includes sampling results collected through January 2003. These cutoff dates represented the data available at the time risk evaluations began (evaluations for OU4 preceded evaluations for OU9). The data used in the HHRAs were evaluated for quality and usability, and only the resulting validated soil and groundwater data were used for these assessments.

The assessment of potential health impacts was performed using a tiered process. First, a conservative, screening-level assessment was performed for all sites. Then the risk results for all exposure scenarios evaluated in the initial assessment were compared to benchmark risk criteria to determine if additional evaluation of the results was warranted or if a more detailed assessment was necessary. The benchmark risk criteria used were a cancer risk of 1×10^{-6} and a non-cancer Hazard Quotient (HQ) of 1. For those chemicals that exceeded the benchmark criteria under exposure pathways considered likely to occur at a site, a detailed evaluation of risk was performed. Results from the detailed risk assessment were evaluated according to the risk ranges cited below.

To manage risks to human health, the USEPA has developed the following risk ranges: a cancer risk of greater than 10^{-4} is unacceptable; from 10^{-4} to 10^{-6} is considered generally acceptable when site-specific circumstances allow; and less than 10^{-6} is considered acceptable. A non-cancer Hazard Index (HI, the sum of the HQs for each chemical and exposure pathway) of less than "1" is considered acceptable. It should be noted that an HI of greater than 1 does not necessarily mean that an actual adverse health effect will develop, but rather raises a concern of an increased potential for an adverse effect.

2.7.1.1 Preliminary Assessment of Risk

The preliminary evaluation of health impacts was performed for all detected organic chemicals, and inorganic chemicals detected at concentrations exceeding their naturally occurring levels (upper limits on BG at the AFRL developed for both soil [The Earth Technology Corporation 1995] and groundwater [Earth Tech 1999c revised 2000]). This evaluation consisted of a comparison of the maximum detection for each chemical in soil to residential, industrial, and modified-industrial (for construction exposure) USEPA Region 9 PRGs (USEPA 2000a for OU4, USEPA 2002 for OU9). For

groundwater, the maximum detections for each chemical were compared to tap water PRGs (USEPA 2000a for OU4, USEPA 2002 for OU9) under a residential exposure scenario. Because groundwater at the South AFRL is not currently, nor reasonably anticipated to be, used for drinking water, this exposure pathway is assumed to be hypothetical.

PRGs are risk-based concentrations developed by the USEPA for site screening purposes that are protective of human health under residential and industrial exposure scenarios. Because the PRGs for each scenario consider the most common potential pathways (ingestion and dermal contact with soil or groundwater, and inhalation of fugitive dust and ambient air) to be complete, and the maximum concentration of each detected chemical was used, this first step is considered screening-level.

Although the PRGs include the risk associated with various direct and indirect exposures, they do not include the potential for volatilization from soil or groundwater into indoor air spaces. Therefore, in addition to the PRG-derived risks, potential indoor air risks were estimated for the industrial exposure scenario using the approach developed by J&E (September 1998, version 1.2) and maximum detected soil and/or groundwater concentrations to estimate VOC concentrations in indoor air.

The PRG comparison and, where appropriate, the J&E screening models, resulted in estimated cancer risks and non-cancer HIs for each chemical that were then summed to produce total risks for each environmental medium and exposure scenario.

2.7.1.2 Detailed Assessment of Risk

The chemicals that either individually or collectively produced a cancer risk greater than 1×10^{-6} or a non-cancer HQ greater than 1 for exposure pathways considered likely to take place (e.g., dermal contact with or ingestion of impacted soil, and/or inhalation of ambient or indoor air) were considered for further evaluation in a detailed risk assessment. The detailed assessment used statistically representative (rather than maximum) chemical concentrations and site-specific exposure assumptions. Because the current and reasonably foreseeable future land use at the AFRL is exclusively industrial, the detailed assessments presented in the second step of the HHRA did not include more detailed consideration of residential use. However, in response to concerns expressed by the USEPA and State regulators during preparation of the PP for the South AFRL, a detailed evaluation of the VIP under a residential exposure setting was completed in order to evaluate whether the soil medium and indoor air

pathways from soil or groundwater could be cleared for unrestricted use. In this ROD, based on agreements reached at RPM meetings held on 6 April 2006 and 13 March 2007, risks and hazards via the VIP have been re-evaluated using the most recent version (Version 3.1) of the J&E vapor intrusion model available from the USEPA (www.epa.gov/oswer/riskassessment/airmodel/johnson_ettinger.htm). The results of the VIP re-evaluation are included in Appendix B-1.

When estimating potential cancer risks and non-cancer hazards for the indoor air evaluation or in the detailed assessment, toxicity criteria (unit risk factors [URFs] for carcinogens and/or reference concentrations [RfCs] for non-carcinogens) were derived from the following hierarchy of sources (consistent with USEPA guidance and Air Force policy):

1. USEPA's Integrated Risk Information System (IRIS).
2. USEPA provisional peer-reviewed toxicity values (PPRTVs), developed by the Office of Research and Development at the National Center for Environmental Assessment (NCEA).
3. Other peer-reviewed sources including the California Environmental Protection Agency (Cal-EPA) Office of Environmental Health Hazard Assessment (OEHHA), the Office of Environmental Health Hazard Assessment/Air Resources Board (OEHHA/ARB), the Agency for Toxic Substances and Diseases Registry (ATSDR), or the USEPA Health Effects Assessment Summary Tables (HEAST).

When a chemical was listed in more than one of the Tier 3 sources, the most health-protective value was used. A discussion of how toxicity criteria were selected for use in the re-evaluation of risk via the VIP, and the associated uncertainties of this approach, is provided in Appendix B-1.

2.7.1.3 HHRA Results for Site 37

The potentially complete exposure pathways identified in the HHRA for Site 37 were presented on Figure 2.5-13. Results of the initial screening are summarized in Table 2.7-1.

Soil

Based on the results of the HHRA and PERA, No Action was recommended for soil at Site 37, and this recommendation is selected here in this ROD. The HHRA results are summarized below.

TABLE 2.7-1. SUMMARY OF PRELIMINARY RISKS AND HAZARDS - SITES 37, 120, 133, AND 321

(Page 1 of 2)

	Site 37				Site 120			
	Residential Quantifications		Industrial Quantifications		Residential Quantifications		Industrial Quantifications	
Potential Exposure Media	Carcinogens	Noncarcinogens	Carcinogens	Noncarcinogens	Carcinogens	Noncarcinogens	Carcinogens	Noncarcinogens
Soil	1.32E-04	3.609	1.88E-05	0.447	7.01E-08	0.048	3.29E-08	0.002
Groundwater	2.28E-01	445	-	-	3.83E-03	674.2	-	-
Indoor Air (Soil)	-	-	6.27E-06	0.366	2.43E-07	0.001	1.45E-07	<0.001
Indoor Air (Groundwater)	-	-	3.67E-04	4.697	-	-	1.95E-05	0.305
Total Preliminary Evaluation	2.28E-01	448.6	3.92E-04	5.51	3.83E-03	674.2	1.97E-05	0.307
			Carcinogens	Noncarcinogens			Carcinogens	Noncarcinogens
Construction Receptor			2.90E-07	0.172			5.05E-10	<0.001

TABLE 2.7-1. SUMMARY OF PRELIMINARY RISKS AND HAZARDS - SITES 37, 120, 133, AND 321
(Page 2 of 2)

	Site 133				Site 321			
	Residential Quantifications		Industrial Quantifications		Residential Quantifications		Industrial Quantifications	
Potential Exposure Media	Carcinogens	Noncarcinogens	Carcinogens	Noncarcinogens	Carcinogens	Noncarcinogens	Carcinogens	Noncarcinogens
Soil	7.46E-08	0.432	3.49E-08	0.022	1.04E-07	0.034	4.28E-08	0.003
Groundwater	1.53E-02	216.4	-	-	4.24E-03	118.6	-	-
Indoor Air (Soil)	1.25E-06	0.005	5.58E-07	<0.001	-	-	-	-
Indoor Air (Groundwater)	-	-	4.89E-05	0.543	-	-	3.27E-06	0.049
Total Preliminary Evaluation	1.53E - 02	216.9	4.95E-05	0.565	4.24E-03	118.6	3.31E-06	0.052
			Carcinogens	Noncarcinogens			Carcinogens	Noncarcinogens
Construction Receptor			5.37E-10	0.009			6.57E-10	0.001

Notes:
Summarized from results presented in the HHRAs for OU4 (Earth Tech 2004b) and OU9 (Earth Tech 2004c)
HHRA human health risk assessment
OU operable unit

For exposure to soil under both the residential and industrial scenarios, carcinogenic risks exceeded 1×10^{-6} due to the maximum concentration of arsenic detected. Under the residential scenario, the non-cancer HI was greater than 1 due to the maximum detections of iron and manganese. The distributions of these elements in soil samples collected at the site are shown in Appendix C on Figure C-1. The elevated concentrations (i.e., concentrations above BG, shown in green and red on Figure C-1) of all three elements were detected in samples collected at depths greater than 20 feet bgs, whereas the maximum depth likely to be encountered by construction workers is 12 feet bgs. Therefore, the preliminary risks and hazards identified for exposure to soils were not thought to represent completed pathways, and exposure to soil was not carried forward for a more detailed risk evaluation. Based on a review of the HHRA results and an evaluation of the chemical distributions, the USAF, USEPA and state regulators agree that risks associated with soil contact are acceptable at Site 37, and require no response action.

Soil Vapor

On the basis of risks presented in the HHRA, the PP recommended no action for soil vapor at Site 37. However, based on the re-evaluation of risk via the VIP presented in Appendix B-1 as summarized below, LUCs and engineering controls to prevent exposure under residential and industrial use scenarios are selected here in this ROD, with remedy components detailed in Section 2.13.2.

In the HHRA, the preliminary results for exposure (under an industrial setting) to indoor air using the maximum concentration of PCE detected in the soil indicated a cancer risk of 6.27×10^{-6} and an HI below 1. The preliminary results calculated for exposure (under an industrial setting) to indoor air using maximum concentrations detected in the groundwater showed a risk of 3.67×10^{-4} and an HI of 4.7, with the maximum concentration of PCE driving both the carcinogenic health risk and the HI.

Because results of the initial VIP risk evaluation conducted in the HHRA indicated potential risks via exposure to indoor air above 1×10^{-6}, and due to the uncertainties inherent in the J&E model used to estimate these site risks, indoor air samples were collected inside Building 8595 in June 2003 to validate results of the J&E model and more conclusively evaluate the risks to building occupants. These samples were collected over a 22-hour period during a weekend, with the windows closed and the ventilation system shut off; thus the results tend toward a conservative outcome. A sample of the

ambient air outside the building and a sample inside a communications vault were also collected. Results of these samples confirmed a completed VIP for PCE. Based on the maximum indoor air concentration of PCE (approximately 5 micrograms per cubic meter [$\mu g/m^3$]), and using the same exposure factors as were used in the HHRA, the cancer risk and HI estimated from the sampling data were 2.7×10^{-6} and 0.13 for the industrial exposure setting (refer to Appendix B-1, Table B.1-3). Detection of PCE in indoor air samples has been confirmed in subsequent sampling events as summarized on Figure B.1-9 in Appendix B-1.

For this ROD (refer to Appendix B-1), risks via the VIP were re-evaluated (for both residential and industrial scenarios) as summarized in Table 2.7-2. The carcinogenic risks via the VIP from a soil source under residential and industrial exposure settings were estimated at 1.1×10^{-3} and 1.8×10^{-6}, with an estimated non-cancer HI of 21.1 for the residential exposure setting and 0.17 for the industrial exposure setting. Risk-based cleanup levels (RBCLs) for PCE corresponding to a cancer risk of 1×10^{-4} (or an HQ of 1, if lower), 1×10^{-5}, and 1×10^{-6} were calculated as presented in Table B.1-4 in Appendix B. The estimated areas encompassing PCE contamination in soil at concentrations exceeding RBCLs are presented in Appendix B on Figure B.1-1 for residential exposure and Figure B.1-2 for industrial exposure.

The carcinogenic risks via the VIP from a groundwater source under residential and industrial exposure settings were estimated at 1.6×10^{-3} and 3.5×10^{-5}, respectively, with an estimated non-cancer HI of 18.4 for residential exposure and 1.2 for industrial exposure. PCE was the primary contaminant driving the risk (and HI), followed by TCE and then benzene. RBCLs for PCE, TCE, and benzene corresponding to a cancer risk of 1×10^{-4} (or an HQ of 1, if lower), 1×10^{-5}, and 1×10^{-6} were calculated as presented in Table B.1-4 in Appendix B. The estimated areas encompassing PCE and TCE contamination in groundwater at concentrations exceeding RBCLs are presented in Appendix B on Figures B.1-3 and B.1-4 for residential exposure and Figures B.1-5 and B.1-6 for industrial exposure, respectively.

The risk level via the VIP (both from a soil and a groundwater source) for residential use exceeds 1×10^{-4}, and indoor air sampling has confirmed a risk level exceeding 1×10^{-6} for industrial use. Therefore, the USAF, USEPA and state regulators agree that a response action is required at Site 37 to

TABLE 2.7-2. SUMMARY OF DETAILED ASSESSMENT OF RISKS AND HAZARDS IN SOIL AND GROUNDWATER FOR SITES 37, 120, 133, AND 321, J&E INDOOR AIR EXPOSURE MODEL VERSION 3.1

	Residential			Industrial		
Potential Exposure Medium	Cancer Risk	Risk Drivers	Hazard Quotient	Cancer Risk	Risk Drivers	Hazard Quotient
Site 37						
Indoor Air (Soil)	**1.1E-03**	**PCE**	**21.06**	**1.80E-06**	**PCE**	0.17
Indoor Air (Groundwater)	**1.60E-03**	**PCE,TCE,benzene**	**18.4**	**3.50E-05**	**PCE**	**1.21**
Site 120						
Indoor Air (Soil)	**2.00E-06**	MeCl	<0.01	2.1E-08	MeCl	<0.01
Indoor Air (Groundwater)	**1.60E-03**	**PCE,TCE,cis-1,2-DCE**	**22.2**	**9.20E-05**	**PCE**	**3.8**
Site 133						
Indoor Air (Soil)	**4.60E-06**	TCE,MeCl	0.07	6.9E-09	TCE,MeCl	<0.01
Indoor Air (Groundwater)	**1.20E-04**	**TCE,PCE**	**3.3**	**2.9E-06**	TCE	0.23
Site 321						
Indoor Air (Soil)	**9.30E-05**	PCE	**1.1**	3.3E-07	PCE	0.011
Indoor Air (Groundwater)	**1.50E-04**	**PCE**	**1.77**	**6.40E-06**	**PCE**	0.23

Notes:

Risk levels exceeding 10^{-6} shown in bold. Hazard exceeding 1 shown in bold.
Risk drivers shown in bold are considered COCs.
The exposure to indoor air was evaluated using output from the J & E model (Version 3.1).

<	less than
COC	chemicals of concern
J&E	Johnson and Ettinger
MeCl	methylene chloride
PCE	tetrachloroethene
TCE	trichloroethene

reduce risk (or prevent exposure) via the VIP below 1 x 10^{-6} for both residential and industrial exposure settings. See further discussion in Section 2.7.3.

Groundwater

Based on the results of the HHRA summarized below, Further Action was recommended for groundwater at Site 37, with final remedy components selected as documented in Section 2.13.2 of this ROD.

The preliminary risk and hazard results calculated using the tap water PRGs for a hypothetical residential groundwater use scenario were an estimated cancer risk of 2.28 x 10^{-1} and an HI of 445 (Table 2.7-1), with PCE driving the carcinogenic health risk (risks associated with a number of other VOCs, and arsenic, also exceeded 1 x 10^{-6}) and naphthalene primarily driving the HI above 1 (non-cancer hazards above 1 were also associated with several other VOCs and several inorganics including molybdenum, nickel, nitrate and vanadium). Based on a review of the distribution results for arsenic (Figure C-2), molybdenum (Figure C-3), nickel (Figure C-5), and vanadium (Figure C-7) in groundwater (as shown in Appendix C) by comparison to BG concentrations, tap water PRGs, and pMCLs, the USAF, USEPA, and state regulators agree that risks and/or hazards associated with the listed inorganic elements in groundwater are acceptable and require no response action. However, based on their respective distributions presented on Figures C-4 and C-6, naphthalene and nitrate have been retained as COCs at Site 37 (added to the list since public review of the PP). The USAF, USEPA, and state regulators agree that those chemicals listed in Table 2.5-1 are the COCs in groundwater posing potential risks at Site 37. Because groundwater at this site is not a source of drinking water now or in the foreseeable future, the residential groundwater use scenario was not considered a completed pathway and this exposure scenario was not carried forward for a more detailed risk evaluation. However, the screening results indicate that use of untreated groundwater at Site 37 for drinking water or other purposes (including industrial, agricultural, or freshwater replenishment) presents unacceptable risks and must be prevented.

2.7.1.4 HHRA Results for Site 120

The potentially complete exposure pathways identified in the HHRA for Site 120 were presented on Figure 2.5-13. Results of the initial screening are summarized in Table 2.7-1.

Soil

Based on the results of the HHRA and PERA, No Action was recommended for soil at Site 120, and this recommendation is selected here in this ROD. The HHRA results are summarized below.

For exposure to soil under both the residential and industrial scenarios, carcinogenic risks were less than 1×10^{-6} and the non-cancer HI was less than 1 (Table 2.7-1). Therefore the USAF, USEPA and state regulators agree that risks associated with soil contact are acceptable at Site 120 and require no response action.

Soil Vapor

On the basis of risks presented in the HHRA, the PP recommended no action for soil vapor at Site 120. However, based on the re-evaluation of risk via the VIP presented in Appendix B-1 as summarized below, LUCs and engineering controls to prevent exposure under residential and industrial use scenarios are selected here in this ROD, with remedy components detailed in Section 2.13.2.

The VIP from soil into indoor air was evaluated (for the industrial setting in the HHRA and for the residential setting during preparation of the PP) using the maximum concentration of methylene chloride detected. For this ROD (refer to Appendix B-1), risks via the VIP were re-evaluated (for both residential and industrial scenarios) as summarized in Table 2.7-2. Under residential and industrial exposure settings, the carcinogenic risk from a soil source was estimated at 2.0×10^{-6} and 2.1×10^{-8}, respectively, while the non-cancer HI was below 1 for both exposure settings. RBCLs for methylene chloride corresponding to a cancer risk of 1×10^{-4}, 1×10^{-5}, and 1×10^{-6} were calculated as presented in Table B.1-4 in Appendix B. Based on a review of these results, the USAF, USEPA and state regulators agree that risks via the VIP from a soil source at Site 120 require no response action.

The preliminary results for exposure (under an industrial setting) to indoor air using maximum concentrations detected in the groundwater showed a risk of 1.95×10^{-5} and an HI of 0.305, with the maximum concentration of PCE driving the carcinogenic health risk (refer to Table 2.7-1). For this ROD (refer to Appendix B-1), risks via the VIP were re-evaluated (for both residential and industrial scenarios) as summarized in Table 2.7-2. The carcinogenic risks for groundwater via the VIP under residential and industrial exposure settings were estimated at 1.6×10^{-3} and 9.2×10^{-5}, respectively (risk

estimates would be 2.2 x 10^{-3}, and 1.3 x 10^{-4}, respectively, if the USEPA provisional toxicity values were used instead of the OEHHA value; refer to Appendix B-1) with the estimated non-cancer HI of 22.2 and 3.8, respectively. PCE was the primary contaminant driving the risk (and HI), followed by TCE; the HQ for cis-1,2-DCE also exceeded 1. RBCLs corresponding to a cancer risk of 1 x 10^{-4} (or an HQ of 1, if lower), 1 x 10^{-5}, and 1 x 10^{-6} for PCE and TCE and an HQ of 1 for cis-1,2-DCE were calculated as presented in Table B.1-4 in Appendix B. The estimated areas encompassing PCE and TCE contamination in groundwater at concentrations exceeding RBCLs are presented in Appendix B on Figures B.1-3 and B.1-5 for PCE residential and industrial exposures, respectively, and on Figure B.1-4 for TCE residential exposure (risk levels for TCE for the industrial exposure setting did not exceed the 1.0 x 10^{-6} "point of departure" and so RBCLs for this exposure setting are not presented).

The risk level via the VIP (from a groundwater source) for residential use exceeds 1 x 10^{-4}. Therefore, the USAF, USEPA and state regulators agree that a response action is required at Site 120 to reduce risk (or prevent exposure) via the VIP below 1 x 10^{-6} for both residential and industrial exposure settings. See further discussion in Section 2.7.3.

Groundwater

Based on the results of the HHRA summarized below, Further Action was recommended for groundwater at Site 120, and the final remedy is selected as documented elsewhere in this ROD.

The preliminary risk and hazard results calculated using the tap water PRGs for a hypothetical residential groundwater use scenario (Table 2.7-1) were an estimated cancer risk of 3.83 x 10^{-3} and an HI of 674, with PCE driving the carcinogenic health risk (risks associated with several other VOCs also exceeded 1 x 10^{-6}) and thallium driving the HI above 1 (non-cancer hazards above 1 were also associated with several other inorganics including cadmium, nickel, and nitrate). Based on a review of the distribution results for the elements cadmium, nickel and thallium in groundwater (shown on Figure C-10 in Appendix C) by comparison to their BG values and pMCLs, the USAF, USEPA, and state regulators agree that risks associated with these elements in groundwater are acceptable at Site 120 and require no response action. However, as stated previously in Section 2.5.1, nitrate was retained as a COC at Site 120 (added since public review of the PP). The USAF, USEPA, and state regulators agree that those chemicals listed in Table 2.5-1 are the COCs in groundwater posing

potential risks at Site 120. Because groundwater at this site is not a source of drinking water now or in the foreseeable future, the residential groundwater use scenario was not considered a completed pathway and this exposure scenario was not carried forward for a more detailed risk evaluation. However, the screening results indicate that use of untreated groundwater at Site 120 for drinking water or other purposes (including industrial, agricultural, or freshwater replenishment) presents unacceptable risks and must be prevented.

2.7.1.5 HHRA Results for Site 133

The potentially complete exposure pathways identified in the HHRA for Site 133 were presented on Figure 2.5-13. Results of the initial screening are summarized in Table 2.7-1.

Soil

Based on the results of the HHRA and PERA, No Action was recommended for soil at Site 133, and this recommendation is selected here in this ROD. The HHRA results are summarized below.

For exposure to soil under both the residential and industrial scenarios, carcinogenic risks were less than 1×10^{-6} and the non-cancer HI was less than 1 (Table 2.7-1). Therefore the USAF, USEPA, and state regulators agree that risks associated with soil contact are acceptable at Site 133 and require no response action.

Soil Vapor

On the basis of risks presented in the HHRA, the PP recommended no action for soil vapor at Site 133. However, based on the re-evaluation of risk via the VIP presented in Appendix B-1 as summarized below, LUCs and engineering controls to prevent exposure under residential and industrial use scenarios are selected here in this ROD, with remedy components detailed in Section 2.13.2.

The VIP from soil into indoor air was evaluated (under an industrial setting in the HHRA and under a residential setting during preparation of the PP) using the maximum concentrations of TCE and methylene chloride detected. For this ROD (refer to Appendix B-1), risks via the VIP were re-evaluated (for both residential and industrial scenarios) as summarized in Table 2.7-2. Under residential and industrial exposure settings, the carcinogenic risk from a soil source was estimated at 4.6×10^{-6} and 6.9×10^{-9}, respectively (risk estimates would be 1.4×10^{-4}, and 3.1×10^{-7}, if the USEPA

provisional toxicity values were used instead of the OEHHA value; refer to Appendix B-1) while the non-cancer HI was below 1 for both exposure settings. RBCLs corresponding to a cancer risk of 1×10^{-4} (or an HQ of 1, if lower), 1×10^{-5}, and 1×10^{-6} for methylene chloride and TCE were calculated as presented in Table B.1-4 in Appendix B. Based on a review of these results, the USAF, USEPA and state regulators agree that risks via the VIP from a soil source at Site 133 require no response action.

The preliminary results for exposure (under an industrial setting) to indoor air using maximum concentrations of VOCs detected in the groundwater showed a risk of 4.89×10^{-5} and an HI of 0.543 (Table 2.7-1), with the maximum concentrations of TCE and PCE driving the carcinogenic health risk. For this ROD (refer to Appendix B-1), risks via the VIP were re-evaluated (for both residential and industrial scenarios) as summarized in Table 2.7-2. The carcinogenic risks for groundwater under residential and industrial exposure settings were estimated at 1.2×10^{-4} and 2.9×10^{-6}, respectively (risk estimates would be 6.0×10^{-3} and 1.5×10^{-4} if the USEPA provisional toxicity value were used instead of the OEHHA value; refer to Appendix B-1), with the estimated non-cancer HI of 3.3 and 0.23 for residential and industrial exposure settings. TCE was the primary contaminant driving the risk, followed by PCE. RBCLs corresponding to a cancer risk of 1×10^{-4} (or an HQ of 1, if lower), 1×10^{-5}, and 1×10^{-6} for TCE and PCE were calculated as presented in Table B.1-4 in Appendix B. The estimated areas encompassing PCE and TCE contamination in groundwater at concentrations exceeding RBCLs are presented in Appendix B on Figures B.1-3 and B.1-4 for PCE and TCE, respectively, for the residential exposure setting, and on Figure B.1-6 for TCE for the industrial exposure setting (risk levels for PCE under an industrial exposure did not exceed the 1.0×10^{-6} "point of departure" risk level and are not shown).

The risk level via the VIP (from a groundwater source) for residential use exceeds 1×10^{-4}. Therefore, the USAF, USEPA and state regulators agree that a response action is required at Site 133 to reduce risk (or prevent exposure) via the VIP below 1×10^{-6} for both residential and industrial exposure settings. See further discussion in Section 2.7.3.

Groundwater

Based on the results of the HHRA summarized below, Further Action was recommended for groundwater at Site 133, and the final remedy is selected as documented elsewhere in this ROD.

The preliminary risk and hazard results calculated using the tap water PRGs and the maximum concentrations of contaminants in groundwater for a hypothetical residential groundwater use scenario were an estimated cancer risk of 1.53×10^{-2} and an HI of 216 (Table 2.7-1). The majority of the carcinogenic health risks were associated with maximum detected concentrations of arsenic (see Figure C-13 in Appendix C) and VOCs (with TCE, PCE and MTBE showing the highest risks and a number of other VOCs also showing risks exceeding 1×10^{-6}). The majority of the non-carcinogenic hazards were associated with maximum detected concentrations of naphthalene, 1,2,4,- and 1,3,5-trimethylbenzene (refer to Figure C-14) associated with past releases from the AFRL gas station (also the source for MTBE). Non-cancer HQ above 1 were also associated with several inorganic elements including aluminum, cadmium, fluoride, lead, mercury, molybdenum, nickel, nitrate, thallium, and vanadium (refer to Figures C-15 through C-24). Based on a review of the distribution results for the petroleum-related VOCs (Figure C-14), fluoride (Figure C-17), and inorganic elements in groundwater by comparison with BG values, pMCLs, and tapwater PRGs, the USAF, USEPA, and state regulators agree that risks and/or hazards associated with these chemicals in groundwater are acceptable and require no response action. However, as stated previously in Section 2.5.1, nitrate was retained as a COC at Site 133 (added since public review of the PP). The USAF, USEPA, and state regulators agree that those chemicals listed in Table 2.5-1 are the COCs in groundwater posing potential risks at Site 133. Because groundwater at this site is not a source of drinking water now or in the foreseeable future, the residential groundwater use scenario was not considered a completed pathway and this exposure scenario was not carried forward for a more detailed risk evaluation. However, the screening results indicate that use of untreated groundwater at Site 133 for drinking water or other purposes (including industrial, agricultural, or freshwater replenishment) presents unacceptable risks and must be prevented.

2.7.1.6 HHRA Results for Site 321

The potentially complete exposure pathways identified in the HHRA for Site 321 were presented on Figure 2.5-13. Results of the initial screening are summarized in Table 2.7-1.

Soil

Based on the results of the HHRA, No Action was recommended for soil at Site 321, and this recommendation is selected here in this ROD. The HHRA results are summarized below.

For exposure to soil under both the residential and industrial scenarios, carcinogenic risks were less than 1×10^{-6} and the non-cancer HI was less than 1 (Table 2.7-1). Therefore the USAF, USEPA, and state regulators agree that risks associated with soil contact are acceptable at Site 321 and require no response action.

Soil Vapor

On the basis of risks presented in the HHRA, the PP recommended no action for soil vapor at Site 321. However, based on the re-evaluation of risk via the VIP presented in Appendix B-1 as summarized below, LUCs and engineering controls to prevent exposure under residential and industrial use scenarios are selected here in this ROD, with remedy components detailed in Section 2.13.2.

No VOCs were detected in soil samples collected at Site 321 through January 2003; therefore, the indoor air pathway was not evaluated in the HHRA. For this ROD, however, risks via the VIP were re-evaluated (for both residential and industrial scenarios) based on soil data collected through 2006, as summarized in Table 2.7-2. The carcinogenic risks due to PCE in soil under residential and industrial exposure settings were estimated at 9.3×10^{-5} and 3.3×10^{-7}, with an estimated non-cancer HI of 1.1 for residential exposure and below 1 for industrial exposure. RBCLs corresponding to a cancer risk of 1×10^{-4} (or an HQ of 1, if lower), 1×10^{-5}, and 1×10^{-6} for PCE were calculated as presented in Table B.1-4 in Appendix B. The estimated area (single borehole location) encompassing PCE contamination in soil at concentrations exceeding its residential RBCL is presented in Appendix B on Figure B.1-7. Based on a review of these results, the USAF, USEPA and state regulators agree that risks via the VIP from a soil source at Site 321 require no response action.

The preliminary results for exposure (under an industrial setting) to indoor air based on the J&E model using maximum concentrations detected in the groundwater showed a cancer risk of 3.27×10^{-6} and an HI of 0.049, with the maximum concentration of PCE driving both the carcinogenic risk and the HI. For this ROD (refer to Appendix B-1), risks via the VIP were re-evaluated (for both residential and

industrial scenarios) as summarized in Table 2.7-2. The carcinogenic risks for groundwater via the VIP pathway under residential and industrial exposure settings were estimated at 1.5×10^{-4} and 6.4×10^{-6}, respectively, with the estimated non-cancer HI of 1.8 for the residential exposure setting and below 1 for the industrial exposure setting. PCE was the primary contaminant driving the risk, followed by TCE. RBCLs corresponding to a cancer risk of 1×10^{-4} (or an HQ of 1, if lower), 1×10^{-5}, and 1×10^{-6} for PCE were calculated as presented in Table B.1-4 in Appendix B. The estimated areas encompassing PCE contamination in groundwater at concentrations exceeding RBCLs are presented in Appendix B on Figures B.1-7 and B.1-8 for residential and industrial exposures, respectively.

The risk level via the VIP (from a groundwater source) for residential use exceeds 1×10^{-4}. Therefore, the USAF, USEPA and state regulators agree that a response action is required at Site 321 to reduce risk (or prevent exposure) via the VIP below 1×10^{-6} for both residential and industrial exposure settings. See further discussion in Section 2.7.3.

Groundwater

Based on the results of the HHRA summarized below, Further Action was recommended for groundwater at Site 321, and the final remedy is selected as documented elsewhere in this ROD.

The preliminary risk and hazard results calculated using the tap water PRGs for a hypothetical residential groundwater use scenario were an estimated cancer risk of 4.24×10^{-3} and an HI of 118.6 (Table 2.7-1), with PCE and TCE driving the carcinogenic health risk (several other VOCs were associated with risks greater than 1×10^{-6}), and nitrate and cis-1,2-DCE driving the HI. The USAF, USEPA, and state regulators agree that those chemicals listed in Table 2.5-1 are the COCs in groundwater posing potential risks at Site 321. Because groundwater at this site is not a source of drinking water now or in the foreseeable future, the residential groundwater use scenario was not considered a completed pathway and this exposure scenario was not carried forward for a more detailed risk evaluation. However, the screening results indicate that use of untreated groundwater at Site 321 for drinking water or other purposes (including industrial, agricultural, or freshwater replenishment) presents unacceptable risks and must be prevented.

2.7.2 SUMMARY OF ECOLOGICAL RISK ASSESSMENTS

A 3-step ERA was performed to evaluate the potential risk, if any, to environmental receptors associated with chemicals detected in soil and groundwater during the RI. A pre-scoping ERA was performed by the USGS for OU4 (USGS 2004a) and OU9 (USGS 2004b) sites to identify whether habitat was present at each site/AOC. The primary goal of the SERAs for OU4 and OU9 (USGS 2004c and 2004d) was to identify completed or potentially complete pathways existing between site-related contaminants and potential ecological receptors at the ERP sites. PERAs were performed for sites in OU4 and OU9 (Tetra Tech 2004, 2005) advancing beyond the SERA stage. The PERA documents combine site-specific data from applicable media (e.g. soil, groundwater, surface water and sediment) into plant and animal exposure models that quantify the potential risk to representative ecological receptor groups.

Also, a validation study (USGS 2002) was completed at Site 25 (in OU8) on the Main Base, and Sites 37 and 133 at the AFRL. The validation study evaluated potential effects of TCE, PCE, and associated breakdown products of these chemicals on the health and dynamics of small mammal and reptile populations. Sites 25, 37, and 133 were selected for the validation study because these sites had relatively high concentrations of these chemicals in groundwater compared to other ERP sites and therefore provided a "worst case" scenario. Results of the validation study showed very low concentrations of the chlorinated solvent chemicals in soil gas samples from artificial burrows installed for purposes of this study and concluded that there were no observable adverse impacts on small mammal and reptile populations.

Some potential risks to wildlife were identified in the OU4 PERA for Sites 37, 133, and 120 due to inorganic elements detected at concentrations exceeding their calculated BG limits in soil or groundwater; however, after evaluating the distribution and magnitude of these detections at each site, and taking into consideration the fact that there is no evidence of their release as part of site activities, the Air Force, USEPA and state regulators agreed that these inorganic elements likely do not indicate a release but rather represent the high end of concentrations that are naturally occurring. Site 321 did not advance to the OU9 PERA because no complete exposure pathways to ecological receptors were identified.

Based on the findings of these studies, potential risks to ecological receptors are not considered significant at the South AFRL. A summary of the results of the ERAs performed for Sites 37, 133, 120, and 321 is presented below.

2.7.2.1 ERA Results for Site 37

The SERA completed for Site 37 identified potentially complete exposure pathways (Figure 2.5-14) for soil, soil gas, and groundwater to ecological receptors. Therefore, a PERA was performed, the findings of which suggest that several chemicals of potential ecological concern (COPECs) pose a potential risk to certain receptor groups at the site for exposure to cadmium, mercury, and molybdenum via soil; and arsenic, total chromium, cobalt, and nickel via groundwater. In addition, PCE via groundwater (at depths less than 25 feet) was identified as posing a risk to terrestrial plants. The PERA cautions, however, that it is important to consider the highly disturbed, industrial nature of the site when evaluating its suitability as viable habitat for these receptor groups.

The distribution and magnitude of the inorganic COPECs identified at Site 37 (compared to PRGs and the pMCL for groundwater) are presented in Appendix C on Figures C-1 (soil) and C-8 (groundwater). After evaluating these distributions, and taking into consideration the fact that there is no evidence of the release of these inorganic chemicals as part of site activities, the Air Force, USEPA, and state regulators agreed that inorganic elements identified as COPECs at Site 37 likely do not indicate a release but rather represent the high end of concentrations that are naturally occurring. Therefore, these elements were not retained as COCs at Site 37.

2.7.2.2 ERA Results for Site 120

The SERA completed for Site 120 identified potentially complete exposure pathways (Figure 2.5-14) for soil, surface water, and groundwater to ecological receptors. Therefore, a PERA was performed, the findings of which suggest that the following COPECs may pose a potential risk to certain receptor groups at Site 120: silver via exposure to soil; methylene chloride via inhalation of soil vapors; barium and vanadium via exposure to surface water; aluminum, thallium, PCE, TCE, 1,1,2-TCA, trans-1,2-DCE, and cis-1,2-DCE via exposure to groundwater. The PERA cautions, however, that it is important to consider the highly disturbed, industrial nature of the site when evaluating its suitability as viable habitat for these receptor groups.

The distribution and magnitude of the inorganic COPECs identified at Site 120 (compared to PRGs and the pMCL for groundwater) are presented in Appendix C on Figure C-9 (soil) and Figure C-11 (surface water and groundwater). After evaluating these distributions, and taking into consideration the fact that there is no evidence of the release of these chemicals as part of site activities, the Air Force, USEPA, and state regulators agreed that inorganic elements identified as COPECs at Site 120 likely do not indicate a release but rather represent the high end of concentrations that are naturally occurring. Therefore, these elements were not retained as chemicals of concern at Site 120.

Organic COPECs identified in the PERA as posing a potential risk to ecological receptors via inhalation were also evaluated based on their distribution and magnitude. As a result, methylene chloride and 1,1,2-TCA were eliminated as COPECs based on their limited distribution (presented in Appendix C on Figure C-9 [soil] and C-11 [surface water and groundwater]).

2.7.2.3 ERA Results for Site 133

The SERA completed for Site 133 identified potentially complete exposure pathways (Figure 2.5-14) for soil and groundwater to ecological receptors. Therefore, a PERA was performed, the findings of which suggest that COPECs at Site 133 pose a potential risk to certain receptor groups for exposure to silver and mercury via soil and total chromium via groundwater. The PERA cautions, however, that it is important to consider the highly disturbed, industrial nature of the site when evaluating its suitability as viable habitat for these receptor groups.

The distribution and magnitude of the inorganic COPECs identified at Site 133 (compared to PRGs and the pMCL for groundwater) are presented in Appendix C on Figures C-12 (soil) and C-25 (groundwater). After evaluating these distributions, and taking into consideration the fact that there is no evidence of the release of these chemicals as part of site activities, the Air Force, USEPA, and state regulators agreed that inorganic elements identified as COPECs at Site 133 likely do not indicate a release but rather represent the high end of concentrations that are naturally occurring. Therefore, these elements were not retained as COCs at Site 133.

2.7.2.4 ERA Results for Site 321

Because the SERA (USGS 2004d) performed for Site 321 did not identify any potentially complete exposure pathways to ecological receptors at Site 321, no PERA was performed and no COPECs were identified.

2.7.3 DETERMINATION OF RISK BASIS FOR RESPONSE ACTION AT THE SOUTH AFRL

Results of the 3-step ERA (summarized in Section 2.7.2) indicate the potential for various inorganic elements in soil and groundwater, and a limited number of VOCs in groundwater, to pose a risk to various non-human receptor groups. However, based on an evaluation that their distribution suggests a natural origin for inorganic elements at the sites, and the fact that man-made sources have not been identified, the inorganic elements in soil and groundwater were not retained as COCs at the South AFRL. In addition, the distribution of some of the VOCs (at low-level concentrations not posing a risk to human receptors) was localized in highly disturbed source areas; these VOCs were also not retained as COCs. No response action is required to mitigate exposures by environmental receptors.

2.7.3.1 Soil

Based on the results of the HHRA no action was recommended for soil at the South AFRL.

2.7.3.2 Soil Vapor

Results from the re-evaluation of risk via the VIP, conducted as part of this ROD (Appendix B-1), indicate that the COCs listed in bold on Table 2.7-2 pose an unacceptable risk for residential and industrial exposure to indoor air. The Air Force, USEPA, and DTSC participated in a risk management meeting on 17 July 2007. As an outcome of this meeting, groundwater vapor compliance levels (GWVCLs) representing the 10^{-6} "point of departure" risk level for residential (GWVCL-res) and industrial (GWVCL-ind) exposure were selected as appropriate after evaluation of risk via the VIP indicated that soil concentrations of PCE (at Site 37) and groundwater concentrations of PCE (Sites 37, 120, and 321) and TCE (Sites 120 and 133) exceeded a risk level of 10^{-4} for the residential exposure scenario. The response action selected in this ROD, for soil vapor at the South AFRL, is necessary to prevent exposure, under both residential and industrial uses, to COCs identified in Table 2.7-2 at a risk level greater than 1×10^{-6} via the

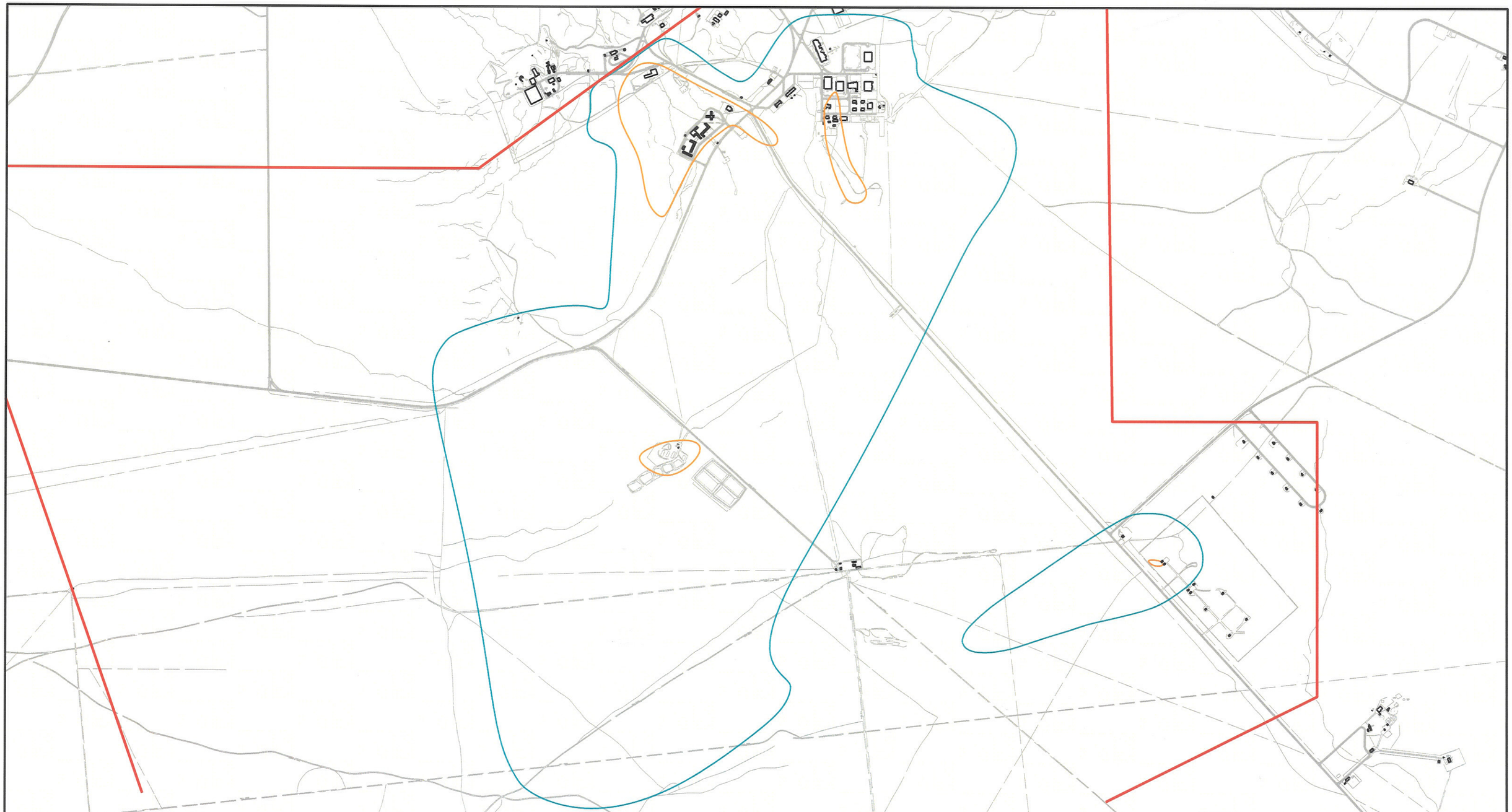
VIP. Figure 2.7-1 presents the VICB, which is designed to be protective at a 10^{-6} risk level, using the 30-year projected extent of PCE and TCE groundwater contamination exceeding RBCLs (listed in Table B.1-4) at a 10^{-6} risk level for residential exposure. In this ROD (refer to Table 2.13-1 and Section 2.13), these RBCLs are re-designated as the GWVCLs-res for the residential exposure scenario. The areas exceeding GWVCLs-ind (refer to Table 2.13-2) based on the 10^{-6} industrial RBCLs for PCE and TCE, are also presented on Figure 2.7-1. The VICB, GWVCLs, and associated indoor air vapor mitigation levels (IAVMLs) are further discussed in Section 2.13.2.

2.7.3.3 Groundwater

Results of the HHRA for Sites 37, 120, 133, and 321 (summarized in Section 2.7.1) indicate that if the groundwater at the South AFRL were used for drinking water purposes (which is not currently the case), such use would pose an unacceptable risk to human health. VOCs and other chemicals (e.g., 1,4-dioxane, NDMA, perchlorate) persistently detected at concentrations contributing to this risk were identified as COCs as listed in Table 2.5-1. The response action selected for the South AFRL in this ROD is necessary to protect the public health or welfare or the environment from contact with the COCs in groundwater listed in Table 2.5-1, including use of the groundwater as a drinking water supply.

2.8 REMEDIAL ACTION OBJECTIVES

Remedial action objectives (RAOs) for groundwater at the South AFRL were developed based upon CERCLA and NCP requirements, human health and ecological risk evaluations, ARARs, and site characteristics including an evaluation of the potential for groundwater restoration. Site-specific factors were considered in RA development, including the technical impracticability (from an engineering perspective) of restoring the groundwater to drinking water pMCLs or removing DNAPL solvents from fractured granite, and the lack of current and future use of the groundwater. There is no unacceptable risk to human health or the environment posed by direct contact with soil or groundwater under the current or reasonably anticipated future industrial use, but due to designation of the groundwater at the South AFRL as a potential drinking water source, a response action is necessary to protect the public health or welfare by preventing future contact with the contaminated groundwater



EXPLANATION

- SOUTH AFRL CONTAINMENT ZONE/GROUNDWATER LUCs BOUNDARY
- CONTOUR LINE OF GWVCL-IND BASED ON CURRENT EXTENT OF TCE AND PCE AT A 10^{-6} RISK LEVEL FOR INDUSTRIAL EXPOSURE
- VICB BASED ON THE 30-YEAR PROJECTED EXTENT OF THE GWVCLs-RES FOR TCE AND PCE AT A 10^{-6} RISK LEVEL FOR RESIDENTIAL USE (SEE SECTION 2.13.2).

µg/L	MICROGRAMS PER LITER
AFRL	AIR FORCE RESEARCH LABORATORY
GWVCL-IND	GROUND WATER VAPOR COMPLIANCE LEVEL FOR INDUSTRIAL EXPOSURE
GWVCL-RES	GROUND WATER VAPOR COMPLIANCE LEVEL FOR RESIDENTIAL EXPOSURE
LUC	LAND USE CONTROL
PCE	TETRACHLOROETHENE
RBCL	RISK-BASED CLEANUP LEVEL
TCE	TRICHLOROETHENE
VICB	VAPOR INTRUSION COMPLIANCE BOUNDARY

NORTH

0 1000 2000 FEET

SCALE: 1"= 2000'

South AFRL ROD

South AFRL
Vapor Intrusion
Compliance Boundaries

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure 2.7-1
Project No. 89160		

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medium including use as a drinking water supply. The exposure pathways that need to be prevented and/or minimized are ingestion of, dermal contact with, and inhalation of vapors from, extracted contaminated groundwater. Also, there are unacceptable risks in localized areas of the South AFRL posed by soil vapor via the VIP into indoor air both for the current industrial and hypothetical future unrestricted land uses.

Although not specifically presented in the South AFRL Focused FS, the primary RAOs for the South AFRL are as follows:

1. Protect human health by preventing (through LUCs) ingestion of groundwater contaminated by COCs (listed in Table 2.5-1) at concentration levels exceeding their respective pMCLs or other RBCGs (for those COCs without pMCLs).

2. Protect human health by preventing (through LUCs and engineering controls) inhalation of vapor-phase COCs in indoor air that pose an unacceptable risk (greater than 1×10^{-6}) under a residential or industrial exposure scenario.

3. Prevent migration outside of the South AFRL CZ boundary of groundwater impacted by COCs at concentration levels exceeding their respective pMCLs or other RBCGs (for those COCs without pMCLs).

The South AFRL Focused FS presents the case (summarized in Section 2.5.8 of this ROD) for a TI waiver of ARARs within an 18-square mile area identified as the South AFRL CZ (reduced to 16.4 square miles in this ROD as shown on Figure 2.1-2), based upon criteria for statutory and regulatory ARAR waivers provided for in CERCLA §121 (d)(4)(C) and NCP §300.430(f)(1)(ii)(C)(3).

2.9 DESCRIPTION OF GROUNDWATER REMEDIAL ALTERNATIVES

The USEPA (1996) guidance document titled *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Groundwater at CERCLA Sites* recommends the following strategy at sites with suspected DNAPL (Items 1 though 4 as early actions; and Items 1 and 5 as components of a long-term remedy for the aqueous phase):

1. Prevent further spread of the aqueous plume (plume containment);

2. Prevent further spread of hot spots in the aqueous plume (hot spot containment);

3. Control further migration of contaminants from subsurface DNAPLs to the surrounding ground water (source control; essentially the same as Item 2 at DNAPL sites);

4. Reduce the quantity of source material (free phase DNAPL) present in the DNAPL zone, to the extent practicable (source removal and/or treatment); and

5. Restore the maximum areal extent of the aquifer to those cleanup levels appropriate for its beneficial uses (aquifer restoration).

During the FS process for the South AFRL, to address RAOs 1 and 3, the response actions of plume containment, hot spot containment (source control), source area treatment, and exposure control (rather than aquifer restoration, which is TI) were assembled into four remedial alternatives for a detailed and comparative analysis against each other and a no action alternative. Because the HHRA had indicated that risks via the VIP were acceptable under the existing industrial use, no alternatives were evaluated to address RAO 2. However, as a result of the re-evaluation of risk presented in this ROD (Appendix B-1 as summarized in Section 2.7), the Air Force has concluded that cancer risks (exceeding 1×10^{-6}) via the VIP are unacceptable for both residential and industrial uses; therefore, remedy components to address the VIP have been assembled as listed in Section 2.13.2.

The following sections (through 2.10) provide a description and evaluation of the remedial alternatives (presented in the FS and PP) that were assembled to address RAOs 1 and 3.

2.9.1 DESCRIPTION OF REMEDY COMPONENTS

The no action and four other alternatives, and their primary components, include:

1. **Alternative 1:** No Action.

2. **Alternative 2:** TI Waiver, No Active Containment, LTM, and LUCs (Selected Alternative).

   TI waiver of drinking water ARARs with LTM and LUCs. No active plume containment or hot spot containment. No source area treatment.

3. **Alternative 3:** TI Waiver, Hot Spot Containment (Source Control), LTM, and LUCs.

   TI waiver of drinking water ARARs with LTM and LUCs. No active plume containment, but continued operation and expansion of existing Sites 37 and 133 treatment systems to contain the 1,000-μg/L isocontour. No source area treatment.

4. **Alternative 4:** TI Waiver, Source Area Treatment, LTM, and LUCs.

TI waiver of drinking water ARARs with LTM and LUCs. No active plume containment, but continued operation of the existing Sites 37 and 133 treatment systems during source area treatment (10 years). Aggressive in-situ treatment (blast fracturing, extraction and injection with amendments for bioenhancement or chemical oxidation) in the source areas.

5. **Alternative 5:** TI Waiver, Source Area Treatment, Plume Containment at Drinking Water Levels, LTM, and LUCs.

   TI waiver of drinking water ARARs with LTM and LUCs. Plume containment to the 5 μg/L isocontour. Aggressive in-situ treatment (blast fracturing, extraction and injection with amendments for bioenhancement or chemical oxidation) of the source areas.

2.9.2 COMMON ELEMENTS OF REMEDIAL ALTERNATIVES

With the exception of the No Action Alternative, all of the other alternatives include the following five major components:

1. TI waiver of chemical-specific ARARs (pMCLs as applicable) within the South AFRL CZ. The details and justification for this waiver were provided in Section 2.5.8.

2. LTM of groundwater plumes using the existing network of monitoring and sentinel wells, expanded as necessary, to track plume size and location.

3. LUCs to ensure groundwater is not used in the future as a drinking water source, and (added to address RAO 2) to prevent exposures above acceptable risk levels (for both an unrestricted [residential] and the current industrial land use) to soil vapor via the VIP into indoor air. The USAF will be responsible for implementing, maintaining, monitoring, enforcing, and reporting the LUCs. LUCs are described in greater detail in Section 2.13.2.1.

4. Because Alternatives 2 through 5 propose to leave a waste in place, it is a statutory requirement (though not a remedy component) that a five-year review be conducted every five years to evaluate whether the remedy remains protective of human health and the environment.

Because all alternatives (except No Action) include a TI waiver of attaining chemical-specific ARARs within the South AFRL CZ, there are no cleanup goals within the South AFRL CZ. Outside the South AFRL CZ, the key ARARs to be met are chemical-specific pMCLs for drinking water; the remedy also entails preventing the migration outside the South AFRL CZ of COCs above RBCGs (for chemicals without pMCLs). Because of the occurrence of groundwater in fractured granitic bedrock, no presumptive remedies were considered to be effective and none are used. For those alternatives

considered during the FS process, the containment options require the treatment or disposal of residuals (i.e., spent granular activated carbon).

The RA implementation assumptions were for cost estimating and comparison purposes only and actual project parameters will be determined during the project design phase. For cost estimates, an assumed PV discount rate of 7% was applied to each alternative. Estimated costs are summarized in Section 2.13.3 and are provided in detail in the South AFRL Focused FS.

2.9.3 DISTINGUISHING FEATURES AND EXPECTED OUTCOMES OF EACH ALTERNATIVE

Distinguishing features of the five alternatives are briefly described below, followed by an evaluation of the expected outcomes with respect to: the overall objective of reducing, to acceptable levels, risks associated with groundwater COCs; whether the RAOs listed in Section 2.8 are met; and impact on the AFRL mission (current and reasonably anticipated land use).

2.9.3.1 Alternative 1 - No Action

This alternative does not meet any of the primary RAOs listed in Section 2.8. Because no action would be taken, this alternative does not trigger chemical-specific ARARs; however, it does not provide justification for a waiver of ARARs. The timeframe for natural processes to disperse contaminants to concentrations below pMCLs is unknown but projected to be very long, and these processes would not be monitored.

This alternative maintains the current South AFRL industrial activities and does not impact current or anticipated future industrial uses, but does not ensure industrial uses in the long-term. The alternative does not include LTM or LUCs; therefore, it cannot be presumed to be protective of human health by preventing exposure to contaminated groundwater. Impacted groundwater will not meet WQOs established for the beneficial uses designated for the Antelope Valley (DWR Basin No. 6-44) of municipal, agricultural, industrial and freshwater replenishment, as listed in Table 2-2 of the Basin Plan. There are no costs associated with Alternative 1.

2.9.3.2 Alternative 2 - TI Waiver, No Active Containment, LTM, and LUCs (Selected Remedy)

This alternative relies on the low K of groundwater in the fractured granitic bedrock at the South AFRL to limit and eventually stop the spread of contaminants within the South AFRL CZ, within which the groundwater would not meet ARARs in a reasonable timeframe; however, the alternative provides a justification for waiver of the ARARs within the South AFRL CZ. The total time required before concentrations in groundwater inside the South AFRL CZ meet the pMCLs is unknown but projected (based on a computer model simulation of contaminant transport) to be greater than 1,000 years.

Although this alternative meets the RAOs listed in Section 2.8 by monitoring (through LTM) contaminant migration and preventing (through LUCs) exposure to contaminated groundwater and indoor air containing COCs above acceptable risk limits, no active treatment or containment occurs. For cost-estimating purposes, it is assumed that the LTM program would include annual to biennial sampling of up to 44 monitoring wells; and a comprehensive sampling event of up to 162 wells would be conducted every 5 years. LUCs are described in Section 2.13.2.1. Operation of the existing GETS at Sites 37 and 133 would not be included under this alternative.

Capital costs for Alternative 2 were estimated to be $0, and total costs for LTM and LUCs associated with this alternative (over the first 30 years) were estimated to be approximately $10.1 million (refer to Table 2.10-1). The total PV cost for the alternative was estimated to be $3.4 million based upon a 30-year analysis period. Since this remedy would involve a period far in excess of 30 years, it would mean long-term costs substantially greater than $3.4 million.

This alternative maintains the current South AFRL industrial activities and does not impact current or anticipated future industrial uses. Alternative 2 uses LUCs to prevent exposure to contaminated groundwater and indoor air containing COCs above acceptable risk limits. Under this alternative, the contaminant plume may migrate and spread within the South AFRL CZ (for comparison purposes, see the modeling scenario on Figure 2.5-17A); however, the situation will be monitored to verify that contaminated groundwater is not migrating outside this area. The alternative includes LTM to confirm that contaminated groundwater does not migrate outside the waiver zone, and to trigger certain contingency responses if sampling results indicate that plume contaminants are migrating more quickly

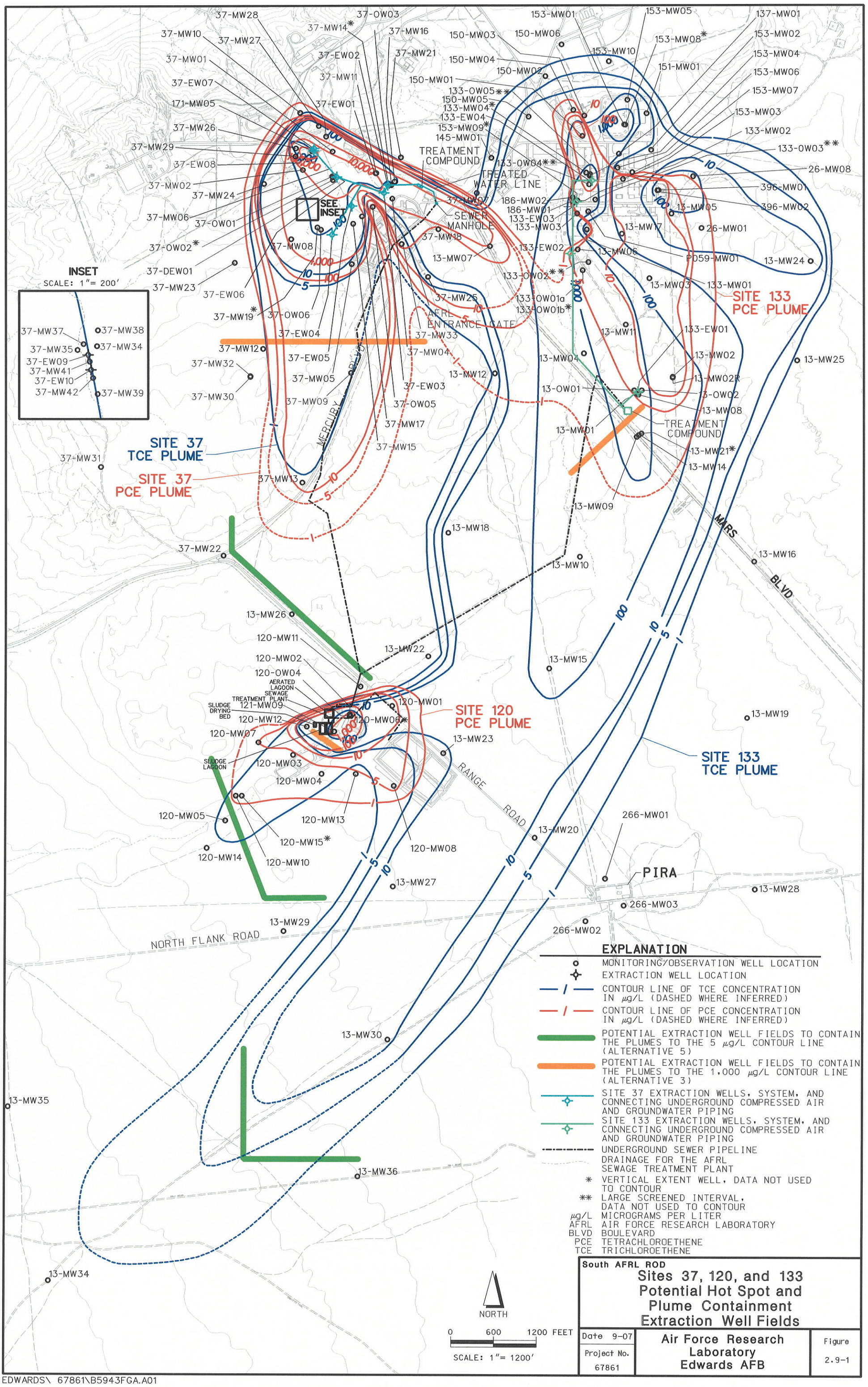
than anticipated. Groundwater within the South AFRL CZ will not be required to meet WQOs for the designated beneficial uses of municipal, agricultural, industrial and freshwater replenishment, as listed for the Antelope Valley DWR Basin No. 6-44 in Table 2-2 of the Basin Plan.

2.9.3.3 Alternative 3 - TI Waiver, Hot Spot Containment (Source Control), LTM, and LUCs

This alternative includes all components in Alternative 2, with the added component of limited expansion and long-term operation of the existing GETS at Sites 37 and 133 to achieve hot spot containment (source control) of contaminants at concentrations greater than 1,000 μg/L. The treatment systems will be used to remove contaminants and lessen their overall concentration in the plume; however, chemicals in the groundwater would not meet ARARs in a reasonable timeframe. As with Alternative 2, this alternative provides a justification for waiver of the ARARs within the South AFRL CZ. The total time required before concentrations in groundwater inside the South AFRL CZ meet the pMCLs is unknown but projected (based on a computer model simulation of contaminant transport) to be greater than 1,000 years.

To accomplish capture of the 1,000 μg/L contour, it is assumed that 23 new extraction wells would be installed to intercept the PCE and TCE plumes, supplementing the 11 existing wells at Sites 37 and 133. Proposed extraction well fields are shown in orange on Figures 2.9-1 and 2.9-2. O&M of the GETS systems would include various tasks such as monthly to quarterly sampling at the influent, midpoint, and effluent sampling ports; annual sampling of extraction wells; periodic carbon replacements when break-through is detected in the midpoint sample; weekly system monitoring; and system maintenance as needed. It is anticipated that the total flow rate from the new and existing extraction wells will exceed the 20 gpm discharge limit allowed to the STP, requiring the construction and additional O&M of evaporation/percolation ponds and piping.

Capital costs for Alternative 3 were estimated to be $11.4 million, and total costs for LTM, O&M, and LUCs associated with this alternative (over the first 30 years) were estimated to be approximately $20.1 million (refer to Table 2.10-1). The total PV cost for the alternative was estimated to be $17.5 million based upon a 30-year analysis period. Since this remedy would involve a period far in excess of 30 years, it would mean long-term costs substantially greater than $17.5 million.

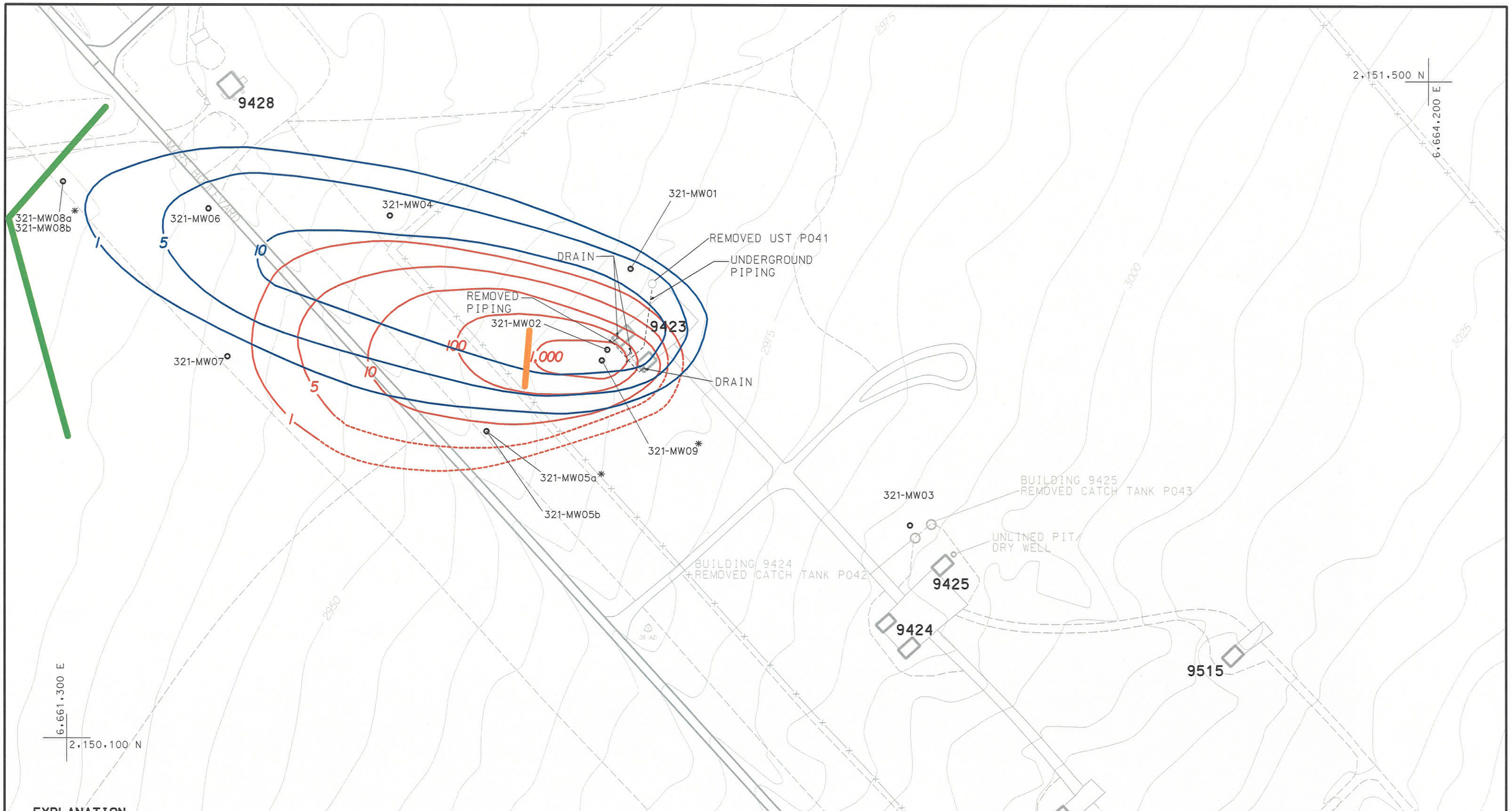


South AFRL ROD

Sites 37, 120, and 133 Potential Hot Spot and Plume Containment Extraction Well Fields

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure 2.9-1
Project No. 67861		

EDWARDS\ 67861\B5943FGA.A01



EXPLANATION

- MONITORING WELL LOCATION
- 10 — CONTOUR LINE OF PCE CONCENTRATION IN µg/L. (DASHED WHERE INFERRED)
- 10 — CONTOUR LINE OF TCE CONCENTRATION IN µg/L.
- POTENTIAL EXTRACTION WELL FIELD TO CONTAIN THE PLUMES TO THE 5 µg/L CONTOUR LINE (ALTERNATIVE 5)
- POTENTIAL EXTRACTION WELL FIELD TO CONTAIN THE PLUMES TO THE 1,000 µg/L CONTOUR LINE (ALTERNATIVE 3)

DATA ARE FROM 2ND QUARTER 2003

* VERTICAL EXTENT WELL, DATA NOT USED TO CONTOUR.
µg/L MICROGRAMS PER LITER
PCE TETRACHLOROETHENE
TCE TRICHLOROETHENE
UST UNDERGROUND STORAGE TANK

NORTH

0 100 200 FEET
SCALE: 1"= 200'

South AFRL ROD

Site 321
Potential Hot Spot and Plume Containment Extraction Well Fields

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure 2.9-2
Project No. 67861		

EDWARDS\ 67861\B5941FGA.A01

This alternative maintains the current South AFRL industrial activities and does not impact current or anticipated future industrial uses. Alternative 3 uses source control in addition to LUCs to prevent exposure to contaminated groundwater and indoor air containing COCs above acceptable risk limits. Under this alternative, the spread of the plume would be less than in Alternative 2, as long as the systems continued to extract groundwater (for comparison purposes see the modeling scenario on Figure 2.5-17B). Alternative 3 meets the RAOs listed in Section 2.8, and if effective, would also prevent further spread of hot spots in the aqueous plume and control the further migration of contaminants from subsurface DNAPLs to the surrounding ground water. This alternative would require management and off-site treatment or disposal of residuals (spent granular activated carbon). Groundwater within the South AFRL CZ will not be required to meet WQOs for the designated beneficial uses of municipal, agricultural, industrial and freshwater replenishment, as listed for the Antelope Valley DWR Basin No. 6-44 in Table 2-2 of the Basin Plan.

2.9.3.4 Alternative 4 - TI Waiver, Source Area Treatment, LTM, and LUCs

This alternative includes all components in Alternative 2, with the added component of aggressive treatment over the first 10 years to remove DNAPL. Based on results of the groundwater modeling (refer to Figure 2.5-17D), even if DNAPL were successfully removed at all four sites within 10 years, a portion of groundwater within the South AFRL CZ would not meet ARARs within a reasonable timeframe. As with Alternative 2, this alternative provides a justification for waiver of the ARARs within the South AFRL CZ. The total time required before concentrations in groundwater inside the South AFRL CZ meet the pMCLs is unknown but projected (based on a computer model simulation of contaminant transport) to be greater than 100 years.

It should be noted that the successful application of DNAPL removal or treatment technologies in fractured granitic bedrock is unproven. However, for purposes of the FS evaluation, the following experimental technologies were assumed: blast fracturing; followed by groundwater extraction, amendment, and re-injection for in-situ treatment (either by ISB or ISCO); and water flushing.

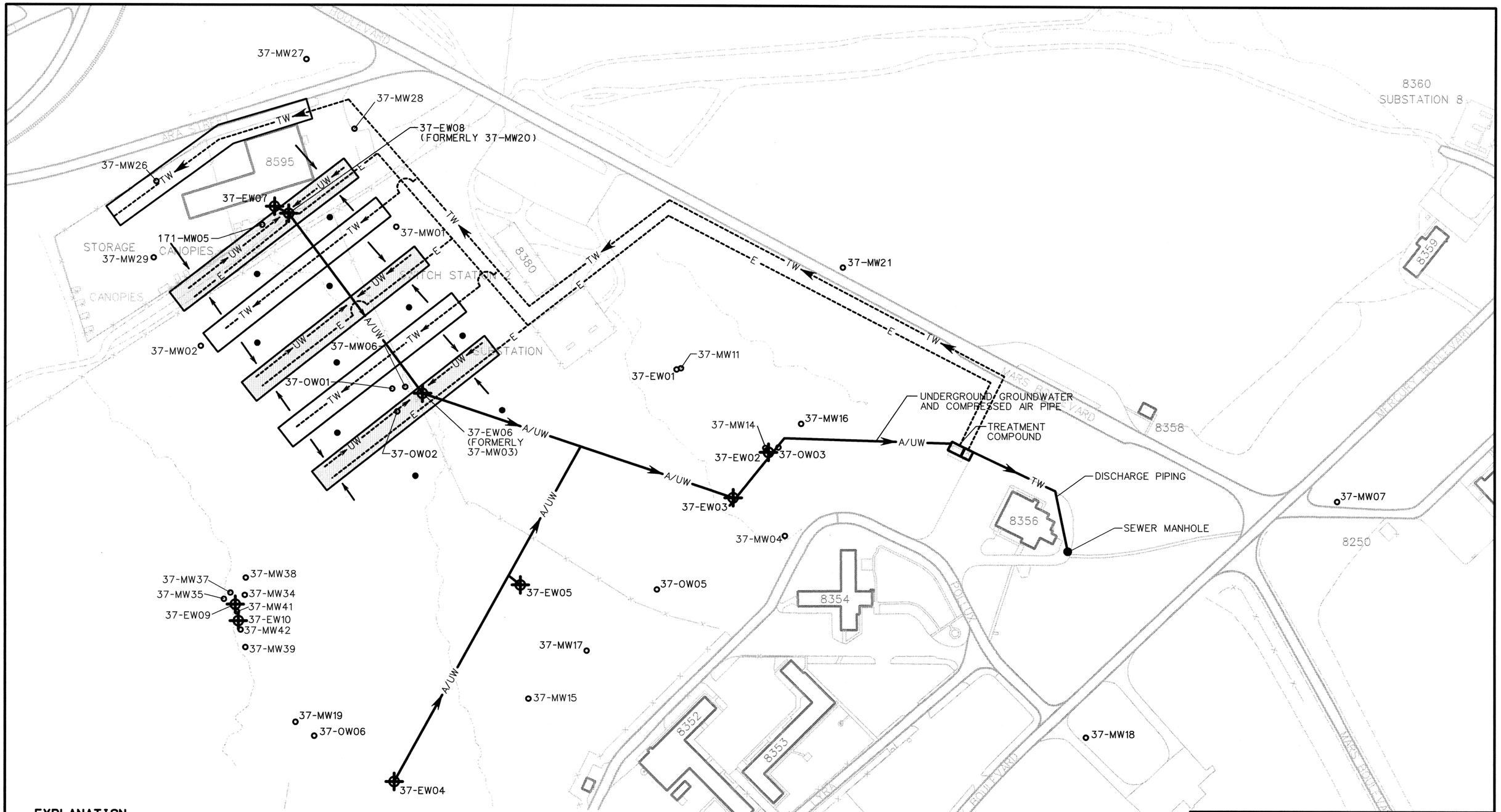
Blast fracturing is a process in which explosive charges are placed into the rock and detonated to create more fractures through which groundwater can travel. If successful, this process can enhance both extraction of contaminated groundwater and injection of chemicals or bioremediation reagents to help

degrade the contaminants in-situ. Blast fracturing would be used to create extraction and injection galleries at three source areas: near Building 8595 in Site 37 (Figure 2.9-3) and surrounding Dry Wells E and F at Site 133 (not shown). In each source area, three extraction galleries and three injection galleries, each measuring approximately 500 feet in length and 250 feet deep, would be installed in an alternating sequence. The artificially fractured galleries would be constructed by sequentially detonating explosive charges in pre-drilled boreholes. The progressive blasting (vertically and horizontally) would propagate the development of fractures within the targeted areas. To achieve maximum effect, boreholes would need to be placed every 4 feet (up to 750 boreholes per system).

Three wells would be installed, each to a depth of 250 to 350 feet bgs, in each blast-fractured extraction gallery (for a total of nine extraction wells per system). At the time of the FS, it was anticipated that the increased flow rate (up to 30 gpm per extraction gallery) induced by blast fracturing would necessitate the use of electric submersible pumps to extract groundwater. The extraction wells would be tied via underground piping and electric power feeds to the existing GETS. Extracted groundwater would be treated by the liquid-phase granular activated carbon (LPGAC) already in use at the existing Site 37 and Site 133 GETS. Following removal of VOCs by the LPGAC, the extracted groundwater would be amended either by (1) the addition of nutrients to stimulate ARD and possibly microbes or (2) chemical reagents. The amended water would then be injected back into the aquifer to stimulate breakdown of groundwater contaminants by ISB or ISCO. Reducing the in-situ concentration of dissolved phase PCE and TCE should further accelerate dissolution of the DNAPL mass.

Six new wells, also to a depth of 250 to 350 feet bgs, would be installed in each injection gallery (for a total of 18 injection wells per system). Treated groundwater injection provides the following benefits: (1) a supply of water to recirculate through and flush the source area; (2) elimination of the need to identify discharge alternatives for the extracted groundwater following treatment (in compliance with Action-specific ARAR Underground Injection Control (UIC) Program if approved by EPA or DTSC); and (3) a means to enhance ISB or ISCO by amending the water prior to re-injection.

Capital costs for Alternative 4 (for source area treatments only at Sites 37 and 133) were estimated to be $18.8 million, and total costs for LTM, O&M, and LUCs associated with this alternative (over the first 30 years) were estimated to be approximately $18.5 million (refer to Table 2.10-1). The total PV



EXPLANATION

- EXISTING MONITORING/OBSERVATION WELL LOCATION
- PROPOSED MONITORING WELL LOCATION
- EXISTING EXTRACTION WELL LOCATION
- INDUCED GROUNDWATER FLOW DIRECTION
- AFRL AIR FORCE RESEARCH LABORATORY
- DNAPL DENSE NON-AQUEOUS PHASE LIQUID
- PROPOSED EXTRACTION GALLERY (THREE EXTRACTION WELLS NOT SHOWN)
- PROPOSED REINJECTION GALLERY (SIX INJECTION WELLS NOT SHOWN)
- E — UNDERGROUND ELECTRICAL (DASHED WHERE PROPOSED)
- UW — UNDERGROUND UNTREATED WATER LINE (DASHED WHERE PROPOSED)
- TW — UNDERGROUND TREATED WATER LINE (DASHED WHERE PROPOSED)
- A/UW — UNDERGROUND COMPRESSED AIR/UNTREATED WATER PIPE

South AFRL ROD

Conceptual Site 37
Proposed Aggressive Treatment of DNAPL Source Area

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure 2.9-3
Project No. 67861		

EDWARDS\ 67861\B5942FGA.A01

cost for the alternative was estimated to be $26.3 million based upon a 30-year analysis period. Since costs for source area treatments at Sites 120 and 321 are not included, and LTM and LUCs would have to continue for a period far in excess of 30 years, both capital and long-term costs would be substantially higher than the present-value estimate of $26.3 million.

This alternative maintains the current South AFRL industrial activities and does not impact current or anticipated future industrial uses. Alternative 4 uses source area treatment in addition to LUCs to prevent exposure to contaminated groundwater and indoor air containing COCs above acceptable risk limits. The source treatment performed under this alternative, if successful, would limit the spread of the plume far better than outcomes projected for Alternatives 2 and 3 (for comparison purposes see the modeling scenario on Figure 2.5-17D). Alternative 4 meets the RAOs listed in Section 2.8, and if effective, would also prevent further spread of hot spots in the aqueous plume, control further migration of contaminants from subsurface DNAPLs to the surrounding groundwater, and reduce the quantity of source material present in the DNAPL zone. However, the success of this strategy is not assured; results from the FBZ pilot study initiated at Site 37 in late 2004 did not indicate an increase in groundwater yield (Earth Tech 2006b).

As with Alternative 3, this alternative would require management and off-site treatment or disposal of residuals (spent granular activated carbon), although only in the first 10 years. Groundwater within the South AFRL CZ will not be required to meet WQOs for the designated beneficial uses of municipal, agricultural, industrial and freshwater replenishment, as listed for the Antelope Valley DWR Basin No. 6-44 in Table 2-2 of the Basin Plan.

2.9.3.5 Alternative 5 - TI Waiver, Source Area Treatment, Plume Containment at Drinking Water Levels, LTM, and LUCs

This alternative includes all components in Alternative 4, with the added component of long-term operation of a GETS designed to prevent migration (plume control) of dissolved-phase plume contaminants at concentrations greater than 5 μg/L (the pMCL for TCE and PCE). Based on results of the groundwater modeling (refer to Figures 2.5-17C and 2.5-17D), a portion of groundwater within the South AFRL CZ would not meet ARARs within a reasonable timeframe. As with Alternative 2, this alternative provides a justification for waiver of the ARARs within the South AFRL CZ. The total time required before concentrations in groundwater inside the South AFRL CZ meet the pMCLs is

unknown but projected (based on a computer model simulation of contaminant transport) to be greater than 100 years.

Obtaining this level of plume containment would require the installation of approximately 60 new extraction wells located outside of the currently contaminated area. The proposed extraction well fields are shown in green on Figures 2.9-1 and 2.9-2. As with Alternative 4, costs for the source area treatment component were developed only for the DNAPL zone at Site 37 (Figure 2.9-3) and hotspots at Site 133 (refer to Figure 2.2-3). Capital costs for Alternative 5 were estimated to be $41.1 million, and total costs for LTM, O&M, and LUCs associated with this alternative (over the first 30 years) were estimated to be approximately $25.1 million (refer to Table 2.10-1). The total PV cost for the alternative was estimated to be $49.4 million based upon a 30-year analysis period. Since source area treatments at Sites 120 and 321 are not included, and plume containment, LTM, and LUCs would have to continue for a period far in excess of 30 years, both capital and long-term costs would be substantially higher than the present-value estimate of $49.4 million.

This alternative maintains the current South AFRL industrial activities and does not impact current or anticipated future industrial uses. Alternative 5 uses source area treatment and plume containment in addition to LUCs to prevent exposure to contaminated groundwater and indoor air containing COCs above acceptable risk limits. As with Alternative 4, the source treatment performed under this alternative, if successful, would limit the spread of the plume far better than outcomes projected for Alternatives 2 and 3 (for comparison purposes see the modeling scenario on Figure 2.5-17D). However, a comparison of the computer simulations on Figures 2.5-17B and 2.5-17C indicates little advantage to selecting plume containment over hot spot containment.

Alternative 5 meets the RAOs listed in Section 2.8, and if effective, would also prevent further spread of the aqueous plume; prevent further spread of hot spots in the aqueous plume; control further migration of contaminants from subsurface DNAPLs to the surrounding groundwater; and reduce the quantity of source material present in the DNAPL zone. Note, however, that the same limitations cited for Alternative 4 would apply.

As with Alternative 3, this alternative would require the long-term management and off-site treatment or disposal of residuals (spent granular activated carbon). Groundwater within the South AFRL CZ

will not be required to meet WQOs for the designated beneficial uses of municipal, agricultural, industrial and freshwater replenishment, as listed for the Antelope Valley DWR Basin No. 6-44 in Table 2-2 of the Basin Plan.

2.10 SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES

During the FS process, the relative performance of the alternatives was evaluated with respect to the nine evaluation criteria to identify the advantages and disadvantages of each alternative. These criteria include:

- Overall protection of human health and the environment;
- Compliance with ARARs;
- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume through treatment;
- Short-term effectiveness;
- Implementability;
- Cost;
- Regulatory agency acceptance; and
- Community acceptance.

A comparative analysis of alternatives presented in the South AFRL Focused FS is summarized in Sections 2.10.1 through 2.10.9 and in Table 2.10-1. Table 2.10-2 summarizes, for each alternative, a reference to Figure 2.5-17 presenting its simulation; cost elements (as applicable) and extended costs (over a 30-year period) for capital outlays, LTM, O&M, LUCs, and 5-year review reports; a brief description of the remedial alternative and its LTM and O&M components; long-term effects in terms of extraction rates and estimated mass of contaminants to be removed, and projected surface area and volumes of groundwater that will be impacted by contaminants (at various time intervals).

TABLE 2.10-1. COMPARATIVE ANALYSIS OF ALTERNATIVES FOR THE SOUTH AFRL
(Page 1 of 7)

Criteria	Alternative 1: No Action	Alternative 2: TI Waiver, No Active Containment, LTM, and LUCs **(Selected Remedy)**	Alternative 3: TI Waiver, Hot Spot Containment (Source Control), LTM, and LUCs	Alternative 4: TI Waiver, Source Area Treatment, LTM, and LUCs	Alternative 5: TI Waiver, Source Area Treatment, Plume Containment at Drinking Water Levels, LTM, and LUCs
Overall Protectiveness [(a)]					
Human Health Protection - Groundwater Ingestion for Current Users	No current users.	No current users.	No current users.	No current users.	No current users.
Human Health Protection - Groundwater Ingestion for Potential Future Users	No future users anticipated, does not maintain incomplete exposure pathways.	No future users anticipated, maintains incomplete exposure pathways.	No future users anticipated, maintains incomplete exposure pathways.	No future users anticipated, maintains incomplete exposure pathways.	No future users anticipated, maintains incomplete exposure pathways.
Human Health Protection - Indoor Air Inhalation for Current Industrial Users	Not protective of current industrial users.	Requires monitoring and LUCs/engineering controls to prevent exposure above 1×10^{-6} cancer risk for industrial use.	Requires monitoring and LUCs/engineering controls to prevent exposure above 1×10^{-6} cancer risk for industrial use.	Requires monitoring and LUCs/engineering controls to prevent exposure above 1×10^{-6} cancer risk for industrial use.	Requires monitoring and LUCs/engineering controls to prevent exposure above 1×10^{-6} cancer risk for industrial use.
Human Health Protection - Indoor Air Inhalation for Future Building Occupants	Not protective of potential future building occupants.	LUCs include restrictions on residential use and incorporates engineering controls into all new construction inside the VICB. These engineering controls include actions such as sub-slab depressurization; installation of vapor barriers; foundation ventilation systems; and HVAC design.	LUCs include restrictions on residential use and incorporates engineering controls into all new construction inside the VICB. These engineering controls include actions such as sub-slab depressurization; installation of vapor barriers; foundation ventilation systems; and HVAC design.	LUCs include restrictions on residential use and incorporates engineering controls into all new construction inside the VICB. These engineering controls include actions such as sub-slab depressurization; installation of vapor barriers; foundation ventilation systems; and HVAC design.	LUCs include restrictions on residential use and incorporates engineering controls into all new construction inside the VICB. These engineering controls include actions such as sub-slab depressurization; installation of vapor barriers; foundation ventilation systems; and HVAC design.
Environmental Protection	Allows further downgradient impact. Does not maintain incomplete exposure pathways. No verification mechanisms.	Allows further downgradient impact to groundwater within the CZ. Maintains incomplete exposure pathways. Provides verification mechanisms.	Allows further downgradient impact to groundwater within the CZ; however impact is reduced relative to Alternatives 1 and 2. Maintains incomplete exposure pathways. Provides verification mechanisms.	Allows further downgradient impact to groundwater within the CZ; however impact may be reduced relative to Alternatives 1 and 2 if source area treatment is highly successful. Maintains incomplete exposure pathways. Provides verification mechanisms.	Allows further downgradient impact to groundwater within the CZ; however impact is reduced relative to all other alternatives, especially if source area treatment is highly successful. Maintains incomplete exposure pathways. Provides verification mechanisms.

TABLE 2.10-1. COMPARATIVE ANALYSIS OF ALTERNATIVES FOR THE SOUTH AFRL
(Page 2 of 7)

Criteria	Alternative 1: No Action	Alternative 2: TI Waiver, No Active Containment, LTM, and LUCs **(Selected Remedy)**	Alternative 3: TI Waiver, Hot Spot Containment (Source Control), LTM, and LUCs	Alternative 4: TI Waiver, Source Area Treatment, LTM, and LUCs	Alternative 5: TI Waiver, Source Area Treatment, Plume Containment at Drinking Water Levels, LTM, and LUCs
Compliance with ARARs [(a)]					
Chemical-Specific ARARs	Does not trigger chemical-specific ARARs.	Those chemical-specific ARARs not met would be waived within the CZ. Concentrations of COCs in groundwater within the CZ may exceed pMCLs indefinitely.	Those chemical-specific ARARs not met would be waived within the CZ. Concentrations of COCs in groundwater within the CZ may exceed pMCLs indefinitely.	Those chemical-specific ARARs not met would be waived within the CZ. Concentrations of COCs in groundwater within the CZ may exceed pMCLs indefinitely.	Those chemical-specific ARARs not met would be waived within the CZ. Concentrations of COCs in groundwater within the CZ may exceed pMCLs indefinitely.
Location-Specific ARARs	Does not trigger location-specific ARARs.	Meets location-specific ARARs.	Meets location-specific ARARs.	Meets location-specific ARARs.	Meets location-specific ARARs.
Action-Specific ARARs	Does not trigger action-specific ARARs.	Meets action-specific ARARs.	Meets action-specific ARARs.	Meets action-specific ARARs.	Meets action-specific ARARs.
Long-Term Effectiveness and Permanence					
Residual Risk from Groundwater Ingestion for Current Users	No current users.	No current users.	No current users.	No current users.	No current users.
Residual Risk from Groundwater Ingestion for Potential Future Users	Does not maintain incomplete exposure pathways. No verification mechanisms.	Maintains incomplete exposure pathways. Provides verification mechanisms.	Maintains incomplete exposure pathways. Provides verification mechanisms.	Maintains incomplete exposure pathways. Provides verification mechanisms. Risk reduced by contaminant destruction in the source area.	Maintains incomplete exposure pathways. Provides verification mechanisms. Risk reduced by contaminant destruction in the source area.
Adequacy and Reliability of Controls	No controls over contaminants. No reliability.	Risks controlled by maintaining incomplete exposure pathways. Reliability of site access controls is high.	Risks controlled by maintaining incomplete exposure pathways and hot spot containment. Site access controls and groundwater PAT are reliable.	Risks controlled by maintaining incomplete exposure pathways and destroying contaminants in areas of highest contaminant concentrations. Site access controls and in situ treatment processes are reliable. Distribution of in situ treatment chemicals within the bedrock fractures is uncertain.	Risks controlled by maintaining incomplete exposure pathways, plume containment, and destroying contaminants in areas of highest contaminant concentrations. Site access controls, groundwater PAT, and in situ treatment processes are reliable. Distribution of in situ treatment chemicals within the bedrock fractures is uncertain.

