DEPARTMENT OF THE AIR FORCE
60TH CIVIL ENGINEER SQUADRON (AMC)

October 28, 2011

MEMORANDUM FOR DISTRIBUTION

FROM: 60 CES/CEANR
411 Airmen Drive
Travis AFB CA 94535-2001

SUBJECT: Final Focused Feasibility Study Report

1. The attached final report contains the results of the Focused Feasibility Study (FFS) that support the selection of groundwater remedial actions within the Travis AFB Environmental Restoration Program. This report describes the development and evaluation of potential remedial alternatives that can be applied to 20 groundwater sites on Travis AFB that are currently undergoing interim groundwater remedial actions.

2. We received a letter from EPA, dated 13 October 2011, which provided a list of corrections to the draft final report and the Response to EPA Comments table. We appreciate EPA's effort to verify the accuracy of the FFS report, and we made all of the corrections to both the report and table. EPA also suggested several editorial improvements which we also incorporated into the report.

3. Several issues also came up during the Response to Comments discussions. One involved the availability of the groundwater analytical data that will support the demonstration of several innovative technologies (e.g., bioreactors and reductive dechlorination via vegetable oil injection). Because this is a programming and scheduling issue, it will be one of several agenda items for the upcoming ROD scoping meeting, which will be held on the same day as the 30 November 2011 Remedial Program Manager's meeting.

4. Another issue involved the original risk assessment tables from the two operable unit Feasibility Study reports that supported the initiation of interim groundwater remedial actions on Travis AFB. Because the data from these tables is outdated and does not support the transition to final remedies, we did not include it in the body of the FFS report. However, we added references to these tables to the risk assessment summary portion of the report in order to tie the report to previous primary documents.

5. We provided the copies of the FFS report that you requested. However, if you have any questions concerning this final report or require additional copies, please contact Mr. Glenn Anderson at (707) 424-4359.

MARK H. SMITH
Chief, Environmental Restoration

Attachment:
Final Focused Feasibility Study Report

Distribution: (see attached)

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TRAVIS AIR FORCE BASE
ENVIRONMENTAL RESTORATION PROGRAM

Final

Basewide Groundwater Focused Feasibility Study

USACE Contract No. W91238-06-D-0013

Delivery Order DK01

Prepared for:

U.S. Army Corps of Engineers
Omaha District

60 CES
Travis Air Force Base, California

Prepared by:

CH2MHILL

October 2011

Executive Summary

Travis Air Force Base (AFB) has conducted a Basewide Groundwater Focused Feasibility Study (FFS) to identify and evaluate potential remedial alternatives to address contaminated groundwater at 18 sites administered under the Environmental Restoration Program (ERP) at Travis AFB. The site locations are shown on Figure ES-1.

Background

As a result of past waste management and disposal practices, groundwater at Travis AFB is contaminated at multiple locations. The primary contaminants are chlorinated volatile organic compounds (VOCs). Trichloroethene (TCE) and related compounds are the most frequently detected and widespread of these VOCs. To address this contamination, Travis AFB has followed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process and implemented multiple groundwater interim remedial actions (IRAs).

In 1983, the Air Force initiated the Installation Restoration Program (IRP) (now the ERP) to investigate the nature and extent of hazardous waste releases to the environment. On the basis of IRP data evaluated by the U.S. Environmental Protection Agency (EPA), Travis AFB was placed on the National Priorities List (NPL) on November 21, 1989 (54 *Federal Register* 48187). Approximately a year later, on September 27, 1990, the Air Force, EPA, California Department of Toxic Substances Control, and the San Francisco Bay Regional Water Quality Control Board negotiated and signed the Federal Facilities Agreement that established the framework and schedule for environmental cleanup at Travis AFB.

Prior Implementation of the CERCLA Process

Following placement on the NPL, Travis AFB followed the requirements of CERCLA to investigate site contamination and design and implement appropriate measures. This process consists of six (6) major steps, as described in Section 300.430 of the National Contingency Plan (NCP) and as shown on Figure ES-2. Travis AFB successfully implemented the CERCLA process. However, the process was modified following completion of the Preliminary Assessment (PA)/Site Inspection (SI)/Remedial Investigation (RI)/Feasibility Study (FS) sequence to take an <u>interim</u> approach to groundwater remediation. The following list provides a summary of the how the CERCLA process has been implemented using the interim remedy approach:

1. **PA/SI –** Completed. Between approximately 1983 and 1994, early IRP investigations, data gathering, and work planning efforts were conducted to preliminarily assess the nature of environmental contamination at sites within each of the operable units (OUs).

2. **RI –** RIs have been completed to characterize the nature and extent of contaminated groundwater at the ERP sites within the North/East/West Industrial Operable Unit (NEWIOU) and West/Annexes/Basewide Operable Unit (WABOU) (Radian, 1996b [West Industrial Operable Unit]; Radian, 1995, [North Operable Unit]; Weston, 1995 [East Industrial Operable Unit]; CH2M HILL, 1997 [WABOU]).

3. **FS –** FSs have been finalized for contaminated groundwater sites within the NEWIOU (Radian, 1996a) and WABOU (CH2M HILL, 1998a).
4. **Interim Remedy Selection –** Groundwater IRAs were selected in the final *Groundwater Interim Record of Decision for the NEWIOU* (NEWIOU Groundwater IROD) (Travis AFB, 1998) and the final *Groundwater Interim Record of Decision for the WABOU* (WABOU Groundwater IROD) (Travis AFB, 1999).
5. **Interim Remedial Design/Remedial Action –** Following finalization of the two (2) groundwater IRODs, multiple groundwater IRAs were designed, constructed, and entered into interim long-term operation. Two (2) basic IRA strategies were employed, either individually or in combination at each site:
   - Groundwater Extraction and Treatment (GET) (i.e., "pump and treat") was implemented using both dual-phase extraction of soil vapor and groundwater and conventional groundwater extraction. Treatment of extracted groundwater was conducted at fixed groundwater treatment plants.
   - Monitored Natural Attenuation (MNA) Assessment – Formal selection of MNA was deferred pending the completion of assessments during the period of interim remediation to evaluate the feasibility of implementing MNA for all or part of several contaminant plumes.
6. **Performance Monitoring and Five-year Reviews –** Basewide performance monitoring of the IRAs is conducted and reported under the Travis AFB Groundwater Sampling and Analysis Program (GSAP). Descriptions of groundwater treatment plant operation and maintenance (O&M) activities are regularly reported to the regulatory agencies in monthly data sheets and in annual O&M reports. Travis AFB has completed two (2) five-year reviews of the groundwater IRAs.

The Path to Final Groundwater Remedies

For the most part, the IRAs operated successfully during a period of interim remediation since the late 1990s to early 2000s. However, after about a decade of interim remediation, the groundwater at most sites remains contaminated at concentrations that exceed federal and California maximum contaminant levels (MCLs).

Travis AFB is now beginning the transition out of interim remediation and starting the process to select and implement the final remedial actions at each site. As part of this process, the FFS describes the development and screening of potential remedial alternatives to succeed the IRAs after the period of interim remediation is concluded.

The FFS uses the IRA GET performance data and MNA assessment results obtained during the period of interim remediation and evaluations of other applicable technologies to support the development and evaluation of potential final remedial actions.

GET System IRA Optimization

Over time, the energy-intensive IRA GET systems used at several ERP sites became less efficient and cost-effective as VOC concentrations decreased. Therefore, beginning in 2008, Travis AFB initiated a program of GET IRA optimization. The basic approach to optimizing the IRAs is to discontinue inefficient GET system operation and focus on the VOC plume source zones (i.e., ”hot spots”) with an in situ treatment technology.

Through 2010, IRA optimizations have included data gaps investigations followed by source area injections of emulsified vegetable oil (EVO) and installation of bioreactors. The performance of these optimization measures is being monitored for the remainder of the period of interim remediation. If the optimization action proves effective, then that technology may be incorporated into the final remedial action.

At several sites, the GET IRA systems have been shut down for rebound studies. Travis AFB is monitoring the groundwater to assess if concentrations will remain stable, decrease, or increase without active pumping. Depending on the results of the rebound studies, the GET systems will remain off or be restarted, either fully or at selected extraction wells.

MNA Assessments

After about a decade of data collection, assessments of MNA performance were conducted for the sites where these actions were selected as either the IRA or part of the IRA. These assessments are provided in the final *Natural Attenuation Assessment Report* (NAAR) (CH2M HILL, 2010a). The fundamental conclusion in the NAAR is that the data are sufficient to conclude that MNA can be an effective remedy, or part of the remedy, at most sites.

Sustainable Remediation

The various IRA optimizations being implemented by Travis AFB include provisions for sustainable remediation. This is a relatively new consideration in evaluating environmental site cleanup methods. Policy statements have been issued by Presidential Executive Order, the Department of Defense, and EPA stating that environmental cleanup programs should fully consider sustainable practices to achieve cleanup objectives. Travis AFB has applied the sustainability consideration in the optimization of the IRAs and in the development of remedial alternatives in this FFS.

Through 2010, sustainable technologies incorporated into the IRA optimizations have included the use of solar-powered groundwater extraction wells, organic mulch bioreactors, and subsurface injection of food-grade EVO. If a sustainable technology proves effective during the remaining period of interim remediation, then that technology may be incorporated into a final remedial alternative.

Current Implementation of the CERCLA Process

As the period of interim remediation concludes, Travis AFB has re-initiated the CERCLA process to develop and implement the final remedial action at each site. This FFS is the first step in the remedial alternative selection process (refer to Figure ES-2). Development of a Proposed Plan and Record of Decision (ROD) will follow the FFS.

The overall objective of the FFS is to develop and evaluate appropriate remedial alternatives for each of the contaminated groundwater sites at Travis AFB. To achieve this objective, the FFS included evaluations summarized in the following list:

- **Preliminary Cleanup Goals**
  - Describes remedial action objectives (RAOs)
  - Identifies applicable or relevant and appropriate requirements (ARARs)
  - Describes and lists numerical preliminary cleanup goals (PCGs) for groundwater
- **Identification and Screening of Technologies**
  - Identifies general response actions (GRAs), technologies, and technology process options to achieve the RAOs.
  - Screens the groundwater technologies and process options against the criteria of effectiveness, technical implementability, and relative cost.
  - Identifies representative process options for the various technologies.
- **Assembly and Screening of Alternatives**
  - Assembles potential remedial alternatives from representative technology process options.
  - Screens the assembled alternatives against the criteria of effectiveness, implementability, and cost.
- **Detailed Analysis of Alternatives –** Conducts detailed evaluations of the potential remedial alternatives against seven (7) CERCLA FS evaluation criteria:
  - 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
- **Comparative Analysis of Alternatives –** Performs comparative analyses of the potential remedial alternatives and existing IRAs against the seven (7) evaluation criteria.

Focusing Criteria

In addition to the standard CERCLA FS evaluations, this *focused* FS used "focusing criteria" to assist in the identification and screening of appropriate remedial technologies and support the subsequent assembly and screening of alternatives. These focusing criteria include considerations of the following factors:

- Past completion of the CERCLA process at Travis AFB
- Existing groundwater IRA performance
- Ongoing IRA optimization actions, studies, and demonstration projects
- Preference for sustainable remediation technologies

If appropriate, components of the existing IRAs were incorporated into the development of remedial alternatives. Similarly, actions taken to optimize the current interim remedies, successful technology demonstration projects, and sustainable remedial technology components were also incorporated into alternative development.

Preliminary Cleanup Goals

Development of PCGs for groundwater includes statements of RAOs and analyses of ARARs.

Remedial Action Objectives

RAOs are narrative statements that define the extent to which sites require cleanup to meet the underlying objectives of protecting human health and the environment. The NCP specifies that RAOs are to be developed to address the following:

- **Contaminants of concern (COCs) –** The primary COCs are chlorinated VOCs and organochlorine pesticides. A listing of all the groundwater COCs at Travis AFB is provided in Table ES-1.
- **Media of concern –** The FFS addresses the groundwater medium.
- **Potential exposure pathways –** Travis AFB is an active military reservation, adjacent to agricultural lands. Potential dermal, ingestion, and inhalation exposure pathways exist for the following receptors: on-base industrial worker, on-base resident, and off-base agricultural worker. There are no ecological receptors of contaminated groundwater at Travis AFB.
- **PCGs –** PCGs for groundwater at Travis AFB are listed in Table ES-1.

Remedial Action Objectives for Protection of Human Health

- Prevent human ingestion and direct dermal contact of groundwater containing contaminant concentrations above the State and federal MCLs. The more stringent of a State or federal chemical-specific MCL is the controlling cleanup standard.
- Prevent inhalation of chlorinated VOCs volatilizing from groundwater to indoor air. Vapor intrusion exposure is considered significant when VOC concentrations exceed risk-based concentrations, cumulative risks are greater than EPA's risk management range of 10^{-6} to 10^{-4}, or hazard indices exceed the threshold of 1.

Remedial Action Objectives for Environmental Protection

- Restore the groundwater aquifer to concentrations not exceeding the chemical-specific State or federal MCLs. The more stringent State or federal MCL for each contaminant is the controlling cleanup standard.
- Maintain existing water quality and prevent migration of groundwater contamination above the more stringent State or federal MCLs beyond existing boundaries.

- Ensure existing contaminant conditions do not change so as to threaten sensitive environmental receptors such as State or federal protected wildlife populations and vegetation communities.

Applicable or Relevant and Appropriate Requirements

An ARAR is a cleanup standard or other legal requirement that addresses a specific aspect of a CERCLA site. An ARAR can come from either a federal or state environmental law.

The review and application of ARARs in the development of remedial actions is required to ensure that compliance with applicable laws and regulations is achieved by the overall remedial action. The ARARs are a key consideration in the analysis of the remedial action alternatives developed in this FFS, because the alternatives must comply with ARARs to be further considered. Also, compliance with ARARs often has a significant effect on the cost and implementability of a particular alternative during both implementation and long-term operation.

Preliminary Cleanup Goals

The general and specific RAOs are used in concert with analyses of ARARs to establish the numerical PCGs. A summary of the PCGs is provided in Table ES-1. These PCGs serve as the performance criteria for remedial alternative designs and provide a benchmark to measure the protectiveness of remedial action alternatives. The final cleanup levels to be achieved through remedial action will be defined in the pending Basewide Groundwater ROD.

TABLE ES-1
Summary of ERP Groundwater Sites, Chemicals of Concern, and Preliminary Cleanup Goals
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Operable Unit	Name/Description	Chemical of Concern	PCG* (µg/L)
FT004	EIOU	Fire Training Area 3	TCE	5
			cis-1,2-DCE	6
			1,2-DCA	0.5
			Chloroform	100
			Bromodichloromethane	100
			1,1-DCE	6
			Vinyl chloride	0.5
			1,4-DCB	5
			bis(2-Ethylhexyl)phthalate	4
			Nickel	100
FT005	EIOU	Fire Training Area 4	TCE	5
			1,2-DCA	0.5
			cis-1,2-DCE	6
			Chloroform	100
			Bromodichloromethane	100
			bis(2-Ethylhexyl)phthalate	4
			Nickel	100

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Site	Operable Unit	Name/Description	Chemical of Concern	PCG* (µg/L)
LF006	NOU	Landfill 1	TCE	5
			1,1-DCE	6
			TPH-G	5
			TPH-D	100
LF007	NOU	Landfill 2	TCE	5
			Benzene	1
			1,4,-DCB	5
			Chlorobenzene	70
			bis(2-Ethylhexyl)phthalate	4
			Vinyl chloride	0.5
			1,1-DCE	6
			1,2-DCA	0.5
			1,2-Dichloropropane	5
LF008	WABOU	Landfill 3	Aldrin	0.023
			Alpha-chlordane	0.1
			Heptachlor	0.01
			Heptachlor epoxide	0.01
SS015	EIOU	Solvent Spill Area and Facility 552	TCE	5
			cis-1,2-DCE	6
			Vinyl chloride	0.5
			1,2-DCA	0.5
			PCE	5
			bis(2-Ethylhexyl)phthalate	4
			Nickel	100
SS016	EIOU	Oil Spill Area Facilities 11, 13/14, 20, 42/1941, and 139/144	TCE	5
			cis-1,2-DCE	6
			Vinyl chloride	0.5
			Benzene	1
			Chloroform	100
			1,4-DCB	5
			Bromodichloromethane	100
			1,2-DCA	0.5
			1,1-DCE	6
			PCE	5
			bis(2-Ethylhexyl)phthalate	4
			Nickel	100

TABLE ES-1
Summary of ERP Groundwater Sites, Chemicals of Concern, and Preliminary Cleanup Goals
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Operable Unit	Name/Description	Chemical of Concern	PCG* (µg/L)
ST027	EIOU	TF33, Facilities 1918, 1919, 1020, and 1040	Benzene	1
			TCE	5
			Toluene	150
			MTBE	13
			TPH-G	5
			TPH-D	100
SS029	EIOU	MW329x29 Area	TCE	5
			1,2-DCA	0.5
			cis-1,2-DCE	6
			Benzene	1
			Chloroform	100
			1,1-DCE	6
			Vinyl chloride	0.5
SS030	EIOU	MW269x30 Area	TCE	5
			Chloroform	100
			Bromodichloromethane	100
			1,2-DCA	0.5
			Nickel	100
SD031	EIOU	Facility 1205	TCE	5
			Benzene	1
			1,1-DCE	6
			cis-1,2-DCE	6
			Carbon tetrachloride	0.5
			Chloroform	100
			1,2-DCA	0.5
			Vinyl chloride	0.5
			Nickel	100
SD033	WIOU	Storm Sewer System 2 (former Storm Sewer System B – includes Facilities 810, 1917, and South Gate Area)	TCE	5
			1,1-DCE	6
			1,2-DCA	0.5
			cis-1,2-DCE	6
			TPH-G	5
			TPH-D	100

TABLE ES-1
Summary of ERP Groundwater Sites, Chemicals of Concern, and Preliminary Cleanup Goals
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Operable Unit	Name/Description	Chemical of Concern	PCG* (µg/L)
SD034	WIOU	Facility 811	LNAPL (PD-680)	NA
			TCE	5
			Vinyl chloride	0.5
			1,1-DCE	6
			Benzene	1
			cis-1,2-DCE	6
			PCE	5
			TPH-G	5
			TPH-D	100
			bis(2-Ethylhexyl)phthalate	4
SS035	WIOU	Facilities 818 and 819	TCE	5
			TPH-D	100
SD036	WIOU	Facilities 872, 873, and 876	Vinyl chloride	0.5
			TCE	5
			1,1-DCE	6
			cis-1,2-DCE	6
			1,2-DCA	0.5
			Benzene	1
			Bromodichloromethane	100
			PCE	5
			TPH-G	5
			TPH-D	100
SD037	WIOU	Sanitary Sewer (includes Facilities 837, 838, 981, 919, the Area G Ramp, and Ragsdale/V Area)	1,1-DCE	6
			1,2-DCA	0.5
			Benzene	1
			Bromodichloromethane	100
			Carbon tetrachloride	0.5
			Chloromethane	1.5
			PCE	5
			TCE	5
			Vinyl chloride	0.5
			cis-1,2-DCE	6
			TPH-G	100
			bis(2-Ethylhexyl)phthalate	4
			Naphthalene	20
			TPH-D	100

TABLE ES-1
Summary of ERP Groundwater Sites, Chemicals of Concern, and Preliminary Cleanup Goals
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Operable Unit	Name/Description	Chemical of Concern	PCG* (µg/L)
DP039	WABOU	Building 755	1,1-DCE	6
			1,2-DCA	0.5
			1,1,1-TCA	0.5
			1,1,2-TCA	0.5
			Acetone	5,110
			Bromodichloromethane	100
			Methylene chloride	5
			PCE	5
			TCE	5
SS041	WABOU	Building 905	Heptachlor epoxide	0.01
SD043	WABOU	Building 916	TCE	0.5

*The lesser of either the federal MCL or California MCL is adopted as the PCG. Section 5.4 describes the selection of PCGs in more detail.

Notes:

µg/L = microgram(s) per liter
DCA = dichloroethane
DCB = dichlorobenzene
DCE = dichloroethene
EIOU = East Industrial Operable Unit
MTBE = methyl tert-butyl ether
NA = not applicable
NOU = North Operable Unit
PCE = tetrachloroethene
TCA = trichloroethane
TPH-D = total petroleum hydrocarbon as diesel
TPH-G = total petroleum hydrocarbon as gasoline
WIOU = West Industrial Operable Unit

Source: Table 1-2 of the final 2009-2010 Travis AFB GSAP Report (CH2M HILL, 2011b).

Identification and Screening of Technologies

The next step in the FFS process is to describe the GRAs, remedial technologies, and technology process options that can be used to achieve the RAOs.

General Response Actions

GRAs describe the broad range of actions that will satisfy the RAOs. GRAs for groundwater may include no action, institutional actions, containment, excavation, collection, removal, treatment, disposal, discharge, or a combination of these.

Descriptions of GRAs that potentially satisfy the RAOs for contaminated groundwater at the Travis AFB ERP sites include the following:

- **No Action –** No attempt is made to satisfy the RAOs, and no remedial measures are implemented. A No Action alternative is required for consideration by the NCP.
- **Land Use Controls (LUCs) –** Actions using physical, legal, or administrative mechanisms to restrict the use of land and limit access to contaminated groundwater. Travis AFB already enforces LUCs to prevent unauthorized exposure to contaminated groundwater.
- **Containment –** Actions that result in contaminated groundwater being contained or controlled, thereby minimizing or eliminating the migration of contaminants and preventing direct exposure to contamination.
- **Removal –** Actions taken to physically remove contaminated groundwater or pure contaminant from an aquifer.
- **Treatment –** In situ or ex situ actions taken to reduce the toxicity, mobility, and/or volume of contaminants in groundwater. Includes actions that rely on natural processes to reduce the toxicity, mobility, and/or volume of contaminants.
- **Disposal –** Actions taken to reuse or dispose of treated groundwater.

Remedial Technologies and Process Options

Except for No Action, each GRA can be achieved by several remedial technologies and technology process options. In this context, the following definitions apply:

- **Remedial Technologies –** General categories of remedies under a GRA. For example, in situ bioremediation is one (1) of the remedial technologies under the GRA of in situ treatment.
- **Process Options –** Specific categories of remedies within each remedial technology. The process options are used to implement each remedial technology. For example, the remedial technology of in situ bioremediation could be implemented using several types of treatment options, including anaerobic degradation, bioaugmentation, phytoremediation, and/or a bioreactor.
- **Representative Process Options –** Technology processes are chosen to *represent* the options under a GRA and technology group. For example, in Table ES-2, carbon substrate injection, phytoremediation, and bioreactor are selected as process options to represent the GRA of in situ treatment and the technology of in situ biological treatment. Representative process options are selected to simplify the subsequent development and evaluation of remedial alternatives. They are selected by considering those that best satisfy the evaluation criteria. Preference is given to sustainable technology processes. Technology process options not selected as *representative* are not eliminated from future consideration.

TABLE ES-2
Summary of General Response Actions, Technologies, and Process Options Screening
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option	Effectiveness, Implementability, and Relative Cost Screening Summary
No Action	None	None	Required for consideration by NCP
Land Use Controls	Administrative mechanisms	**Base Civil Engineer Work Request**	**Representative process option**
		Excavation permit	**Representative process option**
		Base General Plan	**Representative process option**
		Easement purchase	Potentially applicable
	Engineered controls	Vapor barrier	Potentially applicable
		Passive venting	Potentially applicable
		Alternative water supply	Potentially applicable
	Monitoring	**Groundwater monitoring**	**Representative process option**
Containment	Physical barrier	Soil-bentonite slurry wall	Potentially applicable
		Interceptor trench	Potentially applicable
	Hydraulic barrier	Extraction wells	Potentially applicable
Removal	Groundwater extraction	Extraction wells	**Representative process option**
		In situ thermal removal	Screened out
	Free product removal	**Passive skimming**	**Representative process option**
		Bioslurping	Screened out
In Situ Treatment	In situ physical, chemical, and biological degradation	**MNA**	**Representative process option**
		EA	**Representative process option**
	In situ biological treatment	**Carbon substrate injection**	**Representative process option**
		PRB (biobarrier)	Potentially applicable
		Bioaugmentation	Potentially applicable
		Phytoremediation	**Representative process option**
		Bioreactor	**Representative process option**
	In situ chemical treatment	Chemical oxidation	Potentially applicable
		ZVI injection	Screened out
		ZVI PRB	Potentially applicable
Ex Situ Treatment	Physical treatment	**LGAC adsorption**	**Representative process option**
		Air stripping	Potentially applicable
	Chemical treatment	UV/Ox	Potentially applicable
	Thermal treatment	Thermal oxidation	Potentially applicable
Disposal	Treated groundwater discharge	**Stormwater drainage system**	**Representative process option**
		Beneficial reuse	Potentially applicable

Notes:

Boldface process options are selected as being representative of the technology type. Process options not selected as representative are not eliminated from future consideration.

EA = enhanced attenuation
LGAC = liquid-phase granular activated carbon
PRB = permeable reactive barrier
ZVI = zero-valent iron

Screening of Technologies and Process Options

A universe of technology types and process options is available to implement the GRAs. The first step in the evaluation of these potential technologies and process options involves screening the comprehensive list of technologies and process options against the criterion of Technical Implementability. Then, a second screening of the surviving process options is performed against the evaluation criteria of Effectiveness, Implementability, and Relative Cost to further reduce the list. The next step in the screening process involves the selection of representative process options for each applicable technology type to simplify the subsequent development and evaluation of remedial alternatives. The results of these initial screening steps are summarized in Table ES-2.

Sustainability Considerations

Sustainability in remedial action systems is emerging as a consideration for evaluating environmental site cleanup methods. Using sustainability as a factor in developing the final groundwater remedial alternatives at Travis AFB now warrants much more consideration than it did in the past. Groundwater technologies such as in situ bioremediation, once considered innovative, have matured since FSs were completed at Travis AFB in 1996 and 1998. The uncertainty that was once associated with these types of remediation technologies is now much reduced.

Assembly and Screening of Alternatives

Following the screening of technologies, remedial alternatives are assembled from representative process options. The assembled alternatives are then screened against the criteria of Effectiveness, Implementability, and Cost.

Assembly of Alternatives

In this step, representative technology process options are assembled into site-specific remedial alternatives. The assembly of representative process options into site-specific groundwater remedial alternatives is provided in Table ES-3. The assembled alternatives and applicable sites are further summarized in Table ES-4.

TABLE ES-3
Summary of Alternatives Assembled from Representative Process Options
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Representative Process Option	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
No Action																				●	
Base Civil Engineer Work Request	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●
Excavation Permit	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●
Base General Plan*	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Groundwater Monitoring	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●
MNA	●	●	●	●		●	●			●			●	●		●					●
EA								●							●		●	●	●		
Vertical Extraction Well					●				●		●	●									
Horizontal Extraction Well									●												
Passive Skimming															●						
Carbon Substrate Injection								●									●	●	●		
Phytoremediation																			●		
Bioreactor									●										●		
LGAC Adsorption					●				●		●	●									
Stormwater Drainage System					●				●		●	●									

* In accordance with the Base General Plan, the non-representative LUC process options of Vapor Barrier and Passive Venting are potentially applicable to all sites. These vapor intrusion mitigation measures are applicable to address future building construction in proximity to a groundwater contaminant plume.

Notes:

● Representative Process Option that best satisfies the evaluation criteria of Effectiveness, Implementability, and Relative Cost at each site.

Shaded indicates a process option that has already been implemented as a component of the IRA at a site, including demonstration projects and optimization measures. After approximately a decade of interim remediation, some existing process options best satisfy the evaluation criteria of Effectiveness, Implementability, and Cost. Other existing process options currently do not satisfy the criteria as well as other processes and are not selected as being representative.

Bolded technology process options are considered to have aspects of green and sustainable remediation.

Assembly of alternatives:

Alternative 1 – No Action, Base General Plan: Site SS041
Alternative 2 – MNA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring: Sites FT004, FT005, LF006, LF007B, ST027B, SD031, SD033, SS035, and SD043.The off-base portion of Site FT005 also includes the non-representative LUC process option of an off-base easement.
Alternative 3 – Vertical Extraction Wells, LGAC Adsorption, Stormwater Drainage System, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring: Sites LF007C, SS029, and SS030.The off-base portion of Sites LF007C and SS030 also includes the non-representative LUC process option of off-base easement.
Alternative 4 – Bioreactor, Horizontal and Vertical Extraction Wells, LGAC Adsorption, Stormwater Drainage System, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring: Site SS016
Alternative 5 – Carbon Substrate Injection, EA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring: Sites SS015, SD036, and SD037
Alternative 6 – Bioreactor, Carbon Substrate Injection, Phytoremediation, EA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring: Site DP039
Alternative 7 – Passive Skimming, EA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring: Site SD034

TABLE ES-4
Assembly of Remedial Alternatives and Applicable Sites
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

GRA	Remedial Technology	Representative Process Option	Alternative 1	2	3	4	5	6	7
No Action	None	None	●						
Land Use Controls	Administrative mechanisms	Base Civil Engineer Work Request		●	●	●	●	●	●
		Excavation permit		●	●	●	●	●	●
		Base General Plan	●	●	●	●	●	●	●
	Monitoring	Groundwater monitoring		●	●	●	●	●	●
Removal	Groundwater extraction	Extraction wells			●	●			
	Free product removal	Passive skimming							●
In Situ Treatment	In situ physical, chemical, and biological degradation	MNA		●					
		EA					●	●	●
	In situ biological treatment	Carbon substrate injection					●	●	
		Phytoremediation						●	
		Bioreactor				●		●	
Ex Situ Treatment	Physical treatment	LGAC adsorption			●	●			
Disposal	Treated groundwater discharge	Stormwater drainage system			●	●			

* In accordance with the Base General Plan, the non-representative LUC process options of Vapor Barrier and Passive Venting are potentially applicable to all sites. These vapor intrusion mitigation measures are applicable to address future building construction in proximity to a groundwater contaminant plume.

Notes:

Summary of assembled groundwater alternatives and applicable sites:

Alternative 1 – No Action, Base General Plan* (Site SS041)

Alternative 2 – MNA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring (Sites FT004, FT005, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, SS035, and SD043). The off-base portion of Site FT005 also includes the non-representative LUC process option of an off-base easement.

Alternative 3 – Extraction Wells, LGAC Adsorption, Stormwater Drainage System, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring (Sites LF007C, SS029, and SS030). The off-base portions of Sites LF007C and SS030 also include the non-representative LUC process option of an off-base easement.

Alternative 4 – Bioreactor, Extraction Wells, LGAC Adsorption, Stormwater Drainage System, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring (Site SS016)

Alternative 5 – Carbon Substrate Injection, EA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring (Sites SS015, SD036, and SD037)

Alternative 6 – Bioreactor, Phytoremediation, Carbon Substrate Injection, EA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring (Site DP039)

Alternative 7 – Passive Skimming, EA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring (Site SD034)

Most of the alternatives listed in Tables ES-3 and ES-4 have long and unwieldy names when mechanically described in terms of their component process options. To shorten and simplify the naming of the alternatives, the following conventions are used:

- GET – For Alternatives 3 and 4, GET refers to the combination of groundwater extraction, treatment, and discharge process options.
  - Groundwater Extraction – For the groundwater extraction component, horizontal and/or vertical extraction well process options may be used either singly or in combination at a site.
  - Treatment – The Central Groundwater Treatment Plant (CGWTP), North Groundwater Treatment Plant (NGWTP), and South Base Boundary Groundwater Treatment Plant (SBBGWTP) currently all use the LGAC as the treatment process option for multiple sites.
  - Discharge – Treated groundwater effluent from the CGWTP, NGWTP, and SBBGWTP is discharged to the stormwater drainage system.
- Carbon Substrate Injection – For Alternatives 5 and 6, this process option is implemented using an area treatment configuration of EVO injection points or as a linear configuration of EVO injection points to create a PRB. The configuration does affect the treatment process, so the adopted naming conventions are simply EVO or EVO PRB.
- Representative process options comprising the administrative mechanisms of LUCs, including Base Civil Engineer Work Requests, excavation permits, and the Base General Plan, are components of all the alternatives and are omitted from the alternative names for brevity. Subsequent use of the term LUCs refers to the combination of administrative mechanisms, engineered controls, and monitoring that are applicable to each site. The term LUCs is omitted from the alternative names for brevity. The representative process options comprising the administrative mechanisms of LUCs are summarized as follows:
  - Base Civil Engineer Work Requests (Air Force Form 332) is applicable to all on-base sites or on-base portions of sites, except Site SS041 (No Further Response Action Planned [NFRAP] status).
  - Excavation permits using 60th Air Mobility Wing Form 55 is applicable to all on-base sites or on-base portions of sites, except Site SS041 (NFRAP status).
  - The provisions of the Base General Plan are applicable to all sites. Accordingly, LUCs potentially include the non-representative process options of Vapor Barrier and Passive Venting. These process options are potentially applicable to all sites as vapor intrusion mitigation measures for future new building construction in proximity to a groundwater contaminant plume.
  - The administrative mechanism of an easement purchase is not a representative process option because it is applicable only to the off-base portions of Sites FT005, LF007C, and SS030. Therefore, this process option is not included in the naming of Alternative 3.

- Groundwater Monitoring – Groundwater monitoring is another LUC process option and is also omitted from the alternative names for brevity. Groundwater monitoring will continue to be conducted under the GSAP to track the movement of the contaminants and to verify that contaminant concentrations are being remediated. The GSAP will be modified to incorporate any new groundwater wells installed as part of the alternative implementation or optimization.

After applying these naming conventions, the simplified alternative names are as follows:

- Alternative 1 – No Action
- Alternative 2 – MNA
- Alternative 3 – GET
- Alternative 4 – Bioreactor and GET
- Alternative 5 – EVO and EA
- Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA
- Alternative 7 – Passive Skimming and EA

These streamlined alternative names are summarized in Table ES-5 along with the sites applicable to each alternative.

TABLE ES-5
Summary of Assembled Remedial Alternatives and Applicable Sites
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Alternative[a,b]	Applicable Sites
Alternative 1 – No Action	Site SS041
Alternative 2 – MNA	Sites FT004, FT005, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, SS035, SD043
Alternative 3 – GET[c]	Sites LF007C, SS029, SS030
Alternative 4 – Bioreactor and GET[c]	Site SS016
Alternative 5 – EVO and EA	Site SS015[d], SD036[d], SD037[d]
Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA	Site DP039
Alternative 7 – Passive Skimming and EA	Site SD034

[a] Remedial alternatives assembled from representative process options.
[b] Groundwater monitoring and LUCs are components of all the alternatives, except No Action.
[c] Includes discharge of treated groundwater.
[d] EVO injection within the source area portions of the plumes. EA implemented in the distal portions (i.e., non-source areas) of the plumes.

The assembled remedial alternatives address the entirety of a site-specific plume. This is accomplished by assembling representative process options that are applicable to the site and contaminant conditions that exist within the various portions of the plume. At some sites, only one (1) technology process may be required to achieve RAOs. For example, GET may be capable of remediating the entirety of a plume without need of another process.

For other sites, individual technology process options might address contamination within one (1) portion of a plume but not another portion. For example, an in situ bioreactor can be effective, implementable, and cost-effective in a highly contaminated shallow source area but will fail against the three (3) evaluation criteria in the low-concentration distal portion of the same plume. For sites with these characteristics, an alternative is assembled from process options to address both the source and distal portions of the plume.

Screening of Alternatives

In this step, the assembled remedial alternatives are screened against the criteria of Effectiveness, Implementability, and Cost. For comparison purposes, information on the historical development and screening of alternatives leading to the current IRAs is also provided.

Summary of Previous Alternative Screening

Interim remediation of the NEWIOU and WABOU contaminated groundwater sites is currently being conducted under the two (2) IRODs. These IRAs were implemented to quickly begin remediation of groundwater contamination, reduce the levels of contamination and potential risk, and collect some of the data necessary for the selection of final cleanup levels and technically and economically feasible long-term actions. The use of an IROD allowed groundwater IRAs to proceed without having final designated cleanup levels, as will be required for the pending ROD.

Summaries of the IRAs already developed, evaluated, and implemented at the NEWIOU and WABOU sites are provided in Table ES-6 and Table ES-7.

Table ES-8 summarizes the alternative selected for each site in the NEWIOU and WABOU IRODs, the IRA objectives, IRA performance and status, IRA optimization actions, and the post-optimization actions that have been taken to-date at each site.

TABLE ES-6
Summary of Historical NEWIOU Groundwater Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Alternatives Developed in the NEWIOU FS[a]	Remedial Alternatives Evaluated for the Site in the NEWIOU FS[a]	Remedial Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]
FT004	1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain 9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation	1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	3 – Extraction, Treatment, and Discharge (GET)
FT005		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	3 – Extraction, Treatment, and Discharge (GET)
LF006		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA
LF007B		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA Assessment

TABLE ES-6
Summary of Historical NEWIOU Groundwater Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Alternatives Developed in the NEWIOU FS[a]	Remedial Alternatives Evaluated for the Site in the NEWIOU FS[a]	Remedial Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]
LF007C	1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain 9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation	1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA Assessment (on-base plume) 3 – Extraction, Treatment, and Discharge (GET) (Base boundary and off-base plume)
LF007D		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA Assessment
SS015		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA Assessment
SS016		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	3 – Extraction, Treatment, and Discharge (GET)

TABLE ES-6
Summary of Historical NEWIOU Groundwater Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Alternatives Developed in the NEWIOU FS[a]	Remedial Alternatives Evaluated for the Site in the NEWIOU FS[a]	Remedial Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]
SS029	1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain 9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation	1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain 6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain 8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain	3 – Extraction, Treatment, and Discharge (GET)
SS030		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA Assessment 3 – Extraction, Treatment, and Discharge (GET)
SD031		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain Oxidation	2 – MNA Assessment 3 – Extraction, Treatment, and Discharge (GET)
SD033		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA Assessment (South Gate Area, Facility 1917, and Facility 810 plumes) 3 – Extraction, Treatment, and Discharge (GET) (storm sewer)

TABLE ES-6
Summary of Historical NEWIOU Groundwater Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

<table>
<tr><th>Site</th><th>Alternatives Developed in the NEWIOU FS[a]</th><th>Remedial Alternatives Evaluated for the Site in the NEWIOU FS[a]</th><th>Remedial Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]</th></tr>
<tr><td>SD034</td><td rowspan="4">1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain
9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation</td><td>3 – Extraction, Treatment, and Discharge (GET)
(Bioslurp/free product removal and coordination with Site SD037 alternative)</td></tr>
<tr><td>SS035</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment</td></tr>
<tr><td>SD036</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>3 – Extraction, Treatment, and Discharge (GET)</td></tr>
<tr><td>SD037</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment
(portions of plume near Facilities 919, 977, 981, and Area G Ramp)
3 – Extraction, Treatment, and Discharge (GET)
(portions of plume near Facilities 837, 838, and Ragsdale/V Area and the remainder of plume)</td></tr>
</table>

[a] Source: Final NEWIOU FS (Radian, 1996a).
[b] Source: Final Groundwater IROD for the NEWIOU (Travis AFB, 1998).
[c] Historically managed under the POCO program and not addressed in either the Groundwater IROD for the NEWIOU or Groundwater IROD for the WABOU.

TABLE ES-7
Summary of Historical WABOU Groundwater Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

<table>
<tr><th>Site</th><th>Alternatives Developed in WABOU FS[a]</th><th>Alternatives Evaluated in the WABOU FS[a]</th><th>Alternatives Selected in the WABOU Proposed Plan/IROD[b]</th></tr>
<tr><td>LF008</td><td rowspan="4">Alternative G1 – No Action
Alternative G2 – Monitored Natural Attenuation
Alternative G3 – Containment/Treatment/Discharge (GET)
Alternative G4 – Extraction/Treatment/Discharge (GET)
Alternative G5 – Source Area and Groundwater Extraction/Treatment/Monitored Natural Attenuation
Alternative G6 – Source Area Extraction/Treatment/Monitored Natural Attenuation</td><td>G1 – No Action
G2 – Natural Attenuation
G3 – Containment, Treatment, Discharge
G4- Extraction, Treatment, Discharge</td><td>G4 – Extraction, Treatment, Discharge (GET)</td></tr>
<tr><td>DP039</td><td>G1 – No Action
G2 – Natural Attenuation
G3 – Containment, Treatment, Discharge (GET)
G4 – Extraction, Treatment, Discharge (GET)
G5 – Source Area Extraction, Treatment, Natural Attenuation
G6 – Source Area Containment, Treatment, Natural Attenuation</td><td>G3 – Containment, Treatment, Discharge (GET)
G5 – Source Area and Groundwater Extraction, Treatment, MNA</td></tr>
<tr><td>SS041</td><td>G1 – No Action
G2 – Natural Attenuation
G3 – Containment, Treatment, Discharge (GET)</td><td>G3 – Containment, Treatment, Discharge (GET)</td></tr>
<tr><td>SD043</td><td>G1 – No Action
G2 – Natural Attenuation
G3 – Containment, Treatment, Discharge (GET)</td><td>G3 – Containment, Treatment, Discharge (GET)</td></tr>
</table>

[a] Source: Final WABOU FS (CH2M HILL, 1998a).
[b] Source: Final Groundwater IROD for the WABOU (Travis AFB, 1999).

TABLE ES-8
Summary of Interim Remedial Action Performance and Status
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Remedial Alternative Selected in the Proposed Plan and IROD	Implemented IRA (FFS terminology)	IRA Objectives	IRA Performance and Status	IRA Optimization Actions	Post-IRA Optimization Actions
FT004 (NEWIOU)	Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 2 – MNA Assessment Alternative 3 – GET	Assess viability of natural physical, chemical, and biological processes to remediate plume GET for source control	The combination of GET in the Site FT004 source areas and MNA in the downgradient portions of the plume has been effective. Hydraulic capture of the source areas was achieved using GET. The effectiveness of GET is further demonstrated by declining VOC concentrations observed in the majority of site monitoring wells. Declining trends are observed in both shallow and deep monitoring wells, indicating both the horizontal and vertical extent of the target areas are being addressed. The Site FT004 GET system has been shut down for a rebound study for the remaining period of interim remediation because the source area VOC concentrations have declined. The maximum TCE concentrations during the 2010 GSAP were observed within two (2) localized and noncontiguous portions of the plume. These included 165 µg/L in MW266x04 and 130 µg/L in MW131x04. No other concentrations above 100 µg/L were observed at the site. MNA also appears to be a viable remedy at Site FT004. Overall, contaminant concentrations are stable or declining in the downgradient MNA assessment monitoring wells. The MNA network includes both shallow and deep monitoring wells. MNA appears to be effective throughout the entire thickness of the plume.	Air stripping discontinued and replaced with LGAC treatment at NGWTP. GET system shut down for a rebound study in 2007.	Monitoring to evaluate rebound study is ongoing.
FT005 (NEWIOU)	Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 3 – GET	GET for migration control GET for off-base remediation	The Site FT005 GET system has been effective. The existing GET system appears to have achieved hydraulic capture of the plume and is controlling off-base contaminant migration. A large portion of the plume has been remediated to non-detect concentrations. The extraction wells in the areas of the plume where IRA objectives have been achieved have been shut down for a rebound study for the remainder of the interim period of remediation.	Air stripping discontinued and replaced with LGAC treatment at SBBGWTP. GET system partially shut down for a rebound study in 2007.	Monitoring to evaluate rebound study is ongoing.
LF006 (NEWIOU)	Alternative 2 – MNA	Alternative 2 – MNA	Use natural physical, chemical, and biological processes to remediate plume	MNA appears to be a viable remedy at Site LF006. Data from monitoring wells indicate that groundwater contamination at Site LF006 is not migrating, and no contaminants were detected at a concentration exceeding the IRG.	None	Monitoring to evaluate natural attenuation processes is continuing.
LF007B (NEWIOU)	Alternative 2 – MNA Assessment	Alternative 2 – MNA Assessment	Assess viability of natural physical, chemical, and biological processes to remediate plume	MNA appears to be a viable remedy at Site LF007B. No contaminants were detected in Site LF007B wells sampled during the 2009-2010 GSAP events.	None	Monitoring to evaluate MNA processes is continuing.
LF007C (NEWIOU)	Alternative 2 – MNA Assessment[a] Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 2 – MNA Assessment Alternative 3 – GET	GET for migration control[b] GET for off-base remediation[c]	The migration control and off-base remediation IRA objectives for Site LF007C do not appear to be fully achieved. The existing GET system is not fully effective at hydraulically capturing and remediating the TCE plume. TCE continues to migrate off-base at concentrations above the TCE IRG of 5 µg/L. Optimization of the GET IRA is required. A data gaps investigation will be performed during 2011, pending USFWS approval of the request to reinitiate Section 7 consultation for activities within the vernal pool at the site, to define the extent of off-base contamination greater than the IRG, and to clarify groundwater flow directions. Based on the results of the investigation, optimization measures for the current GET system will be conducted.	Air stripping discontinued and replaced with LGAC treatment at NGWTP. Pending in 2011 – additional site characterization and potential expansion of the GET system.	Continuing to resolve site access limitations because of the presence of a vernal pool and associated access restrictions imposed by USFWS. Most of the site is located on off-base private property.
LF007D (NEWIOU)	Alternative 2 – MNA Assessment	Alternative 2 – MNA Assessment	Assess viability of natural physical, chemical, and biological processes to remediate plume	MNA appears to be a viable remedy at Site LF007D. The plume is stable, but concentrations have not decreased significantly during the period of interim remediation. Groundwater contamination is currently limited to a small area in the vicinity of MW261x04. Within this area, PCGs are exceeded for 1,4-DCB (12.6 µg/L vs. PCG of 5 µg/L) and benzene (3 µg/L vs. PCG of 1 µg/L). Concentrations of 1,4-DCB have decreased during the period of interim remediation. However, long-term benzene concentrations have remained relatively stable at about 3 µg/L. Contaminants do not appear to be migrating off-base to the north or east of the site.	None	Monitoring to evaluate natural attenuation processes is continuing.

TABLE ES-8
Summary of Interim Remedial Action Performance and Status
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Remedial Alternative Selected in the Proposed Plan and IROD	Implemented IRA (FFS terminology)	IRA Objectives	IRA Performance and Status	IRA Optimization Actions	Post-IRA Optimization Actions
LF008	Alternative G4 Extraction/Treatment/ Discharge (GET)	Alternative G4 – GET	GET for migration control	The migration control IRA objective at Site LF008 was achieved by the GET system. Hydraulic capture of the source area was achieved. The distribution of contamination in monitoring wells also indicated hydraulic containment of the plume. The GET system had limited effectiveness at removing the residual organochlorine pesticide contamination. Concentrations are stable and not migrating. The GET system is currently shut down as part of a rebound study for the remainder of the period of interim remediation.	GET system shut down for a rebound study in 2008.	Monitoring to evaluate rebound study is ongoing.
SS015 (NEWIOU)	Alternative 2 – MNA Assessment	Alternative 2 – MNA Assessment	Assess viability of natural physical, chemical, and biological processes to remediate plume	Monitoring data indicated that MNA does not appear to be successfully addressing Site SS015 contamination. The plume appears to be migrating, and contaminant concentrations are increasing in some wells. The limited volume of EVO injected during a 2000-2001 vegetable oil injection treatability study appears to be exhausted. Optimization of the MNA IRA was required, and supplemental injection of EVO was conducted during 2010 to enhance natural attenuation processes. The performance of the EVO treatment is being evaluated.	Data gaps investigation in 2010. Installation of injection wells in 2010. Source area EVO injection in 2010. Installation of additional monitoring wells in 2010.	Performance monitoring and evaluation of the 2010 EVO injection in the site source area is ongoing.
SS016 (NEWIOU)	Alternative 2 – MNA Assessment Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 3 – GET	GET for source control[d] GET for migration control[e]	Hydraulic capture of the TARA source area has been achieved. Within the OSA source area, concentrations have decreased, but the extent of hydraulic capture is less certain. Declining TCE concentrations in shallow and deep monitoring wells downgradient of the OSA and TARA source areas indicate that the horizontal and vertical extents of the plume are being addressed by the existing GET system. However, even after several years of IRA operation, the highest TCE concentrations at Travis AFB are found at OSA source area horizontal extraction well EW003x16 (18,000 µg/L). Therefore, IRA optimization actions were taken during 2010. These actions included a data gaps investigation to more fully define the OSA source area. Based on the results of the data gaps investigation, operation of a 2-Phase® extraction/ThOx treatment was discontinued, and an in situ bioreactor was installed. The performance of the bioreactor is being evaluated. The portion of the commingled Site SS016 plume (OSA/TARA that is not hydraulically captured by the OSA and TARA source control GET systems) is eventually hydraulically captured by the downgradient Site SS029 GET system.	2-Phase® extraction within OSA source area discontinued in 2010. UV/Ox and Th/Ox discontinued in 2010. Groundwater treatment replaced by LGAC at CGWTP. Data gaps investigation within OSA source area conducted in 2010. OSA source area bioreactor installation in 2010.	Performance monitoring and evaluation of the 2010 bioreactor installation in the OSA source area is ongoing. Site access is limited. The site is adjacent to, or within, an active area of military flightline operations (i.e., parking apron, taxiways, and runways).
ST027B (NEWIOU)	Historically managed under the POCO program. Site not addressed in either NEWIOU or WABOU Proposed Plan/ IROD.	MNA (POCO)	Assess viability of natural physical, chemical, and biological processes to remediate plume	Site ST027 has historically been managed as part of the POCO program at Travis AFB because petroleum hydrocarbons were believed to be the only contaminants present at this site. However, an investigation conducted in 2007 resulted in the discovery of TCE and several other chlorinated VOCs in groundwater in the southwestern part of the site. The site was subsequently subdivided into Site ST027A (fuels contamination only) and Site ST027B (CERCLA contaminants). A data gaps investigation was conducted during 2010 to characterize the VOC plume within Site ST027B and provide data to support risk assessments and remedy selection.	Data gaps investigation within Site ST027B conducted during 2010.	Monitoring to evaluate natural attenuation processes is continuing. Site is bounded by military flightline operations.
SS029 (NEWIOU)	Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 3 – GET	GET for migration control	The migration control IRA objective at Site SS029 has been achieved. The existing GET system has achieved hydraulic capture of the on-base plume and is effectively controlling potential off-base migration of the contaminant plume.	Air stripping discontinued and replaced with LGAC groundwater treatment at SBBGWTP. Additional site characterization will be conducted during 2011 to assess the technical implementability of installing a PRB to intercept the distal end of the plume.	Monitoring to evaluate GET system performance is continuing. A large portion of the site is within an area of military flightline operations.

TABLE ES-8
Summary of Interim Remedial Action Performance and Status
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Remedial Alternative Selected in the Proposed Plan and IROD	Implemented IRA (FFS terminology)	IRA Objectives	IRA Performance and Status	IRA Optimization Actions	Post-IRA Optimization Actions
SS030 (NEWIOU)	Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 3 – GET	GET for source control GET for migration control GET for off-base remediation	The source control, migration control, and off-base remediation IRA objectives for the Site SS030 IRA have not been fully achieved. Contaminant concentrations are declining in all of the extraction wells and all but two (2) of the monitoring wells. The off-base plume is being captured on the southern and western sides of the plume. However, increasing TCE concentrations on the eastern side of the off-base plume indicate that contamination may be escaping hydraulic capture. The groundwater elevation contours derived from the 2Q10 GSAP sampling event indicate that the hydraulic capture in this eastern area of the plume has improved after several of the adjacent Site FT005 extraction wells were taken offline for a rebound study. Optimization of the GET IRA is required. Investigations will be performed during 2010-2011 to clarify groundwater flow directions and hydraulic capture. Based on the results of the investigation, optimization measures for the current GET system will be conducted as required.	Air stripping discontinued and replaced with LGAC groundwater treatment at SBBGWTP. Increased groundwater extraction rates to improve hydraulic capture of the off-base plume.	Monitoring to evaluate GET system performance is continuing. Most of the site is located on off-base private property.
SD031 (NEWIOU)	Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 2 – MNA Assessment Alternative 3 – GET	Assess viability of natural physical, chemical, and biological processes to remediate plume GET for source control	The combination of GET in the Site SD031 source areas and MNA in the downgradient portions of the plume has been effective. Hydraulic capture of the source areas was achieved using GET. The effectiveness of GET is further demonstrated by declining VOC concentrations observed in the majority of site monitoring wells. Declining trends are observed in both shallow and deep monitoring wells, indicating both the horizontal and vertical extent of the target areas are being addressed. The Site SD031 GET system has been shut down for a rebound study for the remaining period of interim remediation because VOC concentrations have declined. The maximum 1,1-DCE concentrations during the 2010 GSAP were observed within a localized portion of the plume. These included 78.8 µg/L in EW566x31 and 7.4 µg/L in EW567x31. MNA also appears to be a viable remedy at Site SD031. Overall, contaminant concentrations are stable or declining in the downgradient MNA assessment monitoring wells. The MNA network includes both shallow and deep monitoring wells. MNA appears to be effective throughout the entire thickness of the plume.	Air stripping discontinued and replaced with LGAC groundwater treatment at NGWTP. GET system shut down for a rebound study.	Monitoring to evaluate natural attenuation processes is continuing. Monitoring to evaluate rebound study is ongoing.
SD033 (NEWIOU)	Alternative 2 – MNA Assessment[f] Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 2 – MNA Assessment Alternative 3 – GET	Assess viability of natural physical, chemical, and biological processes to remediate plume GET for migration control[g]	The GET system for WIOU Site SD033 achieved the migration control IRA objective. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 µg/L were captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume were addressed by the GET system. In the southern (downgradient) area of the site, MNA appears to be a viable remedy. Groundwater contamination in this area does not appear to be migrating.	UV/Ox groundwater treatment discontinued in 2010 and replaced by LGAC at CGWTP. WIOU GET system, including Site SD033, shut down for a rebound study.	Monitoring to evaluate natural attenuation processes is continuing. Monitoring to evaluate rebound study is ongoing. The site is a component of the overall WIOU plume.
SD034 (NEWIOU)	Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 3 – GET	GET for source control[h] GET for migration control[i]	The GET and passive skimming systems for WIOU Site SD034 are largely achieving the source control and migration control IRA objectives. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 µg/L are being captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume are being addressed by the existing GET system. Floating product removal of Stoddard solvent is achieving the source control IRA for the site. The extent of floating product continues to be limited to the original release area and is not migrating.	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2009-2010 and replaced by LGAC at CGWTP. WIOU GET system, including Site SD034, shut down for a rebound study.	Passive skimming operations are continuing. Monitoring to evaluate rebound study is ongoing. The site is a component of the overall WIOU plume.
SS035 (NEWIOU)	Alternative 2 – MNA Assessment	Alternative 2 – MNA Assessment	Assess viability of natural physical, chemical, and biological processes to remediate plume	The GET system for the WIOU, including Site SS035, achieved the migration control IRA objective. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 µg/L were captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume are being addressed by the existing GET system.	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2010 and replaced by LGAC treatment at CGWTP. WIOU GET system, including Site SS035, shut down for a rebound study.	Monitoring to evaluate natural attenuation processes is continuing. The site is a component of the overall WIOU plume

TABLE ES-8
Summary of Interim Remedial Action Performance and Status
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Remedial Alternative Selected in the Proposed Plan and IROD	Implemented IRA (FFS terminology)	IRA Objectives	IRA Performance and Status	IRA Optimization Actions	Post-IRA Optimization Actions
SD036 (NEWIOU)	Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 3 – GET	GET for source control GET for migration control	The GET system for WIOU Site SD036 is largely achieving the source control and migration control IRA objectives. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 µg/L were captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume are being addressed by the GET existing system. Although IRA objectives are largely being met, even after several years of IRA operation, TCE concentrations greater than 1,000 µg/L continue to be detected at the source area within Site SD036. Optimization of the GET IRA was required. Therefore, data gaps investigations were performed during 2010 to more fully define the extents of these source areas. Based on the results of the data gaps investigations, optimization measures included discontinuing the GET systems and injection of EVO within the plume source area. The performance of the EVO treatment is being evaluated. In the downgradient portions of the plume, MNA appears to be a viable remedy. Groundwater contamination in this area does not appear to be migrating.	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2009-2010 and replaced by LGAC treatment at CGWTP. WIOU GET system, including Site SD036, shut down for a rebound study in 2010. Data gaps investigation conducted during 2010. Source area EVO injection in 2010.	Performance monitoring and evaluation of the 2010 EVO injection in the site source area is ongoing. Monitoring to evaluate rebound study is ongoing. The site is a component of the overall WIOU plume.
SD037 (NEWIOU)	Alternative 2 – MNA Assessment[j] Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 2 – MNA Assessment Alternative 3 – GET	GET for source control[k] GET for migration control[l]	The GET system for WIOU Site SD037 is largely achieving the source control and migration control IRA objectives. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 µg/L were captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume are being addressed by the GET existing system. Although IRA objectives are largely being met, even after several years of IRA operation, TCE concentrations greater than 1,000 µg/L continue to be detected at the source area within Site SD037. Optimization of the GET IRA was required. Therefore, data gaps investigations were performed during 2010 to more fully define the extents of these source areas. Based on the results of the data gaps investigations, optimization measures included discontinuing the GET systems and injection of EVO within the source areas. The performance of the EVO treatment is being evaluated. In the southern (downgradient) area of the WIOU, MNA appears to be a viable remedy. Groundwater contamination in this area does not appear to be migrating.	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2009-2010 and replaced by LGAC treatment at CGWTP. WIOU GET system, including Site SD037, shut down for a rebound study in 2010. Data gaps investigation conducted during 2010. Source area EVO injection in 2010.	Performance monitoring and evaluation of the 2010 EVO injection in the site source area is ongoing. Monitoring to evaluate natural attenuation processes is continuing. Monitoring to evaluate rebound study is ongoing. The site is a component of the overall WIOU plume.
DP039 (WABOU)	Alternative G3 – Containment/ Treatment/Discharge (GET) Alternative G5 – Source Area and Groundwater Extraction/ Treatment/ MNA (GET and MNA)	Alternative G3 – GET Alternative G5 – GET and MNA	GET for migration control GET for source control MNA to assess the viability of natural physical, chemical, and biological processes to remediate plume	The Site DP039 source control IRA objective has been partly achieved. TCE concentrations in the historical contaminant release area (i.e., a former sump) are declining and a portion of the source area plume was hydraulically contained by the existing GET system. However, another portion of the source area plume is not hydraulically captured. This uncaptured portion of the plume, with TCE concentrations exceeding 1,000 µg/L, extends about 800 feet downgradient. This uncaptured portion of the source area plume underlies an ongoing demonstration of phytoremediation. In December 2008, an in situ bioreactor was installed in the former sump area as a technology demonstration. The performance of the bioreactor is being evaluated for the remainder of the period of interim remediation. A data gaps investigation was performed during 2010 to more fully define the extent of the downgradient source area with TCE concentrations greater than 500 µg/L. Based on the results of the data gaps investigations, an in situ PRB of EVO was installed hydraulically downgradient of an existing area of phytoremediation and upgradient of the portion of the plume undergoing MNA. The performance of the EVO PRB is being evaluated. Increasing TCE concentration trends at some monitoring wells in the distal portion of the plume indicate that MNA may not be fully effective if TCE concentrations in the untreated portion of the plume continue to exceed 1,000 µg/L and act as a continuing source of contamination into the downgradient portion of the plume.	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2009-2010 and replaced by LGAC treatment at SBBGWTP. GET system shut down in 2008. Source area in situ bioreactor installation conducted in 2008 as a technology demonstration project. Data gaps investigation conducted during 2010. EVO PRB installed in 2010.	Performance monitoring and evaluations of the 2010 bioreactor and EVO PRB installations are ongoing. Monitoring to evaluate natural attenuation processes is continuing. A phytoremediation treatability study conducted at the site concluded that planted trees can contribute to remediation of the plume. Monitoring within the area of phytoremediation is continuing.
SS041 (WABOU)	Alternative G3 – Containment/ Treatment/Discharge (GET)	Alternative G3 – GET	GET for migration control	Site SS041 has been in NFRAP status. The NFRAP status is documented in a 14 December 2005 consensus statement (Travis AFB, 2005).	None	

TABLE ES-8
Summary of Interim Remedial Action Performance and Status
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Remedial Alternative Selected in the Proposed Plan and IROD	Implemented IRA (FFS terminology)	IRA Objectives	IRA Performance and Status	IRA Optimization Actions	Post-IRA Optimization Actions
SD043 (WABOU)	Alternative G3 – Containment/ Treatment/Discharge (GET)	Alternative G3 – GET	GET for migration control	The IRA GET system has effectively reduced plume size and concentrations. No contaminants were detected above IRGs during the 2010 GSAP.	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2009-2010 and replaced by LGAC treatment at CGWTP. WIOU GET system, including Site SD043, shut down for a rebound study in 2010.	Monitoring to evaluate rebound study is ongoing. The site is a component of the overall WIOU plume.

[a] On-base portion of plume
[b] Plume at Base boundary
[c] Off-base portion of plume
[d] OSA portion of plume
[e] Southern portion of plume
[f] South Gate Area, Facility 1917, and Facility 810 plumes
[g] Storm sewer
[h] Bioslurp/free product removal
[i] Coordinated with Site SD037
[j] Portions of plume near Facilities 919, 977, 981, and Area G Ramp
[k] Portions of plume near Facilities 837, 838, and Ragsdale/V Area
[l] Remainder of plume

Summary of Current Alternative Screening

Travis AFB has successfully operated and monitored the performance of the site-specific groundwater IRAs within the NEWIOU and WABOU for approximately a decade. Now, Travis AFB is beginning the transition out of the period of interim remediation. The long-term performance of the existing IRAs, existing IRA optimization measures, successful demonstration projects, and treatability studies results are factors in the development of alternatives in the FFS. The results of this current alternative screening against the criteria of Effectiveness, Implementability, and Cost are summarized in Table ES-9.

Detailed Analysis of Alternatives

Following alternative screening against the the criteria of Effectiveness, Implementability, and Cost, a more detailed analysis of the site-specific groundwater alternatives is conducted using the following CERCLA evaluation criteria:

1. Overall Protection of Human Health and the Environment
2. Compliance with ARARs
3. Long-term Effectiveness and Permanence
4. Reduction of Toxicity, Mobility, or Volume through Treatment
5. Short-term Effectiveness
6. Implementability
7. Cost
8. State Acceptance
9. Community Acceptance

The last two (2) criteria of State Acceptance and Community Acceptance are evaluated in the Proposed Plan and ROD stages.

Each of the FFS alternatives, except No Action, satisfies the evaluation criteria to varying degrees.

Comparative Analysis of Alternatives

A comparative analysis is conducted between the remedial alternative developed for each site and the interim remedy using the same seven (7) evaluation criteria as used for the detailed analyses. A summary of the implemented groundwater IRAs and the remedial alternatives developed for each site in this FFS is provided in Table ES-10. A summary of the comparative analyses of alternatives against the seven (7) evaluation criteria is provided in Table ES-11. Additional summaries of the IRAs and alternatives are provided in Tables ES-12 and ES-13. These tables provide comparisons between the remedial alternatives previously developed and evaluated in the historical NEWIOU FS (Radian, 1996a), WABOU FS (CH2M HILL, 1998a), and those alternatives developed in the current FFS.

TABLE ES-9
Summary of Alternative Screening
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Remedial Alternative	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
1 – No Action	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○
2 – MNA	■	■	■	■	□	■	■	□	□	■	□	□	■	■	□	■	□	□	□	○	■
3 – GET	◙	◙	□	□	■	□	◙	◙	◙	□	■	■	◙	◙	◙	□	◙	◙	◙	○	◙
4 – Bioreactor and GET	□	□	○	○	○	□	○	□	■	□	○	○	□	○	○	○	□	□	◙	○	○
5 – EVO and EA	□	□	○	○	□	□	○	■	□	□	□	□	□	□	□	○	■	■	◙	○	○
6 – Bioreactor, Phytoremediation, EVO PRB, and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○
7 – Passive Skimming and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○	○	○	○	○

■ = Alternative that best satisfies the evaluation criteria of Effectiveness, Implementability, and Cost.
◙ = Alternative that moderately satisfies the evaluation criteria of Effectiveness, Implementability, and Cost.
□ = Alternative that poorly satisfies the evaluation criteria of Effectiveness, Implementability, and Cost.
○ = Alternative that is not applicable or does not satisfy the evaluation criteria of Effectiveness, Implementability, and Cost.

TABLE ES-10
Summary Comparison of Implemented Interim Remedial Actions and FFS Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Implemented Interim Remedial Action[a]	FFS Remedial Alternative
FT004, SD031, SD033[b]	GET and MNA Assessment	2 – MNA
FT005, LF008, SS035[b], SD043	GET	2 – MNA
LF006, LF007B, LF007D, ST027B	MNA Assessment	2 – MNA
LF007C, SS029, SS030	GET	3 – GET
SS015	MNA Assessment	5 – EVO and EA
SS016	GET	4 – Bioreactor and GET
SD034[b]	GET, Passive Skimming, and MNA Assessment	7 – Passive Skimming and EA
SD036[b], SD037[b]	GET and MNA Assessment	5 – EVO and EA
DP039	GET and MNA Assessment	6 – Bioreactor, Phytoremediation, EVO PRB, and EA

[a] Groundwater IRAs selected by the final NEWIOU Groundwater IROD (Travis AFB, 1998) and final WABOU Groundwater IROD (Travis AFB, 1999).
[b] Component site of WIOU collection of site plumes.

TABLE ES-11
Summary of Comparative Analysis of Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Remedial Alternative	Site																				
	FT004	FT005	LF006	LF007B	LF007C	LF007D	LF008	SS015	SS016	ST027B	SS029	SS030	SD031	SD033	SD034	SS035	SD036	SD037	DP039	SS041	SD043
1 – No Action	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○
2 – MNA	■	■	■	■	□	■	■	□	□	■	□	□	■	■	□	■	□	□	□	□	■
3 – GET	◙	◙	□	□	■	□	◙	◙	◙	□	■	■	◙	◙	◙	□	◙	◙	◙	□	◙
4 – Bioreactor and GET	○	○	○	○	○	○	○	□	■	○	○	○	○	○	○	○	□	□	◙	○	○
5 – EVO and EA	○	○	○	○	○	○	○	■	○	○	○	○	○	○	○	○	■	■	◙	○	○
6 – Bioreactor, Phytoremediation, EVO PRB, and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○
7 – Passive Skimming and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○	○	○	○	○

■ = Alternative that overall best satisfies the evaluation criteria.
◙ = Alternative that overall moderately satisfies the evaluation criteria.
□ = Alternative that overall poorly satisfies the evaluation criteria.
○ = Alternative that is not applicable or does not satisfy the evaluation criteria.

All alternatives include components of LUCs and groundwater monitoring.

TABLE ES-12
Comparison of Historical and Current NEWIOU Sites Alternative Development
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Alternatives Developed in the NEWIOU FS[a]	Alternatives Evaluated in the NEWIOU FS[a]	Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]	Alternatives Developed in the FFS	Alternatives Evaluated in the FFS	Preferred Alternative in the FFS
FT004	1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain 9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation	1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	3 – Extraction, Treatment, and Discharge (GET)	1 – No Action 2 – MNA 3 – GET 4 – Bioreactor and GET 5 – EVO and EA 6 – Bioreactor, Phytoremediation, EVO PRB, and EA 7 – Passive Skimming and EA	1 – No Action 2 – MNA 3 – GET	2 – MNA
FT005		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	3 – Extraction, Treatment, and Discharge (GET)		1 – No Action 2 – MNA 3 – GET	2 – MNA
LF006		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA		1 – No Action 2 – MNA 3 – GET	2 – MNA
LF007B		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA Assessment		1 – No Action 2 – MNA 3 – GET	2 – MNA

TABLE ES-12
Comparison of Historical and Current NEWIOU Sites Alternative Development
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

<table>
<tr><th>Site</th><th>Alternatives Developed in the NEWIOU FS[a]</th><th>Alternatives Evaluated in the NEWIOU FS[a]</th><th>Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]</th><th>Alternatives Developed in the FFS</th><th>Alternatives Evaluated in the FFS</th><th>Preferred Alternative in the FFS</th></tr>
<tr><td>LF007C</td><td rowspan="4">1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain
9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment (on-base plume)
3 – Extraction, Treatment, and Discharge (GET) (Base boundary and off-base plume)</td><td rowspan="4">1 – No Action
2 – MNA
3 – GET
4 – Bioreactor and GET
5 – EVO and EA
6 – Bioreactor, Phytoremediation, EVO PRB, and EA
7 – Passive Skimming and EA</td><td>1 – No Action
2 – MNA
3 – GET</td><td>3 – GET</td></tr>
<tr><td>LF007D</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment</td><td>1 – No Action
2 – MNA
3 – GET</td><td>2 – MNA</td></tr>
<tr><td>SS015</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment</td><td>1 – No Action
2 – MNA
3 – GET
4 – Bioreactor and GET
5 – EVO and EA</td><td>5 – EVO and EA</td></tr>
<tr><td>SS016</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>3 – Extraction, Treatment, and Discharge (GET)</td><td>1 – No Action
2 – MNA
3 – GET
4 – Bioreactor and GET</td><td>4 – Bioreactor and GET</td></tr>
</table>

TABLE ES-12
Comparison of Historical and Current NEWIOU Sites Alternative Development
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

<table>
<tr><th>Site</th><th>Alternatives Developed in the NEWIOU FS[a]</th><th>Alternatives Evaluated in the NEWIOU FS[a]</th><th>Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]</th><th>Alternatives Developed in the FFS</th><th>Alternatives Evaluated in the FFS</th><th>Preferred Alternative in the FFS</th></tr>
<tr><td>ST027B[c]</td><td rowspan="5">1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain
9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation</td><td></td><td></td><td rowspan="5">1 – No Action
2 – MNA
3 – GET
4 – Bioreactor and GET
5 – EVO and EA
6 – Bioreactor, Phytoremediation, EVO PRB, and EA
7 – Passive Skimming and EA</td><td>1 – No Action
2 – MNA
3 – GET</td><td>2 – MNA</td></tr>
<tr><td>SS029</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>3 – Extraction, Treatment, and Discharge (GET)</td><td>1 – No Action
2 – MNA
3 – GET</td><td>3 – GET</td></tr>
<tr><td>SS030</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment
3 – Extraction, Treatment, and Discharge (GET)</td><td>1 – No Action
2 – MNA
3 – GET</td><td>3 – GET</td></tr>
<tr><td>SD031</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain Oxidation</td><td>2 – MNA Assessment
3 – Extraction, Treatment, and Discharge (GET)</td><td>1 – No Action
2 – MNA
3 – GET</td><td>2 – MNA</td></tr>
<tr><td>SD033</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment (South Gate Area, Facility 1917, and Facility 810 plumes)
3 – Extraction, Treatment, and Discharge (GET) (storm sewer)</td><td>1 – No Action
2 – MNA
3 – GET</td><td>2 – MNA</td></tr>
</table>

TABLE ES-12
Comparison of Historical and Current NEWIOU Sites Alternative Development
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

<table>
<tr><th>Site</th><th>Alternatives Developed in the NEWIOU FS[a]</th><th>Remedial Alternatives Evaluated for the Site in the NEWIOU FS[a]</th><th>Remedial Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]</th><th>Alternatives Developed in the Basewide Groundwater FFS</th><th>Alternatives Evaluated in the FFS</th><th>Preferred Alternative in the FFS</th></tr>
<tr><td>SD034</td><td rowspan="4">1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain
9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation</td><td>3 – Extraction, Treatment, and Discharge (GET)
(Bioslurp/free product removal and coordination with Site SD037 alternative)</td><td rowspan="4">1 – No Action
2 – MNA
3 – GET
4 – Bioreactor and GET
5 – EVO and EA
6 – Bioreactor, Phytoremediation, EVO PRB, and EA
7 – Passive Skimming and EA</td><td>1 – No Action
2 – MNA
3 – GET
7 – Passive Skimming and EA</td><td>7 – Passive Skimming and EA</td></tr>
<tr><td>SS035</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment</td><td>1 – No Action
2 – MNA
3 – GET</td><td>2 – MNA</td></tr>
<tr><td>SD036</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>3 – Extraction, Treatment, and Discharge (GET)</td><td>1 – No Action
2 – MNA
3 – GET
5 – EVO and EA</td><td>5 – EVO and EA</td></tr>
<tr><td>SD037</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment
(portions of plume near Facilities 919, 977, 981, and Area G Ramp)
3 – Extraction, Treatment, and Discharge (GET)
(portions of plume near Facilities 837, 838, and Ragsdale/V Area and the remainder of plume)</td><td>1 – No Action
2 – MNA
3 – GET
5 – EVO and EA</td><td>5 – EVO and EA</td></tr>
</table>

[a] Source: Final NEWIOU FS (Radian, 1996a).
[b] Source: Final Groundwater IROD for the NEWIOU (Travis AFB, 1998).
[c] Historically managed under the POCO program and not addressed in either the Groundwater IROD for the NEWIOU or Groundwater IROD for the WABOU.

TABLE ES-13
Comparison of Historical and Current WABOU Sites Alternative Development
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

<table>
<tr><th>Site</th><th>Alternatives Developed in the WABOU FS[a]</th><th>Alternatives Evaluated in the WABOU FS[a]</th><th>Alternatives Selected in the WABOU Proposed Plan/IROD[b]</th><th>Alternatives Developed in the FFS</th><th>Alternatives Evaluated in the FFS</th><th>Preferred Alternative in the FFS</th></tr>
<tr><td>LF008</td><td rowspan="4">G1 – No Action
G2 – Monitored Natural Attenuation
G3 – Containment/Treatment/Discharge (GET)
G4 – Extraction/Treatment/Discharge (GET)
G5 – Source Area and Groundwater Extraction/Treatment/ Monitored Natural Attenuation
G6 – Source Area Extraction/Treatment/Monitored Natural Attenuation</td><td>G1 – No Action
G2 – Natural Attenuation
G3 – Containment, Treatment, Discharge
G4 – Extraction, Treatment, Discharge</td><td>G4 – Extraction, Treatment, Discharge (GET)</td><td rowspan="4">1 – No Action
2 – MNA
3 – GET
4 – Bioreactor and GET
5 – EVO and EA
6 – Bioreactor, Phytoremediation, EVO PRB, and EA
7 – Passive Skimming and EA</td><td>1 – No Action
2 – MNA
3 – GET</td><td>2 – MNA</td></tr>
<tr><td>DP039</td><td>G1 – No Action
G2 – Natural Attenuation
G3 – Containment, Treatment, Discharge (GET)
G4 – Extraction, Treatment, Discharge (GET)
G5 – Source Area Extraction, Treatment, Natural Attenuation
G6 – Source Area Containment, Treatment, Natural Attenuation</td><td>G3 – Containment, Treatment, Discharge (GET)
G5 – Source Area and Groundwater Extraction, Treatment, MNA (GET and MNA)</td><td>1 – No Action
2 – MNA
3 – GET
6 – Bioreactor, Phytoremediation, EVO PRB, and EA</td><td>6 – Bioreactor, Phytoremediation, EVO PRB, and EA</td></tr>
<tr><td>SS041</td><td>G1 – No Action
G2 – Natural Attenuation
G3 – Containment, Treatment, Discharge (GET)</td><td>G3 – Containment, Treatment, Discharge (GET)</td><td>1 – No Action
2 – MNA
3 – GET</td><td>1 – No Action[c]</td></tr>
<tr><td>SD043</td><td>G1 – No Action
G2 – Natural Attenuation
G3 – Containment, Treatment, Discharge (GET)</td><td>G3 – Containment, Treatment, Discharge (GET)</td><td>1 – No Action
2 – MNA
3 – GET</td><td>2 – MNA</td></tr>
</table>

[a] Source: Final WABOU FS (CH2M HILL, 1998a).
[b] Source: Final Groundwater IROD for the WABOU (Travis AFB, 1999).
[c] Site SS041 is currently in NFRAP status.

Performance Enhancement Measures

If performance monitoring identifies any unanticipated or adverse outcomes from implementing the remedial technology components of Alternatives 2 through 7, then the Air Force will carry out performance enhancement measures to correct the deficiencies. The end result of the performance enhancement measures will either be a return of the technology's ability to remediate contaminated groundwater, a transition to a more effective technology component, or the application of additional remedial technology components in hydraulically downgradient locations.

Travis AFB will continue to enforce LUCs to minimize potential unauthorized exposure to contaminated groundwater.

Final Decisions

Once the preferred remedial alternatives are developed, they will be presented in a Basewide Groundwater Proposed Plan. This document provides the information needed for the public to understand and comment on the merits of the preferred alternatives. A public meeting will be held to formally present the preferred alternatives and to obtain public comments on them. After the public comments are received and addressed, the final remedial strategies will be selected in the Basewide Groundwater ROD. The ROD is a legal document that details the actions to be taken at each ERP site.

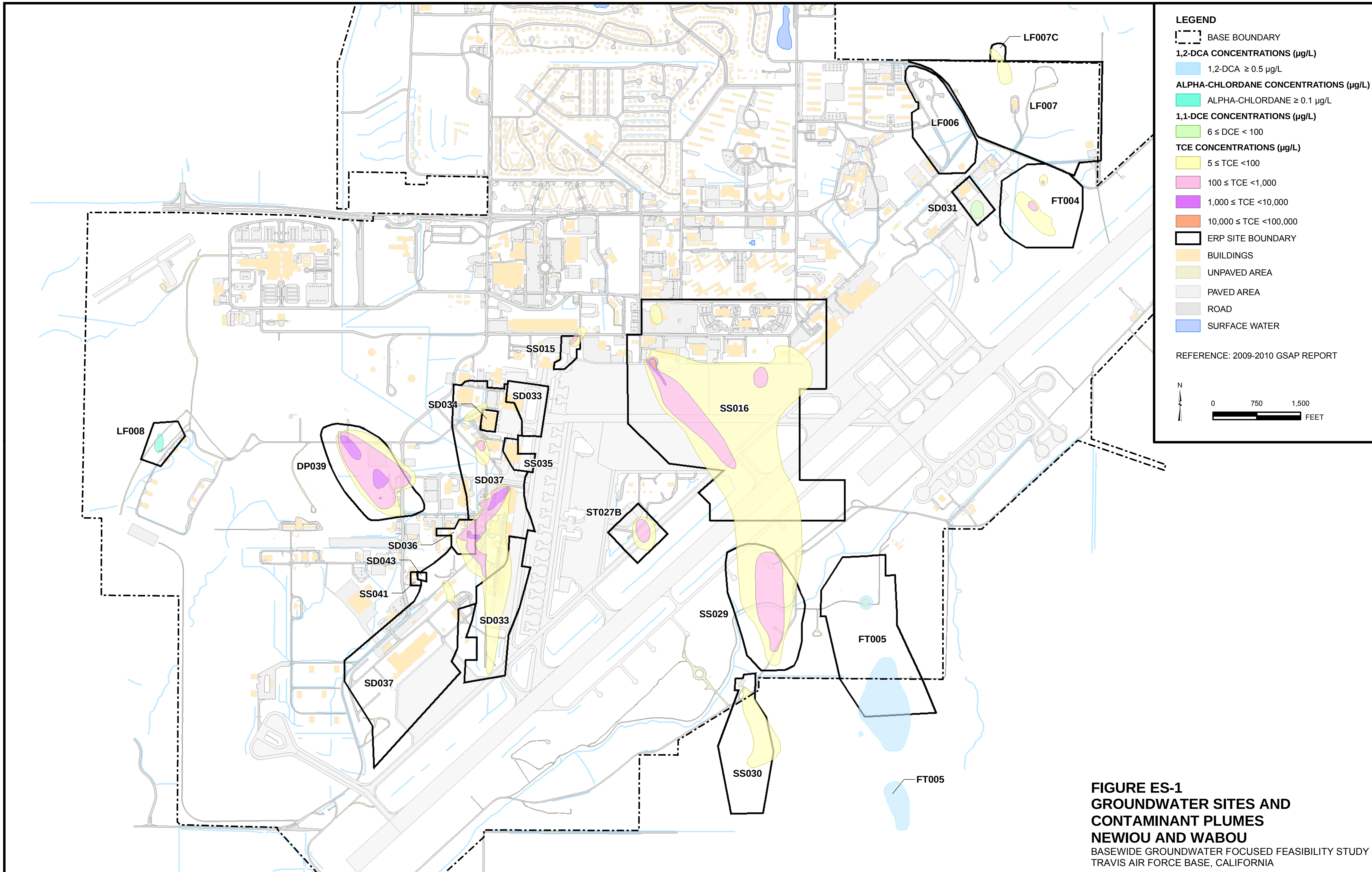

FIGURE ES-1
GROUNDWATER SITES AND CONTAMINANT PLUMES
NEWIOU AND WABOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

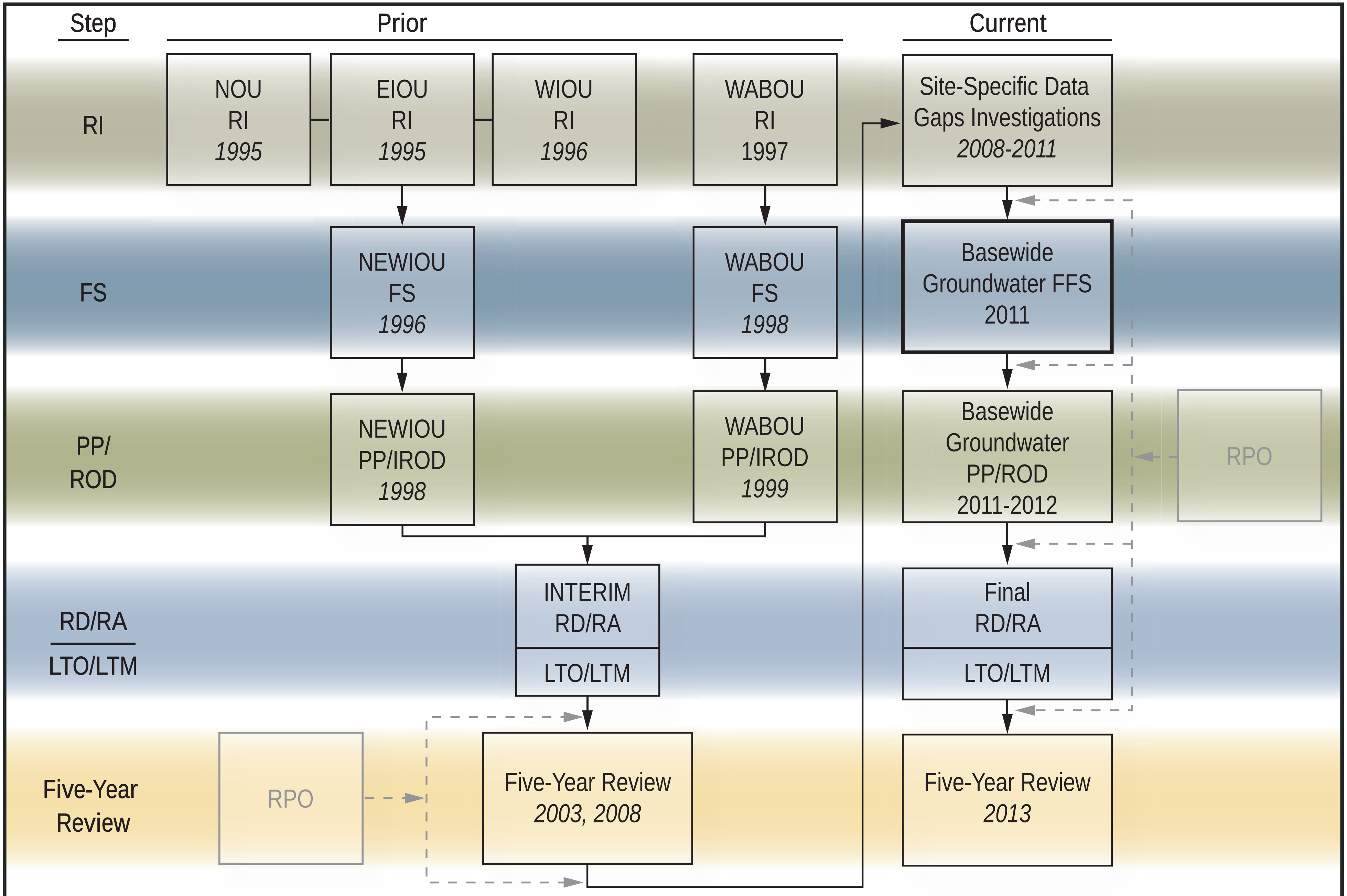

FIGURE ES-2
IMPLEMENTATION OF THE CERCLA PROCESS
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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SECTION 1

Introduction

This Basewide Groundwater Focused Feasibility Study (FFS) develops and evaluates potential remedial alternatives to address contaminated groundwater at multiple sites at Travis Air Force Base (AFB), California. The location of Travis AFB is shown on Figure 1-1.

As a result of past waste management and disposal practices, groundwater at Travis AFB is contaminated at multiple locations. To address this contamination, Travis AFB has followed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process to conduct operable unit (OU)-specific remedial investigations (RIs) and develop feasibility studies (FSs), proposed plans, and interim records of decision (IRODs). Interim remedial actions (IRAs) have been implemented at each of the contaminated groundwater sites in accordance with the final *Groundwater Interim Record of Decision for the North, East, West Industrial Operable Unit* (NEWIOU Groundwater IROD) (Travis AFB, 1998) and the final *Groundwater Interim Record of Decision for the West/Annexes/Basewide Operable Unit* (WABOU Groundwater IROD) (Travis AFB, 1999).

The IRAs have been in operation for approximately a decade, and their performance has been evaluated during the period of interim remediation by two (2) five-year reviews (CH2M HILL, 2003a, 2008a). For the most part, the IRAs operated successfully during the period of interim remediation since the late 1990s to early 2000s. However, after about a decade of interim remediation, the groundwater at most sites remains contaminated at concentrations above interim remediation goals (IRGs).

Travis AFB is now beginning the transition out of interim remediation and is starting the process to select and implement the final remedial actions at each site. As part of this process, the FFS describes the development and screening of potential remedial alternatives to succeed the IRAs after the period of interim remediation is concluded.

The FFS uses the IRA performance data obtained during the period of interim remediation and evaluations of other applicable technologies to support the development and evaluation of potential final remedial actions.

This FFS will lead to a Basewide Groundwater PP and then a Basewide Groundwater Record of Decision (ROD). The ROD will formally select the final groundwater cleanup actions necessary to mitigate potential risks to human health and the environment.

1.1 Purpose

The primary purpose of the FFS is to identify, screen, and evaluate technologies to remediate contaminated groundwater at Travis AFB. In accordance with the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (U.S. Environmental Protection Agency [EPA], 1988), the FFS includes the following main components:

- Identification of potential response actions, technologies, and process options to address groundwater contamination

- Screening of groundwater remedial technologies and process options
- Assembly of representative process options into appropriate groundwater remedial alternatives
- Detailed evaluations of the groundwater remedial alternatives
- Comparative analyses of the groundwater remedial alternatives

Formal OU-specific FSs have already been completed to develop and evaluate interim remedial alternatives for the ERP sites within each OU (Radian, 1996a [NEWIOU]; CH2M HILL, 1998a [WABOU]). This FFS supplements the previously completed FSs by developing and evaluating appropriate final remedial alternatives to be implemented at all Travis AFB Environmental Restoration Program (ERP) sites after the period of interim remediation is concluded.

1.2 Scope

The FFS addresses sites currently managed under the ERP. Sites managed under the Travis AFB Petroleum-only Contaminated (POCO) program are not a part of this FFS.

1.2.1 Environmental Restoration Program Sites

The FFS addresses contaminated groundwater at 19 ERP sites within two (2) OUs at Travis AFB: the NEWIOU and the WABOU. A listing of the ERP sites and their associated OU is provided in Table 1-1. The locations of the OUs are shown on Figure 1-2. The ERP site locations and current groundwater contaminant plumes are shown on Figure 1-3.

1.2.2 Petroleum-only Contaminated Sites

The Travis AFB POCO Sites Program manages petroleum contamination sites. POCO sites are typically associated with surface and subsurface releases from fuel spills, piping leaks, oil-water separators (OWSs), or underground storage tanks (USTs). The POCO Sites Program is involved with the removal of USTs and the remediation of POCO soil and groundwater using risk-based cleanup actions.

The San Francisco Bay Regional Water Quality Control Board (Water Board) is the lead oversight agency for this program, as CERCLA excludes petroleum as a CERCLA contaminant. For this reason, the following POCO sites were not addressed in either IROD and are not addressed in this FFS:

- Site SS014 – Jet Fuel Spill Area
- Site ST018 – North/South Gas Station
- Site ST027Area A (Site ST027A) – Facilities 1918, 1919, and 1754
- Site ST028 – Facilities 363 and 1201
- Site ST032 – Areas MW-107 and MW-246 (transferred from ERP to POCO in 2009)

Site ST027 Area B (Site ST027B) is addressed in this FFS, because previously unknown CERCLA groundwater contamination was encountered at this site after the Groundwater IROD for the NEWIOU was finalized.

1.3 Organization

The organization and content of the FFS report are follows:

- **Volume 1 – Text**
  - **Section 1: Introduction.** Provides the subject, purpose, scope, and plan of development of the FFS.
  - **Section 2: Background.** Describes the physical, administrative, and regulatory background of Travis AFB and contaminated groundwater sites. Summarizes the performance of the groundwater IRAs currently being implemented at each site.
  - **Section 3: Conceptual Site Models.** Provides conceptual site models (CSMs) for Travis AFB and individual groundwater sites. Includes site maps, contaminant distribution maps, and cross sections.
  - **Section 4: Approach.** Describes the approach used to develop remedial alternatives. Includes consideration of how Travis AFB has already implemented the CERCLA process and emerging issues for consideration in alternative development such as green and sustainable remediation.
  - **Section 5: Preliminary Cleanup Goals.** Describes remedial action objectives (RAOs), provides analyses of applicable or relevant and appropriate requirements (ARARs), and lists the numerical preliminary cleanup goals (PCGs) for groundwater.
  - **Section 6: Identification and Screening of Technologies.** Describes general response actions (GRAs), remedial technologies, and process options that will satisfy the remedial action objectives. Provides a screening evaluation of the technologies and process options against the criteria of effectiveness, implementability, and relative cost. Following this screening, representative process options are selected for assembly into alternatives.
  - **Section 7: Assembly and Screening of Alternatives.** Describes the assembly of representative process options into remedial alternatives. The assembled alternatives are then evaluated against the criteria of effectiveness, implementability, and cost.
  - **Section 8: Detailed Analysis of Alternatives.** Provides a more detailed analysis of the assembled groundwater remedial alternatives against the CERCLA evaluation criteria of 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; and cost. Green and sustainability impacts are also included as one (1) of the evaluation criteria.
  - **Section 9: Comparative Analysis of Alternatives.** Provides a comparative analysis of the groundwater remedial alternatives by comparing how each alternative addresses the CERCLA evaluation criteria.

- **Volume 2 – Appendixes**
  - **Appendix A: Acronyms and Abbreviations**
  - **Appendix B: References**
  - **Appendix C: Lines of Evidence for MNA**
  - **Appendix D: Remediation Timeframe Estimates**
  - **Appendix E: Cost Estimates**
  - **Appendix F: Sustainability Evaluations**
  - **Appendix G: Response to Comments**

TABLE 1-1
Summary of NEWIOU and WABOU Groundwater Sites
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

NEWIOU Groundwater Sites[a]	WABOU Groundwater Sites[b]
FT004	DP039
FT005	LF008
LF006	SS041
LF007	SD043
SS015	
SS016	
ST027B[c]	
SS029	
SS030	
SD031	
SD033	
SD034	
SS035	
SD036	
SD037	

[a] Identified in the NEWIOU Groundwater IROD (Travis AFB, 1998) as requiring interim remediation.
[b] Identified in the WABOU Groundwater IROD (Travis AFB, 1999) as requiring interim remediation.
[c] Within the NEWIOU, but not identified in the IROD because CERCLA contamination was detected in the Area B portion of the plume after the NEWIOU Groundwater IROD was finalized.

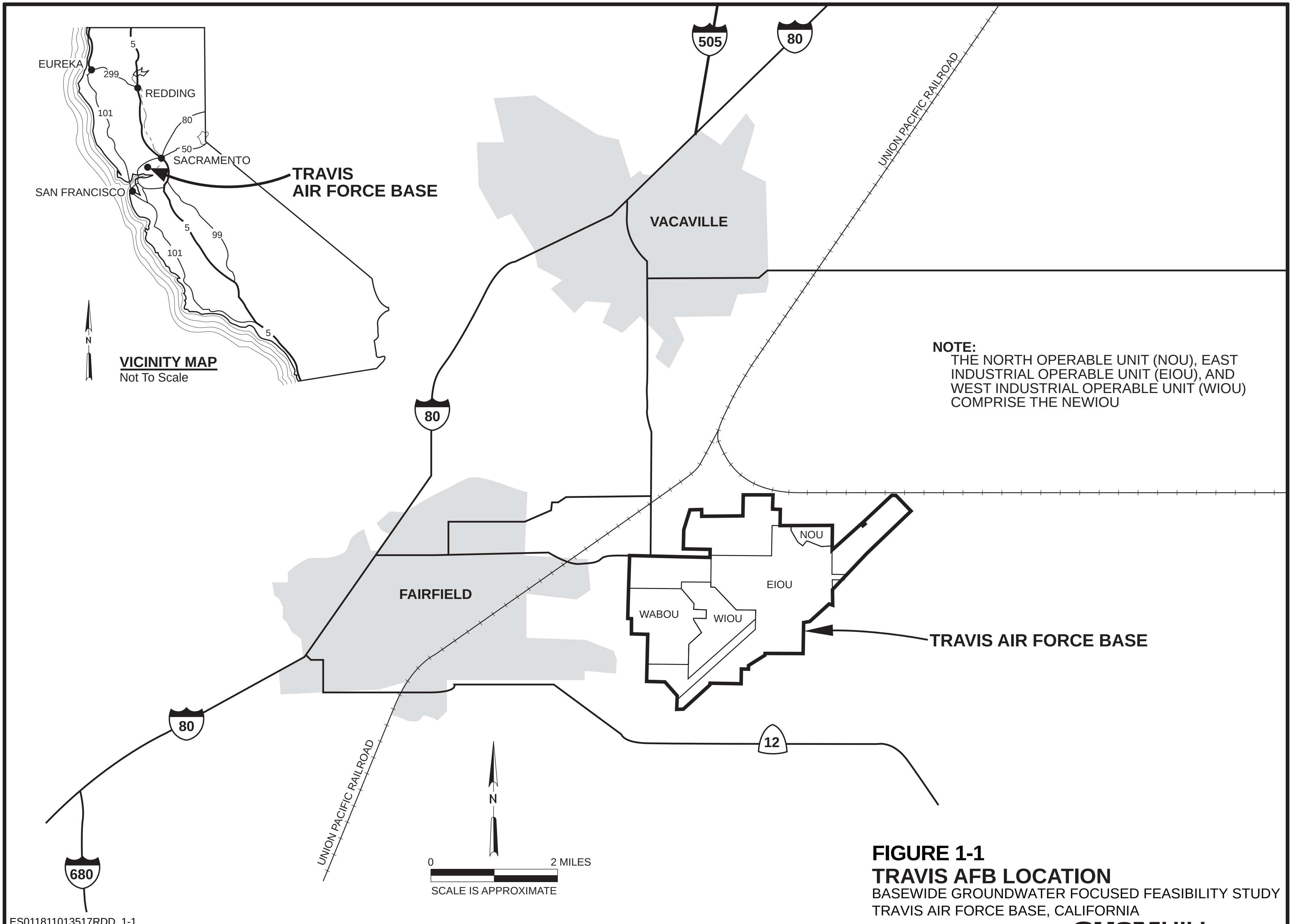

FIGURE 1-1
TRAVIS AFB LOCATION
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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CH2MHILL®

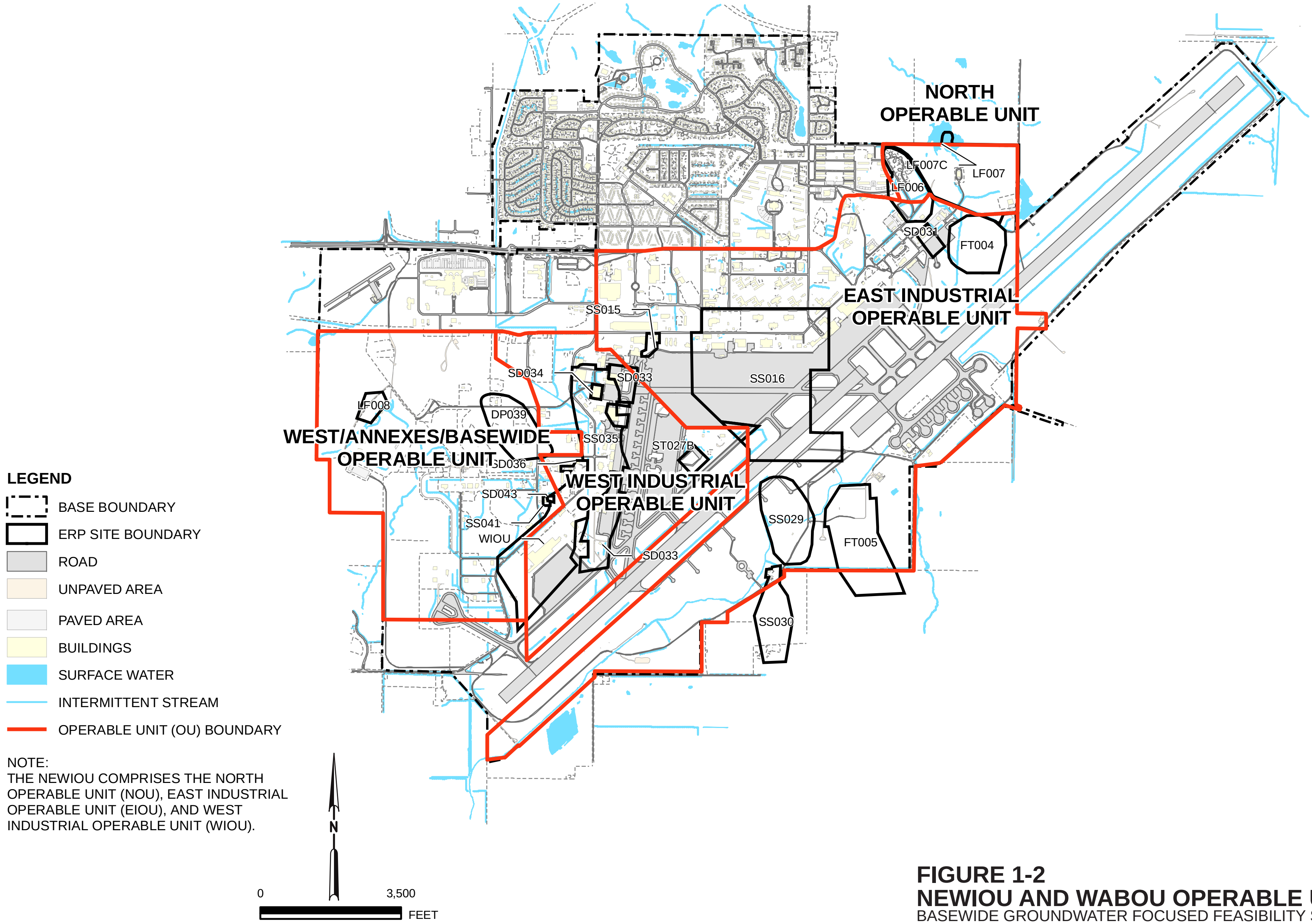

FIGURE 1-2
NEWIOU AND WABOU OPERABLE UNITS
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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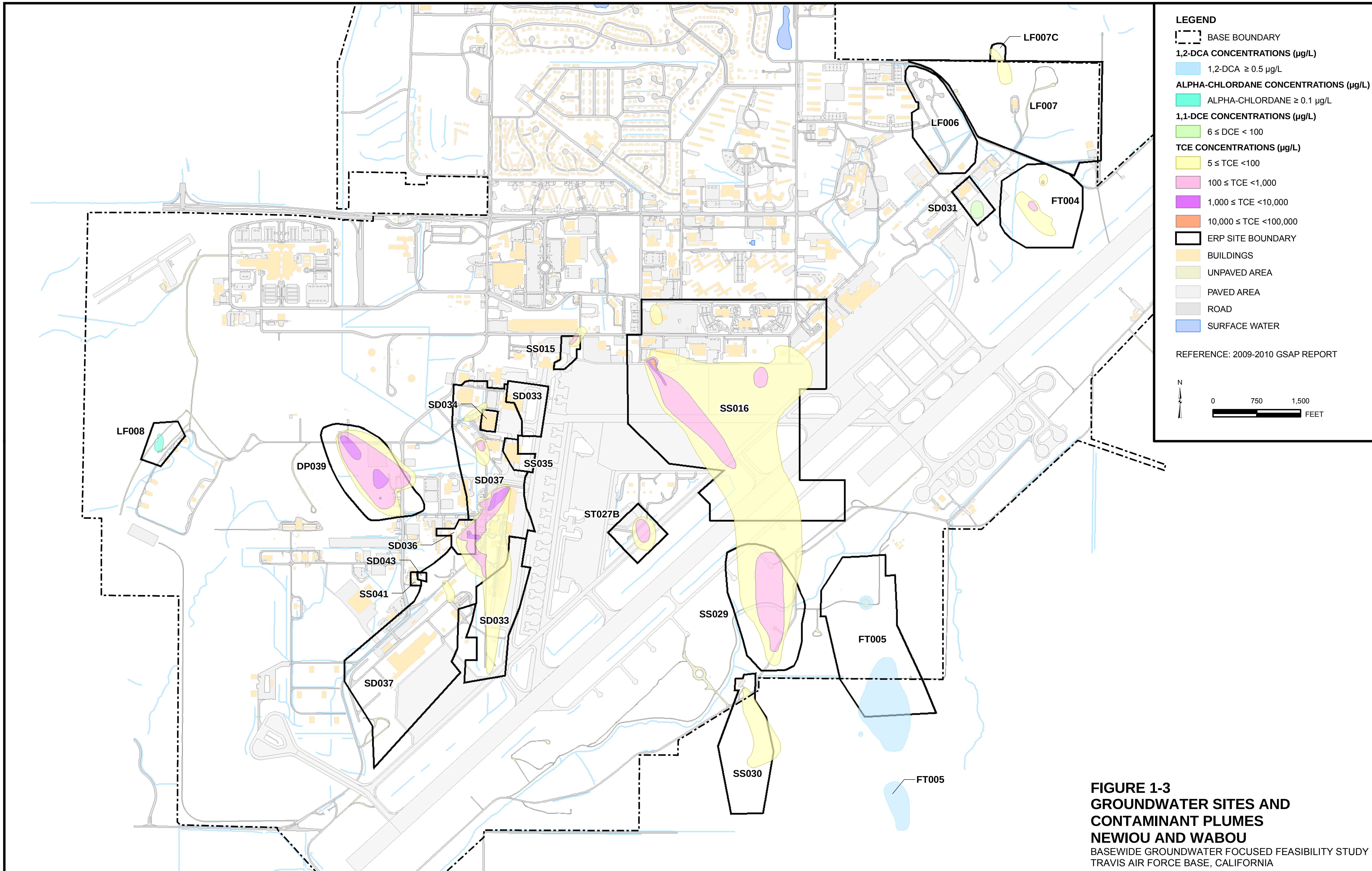


FIGURE 1-3
GROUNDWATER SITES AND CONTAMINANT PLUMES
NEWIOU AND WABOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG1-3_BASEWIDE_PLUME_NETWORK.MXD MSCHROCK 6/15/2011 01:10:56

SECTION 2

Background

As a result of past waste management and disposal practices, groundwater at Travis AFB is contaminated at multiple locations. To address this contamination, Travis AFB has implemented the CERCLA process and installed multiple groundwater IRAs. This section summarizes the development, scope, and performance of these IRAs. Subsequent sections of the FFS describe the development and screening of potential remedial alternatives to succeed the IRAs after the period of interim remediation is concluded.

2.1 Overview of the CERCLA Process at Travis AFB

In 1983, the Air Force initiated the Installation Restoration Program (IRP) (now the ERP) to investigate the nature and extent of hazardous waste releases to the environment. On the basis of IRP data evaluated by EPA, Travis AFB was placed on the National Priorities List (NPL) on November 21, 1989 (54 *Federal Register* 48187). Approximately 1 year later, on September 27, 1990, the Air Force, EPA, California Department of Toxic Substances Control (DTSC), and Water Board negotiated and signed the Federal Facilities Agreement (FFA) (Travis AFB, 1990) that established the framework and schedule for environmental cleanup at Travis AFB.

Travis AFB is the lead agency and is responsible for conducting all actions related to the remediation of contaminated groundwater. The EPA Region 9, Water Board, and DTSC provide regulatory agency oversight of the actions taken by the Air Force.

The following subsections summarize the implementation of the CERCLA process at Travis AFB. A brief chronology of the key events related to the management of groundwater contamination at Travis AFB is also summarized in Table 2-1.

2.1.1 Operable Units

Under the original FFA (Travis AFB, 1990), Travis AFB was treated as a single entity with one (1) associated comprehensive cleanup schedule. Then, in May 1993, the FFA was amended to divide the Base into four (4) OUs to facilitate the overall cleanup program. The OU boundaries are shown on Figure 1-2. The four (4) OUs are as follows:

- East Industrial Operable Unit (EIOU)
- West Industrial Operable Unit (WIOU)
- North Operable Unit (NOU)
- West/Annexes/Basewide Operable Unit (WABOU)

In October 1995, the EIOU, WIOU, and NOU were combined into the composite NEWIOU. Currently, the OUs at Travis AFB include the NEWIOU and the WABOU. This FFS takes a Basewide approach and addresses groundwater contamination within both of these OUs.

2.1.2 Groundwater Sites

Summary descriptions of the ERP sites within the NEWIOU and WABOU are provided in the following subsections. More complete descriptions of the sites are provided in Section 3.

2.1.2.1 NEWIOU Groundwater Sites

Contaminated groundwater ERP sites within the NEWIOU include the following:

- **Site FT004 (Fire Training Area [FTA]-3):** Area used for fire training exercises from approximately 1953 through 1962. During this period, waste fuels, oils, and solvents were burned on open ground. Historical practices resulted in groundwater contamination with chlorinated volatile organic compounds (VOCs).

- **Site FT005 (FTA-4):** Area used for fire training exercises from approximately 1962 through 1987. During this period, waste fuels, oils, and solvents were burned on open ground. Historical practices resulted in groundwater contamination with chlorinated VOCs. The contaminant plume extends onto off-base privately owned property.

- **Site LF006 (Landfill 1):** A general refuse landfill that used trench and cover methods from approximately 1943 through 1950. Historical practices resulted in groundwater contamination with chlorinated VOCs and petroleum-fuel hydrocarbons.

- **Sites LF007B, C, and D (Landfill 2):** A general refuse landfill that used trench and cover methods from approximately 1950 through 1970. Historical practices resulted in groundwater contamination with chlorinated VOCs, dioxins, and polychlorinated biphenyls (PCBs). The Site LF007C contaminant plume extends onto off-base privately owned property.

- **Site SS015 (Solvent Spill Area [SSA] and Facilities 808, 1832, 552):** Facilities used between approximately 1964 through 1980 for solvent stripping of aircraft parts, aircraft maintenance and repair, OWS activities, and hazardous waste accumulation. Historical practices resulted in groundwater contamination with chlorinated VOCs.

- **Site SS016 (Oil Spill Area [OSA]; Facilities 11, 13/14, 18, 20, and 42/1941; and Portions of the Storm Sewer System):** Flightline support areas subject to oil spills, degreasing operations, leaking OWS, equipment maintenance and repair, aircraft and vehicle maintenance, hazardous materials storage, aircraft and vehicle washing, and stormwater runoff. Most of the areas were used from the 1940s through the present day. Historical practices resulted in groundwater contamination with chlorinated VOCs.

- **Site ST027 Area B (Facilities 1918, 1919, and 1754):** Site ST027 was formerly used as a test stand area for aircraft engine testing. Currently, only Facility 1918 is used. Historical activities have resulted in contamination of groundwater at the site with primarily petroleum-fuel constituents and trichloroethene (TCE). The portion of the plume containing only petroleum-fuel contamination is designated as Site ST027 Area A (Site ST027A) and will continue to be managed under the POCO program. The portion of the plume with TCE contamination is designated as Site ST027 Area B (Site ST027B) and will be addressed in this FFS as an ERP site.

- **Site SS029 (Monitoring Well [MW]-329 Area):** Undeveloped land near the southern Base boundary. The historical uses resulting in groundwater contamination with chlorinated VOCs are unknown.
- **Site SS030 (MW-269 Area):** Undeveloped land near the southern Base boundary. Historical practices associated with Building 1125 are believed to have resulted in groundwater contamination with chlorinated VOCs. The contaminant plume extends onto off-base privately owned property.
- **Site SD031 (Facility 1205):** Area used for maintenance and repair of diesel generators, wash rack activities, OWS activities, and aircraft maintenance from approximately 1957 through the present day. Historical practices resulted in groundwater contamination with chlorinated VOCs.
- **Site SD033 (Storm Sewer II, South Gate Area, Facilities 810 and 1917, and West Branch of Union Creek):** Support areas used for management of stormwater runoff, fuel transport, aircraft maintenance, and aircraft washing, including the use of wash racks and OWS. Historical practices resulted in groundwater contamination with chlorinated VOCs, some semivolatile organic compounds (SVOCs), and petroleum-fuel hydrocarbons.
- **Site SD034 (Facility 811):** An active aircraft wash rack facility with OWS and overflow pond. Leaks from the OWS resulted in a layer of Stoddard solvent floating on the groundwater table. The leaking OWS was replaced in 1994. Historical practices resulted in dissolved groundwater contamination with chlorinated VOCs, SVOCs, and petroleum-fuel hydrocarbons (including Stoddard solvent).
- **Site SS035 (Facilities 818/819):** Active facilities used for aircraft repair, painting, and washing. A wash rack with OWS was constructed in 1970. Historical practices resulted in groundwater contamination with chlorinated VOCs.
- **Site SD036 (Facilities 872/873/876):** Facilities 872/873/876 consist of multiple-use shops, including a wash rack and OWS. Current uses include paint shops, electrical shops, landscape maintenance, paint mixing, and paint accumulation. The buildings were constructed in 1953, and are still in use. Historical practices resulted in groundwater contamination with chlorinated VOCs, some SVOCs, and petroleum-fuel hydrocarbons.
- **Site SD037 (Sanitary Sewer System; Facilities 837/838, 919, 977, 981; Ragsdale/V Street Area; and Area G Ramp):** Support areas used for management of domestic and industrial wastewater, aircraft maintenance, heavy equipment maintenance, air cargo handling, vehicle washing, fuel transport, and waste accumulation. Operations began in the 1940s and continue through the present day. Historical practices resulted in groundwater contamination with chlorinated VOCs, some SVOCs, and petroleum-fuel hydrocarbons.

2.1.2.2 WABOU Groundwater Sites

Contaminated groundwater ERP sites within the WABOU are as follows:

- **Site LF008 (Landfill 3):** An inactive historical landfill consisting of a series of small, unlined trenches used to dispose of old pesticide containers. Historical practices resulted in groundwater contamination with organochlorine pesticides.
- **Site DP039 (Building 755, Travis AFB Battery and Electric Shop):** Prior to 1978, battery acid solutions and solvents were discharged from Building 755 into a sump. These historical practices resulted in contamination of the groundwater with chlorinated VOCs, primarily TCE.
- **Site SS041 (Building 905):** The Base Entomology Shop used Building 905 from 1983 to 1992 to prepare pesticides and herbicides for on-base use. A concrete washrack in the back of the building was used to clean pesticide applicator vehicles, and the overspray from the washing resulted in pesticide contamination in the surface soil and groundwater.
- **Site SD043 (Building 916):** An emergency electric power facility. Historical practices resulted in a release of TCE to the groundwater at this site.

2.2 Implementation of the CERCLA Process

Following placement on the NPL, Travis AFB followed the CERCLA process to investigate site contamination and design and implement appropriate measures at the ERP sites. This process consists of six (6) major steps, as described in Section 300.430 of the National Contingency Plan (NCP):

- Preliminary Assessment/Site Inspection (PA/SI)
- RI
- FS
- Remedy Selection (Proposed Plan and ROD)
- Remedial Design/Remedial Action (RD/RA)
- Performance Monitoring/Five-year Reviews

Travis AFB successfully implemented the basic six (6)-step CERCLA process. However, the process was modified following completion of the PA/SI/RI/FS sequence to take an <u>interim</u> approach to groundwater remediation. The following list provides a description of the interim remedy approach used to implement the CERCLA process:

- **Preliminary Assessment/Site Inspection:** Completed. Between approximately 1983 and 1994, early IRP investigations, data gathering, and work planning efforts were conducted to preliminarily assess the nature of environmental contamination at sites within each of the OUs.
- **Remedial Investigation:** RIs to characterize the nature and extent of contaminated groundwater at the ERP sites within the NEWIOU and WABOU have been completed (Radian, 1996b [WIOU]; Radian, 1995, [NOU]; Weston, 1995 [EIOU]; CH2M HILL, 1997 [WABOU]). Human health and ecological risk assessments were components of the RIs.

- **Feasibility Study:** FSs for contaminated groundwater sites within the NEWIOU (Radian, 1996a) and WABOU (CH2M HILL, 1998a) have been finalized.
- **Interim Remedy Selection:** Groundwater IRAs were selected in the final *Groundwater Interim Record of Decision for the NEWIOU* (Travis AFB, 1998) and the final *Groundwater Interim Record of Decision for the WABOU* (Travis AFB, 1999).
- **Interim Remedial Design/Remedial Action:** Following finalization of the two (2) groundwater IRODs, multiple groundwater IRAs were designed, constructed, and entered into interim long-term operation (LTO).
- **Performance Monitoring and Five-year Reviews:** Basewide performance monitoring of the IRAs is conducted and reported under the Travis AFB Groundwater Sampling and Analysis Program (GSAP). Descriptions of groundwater treatment plant operations and maintenance (O&M) activities are regularly reported to the regulatory agencies in monthly data sheets and in annual O&M reports. Travis AFB has completed two (2) five-year reviews of the groundwater IRAs (CH2M HILL, 2003a, 2008a).

2.3 Interim Remedial Actions

Interim remediation of the NEWIOU and WABOU contaminated groundwater sites is being conducted under the two (2) IRODs, as opposed to a final Basewide Groundwater ROD. These IRAs were implemented to quickly begin remediation of groundwater contamination, reduce the levels of contamination and potential risk, and collect some of the data necessary for the selection of final cleanup levels and technically and economically feasible long-term actions. The use of an IROD allowed groundwater IRAs to proceed without having final designated cleanup levels, as will be required for the pending ROD.

The groundwater IRAs use IRGs and interim cleanup goals (ICGs) as performance objectives. These IRGs and ICGs are not legally enforceable standards, but are simply goals used during the period of interim remediation (the term IRG is used synonymously with ICG.)

Following completion of the PA/SI/RI/FS/Proposed Plan/IROD sequence, Travis AFB installed and operated groundwater IRAs to achieve the objectives specified in the IRODs. Two (2) basic IRAs were employed:

- Groundwater extraction and treatment (GET)
- Monitored natural attenuation (MNA) assessment

Listings of the IRAs implemented at each ERP site are provided in Tables 2-2 and 2-3. The IRAs specified in the IRODs are summarized in the following subsections.

2.3.1 NEWIOU Interim Remedial Actions

For NEWIOU groundwater sites, the IRAs specified in the Groundwater IROD for the NEWIOU (Travis AFB, 1998) are as follows:

- Alternative 2 – Natural Attenuation/Monitoring (i.e., MNA)
- Alternative 3 – Extraction, Treatment, and Discharge

At most sites, the formal selection of Alternative 2 – MNA, was deferred pending the completion of MNA assessments during the period of interim remediation to evaluate the feasibility of implementing MNA for all or part of several contaminant plumes. At NEWIOU Site LF006, MNA was the selected IRA.

Alternative 3 uses GET to hydraulically capture areas of groundwater contamination and remove contaminant mass.

2.3.2 WABOU Interim Remedial Actions

For the WABOU groundwater sites, the IRAs specified in the Groundwater IROD for the WABOU (Travis AFB, 1999) are as follows:

- Alternative G3 – Containment/Treatment/Discharge
- Alternative G5 – Source Area and Groundwater Extraction/Treatment/MNA

Similar to the NEWIOU Groundwater IROD Alternative 3, the IRA specified in the WABOU Groundwater IROD as Alternative G3 is a GET action to prevent the migration of groundwater contamination into hydraulically downgradient areas. Under Alternative G5, a vacuum-enhanced version of GET is used to hydraulically contain and remove relatively high concentrations of VOCs from the vadose zone and groundwater at the source of contamination. The GET action is combined with a program of MNA assessment to address the relatively lower levels of contamination at the leading edge of a plume. At WABOU Site DP039, MNA was selected as one (1) of the three (3) components of the site IRA.

2.4 Interim Remedial Action Objectives

2.4.1 GET System Objectives

The GET system IRAs were designed and constructed to achieve the following objectives as specified in the NEWIOU Groundwater IROD (Travis AFB, 1998) and WABOU Groundwater IROD (Travis AFB, 1999):

- Source control
- Migration control
- Off-base remediation

A summary of the GET IRA objectives for each ERP site is provided in Table 2-2.

2.4.1.1 Source Control Objectives

The IRA objective of source control is to hydraulically contain and remove contaminant mass from the groundwater and vadose zone using GET and vapor extraction and treatment in areas where groundwater VOC concentrations are relatively high, typically greater than 1,000 micrograms per liter (µg/L). Source control actions using GET are taken where secondary sources of VOC contamination (e.g., light nonaqueous phase liquid [LNAPL] or dense nonaqueous phase liquid [DNAPL]) are known or are reasonably thought to exist. Dissolved contaminant concentrations of approximately 3,000 µg/L are considered indicators of the possible presence of DNAPL (Travis AFB, 1998). However, as a conservative measure to address uncertainties in the distribution of contamination, source control actions are typically taken where groundwater VOC concentrations exceed 1,000 μg/L.

Source control actions were typically designed and constructed primarily to achieve hydraulic containment and removal of the highest concentrations of groundwater contamination (i.e., VOC contaminants at concentrations of 1,000 μg/L and higher), and to prevent these concentrations from migrating to areas with concentrations below 1,000 μg/L. Additional actions, such as the installation of supplemental extraction wells, specifically for the removal of more contaminant mass, are conducted to the extent that is technically and economically feasible.

2.4.1.2 Migration Control Objectives

The IRA migration control objective is typically achieved using a GET system to hydraulically contain areas of contamination where groundwater concentrations are between 100 and 1,000 μg/L.

Migration control GET systems were designed and constructed primarily to prevent VOC contaminants at concentrations between 100 and 1,000 μg/L from migrating to areas with concentrations below 100 μg/L. However, in areas where it was found to be technically and economically feasible, migration control GET systems were installed to hydraulically contain contamination at lower concentrations. For example, at Site SS029, located near the southern Base boundary, the GET system was designed to hydraulically contain the leading edge of the plume and prevent any off-base migration of groundwater contamination.

Contaminant mass removal is not a primary objective of GET systems installed for the purpose of migration control. Mass removal does occur, but GET extraction wells are typically located within the relatively lower concentration areas of contaminant plumes. Therefore, mass removal is an incidental benefit of the groundwater extraction, but not a specific objective of the migration control action.

2.4.1.3 Off-base Remediation Objectives

The IRA objective of off-base remediation is to prevent further migration of groundwater contaminants using GET to hydraulically contain and remediate the off-base portion of plumes down to the contaminant-specific IRG specified in the NEWIOU Groundwater IROD (Travis AFB, 1998). All known off-base contaminant plumes originate from sites located within the NEWIOU. These include Sites FT005, LF007C, and SS030. The locations of these sites are shown on Figure 2-1.

2.4.2 Monitored Natural Attenuation Assessment Objectives

MNA assessments were specified in the IRODs for the period of interim remediation. The primary objective of these assessments was to collect sufficient data to evaluate the feasibility of implementing MNA for all, or part, of several contaminant plumes. The *Natural Attenuation Assessment Report* (NAAR) documents the findings of the assessments (CH2M HILL, 2010a). The ERP sites undergoing MNA assessment are summarized in Table 2-2.

MNA relies on natural physical, chemical, and/or biological processes to limit the migration of a contaminant plume, or portion of a plume. Areas of groundwater with relatively low-concentration contamination located hydraulically downgradient of a GET system are typically included in MNA assessments at Travis AFB. Data from these assessments support the use of MNA as the final remedial action, or as a component of the remedial action, for these plumes.

The *Natural Attenuation Assessment Plan* (NAAP) (CH2M HILL, 1998b) is the governing document for sites, or portions of sites, undergoing assessments of MNA. The protocols provided in the NAAP are the basis for determining if the migration control objective has been achieved and the contaminant plume has been stabilized through natural physical, chemical, and/or biological processes.

In accordance with the IRODs (Travis AFB, 1999, 1998) and NAAP (CH2M HILL, 1998b), multiple sites at Travis AFB underwent MNA or MNA assessment during the period of interim remediation. These sites include the following:

- **Site LF006 –** MNA
- **Site FT004 –** MNA assessment combined with GET
- **Site SD031 –** MNA assessment combined with GET
- **Sites LF007B and LF007D –** MNA assessment
- **Site SS014 –** MNA assessment (petroleum fuels commingled with VOCs)
- **Site SD033 –** MNA assessment combined with GET
- **Site SD037 –** MNA assessment combined with GET
- **Site SS015 –** MNA assessment
- **Site DP039 –** MNA combined with GET and evaluation of phytoremediation

The listed sites initially underwent preliminary assessment of biodegradation factors as part of the preparation of natural attenuation assessment work plans. The plans established that, on an ongoing basis, the MNA assessments would consist primarily of an assessment of plume stability. Therefore, the focus is on plume stability as the main, but not sole, criterion in assessing the viability of MNA.

At those plumes that combined GET and MNA assessments (Sites FT004, SD031, SD033, SD037, and DP039), the higher concentration areas are undergoing GET for the purposes of source control and/or migration control, and the lower concentration areas (i.e., hydraulically downgradient of the GET system) were assessed to determine if MNA can effectively control plume migration.

Sites LF006 and DP039 are the only sites at which MNA was selected as all, or part, of the IRA in the IROD. At Site LF006, MNA is the selected IRA for the entire site. For Site DP039, MNA is one (1) component of a three (3)-component IRA rather than a stand-alone remedy.

The final selection of MNA as all, or part, of the final remedial action at a site will be made in the upcoming Basewide Groundwater ROD. The NAAR was developed prior to the ROD to document the findings of the MNA assessments, evaluate whether or not natural attenuation processes are effective at remediating contaminated groundwater, and conclude if MNA is viable as all or part of the final remedial action at the applicable sites (CH2M HILL, 2010a).

2.4.3 Site Consolidation

The multiple groundwater IRAs have been described, primarily for administrative reasons, in terms of the actions taken at the individual sites and, in some cases, at collections of sites. Travis AFB is currently employing a more appropriate strategy by consolidating site-specific IRAs with common key components into regional IRAs. The primary objective of this holistic grouping is to maximize contaminant mass removal by avoiding interference between individual groundwater extraction systems. The secondary objective is to reduce costs by avoiding redundancies in the operation and documentation of sites with common components.

The primary criteria for grouping site-specific IRAs into consolidated, regional IRAs include the following:

- Commingled groundwater contaminant plumes
- Shared groundwater conveyance and treatment systems
- Hydraulic interactions between site-specific groundwater extraction systems
- Consolidation that is consistent with the IRA objective(s) provided in the applicable IROD

A summary of the grouped groundwater sites, the IROD-specified IRA for each site, and a checklist evaluation of the consolidation criteria satisfied are provided in Table 2-2.

The strategic groupings of individual contaminated groundwater sites into consolidated IRAs are as follows:

- **North IRA –** ERP Sites FT004, SD031, LF006, LF007B, LF007C (off-base), and LF007D.
- **South IRA –** ERP Sites SS030, SS029, and FT005 (on-base and off-base).
- **Central IRA –** ERP Site SS016, including the component OSA and Tower Area Removal Action (TARA).
- **West IRA –** ERP Sites LF008, SS015, SD033, SD034, SS035, SD036, SD037, DP039, and SD043.

The locations of the consolidated, regional IRAs and associated ERP sites are shown on Figure 2-2. This figure also shows the location of Site ST027B. This site was previously managed under the POCO program but became an ERP site after CERCLA contamination was detected in a portion of the site after the NEWIOU Groundwater IROD was finalized.

2.5 Groundwater IRA Operation and Maintenance

In combination, routine treatment plant O&M, the Basewide GSAP, and ongoing free-product removal efforts comprise LTO of the existing Travis AFB groundwater IRAs. The LTO requirements for each of the consolidated IRAs are summarized in Table 2-3.

2.5.1 Groundwater Extraction and Treatment Systems Operation and Maintenance

Detailed descriptions of treatment plant-specific O&M activities are regularly reported to the regulatory agencies in monthly data sheets and in annual O&M reports. The most current O&M treatment plant data are provided in the *2009 Annual Remedial Process Optimization Report for the Central Groundwater Treatment Plant, North Groundwater Treatment Plant, and South Base Boundary Groundwater Treatment Plant* (2009 Annual RPO Report) (CH2M HILL, 2010b).

For each of the three (3) treatment plants, the O&M reports provide detailed descriptions of treatment plant processes, modifications, volumes of groundwater water treated, reuse of treated water, compliance with discharge requirements, field measurements and observations, influent concentration trends, flow rates, mass removed, treatment plant uptime/downtime, operating costs, electricity consumed, carbon dioxide generated, evaluations of effectiveness, issues, and optimization activities.

Routine O&M of groundwater treatment facilities is conducted in accordance with the O&M manuals developed for the North Groundwater Treatment Plant (NGWTP) (URS, 2005), Central Groundwater Treatment Plant (CGWTP) (URS, 2002a), and South Base Boundary Groundwater Treatment Plant (SBBGWTP) (CH2M HILL, 2004a).

2.5.2 Monitored Natural Attenuation Assessments

During the period of interim remediation, MNA assessments were conducted at multiple sites within the consolidated IRAs. Groundwater samples were collected and analyzed under the GSAP and the data evaluated in accordance with the Travis AFB NAAP (CH2M HILL, 1998b). A listing of the sites that underwent MNA assessment is provided in Table 2-2.

MNA assessments at ERP Sites LF007C, ST032, SS035 and SS016 were discontinued during the interim period of remediation for the following reasons:

- **Site LF007C –** The on-base portion of the plume is under the influence of a GET system completed in 2003.
- **Site ST032 –** This site was transferred from the ERP to the POCO program (CH2M HILL, 2009a).
- **Site SS035 –** The plume is hydraulically captured by the WIOU GET system. Site SS035 is one (1) of several ERP sites that are part of the larger WIOU plume. During the design of the WIOU GET system, the contaminant plumes originating from these individual ERP sites were found, as a practical matter, to be inseparably commingled. Therefore, the contaminant plumes were holistically grouped into a larger plume collectively referred to as the WIOU plume. Contaminants originating from Site SS035 are hydraulically captured by the downgradient WIOU extraction wells (CH2M HILL, 1999a).
- **Site SS016 –** Hydraulic modeling indicated that the portion of the Site SS016 plume not being captured by the Site SS016 GET system would be hydraulically captured by the downgradient Site SS029 GET system (CH2M HILL, 2001).

2.5.3 Free-product Removal

LTO for free-product removal actions has been conducted at the following sites:

- **Site SS014, Area G –** Passive skimming of jet fuel was discontinued in November 2005.
- **Site ST032 –** Passive skimming of jet fuel was discontinued in September 2002. This site was transferred from the ERP to the POCO program in 2009.
- **Site SD034 –** Passive skimming of Stoddard solvent floating on the groundwater table is ongoing.

Monitoring wells at each of these sites continue to be routinely checked for floating product under the GSAP.

2.6 Performance of Groundwater IRAs

Operation of GET systems, MNA assessments, and free-product removal are ongoing at multiple NEWIOU and WABOU sites during the interim period of remediation. A listing of the groundwater IRAs currently being implemented at each site and summary evaluations of IRA performance are provided in Table 2-5.

Evaluations of the performance of the groundwater IRAs are also documented in the *Second Five-year Review Report* (CH2M HILL, 2008a). The findings of completed MNA assessments conducted during the period of interim remediation are documented in the NAAR (CH2M HILL, 2010a).

2.6.1 Historical and Current Groundwater Contamination

After approximately a decade of IRA implementation, groundwater contamination at multiple sites has been reduced but remains at concentrations that exceed the IRGs established by the NEWIOU Groundwater IROD (Travis AFB, 1998) and WABOU Groundwater IROD (Travis AFB, 1999). The locations of the groundwater sites and an overview of the current extent of groundwater contamination are shown on Figure 2-1.

Comparisons between the historical extent of groundwater contamination prior to implementation of the IRAs and the current distribution of contamination after 8 to 10 years of IRA implementation at each site are shown on Figures 2-3 through 2-10.

2.6.2 IRA Optimization

For Sites LF007C, SS015, SS016, SS030, and DP039, the IRAs are not functioning completely as intended by the two (2) IRODs. Also, although the IRAs at Sites SD036 and SD037 are meeting IRA objectives, additional measures are needed to improve the overall effectiveness of the interim remedies. Therefore, the Air Force is taking steps during 2010-2011 to optimize the IRAs and improve their performance. The site-specific IRA optimizations are summarized in the following list:

- **Site LF007C –** The Site LF007C plume has migrated off-base. Optimization measures will be conducted in 2011 to improve the GET system performance. These measures will include additional characterization to improve understanding of off-base contaminant distribution, groundwater flow directions, and the needed GET system modifications.

More complete descriptions of the optimization measures are provided in the *Site LF007C Remedial Process Optimization Work Plan* (CH2M HILL, 2009b). Figure 2-3 shows the historical and current extent of contamination in the North IRA, which includes Site LF007C.

- **Site SS015 –** Increasing contaminant concentrations in some site monitoring wells indicate that the Site SS015 plume is migrating. During 2000-2001, soybean oil was injected into the aquifer during an in situ bioremediation treatability study. The findings of the treatability study were encouraging and indicated that bioremediation was taking place. But the treatability study was terminated early because of a military construction project at the site. The limited volume of oil injected during the treatability study may now be exhausted. During 2010, optimization actions included additional characterization to improve understanding of contaminant distribution and groundwater flow directions. These data will support a design for supplemental injection of emulsified vegetable oil (EVO) in the contaminant source zone. Further descriptions of the optimization measures are provided in the *Site SS015 Remedial Process Optimization Work Plan* (CH2M HILL, 2010c). Figure 2-8 shows the historical and current extent of contamination at Site SS015.
- **Site SS016 –** Although the overall IRA objectives at Site SS016 are being largely achieved, optimization actions were taken within the OSA source zone to improve the overall effectiveness of the existing GET system. Descriptions of the optimization measures are provided in the *Site SS016 Remedial Process Optimization Work Plan* (CH2M HILL, 2010c). During September 2010, these optimization actions included discontinuing operation of an energy-intensive 2-Phase® extraction and thermal oxidation (ThOx) treatment system within the OSA source area. These components of the Site SS016 IRA were replaced with an in situ bioreactor. Figure 2-5 shows the historical and current extent of contamination at Site SS016.
- **Site SS030 –** A portion of the off-base Site SS030 plume appears to be migrating toward Site FT005 under the hydraulic influence of the adjacent Site FT005 GET system. Additional characterization of off-base contaminant distribution, groundwater flow directions, and GET system modifications will be conducted during 2010-2011 to improve the IRA performance. Additional descriptions of the optimization measures are provided in the *Site SS030 Remedial Process Optimization Work Plan* (CH2M HILL, 2010d). Figure 2-10 shows the historical and current extent of contamination in the South IRA, which includes Site SS030.
- **Site SD036 –** Relatively high contaminant concentrations remain in the source area of the plume even after about 10 years of IRA GET system operation. This area provides a continuing source of contamination into hydraulically downgradient portions of the plume. Therefore, optimization actions were taken during 2010. Operation of the GET system was discontinued. Then, additional characterization of contaminant distribution was performed. In situ treatment of the source zone was then conducted using enhanced bioremediation via injection of EVO. More complete descriptions of the optimization measures are provided in the *Sites SD036/SD037 Remedial Process Optimization Work Plan (*CH2M HILL, 2010e). Figure 2-6 shows the historical and current extent of contamination in the WIOU, which includes Site SD036.

- **Site SD037 –** Similar to Site SD036, relatively high contaminant concentrations remain in a localized portion of the Site SD037 plume. This source zone provides a continuing influx of contamination into hydraulically downgradient portions of the plume. During 2010, operation of the GET IRA was discontinued. Additional characterization of contaminant distribution and groundwater flow direction was conducted. Following this characterization, in situ treatment of the source area was conducted using EVO injection. Additional descriptions of the optimization measures are provided in the *Sites SD036/SD037 Remedial Process Optimization Work Plan (*CH2M HILL, 2010e). Figure 2-6 shows the historical and current extent of contamination in the WIOU, which includes Site SD037.
- **Site DP039 –** A portion of the Site DP039 plume appears to be migrating hydraulically downgradient. As a consequence, operation of the inefficient GET IRA within the contaminant source area was discontinued in December 2008 and an in situ bioreactor was installed in the source area. During 2010, additional characterization of contaminant distribution and groundwater flow direction was conducted. Subsequently, a permeable reactive biobarrier (PRB) of injected EVO was installed during the summer of 2010. The performance of phytoremediation was also evaluated (Parsons, 2010). Additional descriptions of the optimization measures are provided in the *Site DP039 Remedial Process Optimization Work Plan* (CH2M HILL, 2010f) and in the final *Sustainable Bioreactor Demonstration, Site DP039 Technical Report* (CH2M HILL, 2011a). Figure 2-7 shows the historical and current extent of contamination at Site DP039.

2.6.3 MNA Assessments

The fundamental finding of the MNA assessments conducted during the period of interim remediation is that MNA is a viable remedial action for all, or part, of the groundwater contaminant plumes at Travis AFB (CH2M HILL, 2010a).

Following 8 to 10 years of data collection after implementation of the groundwater IRAs, the data are sufficient to conclude that MNA can be an effective remedy, or part of the remedy, at Sites FT004, LF006, LF007B, LF007D, SD031, SD033, SD037, and DP039. Monitoring data indicate that MNA does not appear to be successfully addressing contamination at Site SS015. At most sites, the plumes have been stable, or have exhibited declining concentrations of contaminants. A summary of the MNA assessment at each of the applicable sites is provided in Table 2-4 (CH2M HILL, 2010a).

Additional discussion regarding the viability of MNA as a component of the final remedial action at Travis AFB ERP sites is provided in Appendix C. Full discussions of the completed MNA assessments are provided in the NAAR (CH2M HILL, 2010a).

The primary indication of whether natural attenuation is an appropriate remedy at a site is whether or not the groundwater plume is stable or has reduced in size. Over the interim period (8 to 10 years, depending on the site), the GSAP has monitored networks of wells at each site. At most sites, the plume has not only been stable, but has exhibited declining VOC concentrations during the interim period, indicating that MNA is an effective remedy at the site.

In addition to monitoring for plume stability, a biological screening was performed to evaluate the dominant mechanism for natural attenuation at each site. At most sites, the evidence for biological degradation is *inadequate* to *limited*, based on the Air Force Center for Engineering and the Environment scoring methodology used in the NAAR. Aquifer conditions at Travis AFB are generally aerobic, which is not conducive to biodegradation of parent chlorinated solvents such as TCE. At several of these sites, GET is performed in the source area, which introduces oxygen into the aquifer. In addition, there are insufficient natural or anthropogenic carbon donors in most areas to impact geochemical conditions and result in reductive dechlorination. At some sites, the plume may have originally exhibited "mixed behavior," where anthropogenic carbon (such as total petroleum hydrocarbons [TPH]) may have been present in the source area but inadequate carbon was present in the downgradient portion of the plume to drive biodegradation (Wiedemeier et al., 1996).

At most sites, physical processes are currently the dominant mechanism for the attenuation observed over the interim period. Physical processes include diffusion, dispersion, dilution, adsorption, and volatilization, and generally result in a reduction in the concentration, toxicity, or mobility of contaminants without reducing the overall mass or volume of the contaminant. However, the physical process of volatilization does result in a reduction in contaminant mass in groundwater, as the contaminant goes from liquid to vapor phase.

2.6.4 Free-product Removal

Passive skimming to remove floating free product has been effective at Sites SS014, ST032, and SD034.

Between 2008 and 2010, none of the Site SS014, Area G and Site ST032 monitoring wells contained measurable floating jet fuel. Past free-product removal actions have removed most of the floating jet fuel, but some residual free-product may remain. The wells continue to be monitored for floating product under the GSAP. If future GSAP monitoring detects floating product, Travis AFB will evaluate restarting floating product removal actions at the sites.

Passive skimming to remove Stoddard solvent at Site SD034 is ongoing and monitoring continues under the GSAP.

TABLE 2-1
Chronology of Key Events
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Event	Date(s)
Phase I PA	1983
IRP investigations	1983 to 1994
Pre-NPL response	1983 to 1989
NPL listing	November 1989
FFA signature	September 1990
Travis AFB CRP implemented	1991
Fact sheets describing restoration program activities and milestones published	1993 to present
FFA renegotiated to create four (4) OUs	1993
Consolidation of EIOU, WIOU, and NOU into the NEWIOU	October 1995
Travis AFB Restoration Advisory Board formed	1995
Quarterly restoration program newsletter published and mailed	1995 to present
CERCLA RIs/FSs	1993 to 1998
CGWTP online	1995
Final NEWIOU Groundwater IROD signed	January 1998
Travis AFB CRP revised	1998
SBBGWTP online (five-year review trigger)	1998
Final WABOU Groundwater IROD signed	June 1999
WTTP online	2000
NGWTP online	2000
CIP (initial)	August 2001
CIP updated	July 2003
First Five-year Review	July 2003
CIP updated	April 2006
Second Five-year Review	September 2008
Action Plan to Attain Final Remedies in Place at Groundwater Sites	May 2009
RD/RA QAPP update	July 2009
NAAR	July 2010
Basewide Groundwater FFS	Pending (2011)
Basewide Groundwater Proposed Plan	Pending (2011)
Basewide Groundwater ROD	Pending (2012)
Third Five-year Review	Pending (2013)

Notes:

CIP = community involvement plan
CRP = community relations plan
QAPP = quality assurance project plan
WTTP = West Treatment and Transfer Plant

TABLE 2-2
Summary of NEWIOU and WABOU Groundwater Sites and Groundwater Interim Remedial Actions
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

		IRA Objective[a]				IRA Consolidation Criteria				
IRA	**Site**	**Source Control**	**Migration Control**	**Off-base Remediation**	**MNA**	**MNA Assessment**	**Commingled Plumes**	**Shared Treatment Plant**	**Hydraulic Interactions**	**Comments**
North	FT004	✓				✓[b]	✓	✓	✓	
	SD031	✓				✓[b]	✓	✓	✓	
	LF006				✓				✓	
	LF007B					✓			✓	
	LF007C		✓	✓		—[c]		✓	✓	IRA optimization planned for 2010-2011 includes modifications to the existing GET system to more fully address off-base groundwater contamination.
	LF007D					✓			✓	
South	SS030	✓	✓	✓				✓	✓	IRA optimization planned for 2010-2011 includes modifications to existing GET system.
	SS029		✓					✓	✓	
	ST032	✓	✓[d]			—[e]	✓	✓	✓	Source control IRA for removal of floating jet fuel discontinued in September 2002. Dissolved plume is hydraulically captured by Site SS029 migration control IRA. The site was transferred from the ERP to the POCO program in 2009.
	Southern SS016		✓			—[e]	✓	✓	✓	Commingled OSA/TARA/ST032 plume in the southern portion of Site SS016 is hydraulically captured by the Site SS029 migration control IRA.
	FT005 (on-base)		✓					✓	✓	
	FT005 (off-base)			✓				✓	✓	
Central	Northern SS016	✓						✓		Composed of the OSA and TARA source area plumes.[d] Site SS016 IRA optimization during September 2010 within the OSA source area included discontinuing 2-Phase® extraction/ThOx treatment, conducting source area excavation, and installing an in situ bioreactor. Operation of the TARA GET system and the remainder of the OSA GET system will be continued.
West	SS014[f]	✓	✓			✓[b]	✓	✓	✓	POCO site at Area G.
	SD033[g]		✓			✓	✓	✓	✓	
	SD034[h]	✓	✓				✓	✓	✓	Source control action for removal of Stoddard solvent floating product is ongoing.
	SS035[i]		✓[b]			—[e]	✓	✓	✓	Plume is hydraulically captured by Site SD037 migration control.
	SD036[j]	✓	✓			—[e]	✓	✓	✓	IRA optimization during 2010 included discontinuing GET and injection of EVO within the Site SD036 source area.
	SD037[k]	✓	✓			✓	✓	✓	✓	IRA optimization during 2010 included discontinuing GET and injection of EVO within a localized Site SD037 contaminant source area (i.e., hot spot) in the vicinity of MW524x37.
	SS041[l]		✓					✓	✓	A consensus statement has been signed by all the regulatory agencies stating that no additional remedial action is required.
	SD043[m]		✓					✓	✓	
	SS015					✓				IRA optimization during 2010 included EVO injection within the contaminant source area.
	DP039	✓	—[n]		✓			✓		IRA optimization during 2010 included EVO injection to form a PRB to intercept contaminant migration from the source area. In 2008, the plume source area was excavated and an in situ bioreactor was installed.
	LF008		✓					✓		Noncontiguous, single-site plume. Organochlorine pesticide contamination.

TABLE 2-2
Summary of NEWIOU and WABOU Groundwater Sites and Groundwater Interim Remedial Actions
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

		IRA Objective[a]				IRA Consolidation Criteria				
IRA	Site	Source Control	Migration Control	Off-base Remediation	MNA	MNA Assessment	Commingled Plumes	Shared Treatment Plant	Hydraulic Interactions	Comments
	ST027B									Site formerly managed under the POCO program. An IRA was not specified in NEWIOU Groundwater IROD because CERCLA contamination was not detected until after the IROD was finalized. The Site ST027B portion of the site is contaminated with TCE and is now managed under the ERP (beginning in 2009). The Site ST027A portion of the plume, with only petroleum fuel contamination, continues to be managed under the POCO program.

[a] IRA objective specified in the NEWIOU and WABOU Groundwater IRODs (Travis AFB, 1998 and 1999, respectively).
[b] IRA not specified in the NEWIOU Groundwater IROD (Travis AFB, 1998), but implemented by the Air Force to address entirety of commingled plume.
[c] Assessment of MNA not implemented because of plume interactions with the Site LF007C groundwater extraction system.
[d] TARA.
[e] Assessment of MNA not implemented because plume is hydraulically captured by adjacent GET system.
[f] POCO Site SS014 comprises five (5) noncontiguous sites within the WIOU, including Sites 1, 2, 3, 4, and 5. Only Site 1 (Area G) has a source control objective (historical floating jet fuel).
[g] ERP Site SD033 comprises five (5) noncontiguous sites within the WIOU: Facility 810, Facility 1917, Storm Sewer System II, the South Gate area, and the West Branch of Union Creek.
[h] ERP Site SD034 is associated with Facility 811. Located within the WIOU component of the NEWIOU.
[i] ERP Site SS035 is associated with Facilities 818 and 819. Located within the WIOU component of the NEWIOU.
[j] ERP Site SD036 is associated with Facilities 872, 873, and 876. Located within the WIOU component of the NEWIOU.
[k] ERP Site SD037 is associated with the Sanitary Sewer System; Facilities 837, 838, 919, 977, 981; the Area G Ramp; and the Ragsdale/V Street area. All facilities located within the WIOU.
[l] ERP Site SS041 is associated with Facility 905. Located within the WABOU.
[m] ERP Site SD043 is associated with Facility 916. Located within the WABOU.
[n] Migration control not implemented pending evaluation of MNA and phytoremediation effectiveness.

TABLE 2-3
Summary of Consolidated Groundwater Interim Remedial Actions LTO Requirements
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

			LTO Requirement				
				GSAP			
Consolidated IRA	Component Sites	Treatment Plant	Extraction, Conveyance, and Treatment System O&M	Extraction System Performance Monitoring	MNA[a]	Free-product Removal (passive skimming)	Comments
North	FT004	NGWTP	✓	✓	✓	NA	
	SD031	NGWTP	✓	✓	✓	NA	
	LF006	NA	NA	✓	✓	NA	
	LF007B	NA	NA	NA	✓	NA	
	LF007C	NGWTP	✓	✓	NA	NA	
	LF007D	NA	NA	NA	✓	NA	
South	SS030	SBBGWTP	✓	✓	NA	NA	
	SS029	SBBGWTP	✓	✓	NA	NA	
	ST032	SBBGWTP via Site SS029	NA	NA	NA[b]	NA	Passive skimming of jet fuel floating product discontinued in September 2002. Site transferred from the ERP to the POCO program in 2009.
	Southern SS016	SBBGWTP via Site SS029	NA	NA	NA[b]	NA	
	FT005	SBBGWTP	✓	✓	NA	NA	
Central	Northern SS016	CGWTP	✓	✓	NA	NA	
West	SS014	CGWTP via WTTP	NA	NA	✓	NA	Area G (Site 1) jet-fuel floating product removal discontinued in November 2005.
	SD033	CGWTP via WTTP	✓	✓	✓	NA	
	SD034	CGWTP via WTTP	✓	✓	NA	✓	Stoddard solvent floating product removal is ongoing.
	SS035	CGWTP via WTTP	✓	✓	NA[b]	NA	
	SD036	CGWTP via WTTP	✓	✓	NA	NA	
	SD037	CGWTP via WTTP	✓	✓	✓	NA	
	SS041	CGWTP via WTTP	✓	✓	NA	NA	
	SD043	CGWTP via WTTP	✓	✓	NA	NA	
	SS015	NA	NA	NA	✓	NA	EVO treatability study conducted in 2000-2001.
	DP039	CGWTP via WTTP	✓	✓	✓	NA	Evaluations of a phytoremediation study and bioreactor demonstration project ongoing.
	LF008	CGWTP via WTTP	✓	✓	NA	NA	

[a] MNA assessment, except at Sites LF006 and DP039.
[b] MNA assessments at Site SS035, southern portion of Site SS016, and Site ST032 discontinued and no longer applicable because plumes are hydraulically captured by adjacent IRA GET system.

Note:

NA = not applicable

TABLE 2-4
Summary of MNA Assessments
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	MNA Viable?	Plume Stable?	Dominant Mechanism	Comments
FT004	Yes	Yes	Physical	MNA assessment conducted in distal portion of plume. Plume has receded.
LF006	Yes	Yes	Physical	MNA assessment conducted for entirety of plume. Plume has receded.
LF007	Yes	Yes	Biological in source area, physical in distal areas	MNA assessments conducted in plume areas LF007B and LF007D.
SS015	Yes	No	Biological	Biological degradation was enhanced by 2000-2001 vegetable oil injection. Plume was stable for several years, but appears to be migrating. Enhancement of MNA via another injection of EVO during 2010.
SD031	Yes	Yes	Physical	MNA assessment conducted for distal portion of plume.
SD033	Yes	Yes	Physical	MNA assessment conducted for distal portion of plume.
SD037	Yes	Yes	Physical	MNA assessment conducted for distal portion of plume.
DP039	Yes	No	Physical	MNA assessment conducted for distal portion of plume. The distal area has remained stable over several years, but concentrations are increasing in some areas. IRA optimization activities are under way to more fully remediate the source areas of the plume and support MNA. A bioreactor installed in December 2008 will provide enhanced biodegradation of the source area. A biobarrier installed in mid-2010 will enhance degradation in the mid-portion of the plume.

Source: CH2M HILL, 2010a.

Note:

Distal portion of the plume is defined as the portion of the plume beyond the influence of a source area treatment.

TABLE 2-5
Summary of Groundwater Interim Remedial Action Performance
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

IRA	Site	IRA Objective[a]: Source Control	IRA Objective[a]: Migration Control	IRA Objective[a]: Off-base Remediation	IRA Objective[a]: MNA	IRA Objective[a]: MNA Assessment	IRA Objectives Achieved?	Second Five-year Review Performance Assessment Summary
North	FT004 SD031	✓ ✓				✓[b] ✓[b]	Yes Yes	The combination of GET in the Site FT004 and Site SD031 source areas and MNA in the downgradient portions of the commingled plumes appears to be effective. Hydraulic capture of the source areas has been achieved using GET. The effectiveness of GET is further demonstrated by declining VOC concentrations observed in the majority of site monitoring wells. Declining trends are observed in both shallow and deep monitoring wells, indicating both the horizontal and vertical extent of the target areas are being addressed. The Site SD031 GET system and the Site FT004 GET system have been shut down for a rebound study for the remaining period of interim remediation because VOC concentrations have declined below the target concentrations in both areas. MNA also appears to be a viable remedy at Site FT004 and SD031. Overall, contaminant concentrations are stable or declining in the downgradient MNA assessment monitoring wells. The MNA network includes both shallow and deep monitoring wells. MNA appears to be effective throughout the entire thickness of the plume.
	LF006				✓		Yes	MNA appears to be a viable remedy at Site LF006. Data from monitoring wells indicate that groundwater contamination at Site LF006 is not migrating and no contaminants were detected at a concentration exceeding the IRG.
	LF007B					✓	Yes	MNA appears to be a viable remedy at Site LF007B. No contaminants were detected in Site LF007B wells sampled during the 2009-2010 GSAP events.
	LF007C		✓	✓		—[c]	No	The migration control and off-base remediation IRA objectives for Site LF007C do not appear to be fully achieved. The existing GET system is not fully effective at hydraulically capturing and remediating the TCE plume. TCE continues to migrate off-base at concentrations above the TCE IRG of 5 µg/L. Optimization of the GET IRA is required. A data gaps investigation will be performed during 2010-2011, pending U.S. Fish and Wildlife Service (USFWS) approval of the request to reinitiate Section 7 consultation, to define the extent of off-base contamination greater than the IRG and to clarify groundwater flow directions. Based on the results of the investigation, optimization measures for the current GET system will be conducted.
	LF007D					✓	Yes	MNA appears to be a viable remedy at Site LF007D. Groundwater contamination is limited to a small area near MW261x04 – the only well at which groundwater contaminants were detected at concentrations exceeding IRGs. Contaminants do not appear to be migrating off-base to the north or east of the site.
South	SS030	✓	✓	✓			No	The source control, migration control, and off-base remediation IRA objectives for the Site SS030 IRA have not been fully achieved. Contaminant concentrations are declining in all of the extraction wells and all but two (2) of the monitoring wells. The off-base plume is being captured on the southern and western sides of the plume. However, increasing TCE concentrations on the eastern side of the off-base plume indicate that contamination may be escaping hydraulic capture. The groundwater elevation contours derived from the 2Q08 GSAP sampling event indicate that the hydraulic capture in this eastern area of the plume has improved after several of the adjacent Site FT005 extraction wells were taken offline for a rebound study. Optimization of the GET IRA is required. An investigation will be performed during 2010-2011 to clarify groundwater flow directions and hydraulic capture. Based on the results of the investigation, optimization measures for the current GET system will be conducted.
	SS029		✓				Yes	The migration control IRA objective at Site SS029 has been achieved. The existing GET system has achieved hydraulic capture of the plume and is effectively controlling off-base migration of the contaminant plume.
	FT005		✓	✓			Yes	The migration control and off-base remediation IRA objectives at Site FT005 are being achieved. The existing GET system appears to have achieved hydraulic capture of the plume and is controlling off-base contaminant migration. A large portion of the plume has been remediated to non-detect concentrations. The extraction wells in the areas of the plume where IRA objectives have been achieved have been shut down for a rebound study for the remainder of the interim period of remediation.
Central	SS016	✓					Yes	The source control IRA objective at Site SS016 has largely been achieved. Hydraulic capture of the TARA source area has been achieved. Within the OSA source area, concentrations have decreased, but the extent of hydraulic capture is less certain. Declining TCE concentrations in shallow and deep monitoring wells downgradient of the OSA and TARA source areas indicate that the horizontal and the vertical extent of the plume is being addressed by the existing GET system. However, even after several years of IRA operation, the highest TCE concentrations at Travis AFB are found at OSA source area horizontal extraction well EW003x16 (18,000 µg/L). Therefore, IRA optimization actions were taken during 2010. These actions included a data gaps investigation to more fully define the OSA source area. Based on the results of the data gaps investigation, operation of a 2-Phase® extraction/ThOx treatment was discontinued, the source area was excavated, and an in situ bioreactor was installed. The portion of the commingled Site SS016 plume (OSA/TARA/ST032) that is not hydraulically captured by the OSA and TARA source control GET systems is eventually hydraulically captured by the downgradient Site SS029 migration control GET system.
	ST032	✓	✓[d]			—[e]	Yes	The source control IRA objective for removal of floating jet fuel at Site ST032 has been achieved. Floating jet fuel has been only intermittently observed in MW246x16 from 1999 through 2001. No floating product was detected during 2007-2008. Dissolved-phase fuel contamination is hydraulically captured by the Site SS029 migration control GET system. This site was transferred out of the ERP and into the POCO program during 2009.

TABLE 2-5
Summary of Groundwater Interim Remedial Action Performance
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

IRA	Site	IRA Objective[a]					IRA Objectives Achieved?	Second Five-year Review Performance Assessment Summary
		Source Control	Migration Control	Off-base Remediation	MNA	MNA Assessment		
West	SS014[f]	✓	✓			✓[b]	Yes	The GET systems for WIOU Sites SS014, SD033, SD034, SS035, SD036, and SD037; and WABOU Sites SS041 and SD043 are largely achieving the source control and migration control IRA objectives. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 µg/L are being captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume are being addressed by the GET existing system. Although IRA objectives are largely being met, even after several years of IRA operation, TCE concentrations greater than 1,000 µg/L continue to be detected at source areas within Sites SD036 and SD037. Optimization of the GET IRAs was required. Therefore, data gaps investigations were performed during 2010 to more fully define the extents of these source areas. Based on the results of the data gaps investigations, optimization measures included discontinuing the GET systems and injection of EVO within the source areas. At Site SD034, floating product removal of Stoddard solvent is achieving the source control IRA for the site. The extent of floating product continues to be limited to the original release area and is not migrating. In the southern (downgradient) area of the WIOU, MNA appears to be a viable remedy. Groundwater contamination in this area does not appear to be migrating.
	SD033[g]		✓			✓	Yes	
	SD034[h]	✓	✓				Yes	
	SS035[i]		✓[b]			—[e]	Yes	
	SD036[j]	✓	✓			—[e]	Yes	
	SD037[k]	✓	✓			✓	Yes	
	SS041[l]		✓				Yes	
	SD043[m]		✓				Yes	
	SS015					✓	No	Data obtained after the second five-year review indicated that MNA does not appear to be successfully addressing Site SS015 contamination. The plume appears to be migrating, and contaminant concentrations are increasing in some wells. The limited volume of EVO injected during a 2000-2001 treatability appears to be exhausted. Optimization of the MNA IRA was required and supplemental injection of EVO was conducted during 2010 to enhance natural attenuation processes.
	DP039	✓			✓		No	The Site DP039 source control IRA objective is being partly achieved. TCE concentrations in the historical contaminant release area (i.e., a former sump) are declining and a portion of the source area plume is being hydraulically contained by the existing GET system. However, another portion of the source area plume is not hydraulically captured. This uncaptured portion of the plume, with TCE concentrations exceeding 1,000 µg/L, extends about 800 feet downgradient. This uncaptured portion of the source area plume underlies an ongoing phytoremediation study. The effectiveness of the phytoremediation system at controlling migration of the plume continues to be evaluated. Increasing TCE concentration trends at some monitoring wells in the distal area of the plume indicate that MNA may not be effective if TCE concentrations in the uncaptured portion of the plume continue to exceed 1,000 µg/L and act as a continuing source of contamination into the downgradient area. Following the second five-year review, two (2) optimization measures to the existing Site DP039 IRA have been conducted: 1. An in situ bioreactor was installed in the former sump area as a demonstration project in December 2008. 2. A data gaps investigation was performed during 2010 to more fully define the extent of the downgradient source area with TCE concentrations greater than 500 µg/L. Based on the results of the data gaps investigations, an in situ PRB of EVO was installed hydraulically downgradient of an existing area of phytoremediation and upgradient of the portion of the plume undergoing MNA.
	LF008		✓				Yes	The migration control IRA objective at Site LF008 was achieved by the GET system. Hydraulic capture of the source area was achieved. The distribution of contamination in monitoring wells also indicated hydraulic containment of the plume. The GET system is currently shut down as part of a rebound study for the remainder of the period of interim remediation.
	ST027B				✓		—[n]	Site ST027 has historically been managed as part of the POCO program at Travis AFB because petroleum hydrocarbons were believed to be the only contaminants present at this site. However, an investigation conducted in 2007 resulted in the discovery of TCE and several other chlorinated VOCs in groundwater in the southwestern part of the site. The site was subsequently subdivided into Site ST027A (fuels contamination only) and Site ST027B (CERCLA contaminants). Following the second five-year review, a data gaps investigation was conducted during 2010 to characterize the VOC plume within Site ST027B and provide data to support risk assessments and remedy selection.

[a] IRA objective specified in the NEWIOU and WABOU Groundwater IRODs (Travis AFB, 1997 and 1998, respectively).
[b] IRA not specified in the NEWIOU Groundwater IROD, but implemented by the Air Force to address entirety of commingled plume.
[c] Assessment of MNA not implemented because plume is hydraulically captured by the Site LF007C GET system.
[d] TARA.
[e] Assessment of MNA not implemented because plume is hydraulically captured by adjacent GET system.
[f] POCO Site SS014 comprises five (5) noncontiguous sites, including Sites 1, 2, 3, 4, and 5. Only Site 1 (Area G) has a source control objective (i.e., floating jet fuel removal).
[g] ERP Site SD033 comprises five (5) noncontiguous sites: Facility 810, Facility 1917, Storm Sewer System II, the South Gate area, and the West Branch of Union Creek within the NEWIOU.
[h] ERP Site SD034 is associated with Facility 811 within the NEWIOU.
[i] ERP Site SS035 is associated with Facilities 818 and 819 within the NEWIOU.
[j] ERP Site SD036 is associated with Facilities 872, 873, and 876 within the NEWIOU.
[k] ERP Site SD037 is associated with the Sanitary Sewer System; Facilities 837, 838, 919, 977, 981; the Area G Ramp; and the Ragsdale/V Street area within the NEWIOU.
[l] ERP Site SS041 is associated with Facility 905 within the WABOU.
[m] ERP Site SD043 is associated with Facility 916 within the WABOU.
[n] Former POCO Site ST027 not listed in NEWIOU IROD and not evaluated in the Second Five-year Review.

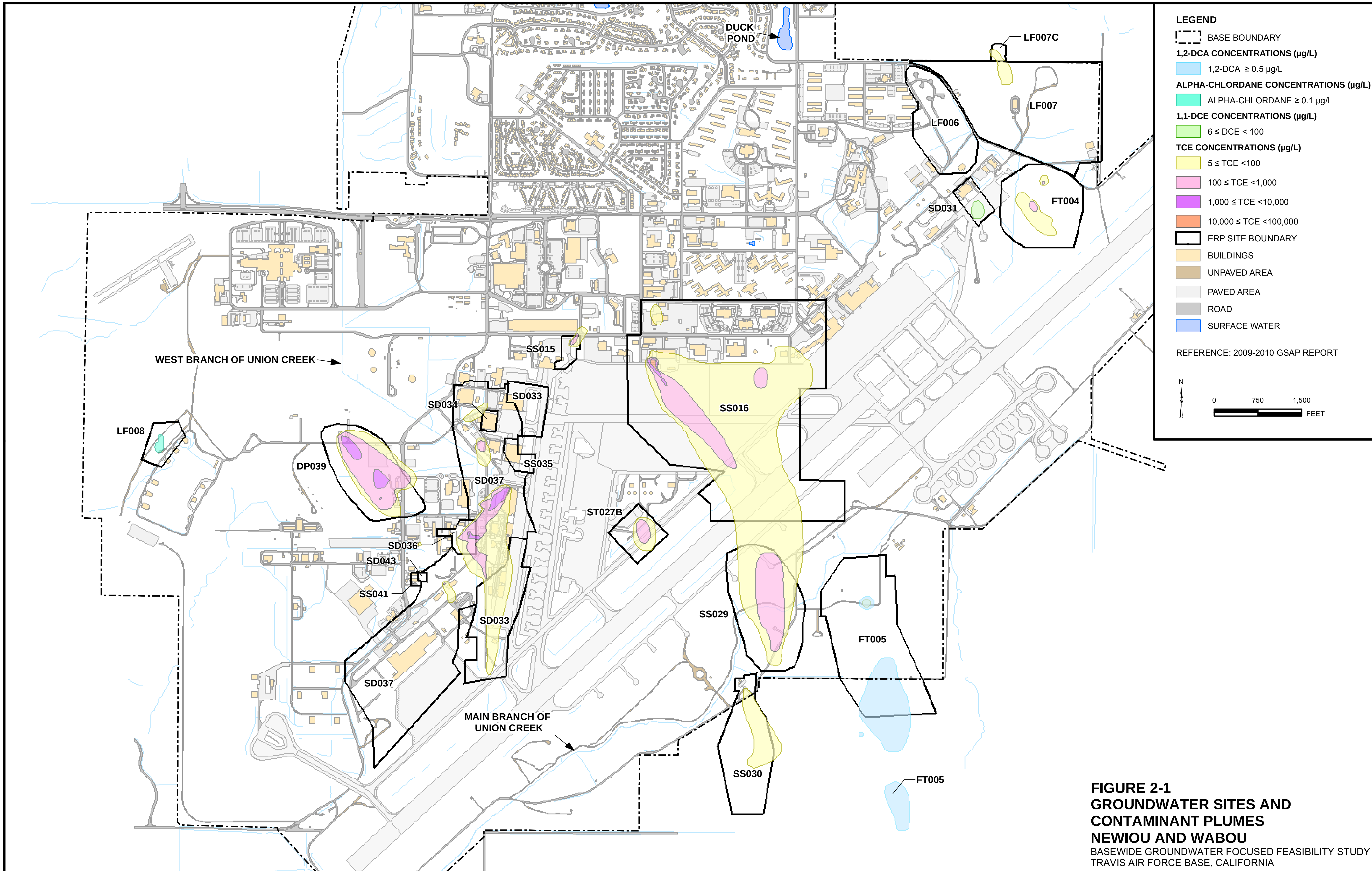


FIGURE 2-1
GROUNDWATER SITES AND CONTAMINANT PLUMES NEWIOU AND WABOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG2-1_BASEWIDE_GWPLUME_NETWORK.MXD MSCHROCK 6/15/2011 01:12:49

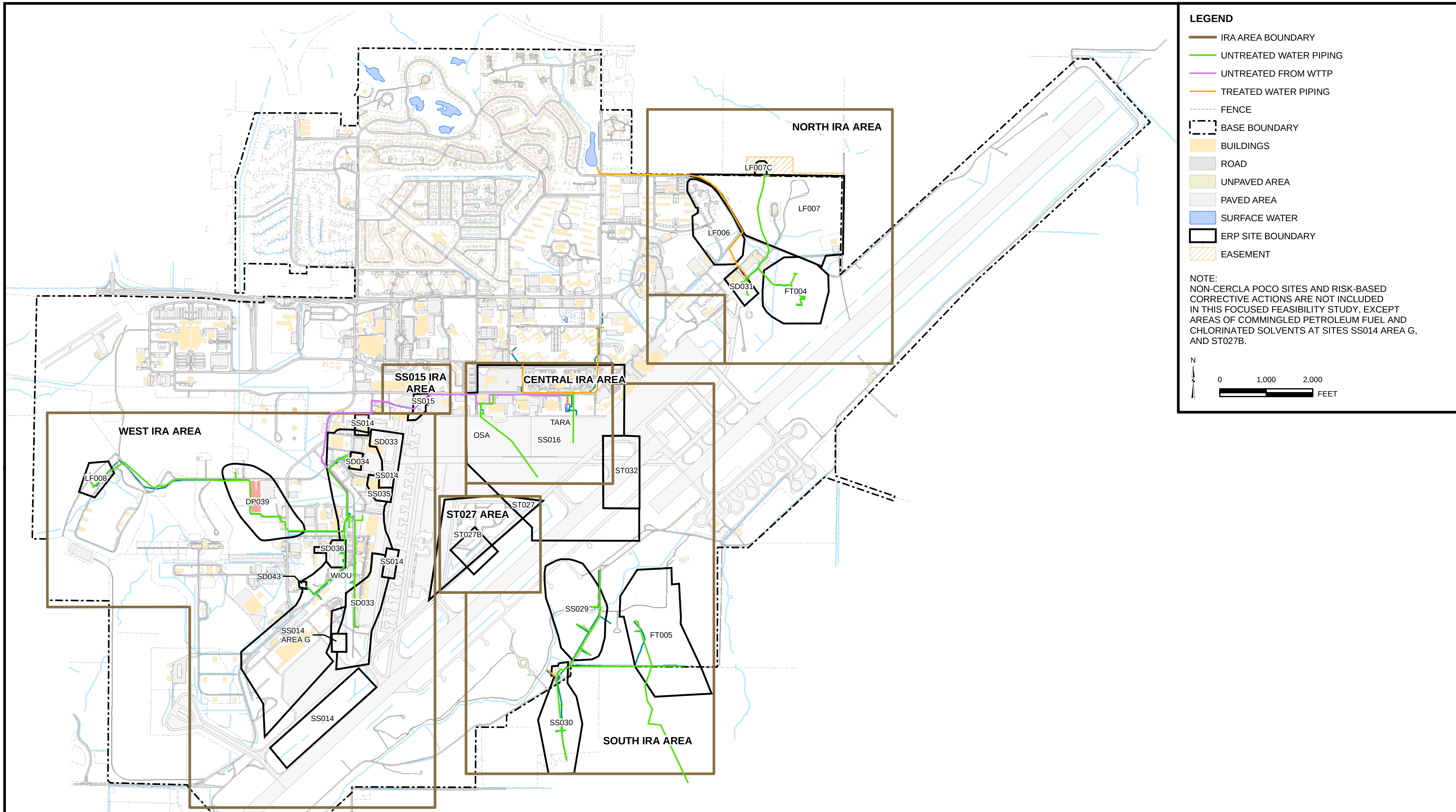
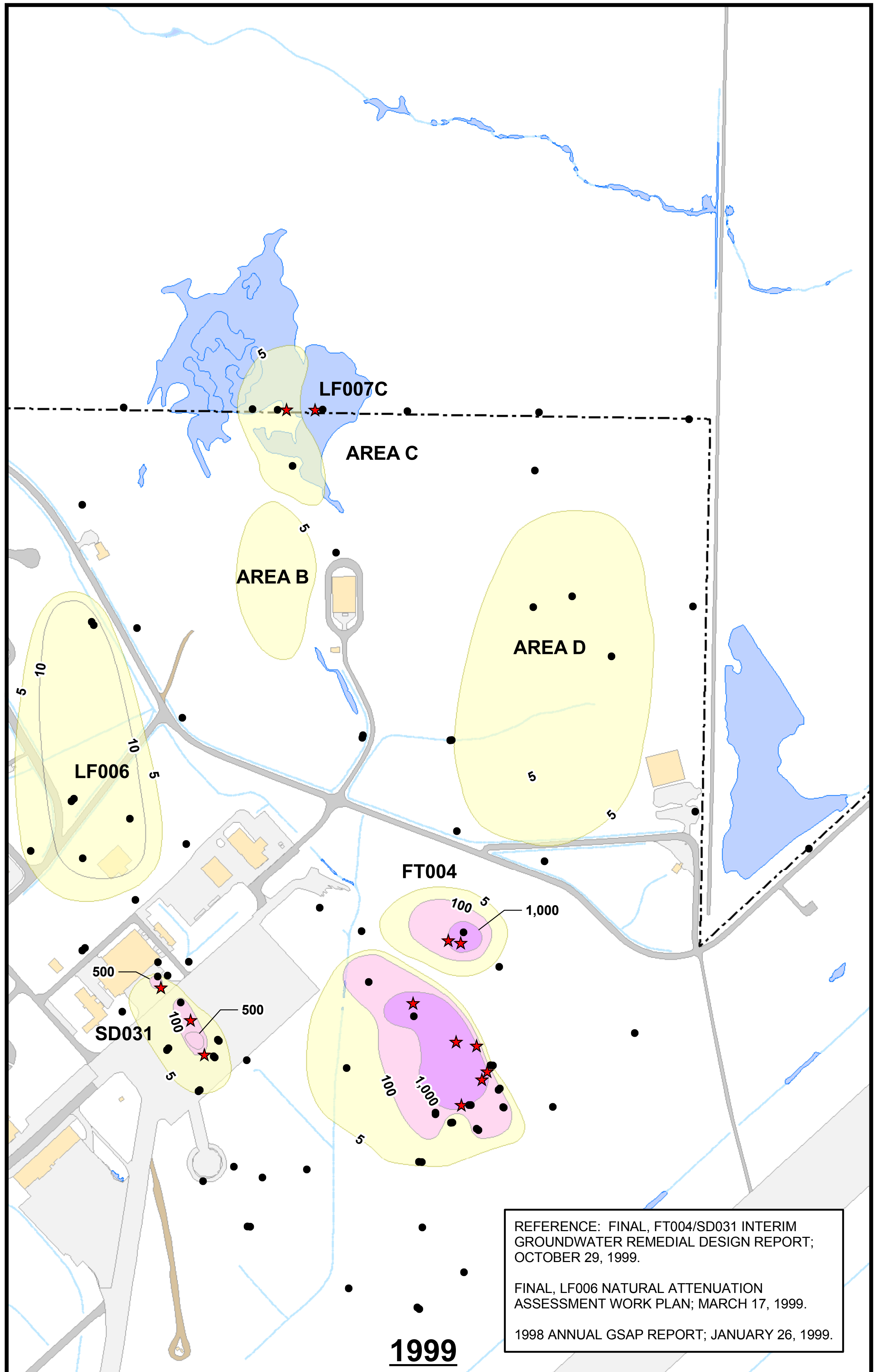
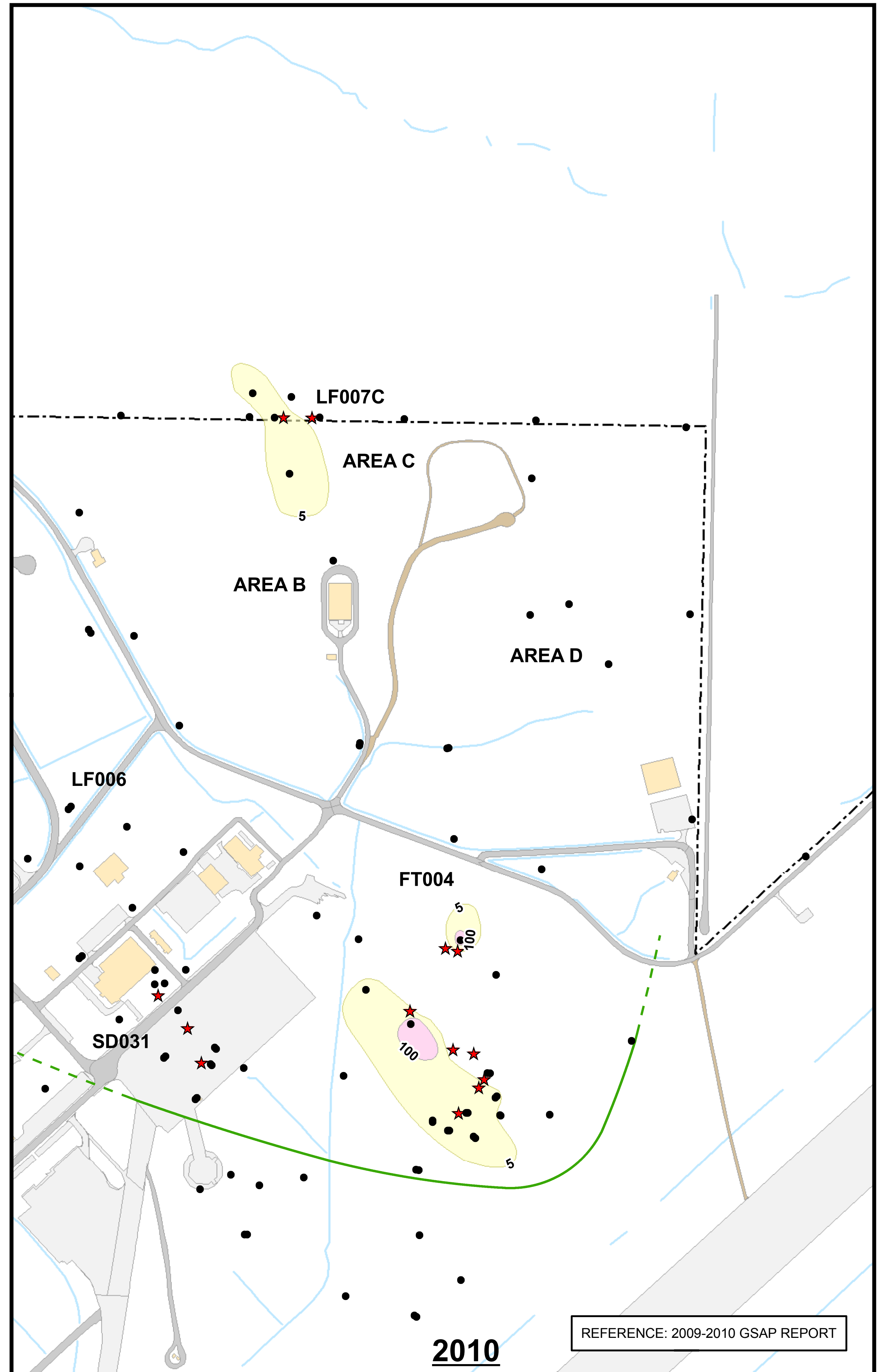