TABLE 2.10-1. COMPARATIVE ANALYSIS OF ALTERNATIVES FOR THE SOUTH AFRL
(Page 3 of 7)

Criteria	Alternative 1: No Action	Alternative 2: TI Waiver, No Active Containment, LTM, and LUCs **(Selected Remedy)**	Alternative 3: TI Waiver, Hot Spot Containment (Source Control), LTM, and LUCs	Alternative 4: TI Waiver, Source Area Treatment, LTM, and LUCs	Alternative 5: TI Waiver, Source Area Treatment, Plume Containment at Drinking Water Levels, LTM, and LUCs
Reduction of Toxicity, Mobility, or Volume Through Treatment					
Treatment Process Used	None	None	Adsorption by LPGAC of organic chemicals in extracted groundwater.	Bioremediation or chemical oxidation of organics in groundwater.	Bioremediation or chemical oxidation of organics in groundwater. Adsorption by LPGAC of organic chemicals in extracted groundwater.
Amount Destroyed or Treated	None	None	>99 percent of organics in extracted groundwater. Note this is a containment not a treatment option.	Unknown but anticipated to be less than 100 percent within treatment zone.	Unknown but anticipated to be less than 100 percent within treatment zone. >99 percent of organics in extracted groundwater. Note that this component of the alternative is a containment not a treatment option.
Reduction of Toxicity, Mobility, or Volume	None	None	Reduction in contaminant mobility and volume of groundwater potentially impacted in the future.	Reduced volume and toxicity of contaminants in groundwater.	Reduced volume and toxicity of contaminants in groundwater. Reduction in contaminant mobility and volume of groundwater potentially impacted in the future.
Irreversible Treatment	None	None	None	Destruction by bioremediation or chemical oxidation is irreversible.	Destruction by bioremediation or chemical oxidation is irreversible.
Type and Quantity of Residuals Remaining After Treatment	No treatment.	No treatment.	Spent granular activated carbon.	Residual contaminants in groundwater outside of treatment area of influence. Spent granular activated carbon during first 10 years.	Residual contaminants in groundwater outside of treatment area of influence. Spent granular activated carbon.

TABLE 2.10-1. COMPARATIVE ANALYSIS OF ALTERNATIVES FOR THE SOUTH AFRL
(Page 4 of 7)

Criteria	Alternative 1: No Action	Alternative 2: TI Waiver, No Active Containment, LTM, and LUCs **(Selected Remedy)**	Alternative 3: TI Waiver, Hot Spot Containment (Source Control), LTM, and LUCs	Alternative 4: TI Waiver, Source Area Treatment, LTM, and LUCs	Alternative 5: TI Waiver, Source Area Treatment, Plume Containment at Drinking Water Levels, LTM, and LUCs
Short-Term Effectiveness					
Community Protection	No current risk to the community.	No current risk to the community.	No current risk to the community.	No current risk to the community.	No current risk to the community.
Worker Protection	No risk to workers.	Protection required against dermal contact with contaminated water during well sampling to limit risk. Monitoring, LUCs and/or engineering controls required for existing buildings overlying groundwater exceeding GWVCLs-ind.	Protection required against dermal contact with contaminated water during well sampling to limit risk. Monitoring, LUCs and/or engineering controls required for existing buildings overlying groundwater exceeding GWVCLs-ind.	Protection and monitoring required against dermal contact with contaminated water and reagents during well sampling, blast fracturing, and injection to limit risk. Monitoring, LUCs and/or engineering controls required for existing buildings overlying groundwater exceeding GWVCLs-ind.	Protection and monitoring required against dermal contact with contaminated water and reagents during well sampling, blast fracturing, and injection to limit risk. Monitoring, LUCs and/or engineering controls required for existing buildings overlying groundwater exceeding GWVCLs-ind.
Environmental Impacts	Further degradation of water quality.	Further degradation of water quality within CZ; No degradation (in excess of the primary MCL) of water quality outside CZ.	Degradation of water quality within CZ reduced with respect to Alternative 2; No degradation (in excess of the primary MCL) of water quality outside CZ.	Degradation of water quality within CZ reduced with respect to Alternative 2; No degradation (in excess of the primary MCL) of water quality outside CZ. Blast fracturing may increase nitrate and perchlorate concentrations in impacted groundwater.	Degradation of water quality within CZ reduced with respect to Alternative 2; No degradation (in excess of the primary MCL) of water quality outside CZ. Blast fracturing may increase nitrate and perchlorate concentrations in impacted groundwater.
Time Until Action is Complete	Indefinite.	Indefinite.	Indefinite.	Indefinite.	Indefinite.

TABLE 2.10-1. COMPARATIVE ANALYSIS OF ALTERNATIVES FOR THE SOUTH AFRL
(Page 5 of 7)

Criteria	Alternative 1: No Action	Alternative 2: TI Waiver, No Active Containment, LTM, and LUCs **(Selected Remedy)**	Alternative 3: TI Waiver, Hot Spot Containment (Source Control), LTM, and LUCs	Alternative 4: TI Waiver, Source Area Treatment, LTM, and LUCs	Alternative 5: TI Waiver, Source Area Treatment, Plume Containment at Drinking Water Levels, LTM, and LUCs
Implementability					
Ability to Construct and Operate	No construction or operation.	Only well installation required. Engineering controls that may be required to disrupt VIP are implementable.	Only well installation required. Straightforward PAT process. No impact to mission-critical activities. Engineering controls that may be required to disrupt VIP are implementable.	Blast-fracturing, well installation, and flushing required. These processes are not proven technologies in fractured bedrock. Potential for impacts to mission-critical activities. Engineering controls that may be required to disrupt VIP are implementable.	Blast-fracturing, well installation and flushing required. These processes are not proven technologies in fractured bedrock. Construction of additional evaporation ponds at the STP. Potential for impacts to mission-critical activities. Engineering controls that may be required to disrupt VIP are implementable.
Ease of Doing More Action if Needed	No action.	Easy to maintain GIS and monitor groundwater indefinitely.	Easy to maintain GIS, maintain GETS operation, and monitor groundwater indefinitely.	Unknown.	Unknown.
Ability to Monitor Effectiveness	No monitoring.	Monitoring will provide verification mechanisms that exposure pathways remain incomplete.	Monitoring will provide verification mechanisms that exposure pathways remain incomplete and that GETS provide hydraulic containment of hot spots.	Monitoring will provide verification mechanisms that exposure pathways remain incomplete. Performance monitoring will be used to assess effectiveness of source area treatment.	Monitoring will provide verification mechanisms that exposure pathways remain incomplete and that GETS provide hydraulic containment of plume migration. Performance monitoring will be used to assess effectiveness of source area treatment.
Ability to Obtain Approvals and Coordinate with Other Agencies	No approvals necessary.	No permitting and minimal coordination required.	No permitting and minimal coordination required.	Intensive coordination with government agencies involved.	Intensive coordination with government agencies involved.
Availability of Equipment, Specialists, and Materials	None required.	None required.	Readily available.	Limited availability of specialists with experience in applying blast fracturing and ISB/ISCO in fractured granitic bedrock. Equipment and materials expected to be readily available.	Limited availability of specialists with experience in applying blast fracturing and ISB/ISCO in fractured granitic bedrock. Equipment and materials expected to be readily available.

TABLE 2.10-1. COMPARATIVE ANALYSIS OF ALTERNATIVES FOR THE SOUTH AFRL
(Page 6 of 7)

Criteria	Alternative 1: No Action	Alternative 2: TI Waiver, No Active Containment, LTM, and LUCs **(Selected Remedy)**	Alternative 3: TI Waiver, Hot Spot Containment (Source Control), LTM, and LUCs	Alternative 4: TI Waiver, Source Area Treatment, LTM, and LUCs	Alternative 5: TI Waiver, Source Area Treatment, Plume Containment at Drinking Water Levels, LTM, and LUCs
Availability of Technologies	None required.	Readily available.	Readily available.	Limited availability of vendors with experience in applying blast fracturing and ISB/ISCO in fractured granitic bedrock.	Limited availability of vendors with experience in applying blast fracturing and ISB/ISCO in fractured granitic bedrock.
Escalated Costs					
Capital Costs	-	-	$11,390,000	$18,750,000	$41,110,000
South AFRL LTM	-	$9,230,000	$9,230,000	$13,300,000 [(b)]	$13,300,000 [(b)]
Sites 37 and 133 GETS O&M	-	-	$5,760,000	$4,760,000 [(c)]	$6,690,000 [(c)]
GETS Storage O&M	-	$340,000[(d)]	-	-	-
Site 172 SVE System O&M	-	-	$3,160,000	-	$3,160,000
Evaporation Ponds O&M	-	-	$1,450,000	-	$1,450,000
Land Use Controls	-	$230,000	$230,000	$230,000	$230,000
5-Year Reviews (Reports)	-	$300,000	$300,000	$300,000	$300,000
Escalated Total	**$0**	**$10,100,000**	**$31,530,000**	**$37,340,000**	**$66,240,000**
Present Value Costs					
Capital Costs	-	-	$10,960,000	$18,050,000	$39,570,000
South AFRL LTM	-	$3,150,000	$3,150,000	$5,890,000 [(b)]	$5,890,000 [(b)]
Sites 37 and 133 GETS O&M	-	-	$1,810,000	$2,210,000 [(c)]	$2,300,000 [(c)]
GETS Storage O&M	-	$100,000[(d)]	-	-	-
Site 172 SVE System O&M	-	-	$980,000	-	$980,000
Evaporation Ponds O&M	-	-	$480,000	-	$480,000
Land Use Controls	-	$70,000	$70,000	$70,000	$70,000
5-Year Reviews (Reports)	-	$90,000	$90,000	$90,000	$90,000
Present Value Total	**$0**	**$3,410,000**	**$17,540,000**	**$26,310,000**	**$49,380,000**

TABLE 2.10-1. COMPARATIVE ANALYSIS OF ALTERNATIVES FOR THE SOUTH AFRL
(Page 7 of 7)

Criteria	Alternative 1: No Action	Alternative 2: TI Waiver, No Active Containment, LTM, and LUCs **(Selected Remedy)**	Alternative 3: TI Waiver, Hot Spot Containment (Source Control), LTM, and LUCs	Alternative 4: TI Waiver, Source Area Treatment, LTM, and LUCs	Alternative 5: TI Waiver, Source Area Treatment, Plume Containment at Drinking Water Levels, LTM, and LUCs
Regulatory Agency Acceptance	Not acceptable.	Acceptable (see Authorizing Signature page of the Declaration in this ROD).	Acceptable.	Acceptable.	Acceptable.
Community Acceptance	No public comments specific to this alternative.	Acceptable based on community response at public meetings and during the public comment period on the South AFRL Proposed Plan.	No public comments specific to this alternative.	No public comments specific to this alternative.	No public comments specific to this alternative.

Notes:

Present value costs are derived using discount factors calculated using the formula $1/(1 + i)^t$, where i=0.07 (discount factor rate) and t=year (USEPA 2000b). Cost estimates used a 7% discount rate instead of 3.1% as recommended by the USEPA guidance, which would have increased the present value costs by 8 to 50%.

Costs are rounded to the nearest $10,000.

(a) These threshold criteria are not used as weighing criteria for selection of the alternative, but must be met (or waived) in order for an alternative to be considered.

(b) Includes 30-year LTM costs for the South AFRL Area and 10-year supplemental LTM costs for source area treatment.

(c) Includes 30-year O&M costs for the Sites 37 and 133 GETS and 10-year supplemental O&M costs for source area treatment.

(d) Costs to maintain the GETS in an operable condition were included during evaluation of this alternative in the FS. However, this element was dropped as a remedy component during preparation of the ROD. Costs will instead be incurred to decommission the two GETS systems.

%	percent
>	greater than
ARAR	applicable or relevant and appropriate requirement
COC	chemical of concern
CZ	containment zone
FS	feasibility study
GETS	groundwater extraction and treatment system
GIS	geographic information system
GWVCL-ind	industrial groundwater vapor compliance level
ISB	in-situ bioremediation
ISCO	in-situ chemical oxidation
LPGAC	liquid-phase granular activated carbon
LTM	long term monitoring
LUCs	land use controls
MCL	maximum contaminant level
O&M	operation and maintenance
PAT	pump and treat
pMCL	primary MCL
PV	present value
ROD	Record of Decision
STP	sewage treatment plant
SVE	soil vapor extraction
TI	technical impracticability
USEPA	United States Environmental Protection Agency
VIP	vapor intrusion pathway

TABLE 2.10-2. SUMMARY OF REMEDIAL ALTERNATIVES FOR GROUNDWATER CONTAMINATION IN THE SOUTH AFRL AREA

Alternatives Presented in the FS and ROD	Modeled Groundwater Simulations	Cost Elements for a 30-Year Period (unless otherwise noted)	Extended Cost	Description of Remedial Alternative	LTM	O&M	Total Extraction Rates and Contaminant Mass Removal	Modeled Area and Volume of Impacted Plume (>1 μg/L)
Alternative 1 No Action	No Action (see Figure 2.5-17A)	NA	$0	NA	NA	NA	NA	See Alternative 2
Alternative 2 TI Waiver, LTM, and LUCs. **(Selected Remedy)**	No Action (see Figure 2.5-17A)	LTM GETS storage LUCs 5-year review reports	$9,230,000 $340,000 $230,000 $300,000 $10,100,000	As a contingency institute containment in the alluvial aquifer if contaminants are detected outside the CZ. Continue to review treatment technologies as part of the 5-year statutory review. If a promising technology is identified, which has been demonstrated to effectively treat the same types of chemicals at similar concentrations and in a similar hydrogeologic setting, conduct a field-test of the technology, at a cost not to exceed $250,000, to be executed by the following 5-year review.[1]	Plume LTM – Sample select wells annually to biennially with comprehensive sampling every 5 years. Timeframe – Although LTM would be indefinite, cost estimates are based on 30 years.	Sites 37 and 133 GETS –Maintenance and storage for possible future use.[2] Timeframe – Although storage would be indefinite, cost estimates are based on 30 years.	NA	30 Years – 2,700 acres and 4,000 acre feet. 100 Years – 3,600 acres and 5,500 acre feet. 1,000 Years – 5,500 acres and 8,400 acre feet.
Alternative 3 TI Waiver, LTM, and LUCs. Contain Hot Spots at 1,000 μg/L.	Hydraulic Containment of PCE and TCE >1,000 μg/L (see Figure 2.5-17B)	Capital costs - Expand GETS; new extraction wells; new evaporation ponds LTM GETS O&M O&M for Site 172 SVE Evaporation Pond O&M LUCs 5-year review reports	$11,390,000 $9,230,000 $5,760,000 $3,160,000 $1,450,000 $230,000 $300,000 $31,530,000	Sites 37 and 133 GETS – Expand the systems to handle additional capacity. Hot Spot Containment – Pump and treat from 23 new extraction wells located along the 1,000 μg/L contours of the PCE (Site 37) and TCE (Site 133) plumes, and from the 11 existing Sites 37 and 133 extraction wells. Wastewater Handling – Treated wastewater in excess of the AFRL STP discharge limit (20 gpm) would be evaporated in new concrete lined ponds to be constructed on site for this purpose. Site 172 SVE Allows operation of the system to remove contaminant mass from the Site 37 source area. Timeframe – Although this containment alternative has an indefinite timeframe, costs are for only 30 years.	Same as Alternative 2	Sites 37 and 133 GETS – Quarterly sampling at the influent, midpoints, and effluent sampling ports; and at the AFRL STP. Long-term annual sampling of 34 extraction wells. Site 172 SVE – Quarterly sampling of the influent; semiannual sampling of the effluent, and annual sampling of the vapor extraction wells. Evaporation Ponds – sampling and maintenance of new ponds. Timeframe - Although the O&M described above would be indefinite, cost estimates are based on 30 years.	Hot spot containment – Total of 25 gpm groundwater extraction and 330 pounds per year contaminant removal.	30 Years – 2,700 acres and 4,100 acre feet. 100 Years – 3,300 acres and 5,000 acre feet. 1,000 Years – 1,500 acres and 2,300 acre feet.
Alternative 4 TI Waiver, LTM, and LUCs. Remove Sources in 10 years. Contain Hot Spots at 10,000 μg/L for 10 years.	Source Removal after 10 Years (see Figure 2.5-17D)	Capital costs - Expand GETS; blast fracturing; source area extraction and reinjection wells; and source area monitoring wells LTM GETS O&M LUCs 5-year review reports	$18,750,000 $13,300,000 $4,760,000 $230,000 $300,000 $37,340,000	Sites 37 and 133 GETS – Expand the systems to handle additional capacity. Source Area Treatment – Use subsurface blasting to enhance fractures in a total of nine extraction and nine reinjection galleries at three different source areas within Sites 37 and 133. Pump and treat from a total of 27 extraction wells in the source area galleries. Hot Spot Containment – Pump and treat from 11 existing Sites 37 and 133 GETS extraction wells. Wastewater Handling – Treated wastewater would be amended to stimulate either ISB or ISCO, then returned to the source area groundwater through a total of 54 wells installed in the reinjection galleries. Excess water would be discharged to the AFRL STP. Timeframe – Source area treatment and hot spot containment is estimated to last 10 years.	Same as Alternative 2, but also includes supplemental well sampling of 30 new source area monitoring wells during the 10-year source area treatment.	Sites 37 and 133 GETS – Quarterly sampling from the sampling ports. Long-term annual sampling of 11 plume-control extraction wells, and short-term annual sampling of 27 source area extraction wells. Timeframe - Although long-term O&M would be indefinite, cost estimates are based on 30 years. Short-term O&M would be for the 10 years during which source area treatment is ongoing.	Source area treatment - Total of 270 gpm of groundwater extraction and 12,000 pounds per year of contaminant removal (initially). Hot spot containment – 18 gpm groundwater extraction and 300 pounds of contaminant removal per year	30 Years – 2,550 acres and 3,900 acre feet. 100 Years – 3,150 acres and 4,800 acre feet. 1,000 Years – 600 acres and 900 acre feet.
Alternative 5 TI Waiver, LTM, and LUCs. Remove Sources in 10 years. Contain Plume at 5 μg/L.	Not specifically modeled but assumed to be similar to Source Removal after 10 Years (see Figure 2.5-17D) with less growth of the 5 μg/L contour (see Figure 2.5-17C)	Capital costs - Expand GETS; blast fracturing; source area extraction and reinjection wells; source area monitoring wells; plume containment extraction wells; and evaporation ponds LTM GETS O&M O&M for Site 172 SVE Evaporation Pond O&M LUCs 5-year review reports	$41,110,000 $13,300,000 $6,690,000 $3,160,000 $1,450,000 $230,000 $300,000 $66,240,000	Sites 37 and 133 GETS – Expand systems to handle additional capacity. Source Area Treatment – Source area treatment as per Alternative 4. Plume Containment – Long term-pump and treat from 60 new extraction wells located along the 5 μg/L contours of the PCE (Site 37) and TCE (Site 133) plumes, and from the 11 existing Sites 37 and 133 extraction wells. Wastewater Handling – Treated and amended wastewater from the source areas would be returned via the reinjection wells. Treated plume-containment wastewater in excess of the AFRL STP discharge limit (20 gpm) would be evaporated in new concrete lined ponds to be constructed on site for this purpose. Site 172 SVE Allows operation of the system to remove contaminant mass from the Site 37 source area. Timeframe – Source area treatment time is estimated at 10 years. Plume containment pump and treat would be indefinite, but costs are for only 30 years.	Same as Alternative 2, but also includes supplemental well sampling of 30 new source area monitoring wells needed for the 10-year source area treatment.	Sites 37 and 133 GETS – Quarterly sampling from the sampling ports. Long-term annual sampling of 71 plume-control extraction wells, and short-term annual sampling of 27 source area extraction wells. Site 172 SVE - O&M as per Alternative 3. Evaporation Ponds – sampling and maintenance of new ponds. Timeframe - Although long-term O&M would be indefinite, cost estimates are based on 30 years. Short-term O&M would be for the 10 years during which source area treatment is ongoing.	Source area treatment - Total of 270 gpm of groundwater extraction and 12,000 pounds per year of contaminant removal (initially). Plume containment – 36 gpm groundwater extraction and 300 pounds of contaminant removal per year.	Not Modeled; the following assumptions are based on the simulation for Alternative 4. 30 Years – <2,550 acres and <3,900 acre feet. 100 Years – <3,150 acres and <4,800 acre feet. 1,000 Years – 600 acres and 900 acre feet.

Notes:
[1] This remedy component was added during preparation of the ROD.
[2] Costs to maintain the GETS in an operable condition were included during evaluation of this alternative in the FS. However, this element was dropped as a remedy component during preparation of the ROD. Costs will instead be incurred to decommission the two GETS systems.

μg/L	micrograms per liter	gpm	gallons per minute	LUCs	land use controls	STP	sewage treatment plant
AFRL	Air Force Research Laboratory	ISB	in-situ bioremediation	O&M	operation and maintenance	SVE	soil vapor extraction
FS	feasibility study	ISCO	in-situ chemical oxidation	PCE	tetrachloroethene	TCE	trichloroethene
GETS	groundwater extraction and treatment system	LTM	long-term monitoring	ROD	record of decision	TI	technical impracticability

2.10.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Overall protection of human health and the environment addresses whether each alternative provides adequate protection of human health and the environment and describes how risks posed through each exposure pathway are eliminated, reduced, or controlled, through treatment, engineering controls, and/or institutional controls (ICs).

Under current land use conditions, no potential risks to human and ecological receptors are posed by ingesting contaminated groundwater due to the absence of exposure mechanisms. No changes in that status, land use, or groundwater use are anticipated. Contaminant concentrations in groundwater exceed USEPA's acceptable risk range and pose potential risks to future users of the groundwater as a drinking water source. Also, inhalation of indoor air via the VIP poses potential risks to human health in localized areas under a hypothetical (future) residential land use and under the existing (current) industrial land use.

With the exception of Alternative 1 (no action), all alternatives are protective of human health and the environment by maintaining incomplete exposure pathways (and instituting engineering controls as described in Section 2.13.2 to disrupt the completed VIP for industrial use). Alternatives 2, 3, 4, and 5 include monitoring and, thus, verification mechanisms to ensure that contaminant concentrations outside the South AFRL CZ remain below acceptable levels of potential risk to human and ecological receptors. Alternative 5 prevents further migration of the leading edge of the groundwater plumes by extracting and treating groundwater to drinking water standards. Alternative 3 prevents further migration of the hot spots by extracting and treating groundwater to drinking water standards. Alternative 2 relies on natural attenuation processes to slow or reduce migration of the plumes so that groundwater outside the CZ (TI waiver zone) is not impacted.

Alternatives 4 and 5 provide further risk reduction in the source areas by aggressively reducing mass. However, if even a small mass of untreated DNAPL remains in the aquifer despite an aggressive attempt at source area treatment, downgradient concentrations would likely rebound once active pumping in the source areas is discontinued. Therefore, DNAPL removal must be nearly complete for source treatment to be effective in permanently reducing risk.

2.10.2 COMPLIANCE WITH ARARS

The NCP requires that RAs at CERCLA sites at least attain ARARs, unless such ARARs are waived. Applicable requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, RA, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable. RARs are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, RA, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well-suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.

The compliance with ARARs criterion addresses whether a remedy will meet all of the ARARs or provides a basis for invoking a waiver.

Alternatives 2 through 5 include a waiver of chemical-specific ARARs; LTMs and LUCs provide compliance verification mechanisms. All alternatives are expected to be able to meet location- and action-specific ARARs listed in Appendix D, although the aggressive source removal alternatives (4 and 5) will provide the most challenges in minimizing disturbance to natural and cultural resources, and in maintaining worker safety. Selection of Alternatives 4 or 5 would trigger two additional action-specific ARARs: the UIC Program briefly mentioned in Section 2.9.3.4 and SWRCB Resolution 68-16. Substantive portions of both ARARs would be applicable to the injection of chemicals used to implement ISB or ISCO; SWRCB Resolution 68-16 would also be applicable to the reinjection of treated groundwater. It is anticipated that LTM and LUC components of Alternatives 2 through 5 under conditions of the South AFRL CZ will be required to extend well beyond 100 years.

2.10.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

Long-term effectiveness and permanence refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time, once cleanup levels have been met. This criterion includes the consideration of residual risk that will remain onsite following remediation and the adequacy and reliability of controls.

If successful, Alternatives 4 and 5 would afford the highest degrees of long-term effectiveness and permanence because they include aggressive source area treatment to destroy contaminant mass both by aboveground treatment of extracted groundwater and enhancement of in-situ biodegradation (or chemical oxidation).

None of the alternatives are likely to reduce contaminant concentrations to below pMCLs, even over an extended timeframe. Alternatives 2 through 5 offer protection verification mechanisms, and some effectiveness may be attributable to natural attenuation processes present at the South AFRL; however, contaminant concentrations in groundwater within a large portion of the South AFRL CZ would not be reduced over a very long timeframe. Both of the active containment options incorporated as components of Alternatives 3 and 5 would be effective while operational, but estimated timeframes required for their operation exceed 200 years. It is possible that the no active containment option presented in Alternative 2 (and Alternative 4 after the 10 years of aggressive source area treatment) may be just as effective in the long run; additional monitoring data are needed to evaluate the current status of the plumes (i.e., are the plumes growing, as predicted by the contaminant fate and transport model, or are they stable due to natural attenuation processes).

2.10.4 REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT

Reduction of toxicity, mobility, or volume through treatment refers to the anticipated performance of the treatment technologies that may be included as part of a remedy.

Alternatives 1 and 2 do not include treatment as a component of the remedy, and therefore would not reduce the toxicity, mobility, or volume of contamination through treatment. Alternative 3 includes hot spot containment, with treatment of extracted groundwater through adsorption of VOCs to granular activated carbon. This alternative would be expected to reduce contaminant mobility and volume more

so than no action or no active containment (Alternatives 1 and 2); however, Alternative 3 would result in the generation of treatment residuals (spent carbon) that would likely require further off-site treatment and/or land disposal. As with the previous criterion, if successful, Alternatives 4 and 5 would afford the greatest reduction in toxicity, mobility, and volume through aggressive source area treatment to destroy contaminant mass both by aboveground treatment of extracted groundwater and enhancement of in-situ biodegradation (or chemical oxidation). This reduction is irreversible because the VOCs would be chemically altered.

2.10.5 SHORT-TERM EFFECTIVENESS

Short-term effectiveness addresses the period of time needed to implement the remedy and any adverse impacts that may be posed to workers, the community and the environment during construction and operation of the remedy until cleanup levels are achieved.

None of the alternatives results in unacceptable short-term risks to the community or the environment, and all achieve protectiveness of workers during RA implementation. Alternatives 2 through 5 involve conventional decontamination practices with standardized environmental monitoring procedures, personal protective equipment (PPE), and engineering controls to address concerns regarding contact with contaminated groundwater. During implementation of the aggressive source removal portions of Alternatives 4 and 5, additional PPE and engineering controls may be necessary to protect workers from contact with injected chemicals and to assure safe storage of chemicals at the site. These alternatives also require significantly greater construction, which may result in moderate to high impacts to natural resources and the environment. Although Alternatives 4 and 5 comparatively present more short-term risk during implementation, if successful, the source removal components would be completed in the shortest timeframe after which long-term risk would be reduced.

2.10.6 IMPLEMENTABILITY

Implementability addresses the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility, and coordination with other governmental entities are also considered.

Alternative 1 would be easiest to implement. Alternatives 2 through 5 would all require long-term (beyond 30 years) monitoring programs and maintenance of LUCs to provide exposure control in conjunction with the TI waiver zone. Outside of these common elements, difficulty of implementation increases from Alternative 2 through Alternative 5. Alternative 2, which would use conventional equipment and methods for groundwater sampling, analysis, and reporting; and Alternative 3, which would also include hot spot containment and waste disposal, would be easily implemented.

Although Alternatives 4 and 5 would use conventional equipment for chemical injection (either for ISB or ISCO), difficulty achieving dispersion of chemical agents in fractured bedrock is anticipated. Based on performance of the FBZ pilot study conducted at Site 37, blast enhanced fracturing is not an effective method to increase distribution of chemicals within the fractured granitic bedrock. Moreover, the success of these alternatives relies on the installation of numerous wells in close proximity to active facilities. The aggressive source removal options would require a massive mobilization of personnel and equipment and could potentially disrupt mission-critical activities.

All materials and equipment needed for implementation of any of the alternatives are readily, commercially available. A limited number of vendors is available with specialized experience in applying blast fracturing and ISB or ISCO to fractured crystalline bedrock.

2.10.7 COST

The estimated PV costs for Alternatives 2 through 5, not including the No Action alternative, range from $3,410,000 for Alternative 2 to $49,380,000 for Alternative 5 over 30 years. Cost summaries are presented in Table 2.10-1. Since this remedy (and all the others considered in this ROD) would involve a period far in excess of at least 200 years it would mean long-term costs substantially greater than those cited in Table 2.10-1. Moreover, the cost differential between Alternative 2 and Alternatives 3, 4, and 5 would be substantially greater over 200 years than the differential cited in Table 2-10-1.

2.10.8 REGULATORY AGENCY ACCEPTANCE

Regulatory agency acceptance was evaluated based upon comments to the South AFRL Focused FS, draft versions of the PP and ROD, and during RPM meetings. Federal and state agencies have

reviewed the South AFRL Focused FS, the PP, and this ROD. The Authorizing Signature page of the Declaration in this ROD identifies the agencies in concurrence with the remedy for soil, soil vapor, and groundwater at the South AFRL, as selected in this ROD.

2.10.9 COMMUNITY ACCEPTANCE

The PP was presented to the community and discussed at public meetings as described in Section 2.3. A public comment period for the South AFRL PP was provided during April and May 2006 so written or oral comments could be made. Comments are summarized in the Responsiveness Summary (Part 3). After considering the public comments, and inputs from regulatory agencies, a decision was made to implement the remedy proposed in the PP, with slight modifications as discussed in Section 2.15.

2.11 ADDITIONAL REMEDY SELECTION CONSIDERATIONS

The USEPA September 1993 TI Guidance recognizes that the choice among available remedial strategy options at a site may involve a consideration of the aggressiveness of the remedy, "a concept that includes both the choice of remedial technologies as well as the relative intensity of how that technology is applied at the site." For example, "there are several options for attaining cleanup levels within the aqueous plume: active PAT throughout the aqueous plume; natural gradient flushing of the plume towards a PAT capture system located at the leading edge of the plume [a component of Alternative 5]; and natural attenuation (dilution, dispersion, and any natural degradation processes active within the affected aquifer) [Alternative 2]. Each alternative will attain the required cleanup levels, but the choice involves a trade-off among several factors, including: (1) remediation timeframe (longer with less aggressive strategies); (2) cost (lower with less aggressive strategies); and (3) potential risk of exposure (may increase with less aggressive strategies)."

The TI Guidance states, "Where conditions favoring more aggressive strategies do not exist, EPA is more likely to choose a less aggressive strategy to achieve the desired remediation objectives." Below are listed conditions as presented in the TI Guidance, which favor more aggressive strategies (i.e., PAT throughout the aqueous plume), and assessment of how they relate to the South AFRL plumes:

1. **The aggressive strategy clearly will result in a significantly shorter restoration timeframe than other available options.** Since the contaminant transport simulations (Figure 2.5-17) show that even under the more aggressive options (Alternatives 4 and 5) contaminant concentrations are likely to persist at levels well above pMCLs for at least 200 years, this is not the case at the South AFRL area.

2. **A shorter remediation timeframe is desired to reduce the potential for human exposure.** If the groundwater is not used, there is no potential for human exposure via groundwater ingestion. LUCs and engineering controls will prevent exposure via the VIP. Therefore, this condition does not apply.

3. **A shorter remediation timeframe is desired to reduce ongoing or potential impacts to environmental receptors.** Results of the *Validation Study* (USGS 2002) conducted at Sites 37 and 133 indicated no adverse effects to burrowing animals from soil vapors contaminated with site VOCs. It is considered likely that any of the more aggressive remedial options would involve more impact to the environment than leaving the contamination in place.

2.12 PRINCIPAL THREAT WASTES

Principal threat wastes are source materials that are considered to be highly toxic or highly mobile that generally cannot be reliably contained, or would present a potential risk considered to be unacceptable to human health or the environment should exposure occur. Source materials are materials that contain hazardous substances, pollutants, or contaminants that act as the starting point of contaminant migration to groundwater and may be highly toxic and not readily contained. Although groundwater is not usually considered a source material, non-aqueous phase liquids such as DNAPL in groundwater may be considered such. The NCP establishes an expectation that treatment will be used to address principal threats posed by sites wherever practicable.

As part of investigation activities, source materials (liquid waste sumps, waste discharge wells, VOCs in soil vapors) were removed from the South AFRL to the extent practicable. No groundwater contaminant sources were identified in soil. Suspected DNAPL solvents remain on site and will not be treated under this action due to TI with the available remedial technologies. However, the remedy includes a commitment to continue review of technologies as part of the 5-year statutory review and to conduct field tests of promising technologies that have been demonstrated to effectively treat similar chemicals at similar concentrations in similar hydrogeologic settings.

2.13 SELECTED REMEDY

The selected remedy for soil at the South AFRL is No Action.

The selected remedy for soil vapor includes LUCs to prevent exposure to indoor air under an unrestricted use (residential) scenario and LUCs/engineering controls to prevent exposure to indoor air under an industrial scenario within areas where soil (at Site 37) and/or groundwater (at Sites 37, 120, 133, and 321) contain VOCs at concentrations that present cancer risks greater than 1×10^{-6} via the VIP under residential (unrestricted) and industrial uses. Figure 2.7-1 shows the VICB inside which the LUCs and building controls must be applied as detailed in Section 2.13.2.

The selected remedy for groundwater at the South AFRL is Alternative 2, a TI Waiver of pMCLs (listed in Table 2.5-1) as ARARs within a 16.4-square-mile area (shown on Figure 2.1-2) to a depth of 500 feet bgs; no active containment (reliance on dilution and dispersion for containment of contaminants within the South AFRL CZ), LTM to monitor remedy performance, and LUCs to maintain incomplete exposure pathways. The proposed dimensions of the CZ reflect the collective and best professional judgment of all the RPMs (Air Force, USEPA, Lahontan Water Board, and DTSC) based on existing data, necessary levels of protection, and engineering limitations. This remedy incorporating a TI waiver zone meets the intent of California's Containment Zone Policy pursuant to Resolution 92-49, Section III.H, as documented in Table E-1 in Appendix E.

In determining the best remedy, the performance of each alternative under three of the balancing criteria (long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; and short-term effectiveness) was considered to determine which alternative provided the most "cost effective" approach. While Alternatives 3 through 5 arguably would provide slightly more protectiveness if fully successful, modeling shows that none of these alternatives would be effective in reducing groundwater contamination to pMCLs within a reasonable time period (or at a reasonable cost) as none of the alternatives are likely to attain pMCLs for at least 200 years. Moreover, the costs of these alternatives are substantially greater than Alternative 2. Given this fact and the fact that LTM and LUCs would ensure continued protection of human health, it has been determined that the incremental benefits under Alternatives 3 through 5 are not proportionate to any expected gain in

overall effectiveness. Alternative 2 is the preferred remedy because it is protective and represents the most cost effective use of taxpayer dollars.

2.13.1 SUMMARY OF THE RATIONALE FOR THE SELECTED REMEDY

The rationale for selecting No Action for soils at the South AFRL is provided in Section 2.7: any risks associated with exposure to soil at Sites 37, 120, 133, and 321 (under all scenarios, including an unrestricted, residential land use) fall within an acceptable range, and do not require any response action.

The rationale for selecting LUCs/engineering controls to prevent exposure (under an unrestricted use and an industrial use scenario) to indoor air containing VOC concentrations presenting a cancer risk greater than 1×10^{-6} level includes the following factors: 1) building controls (e.g., sub-slab depressurization systems to inhibit vapors from migrating into existing buildings and/or vapor barriers incorporated into the design of future buildings [installation costs estimated at $150,000]) represent the "state-of-the-art" and most cost effective technology for addressing risks via the VIP; 2) for soil (at Site 37), the cost to remediate to an unrestricted use by excavation and off-site treatment is estimated at $1.35 million, and the cost and time to remediate by SVE (to a cancer risk level below 1×10^{-6} for industrial use) is estimated at $2.0 million and 8 years (refer to Appendix B-2); and 3) for groundwater, remediation to concentrations representing a risk level of 1×10^{-6} is technically impracticable for the same reasons that cleanup to the pMCLs is technically impracticable as presented in Section 2.13.1.1 below. Moreover, a phased approach including monitoring to confirm a completed VIP offsets the considerable uncertainties in input parameters and default variables used in the J&E model that may result in a significant over-estimate of potential indoor air concentrations and their associated risks (these uncertainties are discussed specifically for Site 37 in Appendix B-1).

The following sections provide the rationale for selecting the groundwater remedy.

2.13.1.1 Rationale for Invoking a TI Waiver of Chemical-Specific ARARs

The ARARs waiver within the South AFRL CZ is invoked due to the technical impracticability, from an engineering perspective, of (1) achieving groundwater restoration in crystalline, fractured granitic

bedrock impacted by dissolved-phase VOCs and other chemicals; and (2) removing DNAPL solvents that are suspected to be present in the fractured granitic bedrock.

The ability to remediate the South AFRL groundwater plumes is limited by the following factors:

1. Groundwater occurs in a complex system of isolated and heterogeneous fractures within the crystalline granitic bedrock. As a result, aquifer permeability is very low, hindering both groundwater extraction for aboveground treatment and the delivery of materials for in-situ treatment.

2. Chlorinated solvents such as PCE and TCE are recalcitrant contaminants when present as DNAPL and have proven difficult (if not impossible) to remediate on a large scale. Results of groundwater sampling, coupled with known historical contaminant releases, strongly suggest that PCE and TCE are present as DNAPL at Site 37 and 133.

3. Analysis of samples from of deep wells indicates that groundwater at depths in excess of 250 feet bgs (Site 37) and 350 feet bgs (Site 133) is impacted. Extraction of groundwater for treatment, or distribution of injected materials (e.g. chemicals and/or bacteria) for in situ treatment, becomes increasingly difficult at greater depth because the fractures become smaller, tighter and less frequent, thus further reducing the permeability of the water-bearing intervals. Moreover, installation of deep monitoring wells is challenging and expensive, especially if care is taken not to carry contamination further downward.

Further support for the TI waiver is provided in Section 2.5.8.

2.13.1.2 Rationale for Selection of Alternative 2 – Dissolved-Phase Plume

Among the alternatives (all of which include a TI waiver of ARARs) considered in Sections 2.9 and 2.10, Alternative 2, which includes no active containment, was selected. Before making this determination, both hot spot containment (Alternative 3) and plume containment (a component of Alternative 5) were carefully considered. By comparison of Simulations 2.5-17B and 2.5-17D, hot spot containment would appear to offer the greater benefit. Although hydraulic control of contaminant migration can be achieved, there are serious limitations to this remedial strategy. For one, the plume as a whole remains untreated. Therefore, this option provides only a temporary benefit while the GETS are actively extracting groundwater. Perpetual operation of the two GETS is not considered a cost-effective or practical option. The costs for operating the current Site 37 GETS on a TS scale averaged approximately $3,000 per pound of removed contaminant (refer to Table A-5 in Appendix A).

Furthermore, cost estimates for containing the hot spot for the next 30 years exceed $31 million or $17 million in PV.

Another drawback to proposing an active containment option is that it is not clear that the measure is necessary. Because no groundwater supply wells are currently impacted, exposure pathways from the dissolved-phase groundwater plumes are considered incomplete. Given the low yield of the water-bearing fractures within the granitic bedrock and the naturally-occurring arsenic at concentrations that exceed the pMCL, it is unlikely that groundwater within the South AFRL CZ would be considered for use as a drinking water source. Even if it were, wellhead treatment could be accomplished far more economically than long-term PAT. Additionally, simulation of a no action scenario by the contaminant transport model suggests that no impact to active downgradient supply wells is anticipated over the next 1,000 years, allowing LUCs to be used to protect workers and potential groundwater users from exposure. Furthermore, it is possible that the contaminant transport model, which does not assume any intrinsic biodegradation, has exaggerated the rate of plume migration, which is eventually anticipated to reach equilibrium with natural attenuation processes such as advection, dispersion, and sorption.

2.13.1.3 Rationale for Selection of Alternative 2 – Source Area Considerations

This section provides the rationale for selecting Alternative 2 over Alternative 4, which includes aggressive source area treatment. The contaminant transport model suggests that the complete removal of continuing sources (i.e., DNAPL) would significantly reduce downgradient concentrations of dissolved-phase PCE and TCE (refer to Figure 2.5-17C). The removal of source area DNAPL, however, relies on technologies that are largely unproven in the challenging aquifer conditions found at Sites 37 and 133. Alternative 4 includes a combination of actions that, at the time the FS was prepared, appeared to offer the best chance of mass removal in the source area. These actions include the use of blast fracturing to improve the permeability of the Sites 37 and 133 source areas, coupled with re-injection of the groundwater (treated through LPGAC) amended with chemicals to stimulate ISB or ISCO. However, based on results of an ongoing pilot study as summarized below, the full-scale implementability of blast fracturing is currently considered impracticable; preliminary results of two pilot studies where ISB is being tested also suggest that application of this technology would be premature.

Preliminary Evaluation of FBZ at Site 37

A pilot study involving the creation of two small engineered FBZs was conducted at Site 37 beginning in late 2004 (Earth Tech 2006b). The objectives of the pilot study included evaluating the ability of an FBZ to increase aquifer yield in the low permeability water-producing zone(s) at Site 37 and assess the long-term sustainability of increased extraction yield. Based on observations and results obtained to date, including during subsequent long-term (4-month) pumping tests of wells installed within each FBZ, the aquifer yield was not increased: in Well 37-EW09 inside the northern FBZ a pumping rate of only 0.02 gpm was sustained while a pumping rate of 0.13 gpm was sustained in Well 37-EW10 in the southern FBZ. Furthermore, due to limitations (for safety reasons and potential damage to utilities) on the amount of explosives that can be used to create the fractures, and the depth of dissolved phase and suspected DNAPL at South AFRL sites, FBZ is now considered impractical in a large-scale design to increase groundwater yields and/or the ability to enhance delivery of treatment components to the aquifer.

Preliminary Evaluation of ISB at Sites 162 and 177

Two pilot studies of ISB using slow-release electron donors to treat chlorinated solvents in groundwater within fractured granitic bedrock are ongoing at the AFRL. Initial results (prior to rebound after approximately 6 months) indicated successful degradation of PCE and TCE to cis-1,2-DCE (and reduction of perchlorate at Site 177) within the localized area impacted by the injection of Emulsified Oil Substrate (EOS®) and Hydrogen Release Compound (HRC®) at Sites 162 and 177, respectively. Each of the pilot studies employs a PRB designed to achieve hot spot containment. Although initial results are somewhat promising, the following limitations should be kept in mind for consideration of a PRB employing ISB on a larger scale:

- The pilot studies target only contamination in the top 10 feet of the first water-bearing zone; past drilling experience has indicated that typically a single borehole will encounter water-bearing zones of varying (but generally low) K at multiple depths.
- The 1,500-square-foot pilot study areas represent only a tiny fraction of the Site 162 and Site 177 dissolved contaminant plumes, which are estimated to cover a surface area of 1,100 acres and 1,300 acres, respectively. At Site 162, the lack of evidence for ARD in a well 10 feet cross gradient from the nearest injection well suggests that the assumed 15-foot ROI used in this design is not overly conservative.

- If complete biodegradation to non-toxic end products (ethene and chloride) rather than a stall at cis-1,2-DCE is not achieved, then ISB will not be useful as a source control remedial alternative for the chlorinated solvent plumes at the AFRL. A future phase of these ISB pilot studies will evaluate whether bioaugmentation (injection of microbes) can stimulate the further ARD of cis-1,2-DCE to ethene.

Until effective performance of one or more innovative treatment technologies can be adequately demonstrated in small-scale pilot tests, selection of a source area treatment technology (anticipated to be very costly and only partially effective) would be premature.

2.13.2 DESCRIPTION OF THE SELECTED REMEDY

The selected remedy for soil is No Action.

The main components of the selected remedy for soil vapor (intrusion into indoor air) include:

- Implement, monitor, maintain, enforce, and report LUCs on soil vapor intrusion into indoor air within the VICB (refer to Figure 2.7-1) in accordance with the Base GP (further details on LUC implementation and administration are provided in Section 2.13.2.1). LUCs include maintaining the integrity of any current or future vapor mitigation or monitoring system. One specific component of these LUCs is maintaining the Edwards AFB GIS as it relates to the extent of groundwater contaminant levels used for determining the VICB. GIS information is consulted and used in the approval process prior to issuance of work permits.

- Monitor and map groundwater plume migration for those plume contours that are at contaminant concentrations that present a potential cancer risk exceeding 1×10^{-6} in indoor air, via the modeled VIP for residential use (Table 2.13-1) and industrial use (Table 2.13-2) scenarios. These concentrations are termed GWVCLs-res and GWVCLs-ind, respectively, for the residential and industrial exposure scenarios. The initial VICB set by this ROD is based on the 30-year projected extent of groundwater that will be impacted by PCE or TCE at a 10^{-6} residential cancer risk level. When subsequent plume migration modeling during a future Five Year Review predicts that the residential risk contours will exceed the current VICB in less than 10 years, revise the appropriate maps and information in the Base GP to show an enlarged VICB with new boundaries based on an additional 30 years of predicted plume migration.

- Incorporate engineering controls to reduce risk via the VIP to less than 1×10^{-6} into all new construction within the VICB. These controls may include, but are not limited to, actions such as sub-slab depressurization; installation of vapor barriers; foundation ventilation systems; and HVAC design.

TABLE 2.13-1. RISK-BASED GROUNDWATER VAPOR COMPLIANCE LEVELS (GWVCLS-RES) AND INDOOR AIR VAPOR MITIGATION LEVELS (IAVMLS-RES) FOR SITES 37, 120, 133, AND 321 PROTECTIVE FOR UNRESTRICTED USE (RESIDENTIAL EXPOSURE SCENARIO)

Site	COC	GWVCLs-res (μg/L)	IAVMLs-res (μg/m^3)
37	PCE	13.1	0.4
37	TCE	60.7	1.2
37	benzene	25.4	0.3
120	PCE	1.8	0.4
120	TCE	8.5	1.2
120	cis-1,2-DCE	672	36.5
133	PCE	13	0.4
133	TCE	57.3	1.2
321	PCE	19	0.4

Notes:

The GWVCL-res is the groundwater concentration that would result in a modeled IAVML-res that would cause a 1 x 10^{-6} cancer risk (or an HQ of 1 for cis-1,2-DCE at Site 120) for each COC via the indoor air vapor intrusion pathway under a residential exposure scenario. In all cases (where applicable), the GWVCL-res and IAVML-res based on a 1 x 10^{-6} indoor air cancer risk are lower than their respective concentration levels based on an HI = 1.0 (see Table B.1-4).

TABLE 2.13-2. RISK-BASED GROUNDWATER VAPOR COMPLIANCE LEVELS (GWVCLS-IND) FOR DETERMINING WHERE TO INITIATE MONITORING TO ASSESS INDOOR AIR CONCENTRATIONS IN EXISTING BUILDINGS OVERLYING SITES 37, 120, 133, AND 321 PLUMES

Site	COC	GWVCLs-ind (μg/L)
37	PCE	607
37	TCE	2,990
120	PCE	32.4
133	TCE	2,340
321	PCE	451

Notes:

GWVCL-ind is the groundwater concentration that would result in a modeled IAVML-ind (Table 2.13-3) that would cause a 1 x 10^{-6} cancer risk for each COC via the indoor air vapor intrusion pathway under an industrial exposure scenario. In all cases, the GWVCL-ind based on a 1 x 10^{-6} cancer risk is lower than the RBCL based on an HI = 1.0 (see Table B.1-4).

- Initiate a sampling program (that may include soil vapor sampling adjacent to and/or beneath buildings) to assess whether the VIP is complete at existing buildings where groundwater contains chemical concentrations in excess of the GWVCLs-ind for Sites 37, 120, 133, and 321 (refer to Table 2.13-2). The areas currently exceeding GWVCLs-ind are shown on Figure 2.7-1. If a completed pathway is confirmed, periodically monitor indoor air for COCs in those existing buildings where groundwater contaminant concentrations exceed GWVCLs-ind. If measured indoor air COC concentrations exceed the risk-based IAVMLs-ind listed in Table 2.13-3, activate appropriate mitigation measures (these may include, but are not limited to, actions such as continued monitoring, SVE, building controls such as sub-slab depressurization or HVAC modifications, foundation repairs or ventilation).

The main components of the selected remedy for groundwater include:

- Implement, monitor, maintain, enforce, and report LUCs on groundwater within the South AFRL CZ in accordance with the Base GP (further details on LUC implementation and administration are provided in Section 2.13.2.1). LUCs will include maintaining the integrity of the current groundwater monitoring system or any future remedial or monitoring system within the groundwater CZ/LUC Compliance Boundary shown on Figure 2.1-2. One specific component of these LUCs is maintaining the Edwards AFB GIS as it relates to the extent of contamination at the South AFRL (as part of a base-wide program). GIS information is consulted and used in the approval process prior to issuance of work permits.

- Contain impacted groundwater within the South AFRL CZ by natural processes (dilution, dispersion). The CZ boundary is drawn with the objective of preventing contaminants from impacting the alluvial aquifer to the west (Lancaster Sub-basin shown on Figure 2.5-3). The Air Force has adopted USGS basin boundaries (as defined in USGS Water Resources Investigations Report 98-4022, Carlson et al 1998) and supported by borehole logs for wells installed by Earth Tech (2003a and 2003b) to define the location of the bedrock/alluvial aquifer interface. Post-ROD documents (i.e., RA work plans, including O&M plans and schedules for the RA) will assess hydrogeologic conditions within the CZ. These documents may also specify additional field investigations to be conducted during the post-ROD period in order to provide greater confidence in the contaminant distribution and to evaluate the plumes' actual behavior against the site conceptual and computer groundwater models. Post-ROD investigations may include, but are not limited to, subsurface geophysics, aquifer pump tests, and/or discrete zone monitoring wells to assess contaminant transport in the fractured bedrock and nature and location of the alluvial aquifer/fractured bedrock interface (particularly in the southwest portion of the CZ where data gaps exist).

- Demonstrate containment of groundwater impacted by COCs at concentrations above the pMCL (or other RBCGs for chemicals without pMCLs) inside the South AFRL CZ by LTM of the groundwater to track contaminant migration. As appropriate, use monitoring data to update and refine groundwater flow and contaminant transport models, which currently project containment within the South AFRL CZ for at least 1,000 years.

TABLE 2.13-3. RISK-BASED INDOOR AIR VAPOR MITIGATION LEVELS (IAVMLS-IND) FOR EXISTING INDUSTRIAL BUILDINGS LOCATED WITHIN THE VICB FOR SITES 37, 120, 133, AND 321

Site	COC	IAVMLs-ind ($\mu g/m^3$)
37	PCE	1.7
37	TCE	5.1
120	PCE	1.7
133	TCE	5.1
321	PCE	1.7

Notes:

IAVML-ind corresponds to a 1 x 10^{-6} cancer risk for each COC under an industrial exposure scenario and these concentrations all exhibit an HI less than 1.0.

- Conduct a TEFA (as defined in Section III.G, State Board Resolution 92-49) and institute active containment measures to ensure that COCs do not migrate outside the CZ. The trigger for both actions would be the projected arrival (based on contaminant transport modeling as validated using actual sampling results) of impacted groundwater at the CZ boundary within the next 10 years; or the detection of any COC in groundwater samples from sentinel wells outside the CZ. The active containment measures may include (but are not limited to) GETs or in situ PRBs.

- Continue to review and evaluate technologies as part of the 5-year statutory review (described in Section 2.13.2.4) and report the results of this evaluation. If a promising technology is identified, which has been demonstrated to effectively treat the same types of chemicals at similar concentrations and in a similar hydrogeologic setting, conduct a field-test of the technology, at a cost not to exceed $250,000 (inflation-adjusted from the date of the ROD), to be executed by the following 5-year review. The Air Force may, at its discretion, consider a field test costing greater than $250,000. Where a field test produces promising results, the Air Force will further evaluate the technology for potential scale-up. If no promising technologies that meet the criteria specified above are identified for field testing within the first 30 years of remedy implementation, the Air Force will select, with agency input at the following 5-year review, a suitable field-test or other RA, for the equivalent inflation-adjusted $250,000 at either the South AFRL or another area at Edwards AFB.

Components of this remedy may change somewhat as a result of the remedial design process. Post-ROD changes to the remedy, if any, will be documented using a technical memorandum in the Administrative Record, and Explanation of Significant Differences (ESD) or a ROD Amendment, as applicable.

The following subsections describe the LUCs, LTM, vapor monitoring, and 5-year review components included in the selected remedy; and the 5-year review process.

2.13.2.1 LUC Implementation and Administration at Edwards AFB

The Air Force is committed to implement, monitor, maintain, and enforce remedies that protect human health and the environment in accordance with CERCLA and the NCP. The AFRL is a tenant of Edwards AFB. Land uses within the AFRL portion of the South AFRL CZ include testing rocket engines, extensive safety zones surrounding the test cells, and industrial, research, development, and administrative activities. The PIRA portion of the South AFRL CZ is used for aircraft flight testing, EOD, and placement of communication equipment; the STP used by AFRL facilities is located on the PIRA. The 95th Air Base Wing, Environmental Restoration Branch (95 ABW/CEVR) works closely

with the AFRL and PIRA facilities on all environmental issues; acts as a conduit to the USEPA and the State; and will be involved in LUC implementation.

Implementation

The selected remedy requires long-term LUCs to be in place for groundwater within the South AFRL CZ where contaminant levels do not allow for unlimited use and unrestricted exposure.

LUC measures to be used at the South AFRL are in accordance with specific provisions of 22 California Code of Regulations (CCR) Section 67391.1 that were determined by the Air Force to be RARs. Subsections (d), (e)(1), and (e)(2) of 22 CCR Section 67391.1 provide that if a remedy at property owned by the federal government will result in hazardous substances remaining on property at levels not suitable for unlimited use and unrestricted exposure, and it is not feasible to record a land use covenant (as is the case for the South AFRL CZ), then the ROD is to clearly define and include limitations on land use and other IC mechanisms to ensure that future land use will be compatible with the levels of hazardous substances remaining on the property.

For the South AFRL, LUCs will be of the following three types:

1. Groundwater use controls to protect receptors from exposure to extracted groundwater at concentrations of COCs (listed in Table 2.5-1) exceeding pMCLs or RBCGs (for chemicals without pMCLs). These LUCs, to be applied throughout the South AFRL CZ (within the boundary shown on Figure 2.1-2), include a) a prohibition on the drilling of new drinking water wells or the use of existing wells to extract groundwater for various purposes; b) allowances for the safety of underground or above ground contaminated groundwater conveyance lines, if operational; and c) access to locations for new wells related to the selected remedy or for the monitoring of existing wells within the South AFRL CZ boundary.

2. Prohibitions and/or restrictions to prevent unrestricted (residential) land use of areas where groundwater concentrations of COCs exceed the GWVCLs-res listed in Table 2.13-1, which are modeled to present an unacceptable cancer risk (greater than 1×10^{-6}) via the VIP into indoor air for residential use. The area requiring these more restrictive LUCs is shown as the VICB on Figure 2.7-1. Any new buildings constructed within the VICB must incorporate engineering controls to reduce risk via the VIP to less than 1×10^{-6} for the intended land use (residential or industrial). These controls may include, but are not limited to, actions such as sub-slab depressurization; installation of vapor barriers; foundation ventilation systems; and HVAC design.

3. Initiation of a monitoring program in areas where groundwater concentrations of COCs exceed the GWVCLs-ind listed in Table 2.13-2, which are modeled to present an unacceptable cancer risk (greater than 1 x 10^{-6}) via the VIP into indoor air for industrial use. The areas currently exceeding GWVCLs-ind are shown on Figure 2.7-1. Where a completed pathway is confirmed, and if measured indoor air concentrations of COCs exceed the risk-based indoor air vapor mitigation levels (IAVMLs-ind) listed in Table 2.13-3, activate appropriate mitigation measures (these may include, but are not limited to, actions such as continued monitoring, SVE, building controls such as sub-slab depressurization or HVAC modifications, foundation repairs or ventilation).

These limitations and mechanisms are more specifically set forth in this section of the ROD, to include annotating the residential development restrictions in the Base's GP, and continuing to follow the review and approval procedures for any construction and ground-disturbing activities within the South AFRL CZ boundary.

The following LUCs apply to groundwater within the South AFRL with VOC concentrations above GWVCLs-res for unrestricted use (i.e., presenting carcinogenic risks greater than 1 x 10^{-6} via the VIP for residential use) or with VOC concentrations above GWVCLs-ind (i.e., presenting carcinogenic risks greater than 1 x 10^{-6} via the VIP for the current industrial use). The objectives are to restrict sensitive uses (including residential building, child development centers [day care facilities], kindergarten through 12th grade [K-12] schools, play areas, and hospitals) where contamination is at levels that do not allow for unlimited use and unrestricted exposure and to maintain worker safety. These goals will be achieved through the following:

- Annotating the residential and industrial development restrictions in the GP (area inside the VICB);
- Prohibiting residential development (including residential building, day care facilities, K-12 schools, play areas, and hospitals) in designated areas (the VICB shown on Figure 2.7-1) set forth in the GP;
- Incorporating engineering controls into any new construction inside the VICB (refer to Figure 2.7-1) to prevent indoor air risks exceeding 1 x 10^{-6};
- Instituting a monitoring program for existing buildings where groundwater concentrations exceed GWVCLs-ind (these areas are outlined in orange on Figure 2.7-1);
- Implementing engineering controls at existing buildings where VOC concentrations in indoor air are confirmed to exceed IAVMLs-ind (Table 2.13-3) indicating a risk level of 1 x 10^{-6}; and

- Continuing administrative measures.

The administrative measures that restrict development are the Edwards AFB CE Work Clearance Request or Work Request procedures, and the Environmental Impact Assessment Process (EIAP). A Work Clearance Request is required for any project that involves mechanical soil excavation or drilling, such as digging trenches for underground lines, excavating soil for building foundations, or drilling to install groundwater monitoring wells. The permit lists the Safety, Health, and Environmental Office and other support offices that review the excavation plans for approval. If constraints involving soil disturbance or worker safety exist at the excavation area, the permit describes the appropriate procedures that will prevent unknowing exposure to groundwater contamination and measures the workers must implement before the start of excavation.

The Air Force will implement the following measures to prevent or control exposures via the VIP in that portion of the South AFRL CZ requiring LUCs for residential and industrial development:

- Include in the GP any specific restrictions required at each site, a statement that restrictions are required because of the presence of pollutants or contaminants, the current land users and uses of the site, the geographic control boundaries, and the objectives of the land use restrictions. Unless a site is cleaned up to levels appropriate for unlimited use and unrestricted exposure, the GP will reflect the prohibitions on residential development (including child development centers, K-12 schools, play areas, and hospitals). Upon completion of an RA at a site, the GP will be updated to modify the site-specific use restrictions as appropriate. The section describing the specific restrictions will also refer the reader to the Base Environmental Office if more information is needed. The GP will contain a map depicting the geographic boundaries where LUCs are in effect.

- Monitor and map groundwater plume migration for those plume contours that are at contaminant concentrations that present a potential cancer risk exceeding 1×10^{-6} in indoor air, via the modeled VIP for residential use (Table 2.13-1) and industrial use (Table 2.13-2) scenarios. These concentrations are termed GWVCLs-res and GWVCLs-ind, respectively, for the residential and industrial exposure scenarios. The initial VICB (Figure 2.7-1) set by this ROD is based on plume migration (corresponding to a cancer risk of 1×10^{-6} for unrestricted use) projected 30 years into the future by groundwater modeling. When subsequent plume migration modeling during a future Five Year Review predicts that the residential risk contours will exceed the current VICB in less than 10 years, revise the appropriate maps and information in the Base GP to show an enlarged area encompassed by the VICB with new boundaries based on an additional 30 years of predicted plume migration.

- Require that engineering controls to reduce risk via the VIP to less than 1 x 10^{-6} be incorporated into all new construction within the VICB shown on Figure 2.7-1. These controls may include, but are not limited to, actions such as sub-slab depressurization; installation of vapor barriers; foundation ventilation systems; and HVAC design.

- Initiate a sampling program (that may include soil vapor sampling adjacent to and/or beneath buildings) to assess whether the VIP is complete at existing buildings where groundwater contains chemical concentrations in excess of the GWVCLs-ind for Sites 37, 120, 133, and 321 (refer to Table 2.13-2). The areas currently exceeding GWVCLs-ind are shown on Figure 2.7-1. If a completed pathway is confirmed, periodically monitor indoor air for COCs in those existing buildings where groundwater contaminant concentrations exceed GWVCLs-ind. If measured indoor air COC concentrations exceed the risk-based IAVMLs-ind listed in Table 2.13-3, activate appropriate mitigation measures (these may include, but are not limited to, actions such as continued monitoring, SVE, building controls such as sub-slab depressurization or HVAC modifications, foundation repairs or ventilation).

- While LUCs are in place, maintain administrative control of the integrity of current and future remedial or monitoring systems and maintain existing administrative controls (presented in the subsequent section). LUCs shall remain in place as long as soil or groundwater contaminant concentrations remain above levels allowing for unlimited use and unrestricted exposure. The Air Force shall not modify or terminate LUCs, implementation actions, or modify land use without USEPA and State approval. The Air Force shall seek prior concurrence before any anticipated action that may disrupt the effectiveness of the LUCs or any action that may alter or negate the need for LUCs.

- Whenever the Air Force transfers real property that is subject to ICs and resource use restrictions to another federal agency, the transfer documents shall require that the federal transferee include the ICs, and applicable resource use restrictions, in its resource use plan or equivalent resource use mechanism. The Air Force shall advise the recipient federal agency of all obligations contained in the ROD, including the obligation that a State Land Use Covenant will be executed and recorded pursuant to 22 CCR Section 67391.1 in the event the federal agency transfers the property to a non-federal entity.

- Whenever the Air Force proposes to transfer real property subject to resource use restrictions and ICs to a non-federal entity, it will provide information to that entity in the draft deed and transfer documents regarding necessary resource use restrictions and ICs, including the obligation that a State Land Use Covenant will be executed and recorded pursuant to 22 CCR Section 67391.1. The signed deed will include ICs and resource restrictions equivalent to those contained in the State Land Use Covenant and this ROD.

- The Air Force will provide notice to USEPA and the State at least 6 months prior to any transfer or sale of the South AFRL area so that USEPA and the State can be involved in discussions to ensure that appropriate provisions are included in the transfer terms or conveyance documents to maintain effective ICs. If it is not possible for the facility to notify USEPA and the State at least 6 months prior to any transfer or sale, then the facility

will notify USEPA and the State as soon as possible but no later than 60 days prior to the transfer or sale of any property subject to ICs. In addition to the land transfer notice and discussion provisions above, the Air Force further agrees to provide USEPA and the State with similar notice, within the same time frames, as federal-to-federal transfer of property. The Air Force shall provide a copy of the executed deed or transfer assembly to USEPA and the State.

- The Air Force will notify the USEPA and the State at least 30 days in advance of any proposed land use changes that are inconsistent with LUC objectives or the selected remedy and any changes to the GP that would affect the LUCs.

- The Air Force will notify the USEPA and the State as soon as practicable, but no longer than 10 days after discovery of any activity that is inconsistent with LUC objectives or use restrictions, or any action that may interfere with the effectiveness of LUCs, as well as provide the USEPA and the State within 10 days of notification of the breach with a tentative plan (including a timeline of proposed actions and delivery dates) regarding how the Air Force will address the breach or with a description of how the breach has been addressed.

- Address as soon as practicable any activity that is inconsistent with LUC objectives or use restrictions or any other action that may interfere with the effectiveness of LUCs, but in no case will the process be initiated later than 30 days after the Air Force becomes aware of the breach.

- Monitoring of the environmental use restrictions and controls will be conducted annually by the Air Force. The monitoring results will be included in a separate report or as a section of another environmental report, if appropriate, and provided to the USEPA and the State. The annual monitoring reports will be used in preparation of the Five Year Review to evaluate the effectiveness of the remedy.

- The annual monitoring report, submitted to the regulatory agencies by the Air Force, will evaluate the status of the ICs and how any IC deficiencies or inconsistent uses have been addressed. The annual evaluation will address whether the use restrictions and controls referenced above were communicated in the deed(s), whether the owners and state and local agencies were notified of the use restrictions and controls affecting the property, and whether use of the property has conformed with such restrictions and controls.

The Air Force is responsible for remedy implementation and ensuring integrity of the remedy, implementing (to the degree controls are not already in place), monitoring, reporting on, maintaining, and enforcing the identified controls. If the Air Force determines that it cannot meet specific LUC requirements, it is understood that the remedy may be reconsidered and that additional measures may be required to ensure the protection of human health and the environment.

To assure the USEPA and the State and the public that the Air Force will fully comply with and be accountable for the performance measures identified herein, the Air Force will timely submit to the USEPA and the State the annual monitoring report on the status of LUCs and/or other RAs, including the O&M and monitoring thereof, and how any LUC deficiencies or inconsistent uses have been addressed. The report also will be filed in the information repositories. The report is not subject to approval and/or revision by USEPA and the State.

Availability of the Edwards AFB General Plan and Existing Administrative Procedures

The GP resides in the office of the Base community planner. Accordingly, the GP will be revised to include any specific restrictions required at each site, a statement that restrictions are required because of the presence of pollutants or contaminants, the current land users and uses of the site, the geographic control boundaries, and the objectives of the land use restrictions.

Any project requiring change in land use designation, and/or construction requires approval by the appropriate Environmental Management Office to ensure compliance with the GP.

The administrative measures are conducted as part of the EIAP 32 Code of Federal Regulations (CFR) 989.27, which ensures that potential environmental concerns are considered as early as possible in the USAF planning process. Only USAF-approved projects are allowed on base and they must be covered by one of the following documents: Air Force Flight Test Center (AFFTC) Form 5926 (EAFB CE Work Clearance Request), AF Form 332 (CE Work Request), or AF Form 813 (Request for Environmental Impact Analysis). The AFFTC Form 5926 is required for any project that involves mechanical soil excavation or drilling, such as digging trenches for underground lines, excavating soil for building foundations, or drilling to install groundwater monitoring wells. The permit process involves submitting and securing approval from the 95 ABW/CEVR office and other support offices that review the excavation plans. The procedures by which work clearance requests are evaluated include review of the GIS database to determine if a worksite falls within any ERP site boundary; this process will be modified to also evaluate if the proposed worksite is within a site boundary where LUCs are in effect. If constraints involving soil disturbance or worker safety exist at the excavation area, the permit describes the appropriate procedures that will prevent unknowing exposure to groundwater contamination and measures the workers must implement before the start of excavation.

AF Form 332, the CE Work Request, must be submitted and approved before the start of any building project on Edwards AFB. Approval of this form involves the comparison of the building site with the constraints in the GP. The Work Request serves as the document for communicating any construction constraints to the appropriate offices. Any constraints at the site result in the disapproval of the form unless the requester makes appropriate modifications to the building plans. The CE Work Management Office is responsible for the final approval of proposed building projects through the Configuration Control Board review process.

AFFTC Form 5926, the EAFB CE Work Clearance Request, will also be used to enforce the groundwater LUCs, as previously discussed. The requester submits AFFTC Form 5926 to the CE Customer Service, for any project that involves any mechanical soil excavation, and it is circulated to appropriate offices for review of needed safety procedures. The CE Real Estate Office is responsible for the final approval of excavation projects through the permit review process.

Work Request forms are subject to an EIAP review conducted pursuant to the National Environmental Policy Act (NEPA), as promulgated in 40 CFR Parts 1500-1508. The EIAP analysis is initiated when a proponent of a proposed action fills out an AF Form 813, Request for Environmental Impact Analysis. A proponent of an action is required to submit the AF Form 332 and/or AFFTC Form 5926 with AF Form 813 to 95 ABW/CEVR so that the appropriate environmental analysis of the proposed action and alternatives to the proposed action is accomplished prior to any construction activities. The environmental staff (air, water, cultural and natural resources, restoration, and others) and the Community Planner review AF Forms 332 and 813 in cases that involve facilities construction. Major new construction may result in a determination that a formal publicized Environmental Assessment is necessary. The EIAP process works to ensure proposed construction sites are reviewed in accordance with the GP. The process also ensures that all environmental factors, as well as the Base's ROD LUCs, are considered in siting construction projects.

The Air Force shall notify the USEPA and the State in advance of any changes to the GP and internal administrative procedures that would affect the LUCs.

Contaminant Levels at which LUCs are No Longer Needed

Based on the current industrial land use and the reasonably foreseeable, future long-term land use that is projected to be industrial, potential risks associated with ingestion and direct contact with COCs in groundwater are mitigated by the lack of complete exposure pathways; risks associated with inhalation of indoor air above IAVMLs-ind as listed in Table 2.13-3 will be mitigated using engineering controls. Within the South AFRL CZ, drinking water ARARs are waived; therefore, no cleanup levels are established within the South AFRL CZ. Until contaminant concentrations in groundwater at the South AFRL are reduced below pMCLs, ingestion of this water would pose a potential risk to human health because of pMCL exceedances. Therefore, pMCLs identified as those ARARs to be waived in Table 2.5-1 were selected as contaminant levels that must be reached before LUCs that prevent the use of groundwater inside the South AFRL CZ for its designated beneficial uses (municipal, agricultural, industrial, and freshwater replenishment) can be removed. GWVCLs-res in groundwater to meet a risk level of 1×10^{-6} for unrestricted use, as listed in Table 2.13-1, are the contaminant levels that must be reached before LUCs to prevent exposure to indoor air concentrations inside the VICB can be lifted. GWVCLs-ind in groundwater to meet a risk level of 1×10^{-6} for industrial use, as listed in Table 2.13-2, are the contaminant levels that must be reached before LUCs requiring monitoring and potentially further actions (e.g., building controls) to protect workers inside the VICB can be lifted.

Based on the CSM presented for the South AFRL including simulations of the groundwater flow and contaminant transport model, there is little likelihood that drinking water pMCLs or 10^{-6} GWVCLs-res for the VIP will be achieved within 100 years or less. Therefore, LUCs required as part of the selected remedy for the South AFRL CZ are anticipated to be in place long-term. However, should groundwater at the South AFRL achieve the ARARs listed in Table 2.5-1 and the GWVCLs-res listed in Table 2.13-1, then the South AFRL will be available for unlimited use and unrestricted exposure, and there would no longer be any need to establish, maintain, monitor, report on, or enforce LUCs. The USEPA and State agree to delete LUCs requirements when site contaminant levels are reduced to a level that allows for unrestricted use.

2.13.2.2 Groundwater Monitoring (LTM)

Groundwater monitoring will be conducted to verify plume containment within the South AFRL CZ, track the migration of groundwater contaminants within the South AFRL CZ, and allow refinement of

the groundwater flow and contaminant transport models. Inside the VICB (Figure 2.7-1), groundwater monitoring results will be used to update areas with groundwater concentrations exceeding the GWVCLs-ind (Table 2.13-2), which trigger a monitoring program for soil vapor and/or indoor air; and to update areas with groundwater concentrations exceeding the GWVCLs-res (Table 2.13-1) for potential re-sizing of the VICB during future 5-year reviews. LTM will be conducted by sampling existing and future wells at Sites 37, 120, 133, and 321 for site chemicals of concern in accordance with post-ROD documents and consistent with the LTM Strategy for the AFRL.

Selected wells, chosen for their locations at critical points within the plumes and for the depth intervals over which they are screened, will be sampled at regular intervals (as specified in post-ROD documents to include the RA work plan and O&M plans) as part of the LTM program. Wells to be included in the LTM program will be selected based on the following criteria:

- Sentinel wells at locations near the downgradient edges of the contaminant plume; data from these wells will be used to assess the rate of contaminant migration into previously uncontaminated groundwater and to validate protectiveness of the VICB;
- Source area wells near the point(s) of contaminant release that generally exhibit the highest concentrations within the plumes;
- Wells inside contours exceeding GWVCLs-ind, particularly those in proximity to existing buildings;
- Mid-plume wells exhibiting intermediate contaminant concentrations; and
- Vertical extent wells to monitor lower water-bearing zones.

Periodically (at least every 5 years), a larger number of wells will be sampled to update contaminant concentration contours. These updates will allow for comparison of contaminant trends to computer simulations based on groundwater flow and contaminant transport models.

The existing monitoring well network a) will be maintained in proper working condition; and b) rehabilitated as necessary to prevent bio-fouling and sediment buildup. Additional wells will be installed per the California Well Standards and added to the monitoring network as necessary if it is determined in the future that the existing well network does not have a well in the proper location or screened in the correct interval to track plume movement.

Periodic monitoring reports providing the results of LTM will be prepared and submitted to USEPA and the State. These monitoring reports will be filed in the information repositories for the South AFRL and used in preparation of the 5-year reviews to evaluate the effectiveness of the remedy.

2.13.2.3 Soil Vapor and Indoor Air Monitoring

Where existing buildings overlie groundwater concentrations of PCE and TCE exceeding GWVCLs-ind as listed in Table 2.13-2, a vapor monitoring program will be initiated 1) to evaluate whether the VIP is complete for the existing buildings; and/or whether VOC concentrations inside the buildings exceed IAVMLs-ind listed in Table 2.13-3; and 2) to provide ongoing evaluation of the effectiveness of any engineering controls implemented to disrupt the VIP. Details for implementation of this monitoring program will be developed during preparation of post-ROD documents.

Results from the soil vapor and indoor air monitoring program will be included in the monitoring reports that provide the results of LTM as described in Section 2.13.2.2.

2.13.2.4 5-Year Reviews

Reviews will be performed every 5 years for as long as contaminants remain in groundwater at the South AFRL at levels that do not allow for unrestricted use (NCP Section 300.430(f)(4)(ii)). The 5-year reviews and associated groundwater monitoring data will be placed in the post-ROD Administrative Record for the South AFRL. Supporting documentation, including groundwater monitoring results, will be used to evaluate the remedy's effectiveness in meeting the primary RAOs, confirm that no contaminants migrate outside the South AFRL CZ, and otherwise assess whether human health and the environment are adequately protected by the implemented RA.

In addition, these 5-year reviews will include (as needed) validation of the groundwater flow and contaminant transport model and validation of the extent of the VICB (Figure 2.7-1). When contaminant transport modeling predicts the migration of plume contours exceeding the GWVCL-res (refer to Table 2.13-1) will exceed the current VICB in less than 10 years, the Base GIS and the Base GP will be revised to show an enlarged VICB with the new boundary based on an additional 30 years of predicted plume migration. Finally, as listed in the final bullet of Section 2.13.2, the Air Force is

committed to a continuing review of technologies and, if a promising technology is identified (that has been demonstrated to the AF to effectively treat the same types of chemicals at similar concentrations and in a similar hydrogeologic setting), will conduct a field test, at a cost not to exceed $250,000 (inflation-adjusted), to be executed by the following 5-year review.

2.13.3 SUMMARY OF THE ESTIMATED REMEDY COSTS

The information in this cost estimate is based on the analysis completed in the South AFRL Focused FS to satisfy RAOs 1 and 3 (refer to Sections 2.8 and 2.9) and is the best available information regarding the anticipated remedial alternative scope. Changes in the cost elements are likely to occur as a result of new information and data collected during the remedial alternative engineering design. Major changes may be documented in the form of a memorandum in the Administrative Record file, an ESD, or a ROD amendment. This is an order-of-magnitude engineering cost estimate that is expected to be within the range of 50% above and 30% below the actual project cost.

The project duration is unknown but expected to exceed 100 years; project duration will be based upon the results of LTM. Cost estimates are provided only for the first 30 years. It is anticipated that within the first 30 years, data obtained during 5-year reviews will be used to refine the long-term cost estimate.

2.13.3.1 Cost Estimates

The cost estimates prepared for the South AFRL Focused FS, and summarized here, represent two cost types: capital costs and O&M costs. Capital costs are associated with the construction and initial implementation of an RA and do not include costs associated with long-term operation. The costs include labor, equipment, material costs, contractor markups, mobilization/demobilization, site work, installation, disposal, and expenditures for supporting professional/technical services associated with construction of the RA. For the selected alternative, one-time capital costs were excluded because no capital construction is anticipated. Further details are provided in Appendix H of the South AFRL Focused FS.

O&M costs are those post-construction costs incurred to verify the effectiveness of an RA. O&M costs were estimated for each year and include labor, equipment, material costs and contractor markups associated with monitoring and professional/technical services.

O&M cost components for the selected remedy identified as Alternative 2 on Table 2.10-1 include LTM, LUCs, and O&M (storage and testing) of the GETS estimated at approximately $10.1 million ($3.4 million in PV) for the first 30 years. Costs associated with LTM include annual to biennial sampling of up to 44 existing monitoring wells for 30 years to assess the migration of the contaminants of concern. The LUC costs include annual GIS system maintenance as part of a base-wide system. The GETS O&M costs include costs for long-term storage of system components, and periodic reactivation to test operation. Although proposed as a contingency measure in the FS and PP, this element (GETS maintenance in an operable condition) has been dropped in the ROD as a component of the selected remedy, resulting in a cost savings of approximately $250,000. However, costs to decommission the two GETS systems will partially offset this savings.

Periodic costs generally occur either 1) once every few years or 2) once during the remedial timeframe (e.g., at site closeout). Periodic costs were not included in the South AFRL Focused FS but have been added to costs presented in Table 2.13-4 prepared for this ROD. The periodic costs assumed for RA at the South AFRL are associated with 5-year reviews in Years 6, 11, 16, 21, and 26 (comprehensive LTM sampling events in Years 1, 6, 11, 16, 21, and 26 were already factored into the LTM costs). One-time site closeout activities are not anticipated during the first 30 years of this RA.

Not included in Table 2.13-4 are costs associated with remedy components to address risks via the VIP (i.e., monitoring of soil vapor and indoor air and implementation of engineering controls to disrupt the VIP); these costs will be developed during preparation of post-ROD documents. Also not included are periodic costs (not to exceed $250,000 per event, inflation-adjusted) to conduct field tests of promising technologies with demonstrated effectiveness at treating similar concentrations in similar hydrogeologic conditions. The Air Force will program and execute these field studies within 5 years of identifying such a technology.

TABLE 2.13-4. SUMMARY OF ESCALATED COSTS AND PRESENT VALUE OF SELECTED REMEDY

Year	LTM [(a)]	LUCs	GETS O&M [(b)]	5-Year Reviews (Reports)	Escalated Total	Present Value Total
1	$425,485	$5,571	$1,501	-	$449,297	$432,557
2	$181,327	$5,571	$7,399	-	$205,178	$181,668
3	$181,327	$5,571	$6,005	-	$207,313	$168,404
4	$181,327	$5,571	$7,399	-	$212,600	$158,546
5	$181,327	$5,571	$11,582	-	$221,107	$151,440
6	$425,485	$5,571	$6,005	$44,855	$546,493	$343,606
7	$181,327	$5,571	$7,399	-	$224,277	$129,402
8	$181,327	$5,571	$6,005	-	$226,680	$120,179
9	$181,327	$5,571	$7,399	-	$232,438	$113,081
10	$181,327	$5,571	$18,554	-	$250,179	$111,766
11	$425,485	$5,571	$6,005	$44,855	$597,383	$244,813
12	$181,327	$5,571	$7,399	-	$245,203	$92,291
13	$181,327	$5,571	$6,005	-	$247,842	$85,649
14	$181,327	$5,571	$7,399	-	$254,102	$80,633
15	$181,327	$5,571	$11,582	-	$264,236	$77,010
16	$425,485	$5,571	$6,005	$44,855	$652,803	$174,454
17	$181,327	$5,571	$7,399	-	$267,625	$65,867
18	$181,327	$5,571	$6,005	-	$270,083	$61,150
19	$181,327	$5,571	$7,399	-	$276,446	$57,512
20	$181,327	$5,571	$18,554	-	$297,001	$56,910
21	$425,485	$5,571	$6,005	$44,855	$707,597	$124,334
22	$181,327	$5,571	$7,399	-	$289,716	$47,020
23	$181,327	$5,571	$6,005	-	$292,017	$43,596
24	$181,327	$5,571	$7,399	-	$298,537	$40,997
25	$181,327	$5,571	$11,582	-	$309,490	$39,101
26	$425,485	$5,571	$6,005	$44,855	$762,391	$88,673
27	$181,327	$5,571	$7,399	-	$311,808	$33,419
28	$181,327	$5,571	$6,005	-	$313,950	$31,057
29	$181,327	$5,571	$7,399	-	$320,629	$29,145
30	$181,327	$5,571	$18,554	-	$343,721	$28,969
Totals	$6,904,758	$167,130	$246,752	$224,275	$10,098,141	$3,413,248

Notes:

Present value costs are derived using discount factors calculated using the formula $1/(1 + i)^t$, where i=0.07 (discount factor rate) and t=year (USEPA 2000b). Cost estimates used a 7% discount rate instead of 3.1% as recommended by the USEPA guidance, which would have increased the PV Costs by 8 to 50%.

[(a)] The costs provided in this table assume an average of 36 wells sampled annually and 121 wells sampled every 5 years.
[(b)] GETS O&M costs include costs for long-term storage of system components, and periodic reactivation to test operation.

%	percent	O&M	operation and maintenance
GETS	groundwater extraction treatment system	PV	present value
LTM	long term monitoring	USEPA	United States Environmental Protection Agency
LUCs	land use controls		

2.13.3.2 Escalation and Present Value

The estimated costs including non-discounted (escalated) and PV costs are presented in Table 2.13-4. Escalation is a cost adjustment used to account for the change of labor rates, productivity, and material prices that occur between the cost estimate date and the date on which work will be performed. For non-discounted costs, an escalation factor was applied to each year's total expenditures for the duration of the project.

PV analysis is a method to evaluate expenditures that occur over varying project durations. This methodology allows for cost comparisons of different remedial alternatives on the basis of a single cost figure for each alternative. The "present value" is the amount needed to be set aside at the project outset to assure that funds will be available for the entire project. A discount rate is used in the PV analysis to adjust for the potential productivity and increasing value of money, assuming positive-return investments. A 7% discount factor was used to calculate PV costs for the South AFRL Focused FS; note that per USEPA (2000b) guidance a 3.1% discount factor should have been used instead (see footnote to Table A-7 in Appendix A). To evaluate the impact of this error, the PV costs for each alternative were re-calculated using the 3.1% discount rate; Table A-7 in Appendix A provides a comparison of PV costs using both discount rates (i.e., 3.1% versus 7%). Based on this evaluation, use of the lower discount rate would have resulted in cost estimates approximately 8 to 50% higher than the PV costs presented in Table 2.13-4.

The total PV of the selected remedy (including periodic costs for the 5-year reviews) is estimated to be approximately $3,410,000. The value of the selected remedy is higher than Alternative 1 (no action), but significantly lower (weighing heavily in the selection decision) than Alternatives 3, 4, or 5.

2.13.4 EXPECTED OUTCOME OF THE SELECTED REMEDY

The selected remedy for the South AFRL will address risks presented by the potential dermal, inhalation, and ingestion pathways of exposure to extracted groundwater and will provide for protection of workers during remedy implementation. The selected remedy will also address the potential risks to human health from inhalation of indoor air containing VOCs above acceptable risk levels by 1) restricting the use of the land and groundwater to prohibit sensitive and residential uses within the VICB (Figure 2.7-1); 2) requiring all new construction within the VICB to incorporate

engineering controls to reduce risk via the VIP to less than 1 x 10^{-6}; 3) requiring soil vapor and/or indoor air monitoring to assess risk to occupants in existing buildings overlying groundwater with PCE or TCE at concentrations that exceed GWVCLs-ind (refer to Table 2.13-2); and 4) requiring mitigation in existing buildings where PCE or TCE is confirmed in indoor air samples at concentrations exceeding IAVMLs-ind that represent a risk level of 1 x 10^{-6} (refer to Table 2.13-3). The selected remedy will not reduce contaminant concentrations below pMCLs in the groundwater within the South AFRL CZ, but will include LTM to verify that contaminants do not migrate outside the South AFRL CZ boundary.

The selected remedy for the South AFRL maintains the current industrial land use with minimal impact on current or anticipated (industrial) uses within the South AFRL, and will meet the primary RAOs. Groundwater within the South AFRL CZ will not be restored in a reasonable timeframe so that remedy components (LTM and LUCs) will be required for an indefinite time period (greater than 100 years). Beneficial groundwater uses will not be available for an indefinite time period. However, risk will be reduced by the LUCs that will prevent exposure to groundwater contaminants by maintaining the current incomplete exposure pathways.

Minimal environmental impacts are expected from implementation of the selected alternative. It will have no adverse impacts on ecological or cultural resources. No adverse human health impacts from the RA are anticipated to occur on or off Base. No local socioeconomic or community revitalization impacts are anticipated.

An alternative remedial strategy such as a CERCLA TI Waiver remains in effect so long as that strategy remains protective of human health and the environment. Protectiveness in this context encompasses long-term reliability of the remedy. If the conditions of protectiveness or reliability cease to be met, additional RAs must be implemented to enhance or augment the existing remedy. The protectiveness of an alternative remedial strategy must be ensured through a monitoring program designed to detect releases from containment areas, migration of contaminants to water supply wells, or other releases that would indicate a possible failure of one of the remedy components. The monitoring data must be provided to the USEPA on a regular basis to ensure adequate performance of the alternative remedy.

The Air Force will conduct a full assessment of the protectiveness of the alternative remedy at least every 5 years at any site where contamination remains above levels that allow for unrestricted use. During this 5-year review period, the effectiveness of any ongoing source area removal actions will also be evaluated.

2.14 STATUTORY DETERMINATIONS

Under CERCLA Section 121 and the NCP, the lead agency must select remedies that are protective of human health and the environment, comply with ARARs (unless a statutory waiver is justified) are cost-effective, and use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. Section 121(e) of CERCLA, United States Code (USC) Section 9621(e), states that no federal, state, or local permit is required for RAs conducted entirely on site; these actions must meet the substantive but not administrative requirements of the ARARs. In addition, CERCLA includes a preference for remedies that employ treatment that permanently and significantly reduces the volume, toxicity, or mobility of hazardous wastes as a principal element and a bias against off-site disposal of untreated wastes. The following statutory determinations apply to the RA selected in this ROD for groundwater at the South AFRL.