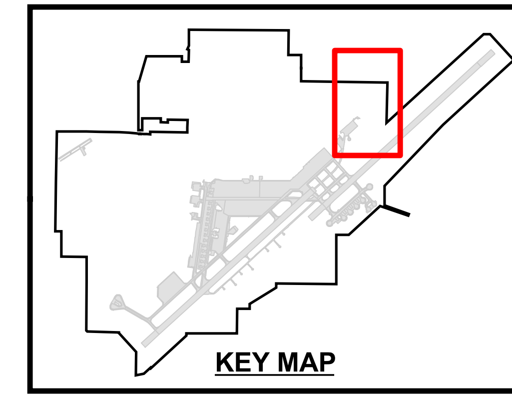
FIGURE 2-2
CONSOLIDATED GROUNDWATER INTERIM REMEDIAL ACTIONS NEWIOU AND WABOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG2-2_GW_REMEDIATION_AREAS.MXD MCLAY1 1/20/2011 08:37:44







LEGEND

- GROUNDWATER MONITORING WELL
- EXTRACTION WELL

TCE CONCENTRATIONS (μg/L)

- 5 ≤ TCE <100
- 100 ≤ TCE <1,000
- 1,000 ≤ TCE <10,000
- APPROXIMATE EXTENT OF HYDRAULIC CAPTURE (DASHED WHERE LESS CERTAIN)
- 5 APPROXIMATE ISOCONCENTRATION CONTOURS (μg/L)
- BASE BOUNDARY
- BUILDINGS
- UNPAVED AREA
- PAVED AREA
- ROAD
- SURFACE WATER

N

0 275 550 FEET

FIGURE 2-3
NORTH IRA –
SITES FT004/SD031/LF006/LF007C
HISTORICAL AND CURRENT TCE GROUNDWATER CONTAMINATION
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

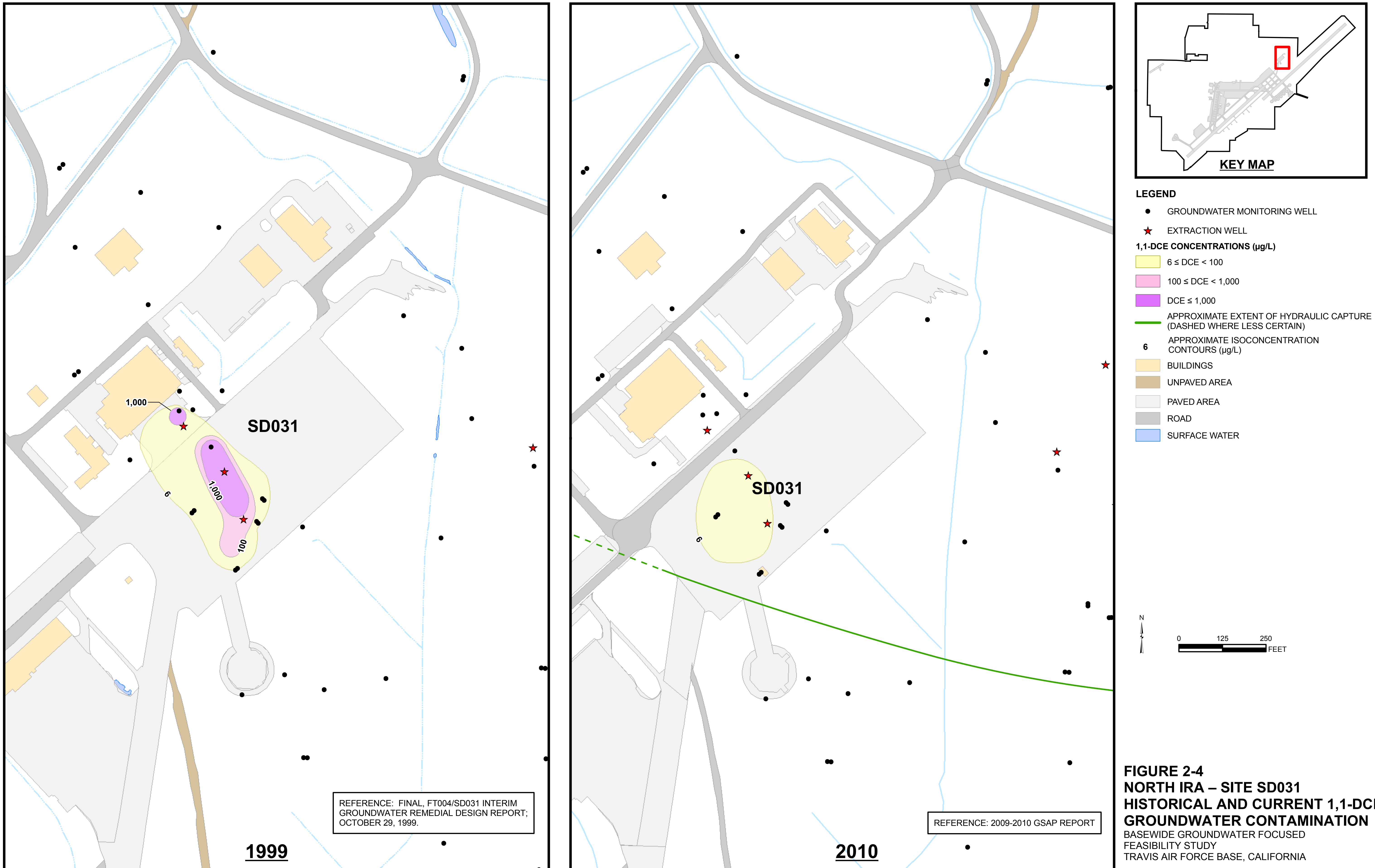


FIGURE 2-4
NORTH IRA – SITE SD031
HISTORICAL AND CURRENT 1,1-DCE GROUNDWATER CONTAMINATION
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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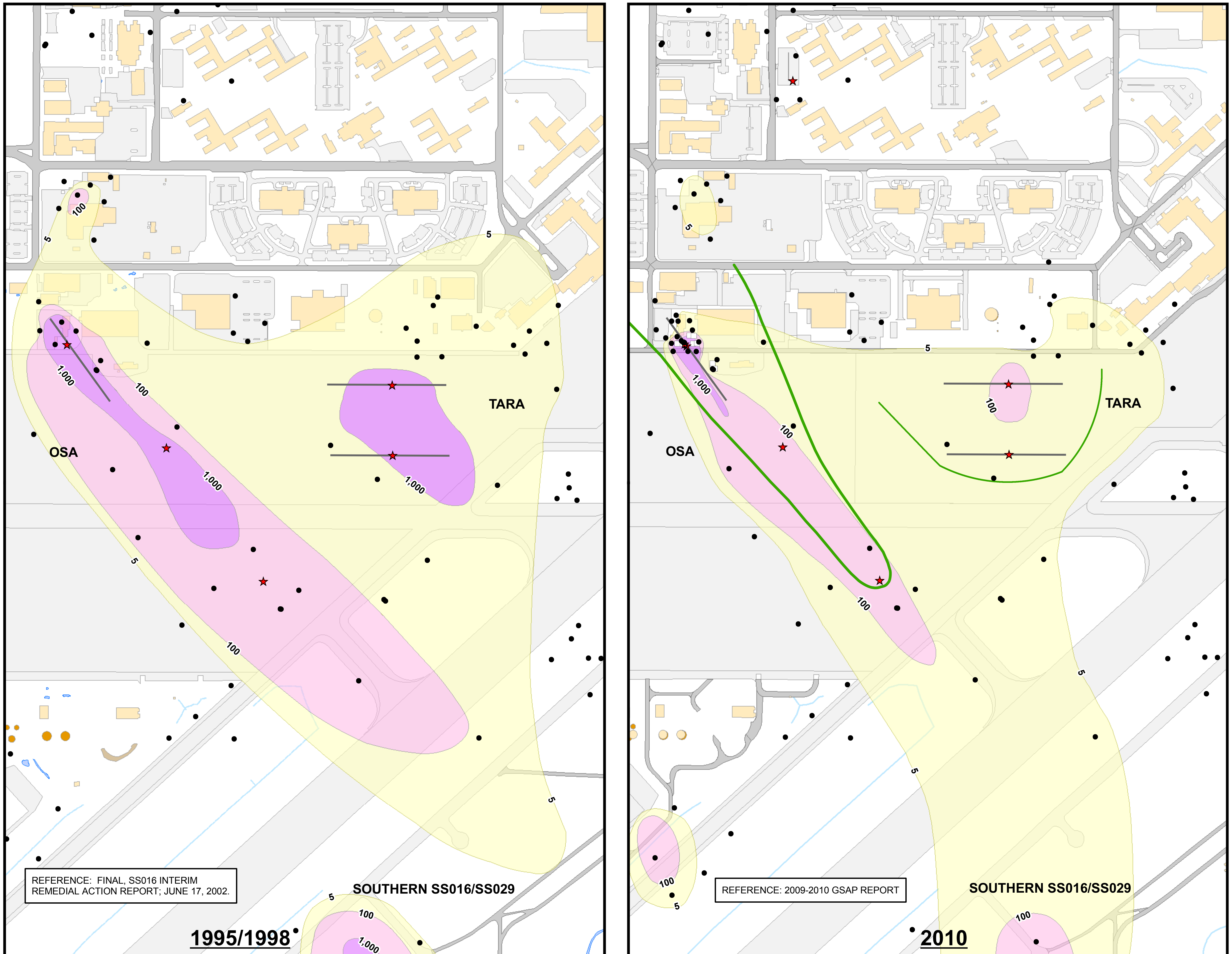
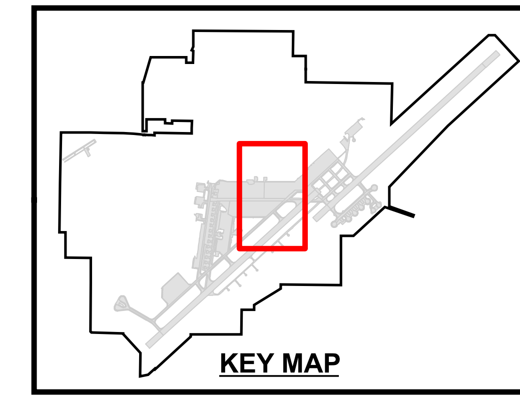
RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG2-4_SD031_DCE_HIST_CURR_GWCONTAM.MXD MCLAY1 1/20/2011 11:39:54





LEGEND

- PIEZOMETER
- GROUNDWATER MONITORING WELL
- VERTICAL EXTRACTION WELL
- HORIZONTAL EXTRACTION WELL

TCE CONCENTRATIONS (µg/L)

- 5 ≤ TCE <100
- 100 ≤ TCE <1,000
- 1,000 ≤ TCE <10,000
- APPROXIMATE EXTENT OF HYDRAULIC CAPTURE
- 5 APPROXIMATE ISOCONCENTRATION CONTOURS (µg/L)
- BUILDINGS
- ABOVEGROUND STORAGE TANKS
- UNPAVED AREA
- PAVED AREA
- ROAD
- SURFACE WATER

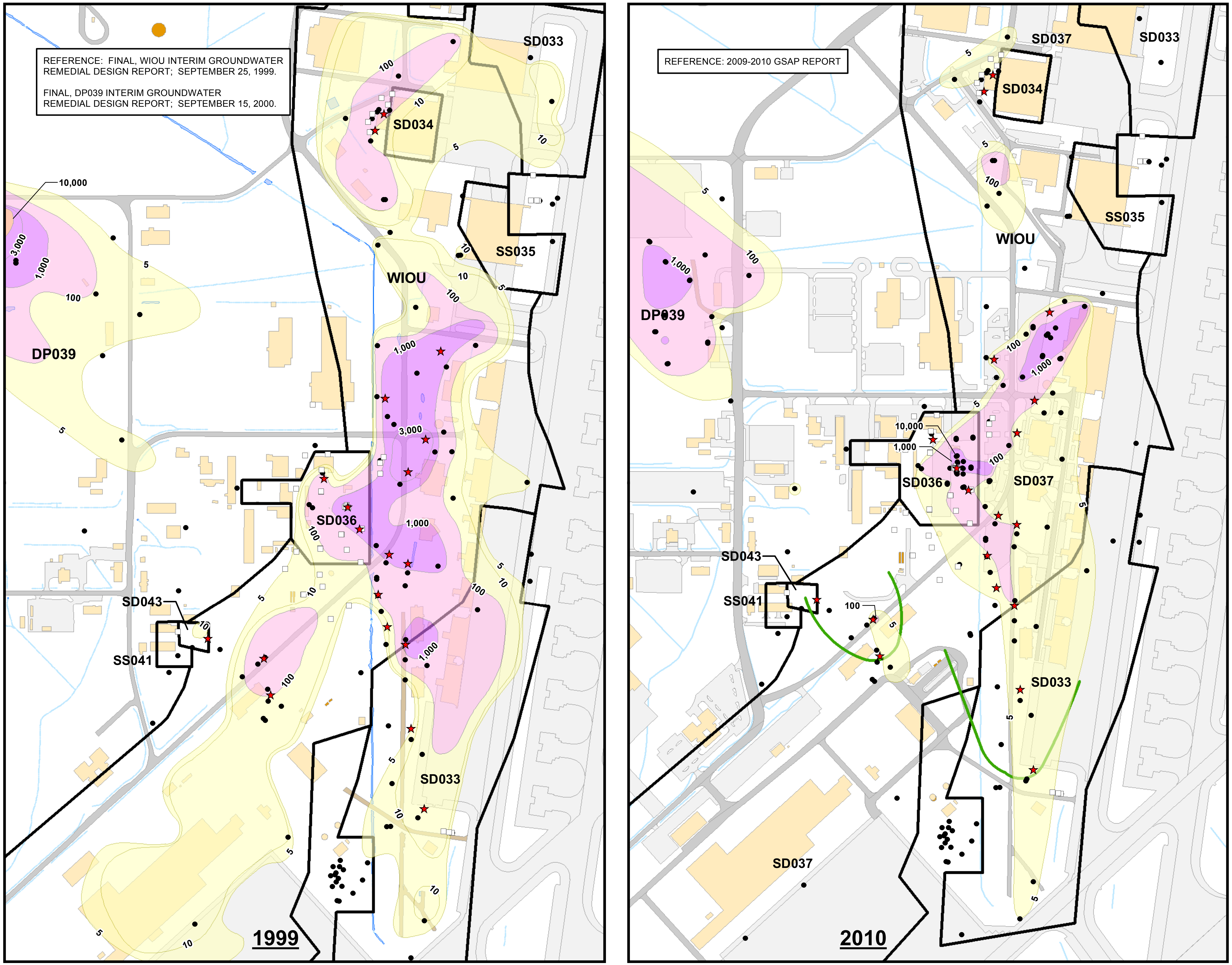
N

0 275 550 FEET

FIGURE 2-5
CENTRAL IRA – SITE SS016
HISTORICAL AND CURRENT
GROUNDWATER CONTAMINATION
BASEWIDE GROUNDWATER FOCUSED
FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG2-5_SS016_HIST_CURR_GWCONTAM.MXD MCLAY1 1/20/2011 12:02:38



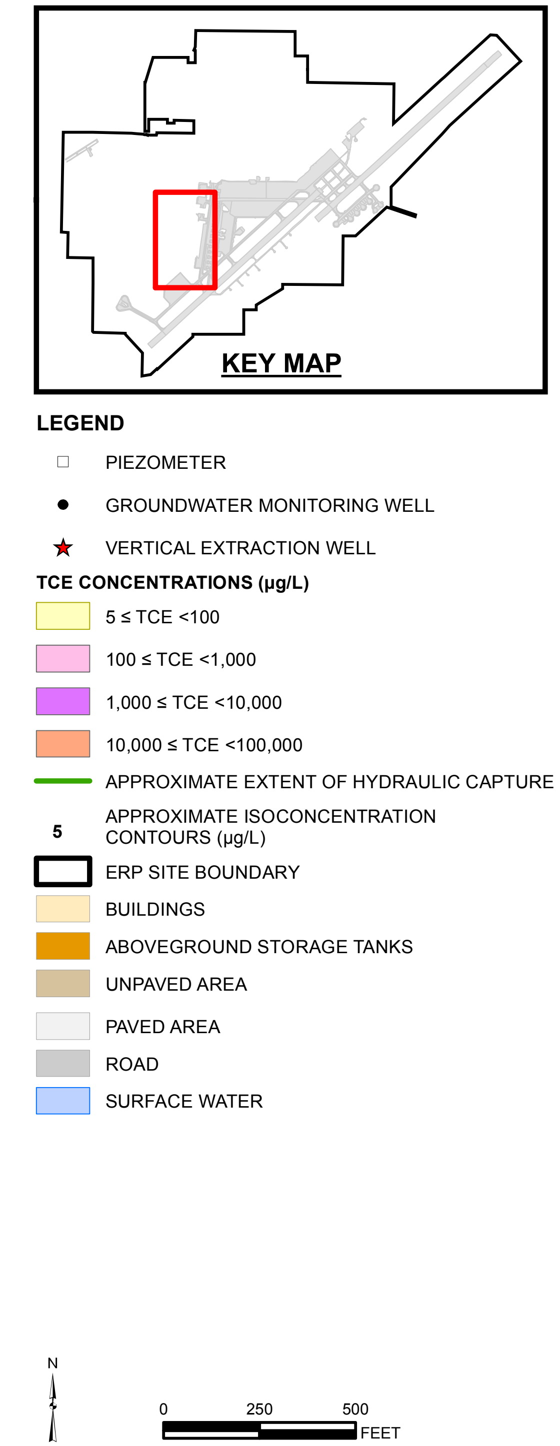
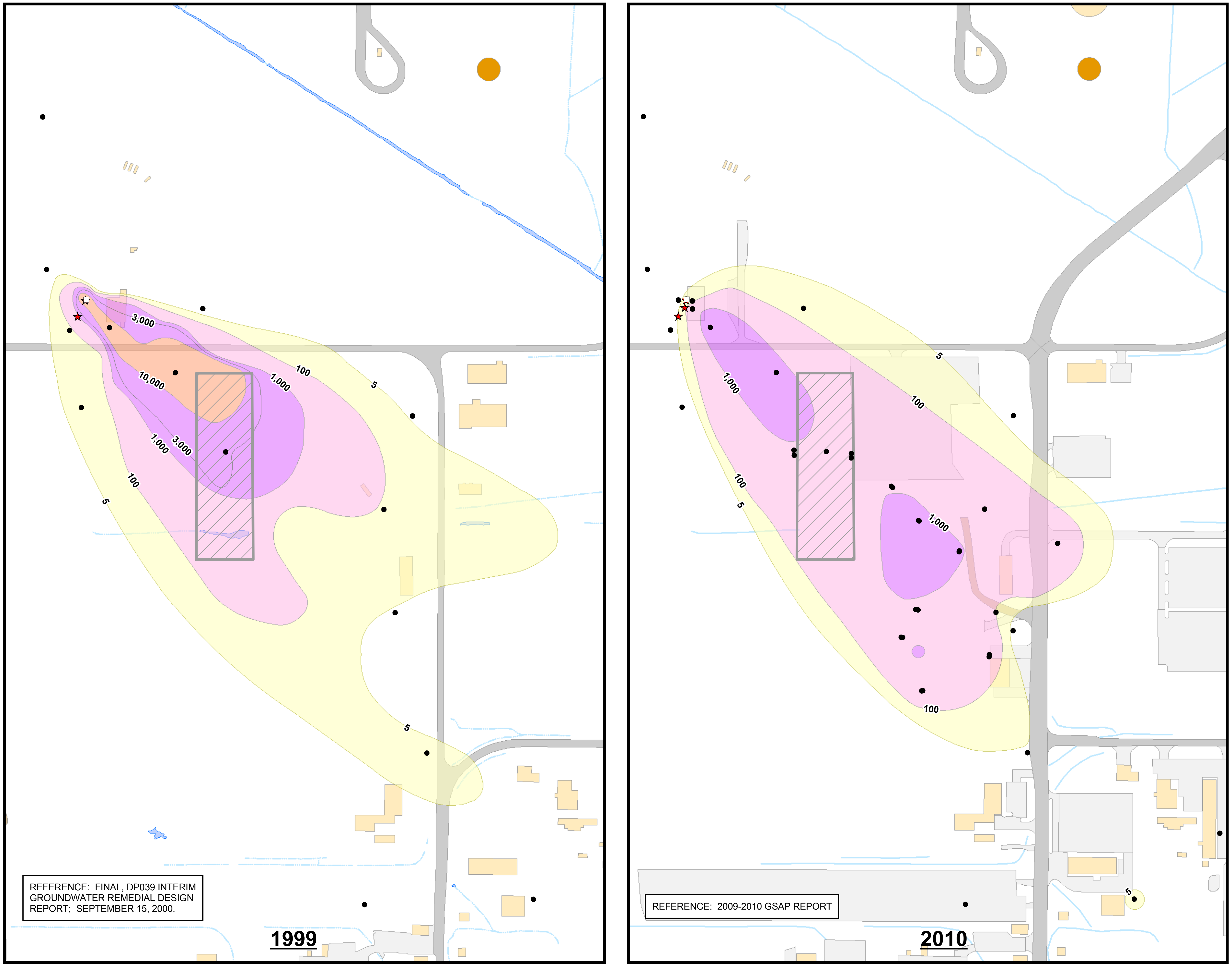


FIGURE 2-6
WEST IRA – WIOU SITES
HISTORICAL AND CURRENT
GROUNDWATER CONTAMINATION
BASEWIDE GROUNDWATER FOCUSED
FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG2-6_WIOU_HIST_CURR_GWCONTAM.MXD MSCHROCK 6/27/2011 5:02:35 PM



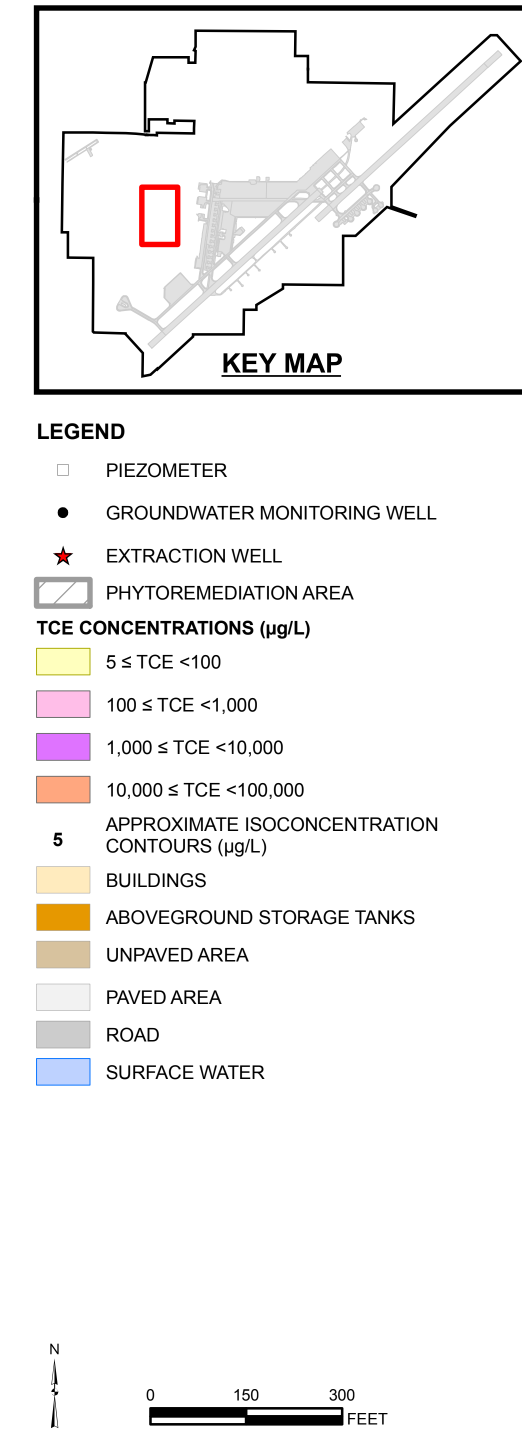
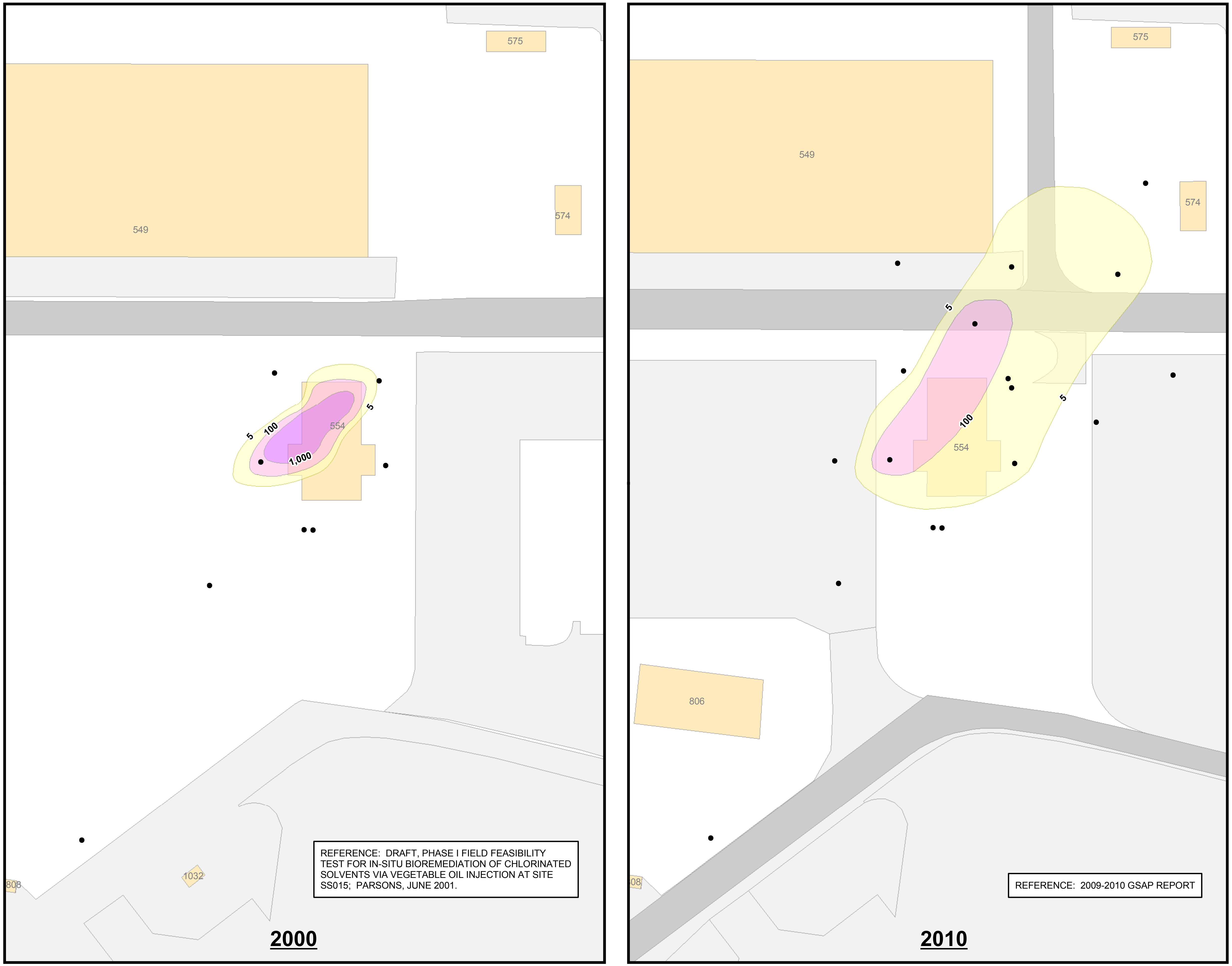


FIGURE 2-7
WEST IRA – SITE DP039
HISTORICAL AND CURRENT GROUNDWATER CONTAMINATION
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL



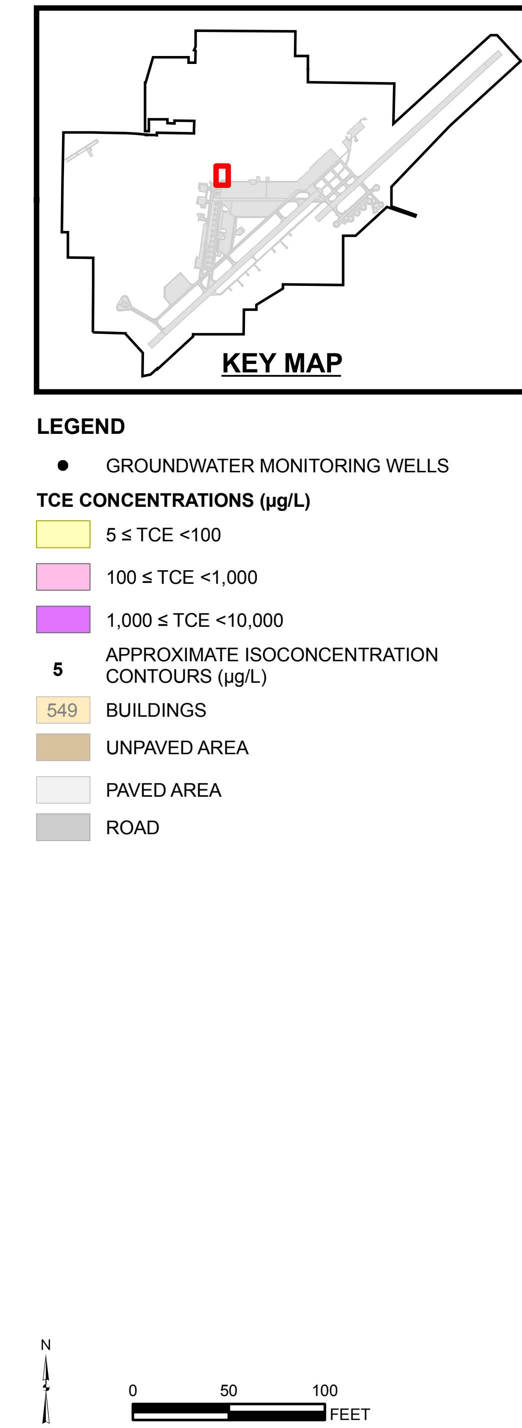


FIGURE 2-8
WEST IRA – SITE SS015
HISTORICAL AND CURRENT GROUNDWATER CONTAMINATION
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG2-8_SS015_HIST_CURR_GWCONTAM.MXD MCLAY1 1/20/2011 13:46:57

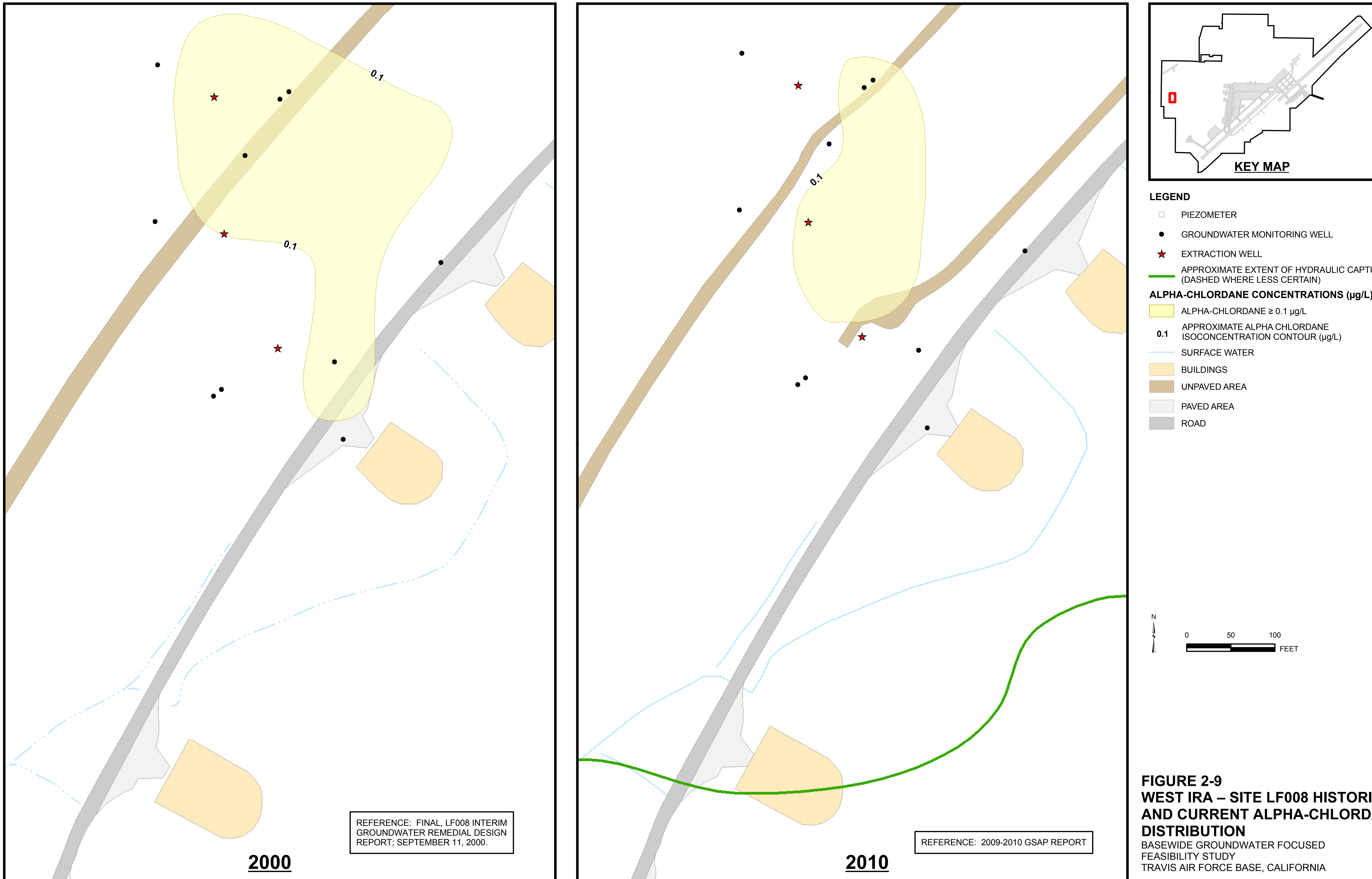
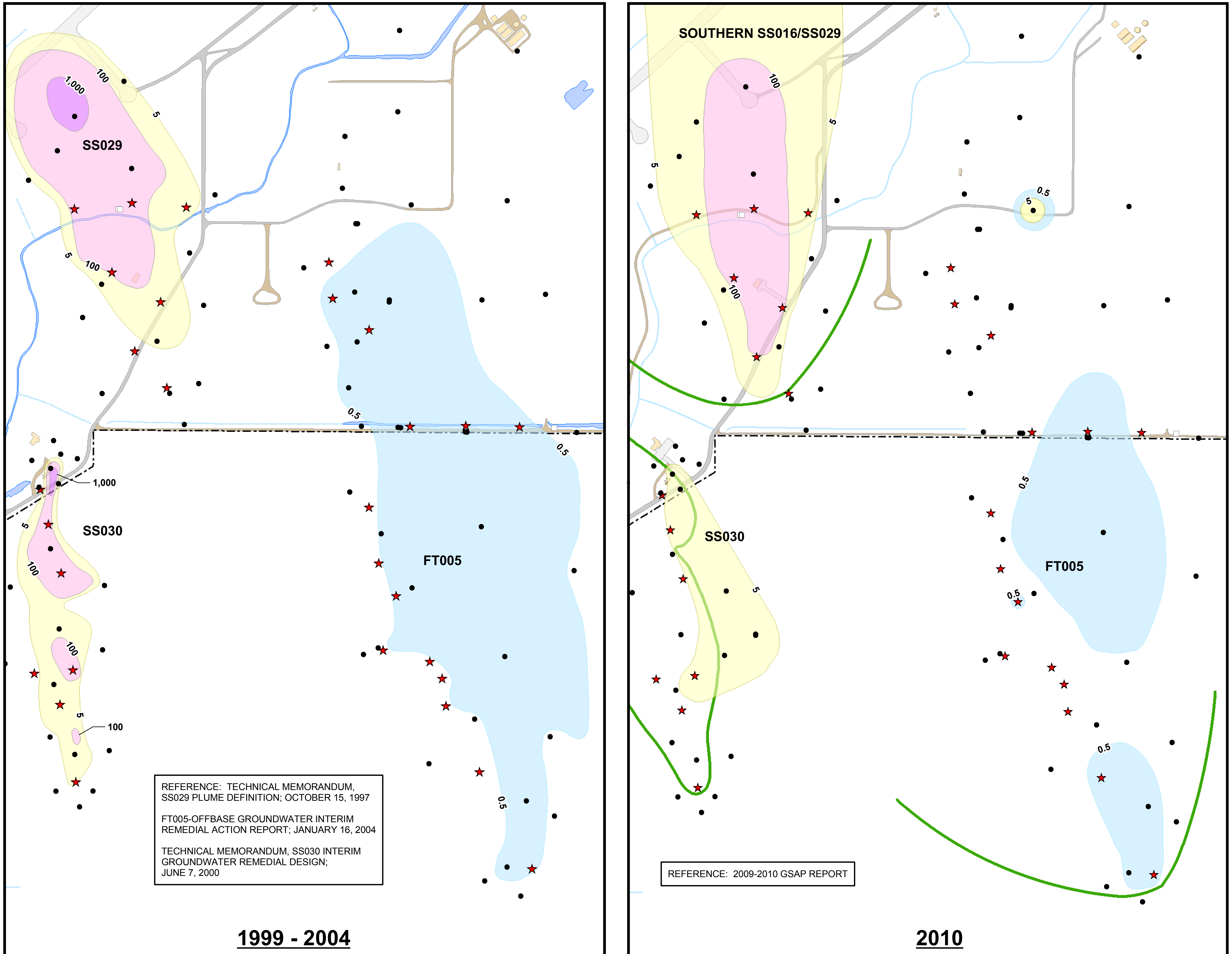
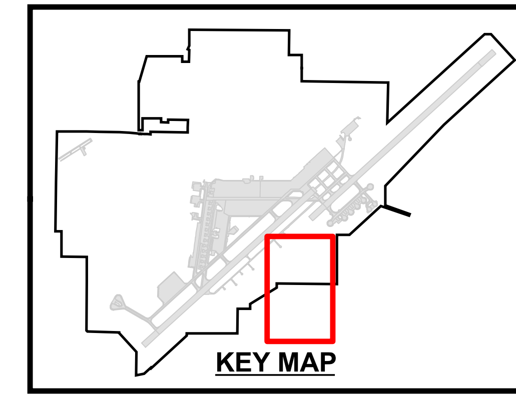


FIGURE 2-9
WEST IRA – SITE LF008 HISTORICAL AND CURRENT ALPHA-CHLORDANE DISTRIBUTION
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG2-9_LF008_AC_HIST_CURR_GWCONTAM.MXD MCLAY1 1/20/2011 14:00:33





LEGEND

- PIEZOMETER
- GROUNDWATER MONITORING WELL
- EXTRACTION WELL

1,2-DCA CONCENTRATIONS (µg/L)

- 1,2-DCA ≥ 0.5 µg/L

TCE CONCENTRATIONS (µg/L)

- 5 ≤ TCE <100
- 100 ≤ TCE <1,000
- 1,000 ≤ TCE <10,000
- APPROXIMATE EXTENT OF HYDRAULIC CAPTURE (DASHED WHERE LESS CERTAIN)
- 5 APPROXIMATE ISOCONCENTRATION CONTOURS (µg/L)
- BASE BOUNDARY
- BUILDINGS
- UNPAVED AREA
- PAVED AREA
- ROAD
- SURFACE WATER

N

0 275 550 FEET

FIGURE 2-10
SOUTH IRA –
SITES FT005/SS029/SS030
HISTORICAL AND CURRENT
GROUNDWATER CONTAMINATION
BASEWIDE GROUNDWATER FOCUSED
FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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SECTION 3

Conceptual Site Models

This section describes the current CSMs for Travis AFB and for the individual ERP groundwater sites described in Section 2. The CSMs are provided in the following subsections:

- Section 3.1 – Travis AFB CSM: Basewide
- Section 3.2 – North IRA CSM: Sites FT004, LF006, LF007, and SD031
- Section 3.3 – Central IRA CSM: Site SS016
- Section 3.4 – West IRA CSM: WIOU Sites SD033, SD034, SS035, SD036, SD037, SS041, SD043; and noncontiguous West IRA Sites SS015, DP039, and LF008
- Section 3.5 – South IRA CSM: Sites FT005, SS029, and SS030
- Section 3.6 – Site ST027B CSM

3.1 Travis AFB Conceptual Site Model

This subsection provides the CSM for Travis AFB. This CSM includes descriptions of climate, topography, land and resource use, habitats and wildlife, geology, surface water, and groundwater at Travis AFB.

Site-specific CSMs are provided in subsequent subsections.

3.1.1 Travis AFB Description

Travis AFB is located midway between San Francisco and Sacramento, California, on low-lying ground within 1 mile of Suisun Marsh, an estuary of San Francisco Bay. It is located 3 miles east of downtown Fairfield in Solano County. The Base occupies over 6,000 acres and maintains ownership of, or administrative control over, several properties at off-base locations. Facilities include two (2) major runways, associated taxiways and aircraft parking aprons, numerous hangars, buildings, shops, offices, freight handling and storage areas, and maintenance facilities. A third runway, called the assault landing zone, is being constructed adjacent to the main instrument-approach runway.

Travis AFB is part of Air Mobility Command and is host to the 60th Air Mobility Wing and other units. The 60th Air Mobility Wing operates C-5 Galaxy and C-17 Globemaster III cargo aircraft and KC-10 Extender refueling aircraft. The primary missions of Travis AFB, since its establishment in 1943, have been strategic reconnaissance and airlift of freight and troops.

3.1.2 Climate

The Travis AFB area has a Mediterranean climate, with wet winters and dry summers. The Base is located near the Carquinez Straits, which is the major break in the Coast Range. Travis AFB usually experiences mild temperatures because of its proximity to the Carquinez Straits and the coast. The mean annual temperature is 60 degrees Fahrenheit (°F). The lowest temperatures occur in January, with a mean of 46°F. The highest temperatures occur in July and August, with a mean of 72°F. Monthly mean relative humidity typically ranges from a low of 50 percent in June to a high of 77 percent in January. The mean annual relative humidity is 60.5 percent.

Travis AFB averages 17.5 inches of rain annually. Approximately 84 percent of the annual precipitation falls during the winter season of November through March. January is the wettest month, averaging 3.7 inches of precipitation; July is the driest month averaging 0.02 inch of precipitation.

Evapotranspiration ranges from about 50 to 75 inches per year. However, because most precipitation occurs in the winter, and most evaporation takes place in the summer, this apparent "net annual negative precipitation" has little impact on water infiltration through the soil column or on groundwater recharge.

Travis AFB experiences sea breezes during the summer because of its proximity to the Carquinez Straits. The average annual wind speed is 8 knots, with a winter average of 5 to 6 knots and a summer average of 12 knots. The predominant wind directions are from the southwest and west-southwest.

3.1.3 Topography

Travis AFB has a gently sloping to nearly flat topography with variations in topographic relief of up to 50 feet. Elevations at Travis AFB range from over 100 feet above mean sea level (msl) near the northern boundary to less than 20 feet above msl near the South Gate. The ground surface generally slopes to the south or southeast at about 30 feet per mile. Areas surrounding Travis AFB have a varied topography.

3.1.4 Land and Resource Use

The following subsections describe the usage of land, groundwater, and surface water at Travis AFB.

3.1.4.1 Land Use

Travis AFB occupies about 6,383 acres of land near the center of Solano County, California, and is located approximately 3 miles east of downtown Fairfield and 8 miles south of downtown Vacaville. Solano County’s estimated population in 2009 was approximately 407,234 (U.S. Census Bureau, 2009a). The 2009 population estimates for Fairfield and Vacaville are 103,586 and 91,991, respectively (U.S. Census Bureau, 2009b).

According to the Travis AFB Office of Public Affairs, Travis AFB currently employs about 7,750 active military personnel and 3,323 reservists. Approximately 5,613 people live in 3,466 on-base housing units. There are 3,006 civilians employed at Travis AFB. Approximately 17,000 military and civilian personnel are present daily on the Base.

The land use areas of Travis AFB are grouped into the following eight (8) functional categories:

- **Mission –** Uses are closely associated with the airfield and include facilities such as maintenance hangars and docks, avionics facilities, and other maintenance facilities. Aircraft operations facilities include control towers, Base operations, flight simulators, and other instructional facilities.
- **Administrative –** Uses include personnel, headquarters, legal, and other support functions.
- **Community –** Uses include both commercial and service activities. Examples of commercial uses include the Base Exchange, dining halls, service station, and clubs; service uses include the schools, chapel, library, and the family support center.
- **Housing –** Uses include both accompanied housing for families and unaccompanied housing for singles, temporary personnel, and visitors.
- **Base Support/Industrial –** Uses are for the storage of supplies and maintenance of Base facilities and utility systems.
- **Medical –** Uses include facilities for medical support, including the David Grant Medical Center.

- **Outdoor Recreation –** Uses include ball fields, golf course, equestrian center, swimming pools, and other recreational activities.
- **Open Space –** Used as buffers between Base facilities and to preserve environmentally sensitive areas.

The lands surrounding Travis AFB on the northeast and east are primarily used for ranching and grazing. Areas to the south are a combination of agricultural and marshland. A few commercial/light industrial areas are present to the north of the Base. The area west of Travis AFB is predominantly residential.

Land use within the western portion of the Base is varied and consists primarily of open grasslands, light industrial support areas, administrative areas, personnel training areas, ammunition storage, and service/storage areas. Over the remainder of the Base, land use includes two (2) major aircraft runways, one (1) smaller practice runway, associated taxiways and aircraft parking aprons, numerous hangars, buildings, shops, offices, freight handling and storage areas, and maintenance facilities.

3.1.4.2 Groundwater Use

No on-base wells are used for potable water production at Travis AFB.

Travis AFB overlies the Suisun-Fairfield Valley groundwater basin. According to the Water Quality Control Plan for the San Francisco Bay Basin, beneficial uses for groundwater in the Suisun-Fairfield Valley groundwater basin are municipal and domestic water supply, industrial process and industrial service water supply, and agricultural water supply. Approximately 3,562 acre-feet per year of groundwater is pumped for agricultural use from the Suisun-Fairfield Valley groundwater basin (U.S. Geological Survey [USGS], 2003). Although there are 15 public water supply wells within the Suisun-Fairfield Valley groundwater basin, they do not serve a municipal population (USGS, 2003). The nearest city to Travis AFB is Fairfield, California, which uses surface water rather than groundwater for the municipal water supply. Fairfield is located west and crossgradient of Travis AFB. Downgradient of Travis AFB is the brackish water of Suisun marsh.

There is no usage of groundwater at Travis AFB for human consumption. No on-base wells are used for potable water production at Travis AFB. There is one known domestic water supply well located immediately downgradient of Travis AFB. This domestic water supply well is downgradient of the Site SS030 TCE plume and is sampled semiannually for VOCs through the GSAP through the 2Q10 GSAP event, no Site SS030 chemicals of concern (COCs) have been detected in this well.

3.1.4.3 Land Use Controls on Groundwater Use

Land Use Controls (LUCs) are used to provide protection from exposure to residual contaminants on a site. LUCs are generally classified as institutional (administrative and/or legal) controls or physical controls. Travis AFB has LUCs in place at all sites with groundwater contamination. These existing LUCs are described in Section 5.6 (Land Use Restrictions) of the WABOU Groundwater IROD (Travis AFB, 1999) and Section 5.1.2 (Institutional Actions) of the NEWIOU Groundwater IROD (Travis AFB, 1998).

Travis AFB actively enforces LUCs at all the ERP groundwater sites described in this FFS. Annual LUC reports are prepared to describe the status of the LUCs being enforced at each site. The most recent of these is the final *Annual Report on the Status of Land Use Controls on Restoration Sites in 2010* (Travis AFB, 2011).

LUCs are currently in place or may be required at contaminated groundwater sites until residual contamination in the groundwater is at levels that allow for unlimited use and unrestricted exposure. The RAO of LUCs is to prevent the exposure of human or ecological receptors to unacceptable risks from soil, groundwater, and surface water. To meet this RAO, Travis AFB restricts the land use to industrial uses, prohibits the development of on-base water supply wells and consumption of contaminated groundwater, and restricts soil excavation and other subsurface work where a worker might encounter contaminated groundwater or vapors. The RAO is accomplished by detailing these restrictions in designated areas set forth in the Base General Plan, administrative measures, and signage. The administrative measures are the Base Civil Engineer Work Request procedures, the Base dig permit procedures, and the environmental impact analysis process (EIAP). Signs warn site visitors that soil disturbance, excavation, and removal are controlled. The EIAP, work request, and Base dig permit procedures restrict development, soil disturbance, and relocation during the interim period before remedial actions are implemented. These measures are in accordance with specific provisions of 22 California Code of Regulations (CCR) Section 67391.1 that have been determined by the Air Force to currently be relevant and appropriate requirements. Subsections (a), (b) and (e)(2) of 22 CCR Section 67391.1 provide that if a remedy at property owned by the federal government will result in levels of hazardous substances remaining on the property at levels not suitable for unlimited use and unrestricted exposure, and it is not feasible, as is the case with the Travis AFB groundwater sites subject to LUCs, to record a land use covenant, then the ROD is to clearly define and include limitations on land use and other institutional control mechanisms to ensure that future land use will be compatible with the levels of hazardous substances remaining on the property. These limitations and mechanisms will be set forth in the Proposed Plan and ROD; they include annotating these restrictions in the Travis AFB General Plan and continuing to follow the review and approval procedures for any well drilling and ground-disturbing activities at groundwater sites with LUCs.

Regarding contaminated plumes off the installation, Travis AFB monitors and enforces the terms and restrictions of its access and environmental response easements to ensure the landowners do not engage in water development or soil disturbing activities that would interfere with the government's rights under the easements.

Travis AFB has effectively implemented LUCs during the period of interim remediation to reduce the possibility of human exposure to contaminated groundwater. The LUC process option is commonly implemented in conjunction with other response actions.

3.1.4.4 Administrative Measures

The Base uses the following tools/administrative measures to promote awareness of and enforce established environmental access restrictions.

Travis AFB General Plan. The Travis AFB General Plan is a long-range planning tool that provides a framework for selecting the locations of future facilities needed to carry out the

Base mission (Travis AFB, 2002b). The Component Plan Overview section of the General Plan describes the specific LUCs for each site, the reasons for the controls, and the areas where the controls are applied. It is also Web-based and accessible to all Base personnel that are authorized to use the Travis AFB local area network. For a LUC to remain protective, Base personnel must have access to information concerning its existence, purpose, and maintenance requirements. The General Plan provides the important information necessary to ensure that LUC management takes place and that the LUC's presence is effectively communicated.

Base Civil Engineer Work Requests. Another tool for LUC enforcement is the Air Force Form 332 (AF332) or Base Civil Engineer Work Request. This form must be submitted and approved before the start of any building project at Travis AFB. One (1) step in the approval process for this form is a comparison of the building site with all constraints that are described in the General Plan. The AF332 serves as the document for communicating any construction constraints to the appropriate offices. Any constraints at the site result in the rejection of the form unless the requester makes appropriate modifications to the building plans.

Excavation Permits. Travis AFB also uses the 60th Air Mobility Wing Form 55 or Excavation Permit to enforce the residential development and soil and sediment disturbance restrictions. The requester submits the permit to the Civil Engineer Squadron for any project that involves mechanical soil or sediment excavation, such as trench digging for underground utilities or soil excavation for building foundations. If constraints involving soil disturbance or worker safety exist at the excavation area, the permit describes the appropriate procedures that workers must implement before the start of excavation to prevent unknowing exposure to contamination.

Both AF332s and excavation permits are subject to an evaluation under the EIAP, conducted pursuant to the National Environmental Policy Act, as promulgated for the Air Force in 32 Code of Federal Regulations (CFR) 989, et. seq. Air Force Form 813 initiates the EIAP. The proponent of a proposed action is required to submit the AF332 or excavation permit with Form 813 so that the appropriate environmental analysis of the proposed action and alternatives to the proposed action is accomplished prior to any construction activities. The EIAP works to ensure that the constraints described in the General Plan are taken into account for proposed construction sites. The EIAP also ensures that all environmental factors, such as LUCs, are considered in the selection of locations for construction projects.

Off-base Plume Management. Three (3) solvent plumes have migrated off-base; they are associated with Sites LF007C, FT005, and SS030 and lie beneath private property. To manage the groundwater IRAs for these sites, Travis AFB purchased long-term easements that grant access rights to the United States, its representatives, agents, and contractors for the purpose of conducting environment responses on the properties. The easements restrict the landowners from interfering or abridging the exercise of the government's rights under the easement. The United States would view any residential development and any well drilling on the properties covered by the easements as interfering with the government's easement and would take appropriate action to prevent interference with its rights under the easement.

Solano County Ordinance, Chapter 13.10, makes it a misdemeanor to construct a well without a Solano County permit and requires the permit requester to notify the County of all wells within a 100-foot radius of the proposed well site. Given the number of monitoring and extraction wells that the government is operating on the easements, this ordinance ensures that Travis AFB will be notified of a landowner's well drilling plans. Additionally, Travis AFB's wells are frequently monitored, and any landowner actions potentially interfering with the easements would be observed. The landowner would be contacted to rectify the situation. To date, no such activities have been observed. There are no known drinking water wells that draw water from the plumes. This is confirmed by the frequent presence of Base and contractor personnel in the off-base area as part of conducting the interim remedies. The Air Force will purchase additional easements in the event the off-base plumes remain contaminated at the expiration of the terms of the existing easements.

Throughout their duration, the easements restrict development of new wells and incompatible use of the water below the property.

3.1.4.5 Surface Water

Surface water is not used as a potable water source at Travis AFB.

Travis AFB is located in the northeastern portion of the Fairfield-Suisun Hydrologic Basin. Within the basin, water generally flows south to southeast toward Suisun Marsh, an 85,000-acre tidal marsh that is the largest contiguous estuarine marsh and the largest wetland in the continental United States. Suisun Marsh drains into Grizzly and Suisun Bays. Water from these bays flows through the Carquinez Straits to San Pablo Bay and San Francisco Bay, and ultimately discharges into the Pacific Ocean near the City of San Francisco.

Union Creek is the primary surface water pathway for runoff at Travis AFB. The head-waters of Union Creek are located approximately 1 mile north of the Base, near the Vaca Mountains, where the creek is an intermittent stream. Union Creek splits into two (2) branches north of the Base (the Main Branch and the West Branch). As it enters Travis AFB, the Main (eastern) Branch is impounded into a recreational pond designated as the Duck Pond. At the exit from the Duck Pond, the creek is routed through an underground storm drain pipe to the southeastern area of the Base, where it empties into an open channel. The locations of the Main Branch of Union Creek, the West Branch of Union Creek, and the Duck Pond are shown on Figure 2-1.

The West Branch of Union Creek flows south and enters the northwestern border of Travis AFB east of the David Grant Medical Center in an excavated channel. This channel flows south to the northeastern corner of the WABOU. The channel forms the boundary between the WIOU and the WABOU and parallels Ragsdale Street for about 4,000 feet. Flow in the channel is then directed to a culvert under the runway and discharges to the main channel of Union Creek at Outfall II. From Outfall II, Union Creek flows southwest and discharges into Hill Slough, a wetland located 1.6 miles from the Base boundary. Surface water from Hill Slough flows into Suisun Marsh.

Local drainage patterns have been substantially altered within the Base by the rerouting of Union Creek, the construction of the aircraft runway and apron, the installation of storm drain pipes and ditches, and general development (e.g., the Base Exchange, industrial shops, maintenance yards, roads, housing, and other facilities). Surface water is collected in a network of underground pipes, culverts, and open drainage ditches. The surface water collection system divides the Base into eight (8) independent drainage areas. The eastern portion of the Base is served by one (1) of the drainage systems that collects runoff from along the runway and the inactive sewage treatment plant area and directs it to Denverton Creek and Denverton Slough. Denverton Creek is an intermittent stream near the Base. The northwestern portion of the WABOU drains to the west toward the McCoy Creek drainage area. McCoy Creek is also an intermittent stream near the Base. With the exception of these drainages, the remaining six (6) drainage areas at the Base empty into Union Creek.

The *West Industrial Operable Unit Interim Groundwater Remedial Design Report* (CH2M HILL, 1999a) presented evidence that the West Branch of Union Creek is a gaining stream (i.e., a stream reach in which the water table adjacent to the stream is higher than the water surface in the stream), at least during part of the year. This means that groundwater discharges into the stream and supports the base flow of the stream. Evidence supporting the gaining stream hypothesis includes low concentrations of VOCs in creek samples, which may have originated from groundwater, and the shape of groundwater elevation contours, which converge toward the creek.

A portion of the Main Branch of Union Creek may also receive groundwater inflow. An upward vertical gradient in Site SS029 piezometer pair PZ01Sx29 and PZ01Dx29, located along the bank of the Main Branch of Union Creek, indicates that this reach of the creek may also be a gaining stream.

This FFS report addresses the groundwater medium. The final *North, East, West Industrial Operable Unit Soil, Sediment, and Surface Water Record of Decision* (Travis AFB, 2006) addresses surface water resources in the NEWIOU, which includes all of the Base portion of Union Creek. No surface water resources exist within the WABOU.

3.1.5 Habitats and Wildlife

Travis AFB has a variety of terrestrial and aquatic/wetland habitats and wildlife that are typical of the region. The locations of the groundwater ERP sites, as well as sensitive habitats such as wetlands, and endangered species occurrences are shown on Figure 3.1-1.

There are no ecological receptors to groundwater contamination at Travis AFB.

3.1.5.1 Terrestrial Habitats

The terrestrial habitats at Travis AFB and adjacent areas consist of herbaceous-dominated habitats (annual grassland, pasture, and early ruderal habitat) and urban habitat (industrial areas, lawns, and ornamental plants), according to the California Department of Fish and Game (CDFG) classification system (Mayer and Laudenslayer, 1988). Aquatic/wetland habitats at Travis AFB include riverine (Union Creek) and riparian habitat, lacustrine (Duck Pond), and herbaceous-dominated wetlands, marshes, and vernal pools.

In general, annual grassland habitat is dominated by non-native plant species, such as slender wild oat (*Avena fatua*), fescues (*Festuca)*, soft chess (*Bromus hordeaceus*), field bindweed (*Convolvulus arvensis*), and yellow star-thistle (*Centaurea solstitialis*). Some native plants, such as bunchgrass (*F. viridula)* and johnny-tuck (*Triphysaria eriantha*) may also be found, usually associated with undisturbed areas.

Mowed/disced grassland is generally composed of soft chess, Italian ryegrass (*Lolium multiflorum*), and wild oats (*Chasmanthium latifolium*). Pasture grassland can contain varying frequencies of filaree (*Erodium* sp.), ripgut brome (*Bromus diandrus*), soft chess, Italian ryegrass, and yellow star-thistle. Ruderal grasslands, on the other hand, contain higher numbers of perennial species and, in some areas, woody species such as coyote brush (*Baccharis pilularis*), eucalyptus (*Eucalyptus* sp.), Peruvian pepper-tree (*Schinus molle*), and black locust (*Robinia pseudoacacia*).

The urban habitat on-base contains maintained lawns and trees and shrubs, such as eucalyptus, Fremont cottonwood (*Populus fremontii*), arroyo willow (*Salix lasiolepis*), and coyote brush. Most isolated stands of shrubs or trees are located within or near urban areas, permanent water sources, or near artificial surface mounds (e.g., rail lines, blast protection, and building and road foundations).

3.1.5.2 Aquatic and Wetland Habitats

Herbaceous wetland vegetation is found along the permanent (natural or artificial) drainages on-base and can also occur seasonally within vernal pools, swales, and ditches. Native species include salt grass (*Distichlis spicata*); non-native species include meadow fescue (*Festuca elatior*), sickle grass (*Parapholis incurva*), and cattails (*Typha* sp.). Vernally inundated areas support seasonal vegetation such as non-native Mediterranean barley (*Hordeum murinum* ssp. *leporinum*) and brass buttons (*Cotula coronopifolia*), and native plants such as downingia (*Downingia* sp.) and toad rush (*Juncus bufonius*).

Travis AFB has limited topographic relief, and the clayey soils prevent rapid drainage. This swale topography leads to the formation of vernal pools. Vernal pools are shallow depressions or small, shallow pools that fill with water during the winter rainy season, then dry out during the spring and become completely dry during the summer. The annual cycle of vernal pools includes standing water during the winter and spring, and desiccation during the summer and fall. During the time that the vernal pools contain water, biotic communities develop over relatively restricted areas. In the larger areas, grasslands form; in more confined, deeper areas, wetlands form. The vernal wetlands are concentrated along the western, southern, and southeastern boundaries of the Base. All of the surface water bodies on and near the Base empty into the Suisun Marsh. No springs have been recorded within the confines of Travis AFB.

The vernal pools at Travis AFB contain indicator species such as goldfields (*Lasthenia fremontii*), coyote thistle (*Eryngium vaseyi*), dwarf woolly-heads (*Psilocarphus brevissimum*), water pygmy-weed (*Crassula aquatica*), and one (1) or more species of downingia and popcornflower (*Plagiobothrys* sp.).

Although a few willows and coyote brush can be found along Union Creek, the dominant plant species found in the riparian zone of Union Creek are mainly herbaceous and consist of beardless wild rye (*Leymus triticoides*), broad-leaved pepperwort (*Lepidium latifolium*), Harding grass (*Phalaris aquatica*), and saltgrass. Hydrophytes such as cattails and rushes are also common.

3.1.5.3 Wildlife

Terrestrial vertebrates associated with non-native annual grasslands are commonly found on-base. Typical avian species include ring-necked pheasant (*Phasianus colchicus*), American kestrel (*Falco sparvarius*), American robin (*Turdus migratorius*), and the western meadowlark (*Sturnella neglecta*). Reptiles observed, or potentially occurring, at the Base include the western fence lizard (*Sceloporus occidentalis*), gopher snake (*Pituophis melanoleucus*), and California red-sided garter snake (*Thamnophis sirtalis* ssp. *infernalis*). Common mammals identified include deer mouse (*Peromyscus maniculatus*), California ground squirrel (*Spermophilus beecheyi*), Botta's pocket gopher (*Thomomys bottae*), black-tailed hare (*Lepus californicus*), and red fox (*Vulpes vulpes*).

Permanent wetlands and seasonally wet areas support aquatic invertebrates, fish, amphibians, reptiles, birds, and mammals. Some aquatic invertebrate species observed in herbaceous wetlands and vernal pools at Travis AFB include vernal pool fairy shrimp (*Branchinecta lynchi*), damselflies (*Odonata sp*.), crayfish (*Orconectes virilis*), and aquatic snails. Amphibian species identified include bullfrog (*Rana catesbeiana*), Pacific tree frog (*Hyla regilla*), and California tiger salamander (*Ambystoma californiense tigrinum*). Aquatic birds observed on or near the Base include mallard (*Anas platyrhynchos*), great egret (*Casmerodiuis albus*), and great blue heron (*Ardea herodias*).

Because wildlife use riverine and riparian habitat somewhat similarly, these habitats are discussed together. Many aquatic invertebrates and amphibians are the same as those discussed above in herbaceous wetlands and vernal pools. These include damselflies, crayfish, aquatic snail, bullfrog, Pacific tree frog, and California tiger salamander. Fish species include mosquitofish (*Gambusia affinis*), fathead minnow (*Pimephales promelas*), threespine stickleback (*Gasterosteus aculeatus*), and bluegill (*Lepomis macrochirus*). Riverine/riparian habitats are also used extensively by birds and terrestrial mammals for forage, shelter, and as a source of water. These include red-winged blackbird (*Agelaius phoenicus*), raccoon (*Procyon lotor*), muskrat (*Ondatra zibethicus*), and beaver (*Castor canadensis*).

Habitats that support special-status species are considered sensitive habitats. Sensitive aquatic/wetland areas include vernal pools, swales, and ditches that can support special-status plants and animals. Urban environments, scattered throughout the Base, can also support special-status species. For example, burrowing owls (*Speotyto cunicularia*) may use man-made culverts, perches, and bare earth areas that contain burrows provided by ground squirrels. Loggerhead shrikes (*Lanius ludovicianus*) may nest on antenna wires and forage in grasslands. Both owls and shrikes are typical species of the grassland habitats on-base. Also, vernal pool fairy shrimp have been found in artificially created depressions that seasonally fill with water.

3.1.6 Geologic Setting

3.1.6.1 Geomorphology

Travis AFB is on the western edge of the Sacramento Valley segment of the Great Valley Geomorphic Province. The Great Valley Province is a southeast-trending, sediment-filled basin. The Coast Range Geomorphic Province, which consists of folded and uplifted bedrock mountains, lies to the west of Travis AFB (Thomasson et al., 1960; Olmstead and Davis, 1961).

The geomorphology of Travis AFB is characterized by gently sloping alluvial plains and fans overlying undulating bedrock. Coalescing, low-relief fans were deposited by the Ulatis, Union, Alamo, Laurel, and Suisun creeks in the area. Most of the alluvial material was deposited before the last period of glaciation during the Pleistocene Epoch and is referred to as Older Alluvium. Drainages were incised into the alluvial fans during the last glaciation in response to the global lowering of the sea level. During the last 15,000 years, as sea levels have risen, the drainages have refilled with alluvium. This material is referred to as Younger Alluvium. Topographic relief in the form of low ridges is provided by outcrops of sedimentary rocks characterized as bedrock in the Travis AFB area. These outcrops are mantled by colluvium deposited by sheetwash and mass wasting from the ridges. The colluvium interfingers with the alluvium, and the two (2) units are indistinguishable in the field.

3.1.6.2 Stratigraphy and Geologic History

Older Alluvium makes up most of the sediment found on the Base. Alluvium beneath Travis AFB ranges in thickness from 0 to about 110 feet. The alluvium is underlain by bedrock consisting of semi-consolidated to consolidated sedimentary units; the alluvium and bedrock are sometimes difficult to distinguish in the field. The alluvium consists primarily of silts and clays that are low in permeability and do not transmit groundwater readily. More permeable units, such as sands and gravels, are geographically restricted and occur as lenses rather than as continuous beds that may be correlated from place to place. A geologic map and generalized cross section illustrating the alluvium and shallow bedrock units in the vicinity of Travis AFB are shown on Figures 3.1-2 and 3.1-3.

Alluvium was carried in several streams (such as Union Creek) that have migrated laterally across the Base. Coarse sands and gravels are deposited in the streambed and immediately adjacent to the stream levee; finer silts and clays are deposited away from the stream during flood events. Consequently, the discontinuous sand lenses are usually elongated parallel to streams and are contained in an overall matrix of fine-grained silts and clays in the vicinity of Travis AFB. Sand lenses throughout the Base trend south-southeast. These discontinuous permeable zones are preferential pathways that create anisotropic groundwater flow in the horizontal plane.

Bedrock in the area includes Tertiary and Pliocene sedimentary rocks overlying Late Cretaceous sedimentary rocks. Individual stratigraphic units outcropping on the Base include, from oldest to youngest, the Domengine Sandstone, the Nortonville Shale, the Markley Sandstone, and the Tehama Formation. Outcrops of the relatively resistant bedrock units form most of the topographic high points on the Base. For example, the Markley Sandstone outcrops in the northeastern corner of the Base and forms the low ridge separating the WIOU from the EIOU (refer to Figure 3.1-2). The Domengine Sandstone forms Hospital Hill at the Consolidated Support Center (the old Base hospital). The Tehama Formation creates the low hills that make up the relief in the western part of the Base in the WABOU.

The northwest-southeast trending axes of folds in the rocks are evident in the bedrock outcrops on the Base. Erosion of the less-resistant bedrock units, such as the Nortonville

Shale, formed the low areas that were later filled with alluvium. These valleys, created by down-cutting of ancient streams into the folded bedrock during the Pleistocene Epoch, are filled with alluvium, as described. The folded units are observed to plunge to the southeast; the depth to bedrock in the alluvium-filled valleys increases to the south.

3.1.6.3 Lithologic Units

Two (2) primary lithologic units underlay Travis AFB. The origin and composition of these units are described below.

Alluvium. The vast majority of surface deposits at Travis AFB are alluvial sediments. This alluvial unit has relatively low permeability and is composed primarily of silt and clay with minor amounts of sand. The sand units occur as small heterogeneous lenses that are laterally discontinuous across the Base. The alluvium is predominantly fluvial in origin; however, some colluvium eroded from bedrock uplands may also be present. All of the unconsolidated sediments discussed in this CSM will be referred to as alluvium.

Bedrock. The bedrock beneath Travis AFB is primarily sandstone and shale (see discussion above for Formation names and ages). The top of the bedrock units are locally weathered and fractured to varying degrees and varying thicknesses, resulting in a higher permeability. Consequently, at some of the sites at Travis AFB (Sites SS015, SS016, and DP039) groundwater contamination has been observed in the shallow bedrock. However, the bedrock generally becomes increasingly unweathered, less fractured, and more competent with depth. The composition of the most weathered portions reflects the composition of the parent material (sand and silt); therefore, the most weathered portions generally have similar permeability to the overlying alluvium.

Almost all of the contaminant mass at Travis AFB restoration sites is found in the upper alluvium; this is supported by the upward gradient shown by shallow/deep well pairs and the decrease in solvent concentrations with depth. However, some contaminants have migrated to the bedrock, since the bedrock beneath Travis AFB is primarily sandstone and shale (see discussion above for Formation names and ages). The top of the bedrock units are locally weathered and fractured to varying degrees and varying thicknesses, resulting in a higher permeability. The composition of the most weathered portions reflects the composition of the parent material (sand and silt); therefore, the most weathered portions generally have similar permeability to the overlying alluvium. Consequently, at some of the sites at Travis AFB (Sites SS015, SS016, and DP039), groundwater contamination has been observed in the shallow bedrock.

The bedrock generally becomes increasingly unweathered, less fractured, and more competent with depth, so unweathered bedrock is likely to have a lower permeability than the overlying alluvium, and diffusion becomes the dominating transport mechanism. Therefore, the rate and volume of contaminant transport into the unweathered bedrock will be limited compared with weathered bedrock and alluvium. At sites where the vertical extent of local weathering in the bedrock is minimal, such as at the WIOU, refusal of a hollow-stem auger rig has been encountered at the alluvium/bedrock interface and is used to identify this interface. Because of auger refusal, significant characterization cannot be conducted in unweathered bedrock, and no field testing of bedrock permeability to confirm these assumptions have been conducted at the Base.

The unweathered bedrock transport mechanisms are assumed to rely upon diffusion into a cleaner, more permeable alluvium to complete the cleanup process. This diffusion limitation leads to longer cleanup times and limited mass removal compared with the alluvial and weathered bedrock cleanups. However, uncertainties associated with the extent of bedrock contamination would be consistent among the various cleanup technologies evaluated in the FFS or have been accounted for in the FFS by the use of groundwater modeling to estimate cleanup times for each technology. As a result, these uncertainties will not have a material impact on the relative differences in cleanup times and thus remedy selection.

3.1.7 Groundwater

Travis AFB is located along the eastern edge of the Fairfield-Suisun Hydrologic Basin, a hydrologically distinct structural depression adjacent to the Sacramento Valley segment of the Central Valley Province. The primary water-bearing deposits at Travis AFB are the coarse-grained sediments (sand and gravel) within the extremely heterogeneous Older Alluvium and Younger Alluvium. At Travis AFB, alluvium reaches a maximum thickness of approximately 110 feet. The depth to groundwater at Travis AFB is typically 10 to 15 feet below ground surface (bgs). In general, groundwater elevations have remained relatively constant over time. Groundwater elevations typically fluctuate from 2 to 5 feet in between fall and spring, with the maximum elevations in spring and the minimum elevations in fall.

The regional groundwater gradient is generally toward the south or southeast. Groundwater recharge occurs from the direct infiltration of rainfall on the valley surface and from the infiltration of runoff through local streambeds and creek beds. Natural groundwater discharge occurs at the marshlands near Potrero Hills, south of Travis AFB (Thomasson et al., 1960).

The groundwater flow system at Travis AFB is influenced by the configuration of alluvium and bedrock at the Base. Flow within the alluvium is consistently to the south, as indicated by the groundwater elevation map shown on Figure 3.1-4. However, three (3) groundwater mounds are visible on the figures. Groundwater in the immediate vicinity of a mound flows radially away from the mound and then rejoins the regional southerly flow. This flow occurs because bedrock geologic materials in the vicinity of the mound are less permeable than materials surrounding the mound.

One (1) of the mounds is in the extreme northeastern corner of the Base in the vicinity of Site LF007 (Landfill 2). This site is above a shallow bedrock ridge composed of Markley Sandstone. In the vicinity of this mound, groundwater in this area flows off-base to the north for a short distance before moving either east or west to follow the regional gradient. This has resulted in the off-base TCE groundwater contamination originating from Site LF007C.

A second groundwater mound is located in the northeastern corner of the Base, about 3,500 feet southwest of the mound at Site LF007. This mound is beneath a high point of surface topography known as Hospital Hill, formed by an outcrop of Domengine Sandstone. Between these two (2) mounds in northeastern Travis AFB, the groundwater flows south-southeast, paralleling a depression in the bedrock filled with alluvium underlain by Nortonville Shale.

A third mound is in the western part of the Base in the WABOU. The mound also corresponds to a high point of surface topography formed by near-surface and outcropping Tehama Formation materials. Groundwater in this area flows away from the mound to both the north and the south. North-flowing groundwater curves to the east and then to the southeast to follow the regional gradient.

Shallow bedrock also influences groundwater flow in the central portion of the Base. A northwest-to-southeast-trending ridge of Markley Sandstone runs approximately along the boundary of the WIOU and the EIOU; it results in a groundwater flow divide in the groundwater elevation contours (refer to Figure 3.1-4). Groundwater in this area flows southeast or southwest away from the divide that also may form a barrier to the movement of contaminants. The ridge plunges to the south, however, and probably affects groundwater flow less in the southern portion of the Base.

Groundwater contours on each side of the ridge of Markley Sandstone in the central portion of the Base (refer to Figure 3.1-4) indicate the diverging directions of flow in the valleys filled with alluvium. The more permeable alluvium provides a preferential pathway for groundwater flow.

3.1.7.1 Aquifer Stratigraphy

The aquifer system underlying Travis AFB should be viewed as a single leaky and heterogeneous aquifer system of unconsolidated alluvium, as opposed to one (1) with multiple and distinct aquifers. The sediments consist primarily of fine-grained silts and clays with interbedded sand lenses that do not correlate well from one (1) location to another. The depth to bedrock is fairly shallow (i.e., a few feet to tens of feet); thus, the saturated thickness of the aquifer is small compared with the length of the groundwater contaminant plumes. It is not usually possible to predict with confidence where the more permeable sand lenses may be encountered or interconnected.

The saturated alluvium thickness at Travis AFB is typically up to 80 feet, and averages approximately 28 feet. Localized thicknesses up to about 100 feet are found in the vicinity of Site SD036. A map of the saturated alluvium thickness at Travis AFB and vicinity is shown on Figure 3.1-5. This map was generated by subtracting the elevation of the bedrock surface from the elevation of the steady state water table using the latest version of the Travis Basewide Groundwater Flow Model (CH2M HILL, 2008a).

3.1.7.2 Groundwater Flow Velocity

Groundwater at Travis AFB is found under unconfined or semi-confined conditions and flows in a predominantly horizontal direction. Typical groundwater flow rates in the alluvium in the Base area are on the order of 100 to 200 feet per year (ft/year), assuming an effective porosity of 20 percent, which is typical for the fine-grained sediments encountered at the Base.

3.1.7.3 Horizontal and Vertical Gradients

The following subsections briefly describe the groundwater horizontal and vertical gradients at Travis AFB. More complete information is provided in the regularly issued GSAP reports.

Horizontal Gradients. Groundwater at Travis AFB flows primarily south, except where groundwater mounds or depressions exist. Local variations in flow direction are the result of the subsurface geology and groundwater pumping. The groundwater elevation contours shown on Figure 3.1-4 indicate the direction and magnitude of groundwater flow (i.e., from higher to lower potential). Typically, the horizontal gradients in the alluvium at Travis AFB range from 0.004 to 0.008 feet per foot (ft/ft). Where groundwater mounds exist, the horizontal gradients are relatively steep (approximately 0.02 ft/ft) when compared with the horizontal gradients in the alluvial basins away from the mounds. The horizontal gradients typically observed in bedrock are approximately 0.01 ft/ft.

Vertical Gradients. In general, the magnitudes of vertical gradients in the alluvium at Travis AFB are less than 0.1 ft/ft. Only a well pair at Site LF008 (MW115x08 and MW311x08) consistently indicate a relatively large downward vertical gradient (-0.1 ft/ft). This downward vertical gradient reflects the location of Site LF008 in a groundwater recharge zone on a topographic high point for the Base. Groundwater tends to flow downward away from these high points.

The greatest upward vertical gradient in the alluvium encountered during recent GSAP events was 0.1 ft/ft at Site SS015 well pair MW624x15/MW2103x15 and at Site DP039 well pair MW2057Ax39/MW2057Bx39. These are new monitoring well pairs (installed in 2010); therefore, it is unknown whether a large upward gradient is typical for these locations. However, the vertical gradients calculated at the six (6) other new Site DP039 well pairs were less than 0.1 ft/ft in magnitude, and the direction of the gradient was variable.

The vertical gradient in alluvium-bedrock well pairs typically have an upward gradient ranging from 0.001 ft/ft downward to 0.1 ft/ft upward. The one (1) well pair that is an exception is MW214x16/MW305x16 at 0.001 ft/ft downward. However, historically, this well pair has had an upward or neutral vertical gradient.

The vertical gradient is defined as the difference in groundwater elevations between two (2) adjacent wells divided by the vertical distance between the midpoints of the well screens. The vertical gradient is used to evaluate the potential for groundwater to flow upward (positive gradient) or downward (negative gradient).

3.1.7.4 Hydraulic Conductivity

The bulk horizontal hydraulic conductivity of the alluvium at Travis AFB and vicinity is up to 35 feet per day (ft/day) (1×10^{-2} centimeters per second [cm/sec]), and averages approximately 22 ft/day (8×10^{-3} cm/sec). A map of the bulk horizontal hydraulic conductivity in the alluvium is shown on Figure 3.1-6.

Bulk horizontal hydraulic conductivity is calculated by dividing the alluvium transmissivity (Figure 3.1-7) by the saturated alluvium thickness (Figure 3.1-5).

3.1.7.5 Transmissivity

The alluvium transmissivity at Travis AFB and vicinity is up to 2,500 square feet per day (ft^2/day), and averages approximately 600 ft^2/day. A map of the total alluvium transmissivity is shown on Figure 3.1-7.

The transmissivity is a measure of the volume of water that is horizontally transmitted by the saturated alluvium thickness under a unit horizontal hydraulic gradient (Fetter, 1988). The basis for the map on Figure 3.1-7 is the Travis Basewide Groundwater Flow Model (CH2M HILL, 2008a).

3.1.8 Groundwater Contamination

As of 2011, even after years of interim remediation, the groundwater at multiple ERP sites remains contaminated at concentrations that exceed IRGs. The most commonly detected contaminant in groundwater at Travis AFB is TCE. This chemical is detected at widely separated sites across the Base, reflecting multiple points of origin. The maximum concentration of TCE detected at all the ERP sites during 2010 was 151,000 µg/L during the Site SS016 data gaps investigation. During sampling events conducted under the 2009-2010 GSAP TCE concentrations greater than 10 times the IRG of 5 µg/L also were detected at Sites FT004, SS015, ST027B, SS029, SS030, SD033, SD034, SD036, SD037, and DP039. Groundwater contaminants, other than TCE, detected at sites at concentrations above their respective IRG include the following:

- Site FT005: 1,2-dichloroethane (1,2-DCA)
- Site LF008: Alpha-chlordane
- Site SD031: 1,1-dichloroethene (1,1-DCE)

A summary of ERP groundwater sites, COCs, and some statistical data is provided in Table 3.1-1. A summary of sites, COCs, and historical analyses is provided in Table 3.1-2.

The primary sources of groundwater contaminant data at Travis AFB are summarized in the following subsections.

3.1.8.1 Groundwater Sampling and Analysis Program Reports

Extensive and detailed documentation of historical and current groundwater contamination at Travis AFB is provided in GSAP reports. Travis AFB routinely conducts groundwater sampling and analysis activities at all ERP sites. The findings of these activities are regularly published in annual GSAP reports. The most current and comprehensive data are provided in the *Groundwater Sampling and Analysis Program 2009-2010 Annual Report* (2009-2010 Annual GSAP Report) (CH2M HILL, 2011b).

3.1.8.2 Data Gaps Investigations

As part of groundwater IRA optimization efforts during 2009 and 2010, data gaps investigations were conducted at Sites SS015, SS016, ST027B, SS030, SD036, SD037, and DP039. The findings of the completed investigations are included in the site-specific CSMs provided in Sections 3.2 through 3.6 of this FFS.

The data gaps investigation at Site LF007C is not yet complete because of restricted access into the seasonal vernal pool areas at the site. Travis AFB is working to resolve these issues with the USFWS and anticipates resolution during 2011.

3.1.8.3 Remedial Investigation Reports

Additional documentation of historical groundwater contamination at all the ERP sites is also provided in the following applicable RI reports:

- NOU RI Report (Radian, 1995)
- EIOU RI Report (Weston, 1995)
- WIOU RI Report (Radian, 1996b)
- WABOU RI Report (CH2M HILL, 1997)

3.1.9 Primary Contaminant Sources

The primary sources of groundwater contamination at Travis AFB are releases of liquid solvents and petroleum fuels from past waste management and disposal practices. These releases primarily involved chlorinated solvents, including those containing TCE. Other typical groundwater contaminants include breakdown products from these solvents. Some organochlorine pesticide and metals contamination has been found at some sites, but these contaminants are not nearly as pervasive as the chlorinated solvents.

In their pure form, the groundwater contaminants are called nonaqueous phase liquids (NAPLs). At Travis AFB, NAPLs include petroleum hydrocarbons (i.e., fuels, lubricants, and non-chlorinated solvents) and chlorinated solvents (primarily TCE). The use of TCE was discontinued in 1982.

3.1.9.1 Light Nonaqueous Phase Liquids

Petroleum-based NAPLs are generally less dense than water and are referred to as LNAPLs. Because they have a density less than that of water, LNAPLs tend to accumulate (float) on top of the water table. In addition, most petroleum hydrocarbons readily degrade in situ; therefore, plumes of dissolved phase LNAPL constituents tend to move only short distances beyond the release zones. Travis AFB sites with LNAPL releases include POCO Sites SS014, ST018, ST027A, ST028, ST032, and ERP Site SD034. The presumptive remedy for LNAPL releases is removal of any mobile LNAPL fraction (free product) followed by a program of MNA.

3.1.9.2 Dense Nonaqueous Phase Liquids

In contrast to LNAPLs, chlorinated solvents such as TCE are denser than water and are referred to as DNAPLs in their pure form. Because they have a density greater than that of water, DNAPLs are sometimes able to penetrate below the water table. Furthermore, degradation rates for dissolved chlorinated solvents under natural aerobic conditions are low; therefore, dissolved-phase chlorinated solvents tend to form relatively large plumes. The interim remedies implemented for large chlorinated solvent releases at Travis AFB involve GET for the purposes of hydraulic containment and mass removal.

Relatively large chlorinated solvent releases resulting in the probable presence of DNAPL have occurred at Sites SS015, SS016, SD036, and DP039. TCE releases of lesser magnitude have also occurred at Sites FT004, ST027B, SS030, SD031, SD036, SD037, and other sites; but if residual pure-phase TCE does exist at these sites, it is evidently bound up by the capillary forces in the alluvium. The relevant mechanisms are discussed in the following sections.

3.1.10 Primary Release Mechanisms

The most significant contaminant release mechanism at Travis AFB is deep percolation of the liquid contaminants downward, and laterally along preferential pathways, through the vadose zone and into the saturated zone. The depth to groundwater at Travis AFB is relatively shallow at approximately 10 to 15 feet bgs. Contaminants released at the ground surface have readily migrated through this shallow vadose zone and into the groundwater.

Groundwater, soil, and soil gas sampling results from four (4) RIs (Weston, 1995; Radian 1995, 1996b; CH2M HILL, 1997) indicate relatively low levels of VOC contamination in the soil and soil gas at the ERP sites, while the groundwater has significantly higher concentrations of

contamination. No significant VOC soil contamination was found during the RI sampling and the low levels detected are not expected to adversely impact the groundwater.
RI concentrations of VOCs in soil and soil gas are consistent with models of diffusion and adsorption from associated groundwater plumes, indicating that the VOC contamination in the soil and soil gas is a result of the underlying contaminated groundwater plume (Travis AFB, 2006).

3.1.10.1 DNAPL Release Mechanisms

Where DNAPLs are released, they may infiltrate through soils following the path of largest pore size or fracture aperture. This typically results in sparse horizontal pools and vertical fingers of DNAPL (Kueper et al., 1989; Cohen et al., 1994). Generally, the volume of DNAPL pools and fingers near the release site is approximately 0.01 to 0.0001 of the overall source zone volume (Sale, 1998). Actually finding DNAPL during site investigations is unlikely.
A conceptualization of DNAPL movement through clayey materials, such as those typically found at Travis AFB, is shown on Figure 3.1-8 (Feenstra et al., 1996). Possible migration pathways for a conceptual DNAPL site are illustrated on Figure 3.1-9. Within the lithologic units at Travis AFB, potential paths for downward DNAPL migration include the following:

- **Alluvium –** Joints associated with consolidation, shrinkage, and desiccation cracking; and sand lenses.
- **Bedrock –** Joints and bedding primarily associated with geologic formation and weathering of the sandstone, siltstone, and claystones; the joints are expected to become tighter with increasing depth.

Several of the known TCE releases at Travis AFB were small-volume releases onto surface or near-surface soils that took place over a period of years (discontinued in 1982 at the latest, since the on-base use of TCE ceased at that time). Through capillary forces and adsorption, this TCE may become immobilized within the vadose zone as ganglia. In this scenario, the near-surface ganglia are then subject to volatilization during repeated cycles of hot summer weather; in fact, surface soil sampling and testing during the RI phase (mid-1990s) encountered virtually no TCE. It is the relatively larger-volume releases of TCE that have migrated to greater depths, affecting groundwater.

3.1.10.2 Dissolution of DNAPL Source Zones

A conceptualized depiction of the dissolution of a DNAPL source zone located beneath the water table is shown on Figure 3.1-10. Three (3) snapshots in time are presented on the figure that, depending on the initial mass of the source and properties of the alluvial matrix, could be considered to take place over a matter of decades or centuries. In the first frame, at time t_0, the length of the DNAPL pool stretches from a distance of x_1 to x_4. The dissolution rate is shown to be highest at the upgradient edge, as the moving groundwater slowly erodes the DNAPL pool and carries high-concentration, dissolved-phase contaminants downgradient.

The second frame, representing time t_1, shows a smaller DNAPL pool, the upgradient side of which has been dissolved over time by the passing groundwater. Note that the point of greatest dissolution rate remains at the upgradient edge of the DNAPL pool, although the location of this point has shifted to a distant, x_2, downgradient.

In the third and final frame, the DNAPL pool has continued to reduce in size. Note that the maximum dissolution rate remains at the upgradient edge of the pool and that the magnitude of this dissolution rate remains constant through time until the DNAPL has been completely depleted. The rapid dissolution rate adjacent to the upgradient side of the source translates into a steep concentration gradient that can drive the diffusion of significant amounts of dissolved-phase contaminant mass into stagnant portions of the lithologic units, creating a problematic long-term in situ source of contamination.

Another key feature related to Figure 3.1-10 is that the downgradient dissolved concentrations in groundwater are unchanged as the source dissolves. The implication is that source remediation (or dissolution) does little to improve downgradient water quality until the entire DNAPL source is gone.

3.1.10.3 Groundwater Plume Formation

Groundwater plumes containing chlorinated solvents originate from DNAPL releases. The rate at which DNAPLs partition into groundwater is sufficiently slow that even modest amounts of DNAPL that find their way beneath the water table can persist as sources of groundwater contamination for perhaps decades and effect order-of-magnitude exceedances of maximum contaminant levels (MCLs) in groundwater. The formation of a plume of dissolved chlorinated solvents in groundwater and soil vapor at a conceptual DNAPL site (similar to Sites SS016 and DP039) is shown on Figure 3.1-11.

The distribution of dissolved-phase contamination near a DNAPL source area (e.g., Sites SS016 and DP039) is dominated by the geometry of the DNAPL release as well as the processes of advection and molecular diffusion. At locations further downgradient, other processes begin to dominate. Primary transport processes for near-source and downgradient plumes are discussed in the following sections.

Near-source Plumes. The movement of a near-source, dissolved, high-concentration solvent plume through a transmissive sand layer is presented on Figure 3.1-12. For time t_1, the dissolved high-concentration plume from the DNAPL source initially moves through higher permeability conduits in a heterogeneous system such as that at Travis AFB. As the plume expands and eventually stabilizes (at time t_2), high-concentration gradients between the highly contaminated groundwater within the preferential flow paths and the less-contaminated groundwater in the low permeability zones drive significant mass transfer into the silt/clay units.

Time t_3 represents the point in time when either final dissolution of the DNAPL source zone (time scale of decades to centuries) or isolation of the DNAPL source zone (either physically or hydraulically) has occurred, and the solute concentrations subsequently decline rapidly in the most accessible/flushable pore space. However, as the concentration gradient shifts, contaminant mass residing in the low-permeability materials is released into the flushable pore space by the process of molecular diffusion that, being driven strictly by concentration gradients, is both slow and occurs at an ever-decreasing rate (i.e., asymptotic behavior).

The implication of the third frame (time t_3) is that even upon "remediation" of the accessible pore space, a concentration gradient still exists within the-low permeability layers that continues to drive a portion of the retained contaminant mass deeper into the clay.

All of this suggests that the attempted remediation of a near-source contaminant plume in a heterogeneous environment may be futile, in that even with the removal of a large percentage of the initially released mass, the presence of a continuing source from the lower-permeability units will require the continued operation of hydraulic remedies and the continued monitoring of groundwater quality. In other words, the site care requirements are essentially identical to those that would be required with no remedial action in place.

Downgradient Plumes. The dominant loss and transport mechanisms that govern downgradient, aqueous-phase dissolved plumes differ from those discussed above for DNAPL source zones and near-source plumes. In downgradient plumes, no steep concentration gradient as described above for near-source plumes occurs; and a combination of physical, chemical, and biological contaminant-loss mechanisms, also referred to as natural attenuation processes, begin to dominate contaminant transport and lead to the eventual stabilization of the plume. The ultimate configuration of the dissolved plume downgradient of the source area is dependent on the collective influences of the processes of adsorption, diffusion, dispersion, biodegradation, and heterogeneity in aquifer properties. These processes are described briefly in this section. For additional information refer to the NAAP (CH2M HILL, 1998b).

As dissolved solvents migrate with the groundwater, a portion of the contaminants may adsorb to organic materials in the soil matrix, and thus become fixed to the soil particle surface. Adsorption is not an irreversible process; as groundwater moves through the aquifer matrix, contaminants may desorb back into groundwater.

The portion of the contaminant that is sorbed to soil and not migrating is said to be "retarded." The extent of retardation is a function of the properties of both the chemical contaminant and the soil. While this process does not actively destroy contaminant mass, if the rate of migration is retarded to a significant degree, biodegradation processes will have longer to act on the contaminant plume and degrade the contaminant of interest.

Molecular diffusion attempts to equalize solute concentrations by moving solute from high concentration zones to low concentration zones. The driving force for diffusion is differential concentrations, and the effect of diffusion is to increase the volume of contaminated groundwater, while decreasing the concentration. Diffusion is generally a slow process, but may be significant in systems where the groundwater velocity is low, as is the case at many sites at Travis AFB.

Hydrodynamic dispersion tends to spread, or disperse, the solute front as it moves through the aquifer. Spreading in the direction of flow is referred to as longitudinal dispersion, which usually has a much stronger influence than spreading perpendicular to the direction of flow, or transverse dispersion (Freeze and Cherry, 1979). Dispersion also occurs at a field scale because of the heterogeneity in hydraulic properties of geologic materials present at a particular site (Gelhar et al., 1992). At Travis AFB, the complex geometry of the more permeable sand lenses occurring within the lower-permeability silt and clay alluvial matrix almost certainly imparts additional dispersion of migrating solute plumes beyond what would occur on a pore scale alone.

Biodegradation of chlorinated compounds typically proceeds through reductive dehalogenation, but may also occur through electron donor reactions and cometabolism. Reductive dehalogenation occurs anaerobically and results in the degradation of the more highly chlorinated compounds such as tetrachloroethene (PCE) and TCE. These processes are described in detail in the NAAP (CH2M HILL, 1998b).

If biodegradation is occurring at rates that are significant with respect to the mass flux of contaminant through the aquifer, this process can ultimately balance with the advective transport mechanism and lead to a plume that is stable in configuration over time. In the absence of significant degradation rates, dispersion and dilution will ultimately lead to a stable plume. However, the influence of these processes is limited, and plumes stabilized by these processes will likely have a much greater areal extent than those limited by biodegradation processes. If the aquifer downgradient of the DNAPL source has a pronounced heterogeneity in permeability, such as a preferred transport pathway, this site feature may significantly influence the ultimate configuration of the downgradient plume.

3.1.11 Secondary Contaminant Sources

Secondary sources are those environmental media that may be affected by releases from primary sources. Potential secondary sources at Travis AFB include VOC-affected subsurface soil and soil gas. Soil gas is considered the only significant secondary source. No significant VOC contamination has been detected in subsurface soil.

Stoddard solvent, an LNAPL floating on the water table at Site SD034, is also considered a secondary contaminant source.

At Sites SD036, DP039, and within the OSA of Site SS016, high contaminant concentrations are indicative of DNAPL below the water table.

3.1.12 Secondary Release Mechanisms

The secondary release mechanism is volatilization of VOCs in groundwater into the soil pore spaces (i.e., soil gas). Under the pressure differential between aboveground and belowground environments, VOC vapors in soil gas can migrate upward through the soil matrix. Soil gas migration would be most prevalent along permeable preferential pathways within the vadose zone. Man made features such as utility conduits, pipelines, storm drains, and sanitary sewers may create preferential pathways for soil gas migration, as the fill around such features is typically more permeable than the surrounding soil.

There would be some attenuation of soil gas concentrations as it migrated upward because of adsorption and degradation. Factors affecting vapor migration are related to soil properties, properties of the VOCs, and source properties (depth to the groundwater plume and concentration). The most important factors directly affecting VOC vapor transport into buildings are related to the building properties, including soil/building pressure difference, cracks within the foundation, utility corridors, the air exchange rate, and the building volume.

3.1.13 Receptors

There are no current human or ecological receptors of contaminated groundwater at Travis AFB. LUCs are currently being implemented at all sites with groundwater contamination in accordance with the WABOU Groundwater IROD and the NEWIOU Groundwater IROD (refer to Section 3.1.4.3). The LUCs are also described in the Travis AFB General Plan.

3.1.14 Risk Assessments

As part of the CERCLA process, RIs were conducted at all Travis AFB groundwater sites, and the results of those investigations were reported in the RI reports listed in Section 3.1.8.3. The RIs included human health and ecological risk assessments, which calculated the potential risk associated with exposure of groundwater contaminants to human and ecological receptors.

The human health risk assessments (HHRAs) calculated the cancer and noncancer risks for each contaminant, using default values associated with both the residential and industrial scenarios. Each calculation consisted of four steps: an identification of chemicals of potential concern, an exposure assessment, a toxicity assessment, and a risk characterization. The end product of the HHRA is an excess lifetime cancer risk value for a carcinogen and a hazard index for a noncarcinogen. Decisions concerning the need for remedial action were based on whether the cumulative excess lifetime cancer risks exceeded 1×10^{-6} or the HI exceeded 1.

The following tables provide the COCs and calculated risks prior to the start of interim groundwater remedial action: Table 1-2 (Summary of NOU Areas, Media, and Contaminants Recommended for Evaluation in the Feasibility Study) of the NEWIOU FS Report for Sites LF006 and LF007; Table 1-3 (Summary of EIOU Areas, Media, and Contaminants Recommended for Evaluation in the Feasibility Study) of the NEWIOU FS Report for Sites FT004, FT005, SS015, SS016, SS029, SS030, and SD031; Table 1-5 (Summary of WIOU Areas, Media, and Contaminants Recommended for Evaluation in the Feasibility Study) of the NEWIOU FS Report for Sites SD033, SD034, SS035, SD036, and SD037; and Table 2-2 (COCs and COECs by Medium and Associated Risks) of the WABOU FS Report for Sites DP039, SS041, SD043, and LF008.

During the period of interim groundwater remediation, the COC concentrations have decreased at all groundwater sites. In some cases, the COC concentrations over portions of the sites have reached or exceeded the interim cleanup goals or interim remediation goals that were established in the two Travis AFB Interim Groundwater RODs. In other cases, the COC concentrations are still above these goals. With the exception of Site SS041 where COCs are no longer detectable, final remedial actions are warranted at all of the groundwater sites mentioned in this FFS Report to achieve the PCGs that are described in Section 5.

Because groundwater is located beneath the depth at which ecological receptors are expected to be present, there are no chemicals of ecological concern for any of the sites.

Site ST027B was historically managed under the POCO Sites Program and not under CERCLA. Under the POCO program, HHRAs and ecological risk assessments (ERAs) were not required and were therefore not conducted. As a result, Site ST027 was not evaluated in any of the four (4) OU-specific RIs (WIOU RI, NOU RI, EIOU RI, and WABOU RI); was not included in either of the two (2) OU-specific FS Reports (NEWIOU FS and WABOU FS Reports); and not included in either of the two (2) Groundwater IRODs (NEWIOU IROD and WABOU IROD).

In 2007-2008, POCO investigations discovered a small, previously unknown TCE plume at concentrations greater than the IRG in the southwestern part of Site ST027, between the southern edge of the aircraft test pad and Taxiway November. This area of TCE contamination has been designated as Site ST027–Area B or Site ST027B. The TCE contamination probably originated from undocumented releases between the southern edge of the aircraft test pad and Taxiway November. Groundwater contamination within this portion of the site is now administered under the ERP and CERCLA. Petroleum fuel contamination found within the remainder of the site, now designated as Site ST027A, continues to be administered under the POCO program.

3.1.15 Vapor Intrusion

During 2008-2009, Travis AFB conducted a vapor intrusion assessment at a number of buildings that lie above solvent plumes in accordance with the *Vapor Intrusion Assessment Work Plan* (CH2M HILL, 2008b). The findings of the vapor intrusion investigations are provided in the final *Vapor Intrusion Assessment Report* (CH2M HILL, 2010g). In summary, under current conditions, no significant risk from vapor intrusion was identified at any of the buildings that were a part of the assessment. The primary reason for the low risk of vapor intrusion at Travis AFB is that the soil that underlies Travis AFB is predominantly silt and clay, and soil gas does not readily pass through it. Soil permeability is not expected to change in the future and therefore future risk for vapor intrusion is likely to remain low. In addition to the low soil permeability, preferential pathways were also evaluated during the vapor intrusion assessment and found not to pose a significant vapor intrusion risk at Travis AFB.

Although no current significant risk from vapor intrusion was identified during the vapor intrusion assessment, the assumptions used in the vapor intrusion assessment may change if the associated land use changes in the future. Travis AFB is an active installation and could plan for and construct a new building over a solvent plume that was identified in the *Vapor Intrusion Assessment Report* to pose a potential for future significant vapor intrusion risk. By itself, this future action would not constitute the establishment of a new complete vapor intrusion pathway. However, to proactively address the vapor intrusion issue under the potential future scenario and expedite the construction of mission-essential infrastructure, the Base has instituted a vapor intrusion mitigation policy. This policy requires the incorporation of a passive ventilation system into the designs of all new construction projects that include office space which overlies or is within 100 feet of a groundwater solvent plume found to pose a potential for future vapor intrusion risk in the *Vapor Intrusion Assessment Report*.

For example, Building 554 is a part of a fuel truck maintenance facility that was built on Site SS015 in 2004. Under existing LUC provisions, this building was constructed with a passive venting system to ensure the protection of the building's occupants from potential contaminated vapor from the underlying Site SS015 groundwater plume. Another example is Building 837, which is a new aircraft maintenance hangar. Because of its design, most of the building is well ventilated. However, there is a small office within this building, and it was constructed with a passive ventilation system to preclude the possibility of vapor intrusion becoming a future issue.

This policy is documented in the Travis AFB General Plan and is enforced by existing layered LUC procedures that are described in Section 3.1.4.3.

TABLE 3.1-1
Summary Statistics of ERP Sites and Chemicals of Concern
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Site	Operable Unit	Name/Description	Chemical Class	Chemicals of Concern	Maximum Historical Concentration[a] (µg/L)	Location of Maximum Historical Detection	Date of Maximum Historical Concentration[a]	Minimum Historical Concentration[a] (µg/L)	Date of Minimum Historical Concentration[a]	Average Historical Concentration[a] (µg/L)	Standard Deviation Historical Concentrations	IRGs[b] (µg/L)
FT004	EIOU	Fire Training Area 3	VOCs	TCE	**5,200**	MW266x04	01/14/1994	0.1	05/07/2001	**263**	727	5
				cis-1,2-DCE	**60.5**	MW131x04	05/20/2003	0.08	05/29/2003	4.54	9.97	6
				1,2-DCA	**5.12**	MW1002x04	09/06/1994	0.07	05/20/2003	**1.95**	1.4	0.5
				Chloroform	15	EW580x04	12/04/2007	0.06	05/10/2001	1.21	2.34	100
				Bromodichloromethane	5.7	EW580x04	12/04/2007	0.81	04/29/2008	1.37	1.89	100
				1,1-DCE	**42**	EW577x04	03/12/2001	0.08	05/23/2003	1.24	3.86	6
				Vinyl chloride	**43.7**	EW576x04	11/30/2009	0.08	05/09/2001	3.16	9.54	0.5
				1,4-DCB	3.8	MW202x04	05/31/1994	0.7	09/11/1997	2.25	2.19	5
			SVOCs	bis(2-Ethylhexyl)phthalate	**5.49**	MW265x04	12/15/1993	3	06/04/2002	3.97	0.948	4
			Metal	Nickel	**6,270**	MW267x04	05/23/2003	2.31	05/16/2003	**480**	941	100
FT005	EIOU	Fire Training Area 4	VOCs	TCE	**120**	MW119x05	06/01/1994	0.17	11/22/2005	**11.0**	24.8	5
				1,2-DCA	**14.2**	MW320x05	09/21/1994	0.1	06/13/2003	**1.88**	2.26	0.5
				cis-1,2-DCE	**19**	MW119x05	06/01/1994	0.09	09/06/1994	3.02	5.27	6
				Chloroform	10	MW117x05	05/31/1994	0.05	05/31/2001	1.41	3.23	100
				Bromodichloromethane	1.8	MW117x05	05/31/1994	1.8	05/31/1994	1.8	---	100
			SVOCs	bis(2-Ethylhexyl)phthalate	**50.3**	MW308x05	09/01/1994	2.3	12/29/1993	**13.4**	17.3	4
			Metal	Nickel	**4,270**	MW254x05	09/01/1994	7.6	02/15/1999	**402**	629	100
LF006	NOU	Landfill 1	VOCs	TCE	**21**	MW01Sx06	06/19/1998	0.08	06/09/1999	**5.70**	4.79	5
				1,1-DCE	0.53	MW258x06	05/10/2005	0.09	05/22/2001	0.201	0.125	6
				TPH-G	**48**	MW130x06	11/16/1994	**5.2**	04/26/2004	**14.9**	10.8	5
				TPH-D	**240**	MW1743x06	05/24/2001	17	09/13/1999	66.5	58.7	100
LF007	NOU	Landfill 2	VOCs	TCE	**87**	MW125x07	06/07/2002	0.21	05/19/2006	**27.4**	26.4	5
				Benzene	**4**	MW261x07	09/11/1997	0.0124	12/13/1996	**2.36**	1.06	1
				1,4-DCB	**39**	MW261x07	09/13/2000	0.21	05/05/2009	**12.2**	13.5	5
			SVOCs	Chlorobenzene	48	MW261x07	05/03/2004	0.15	06/04/2003	16.1	14.7	70
			Pesticides[d]/PCBs[e]	bis(2-Ethylhexyl)phthalate	**8**	MW261x07	06/03/2010	2.9	05/01/2007	**4.37**	2.29	4
			Dioxins	Vinyl chloride	0.49	MW125x07	11/16/2004	0.2	03/04/1999	0.342	0.085	0.5
				1,1-DCE	2	MW284x07	09/08/1997	0.169	11/21/1994	0.421	0.316	6
				1,2-DCA	**0.769**	MWCx07	11/30/1994	0.1	09/17/1999	0.308	0.188	0.5
				1,2-Dichloropropane	0.88	MW619x07	12/14/2005	0.08	09/16/1998	0.325	0.242	5

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LF008	WABOU	Landfill 3	Pesticides	Aldrin	**0.16**	MW01x08	03/07/2001	0.006	03/08/1999	**0.059**	0.053	0.023
				Alpha-chlordane	**1.7**	MW712x08	05/03/2004	0.0037	6/22/2010	**0.282**	0.311	0.1
				Heptachlor	**0.29**	MW01x08	05/07/2001	0.0035	06/27/2002	**0.0712**	0.080	0.01
				Heptachlor epoxide	**0.63**	MW712x08	04/26/2006	0.0032	06/26/2002	**0.106**	0.149	0.01
SS015	EIOU	Solvent Spill Area and Facility 552	VOCs	TCE	**563**	MW2124x15	07/26/2010	0.18	04/19/2006	**166**	179	5
				cis-1,2-DCE	**7,680**	MW216x15	08/17/2010	0.16	11/19/2006	**517**	1,339	6
				Vinyl chloride	**3,220**	MW216x15	08/17/2010	**0.77**	04/14/2004	**277**	676.5	0.5
				1,2-DCA	0.45	MW306x15	04/19/2006	0.39	07/28/1994	0.427	0.032	0.5
				PCE	**105**	MW216x15	12/17/2003	0.25	5/25/2010	**44.2**	35.9	5
			SVOCs	bis(2-Ethylhexyl)phthalate	**6.68**	MW315x015	12/16/1993	2.15	12/15/1993	3.54	1.91	4
			Metal	Nickel	**2,210**	MW215x15	12/15/1993	11.3	12/15/1993	**232**	503	100
SS016	EIOU	Oil Spill Area Facilities 11, 13/14, 20, 42/1941, and 139/144	VOCs	TCE	**210,000**[f]	MW2020x16	09/8/2009	0.1	06/20/2003	**1,967**	11,042	5
				cis-1,2-DCE	**19,100**	EW003x16	10/22/1998	0.06	06/18/2003	**532**	2,296	6
				Vinyl chloride	**1,530**	EW003x16	12/17/1997	0.14	05/18/2001	**63.2**	228	0.5
				Benzene	**9**	MW1714x16	06/02/1994	0.06	06/26/2003	**1.16**	1.89	1
				Chloroform	9.96	EW003x16	05/07/1998	0.05	05/24/2001	1.22	2.04	100
				1,4-DCB	**315**	MW2020x16	09/8/2009	0.08	05/29/2001	6.11	31.57	5
				Bromodichloromethane	1.3	MW1734x16	05/13/2008	0.2	04/15/2010	0.74	0.55	100
				1,2-DCA	**9.16**	EW003x16	12/17/1997	0.1	06/18/2003	**1.25**	2.06	0.5
				1,1-DCE	**84**	MW608x16	09/07/2001	0.09	05/16/2001	3.73	10.0	6
				PCE	**105**	MW2020x16	12/17/2003	0.25	05/25/2010	**44.2**	35.9	5
			SVOCs	bis(2-Ethylhexyl)phthalate	**67.3**	MW1712x16	01/06/1994	1.55	01/06/1994	**13.0**	24.0	4
			Metal	Nickel	**6,560**	MW244x16	12/28/1993	10	01/06/1994	**241**	689	100
ST027[c]	EIOU	TF33, Facilities 1918, 1919, 1020, and 1040	VOCs	Benzene	0.44	MW791x27	01/06/2009	0.0577	03/19/1996	0.23	0.123	1
				Toluene	0.1	MW791x27	05/01/2007	0.0693	03/19/1996	0.088	0.017	150
				MTBE	0.08	MW279x27	06/25/2003	0.08	06/25/2003	0.080	--	13
				TPH-G	**1,210**	MW795x27	02/19/2007	**7.7**	05/16/2008	**205**	264	5
				TPH-D	**862**	MW795x27	02/19/2007	30	12/17/2001	**140**	179	100
SS029	EIOU	MW329x29 Area	VOCs	TCE	**1,400**	MW329x29	09/15/1997	0.05	06/04/2001	**178**	248	5
				1,2-DCA	**3**	MW1031x29	09/03/1997	0.09	06/06/2003	**0.532**	0.758	0.5
				cis-1,2-DCE	**100**	MW329x29	09/15/1997	0.07	06/13/2003	**15.8**	19.07	6
				Benzene	0.55	MW329x29	09/07/1994	0.05	05/22/2001	0.167	0.156	1
				Chloroform	13	EW02x29	11/03/1998	0.04	06/04/2001	2.57	4.11	100
				1,1-DCE	2.9	EW03x29	05/28/2010	0.1	06/12/2003	0.443	0.393	6
				Vinyl chloride	**2.8**	EW03x29	05/28/2010	0.08	05/22/2001	0.453	0.628	0.5

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SS030	EIOU	MW269x30 Area	VOCs	TCE	**3,860**	MW1009x30	09/08/1994	0.1	12/11/2000	**153.8**	437.9	5
				Chloroform	9.3	MW269x30	05/28/2010	0.05	05/31/2001	0.740	1.373	100
				Bromodichloromethane	2	R-1	07/08/1999	0.09	03/03/1999	0.679	0.585	100
				1,2-DCA	0.34	MW1017x30	09/22/1994	0.34	09/22/1994	0.340	--	0.5
			Metal	Nickel	**1,850**	MW282x30	06/01/1994	6.4	05/31/2000	**191**	334	100
SD031	EIOU	Facility 1205	VOCs	TCE	**8,100**	MW1727x31	06/02/1994	0.1	09/28/1998	**85.23**	587	5
				Benzene	**28**	MW1741x31	06/13/2000	0.07	05/14/2001	**4.10**	6.06	1
				1,1-DCE	**7,300**	MW1727x31	06/02/1994	0.07	12/13/2000	**60.62**	315	6
				cis-1,2-DCE	**3,600**	MW1727x31	06/02/1994	0.07	05/29/2003	**62.2**	319	6
				Carbon tetrachloride	**11**	MW572x31	08/29/2001	**1.6**	08/28/2001	**7.87**	5.43	0.5
				Chloroform	11	EW566x31	06/20/2000	0.08	05/16/2001	1.23	2.52	100
				1,2-DCA	**5**	MW1741x31	03/20/2000	0.1	05/29/2003	**1.45**	1.68	0.5
				Vinyl chloride	**1.2**	EW566x31	03/12/2001	0.22	09/08/1994	**0.681**	0.251	0.5
			Metal	Nickel	**6,780**	MW1729x31	09/08/1994	3.7	05/01/2006	**436**	1,130	100
SD033	WIOU	Storm Sewer System 2 (former Storm Sewer System B – includes Facilities 810, 1917, and South Gate Area)	VOCs	TCE	**180**	EW501x33	11/29/2007	0.09	06/10/2003	**20.6**	33.2	5
				1,1-DCE	1.9	EW501x33	11/29/2007	0.2	11/08/2006	0.584	0.3	6
				1,2-DCA	**0.538**	MW1202x33	11/29/1994	0.2	09/03/1999	0.369	0.239	0.5
				cis-1,2-DCE	**75.9**	MW1202x33	11/29/1994	0.095	06/27/2000	3.15	9.44	6
				TPH-G	**117**	MW505x33	06/10/2003	**5.1**	05/01/2008	**23.6**	28.2	5
			SVOCs	TPH-D	**200**	MW270x33	08/25/1994	29	03/05/2010	76.8	39.7	100
SD034	WIOU	Facility 811	VOCs	LNAPL (PD-680)	5 feet thick		NA	NA	NA	NA	NA	NA
				TCE	**456**	MWSSAx34	12/05/1994	0.07	07/01/2003	**39.8**	79.3	5
				Vinyl chloride	**11**	MW02x34	05/12/2008	0.2	09/15/1999	**2.2**	2.21	0.5
				1,1-DCE	3.2	EW01x34	11/26/2007	0.1	10/29/1998	0.577	0.769	6
				Benzene	**1.34**	MW811x34	05/16/1995	0.04	05/22/2001	0.463	0.342	1
				cis-1,2-DCE	**391**	MW811x34	03/15/1995	0.25	04/27/2004	**54.8**	74.2	6
				PCE	**41.4**	MWSSAx34	12/05/1994	0.08	07/01/2003	4.92	8.74	5
				TPH-G	**6,330**	MWSSAx34	12/05/1994	**10**	12/14/2005	**748**	1,410	5
				TPH-D	**4,210,000**	MW811x34	05/16/1995	62	04/18/2006	**142,000**	731,000	100
			SVOCs	bis(2-Ethylhexyl)phthalate	**3,350**	MW811x34	05/16/1995	4	09/23/1998	**679**	1,330	4
SS035	WIOU	Facilities 818 and 819	VOCs	TCE	**5.3**	MW818x15	03/15/1995	0.2	04/14/1998	2.08	1.84	5
			SVOCs	TPH-D	**300,000**	MWRW2x35	12/08/1994	18.2	05/17/1995	**60,500**	134,000	100

TABLE 3.1-1
Summary Statistics of ERP Sites and Chemicals of Concern
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Operable Unit	Name/Description	Chemical Class	Chemicals of Concern	Maximum Historical Concentration[a] (µg/L)	Location of Maximum Historical Detection	Date of Maximum Historical Concentration[a]	Minimum Historical Concentration[a] (µg/L)	Date of Minimum Historical Concentration[a]	Average Historical Concentration[a] (µg/L)	Standard Deviation Historical Concentrations	Interim Remediation Goals[b] (µg/L)
SD036	WIOU	Facilities 872, 873, and 876	VOCs	Vinyl chloride	**360**	MW872x36	03/29/2000	0.09	03/28/2000	**22.0**	62.2	0.5
				TCE	**18,500**	MW2061Bx36	05/11/2010	0.07	06/30/2003	**952.3**	2,200.5	5
				1,1-DCE	3.71	MW872x36	09/28/1994	0.08	05/21/2001	0.830	0.764	6
				cis-1,2-DCE	**3,870**	MW872x36	09/28/1994	0.09	07/01/2003	**147.8**	443	6
				1,2-DCA	**7.9**	PZ12Sx36	3/09/2000	0.09	06/30/2003	**1.58**	2.12	0.5
				Benzene	**3.87**	MW872x36	09/28/1994	0.09	09/11/1998	0.556	0.803	1
				Bromodichloromethane	2.26	MW872x36	11/29/1994	0.26	01/05/2009	1.11	1.00	100
				PCE	**512**	MW872x36	11/29/1994	0.15	05/21/2001	**11.4**	54.1	5
				TPH-G	**7,300**	MW2061Bx36	05/11/2010	**5.2**	05/05/2008	**635.93**	1,397.3	5
			SVOCs	TPH-D	**450**	PZ06Dx36	05/09/2005	43	05/18/2007	**138.24**	106.39	100
SD037	WIOU	Sanitary Sewer (includes Facilities 837, 838, 981, 919, the Area G Ramp, and Ragsdale/V Area)	VOCs	1,1-DCE	**8.2**	EW700x37	05/16/2005	0.05	06/05/2001	0.841	1.16	6
				1,2-DCA	**1**	MW500x37	06/06/2001	0.1	09/13/1999	0.452	0.276	0.5
				Benzene	**4,240**	MWS3M2x37	12/05/1994	0.058	03/22/1996	**115**	469	1
				Bromodichloromethane	3	EW704x37	08/24/1999	0.12	06/07/2001	0.702	0.761	100
				Carbon tetrachloride	**40.4**	MW538x37	03/09/2000	0.1	12/31/2001	**4.00**	7.72	0.5
				Chloromethane	**20**	MWRVM2x37	09/03/1999	0.07	06/14/2001	1.01	3.07	1.5
				PCE	**900**	MWSNSM4x37	04/15/2005	0.0974	12/16/2003	**13.6**	66.2	5
				TCE	**5,800**	MW526x37	11/29/2007	0.1	06/10/2003	**211**	442	5
				Vinyl chloride	**430**	MW919x37	03/23/1998	0.1	03/09/2000	**7.98**	38.3	0.5
				cis-1,2-DCE	**381**	MW810M1x37	11/30/1994	0.07	09/20/1994	**13.3**	31.6	6
				TPH-G	**12,000**	MWS3M2x37	10/12/1998	4.9	05/22/2007	**803**	2,028	5
			SVOCs	bis(2-Ethylhexyl)phthalate	**91**	MW224x37	12/02/1994	0.972	03/20/1995	**14.4**	23.1	4
				Naphthalene	**200**	MW04x37	10/08/1998	0.52	10/09/1998	**36.2**	49.1	20
				TPH-D	**13,800**	MWS3M3x37	06/10/2009	13	06/24/2002	**774**	2,361	100
DP039	WABOU	Building 755	VOCs	1,1-DCE	**7,900**	PZ01x39	03/24/1999	0.11	12/19/2000	**206**	611	6
				1,2-DCA	**33**	MW751x39	04/25/2006	0.1	05/25/2010	**2.99**	5.98	0.5
				1,1,1-TCA	**9,800**	PZ01x39	03/24/1999	0.08	05/10/2001	**163**	1,110	0.5
				1,1,2-TCA	**10.7**	MW750x39	06/26/2009	0.1	09/22/2006	**1.68**	2.78	0.5
				Acetone	89.8	MW778x39	12/07/2009	0.29	08/29/2006	**7.97**	15.4	5,110
				Bromodichloromethane	1	EW563x39	11/16/1999	0.09	11/22/2004	0.549	0.293	100
				Methylene chloride	**29**	MW777x39	12/12/2005	0.15	05/28/2002	4.76	8.20	5
				PCE	4	EW563x39	11/16/1999	0.09	09/05/2006	0.609	0.918	5
				TCE	**230,000**	PZ01x39	03/14/1996	0.08	05/10/2001	**1,927**	16,224	5
SD043	WABOU	Building 916	VOCs and PCB-1254	TCE	**38**	EW555x43	08/25/2005	0.08	07/01/2003	1.84	5.58	5

TABLE 3.1-1
Summary Statistics of ERP Sites and Chemicals of Concern
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

[a] The data set used for this table includes data sent from ERPIMS, current GSAP data, and current and historical O&M data. The following sampling methods were excluded:

- Cone penetrometer
- Composite sample
- Hollow-stem auger
- HydroPunch®
- Sparge and vent pre-treatment collection port

[b] IRGs as specified in the NEWIOU and WABOU Groundwater IRODs (Travis AFB, 1998 and 1999).

Source: Table 1-1 of the final Travis AFB 2009-2010 Annual GSAP Report (CH2M HILL, 2011b).

Notes:

Bold = Concentration is greater than the IRG

ERPIMS = Environmental Resources Program Information Management System
MTBE = methyl tert-butyl ether
NA = not applicable
TPH-D = total petroleum hydrocarbon as diesel
TPH-G = total petroleum hydrocarbon as gasoline

TABLE 3.1-2
Summary of ERP Groundwater Sites, Chemicals of Concern, and Historical Analyses
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Operable Unit	Name/ Description	Chemicals of Concern	Chemical Classes Historically Analyzed
FT004	EIOU	Fire Training Area 3	TCE	Cyanide
			cis-1,2-DCE	Fluorides
			1,2-DCA	Herbicides
			Chloroform	Metals (including hexavalent chromium)
			Bromodichloromethane	Organochlorine pesticides
			1,1-DCE	PCBs
			Vinyl chloride	Phosphorous
			1,4-DCB	Radionuclides
			bis(2-Ethylhexyl)phthalate	SVOCs
			Nickel	Total recoverable phenolics
				TPH-aviation fuel (JP-4)
				TPH-D
				TPH-G
				TPH-oils
				VOCs (including 1,4-dioxane)
FT005	EIOU	Fire Training Area 4	TCE	Fluorides
			1,2-DCA	Metals (including hexavalent chromium)
			cis-1,2-DCE	Organochlorine pesticides
			Chloroform	Herbicides
			Bromodichloromethane	PCBs
			bis(2-Ethylhexyl)phthalate	Phosphorous
			Nickel	SVOCs
				Total recoverable phenolics
				TPH-aviation fuel (JP-4)
				TPH-D
				TPH-G
				TPH-Oils
				VOCs
LF006	NOU	Landfill 1	TCE	Cyanide
			1,1-DCE	Dioxins
			TPH-G	Fluorides
			TPH-D	Furans
				Metals (including hexavalent chromium)
				Organochlorine pesticides
				Herbicides
				PCBs
				Phosphorous
				Radionuclides
				SVOCs
				TPH-aviation fuel (JP-4)
				TPH-D
				TPH-G
				TPH-oils
				Total recoverable phenolics
				VOCs

TABLE 3.1-2
Summary of ERP Groundwater Sites, Chemicals of Concern, and Historical Analyses
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Operable Unit	Name/ Description	Chemicals of Concern	Chemical Classes Historically Analyzed
LF007	NOU	Landfill 2	TCE	Cyanide
			Benzene	Dioxins
			1,4,-DCB	Fluorides
			Chlorobenzene	Furans
			bis(2-Ethylhexyl)phthalate	Herbicides
			Vinyl chloride	Metals (including hexavalent chromium)
			1,1-DCE	Organochlorine pesticides
			1,2-DCA	PCBs
			1,2-Dichloropropane	Radionuclides
				SVOCs
				TPH-aviation fuel (JP-4)
				TPH-D
				TPH-G
				TPH-oils
				Total recoverable phenolics
				VOCs (including 1,4-dioxane)
LF008	WABOU	Landfill 3	Aldrin	Chlorinated herbicides
			Alpha-chlordane	Fluorides
			Heptachlor	Metals
			Heptachlor epoxide	Organochlorine pesticides
				Organophosphorus pesticides
				PCBs
				Phosphorous
				SVOCs
				TPH-aviation fuel (JP-4)
				TPH-D
				TPH-G
				TPH-oils
				VOCs
SS015	EIOU	Solvent Spill Area and Facility 552	TCE	Fluorides
			cis-1,2-DCE	Metals
			Vinyl chloride	Phosphorous
			1,2-DCA	SVOCs
			PCE	TPH-aviation fuel (JP-4)
			bis(2-Ethylhexyl)phthalate	TPH-D
			Nickel	TPH-G
				TPH-oils
				Total recoverable phenolics
				VOCs

TABLE 3.1-2
Summary of ERP Groundwater Sites, Chemicals of Concern, and Historical Analyses
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Operable Unit	Name/ Description	Chemicals of Concern	Chemical Classes Historically Analyzed
SS016	EIOU	Oil Spill Area Facilities 11, 13/14, 20, 42/1941, and 139/144	TCE	Metals
			cis-1,2-DCE	Fluorides
			Vinyl chloride	SVOCs
			Benzene	TPH-aviation fuel (JP-4)
			Chloroform	TPH-diesel
			1,4-DCB	TPH-gasoline
			Bromodichloromethane	TPH-oils
			1,2-DCA	Total recoverable phenolics
			1,1-DCE	VOCs (including 1,4-dioxane)
			PCE	
			bis(2-Ethylhexyl)phthalate	
			Nickel	
ST027	EIOU	TF33, Facilities 1918, 1919, 1020, and 1040	Benzene	Metals (including hexavalent chromium)
			TCE	Fluorides
			Toluene	Organochlorine pesticides
			MTBE	PCBs
			TPH-G	SVOCs
			TPH-D	TPH-aviation fuel (JP-4)
				TPH-D
				TPH-G
				TPH-oils
				TPH-n-octacosane
				VOCs
SS029	EIOU	MW329x29 Area	TCE	Fluoride
			1,2-DCA	Metals (including hexavalent chromium)
			cis-1,2-DCE	Organochlorine pesticides
			Benzene	PCBs
			Chloroform	SVOCs
			1,1-DCE	TPH-D
			Vinyl chloride	TPH-G
				VOCs
SS030	EIOU	MW269x30 Area	TCE	Metals (including hexavalent chromium)
			Chloroform	Dioxins
			Bromodichloromethane	Fluorides
			1,2-DCA	Furans
			Nickel	Organochlorine pesticides
				PCBs
				SVOCs
				TPH-aviation fuel (JP-4)
				TPH-D
				TPH-G
				TPH-oils
				VOCs (including 1,4-dioxane)

TABLE 3.1-2
Summary of ERP Groundwater Sites, Chemicals of Concern, and Historical Analyses
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Operable Unit	Name/ Description	Chemicals of Concern	Chemical Classes Historically Analyzed
SD031	EIOU	Facility 1205	TCE	1,4-Dioxane
			Benzene	Metals
			1,1-DCE	SVOCs
			cis-1,2-DCE	TPH-aviation fuel (JP-4)
			Carbon tetrachloride	TPH-D
			Chloroform	TPH-G
			1,2-DCA	TPH-oils
			Vinyl chloride	VOCs (including 1,4-dioxane)
			Nickel	
ST032	EIOU	MW107x32 Area and MW246x32 Area	Benzene	Fluorides
			TCE	Metals
			1,1-DCE	Phosphorous
			Xylenes	SVOCs
			bis(2-Ethylhexyl)phthalate	TPH-aviation fuel (JP-4)
				TPH-D
				TPH-G
				TPH-oils
				Total recoverable phenolics
				VOCs
SD033	WIOU	Storm Sewer System 2 (former Storm Sewer System B – includes Facilities 810, 1917, and South Gate Area)	TCE	Metals (including hexavalent chromium)
			1,1-DCE	Fluorides
			1,2-DCA	Organochlorine pesticides
			cis-1,2-DCE	PCBs
			TPH-G	SVOCs
			TPH-D	TPH-aviation fuel (JP-4)
				TPH-D
				TPH-G
				TPH-oils
				VOCs
SD034	WIOU	Facility 811	LNAPL (PD-680)	Fluorides
			TCE	Metals
			Vinyl chloride	Organochlorine pesticides
			1,1-DCE	PCBs
			Benzene	SVOCs
			cis-1,2-DCE	TPH-aviation fuel (JP-4)
			PCE	TPH-D
			TPH-G	TPH-G
			TPH-D	TPH-oils
			bis(2-Ethylhexyl)phthalate	VOCs

TABLE 3.1-2
Summary of ERP Groundwater Sites, Chemicals of Concern, and Historical Analyses
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Operable Unit	Name/ Description	Chemicals of Concern	Chemical Classes Historically Analyzed
SS035	WIOU	Facilities 818 and 819	TCE TPH-D	Fluorides Metals Organochlorine pesticides PCBs SVOCs TPH-aviation fuel (JP-4) TPH-D TPH-G TPH-oils VOCs
SD036	WIOU	Facilities 872, 873, and 876	Vinyl chloride TCE 1,1-DCE cis-1,2-DCE 1,2-DCA Benzene Bromodichloromethane PCE TPH-G TPH-D	Metals Organochlorine pesticides PCBs SVOCs TPH-aviation fuel (JP-4) TPH-D TPH-G TPH-oils VOCs
SD037	WIOU	Sanitary Sewer (includes Facilities 837, 838, 981, 919, the Area G Ramp, and Ragsdale/V Area)	1,1-DCE 1,2-DCA Benzene Bromodichloromethane Carbon tetrachloride Chloromethane PCE TCE Vinyl chloride cis-1,2-DCE TPH-G bis(2-Ethylhexyl)phthalate Naphthalene TPH-D	Fluorides Metals (including hexavalent chromium) Organochlorine pesticides PCBs Phosphorous Radionuclides SVOCs TPH-aviation fuel (JP-4) TPH-D TPH-G TPH-oils VOCs (including 1,4-dioxane)
DP039	WABOU	Building 755	1,1-DCE 1,2-DCA 1,1,1-TCA 1,1,2-TCA Acetone Bromodichloromethane Methylene chloride PCE TCE	Fluorides Metals Organochlorine pesticides PCBs SVOCs TPH aviation fuel (JP-4) TPH-D TPH-G TPH-oils VOCs (including 1,4-dioxane)

TABLE 3.1-2
Summary of ERP Groundwater Sites, Chemicals of Concern, and Historical Analyses
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Operable Unit	Name/ Description	Chemicals of Concern	Chemical Classes Historically Analyzed
SS041	WABOU	Building 905	Heptachlor epoxide	Chlorinated herbicides Organochlorine pesticides Organophosphorus pesticides PCBs SVOCs VOCs
SD043	WABOU	Building 916	TCE	Fluorides Organochlorine pesticides PCBs SVOCs TPH-aviation fuel (JP-4) TPH-D TPH-oils VOCs

Source: Table 1-2 of the final 2009-2010 Travis AFB GSAP Report (CH2M HILL, 2011b).

Note:

JP-4 = jet-propulsion fuel, grade 4

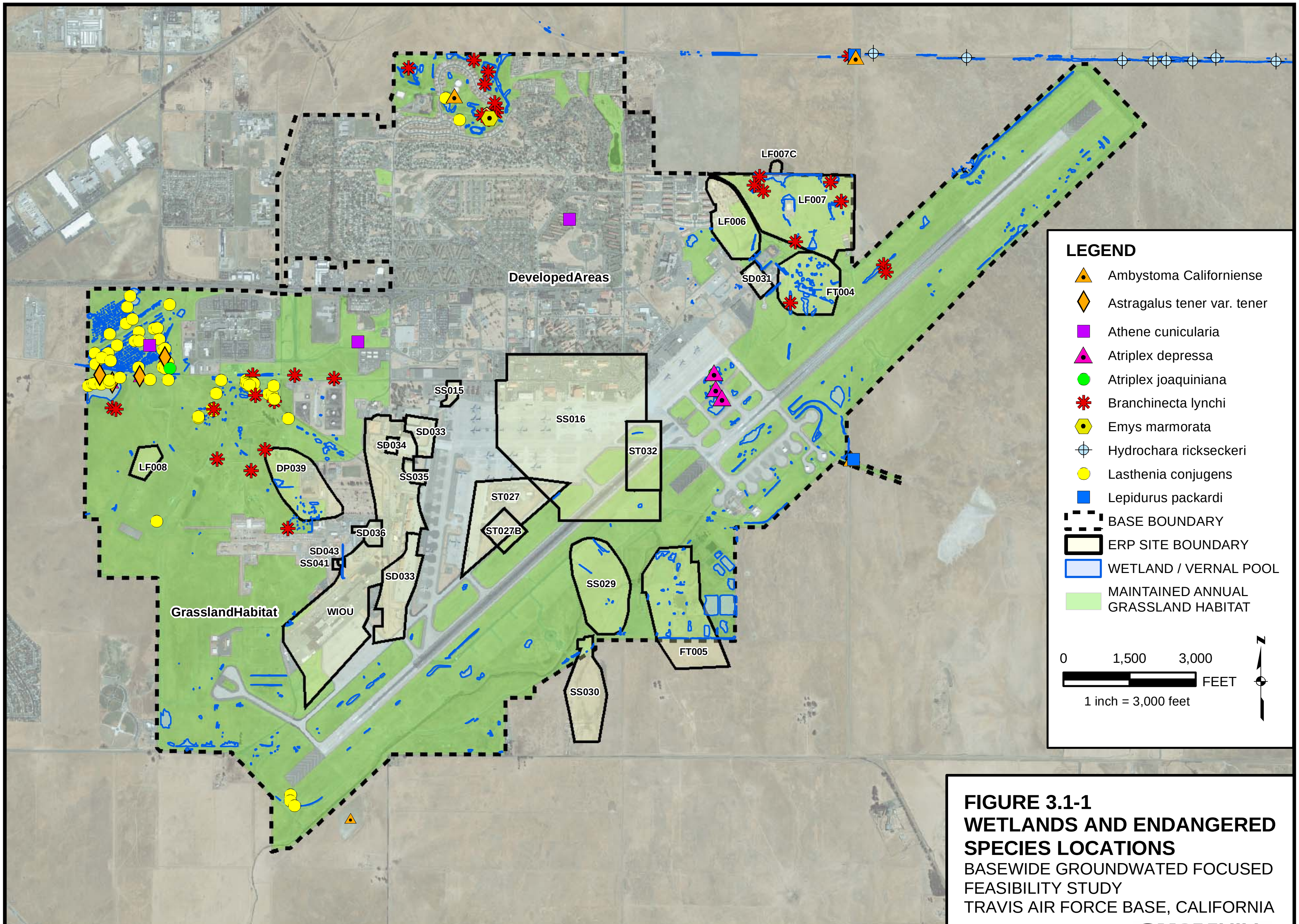
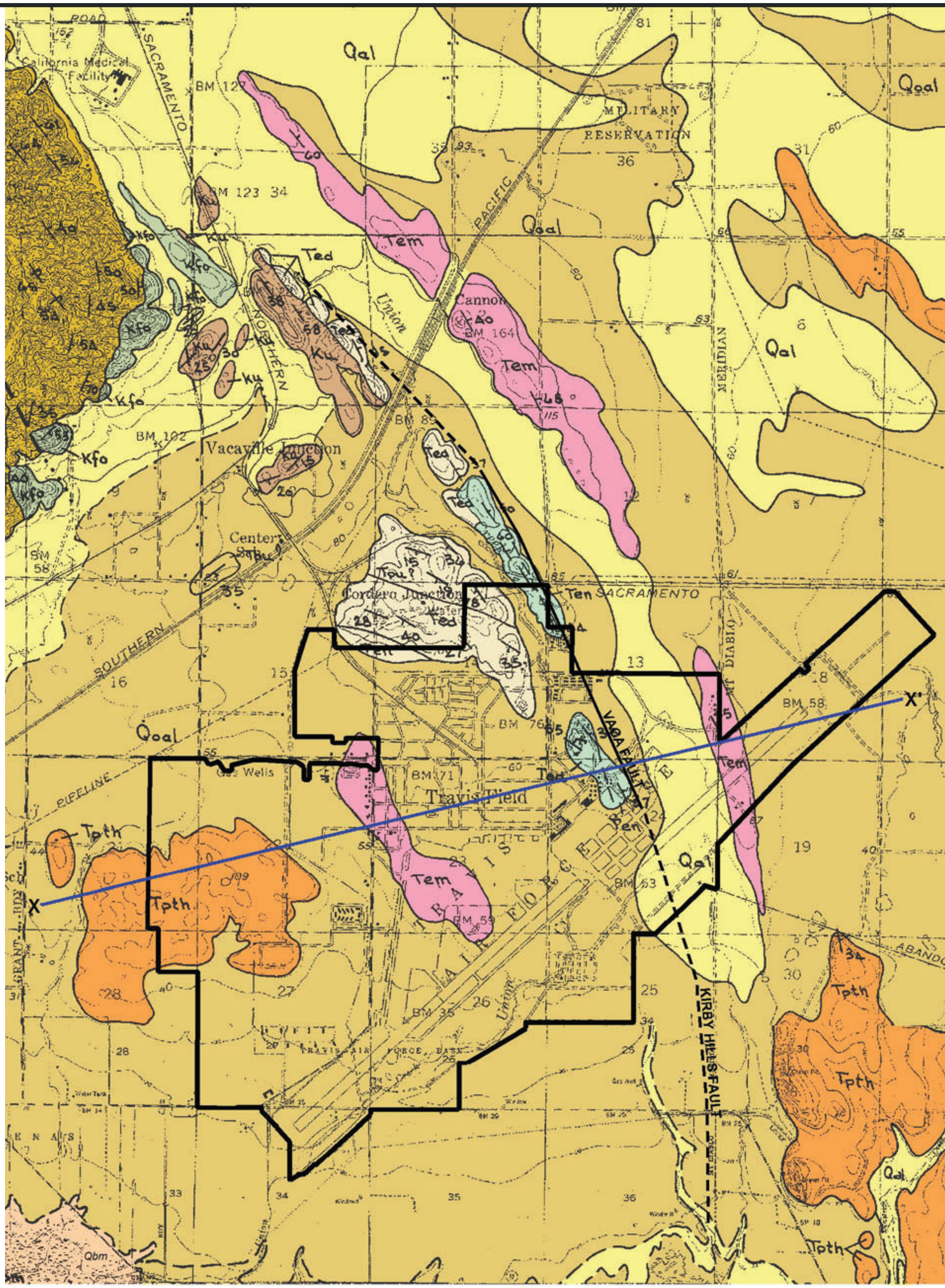


FIGURE 3.1-1
WETLANDS AND ENDANGERED SPECIES LOCATIONS
BASEWIDE GROUNDWATED FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_1-1_WETLANDS_ENDANGERED_SPECIES.MXD MSCHROCK 8/16/2011 2:54:19 PM



LEGEND

- *Qal*-YOUNGER ALLUVIUM
- Qbm-BAY MUD
- *Qoal*-OLDER ALLUVIUM
- Tpth-TEHAMA FORMATION
- *Tem*-MARKLEY SANDSTONE
- *Ten*-NORTONVILLE SHALE
- *Ted*-DOMENGINE SANDSTONE
- *Tpu*-UNNAMED FORMATION
- *Kfo*-FORBES FORMATION
- *Kg*-GUINDA FORMATION

N

0 1500 3000 FEET

SCALE IS APPROXIMATE

FIGURE 3.1-2
GEOLOGIC MAP OF TRAVIS AFB AND VICINITY

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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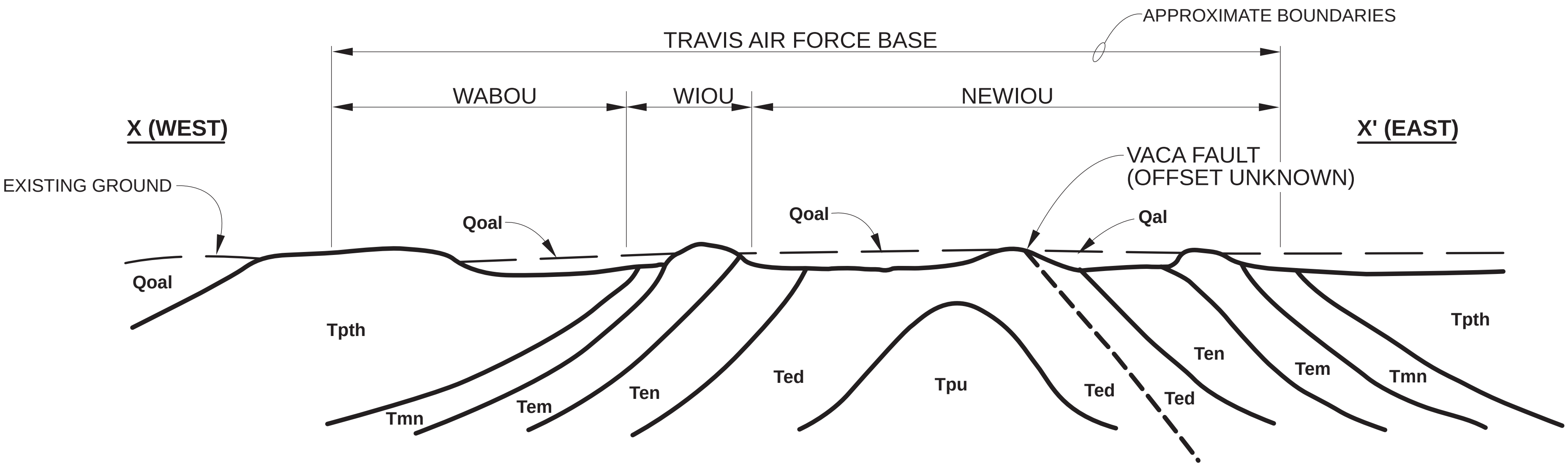

CROSS SECTION

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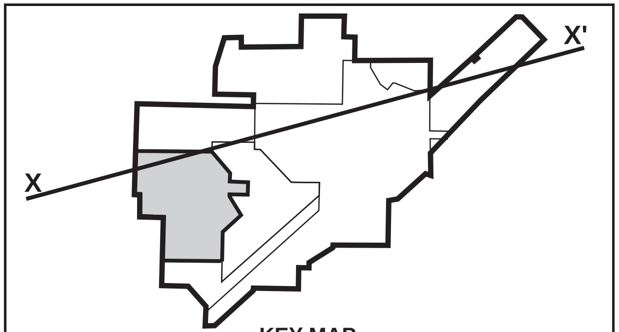

KEY MAP

LEGEND

QUATERNARY

Qal	ALLUVIUM
Qoal	OLDER ALLUVIUM

TERTIARY

Tpth	TEHAMA FORMATION
Tmn	NEROLY SANDSTONE
Tem	MARKELY SANDSTONE
Ten	NORTONVILLE SHALE
Ted	DOMENGINE SANDSTONE
Tpu	UNNAMED FORMATION

FIGURE 3.1-3
SCHEMATIC GEOLOGIC CROSS SECTION
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

ES011811013517RDD_3.1-3

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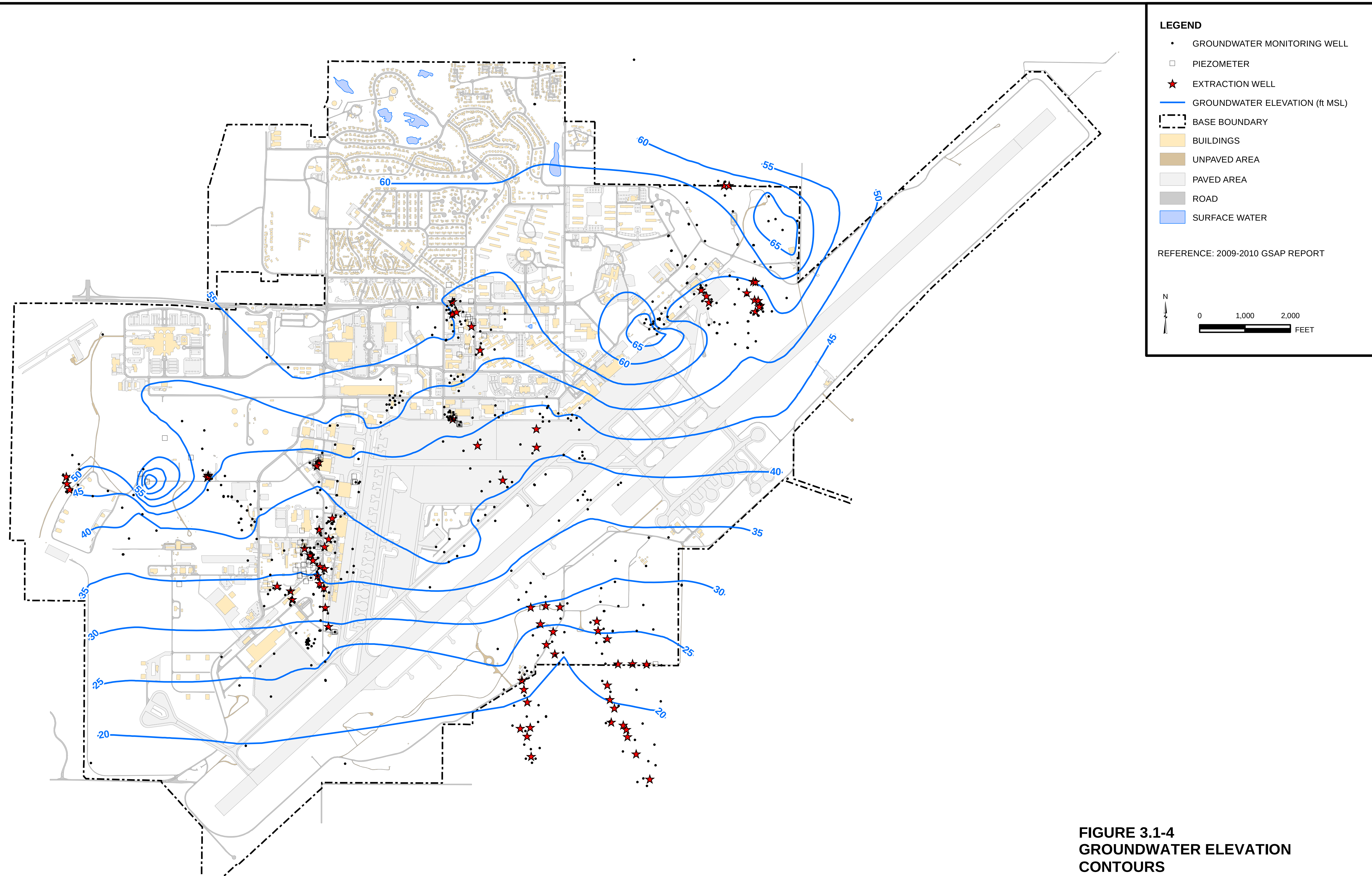

FIGURE 3.1-4
GROUNDWATER ELEVATION CONTOURS
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIGURE_3_1-4_GWELEVCONTOURS.MXD MSCHROCK 8/30/2011 2:41:46 PM

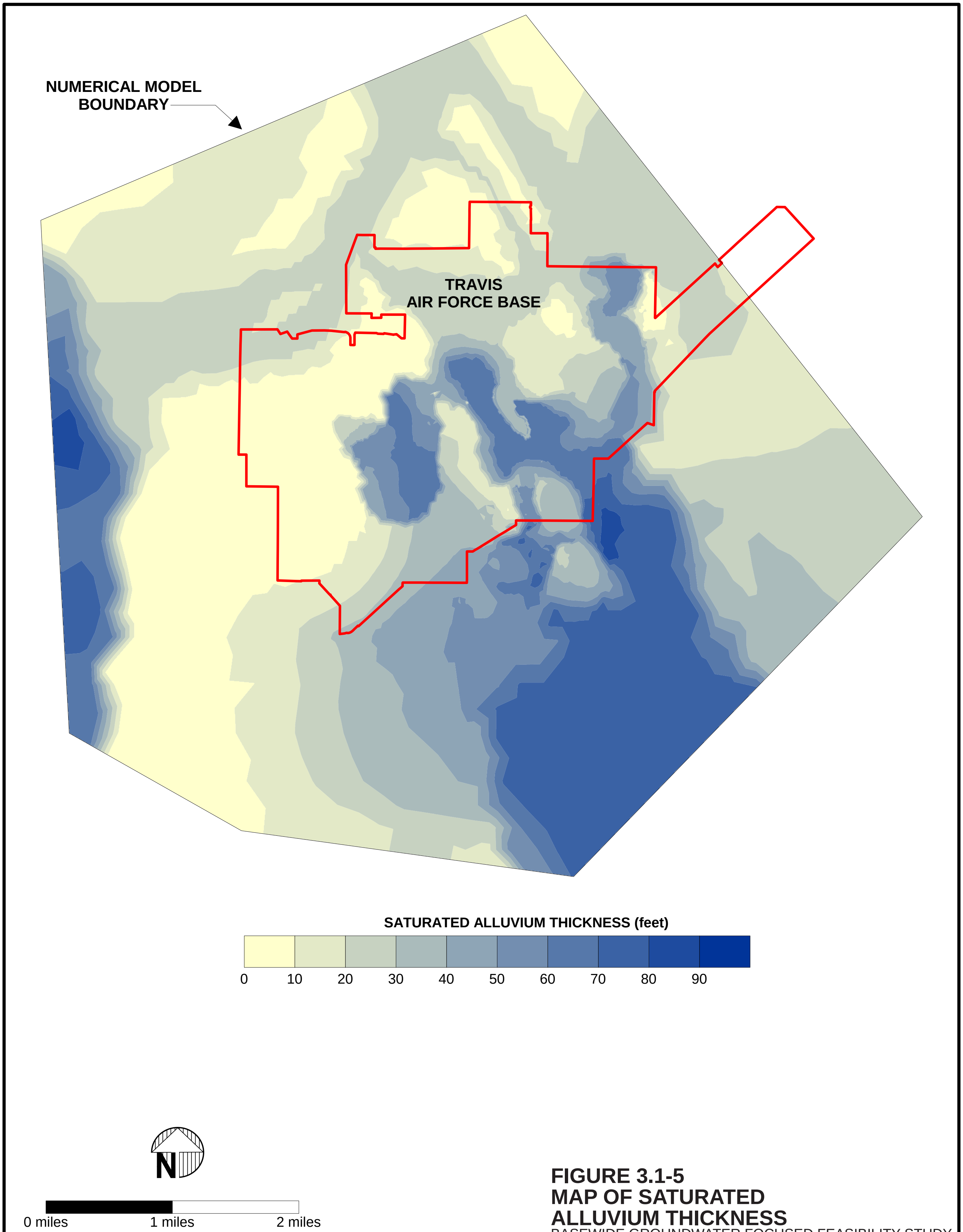

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FIGURE 3.1-5
MAP OF SATURATED ALLUVIUM THICKNESS
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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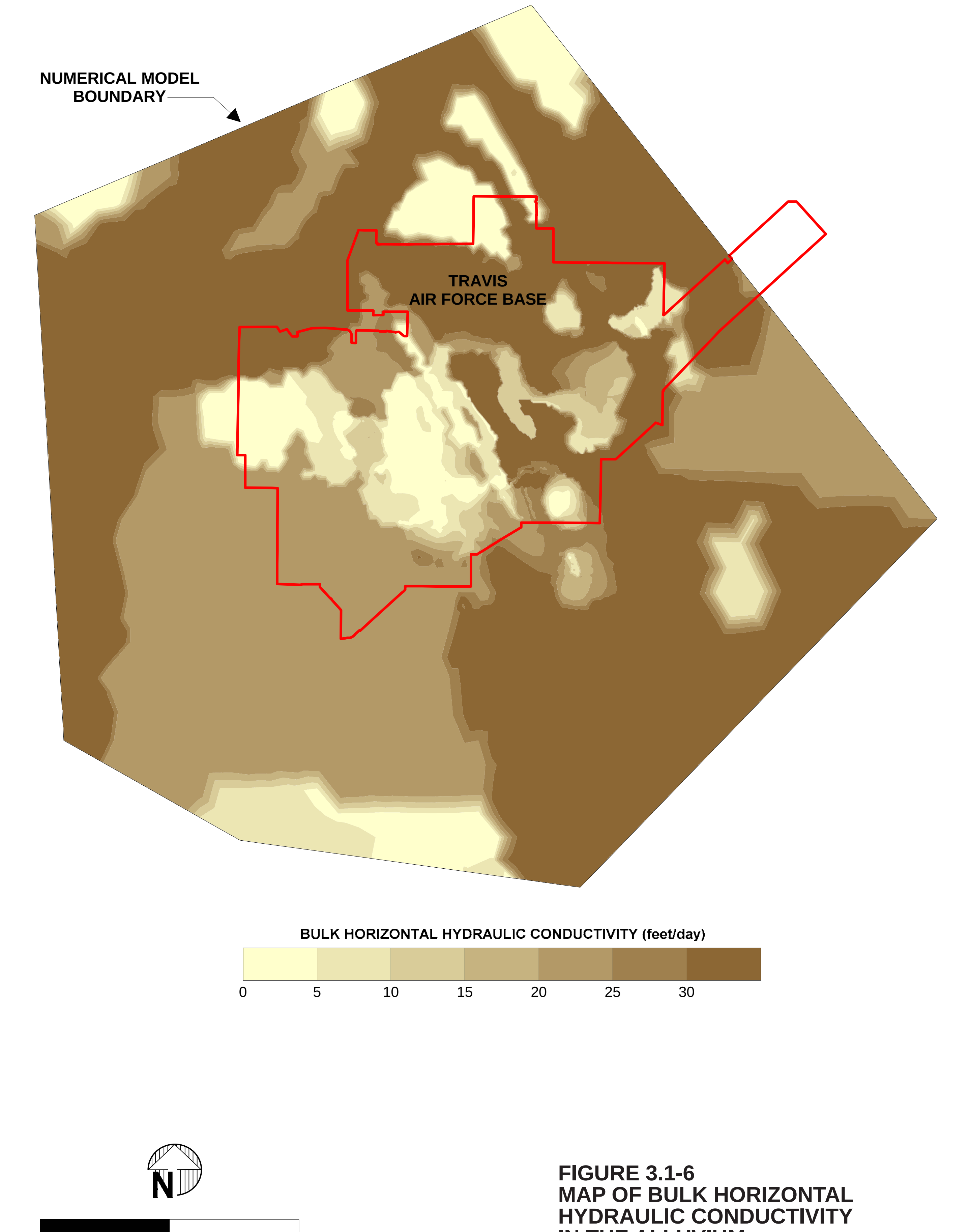

FIGURE 3.1-6
MAP OF BULK HORIZONTAL HYDRAULIC CONDUCTIVITY IN THE ALLUVIUM

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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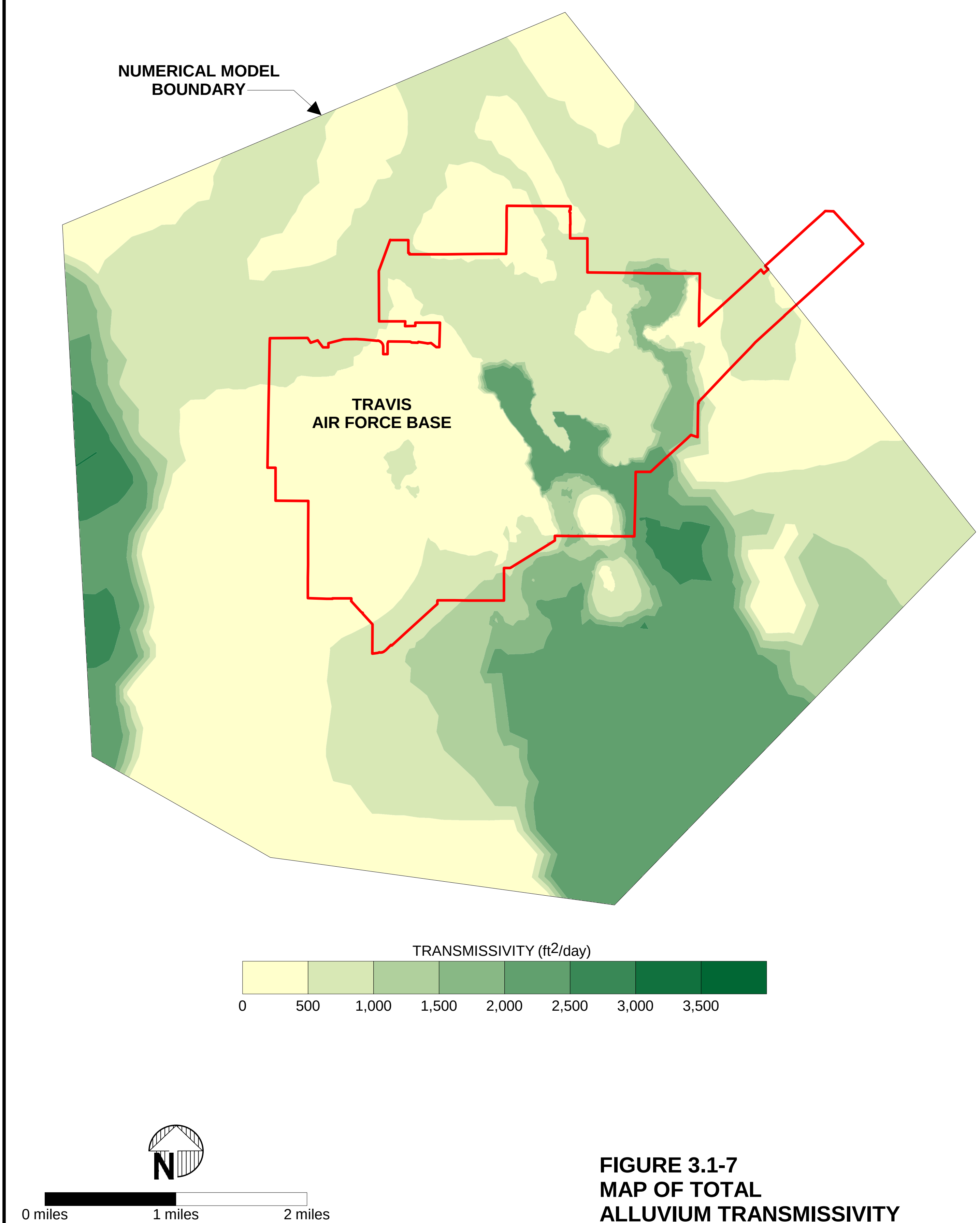

ES011811013517RDD_3.1-7

FIGURE 3.1-7
MAP OF TOTAL ALLUVIUM TRANSMISSIVITY
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA
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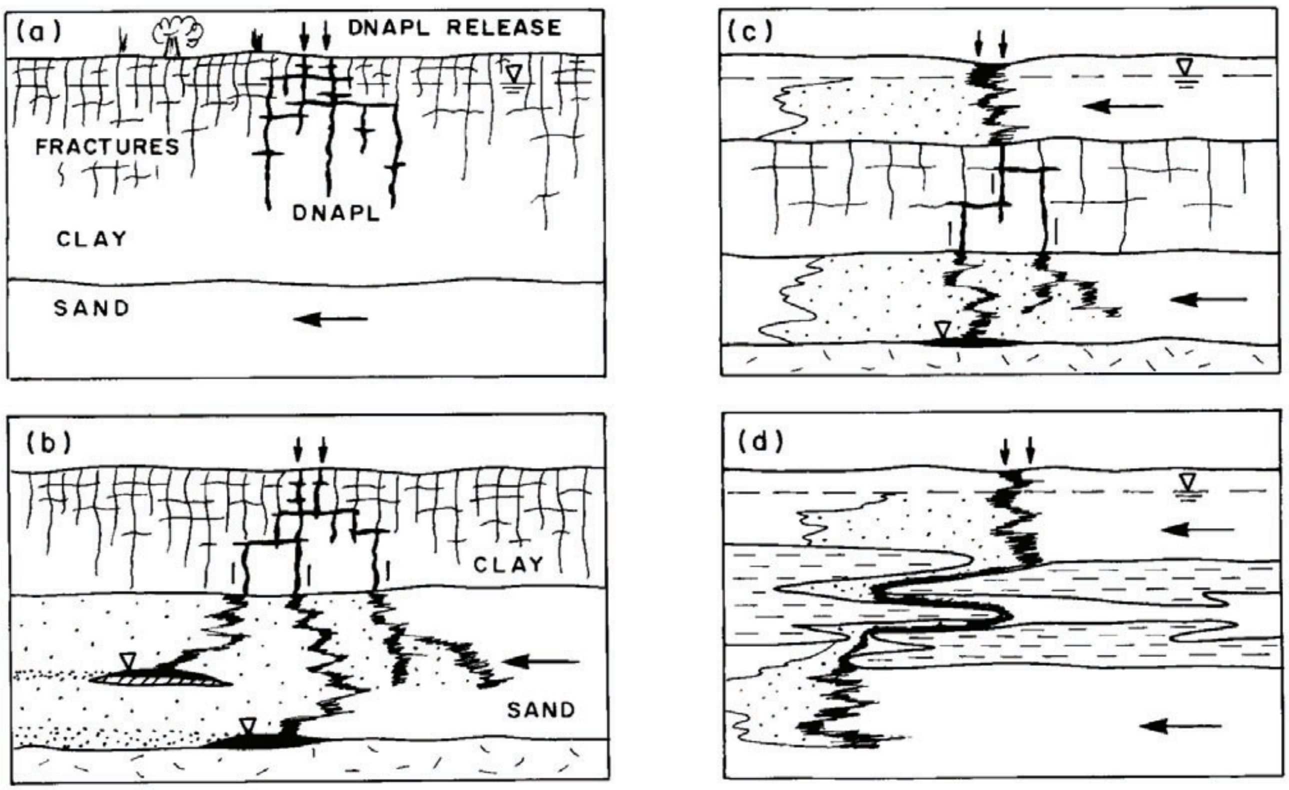

FIGURE 3.1-8
CONCEPTUAL DNAPL MOVEMENT THROUGH CLAYEY SOILS
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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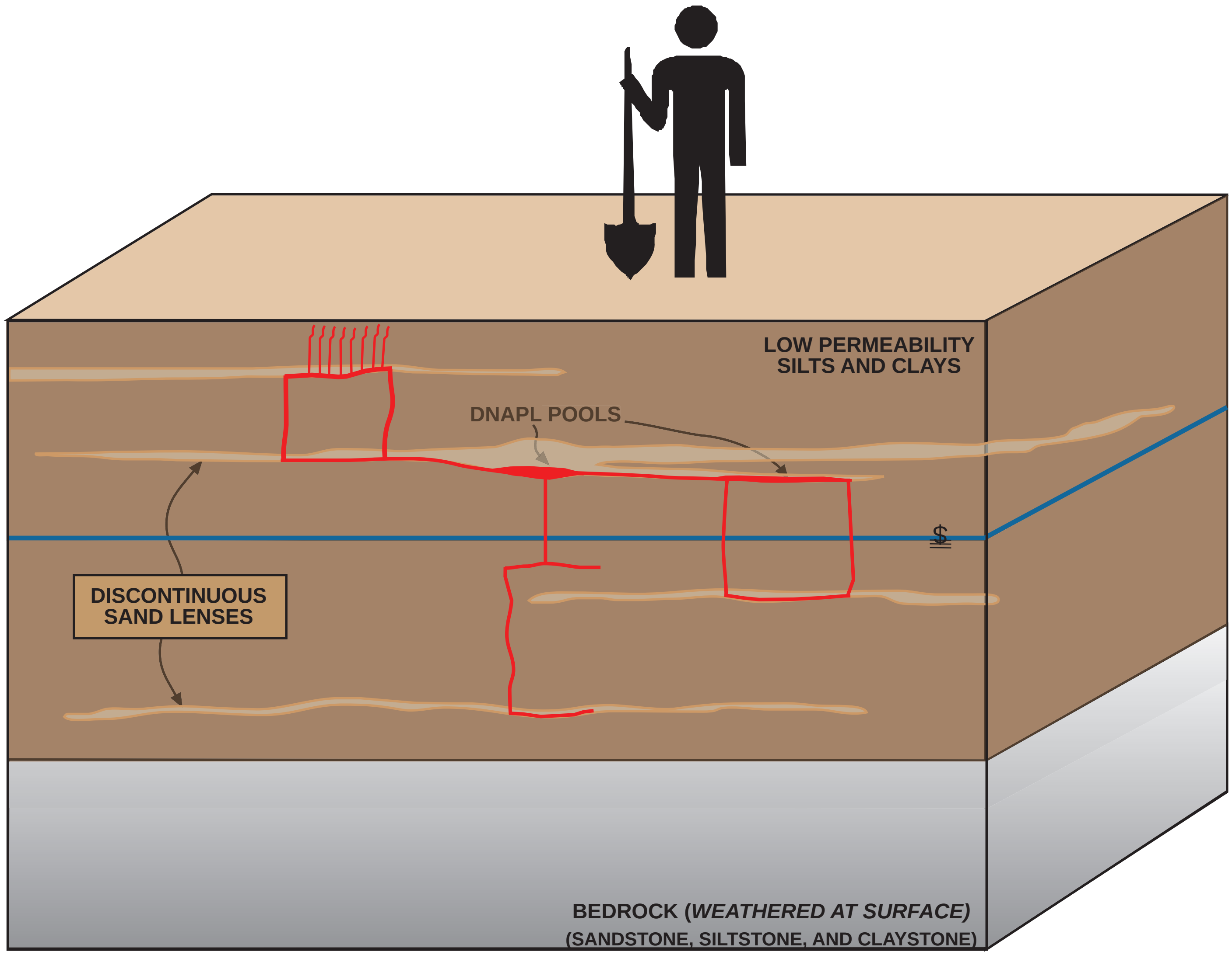

ES011811013517RDD_3.1-9

FIGURE 3.1-9
CONCEPTUAL DNAPL SOURCE ZONE
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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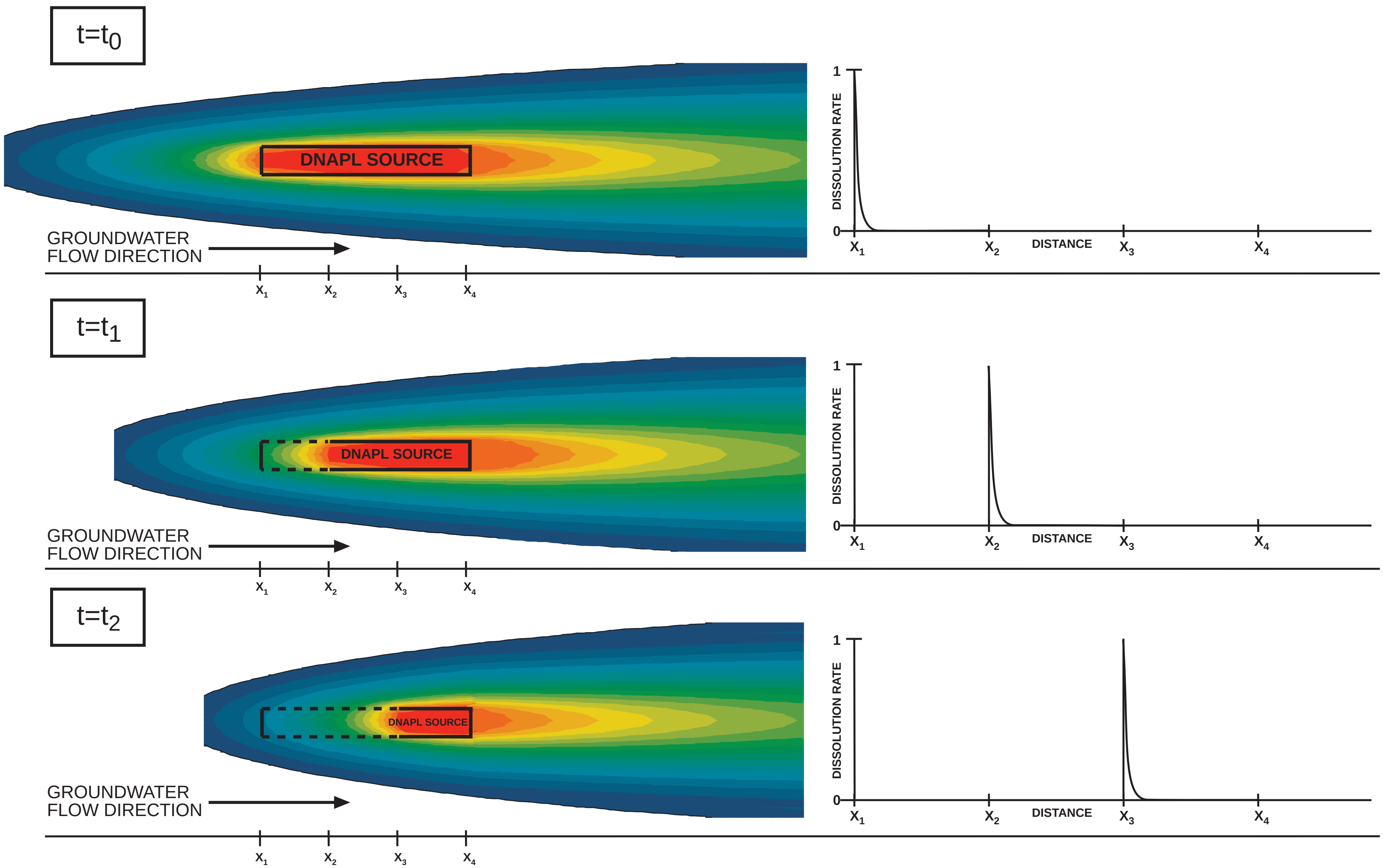

FIGURE 3.1-10
CONCEPTUAL DNAPL SOURCE ZONE DISSOLVING OVER TIME
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

ES011811013517RDD_3.1-10

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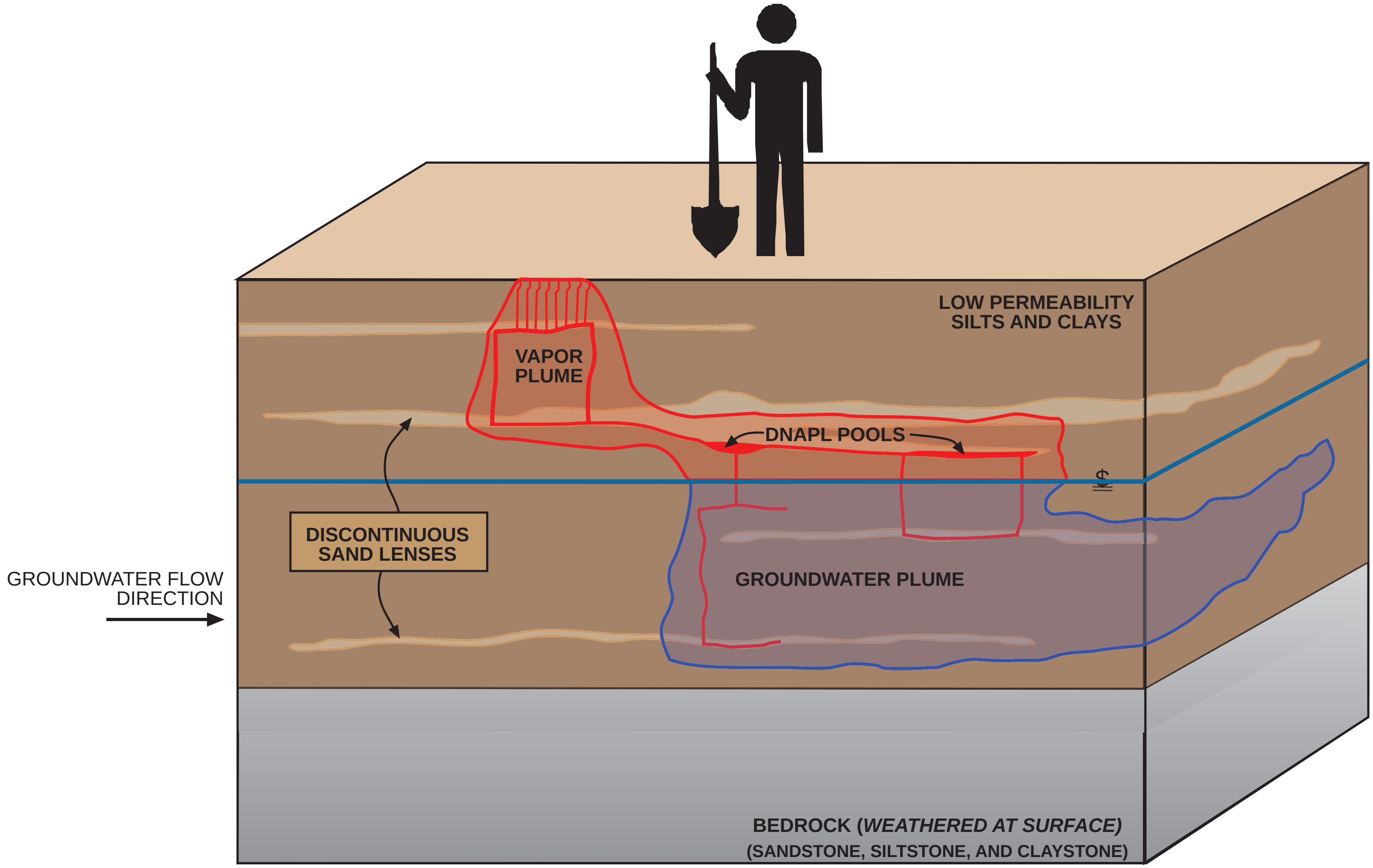

FIGURE 3.1-11
CONCEPTUAL PLUME FORMATION AT A DNAPL SITE
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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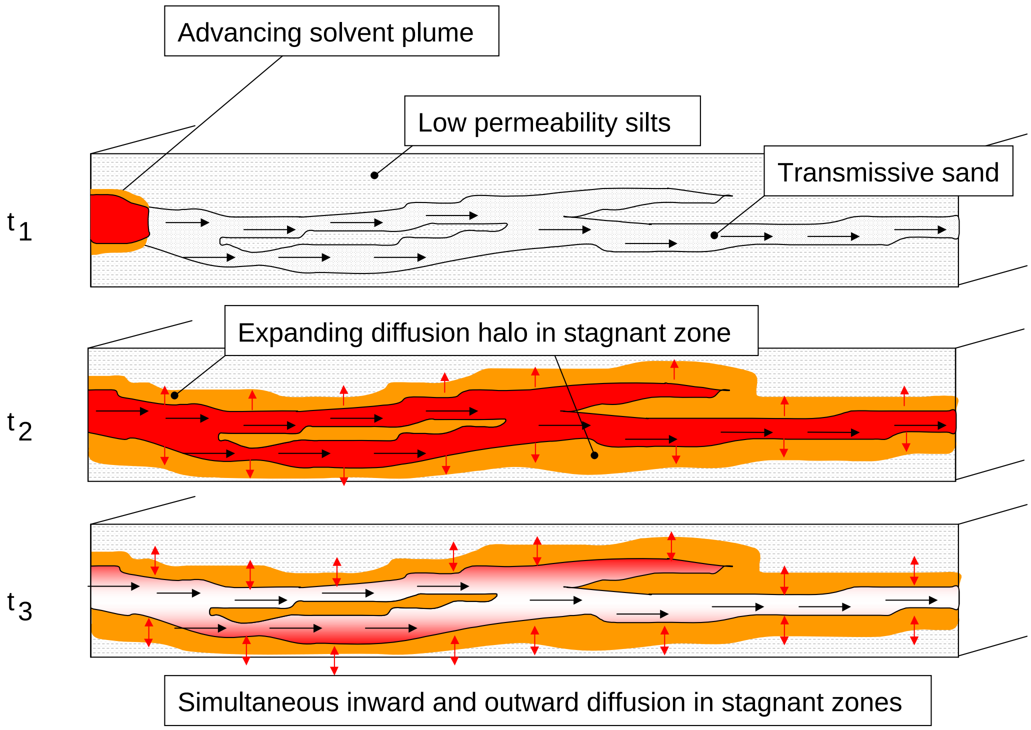


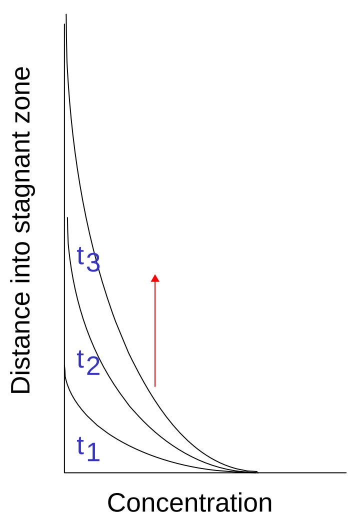


FIGURE 3.1-12
ADVANCING SOLVENT PLUME IN LAYERED ALLUVIUM
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

ES011811013517RDD_3.1-12

3.2 North IRA Conceptual Site Models

In conjunction with the Travis AFB CSM descriptions provided in Section 3.1, this section provides additional information for the sites comprising the North IRA, including NEWIOU ERP Sites FT004, SD031, LF006, and LF007. Site maps of the North IRA are shown on Figures 3.2-1 and 3.2-2.