2.14.1 PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The selected remedy, Alternative 2 - TI Waiver, No Active Containment, LTM, and LUCs will protect human health and the environment by maintaining the current incomplete exposure pathways (i.e., dermal contact and ingestion of groundwater) via access restrictions (LUCs) that prevent contact with or use of contaminated groundwater inside the South AFRL CZ; and by employing LUCs and engineering controls to prevent exposure above a risk level of 1×10^{-6} to VOCs in indoor air via the VIP. Potential risks to ecological receptors are not posed by site-related substances due to the absence of exposure mechanisms and land use conditions, and no change in that status, land use, or groundwater use are anticipated. The groundwater at the South AFRL, should it ever be used as a drinking water source, would present an unacceptable risk. Localized zones of DNAPL serve as a principal threat that continues to contaminate groundwater. However, it is not technically practicable to restore the groundwater to unrestricted use (drinking water levels) or to remove the DNAPL from fractured granitic bedrock. The RA the USAF is selecting for the groundwater contamination at the

South AFRL invokes a TI waiver of drinking water ARARs within a zone where containment via natural processes is projected for 1,000 years; and provides for LTM, and thus verification mechanisms, to confirm that the principal threat and dissolved-phase plume are contained within the South AFRL CZ and exposure pathways remain incomplete via LUCs. Implementation of the selected remedy will not pose unacceptable short-term risks or cross-media impacts. The current South AFRL industrial activities will be maintained, and the selected alternative will not impact current or anticipated (industrial) South AFRL uses.

The selected remedy will address the potential risks to human health from inhalation of indoor air containing VOCs above acceptable risk levels by 1) restricting the use of the land and groundwater to prohibit sensitive and residential uses within the VICB (Figure 2.7-1); 2) requiring all new construction within the VICB to incorporate engineering controls to reduce risk via the VIP to less than 1×10^{-6}; 3) requiring soil vapor and/or indoor air monitoring to assess risk to occupants in existing buildings overlying groundwater with PCE or TCE at concentrations that exceed GWVCLs-ind (refer to Table 2.13-2); and 4) requiring mitigation in existing buildings where PCE or TCE is confirmed in indoor air samples at concentrations exceeding IAVMLs-ind that represent a risk level of 1×10^{-6} (refer to Table 2.13-3).

2.14.2 COMPLIANCE WITH ARARS

The selected remedy will comply with all federal and state ARARs identified for the RA for the South AFRL groundwater contaminant plumes (Appendix D), except for those ARARs that are being waived (Table 2.5-1) based on technical impracticability from an engineering perspective. The specific ARARs that shall apply to this RA, and the ARARs that are subject to TI waiver, are listed and discussed in Appendix D of this ROD. The TI waiver applies only to groundwater to a depth of 500 feet bgs within the South AFRL CZ (Figure 2.1-2) as defined by this ROD.

2.14.2.1 Chemical-Specific ARARs

Chemical-specific ARARs are promulgated, health- or risk-based numerical values that, when applied to site-specific conditions, establish acceptable concentrations of a chemical that may be found in, or discharged to, the ambient environment. If a chemical has more than one cleanup level, the most stringent level is identified as an ARAR (to be met or waived) for this RA. Because the Water Board

considers the South AFRL to be within Antelope Valley Basin 6-44, and the Basin Plan lists "municipal" among the designated beneficial uses of groundwater in this basin, substantive provisions of the following requirements were identified as the most stringent of the potential federal and state groundwater ARARs for South AFRL remedial actions:

- Federal pMCLs listed in the Safe Drinking Water Act (SDWA) (Item 1 in Table D-1);
- State pMCLs in 22 CCR (Item 1 in Table D-1); and
- WQOs in the Basin Plan (Item 2 in Table D-1).

Based on the information presented in Section 2.5.8, the selected alternative waives state and federal pMCLs inside the South AFRL CZ. The ARARs to be waived are identified on Table 2.5-1.

The Air Force has determined that the SWRCB Resolution 92-49 requirement to "clean up and abate the effects of discharges in a manner that promotes attainment of either BG water quality, or the best water quality which is reasonable if background levels of water quality cannot be restored" is not an ARAR for the purpose of this RA. Notwithstanding that determination (see Air Force, USEPA, and State of California positions discussed below), the Air Force has met the intent of elements of SWRCB Resolution 92-49 Section III.H as documented in Table E-1 in Appendix E. A CZ authorized in accordance with SWRCB Resolution 92-49 Section III.H is defined as "a specific portion of a water bearing unit where the Regional Water Board finds it unreasonable to remediate to the level that achieves water quality objectives. The discharger is required to take all actions necessary to prevent the migration of pollutants beyond the boundaries of the CZ in concentrations which exceed the water quality objectives." The term "CZ" used in this ROD is that zone within which the TI waiver of pMCLs will apply.

Air Force's Position

The Air Force's position is that all RAs under CERCLA must, as a threshold matter, be determined by the lead agency to be necessary to protect human health and/or the environment from unacceptable risk, and further be appropriate and relevant to the circumstances of a site release (42 USC Section 9621(a)(1) and (d)(1)). Both CERCLA and the NCP focus on cleaning up contaminated groundwater, where practicable and achievable within a reasonable timeframe, to a level that will

restore the designated uses of the groundwater, not to the lowest level achievable regardless of risk (42 USC Section 9621(d)(2)(B)(i) and 40 CFR Section 300.430(a)(1)(iii)(F)). Accordingly, California non-degradation provisions (to include SWRCB Resolutions 68-16, 92-49 and the Basin Plan) that are based on maintaining high quality waters with maximal beneficial uses or achieving BG or the lowest cleanup level that is technically and economically achievable, are not risk-based, necessary, appropriate or relevant to returning contaminated groundwater to a drinking water level of service; and, therefore, they are not eligible to be considered as potential ARARs.

Without prejudice to the Air Force's position above, the California non-degradation provisions are not applicable because they 1) are directed toward state agencies who in turn are directing cleanup under state law, whereas this is a federal CERCLA cleanup action where the state is a support agency; or 2) apply to current discharges as opposed to historic releases or further migration of such releases; or 3) apply to specific, discrete regulated units that received hazardous waste after July 26, 1982. None of these apply here.

The non-risk-based narrative and numerical goals and objectives - e.g., the Basin Plan Water Quality Objectives (WQOs) which include secondary MCLs (sMCLs) and Notification Levels (NLs) - of the State non-degradation provisions also are not relevant and appropriate requirements (RARs) because: 1) MCL goals that are set at zero are categorically not relevant and appropriate (40 CFR Section 300.430(e)(2)(i)(C)) and as background for the hazardous substances in issue at Edwards AFB South AFRL would be zero, such background provisions in California non-degradation provisions are similarly not relevant and appropriate; and 2) the NCP (40 CFR Section 300.430(e)(2)(i)(C) and 40 CFR Section 300.400(g)(2)(viii)) requires that groundwater cleanup goals be based on beneficial uses, whereas the California non-degradation provisions - including the Basin Plan WQOs - require cleanup levels be set at zero or the lowest level technically and economically feasible, regardless of beneficial uses.

While not recognizing Resolution 68-16 as an ARAR, the Air Force in order to meet the intent of Resolution 68-16 commits to conducting a TEFA, in accordance with the fourth groundwater remedy component listed in Section 2.13.2, at a future time when impacted groundwater is projected to arrive at the CZ boundary within the next 10 years.

With respect to Subsection III.H of Resolution 92-49, the Air Force has determined that it is not an ARAR for three reasons. First, it is directed at the State of California and not responsible parties at CERCLA sites. Second, it is vague and doesn't set a standard as III.H merely states that there should be "reasonable mitigation measures" for "significant adverse environmental impacts attributable to the discharge." Third, it contains language that would allow the Board to overrule a Federal lead agency's determination (the USAF at OUs 4 and 9 or USEPA at other CERCLA sites) that an ARAR waiver is appropriate as it states:

> Approval of Technical Impracticability Waivers by the Department of Toxic Substances Control or the United States Environmental Protection Agency under the requirements of … [CERCLA] are deemed to be equivalent to the actions outlined in Section H. of this Policy if:
>
> - The substantive provisions of Sections III.H.2.b., e., f., and g. are met;
> - Interested parties described in III.H.8.a. are included in the public participation process; and
> - Site information is forwarded from the approving agency to the Regional Water Board so that sites for which Technical Impracticability Waivers have been approved can be included in the master listings described in Section III.H.10.

In summary, the only provisions of the California regulations that are ARARs are those that are substantive, more stringent than federal standards, and consistent with CERCLA groundwater cleanups (see 42 USC Section 9621(d)(2)(A)(ii)) – namely 1) risk-based concentrations protective of human health and the environment and 2) standards tied to beneficial uses. Since groundwater has been designated by the CRWQCB as "MUN" – municipal water supply – then the relevant standards are federal and state primary drinking water standards (i.e., federal and state pMCLs). State WQOs that are not health-risk based (e.g., based on esthetics, such as taste, color or odor or administrative reporting levels, such as NLs) are not ARARs under CERCLA.

USEPA's Position Regarding State Requirements as ARARs for the South AFRL

Only State standards, requirements, criteria, or limitations that have been promulgated under state environmental or facility-siting laws that are more stringent than federal ARARs and that have been identified by the State of California in a timely manner are potential state ARARs.

With regard to the Basin Plan, it is the USEPA's position that only those parts of the Basin Plan which set out the designated uses (beneficial uses), and the water quality criteria based upon such uses (WQOs), meet the NCP's definition of substantive standards. Other parts of the Basin Plan express general goals and/or enumerate factors that the Regional Boards consider in the process of enforcing water quality standards; these do not set standards themselves.

With regard to SWRCB Resolution 92-49, only Section III.G has substantive standards that are potentially relevant and appropriate to CERCLA groundwater cleanups. The first three pages of SWRCB Resolution 92-49 contain the whereas clauses, followed by Sections I and II which state the policies and procedures that the Regional Boards apply in overseeing cleanups.

Likewise, Sections III.A through E simply enumerate the factors the Regional Boards have to consider in implementing cleanups. Section III.F requires the Regional Board to require cleanup actions to conform to Resolution 68-16 and implement the provisions of CCR Title 23 Chapter 15 that are applicable to the cleanup activity. While Resolution 68-16 and CCR Title 23 Chapter 15 regulations have substantive requirements that impact cleanup standards, these two state requirements have to be analyzed in and of themselves as to whether they are potential ARARs, independent of their incorporation by reference to SWRCB Resolution 92-49. It is the USEPA's position that Resolution 68-16 is an ARAR when setting limits for discharge or reinjection into groundwater. It is not an ARAR for setting aquifer cleanup standards in CERCLA groundwater cleanup. This is because the USEPA does not believe that continuing migration of contamination in groundwater is a "discharge" subject to Resolution 68-16. Regarding CCR Title 23 Chapter 15, it is the USEPA's position that CCR Title 23 Chapter 15 has limited applicability to CERCLA cleanups because of the exemption language in Section 2511(d) which generally exempts cleanups taken by or at the direction of public agencies. Incorporation of Resolution 68-16 and CCR Title 23 Chapter 15 into SWRCB Resolution 92-49 does not broaden the applicability of these two state regulations outside these parameters.

With regard to secondary MCLs, the USEPA has consistently stated that these are not ARARs because they are not promulgated federal environmental standards that go to the protection of human health and the environment. Even when promulgated by the State, secondary SMCLs address taste and odor. The USEPA considers taste and odor cosmetic, not health-based environmental standards. The NCP

remedy selection process is founded on CERCLA's overarching mandate to protect human health and the environment.

State of California's Position Regarding State Requirements

The State of California has identified certain provisions of the Porter-Cologne Water Quality Act (Water Code section 13000 et seq.), SWRCB Resolutions 68-16 and 92-49, and Chapter 15 of Title 23 as proposed ARARs for determining cleanup levels in the groundwater at Edwards AFB. The Air Force and the State disagree about whether these state requirements are ARARs for this cleanup.

First of all, there are numerous provisions of the Porter-Cologne Water Quality Act that are ARARs, namely, Water Code sections 13000, 13172, 13240, 13241, 13242, 13243, 13267, and 13304. These statutes do provide authority for other ARARs (e.g., the Basin Plan) and these statutes do impose requirements in and of themselves and are therefore ARARs.

Pertaining to SWRCB Resolution 68-16, Resolution 68-16 is an ARAR for the injection or any discharge of waste or proposed discharge of waste into groundwater and is not strictly limited to a discharge of waste to treat contaminants. Waste is defined pursuant to Water Code section 13050, subdivision (d). Pursuant to Water Code section 13050, subdivision (d), the definition of "waste" is extremely broad and includes the injection of one or more chemicals to groundwater to the extent that there is a discharge to an "area of land."

A discharge also occurs where polluted groundwater migrates to areas of higher or high quality groundwater. Discharges subject to Resolution 68-16 include the continuing migration of any *in-situ* treatment reagents or other waste as defined in Water Code Section 13050, subdivision (d) from the injection wells to groundwater. Under Resolution 68-16, some degradation may be allowed so long as the cleanup action applies best practicable treatment and control to prevent further migration of waste to waters of the State at levels that exceed water quality objectives or impact beneficial uses. "Waters of the State" includes surface water and groundwater pursuant to Water Code Section 13050, subdivision (e). This Resolution is applicable or relevant and appropriate with regard to the migration of waste beyond the containment zone boundary.

Third, with respect to SWRCB Resolution 92-49, the State asserts that this resolution is an applicable requirement for remedial actions of the contaminated groundwater and complies with California Code of Regulation, title 23, section 2550.4. Furthermore, the State does not believe that the application of SWRCB Resolution 92-49 is strictly limited to Section III.G. In this case, SWRCB Resolution 92-49 requires remediation of the contaminated groundwater to the lowest concentration levels of constituents technically and economically feasible, which must at least protect the beneficial uses of groundwater, but need not be more stringent than is necessary to achieve background levels of the constituents in groundwater. Further, Section III.H is applicable with regard to the proposed containment zone as it applies to Technical Impracticability waivers approved by U.S. EPA.

With respect to California Code of Regulations, Title 23, Division 3, Chapter 15, the State asserts that these provisions are ARARs because they regulate all discharges of hazardous waste to land that may affect water quality. A "waste management unit" is defined in California Code of Regulations, Title 23, Chapter 15 as "an area of land, or a portion of a waste management unit, at which waste is discharged" (California Code of Regulations, title 23, section 2601). Pursuant to Water Code section 13050, subdivision (d), the definition of "waste" is extremely broad.

California Code of Regulations, title 23, section 2550.4 requires the consideration of beneficial uses when establishing cleanup levels above background. The factors that are to be considered by Edwards AFB in performing a technical and economic feasibility analysis (TEFA) for groundwater are listed under Section 2550.4, subdivision (d). Section 2550.6 requires monitoring for compliance with remedial action objectives for 3 years from the date of achieving cleanup levels. In order to allow the further degradation of waters of the state beyond the containment zone boundary, it is necessary to first establish that some degradation is appropriate under SWRCB Resolution No. 68-16 and then to determine the allowed concentrations for each constituent of concern after compliance with SWRCB Resolution No. 92-49. Section 2550.10 requires implementation of corrective action measures that ensure California Code of Regulations, Title 23, Chapter 15 cleanup levels are achieved through the zone affected by the release by removing waste constituents or by treating them in place.

In addition, the SWRCB has promulgated regulations pertaining to the treatment, storage, processing, and disposal of solid waste (non-hazardous solid waste and designated waste). Although Title 27 provisions

are similar to those found in Title 23, the applicability of certain sections within either title will depend on the characterization of the waste.

With respect to the Basin Plan, the State asserts that Chapter 2, *Beneficial Uses,* and the sections in Chapter 4, *Implementation* entitled "Requirements for Site Investigation and Remediation" and "Cleanup Levels" are ARARs and apply to determine the appropriate cleanup level in groundwater to protect beneficial uses and to meet the water quality objectives.

With respect to secondary MCLs, the State asserts that the taste and odor WQO specified in the Basin Plan for the Lahontan Region, which incorporates State primary and secondary drinking water standards, is an ARAR that applies to the establishment of cleanup levels. In particular, secondary MCLs for taste and odor based on drinking water standards specified in Table 64449-A (Secondary Maximum Contaminant Levels - Consumer Acceptance Limits) and Table 64449-B of Section 64449 (Secondary Maximum Contaminant Levels - Ranges) of the Basin Plan are ARARs.

In short, (1) certain provisions of the Porter-Cologne Water Quality Control Act (noted above); (2) SWRCB Resolution 92-49; (3) SWRCB Resolution 68-16; (4) Chapter 2, Beneficial Uses, Chapter 3, Water Quality Objectives, and the Sections "Requirements for Site Investigation and Remediation" and "Cleanup Levels" from Chapter 4, *Implementation,* of the Basin Plan; (5) California Code of Regulations, Title 23, Division 3, Chapter 15; and (6) secondary MCLs are applicable requirements because they specifically address remedial actions taken in order to protect the quality of the waters of the State. They are substantive requirements that are legally enforceable, of general applicability, and more stringent than federal requirements.

Summary

The Air Force prepared a Focused FS to support a Technical Impracticability Evaluation for groundwater restoration at the South AFRL. The Focused FS also incorporated elements (including Volume II, a Management Plan) to meet the intent of a CZ in accordance with SWRCB Resolution 92-49 Section III.H. While the Air Force, the USEPA, and the State disagree on whether any portion, or all, of California SWRCB Resolutions 68-16 and 92-49 are ARARs for the South AFRL action, and on which WQOs identified in the Basin Plan ARARs, all parties agree to a TI waiver of the state and Federal pMCLs listed in bold in Table 2.5-1 within the South AFRL CZ shown on Figure 2.1-2; and with the selected remedy as summarized in Sections 2.13 and 2.13.2.

2.14.2.2 Location-Specific ARARs

Location-specific ARARs are restrictions on the concentrations of hazardous substances or on activities solely because they are in specific locations such as floodplains, wetlands, historic places, and sensitive ecosystems or habitats. Location-specific ARARs identified for this RA include the following state requirements in 14 CCR:

- California Endangered Species Act (Item 3 in Table D-1);
- Fish and Wildlife Protection and Conservation regulations (Item 4 in Table D-1);
- Wildlife Species/Habitats regulations (Item 5 in Table D-1);
- Mammals and Reptiles Provisions (Item 6 in Table D-1); and
- Rare Native Plants regulations (Item 7 in Table D-1).

Location-specific ARARs also include the following federal requirements in 16 USC:

- National Historical Preservation Act (Item 8 in Table D-1);
- Archaeological and Historic Preservation Act (Item 9 in Table D-1);

The selected alternative will comply with location-specific ARARs.

2.14.2.3 Action-Specific ARARs

Action-specific ARARs are technology- or activity-based requirements or limitations that apply to particular remedial activities. The primary action-specific ARARs identified for this RA are:

- Generators of Hazardous Waste standards in 40 CFR Part 262 and 22 CCR (Item 10 in Table D-1);
- State beneficial-use designations for groundwater in SWRCB Resolution 88-63 (Item 11 in Table D-1); and
- LUCs requirements in 22 CCR (Item 14 in Table D-1).

This RA will comply with the hazardous waste generators standard by characterizing soil cuttings from well installation (if any), purge water extracted from monitoring wells, and spent carbon from purge water treatment, and disposing of these substances properly including packaging, labeling, marking,

placarding, and accumulation before final disposal. Compliance with the state beneficial-use designation of all state groundwater as potential drinking water will be achieved outside the South AFRL CZ by monitoring to confirm that contaminants do not migrate outside the South AFRL CZ and by commitment to maintaining WQOs and the protection of beneficial uses outside the South AFRL CZ.

Because hazardous substances will remain within the CZ and at Sites 37, 120, 133, and 321 at levels not suitable for unrestricted use, the selected remedy includes LUCs for these areas. The LUCs will conform with the requirements in 22 CCR, Div. 4.5, Ch. 39, Section 67391.1 (d), (e) (1) and (2) (see discussion in ARARs Table in Appendix D).

In the event the land encompassing these areas is transferred to the state or to a private party, the state and federal agency will enter into restrictive land use covenants recorded in the county. In the case of a federal-to-federal land transfer, the state and federal agency will use other mechanisms to ensure that future land use will be compatible with the levels of hazardous materials remaining on the property (e.g., amendment to the base master plan, physical monuments, or agreements between the federal agency and the state). LUCs limiting exposure to contaminated groundwater are required at the South AFRL until hazardous substance concentrations in groundwater have been reduced to levels that allow for unrestricted use of the groundwater and unrestricted land use.

2.14.3 COST EFFECTIVENESS

The remedy selected by this ROD is cost-effective when considered in the context of current and future land uses, and the site hydrogeological constraints. It encompasses past source removal actions, acknowledges the impracticability of groundwater restoration and complete DNAPL removal, uses natural processes to effect containment within the South AFRL CZ, and includes LUCs and LTM to ensure protectiveness. The 5-year review process allows for the potential to implement more aggressive source removal actions that could shorten the remediation timeframe at some future date, when remedial technologies have evolved to practicably address chlorinated solvent contamination in fractured granitic bedrock.

The NCP Section 300.430(f)(1)(ii)(D) states, "A remedy shall be cost-effective if its costs are proportional to its overall effectiveness." Overall effectiveness of the remedial alternatives introduced

in Section 2.9 was evaluated by assessing three of the five balancing criteria in combination (long-term effectiveness and permanence; reduction in toxicity, mobility, or volume through treatment; and short-term effectiveness) to determine whether costs are proportional to the effectiveness achieved (Table 2.14-1). Only Alternatives 4 and 5 provide long-term effectiveness; and reduce the toxicity, mobility, and volume of contaminants in groundwater by active remedial measures that have an effect on contaminant characteristics; however, there are considerable uncertainties regarding their implementability and the permanence of these effects if a significant portion of the DNAPL remains in place. The short-term effectiveness of all alternatives was evaluated in terms of risks to workers, the public, and the environment. No construction is required for Alternative 1, with minimal construction required for Alternatives 2 and 3; short-term effects to workers, the public, and the environment are minimal for these alternatives. Alternatives 4 and 5 require significantly greater construction; increased short-term risks to workers can effectively be addressed by engineering controls and work practices while, due to limited access to the AFRL, impacts to the public are minimal. However, impacts to natural resources and the environment are anticipated to be moderate for Alternates 4 and 5.

Estimated PV costs for the first 30 years of Alternatives 1 through 3 range from $0 for no action to $17.5 million for Alternative 3; the PV cost for the Selected Remedy (Alternative 2) is $3.4 million. These costs compare to $26.3 million and $49.4 million for Alternatives 4 and 5 that include source area treatment.

On the basis of the above assessment and a comparison of the plume simulations derived by the groundwater flow and contaminant transport modeling (see Figure 2.5-17), it may appear that Alternative 4 is the most cost-effective of the remedial alternatives. However, one must be cautioned that the cost estimates were derived for a specific combination of technologies in the Site 37 and Site 133 source areas (as described in Section 2.9.3.4) that, while selected as the most promising of those available (based on an extensive screening presented in the South AFRL Focused FS), yet are perceived as unlikely to achieve even 50% source removal within 10 years. Moreover, all of the alternatives require invoking a TI waiver of drinking water pMCLs, and accomplish the protection of human health by the LUCs and LTM described in Section 2.13.2 to maintain current incomplete exposure pathways and, for existing industrial buildings, engineering controls to reduce risk from a completed VIP to acceptable levels. When these factors are considered, Alternative 2, which includes

TABLE 2.14-1. RELEVANT CONSIDERATIONS FOR THE COST-EFFECTIVENESS DETERMINATION

Alternative (ordered by cost)	Present Value Cost	Long-Term Effectiveness and Permanence	Reduction of Contaminant Toxicity, Mobility, or Volume Through Treatment	Short-Term Effectiveness
1) No Action	$0	(1) Offers no active reduction in long-term risk to human health and the environment.	(1) Offers no reduction in toxicity. (1) Offers no reduction in mobility. (1) Offers no reduction in volume.	No increase in short-term risk to workers. No short-term risk to community. No short-term risk to environment.
2) TI Waiver, No Active Containment, LTM, and LUCs (Selected Remedy)	$3,410,000	(2) Offers no active reduction in long-term risk to human health and the environment.	(2) Offers no reduction in toxicity. (2) Offers no reduction in mobility. (2) Offers no reduction in volume.	No increase in short-term risk to workers. No short-term risk to community. No short-term risk to environment.
3) TI Waiver, Hot Spot Containment (Source Control), LTM, and LUCs	$17,540,000	(3) Offers active reduction in long-term risk to human health and the environment while system is operational.	(2) Offers no reduction in toxicity. (3) Offers reduction in mobility. (3) Offers reduction in volume.	Very limited short-term risk to workers mitigated through use of PPE. No short-term risk to community. No short-term risk to environment.
4) TI Waiver, Source Area Treatment, LTM, and LUCs	$26,310,000	(3) Offers active reduction in contaminant concentrations.	(3) Offers reduction in toxicity. (3) Offers reduction in mobility. (3) Offers reduction in volume.	Limited short-term risk to workers mitigated through use of PPE. No short-term risk to community. Moderate short-term risk to environment.
5) TI Waiver, Source Area Treatment, Plume Containment at Drinking Water Levels, LTM and LUCs	$49,380,000	(3) Offers active reduction in contaminant concentrations.	(3) Offers reduction in toxicity. (3) Offers reduction in mobility. (3) Offers reduction in volume.	Limited short-term risk to workers mitigated through use of PPE. No short-term risk to community. Moderate short-term risk to environment.

Notes:

Present value costs are derived using discount factors calculated using the formula $1/(1 + i)^t$, where i=0.07 (discount factor rate) and t=year (USEPA 2000b). Cost estimates used a 7% discount rate instead of 3.1% as recommended by the USEPA guidance, which would have increased the present value costs by 8 to 50%.

(1) Baseline characteristics

(2) No change by comparison to previous alternative.

(3) More effective by comparison to previous alternative.

% percent
LTM long-term monitoring
LUCs land use controls
PPE personal protection equipment
USEPA United States Environmental Protection Agency

only those costs that maintain protectiveness and provide a means to monitor effectiveness, is selected as the most cost-effective remedy.

2.14.4 USE OF PERMANENT SOLUTIONS AND ALTERNATIVE TREATMENT TECHNOLOGIES

The RA selected by this ROD represents the maximum extent to which permanent solutions and treatment technologies can be used in a practicable manner at the South AFRL. Of those alternatives (2 through 5) that are protective of human health and the environment and comply with (or provide justification for a waiver of) ARARs, the USAF has determined that the Selected Remedy provides the best balance of trade-offs in terms of the five balancing criteria, while also considering the statutory preference for treatment as a principal element and bias against off-site treatment and disposal and considering State and community acceptance.

The Selected Remedy incorporates previously completed source area treatments as documented in Section 2.2.3.2; however, as presented in Section 2.5.8.3, groundwater restoration and DNAPL removal from fractured granitic bedrock are considered technically impracticable at this site. While the USAF is committed (as part of future 5-year reviews) to continue evaluating technologies to remediate source-area dissolved-phase and DNAPL contaminants, a determination was made that aggressive source area treatment (beyond the actions already accomplished or the field tests to be conducted when promising technologies are identified) is neither implementable nor cost-effective at this time.

2.14.5 PREFERENCE FOR TREATMENT AS A PRINCIPAL ELEMENT

The RA selected by this ROD does not meet the statutory preference for treatment of principal threat wastes; however as documented in Section 2.14.3, when balanced against the criteria of implementability and permanence, a determination was made that aggressive source area treatment to remove DNAPL as a principal threat waste is not practicable at this time. It should be noted that previous source removal actions at the South AFRL have not been directed toward the removal or treatment of DNAPLs, therefore, this conclusion is based upon an evaluation of those site characterization and remedial technologies that have been tried at the site, as well as an extensive review of the remediation literature for a successful demonstration of DNAPL removal in fractured crystalline bedrock.

2.14.6 5-YEAR REVIEW REQUIREMENTS

Because the Selected Remedy will result in hazardous substances, pollutants, or contaminants remaining on-site above levels that allow for unrestricted use and unrestricted exposure (i.e., residential levels), a statutory review will be conducted within 5 years after initiation of RA to satisfy NCP Section 300.430(f)(4)(ii), and at 5-year intervals thereafter, as long as hazardous substances remain at the site at levels that do not allow for unrestricted (residential) uses. Five-year reviews will be conducted in accordance with CERCLA Section 121(c) and are required to determine whether the remedy continues to be protective of human health and the environment. In addition, these 5-year reviews will include (as needed) validation of the groundwater flow and contaminant transport models; and will be used to predict when groundwater GWVCL-res (refer to Table 2.13-1) contours, used in defining the VIP LUC boundary, will likely exceed the current VICB (refer to Figure 2.7-1), necessitating an expansion of the boundary before a subsequent Five Year Review. Finally, as listed in the final bullet of Section 2.13.2, the Air Force is committed to a continuing review of technologies and, if a promising technology is identified (that has been demonstrated to effectively treat the same types of chemicals at similar concentrations and in a similar hydrogeologic setting), will conduct a field test, at a cost not to exceed $250,000 (inflation-adjusted), to be executed by the following 5-year review.

2.15 DOCUMENTATION OF SIGNIFICANT CHANGES

The South AFRL PP was released for public comment in April 2006. The PP identified Alternative 2, TI Waiver with No Active Containment, LTM and LUCs, as the Preferred Alternative for groundwater remediation. Based upon the review of written and verbal comments submitted during the public comment period, no significant changes to the remedy, as originally identified in the PP, are proposed. The selection of a different remedial alternative is not considered appropriate.

Minor changes were implemented in this decision document. Nitrate was added as a COC in groundwater at Sites 37, 120, and 133; and naphthalene was added as a COC in groundwater at Site 37. RAOs were more clearly stated, and risks via the VIP into indoor air were re-evaluated (Appendix B). As a result, PCE (in soil and groundwater at Site 37, and in groundwater at Sites 120 and 321), TCE (in groundwater at Sites 37, 120, and 133), benzene (in groundwater at Site 37), and

cis-1,2-DCE (in groundwater at Site 120) were identified as posing an unacceptable risk via the VIP under a residential exposure setting and under the current industrial exposure setting in localized areas. LUCs and engineering controls to reduce exposure to VOCs in indoor air to a cancer risk level below 1 x 10^{-6} and a noncancer HI below 1 were added as remedy components to address these risks via the VIP. Cost estimates (for all alternatives except Alternative 1 - No Action), were increased from those presented in the South AFRL Focused FS to include periodic costs associated with increased sampling and reporting requirements every 5 years; however, cost estimates were not revised for vapor/indoor air monitoring and engineering controls that may be required to address the VIP (these costs will be developed during preparation of post-ROD documents). Maintaining the two existing GETS systems in an operable condition was dropped as an element of the selected remedy; and a commitment to one or more field tests of promising technologies (capped at $250,000 per event) with demonstrated effectiveness for similar contaminants in similar hydrogeologic settings was added. These changes did not impact decisions regarding the selected remedy.

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3.0 RESPONSIVENESS SUMMARY

This Responsiveness Summary is intended to provide a summary of information about the views of the public regarding both the remedial alternatives and general concerns about contamination at the South AFRL submitted during the public comment period. Following notice of the availability of the South AFRL PP published in local newspapers in April 2006, the public comment period was held from 7 April to 13 May 2006 and public meetings were held on 12 April 2006 and on 25 April 2006. No public comments impacted the decision-making process or the intended selection of the remedial approach.

3.1 STAKEHOLDER ISSUES AND LEAD AGENCY RESPONSES

The only written comment submitted during the public comment period questioned the suitability of the selected TI Waiver approach. The comment was submitted based on limited information available in the March Issue of the *Report to Stakeholders Volume 11, No 3* (see Section 2.3).

3.2 ORAL COMMENTS

Comments and questions were solicited from the public regarding the proposed RA at the South AFRL during two meetings held on 12 April 2006 and 25 April 2006. The meeting on 12 April 2006 was held in two sessions at the AFRL Rocket Room to allow base personnel easy access to the public meetings. Approximately 13 AFRL personnel attended the meeting. The public meeting on 25 April 2006 was held at Boron High School in the City of Boron. Only one citizen attended that meeting. This citizen was a representative to the RAB. An interpretive summary of the comments and questions from the public meetings is presented below (responses have been edited to provide more complete answers than were given at the meeting). Transcripts from the meetings are available in the Administrative Record file for OU4 and OU9.

12 April 2006 Meeting Questions and Comments Session I

***Paraphrased question*:** Can the Proposed Plan be posted on base websites/ftp sites?

***Answer*:** The Proposed Plan was posted on www.edwards.af.mil/penvmgn/Documents/reviewdocs.htm website by 11 April 2006.

***Paraphrased question*:** During what years was the contamination released?

***Answer*:** Releases occurred mostly in the 1950s and 1960s. By the 1980s, solvents such as PCE and TCE were not used anymore.

***Paraphrased question*:** Is the contamination in the groundwater?

***Answer*:** Yes, the Proposed Plan for the South AFRL addresses only groundwater. A separate proposed plan will be prepared for sites with soil contamination.

***Paraphrased question*:** Are the groundwater contaminant plumes moving miles away from the source areas?

***Answer*:** The current plume extent at the South AFRL indicates that contaminants have migrated up to 3.2 miles from source areas. Groundwater models have been prepared to estimate future plume migration and groundwater monitoring is performed to monitor current conditions.

***Paraphrased question*:** What is in-situ bioremediation (ISB)?

***Answer*:** ISB involves injecting a carbon source down wells to stimulate bacteria to degrade the contaminants. Two ISB pilot studies are currently being performed at the AFRL.

***Paraphrased question*:** Regarding other potential containment zones at the AFRL, could that contamination go down to Boron?

***Answer*:** A groundwater model is being prepared for the Northeast AFRL area to evaluate that.

***Paraphrased question*:** Is the plume diluting itself to a point where it is not hazardous before it reaches the base boundary?

Answer: Based on our conceptual site model, which is conservative, the outer bounds of the plume are slowed by dilution; not biodegradation. Even after 1,000 years of migration (with no action), the plume is still within the base boundary.

***Paraphrased question*:** Is the Containment Zone within the base boundary?

***Answer*:** Yes.

***Paraphrased question*:** At an Aerojet site, a contaminant plume was thought to be contained. Then a new drinking water well was installed down gradient of the containment boundary and contamination was found.

***Answer*:** The Air Force has installed over 300 wells at the AFRL that were monitored as part of the remedial investigation. Some of these wells will continue to be monitored to evaluate plume movement over time. In addition, sentinel wells have been installed beyond the current extent of contamination. These wells will be used to evaluate plume migration into clean water.

***Paraphrased question*:** If water levels change drastically, can that affect the modeling results?

***Answer*:** Water level measurements are collected on a quarterly basis and no significant changes have been observed over 5 years of quarterly monitoring. Some water level measurements up on the ridge fluctuate due to human activities.

***Paraphrased question*:** How do you determine where monitoring wells will be located and which wells to sample?

***Answer*:** Well locations were selected using professional judgment. Wells are sampled regularly and data are evaluated to determine if more wells are needed. To bring costs down, the regulators overseeing the environmental program at the AFRL agreed to monitoring a limited number of wells annually and performing a full monitoring round every 5 years.

***Paraphrased question*:** Are all wells within the current extent of contamination?

***Answer*:** No, some are at the outer edge and beyond the contaminant extent.

***Paraphrased question*:** How fast is the contamination moving?

***Answer*:** The groundwater flow rate estimate is approximately 140 feet per year.

***Paraphrased question*:** Are there a number of sites that have to be cleaned?

***Answer*:** Yes, but this Proposed Plan only focuses on the four South AFRL sites.

***Paraphrased question*:** Has there been an effect on wildlife [from the contamination]?

***Answer*:** An ecological risk assessment was performed that included measurement of vapor concentrations in artificial burrows and tissue analyses on small animals. No real effects were observed. Base biologists are more concerned about the impact that large-scale remedial actions will have on the wildlife.

***Paraphrased question*:** Is there any airborne contamination or can we only come in contact with it by drinking the water?

***Answer*:** Under the current industrial use, risks due to vapor intrusion into indoor air are believed acceptable. Air samples were collected inside Building 8595 and the results were all within acceptable risk levels. **Note:** Risks via the vapor intrusion pathway (VIP) were re-evaluated in this ROD as presented in Appendix B-1. While risk estimates under the current industrial exposure setting remain within the risk range (10^{-4} to 10^{-6}) considered generally acceptable, risks from PCE and/or TCE are estimated to exceed 10^{-4} for a residential (unrestricted) use. Therefore, the Air Force now plans to institute land use controls (LUCs) and engineering controls to reduce risks under both exposures (residential and industrial) to below 1×10^{-6} as described in Section 2.13.2.

12 April 2006 Meeting Questions and Comments Session II

***Paraphrased question*:** Are there really over 300 sites?

***Answer*:** Basewide, there are 471 sites but more than 80 percent of them have either been cleaned or there wasn't any contamination after they were investigated. The four sites [Sites 37, 120, 133, and 321] at the South AFRL were lumped together because they will be handled in the same way.

***Paraphrased question*:** Nitrate is under the regulatory limit?

***Answer*:** Nitrate is at background levels in the vast majority of wells. Nitrate contamination is very localized. There is only one well at Site 321 with a very high nitrate level because of past use of nitrogen tetroxide. **Note:** As a result of further data review during preparation of the ROD, the background level for nitrate at the AFRL has been withdrawn, and nitrate was identified as a COC at all four South AFRL sites (37, 120, 133, and 321).

***Paraphrased question*:** Because we draw our drinking water from 2 miles away, are we ok?

***Answer*:** Yes. The drinking water wells are not impacted.

***Paraphrased question*:** How long will it take for the contamination to get there [2 miles away]?

***Answer*:** The modeling results show that with no action, the plume will not reach the production wells for at least 1,000 years.

***Paraphrased question*:** Is there anything you can do to validate the model?

***Answer*:** The transport model was calibrated, but only where data was available (i.e., it's not possible to calibrate beyond the plumes' current extent). Extensive monitoring will be performed every 5 years and contaminant distributions will be compared to the model predictions.

***Paraphrased question*:** How do heavier than usual rainfalls at AFRL over the past 2 years impact the model?

***Answer*:** The flow model was calibrated using water levels collected quarterly over 5 years. Water levels will continue to be monitored semiannually over time and compared against model predictions.

***Paraphrased question*:** Has this type of meeting been held at Main Base?

***Answer*:** No. Environmental documents for Main Base are still going through CERCLA process. There will be a meeting when they reach this stage.

***Paraphrased question*:** Where does the money come from [for this environmental work]?

***Answer*:** It comes from the Environmental Restoration Account for the Air Force. It is "set-aside" and does not come out of the general Air Force money.

***Paraphrased question*:** Is there a certain type of cancer that these contaminants can cause?

***Answer*:** Yes. PCE and TCE can cause certain cancers.

***Paraphrased question*:** I live on Main Base and the only contamination I ever hear about is the contamination caused by the AFRL.

***Answer*:** The AFRL is intentionally visible right now because it is going through the TI Waiver process. The South Base (OU2) will be next to go through the Proposed Plan.

25 April 2006 Meeting Questions and Comments

***Paraphrased question*:** Has the base considered other alternatives?

***Answer*:** The Air Force has evaluated a number of technologies including in-situ bioremediation (which is being tested at two sites at the AFRL), surfactants, heat, and chemical oxidation. However, none of these were demonstrated to be practical for full scale implementation in fractured bedrock.

***Paraphrased comment*:** The attendee indicated that she concurs with the preferred alternative although she acknowledged that she was initially unprepared when the RAB was briefed on the proposal for a TI Waiver the previous year. However, she understands that the Base has carefully reviewed the available technologies for cleanup of groundwater and concluded that none are proven to be effective in

fractured bedrock. She also said that she trusts the USEPA and state regulatory agency RPMs reviewing the CERCLA process at Edwards AFB. She said she would have been upset if she thought the Air Force was going to walk away from the contamination, but she trusts that the TI waiver process includes sufficient monitoring and review requirements to ensure continuing stewardship.

3.3 WRITTEN COMMENTS

The only written comment received was a letter dated 2 June 2006 from Mr. Donald T. Kasper. Mr. Kasper's comments were made based on information from the fact sheet insert in the March Issue of the *Report to Stakeholders*. In his letter Mr. Kasper disagreed with the finding that remediation is unfeasible. Mr. Kasper agreed there was no need to act to remediate the groundwater within the fractured bedrock; however, he recommended "flushing" for groundwater in the overlying unconsolidated sands. A response to his letter was mailed to Mr. Kasper on 27 September 2006 by 95 ABW/CEVR. In the response, Mr. Kasper was provided a brief summary of the hydrogeology at the South AFRL noting that groundwater at the South AFRL is found only in the fractured bedrock. A copy of the PP was enclosed to present important details not included in the fact sheet insert in the *Report to Stakeholders*. A copy of Mr. Kasper's letter and the Air Force response are included at the end of this section.

3.4 COMPREHENSIVE RESPONSE TO TECHNICAL AND LEGAL ISSUES

Responses to comments posed by the community have been addressed with sufficient detail in the preceding section. No additional specific legal or technical questions have been identified.

3.5 REMAINING CONCERNS

No additional concerns have been identified.

2 June 2006

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95 ABW/PAE
Gary Hatch
5 E. Popson Ave. Bldg. 2650A
Edwards AFB, CA 93524-8060

Re: Response to Monitor Groundwater Movement around Leuhman Ridge

To whom it may concern,

I writing to respond to the March Report to Stakeholders, Vol 11, No 3, to monitor the Leuhman Ridge plume without further intervention. I disagree with the finding that remediation is unfeasible.

The plume can be separated into three parts.

1. The contamination in the broken bedrock. No remediation is necessary as it is unlikely to move to surface waters.
2. Contamination at or near bedrock level that can mix with groundwater (the bedrock interface zone).
3. The layer above bedrock consisting of unconsolidated sands that has contaminated groundwater.

There is no need to act to clean up item 1 as the contamination has no public or environmental affect. Items 2 and 3 can be resolved by flushing the groundwater upslope from the main plume, and cleaning or filtering it downslope near Rogers Dry Lake. I would presume item 2 would comply with general physics in that as flushing occurs, the interface to contaminated bedrock would exponentially decrease in contamination level relative to the amount of water flushing that occurs.

The issue of flushing with filtered or fresh water in a desert region is the only significant issue to be addressed. This can be done by three means:

1. Using downslope well water in existing well fields to flush the upslope water table.
2. Using water available from the sewage plant at Rogers Dry Lake and pumping it to an area upslope of the plume. This would presume tertiary treated water. If it is not, package plants can be purchased that would benefit current operations, encourage recycled water use at current Rogers facilities, and provide water for the groundwater project.
3. The Rio Tinto/U.S. Borax mine operates just north of Hwy 58 has enormous wastewater ponds and is now constructing more. This water could be piped south to the site to clean up Lehuman Ridge and recharge additional water for use in the Rogers Dry Lake area. Perhaps some pipeline and pumping costs could be shared by U.S. Borax. This would depend on water quality, but my understanding is that the water is used for washing mud to be separated from borax, and is not industrial effluent containing hazardous materials. As the mine is below water table level, some is likely just direct pump out water from the mine pit.

4. Retention basins for some ephemeral streams emptying onto Rogers Dry Lake could capture water for flushing use and groundwater recharge. Not all water would be trapped, nor all sediments, and it appears sediments replenishes the lake surface for aircraft use in later dry periods, but a portion could readily to captured. Once the water is on the lake, the clay of the lake makes recharge there minimal.

It is possible to restore Leuhman ridge groundwater, and add to local groundwater reserves by combining local projects to spread costs and make the cleanup less costly. There is no need to clean up contaminants in bedrock, the evaluation of which muddles the whole issue of cleanup unnecessarily. As water costs rise from rising energy costs to pump water from the aqueduct that currently services Edwards, it appears that recharge/cleanup joint projects can be a valuable source of water for Edwards in the future.

It would seem best that Edwards develop a comprehensive plan to capture, reuse, and recharge as much of its water as possible would fit into a plan to affordably deal with the Leuhman ridge groundwater contamination problem.

Regards,

Donald Kasper
661-946-6903

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS 95TH AIR BASE WING (AFMC)
EDWARDS AIR FORCE BASE CALIFORNIA

27 Sep 06

Mr. Ai D. Duong
95th Air Base Wing, Civil Engineer and Transportation Directorate
Environmental Management Division
Chief, Environmental Restoration Branch
5 East Popson Avenue, Building 2650A
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Mr. Donald T. Kasper
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Dear Mr. Kasper

Thank you for your comments on the *Report to Stakeholders, Volume 11, Number 3* (hereafter referred to as the *Report*). The *Report* presented a brief summary of the proposed remedial solution for the groundwater contamination on the southern side of Leuhman Ridge. To be clear, only the proposed remedial solution for the contaminated groundwater in fractured granitic bedrock for the area identified as South Air Force Research Laboratory (AFRL) (including Sites 37, 120, 133, and 321) was presented. Unfortunately the *Report* does not provide the detail necessary to address all the issues and information that went into making the decision for requesting a Technical Impracticability (TI) waiver for groundwater at South AFRL. The following is a brief summary of important details not included in the *Report*. In addition, you are being sent a copy of the *Proposed Plan for the South AFRL*, which presents the rationale supporting the decision to request a TI waiver, the extent of the zone requested for the TI waiver, and what contingencies the Air Force plans if the plume migrates quicker or farther than anticipated.

The AFRL is divided into two operable units, Operable Unit 4 and Operable Unit 9. South AFRL includes a total of four sites, three (Sites 37, 120, and 133) in Operable Unit 4 and one (Site 321) in Operable Unit 9. At these sites, all contaminated groundwater is located in fractured granitic bedrock at depths ranging from approximately 20 feet to over 200 feet. No remedial technologies have been proven in fractured bedrock. Within South AFRL, there is no groundwater within the alluvium or unconsolidated sands, where proven remediation technologies would be feasible. The regional groundwater flow from South AFRL is to the southwest toward Rogers Dry Lake near the center of the base. Near the lakebed (and outside the South AFRL area), the alluvium thickens and groundwater occurs in unconsolidated soil.

Groundwater and contaminant transport modeling was performed to simulate migration of the contaminated groundwater at South AFRL. Conservative aquifer parameters were used as

inputs for the model, resulting in what is thought to be a worst case scenario, i.e., the simulated movement of contaminated groundwater may be faster and farther than what actually occurs. Even with the conservative inputs, the model simulations show that the contaminated groundwater approaches, but does not actually migrate into, the alluvial aquifer even after 1,000 years. The model projects that natural chemical, physical, and/or biological processes will compensate for migration of the contaminant plume resulting in a stable plume that will not spread farther than the area shown and described as the TI Waiver Zone in the *Report*.

As part of the TI waiver, a management plan has been prepared. The management plan requires the Air Force and U.S. Environmental Protection Agency (EPA) to review the protectiveness of the selected remedial alternative every 5 years and to put a contingency plan into effect if groundwater monitoring shows that the plume is moving significantly faster than the model simulates. As part of the 5-year reviews and the contingency plan, all proven technologies that are available will be reevaluated and, if warranted, additional actions may be implemented in the future.

Your comments include a suggestion to separate the plume into three parts: (1) contamination in the broken bedrock; (2) contamination at or near the bedrock level, the bedrock interface zone; and (3) contamination in the unconsolidated sand layer above bedrock. Although this separation is accurate for parts of Edwards AFB, it is not true at AFRL. All groundwater, and therefore all contaminated groundwater, at South AFRL is located in Part 1, within the broken or fractured bedrock. We agree that the contaminated groundwater in the fractured bedrock poses no immediate public risk. However, the state of California considers the groundwater itself as a receptor requiring protection. Therefore, we cannot use the approach that "...the evaluation of [contaminants in bedrock] muddles the whole issue of cleanup unnecessarily."

Flushing the aquifer is a remediation technology that the Air Force is evaluating as a possible solution at AFRL as well as other Edwards AFB sites. In a very low conductivity aquifer, such as the fractured bedrock at South AFRL, applying this technology would require hundreds of years to flush the suspected contaminated zones. The Air Force presented an evaluation of flushing for the South AFRL area in the *Feasibility Study for the South AFRL* based in part on the *Groundwater Modeling Report for the South AFRL Area*. Both of these documents, finalized in 2005, are available in the Administrative Record. We agree that the source of water for flushing is a significant factor to be considered in evaluating the implementation of a flushing remedial technique. Working closely with the Lahontan Regional Water Quality Control Board to meet the stringent regulations regarding injection into an aquifer, the Air Force has concluded that reinjection of extracted and cleaned groundwater offers an excellent preservation of the resource without piping water from a significant distance such as the sewage treatment plant or the U.S. Borax mine operations.

The Air Force and the regulatory agencies involved, including the U.S. EPA, the California Department of Toxic Substances Control, and the Lahontan Regional Water Quality Control Board, believe that the proposed plan for South AFRL presents the best solution for a technically impracticable contamination problem. Management of the TI Zone for South AFRL will protect human health and the environment while best balancing the associated costs of protectiveness. The evaluation concluded that implementing aggressive remediation techniques that are yet unproven in fractured bedrock is not in the best interest of the public at this time. If the alternative presented in the Proposed Plan is accepted, groundwater monitoring results (to be

collected semiannually to annually) will be reviewed indepth by the Air Force and the U.S. EPA every 5 years to evaluate whether the primary objective of protection of human health and the environment is still being met, and consider whether remedial technologies have evolved that hold promise for more aggressive actions to be taken.

If there are any further questions, please contact Mr. Gary Hatch at (661) 277-1454. Additionally, documents that present the background information, feasibility studies, and rationale leading the Air Force and the regulatory agencies to the decision to propose TI for South AFRL are located at several public repositories including the Los Angeles Public Library in Lancaster, California.

Sincerely

AI D. DUONG

APPENDIX A

TABLES PROVIDED AS SUPPORTING DOCUMENTATION FOR THE SOUTH AFRL ROD

TABLE A-1 SOIL AND DEBRIS SITES OR AOCS WITHIN THE SOIL AFRL CONTAINMENT ZONE

TABLE A-2 SOIL AND DEBRIS SITES OR AOCS WITHIN OU4/9 NOT INCLUDED IN THE SOUTH AFRL CONTAINMENT ZONE

TABLE A-3 OU4/9 CERCLA GROUNDWATER SITES

TABLE A-4 DETAILS ON SOURCE CONTROL ACTIONS AT THE SOUTH AFRL

TABLE A-5 BACKUP FOR COSTS PER POUND TO CONSTRUCT AND OPERATE THE GROUNDWATER EXTRACTION AND TREATMENT SYSTEMS (GETSs) AT SITES 37 AND 133, AND THE SITE 172 SOIL VAPOR EXTRACTION (SVE) SYSTEM

TABLE A-6 COMPARISON OF TCE AND PCE RESULTS FOR 2003 AND 2006

TABLE A-7 EVALUATION OF IMPACT ON PRESENT VALUE COSTS USING 3.1 PERCENT VERSUS 7 PERCENT DISCOUNT RATE

TABLE A-1. SOIL AND DEBRIS SITES OR AOCS WITHIN THE SOUTH AFRL CONTAINMENT ZONE

Site No.	Site Name/Description	Contaminated Media	COCs	IRA or TS Status	Preferred CERCLA Remedy Presented in Proposed Plan
13 (Downgradient of Site 133)	AFRL Landfill	Buried Debris	Debris disposal in landfill trenches	Final landfill cover system completed in June 2002.	LUCs with LTM
26 (Source Area for Site 133)	Former Fire Training Area	Soil	Petroleum hydrocarbons	IRA (excavation) performed in May 2001 to remove accessible contaminated soil in a portion of the site.	No Action
150 (Source Area for Site 133)	Building 8451 Former Waste Evaporation Ponds	None	None	None performed/No COCs in soil.	No Action
153/396 (Source Area for Site 133)	Buildings 8419, 8421, 8425, and 8431 Dry Wells, Building 8421 Waste Discharge Area, and Building 8427 Former Test Stand	None	None	IRA performed in May and June 2001 to destroy the former waste discharge (dry) wells; No COCs in soil.	No Action
166 (Source Area for Site 37)	Building 8240 Former Waste Discharge Area and Removed Waste Oil Underground Storage Tank (UST)	Soil	Petroleum hydrocarbons	Waste Oil UST removed in 1992 and 75 tons of soil removed in 1997 surrounding former site of the waste oil tank.	No Action
170/171 (Source Area for Site 37)	Building 8595 Indoor Vapor Degreaser, Caustic Dip Tanks, and Sump	None	None	IRA performed in October and November 1997 to clean and backfill vapor degreaser pit and sumps; No COCs in soil.	No Action
172 (Source Area for Site 37)	Building 8595 Outdoor Waste Sump	Soil and Soil Vapor	Soil - PCE Soil Vapor – PCE, Freon 113, 1,1,1-TCA, TCE, 1,1-DCE, and toluene	IRA in October 1997 to clean sump. SVE operated from April 2000 through July 2006. Sump backfilled in 2002.	No Action

Notes:

The Decision Document for these sites will be the Soil and Debris Sites ROD. The Proposed Plan was available for public comment between 1 April 2007 and 15 May 2007.

AFRL	Air Force Research Laboratory
AOCs	areas of concern
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COCs	chemicals of concern
DCE	dichloroethene
IRA	interim removal action
LTM	long term monitoring
LUCs	land use controls
No.	number
PCE	tetrachloroethene
ROD	record of decision
SVE	soil vapor extraction
TCA	trichloroethane
TCE	trichloroethene
TS	treatability study

TABLE A-2. SOIL AND DEBRIS SITES OR AOCS WITHIN OU4/9 NOT INCLUDED IN THE SOUTH AFRL CONTAINMENT ZONE

Site No.	Site Name/Description	Contaminated Media	COCs	IRA or TS Status	Preferred CERCLA Remedy Presented in Proposed Plan
6/113* (Outlying Area)	Abandoned Mine Shafts 1 and 2	Buried Debris	Debris disposal in mine shafts	None	Expand existing LUCs
7 (Mars Blvd Area)	Test Area 1-46 Beryllium-Contaminated Earth Piles	Debris and Earth Piles	Beryllium	IRA completed in 1996. Soil and debris disposed of at Site 167 SLDU.	No Action
36* (Source Area for Site 162)	Test Area 1-21 Former Wastewater Evaporation Tank	Soil	Perchlorate	IRA performed in 2004 included removal of wastewater evaporation tank and its associated piping and removal of accessible contaminated soil (estimated 10 cubic yards) beneath the tank.	LUCs
115* (Northeast AFRL Area)	Test Area 1-100 Missile Silos 1 and 2	Buried Debris	Debris disposal in missile silos	None	Expand existing LUCs (Backfill and Cap Silos)
167 (Mars Blvd Area)	Test Area 1-46 Beryllium Firing Range	Soil	Beryllium	IRA performed in 1996 to remove beryllium in soil with disposal in on site SLDU.	Expand existing LUCs
312* (Upgradient of Site 162)	Test Area 1-14 PCB Spill Area	Soil/Concrete	PCBs	None	Clean Closure; Excavate and Remove Impacted Soil and Concrete
318* (Northeast AFRL Area)	Test Area 1-120 Catch Basin and Evaporation Pond	Soil	PAHs: benzo(a)anthracene benzo(a)pyrene benzo(b)fluoranthene dibenzo(a,h)anthracene	None	LUCs
329 (Mars Blvd Area)	Test Area 1-46 Former Wash Rack and Oxidation Pond	None	None	None	No Action

Note:

* These sites are included in the Feasibility Study Report, Soil and Debris Sites at Air Force Research Laboratory (Earth Tech 2006c).
The Decision Document for these sites will be the Soil and Debris Sites ROD. The Proposed Plan was available for public comment between 1 April 2007 and 15 May 2007.

AFRL	Air Force Research Laboratory	No.(s)	number(s)
Blvd	boulevard	OU4/9	Operable Unit Nos. 4 and 9
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act	PAH(s)	polycyclic aromatic hydrocarbon(s)
COCs	chemicals of concern	PCB	polychlorinated biphenyls
IRA	interim removal action	SLDU	subsurface land disposal unit
LUCs	land use controls	TS	treatability study

TABLE A-3. OU4/9 CERCLA GROUNDWATER SITES

Area Designation	Site No.	Site Name/Description	COCs	IRA or TS Status	CERCLA Process Status
South AFRL Area	37	Building 8595 PCE Plume	Chlorinated VOCs, 1,4-dioxane, NDMA, perchlorate, nitrate	GETS 1999–2007 (currently operational); fracture blast zone study	Selected CERCLA Remedy Presented in this ROD document.
	120	AFRL Sewage Treatment Plant	Chlorinated VOCs, 1,4-dioxane, perchlorate, nitrate	None	
	133	AFRL Civil Engineering Yard	Chlorinated VOCs, 1,4-dioxane, benzene, MTBE, NDMA, perchlorate, nitrate	GETS 2001–2007 (currently operational)	
	321	Liquid Propellant Storage Complex Catch Tanks	Chlorinated VOCs, nitrate	None	
AFRL Arroyos Area	162	Test Area 1-40 Former Catch Tanks	Chlorinated VOCs, perchlorate, NDMA	In-situ Bioremediation Pilot Study using Emulsified Oil Substrate began December 2005 and is ongoing.	Recommended CERCLA Remedy Presented in AFRL Arroyos FS submitted Draft Final in February 2007
	461	TS 1-A in Test Area 1-120, and TS1-C and TS1-D in Test Area 1-125	Chlorinated VOCs, NDMA	None	
Northeast AFRL Area	115	Test Area 1-100 Missile Silo Nos. 1 and 2; Former Leachfields; Building 8950 Open Pit and Open Trench	Chlorinated VOCs, perchlorate, NDMA	None	Recommended CERCLA Remedy to be Presented in NE AFRL and Mars Blvd. FS (in prep)
	116	Test Area 1-36, Test Pad A, Rocket Exhaust Area and Oxidation Pond 1	Perchlorate, NDMA	None	
	177	Test Area 1-30 Waste Collection Tanks	Chlorinated VOCs, NDMA	In-situ Bioremediation Pilot Study using Hydrogen Release Compound began November 2005 at Sites 177/325 and is ongoing.	
	178	Test Area 1-32 Large Motor Exhaust Area and Former Burn Pit	Chlorinated VOCs, perchlorate	None	
	318	Test Area 1-120 Catch Basin and Evaporation Pond	Chlorinated VOCs	None	
	325	Test Area 1-90 Former Test Stands 1-91 and 1-92, Former Landfill, Three Burn Pits, Building 8903 Leachfield, Building 8902 Dry Well, and Oxidation Pond 3	Chlorinated VOCs, perchlorate	In-situ Bioremediation Pilot Study using Hydrogen Release Compound began November 2005 at Sites 177/325 and is ongoing.	
Mars Blvd. Area	27	Test Area 1-56 Deluge Discharge System	Chlorinated VOCs, NDMA	None	Recommended CERCLA Remedy to be Presented in NE AFRL and Mars Blvd. FS (in prep)
	125	Test Area 1-42 Oxidation Ponds and Burn Pit	Chlorinated VOCs, NDMA	None	
	127	Test Area 1-52 Pad A Deluge Drainage System	Chlorinated VOCs, NDMA	None	
	333	Test Area 1-46 Catch Tanks	Chlorinated VOCs, perchlorate, NDMA	Work Plan for In-situ Bioremediation Pilot Study at Site 333 in prep.	

Notes:

AFRL	Air Force Research Laboratory	NE	North East
Blvd.	Boulevard	No.	number
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act	OU4/9	Operable Unit Nos. 4 and 9
COCs	chemicals of concern	PCE	tetrachloroethene
FS	feasibility study	ROD	record of decision
GETS	groundwater extraction and treatment system	TS	treatability study
IRA	interim removal action	VOCs	volatile organic compound
NDMA	N-nitrosodimethylamine		

TABLE A-4. DETAILS ON SOURCE CONTROL ACTIONS AT THE SOUTH AFRL
(Page 1 of 2)

Site	Action	Objective	Year	Performance Evaluation (Pounds of Contaminant Removed if Applicable)	Reference *
170/171 and 172 (37)	Decommission Sumps	Clean and backfill sumps/remove sumps as potential continuing source.	1997	Sumps cleaned and backfilled with concrete slurry	Building 8595 Pit and Sumps Investigation and Closure Report, Indoor Vapor Degreaser Pit – AOC 170, Indoor Caustic and Acid Dip Tanks Sump – AOC 171, and Outdoor Waste Sump – Site 172 (Earth Tech 1998).
37	Install GETS	Extract and treat groundwater through LPGAC	1999	n/a (see below)	Site 37 Treatability Study Evaluation Report (Earth Tech 2000c).
37	Operate GETS	Contain hot spot/remove VOC mass	1999-2006	566	AOR for 2006 (Earth Tech 2007b).
172 (37)	Install/expand SVE	Extract and treat soil vapors through VPGAC	2000 and 2002	n/a (see below)	AOR for 2000 (Earth Tech 2001e) and AOR for 2002 (Earth Tech 2003d).
172 (37)	Extract and treat shallow soil vapors	Remove contaminant mass from fill sand underlying outdoor sump	2000-2006	7,379	AOR for 2006 (Earth Tech 2007a).
120	Renovation of sewage treatment plant facility	Compliance with updated waste discharge requirements	1999	n/a	Described in Site Summary Report, AOC 121 Sludge Drying Beds and Overflow Ponds (Earth Tech 1999a).
13 (133)	Closed AFRL Landfill	Landfill closure	2002	n/a	Final Closure and Post-Closure Maintenance Plan for the AFRL Inactive Landfill (Earth Tech 1999b rev 2000); As-Built Certification and Construction Quality Assurance Report for Final Closure of AFRL Landfill Site 13 (Earth Tech 2003a).
26 (133)	Remove tank, pipeline, and soil	Remove petroleum hydrocarbon contaminants in soil	2000	120 cubic yards of petroleum contaminated soil and bedrock removed, confirmation sampling performed allowing NFA for soil	Interim Removal Action Report, Site 26 Former Fire Training Area (Earth Tech 2001a).
137 (133)	Remove USTs and associated piping	Remove petroleum hydrocarbon contaminants in soil	2001	825 cubic yards of petroleum contaminated soil and bedrock removed, confirmation sampling performed allowing site closure	Interim Removal Action Report, Excavation of Hydrocarbon-Contaminated Soils, Site 137 (Earth Tech 2002).
151 (133)	Remove USTs and associated piping and waste disposal area	Remove petroleum hydrocarbon contaminants in soil	1995	100 cubic yards of petroleum contaminated soil and bedrock removed, confirmation sampling performed allowing site closure	Treatability Study Letter Report, Sites 151 and 169 (Earth Tech 1996c).
153/396 (133)	Destroy dry wells	Remove possible conduit for contamination	2000	Active inlet lines redirected to the sanitary sewer, dry well inlets and overflow lines capped, removal of standing water, sludge, soil, and/or gravel from dry wells, destruction of dry wells	Sites 153 and 396 Dry Well Destruction Report (Earth Tech 2001b).
186 (133)	Remove USTs	Remove source of petroleum hydrocarbon contaminants in soil	1995	Source removed	Site 186, Facility 8409, UST Site Characterization Report (Earth Tech 2000a).

TABLE A-4. DETAILS ON SOURCE CONTROL ACTIONS AT THE SOUTH AFRL
(Page 2 of 2)

Site	Action	Objective	Year	Performance Evaluation (Pounds of Contaminant Removed if Applicable)	Reference *
133	Install GETS	Extract and treat groundwater	1999	n/a (see below)	Site 133 Treatability Study Work Plan (Earth Tech 2000d).
133	Operate GETS	Contain hot spot/remove VOC mass	2001-2006	303	AOR for 2006 (Earth Tech 2007c).
321	Remove catch tanks	Remove possible conduit for contamination	1995	n/a	Aman Environmental Construction Inc., Tank Closure Logbooks, UST Removals, Edwards AFB, Volume IV (1996).

Notes:

* References cited here are included in Section 2.16 of this document

AFB	Air Force Base
AFRL	Air Force Research Laboratory
AOC	area of concern
AOR(s)	Annual Operations Report
GETS	groundwater extraction and treatment system
LPGAC	liquid-phase granular activated carbon
n/a	not applicable
NFA	No Further Action
SVE	soil vapor extraction
UST	underground storage tank
VOC(s)	volatile organic compound(s)
VPGAC	vapor-phase granular activated carbon

TABLE A-5. BACKUP FOR COSTS PER POUND TO CONSTRUCT AND OPERATE THE GROUNDWATER EXTRACTION AND TREATMENT SYSTEMS (GETSs) AT SITES 37 AND 133, AND THE SITE 172 SOIL VAPOR EXTRACTION (SVE) SYSTEM

	Site 37 GETS 7 GW extraction wells, LPGAC				Site 133 GETS 4 GW extraction wells, LPGAC				Site 172 SVE 7 VP extraction wells, VPGAC			
Year	Activity	Cost	Pounds	$/pound	Activity	Cost	Pounds	$/pound	Activity	Cost	Pounds	$/pound
1998	Construct System	$650,000	0	n/a								
1999	Annual O&M	$240,000	52	$4,615					Construct System	$154,758	0	n/a
2000	Annual O&M	$328,000	94	$3,489	Construct System	$995,000	0	n/a	Annual O&M	$160,000	4730	$34
2001	Annual O&M	$118,976	42	$2,833	Annual O&M	$68,000	10	$6,800	Annual O&M	$100,800	791	$127
2002	Annual O&M	$204,326	61	$3,350	Annual O&M	$232,000	78	$2,974	Annual O&M	$137,908	463	$298
2003	Annual O&M	$214,148	57	$2,446	Annual O&M	$272,920	102	$2,676	Annual O&M	$134,635	584	$231
2004	Annual O&M	$190,790	78	$1,865	Annual O&M	$161,167	29	$5,557	Annual O&M	$143,487	509	$282
2005	Annual O&M	$192,075	103	$2,058	Annual O&M	$231,414	43	$5,382	Annual O&M	$140,480	250	$562
2006	Annual O&M	$162,616	79	$2,058	Annual O&M	$265,221	41	$6,469	Annual O&M	$90,000	52	$1,731
Totals		$2,300,931	566			$2,225,722	303			$1,062,068	7,379	
Average annual O&M cost per pound				$2,917				$4,062				$123
Overall cost per pound removed (including capital)				$4,065				$7,346				$144

Notes:

Pounds removed were slightly adjusted from those reported in AORs (which reflect calendar years) to match funding periods and simplify the calculation of cost per pound on an annual basis.

AORs	annual operations reports
GETS	groundwater extraction treatment system
GW	groundwater
LPGAC	liquid phase granular activated carbon
n/a	Not applicable
O & M	operation and maintenance
SVE	soil vapor extraction
VP	vapor phase
VPGAC	vapor phase granular activated carbon

TABLE A-6. COMPARISON OF TCE AND PCE RESULTS FOR 2003 AND 2006
(Page 1 of 2)

Well ID	Trichloroethene (TCE) µg/L (2003)	Trichloroethene (TCE) µg/L (2006)	Percentage Change	Tetrachloroethene (PCE) µg/L (2003)	Tetrachloroethene (PCE) µg/L (2006)	Percentage Change
120-MW02	110	120/110	0	4,800	4,800/4,800	0
120-MW06	<1.0	<1.0	0	<1.0	<1.0	0
120-MW08	2.6	1.4	-46	7.2	5.0	-31
120-MW10	4.5	5.1	+13	2.3	2.8	+22
120-MW12	13	6.0	-54	220	72	-67
120-MW15	<1.0	<1.0	0	<1.0	<1.0	0
133-EW01	2,100/2,100	1,300	-38	7.0 J/7.5 J	4.3 J	-39
133-EW02	420	400	-5	5.0	4.2	-16
133-EW03	6,600	4,300	-35	20 J	13 J	-35
133-EW04	3,000	1,700	-43	21	21	0
133-MW02	5,000/4,700	3,300	-30	9.6 J/7.0 J	27	+35
133-MW03	1,400/1,500	3,800	+170	<50/<25	16	-
133-MW04	82,000	76,000	-7	<1,200	190 J	NC
133-OW01a	1,500/1,500	990/970	-35	6.5/3.5 J	6.4/6.8	0
133-OW01b	4.0	3.7	-8	<1.0	<1.0	0
133-OW04	2,700	4,700	+74	37	39	+5
133-OW05	38,000	40,000/42,000	+5	<1,200	<200/95 J	0
13-MW15	310	310	0	<1.0	0.51 J	0
13-MW18	25	16	-36	0.39 J	<1.0	0
13-MW19	<1.0	<1.0	0	<1.0	<1.0	0
13-MW28	<1.0	<1.0	0	<1.0	<1.0	0
13-MW29	<1.0	<1.0	0	<1.0	<1.0	0
153-MW01	4,100/4,000	1,100	-72	<25/<25	<4.0	0
153-MW08	6,500	4,400	-32	<50	<12	0
153-MW09	1.7	21	+1,135	0.43 J	<1.0	0
171-MW05	4,000	3,700/3,700	-7	180,000	130,000/140,000	-28
321-MW01	5.9	7.6	+29	<1.0	<1.0	0

TABLE A-6. COMPARISON OF TCE AND PCE RESULTS FOR 2003 AND 2006
(Page 2 of 2)

Well ID	Trichloroethene (TCE) µg/L (2003)	Trichloroethene (TCE) µg/L (2006)	Percentage Change	Tetrachloroethene (PCE) µg/L (2003)	Tetrachloroethene (PCE) µg/L (2006)	Percentage Change
321-MW02	35 J/38 J	29	-17	2,100/1,800	1,100	-39
321-MW06	5.2	2.5	-52	<1.0	<1.0	0
321-MW07	<1.0	<1.0	0	<1.0	<1.0	0
321-MW08a	<1.0	<1.0	0	<1.0	<1.0	0
321-MW08b	<1.0	<1.0	0	<1.0	<1.0	0
37-EW02	79	58	-27	4,200	3,300	-21
37-EW03	89	19	-79	7,700	1,800	-77
37-EW06	380	250	-34	14,000	25,000	+79
37-EW07	480	85	-82	40,000	7,700	-81
37-EW08	1,600	940	-41	110,000	87,000	-21
37-MW02	150	170	+13	11,000	9,700	-12
37-MW04	45	14	-69	4,600	830	-82
37-MW05	9.2	8.4	-8	130	190	+46
37-MW06	230	310	+35	28,000	19,000	-32
37-MW09	1.1	2.8	+154	38	110	+189
37-MW13	0.79 J	0.79 J	0	18	22	+22
37-MW14	75	59	-21	230	250	+9
37-MW15	76	30	-60	3,300	1,100	-67
37-MW19	180	190	+5	310	310	0
37-MW22	<1.0	<1.0	0	<1.0	<1.0	0
37-MW32	<1.0	<1.0	0	<1.0	<1.0	0
37-OW06	200	120	-40	5,800	4,400	-24

Notes:

µg/L	micrograms per Liter
NC	not calculated
PCE	tetrachlorethene
TCE	trichloroethene

Data Qualifier:

J	Value reported is below reporting limit and is considered an estimated value.

TABLE A-7. EVALUATION OF IMPACT ON PRESENT VALUE COSTS USING 3.1 PERCENT VERSUS 7 PERCENT DISCOUNT RATE

	Alternative 2		Alternative 3		Alternative 4		Alternative 5	
Present Value Percentage	3.10%	7%	3.10%	7%	3.10%	7%	3.10%	7%
Capital Costs	-	-	$10,960,000	$10,960,000	$18,050,000	$18,050,000	$39,570,000	$39,570,000
South AFRL LTM	$4,650,000	$3,150,000	$4,650,000	$3,150,000	$7,830,000	$5,890,000	$7,830,000	$5,890,000
Sites 37 and 133 GETS O&M	-	-	$2,770,000	$1,810,000	$2,900,000	$2,210,000	$3,400,000	$2,300,000
GETS Storage O&M	$160,000	$100,000	-	-	-	-	-	-
Site 172 SVE System O&M	-	-	$1,520,000	$980,000	-	-	$1,520,000	$980,000
Evaporation Ponds O&M	-	-	$720,000	$480,000	-	-	$720,000	$480,000
Land Use Controls	$110,000	$70,000	$110,000	$70,000	$110,000	$70,000	$110,000	$70,000
5-Year Reviews (Reports)	$150,000	$90,000	$150,000	$90,000	$150,000	$90,000	$150,000	$90,000
Present Value Total	**$5,070,000**	**$3,410,000**	**$20,880,000**	**$17,540,000**	**$29,040,000**	**$26,310,000**	**$53,300,000**	**$49,380,000**

Note: USEPA (2000b) recommends use of 7 percent for all non-Federal facility sites; a discount rate from Appendix C of the Office of Management and Budget [OMB] Circular A-94 updated on an annual basis should generally be used for all Federal facility sites. Per this guidance, a 3.1 percent discount factor should have been used instead of the 7 percent used for costs presented on Tables 2.5-6, 2.10-1, 2.13-4, and 2.14-1 in the ROD. This table was prepared to provide a comparison of PV costs using both discount rates (i.e., 3.1 percent versus 7 percent). Based on this evaluation, use of the lower discount rate would have resulted in cost estimates approximately 8 to 50 percent higher than the PV costs calculated using a 7 percent discount rate.

APPENDIX B

EVALUATION OF VAPOR INTRUSION PATHWAY AT THE SOUTH AFRL

APPENDIX B-1	**RE-EVALUATION OF POTENTIAL INDOOR AIR RISK FOR SITES AT THE SOUTH AFRL**
Attachment B.1-1	J & E Version 3.1 Exposure Model Worksheets
APPENDIX B-2	**EVALUATION OF ALTERNATIVES AND ASSOCIATED COSTS TO ADDRESS THE VAPOR INTRUSION PATHWAY (VIP) FROM SOIL INTO INDOOR AIR AT SITE 37**
Attachment B.2-1	Plots of PCE Concentration versus Time (Years of SVE Operation) Fitted with Exponential Regression Curves

APPENDIX B-1

RE-EVALUATION OF POTENTIAL INDOOR AIR RISK FOR SITES AT THE SOUTH AFRL

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APPENDIX B-1
RE-EVALUATION OF POTENTIAL INDOOR AIR RISK FOR SITES AT THE SOUTH AFRL

This appendix describes the process by which incremental risks due to vapor intrusion into indoor air were estimated for the South AFRL Sites 37, 120, 133, and 321 at the Air Force Research Laboratory (AFRL), Operable Units 4 and 9 (OU4 and OU9) at Edwards Air Force Base (AFB), California (CA). This risk evaluation, completed during development of the South AFRL Record of Decision (ROD), was performed in response to concerns expressed by the United States Environmental Protection Agency (USEPA) and State regulators as discussed in Section B.1 below, and supersedes the risk estimates for the vapor intrusion pathway (VIP) included in the *Human Health Risk Assessment for Operable Unit 4* (OU4 HHRA, Earth Tech 2004a), the *Human Health Risk Assessment for Operable Unit 9* (OU9 HHRA, Earth Tech 2004b), and the *Proposed Plan for Cleanup of Groundwater at the South Air Force Research Laboratory* (South AFRL PP, Earth Tech 2006a).

B.1 BACKGROUND

During development of the OU4 and OU9 HHRAs (in accordance with the *Edwards AFB Basewide Human Health Risk Assessment Work Plan* [Earth Tech 2001]), the hypothetical use of each site for residential purposes was evaluated by comparison of the maximum detections of chemicals in soil and groundwater samples to the USEPA Region 9 preliminary remediation goals (PRGs) available at the time (2000 PRGs were used for OU4 and 2002 PRGs were used for OU9). The comparisons were expressed as potential incremental cancer risks (hereafter referred to simply as cancer risks) and non-cancer hazard quotients (HQs) for individual chemicals. These soil and groundwater risks and hazards were then summed for each chemical of potential concern to estimate the total cancer risk and Hazard Index (HI) for each medium at each site. A similar process was used to estimate potential risks and hazards for the hypothetical industrial and construction/excavation scenarios.

B.1.1 INITIAL EVALUATION OF RISK VIA THE VIP IN THE HHRA

Although potential indoor air risks and hazards via the VIP were estimated (using the Johnson and Ettinger [J&E] version 1.2 [1998] model for OU4, and version 2.1 model [2003] for OU9) for the industrial land use scenario at sites with volatile organic compounds (VOCs) and buildings, indoor air

risks and hazards were not estimated for industrial sites without buildings or for the residential land use scenario because none of the sites were used, or were anticipated to be used, for residential purposes.

For the South AFRL Sites 37, 120, and 133, the OU4 HHRA included an estimate of risk in indoor air under an industrial exposure scenario for the VIP via both soil and groundwater. For the South AFRL Site 321, the OU9 HHRA included an estimate of risk in indoor air under an industrial exposure scenario for the VIP via groundwater only (through 2002 no VOCs were detected in soil samples collected at Site 321).

B.1.2 ADDITIONAL EVALUATION OF RISK VIA THE VIP IN THE PP

In early 2006, the USEPA and California Department of Toxic Substances Control (DTSC) requested that each OU feasibility study (FS) include an estimate of risks under the residential land use scenario including the potential for vapor intrusion into indoor air from impacted soil and groundwater. The purpose was to allow an estimate of the cost to remediate sites to an unrestricted future use. This objective is consistent with the Department of Defense (DoD) policy on Land Use Controls (dated January 17, 2001), which directs that cost estimates for unrestricted use cleanups be provided for sites where land use controls (LUCs) are selected as part of the remedy, to inform the decision to rely on LUCs rather than on unrestricted-use cleanups. The Remedial Project Managers (RPMs) for Edwards AFB reached an agreement regarding this issue as documented in meeting minutes (U.S. Air Force 2006) for an RPM meeting held in Burbank, CA on April 6, 2006. As agreed, the process to be followed for OUs in the FS (or earlier) stage of CERCLA process includes:

1. Where an HHRA has been completed, and sites have been screened against the PRGs, those sites that do not have chemicals exceeding residential PRGs can drop out of the process without the need to go back and evaluate risk via the VIP under a residential exposure scenario.

2. Where sites will be screened against PRGs using new data or where an HHRA has not been completed, the screening must be against the 2004 PRGs (however, completed HHRAs can stand with whatever screen was used).

3. For those sites that do not drop out when screened against the residential PRGs, an evaluation of the VIP from soil must be completed. The 95 percent upper confidence limit (UCL) of the mean concentration, rather than the maximum concentration, should be used as input to the most recent J&E model (version 3.1 dated February 2004). The model should be run for both the residential scenario (using the default building size) and the

industrial scenario (using a site-specific building size, or a default industrial building size where no buildings are currently present) and site-specific inputs for depth to groundwater, soil type, etc. The VIP from groundwater (also for both residential and industrial exposure settings) should be run for all groundwater depths.

4. For sites that show a risk under the residential scenario, a cost to clean to unrestricted use must be provided in the FS, as well as a cost to implement and maintain LUCs.

The agreement for sites already past the FS stage (such as those at the South AFRL where the focused FS was finalized in June 2005 [Earth Tech 2005]) was that risks via the VIP need not be updated using the J&E model version 3.1 (2004). For the South AFRL PP, risks at each site via the VIP under a residential exposure scenario were estimated by converting the risk estimated under an industrial scenario (included in the HHRAs) using residential factors for exposure duration and exposure frequency.

B.1.3 AGREEMENT ON TOXICITY VALUES TO BE USED IN THE EVALUATION OF RISK VIA THE VIP

The procedure for estimating risks via the VIP was again discussed in an RPM meeting held on March 13, 2007 in Sacramento CA (U.S. Air Force 2007). The objective for this meeting was to address a concern that the Air Force had about using certain default values in the J&E version 3.1 models. Specifically, use of the provisional USEPA toxicity value for trichloroethene (TCE) is against Air Force policy (memo dated July 14, 2006), which is consistent with USEPA (2003a) guidance (OSWER Directive 9285.7-53 dated December 5, 2003) not to use draft toxicity criteria when estimating human health risk. Rather, the guidance recommends that toxicity criteria (unit risk factors [URFs] for carcinogens and/or reference concentrations [RfCs] for non-carcinogens) be derived from the following hierarchy of sources:

1. USEPA's Integrated Risk Information System (IRIS).

2. USEPA provisional peer-reviewed toxicity values (PPRTVs), developed by the Office of Research and Development at the National Center for Environmental Assessment (NCEA).

3. Other peer-reviewed sources including the California Environmental Protection Agency (Cal-EPA) Office of Environmental Health Hazard Assessment (OEHHA), the Office of Environmental Health Hazard Assessment/Air Resources Board (OEHHA/ARB), the Agency for Toxic Substances and Diseases Registry (ATSDR), or the USEPA Health Effects Assessment Summary Tables (HEAST).

Specifically, the Air Force policy is to use the OEHHA toxicity value for TCE; and any risk-based cleanup levels (RBCLs) (and corresponding costs to meet these levels) to address risk via the VIP will be based on risk estimated using the OEHHA toxicity criteria. The Air Force agreed, at the request of the USEPA, to also present an estimate of risk using the USEPA provisional toxicity value, and add an uncertainty section to include a discussion regarding the discrepancies in toxicity criteria (see Section B.4). For those sites where the older J&E model was used, the USEPA asked that this discrepancy also be addressed in the uncertainty section.

B.1.4 RATIONALE FOR RE-EVALUATION OF RISK VIA THE VIP IN THE ROD

Due to the many changes (since completion of the OU4 and OU9 HHRAs) in the agreed-upon methodology for estimating risks via the VIP, and a desire to reduce the associated uncertainties, the Air Force has decided to include a re-evaluation of risk via the VIP at Sites 37, 120, 133, and 321 as an appendix to the South AFRL ROD. This evaluation was performed in accordance with agreements made in the April 2006 and March 2007 meeting minutes.

In addition to the differences already discussed, the re-evaluation involved the use of more recent soil and groundwater data (where available) to better characterize current conditions, and ProUCL to generate initial soil and groundwater VOC concentrations based on the 95 percent UCL rather than the maximum values used in the HHRAs. For comparison purposes, the J&E model was also used to evaluate risk based on the soil vapor concentration in a sample collected (at a depth of 5 feet below ground surface [bgs]) from Well 172-SG32 (located approximately 10 feet south of Building 8595) on October 30, 2006, 3 months following shutdown (for rebound monitoring) of the Site 172 soil vapor extraction (SVE) system on July 6, 2006 (Earth Tech 2007).

B.2 PROCEDURES

The procedures used to re-evaluate potential risks at Sites 37, 120, 133, and 321 due to the VIP from VOCs in soil and groundwater into indoor air are detailed below.

B.2.1 SELECTION OF DATA

A review of the chemical database (for data collected through 2005) was performed for soil and groundwater. The following methodology was used to screen the database and derive a single result for each sampling location:

1. The selection of chemicals of potential concern (COPCs) was essentially the same as that used in the OU4 and OU9 HHRAs, i.e., only chemicals considered volatile by the USEPA were included for input into the vapor intrusion model. The criteria used for volatility are that the chemical must have a molecular weight of 200 grams/mole or less and have a Henry's coefficient greater than 1 x 10^{-5} atmospheres-cubic meter per mole.

2. For a given monitoring well, the most recent data from samples collected by Earth Tech between 2003 through 2005 were used. The 2003 chemical database is the most complete (includes samples collected from the most wells).

3. Only the results from the shallower well of a nested/clustered pair were used. Data from wells installed for the *Supplemental Hydrogeologic Investigation* (Earth Tech 2006b), which are located down gradient (outside) of plume extents, were not used. The wells used to evaluate risk via the vapor intrusion pathway are shown in regular font on Figures B.1-3 through B.1-8; wells whose sampling results were excluded are grey-shaded.

4. In order to derive a single result for each chemical per sampling location within a site, and to avoid misrepresenting data from VOCs with elevated reporting limits (RLs), a 2-step procedure was used:

    a. First, the "maximum" value for each sampling location was determined as either the maximum hit (of duplicate samples) for that compound, or ½ of the lowest reporting limit (RL) if there were no hits for that compound (i.e., for non-detects [ND]).

    b. ND results greater than 2 times the maximum **detected** result for any given compound within the site dataset (i.e., among all sampling locations) were removed from the value list.

B.2.2 GENERATION OF 95 PERCENT UPPER CONFIDENCE LIMITS OF THE MEAN

The data set for each chemical following the screening completed in Task 1 was used to generate a 95 percent UCL of the mean value for each VOC per site. The computer program ProUCL (www.epa.gov/nerlesd1/tsc/software.htm), Version 3.0 was used to calculate the 95 percent UCL. This program generates various estimates of the 95 percent UCL assuming different data distributions, and recommends the most statistically valid value for the data set. In general, the **lower** of the

recommended 95 percent UCL or the maximum detected concentration of each COPC was used in the next step to estimate the risk associated with the vapor intrusion pathway.

B.2.3 EXPOSURE SCENARIOS AND MODEL INPUT PARAMETERS

The most recent version (Version 3.1) of the J&E vapor intrusion model (Screening Model, with some hand-entered, site-specific inputs) available from the USEPA (2003b) website (http://www.epa.gov/oswer/riskassessment/airmodel/johnson_ettinger.htm) was used to estimate the potential incremental cancer risks and non-cancer hazards from VOCs. The model appropriate to the environmental medium (e.g., soil or groundwater) was used (example spreadsheets for each site are provided in Attachment B-1). For each site, the first and either the second or third of the following three scenarios were modeled:

1. Residential scenario – represents a hypothetical, future exposure condition wherein a residential building is built overlying soil or groundwater VOC contamination.

2. Current industrial scenario – represents the current condition at sites where a building occupied for industrial purposes is present overlying soil or groundwater VOC contamination.

3. Future industrial scenario – represents a potential future condition where a building is not currently present but may be built in the future overlying groundwater VOC contamination.

For the evaluation of risk based on the soil vapor concentration in Well 172-SG32, only an industrial exposure was evaluated per Scenario 2 described below.

A soil type was assigned to each site based on borehole lithology for the unconsolidated soil above the bedrock and/or the groundwater hydraulic conductivity (estimated from results of pumping tests); the J&E model does not allow selection of fractured granite as a soil type. The model's "lookup table" was used to populate values for the parameters soil bulk density, total porosity, and water-filled porosity based on the selected soil type. For each site, an example of the J&E model's input data (datenter), chemical properties (chemprops), interim calculations (intercalcs) and output (results) sheets are provided in Attachment B-1 to this appendix.

Scenario 1. To assess the potential risks and hazards associated with the residential (unrestricted) land use, the J&E model was run using default values for the vapor intrusion simulation (including building size) and exposure (duration and frequency) that are supplied with the model to represent the residential

scenario. The values used for the depth to contaminant were the depth at which the maximum concentration was detected in soil, and the depth to groundwater for groundwater. A default value of 5 liters per minute (L/min) was used for Q_{soil}, the average vapor volumetric flowrate into the building. Model inputs for each site and environmental medium are listed in Table B.1-1.

Scenario 2. To assess the potential risks and hazards associated with the current industrial scenario, the J&E model was run using input parameters that reflect, to the extent feasible, the actual buildings present at the site. These include the building dimensions and various model parameters that are related to these dimensions (e.g., $Q_{building}$, and X_{crack}). A building air exchange rate recommended for use by Base Civil Engineering (CE) and based on industry design specifications (0.15 cubic feet per minute/square foot [cfm/sq ft.] or 1.11 air exchanges per hour, was used to simulate the industrial scenario. Values for depth to contaminant were selected as described above for the residential scenario and are presented in Table B.1-1. No value was input for Q_{soil}, allowing the model to generate this value based on site-specific building parameters. Exposure parameters (e.g., exposure duration and frequency) were consistent with those used in the HHRA. Except for these site-specific inputs, the remaining values for the model parameters were the model default values. Because there are existing buildings at each of Sites 37, 120, and 133, this was the scenario used for these sites.

Scenario 3. To assess the potential risks and hazards associated with industrial use where a building could be built, a hypothetical future building for Base use was assumed. The dimensions of this building were based on a survey of the dimensions of the buildings used for general purposes already on the Base. These dimensions (10 meters by 10 meters) and the values for the related model parameters were used to assess this scenario. The same values for building ventilation rate, depth to contaminant, soil characteristics, and exposure parameters described for Scenario 2 above were used to assess the hypothetical future industrial land use assumed in this scenario. This was the scenario used for Site 321.