Additional descriptions of the sites' geology, groundwater characteristics, and groundwater contamination are provided in Sections 4.1 and 4.2 of the 2009-2010 Annual GSAP Report (CH2M HILL, 2011b).

3.2.1 North IRA Site Descriptions

3.2.1.1 Site FT004

Site FT004 covers approximately 30 acres in the northeastern portion of the EIOU and is the former Fire Training Area No. 3 (FTA-3). The site was used for fire training exercises from 1953 to 1962. During these exercises, waste fuel, oils, and solvents were dumped onto frames or onto the ground and burned. Soil staining and stressed vegetation were observed during historical field investigations (Weston, 1995). The site is currently an unused, open field.

3.2.1.2 Site SD031

Site SD031, west of Site FT004, covers approximately 5.5 acres and encompasses Facility 1205 in the northeastern part of the EIOU. Facility 1205 was constructed in 1957, and operations include the maintenance and repair of diesel-powered generators. Wastes generated at the facility include oils, antifreeze, and solvents. A wash rack, just south of the facility, is still used to clean diesel engine parts; it discharges to an OWS. Accidental releases in the vicinity of this wash rack appear to be the source of groundwater contamination in the area. Since the discovery of the releases, proper material handling and process controls were implemented to prevent additional releases. Historical aerial photographs taken from 1958 to 1963 indicate that Facility 1205 may have been used as an aircraft maintenance hangar during that time.

3.2.1.3 Site LF006

Site LF006 (Landfill 1) is a former burn-and-fill landfill that encompasses approximately 17 acres in the northeastern corner of Travis AFB. Site LF006 operated between 1943 and the early 1950s. Materials disposed of and burned at Site LF006 consisted primarily of wood, paper, glass, residential debris, and construction debris; industrial wastes also were reportedly disposed of at Site LF006 (Radian, 1996b).

3.2.1.4 Site LF007

Site LF007 is former Landfill 2 in the NOU; it encompasses approximately 73 acres. The landfill was operated using trench-and-cover methods beginning in the early 1950s, following the closure of Landfill 1 (Site LF006). The landfill was used primarily for the disposal of general refuse, such as wood, glass, and construction debris. Small amounts of industrial wastes and fuel sludge from tank-cleaning operations also were reported to have been disposed of at Landfill 2. Use of Landfill 2 ceased in 1974 (Radian, 1995).

From the early 1950s until 1964, a portion of the eastern part of the landfill was used by the Defense Reutilization and Marketing Office to store excess waste materials, including oils, hydraulic fluid, and solvents, for resale or disposal. As determined by aerial photographs, a skeet range also was located at the site around 1953; however, the exact dates of operation are not known (Radian, 1995).

In addition to the Base Corrective Action Management Unit (CAMU), current Site LF007 operations include the operations at the Affiliate Radio System, the permitted hazardous waste storage facility, and a small arms range. Several large vernal pools are within the site boundaries; some extend north across the Base boundary. The land north of Site LF007, beyond the Base boundary, is privately owned and used for pasture. Until 2002, extensive seasonal ponding occurred in the eastern-central portion of the site because of the subsidence of the soil cover overlying the former landfill trenches. The elimination of the depressions caused by settling reduced seasonal surface water ponding at the landfill.

A groundwater interceptor trench was constructed upgradient (relative to groundwater movement across the site) from the CAMU to physically capture groundwater and maintain a minimum of 5 feet of separation between contaminated soil in the CAMU and groundwater. Collected groundwater is conveyed around the CAMU and discharged into an infiltration pit downgradient from the CAMU (CH2M HILL, 2002a).

During the NOU RI, Site LF007 was divided into three (3) study areas designated as Sites LF007B, LF007C, and LF007D.

3.2.2 North IRA Geology

Sites FT004, SD031, and LF007 are on Younger Alluvium, which was deposited after the last period of glaciation. This alluvium consists primarily of silts and clays that are low in permeability and do not transmit groundwater readily. On the eastern edge of Site LF007 lies a north-south trending subsurface ridge of Markley Sandstone, resulting in a thinning of the saturated zone toward the east.

The stratigraphy at Site LF007 also consists of fill material (municipal waste) and backfill material. The fill material and municipal waste that overlie the alluvium at Site LF007 consist of sands and gravels interbedded with clay, organic matter, glass, metal, plastic, rubber, construction debris, and small amounts of industrial wastes and fuel sludge. The thickness of the fill material and municipal waste ranges from a few feet to more than 20 feet. Backfill consisting of clayey silt, sand and gravel, and organic matter overlies the fill and is about 1 to 5 feet thick. On the eastern portion of the landfill, the fill and wastes settled unevenly, which resulted in north-south trending depressions in Site LF007D. The depressions were eliminated in 2002 during regrading for the CAMU. The surface at Site LF007B and the western half of the landfill have not been affected by differential settling (CH2M HILL, 2002a).

The saturated zone at Sites FT004 and SD031 ranges in thickness from approximately 20 to 35 feet. The bedrock underlying the alluvium at Sites SD031 and FT004 consists of siltstone and shale (Nortonville Shale). Depth to bedrock ranges from approximately 35 to 50 feet bgs. Groundwater contamination extends to bedrock. The TCE plume extends from the vicinity of MW131x04 approximately 1,000 feet southward, where it was detected at a concentration of 3.4 µg/L at well MW757x04 in 2010. Monitoring well screen intervals vary from 5 to 42 feet bgs at Site FT004 and from 5 to 35 feet bgs at Site SD031 and are adequate to monitor the vertical extent of contamination at these sites.

The saturated zone is approximately 30 to 45 feet thick at Site LF007C. Depth to the shale bedrock in the vicinity of Site LF007C varies from 35 to 55 feet. Monitoring well screen intervals vary from 10 to 50 feet bgs and are adequate to monitor the vertical extent of contamination at the site.

3.2.3 North IRA Groundwater Characteristics

Information regarding groundwater characteristics within the North IRA is summarized in the following list:

- Depth to water within the North IRA is approximately 7 to 15 feet at these sites.
- Regional groundwater flow in the vicinity of Sites FT004, SD031, and LF007 is southeasterly, reflecting the impact of the ridge of Nortonville Shale to the west and the ridge of Markley Sandstone bedrock to the east. Groundwater elevation contours are shown on Figure 3.2-3.
- A groundwater trough is present at Sites FT004 and SD031 because of their location between the groundwater mound at Site LF007 and the ridge of Nortonville Shale to the west. The horizontal hydraulic gradient is approximately 0.004 ft/ft at these sites.
- While the regional groundwater flow direction at Travis AFB is generally toward the south, the groundwater flow system in the vicinity of Site LF007 is influenced by the near-surface bedrock beneath the relatively thin alluvium. A groundwater mound exists in the eastern portion of the site, resulting in radial groundwater flow away from the mound.
- The groundwater elevations at Site LF007, in the vicinity of the groundwater mound, continue to show groundwater movement to the north (off-base) in the vicinity of the landfill. This mound was considered to result from surface water ponding before the CAMU construction. However, the removal of the surface depressions during the CAMU construction and the presence of the interceptor trench do not appear to have affected the groundwater mound. A large seasonal pool is present along the eastern Base boundary, which may be a major source of recharge. The near-surface bedrock also likely affects flow directions in this area.
- It is likely that the groundwater flow direction in the off-base portion of Site LF007C curves back and rejoins the regional southeasterly gradient. Lack of data points and relatively flat horizontal gradients in the off-base area make it difficult to assess groundwater flow directions in Site LF007C.
- In 2Q10, horizontal gradients in the western portion of Site LF007, away from the Site LF007 groundwater mound, were approximately 0.003 ft/ft. Horizontal gradients near the groundwater mound were approximately 0.01 ft/ft.
- In general, vertical gradients at Sites FT004/SD031/LF007 are negligible and ranged from 0.01 ft/ft downward to 0.06 ft/ft upward in 2Q10.

- During 2000 and 2001, the water table dropped from 5 to 10 feet in many Site FT004 wells, which was lower than historical elevations. The decline in groundwater elevations coincided with the startup of the Site FT004 groundwater extraction system. Groundwater elevations have since stabilized and vary seasonally about 2 to 5 feet.
- Groundwater elevations at Site LF007 have a much larger seasonal variation than the rest of the Base. For example, MWEx07 typically varies by as much as 20 feet in 1 year. Other Site LF007 monitoring wells, such as MWDx07 and MWFx07, typically vary by 10 feet in 1 year. These fluctuations are related to the seasonal presence of vernal pools and ponds at Site LF007 that recharge the groundwater system during the winter.

3.2.4 North IRA Groundwater Contamination

This subsection provides summary descriptions of the current groundwater contamination exceeding IRGs at each of the North IRA sites. More complete and detailed information is provided in Sections 4.1 and 4.2 of the 2009-2010 Annual GSAP Report (CH2M HILL, 2011b).

3.2.4.1 Groundwater Contamination at Site FT004

At Site FT004, the primary (i.e., exceeding IRG) groundwater contaminant is TCE. The current horizontal extent of TCE contamination is shown on Figure 3.2-4. A vertical cross section through Site FT004 is shown on Figure 3.2-9.

3.2.4.2 Groundwater Contamination at Site SD031

At Site SD031, the primary groundwater contaminant is 1,1-DCE. The current horizontal extent of 1,1-DCE contamination is shown on Figure 3.2-5. A vertical cross section through Site SD031 is shown on Figure 3.2-8.

3.2.4.3 Groundwater Contamination at Site LF006

The groundwater contaminants at Site LF006 are TCE; 1,1-DCE; total petroleum hydrocarbon as diesel (TPH-D); and total petroleum hydrocarbon as gasoline (TPH-G). TCE is the site indicator chemical. The current horizontal extent of TCE contamination is shown on Figure 3.2-6. A vertical cross section is shown on Figure 3.2-10.

3.2.4.4 Groundwater Contamination at Site LF007

Site LF007B. No groundwater contaminants are present at Site LF007B at concentrations exceeding IRGs.

Site LF007C. At Site LF007C, the primary groundwater contaminant is TCE. The current horizontal extent of TCE contamination is shown on Figure 3.2-7. A vertical cross section is shown on Figure 3.2-11.

Site LF007D. Groundwater contamination at Site LF007D is restricted to a small area in the vicinity of MW261x07 (refer to Figure 3.2-12). At this location, 1,4-dichlorobenzene and benzene were detected at concentrations exceeding IRGs.

3.2.5 Status of Groundwater Interim Remedial Actions

This section summarizes the status of the groundwater IRAs at Sites FT004, SD031, LF006, and LF007C. The main components of the IRA at each site are provided in Table 3.2-1.

3.2.5.1 Status of the Site FT004/SD031 Groundwater IRA

The groundwater IRA at Sites FT004 and SD031 is a combination of GET and MNA. Groundwater extraction and treatment was implemented to achieve the interim RAO of source control in the higher concentration portions of the plumes. MNA assessments were implemented in the portions of the plumes not under the hydraulic influence of the GET system. All the Site FT004 and SD031 extraction wells are currently offline for a rebound study. Groundwater monitoring to assess MNA is ongoing under the GSAP.

The Site FT004/SD031 GET system began operation in 2000 and operated successfully though December 2007. Then, after a steady decline in plume concentrations, the Site SD031 extraction wells and Site FT004 extraction wells EW578x04, EW579x04, and EW580X04 were shut down for a rebound study. Site FT004 extraction wells EW576x04, EW577x04, EW621x04, EW622x04, and EW623x04 remained in operation. The results of the study are reported in the 2009 Annual RPO Report (CH2M HILL, 2010b).

No significant rebound of contaminant concentrations in the Site FT004 and SD031 wells has been observed. Therefore, the rebound study will continue for the remainder of the interim period. In addition, the Site FT004 extraction wells that had continued to pump during the initial stages of the rebound study in 2008 (EW576x04, EW577x04, EW621x04, EW622x04, and EW623x04) were also shut down in March 2009 as part of the ongoing rebound evaluation. None of the Site FT004 and SD031 extraction wells are currently pumping.

3.2.5.2 Status of the Site LF006 Groundwater IRA

The groundwater IRA at Site LF006 is MNA. Groundwater monitoring is being routinely conducted to verify that the downgradient portion of the plume is stable.

3.2.5.3 Status of the Site LF007 Groundwater IRAs

Site LF007B. Routine groundwater monitoring at Site LF007B is being conducted to assess the effectiveness of MNA.

Site LF007C. The Site LF007C GET system continues with normal seasonal operations. Groundwater extraction occurs only when dry conditions exist throughout the vernal pools to avoid adverse impact on the vernal pool habitat. The GET system typically operates between June and October.

The Site LF007C GET began operation in August 2004 using two (2) on-base extraction wells (EW614x07 and EW615x07). The GET system will be optimized in 2011 when the vernal pool is dry. The planned optimization actions are described in the *Site LF007 Remedial Process Optimization Work Plan* (CH2M HILL, 2009b). Figure 3.2-7 shows in situ groundwater samples and potential stepout samples that are planned to be collected after the coordination with USFWS is complete.

Site LF007D. Similar to Site LF007B, routine groundwater monitoring is being conducted at Site LF007D to assess the effectiveness of MNA.

TABLE 3.2-1
Summary of the North Groundwater Interim Remedial Action
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site Contaminant Plume	IRA Objective[a]	Implemented IRA	Primary Components	Status and Comments
FT004 Source Area	Source control	GET	DPE wells, performance monitoring wells, NGWTP air stripper/VGAC (discontinued)	Partial GET system shutdown for a rebound study in January 2008. Complete shutdown in March 2009 to continue the rebound study.
SD031 Source Area	Source control	GET	DPE wells, performance monitoring wells, NGWTP air stripper/VGAC (discontinued)	GET system shutdown for a rebound study since January 2008.
FT004/SD031	MNA[b]	Groundwater monitoring	Monitoring wells	Groundwater monitoring for assessment of MNA is ongoing. The MNA sampling network for Sites FT004/SD031 includes monitoring wells MW134x04, MW584x04, MW587x04, MW591x04, MW757x04, MW571x31, and MW574x31.
LF006	MNA	Groundwater monitoring	Monitoring wells	Groundwater monitoring for MNA is ongoing. The MNA sampling network for Site LF006 includes monitoring wells MW208x06, MW208Dx06, MW259x07, MW1729x31, MW1730x31, and MW1731x31.
LF007B	MNA[b]	Groundwater monitoring	Monitoring wells	Groundwater monitoring for assessment of MNA is ongoing. The MNA sampling network for Site LF007B includes monitoring wells MW207x06, MW210x06, MW128x07, MW129x07, MW303x07, and MWGx07.
LF007C	Migration control	GET	On-base groundwater extraction wells and performance monitoring wells. Treatment using air stripper/VGAC at NGWTP discontinued. Currently using LGAC treatment.	GET system is in seasonal operation. Optimization of the GET system is planned for 2011.
LF007C	Off-base remediation	GET	Off-base performance monitoring wells (groundwater extraction wells located on-base)	GET system is in seasonal operation. Optimization of the GET system is planned for 2011.
LF007D	MNA[b]	Groundwater monitoring	Monitoring wells	Groundwater monitoring for assessment of MNA is ongoing. The MNA sampling network for Site LF007D includes monitoring wells MW201x07, MW261x07, MW284x07, MW600x07, MW601x07, MW612x07, MW613x07, MWAx07, MWBx07, MWCx07, MWDx07, and MWFx07.

[a] IRA objective specified in the NEWIOU Groundwater IROD (Travis AFB, 1998).
[b] MNA Assessment results are documented in the NAAR (CH2M HILL, 2010a).

Notes:

DPE = dual-phase extraction
LGAC = liquid-phase granular activated carbon
VGAC = vapor-phase granular activated carbon

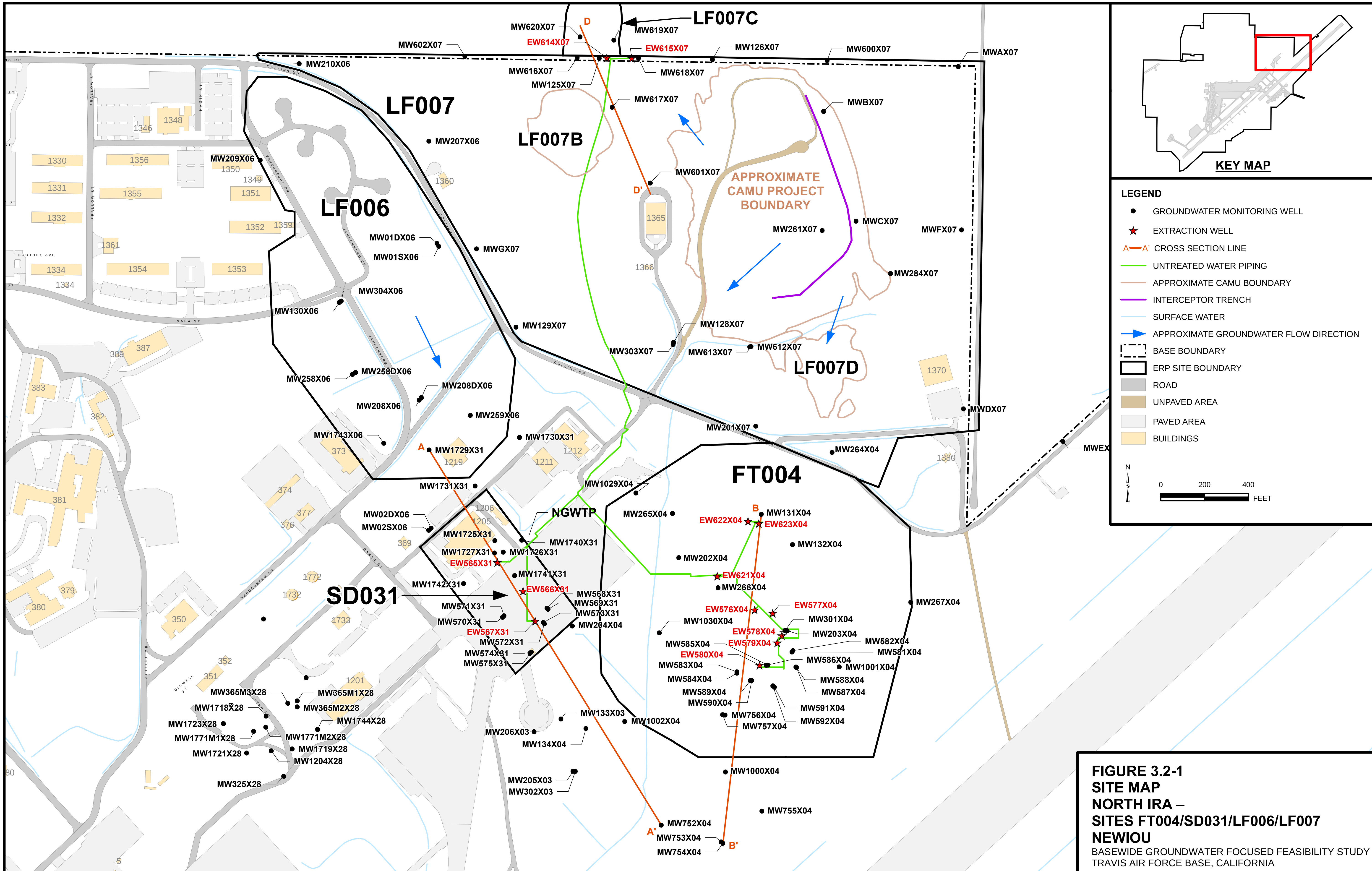


FIGURE 3.2-1
SITE MAP
NORTH IRA –
SITES FT004/SD031/LF006/LF007
NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_2-1_FT004_SD031_LF007_SITE_MAP.MXD MSCHROCK 9/7/2011 10:13:00 AM

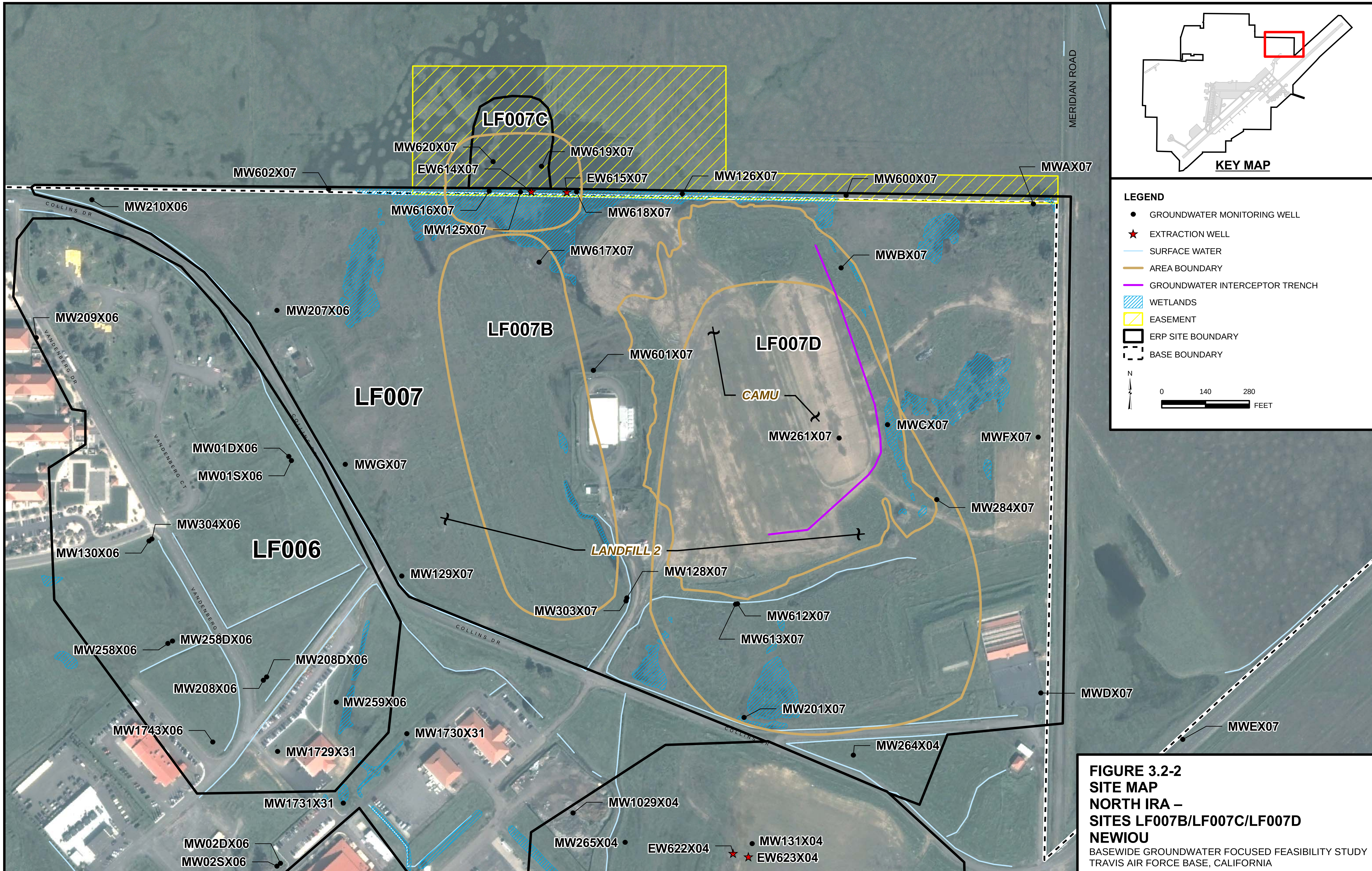


FIGURE 3.2-2
SITE MAP
NORTH IRA –
SITES LF007B/LF007C/LF007D
NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_2-2_SITE_LF007C.MXD MSCHROCK 4/22/2011 17:37:38

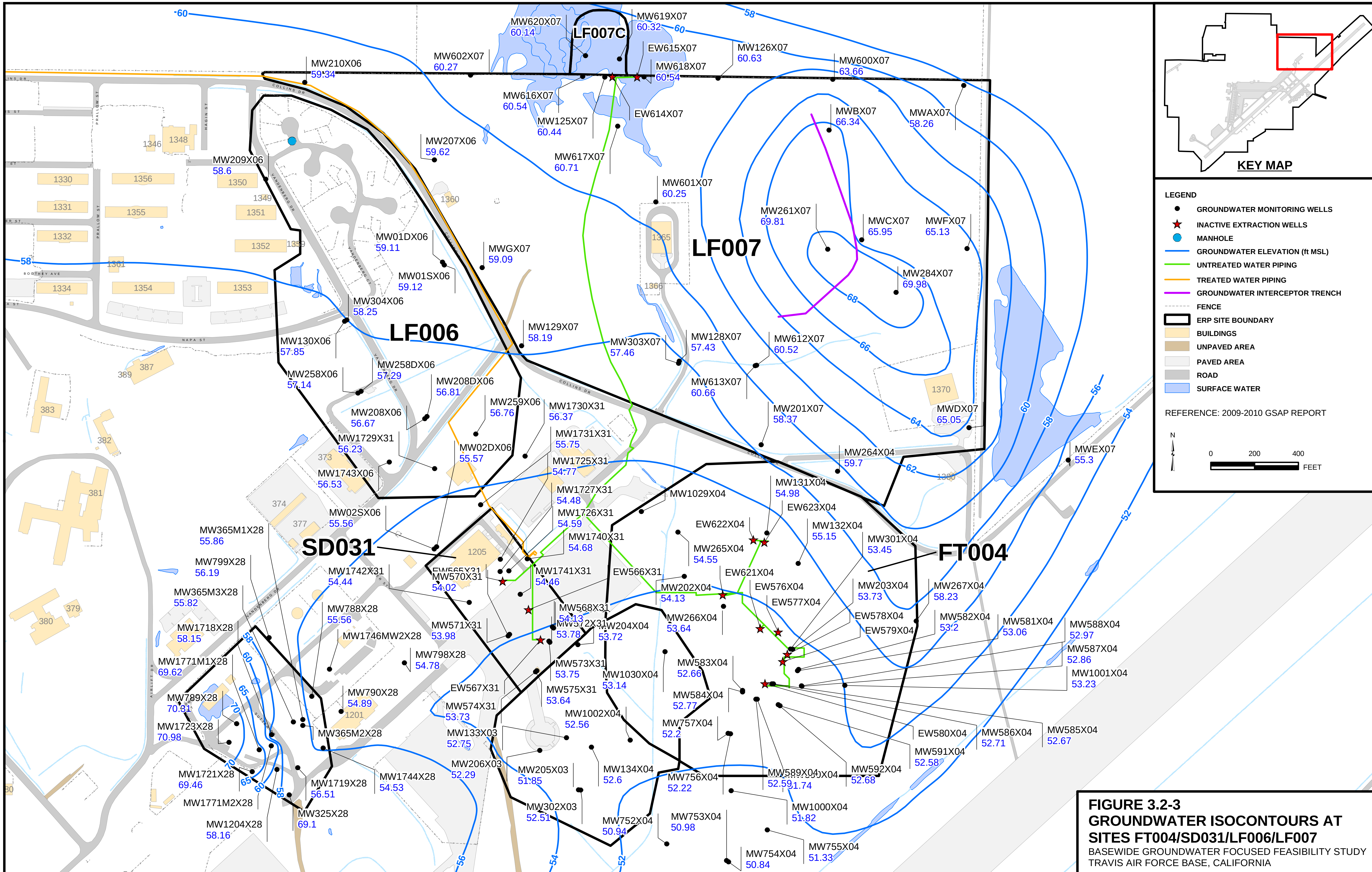
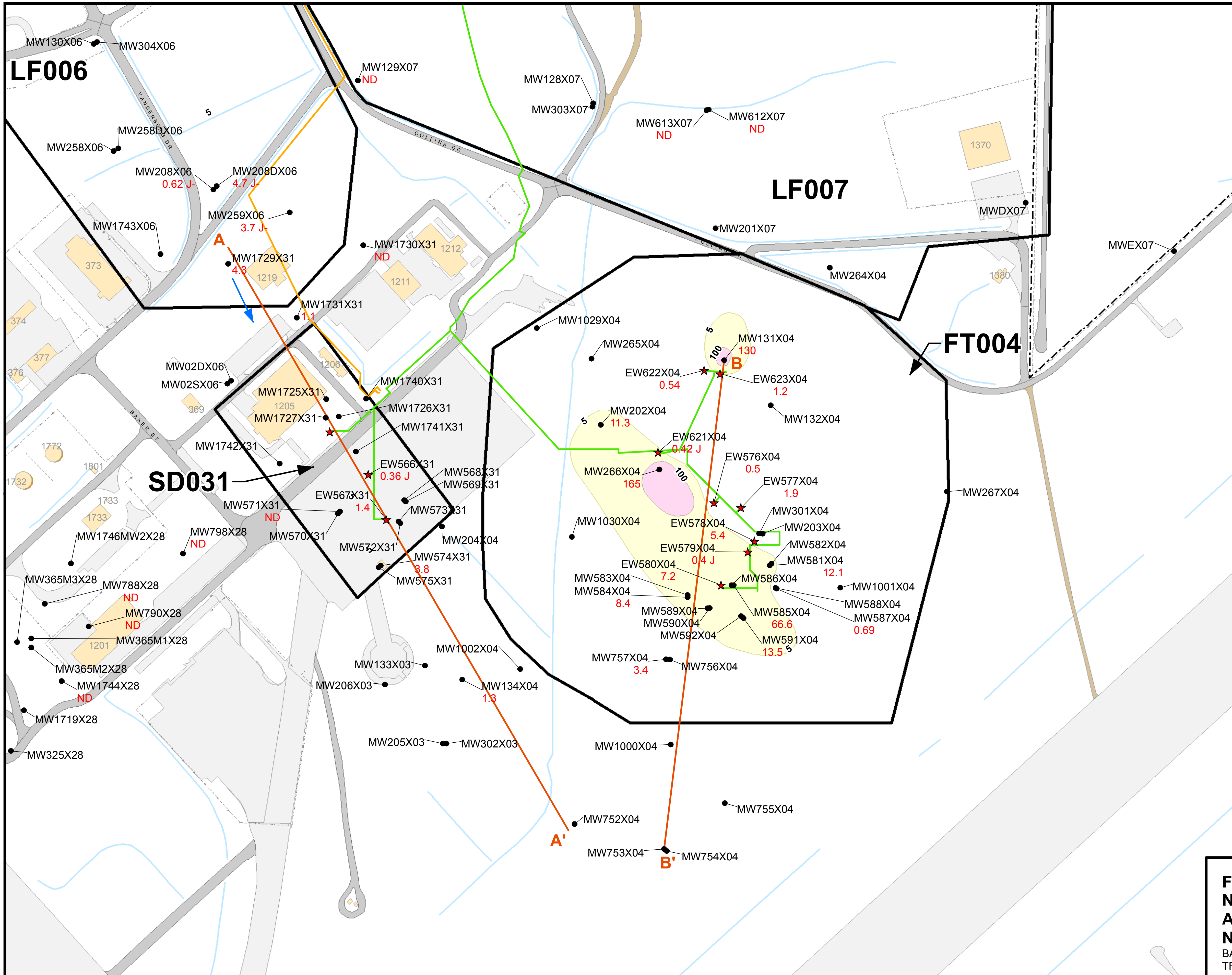


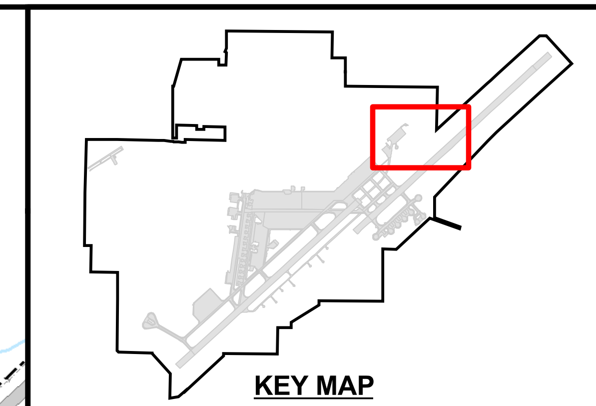
FIGURE 3.2-3
GROUNDWATER ISOCONTOURS AT SITES FT004/SD031/LF006/LF007

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIGURE_3_2-3_FT004_SD031_LF007_GW_2010.MXD MSCHROCK 4/22/2011 17:36:56





LEGEND

- ● GROUNDWATER MONITORING WELL
- □ PIEZOMETER
- ★ EXTRACTION WELL
- A—A' CROSS SECTION LINE
- GROUNDWATER FLOW DIRECTION
- UNTREATED WATER PIPING
- TREATED WATER PIPING

TCE CONCENTRATIONS (µg/L)

- 5 ≤ TCE <100
- 100 ≤ TCE <1,000
- FENCE
- ERP SITE BOUNDARY
- BASE BOUNDARY
- BUILDINGS
- ROAD
- UNPAVED AREA
- PAVED AREA
- SURFACE WATER
- ABOVEGROUND STORAGE TANKS

SAMPLE LOCATION — **MW591X04**
TCE (µg/L) — **0.21J**
FLAG

NOTES:
J = REPORTED ANALYTICAL VALUE IS ESTIMATED
ND = NOT DETECTED; THE DETECTION LIMIT FOR TCE IS 0.5 µg/L.

REFERENCE: 2009-2010 GSAP REPORT

N
0 150 300
FEET

FIGURE 3.2-4
NORTH IRA – TCE DISTRIBUTION AT SITES FT004/SD031
NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_2-4_TCE_FT004.MXD MSCHROCK 4/8/2011 16:31:56

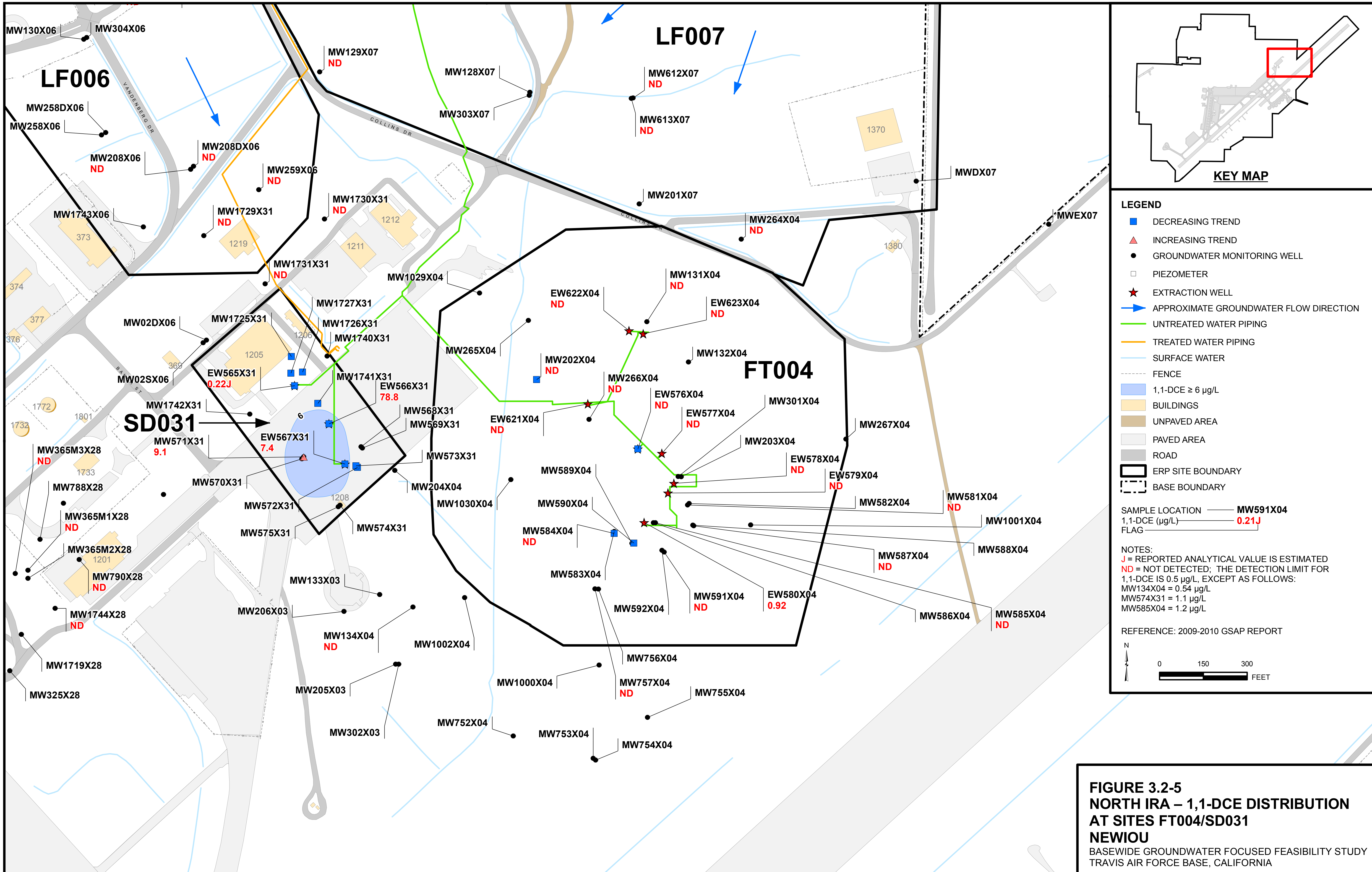


FIGURE 3.2-5
NORTH IRA – 1,1-DCE DISTRIBUTION AT SITES FT004/SD031 NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_2-5_DCE_FT004.MXD MSCHROCK 6/14/2011 23:38:13

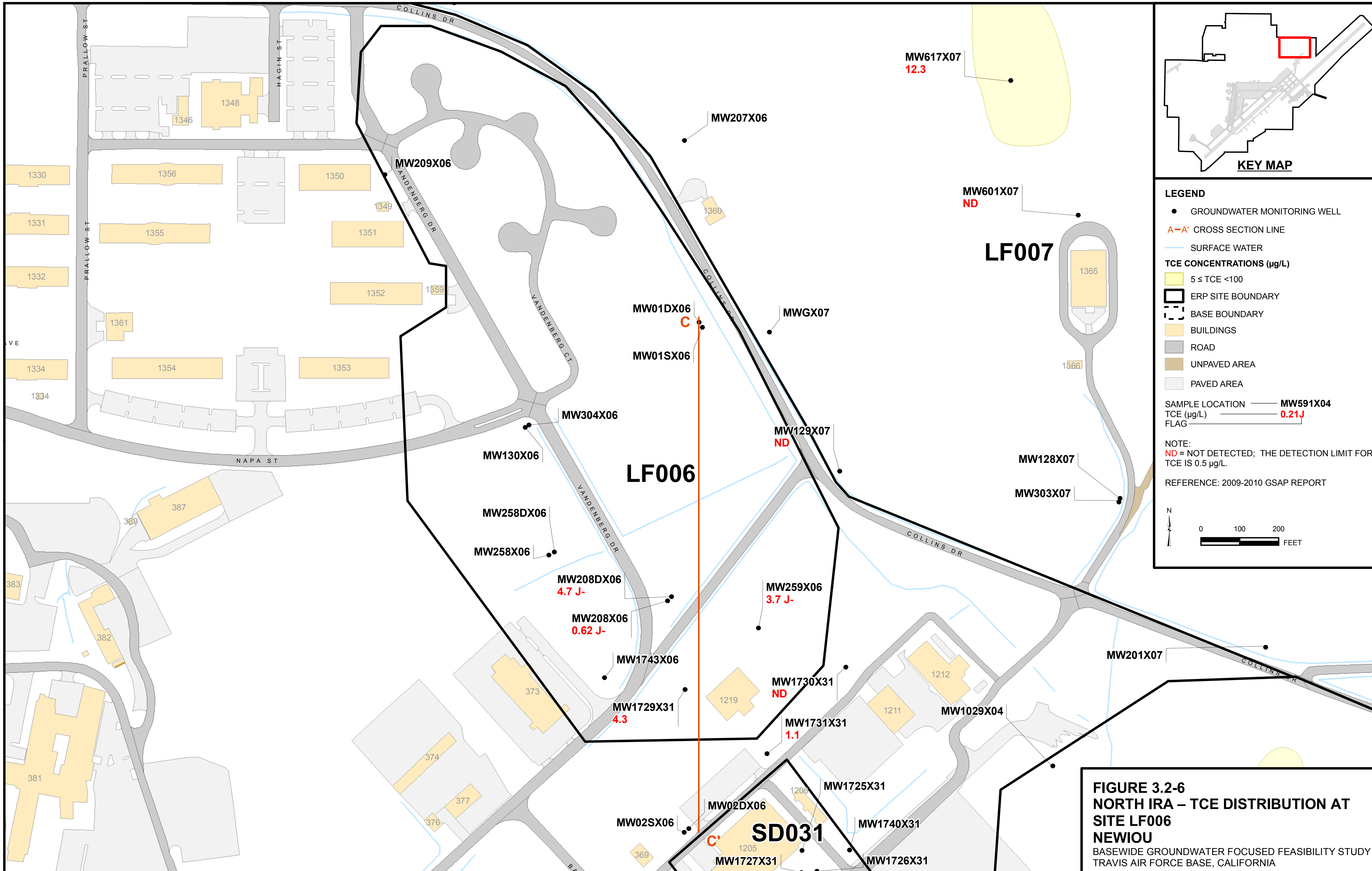


FIGURE 3.2-6
NORTH IRA – TCE DISTRIBUTION AT SITE LF006
NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_2-6_TCE_LF006.MXD MSCHROCK 4/8/2011 17:42:08

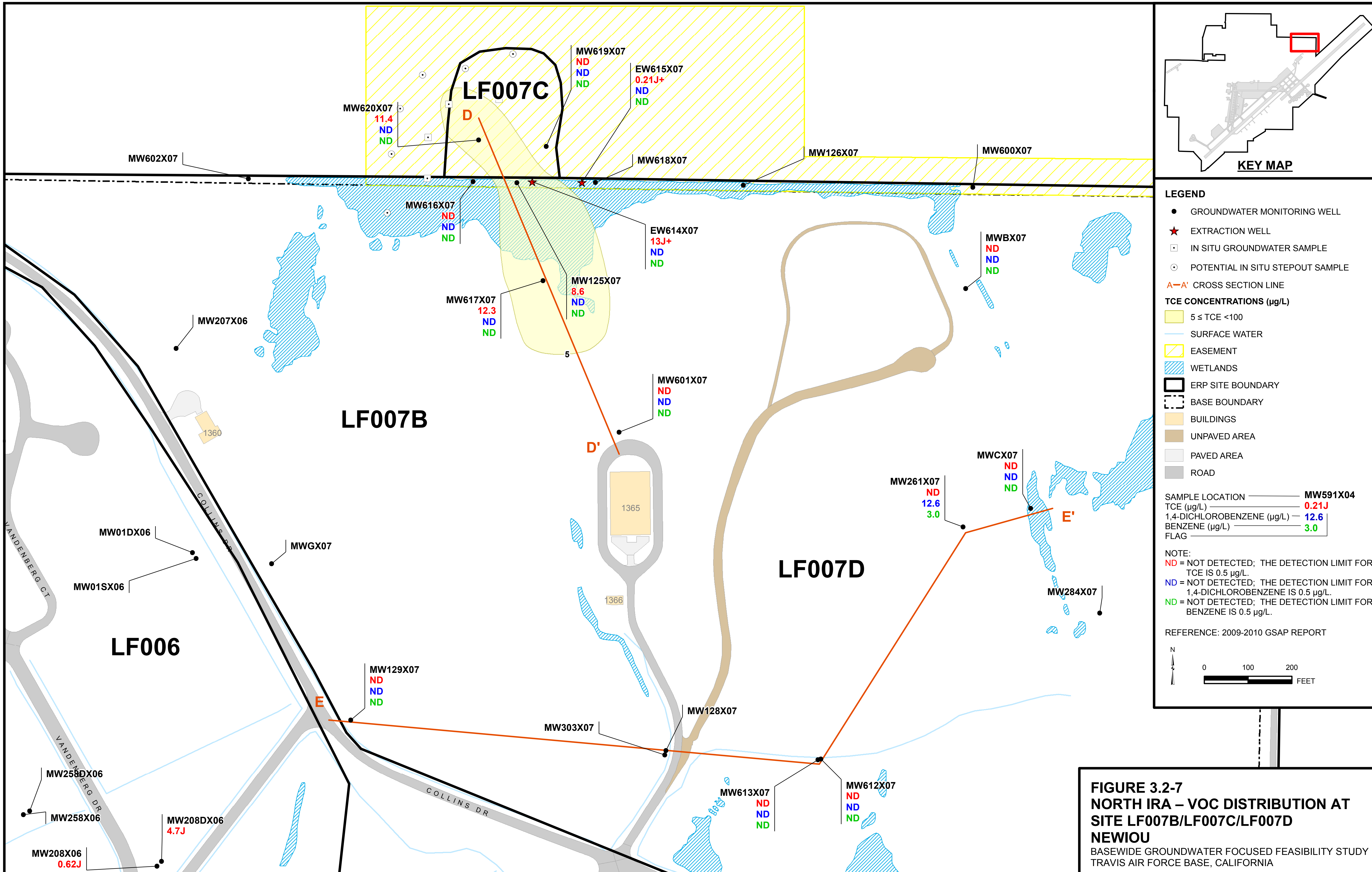


FIGURE 3.2-7
NORTH IRA – VOC DISTRIBUTION AT SITE LF007B/LF007C/LF007D NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_2-7_TCE_LF007C.MXD MSCHROCK 9/7/2011 3:57:32 AM

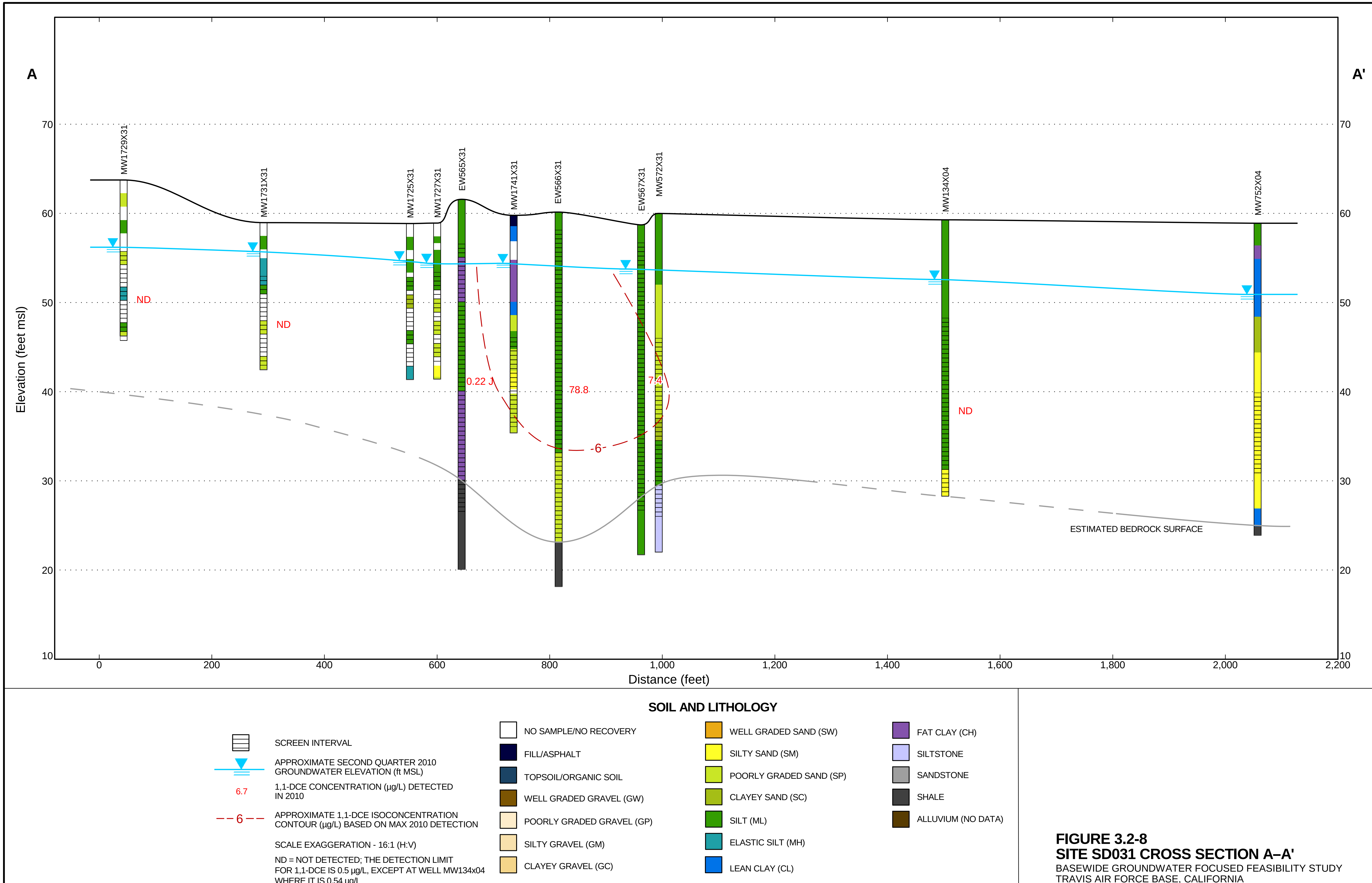


FIGURE 3.2-8
SITE SD031 CROSS SECTION A–A'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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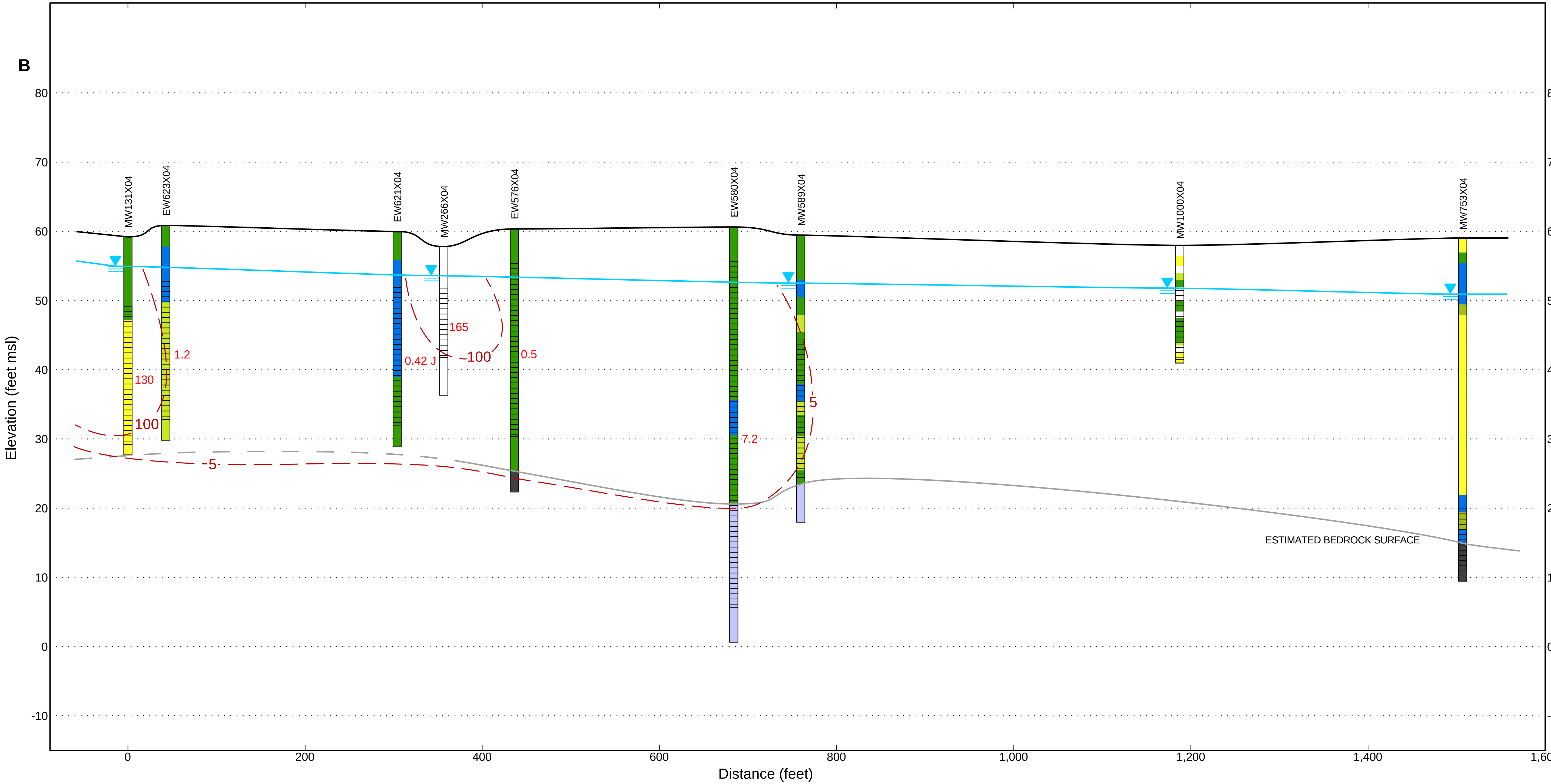

SOIL AND LITHOLOGY

SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)

6.7 TCE CONCENTRATION (µg/L) DETECTED IN 2010

— 5 — APPROXIMATE TCE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION

SCALE EXAGGERATION - 8:1 (H:V)

- NO SAMPLE/NO RECOVERY
- FILL/ASPHALT
- TOPSOIL/ORGANIC SOIL
- WELL GRADED GRAVEL (GW)
- POORLY GRADED GRAVEL (GP)
- SILTY GRAVEL (GM)
- CLAYEY GRAVEL (GC)
- WELL GRADED SAND (SW)
- SILTY SAND (SM)
- POORLY GRADED SAND (SP)
- CLAYEY SAND (SC)
- SILT (ML)
- ELASTIC SILT (MH)
- LEAN CLAY (CL)
- FAT CLAY (CH)
- SILTSTONE
- SANDSTONE
- SHALE
- ALLUVIUM (NO DATA)

FIGURE 3.2-9
SITE FT004 CROSS SECTION B–B'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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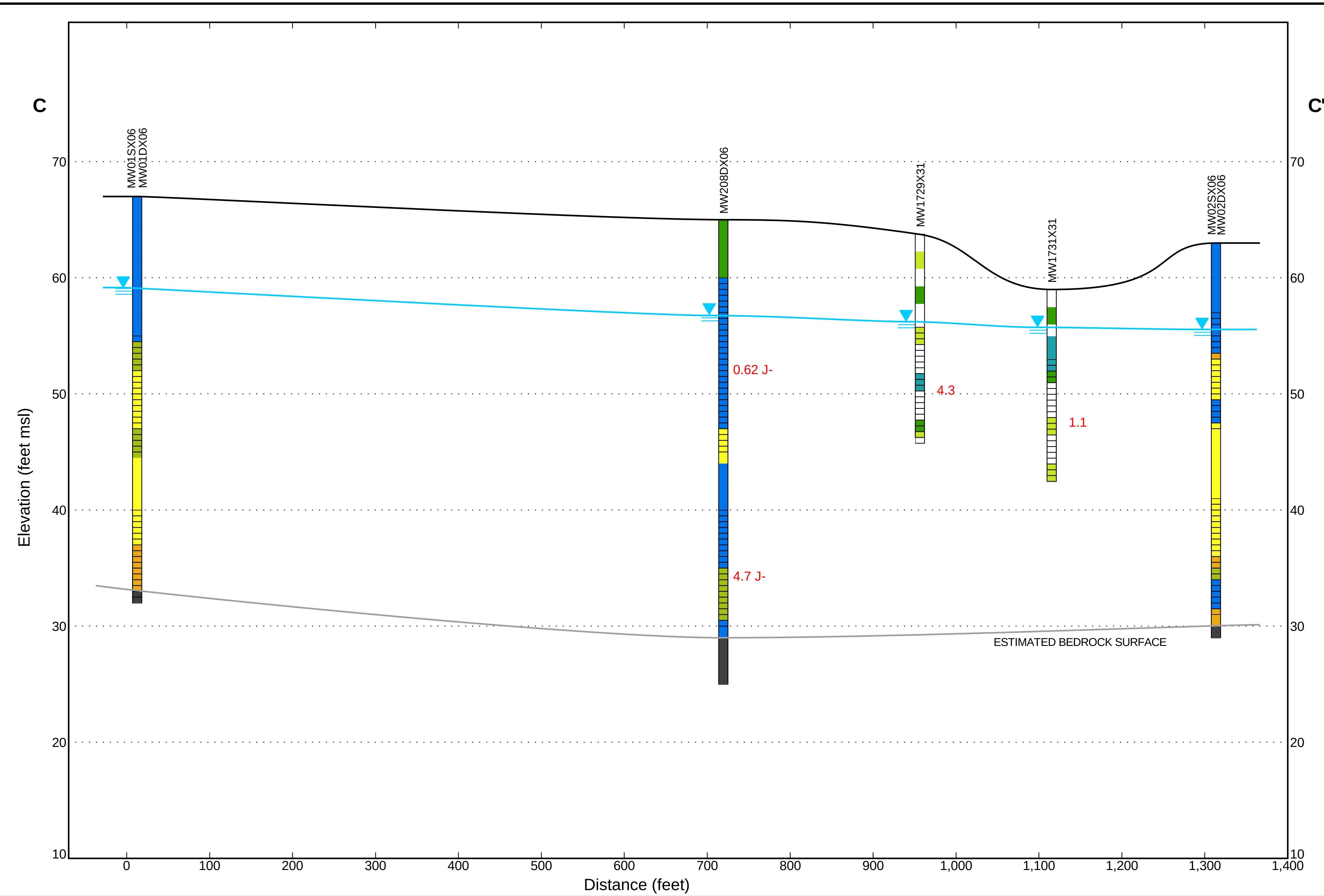
ES082009007SAC Figure_3.2-9.ai 04.11.2011 tdaus



SOIL AND LITHOLOGY

SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)

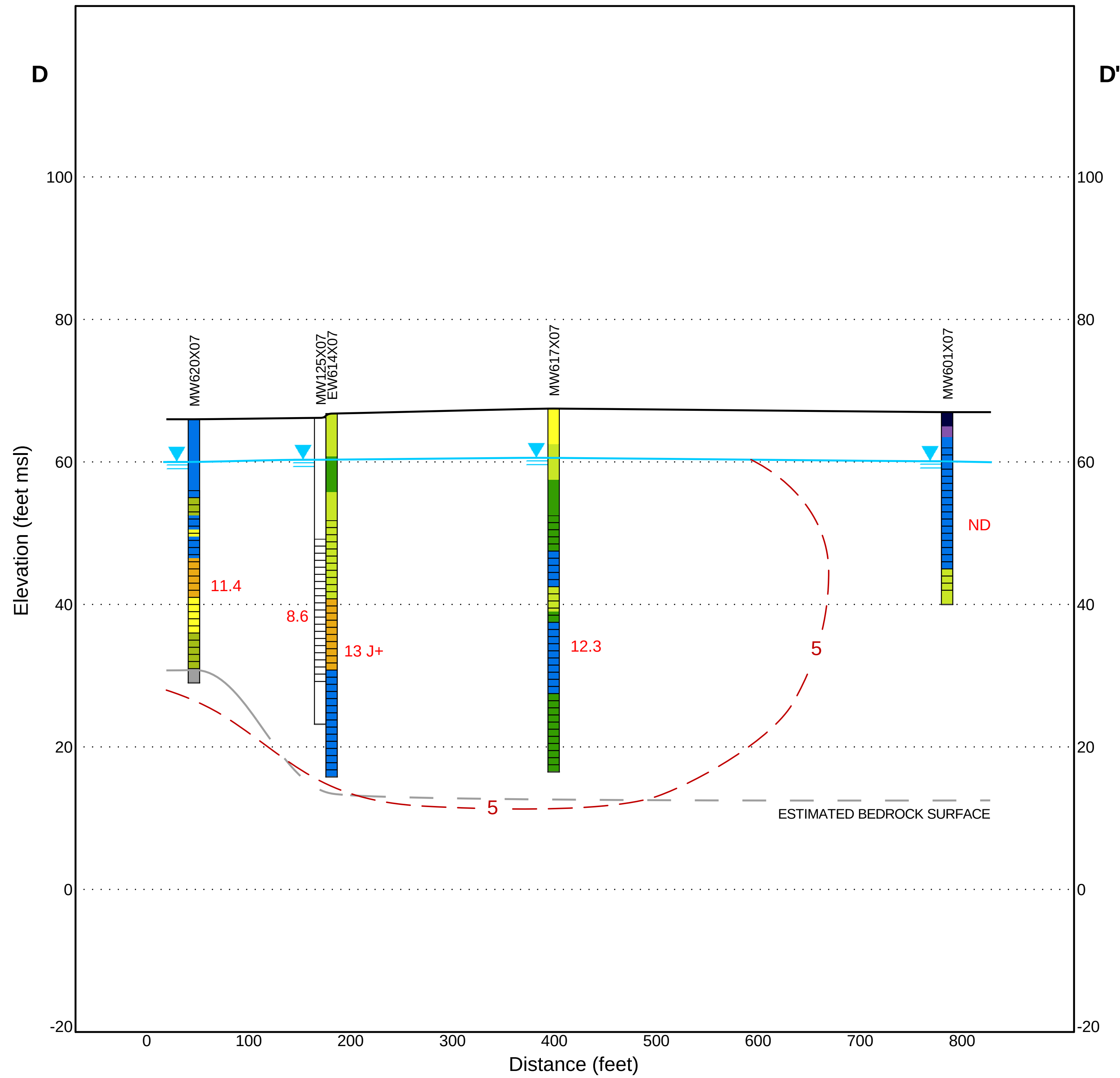
6.7 TCE CONCENTRATION (µg/L) DETECTED IN 2010

SCALE EXAGGERATION - 14:1 (H:V)

- NO SAMPLE/NO RECOVERY
- FILL/ASPHALT
- TOPSOIL/ORGANIC SOIL
- WELL GRADED GRAVEL (GW)
- POORLY GRADED GRAVEL (GP)
- SILTY GRAVEL (GM)
- CLAYEY GRAVEL (GC)
- WELL GRADED SAND (SW)
- SILTY SAND (SM)
- POORLY GRADED SAND (SP)
- CLAYEY SAND (SC)
- SILT (ML)
- ELASTIC SILT (MH)
- LEAN CLAY (CL)
- FAT CLAY (CH)
- SILTSTONE
- SANDSTONE
- SHALE
- ALLUVIUM (NO DATA)

FIGURE 3.2-10
SITE LF006 CROSS SECTION C–C'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL



SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)

6.7 TCE CONCENTRATION (µg/L) DETECTED IN SECOND QUARTER 2010

— — 5 — — APPROXIMATE TCE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION

SCALE EXAGGERATION - 7:1 (H:V)

ND = NOT DETECTED; THE DETECTION LIMIT FOR TCE IS 0.5 µg/L

SOIL AND LITHOLOGY

NO SAMPLE/NO RECOVERY
FILL/ASPHALT
TOPSOIL/ORGANIC SOIL
WELL GRADED GRAVEL (GW)
POORLY GRADED GRAVEL (GP)
SILTY GRAVEL (GM)
CLAYEY GRAVEL (GC)
WELL GRADED SAND (SW)
POORLY GRADED SAND (SP)
SILTY SAND (SM)
CLAYEY SAND (SC)
SILT (ML)
ELASTIC SILT (MH)
LEAN CLAY (CL)
FAT CLAY (CH)
SILTSTONE
SANDSTONE
SHALE
ALLUVIUM (NO DATA)

FIGURE 3.2-11
SITE LF007C CROSS SECTION D–D'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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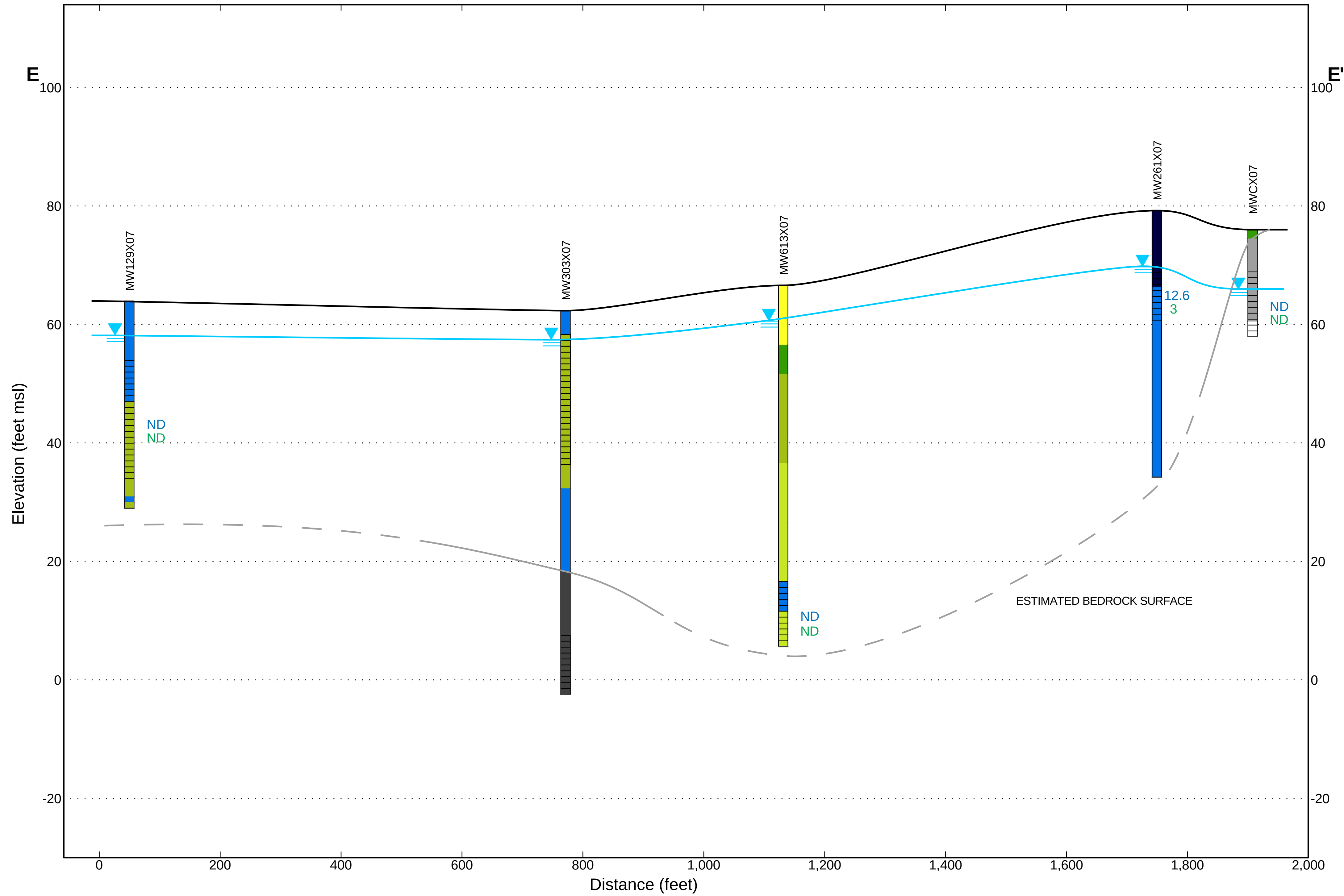
ES082009007SAC Figure_3.2-11.ai 04.11.2011 tdaus



SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)

6.7 — 1,4-DICHLOROBENZENE CONCENTRATION (µg/L) DETECTED IN 2010

3 — BENZENE CONCENTRATION (µg/L) DETECTED IN 2010

SCALE EXAGGERATION - 10:1 (H:V)

ND = NOT DETECTED; THE DETECTION LIMIT FOR BOTH BENZENE AND 1,4-DICHLOROBENZENE IS 0.5 µg/L

SOIL AND LITHOLOGY

NO SAMPLE/NO RECOVERY
FILL/ASPHALT
TOPSOIL/ORGANIC SOIL
WELL GRADED GRAVEL (GW)
POORLY GRADED GRAVEL (GP)
SILTY GRAVEL (GM)
CLAYEY GRAVEL (GC)
WELL GRADED SAND (SW)
SILTY SAND (SM)
POORLY GRADED SAND (SP)
CLAYEY SAND (SC)
SILT (ML)
ELASTIC SILT (MH)
LEAN CLAY (CL)
FAT CLAY (CH)
SILTSTONE
SANDSTONE
SHALE
ALLUVIUM (NO DATA)

FIGURE 3.2-12
SITE LF007D CROSS SECTION E–E'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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ES082009007SAC Figure_3.2-12.ai 08.31.2011 tdaus

3.3 Central IRA Conceptual Site Models

This section provides the CSM for NEWIOU Site SS016 located in the western portion of Travis AFB.

Additional descriptions of the site geology, groundwater characteristics, and groundwater contamination are provided in Section 4.4 of the 2009-2010 Annual GSAP Report (CH2M HILL, 2011b).

3.3.1 Site Description

Site SS016 encompasses approximately 210 acres in the center of Travis AFB, near the Base control tower. The site extends across an active aircraft parking ramp, taxiway, and runway. At the northern periphery of the site are buildings, roads, and other facilities that support airfield operations. A site map is provided on Figure 3.3-1.

Site SS016 comprises two (2) groundwater contaminant source areas: the OSA and the TARA. The locations of the OSA and TARA are shown on Figures 3.3-1 and 3.3-2. A more detailed map of the OSA is shown on Figure 3.3-3.

3.3.1.1 Oil Spill Area

The OSA is located at the northwestern corner of Site SS016 and is associated with Building 18 and an adjacent wash rack. Both were constructed in 1960 as components of a degreasing facility. Historical degreasing operations were conducted in Building 18 and at the wash rack from about 1960 through the 1990s. Degreasing operations are no longer conducted at either of the facilities.

Building 18. Historically, Building 18 housed an industrial degreasing process. Tanks in the northern portion of the building contained chemicals for the degreasing process. These tanks were located in a sub-grade floor approximately 5 feet below the surface-grade floor. The sub-grade tank area is covered by a false floor that is structurally supported by steel columns. At the northern end of the building is a collection sump that was connected to a 28,000-gallon steel-reinforced concrete UST. The 28,000-gallon UST was located adjacent to the northwestern portion of the building and was divided in half by a wall. The eastern half of the UST was used as a retention tank, and the western half was used as an OWS. The OWS was removed in 1997, and the UST was removed from the building and disposed of in January 1998 (Supervisor of Shipbuilding, Conversion and Repair [SSPORTS], 1998).

The southern portion of Building 18 was also historically used as part of the degreasing process and contained additional tanks and spray booths. This area was later remodeled to house a laboratory, a bead blaster and oven room, and multiple offices.

The northern portion of Building 18 is currently used as a storage facility. The southern portion of the building is not currently used.

Historically, wastes generated at Building 18 were disposed of by different means. From about 1960 to 1968, liquid wastes flowed through a north-south pipeline that extended from tanks in Building 18 to a catch basin underlying an adjacent wash rack and subsequently to the storm drain. From 1968 through 1998, liquid wastes were disposed of through the OWS or by contracted disposal services. Some wastes may also have been sent to an on-base fire training facility.

Wash Rack. South of Building 18 was a former wash rack used to degrease jet engines. A canopy over the wash rack was constructed in 2007. The wash rack canopy included a steel frame structure supporting a sheet metal roof. Underneath the roof was a concrete pad with a collection drain near the center. The drain discharged to a catch basin that was connected to an underground stormwater drainage pipe. The connector pipe between the catch basin and the stormwater drainage pipe was constructed of vitrified clay and had been slip lined, possibly to repair a break in the clay pipe. In September 2010, the collection drain, catch basin, and the wash rack structure were removed as part of the installation of a below-grade in situ bioreactor.

Between approximately 1960 and 1968, liquid wastes from degreasing operations in Building 18 were also conveyed to the wash rack catch basin through a separate underground pipeline.

3.3.1.2 Tower Area Removal Action

In 1995, the TARA was implemented to reduce worker exposure to VOC-contaminated groundwater during installation of a new fuel hydrant system underneath the 300 Ramp. The TARA system included two (2) parallel 700-foot-long horizontal extraction wells (600 feet screened). The water in each horizontal extraction well drains to a low point where it is removed by a vertical well and conveyed to the CGWTP by underground pipeline (Radian, 1996a).

3.3.2 Geology

The geology at Site SS016 consists of a relatively thin cover of alluvium overlying the eastern portion of a submerged bedrock ridge. The subsurface bedrock ridge strikes from the northwest to southeast and plunges to the southeast. A surface outcrop of the bedrock ridge is present to the west of Site SS016 near the intersection of Hangar Avenue and Ragsdale Street. The bedrock ridge runs through the OSA source area and along the western portion of Site SS016. The bedrock ridge also runs through Sites SS015 and ST027, where bedrock has been encountered as shallow as 2 feet bgs. Structurally, the bedrock at the OSA is part of the western slope of an anticline that plunges to the southeast. The anticline is composed of Markley Sandstone; the syncline or trough is composed of Nortonville Shale (Weston, 1995). Both the Markley Sandstone and the Nortonville Shale have been observed in site soil borings.

The alluvium in the OSA source area ranges from approximately 10 to 16 feet in thickness and consists of interbedded clays and silts in the vicinity of Building 18. Hydraulically downgradient and to the southeast of the Building 18, beneath the parking apron, alluvium increases to a thickness of approximately 30 feet. As the alluvium thickens away from the source area, it becomes coarser grained with sand zones up to approximately 17 feet thick. The alluvium becomes sandier approximately 200 feet downgradient of the wash rack catch basin where sand intervals were observed in borings for MW214x16 and HP2067x16.

Bedrock at the OSA source area consists predominantly of a highly fractured and weathered siltstone associated with the Nortonville Shale. The siltstone has a pervasive platy texture that appears to have increased the permeability of the formation.

Along the western portion of Site SS016, near monitoring wells MW103x16, MW239x16, MW2020x16, MW2023x16, MW2109x16, MW2111Ax16, MW2111Bx16, and boring HP2024x16, Markley Sandstone has been observed beneath the unconsolidated alluvium.

3.3.3 Groundwater Characteristics

Groundwater flow within the OSA source area is primarily by fracture flow in the siltstone. In areas where the Markley Sandstone is highly weathered, groundwater flow also occurs within the weathered sandstone. During the 2010 field investigation of the OSA source area, groundwater was not observed in the unconsolidated alluvium or along the alluvium/bedrock interface because of the dense clay and silt lithology. Groundwater was only observed in the OSA source area borings that had been drilled into the bedrock. Hydraulically downgradient of the OSA source area, in the area underlying the aircraft parking ramp, the alluvium thickens and becomes more permeable. Sand intervals up to 17 feet thick are present in this area and the groundwater transitions to more alluvial flow. In the central portion of Site SS016, groundwater elevation contours indicate the presence of a southeast-trending groundwater trough caused by the relatively thicker alluvium. Groundwater elevation contours for Site SS016 are shown on Figure 3.3-4.

Groundwater characteristics at Site SS016 are further summarized in the following list:

- **Groundwater Depth –** Depth to groundwater ranges from approximately 7 to 17 feet bgs. Within the OSA source area, the depth ranges from 7 to 14 feet bgs.
- **Flow Direction and Horizontal Gradient –** The regional groundwater flow direction is toward the south-southeast because of the presence of the Markley Sandstone ridge located along the western portion of the site. Horizontal gradients are approximately 0.004 ft/ft in the downgradient alluvium and 0.01 ft/ft in the bedrock within the OSA source area.
- **Vertical Gradient –** Vertical gradients in the alluvium are small (≤0.01 ft/ft). Both upward and downward vertical gradients are observed at the site. The vertical gradient between the alluvium and bedrock is 0.001 ft/ft downward in well pair MW214x16/MW305x16.
- **Seasonal Variation –** Groundwater elevations are relatively stable with no long-term increasing or decreasing trend. Seasonal variations of approximately 2 to 4 ft/year are typically observed.
- **Hydraulic Conductivity –** The hydraulic conductivity for the bedrock fracture flow observed in the OSA source area at MW212x16 (1988) is 0.5 ft/day (Weston, 1988). Hydraulic conductivities observed in the downgradient alluvial transition at MW214x16 range from 85 to 105 ft/day (Weston, 1988, 1992).
- **Flow Velocity –** The approximate groundwater flow velocity in the alluvium downgradient of the OSA source area is about 0.1 ft/day or approximately 40 ft/year. The average linear flow velocity is estimated by Darcy's Law using a horizontal hydraulic gradient of 0.004 ft/ft, an average hydraulic conductivity of 5 ft/day, and assuming an effective porosity of 20 percent (typical for the fine-grained sediments encountered at the site).

Groundwater in monitoring wells within the OSA source area have groundwater potentiometric heads that are up to 5 feet above the alluvium/bedrock interface, suggesting that the groundwater system is partially confined.

3.3.4 Soil Contamination

The most frequently detected and most widely distributed soil contaminant at Site SS016 is TCE. Soil sampling conducted as part of a 2010 data gaps investigation evaluated soils located beneath the Building 18 sump, underlying the central portion of the tank room, and adjacent to the catch basin beneath the drain in the wash rack. The analytical results of the soil samples indicated elevated concentrations of TCE in the soils immediately adjacent to the catch basin. TCE concentrations from soil samples collected at 5-foot intervals from 5 to 25 feet ranged from 8,400 to 634,000 micrograms per kilogram, with the highest TCE concentration found at 15 feet bgs. These analytical results are consistent with historical soil results indicating elevated TCE concentrations in the wash rack area.

During air knifing activities for utility clearance of the borehole adjacent to the catch basin, a clear liquid with a strong odor was observed seeping from the soil at 2.5 feet bgs. The seeping liquid partially filled the boring. A sample of the liquid was collected and analyzed. Three (3) primary contaminants were detected: TCE (8.6 µg/L); cis-1,2-DCE (1,180 µg/L); and vinyl chloride (321 µg/L). Stained soils with strong solvent odors were also observed during air knifing activities at MW2022x16, from 1 to 5 feet bgs, and at MW2112Ax16 and MW2112Bx16, from 1 to 4 feet bgs; these borings are located in the wash rack area, near the catch basin.

Stained soils with strong solvent odors were also observed during air knifing activities from 2 to 2.5 feet bgs at MW2111Ax16 and MW2111Bx16, which are located in a roadway adjacent to the parking apron southwest of the wash rack area. Boring MW2111Ax16 is near the historically reported site of soapy runoff from Building 18.

Although elevated TCE concentrations were detected in the catch basin area, low to non-detect concentrations of TCE were detected in the soil beneath the sump and in the central portion of the tank room. Additionally, TCE concentrations detected in the groundwater samples for MW2111Ax16 and MW2111Bx16 were 16.5 and 254 µg/L, respectively.

3.3.5 Groundwater Contamination

TCE and cis-1,2-DCE are the most frequently detected and most widely distributed groundwater contaminants at Site SS016. The current distribution of TCE is shown on Figure 3.3-5. A more detailed map that shows TCE distribution within the OSA source area is shown on Figure 3.3-6. The distribution of cis-1,2-DCE is shown on Figure 3.3-7. Cross sections showing the vertical distribution of contamination are shown on Figures 3.3-8. 3.3-9, and 3.3-10.

The highest concentration of TCE observed within the OSA is from an in situ groundwater sample collected near MW2020x16. The concentration of TCE in this sample was 319,000 µg/L in August 2009. Subsequent sampling results from MW2020x16 also detected TCE at concentrations exceeding 100,000 µg/L: 210,000 µg/L in September 2009 and 151,000 µg/L in April 2010. This well is located adjacent to the former wash rack catch basin.

The concentrations of TCE in MW2020x16 also suggest that DNAPL is likely present at this location.

In addition to MW2020x16, samples from eight (8) wells or in situ sampling locations (EW003x16, MW2026x16, HP2067x16A, HP2067x16B, MW2109x16, PZ-Ax16, PZ-Bx16, and TPE-Wx16) have also had concentrations of TCE greater than 10,000 µg/L. Seven (7) of these locations appear to be screened in bedrock. Only the shallow sample from HP2067x16 is believed to have been collected in alluvium. This boring is located where the alluvium begins to thicken and TCE contamination within the bedrock is released to the alluvium.

3.3.6 Contaminant Source

The likely source of soil and groundwater contamination within the OSA source area is the wash rack catch basin. From 1960 to 1968, degreasing waste liquids that contained TCE were transported via pipeline from the tank room in Building 18 to the wash rack catch basin. Long-term leakage of wastewater from the catch basin likely occurred. Additional releases of wastewater from the catch basin were likely associated with jet engine degreasing operations at the wash rack.

The source of the TCE release at the OSA is believed to be a break in the storm sewer drainage line immediately downgradient of the catch basin for the following reasons:

- The elevated TCE concentrations in the soil and the groundwater in the boring adjacent to the catch basin suggest the presence of DNAPL.
- The highest TCE concentrations detected at the site are in the vicinity of the catch basin.
- During 2010 field activities, the storm sewer drainage line immediately adjacent to and downgradient of the catch basin was observed to be slip-lined, indicating that it had been damaged and repaired.

It is likely that water from the cleaning activities at the wash rack and from runoff associated with rain events that entered the wash rack drainage system was the driving mechanism for the migration of the TCE into and through the shallow and highly fractured bedrock. Further downgradient, dissolved TCE flows from the fractured, more permeable bedrock into the alluvium downgradient of the OSA source area beneath the parking apron which is thicker, coarser grained, and can transport groundwater.

3.3.7 Status of Groundwater Interim Remedial Action

Active groundwater IRAs are in operation within both the OSA and TARA components of Site SS016. The main components of the IRAs are summarized in Table 3.3-1.

3.3.7.1 Status of the OSA Component of the Site SS016 IRA

Between April 1997 and April 2010, the OSA groundwater IRA consisted of a horizontal extraction well (EW003x16) that runs through the OSA source area, a vertical 2-Phase® extraction well (TPE-W) adjacent to the southern side of the wash rack, and two (2) vertical extraction wells (EW610x16 and EW605x16) located within the aircraft parking ramp approximately 800 and 1,700 feet southeast of the wash rack. The locations of these extraction wells are shown on Figures 3.3-1, 3.3-2, and 3.3-3.

During the interim operation period, soil vapor from 2-Phase® extraction well TPE-W was treated by ThOx at a wellhead treatment unit. In April 2010, 2-Phase® extraction of soil vapor and groundwater and the vapor treatment using the ThOx unit were discontinued.

Treatment of groundwater removed by extraction wells TPE-W, EW003x16, EW610x16, and EW605x16 at the CGWTP using ultraviolet oxidation (UV/Ox) was also discontinued in April 2010. The CGWTP now uses LGAC to treat groundwater extracted from the OSA.

3.3.7.2 OSA Source Area IRA Optimization

During 2010, an optimization of the current OSA source area IRA was conducted. In lieu of the inefficient and energy-intensive 2-Phase® extraction well, an in situ bioreactor was installed within the footprint of the former wash rack. The bioreactor design is similar to that previously installed at Site DP039 in December 2008. The construction of the bioreactor began with the excavation of the highly contaminated soil underlying the wash rack. Then the excavation void was backfilled with organic mulch that was sprayed with EVO. Horizontal extraction well EW003x16 is used as a source of contaminated groundwater. This groundwater is continually circulated through the bioreactor to create the aquifer conditions needed for anaerobic degradation of TCE and related compounds.

Vertical extraction wells EW610x16 and EW605x16 remain in operation. Groundwater extracted by these wells continues to be conveyed by underground pipeline to the CGWTP for LGAC treatment.

3.3.7.3 Status of the TARA Component of the Site SS016 IRA

The TARA extraction system is currently operating normally, and no optimization measures are planned. Since 1995, the system consists of two (2) parallel 700-feet long horizontal extraction wells (EW001x16 and EW002x16). The groundwater extracted from both wells continues to be treated by LGAC at the CGWTP.

Groundwater contamination not hydraulically captured by either the OSA or TARA extraction wells currently flows under the active aircraft runway and is captured by the Site SS029 GET system. The Site SS016 contaminant plume and locations of the Site SS029 extraction wells are shown on Figure 3.3-5.

TABLE 3.3-1
Summary of Central Groundwater IRA Components
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Contaminant Plume	IRA Objective*	Implemented IRA	Primary Components	Status Comments
OSA Source Area	Source control	GET with bioreactor optimization	2-Phase® extraction well (TPE-W), one (1) horizontal extraction well (EW003x16), two (2) groundwater extraction wells (EW605x16 and EW610x16), performance monitoring wells, vapor treatment with ThOx, groundwater treatment at the CGWTP using LGAC	IRA optimization actions included discontinuing operation of the 2-Phase® well and ThOx treatment unit during April 2010. UV/Ox treatment at the CGWTP was replaced by LGAC. An in situ bioreactor was installed in September 2010.
TARA Source Area	Source control	GET	Two (2) horizontal extraction wells (EW001x16 and EW002x16), performance monitoring wells, groundwater treatment at CGWTP using LGAC	No IRA optimizations planned within the TARA portion of Site SS016.

*IRA objective specified in the NEWIOU Groundwater IROD (Travis AFB, 1998).

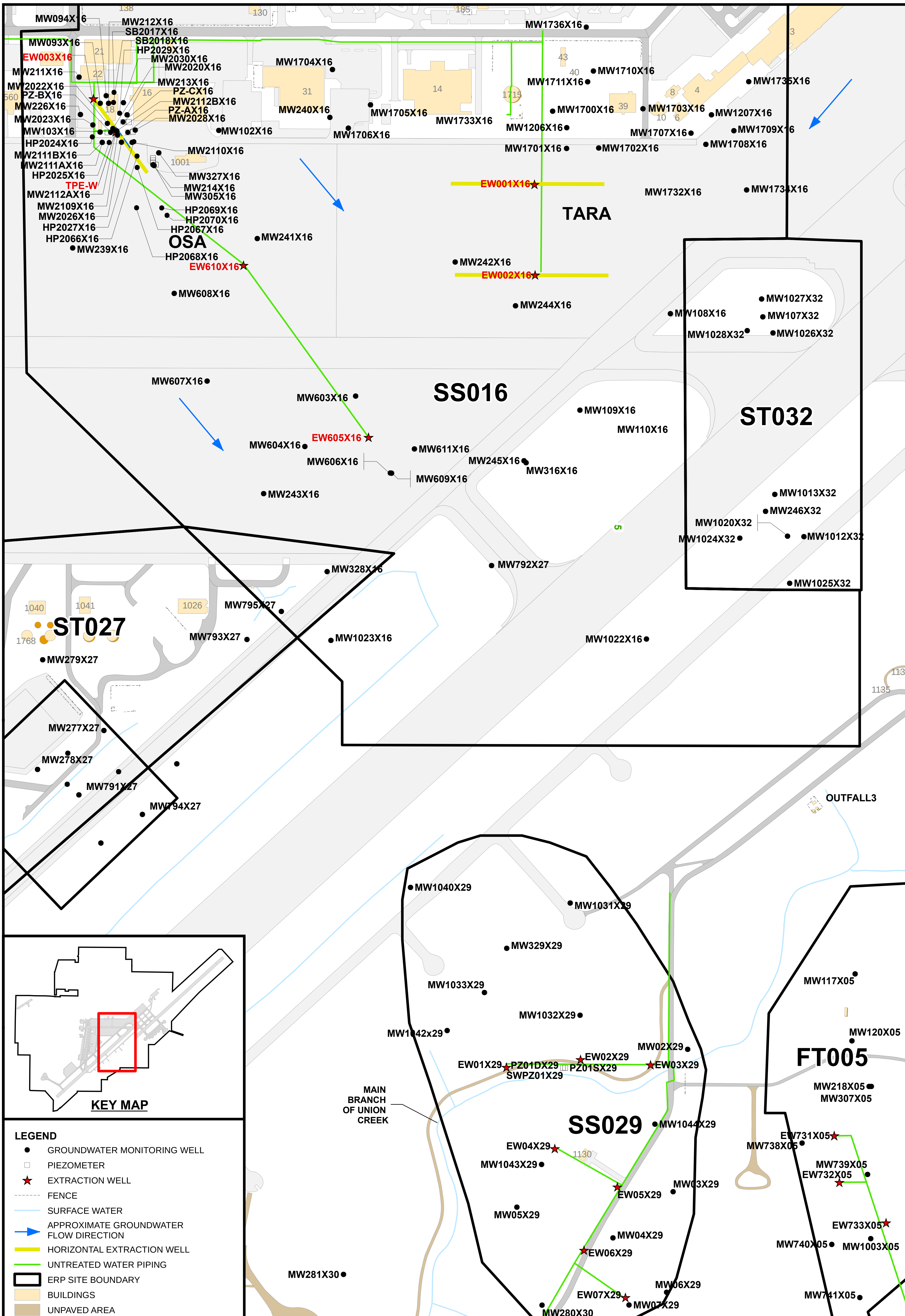

FIGURE 3.3-1
SITE MAP
CENTRAL IRA – SITE SS016
NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_3-1_SS016_SITEMAP.MXD MCLAY1 1/20/2011 19:42:19

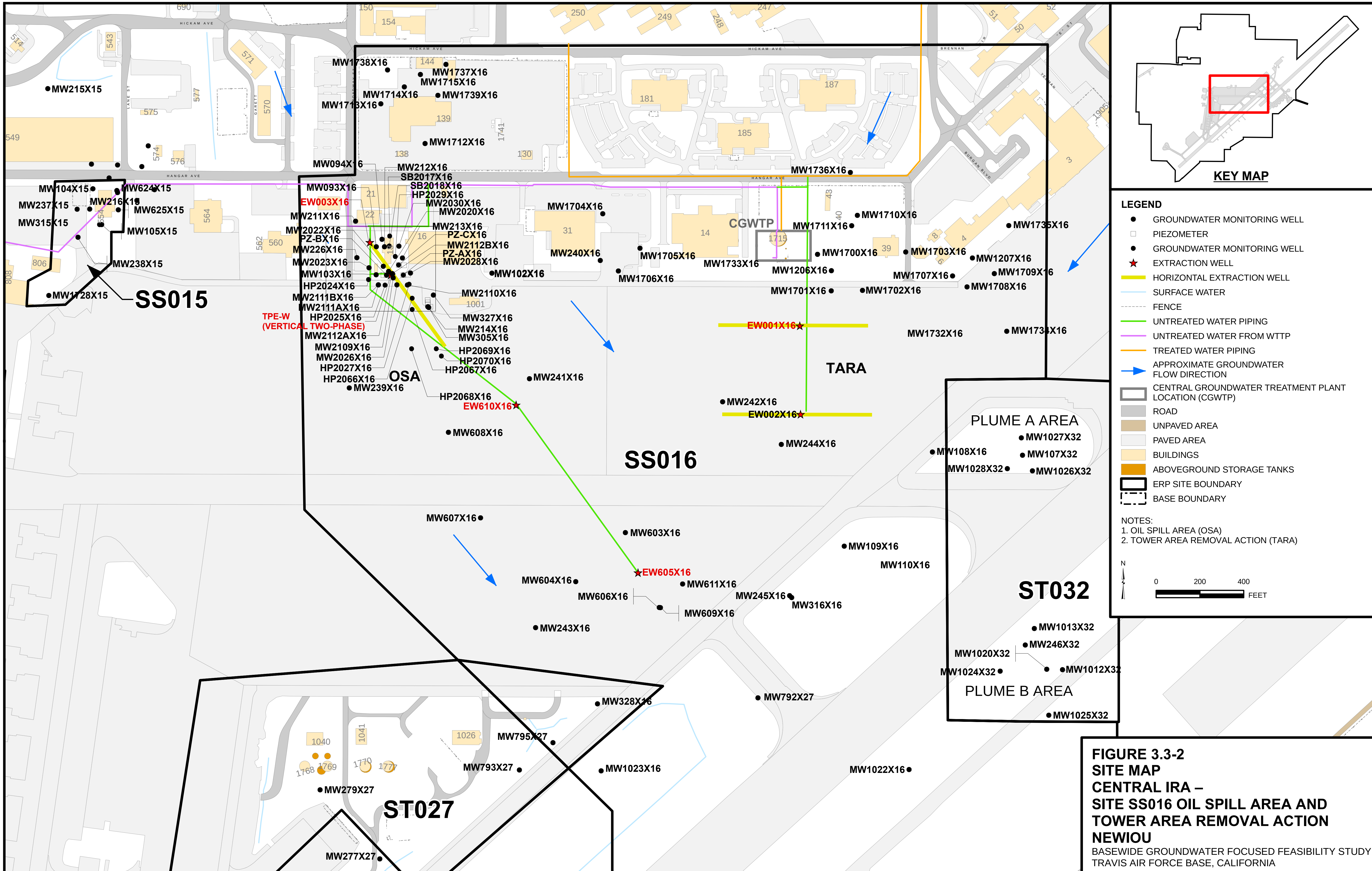

FIGURE 3.3-2
SITE MAP
CENTRAL IRA –
SITE SS016 OIL SPILL AREA AND TOWER AREA REMOVAL ACTION NEWIOU

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_3-2_SS016_OSA_SITEMAP.MXD MCLAY1 1/20/2011 20:32:13

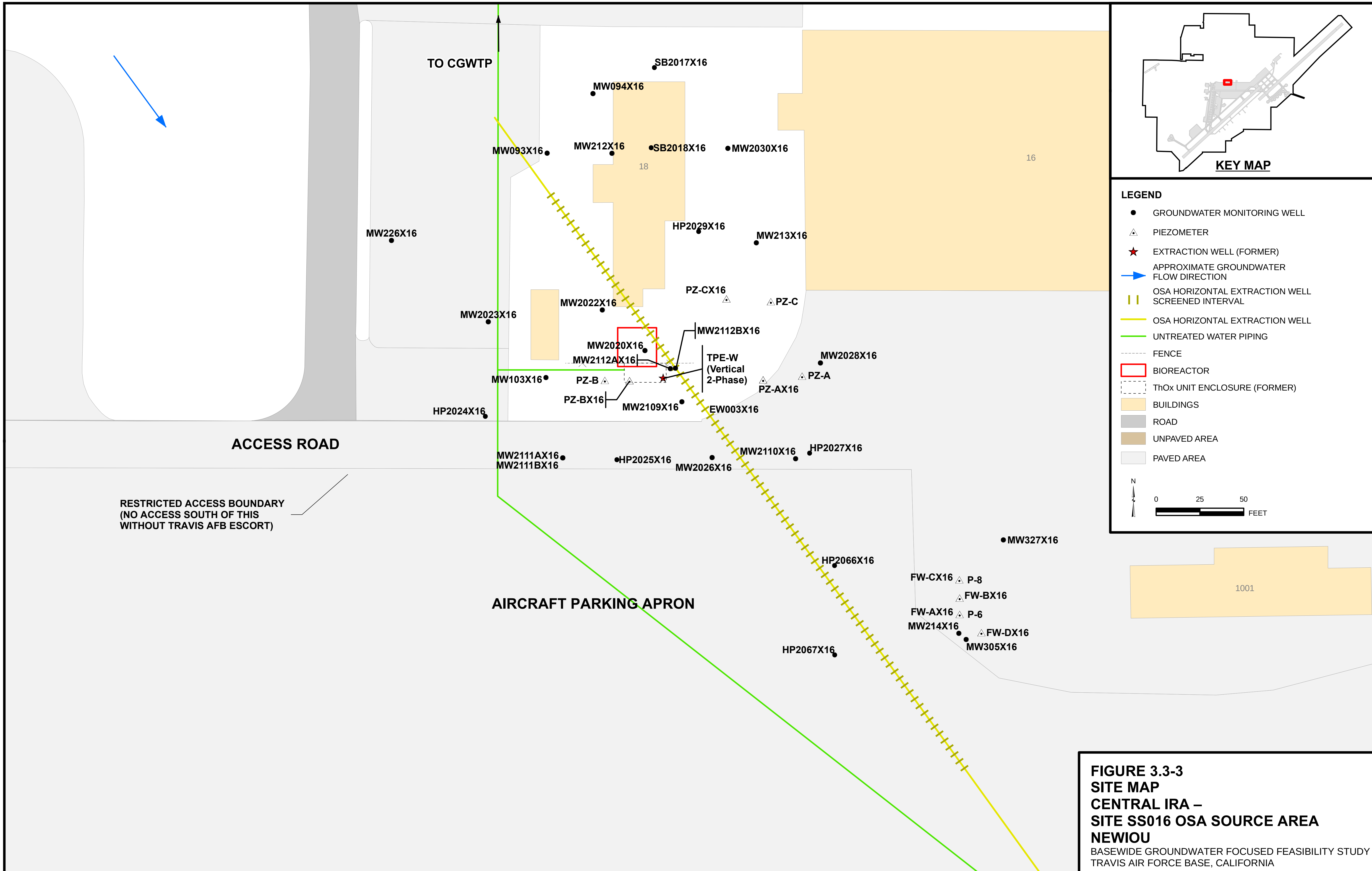

FIGURE 3.3-3
SITE MAP
CENTRAL IRA –
SITE SS016 OSA SOURCE AREA
NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_3-3_SS016_OSA_SOURCEAREA.MXD MCLAY1 1/20/2011 21:06:07

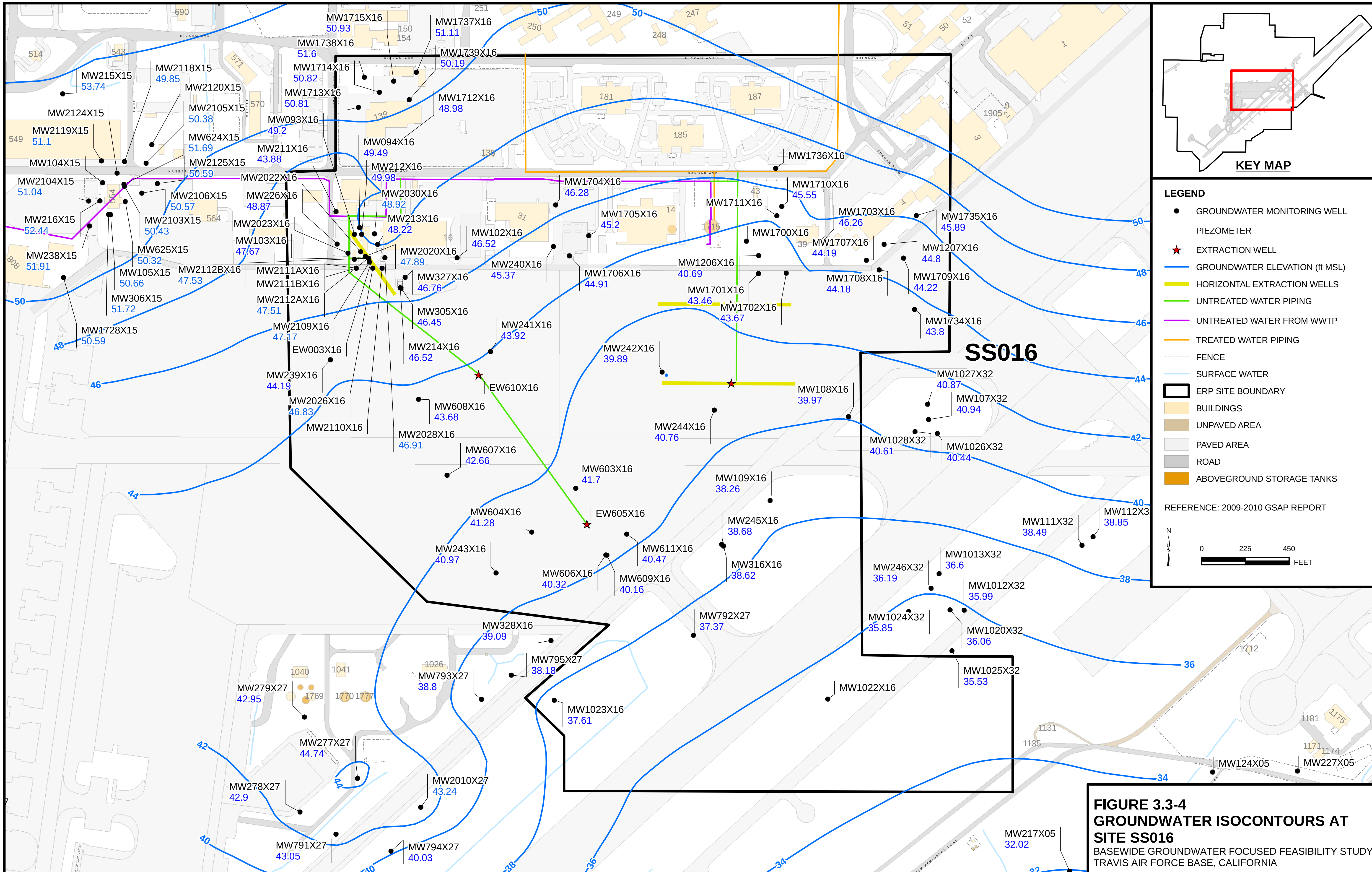

FIGURE 3.3-4
GROUNDWATER ISOCONTOURS AT SITE SS016
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIGURE_3_3-4_SS016_GW_2010.MXD MCLAY1 1/20/2011 21:28:12

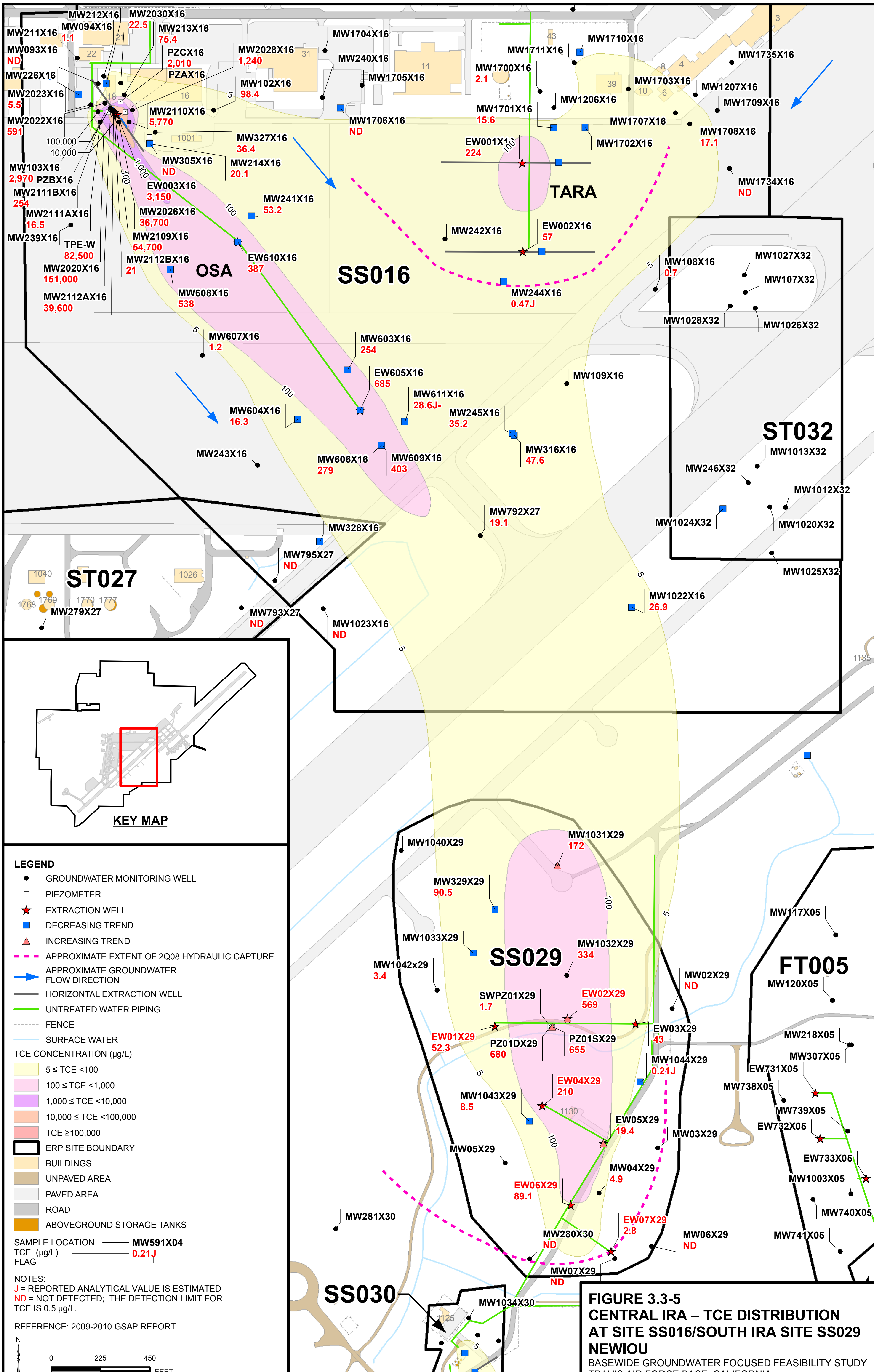

FIGURE 3.3-5
CENTRAL IRA – TCE DISTRIBUTION AT SITE SS016/SOUTH IRA SITE SS029 NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_3-5_TCE_SS016_SS029.MXD MSCHROCK 4/14/2011 01:06:29

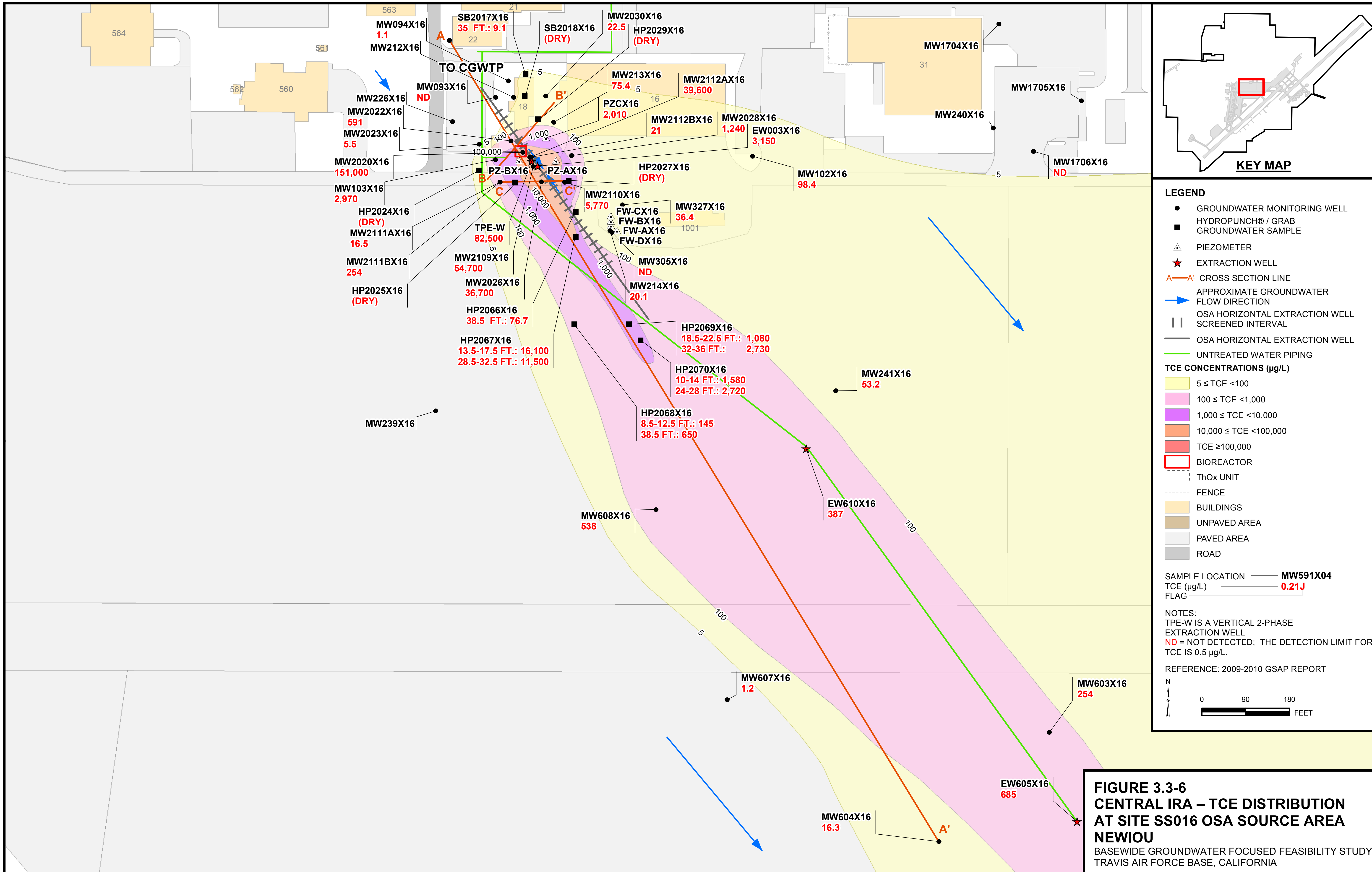

FIGURE 3.3-6
CENTRAL IRA – TCE DISTRIBUTION AT SITE SS016 OSA SOURCE AREA NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_3-6_TCE_OSASOURCEAREA_SS016.MXD MSCHROCK 6/27/2011 5:10:27 PM

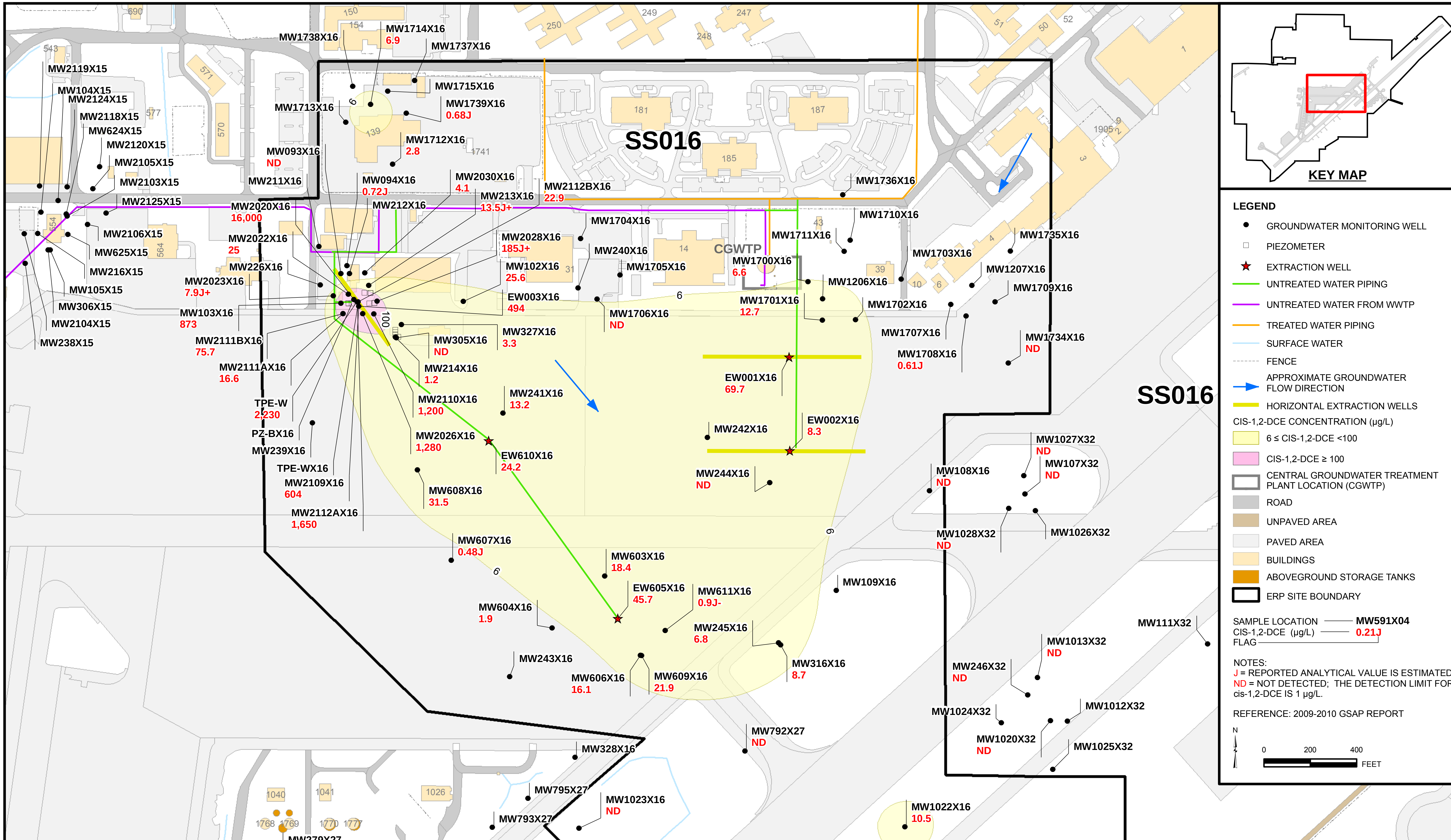

FIGURE 3.3-7
CIS-1,2-DCE DISTRIBUTION AT SITE SS016
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIGURE_3_3-7_DCE_SS016.MXD MSCHROCK 5/2/2011 13:22:31

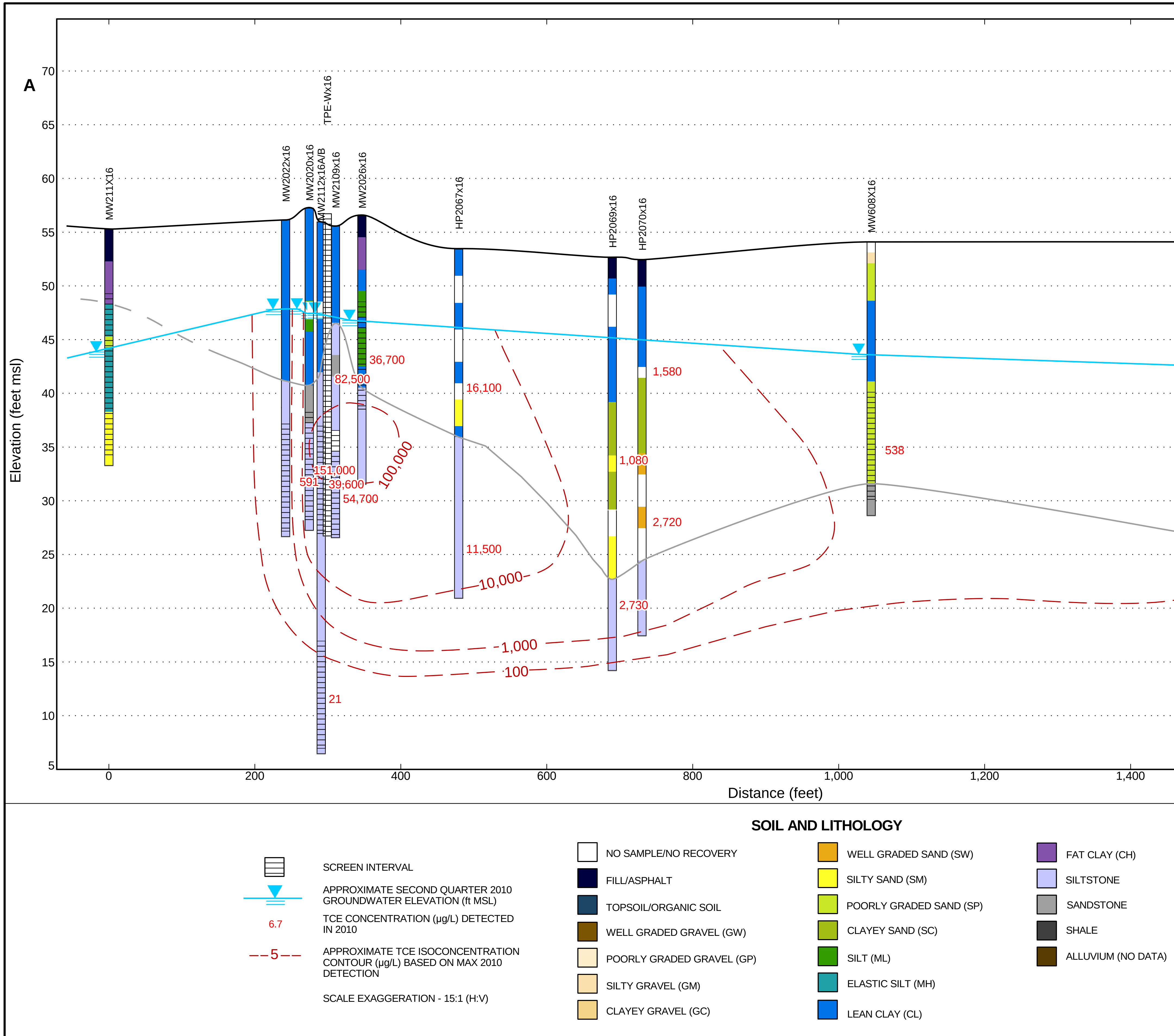

FIGURE 3.3-8
SITE SS016 CROSS SECTION A–A'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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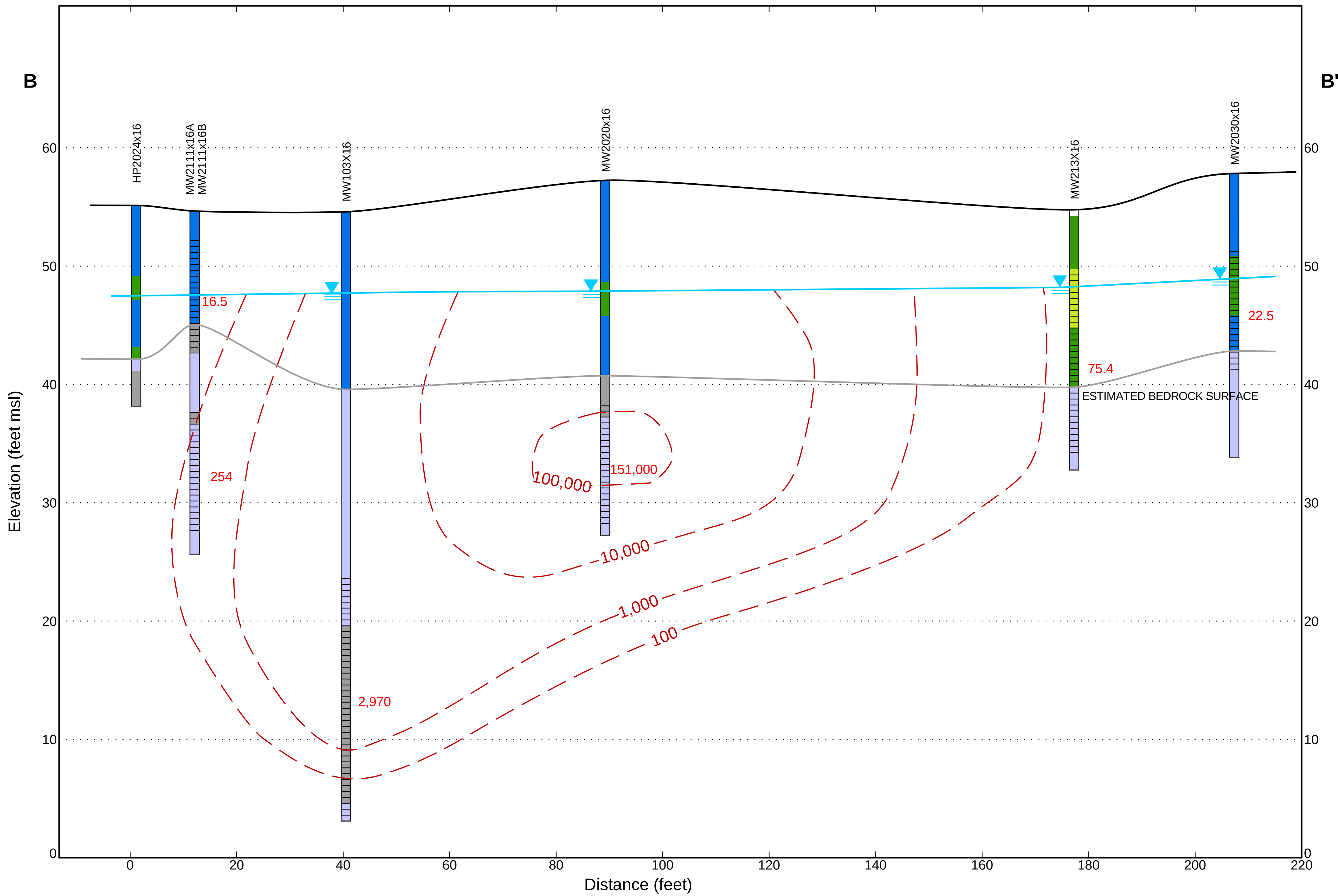

SOIL AND LITHOLOGY

- SCREEN INTERVAL
- APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)
- 6.7 — TCE CONCENTRATION (µg/L) DETECTED IN 2010
- – –5– – — APPROXIMATE TCE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION
- SCALE EXAGGERATION - 2.2:1 (H:V)

- NO SAMPLE/NO RECOVERY
- FILL/ASPHALT
- TOPSOIL/ORGANIC SOIL
- WELL GRADED GRAVEL (GW)
- POORLY GRADED GRAVEL (GP)
- SILTY GRAVEL (GM)
- CLAYEY GRAVEL (GC)
- WELL GRADED SAND (SW)
- SILTY SAND (SM)
- POORLY GRADED SAND (SP)
- CLAYEY SAND (SC)
- SILT (ML)
- ELASTIC SILT (MH)
- LEAN CLAY (CL)
- FAT CLAY (CH)
- SILTSTONE
- SANDSTONE
- SHALE
- ALLUVIUM (NO DATA)

FIGURE 3.3-9
SITE SS016 CROSS SECTION B–B'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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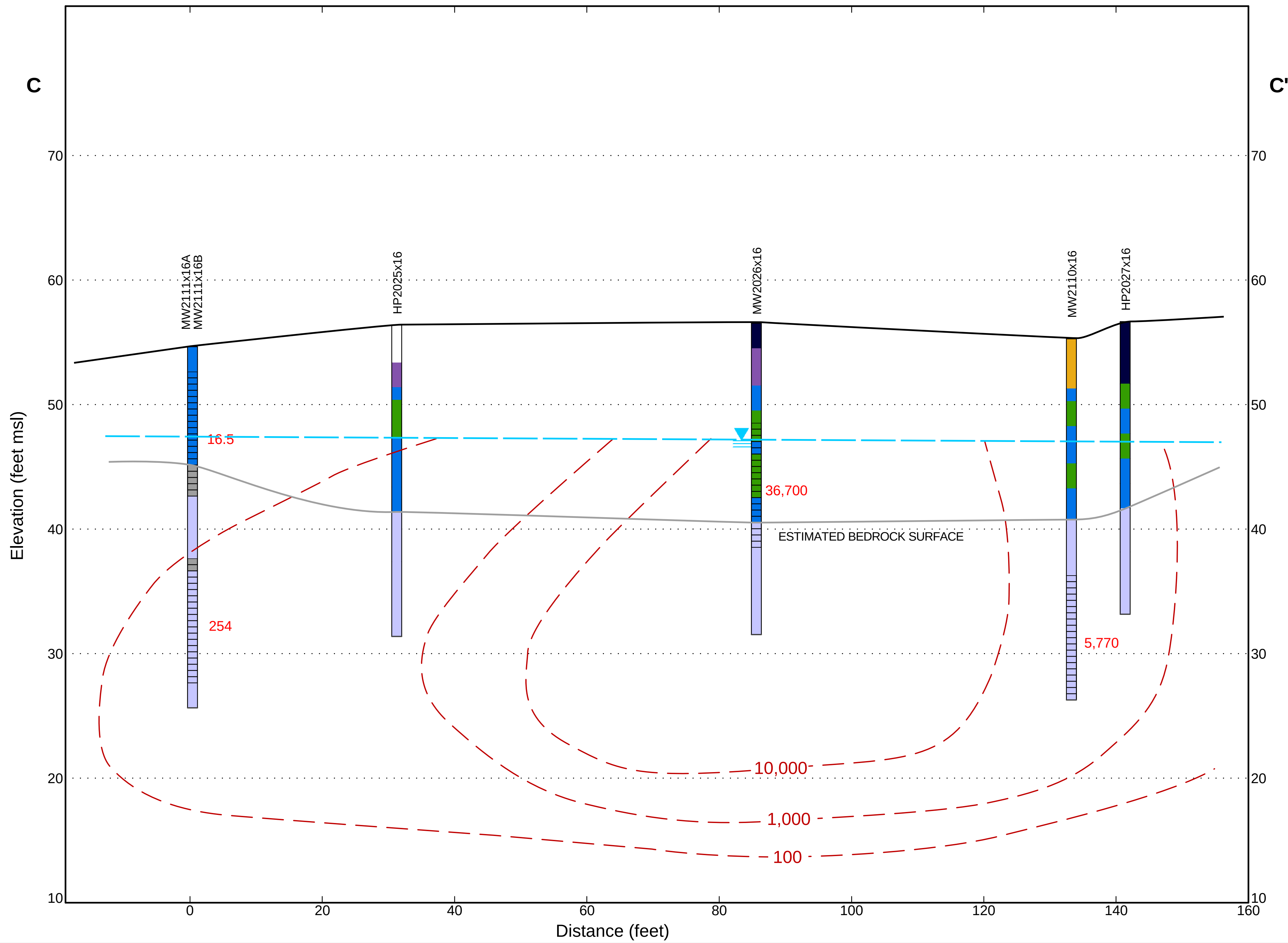

SOIL AND LITHOLOGY

- SCREEN INTERVAL
- APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)
- 6.7 — TCE CONCENTRATION (µg/L) DETECTED IN 2010
- – – 5 – – — APPROXIMATE TCE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION
- SCALE EXAGGERATION - 2:1 (H:V)

NO SAMPLE/NO RECOVERY	WELL GRADED SAND (SW)	FAT CLAY (CH)
FILL/ASPHALT	SILTY SAND (SM)	SILTSTONE
TOPSOIL/ORGANIC SOIL	POORLY GRADED SAND (SP)	SANDSTONE
WELL GRADED GRAVEL (GW)	CLAYEY SAND (SC)	SHALE
POORLY GRADED GRAVEL (GP)	SILT (ML)	ALLUVIUM (NO DATA)
SILTY GRAVEL (GM)	ELASTIC SILT (MH)	
CLAYEY GRAVEL (GC)	LEAN CLAY (CL)	

FIGURE 3.3-10
SITE SS016 CROSS SECTION C–C'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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ES082009007SAC Figure_3.3-10.ai 06.14.2011 tdaus

3.4 West IRA Conceptual Site Models

The West IRA comprises consolidated groundwater interim actions at ERP Sites LF008, SS015, SD033, SD034, SS035, SD036, SD037, DP039, and SD043.

Primarily because of their geographic locations, the following subsections are provided, under separate tabs, for the following West IRA sites:

- Section 3.4.1 – WIOU Sites SD033, SD034, SS035, SD036, SD037, and SD043: Contiguous sites with commingled plumes of groundwater contamination
- Section 3.4.2 – Site SS015: Site is noncontiguous to any other West IRA site
- Section 3.4.3 – Site DP039: Site is noncontiguous to any other West IRA site
- Section 3.4.4 – Site LF008: Site is noncontiguous to any other West IRA site

3.4.1 WIOU Conceptual Site Models

This section provides the CSMs for the WIOU sites within the West IRA. These sites include ERP Sites SD033, SD034, SS035, SD036, SD037, and SD043. Regional site maps of the northern and southern areas of the WIOU are provided on Figures 3.4-1 and 3.4-2. More detailed maps of Sites SD034, SD036, and SD037 (vicinity of Building 837) are shown on Figures 3.4-3, 3.4-4, and 3.4-5.

Additional descriptions of the WIOU sites' geology, groundwater characteristics, and groundwater contamination are provided in Section 4.6 of the 2009-2010 Annual GSAP Report (CH2M HILL, 2011b).

3.4.1.1 WIOU Site Descriptions

The WIOU sites are located within industrialized areas of the western-central portion of Travis AFB. The West Branch of Union Creek flows through the WIOU, generally north to south, with the slope of the topography. Numerous buildings, shops, offices, freight handling and storage areas, vehicle maintenance shops, and aircraft maintenance facilities are in the WIOU. Summary descriptions of the WIOU sites are provided in the following list:

- **Site SD033 – Storm Sewer II, South Gate Area, Facilities 810 and 1917, and West Branch of Union Creek.** This site includes support areas used for management of stormwater runoff, fuel transport, aircraft maintenance, and aircraft washing, including the use of wash racks and OWS. Historical practices resulted in groundwater contamination with chlorinated VOCs, some SVOCs, and petroleum-fuel hydrocarbons.

- **Site SD034 – Facility 811.** This site is an active aircraft wash rack facility with OWS and overflow pond. Leaks from the OWS resulted in a layer of Stoddard solvent floating on the groundwater table. The leaking OWS was replaced in 1994. Historical practices resulted in dissolved groundwater contamination with chlorinated VOCs, SVOCs, and petroleum-fuel hydrocarbons (including Stoddard solvent).

- **Site SS035 – Facilities 818/819.** This site includes active facilities used for aircraft repair, painting, and washing. A wash rack with OWS was constructed in 1970. Historical practices resulted in groundwater contamination with chlorinated VOCs.

- **Site SD036 – Facilities 872/873/876.** This site includes Facilities 872/873/876 and consists of multiple-use shops, including a wash rack and OWS. Current uses include paint shops, electrical shops, landscape maintenance, paint mixing, and paint accumulation. The buildings were constructed in 1953 and are still in use. Historical practices resulted in groundwater contamination with chlorinated VOCs, some SVOCs, and petroleum-fuel hydrocarbons. A segment of the sanitary sewer system traverses the northern and eastern portions of the site. Along the eastern boundary of the site is the north-south trending West Branch of Union Creek.

- **Site SD037 – Sanitary Sewer System; Facilities 837/838, 919, 977, 981; Ragsdale/ V Street Area; and Area G Ramp.** This site includes support areas used for management of domestic and industrial wastewater, aircraft maintenance, heavy equipment maintenance, air cargo handling, vehicle washing, fuel transport, and waste accumulation. Operations began in the 1940s and continue through the present day. Historical waste management practices resulted in groundwater contamination with chlorinated VOCs, some SVOCs, and petroleum-fuel hydrocarbons.

Site SD037 is a large site that is located in the central portion of the WIOU and extends from north to south across the entire WIOU. The site includes Buildings 837, 838, 919, 977, and 981; the Area G Ramp; the Ragsdale/V Street Area; and the sanitary sewer system within the WIOU. Buildings 837 and 838 were constructed in 1954 and were used to maintain aircraft. Building 837 and 838 both had sumps and transformers that previously held PCB-containing oil. Building 919 was constructed in 1984 and was used to maintain heavy equipment. An OWS was connected from the building to the sanitary sewer system. Located to the east of the building were a wash rack and a hazardous waste accumulation area. Building 977 was constructed in 1972 and is used as an air terminal where personnel use hydraulic equipment to load and unload cargo. In the past, leaks were reported from the Building 977 hydraulic rams. Building 981 was constructed in 1975. A waste accumulation area was located to the northeast of the facility and a vehicle wash area was located to the east of the facility. The Area G Ramp is located just to the south of Building 977 and contains a hydrant system with a pressurized fuel pipeline that is used for fueling aircraft. Releases have occurred in the Area G Ramp from surface spills or through the jet fuel distribution pipeline. The Ragsdale/V Street Area is an open grass area on the northwest corner of the intersection Ragsdale Street and V Street where there was a release from the jet fuel distribution pipeline. The sanitary sewer system within Site SD037 includes approximately 22,000 feet of underground piping, which is used to convey domestic and industrial wastewater from facilities within the WIOU to the Fairfield-Suisun publicly owned treatment works.

- **Site SS041 – Building 905.** This site includes an active entomology shop that provides pest management services for the Base. From 1983 to 1992, the shop prepared pesticides and herbicides for on-base use. A concrete washrack in the back of the building was used to clean pesticide applicator vehicles, and the overspray from the washing resulted in pesticide contamination in the soil and groundwater. A groundwater extraction system was built around the building as an interim groundwater remedial action and was connected to the WTTP. The interim groundwater action achieved a cleanup of the pesticide contaminants to below detection levels. A surface soil remedial action in 2003 achieved residential cleanup levels. Since all media of concern were addressed by these two (2) actions, Site SS041 was placed in a No Further Response Action Planned (NFRAP) status, which is documented in a 14 December 2005 consensus statement that was signed by the representatives of the lead and regulatory agencies (Travis AFB, 2005). The completion of all environmental restoration activities will be documented in the upcoming Basewide Groundwater ROD.
- **Site SD043 – Building 916.** Site SD043 comprises an emergency electric power facility. Historical waste management practices resulted in a release of TCE to the groundwater at this site.

3.4.1.2 WIOU Geology

The sediments of the WIOU comprise approximately 30 to 90 feet of fine-grained alluvium (known as the Older Alluvium) underlain by semi-consolidated to consolidated folded bedrock known as the Neroly Sandstone.

The Older Alluvium consists primarily of silts and clays that are low in permeability and do not readily transmit groundwater. More permeable units, such as sands and gravels, are geographically restricted and locally occur as discontinuous lenses rather than continuous beds. These sand and gravel lenses, deposited by streams such as Union Creek, typically trend to the south-southeast.

The Neroly Sandstone bedrock is bordered on the east by the Markley Sandstone, which outcrops at the boundary between the WIOU and the EIOU and on the west by the Tehama Formation. Depth to bedrock varies across the WIOU but is typically encountered at depths ranging from approximately 5 to 60 feet bgs. The bedrock surface in the WIOU is weathered, which can make it difficult to identify in the field. The center of the WIOU is underlain by a synclinal basin that reaches a depth of approximately 110 feet bgs in some places.

More focused descriptions of the geology at Sites SD036 and SD037 within the WIOU are provided in the following subsections.

Site SD036. The geology of Site SD036 consists of a relatively thick cover of fine-grained alluvium overlaying sandstone bedrock. The alluvium consists of clay, silt, and discontinuous lenses of sand, clayey sand, and silty sand. Alluvium along the western portion of the site is up to 68 feet thick at MW2107x36C.

Along the eastern portion of Site SD036 the alluvium is thicker and appears to be associated with the incising of a paleochannel. The alluvium in this portion of the site is as thick as 110 feet at the location of HP2063x36. The paleochannel appears to trend to the south-southwest and includes the boring locations at HP2033x36, HP2034x36, HP2062x36, MW2063x36, HP2064x36, HP2065x36, HP2075x36, MW2076x36C, MW2077x36C, and MW2108x36C. The alluvium within the paleochannel ranges in depth from 93 to 110 feet bgs. It also appears that the western edge of the paleochannel is abrupt, as the depth of bedrock goes from a depth of at least 95 feet bgs in HP2034x36 to 68 feet bgs in MW2107x36C. Site SD036 cross sections A-A’, B-B’, C-C’, and WIOU cross section A-A’ show the extent of the paleochannel.

The sand, clayey sand, and silty sand lenses are generally thin. However, at MW2108x36C, which is located adjacent to the West Branch of Union Creek, a 19-foot-thick interval of sand was observed from 57 to 76 feet bgs. Based on the location and depth of the thick sand lens, the sand is likely associated with the paleochannel of the West Branch of Union Creek.

Bedrock at Site SD036 consists of the Neroly Sandstone, which is a finely grained sandstone that is poorly graded. Locally, at the alluvium/bedrock interface, the sandstone has been observed to be highly weathered and has consequently been historically interpreted as poorly graded sand in some locations. Where the sandstone is highly weathered, it transports groundwater.

Site SD037. The geology of Site SD037 is variable. In the northern portion of Site SD037 the geology consists of a relatively thick cover of alluvium consisting of clay; silt; and discontinuous lenses of sand, clayey sand, silty sand, and gravel. Alluvium along the eastern portion of Site SD037 is up to 60 feet thick (based on the soil boring for well MW2102x37C). Along the western portion of Site SD037, the alluvium is thicker and appears to be associated with the incising of a paleochannel, which is also observed at neighboring Site SD036. The alluvium in the western portion of Site SD037 (near Site SD036) is as thick as

91.5 feet (MW2077x36). The eastern slope of the paleochannel appears to be relatively gentle. The trend of the paleochannel appears to be to the south-southwest.

In the southern portion of Site SD037, the geology consists of a relatively thin cover of alluvium consisting of clay; silt; and discontinuous lenses of sand, clayey sand, and silty sand. Soil borings in the southern portion of Site SD037 indicate alluvium thicknesses range from 15 to 33.5 feet.

Bedrock at Site SD037 consists of the Neroly Sandstone, which is a finely grained sandstone that is poorly graded and interbedded with siltstone.

3.4.1.3 WIOU Groundwater Characteristics

Information regarding overall hydrogeologic characteristics within the WIOU is summarized in the following list. Groundwater elevation contours are shown on Figure 3.4-6.

- Depth to water is approximately 10 to 15 feet bgs.
- Groundwater flow is southerly. A groundwater trough traverses the approximate center of the WIOU in a north-south direction.
- Horizontal hydraulic gradients range from approximately 0.004 to 0.006 ft/ft.
- Vertical gradients derived from shallow/deep monitoring well pairs are generally negligible (less than 0.01 ft/ft). Vertical gradients are both upward and downward. However, one (1) well pair, MW535x37/MW512x37, consistently has larger vertical gradients, ranging from 0.1 ft/ft downward to 0.1 ft/ft upward. Vertical gradients are typically downward at this well pair. The relatively large vertical gradients calculated for this well are likely due to the effect of groundwater extraction.
- Groundwater elevations typically vary by approximately 2 to 5 ft/year and are relatively stable, with no long-term trends.
- Low detections of TCE (typically below 1 μg/L) from surface water in the West Branch of Union Creek indicate that some contaminated groundwater discharges from the aquifer into the creek. These results indicate that the creek is a gaining stream at least part of the year. When groundwater elevations are high (spring), groundwater also infiltrates into the storm drain piping.

More focused descriptions of the hydrogeology at Sites SD036 and SD037 are provided in the following subsections.

Site SD036. The flow of groundwater at Site SD036 is generally to the south. However, the site is located in a groundwater trough as evidenced by relatively thick alluvium and deep bedrock. As a consequence, groundwater flow from the northwest, the north, and the northeast converges at the site. The hydrogeology at Site SD036 is as follows:

- Depth to water ranges from 7 to 13 feet bgs.
- The regional groundwater flow direction is southerly. Horizontal gradients are approximately 0.005 ft/ft.

- In general, vertical gradients are small. Both upward and downward vertical gradients were calculated for the site. The largest upward gradient is 0.01 ft/ft (MW2075Bx36/MW2075Ax36), and the largest downward gradient is -0.04 ft/ft (PZ06Dx36/PZ06Sx36 and MW2031Bx36/MW2031Ax36).
- Groundwater flow is predominantly within the alluvium and along the alluvium/bedrock interface.
- Potentiometric heads up to 15 feet above the highest saturated soil zone indicates that the groundwater system is partially confined.
- Hydraulic conductivity for the alluvium is approximately 0.9 ft/day.
- Groundwater elevations are relatively stable, with seasonal variations of approximately 2 to 5 ft/year, but no long-term trends.

Site SD037. Similar to Site SD036, the flow of groundwater within Site SD037 is regionally to the south. The hydrogeology at Site SD037 is as follows:

- Depth to water typically ranges from 6 to 23 feet bgs at Site SD037. In the vicinity of Building 837, the range is from 6 to 13 feet bgs.
- The regional groundwater flow direction is typically to the south. In the vicinity of Building 837, the flow direction is southwest. Horizontal gradients are approximately 0.004 ft/ft across Site SD037 and approximately 0.003 ft/ft in the vicinity of Building 837. In bedrock, a flow direction and gradient cannot be determined because there are only two (2) monitoring wells installed within the bedrock at the site.
- Vertical gradients across the site are negligible (less than 0.01 ft/ft). Both upward and downward vertical gradients are observed. However, one (1) well pair has a vertical gradient greater than 0.01 ft/ft. Alluvium well pair MW535x37/MW531x37 has a downward gradient of 0.05 ft/ft. Two (2) alluvium-bedrock well pairs, MW2039x37A/MW2039x37B and MW2102x37B/MW2102x37C, have upward gradients of 0.02 and 0.03 ft/ft.
- Groundwater elevations are relatively stable at Site SD037, with seasonal variations of approximately 2 to 5 ft/year, but no long-term trends.
- Groundwater flow is predominantly in the alluvium and locally in weathered or fractured bedrock.
- The hydraulic conductivity for the alluvium at Site SD037 typically ranges from 1 to 7 ft/day. However, hydraulic conductivities outside of this range were calculated for Site SD037 wells from recovery and gravity-injection tests conducted in 1988 at three (3) wells. Two (2) recovery tests indicated a hydraulic conductivity of 60 ft/day (MW223x37) and 25 ft/day (MW224x37). The gravity-injection test indicated a hydraulic conductivity of 0.1 ft/day (MW222x37).
- Potentiometric heads up to 12 feet above the highest saturated soil zone indicate that the groundwater system is partially confined.

3.4.1.4 Groundwater Contamination

The primary groundwater contaminants within the WIOU are TCE, PCE; 1,1-DCE; 1,2-DCA; cis-1,2-DCE; vinyl chloride; carbon tetrachloride; bromodichloromethane; chloromethane; benzene; naphthalene; TPH-G; and TPH-D. The indicator chemical is TCE.

The distribution of commingled TCE contamination originating from the multiple sites within the WIOU is shown on Figure 3.4-7. Localized areas of relatively high TCE concentrations (i.e., hot spots) exist at two (2) source areas within the WIOU, including Site SD036 and in the vicinity of Building 837 within Site SD037. More detailed maps of TCE contamination at Site SD036 and the Site SD037 hot spot are shown on Figures 3.4-8 and 3.4-9.

The distribution of groundwater contaminants is consistent with the direction of groundwater flow within the WIOU. Groundwater elevation contours are shown on Figure 3.4-6.

A vertical cross section through the WIOU is shown on Figure 3.4-10. Additional cross sections for areas of elevated TCE concentrations within Sites SD036, SD037 (vicinity of Building 837 hot spot), and SD043 are shown on Figures 3.4-11 through 3.4-15.

The following subsections provide more details on the nature of groundwater contamination at Site SD034, Site SD036, and the hot spot in the vicinity of Building 837 within Site SD037.

Site SD034. SD034 is located to the north of the main WIOU TCE plume and is discussed separately because, in addition to VOCs, floating product (i.e., Stoddard solvent) is present at the site. The source of the floating product was a leaky OWS that serviced Facility 811. The defective OWS has been replaced. Stoddard solvent was historically used to wash aircraft inside Facility 811, and this practice is ongoing. Wastewater and solvent from the washing process drain to a sump in the facility floor and are piped to the OWS.

Passive skimmers are currently installed in wells EW01x34, MW02x34, MW811x34, MWSSAx34, and MWSSBx34 to address the floating product at the site. Typically, a significant amount of floating product (i.e., greater than 0.1 foot) is measured only at well MWSSBx34. The floating Stoddard solvent plume remains in the immediate vicinity of the original release point and is not migrating.

Relatively high TPH-D concentrations (exceeding 1,000 μg/L) detected in monitoring and extraction wells located within the Stoddard solvent plume indicate the presence of dissolved Stoddard solvent in groundwater. Beyond the floating product plume, TPH-D is usually detected at a lower concentration at downgradient well MW04x34.

Detections of TPH-G may result from the presence of the lighter range hydrocarbons of Stoddard solvent.

Site SD036. The source of chlorinated VOC contamination at the site is likely the result of a historical break in the sanitary sewer line that traverses the site. The break has since been repaired.

Historically, liquid wastes containing TCE from facilities in the WIOU were likely flushed into the sanitary sewer system. A portion of this waste stream was likely released directly into the groundwater at Site SD036 from a damaged segment of the sanitary sewer. TCE has dissolved into groundwater from the source and migrated along small discontinuous sandy lenses downgradient to the south and southeast, following the regional groundwater gradient. Although none has been directly observed at the site, the presence of DNAPL is suggested by the high TCE concentrations detected in the source area. Groundwater TCE concentrations exceed 10,000 µg/L in the vicinity of the historical release point in the sanitary sewer.

The highest 2009-2010 concentrations of TCE groundwater contamination are associated with monitoring wells MW2061Bx36 and MW2031Bx36. TCE concentrations in these wells are 18,500 and 14,000 µg/L, respectively. Both MW2061Bx36 and MW2031Bx36 are located adjacent to the north-south trending sanitary sewer in the central portion of the site. The wells are screened from 37 to 47 feet bgs (MW2061Bx36) and 34.5 to 44.5 feet bgs (MW2031Bx36).

Results of historical soil gas investigations indicate relatively low vadose zone TCE soil gas concentrations in the vicinity of monitoring well MW2031Bx36 (maximum detection of 150 parts per billion by volume). The concentration of TCE found in the soil gas was likely due to volatilization from the underlying groundwater plume. These soil gas data, combined with the high TCE concentrations in groundwater (exceeding 10,000 µg/L) in the vicinity of the sanitary sewer suggest that the TCE was released by direct discharge to groundwater from the damaged sanitary sewer. The sanitary sewer invert elevation is approximately 10 feet bgs and near the water table. The concentration of TCE in monitoring wells MW2061Bx36 and MW2031Bx36 (exceeding 10,000 µg/L) also suggests that DNAPL is present.

Monitoring wells MW2061Bx36 and MW2031Bx36 (screened between 34.5 and 47 feet bgs) are the deepest Site SD036 wells with TCE concentrations exceeding 1,000 µg/L. Downgradient to the south and southeast of MW2061Bx36 and MW2031Bx36, the maximum depth with TCE concentrations exceeding 1,000 µg/L was detected in MW2033Ax36, MW2063x36, MW2064Ax36, and PZ550Cx36 at 34 feet bgs. TCE concentrations detected in these wells ranged from 1,600 µg/L (MW2064Ax36) to 3,760 µg/L (PZ550Cx36).

In addition to the likely Site SD036 source discussed above, TCE is also migrating into the site from an upgradient source to the northeast, where TCE concentrations also exceed 1,000 µg/L.

Concentrations of TPH-G (maximum concentration of 7,300 µg/L in MW2061Bx36); TPH-D (maximum concentration of 330 µg/L in MW2065x36); cis-1,2-DCE (maximum concentration of 160 µg/L in MW2032x16); PCE (maximum concentration of 13.6 µg/L in MW2031Bx16); vinyl chloride (maximum concentration of 4.0 µg/L in MW2061Ax36); and 1,2-DCA (maximum concentration of 0.79 µg/L in MW2032x36) have also been detected in the vicinity of the sanitary sewer at concentrations above their respective IRGs.

Site SD037 Hot Spot. The highest concentrations of groundwater contamination within Site SD037 are at a hot spot located west of Building 837. The source of chlorinated VOC contamination is likely the result of a historical break in the sanitary sewer line that traverses the site. The break has since been repaired.

Historically, liquid wastes containing TCE from facilities in the WIOU were likely flushed into the sanitary sewer system. A portion of this waste stream was released directly into the groundwater at Site SD037 from a damaged segment of the sanitary sewer. TCE has dissolved into groundwater from the source and migrated along small discontinuous sandy lenses downgradient to the south and southeast, following the regional groundwater gradient. Groundwater contamination at Site SD037 consists of a series of discontinuous groundwater plumes that extend from Building 811 in the north to Taxiway November in the south. The extent of the TCE plume is shown on Figure 3.4-7.

The portion of the plume with the highest concentration of TCE is located near Building 837, which is a newly constructed C-17 two (2)-bay hangar. In this area, eleven (11) wells have concentrations of TCE that are greater than 1,000 µg/L. These wells are MW524x37 (1,320 µg/L), MW532x37 (1,090 µg/L), MW2039Ax37 (1,550 µg/L), IW2094x37 (1,140 µg/L), IW2095x37 (1,450 µg/L), IW2096x37 (1,480 µg/L), IW2097x37 (1,120 µg/L), IW2100x37 (1,410 µg/L), MW2101Bx37 (1,800 µg/L), and MW2121x37 (1,050 µg/L) (CH2M HILL, 2011b).

The furthest upgradient well near Building 837 that has a TCE concentration greater than 1,000 µg/L is MW532x37. This well is located adjacent to the northwestern corner of Building 837 and southwest of the intersection of east-west and north-south trending sanitary sewer pipelines. The TCE concentration detected in monitoring well MW2122x37, located upgradient of the sanitary sewers and well MW532x37, is 0.79 µg/L.

The distribution of TCE in groundwater indicates that the source of the TCE hot spot plume is likely the sanitary sewer line near intersection of the two (2) segments. Historical reports indicate that the east-west trending sanitary sewer to the north of MW532x37 had been damaged and later repaired. It is likely that the historical release of TCE from a break in the sanitary sewer was a direct discharge to the groundwater. The invert of the sanitary sewer is approximately 13 feet bgs, which is approximately at the water table.

The highest TCE concentration in the hot spot plume was detected in MW2102Bx37, which is located approximately 370 feet downgradient (southwest) of the probable TCE release point. TCE concentrations exceeding 1,000 µg/L extend from the intersection of the sanitary sewers approximately 530 feet downgradient (southwest) to well MW2121x37. However, the portion of the TCE plume originating at the Site SD037 hot spot extends to and merges with the TCE plume at Site SD036.

In addition to TCE, concentrations of TPH-G (maximum concentration of 690 µg/L in MW224x37); TPH-D (maximum concentration of 230 µg/L in MW224x37); cis-1,2-DCE (maximum concentration of 63.8 µg/L in IW2096x37); benzene (maximum concentration of 25 µg/L in MW224x37); PCE (maximum concentration of 22.7 µg/L in EW707x37); carbon tetrachloride (maximum concentration of 1.8 µg/L in EW706x37); and vinyl chloride (maximum concentration of 0.91 µg/L in MW531x37) have been detected at Site SD037 at levels above their respective IRGs.

3.4.1.5 Status of Groundwater Interim Remedial Actions

The groundwater IRA in the WIOU is a combination of GET and MNA assessment. Free-product removal is also conducted at Site SD034. The WIOU GET system is currently turned off for a rebound study for the remainder of the period of interim remediation. The entirety of the plume continues to be monitored under the GSAP. Free-product removal at Site SD034 is intermittent, but ongoing. The main components of the WIOU IRA are summarized in Table 3.4-1.

WIOU GET System. The WIOU GET System was started up in February 2000. Until it was shut down for a rebound study in 2010, GET was the active component of the interim remedy within the WIOU. Within the contaminant source areas, GET was used to hydraulically capture the plumes and remove contaminant mass. Outside of the source areas, GET was used to hydraulically capture the portions of the plumes where VOC concentrations exceeded 100 µg/L.

In total, 18 DPE wells and groundwater extraction wells have operated in the WIOU. Soil vapor from the all of the DPE wells was treated at the WTTP by VGAC. Groundwater from all of the DPE and groundwater extraction wells was conveyed to the WTTP and then to the CGWTP for treatment.

In the southern portion of the WIOU plume, extraction well EW542x41 at Site SS041 (a component of the WIOU GET system) was decommissioned in January 2004 because of the expansion of Building 906 (URS, 2004).

MNA Assessment. A program of MNA assessment is continuing in the distal portions of the plumes hydraulically downgradient of the GET system. This portion of the WIOU plume has been continually monitored for the viability of MNA processes to remediate groundwater since the GET system was installed. The GET system was shut down for a rebound study in 2010.

Floating Product Removal. The GET remedy at Site SD034 is supplemented by floating product removal using passive skimmers. From 1998 through 2009, approximately 43 gallons of floating product were removed from the site. Passive skimmers are currently installed in wells EW01x34, MW02x34, MW811x34, MWSSAx34, and MWSSBx34. Floating product removal using the passive skimmers is ongoing and conducted as required.

3.4.1.6 IRA Optimization

During 2010, an optimization of the current groundwater IRA within the Site SD036 and SD037 contaminant source areas was conducted. Optimization activities included site-specific data gaps investigations, installation of additional groundwater monitoring wells, and injection of EVO within both source areas (CH2M HILL, 2010e). A more complete description of the EVO treatment technology is provided in Section 6. More information on the EVO injection optimization action at the sites is provided in Section 7.

The performance of the EVO optimization actions at Sites SD036 and SD037 will be monitored for the remainder of the period of interim remediation. If the performance data indicate that EVO treatment is effective at remediating contamination, then it may be incorporated into the final remedial action at the sites. The formal selection of a remedial action will be made in the pending Basewide Groundwater ROD.

TABLE 3.4-1
Summary of the WIOU Sites Component of the West Groundwater Interim Remedial Action
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Contaminant Plume	IRA Objective*	Implemented IRA	Primary Components	Status
SD034 Source Area	Source control	GET	DPE wells, performance monitoring wells, free-product removal with active skimmers, VGAC vapor treatment at WTTP, UV/Ox/LGAC groundwater treatment at CGWTP via WTTP	Source control GET system turned off for a rebound study. The CGWTP treatment process was converted to LGAC-only during 2010. Stoddard solvent floating-product removal is ongoing.
SD036/SD037 Source Areas	Source control	GET	DPE wells, performance monitoring wells, VGAC vapor treatment at WTTP, UV/Ox/LGAC groundwater treatment at CGWTP via WTTP	Source control GET system turned off for a rebound study. Site SD036 and SD037 source control actions optimized during 2010 using EVO injection.
SD033/SD034/ SS035/SD036/ SD037	Migration control	GET	Conventional extraction wells, performance monitoring wells, VGAC vapor treatment at WTTP, UV/Ox/LGAC groundwater treatment at CGWTP via WTTP	Migration control GET system turned off for a rebound study. Free-product removal of Stoddard solvent at Site SD034 is ongoing.
SS041	Migration control	GET	Conventional extraction well, performance monitoring wells, UV/Ox/ LGAC groundwater treatment at CGWTP via WTTP	Site SS041 in a No Further Remedial Action Planned status. This is documented in a 14 December 2005 consensus statement that was signed by the representatives of the lead and regulatory agencies (Travis AFB, 2005).
SD043	Migration control	GET	Conventional extraction well, performance monitoring wells, UV/Ox/ LGAC groundwater treatment at CGWTP via WTTP	Migration control GET system turned off for a rebound study.
SD033/SD037	MNA assessment	Groundwater monitoring	Monitoring wells	MNA assessment is ongoing during the period of interim remediation. Addresses portion of commingled plume that is not hydraulically captured by source control and migration control GET systems.

* IRA objective specified in the NEWIOU and WABOU Groundwater IRODs (Travis AFB, 1998 and 1999, respectively).

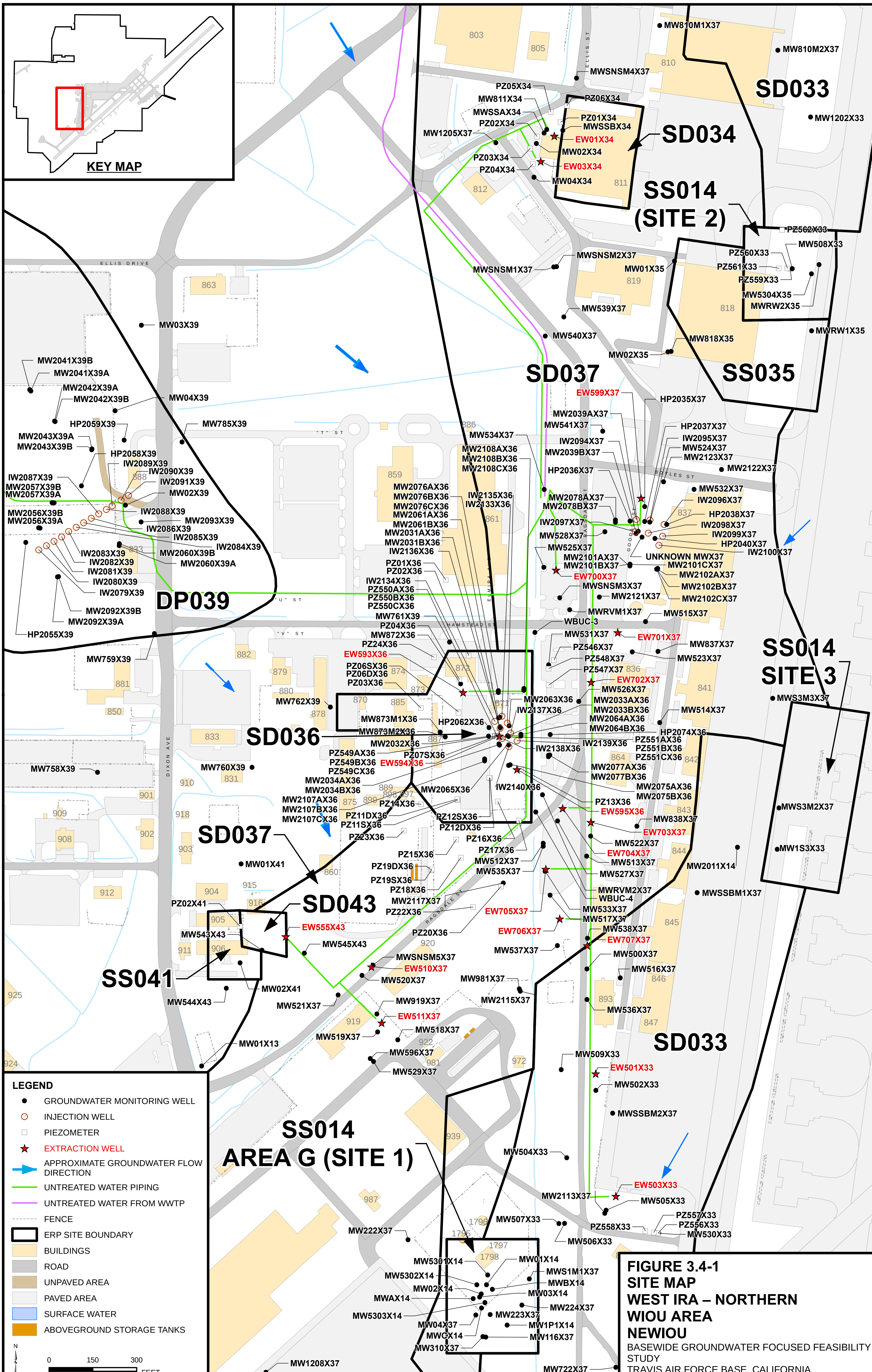


FIGURE 3.4-1
SITE MAP
WEST IRA – NORTHERN WIOU AREA
NEWIOU

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_4-1_NORTHWIOU.MXD MCLAY1 1/20/2011 23:38:45

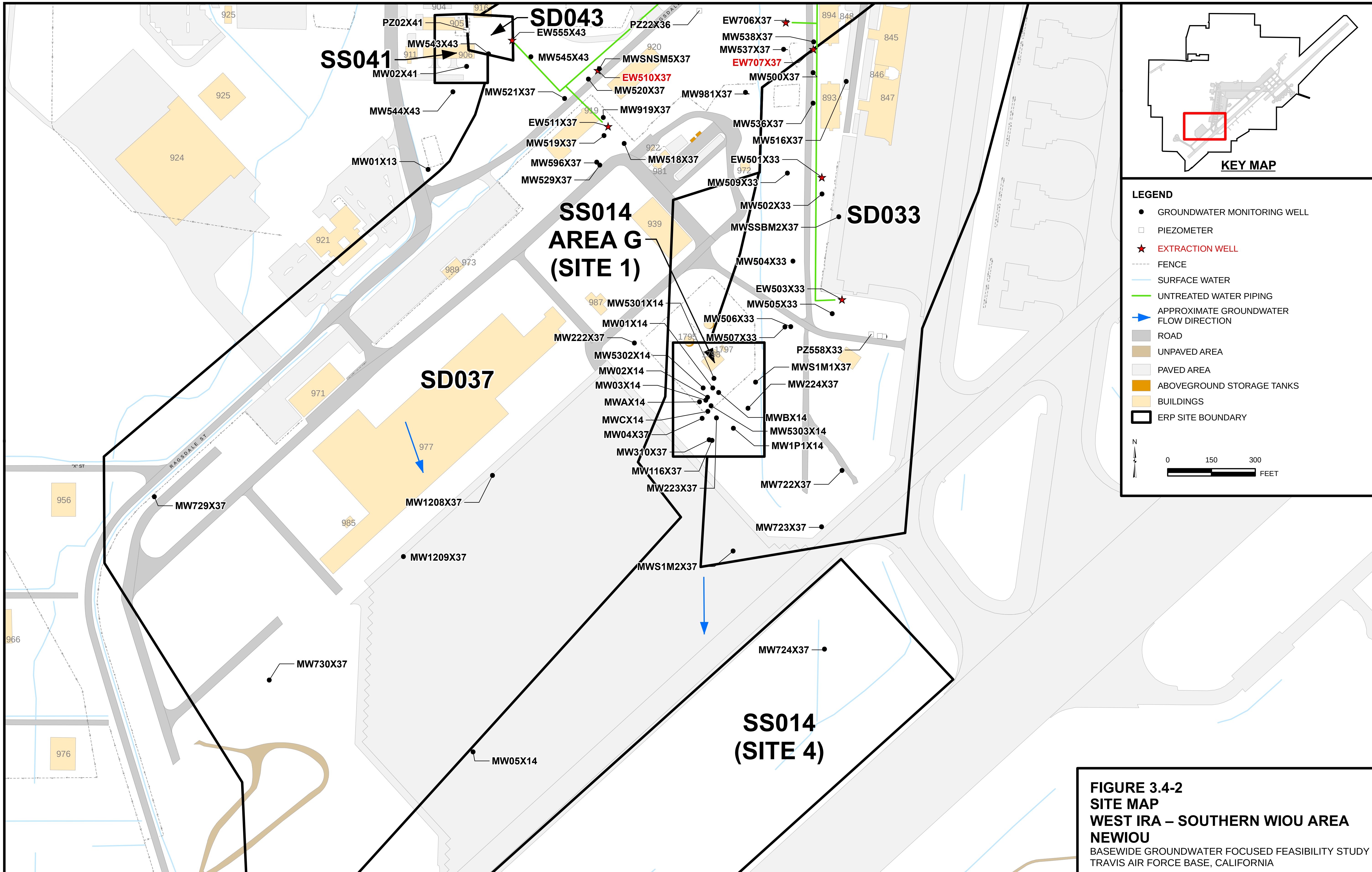


FIGURE 3.4-2
SITE MAP
WEST IRA – SOUTHERN WIOU AREA
NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3-4_2_WIOU_MNA.MXD MCLAY1 1/20/2011 23:57:37

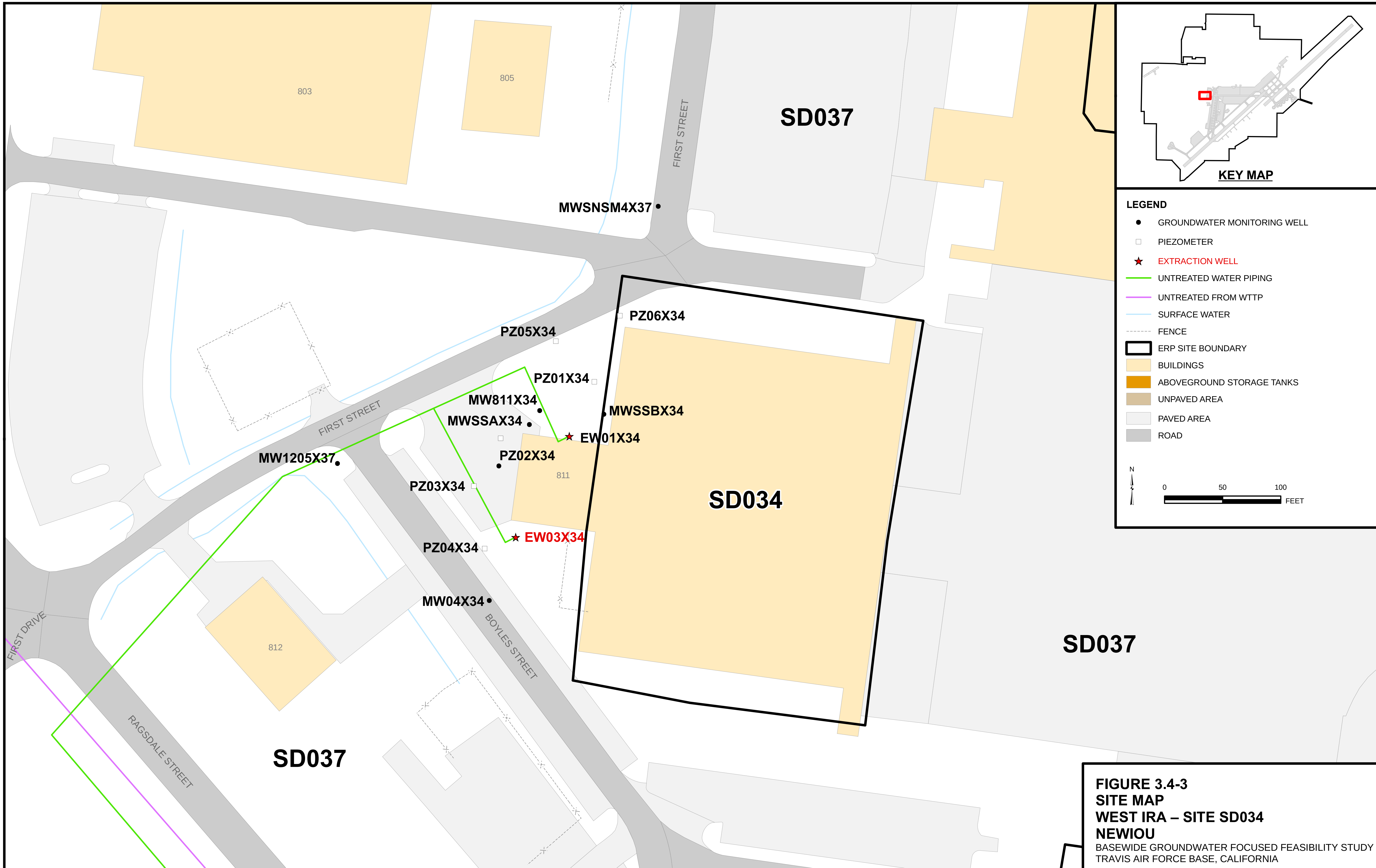


FIGURE 3.4-3
SITE MAP
WEST IRA – SITE SD034
NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3-4_3_SD034.MXD MCLAY1 1/21/2011 00:13:15

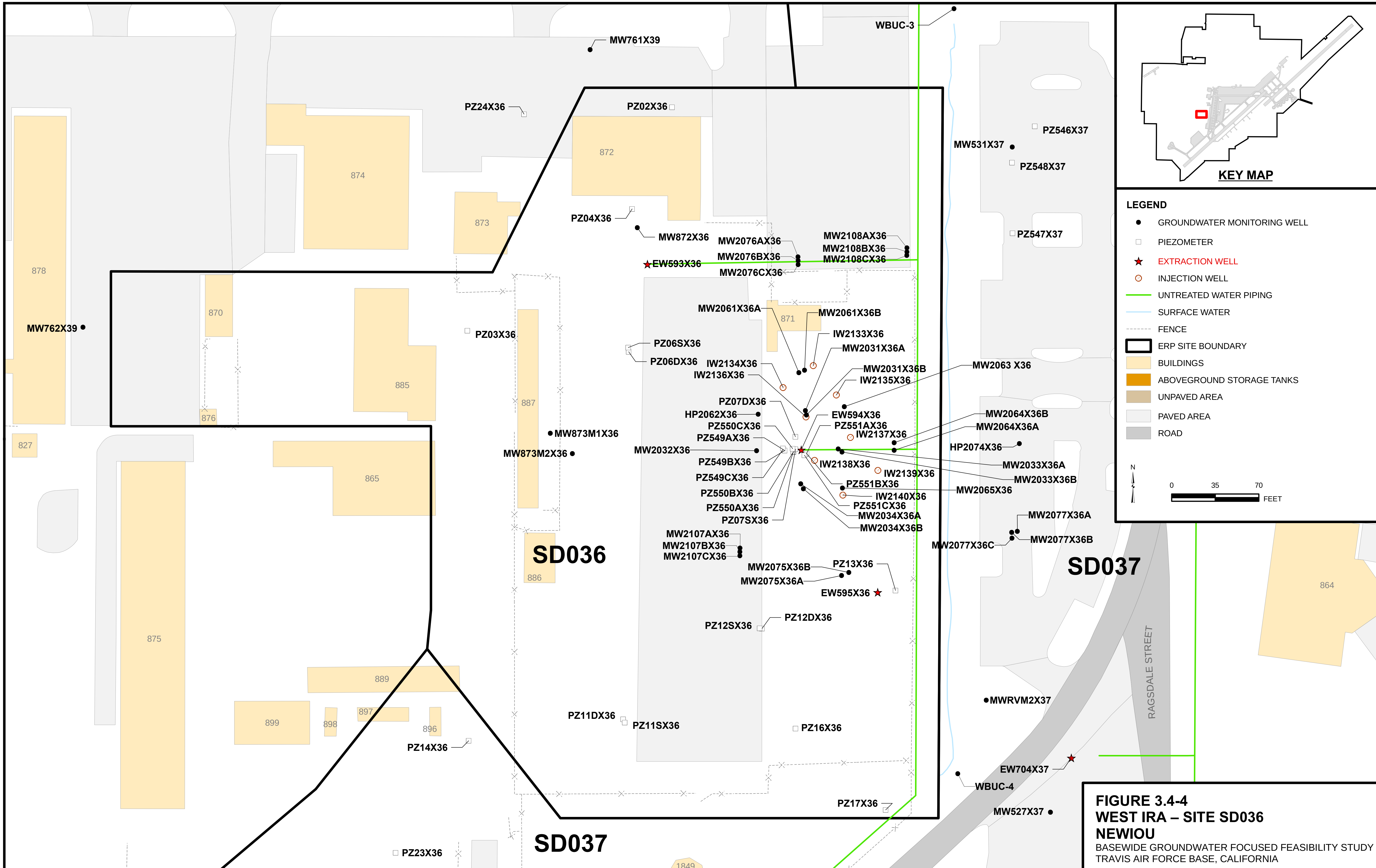


FIGURE 3.4-4
WEST IRA – SITE SD036
NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_4-4_SD036.MXD MCLAY1 1/21/2011 00:52:32

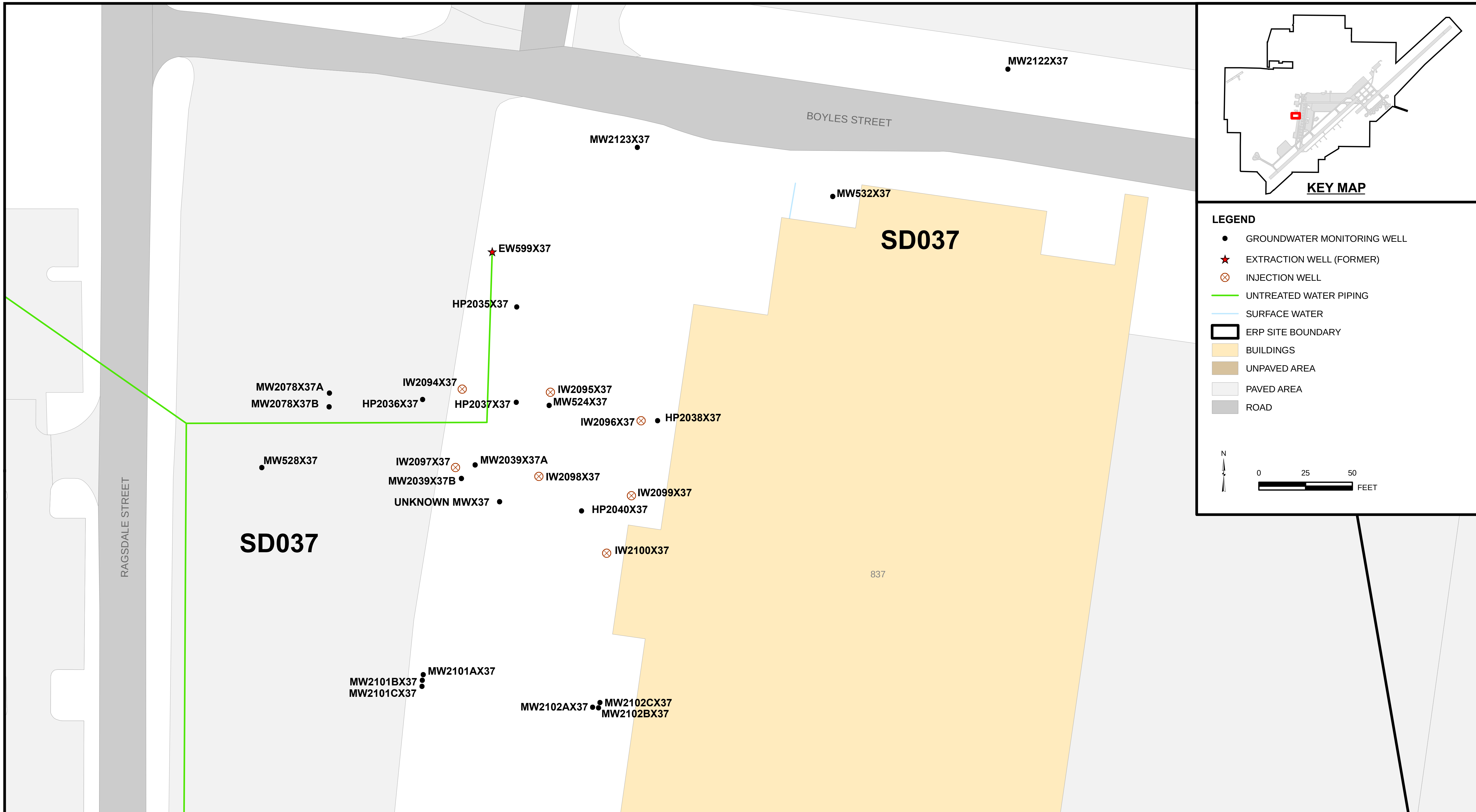


FIGURE 3.4-5
SITE MAP
WEST IRA – SITE SD037 MW524 AREA
NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