B.2.4 TOXICITY VALUES USED FOR RISK CALCULATIONS

The toxicity values used were selected in accordance with the criteria discussed in Section B.1.3, above, and are listed in Table B.1-2. In general, the model default values were used, with several

TABLE B.1-1. J & E VERSION 3.1 EXPOSURE SITE INPUT PARAMETERS

				Building Parameters (Industrial Scenario)[b]				
Site	Medium Being Evaluated	Depth to Water[a] (cm)	Soil Type	Length x Width[e] (m)	X_{crack} (cm)	A_B (cm^2)	h (unitless)	$Q_{building}$ (cm^3/sec)
37	soil vapor [c]	n/a	S	48.8 x 15.8	1.29E+04	7.73E+06	1.67E-04	5.81E+05
37	soil vapor [d]	n/a	S	36.6 x 36.6	1.46E+04	1.34E+07	1.09E-04	1.01E+06
37	soil, groundwater	2,319	SIL	36.6 x 36.6	1.46E+04	1.34E+07	1.09E-04	1.01E+06
120	soil, groundwater	1,219	S	4.57 x 7.62	2.44E+03	3.48E+05	7.00E-04	2.62E+04
133	soil, groundwater	405	SCL	21.3 x 18.3	7.92E+03	3.90E+06	2.03E-04	2.94E+05
321	soil, groundwater	4,359	SIL	10 x 10	4.00E+03	1.00E+06	4.00E-04	7.52E+04

Notes:

Residential exposure frequency is 350 days/yr with an exposure duration of 30 years. Industrial exposure frequency is 250 days/yr with an exposure duration of 10 years. Inhalation rate of 20 m^3/day for both residential and industrial exposure scenarios.

[a] Depth to water is the distance from the surface to first-encountered groundwater.

[b] For the residential scenario, values for building parameters were the model defaults. For the industrial scenario, the default industrial building was used for sites without buildings (Site 321). Otherwise the dimensions for the building nearest the impacted area were used.

[c] Parameters used to estimate risk based on assumption of vapor intrusion into the metal portion of Building 8595 and starting soil vapor concentrations as measured in Well 172-SG32.

[d] Parameters used to estimate risk based on assumption of vapor intrusion into the cinder-block portion of Building 8595 and starting soil vapor concentrations as measured in Well 172-SG32.

[e] Building height default value of 2.44 meters (8 feet) used.

A_B	area of foundation	m^3/day	cubic meters per day
A_{crack}	area of crack	n/a	not applicable
cm	centimeters	$Q_{building}$	volumetric air flow through building
cm^3/sec	cubic centimeters per second	S	Soil Conservation Service abbreviation for sand
days/yr	days per year	SCL	Soil Conservation Service abbreviation for sandy clay loam
h	A_{crack}/A_B	SIL	Soil Conservation Service abbreviation for silty loam
J & E	Johnson and Ettinger	X_{crack}	floor-wall seam perimeter
m	meters		

TABLE B.1-2. TOXICITY VALUES AND SOURCES USED IN THE J & E VERSION 3.1 EXPOSURE MODEL

chemical	URF ($\mu g/m^3)^{-1}$	source	Tier	RfC (mg/m^3)	source	Tier
1,1-dichloroethane	1.60E-06	OEHHA	3	5.00E-01	HEAST	3
1,1-dichloroethene	NA			2.00E-01	IRIS	1
1,1,1-trichloroethane	NA			2.20E+00	pprtv	2
1,1,1,2-tetrachloroethane	7.40E-06	IRIS	1	1.10E-01	IRIS	1
1,1,2,2-tetrachlorethane	5.80E-05	IRIS	1	2.10E-01	IRIS	1
1,2-dichloroethane	2.60E-05	IRIS	1	NE		
1,2-dichlorobenzene	NA			2.00E-01	HEAST	3
1,2,3-trichlorobenzene[a]	NA			4.00E-03	pprtv	2
1,2,4-trichlorobenzene	NA			4.00E-03	pprtv	2
1,2,4-trimethylbenzene	NA			6.00E-03	pprtv	2
1,3-dichlorobenzene	NA			1.10E-01		
1,3,5-trimethylbenzene	NA			6.00E-03	pprtv	2
1,4-dichlorobenzene	1.10E-05	OEHHA	3	8.00E-01	IRIS	1
2-butanone (MEK)	NA			5.00E+00	IRIS	1
2-hexanone[b]	NA			2.00E-01	IRIS	1
2-methylnaphthalene	NA			1.00E-02	IRIS	1
4-methyl-2-pentanone (MIBK)	NA			3.00E+00	IRIS	1
acetone	NA			3.15E+00	IRIS	1
benzene	7.80E-06	IRIS	1	3.00E-02	IRIS	1
CFC 113	NA			3.00E+01	HEAST	3
bromochloromethane[c]	1.80E-05	IRIS	1	7.00E-02	IRIS	1
bromodichloromethane	1.80E-05	IRIS	1	7.00E-02	IRIS	1
bromomethane	NA			5.00E-03	IRIS	1
carbon disulfide	NA			7.00E-01	IRIS	1
carbon tetrachloride	1.50E-05	IRIS	1	NE		
chloroethane	8.30E-07	NCEA	2	1.00E+01	IRIS	1
chloroform	2.30E-05	IRIS	1	NE		
chloromethane	1.80E-06	NCEA	2	9.00E-02	IRIS	1
cis -1,2-dichloroethene	NA			3.50E-02	pprtv	2
ethylbenzene	NA			1.00E+00	IRIS	1
ethylene dibromide (EDB)	5.70E-04	IRIS	1	9.10E-03	IRIS	1
isopropylbenzene	NA			4.00E-01	IRIS	1
MTBE	2.60E-07	OEHHA	3	3.00E+00	IRIS	1
methylene chloride	4.70E-07	IRIS	1	3.00E+00	HEAST	3
n-butylbenzene	NA			1.40E-01	NCEA	2
n-propylbenzene	NA			1.40E-01	NCEA	2
naphthalene	3.40E-05	OEHHA	3	3.00E-03	IRIS	1
p-isopropyltoluene[d]	NA			4.00E-01	IRIS	1
tetrachloroethene (PCE)	5.90E-06	OEHHA	3	3.50E-02	OEHHA	3
sec -butylbenzene	NA			1.40E-01	NCEA	2
styrene	NA			1.00E+00	IRIS	1
trans -1,2-dichlororethene	NA			7.00E-02	IRIS	1
TCE	1.10E-04	epa prov		4.00E-02	NCEA	2
TCE (OEHHA)	2.00E-06	OEHHA	3	4.00E-02	NCEA	2
tert -butylbenzene	NA			1.40E-01	NCEA	2
toluene	NA			5.00E+00	IRIS	1
trichlorofluoromethane	NA			7.00E-01	HEAST	3
m,p,o-xylenes[e]	NA			1.00E-01	IRIS	1
vinyl chloride	8.80E-06	IRIS	1	1.00E-01	IRIS	1

Notes:

[a] 1,2,4-trichlorobenzene used as a surrogate for 1,2,3-trichlorobenzene.
[b] n-hexane used as a surrogate for 2-hexanone.
[c] bromodichloromethane used as a surrogate for bromochloromethane.
[d] isopropylbenzene used as a surrogate for isopropyltoluene.
[e] m-xylene used as a surrogate for m,p,o-xylenes and total xylenes.

epa prov = USEPA provisional value. To be consistent with AF 14 July 2006 memo, the OEHHA value of 2 x 10^{-6} should be used instead.

$\mu g/m^3$	micrograms per cubic meter
mg/m^3	milligrams per cubic meter
AF	Air Force
HEAST	Health Effects Assessment Summary Tables
IRIS	Integrated Risk Information System
J & E	Johnson and Ettinger
MTBE	methyl tert-butyl ether
NA	not applicable
NCEA	National Center for Environmental Assessment
NE	not established
OEHHA	Office of Environmental Health Hazard Assessment
pprtv	provisional peer reviewed toxicity value
RfC	reference concentration
TCE	trichloroethene
URF	unit risk factor
USEPA	United States Environmental Protection Agency

exceptions. For example, consistent with its treatment in the OU4 HHRA, naphthalene was evaluated as a carcinogen using the inhalation URF developed by OEHHA in addition to its evaluation as a non-carcinogen using the model default RfC value. Similarly, methyl tertiary-butyl ether (MTBE) was evaluated as a carcinogen using the inhalation URF developed by OEHHA in addition to its evaluation as a non-carcinogen using the model default RfC value. Also, as described in Section B.1.3, two different inhalation URFs were used to assess TCE: the OEHHA value consistent with Air Force policy and the USEPA provisional value (USEPA 2001) as requested for comparison purposes.

B.2.5 CALCULATION OF RISK-BASED CLEANUP LEVELS

Following the calculation of risks and hazards by the J&E model as described above, the risk calculations were essentially run in reverse to calculate RBCLs, i.e., the concentrations of soil vapor, soil and groundwater VOCs present at each site that correspond to a cancer risk of 1×10^{-4}, 1×10^{-5}, and 1×10^{-6} in the case of carcinogens, or to an HQ of 1 in the case of non-carcinogens. These calculations were performed only for environmental media (i.e., soil or groundwater) and sites where the total risk exceeds 1×10^{-6}, or the HI exceeds 1, and only for those chemicals whose risks or hazards, either separately or in combination with other chemicals, exceeded these risk criteria. For chemicals exhibiting both cancer and noncancer endpoints, the cleanup level corresponding to the greatest potential risk was calculated.

B.3 RESULTS

The results from the re-evaluation of risks via the VIP are discussed for each site and environmental medium below. Risk results are summarized in Table B.1-3. RBCLs for soil and groundwater to meet cancer risk levels of 1×10^{-4} (or an HQ of 1, if lower) 1×10^{-5}, and 1×10^{-6} are summarized in Table B.1-4.

B.3.1 SITE 37

B.3.1.1 Soil Gas

Table B.1-5 presents risk results for inhalation of indoor air via the VIP from the soil vapor detected in Well 172-SG32 under the industrial exposure scenario. PCE was the only contaminant contributing to

TABLE B.1-3. SUMMARY OF DETAILED ASSESSMENT OF RISKS AND HAZARDS IN SOIL AND GROUNDWATER FOR SITES 37, 120, 133, AND 321, J&E VERSION 3.1 EXPOSURE MODEL

	Site 37						Site 120					
	Residential			Industrial			Residential			Industrial		
Potential Exposure Medium	Cancer Risk	Risk Driver	Hazard Quotient	Cancer Risk	Risk Driver	Hazard Quotient	Cancer Risk	Risk Driver	Hazard Quotient	Cancer Risk	Risk Driver	Hazard Quotient
Indoor Air [(a)]	n/c		n/c	**2.71E-06**		0.13	n/c		n/c	n/c		n/c
Indoor Air (Soil Vapor) [(b)]	n/c		n/c	**1.60E-04**		5.5	n/c		n/c	n/c		n/c
Indoor Air (Soil)	**1.1E-03**	**PCE**	**21.06**	**1.80E-06**	**PCE**	0.17	**2.00E-06**	MeCl	<0.01	2.1E-08	MeCl	<0.01
Indoor Air (Groundwater)	**1.60E-03**	**PCE,TCE, benzene**	**18.4**	**3.50E-05**	**PCE**	**1.21**	**1.60E-03**	**PCE,TCE, cis-1,2-DCE**	**22.2**	**9.20E-05**	**PCE**	**3.8**
Indoor Air (Groundwater) [(c)]	**2.0E-03**	**PCE,TCE, benzene**	**18.4**	**4.2E-05**	**PCE,TCE**	**1.21**	**2.2E-03**	**PCE,TCE, cis-1,2-DCE**	**22.2**	**1.3E-04**	**PCE,TCE**	**3.8**

	Site 133						Site 321					
	Residential			Industrial			Residential			Industrial		
Potential Exposure Medium	Cancer Risk	Risk Driver	Hazard Quotient	Cancer Risk	Risk Driver	Hazard Quotient	Cancer Risk	Risk Driver	Hazard Quotient	Cancer Risk	Risk Driver	Hazard Quotient
Indoor Air (Soil)	**4.60E-06**	TCE,MeCl	0.07	6.90E-09	NA	<0.01	**9.30E-05**	PCE	**1.1**	3.3E-07	PCE	0.011
Indoor Air (Soil) [(c)]	**1.4E-04**	TCE,MeCl	0.07	3.1E-07	NA	<0.01	NA	NA	NA	NA	NA	NA
Indoor Air (Groundwater)	**1.20E-04**	**TCE,PCE**	**3.3**	**2.9E-06**	TCE	0.23	**1.50E-04**	**PCE**	**1.77**	**6.40E-06**	**PCE**	0.23
Indoor Air (Groundwater) [(c)]	**6.0E-03**	**TCE,PCE**	**3.3**	**1.5E-04**	**TCE**	0.23	**1.70E-04**	**PCE,TCE**	**1.77**	**7.10E-06**	**PCE**	0.23

Notes :

Risk levels approaching or exceeding 10^{-6} are shown in bold. Risk drivers shown in bold are considered COCs.

[(a)] Risk calculated for indoor air sample collected in June 2003 that contained PCE at 4.7 μg/m3.

[(b)] Risk calculated using J&E model based on soil gas sample from 172-SG32 with a PCE concentration of 110,000 ppb(v).

[(c)] Risk calculated using the proposed provisional USEPA toxicity criteria for TCE.

<	less than
COC	chemicals of concern
DCE	dichloroethene
J&E	Johnson and Ettinger. The exposure to indoor air was evaluated using output from the J & E model (Version 3.1)
MeCl	methylene chloride
NA	not applicable
n/c	not calculated
OEHHA	risk calculated using the inhalation unit risk factor for TCE developed by the Office of Environmental Health Hazard Assessment (OEHHA).
PCE	tetrachloroethene
TCE	trichloroethene
USEPA	United States Environmental Protection Agency

TABLE B.1-4. RISK BASED CLEANUP LEVELS FOR RESIDENTIAL AND INDUSTRIAL EXPOSURE VIA THE VAPOR INTRUSION PATHWAY FOR SITES 37, 120, 133, AND 321

Site	COC	Residential Exposure			Industrial Exposure		
		Soil RBCL in mg/kg					
		10^{-4}	10^{-5}	10^{-6}	10^{-4}	10^{-5}	10^{-6}
Site 37	PCE	0.03	0.003	0.0003	5.87[a] [c]	1.99[c]	0.2
	naphthalene	2.23[c]	0.51	0.05	NA	NA	NA
Site 120	MeCL	0.223[c]	0.022[c]	0.0022	NA	NA	NA
Site 133	MeCL	0.176[c]	0.018[c]	0.0018	NA	NA	NA
	TCE	0.049[a] [c]	0.014[c]	0.0014	NA	NA	NA
	TCE[b]	0.0026	0.0003	0.00003	NA	NA	NA
Site 321	PCE	0.017[a]	0.0019	0.0002	NA	NA	NA
		Groundwater RBCL in μg/L					
		10^{-4}	10^{-5}	10^{-6}	10^{-4}	10^{-5}	10^{-6}
Site 37	benzene	2,540	254	25.4	NA	NA	NA
	PCE	1,160[a]	131	13.1	17,900[a]	6,070	607
	TCE	2,080[a]	607	60.7	34,200[c]	29,900[c]	2,990
	TCE[b]	110	11	1.1	5,440	544	54.4
Site 120	PCE	161[a]	18.1	1.8	957[a]	324	32.4
	TCE	292[a] [c]	85.2	8.5	NA	NA	NA
	TCE[b]	15.5	1.55	0.2	276[c]	27.6	2.8
	cis-1,2-DCE	672[a]	NA	NA	NA	NA	NA
Site 133	PCE	1,150[a] [c]	130[c]	13	NA	NA	NA
	TCE	1,960[a]	573	57.3	26,800[a] [c]	23,400[c]	2,340
	TCE[b]	104	10.4	1	4,260	426	42.6
Site 321	PCE	1,680[a]	190	19	13,300[a] [c]	4,510[c]	451

Notes:

[a] RBCL based on an HI of 1.0.
[b] RBCL estimated using USEPA provisional toxicity value for TCE.
[c] No site concentrations exceed these values.

Concentrations are in mg/kg for soil and μg/L for groundwater.

μg/L	micrograms per liter
COC	chemical of concern
HI	hazard index
MeCL	methylene chloride
mg/kg	milligrams per kilogram
NA	Not applicable. Risk did not exceed 10^{-6} risk levels for these analytes at these sites for industrial exposure scenario.
PCE	tetrachloroethene
RBCL	risk based cleanup level
TCE	trichloroethene
USEPA	United States Environmental Protection Agency

TABLE B.1-5. QUANTIFICATION OF RISKS AND HAZARDS FOR VOCs IN SOIL VAPOR AT SITE 37, J & E VERSION 3.1 EXPOSURE MODEL

Analyte	Measured Soil Vapor Concentration[(a)] (ppbv)	Calculated Indoor Air Concentration ($\mu g/m^3$)	risk		Risk-Based Soil Vapor Concentration (ppbv)
			cancer	noncancer	
Metal Addition					
1,1-dichloroethene	250	0.4		1.40E-03	
tetrachloroethene	110,000	281	**1.60E-04**	5.5	710
1,1,1-trichloroethane	350	0.738		2.30E-04	
1,1,2-trichlorotrifluoroethane	1,500	4.45		1.00E-04	
Cinder Block					
1,1-dichloroethene	250	0.289		9.90E-04	
tetrachloroethene	110,000	207	**1.20E-04**	4	960
1,1,1-trichloroethane	350	0.539		1.70E-04	
1,1,2-trichlorotrifluoroethane	1,500	3.24		7.40E-05	

Notes:

[(a)] Sampling results are for soil vapor in Well 172-SG32, collected in 2006 during rebound monitoring for the Site 172 SVE System.

$\mu g/m^3$	micrograms per cubic meter
J & E	Johnson and Ettinger
ppbv	parts per billion by volume
SVE	soil vapor extraction

an estimated cancer risk (under an industrial scenario) of 1.6 x 10^{-4} in the metal portion of the building or 1.2 x 10^{-4} in the cinderblock portion of the building. A discussion of how the model-generated indoor air concentration of PCE (281 micrograms per cubic meter [$\mu g/m^3$] in the metal addition and 207 $\mu g/m^3$ in the cinderblock portion of the building) derived from the soil vapor concentration at Well 172-SG32 compares to actual measured concentrations in the indoor air is presented in Section B.4.

B.3.1.2 Soil

Table B.1-6 presents risk results for inhalation of indoor air via the VIP from the soil medium at Site 37 under residential and industrial exposure scenarios. PCE and naphthalene were the only contaminants contributing to the cancer risk via the VIP from soil at Site 37. PCE was the primary chemical driving a cancer risk of 1.1 x 10^{-3} for the residential scenario and 1.8 x 10^{-6} for the industrial scenario.

RBCLs were calculated for those chemicals that individually contribute a cancer risk exceeding the 10^{-6} benchmark level considered generally acceptable under all site conditions. The RBCLs for PCE under a residential exposure setting are 0.0003 milligrams per kilogram (mg/kg) to meet a cancer risk level of 1 x 10^{-6} and 0.03 mg/kg to meet a cancer risk level of 1 x 10^{-4} (or an HQ of 1). RBCLs for PCE under an industrial exposure setting are 0.2 mg/kg to meet a cancer risk level of 1 x 10^{-6} and 5.87 mg/kg to meet an HQ of 1. The estimated areas encompassing PCE contamination in soil at concentrations exceeding RBCLs are presented on Figure B.1-1 for residential exposure and Figure B.1-2 for industrial exposure.

In addition to PCE and naphthalene, VOCs contributing to the non-cancer HI in the soil at Site 37 include 1,2,4-trimethylbenzene (TMB), 1,3,5-TMB, m,p-xylenes, n-butylbenzene, and p-isopropyltoluene (refer to Table B.1-6). The TMBs and PCE were the primary chemicals contributing to an HI of 21.06 for the residential scenario and 0.17 for the industrial scenario. An HI at or below 1 is considered acceptable.

B.3.1.3 Groundwater

Table B.1-7 presents risk results for inhalation of indoor air via the VIP for the groundwater medium at Site 37 under residential and industrial exposure scenarios. The evaluation included 18 VOCs

TABLE B.1-6. QUANTIFICATION OF RISKS AND HAZARDS FOR VOCS IN SOIL AT SITE 37, J & E VERSION 3.1 EXPOSURE MODEL

Analyte	Concentration* (μg/kg)	Depth (cm)	Potential Risks and Hazards: Residential cancer	Residential non-cancer	Industrial cancer	Industrial non-cancer
1,2,4-trimethylbenzene	1400	457.2	NA	**6.20**	NA	0.08
1,3,5-trimethylbenzene	470	457.2	NA	**2.00**	NA	0.03
acetone	8.91	15.2	NA	<0.01	NA	<0.01
m,p-xylenes	173.7	259.1	NA	0.32	NA	<0.01
naphthalene	381.7	457.2	**7.50E-06**	0.17	3.20E-08	<0.01
n-butylbenzene	430	457.2	NA	0.19	NA	<0.01
p-isopropyltoluene	310	304.8	NA	0.18	NA	<0.01
PCE	359.6	182.9	**1.10E-03**	**12.00**	**1.80E-06**	0.06
			1.1E-03	**21.06**	**1.8E-06**	0.17

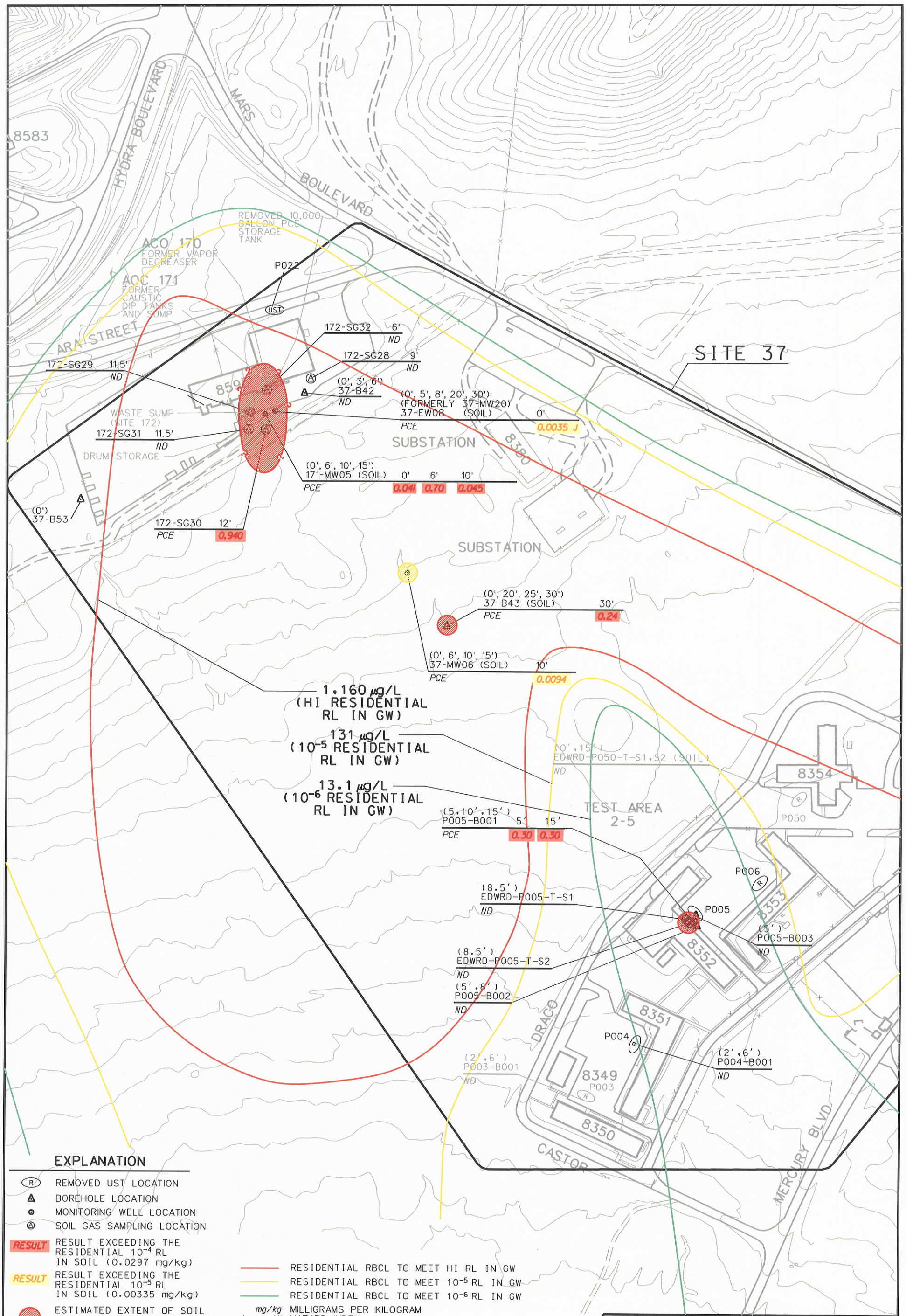
Analyte	Risk Based Cleanup (1E-06/1E-05/1E-04) (mg/kg): Residential	Industrial
naphthalene	0.05/0.51/2.23[(a)]	NA
PCE	0.0003 / 0.003 / 0.03	0.2/1.99[(b)]/5.87[(a)(b)]

Notes:

*Concentrations are 95 percent UCLs for samples collected through 2005.
p-isopropylbenzene used as a surrogate for p-isopropyltoluene.

(a) RBCL based on an HI of 1.0.
(b) No site concentrations exceed these values.

<	less than
μg/kg	micrograms per kilogram
cm	centimeter
J&E	Johnson and Ettinger
mg/kg	milligrams per kilogram
NA	not applicable
PCE	tetrachloroethene
RBCL	risk-based cleanup level
UCL	upper confidence limits



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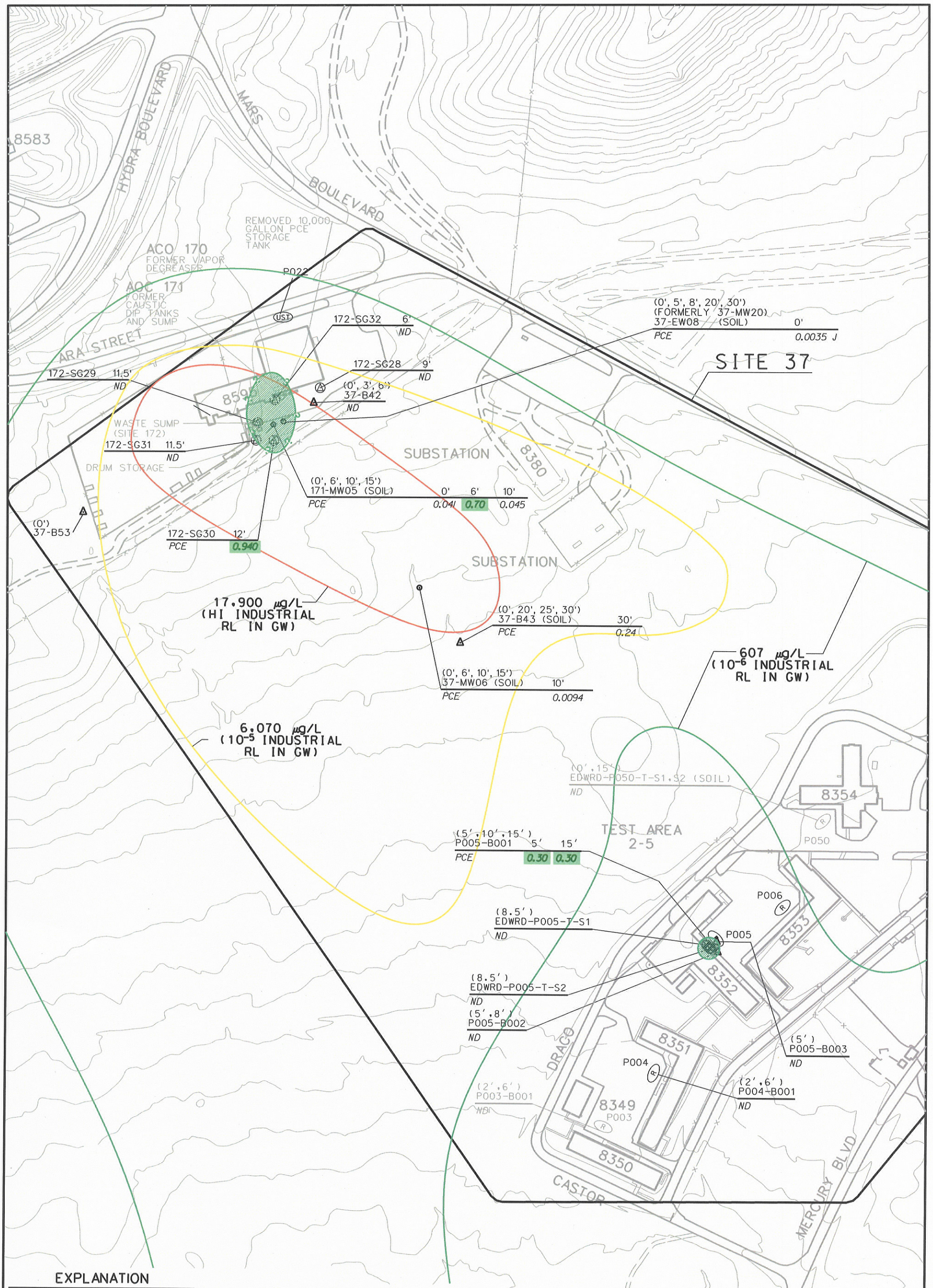

EXPLANATION

- (R) REMOVED UST LOCATION
- BOREHOLE LOCATION
- MONITORING WELL LOCATION
- SOIL GAS SAMPLING LOCATION
- RESULT — RESULT EXCEEDING THE INDUSTRIAL 10^{-6} RL IN SOIL (0.2 mg/kg)
- ESTIMATED EXTENT OF SOIL CONTAMINATION THAT EXCEEDS 10^{-6} INDUSTRIAL (0.2 mg/kg) RBCL

(DEPTHS SAMPLED)
LOCATION NAME — SAMPLE DEPTH (DEPTH BELOW UST)
PARAMETER NAME — *VALUE DETECTED*
SOILS - mg/kg

- INDUSTRIAL RBCL TO MEET HI RL IN GW
- INDUSTRIAL RBCL TO MEET 10^{-5} RL IN GW
- INDUSTRIAL RBCL TO MEET 10^{-6} RL IN GW

mg/kg MILLIGRAMS PER KILOGRAM
HI HAZARD INDEX
GW GROUND WATER
J RESULT IS DETECTED BELOW THE REPORTING LIMIT
ND NOT DETECTED
PCE TETRACHLOROETHENE
RBCL RISK-BASED CONTAMINANT LEVEL
RL RISK LEVEL
UST UNDERGROUND STORAGE TANK

NOTE:
SOIL RESULTS FROM 172-SG28 TO 172-SG32 ARE FROM 2006.

NORTH

0 100 200 FEET
SCALE: 1"= 200'

South AFRL ROD

Site 37
Estimated Areas with Soil PCE Exceeding Industrial RBCLs

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure B.1-2
Project No. 67861		

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TABLE B.1-7. QUANTIFICATION OF RISKS AND HAZARDS FOR VOCS IN GROUNDWATER AT SITE 37, J & E VERSION 3.1 EXPOSURE MODEL

Analyte	Concentration* (μg/L)	Residential cancer	Residential non-cancer	Industrial cancer	Industrial non-cancer
1,1-dichloroethane	37.9	2.7E-07	<0.01	5.6E-09	<0.01
1,1-dichloroethene	365.9	**NA**	0.11	**NA**	<0.01
1,1,1-trichloroethane	154.97	**NA**	<0.01	**NA**	<0.01
1,1,1,2-tetrachloroethane	47.05	5.9E-07	<0.01	1.2E-08	<0.01
1,1,2-trichlorotrifluroethane	3011	**NA**	0.09	**NA**	<0.01
2-butanone (MEK)	3.5	NA	<0.01	NA	<0.01
acetone	72.84	**NA**	<0.01	**NA**	<0.01
benzene	84.23	**3.3E-06**	0.03	6.3E-08	<0.01
bromodichloromethane	3.37	3.5E-08	<0.01	1.1E-09	<0.01
chloroform	7.71	7.1E-07	NA	1.2E-08	NA
cis -1,2-dichloroethene	37.57	NA	<0.01	NA	<0.01
ethylbenzene	6.98	**NA**	<0.01	**NA**	<0.01
methylene chloride	124.83	1.4E-07	<0.01	2.4E-09	<0.01
o-xylene	7.38	**NA**	<0.01	**NA**	<0.01
styrene	7.01	NA	<0.01	NA	<0.01
tetrachloroethene (PCE)	21338	**1.6E-03**	**18**	**3.5E-05**	**1.20**
toluene	44.15	NA	<0.01	NA	<0.01
trichloroethene (TCE), OEHHA	402.8	**6.6E-06**	0.19	1.3E-07	0.01
trichloroethene (TCE), EPA		**3.6E-04**	0.19	**7.4E-06**	0.01
	Totals (OEHHA):	**1.6E-03**	**18.4**	**3.5E-05**	**1.21**
	Totals (EPA):	**2.0E-03**	**18.4**	**4.2E-05**	**1.21**

Analyte	Risk-Based Cleanup (based on 1E-06/1E-05/1E-04 risk) (μg/L) Residential	Industrial
benzene	25.4/254/2,540	NA
tetrachloroethene	13.1/131/1,160[a]	607/6,070/17,900[a]
trichloroethene (OEHHA)	60.7/607/2,080[a]	2,990/29,900[b]/34,200[a][b]
trichloroethene (EPA)	1.1/11/110	54.4/544/5,440

Notes:

* Concentrations are 95 percent UCLs for a data set that includes, for a given well, the most recent result for groundwater samples collected between 2003 and 2005.

[a] RBCL based on an HI of 1.0.
[b] No site concentrations exceed these values.

EPA = risk calculated using the proposed provisional USEPA toxicity value for TCE.
OEHHA = risk calculated using the inhalation unit risk factor for TCE developed by the Office of Environmental Health Hazard Assessment (OEHHA).
1,1,2,2-tetrachloroethane used as a surrogate for 1,1,1,2-tetrachloroethane.

<	less than
μg/L	micrograms per liter
EPA	Environmental Protection Agency
J&E	Johnson and Ettinger
MEK	methylethylketone
NA	not applicable
OEHHA	Office of Environmental Health Hazard Assessment
PCE	tetrachloroethene
RBCL	risk-based cleanup level
TCE	trichloroethene

(1,1-dichloroethane, 1,1-dichloroethene, 1,1,1-trichloroethane, 1,1,1,2-tetrachloroethane, 1,1,2-trichlorotrifluoroethane, 2-butanone, acetone, benzene, bromodichloromethane, chloroform, cis-1,2-DCE, ethylbenzene, methylene chloride, o-xylene, styrene, PCE, toluene, and TCE) detected in groundwater at Site 37. The estimated cumulative cancer risk based on 95 percent UCLs for the detected carcinogens was 1.6×10^{-3} (2.0×10^{-3} using the USEPA provisional toxicity value for TCE) for the hypothetical residential exposure scenario and 3.5×10^{-5} (4.2×10^{-5}) for the industrial exposure scenario, with PCE and TCE as the primary risk drivers.

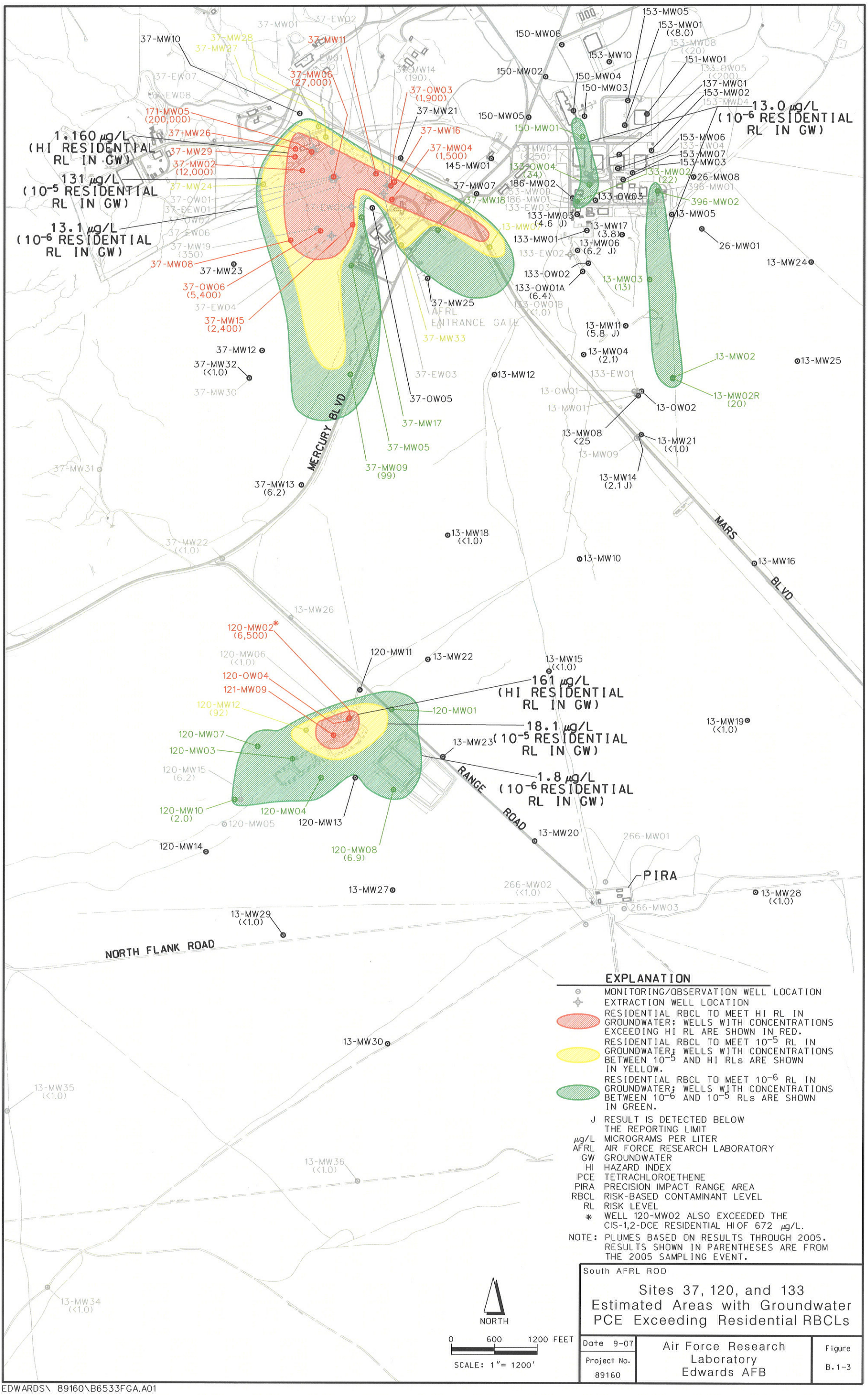
RBCLs were calculated for those chemicals that individually contribute a risk level exceeding the 10^{-6} benchmark level considered generally acceptable under all site conditions. The 10^{-6} RBCLs for PCE and TCE are 13.1 μg/L and 60.7 μg/L (1.1 μg/L using the USEPA provisional toxicity value) for the residential exposure setting; the 10^{-6} RBCL for PCE under an industrial scenario is 607 μg/L (risk due to TCE under an industrial exposure setting was less than 10^{-6} unless the USEPA provisional toxicity value is used, in which case the RBCL would be 54.4 μg/L). RBCLs for a 10^{-4} and 10^{-5} risk level (or an HQ of 1, if lower) are also listed in Table B.1-7. The approximate areas encompassing PCE contamination in Site 37 groundwater at concentrations exceeding these RBCLs are presented on Figure B.1-3 for residential exposure and Figure B.1-5 for industrial exposure. Figures B.1-4 and B.1-6 present the approximate areas encompassing TCE contamination in groundwater at concentrations exceeding the RBCLs (based on the OEHHA toxicity value) for residential and industrial exposures.

PCE was the primary chemical contributing to an HI of 18.4 for the residential scenario and 1.2 for the industrial scenario. An HI below 1 is considered acceptable.

B.3.2 SITE 120

B.3.2.1 Soil

Table B.1-8 presents risk results for inhalation of indoor air via the VIP for the soil medium at Site 120 under the residential and industrial exposure scenarios. Methylene chloride was the only VOC detected in soil at Site 120, yielding a cancer risk of 2.0×10^{-6} for the residential scenario and 2.10×10^{-8} for the industrial scenario; and an HI below 0.01 for both the residential and industrial exposure settings. The 10^{-6} RBCL for methylene chloride under a residential exposure setting is 0.002 mg/kg. Because risk



EXPLANATION

- MONITORING/OBSERVATION WELL LOCATION
- EXTRACTION WELL LOCATION
- RESIDENTIAL RBCL TO MEET HI RL IN GROUNDWATER; WELLS WITH CONCENTRATIONS EXCEEDING HI RL ARE SHOWN IN RED.
- RESIDENTIAL RBCL TO MEET 10^{-5} RL IN GROUNDWATER; WELLS WITH CONCENTRATIONS BETWEEN 10^{-5} AND HI RLs ARE SHOWN IN YELLOW.
- RESIDENTIAL RBCL TO MEET 10^{-6} RL IN GROUNDWATER; WELLS WITH CONCENTRATIONS BETWEEN 10^{-6} AND 10^{-5} RLs ARE SHOWN IN GREEN.

J RESULT IS DETECTED BELOW THE REPORTING LIMIT
µg/L MICROGRAMS PER LITER
AFRL AIR FORCE RESEARCH LABORATORY
GW GROUNDWATER
HI HAZARD INDEX
PCE TETRACHLOROETHENE
PIRA PRECISION IMPACT RANGE AREA
RBCL RISK-BASED CONTAMINANT LEVEL
RL RISK LEVEL
* WELL 120-MW02 ALSO EXCEEDED THE CIS-1,2-DCE RESIDENTIAL HI OF 672 µg/L.

NOTE: PLUMES BASED ON RESULTS THROUGH 2005. RESULTS SHOWN IN PARENTHESES ARE FROM THE 2005 SAMPLING EVENT.

South AFRL ROD

Sites 37, 120, and 133
Estimated Areas with Groundwater PCE Exceeding Residential RBCLs

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure B.1-3
Project No. 89160		

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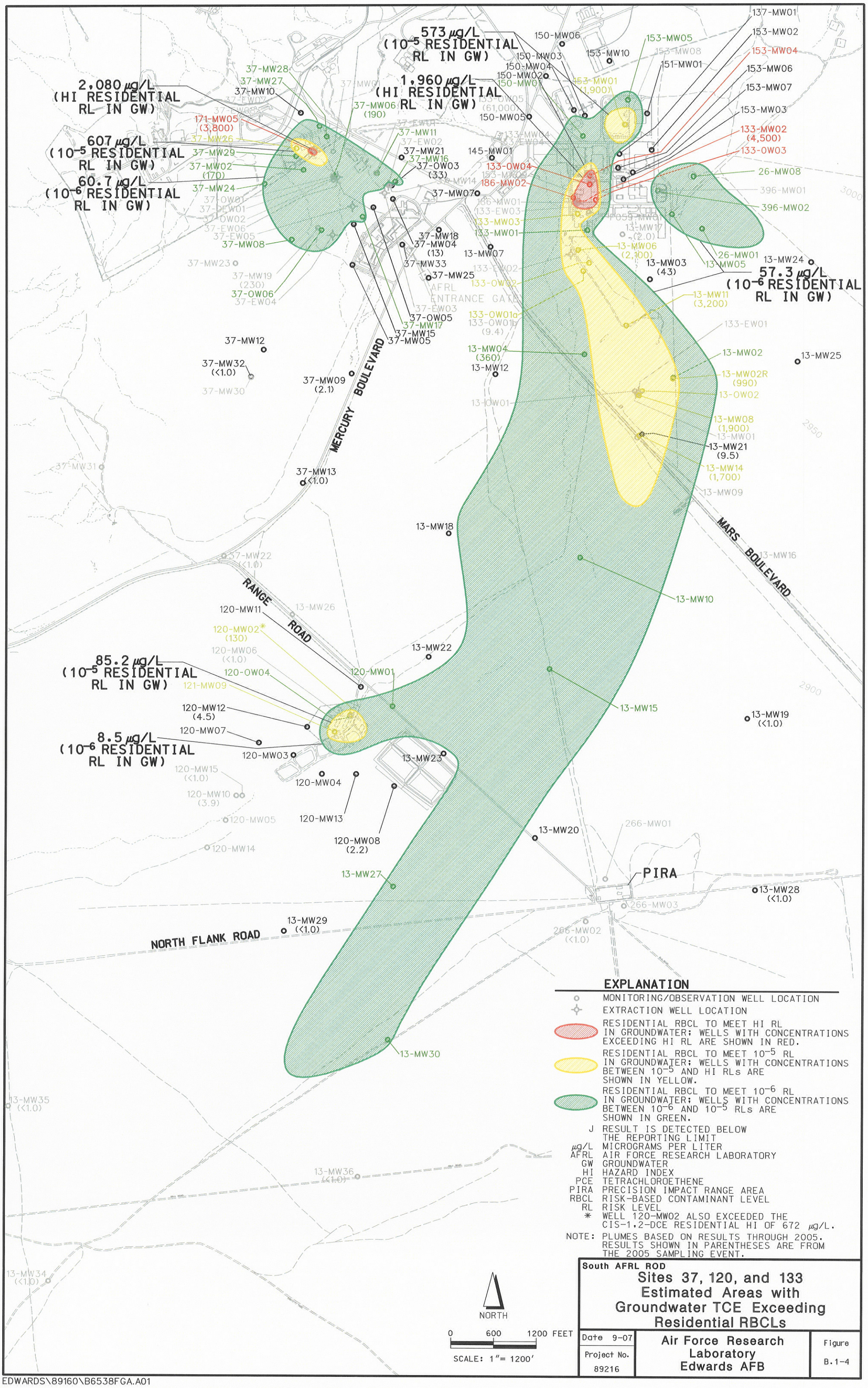

EXPLANATION

- MONITORING/OBSERVATION WELL LOCATION
- EXTRACTION WELL LOCATION
- RESIDENTIAL RBCL TO MEET HI RL IN GROUNDWATER; WELLS WITH CONCENTRATIONS EXCEEDING HI RL ARE SHOWN IN RED.
- RESIDENTIAL RBCL TO MEET 10^{-5} RL IN GROUNDWATER; WELLS WITH CONCENTRATIONS BETWEEN 10^{-5} AND HI RLs ARE SHOWN IN YELLOW.
- RESIDENTIAL RBCL TO MEET 10^{-6} RL IN GROUNDWATER; WELLS WITH CONCENTRATIONS BETWEEN 10^{-6} AND 10^{-5} RLs ARE SHOWN IN GREEN.

J	RESULT IS DETECTED BELOW THE REPORTING LIMIT
µg/L	MICROGRAMS PER LITER
AFRL	AIR FORCE RESEARCH LABORATORY
GW	GROUNDWATER
HI	HAZARD INDEX
PCE	TETRACHLOROETHENE
PIRA	PRECISION IMPACT RANGE AREA
RBCL	RISK-BASED CONTAMINANT LEVEL
RL	RISK LEVEL
*	WELL 120-MW02 ALSO EXCEEDED THE CIS-1,2-DCE RESIDENTIAL HI OF 672 µg/L.

NOTE: PLUMES BASED ON RESULTS THROUGH 2005. RESULTS SHOWN IN PARENTHESES ARE FROM THE 2005 SAMPLING EVENT.

NORTH

0 600 1200 FEET

SCALE: 1" = 1200'

South AFRL ROD

Sites 37, 120, and 133 Estimated Areas with Groundwater TCE Exceeding Residential RBCLs

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 89216		B.1-4

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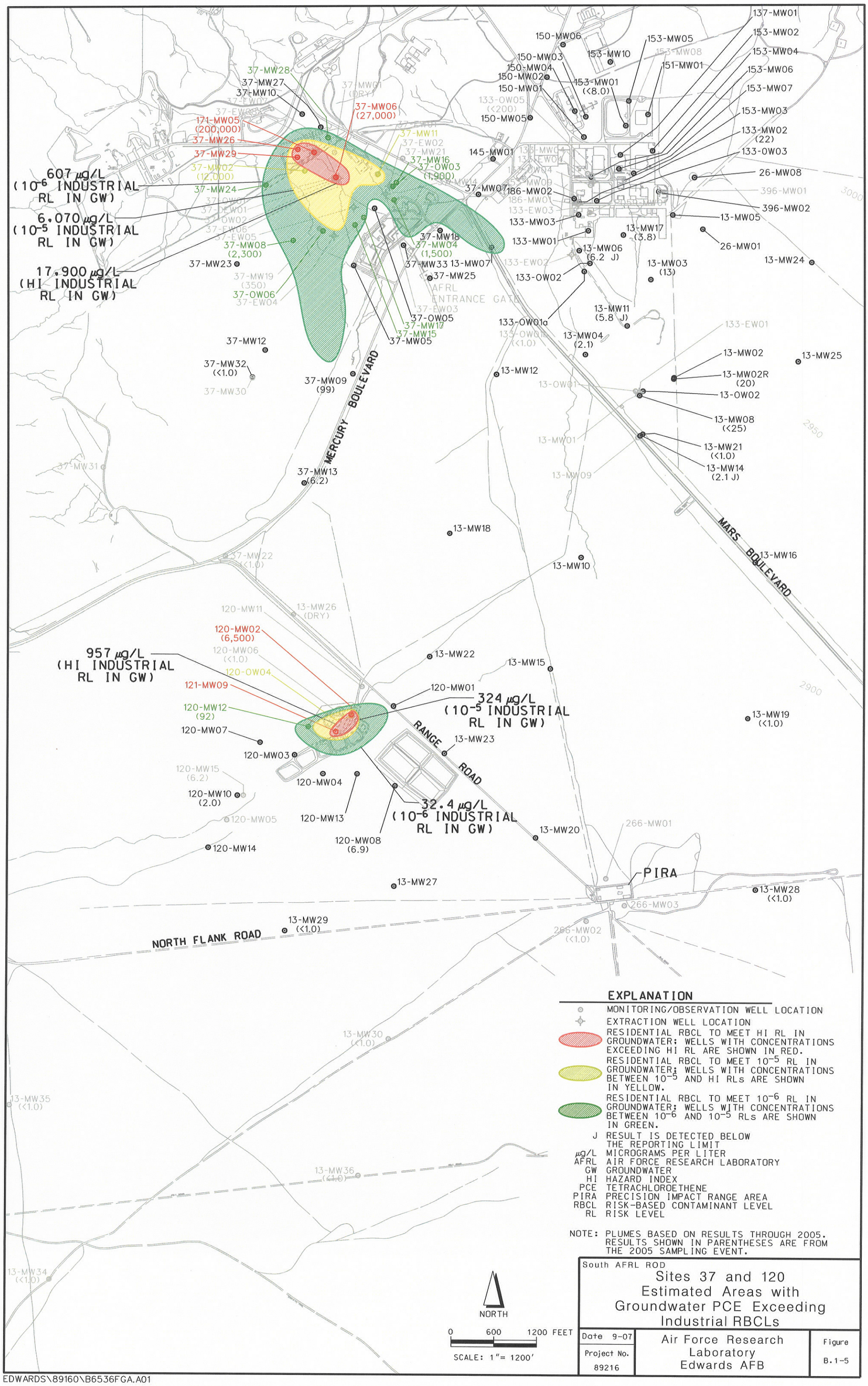

EXPLANATION

- MONITORING/OBSERVATION WELL LOCATION
- EXTRACTION WELL LOCATION
- RESIDENTIAL RBCL TO MEET HI RL IN GROUNDWATER; WELLS WITH CONCENTRATIONS EXCEEDING HI RL ARE SHOWN IN RED.
- RESIDENTIAL RBCL TO MEET 10^{-5} RL IN GROUNDWATER; WELLS WITH CONCENTRATIONS BETWEEN 10^{-5} AND HI RLs ARE SHOWN IN YELLOW.
- RESIDENTIAL RBCL TO MEET 10^{-6} RL IN GROUNDWATER; WELLS WITH CONCENTRATIONS BETWEEN 10^{-6} AND 10^{-5} RLs ARE SHOWN IN GREEN.

J	RESULT IS DETECTED BELOW THE REPORTING LIMIT
µg/L	MICROGRAMS PER LITER
AFRL	AIR FORCE RESEARCH LABORATORY
GW	GROUNDWATER
HI	HAZARD INDEX
PCE	TETRACHLOROETHENE
PIRA	PRECISION IMPACT RANGE AREA
RBCL	RISK-BASED CONTAMINANT LEVEL
RL	RISK LEVEL

NOTE: PLUMES BASED ON RESULTS THROUGH 2005. RESULTS SHOWN IN PARENTHESES ARE FROM THE 2005 SAMPLING EVENT.

South AFRL ROD

Sites 37 and 120 Estimated Areas with Groundwater PCE Exceeding Industrial RBCLs

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure B.1-5
Project No. 89216		

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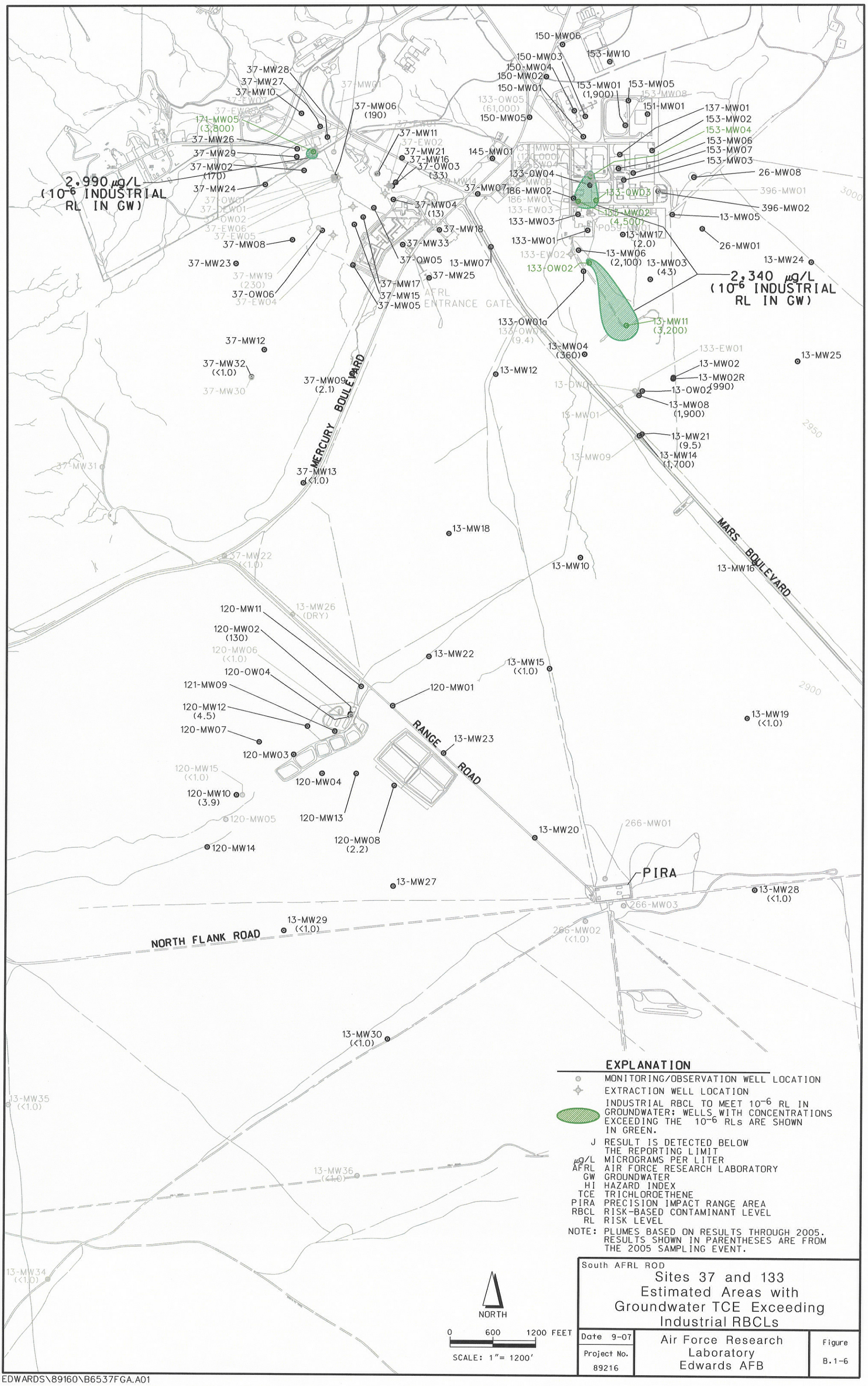

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TABLE B.1-8. QUANTIFICATION OF RISKS AND HAZARDS FOR VOCS IN SOIL AT SITE 120, J & E VERSION 3.1 EXPOSURE MODEL

			Potential Risks and Hazards			
			Residential		Industrial	
Analyte	Concentration* (μg/kg)	Depth (cm)	cancer	non-cancer	cancer	non-cancer
methylene chloride	4.44	15.2	**2.0E-06**	<0.01	2.10E-08	<0.01
			2.0E-06	<0.01	2.10E-08	<0.01

	Risk-Based Cleanup (1E-06/1E-05/1E-04) (mg/kg)	
Analyte	Residential	Industrial
methylene chloride	0.0022/0.022[(a)]/0.223[(a)]	NA

Notes:

* Concentration is the 95 percent UCL for samples collected through 2005.

[(a)] No site concentrations exceed these values.

<	less than
μg/kg	micrograms per kilogram
cm	centimeter
J&E	Johnson and Ettinger
mg/kg	milligram per kilogram
NA	not applicable

via the VIP from a soil source at Site 120 is acceptable under the current industrial land use, and only slightly exceeds 10^{-6} for the hypothetical residential scenario, no action is required to address this risk.

B.3.2.2 Groundwater

Table B.1-9 presents risk results for inhalation of indoor air via the VIP for the groundwater medium at Site 120 under residential and industrial exposure scenarios. The evaluation included seven VOCs (1,1-DCE, acetone, chloroform, cis-1,2-DCE, PCE, TCE, and trans-1,2-DCE) detected in the groundwater at Site 120. The estimated cumulative cancer risk based on 95 percent UCLs for the detected carcinogens was 1.6×10^{-3} (2.2×10^{-3} using the USEPA provisional toxicity value for TCE) for the hypothetical residential exposure scenario and 9.2×10^{-5} (1.3×10^{-4}) for the industrial exposure scenario, with PCE and TCE as the primary risk drivers.

RBCLs were calculated for those chemicals that individually contribute a risk level exceeding the 10^{-6} benchmark level considered generally acceptable under all site conditions. The 10^{-6} RBCLs for PCE and TCE are 1.8 μg/L and 8.5 μg/L (0.2 μg/L using the USEPA provisional toxicity value) for the residential exposure scenario; the 10^{-6} RBCL for PCE for the industrial exposure scenario is 32.4 μg/L (risk due to TCE was less than 10^{-6} under the industrial exposure setting, unless the USEPA provisional toxicity value is used, in which case the RBCL would be 2.8 μg/L for the industrial scenario). RBCLs for a 10^{-4} and 10^{-5} risk level (or an HQ of 1, if lower) also are listed in Table B.1-9. The approximate areas encompassing PCE contamination in Site 120 groundwater at concentrations exceeding these RBCLs are presented on Figure B.1-3 for residential exposure and Figure B.1-5 for industrial exposure. Figures B.1-4 and B.1-6 present the approximate areas encompassing TCE contamination in groundwater at concentrations exceeding the RBCLs (based on the OEHHA toxicity value) for residential and industrial exposures (note there was no exceedance of the 10^{-6} RBCL for TCE under an industrial exposure at Site 120).

PCE and cis-1,2-DCE were the primary chemicals contributing to an HI of 22.2 for the residential exposure scenario and 3.8 for the industrial scenario. An HI below 1 is considered acceptable.

TABLE B.1-9. QUANTIFICATION OF RISKS AND HAZARDS FOR VOCS IN GROUNDWATER AT SITE 120, J & E VERSION 3.1 EXPOSURE MODEL

Analyte	Concentration[a] (μg/L)	Residential cancer	Residential non-cancer	Industrial cancer	Industrial non-cancer
1,1-dichlorothene	4.61	NA	<0.01	NA	<0.01
acetone	5	NA	<0.01	NA	<0.01
chloroform	0.5	3.2E-07	NA	1.8E-08	NA
cis -1,2-dichloroethene	2,547	NA	**3.8**	NA	0.64
tetrachloroethene	2,951	**1.6E-03**	**18**	**9.1E-05**	**3.1**
trichloroethene (OEHHA)	95.25	**1.1E-05**	0.33	6.3E-07	0.06
trichloroethene (EPA)		**6.1E-04**	0.33	**3.4E-05**	0.06
trans -1,2-dichloroethene	28.20	NA	0.05	NA	<0.01
	Total (OEHHA):	**1.6E-03**	**22.2**	**9.2E-05**	**3.8**
	Total (EPA):	**2.2E-03**	**22.2**	**1.3E-04**	**3.8**

Analyte	Risk-Based Cleanup (based on 1E-06/1E-05/1E-04 risk) (μg/L) Residential	Industrial
cis -1,2-dichloroethene	672[b]	NA
tetrachloroethene	1.8/18.1/161[b]	32.4/324/957[b]
trichloroethene (OEHHA)	8.5/85.2/292[b][c]	152[c]/1,520[c]/1,740[b][c]
trichloroethene (EPA)	0.2/1.55/15.5	2.8/27.6/276

Notes:

[a] Concentrations are 95 percent UCLs for a data set that includes, for a given well, most recent result collected between 2003 and 2005.
[b] RBCL based on hazard index of 1.0.
[c] No site concentrations exceed these values.

EPA = risk calculated using the proposed provisional USEPA toxicity value for TCE.
OEHHA = risk calculated using the inhalation unit risk factor for TCE developed by the Office of Environmental Health Hazard Assessment (OEHHA).

<	less than
μg/L	micrograms per liter
EPA	Environmental Protection Agency
NA	not applicable
OEHHA	Office of Environmental Health Hazard Assessment
RBCL	risk-based cleanup level

B.3.3 SITE 133

B.3.3.1 Soil

Table B.1-10 presents risk results for inhalation of indoor air via the VIP from the soil medium at Site 133 under residential and industrial exposure scenarios. TCE and methylene chloride were the only VOCs detected in soil at Site 133, yielding a cumulative residential risk of 4.60×10^{-6} (1.42×10^{-4} using the USEPA provisional toxicity value) and a cumulative industrial risk of 6.90×10^{-9} (3.11×10^{-7} using the USEPA provisional toxicity value).

Because the cumulative cancer risk under a residential scenario slightly exceeded 10^{-6}, RBCLs were calculated for methylene chloride and TCE. Under a residential scenario, the 10^{-6} RBCL for methylene chloride is 0.0018 mg/kg and the 10^{-6} RBCL for TCE is 0.0014 mg/kg. Because risk via the VIP from a soil source at Site 133 is acceptable under the current industrial land use, and only slightly exceeds 10^{-6} for the hypothetical residential scenario, no action is required to address this risk.

B.3.3.1 Groundwater

Table B.1-11 presents risk results for inhalation of indoor air via the VIP for the groundwater medium at Site 133 under residential and industrial exposure scenarios. The evaluation included the 20 VOCs listed in Table B.1-11. Under the hypothetical residential exposure scenario, the estimated cumulative cancer risk based on 95 percent UCLs for the detected carcinogens is 1.2×10^{-4} (6.0×10^{-3} using the USEPA provisional toxicity value) with TCE as the primary risk driver. Under the industrial exposure scenario, the cumulative risk is 2.9×10^{-6} (1.5×10^{-4} using the USEPA provisional TCE value).

RBCLs were calculated for those chemicals that individually contribute a risk level exceeding the 10^{-6} benchmark level considered generally acceptable under all site conditions. The 10^{-6} RBCLs for PCE and TCE are 13 μg/L and 57 μg/L (1.0 μg/L using the USEPA provisional toxicity value) for the residential exposure setting; the 10^{-6} RBCL for TCE under an industrial scenario is 2,340 μg/L (43 μg/L using the USEPA provisional toxicity value); risk due to PCE under an industrial exposure setting was less than 10^{-6}. RBCLs for a 10^{-4} and 10^{-5} risk level (or an HQ of 1, if lower) also are listed in Table B.1-11. The approximate areas encompassing PCE contamination in Site 133 groundwater at concentrations exceeding the 10^{-6} RBCL are presented on Figure B.1-3 for residential exposure (note there was no exceedance of the 10^{-6} RBCL for PCE under an industrial exposure at Site 133).

TABLE B.1-10. QUANTIFICATION OF RISKS AND HAZARDS FOR VOCS IN SOIL AT SITE 133, J & E VERSION 3.1 EXPOSURE MODEL

Analyte	Concentration[c] (μg/kg)	Depth (cm)	Potential Risks and Hazards: Residential cancer	Residential non-cancer	Industrial cancer	Industrial non-cancer
methylene chloride	3.66	15.2	**2.10E-06**	<0.01	1.20E-09	<0.01
trichloroethene (OEHHA)	3.55	182.9	**2.50E-06**	0.07	5.7E-09	<0.01
trichloroethene (EPA)			**1.40E-04**	0.07	3.10E-07	<0.01
		Total (OEHHA) :	**4.60E-06**	0.07	6.90E-09	<0.01
		Total (EPA) :	**1.42E-04**	0.07	3.11E-07	<0.01

Analyte	Risk-Based Cleanup (1E-06/1E-05/1E-04) (mg/kg) Residential	Industrial
methylene chloride	0.0018/0.018[c]/0.18[c]	NA
trichloroethene (OEHHA)	0.0014/0.0143[c]/0.049[b][c]	NA
trichloroethene (EPA)	0.00003/0.00026/0.0026	NA

Notes:

[a] Concentrations are 95 percent UCLs for samples collected through 2005.

[b] RBCL based on an HI of 1.0.

[c] No site concentrations exceed tthese values.

EPA = risk calculated using the proposed provisional USEPA toxicity value for TCE.

OEHHA = risk calculated using the inhalation unit risk factor for TCE developed by the Office of Environmental Health Hazard Assessment (OEHHA).

<	less than
μg/kg	micrograms per kilogram
mg/kg	milligrams per kilogram
cm	centimeter
EPA	Environmental Protection Agency
HI	hazard index
NA	Not applicable
OEHHA	Office of Environmental Health Hazard Assessment
RBCL	risk-based cleanup level

TABLE B.1-11. QUANTIFICATION OF RISKS AND HAZARDS FOR VOCS IN GROUNDWATER AT SITE 133, J & E VERSION 3.1 EXPOSURE MODEL

Analyte	Concentration[a] (μg/L)	Residential cancer	Residential non-cancer	Industrial cancer	Industrial non-cancer
1,1-dichloroethane	0.877	7.50E-09	<0.01	1.80E-10	<0.01
1,1-dichloroethene	1.23	NA	<0.01	NA	<0.01
1,1,2-trichloro 2,1,1-trifluoroethane	0.5	NA	<0.01	NA	<0.01
1,2,4-trimethylbenzene	0.5	NA	<0.01	NA	<0.01
1,2-dichloroethane	3.493	1.9E-07	NA	2.6E-09	NA
2-butanone	3.64	NA	<0.01	NA	<0.01
acetone	6.72	NA	<0.01	NA	<0.01
benzene	3.279	1.5E-07	<0.01	3.3E-09	<0.01
bromodichloromethane	0.865	2.4E-08	<0.01	5.4E-10	<0.01
chloroform	3.581	4.1E-07	NA	7.7E-09	NA
chloromethane	1.01	2.2E-08	<0.01	4.3E-10	<0.01
cis-1,2-dichloroethene	32.57	NA	<0.01	NA	<0.01
MTBE	12.85	5.9E-09	<0.01	6.6E-11	<0.01
methylene chloride	2.248	3.8E-09	<0.01	6.3E-11	<0.01
naphthalene	2.169	7.4E-08	<0.01	9.4E-10	<0.01
p-isopropyltoluene	4.933	NA	<0.01	NA	<0.01
tetrachloroethene	116.66	**8.9E-06**	0.10	2.4E-07	<0.01
trans-1,2-dichloroethene	2.33	NA	<0.01	NA	<0.01
trichloroethene (OEHHA)	6200	**1.1E-04**	**3.2**	**2.6E-06**	0.23
trichloroethene (EPA)		**6.0E-03**	**3.2**	**1.5E-04**	0.23
trichlorofluoromethane	11.78	NA	<0.01	NA	<0.01
	Total (OEHHA):	**1.2E-04**	**3.3**	**2.9E-06**	0.23
	Total (EPA):	**6.0E-03**	**3.3**	**1.5E-04**	0.23

Analyte	Risk-Based Cleanup (based on 1E-06/1E-05//1E-04 risk) (μg/L) Residential	Industrial
tetrachloroethene	13.0/130[c]/1,150[b][c]	493/4,930/14,500[c]
trichloroethene (OEHHA)	57.3/573/1,960[b]	2,340/23,400[c]/26,800[b][c]
trichloroethene (EPA)	1.0/10.4/104	42.6/426/4,260

Notes:

[a] Concentrations are 95 percent UCLs for a data set that includes, for a given well, most recent result collected between 2003 and 2005.
[b] RBCL based on an HI of 1.0.
[c] No site concentrations exceed these values.

EPA = risk calculated using the proposed provisional USEPA toxicity value for TCE.
OEHHA = risk calculated using the inhalation unit risk factor for TCE developed by the Office of Environmental Health Hazard Assessment (OEHHA).
Isopropylbenzene used as a surrogate for p-isopropyltoluene.

<	less than
μg/L	micrograms per Liter
EPA	Environmental Protection Agency
HI	hazard index
MTBE	methyl tertiary-butyl ether
NA	not applicable
OEHHA	Office of Environmental Health Hazard Assessment
RBCL	risk-based cleanup level

Figures B.1-4 and B.1-6 present the approximate areas encompassing TCE contamination in groundwater at concentrations exceeding the RBCLs (based on the OEHHA toxicity value) for residential and industrial exposures.

TCE was the primary chemical contributing to an HI of 3.3 for the residential scenario and 0.23 for the industrial scenario. An HI at or below 1 is considered acceptable.

B.3.4 SITE 321

B.3.4.1 Soil

Table B.1-12 presents risk results for inhalation of indoor air via the VIP from the soil medium at Site 321 under residential and industrial exposure scenarios. PCE was the only contaminant contributing to the cancer risk in soil at Site 321 driving a risk of 9.30×10^{-5} for the residential scenario and 3.3×10^{-7} for the industrial scenario. The 10^{-6} RBCL for PCE under a residential exposure setting is 0.0002 mg/kg. The HQ for PCE was 1.1 for the residential and 0.011 for the industrial exposure settings. An HI below 1 is considered acceptable.

The soil borehole (321-HB02) location where a PCE concentration of 0.04 mg/kg was detected (exceeding its RBCL of 0.017 mg/kg based on an HQ of 1) for residential exposure is presented on Figure B.1-7. Due to its limited distribution, and because it does not pose as an acceptable risk under the current industrial use, PCE in soil at Site 321 was not identified as a COC via the VIP.

B.3.4.2 Groundwater

Table B.1-13 presents risk results for inhalation of indoor air via the VIP for the groundwater medium at Site 321 under residential and industrial exposure scenarios. The evaluation included nine VOCs (acetone, bromomethane, carbon disulfide, chloroform, cis-1,2-DCE, 2-butanone (MEK), naphthalene, PCE, and TCE) detected in groundwater at Site 321. Under the hypothetical residential exposure scenario, the estimated cumulative cancer risk is 1.5×10^{-4} (1.7×10^{-4} using the USEPA provisional toxicity value) based primarily on the 95 percent UCL for PCE. Under the industrial exposure scenario, the cumulative risk is 6.4×10^{-6} (7.1×10^{-6} using the USEPA provisional TCE toxicity value).

RBCLs were calculated for those chemicals that individually contribute a risk level exceeding the 10^{-6} benchmark level considered generally acceptable under all site conditions. The 10^{-6} RBCL for PCE is

TABLE B.1-12. QUANTIFICATION OF RISKS AND HAZARDS FOR VOCS IN SOIL AT SITE 321, J & E VERSION 3.1 EXPOSURE MODEL

			Potential Risks and Hazards			
			Residential		Industrial	
Analyte	Concentration[a] (μg/kg)	Depth (cm)	cancer	non-cancer	cancer	non-cancer
acetone	5.57	182.9	**NA**	<0.01	NA	<0.01
tetrachloroethene	18.1	91.4	**9.30E-05**	**1.1**	3.3E-07	0.011
			9.30E-05	**1.1**	3.3E-07	0.011

	Risk-Based Cleanup (1E-06/1E-05/1E-04) (mg/kg)	
Analyte	Residential	Industrial
tetrachloroethene	0.0002/0.0019/0.0172[b]	NA

Notes:

[a] Concentrations are 95 percent UCLs for samples collected through 2005.
[b] RBCL based on an HI of 1.0.

<	less than
μg/kg	micrograms per kilogram
cm	centimeter
HI	hazard index
J&E	Johnson & Ettinger
mg/kg	milligrams per kilogram
NA	not applicable
RBCL	risk-based cleanup level
UCL	upper confidence limit

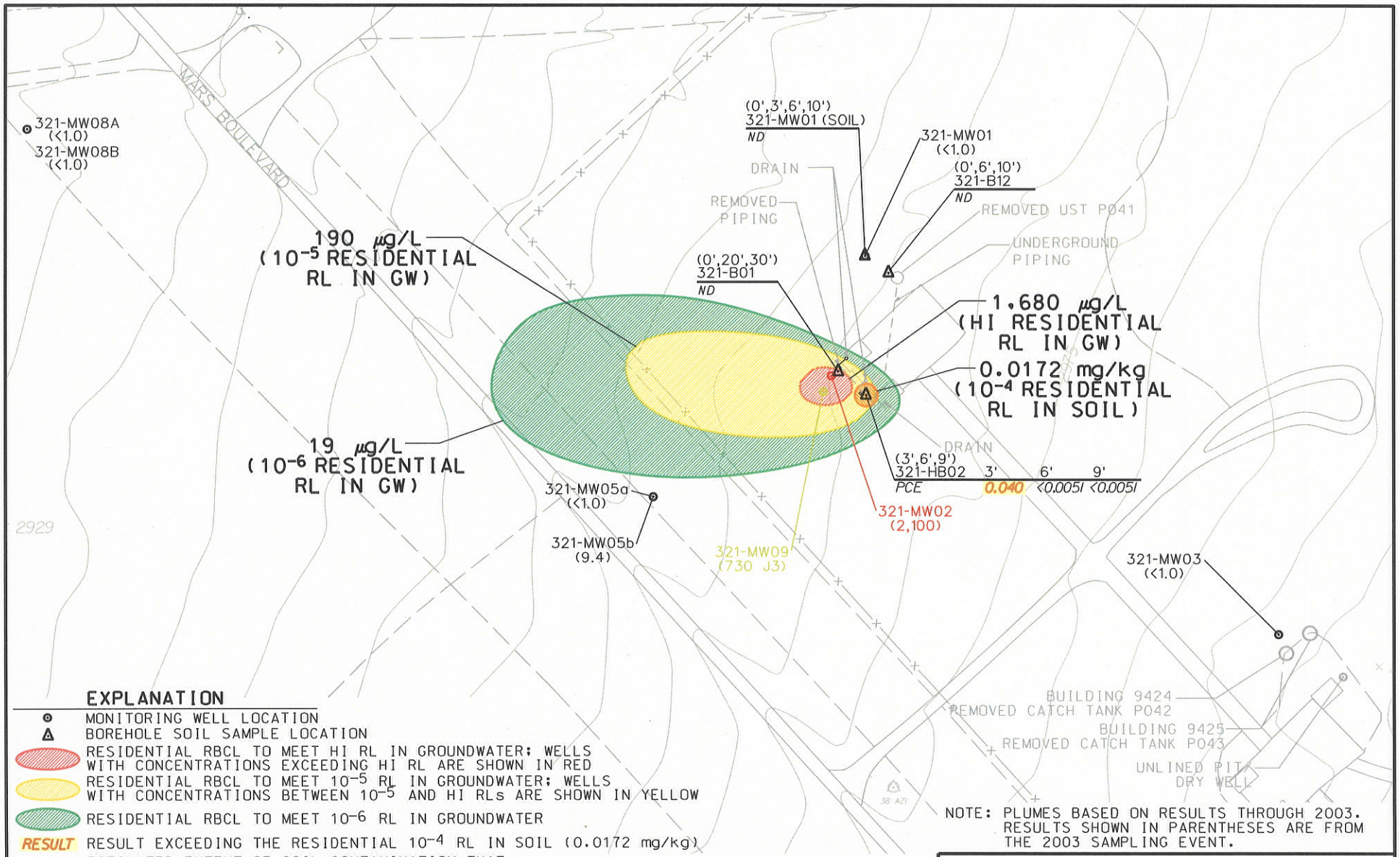

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TABLE B.1-13. QUANTIFICATION OF RISKS AND HAZARDS FOR VOCS IN GROUNDWATER AT SITE 321, J & E VERSION 3.1 EXPOSURE MODEL

		Potential Risks and Hazards			
	Concentration[a]	Residential		Industrial	
Analyte	(μg/L)	cancer	non-cancer	cancer	non-cancer
acetone	13	NA	<0.01	NA	<0.01
bromomethane	0.14	NA	<0.01	NA	<0.01
carbon disulfide	5.5	NA	<0.01	NA	<0.01
chloroform	1.04	6.6E-08	NA	2.5E-09	NA
cis-1,2-dichloroethene	480.7	NA	0.07	NA	<0.01
methylethyl ketone	1	NA	<0.01	NA	<0.01
naphthalene	0.19	1.4E-10	<0.01	5.8E-11	<0.01
tetrachloroethene	2,864	**1.5E-04**	**1.70**	**6.4E-06**	0.22
trichloroethene (OEHHA)	28.83	3.3E-07	<0.01	1.3E-08	<0.01
trichloroethene (EPA)		**1.8E-05**	<0.01	7.4E-07	<0.01
	Total (OEHHA):	**1.5E-04**	**1.77**	**6.4E-06**	0.23
	Total (EPA):	**1.7E-04**	**1.77**	**7.1E-06**	0.23

	Risk-Based Cleanup (based on 1E-06/1E-05/1E-04 risk) (μg/L)	
Analyte	Residential	Industrial
tetrachloroethene	19/190/1,680[b]	451/4,510[c]/13,300[b][c]
trichloroethene (OEHHA)	88.2/882/3,030[b]	2,140/21,400/24,400[b]
trichloroethene (EPA)	1.6/16/160	38.9/389/3,890

Notes:

[a] Concentrations are 95 percent UCLs for a data set that includes, for a given well, most recent result collected between 2003 and 2005.

[b] RBCL based on an HI of 1.0.

[c] No site concentrations exceed tthese values.

EPA = risk calculated using the proposed provisional USEPA toxicity value for TCE.

OEHHA = risk calculated using the inhalation unit risk factor for TCE developed by the Office of Environmental Health Hazard Assessment (OEHHA).

< less than
μg/L micrograms per liter
AF Air Force
EPA Environmental Protection Agency
HI hazard index
J&E Johnson & Ettinger
NA not applicable
RBCL risk-based cleanup level
TCE trichloroethene
UCL upper confidence limit

19 μg/L for the residential exposure setting and 451 μg/L under an industrial scenario. RBCLs for a 10^{-4} and 10^{-5} risk level (or an HQ of 1, if lower) also are listed in Table B.1-12. The approximate areas encompassing PCE contamination in Site 321 groundwater at concentrations exceeding these RBCLs are presented on Figure B.1-7 for residential exposure and Figure B.1-8 for industrial exposure.

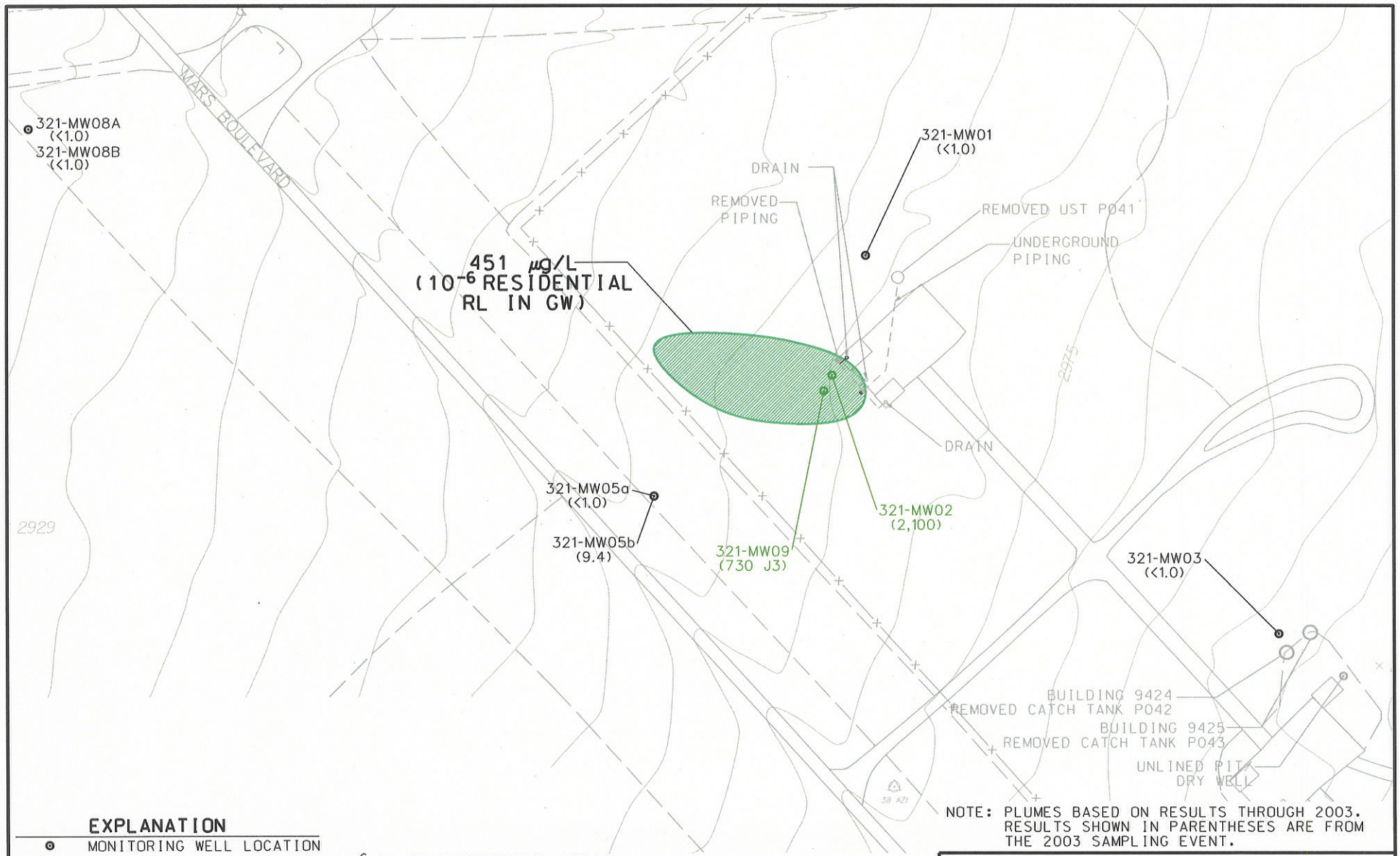
PCE was also the primary chemical contributing to an HI of 1.77 for the residential scenario and 0.23 for the industrial scenario. An HI below 1 is considered acceptable.

B.4 UNCERTAINTIES

In this section, some of the uncertainties associated with the preceding risk estimates are briefly discussed. Uncertainties associated with use of the J&E model to estimate risk via the VIP fall into two general categories: those associated with model input parameters used to derive estimates of the indoor air concentrations of VOCs ($C_{building}$) based on their concentrations in soil or groundwater underlying a building (C_{source}); and those associated with toxicity values used to estimate the health risks corresponding to those indoor air concentrations. In general, these uncertainties are expected to lead to an overly conservative (i.e., health-protective) estimate of actual site risks.

B.4.1 UNCERTAINTIES ASSOCIATED WITH MODEL INPUT PARAMETERS USED TO DERIVE INDOOR AIR CONCENTRATIONS

Since its initial release to the public in 1997, the USEPA versions of the J&E model have been periodically revised. Although these revisions have not changed the theoretical approach or calculations used to estimate risks via the VIP, the values for some of the default parameters (soil and building-related factors selected to provide a health-protective assessment in cases where site-specific values are not available) used to simulate the movement of VOCs from the subsurface into indoor air have been changed. For example, the values for critical soil parameters such as permeability, total porosity and water-filled porosity have been revised, as well as various building-related parameters, such as the building air exchange rate (0.25 $hour^{-1}$) and the volumetric flow rate of subsurface vapor into the building living space (Q_{soil}) to which the model is especially sensitive. Versions 2 and 3 of the J&E model have included a default value for Q_{soil} of 5 liters per minute (L/min), which was selected to represent the midpoint of the range regarded as typical for the situation in which advection constitutes the primary influx mechanism at buildings where the foundation is underlain by a coarse material.



NOTE: PLUMES BASED ON RESULTS THROUGH 2003. RESULTS SHOWN IN PARENTHESES ARE FROM THE 2003 SAMPLING EVENT.

EXPLANATION

- ⊙ MONITORING WELL LOCATION
- RESIDENTIAL RBCL TO MEET 10^{-6} RL IN GROUNDWATER; WELLS WITH CONCENTRATIONS EXCEEDING 10^{-6} RL ARE SHOWN IN GREEN
- J — RESULT IS DETECTED BELOW THE REPORTING LIMIT.
- J3 — ESTIMATED VALUE. EXTRACTION OR ANALYSIS OUT OF HOLD TIME. MAY INDICATE LOW BIAS.
- µg/L — MICROGRAMS PER LITER
- HI — HAZARD INDEX
- PCE — TETRACHLOROETHENE
- RBCL — RISK-BASED CONTAMINANT LEVEL
- RL — RISK LEVEL
- TCE — TRICHLOROETHENE
- UST — UNDERGROUND STORAGE TANK

NORTH

0 100 200 FEET

SCALE: 1"= 200'

South AFRL ROD

Site 321
Estimated Areas with Groundwater PCE Exceeding Industrial RBCLs

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure B.1-8
Project No. 67861		

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Because it is extremely difficult to obtain a site-specific value for Q_{soil}, the use of 5 L/min is generally required as a health-protective feature, introducing significant uncertainty depending on the specific building and soil conditions at each site. For this re-evaluation, the default value was used only for the residential exposure scenario. Note that for Site 321, a Q_{soil} of 5 L/min was assumed for the default residential building (10 meters by 10 meters); however, a model-generated Q_{soil} of 0.1356 L/min was used for the default industrial building (also 10 meters by 10 meters). Risk results presented in Tables B.1-12 and B.1-13 are based on these model-generated Q_{soil} values; if a Q_{soil} of 5 L/min had been used instead, risk results under the industrial setting at Site 321 would have been slightly higher as presented in Table B.1-14.

TABLE B.1-14. COMPARISON OF RISK RESULTS, INDUSTRIAL SCENARIO AT SITE 321 USING Q_{SOIL} OF 5 L/MIN VERSUS MODEL-GENERATED Q_{SOIL}

Contaminant	Cancer Risk/HI for VIP from Soil Using Model-Generated Q_{soil} of 0.1356 L/min*	Cancer Risk/HI for VIP from Soil Using a Q_{soil} of 5 L/min	Cancer Risk/HI for VIP from Groundwater Using Model-Generated Q_{soil} of 0.1356 L/min*	Cancer Risk/HI for VIP from Groundwater Using a Q_{soil} of 5 L/min
PCE	3.3E-07/0.011	5.0E-06/0.17	6.4E-06/0.22	8.1E-06/0.27
TCE(OEHHA)	NA	NA	1.3E-08/<0.01	1.8E-08/<0.01
TCE(EPA)	NA	NA	7.4E-07/<0.01	9.6E-07/<0.01

*Values reported in Tables B.1-12 and B.1-13

The greatest uncertainties associated with use of the J&E model are related to assumptions that have not been changed since the model was developed. The first of these assumptions is that of a uniform distribution of VOC source concentrations beneath the building. While this assumption may be reasonable if the source is contaminated groundwater, it is not expected to be valid when the source is contaminated soil, and is likely to lead to an over-estimation of calculated VOC concentrations in indoor air. This uncertainty can be minimized to a certain extent by using a statistically generated value (such as the 95 percent UCL of the mean) for source concentrations of VOCs in each medium.

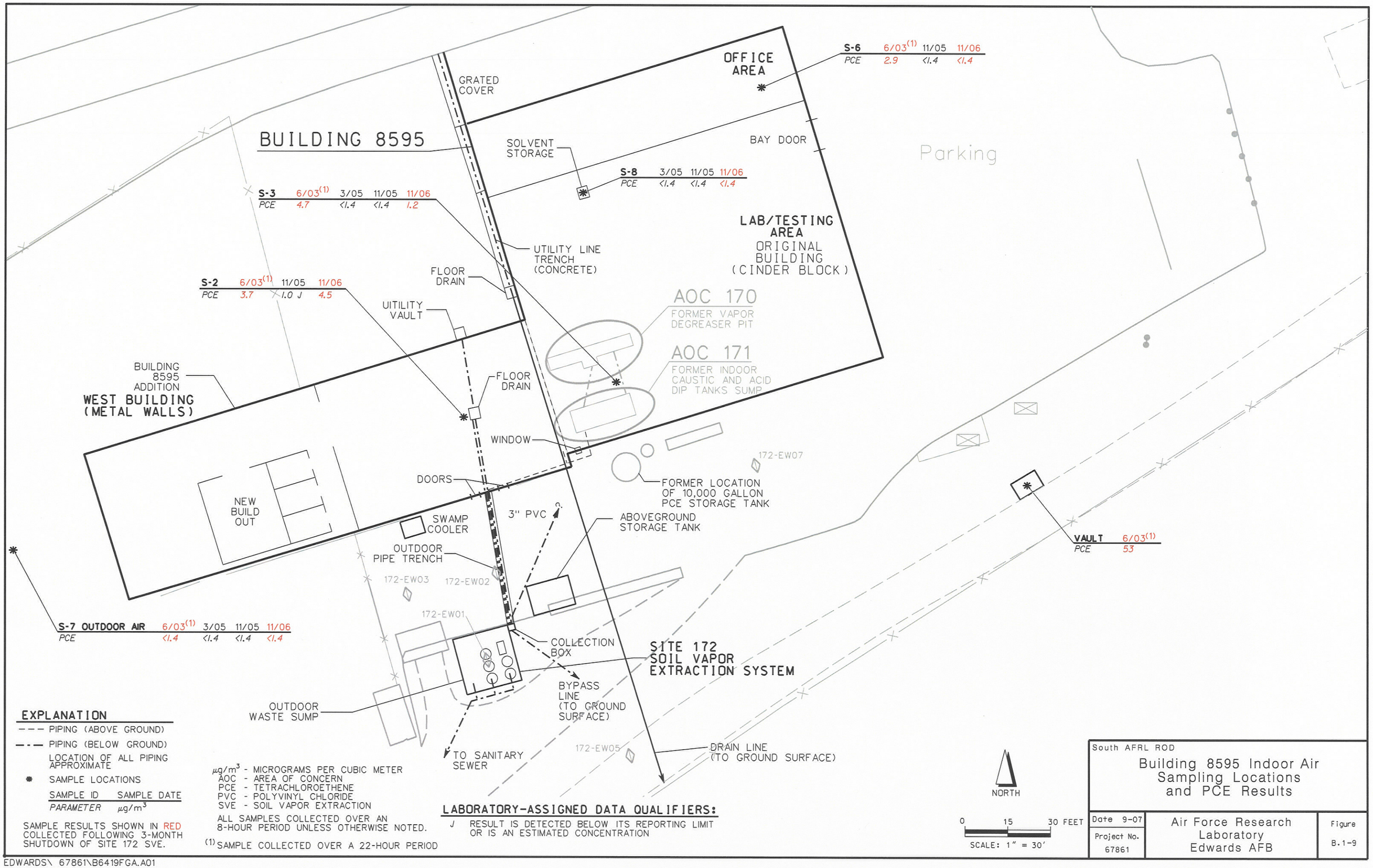
The second basic assumption representing a significant source of uncertainty in the model is that the driving force for subsurface vapor intrusion is advection. Specifically, the model assumes that a building generates a negative pressure relative to the subsurface soil, and thus VOCs are drawn into the building at a rate (Q_{soil}) that is a direct function of that pressure difference. However, unlike the typical residential structures for which the J&E model was developed, buildings used for industrial purposes

typically are characterized as having positive pressures generated by their heating and cooling air handling systems (*Air/Superfund National Technical Guidance Study Series, Assessing Potential Indoor Air Impacts for Superfund Sites*, EPA-451/R-92-002, USEPA 1992). Under these circumstances, the J&E model is likely to significantly over-estimate potential indoor air concentrations and their subsequent risks.

As an example of the degree of uncertainty that may be associated with the use of modeled versus measured indoor air concentrations, the indoor air PCE concentration (industrial scenario) estimated from the soil vapor concentration measured (in October 2006) in Well 37-SG32 (as cited in Section B.3.1) and using Version 3.1 of the J&E model was approximately 207 $\mu g/m^3$ in the cinderblock portion of the building and 281 $\mu g/m^3$ in the metal addition; the indoor air PCE concentration using the 95 percent UCL for soil is 3 $\mu g/m^3$; and the indoor air PCE concentration using the 95 percent UCL for groundwater is 61 $\mu g/m^3$. By comparison, the maximum indoor air concentrations of PCE that have been measured, as presented on Figure B.1-9, are 4.7 $\mu g/m^3$ at sampling location S-3 (in the cinderblock portion of the building) in June 2003 (Earth Tech 2004c) and 4.5 $\mu g/m^3$ at sampling location S-2 (in the metal addition) in November 2006 (Earth Tech 2007). Thus, the modeled concentration from a soil source slightly underestimates, and the modeled concentrations from soil vapor and groundwater over-estimate actual concentrations by a factor of 13 to 60. Both the June 2003 and November 2006 samples were collected under conservative conditions when the soil vapor extraction (SVE) system had been off-line for approximately 3 months; moreover, in June 2003 the samples were collected over a weekend when all building windows and doors were closed allowing for no ventilation. Indoor air concentrations were lower when the SVE system was operating and under conditions of normal building ventilation (refer to results for March and November 2005 on Figure B.1-9). While these results cannot be extrapolated to every site and every building at Edwards AFB, it is clear that the potential for modeled vapor intrusion pathway concentrations to over-estimate actual indoor air concentrations is present for buildings at these OUs.

B.4.2 UNCERTAINTIES ASSOCIATED WITH SELECTION OF TOXICITY CRITERIA

The selection of values used to represent the potential toxic effects of the chemicals evaluated in this assessment introduces further uncertainty in the estimate of risk. As described in Section B.2.4, the model default values were used for this assessment, except in the case of naphthalene, MTBE, and TCE.



EXPLANATION

- – – – PIPING (ABOVE GROUND)
- —·— PIPING (BELOW GROUND)
- LOCATION OF ALL PIPING APPROXIMATE
- ✱ SAMPLE LOCATIONS

SAMPLE ID — SAMPLE DATE
PARAMETER — $\mu g/m^3$

SAMPLE RESULTS SHOWN IN RED COLLECTED FOLLOWING 3-MONTH SHUTDOWN OF SITE 172 SVE.

$\mu g/m^3$ - MICROGRAMS PER CUBIC METER
AOC - AREA OF CONCERN
PCE - TETRACHLOROETHENE
PVC - POLYVINYL CHLORIDE
SVE - SOIL VAPOR EXTRACTION

ALL SAMPLES COLLECTED OVER AN 8-HOUR PERIOD UNLESS OTHERWISE NOTED.

(1) SAMPLE COLLECTED OVER A 22-HOUR PERIOD

LABORATORY-ASSIGNED DATA QUALIFIERS:

J RESULT IS DETECTED BELOW ITS REPORTING LIMIT OR IS AN ESTIMATED CONCENTRATION

South AFRL ROD

Building 8595 Indoor Air Sampling Locations and PCE Results

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure B.1-9
Project No. 67861		

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In the case of naphthalene, including the inhalation URF developed by OEHHA did not significantly increase the cumulative risk estimated from soil at Site 37 because the risk from PCE was several orders of magnitude greater (refer to Table B.1-6). Similarly, the assessment of MTBE as a carcinogen via the VIP from groundwater at Site 133 did not significantly increase the overall risk because the risk from TCE was five to six orders of magnitude greater (refer to Table B.1-11).

By contrast, risks estimated using the inhalation URF for TCE provided by OEHHA are significantly less than those estimated using the USEPA provisional value (USEPA 2001). This discrepancy is most apparent in the cumulative risk estimates for groundwater at Site 133 (refer to Table B.1-11), where TCE is the primary chemical of concern.

In its draft review of potential health risks from exposure to TCE released in August 2001, the USEPA stated that TCE is "highly likely to produce cancer in humans" and developed (for each exposure route, i.e., ingestion, inhalation, skin contact) a range of cancer slope factors for the chemical. Due to uncertainties associated with their assessment, the USEPA recommended that the most stringent values in the range be adopted as the new criteria. The proposed provisional USEPA inhalation toxicity criterion for TCE is approximately 57 times more stringent than the previous value recommended by the USEPA and the current California OEHHA value.

Following the release of its draft report recommending the revised toxicity criteria for TCE, USEPA's Science Advisory Board (SAB) reviewed and commented on the assessment. The Office of Research and Development and the National Academy of Sciences (NAS) prepared responses to the SAB comments on July 27, 2006. While the NAS recommended adoption of the proposed revisions, the academy commented that there were still many questions that created significant uncertainty with regard to nearly every toxicological endpoint used in the assessment. For example, the NAS found, "The magnitude of exposure needed to produce kidney damage is not clear…" and in particular noted that the USEPA assessment had relied heavily on a study by Wartenburg et al (2000), which the NAS rejected. With regard to information used to quantify the liver cancer endpoint, NAS concluded, "Thus, exposure to trichloroethylene at concentrations relevant to the general public is not likely to induce liver cancer in humans…" With regard to respiratory toxicity and cancer, the NAS concluded, "… pulmonary cancer does not appear to be a critical endpoint in assessing human health risks…" Ultimately the NAS

recommendation to adopt the provisional toxicity criterion, while questioning its scientific basis, was based on a qualitative assessment that TCE is too toxic to be without a standard.

The next step that USEPA must take in the process toward finalizing the provisional criteria is to review the available findings in IRIS. Until the IRIS database is updated, federal and state drinking water standards (that is, the federal and state drinking water primary maximum contaminant levels [pMCLs]) will not be affected, and will remain at 5 μg/L. The new toxicity criteria are still controversial: the Air Force's Health Risk Assessment Branch as well as others in DoD, industry, and academia are opposed to finalizing the draft document as it now stands. The USEPA's official position at the national level is that the new numbers are only draft, and the old numbers are still in official use. Some USEPA regions have adopted the draft criteria while some continue to use the official criteria. The state of California prefers to use the OEHHA toxicity criteria for TCE in risk assessments until the scientific questions surrounding the issue can be resolved.

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ATTACHMENT B.1-1

J & E VERSION 3.1 EXPOSURE MODEL WORKSHEETS

- Site 37 (172-SG32) – Soil Vapor-PCE-Metal Portion of Building 8595
- Site 37 – Soil-PCE-Residential and Industrial Exposure
- Site 37 – Groundwater-PCE-Residential and Industrial Exposure
- Site 120 – Soil-Methylene Chloride-Residential and Industrial Exposure
- Site 120 – Groundwater-PCE-Residential and Industrial Exposure
- Site 133 – Soil-TCE (OEHHA and EPA)-Residential and Industrial Exposure
- Site 133 – Groundwater-TCE (OEHHA and EPA)-Residential and Industrial Exposure
- Site 321 – Soil-PCE-Residential and Industrial Exposure
- Site 321 – Groundwater-PCE-Residential and Industrial Exposure

Site 37 (172-SG32) – Soil Vapor-PCE-Metal Portion of Building 8595

SG-SCREEN
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
127184			1.10E+02	Tetrachloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
15	152.4	20	S		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
S	1.66	0.375	0.054	

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
70	10	10	250

END

CHEMICAL PROPERTIES SHEET - SITE 37 (172-SG32) - SOIL VAPOR - PCE - METAL PORTION OF BUILDING 8595

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Molecular weight, MW (g/mol)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	5.9E-06	3.5E-02	165.83

END

INTERMEDIATE CALCULATIONS SHEET - SITE 37 (172-SG32) - SOIL VAPOR - PCE - METAL PORTION BUILDING OF 8595

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. ($\mu g/m^3$)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
137.4	0.321	0.003	1.01E-07	0.998	1.01E-07	12,900	7.58E+05	5.81E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
7.73E+06	1.67E-04	15	9,451	1.40E-02	5.81E-01	1.78E-04	1.16E-02	137.4

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)
15	7.58E+05	0.10	3.21E+02	1.16E-02	1.29E+03	6.18E+92	3.71E-04	2.81E+02

Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
5.9E-06	3.5E-02

END

RESULTS SHEET - SITE 37 (172-SG32) - SOIL VAPOR - PCE - METAL PORTION OF BUILDING 8595

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.6E-04	5.5E+00

MESSAGE SUMMARY BELOW:

END

Site 37 – Soil-PCE-Residential and Industrial Exposure

SL-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
127184	3.60E+02	Tetrachloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
15	182.9	20	SIL		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	ENTER Vadose zone soil organic carbon fraction, f_{oc}^V (unitless)
SIL	1.49	0.439	0.18	0.002

ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based soil concentration.

END

CHEMICAL PROPERTIES SHEET - SITE 37 SOIL PCE RESIDENTIAL EXPOSURE

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	3.5E-02	L

END

INTERMEDIATE CALCULATIONS SHEET - SITE 37 - SOIL - PCE - RESIDENTIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
167.9	0.259	0.307	2.87E-09	0.798	2.29E-09	4,000	3.60E+02	1.69E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
1.00E+06	4.00E-04	15	9,451	1.40E-02	5.81E-01	1.78E-04	4.16E-03	167.9

Convection path length, L_p (cm)	Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)
15	3.10E-01	3.93E+05	0.10	8.33E+01	4.16E-03	4.00E+02	4.83E+217	1.13E-03	4.43E+02

Unit risk factor, URF (µg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
5.9E-06	3.5E-02

END

RESULTS SHEET - SITE 37 - SOIL - PCE - RESIDENTIAL EXPOSURE

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	NA	NA	1.06E+05	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.1E-03	1.2E+01

MESSAGE SUMMARY BELOW:

END

SL-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
127184	3.60E+02	Tetrachloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
15	182.9	20	SIL		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	ENTER Vadose zone soil organic carbon fraction, f_{oc}^V (unitless)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
SIL	1.49	0.439	0.18	0.002	

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	10	10	250	1.0E-06	1

Used to calculate risk-based soil concentration.

END

CHEMICAL PROPERTIES SHEET - SITE 37 - SOIL - PCE - INDUSTRIAL EXPOSURE

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	3.5E-02	L

END

INTERMEDIATE CALCULATIONS SHEET - SITE 37 - PCE - SOIL - INDUSTRIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
167.9	0.259	0.307	2.87E-09	0.798	2.29E-09	14,600	3.60E+02	1.01E+06

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
1.34E+07	1.09E-04	15	9,451	1.40E-02	5.81E-01	1.78E-04	4.16E-03	167.9

Convection path length, L_p (cm)	Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)
15	3.10E-01	3.93E+05	0.10	8.24E+00	4.16E-03	1.46E+03	7.83E+05	7.96E-06	3.13E+00

Unit risk factor, URF (µg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
5.9E-06	3.5E-02

END

RESULTS SHEET - SITE 37 - SOIL - PCE - INDUSTRIAL EXPOSURE

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	NA	NA	1.06E+05	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.8E-06	6.1E-02

MESSAGE SUMMARY BELOW:

END

Site 37 – Groundwater-PCE-Residential and Industrial Exposure

DATA ENTRY SHEET - SITE 37 - GROUNDWATER - PCE - RESIDENTIAL EXPOSURE

GW-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (µg/L)	Chemical
127184	2.13E+04	Tetrachloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
15	2319	SIL	20	5

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm^2)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^V (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)
SIL			SIL	1.49	0.439	0.18

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
1.0E-06	1	70	30	30	350

Used to calculate risk-based groundwater concentration.

CHEMICAL PROPERTIES SHEET - SITE 37 - GROUNDWATER - PCE - RESIDENTIAL EXPOSURE

ABC

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	3.5E-02

END

INTERMEDIATE CALCULATIONS SHEET - SITE 37 - GROUNDWATER - PCE - RESIDENTIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
2304	0.259	0.307	2.87E-09	0.798	2.29E-09	68.18	0.439	0.090	0.349	4,000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)
1.69E+04	1.00E+06	4.00E-04	15	9,451	1.40E-02	5.81E-01	1.78E-04	4.16E-03	1.27E-04	2.14E-03

Diffusion path length, L_d (cm)	Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
2304	15	1.24E+07	0.10	8.33E+01	4.16E-03	4.00E+02	4.83E+217	5.42E-05	6.73E+02	5.9E-06	3.5E-02

RESULTS SHEET - SITE 37 - GROUNDWATER - PCE - RESIDENTIAL EXPOSURE

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
NA	NA	NA	2.00E+05	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.6E-03	1.8E+01

MESSAGE SUMMARY BELOW:

END

DATA ENTRY SHEET - SITE 37 - GROUNDWATER - PCE - INDUSTRIAL EXPOSURE

GW-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (µg/L)	Chemical
127184	2.13E+04	Tetrachloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
15	2319	SIL	20	

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm^2)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^V (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)
SIL			SIL	1.49	0.439	0.18

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
1.0E-06	1	70	10	10	250

Used to calculate risk-based groundwater concentration.

CHEMICAL PROPERTIES SHEET - SITE 37 - GROUNDWATER - PCE - INDUSTRIAL EXPOSURE

ABC

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	3.5E-02

END

INTERMEDIATE CALCULATIONS SHEET - SITE 37 - GROUNDWATER - PCE - INDUSTRIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
2304	0.259	0.307	2.87E-09	0.798	2.29E-09	68.18	0.439	0.090	0.349	14,600

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)
1.01E+06	1.34E+07	1.09E-04	15	9,451	1.40E-02	5.81E-01	1.78E-04	4.16E-03	1.27E-04	2.14E-03

Diffusion path length, L_d (cm)	Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
2304	15	1.24E+07	0.10	8.24E+00	4.16E-03	1.46E+03	7.83E+05	4.91E-06	6.09E+01	5.9E-06	3.5E-02

RESULTS SHEET - SITE 37 - GROUNDWATER - PCE - INDUSTRIAL EXPOSURE

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
NA	NA	NA	2.00E+05	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
3.5E-05	1.2E+00

MESSAGE SUMMARY BELOW:

END

Site 120 – Soil-Methylene Chloride-Residential and Industrial Exposure

SL-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
75092	4.44E+00	Methylene chloride

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
15	15.2	20	S		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	ENTER Vadose zone soil organic carbon fraction, f_{oc}^V (unitless)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
S	1.49	0.439	0.18	0.002	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1
				Used to calculate risk-based soil concentration.	

END

CHEMICAL PROPERTIES SHEET - SITE 120 - SOIL - METHYLENE CHLORIDE - RESIDENTIAL EXPOSURE

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
1.01E-01	1.17E-05	2.18E-03	25	6,706	313.00	510.00	1.17E+01	1.30E+04	4.7E-07	3.0E+00	L

END

INTERMEDIATE CALCULATIONS SHEET - SITE 120 - SOIL - METHYLENE CHLORIDE - RESIDENTIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
0.2	0.259	0.329	1.01E-07	0.606	6.12E-08	4,000	4.44E+00	1.69E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
1.00E+06	4.00E-04	15	6,927	1.79E-03	7.44E-02	1.78E-04	5.83E-03	0.2

Convection path length, L_p (cm)	Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)
15	2.34E-02	2.10E+03	0.10	8.33E+01	5.83E-03	4.00E+02	1.31E+155	4.90E-03	1.03E+01

Unit risk factor, URF (µg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
4.7E-07	3.0E+00

END

RESULTS SHEET - SITE 120 - SOIL - METHYLENE CHLORIDE - RESIDENTIAL EXPOSURE

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	NA	NA	2.05E+06	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
2.0E-06	3.3E-03

MESSAGE SUMMARY BELOW:

END

SL-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
75092	4.44E+00	Methylene chloride

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
15	15.2	20	S		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	ENTER Vadose zone soil organic carbon fraction, f_{oc}^V (unitless)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
S	1.49	0.439	0.18	0.002	

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	10	10	250	1.0E-06	1
				Used to calculate risk-based soil concentration.	

END

CHEMICAL PROPERTIES SHEET - SITE 120 - SOIL - METHYLENE CHLORIDE - INDUSTRIAL EXPOSURE

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
1.01E-01	1.17E-05	2.18E-03	25	6,706	313.00	510.00	1.17E+01	1.30E+04	4.7E-07	3.0E+00	L

END

INTERMEDIATE CALCULATIONS SHEET - SITE 120 - SOIL - METHYLENE CHLORIDE - INDUSTRIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
0.2	0.259	0.329	1.01E-07	0.606	6.12E-08	14,600	4.44E+00	1.01E+06

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
1.34E+07	1.09E-04	15	6,927	1.79E-03	7.44E-02	1.78E-04	5.83E-03	0.2

Convection path length, L_p (cm)	Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)
15	2.34E-02	2.10E+03	0.10	2.21E+02	5.83E-03	1.46E+03	2.76E+112	2.18E-04	4.59E-01

Unit risk factor, URF (µg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
4.7E-07	3.0E+00

END

RESULTS SHEET - SITE 120 - SOIL - METHYLENE CHLORIDE - INDUSTRIAL EXPOSURE

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	NA	NA	2.05E+06	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
2.1E-08	1.0E-04

MESSAGE SUMMARY BELOW:

END

Site 120 – Groundwater-PCE-Residential and Industrial Exposure

DATA ENTRY SHEET - SITE 120 - GROUNDWATER - PCE - RESIDENTIAL EXPOSURE

GW-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (µg/L)	Chemical
127184	2.95E+03	Tetrachloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
15	1219	S	20	5

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm^2)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^V (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)
S			S	1.66	0.375	0.054

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
1.0E-06	1	70	30	30	350

Used to calculate risk-based groundwater concentration.

CHEMICAL PROPERTIES SHEET - SITE 120 - GROUNDWATER - PCE - RESIDENTIAL EXPOSURE

ABC

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	3.5E-02

END

INTERMEDIATE CALCULATIONS SHEET - SITE 120 - GROUNDWATER - PCE - RESIDENTIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
1204	0.321	0.003	1.01E-07	0.998	1.01E-07	17.05	0.375	0.122	0.253	4,000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)
1.69E+04	1.00E+06	4.00E-04	15	9,451	1.40E-02	5.81E-01	1.78E-04	1.16E-02	4.62E-04	8.67E-03

Diffusion path length, L_d (cm)	Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
1204	15	1.72E+06	0.10	8.33E+01	1.16E-02	4.00E+02	5.42E+77	3.91E-04	6.71E+02	5.9E-06	3.5E-02

RESULTS SHEET - SITE 120 - GROUNDWATER - PCE - RESIDENTIAL EXPOSURE

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
NA	NA	NA	2.00E+05	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.6E-03	1.8E+01

MESSAGE SUMMARY BELOW:

END

DATA ENTRY SHEET - SITE 120 - GROUNDWATER - PCE - INDUSTRIAL EXPOSURE

GW-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (µg/L)	Chemical
127184	2.95E+03	Tetrachloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
15	1219.2	S	20	

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm^2)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^V (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)
S			S	1.66	0.375	0.054

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
1.0E-06	1	70	10	10	250

Used to calculate risk-based groundwater concentration.

CHEMICAL PROPERTIES SHEET - SITE 120 - GROUNDWATER - PCE - INDUSTRIAL EXPOSURE

ABC

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	3.5E-02

END

INTERMEDIATE CALCULATIONS SHEET - SITE 120 - GROUNDWATER - PCE - INDUSTRIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
1204.2	0.321	0.003	1.01E-07	0.998	1.01E-07	17.05	0.375	0.122	0.253	2,438

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)
2.62E+04	3.48E+05	7.00E-04	15	9,451	1.40E-02	5.81E-01	1.78E-04	1.16E-02	4.62E-04	8.67E-03

Diffusion path length, L_d (cm)	Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
1204.2	15	1.72E+06	0.10	6.07E+01	1.16E-02	2.44E+02	8.09E+92	9.18E-05	1.58E+02	5.9E-06	3.5E-02

RESULTS SHEET - SITE 120 - GROUNDWATER - PCE - INDUSTRIAL EXPOSURE

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
NA	NA	NA	2.00E+05	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
9.1E-05	3.1E+00

MESSAGE SUMMARY BELOW:

END

Site 133 – Soil-TCE (OEHHA and EPA)-Residential and Industrial Exposure

SL-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
79016	3.55E+00	Trichloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
15	182.9	20	SCL		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	ENTER Vadose zone soil organic carbon fraction, f_{oc}^V (unitless)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
SCL	1.63	0.384	0.146	0.002	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based soil concentration.

END

CHEMICAL PROPERTIES SHEET - SITE 133 - SOIL - TCE (OEHHA) - RESIDENTIAL EXPOSURE

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
7.90E-02	9.10E-06	1.03E-02	25	7,505	360.36	544.20	1.66E+02	1.47E+03	2.0E-06	4.0E-02	L

END

INTERMEDIATE CALCULATIONS SHEET - SITE 133 - SOIL - TCE (OEHHA) - RESIDENTIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
167.9	0.238	0.259	2.07E-09	0.859	1.78E-09	4,000	3.55E+00	1.69E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
1.00E+06	4.00E-04	15	8,433	8.06E-03	3.35E-01	1.78E-04	4.50E-03	167.9

Convection path length, L_p (cm)	Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)
15	3.32E-01	2.53E+03	0.10	8.33E+01	4.50E-03	4.00E+02	1.46E+201	1.20E-03	3.02E+00

Unit risk factor, URF (µg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
2.0E-06	4.0E-02

END

RESULTS SHEET - SITE 133 - SOIL - TCE (OEHHA) - RESIDENTIAL EXPOSURE

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	NA	NA	6.93E+05	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
2.5E-06	7.3E-02

MESSAGE SUMMARY BELOW:

MESSAGE: Risk/HQ or risk-based soil concentration is based on a route-to-route extrapolation.

END

SL-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
79016	3.55E+00	Trichloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
15	182.9	20	SCL		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	ENTER Vadose zone soil organic carbon fraction, f_{oc}^V (unitless)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
SCL	1.63	0.384	0.146	0.002	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1
				Used to calculate risk-based soil concentration.	

END

CHEMICAL PROPERTIES SHEET - SITE 133 - SOIL - TCE (EPA) - RESIDENTIAL EXPOSURE

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
7.90E-02	9.10E-06	1.03E-02	25	7,505	360.36	544.20	1.66E+02	1.47E+03	1.1E-04	4.0E-02	L

END

INTERMEDIATE CALCULATIONS SHEET - SITE 133 - SOIL - TCE (EPA) - RESIDENTIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
167.9	0.238	0.259	2.07E-09	0.859	1.78E-09	4,000	3.55E+00	1.69E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
1.00E+06	4.00E-04	15	8,433	8.06E-03	3.35E-01	1.78E-04	4.50E-03	167.9

Convection path length, L_p (cm)	Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)
15	3.32E-01	2.53E+03	0.10	8.33E+01	4.50E-03	4.00E+02	1.46E+201	1.20E-03	3.02E+00

Unit risk factor, URF (µg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
1.1E-04	4.0E-02

END

RESULTS SHEET - SITE 133 - SOIL - TCE (EPA) - RESIDENTIAL EXPOSURE

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	NA	NA	6.93E+05	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.4E-04	7.3E-02

MESSAGE SUMMARY BELOW:

MESSAGE: Risk/HQ or risk-based soil concentration is based on a route-to-route extrapolation.

END

SL-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
79016	3.55E+00	Trichloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
15	182.9	20	SCL		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	ENTER Vadose zone soil organic carbon fraction, f_{oc}^V (unitless)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
SCL	1.63	0.384	0.146	0.002	

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	10	10	250	1.0E-06	1

Used to calculate risk-based soil concentration.

END

CHEMICAL PROPERTIES SHEET - SITE 133 - SOIL - TCE (OEHHA) - INDUSTRIAL EXPOSURE

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
7.90E-02	9.10E-06	1.03E-02	25	7,505	360.36	544.20	1.66E+02	1.47E+03	2.0E-06	4.0E-02	L

END

INTERMEDIATE CALCULATIONS SHEET - SITE 133 - SOIL - TCE (OEHHA) - INDUSTRIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
167.9	0.238	0.259	2.07E-09	0.859	1.78E-09	7,926	3.55E+00	2.94E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
3.90E+06	2.03E-04	15	8,433	8.06E-03	3.35E-01	1.78E-04	4.50E-03	167.9

Convection path length, L_p (cm)	Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)
15	3.32E-01	2.53E+03	0.10	3.49E+00	4.50E-03	7.92E+02	1.79E+04	1.15E-05	2.90E-02

Unit risk factor, URF (µg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
2.0E-06	4.0E-02

END

RESULTS SHEET - SITE 133 - SOIL - TCE (OEHHA) - INDUSTRIAL EXPOSURE

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	NA	NA	6.93E+05	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
5.7E-09	5.0E-04

MESSAGE SUMMARY BELOW:

MESSAGE: Risk/HQ or risk-based soil concentration is based on a route-to-route extrapolation.

END

SL-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
79016	3.55E+00	Trichloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
15	182.9	20	SCL		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	ENTER Vadose zone soil organic carbon fraction, f_{oc}^V (unitless)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
SCL	1.63	0.384	0.146	0.002	

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	10	10	250	1.0E-06	1
				Used to calculate risk-based soil concentration.	

END

CHEMICAL PROPERTIES SHEET - SITE 133 - SOIL - TCE (EPA) - INDUSTRIAL EXPOSURE

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
7.90E-02	9.10E-06	1.03E-02	25	7,505	360.36	544.20	1.66E+02	1.47E+03	1.1E-04	4.0E-02	L

END

INTERMEDIATE CALCULATIONS SHEET - SITE 133 - SOIL - TCE (EPA) - INDUSTRIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
167.9	0.238	0.259	2.07E-09	0.859	1.78E-09	7,926	3.55E+00	2.94E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
3.90E+06	2.03E-04	15	8,433	8.06E-03	3.35E-01	1.78E-04	4.50E-03	167.9

Convection path length, L_p (cm)	Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)
15	3.32E-01	2.53E+03	0.10	3.49E+00	4.50E-03	7.92E+02	1.79E+04	1.15E-05	2.90E-02

Unit risk factor, URF (µg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
1.1E-04	4.0E-02

END

RESULTS SHEET - SITE 133 - SOIL - TCE (EPA) - INDUSTRIAL EXPOSURE

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	NA	NA	6.93E+05	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
3.1E-07	5.0E-04

MESSAGE SUMMARY BELOW:

MESSAGE: Risk/HQ or risk-based soil concentration is based on a route-to-route extrapolation.

END

Site 133 – Groundwater-TCE (OEHHA and EPA)-Residential and Industrial Exposure

GW-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (µg/L)	Chemical
79016	6.20E+03	Trichloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
15	405	SCL	20	5

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm^2)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^V (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)
SCL			SCL	1.63	0.384	0.146

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
1.0E-06	1	70	30	30	350

Used to calculate risk-based groundwater concentration.

CHEMICAL PROPERTIES SHEET - SITE 133 - GROUNDWATER - TCE (OEHHA) - RESIDENTIAL EXPOSURE

ABC

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
7.90E-02	9.10E-06	1.03E-02	25	7,505	360.36	544.20	1.66E+02	1.47E+03	2.0E-06	4.0E-02

END

INTERMEDIATE CALCULATIONS SHEET - SITE 133 - GROUNDWATER - TCE (OEHHA) - RESIDENTIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
390	0.238	0.259	2.07E-09	0.859	1.78E-09	25.86	0.384	0.051	0.333	4,000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)
1.69E+04	1.00E+06	4.00E-04	15	8,433	8.06E-03	3.35E-01	1.78E-04	4.50E-03	3.09E-05	4.25E-04

Diffusion path length, L_d (cm)	Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
390	15	2.08E+06	0.10	8.33E+01	4.50E-03	4.00E+02	1.46E+201	6.34E-05	1.32E+02	2.0E-06	4.0E-02

RESULTS SHEET - SITE 133 - GROUNDWATER - TCE (OEHHA) - RESIDENTIAL EXPOSURE

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
NA	NA	NA	1.47E+06	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.1E-04	3.2E+00

MESSAGE SUMMARY BELOW:

MESSAGE: Risk/HQ or risk-based groundwater concentration is based on a route-to-route extrapolation.

END

DATA ENTRY SHEET - SITE 133 - GROUNDWATER - TCE (EPA) - RESIDENTIAL EXPOSURE

GW-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (µg/L)	Chemical
79016	6.20E+03	Trichloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
15	405	SCL	20	5

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm^2)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^V (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)
SCL			SCL	1.63	0.384	0.146

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
1.0E-06	1	70	30	30	350

Used to calculate risk-based groundwater concentration.

CHEMICAL PROPERTIES SHEET - SITE 133 - GROUNDWATER - TCE (EPA) - RESIDENTIAL EXPOSURE

ABC

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
7.90E-02	9.10E-06	1.03E-02	25	7,505	360.36	544.20	1.66E+02	1.47E+03	1.1E-04	4.0E-02

END

INTERMEDIATE CALCULATIONS SHEET - SITE 133 - GROUNDWATER - TCE (EPA) - RESIDENTIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
390	0.238	0.259	2.07E-09	0.859	1.78E-09	25.86	0.384	0.051	0.333	4,000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)
1.69E+04	1.00E+06	4.00E-04	15	8,433	8.06E-03	3.35E-01	1.78E-04	4.50E-03	3.09E-05	4.25E-04

Diffusion path length, L_d (cm)	Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
390	15	2.08E+06	0.10	8.33E+01	4.50E-03	4.00E+02	1.46E+201	6.34E-05	1.32E+02	1.1E-04	4.0E-02

RESULTS SHEET - SITE 133 - GROUNDWATER - TCE (EPA) - RESIDENTIAL EXPOSURE

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
NA	NA	NA	1.47E+06	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
6.0E-03	3.2E+00

MESSAGE SUMMARY BELOW:

MESSAGE: Risk/HQ or risk-based groundwater concentration is based on a route-to-route extrapolation.

END

DATA ENTRY SHEET - SITE 133 - GROUNDWATER - TCE (OEHHA) - INDUSTRIAL EXPOSURE

GW-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (µg/L)	Chemical
79016	6.20E+03	Trichloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
15	405	SCL	20	

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm^2)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^V (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)
SCL			SCL	1.63	0.384	0.146

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
1.0E-06	1	70	10	10	250

Used to calculate risk-based groundwater concentration.

CHEMICAL PROPERTIES SHEET - SITE 133 - GROUNDWATER - TCE (OEHHA) - INDUSTRIAL EXPOSURE

ABC

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
7.90E-02	9.10E-06	1.03E-02	25	7,505	360.36	544.20	1.66E+02	1.47E+03	2.0E-06	4.0E-02

END

INTERMEDIATE CALCULATIONS SHEET - SITE 133 - TCE (OEHHA) - INDUSTRIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
390	0.238	0.259	2.07E-09	0.859	1.78E-09	25.86	0.384	0.051	0.333	7,920

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)
2.94E+05	3.90E+06	2.03E-04	15	8,433	8.06E-03	3.35E-01	1.78E-04	4.50E-03	3.09E-05	4.25E-04

Diffusion path length, L_d (cm)	Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
390	15	2.08E+06	0.10	3.48E+00	4.50E-03	7.92E+02	1.77E+04	6.51E-06	1.35E+01	2.0E-06	4.0E-02

RESULTS SHEET - SITE 133 - GROUNDWATER - TCE (OEHHA) - INDUSTRIAL EXPOSURE

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
NA	NA	NA	1.47E+06	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
2.6E-06	2.3E-01

MESSAGE SUMMARY BELOW:

MESSAGE: Risk/HQ or risk-based groundwater concentration is based on a route-to-route extrapolation.

END

DATA ENTRY SHEET - SITE 133 - GROUNDWATER - TCE (EPA) - INDUSTRIAL EXPOSURE

GW-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (µg/L)	Chemical
79016	6.20E+03	Trichloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
15	405	SCL	20	

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm^2)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^v (g/cm^3)	ENTER Vadose zone soil total porosity, n^v (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^v (cm^3/cm^3)
SCL			SCL	1.63	0.384	0.146

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
1.0E-06	1	70	10	10	250

Used to calculate risk-based groundwater concentration.

CHEMICAL PROPERTIES SHEET - SITE 133 - GROUNDWATER - TCE (EPA) - INDUSTRIAL EXPOSURE

ABC

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
7.90E-02	9.10E-06	1.03E-02	25	7,505	360.36	544.20	1.66E+02	1.47E+03	1.1E-04	4.0E-02

END

INTERMEDIATE CALCULATIONS SHEET - SITE 133 - GROUNDWATER - TCE (EPA) - INDUSTRIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
390	0.238	0.259	2.07E-09	0.859	1.78E-09	25.86	0.384	0.051	0.333	7,920

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)
2.94E+05	3.90E+06	2.03E-04	15	8,433	8.06E-03	3.35E-01	1.78E-04	4.50E-03	3.09E-05	4.25E-04

Diffusion path length, L_d (cm)	Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
390	15	2.08E+06	0.10	3.48E+00	4.50E-03	7.92E+02	1.77E+04	6.51E-06	1.35E+01	1.1E-04	4.0E-02

RESULTS SHEET - SITE 133 - GROUNDWATER - TCE (EPA) - INDUSTRIAL EXPOSURE

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
NA	NA	NA	1.47E+06	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.5E-04	2.3E-01

MESSAGE SUMMARY BELOW:

MESSAGE: Risk/HQ or risk-based groundwater concentration is based on a route-to-route extrapolation.

END

Site 321 – Soil-PCE-Residential and Industrial Exposure

SL-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
127184	1.81E+01	Tetrachloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
15	91.4	20	SIL		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	ENTER Vadose zone soil organic carbon fraction, f_{oc}^V (unitless)
SIL	1.49	0.439	0.18	0.002

ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based soil concentration.

END

CHEMICAL PROPERTIES SHEET - SITE 321 - SOIL - RESIDENTIAL EXPOSURE

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	3.5E-02	L

END

INTERMEDIATE CALCULATIONS SHEET - SITE 321 - SOIL - RESIDENTIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
76.4	0.259	0.307	2.87E-09	0.798	2.29E-09	4,000	1.81E+01	1.69E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
1.00E+06	4.00E-04	15	9,451	1.40E-02	5.81E-01	1.78E-04	4.16E-03	76.4

Convection path length, L_p (cm)	Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)
15	3.10E-01	1.98E+04	0.10	8.33E+01	4.16E-03	4.00E+02	4.83E+217	1.94E-03	3.84E+01

Unit risk factor, URF (µg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
5.9E-06	3.5E-02

END

RESULTS SHEET - SITE 321 - SOIL - PCE - RESIDENTIAL EXPOSURE

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	NA	NA	1.06E+05	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
9.3E-05	1.1E+00

MESSAGE SUMMARY BELOW:

END

SL-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
127184	1.81E+01	Tetrachloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
15	91.4	20	SIL		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	ENTER Vadose zone soil organic carbon fraction, f_{oc}^V (unitless)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
SIL	1.49	0.439	0.18	0.002	

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	10	10	250	1.0E-06	1
				Used to calculate risk-based soil concentration.	

END

CHEMICAL PROPERTIES SHEET - SITE 321 - SOIL - PCE - INDUSTRIAL EXPOSURE

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	3.5E-02	L

END

INTERMEDIATE CALCULATIONS SHEET - SITE 321 - SOIL - PCE - INDUSTRIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
76.4	0.259	0.307	2.87E-09	0.798	2.29E-09	4,000	1.81E+01	7.52E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
1.00E+06	4.00E-04	15	9,451	1.40E-02	5.81E-01	1.78E-04	4.16E-03	76.4

Convection path length, L_p (cm)	Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)
15	3.10E-01	1.98E+04	0.10	2.26E+00	4.16E-03	4.00E+02	7.86E+05	2.88E-05	5.70E-01

Unit risk factor, URF (µg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
5.9E-06	3.5E-02

END

RESULTS SHEET - SITE 321 - SOIL - PCE - INDUSTRIAL EXPOSURE

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	NA	NA	1.06E+05	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
3.3E-07	1.1E-02

MESSAGE SUMMARY BELOW:

END

Site 321 – Groundwater-PCE-Residential and Industrial Exposure

DATA ENTRY SHEET - SITE 321 - GROUNDWATER - PCE - RESIDENTIAL EXPOSURE

GW-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (µg/L)	Chemical
127184	2.86E+03	Tetrachloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
15	4359	SIL	20	5

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm^2)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^V (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)
SIL			SIL	1.49	0.439	0.18

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
1.0E-06	1	70	30	30	350

Used to calculate risk-based groundwater concentration.

CHEMICAL PROPERTIES SHEET - SITE 321 - GROUNDWATER - PCE - RESIDENTIAL EXPOSURE

ABC

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	3.5E-02

END

INTERMEDIATE CALCULATIONS SHEET - SITE 321 - GROUNDWATER - PCE - RESIDENTIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
4344	0.259	0.307	2.87E-09	0.798	2.29E-09	68.18	0.439	0.090	0.349	4,000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)
1.69E+04	1.00E+06	4.00E-04	15	9,451	1.40E-02	5.81E-01	1.78E-04	4.16E-03	1.27E-04	2.77E-03

Diffusion path length, L_d (cm)	Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
4344	15	1.66E+06	0.10	8.33E+01	4.16E-03	4.00E+02	4.83E+217	3.74E-05	6.22E+01	5.9E-06	3.5E-02

RESULTS SHEET - SITE 321 - GROUNDWATER - PCE - RESIDENTIAL EXPOSURE

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
NA	NA	NA	2.00E+05	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.5E-04	1.7E+00

MESSAGE SUMMARY BELOW:

END

DATA ENTRY SHEET - SITE 321 - GROUNDWATER - PCE - INDUSTRIAL EXPOSURE

GW-SCREEN
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION
(enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (µg/L)	Chemical
127184	2.86E+03	Tetrachloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER SCS soil type directly above water table	ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
15	4359	SIL	20	

MORE ↓

ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vandose zone soil vapor permeability, k_v (cm^2)	ENTER Vadose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^V (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)
SIL			SIL	1.49	0.439	0.18

MORE ↓

ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)	ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
1.0E-06	1	70	10	10	250

Used to calculate risk-based groundwater concentration.

CHEMICAL PROPERTIES SHEET - SITE 321 - GROUNDWATER - PCE - INDUSTRIAL EXPOSURE

ABC

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	3.5E-02

END

INTERMEDIATE CALCULATIONS SHEET - SITE 321 - GROUNDWATER - PCE - INDUSTRIAL EXPOSURE

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
4344	0.259	0.307	2.87E-09	0.798	2.29E-09	68.18	0.439	0.090	0.349	4,000

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)
7.52E+04	1.00E+06	4.00E-04	15	9,451	1.40E-02	5.81E-01	1.78E-04	4.16E-03	1.27E-04	2.77E-03

Diffusion path length, L_d (cm)	Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
4344	15	1.66E+06	0.10	2.26E+00	4.16E-03	4.00E+02	7.86E+05	6.61E-06	1.10E+01	5.9E-06	3.5E-02

RESULTS SHEET - SITE 321 - GROUNDWATER - PCE - INDUSTRIAL EXPOSURE

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
NA	NA	NA	2.00E+05	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
6.4E-06	2.2E-01

MESSAGE SUMMARY BELOW:

END

APPENDIX B-2

EVALUATION OF ALTERNATIVES AND ASSOCIATED COSTS TO ADDRESS THE VAPOR INTRUSION PATHWAY (VIP) FROM SOIL INTO INDOOR AIR AT SITE 37

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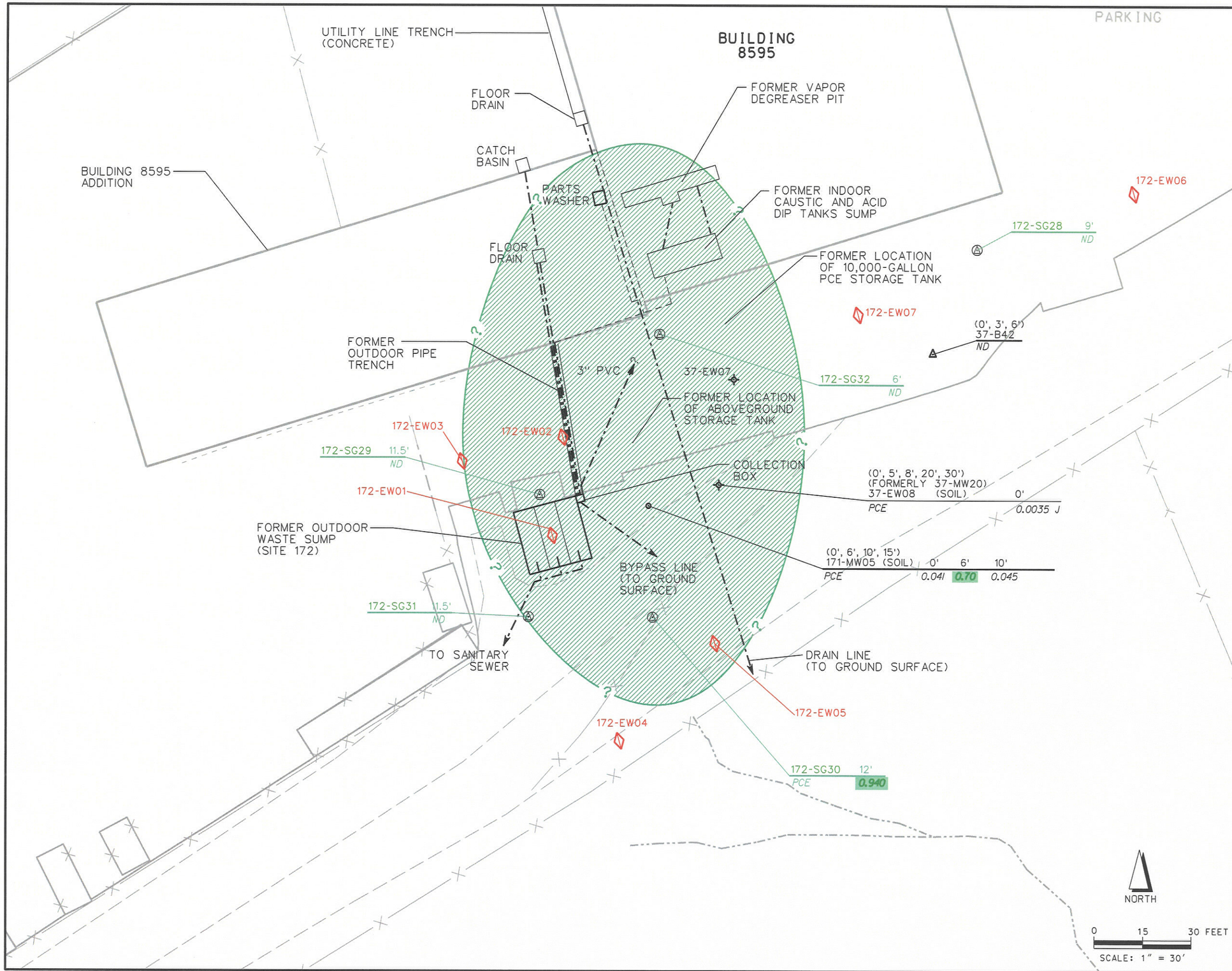
APPENDIX B-2

EVALUATION OF ALTERNATIVES AND ASSOCIATED COSTS TO ADDRESS THE VAPOR INTRUSION PATHWAY (VIP) FROM SOIL INTO INDOOR AIR AT SITE 37

B.2.1 INTRODUCTION

This appendix presents a preliminary analysis of remedial alternatives to reduce exposure (under the current industrial and future residential scenarios) to volatile organic compounds (VOCs) via the vapor intrusion pathway (VIP) into indoor air at the South Air Force Research Laboratory (South AFRL). Specifically, this appendix presents cost estimates for various remedial alternatives designed to reduce risks via the VIP from tetrachloroethene (PCE) in soil in the vicinity of Building 8595 (the source area for Site 37). The remedial alternatives considered include 1) excavation and removal of soil containing PCE concentrations that present a carcinogenic risk level greater than 1×10^{-6} (industrial scenario only); 2) continued operation of an existing soil vapor extraction (SVE) and treatment system to reduce the concentrations of PCE in soil vapors to a cancer risk level below 1×10^{-6} (industrial and residential scenarios); and 3) implementing engineering controls to disrupt the VIP from soil into indoor air (industrial and residential scenarios). As presented in Appendix B-1 (refer to Table B.1-4) of the Record of Decision (ROD), the risk-based cleanup level (RBCL) for PCE in soil at Site 37 to meet a cancer risk level of 1×10^{-6} is 0.2 milligrams per kilogram (mg/kg), equivalent to 200 micrograms per kilogram (μg/kg) for an industrial setting; for a residential setting, the 10^{-6} RBCL is much lower, at 0.0003 mg/kg (equivalent to 0.335 μg/kg).

In July 2006, a borehole was drilled for installation of Well 172-SG30 subsequently used in rebound monitoring of VOCs in soil vapor following temporary shutdown of the SVE system south of Building 8595 (Earth Tech 2007). Soil sampled from Well 172-SG30, located approximately 95 feet south of the building (Figure B.2-1), was found to contain PCE at a concentration of 0.94 mg/kg (940 μg/kg), exceeding the 10^{-6} industrial RBCL by approximately 5 times. The area (approximately 14,500 square feet) conceptually estimated to encompass PCE contamination in soil at concentrations that exceed the industrial RBCL is shown hatched in green on Figure B.2-1.



EXPLANATION

- PIPING (ABOVEGROUND)
- PIPING (BELOWGROUND)
- SOIL VAPOR EXTRACTION WELL
- GROUNDWATER MONITORING WELL
- GROUNDWATER EXTRACTION WELL
- RESULT — RESULT EXCEEDING THE INDUSTRIAL 10^{-6} RL IN SOIL (0.2 mg/kg)
- ESTIMATED EXTENT OF SOIL CONTAMINATION THAT EXCEEDS 10^{-6} INDUSTRIAL (0.2 mg/kg) RBCLs (QUERIED WHERE INFERRED OR UNKNOWN)

AFB	AIR FORCE BASE
mg/kg	MILLIGRAMS PER KILOGRAM
J	RESULT IS DETECTED BELOW THE REPORTING LIMIT
ND	NOT DETECTED
PCE	TETRACHLOROETHENE
PVC	POLYVINYL CHLORIDE
RBCL	RISK-BASED CONTAMINANT LEVEL
RL	RISK LEVEL

(DEPTHS SAMPLED) LOCATION NAME	SAMPLE DEPTH (DEPTH BELOW UST)
PARAMETER NAME	*VALUE DETECTED SOILS - mg/kg*

NOTES:

1. SOIL RESULTS FROM 172-SG28 TO 172-SG32 ARE FROM 2006.
2. LOCATION OF ALL PIPING APPROXIMATE.

South AFRL ROD — Appendix B-2

Building 8595
Estimated Area with Soil PCE Exceeding the 10^{-6} Industrial RBCL

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure B.2-1
Project No. 93843		

EDWARDS\ 67861\B6497FGA.A01

In the ROD, the remedy selected to prevent exposure to VOCs in indoor air above a risk level of 1×10^{-6} includes the institution of land use controls (LUCs) to prohibit residential development within the vapor intrusion compliance boundary (VICB, outlined in blue on Figure 2.7-1); incorporation of building controls to disrupt the VIP on all new construction within the VICB; and initiation of monitoring followed by the implementation of engineering controls (dependent on monitoring results) at existing buildings within areas (outlined in orange on Figure 2.7-1) where groundwater and/or soil concentrations of VOCs exceed their 10^{-6} industrial RBCLs (re-designated as groundwater vapor compliance levels – industrial [GWVCLs-ind] as listed in Table 2.13-2 of the ROD).

The objective of this appendix (consistent with the Department of Defense (DoD) policy on Land Use Controls [dated January 17, 2001]), is to inform the decision for the selected remedy involving LUCs, by presenting estimated costs for remedial alternatives (including cleanup to an unrestricted use) other than LUCs to reduce risks via the VIP from soil to below 1×10^{-6} for its current industrial use and hypothetical future residential use within the area shown on Figure B.2-1. Not addressed are remedial options to reduce risks via the VIP from groundwater at Site 37 (or at Sites 120, 133, and 321 in the South AFRL) to levels below 1×10^{-6}; the much larger areas encompassing the 10^{-6} risk levels via the VIP from groundwater for residential and industrial exposure settings are shown on Figures B.1-3 to B.1-6 in Appendix B-1.

B.2.2 DESCRIPTION OF REMEDIAL ALTERNATIVES

Costs were estimated for the following three scenarios as remedial alternatives to reduce risk via the VIP from soils south of Building 8595 to a cancer risk level below 10^{-6} for the current industrial use:

- **Scenario 1** – Removal (by excavation and off-site disposal) of PCE-contaminated soil within the area where concentrations exceed the 10^{-6} industrial RBCL.
- **Scenario 2** – Installation of a sub-slab depressurization (SSD) system to inhibit vapors from migrating into the existing Building 8595.
- **Scenario 3** – Operation (and limited expansion) of the existing SVE system to reduce PCE soil concentrations below the 1×10^{-6} risk level for industrial and residential use.

Costs also were developed for a fourth scenario to reduce risk via the VIP from soils south of Building 8595 to a cancer risk level below 1 x 10^{-6} for unrestricted (i.e., a hypothetical, future residential) use:

- **Scenario 4** – Installation of a vapor barrier (engineering control) to restrict the ability of vapors to migrate into a hypothetical residential building in the vicinity of Building 8595.

These scenarios are described in greater detail below.

SCENARIO 1. This scenario includes removal of all unconsolidated soil and highly weathered bedrock contaminated with PCE at levels greater than 200 μg/kg within the area shown in green on Figure B.2-1. Prior to excavation, the existing Building 8595 and other structures within this zone would be removed (costs for building demolition were not included). Based on the conceptual site model (CSM) presented as Figure 2.5-7 of the ROD, residual PCE contamination in the soil is thought to occur primarily within the highly weathered bedrock underlying the loose sands of the unconsolidated soil. Therefore the cost estimate assumes that the top 7 feet of soil is clean and would be disposed of on site. The soil below 7 feet, including 3 feet of unconsolidated soil and 3 feet of weathered bedrock, would be excavated and sent off site for disposal. The estimated excavation volumes are 102,000 cubic feet of clean soil, and 88,000 cubic feet of contaminated soil and weathered bedrock.

The total cost, generated using the Remedial Action Cost Engineering and Requirements (RACER™) 2007 cost estimating software (and rounded to the nearest $10,000), is estimated at $1,350,000 (and as noted above, does not include costs for demolition of existing buildings). The detailed costs generated by RACER are presented on RACER Table 1 in Attachment B.2-1 at the end of this appendix. Note that this scenario assumes that all of the PCE-contaminated weathered bedrock can be removed. Based on Earth Tech's past experience with excavations at the AFRL, it is likely that the contamination will extend in dipping fractures into a more competent bedrock zone that may be too deep and/or otherwise too difficult to remove with standard excavation equipment. Any residual PCE that cannot be excavated from the fractured bedrock could continue to generate vapors capable of migration via the VIP into indoor air.

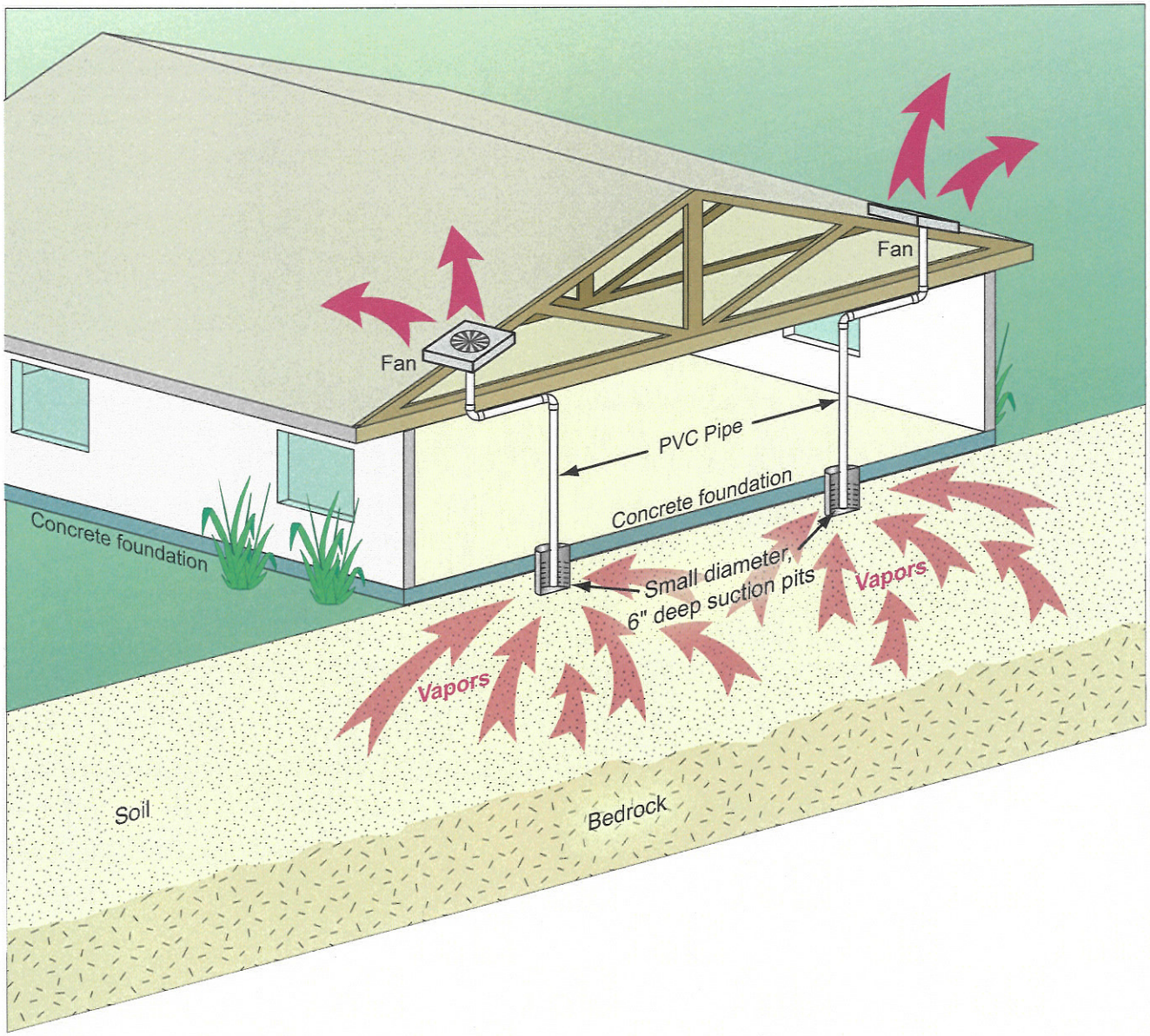
SCENARIO 2. This alternative includes installation of a sub-slab depressurization (SSD) system to disrupt vapor flow into the existing Building 8595. The SSD would consist of two fans mounted on the roof of the building and connected to suction pits installed beneath the building's concrete slab. Operation of the fans would pull air from the suction pits, creating a lower pressure below the concrete slab as compared to the indoor air pressure and thus preventing soil vapors from migrating through the concrete slab and into the building. A diagram of the sub-slab depressurization system is presented on Figure B.2-2. The cost estimate assumes that a total of 16 small-diameter suction pits would be installed at a spacing of approximately one pit per 1,500 square feet inside the 23,500-square-foot Building 8595. The pits would be installed by drilling core holes through the concrete slab and hand-augering to extend the depth to 6 inches below the foundation. A small screen attached to polyvinyl chloride (PVC) piping would be placed into each borehole and backfilled with sand before the core hole is plugged and capped. Two fans mounted on the roof would then be connected with PVC piping to the 16 suction pits to draw vapors from below the slab, emitting them to the atmosphere. It is assumed that the concentrations of VOCs within vapors emitted by the fans would not exceed any air discharge limits.

The total cost, generated using RACER™ 2007 cost estimating software, is estimated at $150,000. The detailed costs generated by RACER are presented on RACER Table 2 in Attachment B.2-1.

SCENARIO 3. This cost estimate assumes a limited expansion and continued operation of the existing SVE system south of Building 8595 until PCE concentrations in the soil are reduced below a) the 10^{-6} industrial RBCL (200 μg/kg); or b) the 10^{-6} residential RBCL (0.335 μg/kg). The SVE well field would be expanded by installation of six additional wells (to supplement the seven existing wells) in locations where soil vapor concentrations of PCE in excess of 100,000 parts per billion by volume [ppb(v)] were identified during the rebound monitoring study (Earth Tech 2007). The method used to estimate the number of additional years the SVE system would be required to operate is presented below.

SVE System Operational History

Operation of the SVE system was initiated in January 2000 with one on-line vapor extraction well (172-EW01 shown in red on Figure B.2-1), screened in unconsolidated soils to a depth of 16.5 feet



Adapted From The Interstate Technology & Regulatory Council (ITRC) internet-based training program of Vapor Intrusion Pathway: A Practical Guideline. www.itrcweb.org

South AFRL ROD		Appendix B-2
Conceptual Representation of a Sub-Slab Depressurization (SSD) System		
Date 09-07 Project No. 94591	Air Force Research Laboratory Edwards AFB	Figure **B.2-2**

94591.10.04.01 Fig. B.2-2

below the former outdoor waste sump (Site 172). Two additional vapor extraction wells (172-EW02 and 172-EW03) located north of the sump were added to the SVE system in August 2000 and four more vapor extraction wells (172-EW04 through 172-EW07) located to the east and south of the sump were added in September 2002. In soil samples collected underneath the outdoor sump prior to start-up of the SVE system, a maximum PCE soil concentration of 1,200 mg/kg was detected. Soil samples collected from beneath the sump in March 2002 (maximum PCE concentration of 2.2 mg/kg) following 2 years of SVE operation, and from the vicinity of the outdoor waste sump (backfilled in 2002) in July 2006 (maximum PCE concentration of 0.94 mg/kg) following 6.5 years of operation, showed a significant reduction in soil PCE concentrations. It is assumed that continued reduction of the PCE concentration in soil will be achieved with continued operation of the SVE.

Calculation of Target Soil Vapor Cleanup Concentrations

The equilibrium equation used in the Johnson and Ettinger (J&E) version 3.1 vapor intrusion model (Environmental Quality Management, Inc. 2003), as shown in Table B.2-1, was used to calculate a soil vapor concentration of 218,570 micrograms per cubic meter ($\mu g/m^3$), or 32,222 ppb(v), which corresponds to the 10^{-6} industrial RBCL of 200 μg/kg for soil. The equilibrium equation is based on the principle that PCE contained within a permeable soil will equilibrate among three environmental compartments: adsorbed onto soil organic matter; dissolved into soil moisture; and volatilized into soil air pore spaces. This equation assumes that there has been sufficient time for the PCE soil vapor concentration to have reached equilibrium with the PCE soil concentrations.

Based on observations made during the recent rebound monitoring, and historically during 6.5 years of SVE system operation, PCE concentrations in the soil vapor around Building 8595 can fluctuate by a factor of 8.5. This factor is additive of: 1) a 5-fold increase in PCE concentrations observed in vapor monitoring wells during rebound monitoring following shutdown of the Site 172 SVE system in July 2006; and 2) a 3.5-fold seasonal fluctuation in PCE vapor concentrations in Well 172-EW01 (screened underneath the sump) between winter/spring and summer/fall (refer to Figures 2 through 6 in Attachment B.2-2 following this appendix). Therefore, to safely bracket the estimate of a "safe" soil vapor concentration to meet the soil industrial RBCL of 200 μg/kg, the vapor concentration of 32,222 ppb(v) calculated as the "equilibrium" concentration was divided by 8.5 to account for seasonal

TABLE B.2-1. CALCULATED SOIL VAPOR CLEANUP LEVELS TO ACHIEVE PCE SOIL CONCENTRATIONS BELOW INDUSTRIAL AND RESIDENTIAL RISK-BASED CLEANUP LEVELS

Risk Level	Soil RBCL for Vapor Intrusion Pathway	Calculated PCE Vapor Concentration Based on RBCL Soil Concentrations (1)	Calculated PCE Vapor Concentration Based on RBCL Soil Concentrations (ppb[v])	Observed Maximum Rebound of PCE Concentrations following July 2006 SVE Shutdown (2)	Observed Average Rebound of PCE Concentrations following July 2006 Shutdown of SVE (2)	Seasonal Variation in PCE Concentrations at Well 172-EW01 (3)	Target Soil Clean-up PCE Vapor Concentration (4)
Industrial 10^{-6}	200 μg/kg	218,570 $\mu g/m^3$	32,222 ppb(v)	500 %	330 %	350 %	3,791 ppb(v)
Residential 10^{-6}	0.335 μg/kg	366 $\mu g/m^3$	54 ppb(v)	500 %	330 %	350 %	6 ppb(v)

Notes:

Concentration in ppb(v) was calculated as (concentration in $\mu g/m^3$ x 24.45)/MW, where MW = 165.85 grams/mole

(1) Soil vapor concentrations calculated using the following equilibrium equation $Csv = (\{H' \times Cs \times \rho b\}/\{\theta w + [Koc \times Foc \times \rho b] + [H' \times \theta a]\} \times CF)$

Where:

symbol	Description	unit	value
Csv	soil vapor conc.	$\mu g/cm^3$	Calculated Value
H'	Henry's Law Constant	dimensionless	0.58
Cs	conc. in soil	μg/kg	Input RBCL Soil Concentration of 200 for industrial and 0.35 for residential (for 10^{-6})
ρb	vadose zone soil dry bulk density	g/cm^3	1.49
θw	vadose zone soil water-filled porosity	cm^3/cm^3	0.18
Koc	organic carbon partition coefficient	cm^3/g	155
Foc	vadose zone soil organic carbon fraction	dimensionless	0.002
θa	vadose zone air water-filled porosity	cm^3/cm^3	0.259
CF	unit conversion factor	g/kg	

(2) Maximum and average rebound calculated based on laboratory results for PCE concentrations in vapor samples collected from monitoring wells just prior to shutdown of the SVE in July 2006 as compared to concentrations in samples collected after 3 months of SVE shutdown. The PCE concentration in Well 172-SG32 increased from 22,000 ppb(v) prior to SVE shutdown to 110,000 ppb(v) 3 months following shutdown.

(3) PCE vapor concentrations in Well 172-EW01 fluctuate seasonally, with concentrations higher in the late summer/fall than in winter/spring.

(4) The calculated PCE vapor concentration based on RBCL soil concentrations was divided by 8.5 to account for the maximum rebound and seasonal variations.

%	percent	MW	molecular weight
μg/kg	micrograms per kilogram	PCE	tetrachloroethene
$\mu g/m^3$	micrograms per cubic meter	ppb(v)	parts per billion by volume
g/cm^3	grams per cubic centimeter	RBCL	risk-based cleanup level
g/kg	grams per kilogram	SVE	soil vapor extraction

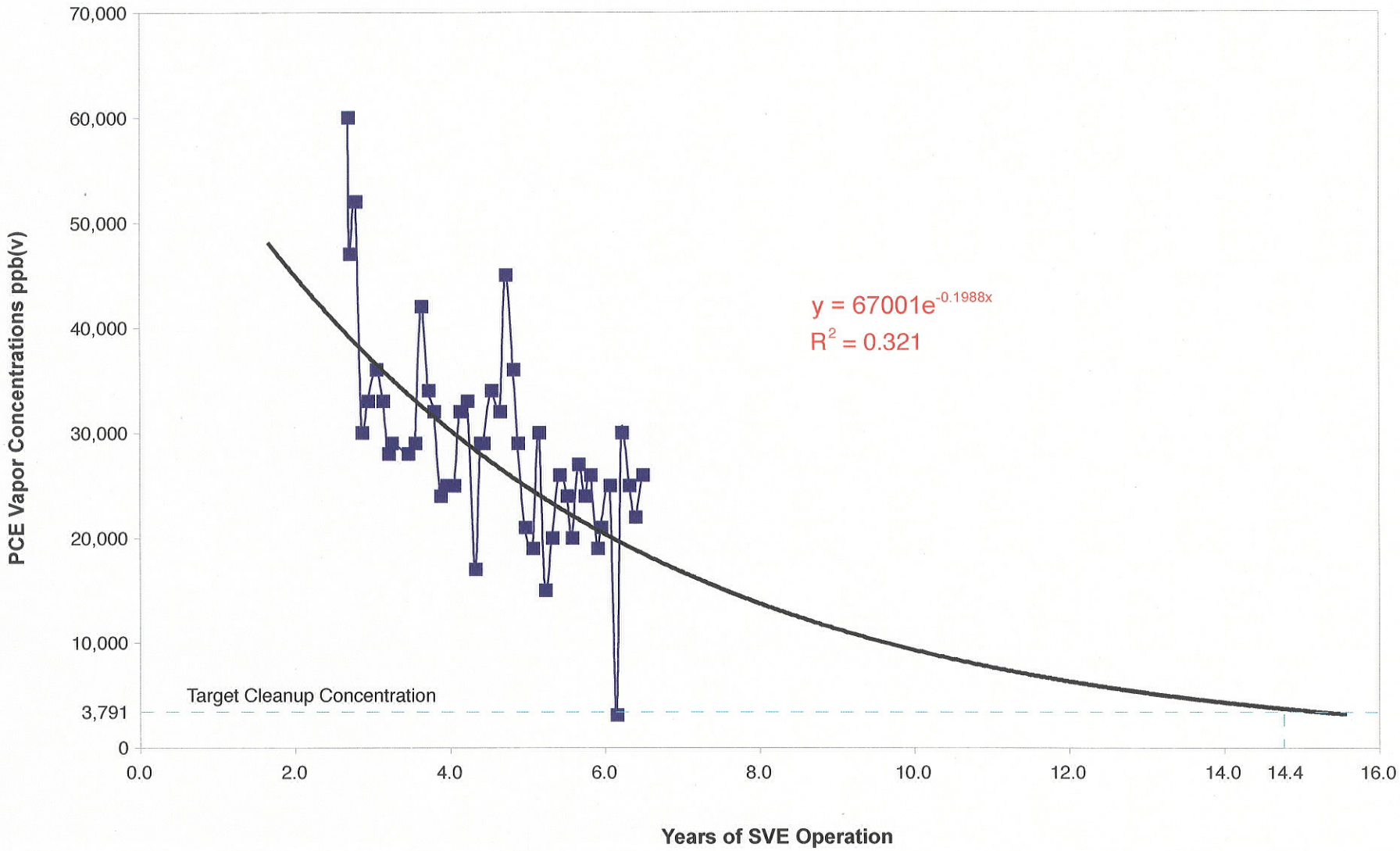
variation and rebound that may occur following shutdown of the SVE. This adjustment resulted in a target cleanup vapor concentration of 3,791 ppb(v) for industrial use.

Using the same process described above, the 10^{-6} residential RBCL of 0.335 μg/kg in soil corresponds to a soil vapor concentration of 366 $\mu g/m^3$, or 54 ppb(v). If this vapor concentration is divided by 8.5, a value of 6 ppb(v) is calculated as the target cleanup vapor concentration for residential use.

Estimated Number of Years for SVE System to Continue Operation

To estimate the number of additional years required for SVE system operation to reach the target cleanup levels presented in Table B.2-1, the historic performance of the system was evaluated as follows. First, PCE concentrations measured monthly at the system influent were plotted versus time (in years of operation), after which the plotted results were fitted with an exponential curve that best fit the data. The regression curve fitting a plot of influent PCE concentrations over the time period from September 2002 (when all seven wells were first brought online following system expansion) through July 2006 (when the system was shut down for rebound monitoring) is presented on Figure B.2-3. As shown in Table B.2-2, by plugging the target cleanup level for industrial use (3,800 ppb(v)) into the regression equation, a total operating time of 14.4 years (or 8 additional years) is estimated as the time required for the SVE system to reduce soil PCE concentrations below the 10^{-6} industrial RBCL of 200 μg/kg in soil. Similarly, a total operating time of 46 years (or 40 additional years) would be required for the SVE system to achieve the target cleanup level of 6 ppb(v) that corresponds to the 10^{-6} residential RBCL of 0.3 μg/kg in soil.

Note that these time estimates are more conservative than others, also presented in Table B.2-2, that were developed for this analysis. The other estimates, which range from less than 1 to 4.5 additional years to reach the target cleanup level for industrial use (and from 8 to 25 additional years to reach the target cleanup level for residential use), were based on the regression equations for plots (presented in Attachment B.2-2) that evaluated the trend in PCE concentrations over different timeframes either for the system influent (Figure 1) or for Well 172-EW01 (Figures 2 through 6). The trend at Well 172-EW01 was evaluated because this well has been on line longer than any of the other vapor extraction wells, and has shown the greatest decrease in PCE concentrations. In general, the regression



172-SPT
Expon. (172-SPT)
Target Cleanup Concentration

South AFRL ROD — Appendix B

Combined Influent PCE Concentrations from September 2002 to July 2006

Date 09-07	Edwards AFB	Figure
Project No. 94591		**B.2-3**

94591.10.04.01 Fig. B.2-3

TABLE B.2-2. ESTIMATED TIME OF SVE OPERATION REQUIRED TO REACH A PCE SOIL VAPOR CONCENTRATION CORRESPONDING TO 10^{-6} INDUSTRIAL OR RESIDENTIAL RBCLs

Sampling Point	Target Cleanup Level for the Industrial Use at 10^{-6} Risk Level	Target Cleanup Level for the Residential Use at 10^{-6} Risk Level	Timeframe	Starting PCE Vapor Concentration	Regression equation based on exponential fit	Industrial Risk 1 X 10^{-6}: Total Years of SVE System Operation to Reach PCE Concentration of 3,791 ppb(v) [1]	Industrial Risk 1 X 10^{-6}: Remaining Years of SVE Operation to Reach 12,000 ppb(v)	Residential Risk 1 X 10^{-6}: Total Years of SVE System Operation to Reach PCE Concentration of 6 ppb(v) [1]	Residential Risk 1 X 10^{-6}: Remaining Years of SVE Operation to Reach 6 ppb(v)
Combined Influent									
Figure B.2-3	**3,791 ppb**	**6 ppb**	**Sept-02[4] to July-06**	**60,000**	$y = 67{,}001e^{-0.1988x}$	**14.4**	**8.0**	**46.1**	**39.6**
Figure 1	3,791 ppb	6 ppb	Oct-00 to July-06	240,000	$y = 113{,}078e^{-0.308x}$	11.0	4.5	31.5	25.0
172-EW01									
Figure 2	3,791 ppb	6 ppb	Aug-00[2] to July-06	2,300,000	$y = 675{,}924e^{-0.5632x}$	9.2	2.7	20.4	13.9
Figure 3	3,791 ppb	6 ppb	Sept-00[3] to July-06	590,000	$y = 353{,}172e^{-0.4229x}$	10.7	4.2	25.6	19.1
Figure 4	3,791 ppb	6 ppb	Sept-02[4] to July-06	440,000	$y = 467{,}158e^{-0.4733x}$	10.2	3.7	23.5	17.0
Figure 5	3,791 ppb	6 ppb	Start-up (Jan-00) to July-06	5,600,000	$y = 2E{+}06e^{-0.8557x}$	7.3	0.8	14.7	8.2
Figure 6	3,791 ppb	6 ppb	July-00 to July-06	1,100,000[5]	$y = 497{,}272e^{-0.4969x}$	9.8	3.3	22.5	16.0

Notes:

Figures 1 through 6 are included in Attachment B.2-2.

[1] SVE has been operating in some capacity for 6.5 years

[2] Wells 172-EW01 and 172-EW02 added to SVE system

[3] One month after Wells 172-EW01 and 172-EW02 were added to SVE system

[4] Wells 172-EW04, 172-EW05, 172-EW06, and 172-EW07 added to the SVE system

[5] Starting concentration approximately equal to current concentration in Well 172-SG30

PCE	tetrachloroethene
ppb	parts per billion
ppb(v)	parts per billion by volume
RBCL	risk-based cleanup level
SVE	soil vapor extraction

Exponential Regression Equation:

$$y = C_1 e^{C_2 X} \longrightarrow x = \frac{1}{C_2} \ln\left(\frac{y}{C_1}\right)$$

Where: y = 3,791 ppb(v) for Industrial Risk 10^{-6}
y = 6 ppb(v) for Residential Risk 10^{-6}
x = Estimated number of years to reach PCE soil concentration corresponding to industrial or residential RBCL

equations based on the data from Well 172-EW01 showed a better fit (coefficient of determination [r^2] as high as 0.77 for figures 2 and 5). Nevertheless, the plot presented on Figure B.2-3 showing a slower decline based on the combined influent concentration from all seven wells is believed to better represent the timeframe that would be needed for the SVE system to reduce soil concentrations throughout the area to below the 10^{-6} industrial and residential RBCLs.

Estimated Costs for SVE Operation

The total cost (generated using RACER™ 2007 cost estimating software) to operate the SVE system until the target vapor concentration of 3,791 ppb(v) for continued industrial use is achieved in 8 years is estimated at approximately $2 million ($94,000 for installation of six additional vapor extraction wells, $541,000 for 8 years of operation and maintenance [O&M], and $1,364,000 for sampling and annual reporting on system performance). The total cost to operate the SVE system until the target vapor concentration of 6 ppb(v) for a residential use is achieved in 40 years is estimated at approximately $12.8 million ($94,000 for installation of six additional vapor extraction wells, $3 million for 40 years of O&M, and $9.7 million for sampling and annual reporting on system performance). The costs are summarized in Table B.2-3 for industrial use; detailed backup costs are presented in RACER Table 3A for industrial use and RACER Table 3B for residential use in Attachment B.2-1. Note this scenario assumes that all of the residual PCE in soil will be within the zone of influence of a vapor extraction well. Also, vapor extraction wells located south of the former waste sump in an area not covered by asphalt may require substantially longer SVE operation due to a reduced zone of influence.

SCENARIO 4. This alternative includes installation of an impervious layer incorporating a high density polyethylene (HDPE) overlying a geosynthetic clay liner (GCL) to act as a barrier against PCE vapors migrating into a future building to be constructed at the site. As with Scenario 1, this scenario assumes that the existing Building 8595 and other structures would be removed prior to installation of the vapor barrier (building demolition costs are not included). Installation of the vapor barrier would include grading, placement of fill soil as needed to level the sub-layer, and compacting the soil to create a leveling layer that slopes slightly upward from its center. The impervious layer, consisting of a GCL overlain by a 40 mil HDPE liner, would be placed on top of the leveling layer. A drainage layer

TABLE B.2-3. ESTIMATED COSTS FOR SVE WELL INSTALLATION, O&M, AND REPORTING TO ACHIEVE INDUSTRIAL TARGET CLEANUP CONCENTRATION (8 YEARS)

	Fiscal Year 1 2007	Fiscal Year 2 2008	Fiscal Year 3 2009	Fiscal Year 4 2010	Fiscal Year 5 2011	Fiscal Year 6 2012	Fiscal Year 7 2013	Fiscal Year 8 2014	Fiscal Year 9 2015	Total
Soil Vapor Extraction Well Installation [a]	$93,676									$93,676
SVE O&M [b]	$10,597	$68,722	$68,420	$68,722	$69,629	$68,420	$56,716	$44,408	$40,181	$495,816
Yearly AOR and Sampling [c]	$158,120	$158,120	$158,120	$158,120	$158,120	$158,120	$158,120	$158,120		$1,264,959
Sub-Total	$262,392	$226,842	$226,540	$226,842	$227,749	$226,540	$214,836	$202,528	$40,181	$1,854,451
Escalation Factor	1.0000	1.0220	1.0435	1.0654	1.0877	1.1117	1.1361	1.1611	1.1867	
Total	$262,392	$231,833	$236,395	$241,678	$247,722	$251,845	$244,075	$235,155	$47,683	$1,998,778

Notes:

Costs developed using RACER™ 2007 software.

[a] Includes the installation of six soil vapor extraction wells and tie in with the existing SVE system.

[b] Includes one annual operating report and sampling of 13 soil vapor extraction wells and two duplicate sample.

[c] Assumes one weekly visit for 52 weeks a year.

AOR annual operating report

O&M operating and maintenance

RACER remedial action cost and engineering requirements

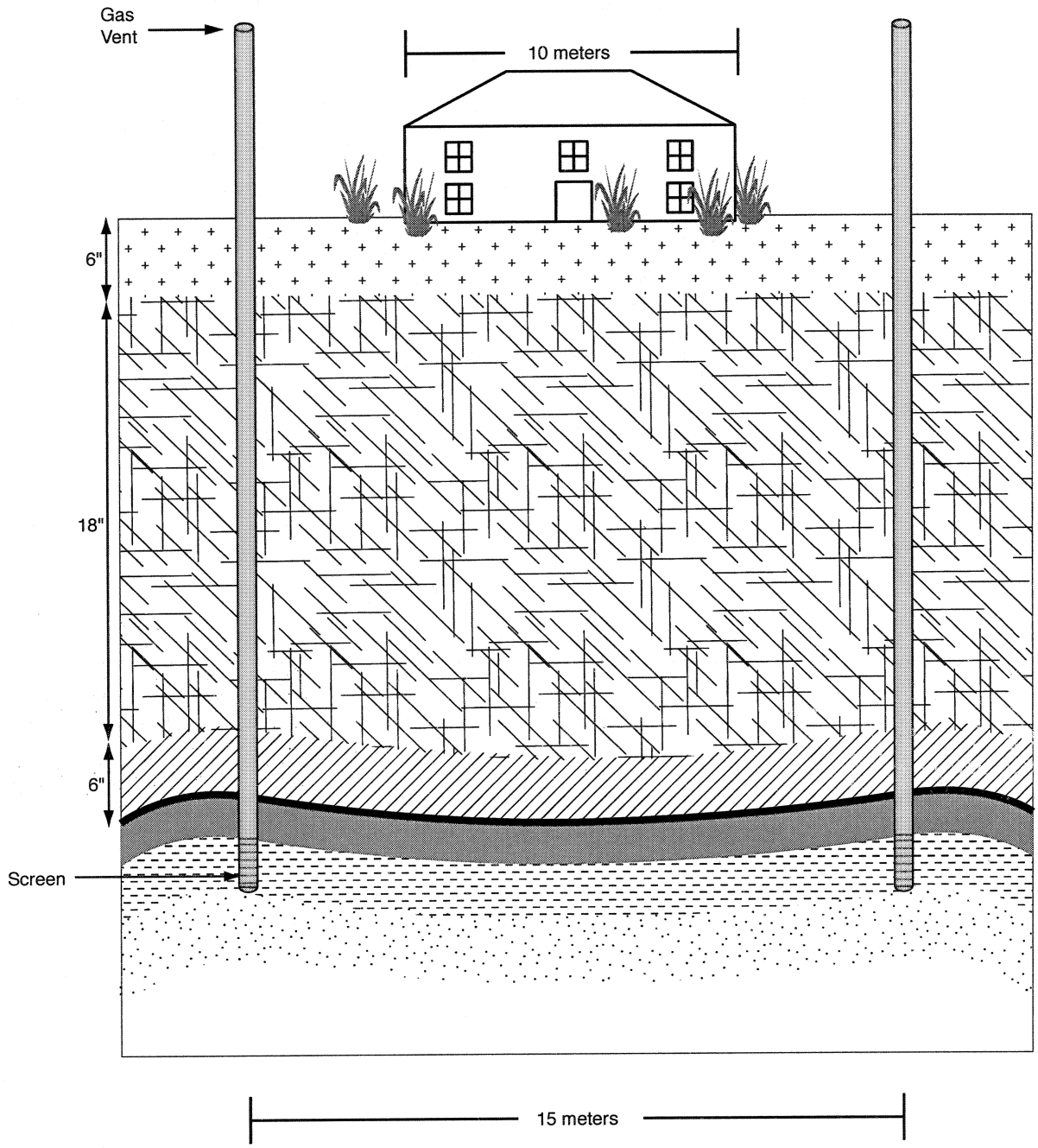
SVE soil vapor extraction

consisting of composite soil would be placed on top of the impervious layer, topped by 18 inches of soil. Following installation of the vapor barrier, a passive gas vent system consisting of two vertical pipes located on either side of the barrier would be installed to capture and passively vent vapors migrating from beneath the sloped impervious layer to the surface. A conceptual cross-section of a vapor barrier system is presented on Figure B.2-4. The barrier dimensions were assumed to cover an area of 15 x 15 meters, slightly larger than the foot print for a standard residential building (10 x 10 meters).

The total cost, generated using RACER™ 2007 cost estimating software, is estimated at $25,000. The detailed costs generated by RACER are presented in RACER Table 4 in Attachment B.2-1.

B.2.3 SUMMARY OF ALTERNATIVES

The remedial alternatives evaluated in this appendix and the assumptions and costs developed for implementation of each, are summarized in Table B.2-4. Based on this comparison, the two scenarios (2 and 4) involving building (engineering) controls are the least costly alternatives that are considered capable of disrupting the VIP, thereby preventing an exposure to PCE in indoor air at cancer risk levels exceeding 1×10^{-6}. In the ROD, a combination of LUCs and engineering controls was selected as the final remedy to address risks at the South AFRL via the VIP. The evaluation presented in this appendix, while limited in scope, supports the selected remedy. During the short-term, while the remedial design to implement monitoring and building controls is developed, the SVE system will be reactivated in part as a temporary measure to mitigate exposure by occupants of Building 8595 (Earth Tech 2007). Details for full implementation of LUCs, a vapor monitoring program, and implementation of building controls will be developed during preparation of post-ROD documents.



Top Cover
Soil Cover
Drainage Layer (gravel)
40 mil HDPE
0.25 inch GCL
Leveling Layer (sand)
6" Native Soil

Notes:

HDPE high-density polyethylene geomembrane
GCL geosynthetic clay liner

South AFRL ROD		Appendix B-2
Cross Sectional (Conceptual) View of a Vapor Barrier System		
Date 09-07 Project No. 94591	Air Force Research Laboratory Edwards AFB	Figure **B.2-4**

94591.10.04.01 Fig. B.2-2

TABLE B.2-4. SUMMARY OF SCENARIO COSTS

Scenario	Scenario Description	Assumptions	Initial Year Cost	Total Cost
#1	Dig and haul of PCE contaminated soil	1. No buildings exist on site. 2. Costs do not include removal of any existing buildings or structures. 3. Excavation of 102,000 cubic feet of clean soil (with onsite disposal) and 88,000 cubic feet of contaminated soil/rock with disposal off site as a nonhazardous waste.	$1,350,000	$1,350,000
#2	Installation of a sub-slab depressurization system in Building 8595	1.Two 1.5 HP fans mounted on the roof of Building 8595 can create a sufficient flow to draw vapors below the foundation of Building 8595. 2. The effluent vapors from the fans will be allowed to vent directly to the atmosphere without treatment. 3. Costs to maintain fans is not included.	$150,000	$150,000
#3a	Limited expansion and continued operation of the SVE system south of Building 8595 until PCE soil concentrations reach the 10^{-6} industrial RBCL.	1. Installation of six wells is sufficient to cover the extent of the PCE contaminated soil. 2. The percent by which PCE concentration is reduced in soil vapor is equivalent to its percent reduction in soil (i.e., a 50% reduction in soil vapor concentration will result in a 50% reduction in soil concentration). 3. The equation for an exponential regression curve fitting a plot of PCE influent concentrations versus time of SVE operation provides sufficient accuracy to allow a useful prediction of operating years until a target cleanup concentration is reached. 4. Soil vapors detected at the site are associated with soil (rather than groundwater) contamination. Vapors arising from contaminated groundwater are sufficiently impeded by competent bedrock that they do not appreciably affect shallow soil vapor concentrations. 5. Operation of the SVE system for an additional 8 years will be sufficient to reduce PCE soil contamination to a risk level at or below 10^{-6} for an industrial use.	$262,000	$1,999,000
#3b	Limited expansion and continued operation of the SVE system south of Building 8595 until PCE soil concentrations reach the 10^{-6} residential RBCL.	1-4. Same assumptions as outlined in Scenario 3a 5. Operation of the SVE system for an additional 40 years will be sufficient to reduce PCE soil contamination to a risk level at or below 10^{-6} for a residential use.	$262,000	$12,823,000
#4	Installation of vapor barrier	1. No buildings exist on the site. 2. Not applicable for existing Building 8595.	$24,000	$24,000

B.2.4 REFERENCES

Earth Tech 2007. *Environmental Restoration Program, Soil Vapor Extraction System Annual Operations Report for 2006, Site 172 ,Air Force Research Laboratory, Operable Unit 4, Edwards Air Force Base, California*. Final. Prepared for 95 ABW/CEVR, Edwards Air Force Base, CA and AFCEE/ISM, Brooks City-Base, TX. Long Beach, CA. August.