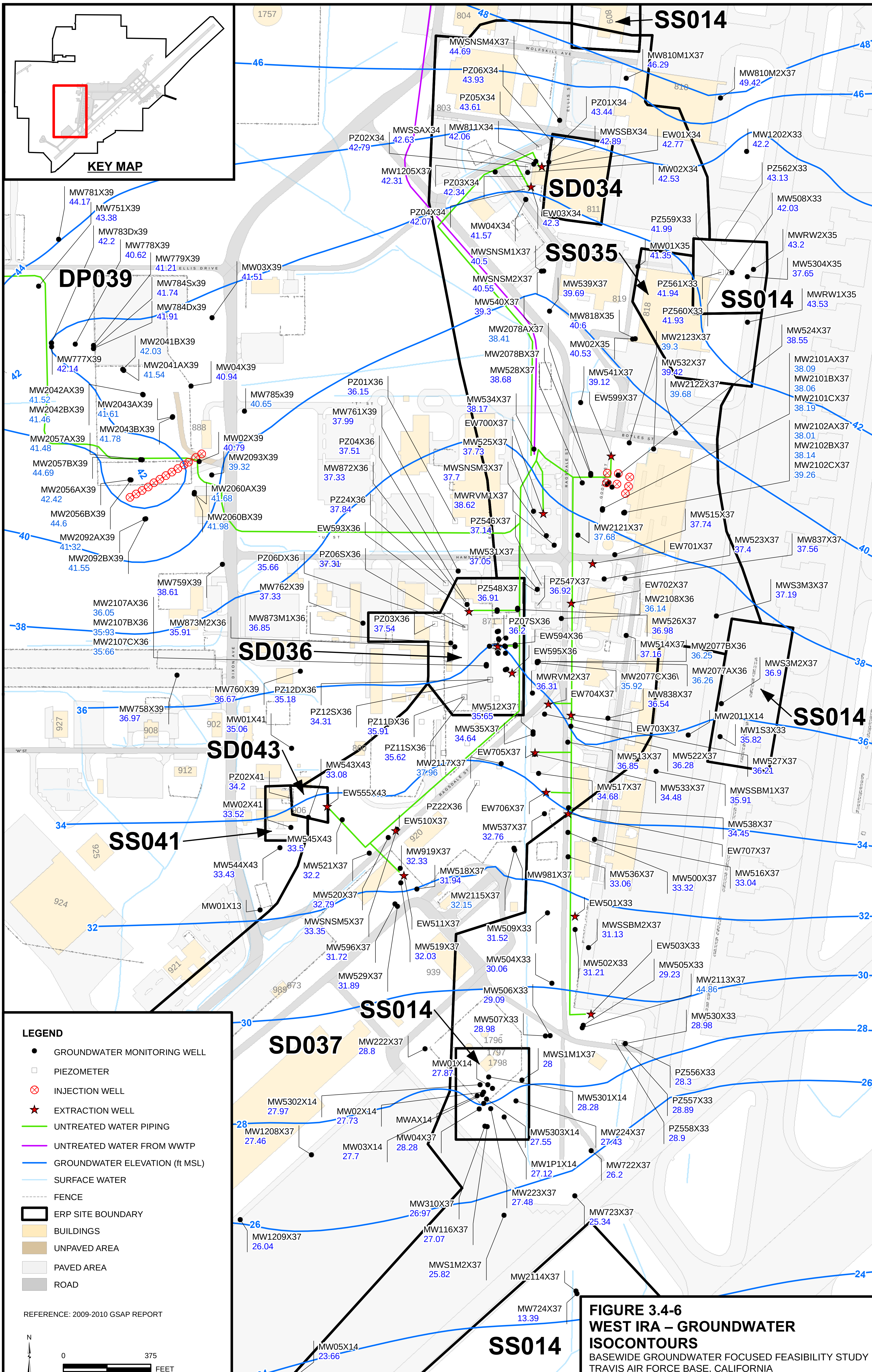


FIGURE 3.4-6
WEST IRA – GROUNDWATER ISOCONTOURS
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

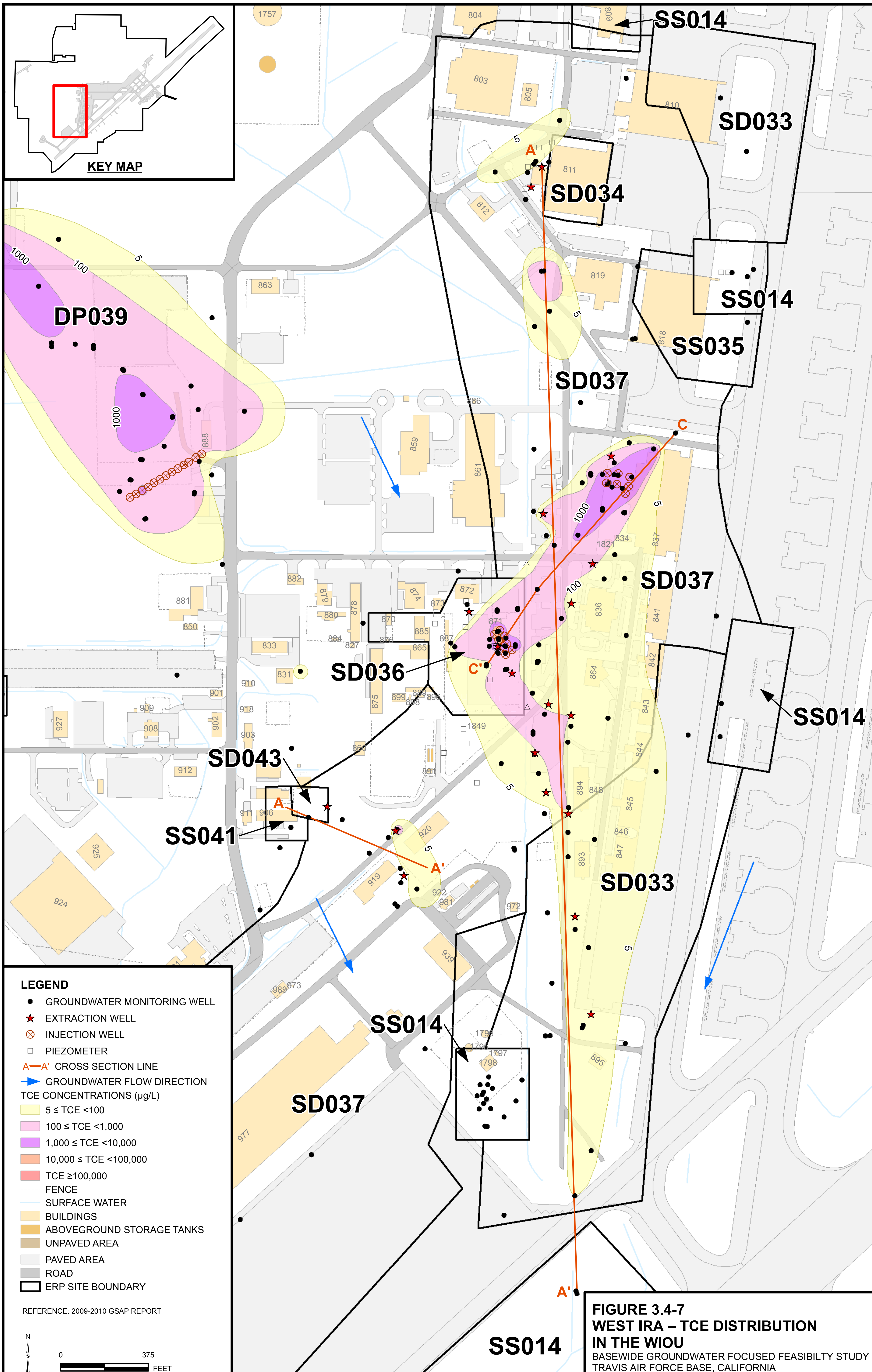
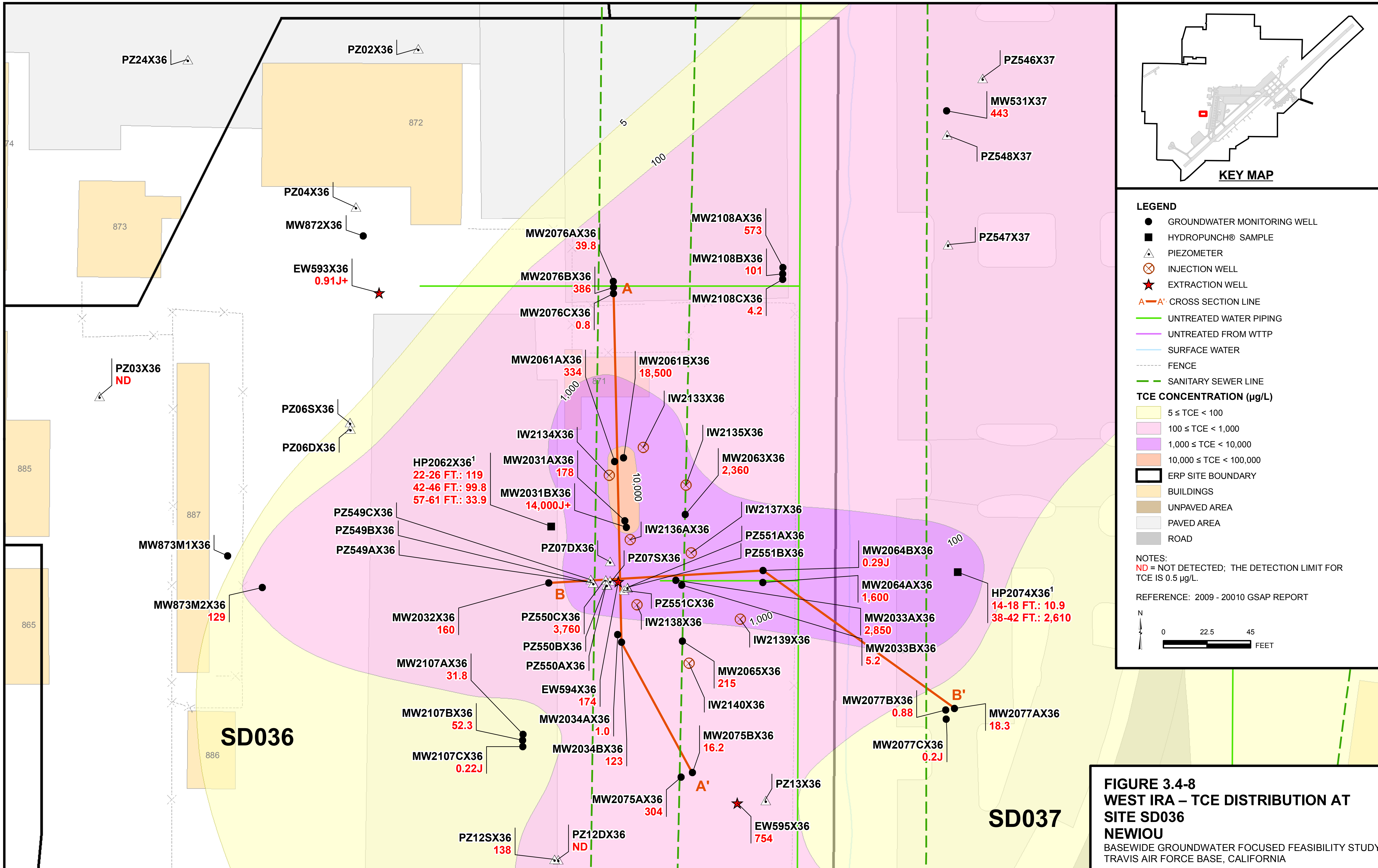


FIGURE 3.4-7
WEST IRA – TCE DISTRIBUTION
IN THE WIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILTY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIGURE_3_4-7_TCE_WIOU.MXD MCLAY1 1/21/2011 02:20:03



\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_4-8_SD036.MXD MSCHROCK 6/15/2011 01:49:35

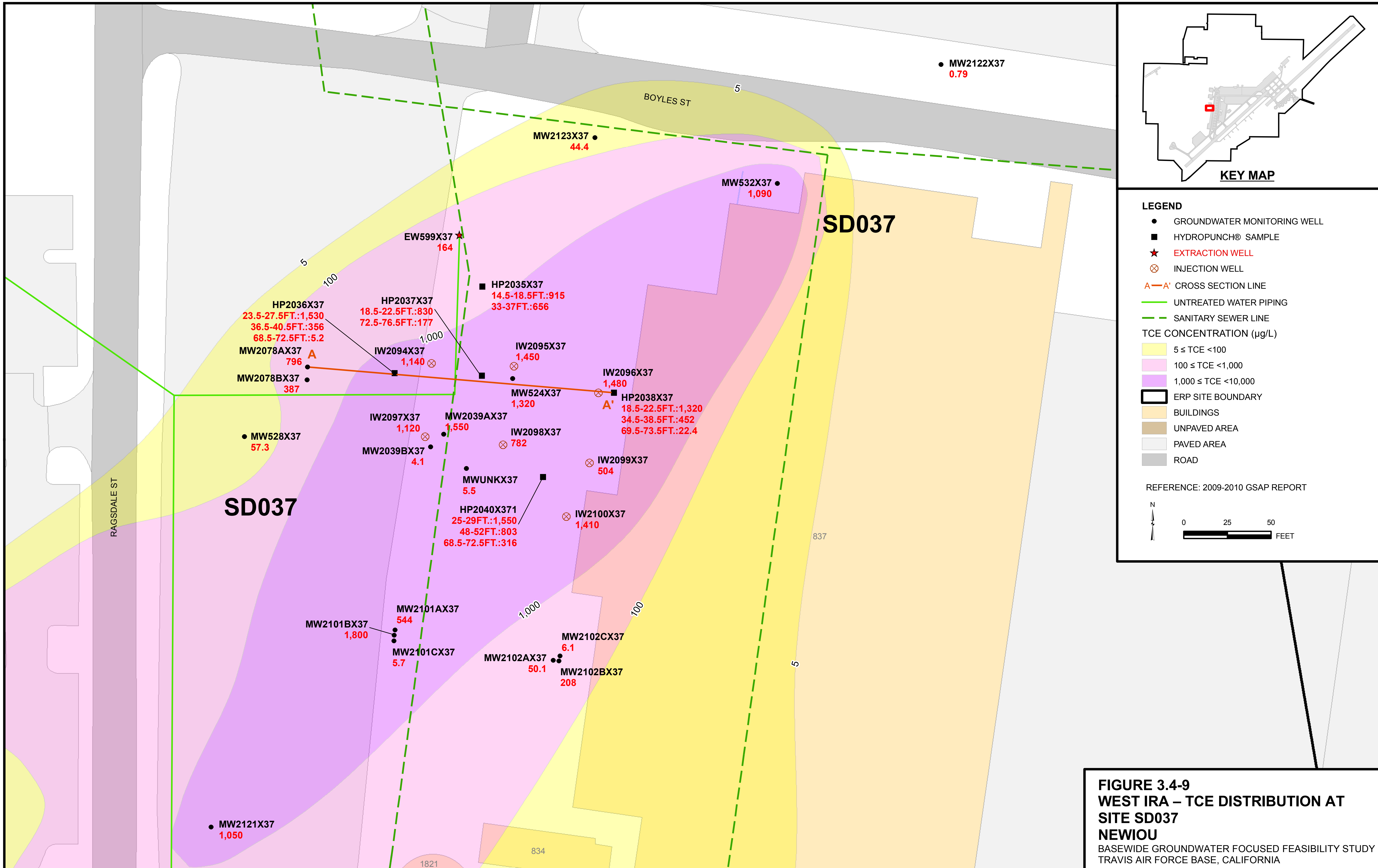
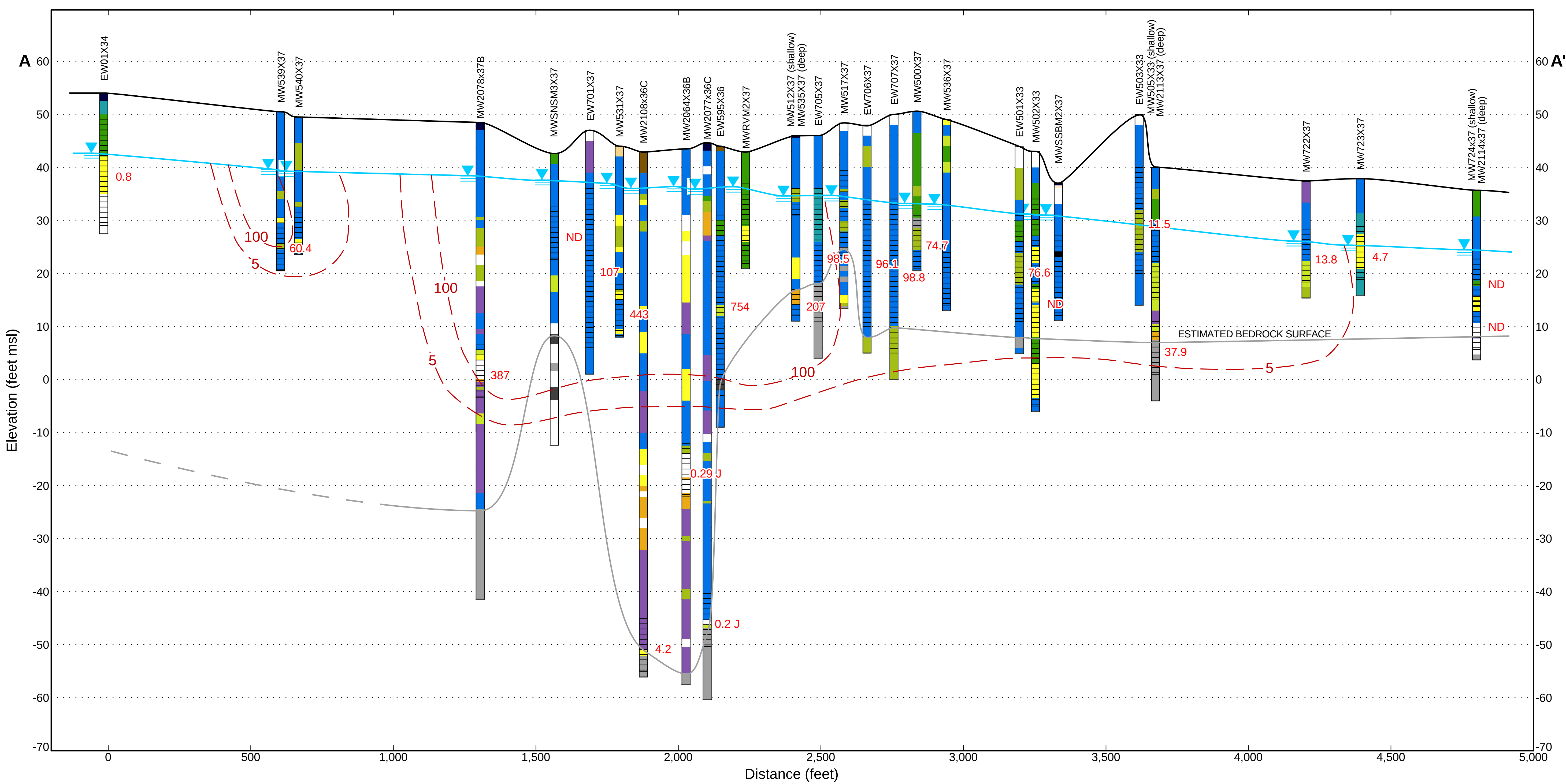


FIGURE 3.4-9
WEST IRA – TCE DISTRIBUTION AT SITE SD037
NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_4-9_SD037.MXD MSCHROCK 6/15/2011 02:35:18



SOIL AND LITHOLOGY

SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)

APPROXIMATE TCE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION

SCALE EXAGGERATION - 18.6:1 (H:V)

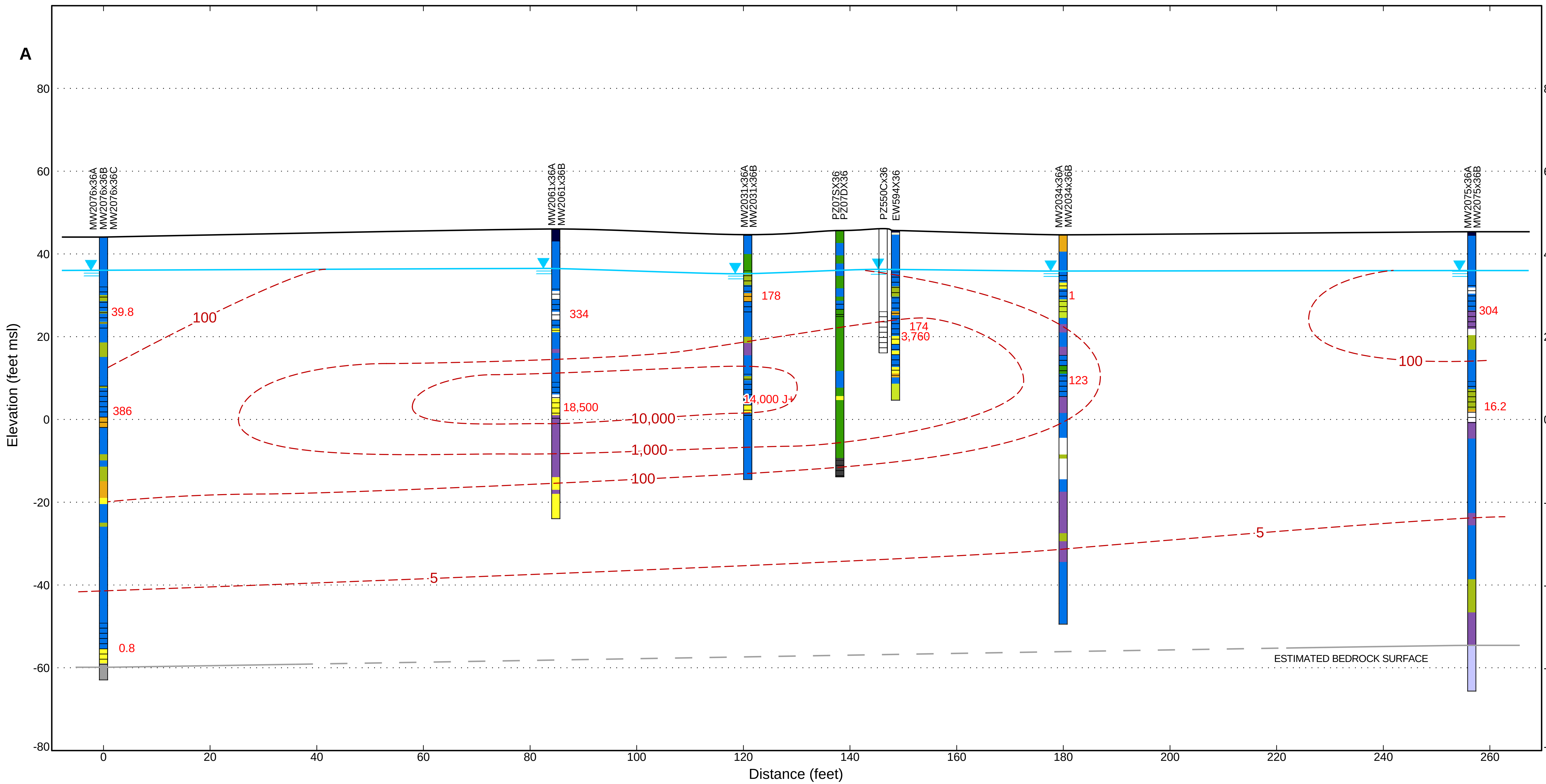
ND = NOT DETECTED; THE DETECTION LIMIT FOR TCE IS 0.5 µg/L

- NO SAMPLE/NO RECOVERY
- FILL/ASPHALT
- TOPSOIL/ORGANIC SOIL
- WELL GRADED GRAVEL (GW)
- POORLY GRADED GRAVEL (GP)
- SILTY GRAVEL (GM)
- CLAYEY GRAVEL (GC)
- WELL GRADED SAND (SW)
- POORLY GRADED SAND (SP)
- SILTY SAND (SM)
- CLAYEY SAND (SC)
- SILT (ML)
- ELASTIC SILT (MH)
- LEAN CLAY (CL)
- FAT CLAY (CH)
- SILTSTONE
- SANDSTONE
- SHALE
- ALLUVIUM (NO DATA)

FIGURE 3.4-10
WIOU CROSS SECTION A–A'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

\\YOSEMITE\PROJ\TRAVISAIRFORCEBASE\COMMONFILES\GINT FILES\TRAVIS_AFB_GINT_SECTIONS\2010\WIOU\TRAVIS_2010_WIOU.GPJ WIOU_GSAP_2010.GDW
ES082009007SAC Figure_3.4-10.ai 04.11.2011 tdaus



SOIL AND LITHOLOGY

SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)

6.7 TCE CONCENTRATION (µg/L) DETECTED IN 2010

— 5 — APPROXIMATE TCE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION

SCALE EXAGGERATION - 0.75:1 (H:V)

- NO SAMPLE/NO RECOVERY
- FILL/ASPHALT
- TOPSOIL/ORGANIC SOIL
- WELL GRADED GRAVEL (GW)
- POORLY GRADED GRAVEL (GP)
- SILTY GRAVEL (GM)
- CLAYEY GRAVEL (GC)
- WELL GRADED SAND (SW)
- POORLY GRADED SAND (SP)
- SILTY SAND (SM)
- CLAYEY SAND (SC)
- SILT (ML)
- ELASTIC SILT (MH)
- LEAN CLAY (CL)
- FAT CLAY (CH)
- SILTSTONE
- SANDSTONE
- SHALE
- ALLUVIUM (NO DATA)

FIGURE 3.4-11
SITE SD036 CROSS SECTION A–A'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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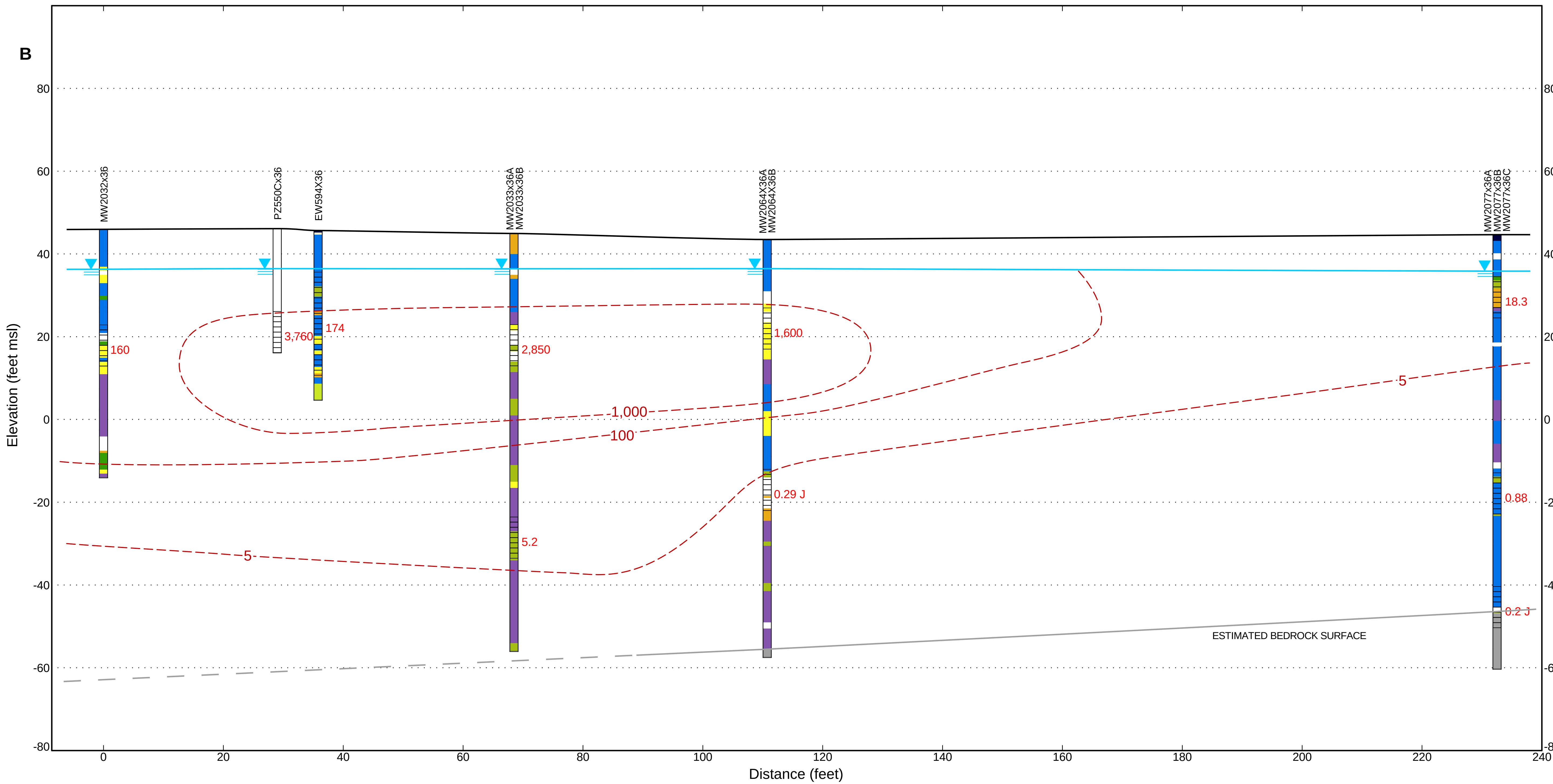

SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)

6.7 TCE CONCENTRATION (µg/L) DETECTED IN 2010

— 5 — APPROXIMATE TCE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION

SCALE EXAGGERATION - 0.7:1 (H:V)

SOIL AND LITHOLOGY

NO SAMPLE/NO RECOVERY
FILL/ASPHALT
TOPSOIL/ORGANIC SOIL
WELL GRADED GRAVEL (GW)
POORLY GRADED GRAVEL (GP)
SILTY GRAVEL (GM)
CLAYEY GRAVEL (GC)
WELL GRADED SAND (SW)
POORLY GRADED SAND (SP)
SILTY SAND (SM)
CLAYEY SAND (SC)
SILT (ML)
ELASTIC SILT (MH)
LEAN CLAY (CL)
FAT CLAY (CH)
SILTSTONE
SANDSTONE
SHALE
ALLUVIUM (NO DATA)

FIGURE 3.4-12
SITE SD036 CROSS SECTION B–B'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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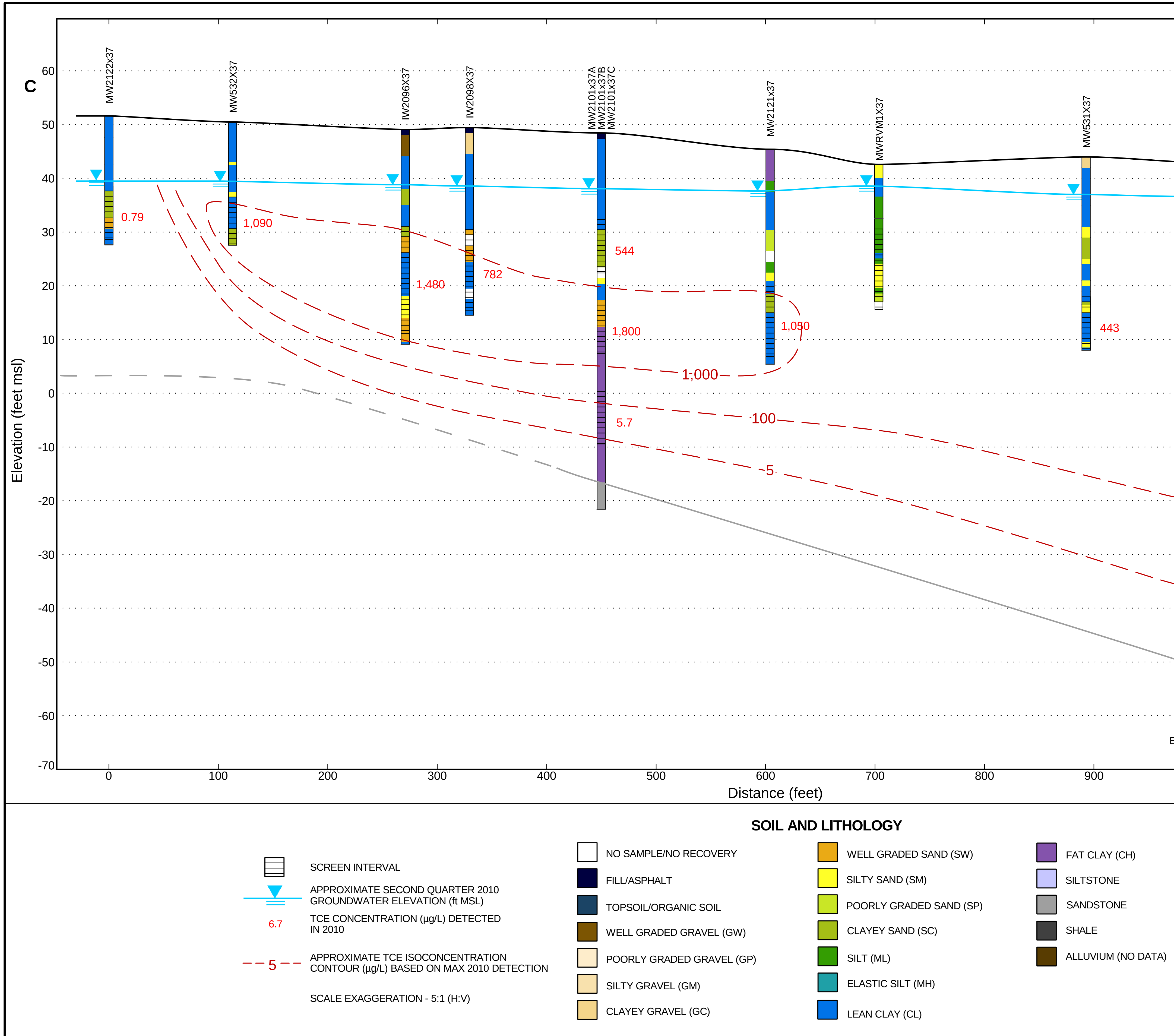

FIGURE 3.4-13
SITE SD036/SD037 CROSS SECTION C–C'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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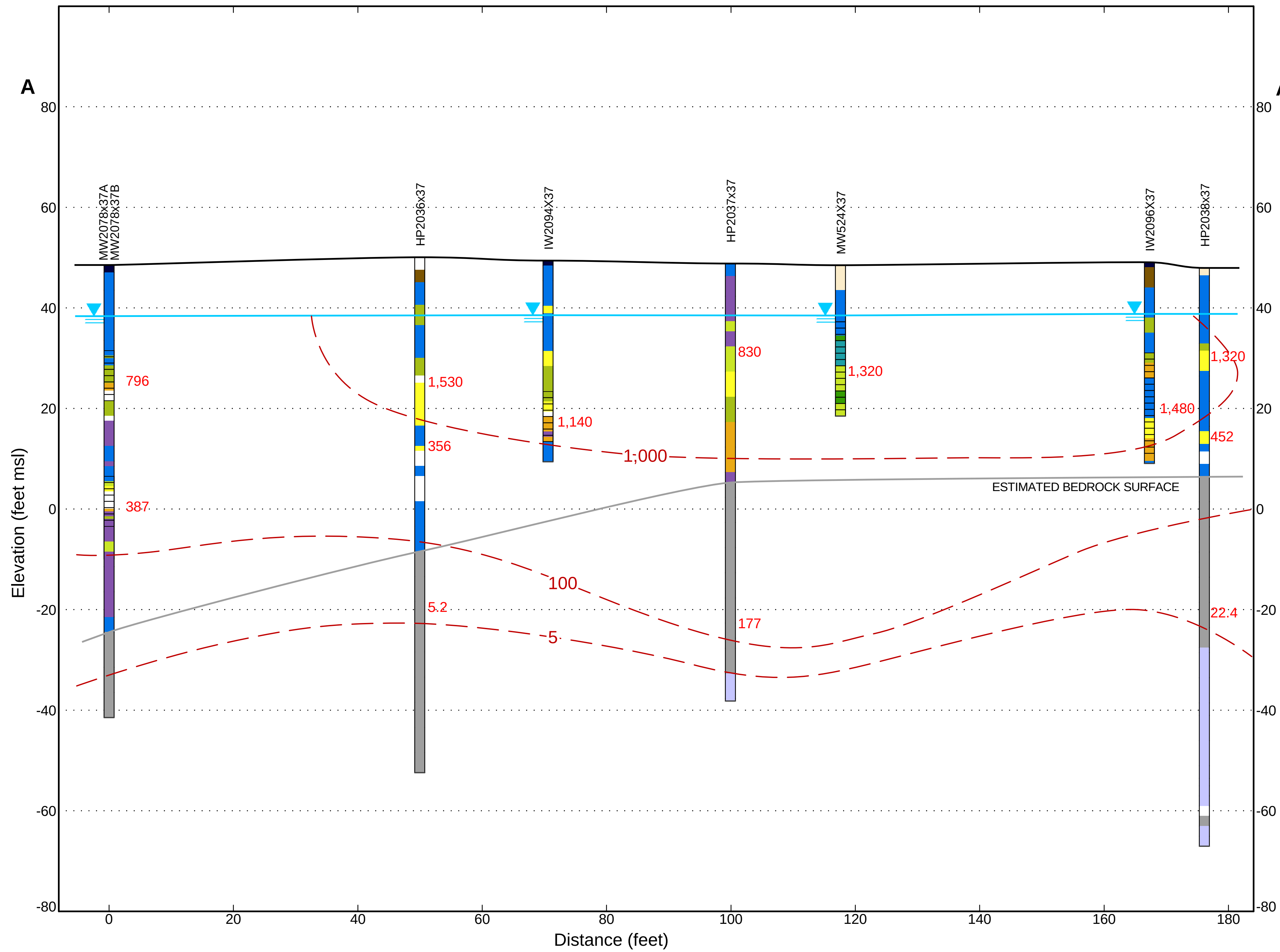
ES082009007SAC Figure_3.4-13.ai 06.14.2011 tdaus



SOIL AND LITHOLOGY

SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)

6.7 TCE CONCENTRATION (µg/L) DETECTED IN 2010

5 APPROXIMATE TCE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION

SCALE EXAGGERATION - 0.8:1 (H:V)

- NO SAMPLE/NO RECOVERY
- FILL/ASPHALT
- TOPSOIL/ORGANIC SOIL
- WELL GRADED GRAVEL (GW)
- POORLY GRADED GRAVEL (GP)
- SILTY GRAVEL (GM)
- CLAYEY GRAVEL (GC)
- WELL GRADED SAND (SW)
- SILTY SAND (SM)
- POORLY GRADED SAND (SP)
- CLAYEY SAND (SC)
- SILT (ML)
- ELASTIC SILT (MH)
- LEAN CLAY (CL)
- FAT CLAY (CH)
- SILTSTONE
- SANDSTONE
- SHALE
- ALLUVIUM (NO DATA)

FIGURE 3.4-14
SITE SD037 CROSS SECTION A–A'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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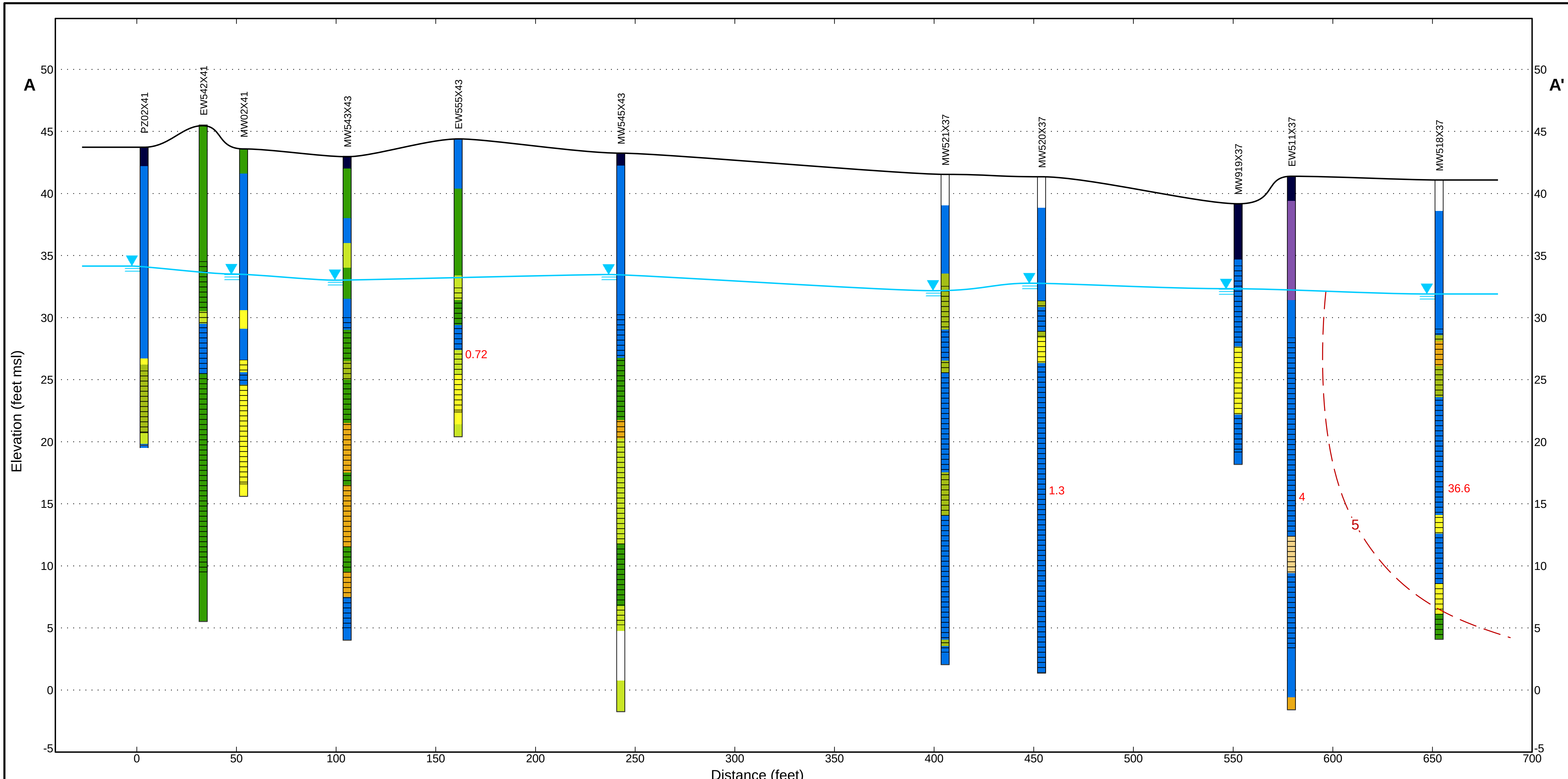

SOIL AND LITHOLOGY

- SCREEN INTERVAL
- APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)
- 6.7 — TCE CONCENTRATION (µg/L) DETECTED IN 2010
- – – 5 – – APPROXIMATE TCE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION
- SCALE EXAGGERATION - 6:1 (H:V)

- NO SAMPLE/NO RECOVERY
- FILL/ASPHALT
- TOPSOIL/ORGANIC SOIL
- WELL GRADED GRAVEL (GW)
- POORLY GRADED GRAVEL (GP)
- SILTY GRAVEL (GM)
- CLAYEY GRAVEL (GC)
- WELL GRADED SAND (SW)
- SILTY SAND (SM)
- POORLY GRADED SAND (SP)
- CLAYEY SAND (SC)
- SILT (ML)
- ELASTIC SILT (MH)
- LEAN CLAY (CL)
- FAT CLAY (CH)
- SILTSTONE
- SANDSTONE
- SHALE
- ALLUVIUM (NO DATA)

FIGURE 3.4-15
SITE SS041/SD043 CROSS SECTION A–A'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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ES082009007SAC Figure_3.4-15.ai 01.20.2011 tdaus

3.4.2 Site SS015 Conceptual Site Model

This section provides the CSM for Site SS015 located in the western portion of Travis AFB. An MNA assessment has been implemented at the site in accordance with the NEWIOU Groundwater IROD (Travis AFB, 1998).

Additional descriptions of the site geology, groundwater characteristics, and groundwater contamination are provided in Section 4.7 of the 2009-2010 Annual GSAP Report (CH2M HILL, 2011b).

3.4.2.1 Site Description

Site SS015 occupies about 3.5 acres in the western-central portion of Travis AFB. A site map is shown on Figure 3.4-16. The main feature at the site includes Building 554, which is a petroleum, oil, and lubricants (POL) military compound consisting of an office building, a fuel truck maintenance facility, and a large concrete truck parking area. The POL building was constructed with a vapor barrier and passive vent system to protect the building from potential vapor intrusion from an underlying plume of groundwater contamination.

Three (3) potential sources of historical groundwater contamination have existed at Site SS015:

- Former Facility 550
- Former Facility 552 (including the area at Facility 1832)
- SSA east of former Facility 550

Of these, the primary source area is currently considered to be the SSA.

Facility 550. Former Facility 550 was located south of Hangar Avenue. Beginning in 1952, the facility housed a corrosion control shop, a metals processing shop, and a fiberglass shop. Paints, paint thinners, methyl ethyl ketone, acids, and stripping wastes were used or generated at the facility. A floor drain, connected to the sanitary sewer, was used to discharge wastes from the corrosion control shop. Facility 550 was demolished in 2004.

Facility 552. Former Facility 552 was a fenced, bermed concrete pad located south of Hangar Avenue and immediately east of Facility 550. Historically, the facility was used as a hazardous waste collection area. Paint, chromic acid, and waste solvents generated during aircraft maintenance activities at Facility 550 were stored in Facility 552. From 1954 to 1980, radomes were stripped of paint in an area adjacent to Facility 552 (Weston, 1995). The associated Facility 1832 is a 15,000-gallon OWS that received liquids generated at a wash rack on the aircraft parking apron. In 1992, a new hazardous waste accumulation facility was constructed at the site. Facility 552 was demolished in 2004.

SSA. The SSA occupied approximately 1.4 acres east of Facility 550. Paint was stripped from aircraft in the area for an undocumented period of time. Accidental releases included an estimated 100 to 150 gallons per month of methyl ethyl ketone, toluene, or tetraethylene glycol dimethyl ether (tetraglyme) from work trays used to collect stripping wastes. Soil was visibly stained in the SSA in aerial photographs taken before 1970 (Weston, 1995).

3.4.2.2 MNA Assessment Investigation

In 1998, a pre-design investigation was conducted to support the MNA assessment specified in the NEWIOU Groundwater IROD. The findings of this investigation are documented in the *Summary of the Site SS015 Investigation Technical Memorandum* (CH2M HILL, 1999b). However, the initial MNA assessment was delayed because the site was subsequently selected for a treatability study of enhanced MNA using vegetable oil injection.

3.4.2.3 Vegetable Oil Injection Treatability Study

A limited treatability study was conducted at the site during 2000 and 2001. During this study, two (2) phases of partially hydrogenated soybean oil injection were conducted. Phase I was conducted in June 2000 when approximately 62 gallons of soybean oil were injected. During Phase II, conducted in December 2000, approximately 165 gallons were injected. The study is documented in the *Phase I and Phase II Field Feasibility Test for In-Situ Bioremediation of Chlorinated Solvents Via Vegetable Oil Injection at Site SS015* (Parsons, 2001, 2002). The historical soybean oil injection locations are shown on Figure 3.4-17.

The treatability study was terminated early because of a military construction project at the site. In 2004, Building 554, the POL building, was constructed over a portion of the vegetable oil injection area. Following construction of Building 554, monitoring wells MW624x15 and MW625x15 were installed to monitor the plume.

Although the vegetable oil injection treatability study was concluded prematurely, the initial results were promising and demonstrated that suitable bacterial populations were present and reductive dechlorination was occurring at the site (Parsons, 2002).

3.4.2.4 Geology

The geology in the vicinity of Site SS015 consists of a relatively thin cover of low permeability alluvium overlying a shallow bedrock ridge. The alluvium ranges from 0 to 19 feet in thickness and consists primarily of clays, sandy clays, and clayey sand. The bedrock ridge strikes across the site from the northwest to the southeast and plunges to the southeast. The bedrock ridge dips to the northeast. A surface outcrop of the bedrock is present to the west of the site near the intersection of Hangar Avenue and Ragsdale Street. The bedrock ridge also runs along the western side of adjacent Site SS016 and through Site ST027, where bedrock has been encountered as shallow as 2 feet bgs. The ridge is associated with a regional anticline. Site SS015 is located near the apex of that anticline. The submerged bedrock ridge (anticline) is composed of Markley Sandstone, and the basin to the east (syncline) is composed of Nortonville Shale.

Bedrock at the site consists of a highly weathered Markley Sandstone and highly fractured and weathered siltstone associated with the Nortonville Shale. The Markley Sandstone is weathered to such a degree that it resembles poorly graded sand. The siltstone has a pervasive platy texture that likely increases the permeability of the siltstone.

In the central portion of Site SS015, near monitoring well MW216x15, a bedrock high is present where the bedrock is just below the ground surface. In the northeastern portion of the site, near monitoring wells MW624x15, MW2103x15, and MW2105x15 and borings 15-SB04 and 15-SB09, there is an apparent depression where bedrock is encountered as deep as 19 feet bgs. Further to the east, bedrock becomes shallow again. The local bedrock depression at Site SS015, likely an erosional feature, extends to the north/northeast.

3.4.2.5 Groundwater Characteristics

Groundwater flow at Site SS015 is predominantly within the highly weathered Markley Sandstone and by fracture flow in the siltstone of the Nortonville Shale. The bedrock becomes more competent with depth, limiting the vertical distribution of contamination. During the installation of monitoring wells in 2010, groundwater was frequently encountered within the weathered and fractured bedrock rather than in the overlying, relatively impermeable (silt and clay) alluvium. However, the presence of groundwater within the alluvium was noted at some locations. For instance, groundwater was encountered in a thin lens of alluvial sand just above the alluvium-siltstone interface in the vicinity of monitoring well MW2103x15.

The regional flow of groundwater at Travis AFB is typically south-southeast. However, at Site SS015, the local flow of groundwater is controlled by the features of the shallow bedrock. Local groundwater elevation contours are shown on Figure 3.4-18. Groundwater flow is radial, away from the bedrock high near MW216x15. A northeast-trending groundwater trough evident in the groundwater elevation contours is indicative of an area where the bedrock is highly weathered and fractured, resulting in a preferential northeastern local groundwater flow direction. This area also coincides with a bedrock depression, likely an erosional feature where increased weathering of the bedrock would be expected. Groundwater characteristics at Site SS015 are summarized in the following list:

- Depth to water ranges from 7 to 12 feet bgs.
- The regional alluvium groundwater flow direction is south-southeast at a horizontal gradient of approximately 0.007 ft/ft.
- The predominant local bedrock groundwater flow direction is north-northeast at a horizontal gradient of 0.01 ft/ft. The local groundwater flow direction and horizontal gradient in the alluvium cannot be determined because only one (1) alluvium well exists at the site.
- The largest vertical gradient at the site is 0.1 ft/ft upwards at well pair MW624x15/MW2103x15, located in the center of the bedrock depression. The gradient indicates that the well is in a recharge zone, consistent with its location in a groundwater trough.
- The potentiometric head in some of the site monitoring wells is between 0.5 to 11 feet above the alluvium/bedrock interface. This suggests that some of the groundwater system is partially confined. The alluvium encountered at Site SS015 is generally less permeable than the underlying highly weathered Markley Sandstone and fractured siltstone and may locally act as a semi-confining layer.
- Groundwater elevations are relatively stable, with seasonal variations of approximately 2 to 4 ft/year, but there are no long-term trends.

3.4.2.6 Groundwater Contamination

The primary groundwater contaminants at Site SS015 include TCE (parent) and daughter products cis-1,2-DCE and vinyl chloride. Contaminant distribution maps for these compounds are shown on Figures 3.4-19, 3.4-20, and 3.4-21. Cross sectional views of the contaminant concentrations are shown on Figures 3.4-22 and 3.4-23.

During 2010, the highest VOC concentrations are found at MW216x15:

- TCE – 432 µg/L
- Cis-1,2-DCE – 7,680 µg/L
- Vinyl chloride – 3,220 µg/L

The high localized concentrations of 1,2-DCE and vinyl chloride relative to TCE indicate incomplete biodegradation of TCE following the vegetable oil injection treatability study conducted in 2000 and 2001 (Parsons, 2001, 2002). However, the data also demonstrate that suitable bacterial populations are present for reductive dechlorination processes to take place (Parsons, 2002). The presence of incomplete degradation products suggests that the limited volume of vegetable oil injected a decade ago has been exhausted as a bacterial food source.

During 2008-2009, Travis AFB conducted a vapor intrusion assessment in accordance with the *Vapor Intrusion Assessment Work Plan* (CH2M HILL, 2008b). The findings of the vapor intrusion investigations are provided in the final *Vapor Intrusion Assessment Report* (CH2M HILL, 2010g). Section 6.3.2 of this report describes the results of the investigation of Building 554 within Site SS015, which concluded that the passive vent system within Building 554 is adequate for eliminating the vapor intrusion exposure pathway and protecting office personnel.

The northeastern groundwater flow direction at the site is consistent with the observed distribution of groundwater contamination, which extends to the northeast from monitoring well MW216x15.

3.4.2.7 Status of Groundwater Interim Remedial Action

In accordance with the NEWIOU Groundwater IROD, Travis AFB initiated MNA assessment at Site SS015. MNA assessment data have been collected for approximately 10 years, and data collection continues into 2010.

Following the conclusion of the 2000–2001 vegetable oil treatability study, routine monitoring has been conducted under the GSAP. Seven (7) monitoring wells have been routinely sampled to support the ongoing MNA assessment. These historically sampled wells are MW104x15, MW105x15, MW216x15, MW238x15, MW306x15, MW624x15, and MW625x15. The locations of these monitoring wells are shown on Figure 3.4-16. Additional wells installed as part of the 2010 IRA optimization will be added to the GSAP monitoring, as required. The validated analytical results of groundwater sampling events are regularly provided in annual GSAP reports.

The *Second Five-Year Review Report* and the NAAR (CH2M HILL, 2008a, 2010a) concluded that MNA is a viable remedy for Site SS015. This assessment of MNA viability was based on the 10 years of data collected from the site monitoring wells. However, the five-year review and NAAR also concluded that IRA optimization was required.

Optimization of the current MNA assessment IRA is required because the concentrations of chlorinated VOC concentrations (both TCE parent and daughter products) have been increasing in source area well MW216x15. Also, until the 4Q08 GSAP event, only trace concentrations had been detected in downgradient wells. More recently, VOCs were also detected in one (1) downgradient well at concentrations exceeding the IRGs specified in the NEWIOU Groundwater IROD.

The NAAR made the following conclusions about the Site SS015 MNA assessment:

- In the source area well, there is adequate evidence for biodegradation of chlorinated solvents. Biodegradation potential in this area was enhanced by the vegetable oil injections performed in 2000 and 2001.
- In the portion of the MNA assessment areas where contaminants are near or below IRGs, there is inadequate to limited evidence for biodegradation of chlorinated solvents.
- TCE; PCE; and cis-1,2-DCE concentrations decreased in source area well MW216x15 from 2004 to 2007 but rebounded from 2007 to 2008. Vinyl chloride concentrations have continuously increased from 2004 to 2008.
- The elevated concentrations of breakdown products cis-1,2-DCE and vinyl chloride relative to the concentration of parent compounds PCE and TCE in the source area confirm that the vegetable oil injection enhanced biodegradation, but insufficient vegetable oil remains to complete the degradation process. The concentrations of daughter products are currently an order of magnitude higher than the concentrations of the parent compounds.
- After several years of stability, the plume appears to be migrating northeasterly. The increase in contaminant concentrations at downgradient well MW625x15 and rebound in concentrations at source area well MW216x15 indicate that the vegetable oil injected in 2000 and 2001 has been consumed and can no longer provide adequate substrate for the native microorganisms.

3.4.2.8 IRA Optimization

During 2010, an optimization of the current MNA program was conducted within the Site SS015 contaminant source area. Optimization activities included a data gaps investigation, installation of additional groundwater monitoring wells, and injection of EVO within the contaminant source area (CH2M HILL, 2010c). A more complete description of the EVO treatment technology is provided in Section 6. More information on the EVO injection optimization action at the site is provided in Section 7.

The performance of the EVO optimization actions at Site SS015 will be monitored for the remainder of the period of interim remediation. If the performance data indicate that the EVO treatment is effective at remediating contamination, then it may be incorporated into the final remedial action at the site. The formal selection of a remedial action will be made in the pending Basewide Groundwater ROD.

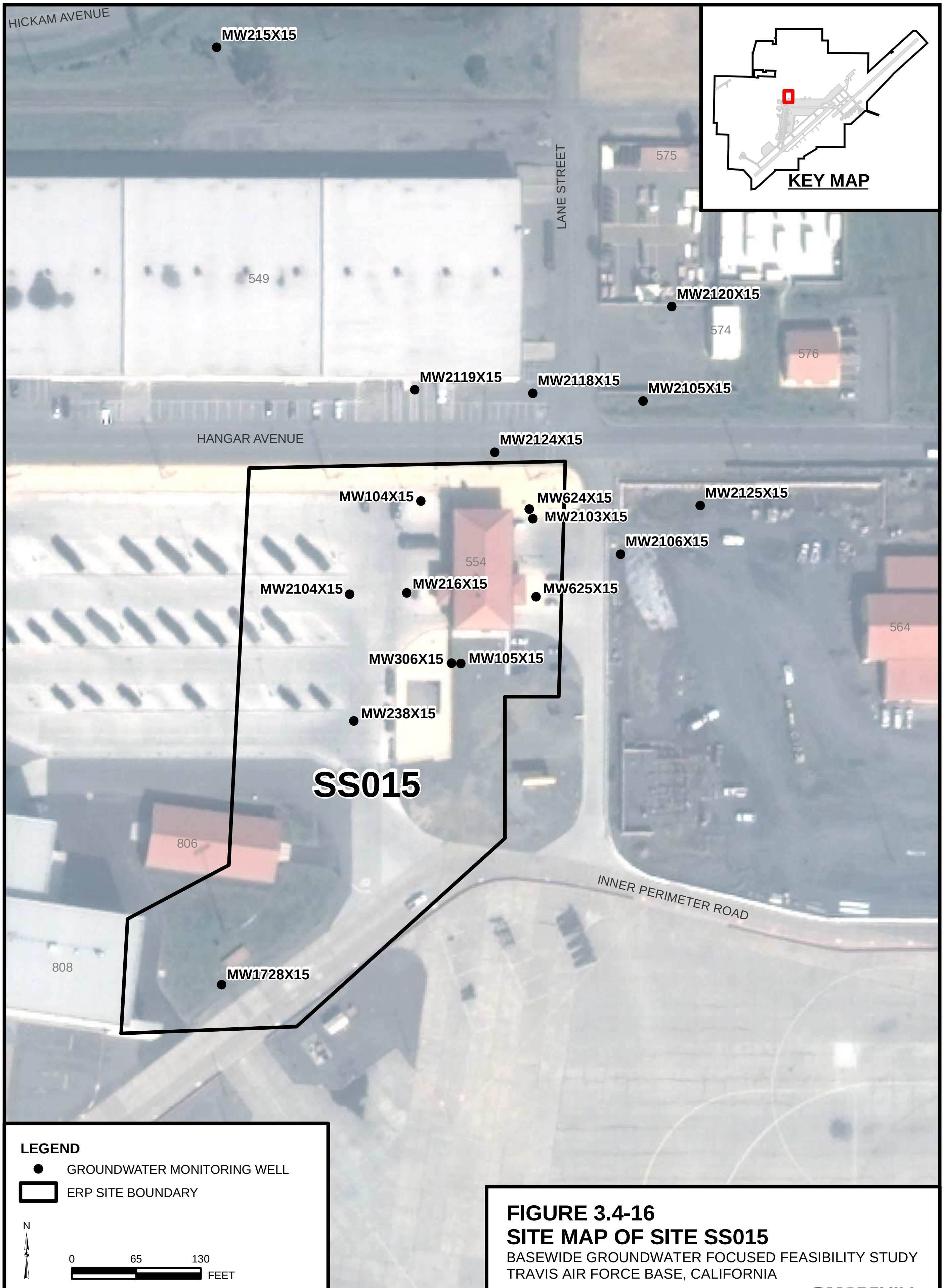

FIGURE 3.4-16
SITE MAP OF SITE SS015
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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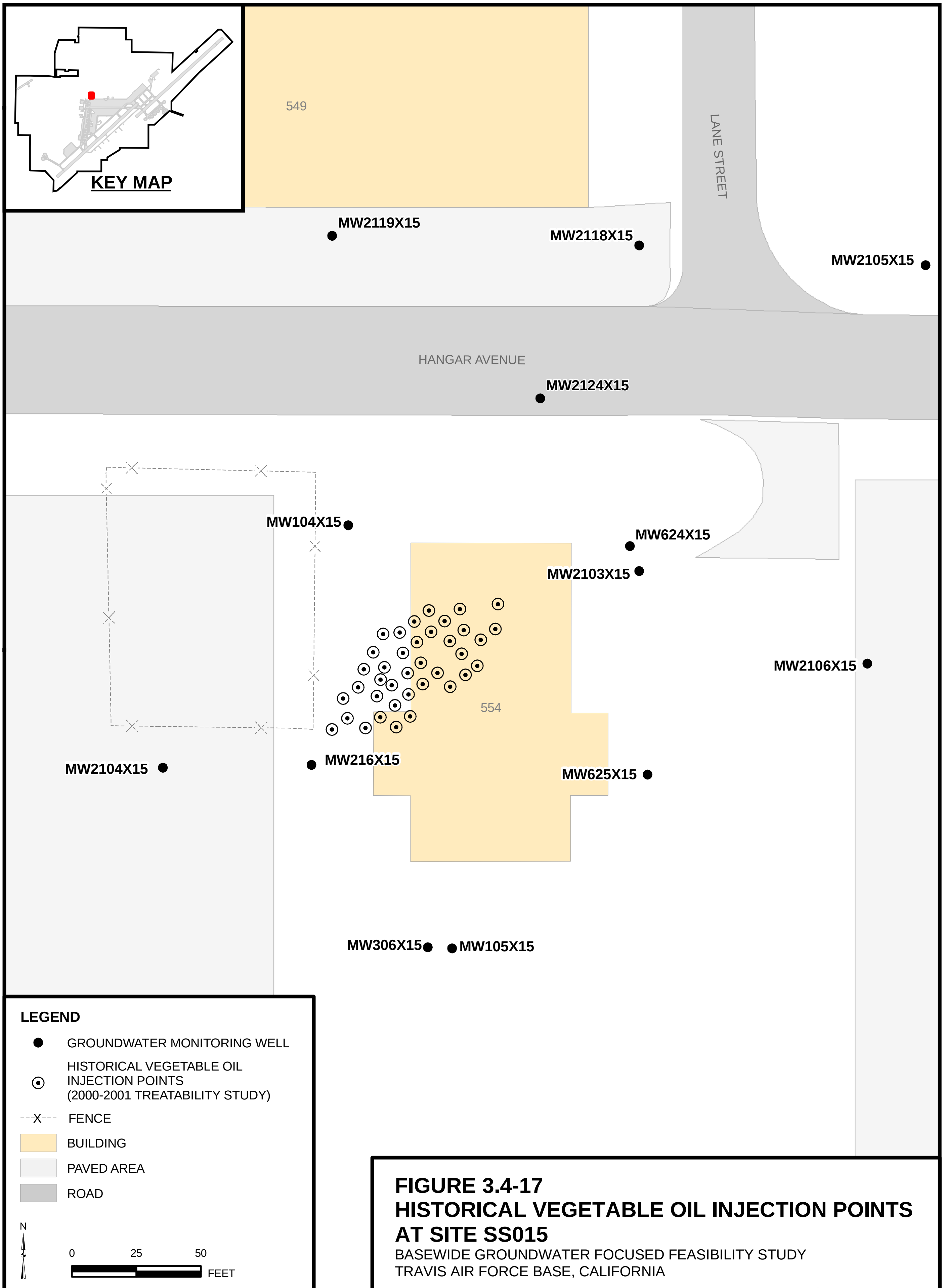

FIGURE 3.4-17
HISTORICAL VEGETABLE OIL INJECTION POINTS AT SITE SS015
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

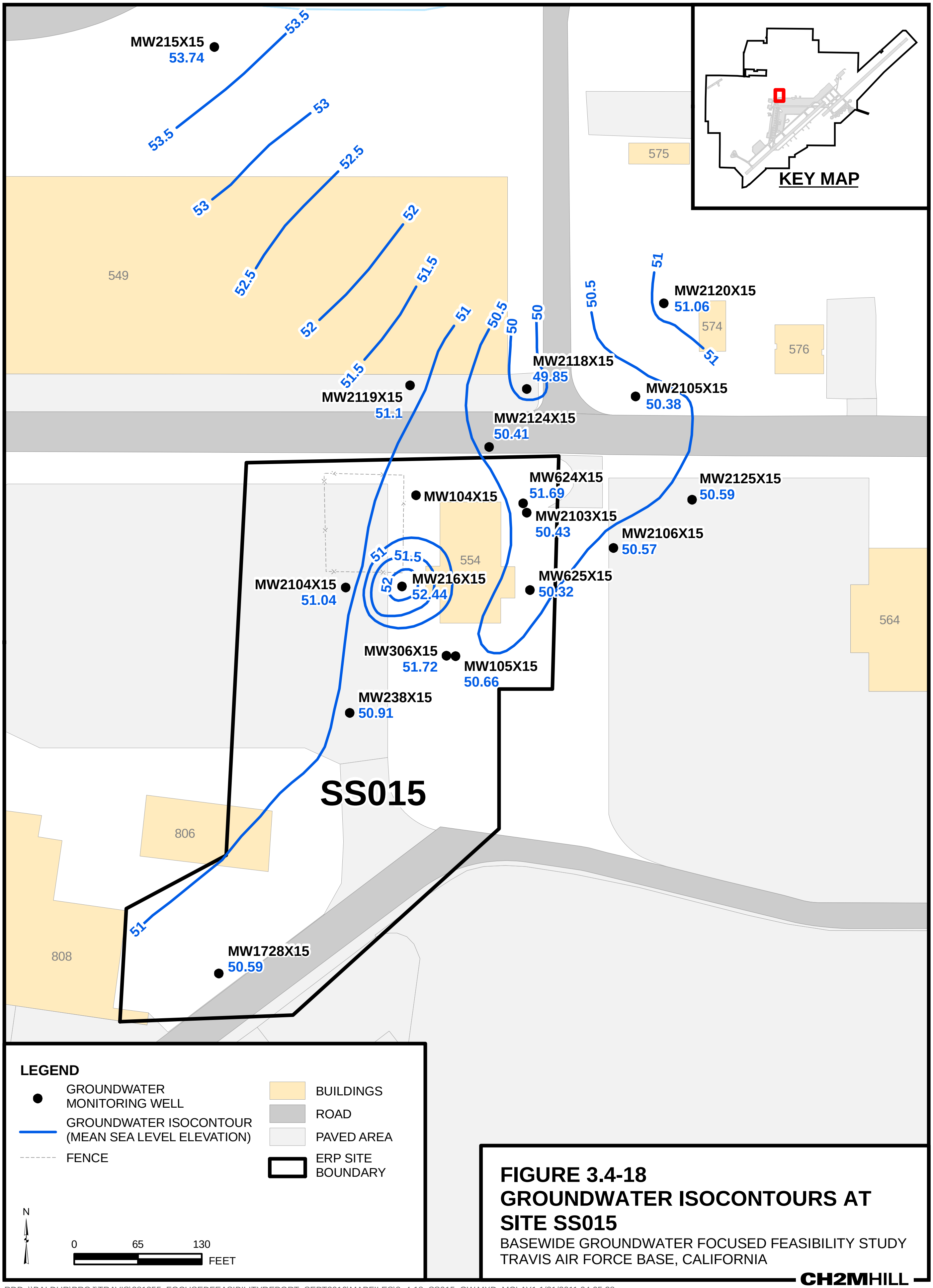

FIGURE 3.4-18
GROUNDWATER ISOCONTOURS AT SITE SS015
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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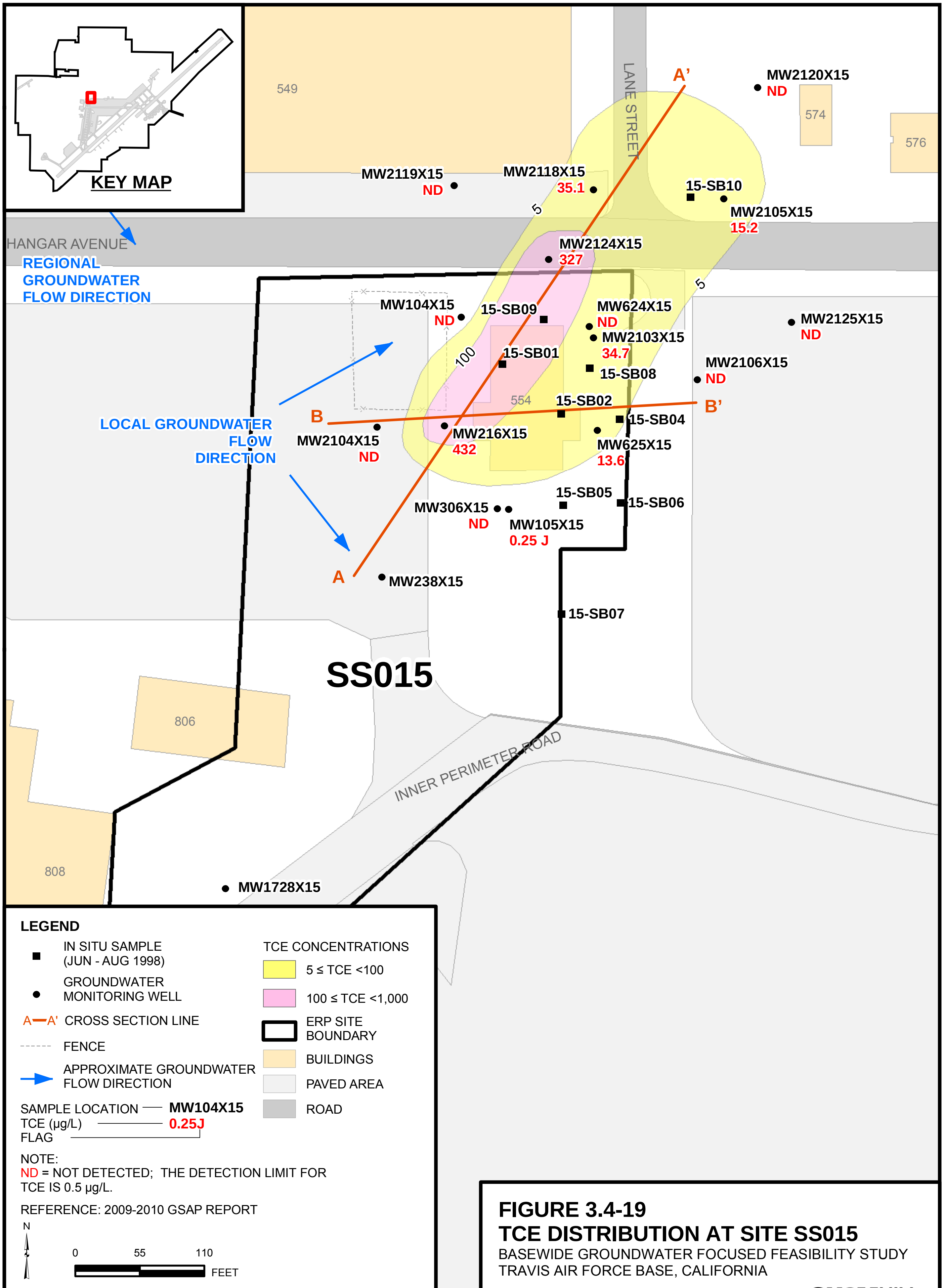

FIGURE 3.4-19
TCE DISTRIBUTION AT SITE SS015
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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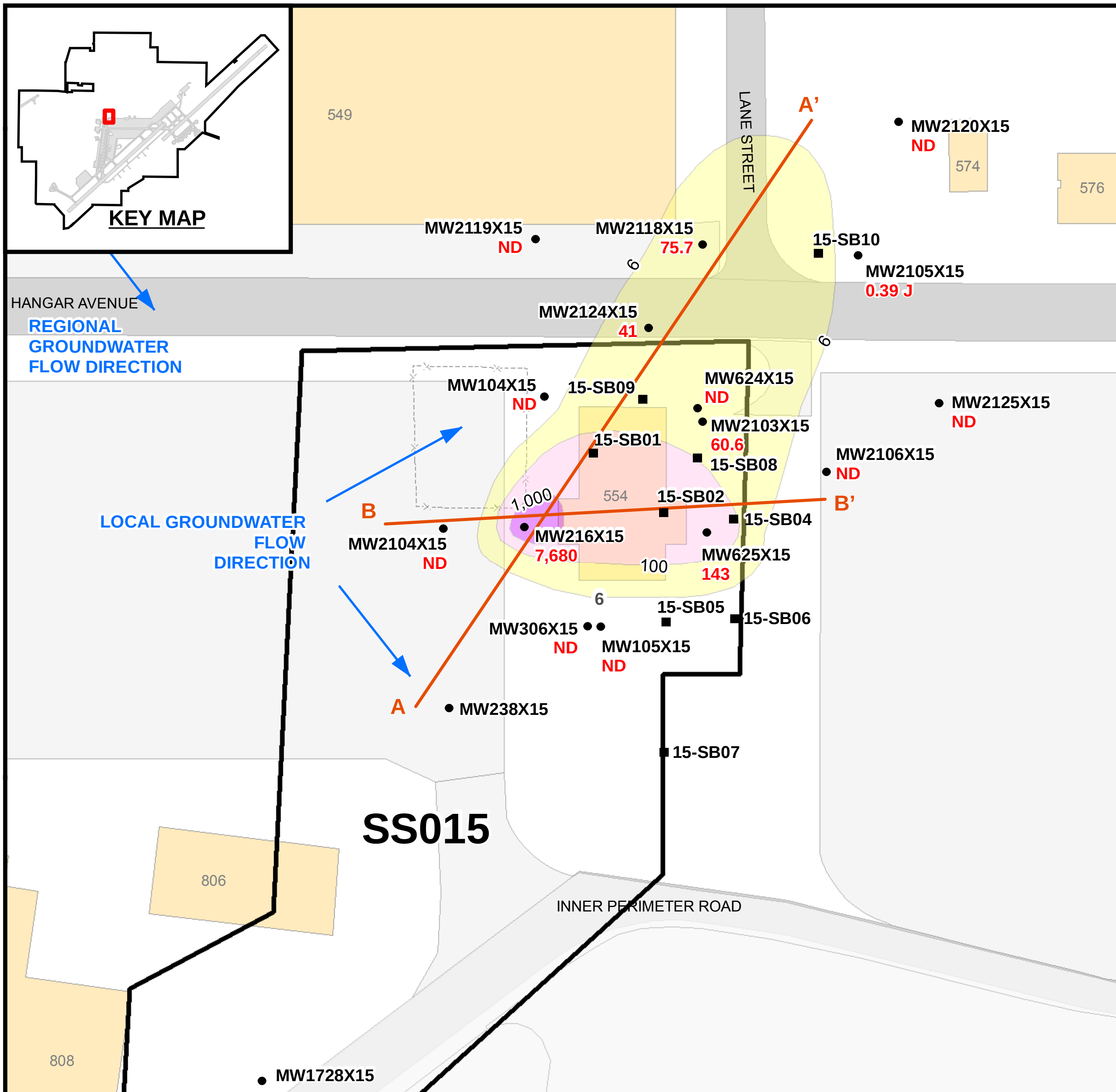

LEGEND

- ■ IN SITU SAMPLE (JUN - AUG 1998)
- ● GROUNDWATER MONITORING WELL
- A — A' CROSS SECTION LINE
- APPROXIMATE GROUNDWATER FLOW DIRECTION
- FENCE

CIS-1,2-DCE CONCENTRATIONS (µg/L)

- 6 ≤ CIS-1,2-DCE <100
- 100 ≤CIS-1,2-DCE <1,000
- CIS-1,2-DCE ≥ 1,000
- ERP SITE BOUNDARY
- BUILDING
- PAVED AREA
- ROAD

SAMPLE LOCATION — **MW104X15**
CIS-1,2-DCE (µg/L) — **0.25J**
FLAG

REFERENCE:
2009-2010 GSAP REPORT

NOTE:
ND = NOT DETECTED; THE DETECTION LIMIT FOR cis-1,2-DCE IS 1 µg/L.

N

0 55 110
FEET

FIGURE 3.4-20
CIS-1,2-DCE DISTRIBUTION AT SITE SS015

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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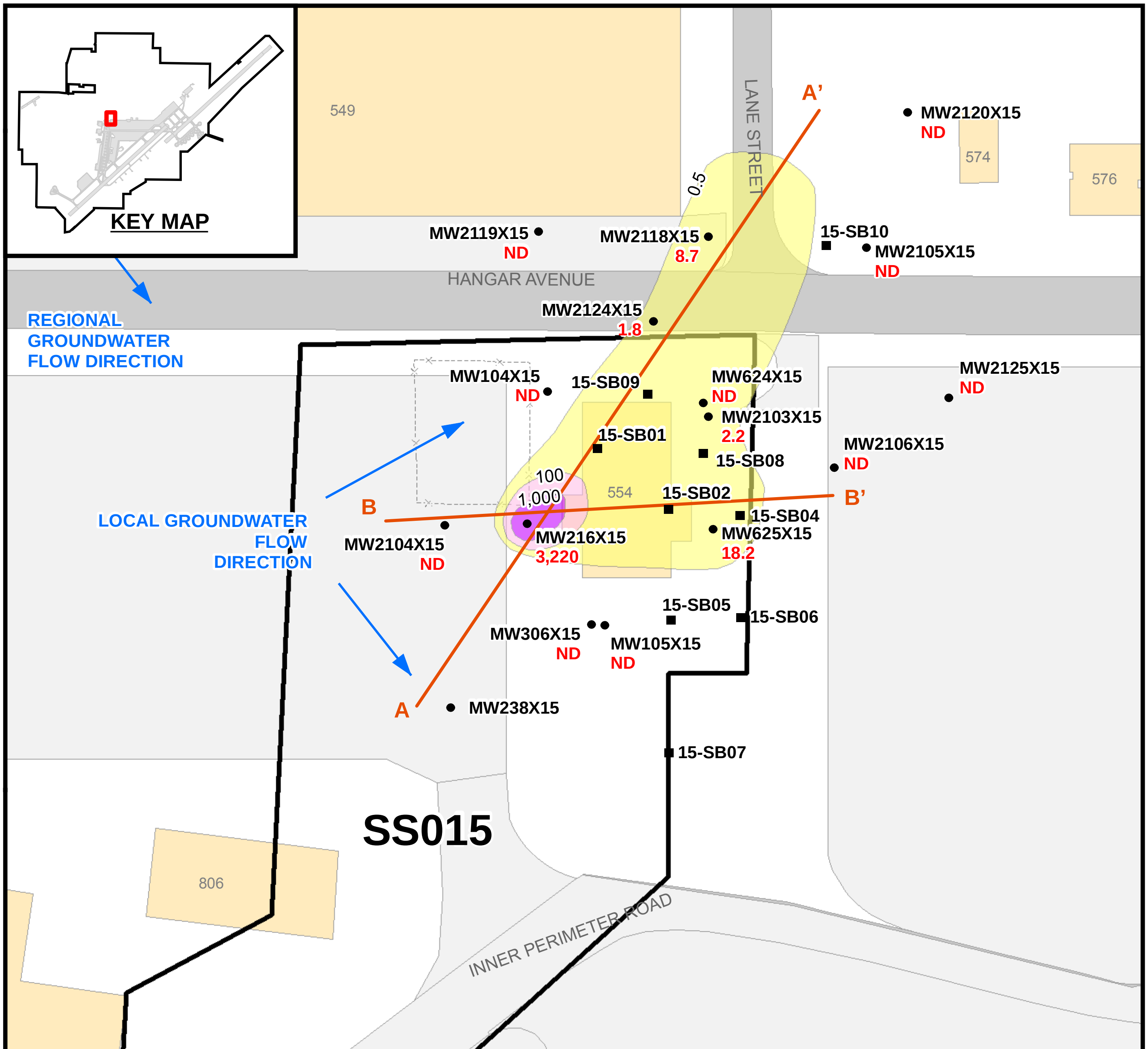

LEGEND

- IN SITU SAMPLE (JUN - AUG 1998)
- GROUNDWATER MONITORING WELL
- A—A' CROSS SECTION LINE
- APPROXIMATE GROUNDWATER FLOW DIRECTION
- FENCE
- BUILDINGS
- PAVED AREA
- ROAD
- ERP SITE BOUNDARY

VINYL CHLORIDE CONCENTRATIONS (µg/L)

- 0.5 ≤ VC <100
- 100 ≤ VC <1,000
- VC ≥ 1,000

SAMPLE LOCATION — MW104X15
VINYL CHLORIDE (µg/L) — 0.25J
FLAG

NOTE:
ND = NOT DETECTED; THE DETECTION LIMIT FOR VINYL CHLORIDE IS 0.5 µg/L.

N

0 55 110 FEET

REFERENCE: 2009-2010 GSAP REPORT

FIGURE 3.4-21
VINYL CHLORIDE DISTRIBUTION AT SITE SS015

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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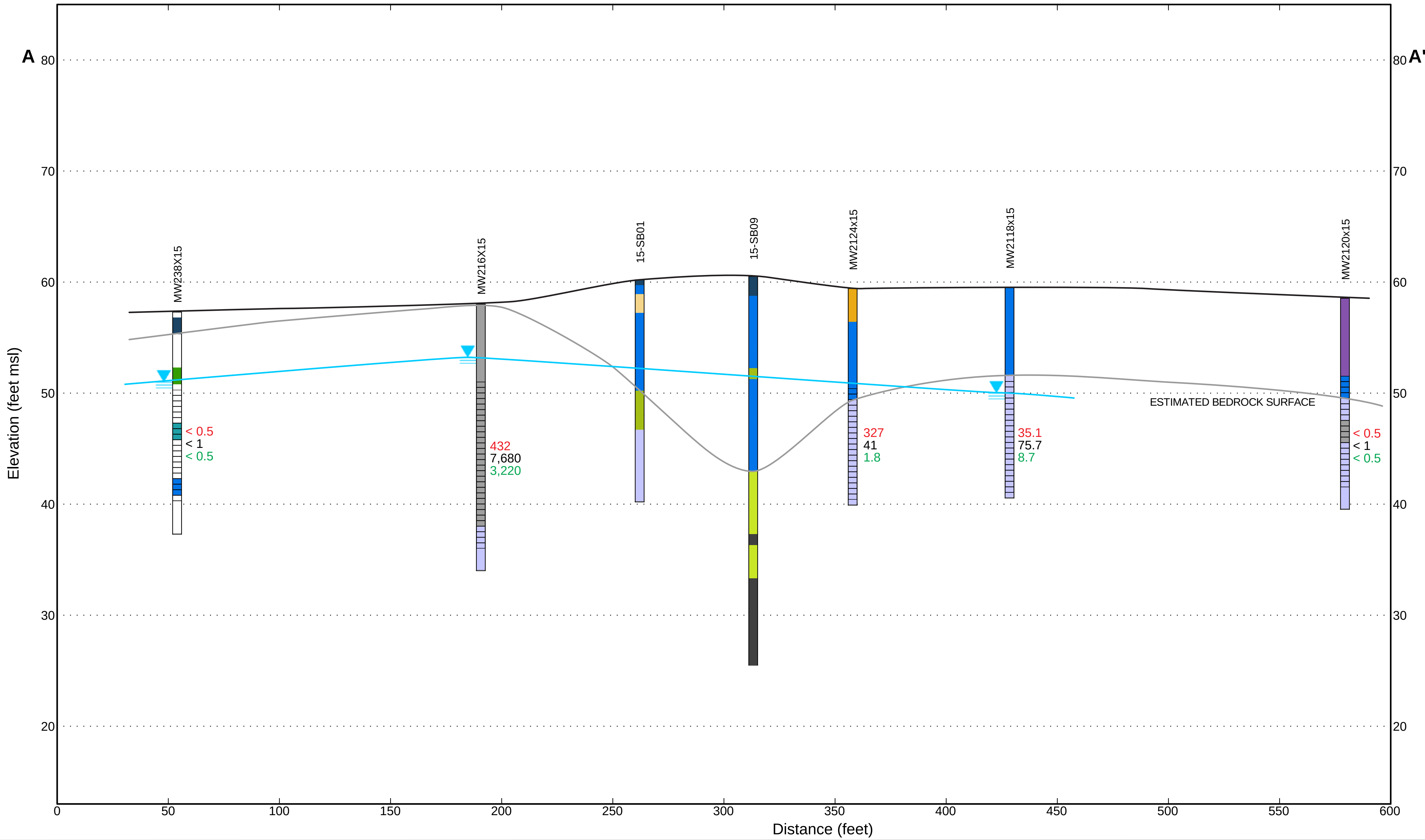

SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2009 GROUNDWATER ELEVATION (ft MSL)

VOC CONCENTRATION IN GROUNDWATER IN MICROGRAMS PER LITER

35.1 TCE
75.7 CIS-1,2-DCE
8.7 VINYL CHLORIDE

SCALE EXAGGERATION - 5:1 (H:V)

SOIL AND LITHOLOGY

NO SAMPLE/NO RECOVERY
FILL/ASPHALT
TOPSOIL/ORGANIC SOIL
WELL GRADED GRAVEL (GW)
POORLY GRADED GRAVEL (GP)
SILTY GRAVEL (GM)
CLAYEY GRAVEL (GC)
WELL GRADED SAND (SW)
POORLY GRADED SAND (SP)
SILTY SAND (SM)
CLAYEY SAND (SC)
SILT (ML)
ELASTIC SILT (MH)
LEAN CLAY (CL)
FAT CLAY (CH)
SILTSTONE
SANDSTONE
SHALE
ALLUVIUM (NO DATA)

FIGURE 3.4-22
SITE SS015 CROSS SECTION A–A'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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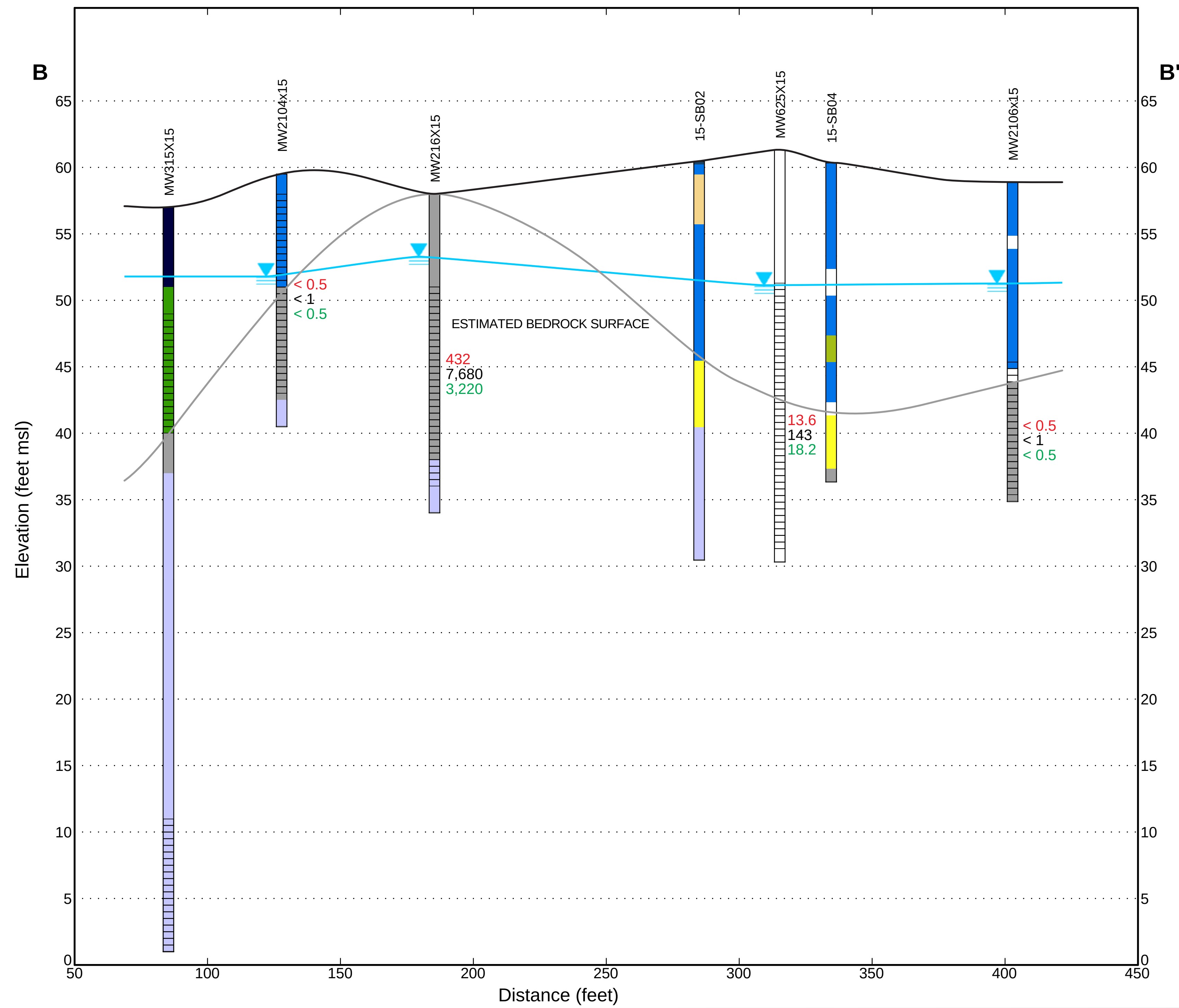

SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2009 GROUNDWATER ELEVATION (ft MSL)

VOC CONCENTRATION IN GROUNDWATER IN MICROGRAMS PER LITER

35.1 TCE

75.7 CIS-1,2-DCE

8.7 VINYL CHLORIDE

SCALE EXAGGERATION - 5:1 (H:V)

SOIL AND LITHOLOGY

NO SAMPLE/NO RECOVERY	WELL GRADED SAND (SW)	FAT CLAY (CH)	
FILL/ASPHALT	POORLY GRADED SAND (SP)	SILTSTONE	
TOPSOIL/ORGANIC SOIL	SILTY SAND (SM)	SANDSTONE	
WELL GRADED GRAVEL (GW)	CLAYEY SAND (SC)	SHALE	
POORLY GRADED GRAVEL (GP)	SILT (ML)	ALLUVIUM (NO DATA)	
SILTY GRAVEL (GM)	ELASTIC SILT (MH)		
CLAYEY GRAVEL (GC)	LEAN CLAY (CL)		

FIGURE 3.4-23
SITE SS015 CROSS SECTION B–B'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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ES082009007SAC Figure_3.4-23.ai 04.11.2011 tdaus

3.4.3 Site DP039 Conceptual Site Model

This section provides the CSM for WABOU Site DP039 located in the western portion of Travis AFB.