Environmental Quality Management, Inc., 2003. *User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings*. Prepared for Industrial Economics, Inc, and presented to U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. June.

ITRC (Interstate Technology & Regulatory Council). 2007. *Vapor Intrusion Pathway: Investigative Approaches for Typical Scenarios*. VI-1A. Washington, D.C.: Interstate Technology & Regulatory Council, Vapor Intrusion team. www.itrcweb.org

ATTACHMENT B.2-1

RACER COST ESTIMATING TABLES

Table 1

Racer™ Generated Costs for Removal of PCE Contaminated Soil within the Area Encompassing the 10^{-6} Industrial RBCL (Scenario 1)

Table 1. RACER™ Generated Costs for Removal of PCE Contaminated Soil Within the Area Encompassing the 10^{-6} Industrial RBCL (Scenario 1)

Phase:

Phase Type: Removal/Interim Action

Phase Name: Removal Action

Description: Costs are for the hypothetical excavation of soil and first 3 feet of bedrock beneath and downgradient of Building 8595. The area (shown in green hatching on Figure B.2-1) contaminated with PCE concentrations exceeding the 10^{-6} industrial RBCL is estimated to cover approximately 14,500 square feet. The upper layer of soil (averaging 7 feet thick) is considered "clean" and is assumed to be disposed of onsite. The top 3 feet of soil below the clean layer, and the top 3 feet of bedrock are assumed to be contaminated and will be disposed of offsite as nonhazardous waste. The following is the volume to be excavated: 102,000 cubic feet of clean soil, 44,000 cubic feet of contaminated soil, and 44,000 cubic feet of contaminated bedrock. In total, 190,000 cubic feet of soil and bedrock is to be excavated.

The cost estimate assumes 2 days of geophysical clearance prior to excavation; an average excavation depth of 13 feet at a side slope of 1:1.5 to stabilize the sand/gravelly sand; and collection of 25 soil samples to confirm contaminant levels. The task was assumed to require a professional labor management level of high complexity.

Media/Waste Type

Primary: Soil

Secondary: N/A

Contaminant

Primary: Volatile Organic Compounds (VOCs)

Secondary: None

Approach: Ex Situ

Start Date: September, 2007

Rate Groups

Labor: System Labor Rate

Analysis: System Analysis Rate

Phase Markups: System Defaults+Risk at 10%

Technology	Direct Cost	Markups	Total Cost
Excavation	$132,118	$70,071	$202,189
Residual Waste Management	$431,567	$178,305	$609,872
Professional Labor Management	$161,242	$374,229	$535,471
Total Capital Cost	$724,927	$622,605	$1,347,532

	Direct Cost	Markups	Total Cost
Total Phase Cost	$724,927	$622,605	$1,347,532
		Escalation	$0
		Escalated Phase Cost	$1,347,532

Table 2

RACER™ Generated Costs for Installation of a Sub-Slab Depressurization System Beneath Building 8595

(Scenario 2)

Table 2. RACER™ Generated Costs for Installation of a Sub-Slab Depressurization System Beneath Building 8595

Phase:

Phase Type: Removal/Interim Action

Phase Name: Removal Action

Description: Cost elements include the coring and drilling of 16, small-diameter suction pits to a depth of 6 inches below the concrete slab of Building 8595, and installation of polyvinyl chloride (PVC) piping to draw vapors from each suction pit to one of two fans to be mounted on the building's roof. The 16 sub-slab suction pits will be installed at an approximate spacing of one per 1,500 square feet inside the 23,500-square foot building. The PVC piping from each suction pit will be connected to one of two central headers, each of which will transfer the subsurface vapors to a depression fan mounted on the building's roof. The fans will pull vapors from beneath the building's concrete slab to the roof, where they will be vented to the atmosphere.

Media/Waste Type

Primary: Soil

Secondary: N/A

Contaminant

Primary: Volatile Organic Compounds (VOCs)

Secondary: None

Approach: Ex Situ

Start Date: September, 2007

Rate Groups

Labor: System Labor Rate

Analysis: System Analysis Rate

Phase Markups: System Defaults+Risk at 10%

Technology	Direct Cost	Markups	Total Cost
Sub-Slab Depressurization	$40,965	$30,935	$71,900
Professional Labor Management	$23,217	$54,612	$77,829
Total Capital Cost	$64,182	$85,547	$149,729

	Direct Cost	Markups	Total Cost
Total Phase Cost	$64,182	$85,547	$149,729
		Escalation	$0
		Escalated Phase Cost	$149,729

Table 3A

Racer™ Generated Costs for Well Installation, Operation, and Reporting at the SVE System to Achieve Target Cleanup Concentrations for Industrial Use

(Scenario 3A)

3A-1 – Costs for Well Installation

3A-2 – Costs for O&M for 8 years

3A-3 – Costs for Reporting (AORs) and Sampling

TABLE 3A-1. SVE System Well Installation - Phase Cost Summary Report (with Markups)

Phase:

Phase Type: Remedial Action
Phase Name: Soil Vapor Extraction Well Installation
Description: Installation of six vapor extraction wells each to a depth of 15 feet; and tie-in to the system.

Media/Waste Type
Primary: Soil
Secondary: N/A

Contaminant
Primary: Volatile Organic Compounds (VOCs)
Secondary: None

Approach: Ex Situ
Start Date: September, 2007

Rate Groups
Labor: System Labor Rate
Analysis: System Analysis Rate

Phase Markups: System Defaults+Risk at 10%

Technology	Direct Cost	Markups	Total Cost
Soil Vapor Extraction	$24,810	$18,894	$43,704
Professional Labor Management	$14,503	$34,567	$49,070
Residual Waste Management	$632	$270	$902
Total Capital Cost	$39,945	$53,731	$93,676

	Direct Cost	Markups	Total Cost
Total Phase Cost	$39,945	$53,731	$93,676
		Escalation	$0
		Escalated Phase Cost	$93,676

TABLE 3A-2. Racer™ Generated Costs for SVE System O&M over an 8 Year Period - Phase Cost Summary Report (with Markups)

Phase:

Phase Type: Operations & Maintenance
Phase Name: O&M
Description: SVE System O&M for 8 years. Includes once a week visits to the SVE system for 52 weeks per year.

Media/Waste Type
Primary: Soil
Secondary: N/A

Contaminant
Primary: Volatile Organic Compounds (VOCs)
Secondary: None

Start Date: September, 2007

Rate Groups
Labor: System Labor Rate
Analysis: System Analysis Rate
Phase Markups: System Defaults+Risk at 10%

Technology	Direct Cost	Markups	Total Cost
Operations and Maintenance	$244,725	$251,091	$495,816
Total O&M Cost	$244,725	$251,091	$495,816

	Direct Cost	Markups	Total Cost
Total Phase Cost	$244,725	$251,091	$495,816
		Escalation	$45,107
		Escalated Phase Cost	$540,923

TABLE 3A-3. RACER™ Generated Costs for SVE System AOR and Sampling over an 8 Year Period - Phase Cost Summary Report

(with Markups)

Phase:

Phase Type: Remedial Action
Phase Name: Yearly SVE System Annual Operations Report and Sampling
Description: Costs include yearly sampling (13 soil vapor extraction wells and two duplicate samples) and one annual operating report for the Soil Vapor Extraction System.

Media/Waste Type
Primary: Soil
Secondary: N/A

Contaminant
Primary: Volatile Organic Compounds (VOCs)
Secondary: None

Approach: Ex Situ
Start Date: September, 2007

Rate Groups
Labor: System Labor Rate
Analysis: System Analysis Rate

Phase Markups: System Defaults+Risk at 10%

Technology	Direct Cost	Markups	Total Cost
Monitoring	$388,097	$876,862	$1,264,959
Total Capital Cost	$388,097	$876,862	$1,264,959

	Direct Cost	Markups	Total Cost
Total Phase Cost	$388,097	$876,862	$1,264,959
		Escalation	$99,220
		Escalated Phase Cost	$1,364,179

Table 3B

Racer™ Generated Costs for Well Installation, Operation, and Reporting at SVE System to Achieve Target Cleanup Concentrations for Residential Use

(Scenario 3B)

3B-1 – Costs for Well Installation

3B-2 – Costs for O&M for 40 years

3B-3 – Costs for Reporting (AORs) and Sampling

TABLE 3B-1. SVE System Well Installation - Phase Cost Summary Report (with Markups)

Phase:

Phase Type: Remedial Action
Phase Name: Soil Vapor Extraction Well Installation
Description: Installation of six vapor extraction wells each to a depth of 15 feet; and tie-in to the system.

Media/Waste Type
Primary: Soil
Secondary: N/A

Contaminant
Primary: Volatile Organic Compounds (VOCs)
Secondary: None

Approach: Ex Situ
Start Date: September, 2007

Rate Groups
Labor: System Labor Rate
Analysis: System Analysis Rate

Phase Markups: System Defaults+Risk at 10%

Technology	Direct Cost	Markups	Total Cost
Soil Vapor Extraction	$24,810	$18,894	$43,704
Professional Labor Management	$14,503	$34,567	$49,070
Residual Waste Management	$632	$270	$902
Total Capital Cost	$39,945	$53,731	$93,676

	Direct Cost	Markups	Total Cost
Total Phase Cost	$39,945	$53,731	$93,676
		Escalation	$0
		Escalated Phase Cost	$93,676

TABLE 3B-2. Racer™ Generated Costs for SVE System O&M over a 40 Year Period - Phase Cost Summary Report (with Markups)

Phase:

Phase Type: Operations & Maintenance

Phase Name: O&M

Description: SVE System O&M for 40 years. Includes once a week visits to the SVE system for 52 weeks per year.

Media/Waste Type

Primary: Soil

Secondary: N/A

Contaminant

Primary: Volatile Organic Compounds (VOCs)

Secondary: None

Start Date: September, 2007

Rate Groups

Labor: System Labor Rate

Analysis: System Analysis Rate

Phase Markups: System Defaults+Risk at 10%

Technology	Direct Cost	Markups	Total Cost
Operations and Maintenance	$2,022,612	NA	$2,022,612
Total O&M Cost	$2,022,612	NA	$2,022,612

	Direct Cost	Markups	Total Cost
Total Phase Cost	$2,022,612	NA	$2,022,612
		Escalation	$1,016,920
		Escalated Phase Cost	$3,039,532

TABLE 3B-3. RACER™ Generated Costs for SVE System AOR and Sampling over a 40 Year Period - Phase Cost Summary Report

(with Markups)

Phase:

Phase Type: Remedial Action

Phase Name: Yearly SVE System Annual Operations Report and Sampling

Description: Costs include yearly sampling (13 soil vapor extraction wells and two duplicate samples) and one annual operating report for the Soil Vapor Extraction System.

Media/Waste Type

Primary: Soil

Secondary: N/A

Contaminant

Primary: Volatile Organic Compounds (VOCs)

Secondary: None

Approach: Ex Situ

Start Date: September, 2007

Rate Groups

Labor: System Labor Rate

Analysis: System Analysis Rate

Phase Markups: System Defaults+Risk at 10%

Technology	Direct Cost	Markups	Total Cost
Monitoring	$6,324,795	NA	$6,324,795
Total Capital Cost	$6,324,795	NA	$6,324,795

	Direct Cost	Markups	Total Cost
Total Phase Cost	$6,324,795	NA	$6,324,795
		Escalation	$3,364,586
		Escalated Phase Cost	$9,689,381

Table 4

Racer™ Generated Costs for Installation of a Vapor Barrier (Scenario 4)

Table 4. RACER™ Generated Costs for Installation of a Vapor Barrier (Scenario 4)

Phase:

Phase Type: Remedial Action

Phase Name: Vapor Intrusion Barrier Membrane

Description: This scenario includes the construction of a vapor intrusion barrier membrane for a residential building (10 by 10 meters) within the area encompassing PCE soil contamination exceeding the 10-6 risk level for residential use. Assumes prior removal of existing structures prior to installation of the vapor barrier (costs for demolition of structures is not included). Cost elements include installing a geosynthetic/composite liner to cover an area of 0.056 acres; and placement of top soil and soil cover brought from an offsite location. The impervious vapor barrier will consist of a 40 Mil HDPE liner underlain by a geosynthetic clay liner. At the base of the cover a leveling layer of fill (also brought from offsite) will be placed. Costs include installation of a passive gas vent system and associated piping.

Media/Waste Type

Primary: Air

Secondary: N/A

Contaminant

Primary: Volatile Organic Compounds (VOCs)

Secondary: None

Approach: Ex Situ

Start Date: September, 2007

Rate Groups

Labor: System Labor Rate

Analysis: System Analysis Rate

Phase Markups: System Defaults+Risk @ 10%

Technology	Direct Cost	Markups	Total Cost
Capping	$15,115	$ 9,252	$24,367
Total Capital Cost	$15,115	$ 9,252	$24,367

	Direct Cost	Markups	Total Cost
Total Phase Cost	$15,115	$ 9,252	$24,367
		Escalation	$0
		Escalated Phase Cost	$24,367

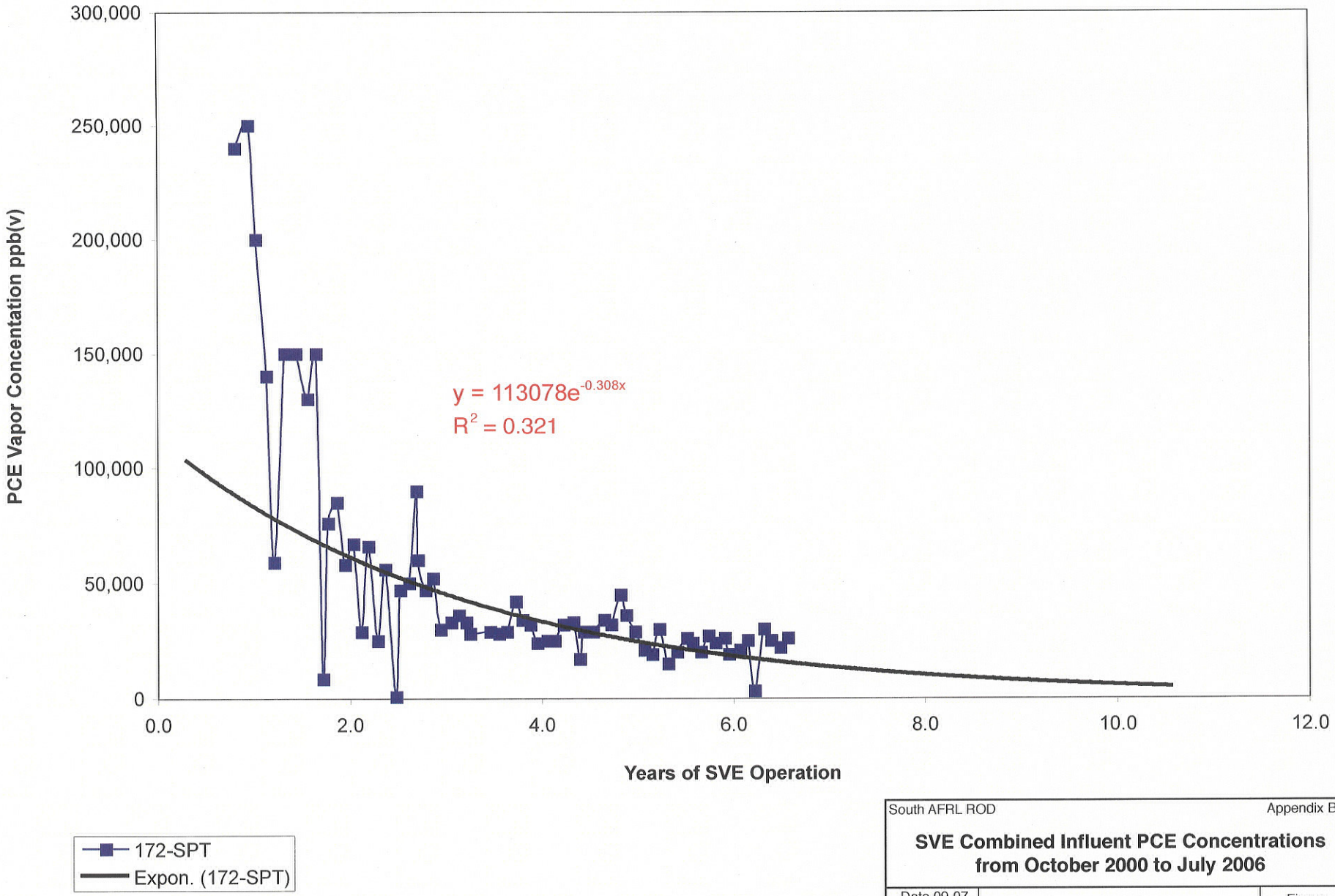
ATTACHMENT B.2-1

PLOTS OF PCE CONCENTRATION VERSUS TIME
(YEARS OF SVE OPERATION FITTED WITH EXPONENTIAL REGRESSION CURVES)

- Figure 1. SVE Combined Influent PCE Concentrations from October 2000 to July 2006
- Figure 2. Well 172-EW01 PCE Concentrations from August 2000 to July 2006
- Figure 3. Well 172-EW01 PCE Concentrations from September 2000 to July 2006
- Figure 4. Well 172-EW01 PCE Concentrations from September 2002 to July 2006
- Figure 5. Well 172-EW01 PCE Concentrations from Start-up (January 2000) to July 2006
- Figure 6. Well 172-EW01 PCE Concentrations from July 2000 to July 2006

Figure 1

SVE Combined Influent PCE Concentrations from October 2000 to July 2006

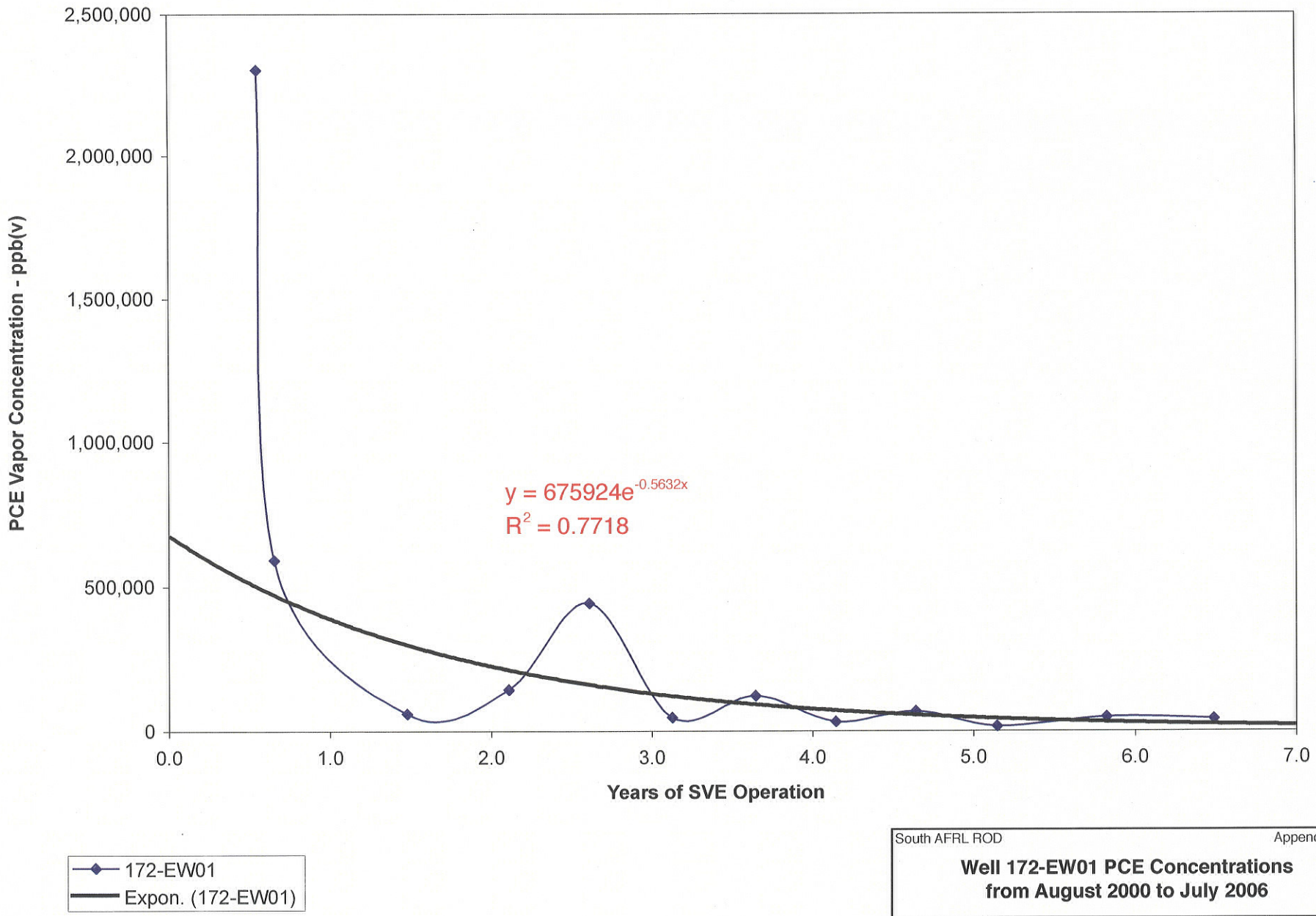


South AFRL ROD		Appendix B-2
SVE Combined Influent PCE Concentrations from October 2000 to July 2006		
Date 09-07 Project No. 89160	Edwards AFB	Figure **1**

89160.10.03.09 Fig. 1

Figure 2

Well 172-EW01 PCE Concentrations from August 2000 to July 2006

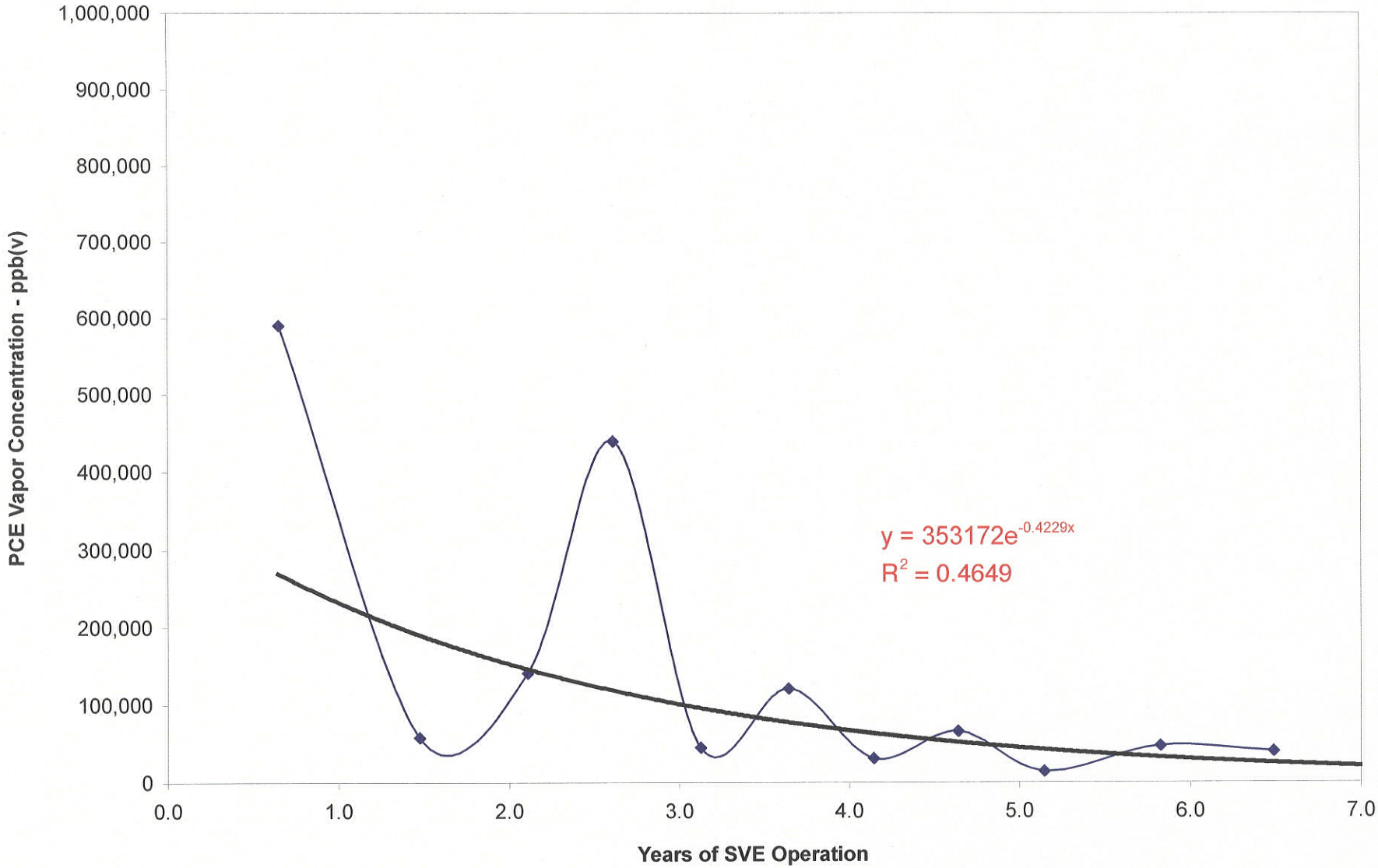


South AFRL ROD		Appendix B-2
Well 172-EW01 PCE Concentrations from August 2000 to July 2006		
Date 09-07	Edwards AFB	Figure
Project No. 89160		2

89160.10.03.09 Fig. 2

Figure 3

Well 172-EW01 PCE Concentrations from September 2000 to July 2006

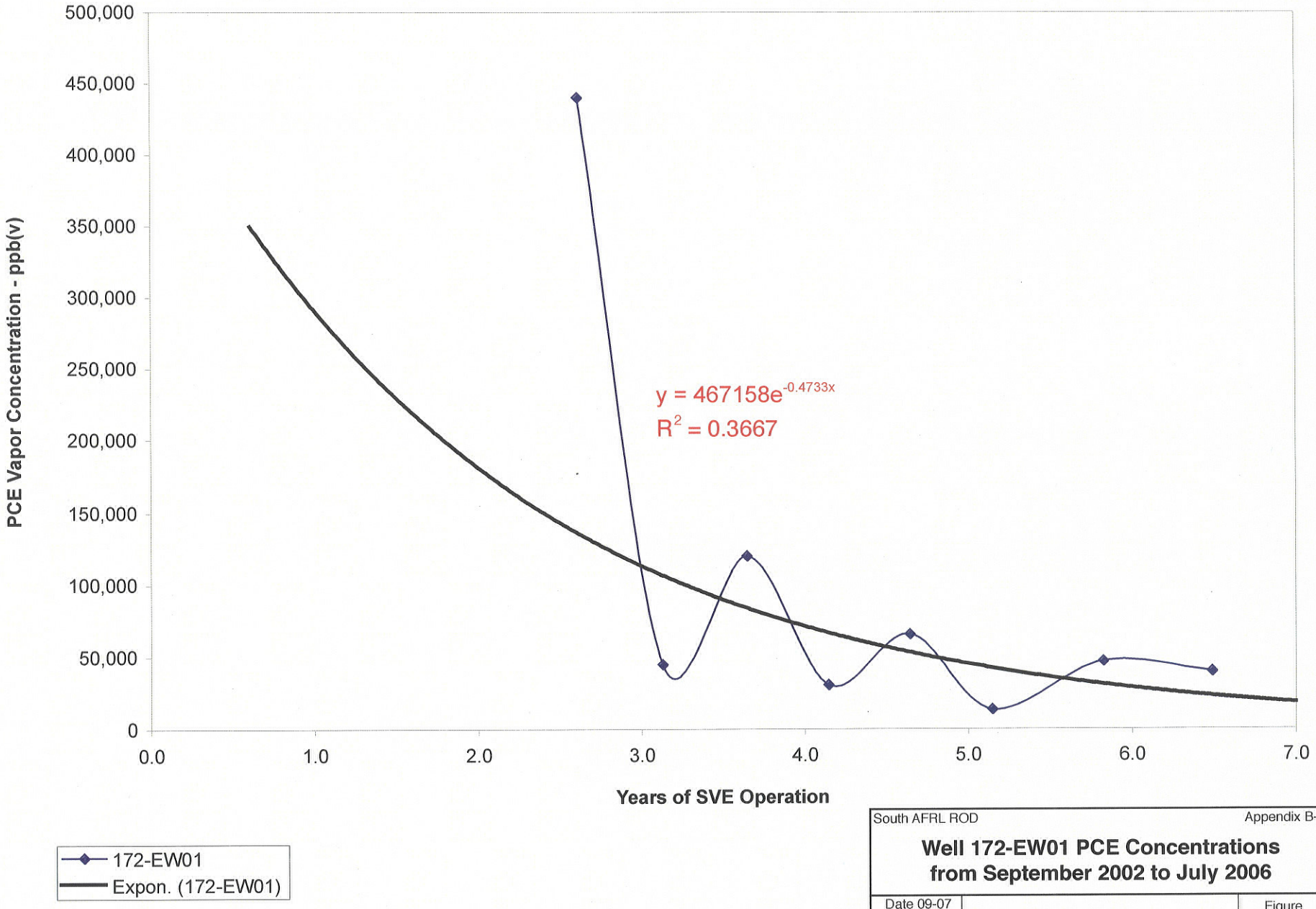


South AFRL ROD		Appendix B-2
Well 172-EW01 PCE Concentrations from September 2000 to July 2006		
Date 09-07	Edwards AFB	Figure
Project No. 89160		3

89160.10.03.09 Fig. 3

Figure 4

Well 172-EW01 PCE Concentrations from September 2002 to July 2006



South AFRL ROD

Appendix B-2

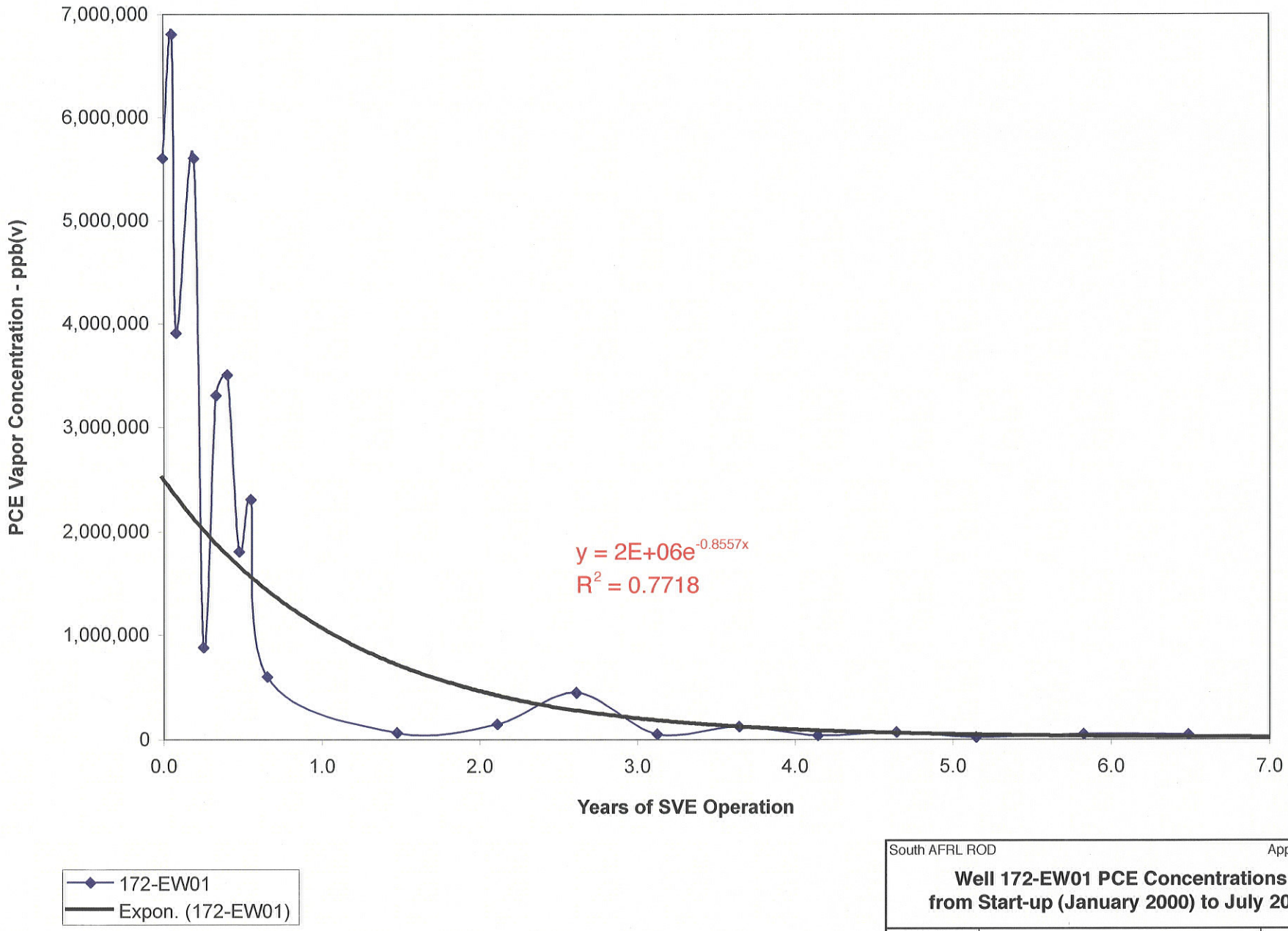
Well 172-EW01 PCE Concentrations from September 2002 to July 2006

Date 09-07	Edwards AFB	Figure
Project No. 89160		4

89160.10.03.09 Fig. 4

Figure 5

Well 172-EW01 PCE Concentrations from Start-up (January 2000) to July 2006

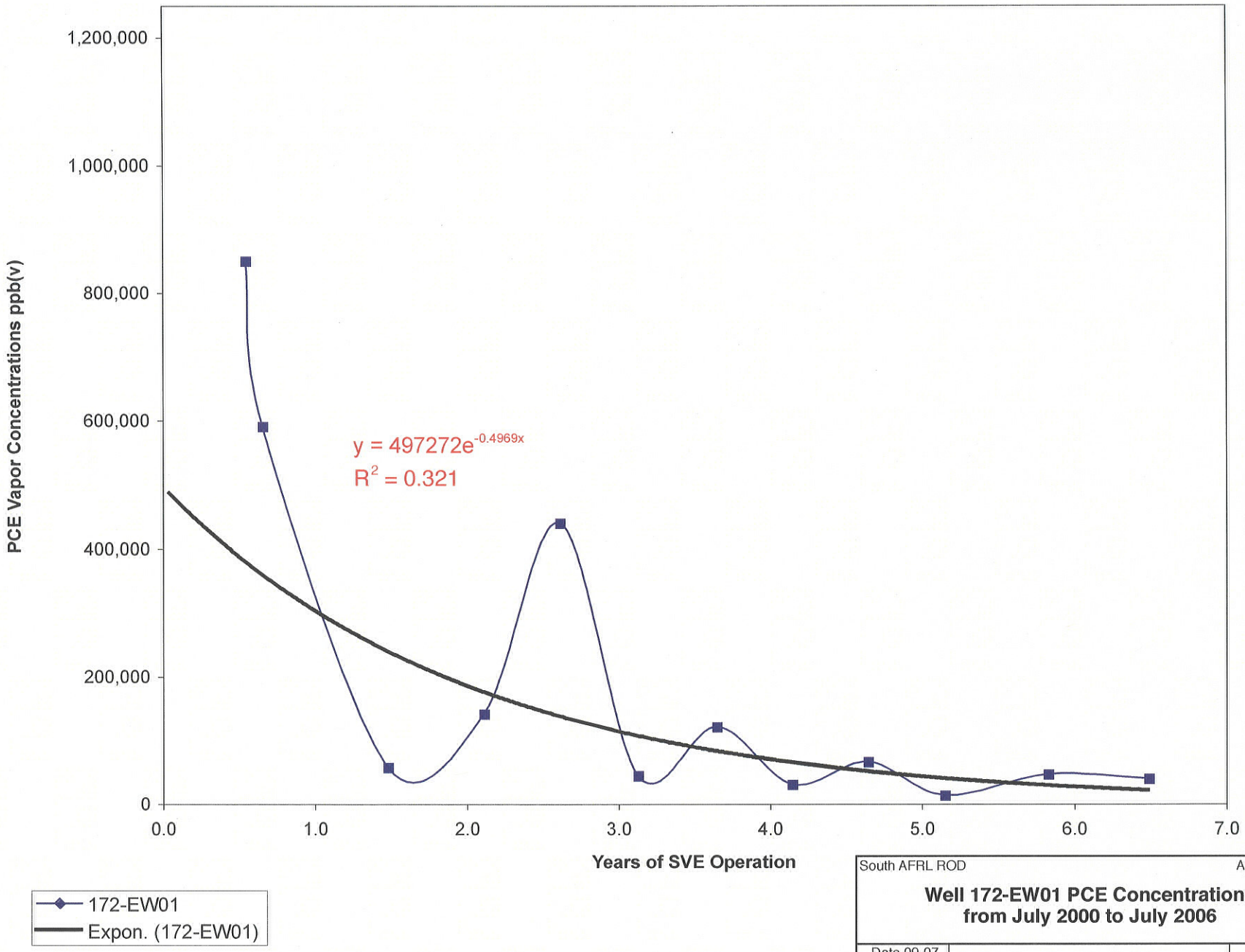


South AFRL ROD		Appendix B-2
Well 172-EW01 PCE Concentrations from Start-up (January 2000) to July 2006		
Date 09-07 Project No. 89160	Edwards AFB	Figure **5**

89160.10.03.09 Fig. 5

Figure 6

Well 172-EW01 PCE Concentrations from July 2000 to July 2006



South AFRL ROD

Appendix B-2

Well 172-EW01 PCE Concentrations from July 2000 to July 2006

Date 09-07	Edwards AFB	Figure
Project No. 89160		6

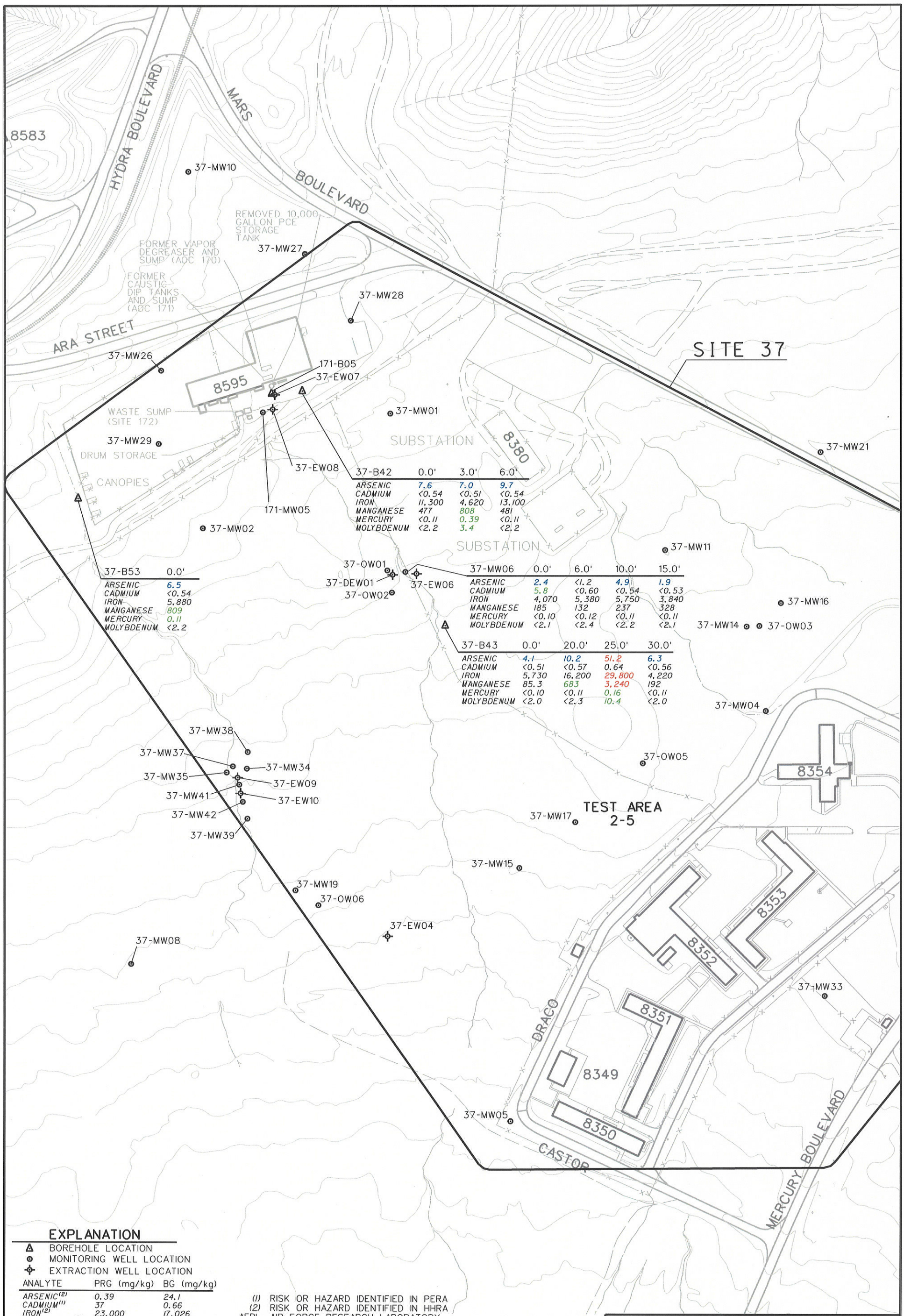
89160.10.03.09 Fig. 6

APPENDIX C

DISTRIBUTIONS OF INORGANIC AND SELECTED ORGANIC CHEMICALS IN SOIL AND GROUNDWATER IDENTIFIED AS POSING RISK OR HAZARDS IN THE HHRA OR PERA

APPENDIX C FIGURES

C-1 Site 37 Distribution of Inorganic Analytes in Soils Showing Risk or Hazard in HHRA or PERA
C-2 Site 37 Distribution of Arsenic in Groundwater
C-3 Site 37 Distribution of Molybdenum in Groundwater
C-4 Site 37 Distribution of Naphthalene in Groundwater
C-5 Site 37 Distribution of Nickel in Groundwater
C-6 Site 37 Distribution of Nitrate in Groundwater
C-7 Site 37 Distribution of Vanadium in Groundwater
C-8 Site 37 Distribution of Inorganic Analytes in Groundwater Showing Risk in PERA
C-9 Site 120 Distribution of Analytes in Soil and Surface Sediment Showing Risk in PERA
C-10 Site 120 Distribution of Inorganic Analytes in Groundwater Showing Hazard in HHRA
C-11 Site 120 Distribution of Inorganic Analytes and 1,1,2-TCA in Groundwater and Surface Water Showing Risk in PERA
C-12 Site 133 Distribution of Inorganic Analytes in Soil Showing Risk in PERA
C-13 Site 133 Distribution of Arsenic in Groundwater
C-14 Site 133 Distribution of Naphthalene, 1,2,4 and 1,3,5-Trimethylbenzene in Groundwater
C-15 Site 133 Distribution of Aluminum in Groundwater
C-16 Site 133 Distribution of Cadmium in Groundwater
C-17 Site 133 Distribution of Fluoride in Groundwater
C-18 Site 133 Distribution of Lead in Groundwater
C-19 Site 133 Distribution of Mercury in Groundwater
C-20 Site 133 Distribution of Molybdenum in Groundwater
C-21 Site 133 Distribution of Nickel in Groundwater
C-22 Site 133 Distribution of Nitrate in Groundwater
C-23 Site 133 Distribution of Thallium in Groundwater
C-24 Site 133 Distribution of Vanadium in Groundwater
C-25 Site 133 Distribution of Total Chromium in Groundwater Showing Risk in PERA



37-B42	0.0'	3.0'	6.0'
ARSENIC	7.6	7.0	9.7
CADMIUM	<0.54	<0.51	<0.54
IRON	11,300	4,620	13,100
MANGANESE	477	808	481
MERCURY	<0.11	0.39	<0.11
MOLYBDENUM	<2.2	3.4	<2.2

37-B53	0.0'
ARSENIC	6.5
CADMIUM	<0.54
IRON	5,880
MANGANESE	809
MERCURY	0.11
MOLYBDENUM	<2.2

37-MW06	0.0'	6.0'	10.0'	15.0'
ARSENIC	2.4	<1.2	4.9	1.9
CADMIUM	5.8	<0.60	<0.54	<0.53
IRON	4,070	5,380	5,750	3,840
MANGANESE	185	132	237	328
MERCURY	<0.10	<0.12	<0.11	<0.11
MOLYBDENUM	<2.1	<2.4	<2.2	<2.1

37-B43	0.0'	20.0'	25.0'	30.0'
ARSENIC	4.1	10.2	51.2	6.3
CADMIUM	<0.51	<0.57	0.64	<0.56
IRON	5,730	16,200	29,800	4,220
MANGANESE	85.3	683	3,240	192
MERCURY	<0.10	<0.11	0.16	<0.11
MOLYBDENUM	<2.0	<2.3	10.4	<2.0

EXPLANATION

- BOREHOLE LOCATION
- MONITORING WELL LOCATION
- EXTRACTION WELL LOCATION

ANALYTE	PRG (mg/kg)	BG (mg/kg)
ARSENIC(2)	0.39	24.1
CADMIUM(1)	37	0.66
IRON(2)	23,000	17,026
MANGANESE(2)	1,800	596
MERCURY(1)	23	PQL (0.10)
MOLYBDENUM(1)	390	PQL (2.0)

RESULTS SHOWN IN GREEN EXCEED BACKGROUND CONCENTRATIONS

RESULTS SHOWN IN BLUE EXCEED PRG CONCENTRATIONS

RESULTS SHOWN IN RED EXCEED BOTH PRG AND BACKGROUND CONCENTRATIONS

(1) RISK OR HAZARD IDENTIFIED IN PERA
(2) RISK OR HAZARD IDENTIFIED IN HHRA
AFRL AIR FORCE RESEARCH LABORATORY
AOC AREA OF CONCERN
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
mg/kg MILLIGRAMS PER KILOGRAM
HHRA HUMAN HEALTH RISK ASSESSMENT
PERA PREDICTIVE ECOLOGICAL RISK ASSESSMENT
PRG RESIDENTIAL PRELIMINARY REMEDIATION GOAL (USEPA 2004)
PCE TETRACHLOROETHENE
PQL PRACTICAL QUANTITATION LIMIT
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 37
Distribution of Inorganic Analytes in Soils Showing Risk or Hazard in HHRA or PERA

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure C-1
Project No. 67861		

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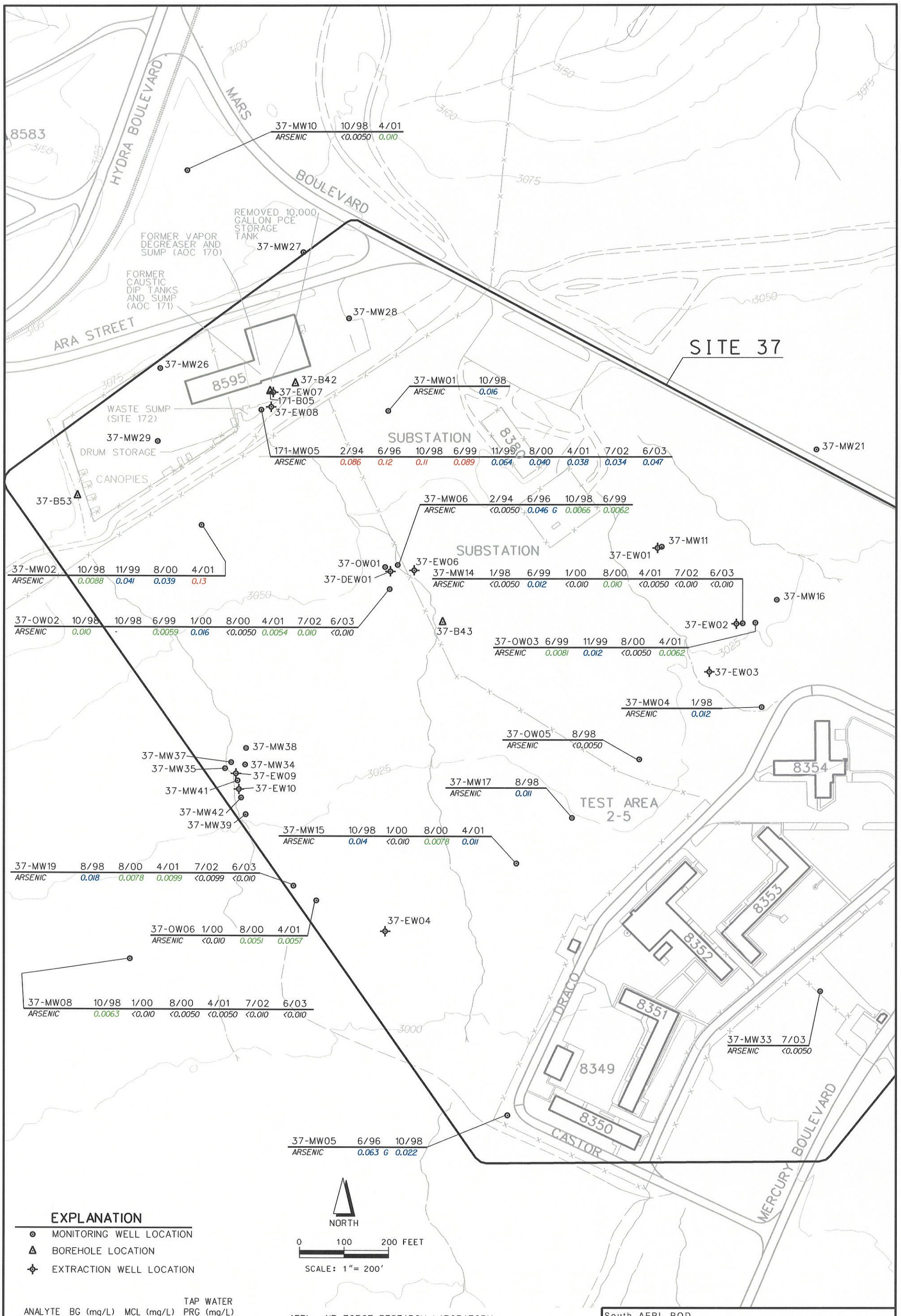


EXPLANATION

- ⊙ MONITORING WELL LOCATION
- △ BOREHOLE LOCATION
- ⊕ EXTRACTION WELL LOCATION

ANALYTE	BG (mg/L)	MCL (mg/L)	TAP WATER PRG (mg/L)
ARSENIC	0.081	0.01	4.5E-5

RESULTS SHOWN IN GREEN EXCEED TAP WATER PRG.

RESULTS SHOWN IN BLUE EXCEED MCL AND TAP WATER PRG.

RESULTS SHOWN IN RED EXCEED BG, MCL AND TAP WATER PRG.

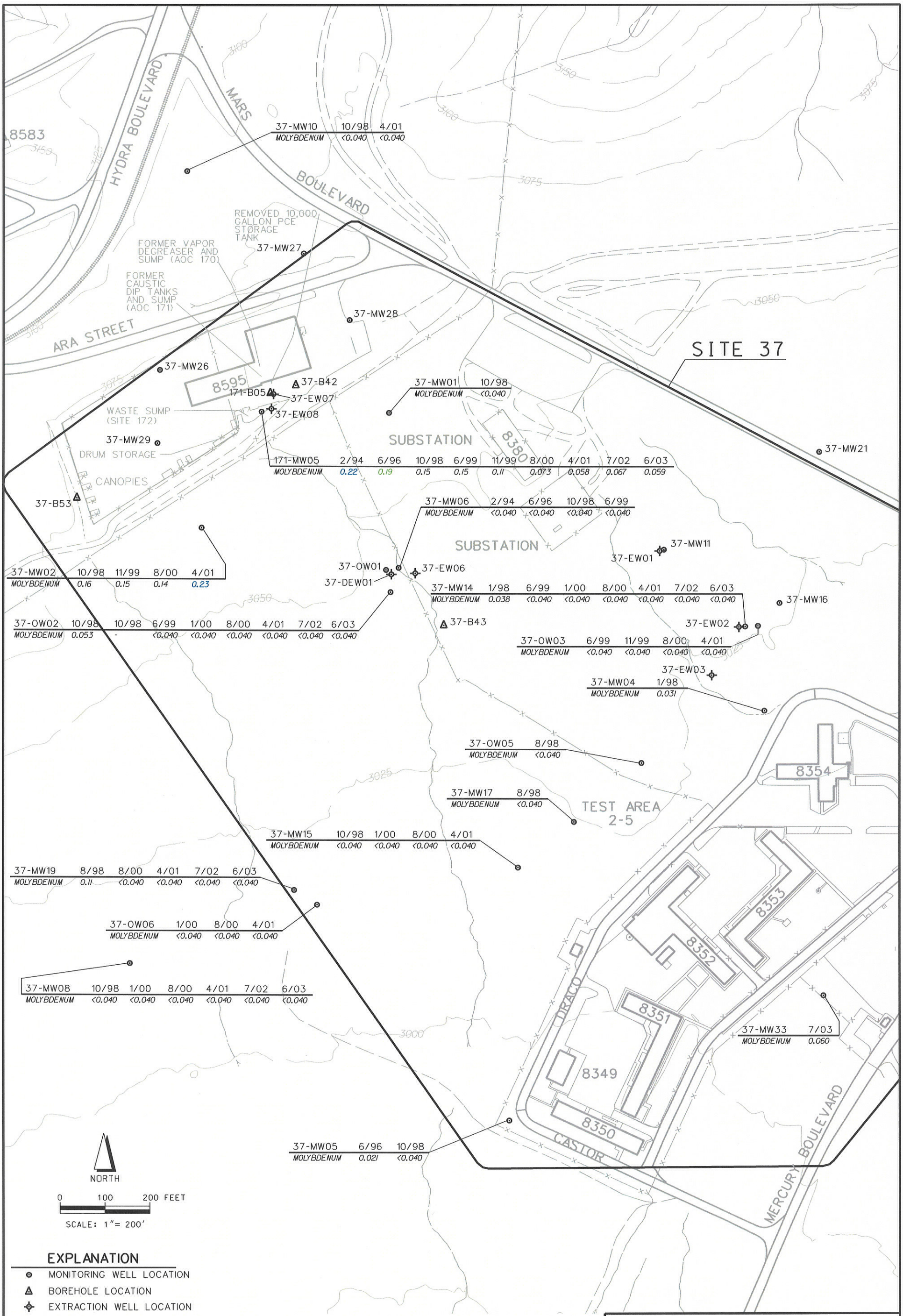
AFRL	AIR FORCE RESEARCH LABORATORY
AOC	AREA OF CONCERN
BG	AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
HHRA	HUMAN HEALTH RISK ASSESSMENT
MCL	MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L	MILLIGRAMS PER LITER
PCE	TETRACHLOROETHENE
PRG	PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA	UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 37
Distribution of Arsenic in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure C-2
Project No. 67861		

EDWARDS\ 67861\B5936FGA.A01



EXPLANATION

- MONITORING WELL LOCATION
- BOREHOLE LOCATION
- EXTRACTION WELL LOCATION

ANALYTE	BG (mg/L)	MCL (mg/L)	TAP WATER PRG (mg/L)
MOLYBDENUM	0.19	NONE	0.18

RESULTS SHOWN IN GREEN EXCEED TAP WATER PRG.

RESULTS SHOWN IN BLUE EXCEED BG AND TAP WATER PRG.

AFRL AIR FORCE RESEARCH LABORATORY
AOC AREA OF CONCERN
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
PCE TETRACHLOROETHENE
PRG PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 37
Distribution of Molybdenum in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure C-3
Project No. 67861		

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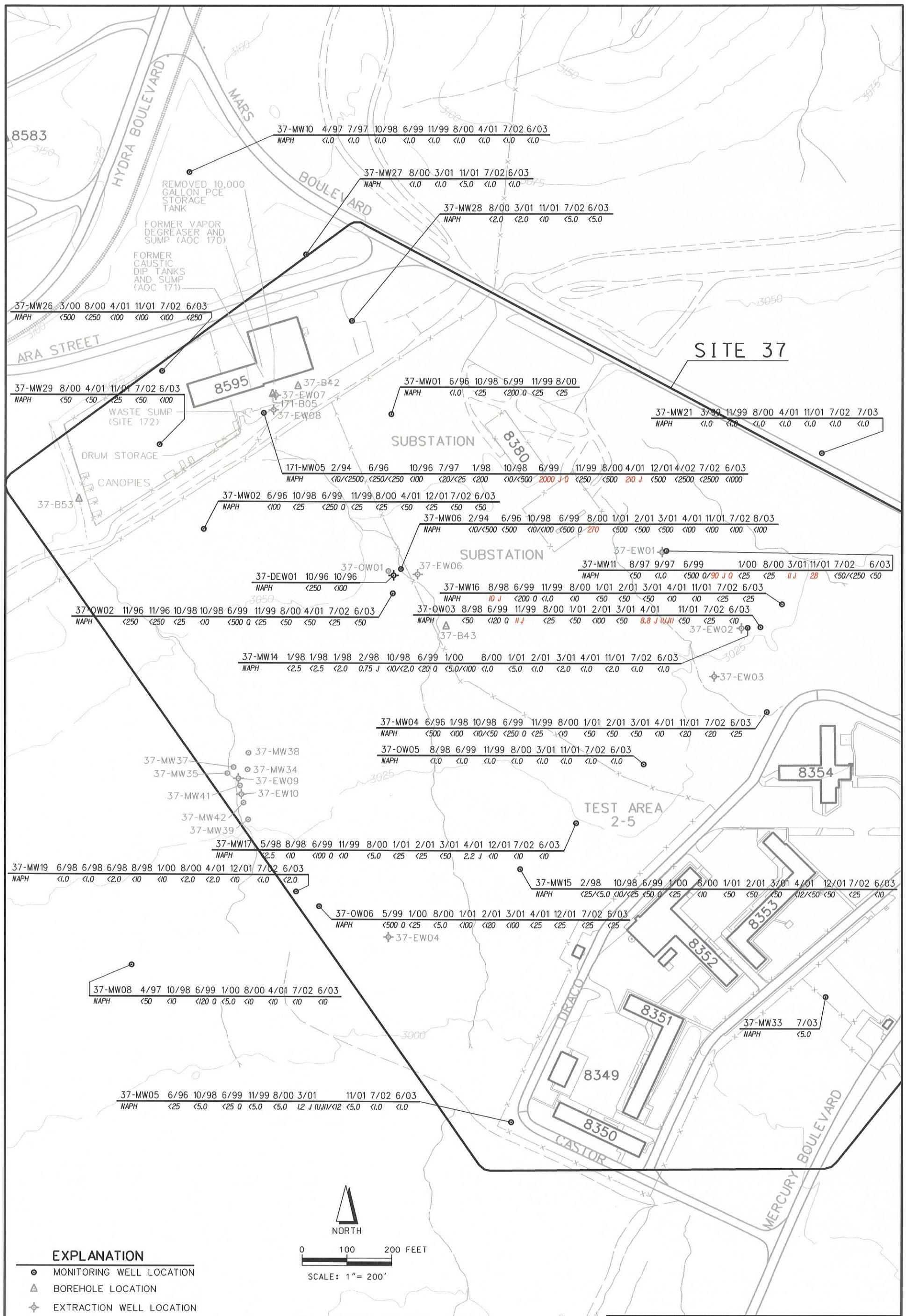


EXPLANATION

- ⊙ MONITORING WELL LOCATION
- △ BOREHOLE LOCATION
- ⊕ EXTRACTION WELL LOCATION

ANALYTE	BG (µg/L)	NL (µg/L)	TAP WATER PRG (µg/L)
NAPH	0	17	6.2

RESULTS SHOWN IN GREEN EXCEED TAP WATER PRG AND BG.

RESULTS SHOWN IN RED EXCEED BG, MCL AND TAP WATER PRG.

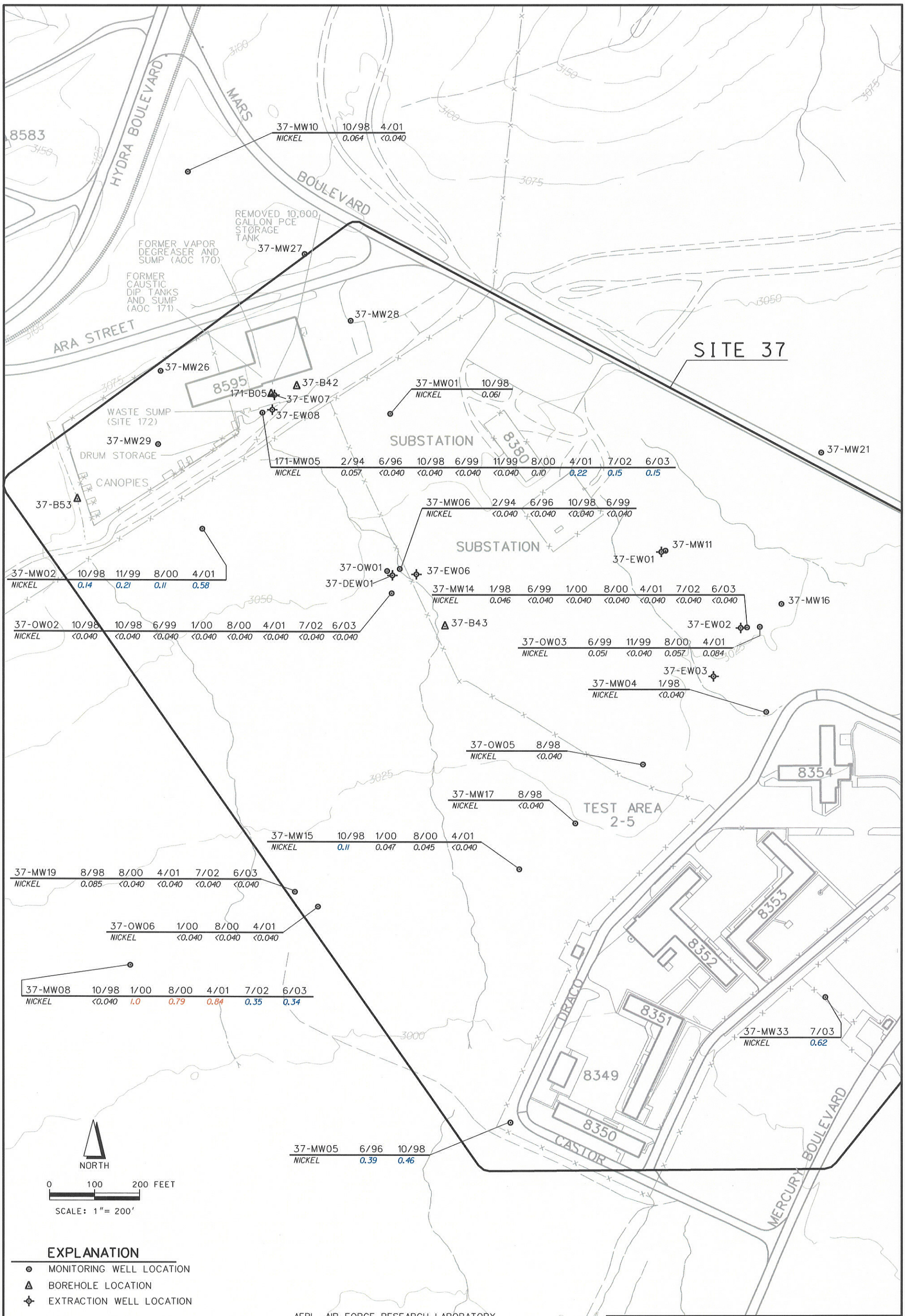
AFRL AIR FORCE RESEARCH LABORATORY
AOC AREA OF CONCERN
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
HHRA HUMAN HEALTH RISK ASSESSMENT
NL NOTIFICATION LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
NAPH NAPHTHALENE
PCE TETRACHLOROETHENE
PRG PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 37
Distribution of Naphthalene in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		C-4

EDWARDS\ 67861\B6406FGA.A01



EXPLANATION

- MONITORING WELL LOCATION
- BOREHOLE LOCATION
- EXTRACTION WELL LOCATION

ANALYTE	BG (mg/L)	MCL (mg/L)	TAP WATER PRG (mg/L)
NICKEL	0.65	0.1	0.73

RESULTS SHOWN IN BLUE EXCEED MCL.

RESULTS SHOWN IN RED EXCEED BG, MCL, AND TAP WATER PRG.

AFRL AIR FORCE RESEARCH LABORATORY
AOC AREA OF CONCERN
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
PCE TETRACHLOROETHENE
PRG PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 37
Distribution of Nickel in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure C-5
Project No. 67861		

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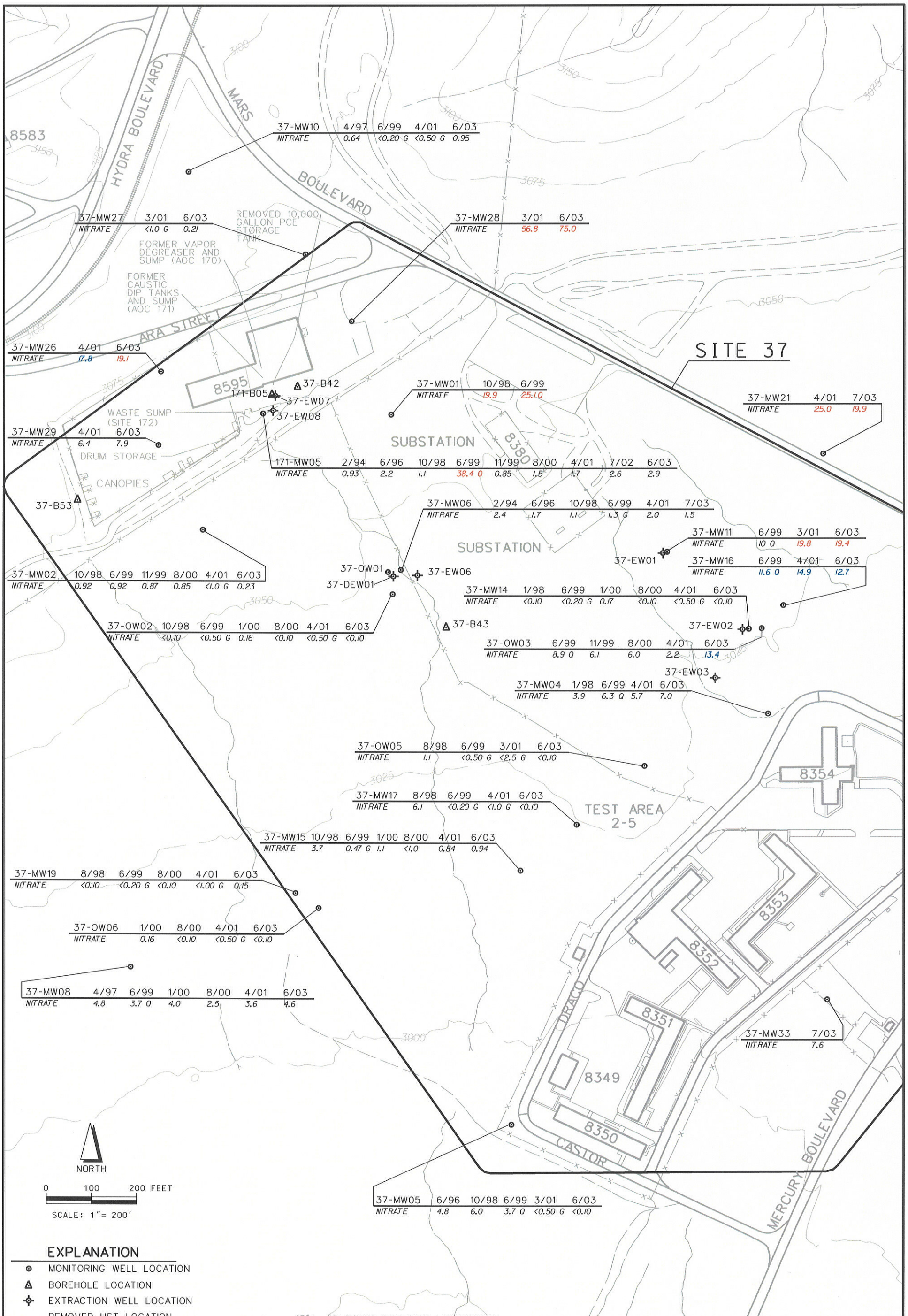

EXPLANATION

- ⊙ MONITORING WELL LOCATION
- ▲ BOREHOLE LOCATION
- ⊕ EXTRACTION WELL LOCATION
- REMOVED UST LOCATION

ANALYTE	BG (mg/L)	MCL (mg/L)	TAP WATER PRG (mg/L)
NITRATE	18.2	10	10

RESULTS SHOWN IN BLUE EXCEED MCL AND TAP WATER PRG.

RESULTS SHOWN IN RED EXCEED BG, MCL, AND TAP WATER PRG.

AFRL AIR FORCE RESEARCH LABORATORY
AOC AREA OF CONCERN
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
PCE TETRACHLOROETHENE
PRG PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 37
Distribution of Nitrate in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure C-6
Project No. 67861		

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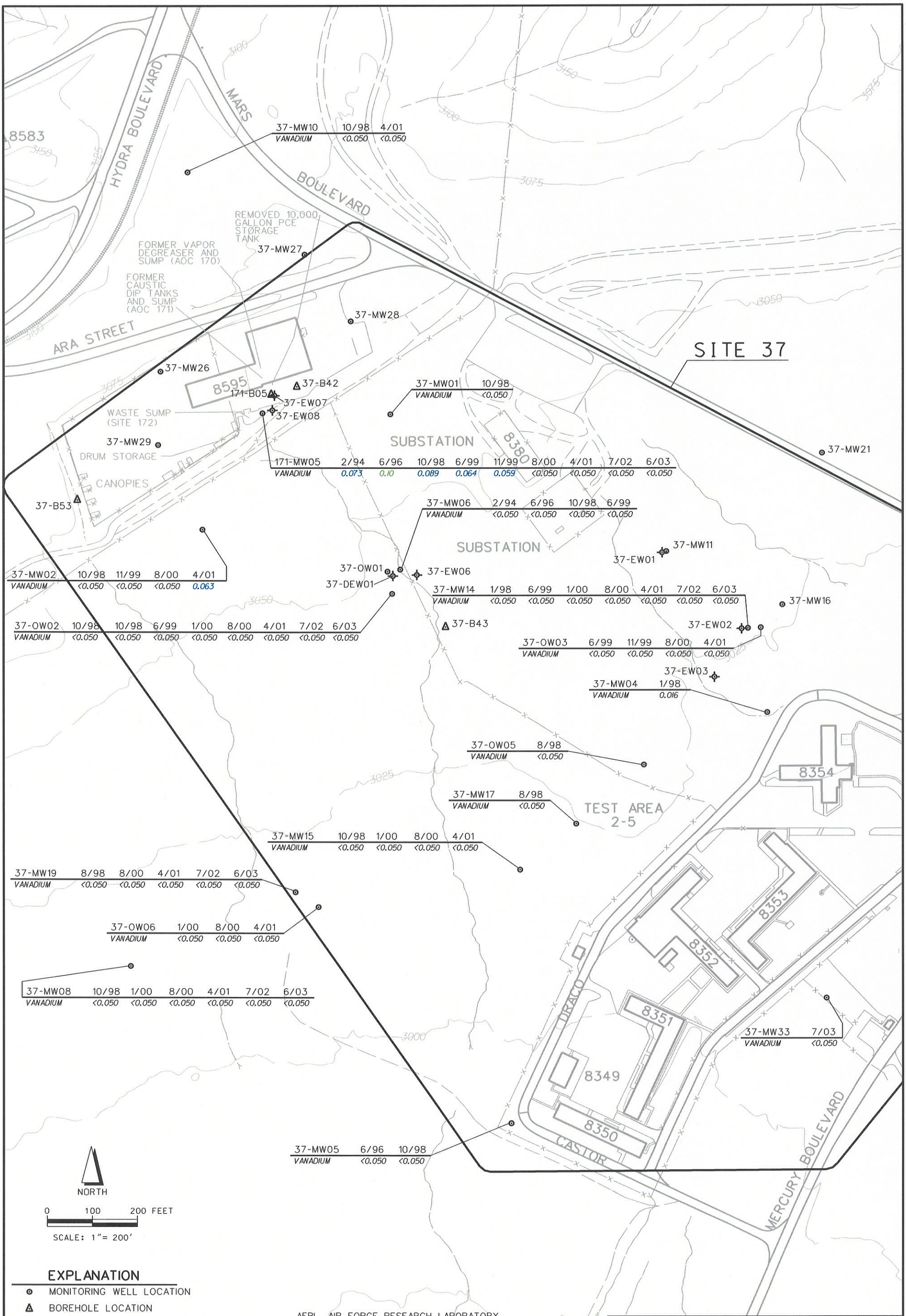

EXPLANATION

- MONITORING WELL LOCATION
- BOREHOLE LOCATION
- EXTRACTION WELL LOCATION

ANALYTE	NL (mg/L)	BG (mg/L)	TAP WATER PRG (mg/L)
VANADIUM	0.05	0.090	0.036

RESULTS SHOWN IN BLUE EXCEED NL.

RESULTS SHOWN IN GREEN EXCEED NL AND BG.

AFRL AIR FORCE RESEARCH LABORATORY
AOC AREA OF CONCERN
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
HHRA HUMAN HEALTH RISK ASSESSMENT
mg/L MILLIGRAMS PER LITER
NL NOTIFICATION LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
PCE TETRACHLOROETHENE
PRG PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 37
Distribution of Vanadium in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure C-7
Project No. 67861		

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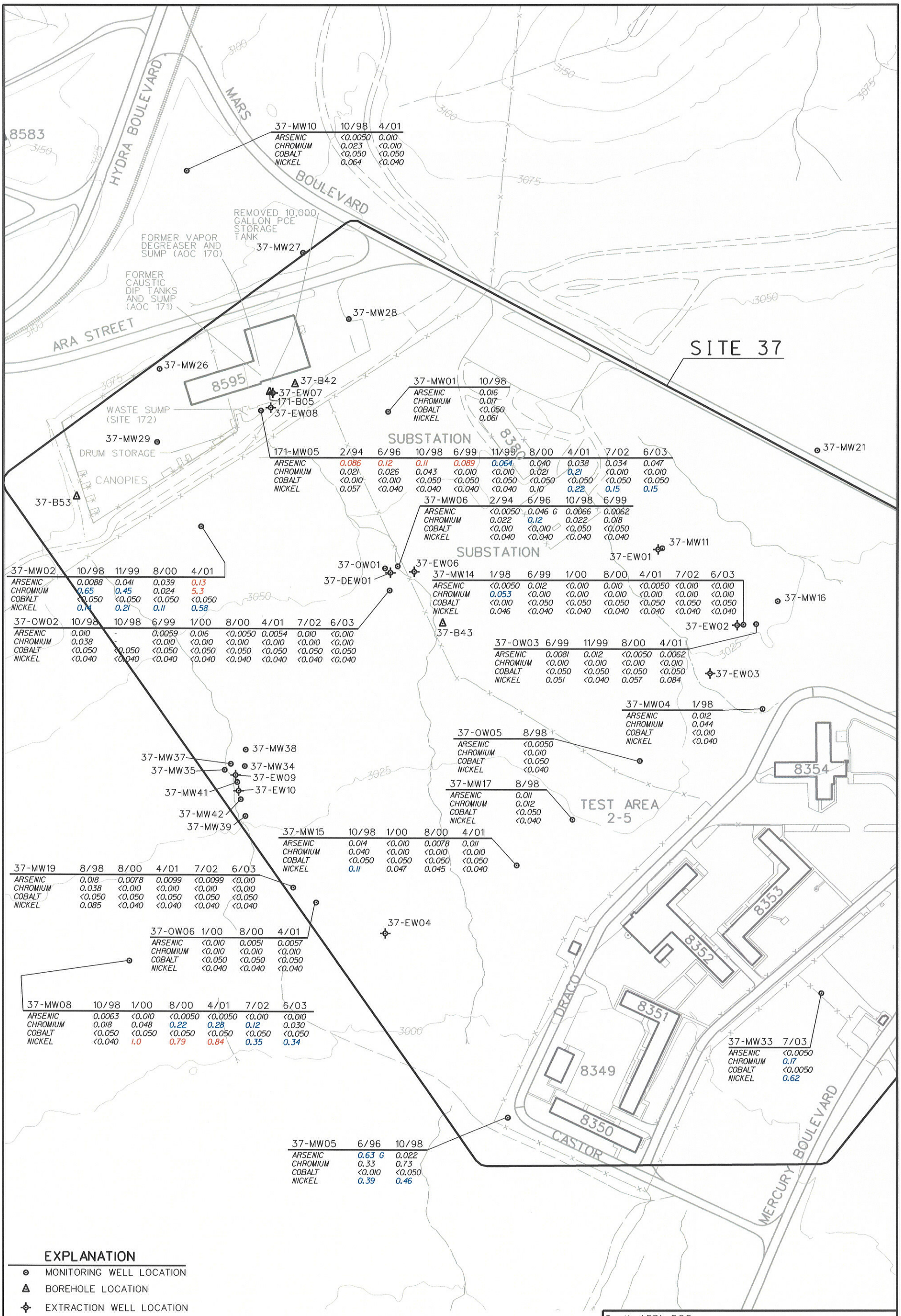

37-MW10	10/98	4/01
ARSENIC	<0.0050	0.010
CHROMIUM	0.023	<0.010
COBALT	<0.050	<0.050
NICKEL	0.064	<0.040

37-MW01	10/98
ARSENIC	0.016
CHROMIUM	0.017
COBALT	<0.050
NICKEL	0.061

171-MW05	2/94	6/96	10/98	6/99	11/99	8/00	4/01	7/02	6/03
ARSENIC	0.086	0.12	0.11	0.089	0.064	0.040	0.038	0.034	0.047
CHROMIUM	0.021	0.026	0.043	<0.010	<0.010	0.021	0.21	<0.010	<0.010
COBALT	<0.010	<0.010	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
NICKEL	0.057	<0.040	<0.040	<0.040	<0.040	0.10	0.22	0.15	0.15

37-MW06	2/94	6/96	10/98	6/99
ARSENIC	<0.0050	0.046 G	0.0066	0.0062
CHROMIUM	0.022	0.12	0.022	0.018
COBALT	<0.010	<0.010	<0.050	<0.050
NICKEL	<0.040	<0.040	<0.040	<0.040

37-MW02	10/98	11/99	8/00	4/01
ARSENIC	0.0088	0.041	0.039	0.13
CHROMIUM	0.65	0.45	0.024	5.3
COBALT	<0.050	<0.050	<0.050	<0.050
NICKEL	0.14	0.21	0.11	0.58

37-OW02	10/98	10/98	6/99	1/00	8/00	4/01	7/02	6/03
ARSENIC	0.010	-	0.0059	0.016	<0.0050	0.0054	0.010	<0.010
CHROMIUM	0.038	-	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
COBALT	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
NICKEL	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040

37-MW14	1/98	6/99	1/00	8/00	4/01	7/02	6/03
ARSENIC	<0.0050	0.012	<0.010	0.010	<0.0050	<0.010	<0.010
CHROMIUM	0.053	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
COBALT	<0.010	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
NICKEL	0.046	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040

37-OW03	6/99	11/99	8/00	4/01
ARSENIC	0.0081	0.012	<0.0050	0.0062
CHROMIUM	<0.010	<0.010	<0.010	<0.010
COBALT	<0.050	<0.050	<0.050	<0.050
NICKEL	0.051	<0.040	0.057	0.084

37-MW04	1/98
ARSENIC	0.012
CHROMIUM	0.044
COBALT	<0.010
NICKEL	<0.040

37-OW05	8/98
ARSENIC	<0.0050
CHROMIUM	<0.010
COBALT	<0.050
NICKEL	<0.040

37-MW17	8/98
ARSENIC	0.011
CHROMIUM	0.012
COBALT	<0.050
NICKEL	<0.040

37-MW15	10/98	1/00	8/00	4/01
ARSENIC	0.014	<0.010	0.0078	0.011
CHROMIUM	0.040	<0.010	<0.010	<0.010
COBALT	<0.050	<0.050	<0.050	<0.050
NICKEL	0.11	0.047	0.045	<0.040

37-MW19	8/98	8/00	4/01	7/02	6/03
ARSENIC	0.018	0.0078	0.0099	<0.0099	<0.010
CHROMIUM	0.038	<0.010	<0.010	<0.010	<0.010
COBALT	<0.050	<0.050	<0.050	<0.050	<0.050
NICKEL	0.085	<0.040	<0.040	<0.040	<0.040

37-OW06	1/00	8/00	4/01
ARSENIC	<0.010	0.0051	0.0057
CHROMIUM	<0.010	<0.010	<0.010
COBALT	<0.050	<0.050	<0.050
NICKEL	<0.040	<0.040	<0.040

37-MW08	10/98	1/00	8/00	4/01	7/02	6/03
ARSENIC	0.0063	<0.010	<0.0050	<0.0050	<0.010	<0.010
CHROMIUM	0.018	0.048	0.22	0.28	0.12	0.030
COBALT	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
NICKEL	<0.040	1.0	0.79	0.84	0.35	0.34

37-MW33	7/03
ARSENIC	<0.0050
CHROMIUM	0.17
COBALT	<0.0050
NICKEL	0.62

37-MW05	6/96	10/98
ARSENIC	0.63 G	0.022
CHROMIUM	0.33	0.73
COBALT	<0.010	<0.050
NICKEL	0.39	0.46

EXPLANATION

- MONITORING WELL LOCATION
- BOREHOLE LOCATION
- EXTRACTION WELL LOCATION

ANALYTE	BG (mg/L)	MCL (mg/L)
ARSENIC	0.081	0.05
CHROMIUM	2.7	0.05
COBALT	0.010	NONE
NICKEL	0.65	0.1

RESULTS SHOWN IN BLUE EXCEED MCL.

RESULTS SHOWN IN RED EXCEED BG AND MCL.

AFRL AIR FORCE RESEARCH LABORATORY
AOC AREA OF CONCERN
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
MCL MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
PCE TETRACHLOROETHENE

NORTH

0 100 200 FEET

SCALE: 1"= 200'

South AFRL ROD

Site 37
Distribution of Inorganic Analytes in Groundwater Showing Risk in PERA

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure C-8
Project No. 67861		

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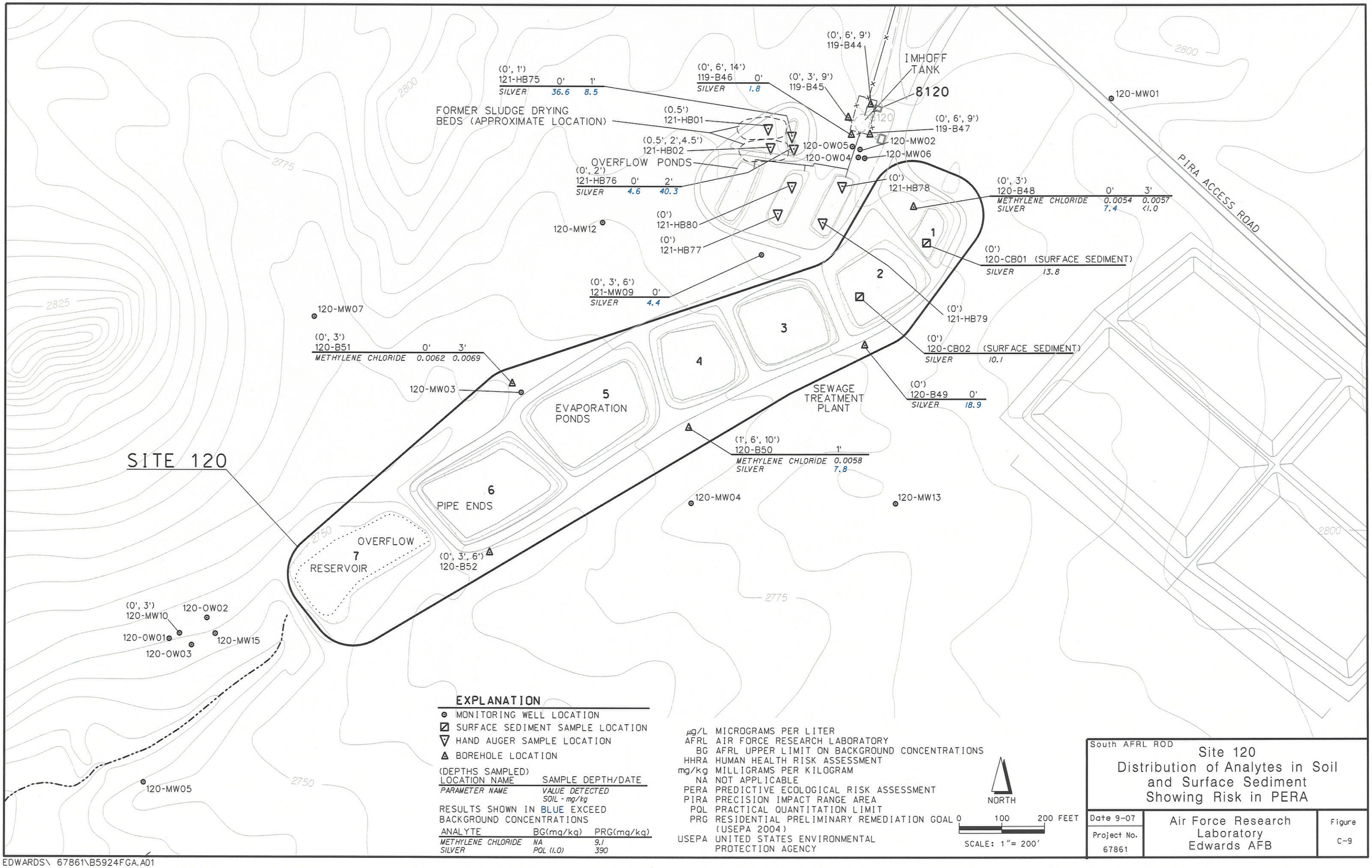

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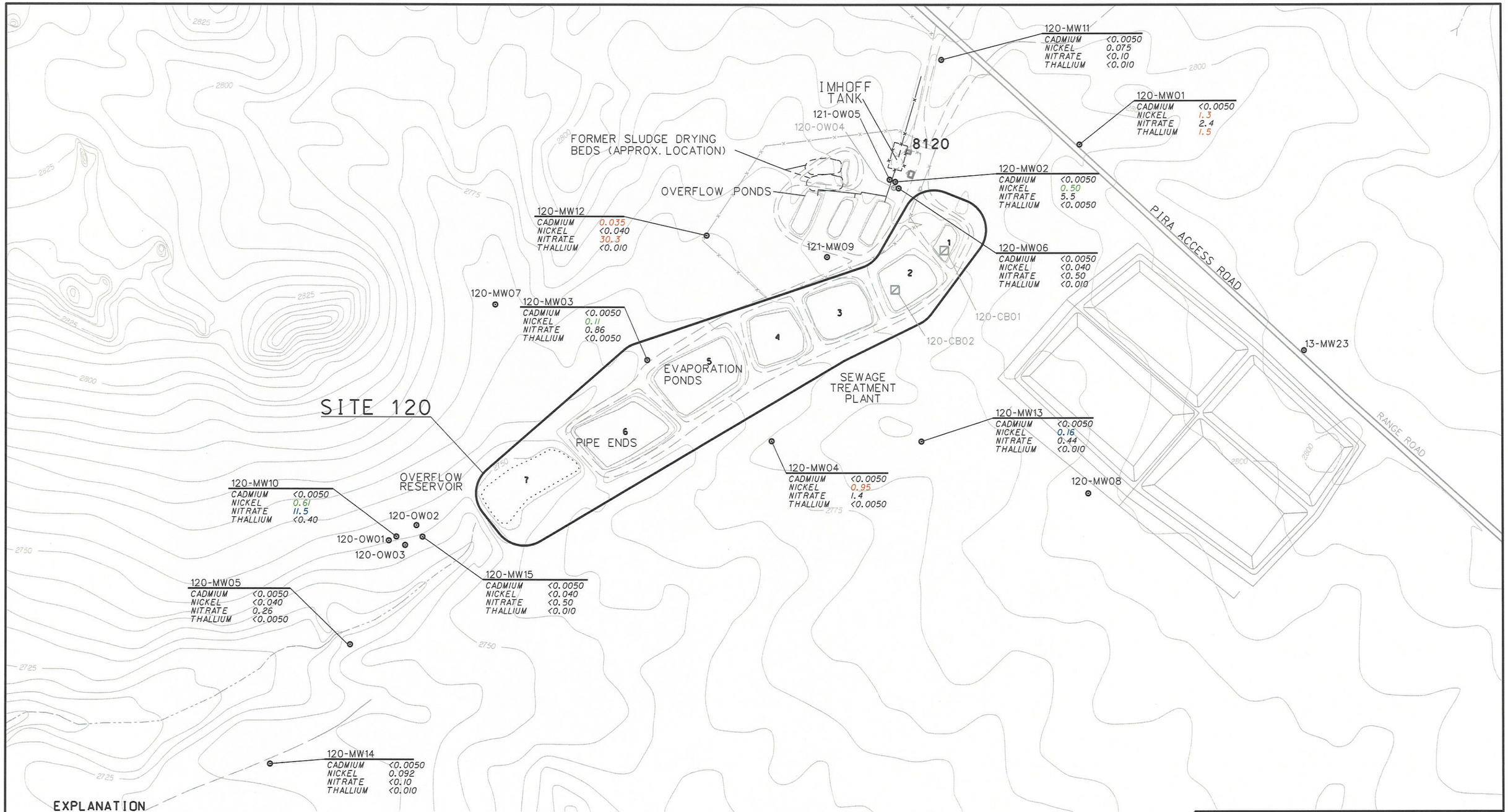


EXPLANATION

- ⊙ MONITORING WELL LOCATION
- ▨ SURFACE WATER SAMPLE LOCATION

AFRL AIR FORCE RESEARCH LABORATORY
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVELS (CALIFORNIA DEPTARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
PERA PREDICTIVE ECOLOGICAL RISK ASSESSMENT
PIRA PRECISION IMPACT RANGE AREA
PRG PRELIMINARY REMEDIATION GOALS (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

(1) RISK IDENTIFIED IN PERA
(2) RISK IDENTIFIED IN HHRA

RESULTS SHOWN IN GREEN EXCEED MCL.
RESULTS SHOWN IN BLUE EXCEED MCL AND TAP WATER PRG.
RESULTS SHOWN IN RED EXCEED BG, MCL, AND TAP WATER PRG.

LOCATION NAME
PARAMETER NAME VALUE DETECTED (mg/L)

ANALYTES	BG(mg/L)	MCL(mg/L)	TAP WATER PRG(mg/L)
CADMIUM(2)	0.0050	0.005	0.018
NICKEL(2)	0.65	0.1	0.73
NITRATE(2)	18.2	10	10
THALLIUM(1,2)	0.0050	0.002	0.0024

NORTH

0 150 300 FEET

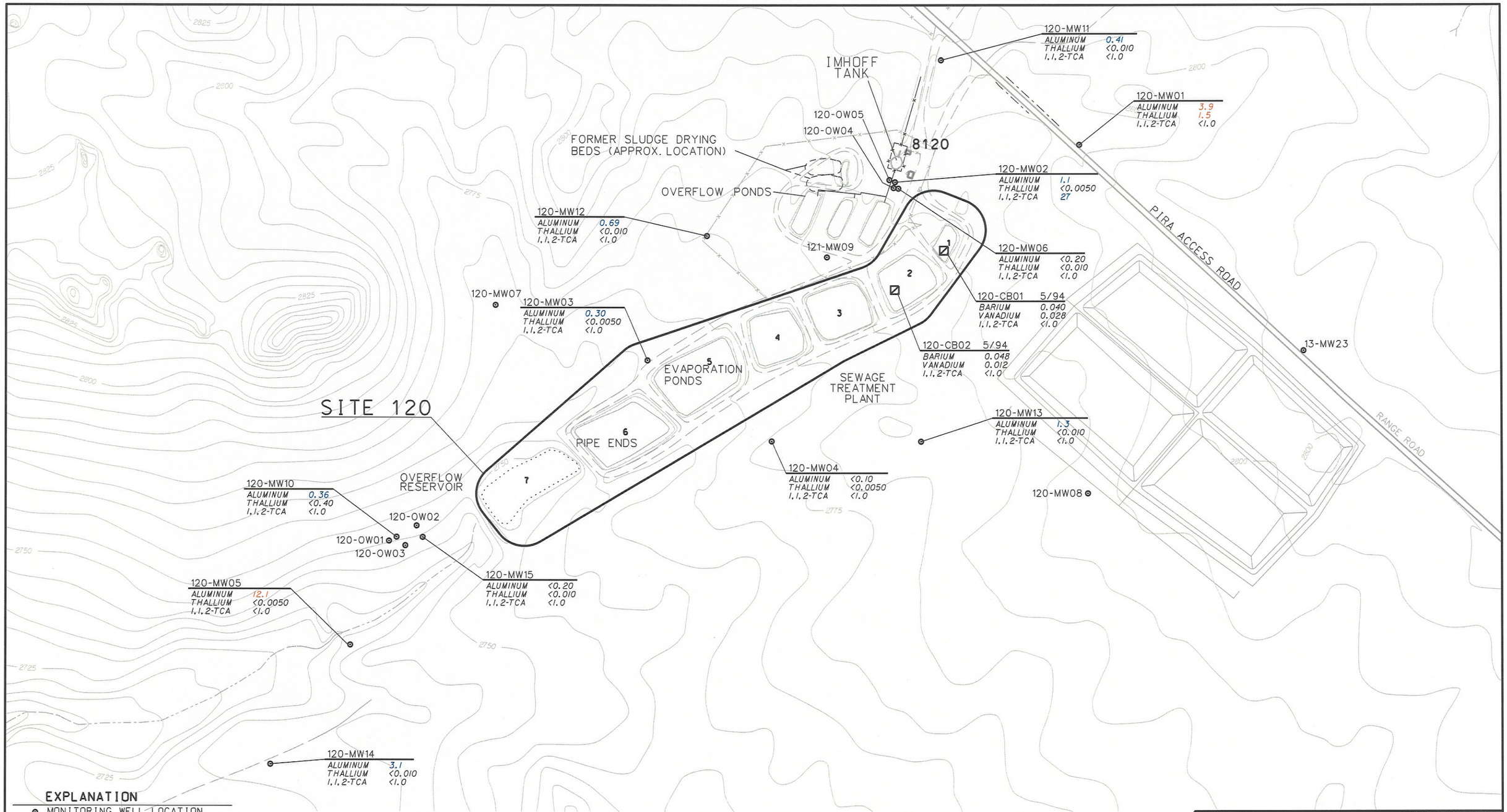
SCALE: 1"= 300'

South AFRL ROD

Site 120
Distribution of Inorganic Analytes in Groundwater Showing Hazard in HHRA

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		C-10

EDWARDS\ 67861\B5932FGA.A01



EXPLANATION

- ⊙ MONITORING WELL LOCATION
- ▨ SURFACE WATER SAMPLE LOCATION

μg/L MICROGRAMS PER LITER
AFRL AIR FORCE RESEARCH LABORATORY
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVELS (CALIFORNIA DEPTARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
NA NOT APPLICABLE
PERA PREDICTIVE ECOLOGICAL RISK ASSESSMENT
PIRA PRECISION IMPACT RANGE AREA
TCA TRICHLOROETHANE

(a) SECONDARY MCL

RESULTS SHOWN IN GREEN EXCEED BG.
RESULTS SHOWN IN BLUE EXCEED MCL.
RESULTS SHOWN IN RED EXCEED BG AND MCL.

LOCATION NAME
PARAMETER NAME VALUE DETECTED (mg/L)

ANALYTES	BG(mg/L)	MCL(mg/L)
ALUMINUM	3.7	0.2[a]
BARIUM	0.11	1.0
THALLIUM	0.0050	0.002
VANADIUM	0.090	NONE
1,1,2-TCA	NA	5 (μg/L)

NORTH

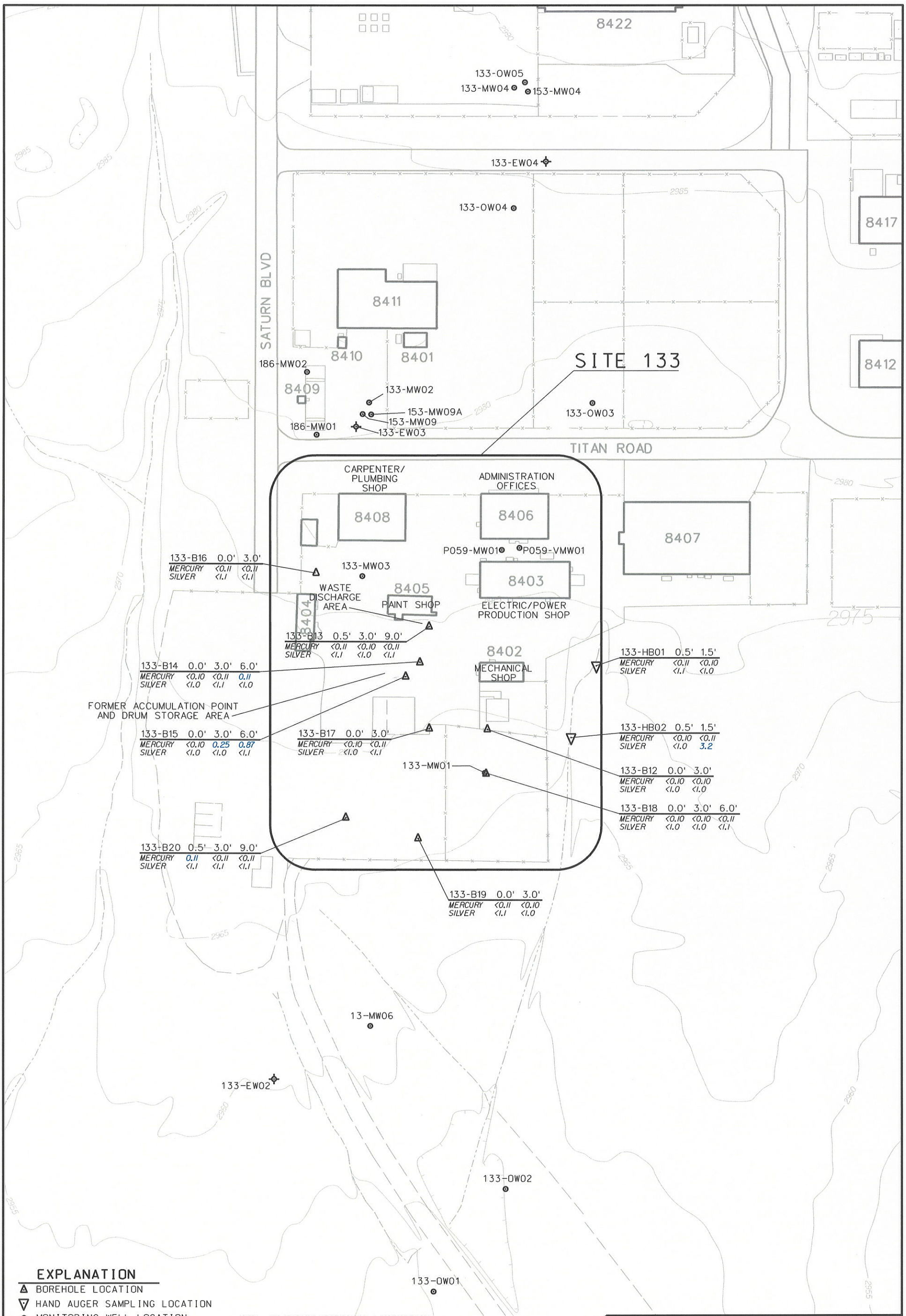
0 150 300 FEET
SCALE: 1"= 300'

South AFRL ROD

Site 120
Distribution of Inorganic Analytes and 1,1,2-TCA in Groundwater and Surface Water Showing Risk in PERA

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure C-11
Project No. 67861		

EDWARDS\ 67861\B6041FGA.A01



EXPLANATION

- ▲ BOREHOLE LOCATION
- ▽ HAND AUGER SAMPLING LOCATION
- ⊙ MONITORING WELL LOCATION
- ⊕ EXTRACTION WELL LOCATION

LOCATION NAME	SAMPLE DEPTH
ANALYTE	*VALUE DETECTED (mg/kg)*

RESULTS SHOWN IN BLUE EXCEED BG.

ANALYTE (1)	BG(mg/kg)	PRG(mg/kg)
MERCURY	*PQL (0.10)*	*23*
SILVER	*PQL (1.0)*	*390*

AFRL AIR FORCE RESEARCH LABORATORY
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATION
HHRA HUMAN HEALTH RISK ASSESSMENT
mg/kg MILLIGRAMS PER KILOGRAM
PERA PREDICTIVE ECOLOGICAL RISK ASSESSMENT
PQL PRACTICAL QUANTITATION LIMIT
PRG RESIDENTIAL PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
(1) RISK IDENTIFIED IN PERA

NORTH

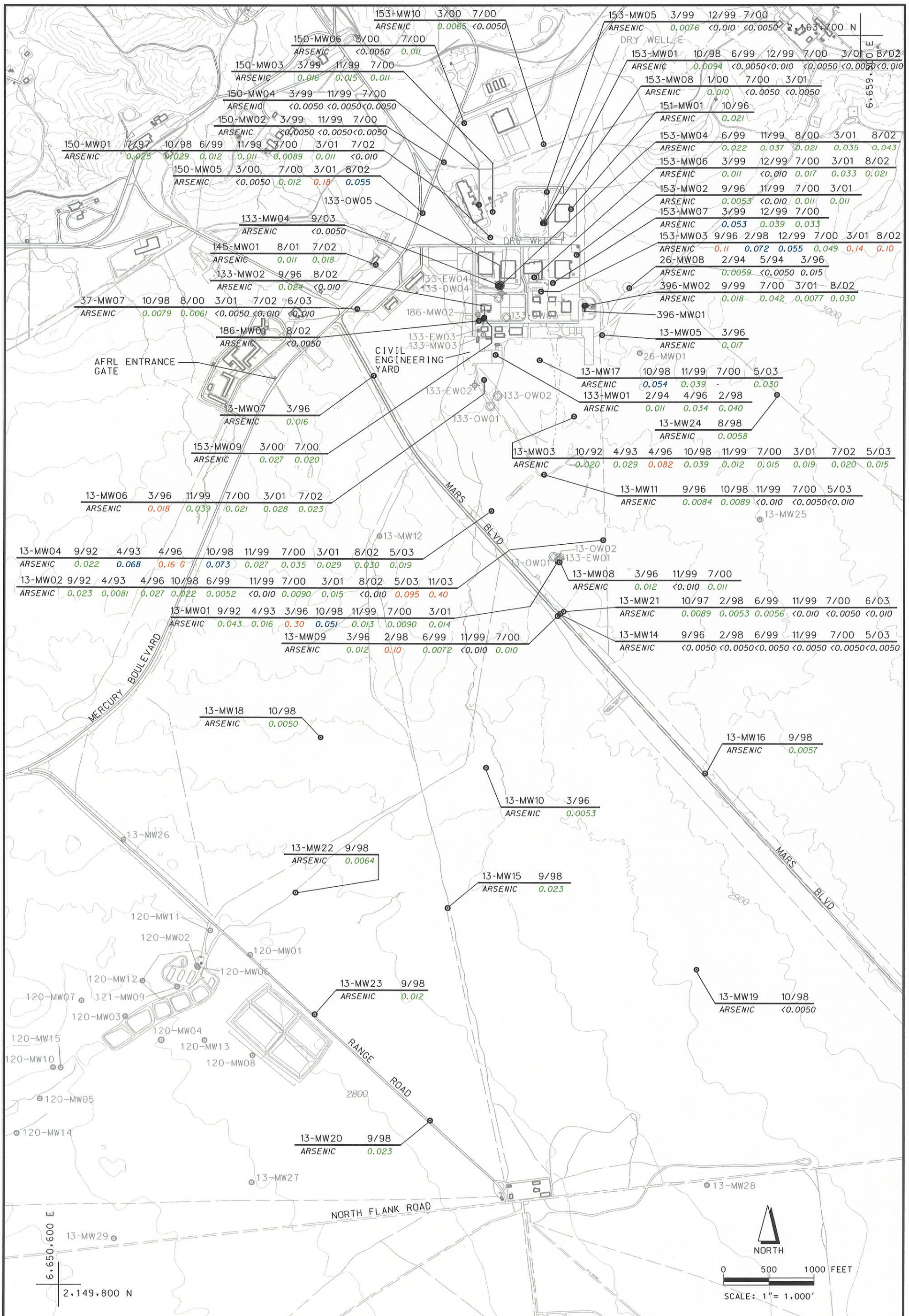
0 50 100 FEET
SCALE: 1"= 100'

South AFRL ROD

Site 133
Distribution of Inorganic Analytes in Soil Showing Risk in PERA

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure C-12
Project No. 67861		

EDWARDS\ 67861\B5930FGA.A01



EXPLANATION

- MONITORING WELL LOCATION
- EXTRACTION WELL LOCATION
- OBSERVATION WELL LOCATION
- DRY WELL LOCATION

ANALYTE	BG (mg/L)	MCL (mg/L)	TAP WATER PRG (mg/L)
ARSENIC	0.081	0.05	4.5E-5

RESULTS SHOWN IN GREEN EXCEED TAP WATER PRG.

RESULTS SHOWN IN BLUE EXCEED MCL AND TAP WATER PRG.

RESULTS SHOWN IN RED EXCEED BG, MCL, AND TAP WATER PRG.

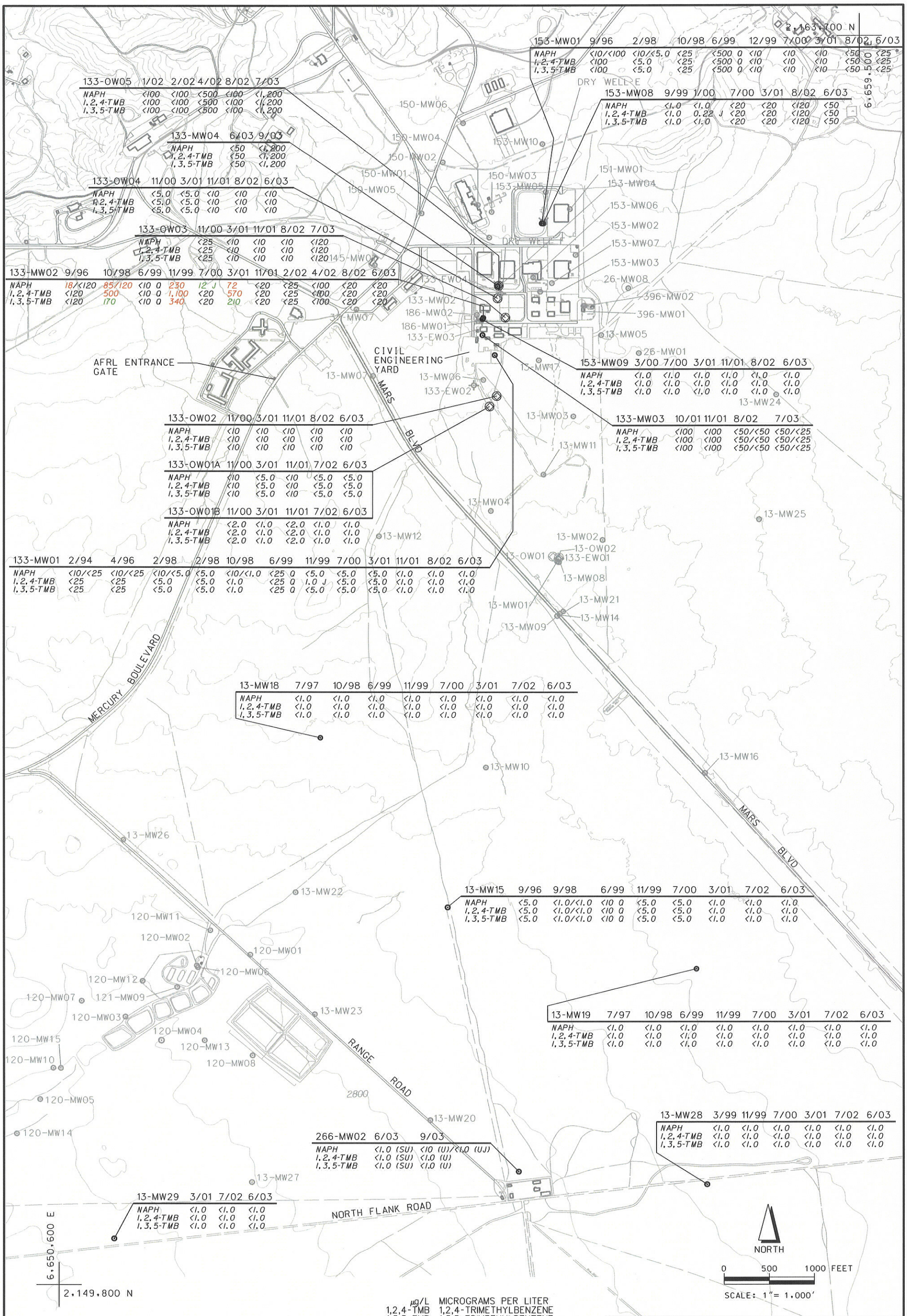
AFRL AIR FORCE RESEARCH LABORATORY
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
BLVD BOULEVARD
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
PRG PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 133 Distribution of Arsenic in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		C-13

EDWARDS\ 67861\B6042FGA.A01



133-OW05	1/02	2/02	4/02	8/02	7/03
NAPH	<100	<100	<500	<100	<1,200
1,2,4-TMB	<100	<100	<500	<100	<1,200
1,3,5-TMB	<100	<100	<500	<100	<1,200

133-MW04	6/03	9/03
NAPH	<50	<1,200
1,2,4-TMB	<50	<1,200
1,3,5-TMB	<50	<1,200

133-OW04	11/00	3/01	11/01	8/02	6/03
NAPH	<5.0	<5.0	<10	<10	<10
1,2,4-TMB	<5.0	<5.0	<10	<10	<10
1,3,5-TMB	<5.0	<5.0	<10	<10	<10

133-OW03	11/00	3/01	11/01	8/02	7/03
NAPH	<25	<10	<10	<10	<120
1,2,4-TMB	<25	<10	<10	<10	<120
1,3,5-TMB	<25	<10	<10	<10	<120

133-MW02	9/96	10/98	6/99	11/99	7/00	3/01	11/01	2/02	4/02	8/02	6/03
NAPH	18/<120	85/120	<10 Q	230	12 J	72	<20	<25	<100	<20	<20
1,2,4-TMB	<120	500	<10 Q	1,100	<20	570	<20	<25	<100	<20	<20
1,3,5-TMB	<120	170	<10 Q	340	<20	210	<20	<25	<100	<20	<20

133-OW02	11/00	3/01	11/01	8/02	6/03
NAPH	<10	<10	<10	<10	<10
1,2,4-TMB	<10	<10	<10	<10	<10
1,3,5-TMB	<10	<10	<10	<10	<10

133-OW01A	11/00	3/01	11/01	7/02	6/03
NAPH	<10	<5.0	<10	<5.0	<5.0
1,2,4-TMB	<10	<5.0	<10	<5.0	<5.0
1,3,5-TMB	<10	<5.0	<10	<5.0	<5.0

133-OW01B	11/00	3/01	11/01	7/02	6/03
NAPH	<2.0	<1.0	<2.0	<1.0	<1.0
1,2,4-TMB	<2.0	<1.0	<2.0	<1.0	<1.0
1,3,5-TMB	<2.0	<1.0	<2.0	<1.0	<1.0

133-MW01	2/94	4/96	2/98	2/98	10/98	6/99	11/99	7/00	3/01	11/01	8/02	6/03
NAPH	<10/<25	<10/<25	<10/<5.0	<5.0	<10/<1.0	<25 Q	<5.0	<5.0	<5.0	<1.0	<1.0	<1.0
1,2,4-TMB	<25	<25	<5.0	<5.0	<1.0	<25 Q	1.0 J	<5.0	<5.0	<1.0	<1.0	<1.0
1,3,5-TMB	<25	<25	<5.0	<5.0	<1.0	<25 Q	<5.0	<5.0	<5.0	<1.0	<1.0	<1.0

153-MW01	9/96	2/98	10/98	6/99	12/99	7/00	3/01	8/02	6/03
NAPH	<10/<100	<10/<5.0	<25	<500 Q	<10	<10	<10	<50	<25
1,2,4-TMB	<100	<5.0	<25	<500 Q	<10	<10	<10	<50	<25
1,3,5-TMB	<100	<5.0	<25	<500 Q	<10	<10	<10	<50	<25

153-MW08	9/99	1/00	7/00	3/01	8/02	6/03
NAPH	<1.0	<1.0	<20	<20	<120	<50
1,2,4-TMB	<1.0	0.22 J	<20	<20	<120	<50
1,3,5-TMB	<1.0	<1.0	<20	<20	<120	<50

153-MW09	3/00	7/00	3/01	11/01	8/02	6/03
NAPH	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2,4-TMB	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,3,5-TMB	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

133-MW03	10/01	11/01	8/02	7/03
NAPH	<100	<100	<50/<50	<50/<25
1,2,4-TMB	<100	<100	<50/<50	<50/<25
1,3,5-TMB	<100	<100	<50/<50	<50/<25

13-MW18	7/97	10/98	6/99	11/99	7/00	3/01	7/02	6/03
NAPH	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2,4-TMB	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,3,5-TMB	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

13-MW15	9/96	9/98	6/99	11/99	7/00	3/01	7/02	6/03
NAPH	<5.0	<1.0/<1.0	<10 Q	<5.0	<5.0	<1.0	<1.0	<1.0
1,2,4-TMB	<5.0	<1.0/<1.0	<10 Q	<5.0	<5.0	<1.0	<1.0	<1.0
1,3,5-TMB	<5.0	<1.0/<1.0	<10 Q	<5.0	<5.0	<1.0	<1.0	<1.0

13-MW19	7/97	10/98	6/99	11/99	7/00	3/01	7/02	6/03
NAPH	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2,4-TMB	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,3,5-TMB	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

266-MW02	6/03	9/03
NAPH	<1.0 (SU)	<10 (U)/<1.0 (UJ)
1,2,4-TMB	<1.0 (SU)	<1.0 (U)
1,3,5-TMB	<1.0 (SU)	<1.0 (U)

13-MW28	3/99	11/99	7/00	3/01	7/02	6/03
NAPH	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,2,4-TMB	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,3,5-TMB	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

13-MW29	3/01	7/02	6/03
NAPH	<1.0	<1.0	<1.0
1,2,4-TMB	<1.0	<1.0	<1.0
1,3,5-TMB	<1.0	<1.0	<1.0

EXPLANATION

- MONITORING WELL LOCATION
- EXTRACTION WELL LOCATION
- OBSERVATION WELL LOCATION
- DRY WELL LOCATION

ANALYTE	BG (µg/L)	NL (µg/L)	TAP WATER PRG (µg/L)
NAPH	0	17	6.2
1,2,4-TMB	0	330	12
1,3,5-TMB	0	330	12

RESULTS SHOWN IN GREEN EXCEED TAP WATER PRG AND BG.

RESULTS SHOWN IN RED EXCEED BG, MCL, AND TAP WATER PRG.

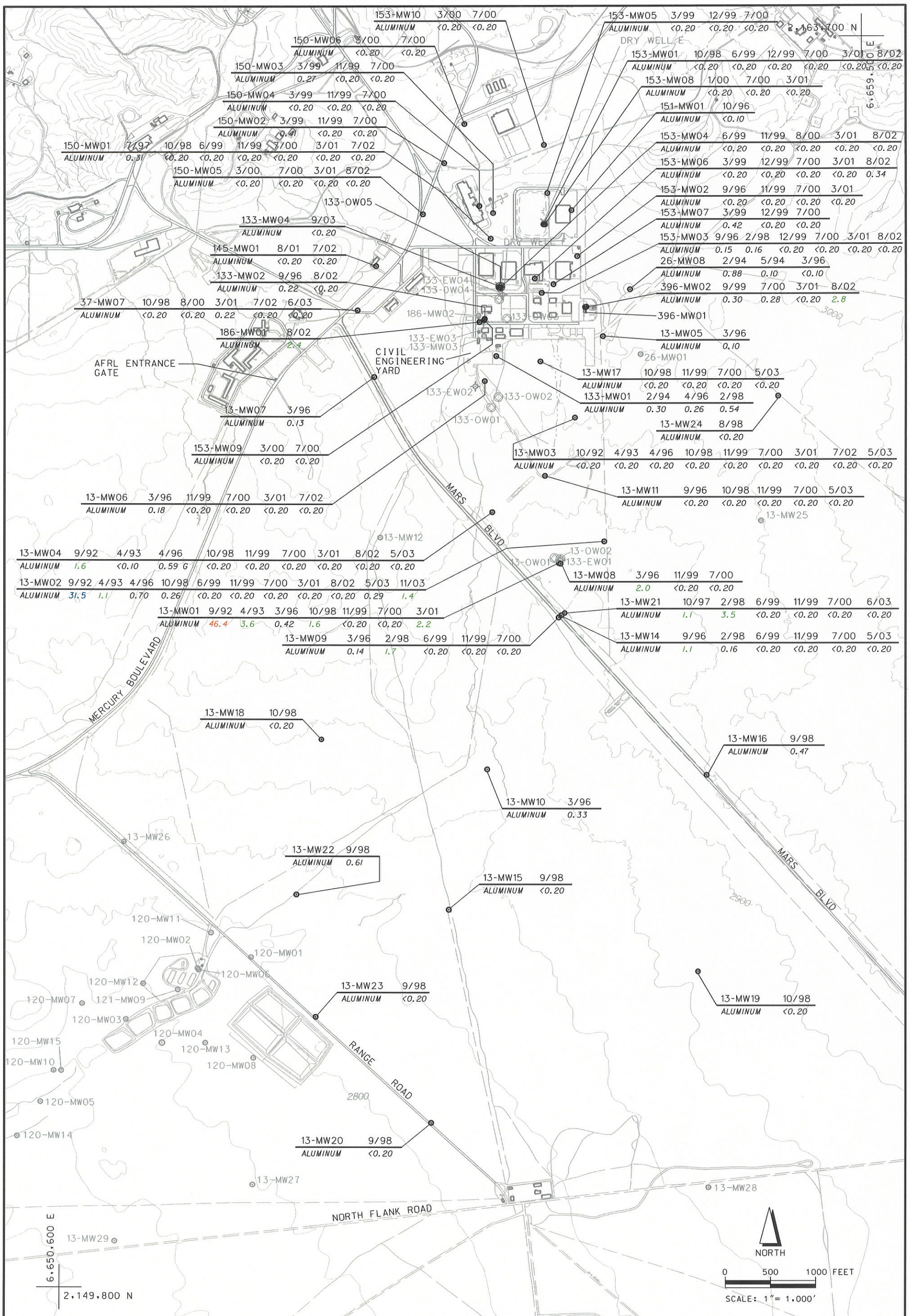
µg/L	MICROGRAMS PER LITER
1,2,4-TMB	1,2,4-TRIMETHYLBENZENE
1,3,5-TMB	1,3,5-TRIMETHYLBENZENE
AFRL	AIR FORCE RESEARCH LABORATORY
BG	AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
BLVD	BOULEVARD
HHRA	HUMAN HEALTH RISK ASSESSMENT
NAPH	NAPHTHALENE
NL	NOTIFICATION LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
PRG	PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA	UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 133 Distribution of Naphthalene, 1,2,4 and 1,3,5-Trimethylbenzene in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		C-14

EDWARDS\ 67861\B6405FGA.A01



EXPLANATION

- MONITORING WELL LOCATION
- EXTRACTION WELL LOCATION
- OBSERVATION WELL LOCATION
- DRY WELL LOCATION

RESULTS SHOWN IN GREEN EXCEED MCL.

RESULTS SHOWN IN BLUE EXCEED BG AND MCL.

RESULTS SHOWN IN RED EXCEED BG, MCL, AND TAP WATER PRG.

ANALYTE	BG (mg/L)	MCL (mg/L)	TAP WATER PRG (mg/L)
ALUMINUM	3.7	1.0	36

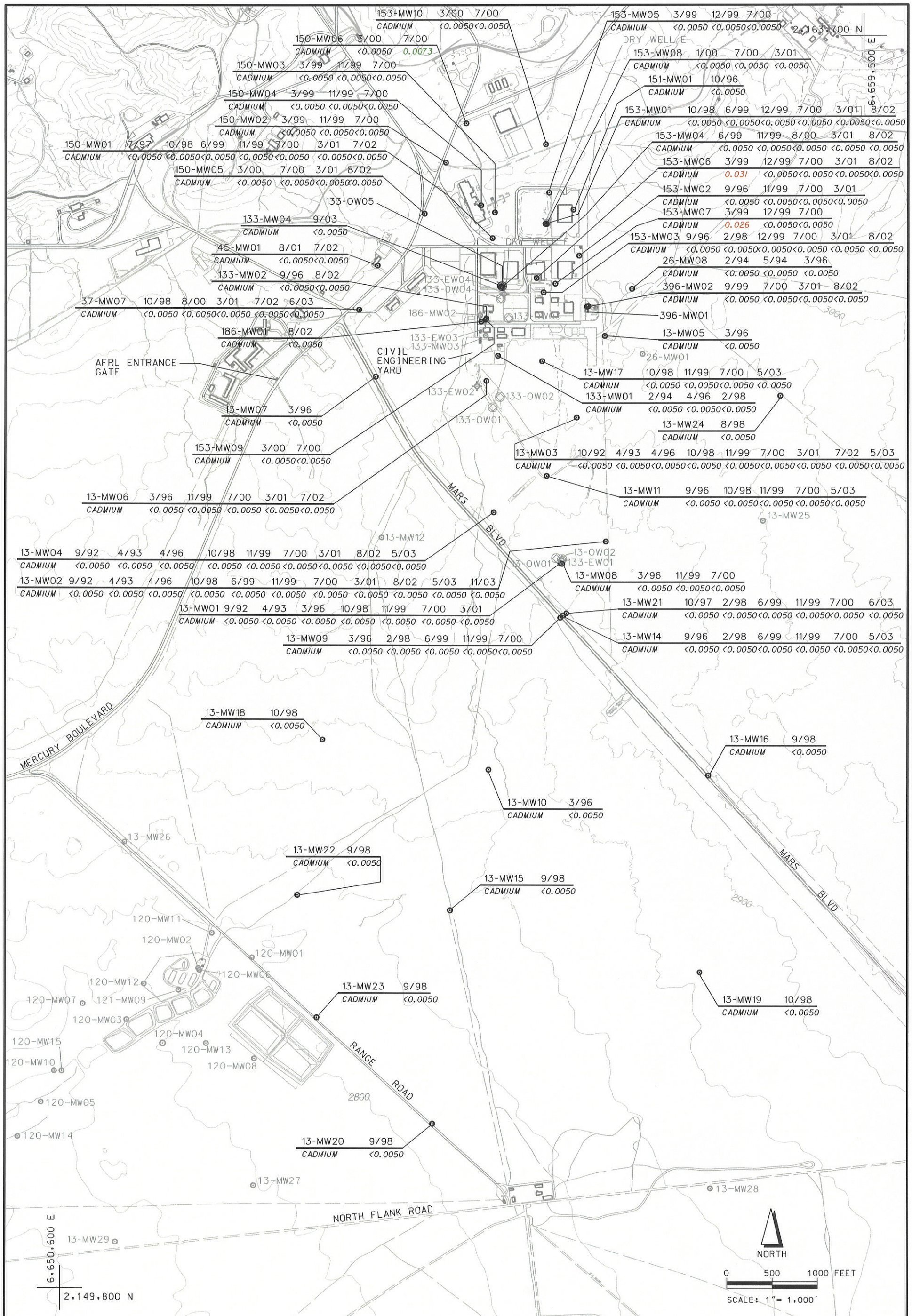
AFRL AIR FORCE RESEARCH LABORATORY
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
BLVD BOULEVARD
DL DETECTION LIMIT
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
PRG PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 133 Distribution of Aluminum in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		C-15

EDWARDS\ 67861\B6043FGA.A01



EXPLANATION

- MONITORING WELL LOCATION
- EXTRACTION WELL LOCATION
- OBSERVATION WELL LOCATION
- DRY WELL LOCATION

RESULTS SHOWN IN GREEN EXCEED BOTH BG AND MCL.

RESULTS SHOWN IN RED EXCEED BOTH BG, MCL, AND TAP WATER PRG.

ANALYTE	BG (mg/L)	MCL (mg/L)	TAP WATER PRG (mg/L)
CADMIUM	0.005 (DL)	0.005	0.018

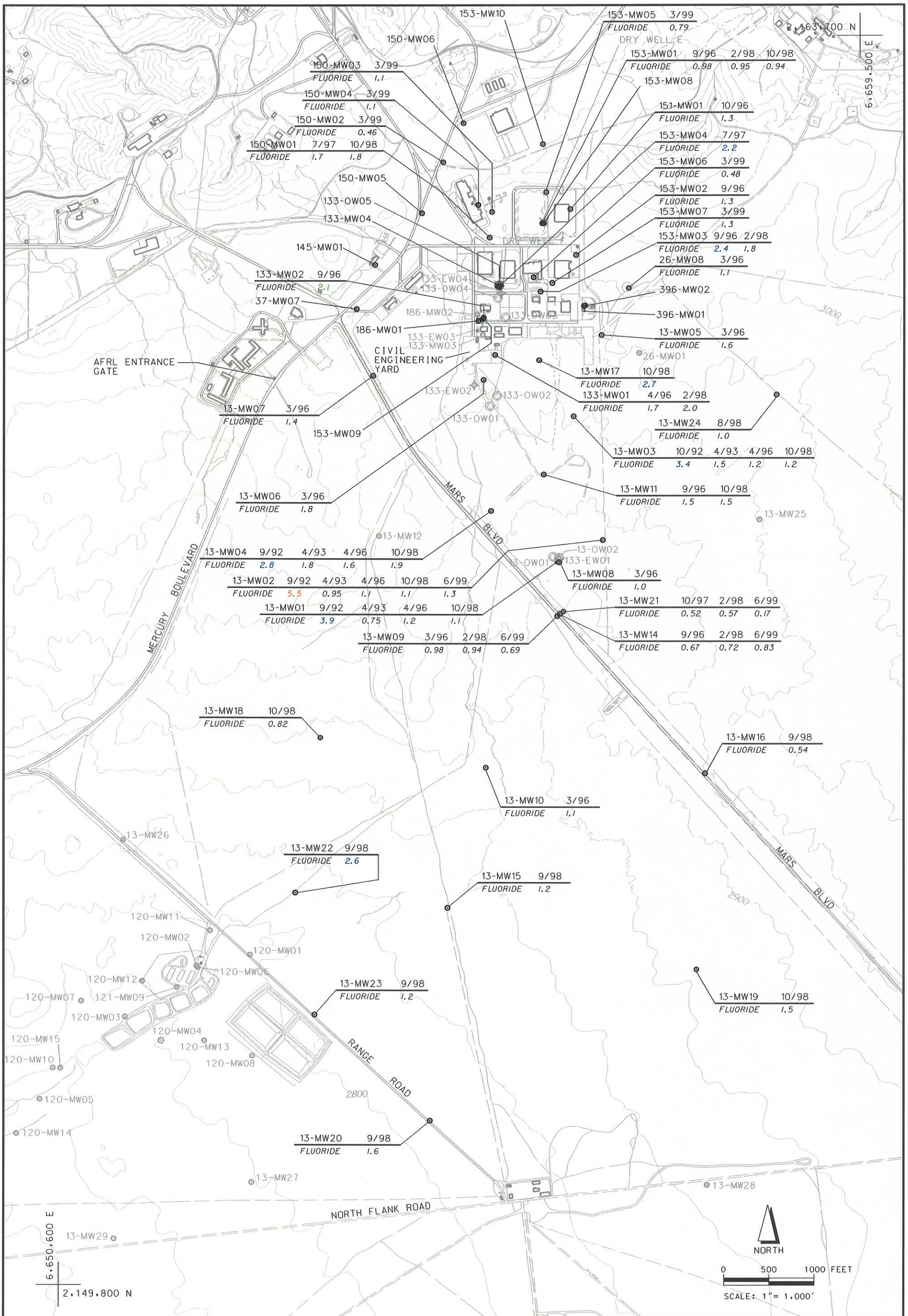
AFRL AIR FORCE RESEARCH LABORATORY
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
BLVD BOULEVARD
DL DETECTION LIMIT
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
PRG PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 133 Distribution of Cadmium in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		C-16

EDWARDS\ 67861\B6044FGA.A01



EXPLANATION

- MONITORING WELL LOCATION
- EXTRACTION WELL LOCATION
- OBSERVATION WELL LOCATION
- DRY WELL LOCATION

ANALYTE	BG (mg/L)	MCL (mg/L)	TAP WATER PRG (mg/L)
FLUORIDE	4.9	2.0	2.2

RESULTS SHOWN IN GREEN EXCEED MCL.

RESULTS SHOWN IN BLUE EXCEED MCL AND TAP WATER PRG.

RESULTS SHOWN IN RED EXCEED BG, MCL, AND TAP WATER PRG.

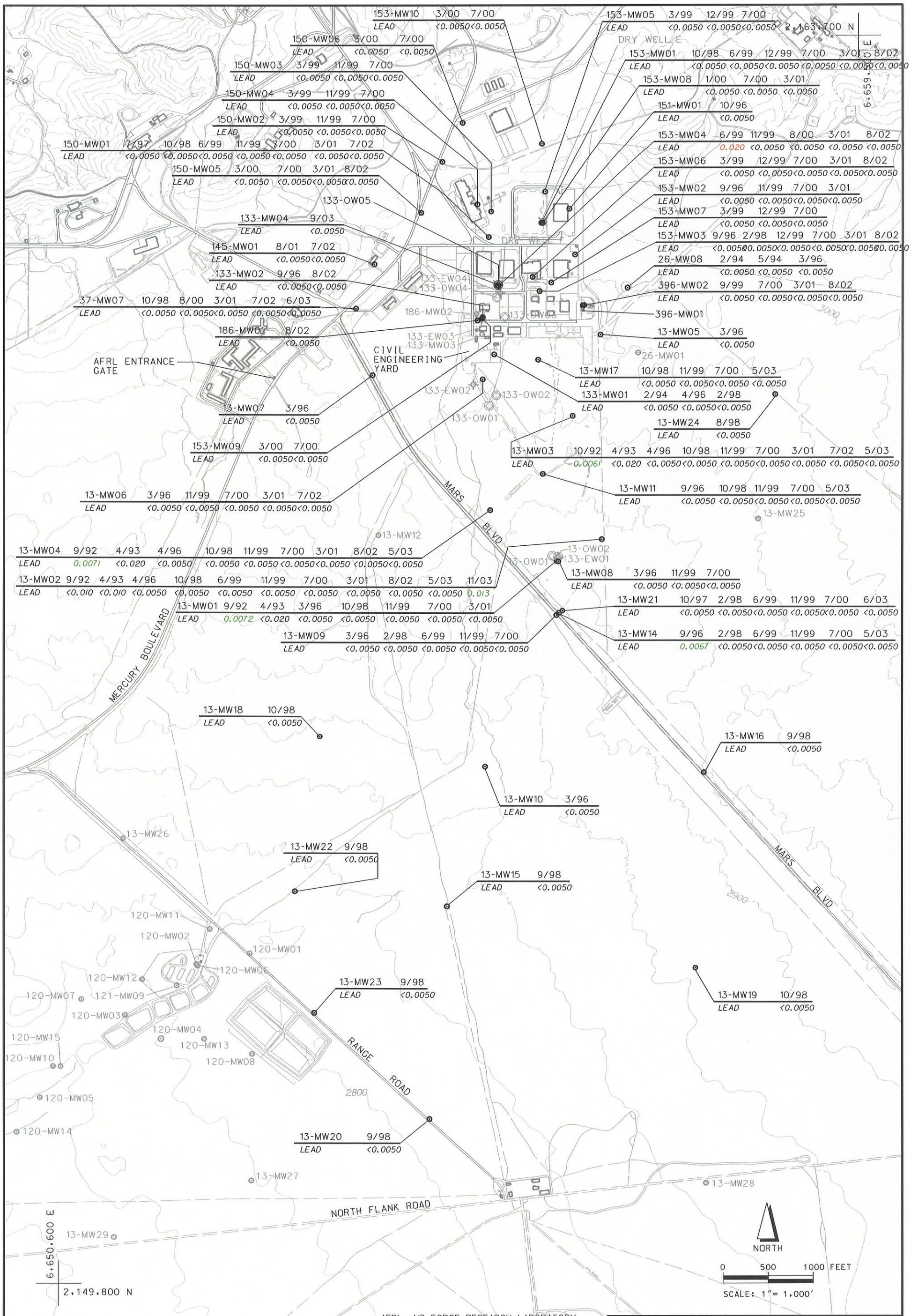
AFRL AIR FORCE RESEARCH LABORATORY
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
BLVD BOULEVARD
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
PRG PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 133
Distribution of
Fluoride in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		C-17

EDWARDS\ 67861\B6045FGA.A01



EXPLANATION

- MONITORING WELL LOCATION
- EXTRACTION WELL LOCATION
- OBSERVATION WELL LOCATION
- DRY WELL LOCATION

RESULTS SHOWN IN GREEN EXCEED BG.

RESULTS SHOWN IN RED EXCEED BOTH AL AND BG.

ANALYTE	AL (mg/L)	BG (mg/L)
LEAD	0.015	0.0050 (DL)

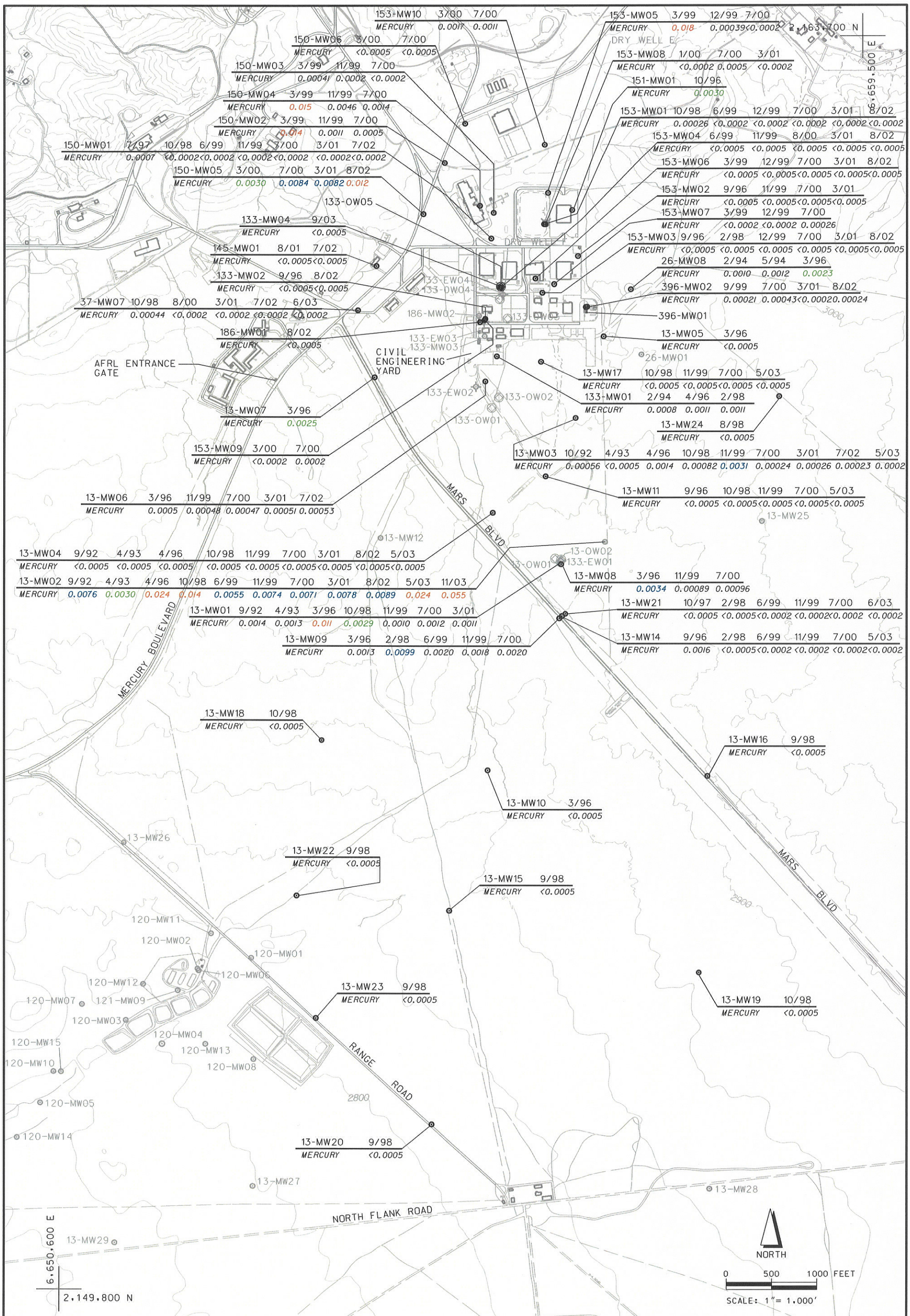
AFRL AIR FORCE RESEARCH LABORATORY
AL USEPA DRINKING WATER ACTION LEVEL
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
BLVD BOULEVARD
DL DETECTION LIMIT
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 133 Distribution of Lead in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		C-18

EDWARDS\ 67861\B6046FGA.A01



EXPLANATION

- MONITORING WELL LOCATION
- EXTRACTION WELL LOCATION
- OBSERVATION WELL LOCATION
- DRY WELL LOCATION

RESULTS SHOWN IN GREEN EXCEED MCL.

RESULTS SHOWN IN BLUE EXCEED BOTH BG AND MCL.

RESULTS SHOWN IN RED EXCEED BG, MCL, AND TAP WATER PRG.

ANALYTE	BG (mg/L)	MCL (mg/L)	TAP WATER PRG (mg/L)
MERCURY	0.003	0.002	0.011

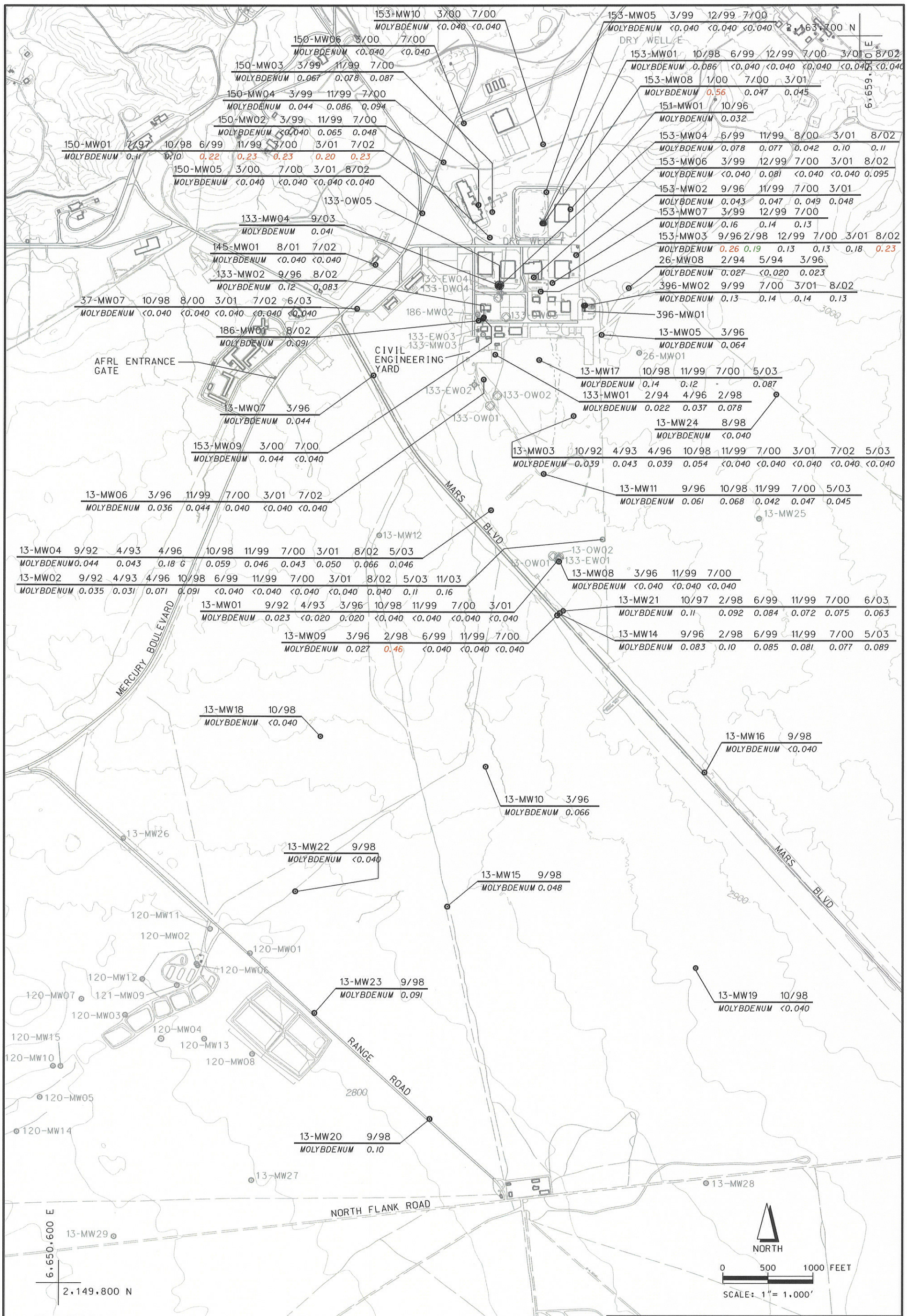
AFRL AIR FORCE RESEARCH LABORATORY
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
BLVD BOULEVARD
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
PRG PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 133 Distribution of Mercury in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		C-19

EDWARDS\ 67861\B6047FGA.A01



EXPLANATION

- MONITORING WELL LOCATION
- EXTRACTION WELL LOCATION
- OBSERVATION WELL LOCATION
- DRY WELL LOCATION

RESULTS SHOWN IN GREEN EXCEED TAP WATER PRG.

RESULTS SHOWN IN RED EXCEED BG AND TAP WATER PRG.

ANALYTE	BG (mg/L)	MCL	TAP WATER PRG (mg/L)
MOLYBDENUM	0.19	NONE	0.18

AFRL AIR FORCE RESEARCH LABORATORY
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
BLVD BOULEVARD
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
PRG PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 133
Distribution of
Molybdenum in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure C-20
Project No. 67861		

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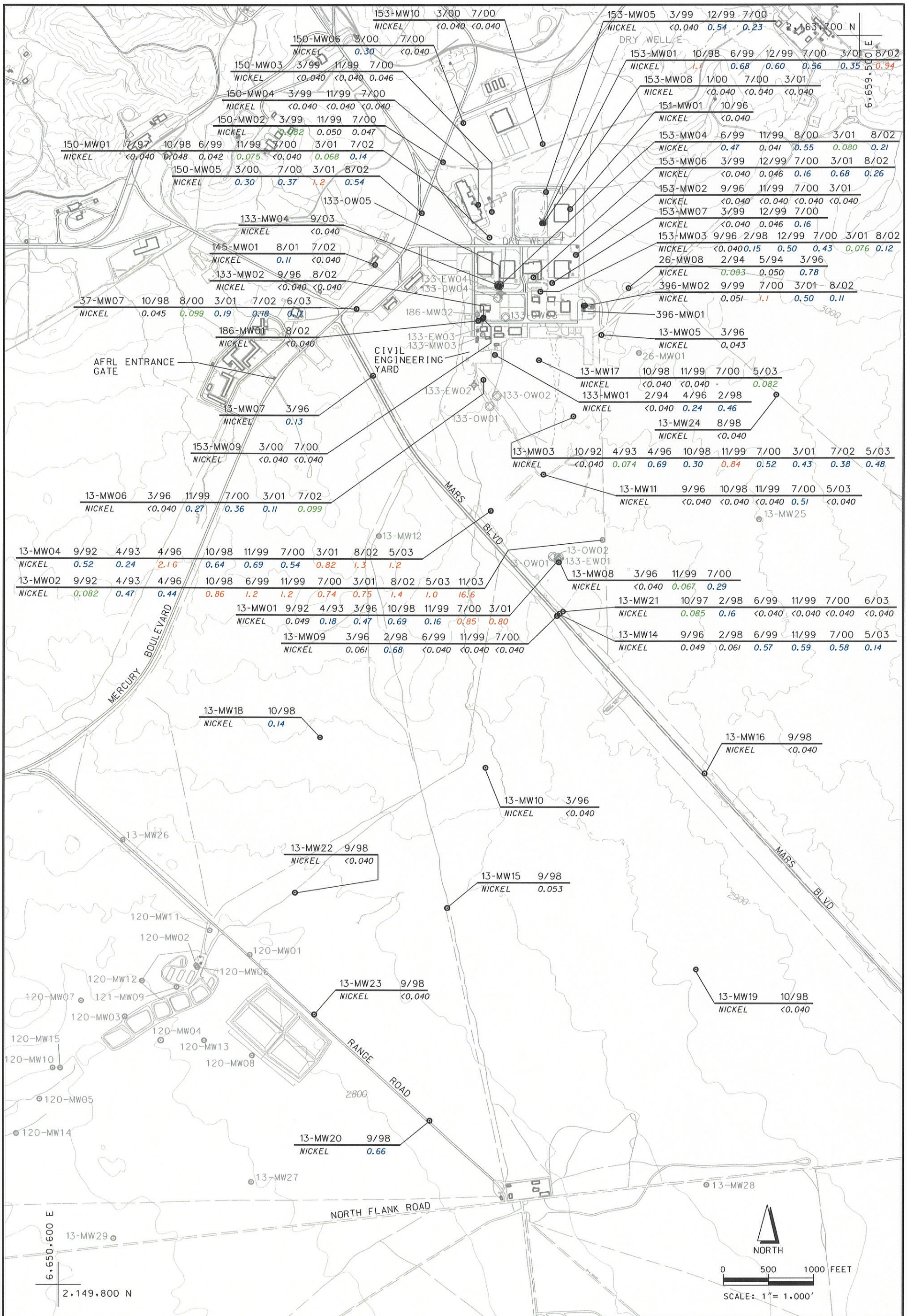


EXPLANATION

- MONITORING WELL LOCATION
- EXTRACTION WELL LOCATION
- OBSERVATION WELL LOCATION
- DRY WELL LOCATION

RESULTS SHOWN IN GREEN EXCEED BG.
RESULTS SHOWN IN BLUE EXCEED BOTH BG AND MCL.
RESULTS SHOWN IN RED EXCEED BG, MCL, AND TAP WATER PRG.

ANALYTE	BG (mg/L)	MCL (mg/L)	TAP WATER PRG (mg/L)
NICKEL	0.065	0.1	0.73

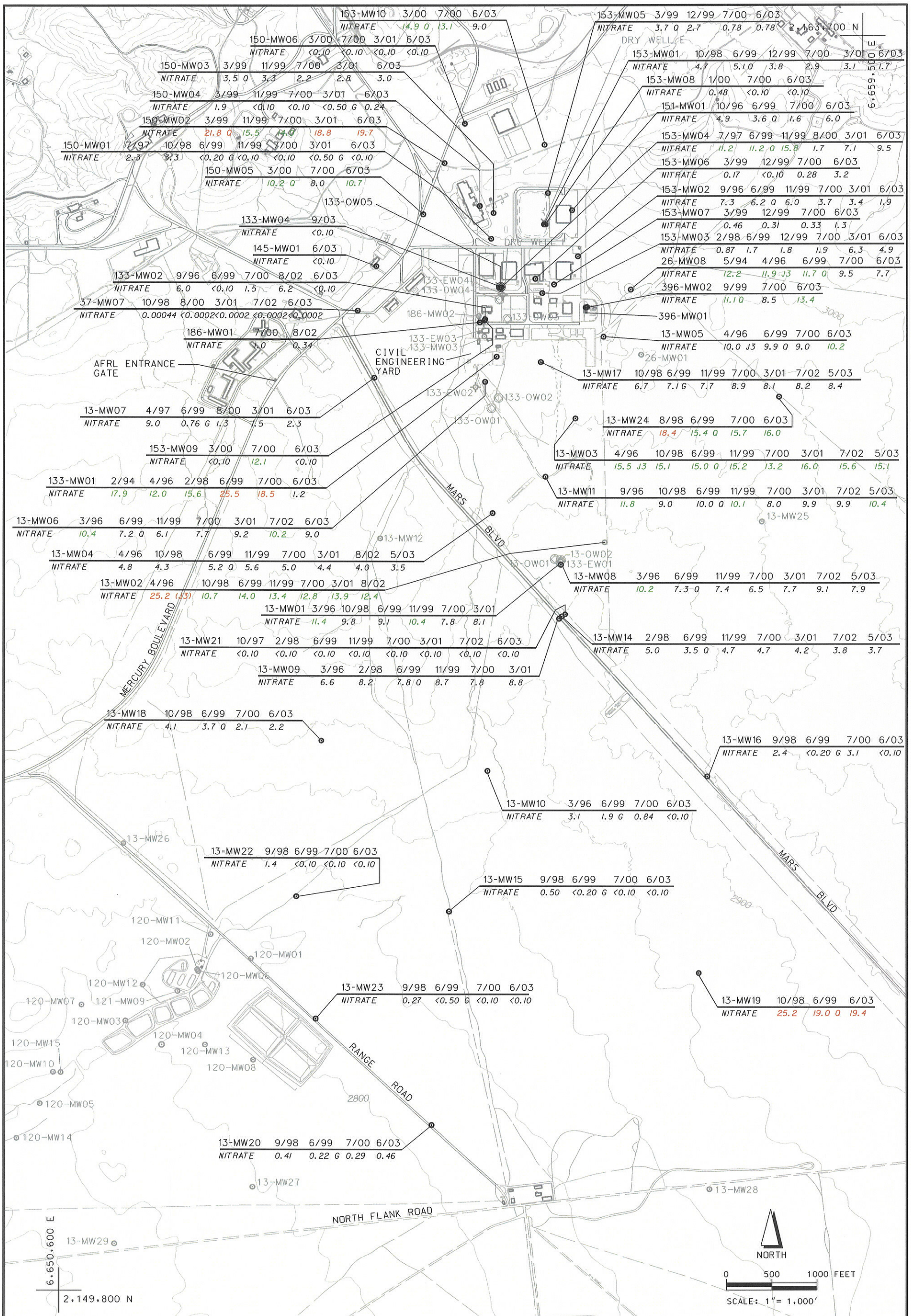
AFRL AIR FORCE RESEARCH LABORATORY
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
BLVD BOULEVARD
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
PRG PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 133
Distribution of
Nickel in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		C-21

EDWARDS\ 67861\B6049FGA.A01



EXPLANATION

- MONITORING WELL LOCATION
- EXTRACTION WELL LOCATION
- OBSERVATION WELL LOCATION
- DRY WELL LOCATION

ANALYTE	BG (mg/L)	MCL (mg/L)	TAP WATER PRG (mg/L)
NITRATE	18.2	10	10

RESULTS SHOWN IN GREEN EXCEED MCL AND TAP WATER PRG.

RESULTS SHOWN IN RED EXCEED BG, MCL, AND TAP WATER PRG.

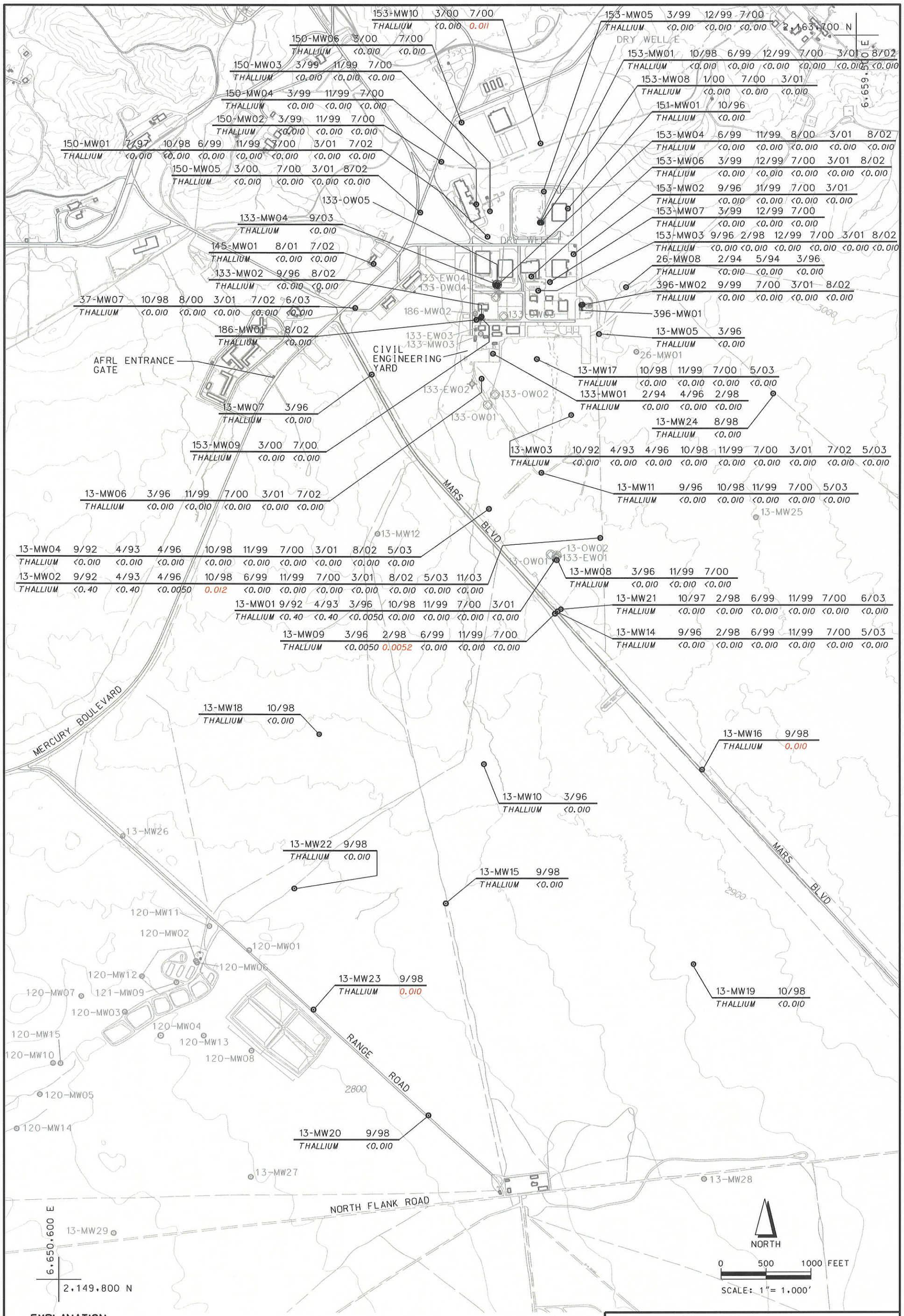
AFRL AIR FORCE RESEARCH LABORATORY
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
BLVD BOULEVARD
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
PRG PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 133
Distribution of
Nitrate in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		C-22

EDWARDS\ 67861\B6050FGA.A01



EXPLANATION

- MONITORING WELL LOCATION
- EXTRACTION WELL LOCATION
- OBSERVATION WELL LOCATION
- DRY WELL LOCATION

ANALYTE	BG (mg/L)	MCL (mg/L)	TAP WATER PRG (mg/L)
THALLIUM	0.005 (DL)	0.002	0.00241

RESULTS SHOWN IN RED EXCEED BG, MCL, AND TAP WATER PRG.

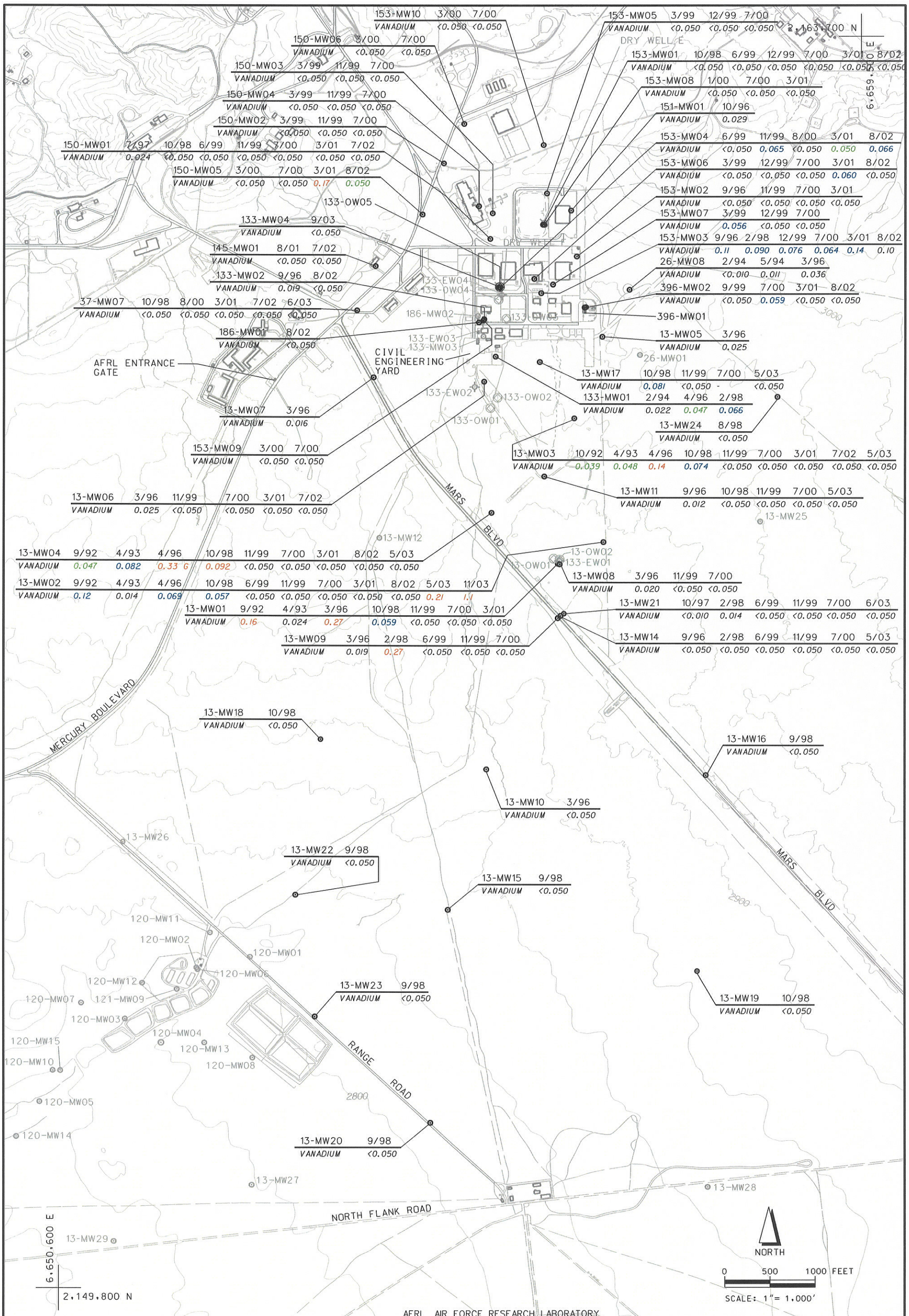
AFRL AIR FORCE RESEARCH LABORATORY
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
BLVD BOULEVARD
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
PRG PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 133 Distribution of Thallium in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure
Project No. 67861		C-23

EDWARDS\ 67861\B6051FGA.A01



EXPLANATION

- MONITORING WELL LOCATION
- EXTRACTION WELL LOCATION
- OBSERVATION WELL LOCATION
- DRY WELL LOCATION

ANALYTE	BG (mg/L)	NL (mg/L)	TAP WATER PRG (mg/L)
VANADIUM	0.090	0.05	0.036

RESULTS SHOWN IN GREEN EXCEED PRG.

RESULTS SHOWN IN BLUE EXCEED NL AND PRG.

RESULTS SHOWN IN RED EXCEED NL, BG, AND TAP WATER PRG.

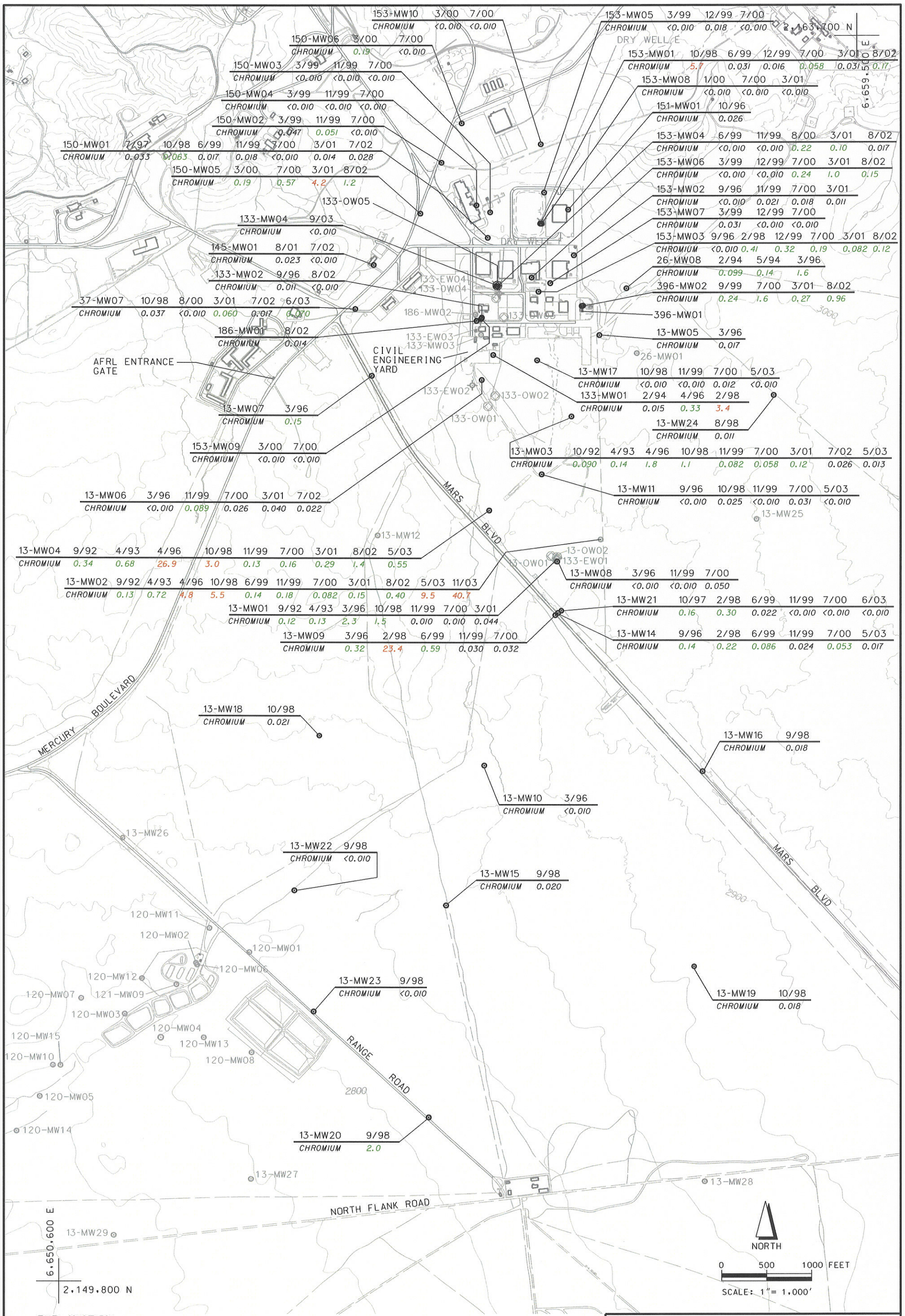
AFRL AIR FORCE RESEARCH LABORATORY
BG AFRL UPPER LIMIT ON BACKGROUND CONCENTRATIONS
BLVD BOULEVARD
HHRA HUMAN HEALTH RISK ASSESSMENT
mg/L MILLIGRAMS PER LITER
NL NOTIFICATION LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
PRG PRELIMINARY REMEDIATION GOAL (USEPA 2004)
USEPA UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

South AFRL ROD

Site 133
Distribution of
Vanadium in Groundwater

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure C-24
Project No. 67861		

EDWARDS\ 67861\B6052FGA.A01



EXPLANATION

- MONITORING WELL LOCATION
- EXTRACTION WELL LOCATION
- OBSERVATION WELL LOCATION
- DRY WELL LOCATION

LOCATION NAME	DATE
ANALYTE	*VALUE DETECTED (mg/L)*

ANALYTE	BG(mg/L)	MCL(mg/L)
CHROMIUM	*2.7*	*0.05*

RESULTS SHOWN IN GREEN EXCEED MCL.

RESULTS SHOWN IN RED EXCEED BOTH MCL AND BG.

AFRL AIR FORCE RESEARCH LABORATORY
BLVD BOULEVARD
BG AFRL UPPER BACKGROUND CONCENTRATIONS
DL DETECTION LIMIT
HHRA HUMAN HEALTH RISK ASSESSMENT
MCL MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES 2007)
mg/L MILLIGRAMS PER LITER
PERA PREDICTIVE ECOLOGICAL RISK ASSESSMENT

South AFRL ROD

Site 133
Distribution of Total Chromium in Groundwater Showing Risk in PERA

Date 9-07	Air Force Research Laboratory Edwards AFB	Figure C-25
Project No. 67861		

EDWARDS\ 67861\B5931FGA.A01

APPENDIX D

SUMMARY OF ARARS IDENTIFIED FOR SOUTH AFRL

TABLE D-1. ARARS – SOUTH AFRL ARARS, EDWARDS AFB, CA
(Page 1 of 5)

Item No.	Requirement	Citation	Federal, State or Local Requirement	Description	ARAR Determination	Comments	Applicable Sites
Chemical-specific ARARs							
1	Primary Drinking Water Standards (Non-zero MCLGs and MCLs)	Safe Drinking Water Act, 40 CFR Part 141, Sections 141.11, 141.50-.51, 141.61-.62	Federal	MCLGs are goals under the SDWA which are set at levels at which no adverse health effects will occur and allow an adequate margin of safety. MCLs are promulgated and enforceable maximum concentrations of drinking water priority pollutants that are set as closely as feasible to MCLGs, considering best technology, treatment techniques, and other factors. The NCP states that primary drinking water standards are legally applicable only to drinking water at the tap, but are relevant and appropriate as cleanup standards for groundwater and surface water that have been determined to be current or future drinking water sources. Under CERCLA 121(d)(2)(A), remedial actions shall attain MCLGs where relevant and appropriate. The NCP provides that where an MCLG has been set at a level of zero, the MCL for that contaminant shall be attained.	Relevant and appropriate	This regulation addresses drinking water-based cleanup goals to be waived inside the South AFRL CZ. The AF and State agree, in this particular case, that the use of MCLs as cleanup standards and the waiver thereof inside the CZ, in conjunction with ICs, is protective of human health at the South AFRL. Only State MCLs that are more stringent than Federal MCLs are ARARs. For the constituents at the South AFRL, those State MCLs in bold print on Table 2.5-1 are more stringent than Federal MCLs.	37, 120, 133, and 321 in the South AFRL. A TI Waiver is required for this ARAR because attainment of MCLs within the CZ is technically impracticable from an engineering perspective.
		40 CFR Part 300, Section 300.430(e)(2)(i)(C)	State	Establishes standards for public water supply systems, including primary MCLs. State MCLs must be at least as stringent as Federal MCLs. State MCLs are incorporated into State and Regional Water Quality Board Water Quality Control Plans as water quality objectives for protection of current and potential drinking water supply sources. MCLs are some of the applicable upper-end objectives for ambient ground and surface water where the water is a source of drinking water, as defined in the Water Quality Control Plans.			
		22 CCR, Div. 4, Ch. 15, Articles 4, 4.5, and 5.5, Sections 64431 et seq., 64444					
2	Water Quality Control Plan, South Lahontan Basin (Basin Plan)	23 CCR Div. 4, Ch. 1, Article 6, Section 3950; Water Code Sections 13140 and 13240	State	The Porter-Cologne Water Quality Control Act established authority of the SWRCB and RWQCB to regulate discharges into Waters of the State. The Basin Plan establishes beneficial uses and the water quality criteria based upon such uses (WQOs). The Basin Plan serves to protect the beneficial uses and water quality of the surface and groundwater in the South Lahontan Basin.	Relevant and appropriate	The WQOs for chemical constituents in groundwater are relevant and appropriate.	37, 120, 133, and 321 in the South AFRL. A TI Waiver is required for this ARAR because attainment of WQOs within the CZ is technically impracticable from an engineering perspective.

TABLE D-1. ARARS – SOUTH AFRL ARARS, EDWARDS AFB, CA
(Page 2 of 5)

Item No.	Requirement	Citation	Federal, State or Local Requirement	Description	ARAR Determination	Comments	Applicable Sites
Location-specific ARARs							
3	California Endangered Species Act	CDFG Code Section 2050-2055; 14 CCR Div. 1, Subdivision 3, Ch. 6 Section 783.1	State	Establishes species, subspecies, and varieties of native California plants or animals as endangered, threatened, or rare. Prohibits the taking, importation, or sale of any species, or any part thereof, of an endangered species or a threatened species. Contains provisions concerning CDFG coordination with State and Federal agencies and with project applicants. Recommends avoidance of adverse impacts on species of special concern and their habitat.	Relevant and appropriate	Potentially an ARAR where the State law has a listing that is more stringent than the Federal Endangered Species Act and Migratory Bird Treaty Act. As stated in Air Force Instruction 32-7064, dated 17 September 2004, State protected species will be protected when practicable and the appropriate State authority will be contacted if conflicts arise. State may provide procedures for minimization of impacts and harm to species.	37, 120, 133, and 321 in the South AFRL
4	Fish and Wildlife Protection and Conservation	CDFG Code Section 1600-1607 (except 1606); 14 CCR, Div. 1.5, Ch. 4, Subchapter 4, Sections 916, 916.2, Subchapter 5, Sections 936, 936.2, and Subchapter 6 Sections 956, 956.2	State	Declares the protection and conservation of fish and wildlife to be an important public interest. Section 1602 prohibits substantial diversion or obstruction of the natural flow of, or substantial change or use of any material from the bed, channel, or bank of, any river, stream, or lake, or deposition or disposal of debris, waste, or other material containing crumbled, flaked, or ground pavement where it may pass into any river, stream, or lake without prior notification and approval from CDFG. The substantive requirement is this section is the prohibition without prior coordination, whereas the requirement for prior notification and approval by CDFG is a non-substantive general statement of policy.	Relevant and appropriate	Remedial action must be protective and conserve fish and wildlife resources. As stated in Air Force Instruction 32-7064, dated 17 September 2004, State protected species will be protected when practicable and the appropriate State authority will be contacted if conflicts arise. State may provide procedures for minimization of impacts and harm to species.	37, 120, 133, and 321 in the South AFRL
5	Wildlife Species/Habitats	CDFG Code Sections 2000, 2014, 3005, 3511, 3513, and 12000 et seq. 14 CCR, Div. 1, Subchapter 2, Section 250, Section 507; Subchapter 3, Section 650	State	Prohibits the taking of birds and mammals. This code section imposes a substantive, promulgated environmental protection requirement covering destruction of wildlife caused by unlawful discharges of pollutants to waters of the State in violation of Division 7 (Section 13000 et seq.) of the Water Code.	Relevant and appropriate	As stated in Air Force Instruction 32-7064, dated 17 September 2004, State protected species will be protected when practicable and the appropriate State authority will be contacted if conflicts arise. State may provide procedures for minimization of impacts and harm to species.	37, 120, 133, and 321 in the South AFRL
6	Mammals and Reptiles Provisions	CDFG Code Sections 4700 and 5050; 14 CCR, Div. 1, Subdivision 3, Ch. 3, Section 670	State	Prohibits the possession of mammals and reptiles that are identified as "fully protected."	Relevant and appropriate.	Potentially applicable where the State law has a listing that is more stringent than the Federal and State Endangered Species Act or Migratory Bird Treaty Act. As stated in Air Force Instruction 32-7064, dated 17 September 2004, State protected species will be protected when practicable and the appropriate State authority will be contacted if conflicts arise. State may provide procedures for minimization of impacts and harm to species.	37, 120, 133, and 321 in the South AFRL
7	Rare Native Plants	CDFG Code Sections 1900 et seq. and 2080; 14 CCR, Div. 1, Subdivision 3, Ch. 6, Section 783	State	Contain provisions concerning native plant protection including: criteria for determining endangered plant species; designation of endangered plants; and other prohibitions.	Relevant and appropriate	As stated in Air Force Instruction 32-7064, dated 17 September 2004, State protected species will be protected when practicable and the appropriate State authority will be contacted if conflicts arise. State may provide procedures for minimization of impacts and harm to species. Future drilling and sampling at the South AFRL will be monitored to avoid impacts to any identified or unidentified protected species.	37, 120, 133, and 321 in the South AFRL

TABLE D-1. ARARS – SOUTH AFRL ARARS, EDWARDS AFB, CA
(Page 3 of 5)

Item No.	Requirement	Citation	Federal, State or Local Requirement	Description	ARAR Determination	Comments	Applicable Sites
8	National Historical Preservation Act	16 USC Section 470 et seq.	Federal	Requires federal agencies to consider the effect of any federally assisted undertaking or licensing on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register of Historic Places. All Federal structures dating around WWII or earlier are eligible for inclusion in the National Register of Historic Places until determined otherwise, per Section 106.	Relevant and appropriate	There are historic buildings inside the South AFRL CZ (however, none are currently listed on the National Register); also surveys in the South AFRL area may be incomplete. The selected remedy involves, at a minimum, well drilling and sampling. Future drilling and sampling at the South AFRL will be monitored to avoid impacts to any identified or unidentified historically significant sites.	37, 120, 133, and 321 in the South AFRL
9	Archeological and Historic Preservation Act	16 USC Section 470 et seq.	Federal	Requires federal agencies to notify the Secretary of the Interior and implement approved mitigation measures when undertakings will impact significant archeological sites.	Relevant and appropriate	Archaeological sites are located within the South AFRL CZ. The selected remedy involves, at a minimum, well drilling and sampling. Future drilling and sampling at the South AFRL will be monitored to avoid impacts to any identified or unidentified prehistoric archaeological sites.	37, 120, 133, and 321 in the South AFRL
Action-specific ARARs							
10	Standards Applicable to Generators of Hazardous Waste	40 CFR Part 262 22 CCR, Div. 4.5, Ch. 12, Articles 1-4, Sections 66262.10-.47	Federal State	These regulations apply to generators of hazardous waste. Edwards AFB is a large quantity generator of hazardous waste (EPA ID CA1570024504) and already subject to these requirements. Establishes standards for generators of RCRA and [1]California hazardous wastes, including those for hazardous waste determination, accumulation, identification numbers, manifesting, pre-transport, and record keeping and reporting requirements.	Applicable if soil cuttings, purge water or spent carbon are hazardous waste.	Applicable to waste generated (soil cuttings, purge water from groundwater sampling, and spent carbon from onsite treatment of purge water) as part of South AFRL groundwater remedies if these wastes are hazardous. Substantive requirements are potentially ARARs if excavated soils or treatment residuals exceed RCRA or [1]California hazardous waste thresholds. Hazardous remediation waste may be stored onsite in Corrective Action Temporary Units. These Corrective Action Temporary Units are not subject to the less than 90-day accumulation time requirement. Temporary units may operate for 1 year with an opportunity for a 1-year extension.	Soil cuttings, purge water, and spent carbon generated from groundwater monitoring at Sites 37, 120, 133, and 321 in the South AFRL
11	Sources of Drinking Water Policy	SWRCB Resolution No. 88-63; Porter-Cologne Water Quality Act (CWC Sections 13000, 13140, 13240); H&S Code Section 25356.1.5 (a)	State	Resolution 88-63 has been incorporated into all Regional Board Basin Plans, including the Lahontan Water Board's Basin Plan. This resolution designates all ground and surface waters of the State as drinking water except where the TDS is greater than 3,000 ppm, the well yield is less than 200 gpd from a single well, the water is a geothermal resource or in a waste water conveyance facility, or the water cannot reasonably be treated for domestic use using either best management practices or best economically achievable treatment practices.	Applicable	The AF agrees with the designation of the current and potential use of the groundwater for the South AFRL as drinking/domestic use.	37, 120, 133, and 321 in the South AFRL. Note: LUCs will be implemented to prevent the use of groundwater within the CZ as a drinking water source.

TABLE D-1. ARARS – SOUTH AFRL ARARS, EDWARDS AFB, CA
(Page 4 of 5)

Item No.	Requirement	Citation	Federal, State or Local Requirement	Description	ARAR Determination	Comments	Applicable Sites
12	Definition of and Criteria for Identifying Hazardous Wastes	40 CFR 261.3 22 CCR, Div. 4.5, Ch. 11, Article 1, Sections 66261.2-.3; Articles 3, Sections 66262.24 -.33; Article 5, Sections 66261.100-.101	Federal State	Defines wastes that are subject to regulation as a RCRA or [1]California hazardous waste. Excavated contaminated soil, extracted groundwater, and spent treatment residuals (e.g., granular activated carbon) must be classified using AF knowledge of the timing and nature of the release as well as waste toxicity characteristic testing. If, after good faith effort, the AF determines that the contaminated soil or groundwater contains a listed RCRA or [1]California hazardous waste or fails the Federal or State toxicity characteristic tests, then the excavated soil or extracted groundwater is considered hazardous based on EPA's "contained-in" policy and must be managed as hazardous remediation waste. Contaminated soils or groundwater that are treated in situ are not subject to the identification or classification requirements.	Applicable	The definitions of hazardous waste in Article 1 and toxicity characteristic criteria (i.e., TTLC and STLC levels) in Section 66261.24 are applicable for the characterization of soil cuttings from well installation, as well as purge water and spent carbon from groundwater monitoring and onsite water treatment. The soil cuttings are not expected to be hazardous. Treated purge water that is discharged to the Base sanitary wastewater treatment facility will no longer be hazardous waste and will be subject to discharge limits based on the facility's discharge permit limits. Spent carbon will be tested prior to off-site disposal or regeneration.	Soil cuttings, purge water, and spent carbon generated from groundwater monitoring at Sites 37, 120, 133, and 321 in the South AFRL
13	Hazardous Waste Land Disposal Restrictions	40 CFR Part 268 22 CCR, Div. 4.5, Ch. 18, Section 66268	Federal State	Identifies hazardous wastes that are restricted from land disposal without prior treatment to UTS. Hazardous remediation wastes that are managed off-site are subject to the LDR UTS specified in Section 66268 for wastewater (liquid) and non-wastewater (solid). Hazardous soils must be treated to 90% reduction in concentration capped at 10 times the UTS for principal hazardous constituents (90% capped at 10 x UTS). On-site treatment or disposal of hazardous remediation wastes are not strictly subject to the LDR treatment standards, but are subject to similar treatment standards specified in the Corrective Action Management Unit Amendment Rule codified in 40 CFR 264.550-.555 and 22 CCR 66264.550-.553.	Applicable	LDR applicable to off-site disposal of soil cuttings, treated groundwater, and spent carbon if these remediation wastes are RCRA or [1]California hazardous waste, as determined through toxicity characteristic testing using TCLP and TTLC/STLC.	Soil cuttings and spent carbon generated from groundwater monitoring at Sites 37, 120, 133, and 321 in the South AFRL
14	Land Use Controls	22 CCR, Div. 4.5, Ch. 39, Section 67391.1 (d), (e) (1) and (2)	State	Requires that if a remedy will result in hazardous substances remaining on a property at levels not suitable for unrestricted use, the limitations or controls are clearly set forth and defined in the response action decision document, and that the decision document include an implementation and enforcement plan. In the event of property transfer, the state and federal agency will enter into restrictive land use covenants recorded in the county. In the case of federal-to-federal land transfers, the state and federal agency will use other mechanisms to ensure that future land use will be compatible with the levels of hazardous materials remaining on the property (e.g., amendment to the base master plan, physical monuments, or agreements between the federal agency and the state).	Relevant and appropriate	ICs, limiting exposure to contaminated groundwater, are required at the South AFRL until hazardous substance concentrations in groundwater are suitable for unrestricted use. Although it is not contemplated that property at the South AFRL will be transferred, in the event that such property is transferred, the AF and the State have agreed to follow the procedure laid out in Section 2.13.2.1 (LUC Implementation and Administration at Edwards AFB) of this ROD.	All portions of the South AFRL CZ groundwater plumes with original sources at Sites 37, 120, 133, and 321 requiring institutional controls

Notes:

[1]California hazardous waste (as used in this table) is the same as non-RCRA hazardous waste as defined in Section 66261.101 of CCR Title 22.

%	=	percent
AF	=	Air Force
AFB	=	Air Force Base
AFRL	=	Air Force Research Laboratory
ARAR	=	Applicable or Relevant and Appropriate Requirement
CA	=	California
CCR	=	California Code of Regulations
CDFG	=	California Department of Fish and Game
CERCLA	=	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	=	Code of Federal Regulations
Ch.	=	Chapter
CWC	=	California Water Code
CZ	=	containment zone
Div.	=	Division
e.g.	=	*exempli gratia* (for example)
EPA	=	Environmental Protection Agency
et seq.	=	*et sequentes* (and the following)
gpd	=	gallons per day
H&S	=	health and safety
IC	=	institutional control
ID	=	identification
i.e.	=	*id est*, that is
LDR	=	land disposal restriction
LUC	=	land use controls
MCL	=	Maximum Contaminant Level
MCLG	=	Maximum Contaminant Level Goal
NCP	=	National Contingency Plan
ppm	=	parts per million
RCRA	=	Resource Conservation and Recovery Act
ROD	=	Record of Decision document
RWQCB	=	Regional Water Quality Control Board
SDWA	=	Safe Drinking Water Act
STLC	=	soluble threshold limit concentration
SWRCB	=	State Water Resources Control Board
TCLP	=	toxic characteristic leaching procedure
TDS	=	total dissolved solid
TI	=	technical impracticability
TTLC	=	total threshold limit concentration
USC	=	United States Code
UTS	=	universal treatment standard
WQO	=	water quality objective
WWII	=	World War Two

APPENDIX E

CROSS-REFERENCE TABLE E-1 AND BACKUP TABLES (E-2, E-3) DOCUMENTING HOW THE SELECTED REMEDY MEETS THE INTENT OF COMPLIANCE WITH STATE WATER BOARD RESOLUTION 92-49, APPENDIX III.H.

TABLE E-1 REFERENCE TABLE SHOWING HOW THE SOUTH AFRL RECORD OF DECISION, IN WHICH A CERCLA TECHNICAL IMPRACTICABILITY WAIVER IS SELECTED, MEETS THE INTENT OF CONTAINMENT ZONE REQUIREMENTS IN CALIFORNIA SWRCB RESOLUTION 92-49 SECTION III.H

TABLE E-2 SUMMARY OF IN SITU TECHNOLOGIES TESTED AT EDWARDS AFB

TABLE E-3 EDWARDS AIR FORCE BASE CONTRACTED GROUNDWATER STUDIES

TABLE E-1. REFERENCE TABLE SHOWING HOW THE SOUTH AFRL RECORD OF DECISION, IN WHICH A CERCLA TECHNICAL IMPRACTICABILITY WAIVER IS SELECTED, MEETS THE INTENT OF CONTAINMENT ZONE REQUIREMENTS IN CALIFORNIA SWRCB RESOLUTION 92-49 SECTION III.H

Item	Resolution 92-49 Section	Relevant Citation	Components of the Requirement	Reference Where Addressed
1	H.7	Approval of Technical Impracticability Waivers by the Department of Toxic Substances Control or the United States Environmental Protection Agency under the requirements of the Federal Resource Conservation and Recovery Act or the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) are deemed to be equivalent to the actions outlined in Section H. of this Policy if: 1. the substantive provisions of Sections III.H.2.b., e., f., and g. are met; 2. interested parties described in III.H.8.a. are included in the public participation process; and 3. site information is forwarded from the approving agency to the Regional Water Board so that sites for which Technical Impracticability Waivers have been approved can be included in the master listings described in Section III.H.10	In general, this column will be used to show how the remedial project manager (RPM) for the Water Board broke the relevant citation into discrete discharger requirements.	1. Items 2-9 in this table reference how the South AFRL Record of Decision (ROD) meets the intent of substantive requirements in Sections III.: ■ H.2.b. (and cited section H.2.d. and footnotes) ■ H.2.e. ■ H.2.f. ■ H.2.g. 2. Items 10-27 reference how the ROD meets the intent of Section H.3. 3. Items 28-30 reference how the ROD meets the intent of Sections H.8, H.9 and H.10.
2	H.2.b.	Containment, and storage vessels that have caused, are causing, or are likely to cause ground water degradation must be removed or repaired, or closed in accordance with applicable regulations. Floating free product must be removed to the extent practicable. If necessary, as determined by the Regional Water Board, to prevent further water degradation, other sources (e.g., soils, nonfloating free product) must be either removed, isolated, or managed. The significance and approach to be taken regarding these sources must be addressed in the management plan developed under H.2.d;	1. Remove, repair, or close containment and storage vessels that have caused, are causing, or are likely to cause ground water degradation in accordance with applicable regulations 2. Remove to the extent practicable floating free product 3. Remove, isolate, or manage if necessary, as determined by the Regional Water Board, to prevent further water degradation, other sources (e.g., soils, nonfloating free product). The significance and approach to be taken regarding these sources must be addressed in the management plan developed under H.2.d.	1. Description of source control actions to prevent container leakage presented in ROD Section 2.2.3.2 with Table A-4 in Appendix A providing supporting documentation 2. Not applicable: No floating free product at the South AFRL. DNAPL suspected. 3. Description of treatability studies and interim removal actions to reduce contaminant migration and remove contaminant mass provided in ROD Section 2.2.3.3 with Tables A-4 and A-5 in Appendix A providing supporting documentation. With respect to management plan (MP), see Item H.2.d.
3	H.2.d.	The discharger or a group of dischargers must propose and agree to implement a management plan to assess, cleanup, abate, manage, monitor, and mitigate the remaining significant human health, water quality, and environmental impacts to the satisfaction of the Regional Water Board. Impacts will be evaluated in accordance with Section III.H.3. The management plan may include management measures, such as land use controls (footnote 1), engineering controls (footnote 2), and agreements with other landowners or agreements with the landlord or lessor where the discharger is a tenant or lessee (footnote 3). The contents of the management plan shall be dependent upon the specific characteristics of the proposed containment zone and must include a requirement that the Regional Water Board be notified of any transfer of affected property to a new owner (s).	Propose and agree to implement a management plan to assess, cleanup, abate, manage, monitor, and mitigate the remaining significant human health, water quality, and environmental impacts to the satisfaction of the Regional Water Board. Impacts will be evaluated in accordance with Section III.H.3. The contents of the management plan shall be dependent upon the specific characteristics of the proposed containment zone and must include a requirement that the Regional Water Board be notified of any transfer of affected property to a new owner(s);	A Management Plan was prepared and submitted as Volume II of the *Focused Feasibility Study to Support a Technical Impracticability Evaluation/Containment Zone Application for the South AFRL (Sites 37, 133, 120, and 321)* (South AFRL Focused FS) dated June 2005. As mentioned in Section 2.13.2.2 of the ROD, and in accordance with CERCLA requirements, post-ROD documents (e.g., a remedial action [RA] work plan, operation and maintenance [O&M] plans and schedules) will be prepared that will meet the intent of the Management Plan requirements of 92-49 Section III.H. Specific components addressed in Footnotes 1 through 3 are addressed below.
4	Footnote 1	For the purposes of this section, "land use controls" means recorded instruments, proposed by the discharger and agreed to by the owner of the affected property, restricting the present and future uses of the affected property, including, but not limited to, recorded easements, covenants, restrictions or servitudes, or any combination thereof, as appropriate. Land use controls shall run with the land from the date of recordation, shall bind all of the owners of the land, and their heirs, successors, and assignees, and the agents, employees, and lessees of the owners, heirs, successors, and assignees. Such instruments shall provide for (a) amendment or rescission of the restriction upon application of the holder of fee interest in the property and upon the approval of the Regional Water Board if warranted by changed circumstances (e.g., new information demonstrates that a modification to land use restriction is appropriate, the containment zone designation has been rescinded because water quality objectives have been attained throughout the containment zone, etc.), and (b) except for the restriction contained in the instrument, the establishment of a containment zone shall not prohibit the full use or enjoyment of the property.	Include in the management plan land use controls as defined in the preceding column.	Proposed land use controls (LUCs) are presented in Section 2.13.2.1 of the ROD.

TABLE E-1. REFERENCE TABLE SHOWING HOW THE SOUTH AFRL RECORD OF DECISION, IN WHICH A CERCLA TECHNICAL IMPRACTICABILITY WAIVER IS SELECTED, MEETS THE INTENT OF CONTAINMENT ZONE REQUIREMENTS IN CALIFORNIA SWRCB RESOLUTION 92-49 SECTION III.H

Item	Resolution 92-49 Section	Relevant Citation	Components of the Requirement	Reference Where Addressed
5	Footnote 2	For purposes of this section, "engineering controls" means measures to prevent migration of pollutants and to prevent, minimize or mitigate environmental damage which may otherwise result from a release or threatened release, including, but not limited to, caps, covers, dikes, trenches, leachate collection systems, treatment systems, and ground water containment systems or procedures and decommissioning of wells.	Include in the management plan engineering controls as defined in the preceding column.	Section H.2.d. states (italics added for emphasis), "The management plan *may include* management measures, such as land use controls (footnote 1), engineering controls (footnote 2), …" No engineering controls are proposed as part of the selected remedy for groundwater. Potential Engineering control to reduce risk of exposure to contaminants in indoor air via the vapor intrusion pathway (VIP) are listed in Section 2.13.2.2.
6	Footnote 3	For the purposes of this section, these agreements could be formal, private agreements between parties related to the property use, existing or potential water use, etc.	Include in the management plan agreements with other landowners or agreements with the landlord or lessor where the discharger is a tenant or lessee.	The Air Force is the only landowner. As such, Footnote 3 is not applicable to the selected remedy at the South AFRL.
7	H.2.e.	The proposed management plan must provide reasonable mitigation measures to substantially lessen or avoid any significant adverse environmental impacts attributable to the discharge. At a minimum, the plan must provide for control of pollutants within the containment zone such that water quality objectives are not exceeded outside the containment zone as a result of the discharge. The plan must also provide, if appropriate, for equivalent alternative water supplies, reimbursement for increased water treatment costs to affected users, and increased costs associated with well modifications. Additional mitigation measures may be proposed by the discharger based on the specific characteristics of the proposed containment zone. Such measures must assist in water quality improvement efforts within the ground water basin and may include participating in regional ground water monitoring, contributing to ground water basin cleanup or management programs, or contributing to research projects which are publicly accessible (i.e., not protected by patents and licenses) and aimed at developing remedial technologies that would be used in the ground water basin. Proposals for off-site cleanup projects may be considered by the Regional Water board as a mitigation measure under the following criteria: 1. Off-site cleanup projects must be located in the same ground water basin as the proposed containment zone; and 2. Implementation of an off-site project must result in an improvement in the basin's water quality or protect the basin's water quality from pollution; and 3. Off-site projects must include source removal or other elements for which water quality benefits or water quality protection can be easily demonstrated, and 4. Off-site projects may be proposed independently by the discharger or taken from projects identified as acceptable by the Regional Water Board through a clearinghouse; or 5. In lieu of choosing to finance a specific off-site project, the discharger may contribute moneys to the SWRCB's Cleanup and Abatement Account (Account) or other funding source. Use of such contributions to the Account or other source will be limited to cleanup projects or water quality protection projects for the basin in which the containment zone is designated. Contributions are not to exceed ten percent of the savings in continued active remediation that discharger will accrue over a ten-year period due to designation of a containment zone (less any additional costs of containment zone designation during this period, e.g., additional monitoring requirements, Regional Water Board application costs, etc.). Contributions of less than ten percent just be accompanied by a detailed justification as to why a lesser contribution would provide adequate mitigation. Except where prohibited by Federal law, Federal agencies may be required, based on specific site conditions, to implement mitigation measures;	1. Propose in the management plan reasonable mitigation measures to substantially lessen or avoid any significant adverse environmental impacts attributable to the discharge based on the site-specific characteristics of the proposed containment zone. Such measures must assist in water quality improvement efforts within the ground water basin and may include participating in regional ground water monitoring, contributing to ground water basin cleanup or management programs, or contributing to research projects which are publicly accessible (i.e., not protected by patents and licenses) and aimed at developing remedial technologies that would be used in the ground water basin. 2. Propose in the management plan control of pollutants within the containment zone such that water quality objectives are not exceeded outside the containment zone as a result of the discharge 3. Propose in the management plan for equivalent alternative water supplies, reimbursement for increased water treatment costs to affected users, and increased costs associated with well modifications H.2.e.1 Indicate if any proposed offsite projects are located in the same groundwater basin as the proposed containment zone. H.2.e.2 Indicate if implementation of an off-site project results in an improvement in the basin's water quality or protect the basin's water quality from pollution. H.2.e.3 Indicate if an off-site project includes source removal or other elements for which water quality benefits or water quality protection can be easily demonstrated H.2.e.4 Indicate if an off-site project is proposed independently by the discharger that is taken from projects identified as acceptable by the Regional Water Board through a clearinghouse project. H.2.e.5 In lieu of choosing to finance a specific off-site project, indicate if the discharger proposes to contribute moneys to the SWRCB's Cleanup and Abatement Account or other funding	1. The Air Force has completed and/or is continuing a number of treatability studies (TSs) and interim removal actions (IRAs) on Edwards Air Force Base within the Antelope Valley Basin 6-44 (refer to Figure 2.5-3) that meet the intent of mitigation measures; and conducts annual groundwater monitoring throughout Edwards Air Force Base. The TSs and IRAs are summarized briefly in Table E-2; all documents evaluating treatment results are publicly accessible. Moreover, the Air Force has funded (and intends to continue funding) a number of studies of the Basin hydrogeology as listed in Table E-3. Finally, as a remedy component listed in ROD Section 1.4 and 2.13.2, the Air Force has committed to continue review of technologies as part of the 5-year statutory review. If a promising technology is identified, which has been demonstrated to effectively treat the same types of chemicals at similar concentrations and in a similar hydrogeologic setting, the Air Force will conduct a field-test of the technology, at a cost not to exceed $250,000 (inflation adjusted from the date of the ROD), to be executed by the following 5-year review. 2. As listed in Sections 1.4 and 2.13.2 of the ROD, containment of groundwater impacted by chemicals of concern (COCs listed in Table 2.5-1) at concentrations exceeding their primary maximum contaminant levels (pMCLs) or other risk-based cleanup goals (RBCGs) for chemicals without MCLs will be demonstrated by long-term monitoring (LTM) of the groundwater to track contaminant migration. As appropriate, monitoring data will be used to update and refine the groundwater flow and contaminant transport models. A technical and economic feasibility analysis (TEFA, as defined in Section III.G, SWRCB Resolution 92-49) will be conducted and active containment measures will be instituted as necessary to

TABLE E-1. REFERENCE TABLE SHOWING HOW THE SOUTH AFRL RECORD OF DECISION, IN WHICH A CERCLA TECHNICAL IMPRACTICABILITY WAIVER IS SELECTED, MEETS THE INTENT OF CONTAINMENT ZONE REQUIREMENTS IN CALIFORNIA SWRCB RESOLUTION 92-49 SECTION III.H

Item	Resolution 92-49 Section	Relevant Citation	Components of the Requirement	Reference Where Addressed
			source.	ensure that COCs do not migrate outside the CZ. The trigger for both actions would be the projected arrival of impacted groundwater at the Containment Zone [CZ] boundary within the next 10 years; or the detection of any COC in groundwater samples from sentinel wells outside the CZ. 3. No drinking water supplies are currently threatened. H.2.e.1 through H.2.e.5 are not applicable to the selected remedy for the South AFRL.
8	H.2.f	The proposed management plan must include a detailed description of the proposed monitoring program, including the location and construction of monitoring points, a list of proposed monitoring parameters, a detailed description of sampling protocols, the monitoring frequency, and the reporting requirements and frequency. The monitoring points must be at or as close as reasonable to the boundary of the containment zone so as to clearly demonstrate containment such that water quality objectives outside the containment zone are not violated as the result of the discharge. Specific monitoring points must be defined on a case-by-case basis by determining what is necessary to demonstrate containment, horizontally and vertically. All technical or monitoring program requirements and requirements for access shall be designated pursuant to WC Section 13267. The monitoring program may be modified with the approval of the Regional Water Board's Executive Officer based on an evaluation of monitoring data;	1. Include in the management plan a detailed description of the monitoring program. 2. Include in the management plan the location and construction of monitoring points. The monitoring points must be at or as close as reasonable to the boundary of the containment zone so as to clearly demonstrate containment such that water quality objectives outside the containment zone are not violated as the result of the discharge. Specific monitoring points must be defined on a case-by-case basis by determining what is necessary to demonstrate containment, horizontally and vertically. 3. Include in the management plan a list of proposed monitoring parameters. 4. Include in the management plan a detailed description of sampling protocols. 5. Include in the management plan proposed reporting requirements and frequency.	The Management Plan (MP) submitted as Volume II of the South AFRL Focused FS included: 1. a detailed description of the monitoring program proposed for the South AFRL CZ 2. maps showing the locations, and tables summarizing well construction details, of monitoring points 3. a list of proposed monitoring parameters 4. a detailed description of sampling protocols (note, the protocols listed in the MP have been superseded by those detailed in a Base-wide Sampling and Analysis Plan, to be issued in 2007). The MP did not specifically address proposed reporting requirements and frequency. The LTM program proposed for the South AFRL is briefly described in Section 2.13.2.2 of the ROD, which states that LTM will be conducted in accordance with post-ROD documents (as previously stated for Item 3 in this table). It is the Air Force's intent to adopt a similar approach to that proposed in the previously submitted MP, with updates and revisions as appropriate.
9	H.2.g.	The management plan must include a detailed description of the method to be used by the discharger to evaluate monitoring data and a specific protocol for actions to be taken in response to evidence that water quality objectives have been exceeded outside the containment zone as a result of the migration of pollutants from within the containment zone.	Include in the management plan a detailed description of the method to be used by the discharger to evaluate monitoring data and a specific protocol for actions to be taken in response to evidence that water quality objectives have been exceeded outside the containment zone as a result of the migration of pollutants from within the containment zone.	The Management Plan (MP) submitted as Volume II of the South AFRL Focused FS included data quality objectives (DQOs) for the monitoring program and a decision rule. As stated above, it is the Air Force's intent to adopt (in the post-ROD RA work plan) a similar approach to that proposed in the previously submitted MP, with updates and revisions as appropriate.
10	H.3	In order for a containment zone to be designated, it shall be limited in vertical and lateral extent; as protective as reasonably possible of human health and safety and the environment; and should not result in violation of water quality objectives outside the containment zone. The following factors must be considered by the Regional Water Board in making such findings:		See Items 11-27.

TABLE E-1. REFERENCE TABLE SHOWING HOW THE SOUTH AFRL RECORD OF DECISION, IN WHICH A CERCLA TECHNICAL IMPRACTICABILITY WAIVER IS SELECTED, MEETS THE INTENT OF CONTAINMENT ZONE REQUIREMENTS IN CALIFORNIA SWRCB RESOLUTION 92-49 SECTION III.H

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11	H.3.a.	The size of a containment zone shall be no larger than necessary based on the facts of the individual designation. In no event shall the size of a containment zone or the cumulative effect of containment zones cause a substantial decline in the overall yield, storage, or transport capacity of a ground water basin;	Provide information to assess whether the size of a containment zone is no larger than necessary based on the facts of the individual designation. In no event shall the size of a containment zone or the cumulative effect of containment zones cause a substantial decline in the overall yield, storage, or transport capacity of a ground water basin.	In Section 2.6, the area and estimated groundwater volume within the South AFRL CZ are compared to the total groundwater storage capacity of the Antelope Valley Basin (Basin 6-44). The average yield of wells in the South AFRL CZ is compared to the average yield for wells in the Basin. A case is made that the percent of the total capacity represented by the South AFRL CZ, and the loss of well yield, are not significant and do not "cause a substantial decline in the overall yield, storage, or transport capacity of a ground water basin."
12	H.3.b.	Evaluation of potentially significant impacts to water quality, human health, and the environment, shall take into consideration the following, as applicable to the specific factual situation:	Provide information to evaluate potentially significant impacts to water quality. human health, and the environment, and to consider the specific factual situations listed under Relevant Citation below:	Section 2.5.5 presents exposure pathways and Section 2.7 presents results of a human health risk assessment (HHRA) and an ecological risk assessment (ERA); Section 2.6 presents information useful in determining the potential significance of a CZ designation to water resources.
13	H.3.b.1	The physical and chemical characteristics of the discharge, including its potential for migration;		Sections 2.2.2 and 2.2.3 present a description of the sites and summary of investigation activities. Section 2.5 gives the site characteristics including identification of chemicals of concern (2.5.1), environmental setting (2.5.2), contaminant nature and extent (2.5.4), conceptual site models (2.5.6), and results of computer-based modeling simulations of groundwater flow and contaminant transport (2.5.7).
14	H.3.b.2	The hydrogeological characteristics of the site and surrounding land;		Sections 2.5.2 (environmental setting), 2.5.3 (South AFRL features), and 2.6 (current and potential future land and resource uses).
15	H.3.b.3	The quantity of ground water and surface water and the direction of ground water flow;		Sections 2.5.2.2 and 2.6.
16	H.3.b.4	The proximity and withdrawal rates of ground water users.		The proximity of potable water supply wells is addressed in Section 2.1 and 2.5.2.2. The withdrawal rate for the Antelope Valley Basin and estimated storage capacity at the South AFRL are discussed in Section 2.6.
17	H.3.b.5	The patterns of rainfall in the region and the proximity of the site to surface waters;		Rainfall discussed in Section 2.5.2; surface water at the end of Section 2.6.
18	H.3.b.6.	The present and probable future uses of ground water and surface water in the area;		Section 2.6.
19	H.3.b.7.	The existing quality of ground water and surface water, including other sources of pollution and their cumulative impact on water quality;		An evaluation of South AFRL CZ as a potential drinking water source is included in Section 2.5.2.2.
20	H.3.b.8	The potential for health impacts caused by human exposure to waste constituents;		Section 2.7.1 and Appendix B-1 present results of the HHRA and a re-evaluation of risk via the VIP.
21	H.3.b.9.	The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents;		Section 2.7.2 presents results of the ERA.
22	H.3.b.10	The persistence and permanence of any potential adverse effects;		Potential long-term impacts to groundwater quality are presented on Table 2.10-2.

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23	H.3.b.11	Exposure to human or other biological receptors from the aggregate of hazardous constituents in the environment;		Cumulative risks from site contaminants considered as part of the HHRA (Section 2.7.1) and ERA (Section 2.7.2).
24	H.3.b.12	The potential for the pollutants to attenuate or degrade and the nature of the breakdown products;		Briefly discussed in Section 2.5.4 Contaminant Nature and Extent.
25	H.3.b.13	Potential adverse effects on approved local development plans, including plans approved by redevelopment agencies or the California Coastal Commission.		Not applicable to this federal facility.
26	H.3.c	No provision of this Policy shall be interpreted to allow exposure levels of constituents of concern that could have a significant adverse effect on human health or the environment;	Determine whether there would be exposure levels of constituents of concern that could have a significant adverse effect on human health or the environment;	Section 2.13.4 presents the expected outcome of the selected remedy. The intent is to keep risk in the acceptable range by maintaining the current incomplete exposure pathways.
27	H.3.d	A containment zone shall not be designated in a critical recharge area. A critical recharge area is an artificial recharge area or an area determined by the Regional Water Board to be a critical recharge area after the consultation process required by Section III.H.9. Further a containment zone shall not be designated if it would be inconsistent with a local ground water management plan developed pursuant to Part 2.75 of Division 6 of the WC (commencing at Section 10750) or other provisions of law or court order, judgment or decree.	Determine whether the containment zone is in a critical recharge area after following the consultation process required by Section III.H.9 or is inconsistent with a local ground water management plan developed pursuant to Part 2.75 of Division 6 of the WC (commencing at Section 10750) or other provisions of law or court order, judgment or decree;	Section 2.5.2 presents information that should be considered for this determination.
28	H.8	The Regional Water Board shall comply with the following public participation requirements, in addition to any other legal requirements for notice and public participation, prior to the designation of a containment zone; a. Public notice of an intention to designate a containment zone shall be provided to all known interested persons, including the owner of the affected property(s), owners and residents of properties adjacent to the containment zone, and agencies identified in Section III.H.9, at least 45 days prior to the proposed designation of a containment zone; b. Interested persons shall be given the opportunity to review the application, including the proposed management plan, and any other available materials and to comment on any proposed designation of a containment zone. These materials, which contain information upon which the proposed designation of a containment zone is based, must be available for review at least 45 days prior to the proposed designation of a containment zone; c. The proposed designation of a containment zone shall be placed on the agenda for consideration at a Regional Water Board meeting;	See relevant citation.	Sections 2.3 and 3.0 of the ROD describe how the Air Force solicited public participation in reviewing the preferred alternative presented in the South AFRL Proposed Plan. a. The Water Board posted Public Notice by 15 July 2007 (in the Antelope Valley Press and Ridgecrest Daily Independent), 45 days in advance of its Board meeting on 29-30 August 2007, that it was considering the Air Force's proposal (with USEPA concurrence) to designate the South AFRL CZ. b. The Proposed Plan, which included a public comment period from 7 April to 13 May 2006, publicized the availability of documents, including the Management Plan, that are available for public review in the Administrative Record file for OU4 and OU9 found at Edwards AFB (95th Air Base Wing, Environmental Management Division, 5 East Popson Avenue, Building 2650A). This information is also in Section 1.2 of the South AFRL ROD. c. The proposed designation of the South AFRL CZ was on the agenda and considered in a Regional Board meeting held in Lancaster CA on 29-30 August 2007.

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29	H.9	At least 45 days prior to the proposed designation of a containment zone, the Regional Water Board shall invite a technical advisory committee to review any proposed designation and shall meet as a committee at the request of any committee member. The committee or any committee member shall provide advice to the Regional Water Board as to the appropriateness of the requested designation and such designation will become part of the public record. No person or agency shall be made a member of the committee who is employed by or has a financial interest with the discharger seeking the designation. The following agencies shall be invited to participate in the advisory committee: a. The California Department of Toxic Substances Control; b. The California Department of Health Services, Drinking Water Branch; c. The California Department of Fish and Game; d. The local health authority; e. The local water purveyor, in the event ground water is used or planned to be used as a source of water supply; f. Any local ground water management agency including an appointed water master; g. The United States Environmental Protection Agency; and h. The California Coastal Commission if the site is located within the coastal zone of California.	Invite a technical advisory committee comprised of the following to review any proposed designation and meet at the request of any member: ■ CA DTSC ■ CA DHS, DWB ■ CA DFG ■ Local Health Authority (KCEHSD) ■ Local Water Purveyor ■ Local ground water management agency and/or water master ■ US EPA	The CA DTSC (listed in Item a) and USEPA (listed in Item g) are signatories to the Federal Facility Agreement for the CERCLA cleanup action at Edwards AFB and as such have reviewed all relevant documents leading to the evaluation, recommendation, and selection of the proposed remedy incorporating designation of at TI waiver in the proposed South AFRL CZ. The CA DHS, DWB; CA DFG; and KCEHSD concur with the CZ designation. The Air Force is the local water purveyor of groundwater extracted on base. Review of the Proposed Plan by a local ground water management agency or water master is not applicable at this time.
30	H.10	The Regional Water Boards shall keep a master listing of all designated containment zones. The master listing shall describe the location and physical boundaries of the containment zone, the pollutants which exceed applicable water quality objectives, and any land use controls associated with the containment zone designation. The Regional Water Board shall forward the information on the master list to the State Water Board and to the local well permitting agency whenever a new containment zone is designated. The State Water Board will compile the lists from the Regional Water Boards into a comprehensive master list;	Keep a master listing of all designated containment zones describing the location and physical boundaries of the containment zone, the pollutants which exceed applicable water quality objectives, and any land use controls associated with the containment zone designation.	Upon final signature of the South AFRL ROD, the Regional Water Board will forward the required information regarding the South AFRL CZ to the State Water Resources Control Board for inclusion on the Master List.

TABLE E-2. SUMMARY OF IN SITU TECHNOLOGIES TESTED AT EDWARDS AFB

Site	Technology	Geology and Hydrogeology	Extent of Contamination	Treatment Area	Target Contaminants	Test Objectives	Test Implementation	Results	Current Status	Report Title
OU1										
18	**Chemical Oxidation** - Sodium Persulfate	Alluvium overlies weathered and competent bedrock. Alluvium is typically 5 to 10 feet thick and is composed of mainly sand and gravel with occasional silt and clay layers. Weathered bedrock in the pilot study area is approximately 25 feet bgs. Depth to static groundwater in the pilot study area is expected to be approximately 30 feet bgs. Groundwater flow is generally to the west with an average gradient of 0.0048 ft/ft.	TCE concentrations of >1,000 μg/L encompass the area from Wolfe Avenue to just east of Taxiway E. TCE concentrations of >10,000 μg/L exist within and immediately down gradient of the pilot study area.	Two injection wells and up to eight monitoring wells, three of which will be screened at multiple intervals.	*Groundwater:* TCE (max 13,000 μg/L), 1,1,1-TCA (18 μg/L), 1,1-DCE (35 μg/L), 1,1-DCA (84 μg/L), benzene (58 μg/L), and TBA (220 μg/L) in April and May 2006, and 1,4-dioxane (100 μg/L) in July 2004. *Soil:* 1,1,1-TCA (max 12,000 mg/kg) in December 1997.	Evaluate effectiveness of technique to directly oxidize organic contaminants. Determine reduction in contaminant concentrations, radius of influence, down gradient migration and decomposition of reagent, and effects on groundwater quality. Optimize injection technique	Under Construction	NA	Rock coring of one of the proposed injection wells was performed February 12 through 15, 2007 and rock cores, along with groundwater from the pilot study area, were shipped to laboratories to determine total oxidant demand, which will be used to determine oxidant dosing.	*Site 18 In Situ Chemical Oxidation Treatability Study Work Plan, Main Base Flightline, Operable Unit, Draft* (Earth Tech 2007)
19	**Bioenhanced In-Well Vapor Stripping (BEHIVS) system**	Alluvium is typically 40- to 50-feet thick, composed of alluvial fan deposits interbedded with fine-grained lacustrine sediments and overlies weathered and competent biotite-granitic bedrock. Groundwater occurs 28 to 30.5 feet bgs and flows southeast. A semi-confining layer is hypothesized to exist separating the aquifer at Site 19 into an upper and lower zone.	The Site 19 Groundwater Plume is located east of Taxiway E and south of Taxiway D near the Egress and Environmental Control Shop (ECS) Facility, which includes Building 1928. This plume extends for more than 0.5-mile east-west and 0.3-mile north-south through the Storm water Retention Pond. TCE concentrations of >1,000 mg/L occur throughout the active treatment area.	Active treatment area contains three treatment wells and is approximately 140 feet long by 105 feet wide. A monitored region of approximately 185 feet long by 160 feet wide encloses the active treatment area and includes 48 groundwater monitoring wells.	*Groundwater:* TCE (max 8,273 μg/L), cis 1,2 DCE (max 66 μg/L), and 1,1-DCE (max 35 μg/L). *Soil:* No observed contamination.	Evaluate the effectiveness of using in-well vapor stripping in combination with cometabolic bioremediation to reduce the mass of TCE in groundwater.	From 12 August 2001 to 26 January 2002 the BEHIVS system, consisting of an up gradient vapor stripping well used to reduce the TCE source concentrations (ranging from 3,700 to 8,300 μg/L) below 400 μg/L and two biotreatment wells 25 feet down gradient, acting as polishers, were operational. An automated sampling system (Automated Sampling and Analysis Platform [ASAP]) was used to monitor upper and lower zones of the aquifer via the groundwater monitoring wells.	**TCE:** Overall concentrations of TCE within the treatment area decreased by 60% (1,276 μg/L to 506 μg/L) in the upper aquifer, and by 90% (5,089 μg/L to 518 μg/L) in the lower aquifer after 140 days of BEHIVS treatment. Overall concentrations of TCE within the monitored area decreased by 40% (1,236 μg/L to 760 μg/L) in the upper aquifer, and by 70% (4,611 μg/L to 1,398 μg/L) in the lower aquifer after 140 days of BEHIVS treatment. **Effectiveness:** Rebound studies conducted over a 4 ½-month period after discontinuing BEHIVS operation indicated that sources of TCE exist in the lower aquifer along a northwest-southeast axis through the center of the BEHIVS site. Here, rebound brought TCE concentrations up to near pre-operational levels within 3 ½-months after BEHIVS operations were suspended; however, TCE concentrations did not rebound as high throughout the entire treatment and monitoring area.	The Site 19 BEHIVS system is not operational at this time. The in-well vapor stripping and cometabolic bioremediation systems ran until January 26, 2002, and the well field was monitored until June 2002 to measure TCE-rebound levels.	*Operable Unit No. 1 Groundwater Monitoring and Sampling Report for 2001* (Earth Tech 2002), *Operation and Analysis of the BEHIVS System at Edwards Air Force Base* (Stanford University 2002), and the *Site 19 Technology Evaluation Report BEHIVS System,* (Earth Tech 2003).

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Site	Technology	Geology and Hydrogeology	Extent of Contamination	Treatment Area	Target Contaminants	Test Objectives	Test Implementation	Results	Current Status	Report Title
19	**Bioremediation** - Whey Powder	Alluvium is typically 40- to 50-feet thick, composed of alluvial fan deposits interbedded with fine-grained lacustrine sediments and overlies weathered and competent biotite-granitic bedrock. Groundwater occurs 28 to 30.5 feet bgs and flows southeast. A semi-confining layer is hypothesized to exist separating the aquifer at Site 19 into an upper and lower zone.	The Site 19 Groundwater Plume is located east of Taxiway E and south of Taxiway D near the Egress and Environmental Control Shop (ECS) Facility, which includes Building 1928. This plume extends for more than 0.5-mile east-west and 0.3-mile north-south through the Stormwater Retention Pond. TCE concentrations of >1,000 mg/L occur throughout the active treatment area.	Site 19 source area; Deep aquifer zone only.	*Groundwater:* TCE (max 7,000 µg/L), and cis-1,2-DCE (max 50 µg/L). *Soil:* No observed contamination.	Stimulate natural biologic activity with nutrient source for the anaerobic reductive dechlorination of TCE. Evaluate electron donor dosage, decomposition rates, radii of influence, contaminant reduction, and design parameters for possible scale up.	Four injections have been completed at different concentrations. TCE degradation has been significant near and up to 56 feet down gradient of the injection well. Degradation beyond cis-1,2 dichloroethylene has been limited. Vinyl Chloride has been detected, but at very low levels. Next step is to inoculate the wells with dehalococcoides (DHC) to evaluate further degradation.	TCE has been reduced from greater than 4500 ppb to near the detection limit. Cis-1,2-DCE has increased significantly. Vinyl Chloride levels are below detection limits and as of October 2006 and there has not been clear evidence of subsequent reduction in cis-1,2-DCE concentrations. Dechlorination is observed up to 56 feet from the injection well. Upcoming fieldwork at this site includes bioaugmentation, using a commercial bacterial culture (KB-1), which has been proven to have the ability to completely reduce cis-1,2-DCE to ethene.	First phase of TS complete, bioaugmentation and additional whey powder injections in progress	*Site 19 In Situ Bioremediation Treatability Study Report Main Base Flightline Operable Unit 1* (Earth Tech 2006)
20	**Chemical Oxidation** - Sodium Persulfate	Alluvium overlies weathered and competent bedrock. Alluvium is typically 5 to 10 feet thick and is composed of mainly sand and gravel with occasional silt and clay layers. Weathered bedrock in the western portion of the site is less than 5 feet bgs, increasing to approximately 25 feet bgs towards the east. Depth to static groundwater ranges from approximately 4 feet to 25 feet. Groundwater flow is generally to the east-northeast with an average gradient of 0.01 ft/ft.	TCE concentrations of >1,000 µg/L encompass the area from Wolfe Avenue to just east of Taxiway E. TCE concentrations of >10,000 µg/L exist predominantly between the treatment compound and Taxiway E.	One injection well and nine monitoring wells.	*Groundwater:* TCE (max 230,000 µg/L), cis-1,2-DCE (max 32,000 µg/L), 1,1,1-TCA (max 41,000 µg/L), 1,1-DCE (max 31,000 µg/L) and BTEX (max 39,000, 64,500, 15,000, and 62,600 µg/L, respectively). *Soil:* 1,1,1-TCA (max 12,000 mg/kg) and BTEX (max 8.4, 134.1, 42.68, and 280.5 mg/kg, respectively). Concentrations are historical maximums.	Evaluate effectiveness of technique to directly oxidize organic contaminants. Determine reduction in contaminant concentrations, radius of influence, down gradient migration and decomposition of reagent, and effects on groundwater quality. Optimize injection technique.	Under Construction	NA	Under Construction	Work Plan

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Site	Technology	Geology and Hydrogeology	Extent of Contamination	Treatment Area	Target Contaminants	Test Objectives	Test Implementation	Results	Current Status	Report Title
OU2										
5	**Chemical Oxidation** - Alkaline-activated Sodium Persulfate	Alluvial deposits overlying bedrock. Silty and clayey sands at the capillary fringe and upper portion of the saturated zone. Depth to groundwater is approximately 50 to 55 feet bgs. Static groundwater flow is generally east south east at a gradient of 0.01 ft/ft.	Site 5 is the source area of the Sites 5/14 Contaminant Plume, a 5,600 feet long commingled fuel and solvent plume. Contamination at Site 5 includes floating free-product (one well and dissolved-phase fuels and solvents in the upper 10 feet of the aquifer.	Immediate vicinity of one well that contains a thin layer of floating free-product and from a few feet above and below the water table.	Residual floating free-product.	Evaluate the efficacy of alkaline-activated sodium persulfate, either alone or in conjunction with air sparging, to eliminate residual floating free-product at the Site 5.	Following activities are planned. Inject alkaline activated persulfate mixture into one well with floating free-product followed by 1-month of monitoring. If product still present, a second injection will occur followed by 1 to 2 months of air sparging and monitoring	Field work planned for summer/fall 2007.	Field work planned for summer/fall 2007.	TSWP currently being prepared.
5	**Aerobic Bioremediation** - PHOSter Technology	Alluvial deposits overlying bedrock. Silty and clayey sands at the capillary fringe and upper portion of the saturated zone. Depth to groundwater is approximately 50 to 55 feet bgs. Static groundwater flow is generally east south east at a gradient of 0.01 ft/ft.	Site 5 is the source area of the Sites 5/14 Contaminant Plume, a 5,600 feet long commingled fuel and solvent plume. Contamination at Site 5 included floating free-product (two wells at start of pilot tests) and dissolved-phase fuels and solvents in the upper 10 feet of the aquifer.	Approximately 45 feet ROI (based on pilot test results) by 10 feet deep.	Thin layer of floating free-product and dissolved-phase fuels (TEPH 34 mg/L, benzene 34 μg/L, xylenes 570 μg/L) and solvents (TCE 18 μg/L, cis-1,2-DCE 28 μg/L).	Evaluate the efficacy of the PHOSter technology for treating residual floating free-product and dissolved-phase fuels and solvents.	Two pilot tests during which a mixture of gaseous mixture of air, methane, and nutrients (triethyl phosphate and nitrous oxide) were injected into the aquifer. The first 3-month pilot test (April to July 2005) including injecting through two injection wells at total average flow rates of 1.8 and 3.6 scfm. Monitoring and sampling was performed at ten monitoring wells. The second 4-month pilot test (May to September 2006) including injecting through one injection well at a total average flow rate of 5.1 scfm. Monitoring and sampling was performed at four monitoring wells.	**DO:** Concentrations increased at monitoring wells located within 25 feet of the injection wells, with final concentrations between 4 and 8 mg/L. **Free-product:** During 1st pilot test, thickness decreased from a sheen to undetected in one well, and from 2.40 feet to 0.85 feet in another. No rebound occurred over a 10-month period between the 1st and 2nd pilot tests. During the 2nd pilot test, no additional reduction in thickness occurred. **Dissolved-phase:** TEPH, BTEX, and cis-1,2-DCE reduced 47%, 81%, and 84%, respectively. Cis-1,2-DCE reduced to below MCL. No apparent reduction in TCE. **ROI:** Based on changes in DO concentration, ROI was estimated at between 25 and 48 feet. Based on changes in dissolved-phase concentrations, ROI was estimated to be greater than 48 feet.	Treatability study completed	*Site 5/14 Contaminant Plume PHOSter Treatability Study Report, OU2, South Base* (Earth Tech 2007).

TABLE E-2. SUMMARY OF IN SITU TECHNOLOGIES TESTED AT EDWARDS AFB

Site	Technology	Geology and Hydrogeology	Extent of Contamination	Treatment Area	Target Contaminants	Test Objectives	Test Implementation	Results	Current Status	Report Title
14	**Aerobic Bioremediation** - PHOSter Technology	Alluvial deposits overlying bedrock. Silty and clayey sands at the capillary fringe and upper portion of the saturated zone. Depth to groundwater is approximately 50 to 55 feet bgs. Static groundwater flow is generally east south east at a gradient of 0.01 ft/ft.	Site 14 is located at the leading edge of the Sites 5/14 Contaminant Plume, a 5,600 feet long commingled fuel and solvent plume that originates at Site 5 (the source area). Contamination at Site 14 is limited to dissolved-phase TCE in the upper 10 feet of the aquifer.	Approximately 50 feet ROI (based on pilot test results) by 10 feet deep.	TCE (max 600 μg/L).	Evaluate the efficacy of the PHOSter technology for reducing dissolved-phase TCE to below the MCL.	Three month pilot test (August to November 2005). A gaseous mixture of air, methane, and nutrients (triethyl phosphate and nitrous oxide) were injected into the aquifer through one injection well at a total average flow rate of 2.9 scfm. Monitoring and sampling was performed at six monitoring wells.	**DO:** Concentrations increased at all monitoring wells located within 45 feet of the injection well, with final concentrations between 6 and 8 mg/L. **Microbial:** At all monitoring wells located within 45 feet of the injection well, the biomass of target microbial groups increased by 1 to 2 orders of magnitude. **TCE:** Concentrations decreased by an average of 92%at the 4 monitoring wells located within 45 feet of the injection well, and to below the MCL in the well closest to the injection well. **ROI:** Greater than 44 feet but less than 154 feet based on increase in DO concentrations and microbial biomass increase, reduction in TCE concentrations.	Treatability Study Completed	Site 5/14 Contaminant Plume PHOSter Treatability Study Report, OU2, South Base (Earth Tech 2007).
5/14	**Chemical Oxidation** - Potassium Permanganate ($KMnO_4$)	Alluvial deposits overlying bedrock. Silty and clayey sands at the capillary fringe and upper portion of the saturated zone. Depth to groundwater is approximately 50 to 55 feet bgs. Static groundwater flow is generally east south east at a gradient of 0.01 ft/ft.	Site 14 is located at the leading edge of the Sites 5/14 Contaminant Plume, a 5,600 feet long commingled fuel and solvent plume that originates at Site 5. Contamination at Site 14 is limited to dissolved-phase TCE in the upper 10 feet of the aquifer.	Target area is 400 feet long by 700 feet wide by 10 feet deep.	TCE (max 500 μg/L).	Evaluate the efficacy of $KMnO_4$ for reducing dissolved-phase TCE concentration to below MCL at the Sites 5/14 Contaminant Plume. Evaluate the efficacy and performance of a horizontal well for use as an ISCO injection well at the Sites 5/14 Contaminant Plume.	Following activities are planned as specified in the TSWP. Perform bench scale test to determine soil oxidant demand. Install 1 horizontal well, 700 feet long screen at approximately 53 feet bgs. Install 10 groundwater monitoring wells. Inject up to 24,000 gallons of 3% KMnO4 solution during one injection event. Perform groundwater monitoring and sampling for a period of 12-months following injection operations.	Well installation and injection operations planned for March to May 2007. Monitoring and sampling through May 2008 (12-month period after injection operations).	Well installation and injection operations planned for March to May 2007. Monitoring and sampling through May 2008 (1-year period after injection operations).	*Site 5/14 Contaminant Plume In Situ Chemical Oxidation Treatability Study Work Plan, OU2, South Base* (Earth Tech 2007).

TABLE E-2. SUMMARY OF IN SITU TECHNOLOGIES TESTED AT EDWARDS AFB

Site	Technology	Geology and Hydrogeology	Extent of Contamination	Treatment Area	Target Contaminants	Test Objectives	Test Implementation	Results	Current Status	Report Title
OU4/9										
37	**Fractured Bedrock Zone**	Subsurface geology at the site is characterized by quartz monzonite overlain by thin, unconsolidated eluvium. Bedrock is encountered from 1 foot to 25 feet. The weathered zone ranges from 0 feet to at least 149 feet thick. Groundwater occurs under pressure in fractures within the competent granitic bedrock at depths ranging from 24 feet to 266 feet. Static water levels range from 21 feet to 135 feet bgs and groundwater generally flows to the south-southwest.	Chemicals of concern at the site include eight VOCs including PCE, 1,4-Dioxane, N-nitrosodimethylamine, and perchlorate.	The FBZ encompasses an area approximately 50 feet by 80 feet. The blast depths ranged from 50 to 143 feet bgs.	Eight VOCs including PCE, 1,4-Dioxane, N-nitrosodimethylamine, and perchlorate.	Evaluate the ability of an FBZ to increase aquifer yield in the low permeability water-producing zone(s) at Site 37. Assess the long-term sustainability of increased extraction yield. Evaluate the feasibility of blast fracturing for use in a large-scale design and/or at other sites to increase groundwater yields and/or the ability to enhance delivery of treatment components to the aquifer.	Northern FBZ - Boreholes were drilled in a "Y" pattern to depths ranging from 139 feet to 146 feet bgs. Blasting occurred at depths ranging from 50 to 143 feet bgs. Pumping from the central extraction well (37-EW09) occurred in the summer and fall of 2006. Southern FBZ - Boreholes were drilled within a 5-foot by 10-foot area to depths ranging from 67 feet to 145 feet bgs. Blasting occurred at depths ranging from 75 feet to 144 feet bgs. Pumping from the central extraction well (37-EW10) began at the end of 2006 and is in progress.	Based on results from two long-term pumping tests, installation of the FBZ did not meet the objective of increasing sustainable yields. Extraction wells located inside the Northern FBZ and Southern FBZ were observed to have sustainable yields of 0.02 gpm and 0.12 gpm, respectively. Moreover, the quantity of explosives detonated to create the FBZ caused vibrations in excess of limits recommended by the AFRL Safety Office as protective to underground utilities and building foundations.	Continuing to monitoring groundwater recovery following conclusion of a long-term pumping test in the Southern FBZ. A TSER is to be submitted in September 2007 summarizing the results of the pumping tests conducted in the FBZ area.	*Summary of Field Activities and Initial Results, Phase I/II Fractured Bedrock Zone Installation, Site 37*, (Earth Tech 2006).
162	**Bioremediation** - Edible Oil Substrate	Alluvium is typically 25 to 45 feet thick, composed of sand with low percentages of gravel, clay, and silt and overlies weathered and competent quartz monzonite bedrock. Groundwater occurs between 2,744 feet and 2,747 feet above mean sea level. The hydraulic gradient is approximately 0.05 ft/ft and the local groundwater flow direction is to the southwest.	Alluvium is typically 25 to 45 feet thick, composed of sand with low percentages of gravel, clay, and silt and overlies weathered and competent quartz monzonite bedrock. Groundwater occurs between 2,744 feet and 2,747 feet above mean sea level. The hydraulic gradient is approximately 0.05 feet per foot and the local groundwater flow direction is to the southwest.	Three injection wells and nine monitoring wells (2 up gradient and 7 down gradient), 10-foot screened interval.	Groundwater: PCE (600 μg/L) and TCE (55 μg/L) in July 2004.	Stimulate anaerobic reductive dechlorination via a permeable bioreactive barrier to degrade PCE. Evaluate barrier dimensions achieved, electron donor longevity, and effectiveness of native microbial population to completely degrade PCE.	One injection of EOS® into three injection wells was completed in December 2005, followed by bi-monthly monitoring of the three injection wells and nine monitoring wells for a period of 11 months. Analyses included both standard laboratory analytes as well as microbial DNA analysis.	At the end of the monitoring period, reduction of PCE had been achieved to varying extents in most of the down gradient monitoring wells. However, the reduction stalled at cis-1,2-DCE. These results are currently being evaluated to determine the best course of action, which may include another injection of EOS® and/or bioaugmentation.	In Progress	*Site 162 and Site 177/2325 In Situ Bioremediation Treatability Study Work Plan, Air Force Research Laboratory, Operable Units 4 and 9, Edwards AFB* (Earth Tech 2005)
177/ 325	**Bioremediation** - Hydrogen Release Compound	Alluvium is typically 25 to 45 feet thick, composed of sand with low percentages of gravel, clay, and silt and overlies weathered and competent quartz monzonite bedrock. Groundwater occurs between 85 feet and 90 feet bgs. The hydraulic gradient is approximately 0.05 ft/ft and the local groundwater flow direction is to the southwest.	Plumes from Site 177 and Site 325 have commingled and now extends from Site 177 through Site 325 to the north.	Three injection wells and six monitoring wells (one up gradient and five down gradient).	*Groundwater:* PCE (1,000 μg/L), TCE (1,100 μg/L), and perchlorate (720 μg/L) in July 2004)	Stimulate anaerobic reductive dechlorination via a permeable bioreactive barrier to degrade PCE. Evaluate barrier dimensions achieved, electron donor longevity, and effectiveness of native microbial population to completely degrade PCE.	One injection of HRC® was performed in November 2005, followed by 11 months of bi-monthly monitoring of one of the injection wells and all six monitoring wells. (Due to the high viscosity of the HRC®, two of the three injection wells were unable to be sampled after injection.) Analyses included both standard laboratory analytes as well as microbial DNA analysis.	At the end of the monitoring period, significant reduction of PCE and TCE had been achieved in all down gradient wells and a corresponding increase in cis-1,2-DCE. Contamination at the site began to rebound after the fifth month following injection. Perchlorate was reduced to levels below the detection limit by the first post-injection sampling round, but concentrations were beginning to rebound by the end of the monitoring period as electron donor was depleted. These results are currently being evaluated to determine the best course of action, which may include installation of additional wells, another injection of HRC®, and/or bioaugmentation.	In Progress	*Site 162 and Site 177/2325 In Situ Bioremediation Treatability Study Work Plan, Air Force Research Laboratory, Operable Units 44 and 9, Edwards AFB, CA*, (Earth Tech 2005)

TABLE E-2. SUMMARY OF IN SITU TECHNOLOGIES TESTED AT EDWARDS AFB

Site	Technology	Geology and Hydrogeology	Extent of Contamination	Treatment Area	Target Contaminants	Test Objectives	Test Implementation	Results	Current Status	Report Title
OU5										
207 (N3)	**Chemical Oxidation** - Fenton's reagent (patented by ISOTEC) and persulfate	Granitic bedrock with surface weathering and localized fractures is overlain by 5 feet of silty sand. Groundwater occurs between 5 feet to 12 feet bgs and flows east.	The Site N3 groundwater plume is located in the northwestern portion of Dryden and consists of the Former Gas Station, Buildings 4803, 4886, and 4889 as well as the Former Drum Dispensing Area. Three underground storage tanks (USTs) were removed from under the Former Gas Station in 1991. An open-concrete lined drainage ditch runs north to south along the western boundary of the site and east of Forbes Avenue just north and west of the Former Gas Station. Outfall of the drainage ditch is the Southern Retention Pond.	Area 1 is 140 feet long by 100 feet wide by 100 feet deep and Area 2 is 80 feet long by 80 feet wide by 100 feet deep.	TCE (max 45,000 μg/L) and benzene (max 2,100 μg/L) in pre-injection samples.	Evaluate the effectiveness of Fenton-based reagents and persulfate in destroying TCE, DCE, BTEX, and carbon tetrachloride in groundwater and determine the most effective injection approach for the fractured bedrock geology at Site N3.	From June 2002 through August 2002 approximately 2,243 gallons of Fenton-based reagent was injected in three events via eight injection wells at depths of 15 to 100 feet bgs. Injection pressures were increased from an initial range of 0 to 30 psi to a range of 38 to 70 psi during the injection, while the hydrogen peroxide concentrations was reduced from 12% to 1% for the last two injection events. A second study was conducted between April and May 2003 in which approximately 1,908 gallons of Fenton-based reagent and 3,195 gallons of sodium persulfate were injected in two events via the eight injection wells.	**VOCs:** An overall decrease of 27% and 98% for TCE in monitoring and injection wells, respectively, was measured after completion of the first three injection events; however, the majority of well concentrations still exceeded the MCL of 5 μg/L. Benzene also was reduced by 99% overall in the injection wells, but increased overall by 30% in the monitoring wells. The subsequent two injection events resulted in TCE reduction of 24 percent in monitoring wells and 87% in injection wells. **ROI during Injection:** 10 feet to 60 feet.	Monitoring for rebound.	*Site N3 Treatability Study Work Plan In-Situ Chemical Oxidation, OU6, Final* (Earth Tech 2002). *NASA OU6 FS* (Earth Tech 2004).

TABLE E-2. SUMMARY OF IN SITU TECHNOLOGIES TESTED AT EDWARDS AFB

Site	Technology	Geology and Hydrogeology	Extent of Contamination	Treatment Area	Target Contaminants	Test Objectives	Test Implementation	Results	Current Status	Report Title
207 (N3) and 211 (N7)	**Chemical Oxidation** - Sodium Permanganate	Granitic bedrock with surface weathering and localized fractures. Depth to groundwater is approximately 10 feet. Groundwater flow is generally eastward.	Not Specified	Site N3 and N7 hotspots.	TCE (max 13,000 μg/L) and cis-1,2-DCE (max 1,000 μg/L) in pre-injection samples.	To perform source control by oxidizing contaminants of concern in situ by injecting sodium permanganate in Site N3 and N7 source areas. The second objective is to gather data to refine the approach for post Record of Decision remedial design including: (1)Evaluating the radial effects associated with the in situ application of the reagents by groundwater sampling and real-time monitoring of those samples for permanganate and (2) Determining the most effective injection approach for contaminant oxidation in fractured bedrock by varying injection rates and pressures.	From 21 Juneto 28 June 2005 and from 21 July to 28 July 2005, directly injected 16,707 gallons of sodium permanganate into 11 wells.	NA	Monitoring in progress	NA
211 (N7)	**Chemical Oxidation** - Potassium Permanganate	Granitic bedrock with surface weathering and localized fractures. Depth to groundwater is approximately 10 feet. Groundwater flow is generally eastward.	Not Specified	100 feet long by 50 feet wide and 100 feet deep (injection and monitoring area).	TCE (max 6,500 μg/L) and cis-1,2-DCE (max 710 μg/L) in pre-injection samples. Vinyl chloride is also present.	Evaluate effectiveness of technique to directly oxidize organic contaminants. Determine reduction in contaminant concentrations, radius of influence, down gradient migration and decomposition of permanganate reagent, and effects on groundwater quality. Optimize injection technique.	From 22 August to 25 August 2000, directly injected 7,450 gallons of potassium permanganate into 7 wells and 2 open boreholes. Monitored VOCs, metals, and permanganate concentrations in the 9 injection points and 2 monitoring wells at 5, 30 and 60 days following injection.	**VOCs:** Target contaminants in treatment area were reduced below detection limits (~ 3 μg/L) within 5 days after injection, and remained non detect through 60 days of monitoring. Acetone increased to maximum 3,000 μg/L following injection; attenuated to 160 μg/L after 60 days. Metals: Metal (and inorganic) concentrations increased following injection, but decreased to less than 80% of their post injection maxima with the exception of chromium and nickel (which are anticipated to also attenuate). **ROI during Injection:** Horizontal at least 30 to 55 feet, vertical at least 28 feet (based on mounding and visual observation of permanganate in monitoring points during injections). **Editor's note:** VOCs concentrations were reduced to non-detect in a larger area than the estimated ROI area.	Rebound of VOC concentrations by 2003 with permanganate concentrations remaining elevated.	*Site N7 Treatability Study Report, Permanganate In-Situ Chemical Oxidation* (Earth Tech 2000). *NASA OU6 FS* (Earth Tech 2004).

TABLE E-2. SUMMARY OF IN SITU TECHNOLOGIES TESTED AT EDWARDS AFB

Site	Technology	Geology and Hydrogeology	Extent of Contamination	Treatment Area	Target Contaminants	Test Objectives	Test Implementation	Results	Current Status	Report Title
OU7										
3	**Bioremediation** - Sodium Lactate	Alluvium overlies weathered and competent granitic bedrock with localized fractures. Alluvium in the area of the TS is approximately 20 feet thick and is composed mainly of silty sand, clayey sand, and clay. Depth to groundwater during drilling in the vicinity of the TS area was about 97 feet bgs, and static groundwater was about 65 feet bgs. Groundwater flow in the vicinity of the TS is inferred to be generally southward.	Study to focus on the TCE hotspot with expected concentrations in the range of 20 to 40 μg/L.	Study to focus on an approximately 70 foot long by 40 foot wide area centered at the TCE groundwater hot spot.	TCE (max 32 μg/L at TS area); cis-1,2-DCE (max 9.6 μg/L at TS area); PCE (max 5.3 μg/L at TS area); 1,1-DCA (max 8 μg/L at TS area); vinyl chloride (16 μg/L).	Evaluate the effectiveness of in situ enhanced biodegradation using sodium lactate and KB-1™ (Dehalococcoides bacteria) for treatment of PCE, TCE and/or other chlorinated solvents in groundwater. Estimate the mass, volume, concentration, and degradation rate of PCE and TCE using a closed-loop recirculation system. Provide recommendations for cost and operational data for system optimization of a larger scale system, if warranted.	Planning to implement in 2007. A conservative baseline tracer study using bromide is planned to evaluate the recirculation system behavior and the hydraulics within the treatability area. Once the hydraulic connectivity is established via the recirculation cells, approximately 70,000 mg/L (7%) food grade sodium lactate with fluoride tracer are planned to be injected via a recirculation cell for a period of 4 weeks, followed bioaugumentation with KB-1TM injection. If needed, lactate injection will be continued via the recirculation system during performance sampling of up to 5 monitoring wells.	NA	Study planned for 2007	NA

TABLE E-2. SUMMARY OF IN SITU TECHNOLOGIES TESTED AT EDWARDS AFB

Site	Technology	Geology and Hydrogeology	Extent of Contamination	Treatment Area	Target Contaminants	Test Objectives	Test Implementation	Results	Current Status	Report Title
OU8										
25	**Chemical Oxidation** - Fenton's Reagent and Potassium Permanganate (Geo-Cleanse International)	Groundwater occurs 20 to 42 feet bgs and flows east-southeast. Subsurface geology consists of unconsolidated surficial deposits overlying granitic bedrock.	Bench Scale Test	NA	TCE (max 49,000 μg/L)	Evaluate suitability of chemical oxidation for Site 25. Determine the reagent requirements for each oxidant. Evaluate Fenton's reagent for TCE destruction, bedrock reactivity, and acid demand. Determine oxidation efficiency of potassium permanganate.	On 20 December 1999, Geo-Cleanse International, Inc. conducted a bench-scale test of 17 experiments evaluating Fenton's reagent and potassium permanganate using groundwater and bedrock samples from Site 25 source area.	**VOCs:** Potassium permanganate is more effective than Fenton's reagent in complete destruction of TCE. Potassium permanganate destroyed 100% of the TCE in each experiment, while Fenton's reagent only reduced the TCE concentration by 51%. **Effectiveness:** The Fenton's reagent can treat high concentrations of TCE and has no bedrock reactivity or acid demand. However, Fenton's reagent is highly sensitive to the groundwater pH whereas the permanganate is less sensitive. Permanganate's longer half-life permits increased dispersal compared to Fenton's reagent, which reduces the quantity of reagent injected. **ROI during Injection:** Not available for bench-scale test.	Site N7 conducted a treatability study using potassium permanganate	*Site 25 Pilot Study and Bench-Scale Test Report* (Earth Tech 2003). *NASA OU6 FS* (Earth Tech 2004).
25	**Hydraulic Fracturing**	Groundwater occurs 20 to 42 feet bgs and flows east-southeast. Subsurface geology consists of unconsolidated surfical deposits overlying granitic bedrock.	Not Specified	Approximately 500 feet long by 400 feet wide by 300 feet deep.	TCE (max 77,000 μg/L). PCE (max 650 μg/L), 1,2-DCE (max 5,400 μg/L), and chloroform (max 1,600 μg/L) (Earth Tech 1999a).	Hydraulic fracturing is used to improve fracture interconnections, hydraulic conductivity, and areal extent of captured contaminated groundwater.	Three test fracturing wells, with total depths of 130 ft bgs to 300 ft bgs, were installed 40 to 50 feet apart to facilitate and record the hydraulic fracturing process. Fractures were initiated by direct injection under high pressure of fracturing fluid (water, polymer gel & friction minimizer) and proppant (20/40 Ottawa sand). Tiltmeter installation and tilt monitoring were used to measure the fracture azimuth, fracture dip and depth of fracture center. An array of 25 tiltmeters was installed at distances of 25 to 150 ft from the 3 test fracturing wells. Aquifer testing was conducted before and after hydraulic fracturing to determine the aquifer characteristics.	**Fractures:** New fractures were relatively shallow. Proppant concentrations were limited and minimally improved aquifer conductivity. Induced fractures caused no significant differences in the aquifer parameters. No significant improvement in conductivity or sustainable rate was observed. Hydraulic fracturing added no significant benefit over pumping from wells installed without fracture enhancement according to aquifer testing results. **ROI during Injection:** A minimal increase from 135 feet before fracturing to 140 feet after fracturing resulted. Since the test did not reach equilibrium conditions, the ROI may be greater for longer durations. Therefore, no significant improvement in the ROI was observed.	Pilot Study Completed	*Site 25 Pilot Study and Bench-Scale Test Report, OU8, Main Base Unconventional Fuels Storage Area* (Earth Tech 2003).

TABLE E-2. SUMMARY OF IN SITU TECHNOLOGIES TESTED AT EDWARDS AFB

Site	Technology	Geology and Hydrogeology	Extent of Contamination	Treatment Area	Target Contaminants	Test Objectives	Test Implementation	Results	Current Status	Report Title
301	**Bioremediation** - Sodium Lactate	Alluvium overlies weathered and competent granitic bedrock with localized fractures. Alluvium in the area of the TS is approximately 8 feet thick and is composed mainly of silty sand. Depth to static groundwater in the vicinity of the TS area is approximately 20 feet bgs. Groundwater flow in the vicinity of the TS is generally eastward.	Study to focus on the TCE hotspot with expected concentrations in the range of 100 to 200 μg/L. The entire TCE plume is approximately 2,200 feet long by 500 feet wide.	Study to focus on a 1,000 square foot area centered at the TCE groundwater hot spot.	TCE (max 140 μg/L at TS area); cis-1,2-DCE (max 12 μg/L at TS area); PCE (max 4.3 μg/L at TS area); 1,2-DCA (max 7 μg/L at TS area).	Evaluate the effectiveness of in situ enhanced biodegradation using sodium lactate and KB-1TM (Dehalococcoides bacteria) for treatment of TCE and/or other chlorinated solvents in groundwater. Estimate the mass, volume, concentration, and degradation rate of TCE. Provide recommendations for cost and operational data for system optimization of a larger scale system, if warranted.	Planning to implement in 2007. Approximately 2,400 to 4,800 gallons of 60,000 mg/L (6%) food grade sodium lactate are planned to be injected (by gravity) into one injection well over a period of 2 weeks, followed by bioaugumentation with KB-1 TM injection via the injection well. If needed, additional sodium lactate injections will be conducted during performance sampling of up to 5 monitoring wells. Approximately 480 to 960 gallons of 60,000 mg/L food grade sodium lactate will be injection into one injection well over a period of 2 days	NA	Study planned for 2007	NA

TABLE E-2. SUMMARY OF IN SITU TECHNOLOGIES TESTED AT EDWARDS AFB

Site	Technology	Geology and Hydrogeology	Extent of Contamination	Treatment Area	Target Contaminants	Test Objectives	Test Implementation	Results	Current Status	Report Title
OU5/10										
238	**Bioventing**	Site 238 is underlain by over 100 feet of unconsolidated alluvial sediments. The alluvial sediments, in turn, are underlain by a fractured quartz monzonite bedrock complex, which forms the gently sloping hills to the west and extends eastward at increasingly greater depths beneath Rogers Dry Lake. Groundwater flow at the site is generally to the northeast.	A 2,000 ft^3 area beneath former UST N010.	Approximately 6,000 ft^3 of soil beneath former UST N010.	Diesel Fuel (max 13,000 mg/kg)	Remove petroleum contamination from soil beneath former UST N010 using bioventing techniques.	Implementing bioventing technology at Site 238 will consist of installing, operating, and evaluating the performance of a bioventing system. Three existing wells (N010-BVW01, N010-VMW01, and N010-VMW03) with screened intervals close to contaminated areas will be used to inject ambient air into the subsurface at a flow rate of approximately 20 cubic feet per minute. By introducing air to the contaminated area, the oxygen level will increase causing an increase in microbial activity and decomposition of the petroleum-related contaminants.	NA (Work Plan only available document)	Study complete (January 2001 to July 2002)	Work Plan
282	**Bioremediation** - Sodium Lactate	Subsurface materials beneath this portion of Edwards AFB have been characterized as having been deposited in a lakeshore-type environment. Subsurface sedimentary materials include interbedded coarse alluvial deposits, which generally dip toward the dry lake bed, interfingered with playa and lacustrine deposits. Groundwater at the site flows to the east at an average depth of 125 feet bgs.		Area adjacent to the AOC 189 leachfield	Trichloroethene (TCE), carbon tetrachloride (CT), and perchlorate	Install and injection/recirculation system to deliver amendment and bioaugmented treated water to the saturated zone in order to create a reactive zone surrounding the injection well. Reactive conditions would degrade TCE, CT, and perchlorate to their respective transformation daughter products.	The installation of injection and extraction points to recirculate groundwater. Conduct a tracer test to assess connectivity, monitor groundwater, precondition the aquifer with carbon source/electron donor.	NA	Injection and bioaugmentation performed in April and October 2006. Performance monitoring is ongoing.	*Site 282 Enhanced Anaerobic* In Situ *Bioremediation Treatability Study Work Plan* (Earth Tech 2005)

TABLE E-2. SUMMARY OF IN SITU TECHNOLOGIES TESTED AT EDWARDS AFB

Site	Technology	Geology and Hydrogeology	Extent of Contamination	Treatment Area	Target Contaminants	Test Objectives	Test Implementation	Results	Current Status	Report Title
282	**Nanoscale Zero Valent Iron (NZVI)**	Subsurface materials beneath this portion of Edwards AFB have been characterized as having been deposited in a lakeshore-type environment. Subsurface sedimentary materials include interbedded coarse alluvial deposits, which generally dip toward the dry lake bed, interfingered with playa and lacustrine deposits. Groundwater at the site flows to the east at an average depth of 125 feet bgs.		Area adjacent to the AOC 189 leachfield	Trichloroethene (TCE) and carbon tetrachloride (CT)	Evaluate the use of nanoscale zero valent iron (NZVI) technology at Site 282 for treatment of contaminated groundwater.	Phase I included groundwater extraction through an existing monitoring well, addition of NZVI particles and a conservative tracer to the extracted groundwater, injection of the amended groundwater back into the well it was extracted from, and groundwater monitoring. Phase II included groundwater extraction through an existing well down gradient of the well used for NZVI injection during Phase I, addition of a tracer to the extracted groundwater, injection of the amended groundwater into the well used during Phase I, and groundwater monitoring.	The pilot study results demonstrate that NZVI can be used to effectively treat chlorinated solvents in groundwater within a limited radius of influence (ROI) proximal to the injection well. The results also clearly indicate that the mobility of NZVI, specifically, RNIP-10DS aged 3.5 months, is extremely limited in the saturated water table aquifer at the site as the pilot study failed to successfully distribute NZVI throughout the 25-foot-long treatment zone.		Final Summary Report (Earth Tech 2006)
285	**Bioremediation** - Sodium Lactate	Subsurface materials beneath this portion of Edwards AFB have been characterized as having been deposited in a lakeshore-type environment. Subsurface sedimentary materials include interbedded coarse alluvial deposits, which generally dip toward the dry lake bed, interfingered with playa and lacustrine deposits. Groundwater at the site flows to the east at an average depth of 125 feet bgs.		Area between and immediately surrounding Wells 196-MW01 (injection well), MW14 (extraction well), and MW17 (monitoring well).	Perchlorate	The overall TS objective is to determine if enhanced in situ anaerobic bioremediation is an effective remediation technology at Site 285.	At Site 285, the TS will include extracting contaminated groundwater from the aquifer, treating the groundwater utilizing ion exchange resin vessels, adding amendment and tracer compounds to the groundwater, injecting the groundwater back into the aquifer, and tracking tracer and perchlorate concentrations over the life of the study.	NA	In Progress	

TABLE E-2. SUMMARY OF IN SITU TECHNOLOGIES TESTED AT EDWARDS AFB

Site	Technology	Geology and Hydrogeology	Extent of Contamination	Treatment Area	Target Contaminants	Test Objectives	Test Implementation	Results	Current Status	Report Title
285	**Perchlorate Soil Flushing**	Subsurface materials beneath this portion of Edwards AFB have been characterized as having been deposited in a lakeshore-type environment. Subsurface sedimentary materials include interbedded coarse alluvial deposits, which generally dip toward the dry lake bed, interfingered with playa and lacustrine deposits. Groundwater at the site flows to the east at an average depth of 125 feet bgs.		25-foot diameter area of perchlorate contaminated soil.	Perchlorate	Use water (treated by the Site 285 GETS) to mobilize contaminants in the vadose zone via the "infiltration gallery", applying a hydraulic head to the perchlorate contaminated groundwater, and capturing it with an extraction well.		Soil flushing was successful in removing perchlorate form the vadose zone. Increased perchlorate concentrations in groundwater and decreased concentration in confirmation soil sampling indicate that contaminate was successfully mobilized. 50 lbs of perchlorate was removed form the soil at Site 285.	Study completed	Final Summary Report, December 2006

Notes:

%	percent
AFB	Air Force Base
ASAP	automated sampling and analysis platform
BEHIVS	Bioenhanced In-Well Vapor Stripping
Bgs	below ground surface
BTEX	benzne, toluene, ethylbenzene, xylenes
DCE	dichloroethene
DO	dissolved oxygen
ECS	Egress and Environmental Control Shop
EOS	Edible Oil Substrates
FBZ	Fractured Bedrock Zone
FS	Feasability Study
ft/ft	vertical feet per horizontal foot
GETS	Groundwater Extraction and Treatment System
HRC	Hydrogen Release Compound
MCL	maximum contaminant level
NA	not applicable
NZVI	Nanoscale Zero Valent Iron
PCE	tetrachloroethene
ROI	radius of influence
scfm	standard cubic feet per minute
TBA	tertiary-butyl alcohol
TCA	trichloroethane
TCE	trichloroethene
TEPH	total extractable petroleum hydrocarbons
TS	treatibility study
TSWP	treatibility study work plan
UST	underground storage tank
VOC	volatile organic compound

TABLE E-3. EDWARDS AIR FORCE BASE CONTRACTED GROUNDWATER STUDIES

USGS studies contracted by Base Civil Engineering:

U. S. Geological Survey Water-Resources Investigations Report 95-4114, Hydrology and Land Subsidence, Edwards Air Force Base, Antelope Valley, California, January 1989-December 1991.

U.S Geological Survey Open-File Report 93-148, Drilling, Construction, and Subsurface Data for Piezometers on Edwards Air Force Base, Antelope Valley, California, 1991-92.

U. S. Geological Survey Water-Resources Investigations Report 95-4131, Ground-Water-Level Monitoring, Basin Boundaries, and Potentiometric Surfaces of the Aquifer System at Edwards Air Force Base, California, 1992.

U.S Geological Survey Open-File Report 96-186, Time-Series Ground-Water-Level and Aquifer-System Compaction Data, Edwards air Force Base, Antelope Valley, California, January 1991 through September 1993.

USGS Water-Resources Investigations Report 00-4015, Aquifer-System Compaction and Land Subsidence: Measurements, Analysis, and Simulations-the Holly Site, Edwards Air Force Base, Antelope Valley, California.

USGS Water-Resources Investigations Report 01-4038, Numerical Stimulation of Ground-Water Flow and Land Subsidence at Edwards Air Force Base, Antelope Valley, California.

Earth Tech groundwater studies contracted by NASA Dryden:

Rogers Dry Lake groundwater study, part 1 1997 ($300K) – 10 boreholes drilled on Rogers Dry Lake to evaluate groundwater flow patterns. Groundwater samples were analyzed for tritium. Study showed that groundwater flowing away from Dryden does not encounter a groundwater divide, as had been proposed by the USGS.

Rogers Dry Lake groundwater study, part 2 1998 ($300K) – 4 wells installed on Rogers Dry Lake to evaluate groundwater flow patterns. Groundwater samples were analyzed for tritium and carbon-14 to determine the age of the water. This study confirmed that groundwater flowing away from Dryden does not encounter a groundwater divide, as has been proposed by the USGS. It also revealed that the groundwater is "old" (Pleistocene age = 1.8M-10K yr).

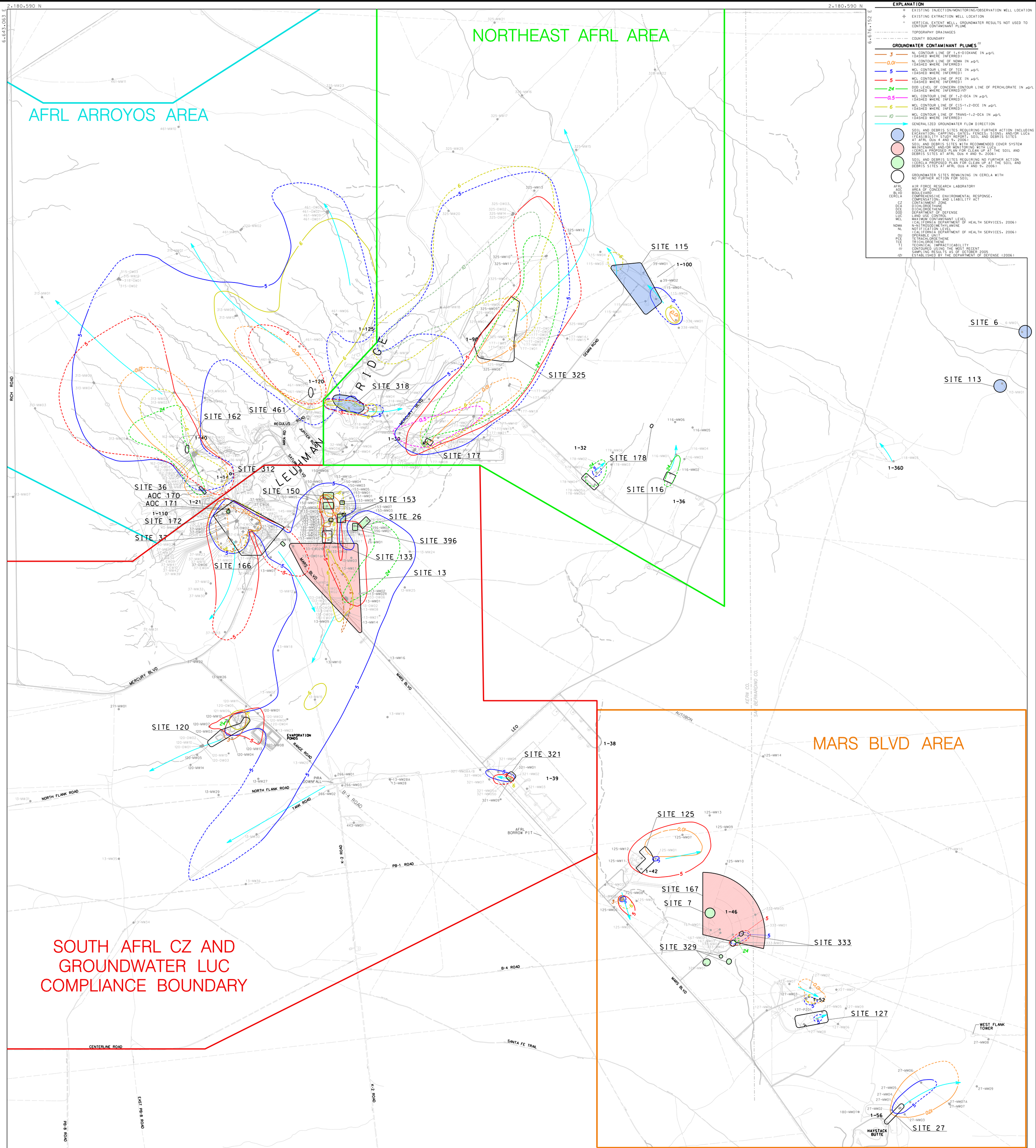
Earth Tech groundwater studies contracted by Environmental Management/Restoration:

North Muroc hydrogeologic investigation 1999 – 2000 (follow up investigation in 2003)($500K) –13 wells installed, including 7 sentinel wells along the northern base boundary, to better understand the regional groundwater flow pattern. Groundwater samples were analyzed for stable isotopes of carbon and hydrogen, carbon-14, and tritium to determine the age of the water, movement trends, recharge zones, and possible boundary conditions. Soil samples collected from four boreholes were analyzed for geotechnical parameters. A two-dimensional seismic survey was conducted across the inferred extension of the Muroc fault within the North Muroc study area. The data collected was used to develop and refine a regional groundwater flow and contaminant transport model for the North Base area.

Vadose zone infiltration study 2002 ($100K) – evaluated the potential of infiltration in the North Base area, also generally applicable to other arid areas with similar stratigraphy and rainfall. It concluded that under present climatic conditions natural precipitation will not reach groundwater at North Base, so contaminants in the unsaturated zone cannot be driven downward by natural precipitation infiltration to impact groundwater.

PLATE 1

SOIL AND DEBRIS SITES AND GROUNDWATER AREAS AT EDWARDS AFB OPERABLE UNITS 4 AND 9



EXPLANATION

- EXISTING INJECTION/MONITORING/OBSERVATION WELL LOCATION
- EXISTING EXTRACTION WELL LOCATION
- VERTICAL EXTENT WELL. GROUNDWATER RESULTS NOT USED TO CONTOUR CONTAMINANT PLUME
- TOPOGRAPHY DRAINAGES
- COUNTY BOUNDARY

GROUNDWATER CONTAMINANT PLUMES (1)

- 3 — NL CONTOUR LINE OF 1,4-DIOXANE IN µg/L (DASHED WHERE INFERRED)
- 0.01 — NL CONTOUR LINE OF NDMA IN µg/L (DASHED WHERE INFERRED)
- 5 — MCL CONTOUR LINE OF TCE IN µg/L (DASHED WHERE INFERRED)
- 5 — MCL CONTOUR LINE OF PCE IN µg/L (DASHED WHERE INFERRED)
- 24 — DOD LEVEL OF CONCERN CONTOUR LINE OF PERCHLORATE IN µg/L (DASHED WHERE INFERRED)(2)
- 0.5 — MCL CONTOUR LINE OF 1,2-DCA IN µg/L (DASHED WHERE INFERRED)
- 6 — MCL CONTOUR LINE OF CIS-1,2-DCE IN µg/L (DASHED WHERE INFERRED)
- 10 — MCL CONTOUR LINE OF TRANS-1,2-DCA IN µg/L (DASHED WHERE INFERRED)
- GENERALIZED GROUNDWATER FLOW DIRECTION
- SOIL AND DEBRIS SITES REQUIRING FURTHER ACTION INCLUDING EXCAVATION, CAPPING, GATES, FENCES, SIGNS, AND/OR LUCs (FEASIBILITY STUDY REPORT, SOIL AND DEBRIS SITES AT AFRL OUs 4 AND 9, 2006)
- SOIL AND DEBRIS SITES WITH RECOMMENDED COVER SYSTEM MAINTENANCE AND/OR MONITORING WITH LUCs (CERCLA PROPOSED PLAN FOR CLEAN UP AT THE SOIL AND DEBRIS SITES AT AFRL OUs 4 AND 9, 2006)
- SOIL AND DEBRIS SITES REQUIRING NO FURTHER ACTION (CERCLA PROPOSED PLAN FOR CLEAN UP AT THE SOIL AND DEBRIS SITES AT AFRL OUs 4 AND 9, 2006)
- GROUNDWATER SITES REMAINING IN CERCLA WITH NO FURTHER ACTION FOR SOIL

AFRL	AIR FORCE RESEARCH LABORATORY
AOC	AREA OF CONCERN
BLVD	BOULEVARD
CERCLA	COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT
CZ	CONTAINMENT ZONE
DCA	DICHLOROETHANE
DCE	DICHLOROETHENE
DOD	DEPARTMENT OF DEFENSE
LUC	LAND USE CONTROL
MCL	MAXIMUM CONTAMINANT LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES, 2006)
NDMA	N-NITROSODIMETHYLAMINE
NL	NOTIFICATION LEVEL (CALIFORNIA DEPARTMENT OF HEALTH SERVICES, 2006)
OU	OPERABLE UNIT
PCE	TETRACHLOROETHENE
TCE	TRICHLOROETHENE
TI	TECHNICAL IMPRACTICABILITY
(1)	CONTOURED USING THE MOST RECENT SAMPLING RESULTS AS OF OCTOBER 2005
(2)	ESTABLISHED BY THE DEPARTMENT OF DEFENSE (2006)

NORTH

1200 0 1200 2400 3600

SCALE IN FEET: 1" = 1200'
MAIN BASE AIRFIELD ELEVATION: 2302 FT.

SOUTH AFRL ROD

SOIL AND DEBRIS SITES AND GROUNDWATER AREAS AT EDWARDS AFB OPERABLE UNITS 4 AND 9

DRAWN BY: RM	DESIGNED BY: GW	SCALE: 1"= 1200'
CHECKED BY:	APPROVED BY:	DATE: 07-2006
PROJECT NUMBER 67861	MAP SHEET NUMBER: SHEET 1 OF 1	REV. NO. A01

EDWARDS\ 67861\B5920MPB.A01