Additional descriptions of the site geology, groundwater characteristics, and groundwater contamination are provided in Section 4.8 of the 2009-2010 Annual GSAP Report (CH2M HILL, 2011b).

3.4.3.1 Site Description

Site DP039 primarily consists of the former Travis AFB Battery and Electric Shop (Building 755). Site maps are shown on Figures 3.4-24 and 3.4-25.

Starting in 1968, Building 755 was originally used to test rocket engines, but only petroleum-based liquid fuel was used at the site as part of this testing. Afterwards, Building 755 became the Battery and Electric Shop. Prior 1978, battery acid solutions and chlorinated solvents were dumped into a sink within Building 755 and conveyed by pipeline less than 100 feet to a former rock-filled acid neutralization sump. This practice was discontinued in 1978, when the pipeline was dismantled and reconnected to the sanitary sewer line. In July 1993, the sump was excavated and disposed of off-base. The removed sump was 8 feet long, 8 feet wide, and 4 feet deep.

Building 755 was demolished in 2009. The lot is currently vacant.

3.4.3.2 Geology

The subsurface geology at Site DP039 should be viewed as a single, complex, heterogeneous hydrogeologic system of unconsolidated sediments. No clearly defined, laterally extensive layers of discrete aquifers or aquitards are present. The alluvium is highly heterogeneous, varying from clays and silts to sands with little or no horizontal continuity of layers (Older Alluvium). Relatively permeable sands and silty/clayey sands are encountered primarily as thin zones, ranging from 2 to 5 feet thick, and are not extensive.

Bedrock at the site is the Tehama Formation, composed of lithic sandstones and siltstones. Lithic fragments associated with the sandstone are from the Sonoma Volcanics and the Franciscan Formation. The sandstones and siltstones are moderately to highly weathered near the alluvium-bedrock contact and become more competent with depth. The precise depth that the Tehama Formation is encountered is not well defined because the alluvium-bedrock contact is not readily discernible in the field as a result of localized weathering of the bedrock surface. However, well consolidated siltstone is observed in the soil boring for injection well IW2083x39 at a depth of approximately 25 feet bgs. Groundwater is present in the weathered portion of the bedrock. The depth where bedrock becomes more competent ranges from 35 to 73 feet bgs. Based on surface exposures of the Tehama Formation and the depth of competent bedrock, the bedrock plunges to the southeast and becomes progressively deeper in that direction.

3.4.3.3 Groundwater

Groundwater characteristics at Site DP039 are summarized as follows:

- Depth to groundwater ranges from approximately 7 to 29 feet bgs.
- The regional groundwater flow direction is toward the southeast because the ridge of the Tehama Formation lies along the western boundary of the site. Horizontal gradients are approximately 0.004 ft/ft.
- Vertical hydraulic gradients are typically negligible (less than 0.1 ft/ft) and range from 0.02 ft/ft downward to 0.1 ft/ft upward. The relatively large upward vertical gradient of 0.1 ft/ft is encountered at well pair MW2057A/Bx39. This well pair was installed in 2010, and it is unclear if the gradient is typical. Further measurements will be made under the GSAP.
- Potentiometric heads up to 13 feet above the first saturated soil observed during drilling have been measured at some of the newly installed injection and monitoring wells (immediately following installation). This indicates that the groundwater system is partially confined.
- Hydraulic conductivities range from 0.3 to 10 ft/day, reflecting the low permeability of the sediments across the site. The average hydraulic conductivity is approximately 5 ft/day.
- The approximate groundwater flow velocity is about 0.1 ft/day or approximately 40 ft/year. The average linear flow velocity is estimated by Darcy’s Law using a horizontal hydraulic gradient of 0.004 ft/ft, an average hydraulic conductivity of 5 ft/day, and assuming an effective porosity of 20 percent (typical for the fine-grained sediments encountered at the site).
- Groundwater elevations are relatively stable with no long-term increasing or decreasing trend. Seasonal variations of approximately 2 to 4 ft/year are typically observed.

Groundwater elevation contours are shown on Figure 3.4-26.

3.4.3.4 Groundwater Contamination

TCE is the most frequently detected and most widely distributed groundwater contaminant at Site DP039. The current distributions of TCE and cis-1,2-DCE are shown on Figures 3.4-27 and 3.4-28, respectively. The vertical distribution of contamination is shown on Figures 3.4-29 and 3.4-30.

Groundwater contamination at Site DP039 consists of a large plume that extends from well EW563x39 approximately 1,750 feet downgradient (southeast) near MW759x39. In 2Q10, the highest concentration of TCE detected at Site DP039 was 7,000 µg/L at monitoring well MW750x39. Also in 2Q10, TCE concentrations of greater than 500 µg/L were detected in monitoring wells MW750x39 (7,000 µg/L), MW751x39 (1,230 µg/L), MW777x39 (715 µg/L), MW2041Bx39 (701 J µg/L), MW2042Ax39 (670 µg/L), MW2042Bx39 (1,260 J- µg/L), MW2043Bx39 (1,150 µg/L), MW2056Ax39 (664 µg/L), MW2057Bx39 (965 µg/L), IW2079x39 (667 µg/L), IW2080x39 (601 µg/L), and IW2081x39 (1,100 µg/L) (CH2M HILL 2011a).

There appears to be an area of decreased TCE concentrations in the central portion of the groundwater plume in the center of the phytoremediation area (i.e., monitoring well MW778x39). This monitoring well, where TCE was detected at a concentration of 44 µg/L in 2Q10) has a long-term trend of decreasing TCE concentrations. This decline may be partly explained by the beneficial effect of the source area GET. However, the phytoremediation area also appears to be having a positive effect on the TCE concentrations. TCE concentrations at this well are an order of magnitude lower than those detected upgradient and downgradient of the phytoremediation area. In addition, concentrations of biodegradation daughter products such as cis-1,2-DCE and vinyl chloride detected at this well are the highest concentrations detected at the site. Concentrations of both daughter products are increasing at this well. These results imply that reducing conditions have been established in the root zone of the eucalyptus trees in the phytoremediation area and TCE is being degraded (Parsons, 2010).

In addition to TCE, concentrations of cis-1,2-DCE (maximum concentration of 2,590 µg/L in MW778x39); 1,1-DCE (maximum concentration of 1,800 µg/L in MW750x39); vinyl chloride (maximum concentration of 20.7 µg/L in MW778x39); and 1,2-DCA (maximum concentration of 10 µg/L in MW750x39) were detected at Site DP039 in 2Q10 at levels above the IRG (CH2M HILL, 2011b).

3.4.3.5 Status of Groundwater Interim Remedial Actions

The groundwater IRA at Site DP039 has evolved over time. The Groundwater IROD for the WABOU (Travis AFB, 1999) specified two (2) alternatives:

- **Alternative G5 –** Source Area and Groundwater Extraction/Treatment/Monitored Natural Attenuation
- **Alternative G3 –** Containment/Treatment/Discharge

Design and installation of the IRA based on this combination of actions began with the treatability studies and demonstration projects summarized in the following subsections.

Treatability Studies and Demonstration Projects. Four (4) treatability studies or demonstration projects have also been conducted at the site:

- **Soil Vapor Extraction (SVE) and Vacuum Dewatering Treatability Study –** An SVE and vacuum dewatering treatability study was conducted within the Site DP039 source area from January to October 2000 to assess the effectiveness of dual-phase groundwater extraction for removing contaminant mass from the source area. The treatability study lasted approximately 6 months and was successful at removing approximately 495 pounds of VOCs. Of the contaminants removed, 99 percent came from the vapor phase. As a result of this study, a full-scale groundwater and soil vapor DPE system was installed in the Site DP039 source area and brought online in February 2001 (CH2M HILL, 2007). A more complete discussion of the SVE and vacuum dewatering treatability study is available in the *DP039 Phase Two Vacuum Dewatering Treatability Study Report* (CH2M HILL, 2002b).
- **Permeable Reactive Treatment Wall Treatability Study –** A 2-year permeable reactive treatment wall treatability study was completed at the site between 2000 and 2002. This

treatability study was conducted to assess the effectiveness of using injected iron filings to provide an in situ treatment zone downgradient of the Site DP039 source area. During the study, a zero-valent iron (ZVI) filings mixture was injected into a line of boreholes to create the permeable wall. Although data collected during the study identified areas of decreased TCE concentrations within the body of the reactive wall, the overall results from the study were inconclusive. The innovative jet grouting approach used to inject the iron filings mixture into the subsurface was found to be ineffective under the conditions at Site DP039. Apparently, only a small fraction of groundwater was passing through the injected ZVI wall. More complete discussion of the permeable reactive treatment wall treatability study is available in the *Demonstration of Columnar Wall Jet Grouting of a Permeable Reactive Treatment Wall* report (MACTEC, 2002).

- **Phytoremediation Treatability Study –** A phytoremediation treatability study was initiated in August 1998 to assess the effectiveness of planted trees to hydraulically control and remove VOC contamination from the groundwater migrating from the Site DP039 source area. The phytoremediation study involved planting red ironbark eucalyptus trees hydraulically downgradient of the source area. An evaluation of the study in 2005 concluded that as the eucalyptus trees continue to mature, they have the potential to remediate the TCE-contaminated groundwater at the site (Parsons, 2005). At the time of the evaluation, the root systems of the trees were found to have reached the water table, and contaminants were being removed through transpiration processes.

  The effectiveness of phytoremediation continued to be evaluated as an ongoing study through 2010. The most recent findings are documented in the final *Phytostabilization at Travis Air Force Base, California* technical report (Parsons, 2010). Among the key findings documented in the report was that phytoremediation posed a beneficial impact to the goal of reducing groundwater contaminant concentrations. The overall TCE removal rate within the phytoremediation study area was about 1.99 pounds per year. In the future, maximum removal rates could rise to 15.4 pounds per year.

- **Bioreactor Demonstration Project –** In December 2008, an in situ bioreactor was installed in the location of the former sump near Building 775. The highly contaminated soil underlying the sump was excavated and organic mulch was placed in the excavation void. Using existing extraction well EW782X39, a solar-powered pump was installed to extract groundwater immediately downgradient of the bioreactor and recirculate the groundwater through the bioreactor. Inside the bioreactor, TCE and its daughter products are degraded anaerobically to inert byproducts. Initial results from the bioreactor monitoring are positive, but assessments of its long-term effectiveness are ongoing (CH2M HILL, 2010h).

Initial Groundwater IRA Implementation. Following completion of the SVE and vacuum dewatering treatability study, a permanent DPE well was installed near the former disposal sump (EW563x39). Groundwater and vapor extraction from this well began in February 2001 and continued until February 2003. Well EW563x39 was once again brought online in October 2005 as part of a system optimization effort as described in the *DP039 Optimization Field Report* (CH2M HILL, 2007). In addition to well EW563x39 being brought back online, an additional DPE well (EW782x39) was installed immediately south of the Site DP039 source area and integrated with the existing extraction system. Operation of the expanded DPE system continued through November 2008, when it was discontinued to facilitate construction and operation of the in situ bioreactor.

3.4.3.6 Current Groundwater IRA Strategy

At the conclusion of 2008, the IRA strategy at the site changed. The energy-intensive and increasingly inefficient DPE system was shut down, and a different approach began, using more sustainable technologies. The current IRA strategy for Site DP039 includes the following components:

- **Excavation and Bioreactor –** incorporating the technology study located within the former disposal sump source area (CH2M HILL, 2010h). The location of the bioreactor is shown on Figures 3.4-24 and 3.4-25.
- **Phytoremediation –** incorporating another technology study located within the mid-portion of the plume (Parsons, 2005, 2010). The location of the phytoremediation area is shown on Figure 3.4-24.
- **EVO PRB –** incorporating a 2010 IRA optimization action within the mid-portion of the plume and located downgradient of the phytoremediation area (CH2M HILL, 2010f). The location of the EVO PRB is shown on Figure 3.4-24.
- **Enhanced Attenuation (EA) –** continued monitoring of natural physical, chemical, and/or biological processes within the downgradient portion of the plume hydraulically downgradient and southeast of the EVO biobarrier.

Travis AFB also enforces LUCs to prevent unauthorized exposure to contaminated groundwater.

Additional summary descriptions of these IRA components within the various portions of the plume are provided in the following subsections.

Source Area IRA. The source area portion of the Site DP039 plume is currently undergoing interim remediation using the demonstration bioreactor. The location of the bioreactor is shown on Figures 3.4-24 and 3.4-25.

After approximately 7 years of DPE, samples taken from both Site DP039 source area extraction wells (EW563x39 and EW782x39) had concentrations less than 400 μg/L of TCE. As contaminant concentrations declined and TCE removal became diffusion-dominated, contaminant removal and cost efficiencies in the DPE system also decreased. Therefore, in November 2008, DPE was discontinued, the source area underlying the historical disposal sump was excavated, and a bioreactor was installed to address the residual TCE concentration in soil and groundwater.

Since coming online in November 2008, the initial observations of bioreactor performance have shown its ability to chemically and/or biologically break down TCE and DCE mass. Early data collection indicates that more than 75 percent of the TCE and DCE entering the bioreactor in recirculated groundwater degrades within the reactor. In areas immediately surrounding the bioreactor, concentrations of TCE have started to decrease, and concentrations of cis-1,2-DCE (the daughter product of TCE) have begun to increase. As the bioreactor continues to operate, the anaerobic conditions required for TCE biodegradation are expected to expand to the aquifer throughout the Site DP039 source area. The downgradient extent of plume remediation achieved by the bioreactor is currently under evaluation (CH2M HILL, 2010h).

The source area is defined as the portion of the plume that originates at the former battery acid neutralization sump from the former Building 755. This portion of the plume is being remediated by an in situ bioreactor as a demonstration project.

Additional description of the bioreactor technology is provided in Section 6.

Mid-plume IRA. IRAs in the mid-portion of the plume include the existing area of phytoremediation and an EVO PRB. The locations of the area of phytoremediation and the EVO PRB are shown on Figures 3.4-24 and 3.4-25.

The mid-portion of the plume is associated with high concentrations of dissolved solvents that migrated from the source area. The boundaries of this portion start in the vicinity of Ellis Drive and end at the downgradient extent of the 500-µg/L TCE isocontour line. The EVO PRB intercepts the plume at this isocontour.

Additional descriptions of phytoremediation and EVO technologies are provided in Section 6.

Downgradient Plume IRA. The portion of the Site DP039 plume located hydraulically downgradient of the biobarrier is suitable for remediation through physical, chemical, and/or biological natural attenuation processes. The effectiveness of natural attenuation is being routinely monitored under the GSAP.

Additional description of natural attenuation is provided in Section 6.

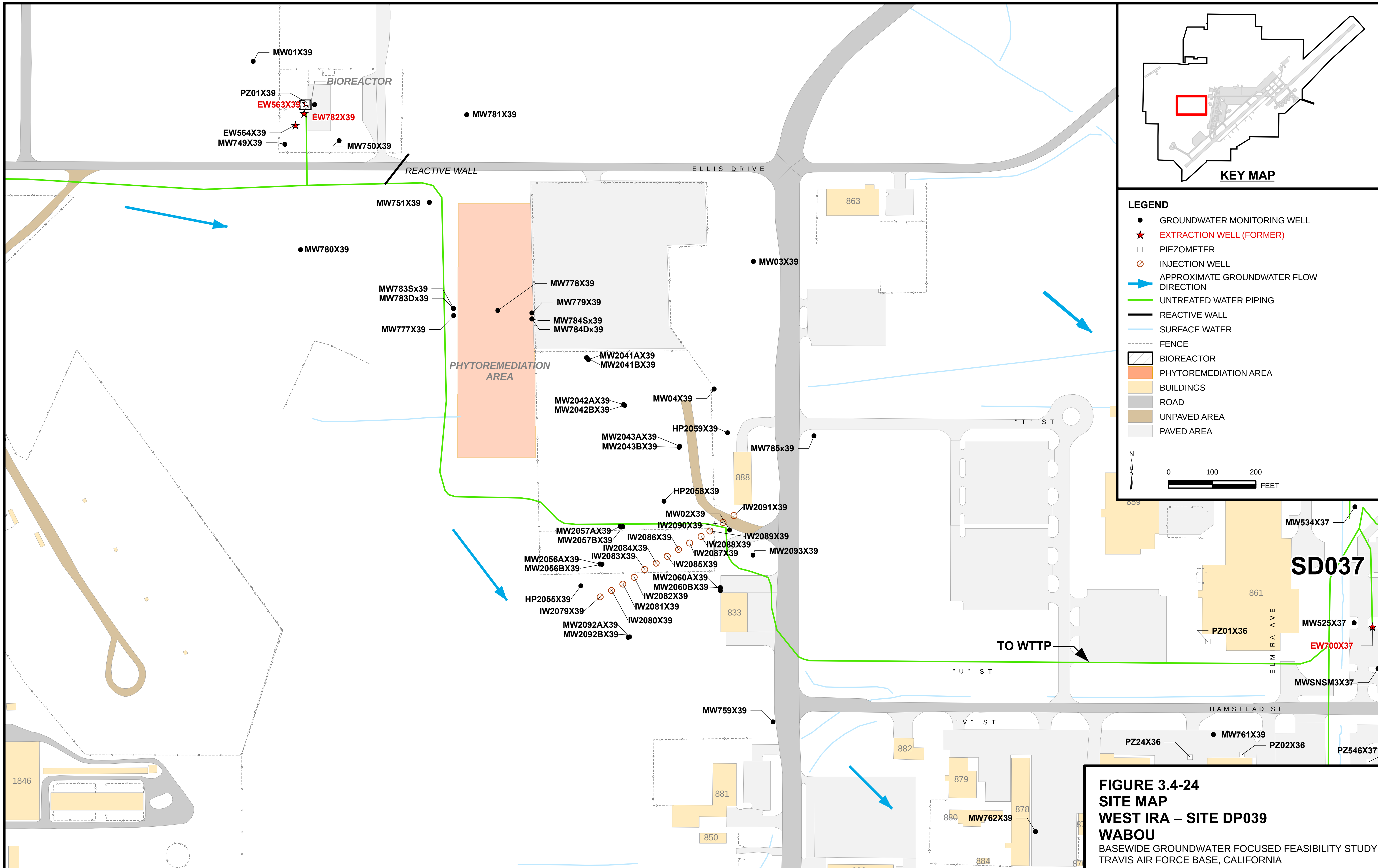

FIGURE 3.4-24
SITE MAP
WEST IRA – SITE DP039
WABOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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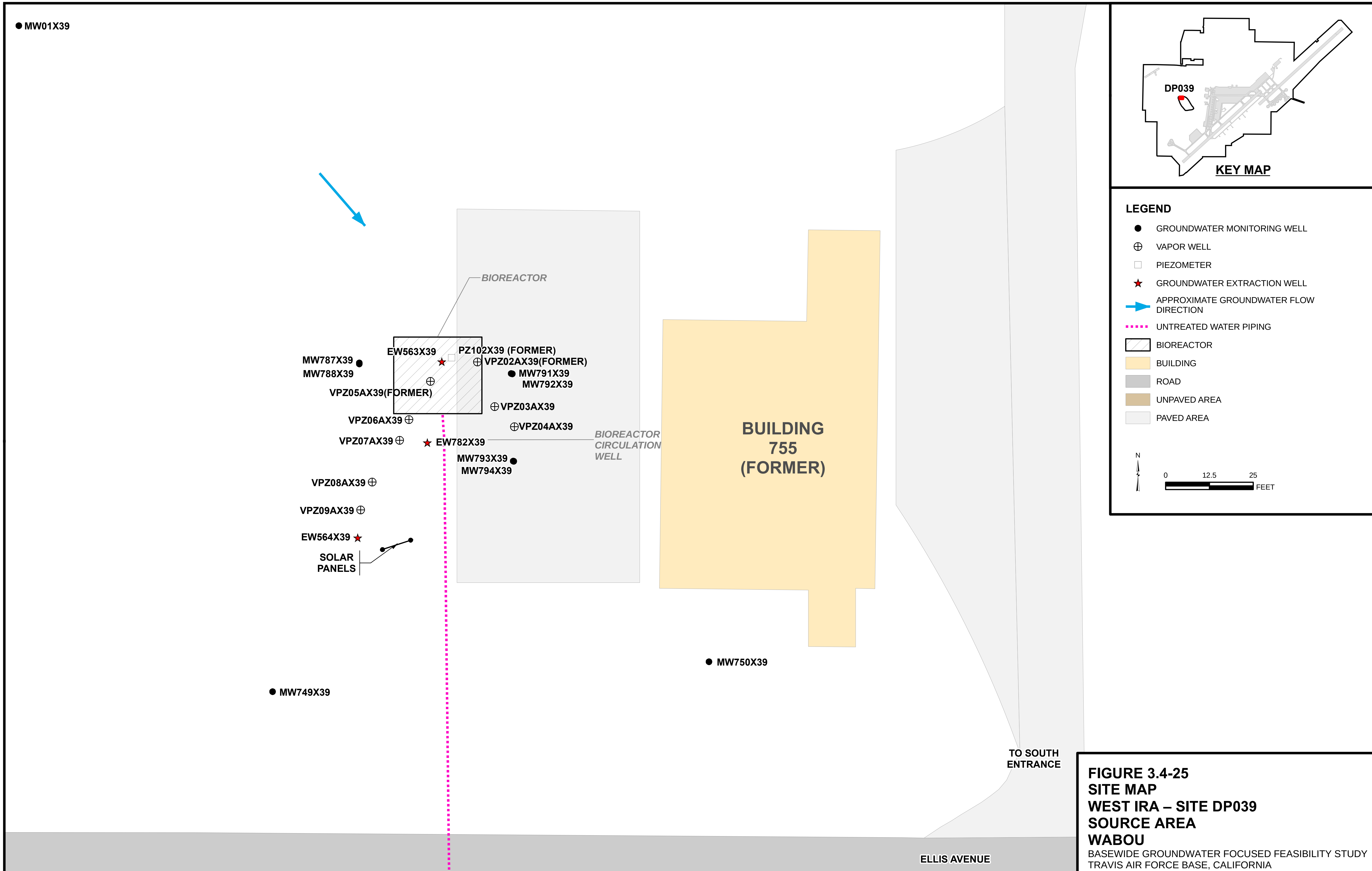


FIGURE 3.4-25
SITE MAP
WEST IRA – SITE DP039
SOURCE AREA
WABOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA
CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3-4_25_DP039_WEST_IRA.MXD MCLAY1 1/21/2011 07:54:43

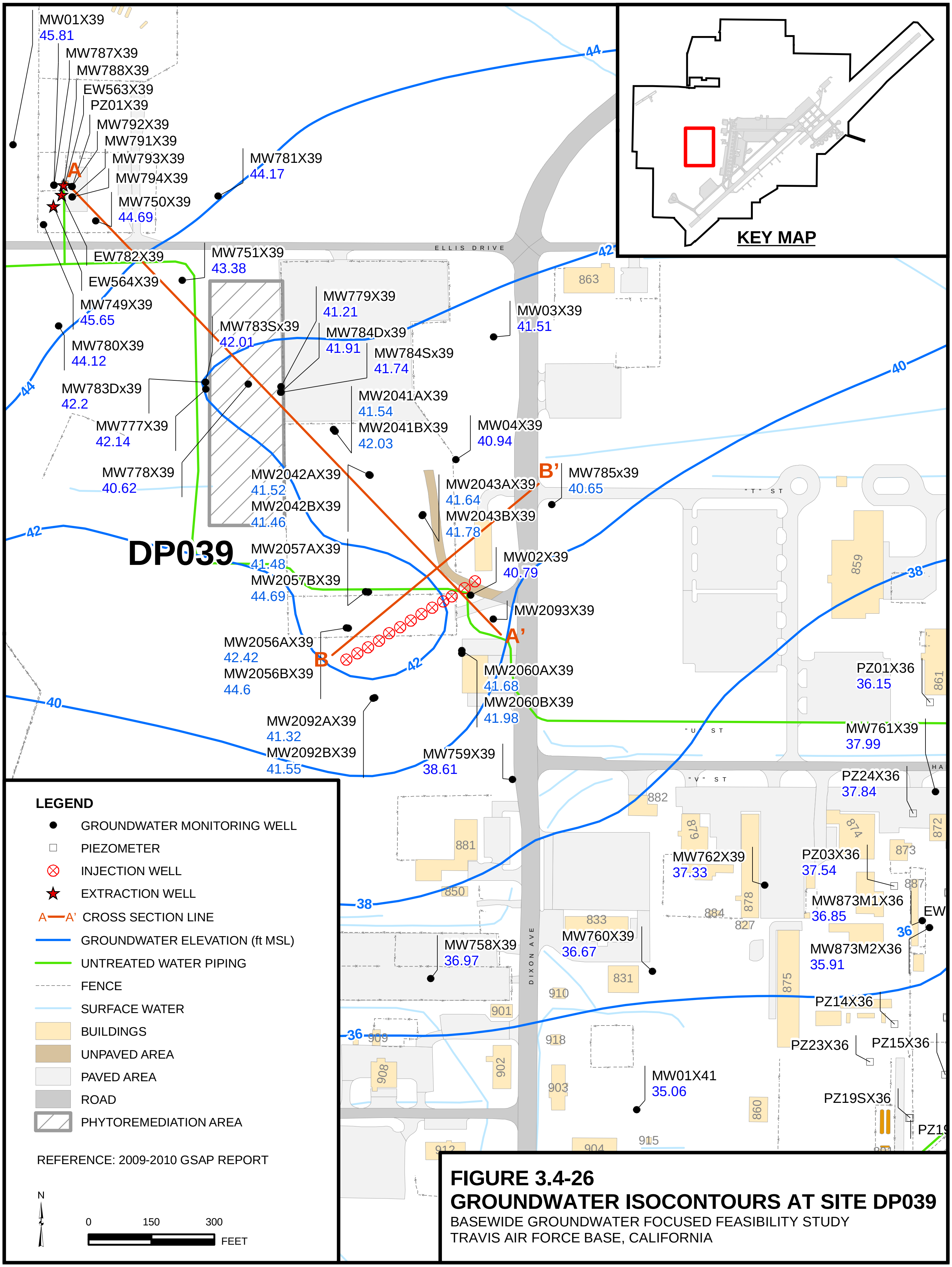


FIGURE 3.4-26
GROUNDWATER ISOCONTOURS AT SITE DP039
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIGURE_3_4-26_DP039_GW_2010.MXD MSCHROCK 4/14/2011 02:01:10

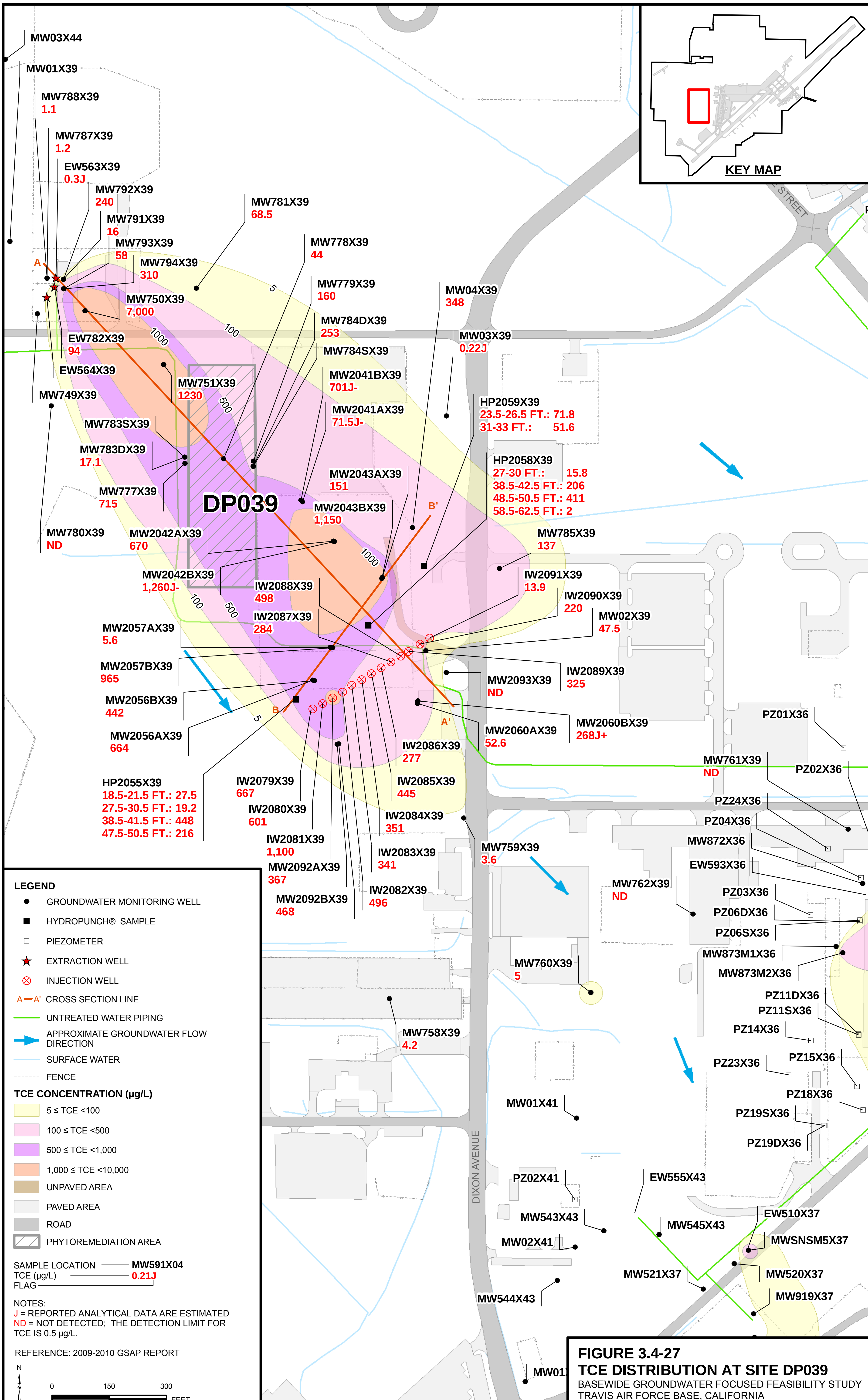


FIGURE 3.4-27
TCE DISTRIBUTION AT SITE DP039
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIGURE_3_4-27_TCE_DP039.MXD MSCHROCK 6/15/2011 03:08:39

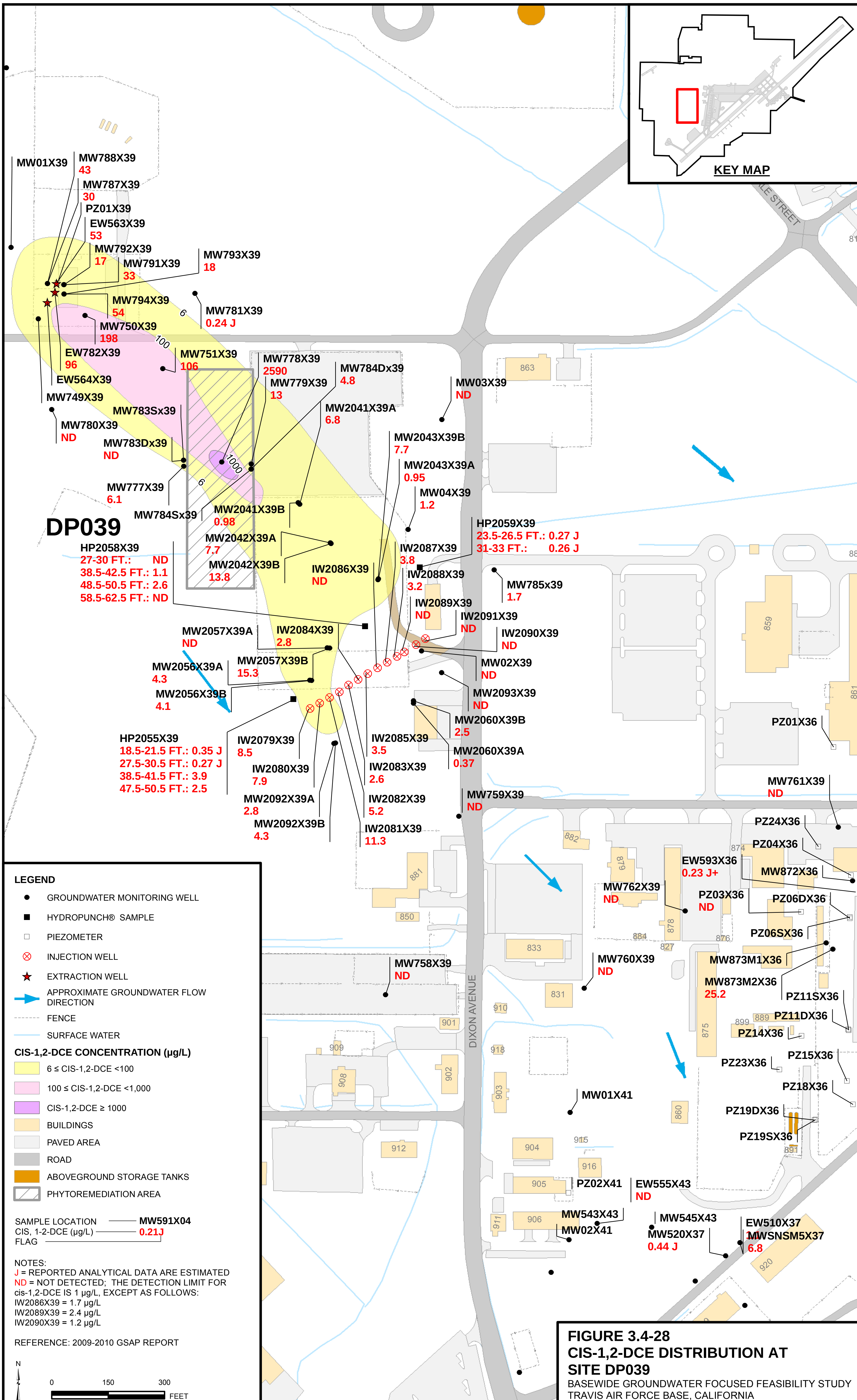
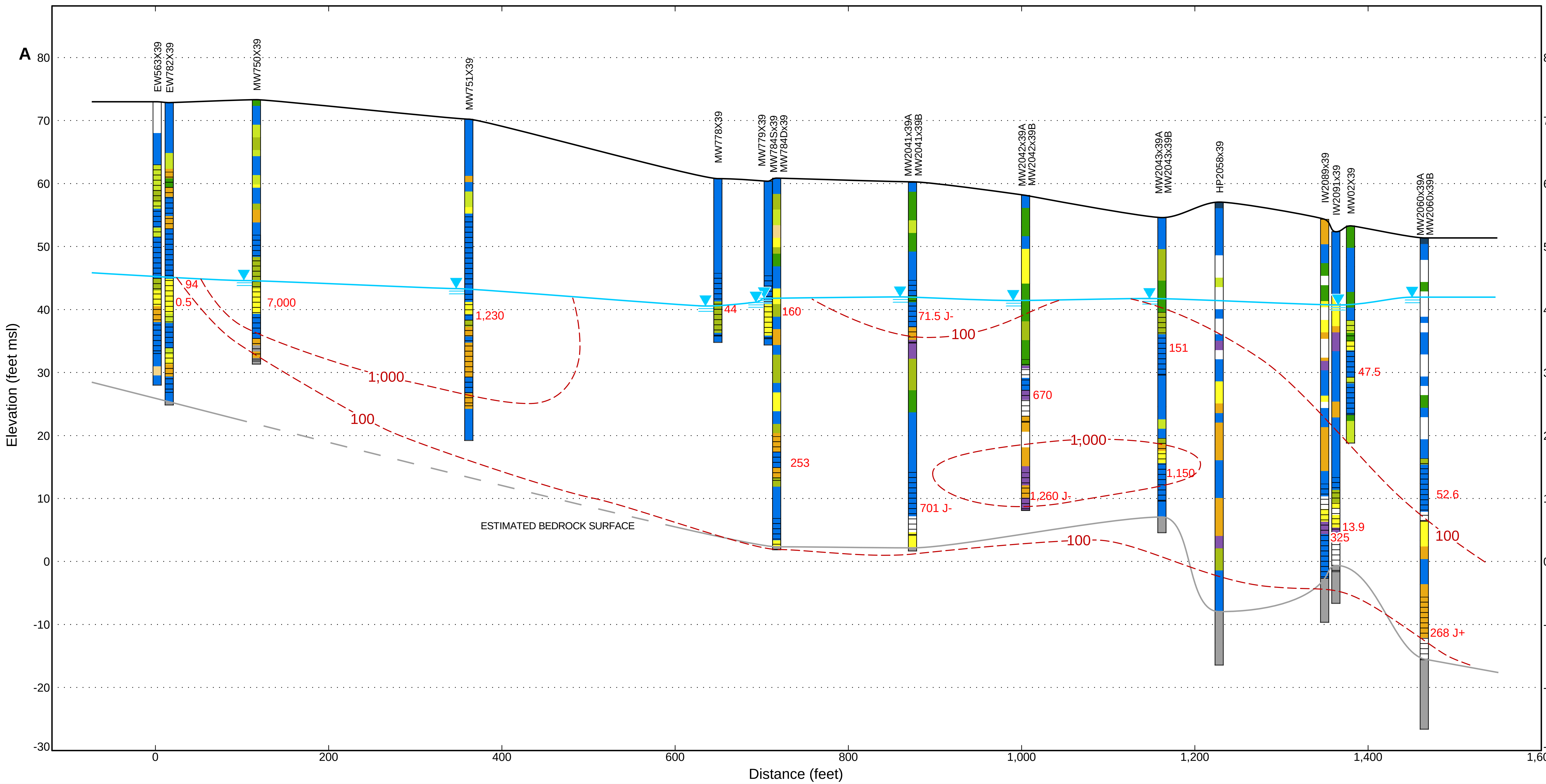


FIGURE 3.4-28
CIS-1,2-DCE DISTRIBUTION AT SITE DP039
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIGURE_3_4_28_DCE_DP039.MXD MSCHROCK 6/27/2011 5:28:40 PM



SOIL AND LITHOLOGY

SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)

6.7 TCE CONCENTRATION (µg/L) DETECTED IN 2010

– – 5 – – APPROXIMATE TCE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION

SCALE EXAGGERATION - 7.3:1 (H:V)

NO SAMPLE/NO RECOVERY
FILL/ASPHALT
TOPSOIL/ORGANIC SOIL
WELL GRADED GRAVEL (GW)
POORLY GRADED GRAVEL (GP)
SILTY GRAVEL (GM)
CLAYEY GRAVEL (GC)
WELL GRADED SAND (SW)
POORLY GRADED SAND (SP)
SILTY SAND (SM)
CLAYEY SAND (SC)
SILT (ML)
ELASTIC SILT (MH)
LEAN CLAY (CL)
FAT CLAY (CH)
SILTSTONE
SANDSTONE
SHALE
ALLUVIUM (NO DATA)

FIGURE 3.4-29
SITE DP039 CROSS SECTION A–A'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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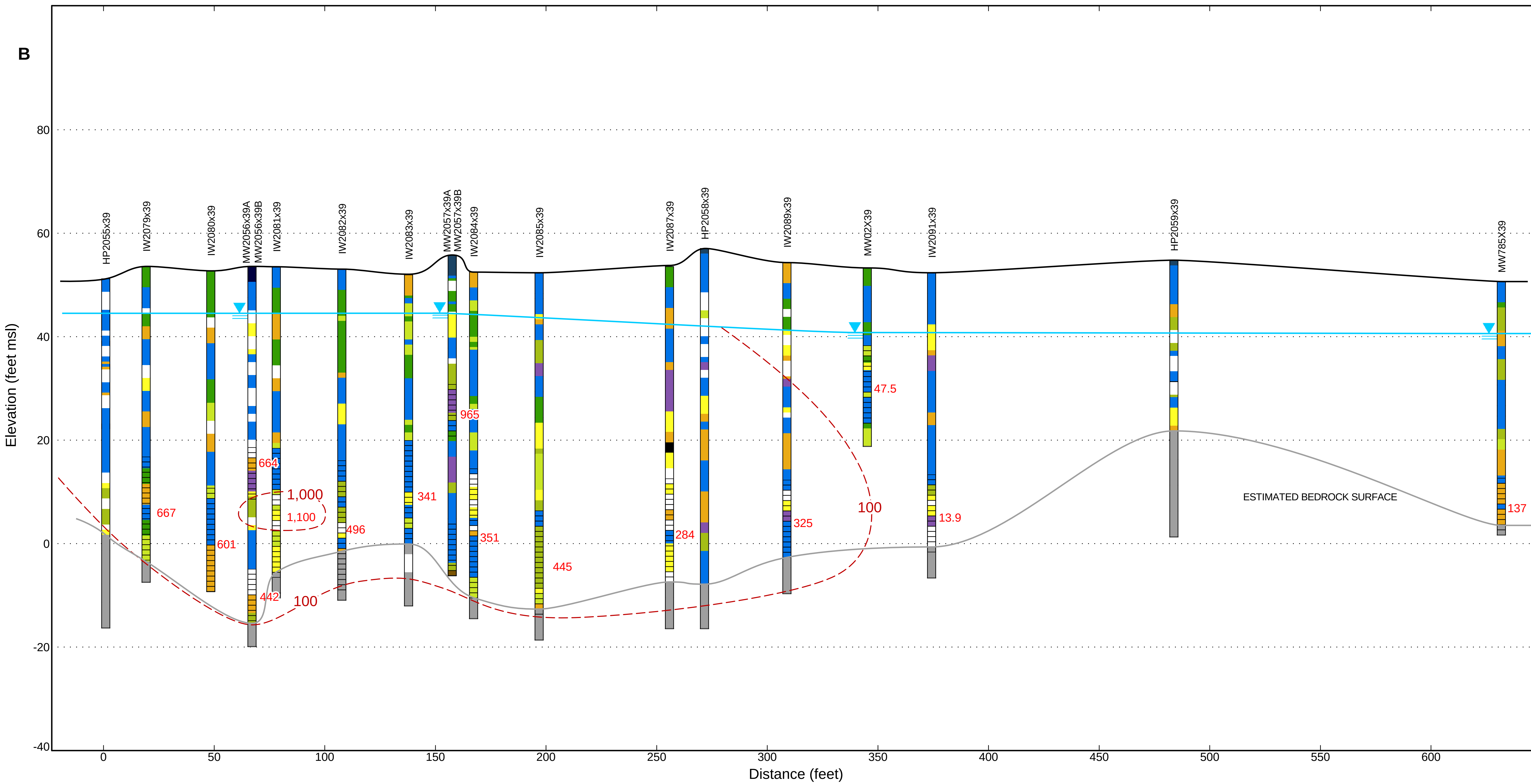
ES082009007SAC Figure_3.4-29.ai 06.14.2011 tdaus



SOIL AND LITHOLOGY

SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)

6.7 TCE CONCENTRATION (µg/L) DETECTED IN 2010

– – 5 – – APPROXIMATE TCE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION

SCALE EXAGGERATION - 7.3:1 (H:V)

- NO SAMPLE/NO RECOVERY
- FILL/ASPHALT
- TOPSOIL/ORGANIC SOIL
- WELL GRADED GRAVEL (GW)
- POORLY GRADED GRAVEL (GP)
- SILTY GRAVEL (GM)
- CLAYEY GRAVEL (GC)
- WELL GRADED SAND (SW)
- POORLY GRADED SAND (SP)
- SILTY SAND (SM)
- CLAYEY SAND (SC)
- SILT (ML)
- ELASTIC SILT (MH)
- LEAN CLAY (CL)
- FAT CLAY (CH)
- SILTSTONE
- SANDSTONE
- SHALE
- ALLUVIUM (NO DATA)

FIGURE 3.4-30
SITE DP039 CROSS SECTION B–B'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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ES082009007SAC Figure_3.4-30.ai 05.20.2011 tdaus

3.4.4 Site LF008 Conceptual Site Model

This section provides the CSM for Site LF008 located within the WABOU in the western portion of Travis AFB.

Additional descriptions of the site geology, groundwater characteristics, and groundwater contamination are provided in Section 4.9 of the 2009-2010 Annual GSAP Report (CH2M HILL, 2011b).

3.4.4.1 Site Description

Site LF008 is a historical pesticide container landfill. A site map is shown on Figures 3.4-31.

During the 1970s, multiple burial trenches were used to dispose of approximately 30 cubic yards of pesticide containers. All of the trenches were located within Bunker A of the Weapons Storage Area, a secured area surrounded by a fence with a locked gate. An RI of the WABOU in 1995-1996 used geophysical surveys, exploration trenching, and soil borings to identify the approximate locations of these burial trenches. Debris was discovered in six (6) of the nine (9) excavated trenches and included 1- and 5-gallon metal containers, plastic and paper bags, other paper and plastic debris, 1-gallon glass bottles, and two (2) 55-gallon drums (CH2M HILL, 1997).

The pesticide containers and contaminated soil were removed in 2003 by an Excavation/Off-base Disposal remedial action in accordance with the *Soil Record of Decision for the West/Annexes/Basewide Operable Unit* (Travis AFB, 2002a). Approximately 1,984 cubic yards of pesticide-contaminated soil and debris were removed. Residential cleanup levels were achieved by the excavation, and LUCs are no longer required at the site.

3.4.4.2 Geology

Site LF008 lies on top of a ridge composed of weathered Tehama Formation materials. The upper 25 to 35 feet of sediments (above the water table) consists primarily of interbedded sands and silty sand. Below the water table, the deeper stratigraphy consists of highly variable silts, clays, and sands. Some of these deeper sediments are partially consolidated. Bedrock is found at a depth of approximately 65 feet bgs (CH2M HILL, 1997).

The saturated zone is approximately 30 to 40 feet thick, and contamination extends throughout the saturated zone to bedrock. Monitoring well screened intervals range from 21 to 65 feet bgs and are adequate to monitor the vertical extent of contamination at the site.

3.4.4.3 Groundwater

The topographic ridge at Site LF008 trends from the northeast to the southwest. The regional groundwater flow direction is generally toward the southwest. This ridge acts as a groundwater divide that causes flow to move in three (3) directions locally: southeast, southwest, and west-southwest. Groundwater elevation contours are shown on Figure 3.4-32.

Other groundwater characteristics at Site LF008 are summarized as follows:

- Depth to groundwater varies from 25 to 39 feet bgs.
- The horizontal hydraulic gradient toward the southwest is approximately 0.02 ft/ft.
- Vertical hydraulic gradients are assessed using two (2) well pairs: MW01x08/MW712x08 and MW115x08/MW311x08. Both well pairs generally have large downward vertical gradients (approximately 0.1 ft/ft downward), typical for a ridge top location. In 2Q10, well pair MW115x08/MW311x08 had a downward vertical gradient of 0.2 ft/ft. A vertical gradient could not be calculated for well pair MW01x08/MW712x08 in 2Q10 because well MW01x08 was dry.
- Groundwater elevations have an overall declining trend at Site LF008, which is not evident in other areas of the Base. The average seasonal fluctuation in groundwater elevations at this site is about 1 to 2 ft/year.

3.4.4.4 Groundwater Contamination

Organochlorine pesticides are the groundwater contaminants at Site LF008. Historically, alpha-chlordane is the most widespread of these pesticides. The current distribution of alpha-chlordane is shown on Figure 3.4-33. The vertical distribution of alpha-chlordane is shown on Figure 3.4-34.

In 2Q10, alpha-chlordane was the only contaminant detected at concentrations exceeding IRGs. The maximum concentration detected was 0.34 J µg/L at monitoring well MW712x08. In 2Q10, the IRG (0.1 µg/L) was exceeded at only one (1) extraction well and one (1) plume well.

3.4.4.5 Status of Groundwater Interim Remedial Actions

In accordance with the Groundwater IROD for the WABOU, GET was implemented at Site LF008 to hydraulically contain the pesticide contamination (Travis AFB, 1999). The GET IRA operated for more than 7 years.

As part of the GET IRA system implementation, three (3) extraction wells (EW719x08, EW720x08, and EW721x08) were installed around the pesticide trenches to prevent contaminated groundwater from moving away from the site. Each of the wells is conventional (i.e., vertical with no vacuum enhancement). In June 2001, the Site LF008 extraction wells were brought online. Extracted groundwater was pumped to the WTTP and then transferred to the CGWTP for treatment and discharge. Because of the low permeability of the alluvial sediments, extraction rates were approximately 1 gallon per minute (gpm) for the wells at this site.

After more than 7 years of operation, the GET system had minimal impact on groundwater pesticide concentrations. Pesticide concentrations were stable and the extent of groundwater contamination remained unchanged. This is likely because of the strong adsorption of alpha-chlordane and other pesticides to natural organic carbon or fine-grained soil particles in the subsurface and the low permeability of the saturated sediments.

Beginning in December 2008, the three (3) groundwater extraction wells were shut down to perform a rebound study. Results of the rebound study are presented in the *Technical Memorandum: June 2009 6-month Rebound Study Completion at Site LF008* (CH2M HILL, 2010i).

The fundamental finding of the rebound study is that no significant rebound of alpha-chlordane, or any other pesticide, is evident since the rebound study began. In fact, ongoing monitoring indicates that alpha-chlordane concentrations are slightly lower than those detected prior to the rebound study (CH2M HILL, 2011b).

The rebound study will continue through the period of interim remediation.

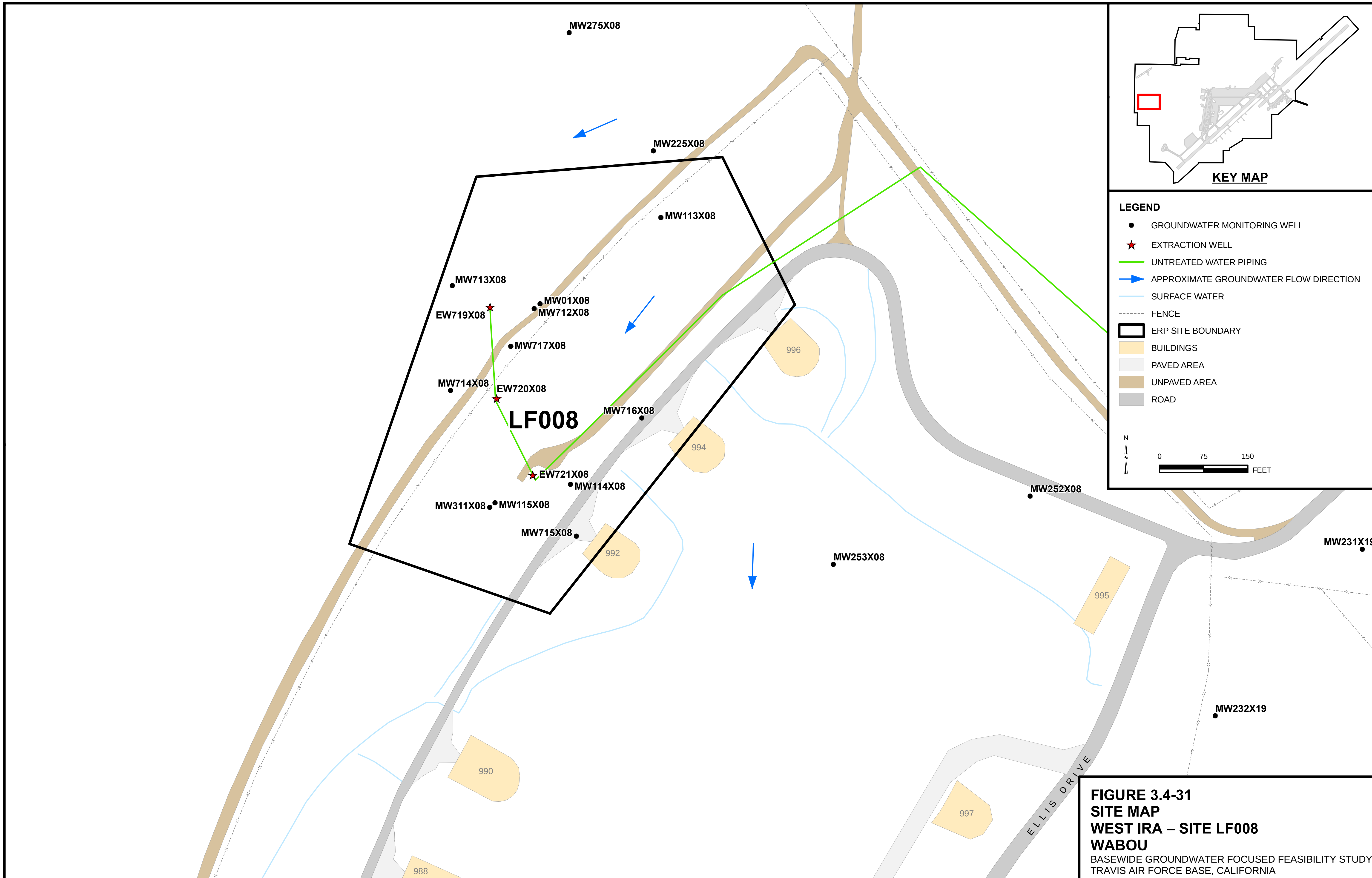


FIGURE 3.4-31
SITE MAP
WEST IRA – SITE LF008
WABOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3-4_31_LF008_SITE_MAP.MXD MCLAY1 1/21/2011 10:14:32

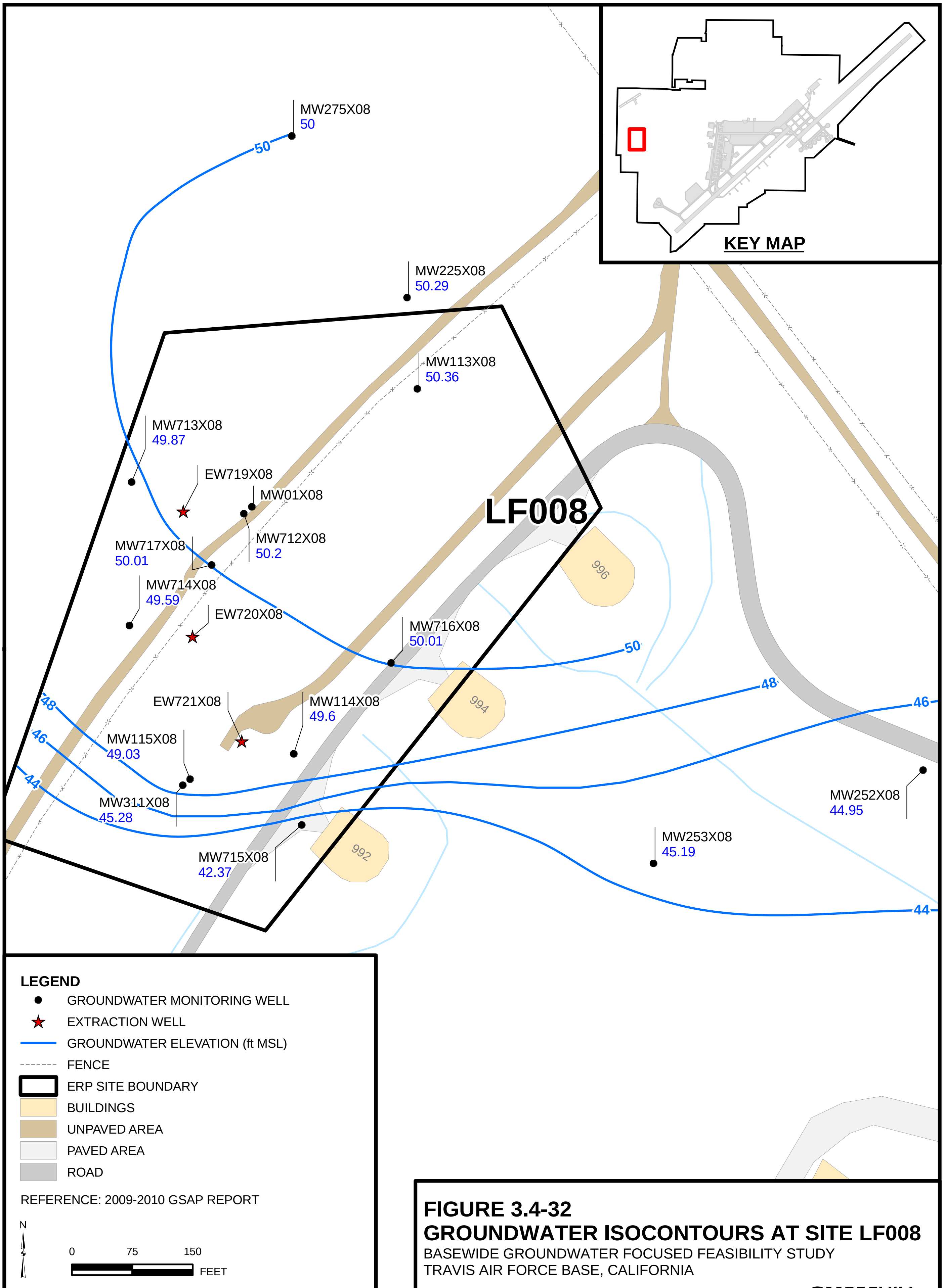


FIGURE 3.4-32
GROUNDWATER ISOCONTOURS AT SITE LF008
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIGURE_3_4_32_LF008_GW_2010.MXD MCLAY1 1/21/2011 10:25:10

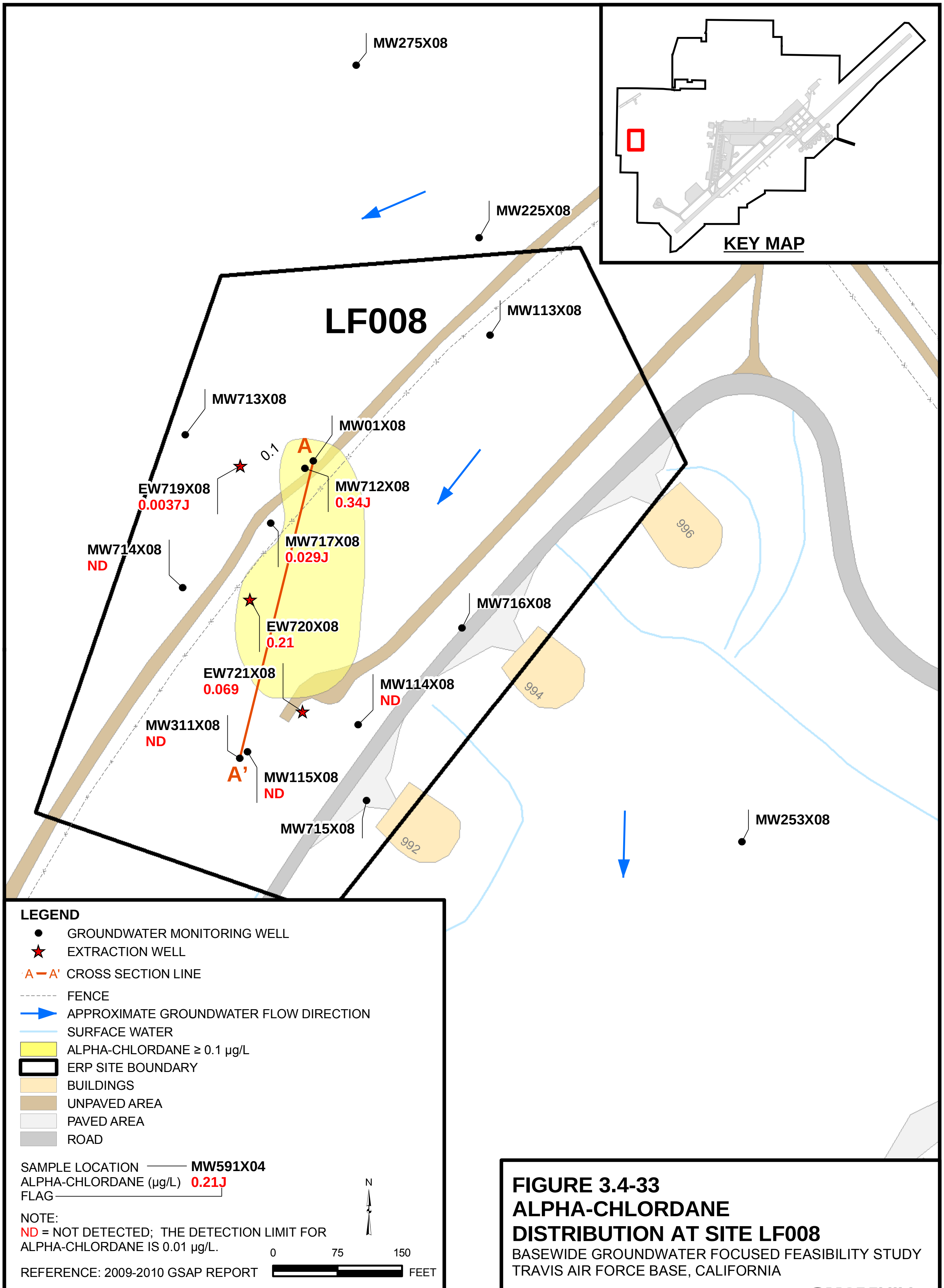
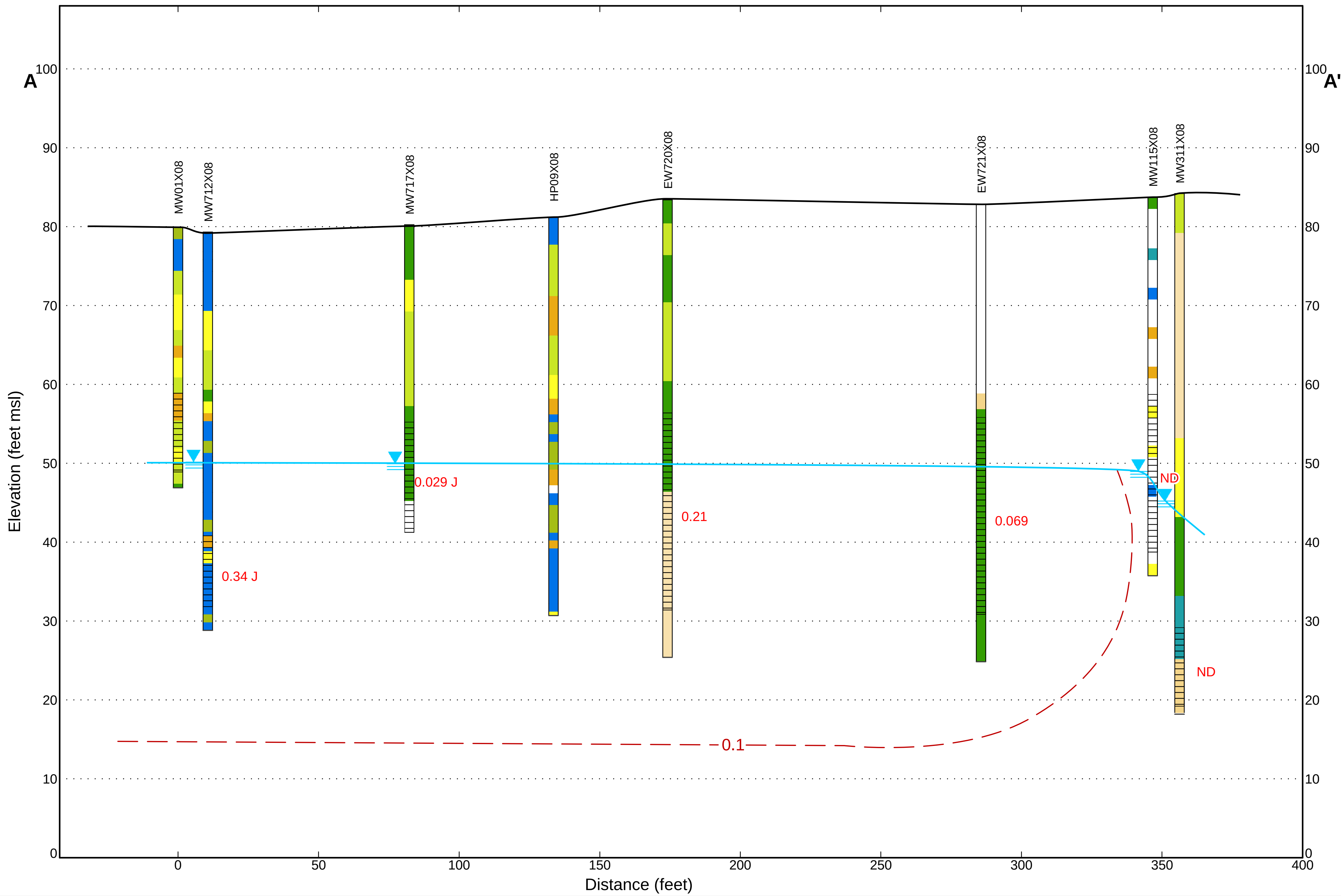


FIGURE 3.4-33
ALPHA-CHLORDANE DISTRIBUTION AT SITE LF008
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIGURE_3_4-33_CHLORADE_LF008.MXD MSCHROCK 6/15/2011 00:05:31



SOIL AND LITHOLOGY

SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)

0.69 ALPHA-CHLORDANE CONCENTRATION (µg/L) DETECTED IN 2010

--0.1-- APPROXIMATE ALPHA-CHLORDANE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION

SCALE EXAGGERATION - 3:1 (H:V)

ND = NOT DETECTED; THE DETECTION LIMIT FOR ALPHA-CHLORDANE IS 0.01 µg/L

NO SAMPLE/NO RECOVERY
FILL/ASPHALT
TOPSOIL/ORGANIC SOIL
WELL GRADED GRAVEL (GW)
POORLY GRADED GRAVEL (GP)
SILTY GRAVEL (GM)
CLAYEY GRAVEL (GC)
WELL GRADED SAND (SW)
SILTY SAND (SM)
POORLY GRADED SAND (SP)
CLAYEY SAND (SC)
SILT (ML)
ELASTIC SILT (MH)
LEAN CLAY (CL)
FAT CLAY (CH)
SILTSTONE
SANDSTONE
SHALE
ALLUVIUM (NO DATA)

FIGURE 3.4-34
SITE LF008 CROSS SECTION A–A'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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ES082009007SAC Figure_3.4-34.ai 06.14.2011 tdaus

3.5 South IRA Conceptual Site Models

This section provides the CSMs for sites within the South IRA, which includes Sites FT005, SS029, and SS030. A site map is shown on Figure 3.5-1.

Additional descriptions of the sites, geology, groundwater, and groundwater contamination are provided in Section 4.3 of the 2009-2010 Annual GSAP Report (CH2M HILL, 2011b).

3.5.1 South IRA Site Descriptions

The following subsections provide summary descriptions of Sites FT005, SS029, and SS030.

3.5.1.1 Site FT005

Site FT005, also known as FTA-4, is located within the EIOU, in the southeastern portion of Travis AFB. 1,2-DCA is the indicator chemical for Site FT005. Concentrations of 1,2-DCA are relatively low; however, they exceed the IRG of 0.5 μg/L at some locations. Groundwater contaminated with 1,2-DCA has migrated approximately 2,600 feet south of the Base boundary and underlies private property.

Contamination at Site FT005 is the result of fire training exercises conducted between 1962 and approximately 1986. Historical photographs indicate that the area may have been used for munitions storage prior to 1958. From 1962 until the early 1970s, waste fuels, oils, and solvents were used as ignitable materials during fire training exercises. In the early 1970s, the use of oil and solvent was discontinued, and only contaminated fuel was used in the training. As late as 1988, airplane mockups and an airplane fuselage were observed at the site. From 1990 to 1994, the area was used as a dump site for miscellaneous wastes, such as concrete, fencing, and street sweepings. These activities ceased in 1994, and some of the debris was removed. The site is currently inactive (Weston, 1995).

3.5.1.2 Site SS029

Site SS029 also is located in the southeastern portion of Travis AFB, south of the runway and west of Site FT005. Site SS029 is an open field south of Taxiway R. Site topography is relatively flat and slopes gently from the north-northwest to the south-southeast. The main branch of Union Creek traverses the middle of the site and flows from northeast to southwest.

Groundwater contamination at Site SS029 consists primarily of a TCE and cis-1,2-DCE plume that lies within the boundaries of Travis AFB. The source of groundwater VOC contamination at Site SS029 is unknown. Historical photographs indicate that airplanes had been parked in the vicinity of monitoring well MW329x29, but little is known about historical activities at the site. Site SS029 was investigated initially during the EIOU RI to assess the downgradient extent of groundwater contamination originating from Site SS016 (upgradient). The data from this investigation and subsequent investigations indicated a discrete groundwater plume and source area. However, these investigations did not identify the specific source of the groundwater contamination (Weston, 1995). Subsequent investigations have confirmed that groundwater contamination that originates from Site SS016 has migrated into the northern portion of the Site SS029 plume.

3.5.1.3 Site SS030

Site SS030 is south of Facility 1125 (a radar facility) and southwest of Site SS029, in the southeastern portion of Travis AFB. The site boundary encompasses an area of groundwater contamination (primarily TCE) that has migrated approximately 1,300 feet south of the Base boundary and underlies private property.

MW269x30 was installed originally during the EIOU RI to evaluate groundwater quality along the southeastern Base boundary. No known historical activities indicated that groundwater contamination would be detected. However, the EIOU RI and subsequent investigations revealed TCE-contaminated groundwater. Historical activities associated with Building 1125 in the vicinity of MW269x30 are believed to be the source of the solvent contamination at Site SS030 (CH2M HILL, 2000a).

3.5.2 Geology

The following subsections provide summary descriptions of the geology at Sites FT005, SS029, and SS030.

Sites FT005, SS029, and SS030 lie above a geologic anticline that plunges to the southeast. A subsurface ridge of the more resistant Markely Sandstone, which forms part of the western limb of the anticline, runs through eastern Site SS030 and western Site SS029. The western portion of Site SS030 is underlain by the Neroly Sandstone, which is also part of the western limb of the regional anticline. Bedrock underlying the eastern portion of Sites SS029 and FT005 is primarily the older and less resistant Nortonville Shale; these two (2) sites are located near the apex of the anticline. The more resistant sandstone units form a subsurface ridge along the western side of the Site FT005, SS029, and SS030 area; while the less resistant shale forms a shallow basin in the center of the Site FT005, SS029, and SS030 area. Bedrock is relatively shallow along the western side of this area (about 5 to 30 feet bgs) and deeper in the eastern and southern portions of the sites (about 50 to 60 feet bgs in the off-base portion of Site FT005). Older alluvium overlies the shallow bedrock. This alluvium consists mainly of silts and clays with thin interbedded sand seams.

3.5.2.1 Site FT005

The surface topography within Site FT005 is relatively flat, sloping gently to the southeast. The geology consists of alluvium, primarily clays, silts, and sands. Low-permeability silts and clays occur between 10 and 20 feet bgs. Relatively permeable sands and silts occur from 20 feet bgs to bedrock. These permeable units are laterally discontinuous and are interlayered with semiconfining clays and silts. Bedrock in this area lies at approximately 30 to 60 feet bgs and dips to the south. Investigations in the off-base portion of Site FT005 have generally found the bedrock at 50 to 60 feet bgs.

3.5.2.2 Site SS029

As with Site FT005, the uppermost alluvial sediments are primarily silts and clays. Relatively permeable sands and silts, which are laterally discontinuous, occur from approximately 20 to 40 feet bgs. Below the more permeable zone is clay or bedrock.

Bedrock in the vicinity of Site SS029 ranges from 4 feet bgs in the western part of the site to about 60 feet bgs in the northeastern part of the site. A shallow bedrock valley is bounded to the southwest by the western flank of a bedrock anticline that reportedly outcrops along

Union Creek (Weston, 1995) and to the northeast by a low bedrock ridge. Union Creek runs through the center of Site SS029, approximately perpendicular to the trend of the bedrock valley. However, Union Creek is not a significant hydraulic barrier to plume migration at Site SS029.

3.5.2.3 Site SS030

The geology in the vicinity of Site SS030 consists primarily of fine-grained alluvium overlying bedrock. The alluvium is composed of interbedded clay, silt, sand, and a small amount of gravel. The intervals of sand and gravel occur as laterally discontinuous lenses. Bedrock consists of interbedded sandstone and siltstone from the Neroly Sandstone along the western and central portion of the site and the Markley Sandstone along the eastern portion of the site. Bedrock ranges from 20 to 67 feet bgs, with the depths of bedrock increasing to the south. The bedrock is deepest along the western and central portion of the site. In the northern and eastern portions of Site SS030 the bedrock is shallower.

3.5.3 Groundwater

The flow of groundwater within the South IRA is regionally to the south and southeast. Groundwater contours indicate a hydraulic trough due to the presence of the southeast trending subsurface bedrock ridge along the western side of the area and the relatively thick alluvium in the central and eastern portion of the area. Groundwater flows southeasterly along this trough. In the southern portion of the site, a groundwater mound appears associated with monitoring wells MW09x30 and MW10x30. The groundwater flow near monitoring wells MW2001x30A and MW2001x30B is to the southwest.

Groundwater flow is within the alluvium. Groundwater yields from extraction wells tend to be low (i.e., less than 5 gpm). However, yields from Site SS030 extraction wells EW04x30, EW05x30, and EW711x30 tend to be higher, ranging from approximately 7 to 21 gpm.

Information regarding overall hydrogeologic characteristics within the South IRA is summarized in the following list. Groundwater elevations contours are shown on Figure 3.5-2.

- Depth to groundwater is between 10 and 20 feet bgs.
- The regional groundwater flow direction in the vicinity of Sites FT005, SS029, and SS030 is toward the south-southeast. The average horizontal gradient across these sites is approximately 0.005 ft/ft.
- Six (6) well pairs are in the vicinity of Sites FT005, SS029, and SS030. In general, vertical gradients at these sites are negligible and ranged from 0.003 ft/ft to 0.02 ft/ft upward. Piezometer pair PZ01Sx29/PZ01Dx2 had the largest vertical gradient (0.02 ft/ft upward). This piezometer pair is located adjacent to Union Creek, and typically has an upward vertical gradient, indicating that groundwater discharges to the creek.
- The hydraulic conductivity at Site SS030 as calculated from an aquifer test at extraction well EW04x30 is 50 ft/day.

- Groundwater potentiometric heads up to 13 feet above the first saturated soil were observed during recent well installations at Site SS030 indicate that the groundwater system is partially confined.
- Groundwater elevations fluctuate from 2 to 5 ft/year with no long-term trend of rising or falling groundwater elevations.

3.5.4 Groundwater Contamination

The primary groundwater contaminants at the sites within the South IRA are TCE at Sites SS029 and SS030 and 1,2-DCA at Site FT005. At Site FT005, TCE is found at detectable concentrations in only three (3) geographically isolated wells (EW01x05, MW119x05, and EW736x05). The only Site FT005 well with TCE detected above the IRG is on-base monitoring well MW119x05 (7.8 µg/L). This well also has a concentration of 1,2-DCA that exceeds the IRG (4.7 µg/L).

The site-specific distribution of TCE for Sites SS029 and SS030 and 1,2-DCA contamination for Site FT005 is shown on Figure 3.5-3. Cross sections depicting the vertical distribution of contaminants at each site are shown on Figures 3.5-4 through 3.5-7.

3.5.5 Status of Groundwater Interim Remedial Actions

In accordance with the NEWIOU IROD, Travis AFB implemented GET IRA systems at each of the sites that compose the South IRA. This section summarizes the status of those groundwater IRAs at Sites FT005, SS029, and SS030. The main components of the South IRA are summarized in Table 3.5-1.

Groundwater extracted from each of the sites is conveyed to the SBBGWTP for treatment via LGAC before being discharged to Union Creek.

The South IRA GET System was started up on 6 July 1998. The GET systems at Sites SS029 and SS030 are active. Most of the Site FT005 GET system is currently turned off (except for three [3] extraction wells – see below) for a rebound study for the remainder of the period of interim remediation. Operation of the GET system at Site SS030 was optimized during 2010 and is under evaluation.

3.5.5.1 Site FT005

At Site FT005, the IRA objective of migration control has been achieved, and the objective of off-base groundwater remediation has nearly been achieved. Consequently, a rebound study is under way at the site. A portion of the GET was shut down in December 2007, and the remainder was shut down in August 2009. Throughout the period of the rebound study, most Site FT005 monitoring wells and extraction wells continued to have decreasing or stable 1,2-DCA concentrations. However, in 2Q10, 1,2-DCA concentrations rebounded in three (3) extraction wells. These extraction wells (EW02x05, EW734x05, and EW735x05) were restarted in August 2010.

3.5.5.2 Site SS029

At Site SS029, the IRA objective of migration control has been achieved. The portion of the plume with TCE exceeding 5 µg/L is within the 2Q10 estimated extent of hydraulic capture.

TCE was not detected in the farthest downgradient monitoring wells (MW01x29, MW06x29, and MW07x29) near the Base boundary.

Upgradient Site SS029 wells MW1031x29 and MW1032x29 have exhibited recent trends of increasing contaminant concentrations. Both of these wells are upgradient from the Site SS029 extraction system, and increasing concentrations at these locations are the result of VOC migration from the upgradient Site SS016 plume. Available physical and analytical data indicate that the Site SS029 GET is capturing the VOC contamination that has migrated from Site SS016.

3.5.5.3 Site SS030

The on-base migration control component of Site SS030 has been achieved. The interim objective of off-base groundwater remediation has partially been achieved. The southern and western portions of the Site SS030 plume have been remediated, and VOCs are no longer detected in these areas. TCE remains above the IRG only in the eastern portion of the off-base plume.

The only monitoring wells exhibiting increasing concentration trends (MW03x30 and MW05x30) are located on the eastern side of the off-base plume. Historically, groundwater elevation contours and the increasing contaminant trends have indicated that contamination may be escaping the Site SS030 GET in this area and flowing toward the southeast under the hydraulic influence of the Site FT005 extraction system.

Groundwater elevation data obtained in 2Q10 indicate that operational changes have improved hydraulic capture of the eastern side of the Site SS030 plume. Groundwater elevation contours developed after shutdown of the Site FT005 GET system and increased extraction rates from the Site SS030 GET system have been at least partially effective at improving plume capture. Monitoring wells MW03x30 and MW05x30 now appear to be within the extent of hydraulic capture of the Site SS030 GET system. It is uncertain if the easternmost portion of the plume (in the vicinity of new well pair MW2001Ax30 and MW2001Bx30) is being hydraulically captured to the MCL. Ongoing monitoring of this well pair will verify the extent of capture. It is expected that TCE concentrations in this well pair will decline if plume capture is truly achieved.

TABLE 3-5-1
Summary of the South Groundwater Interim Remedial Action
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Contaminant Plume	IRA Objective*	Implemented IRA	Primary Components	Status and Comments
Site SS030 On-base Source Area	Source Control	GET	Interceptor trench, performance monitoring wells, LGAC groundwater treatment at SBBGWTP	Extracted groundwater flow to SBBGWTP is combination of flows from Sites SS030, SS029, and FT005. Groundwater treatment at the SBBGWTP changed from air stripping to LGAC in 2010.
Site SS030 Off-base	Off-base Remediation	GET	Conventional extraction wells, performance monitoring wells, LGAC groundwater treatment at SBBGWTP	Optimization of the GET system is in progress. Extraction flow rates increased in 2010 to improve hydraulic capture of the eastern portion of the off-base plume.
Site SS029	Migration Control	GET	Conventional extraction wells, performance monitoring wells, LGAC groundwater treatment at SBBGWTP	GET system is operating normally. Plume is hydraulically captured.
Site FT005 On-base	Migration Control	GET	Conventional extraction wells, performance monitoring wells, LGAC groundwater treatment at SBBGWTP	Three (3) on-base extraction wells turned off for a rebound study beginning in December 2007. Evidence of contaminant rebound in EW02x05 resulted in restarting this on-base extraction well in August 2010.
Site FT005 Off-base	Off-base Remediation	GET	Conventional extraction wells, performance monitoring wells, air stripper groundwater treatment at SBBGWTP	All on-base and off-base extraction wells turned off for a continued rebound study in August 2009. Evidence of contaminant rebound in EW734x05, and EW735x05 resulted in restarting these off-base extraction wells in August 2010.

* IRA objective specified in the NEWIOU Groundwater IROD (Travis AFB, 1998).

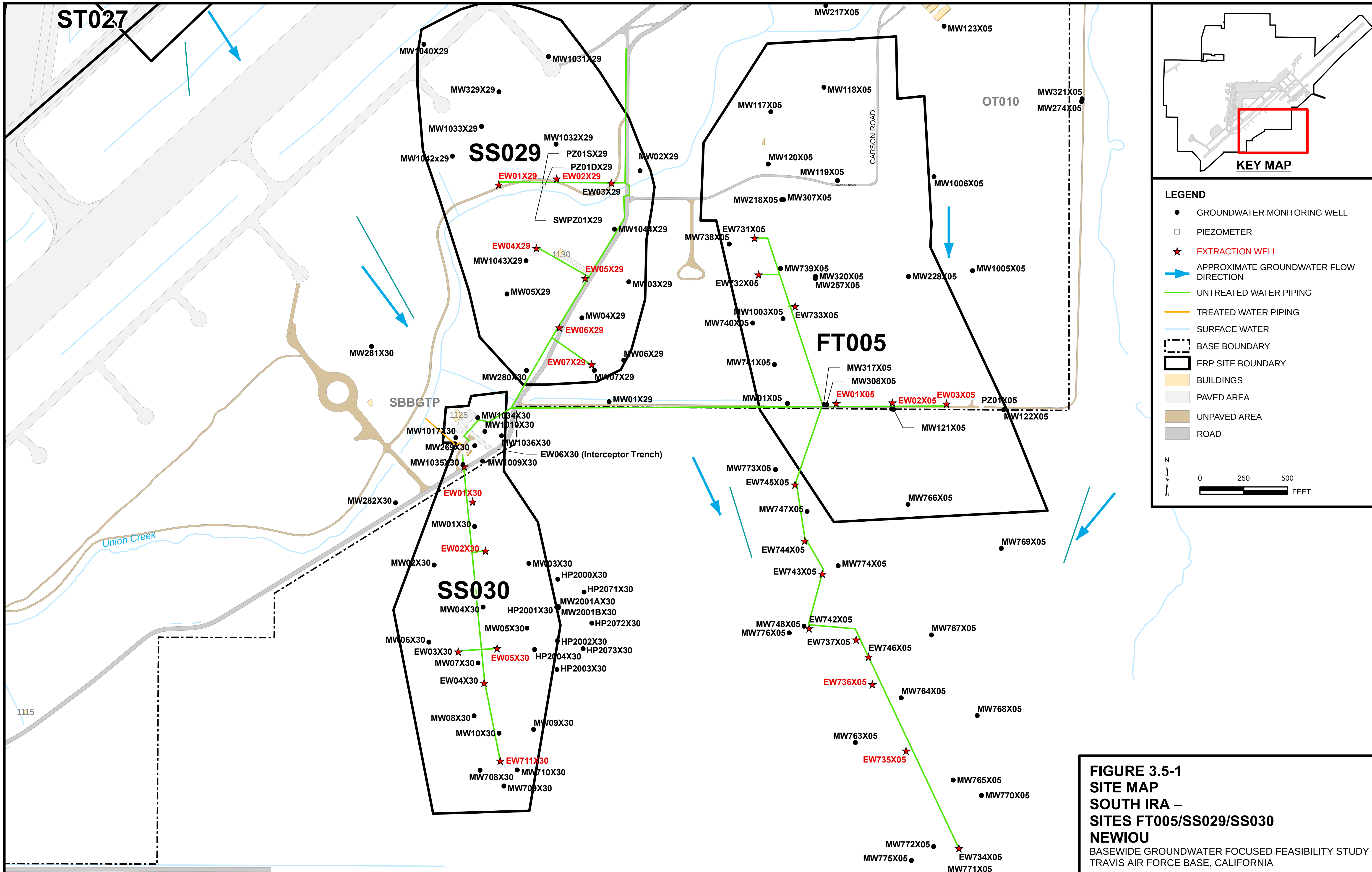


FIGURE 3.5-1
SITE MAP
SOUTH IRA –
SITES FT005/SS029/SS030
NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_5-1_FT005_SITE_MAP.MXD MCLAY1 1/21/2011 10:56:43

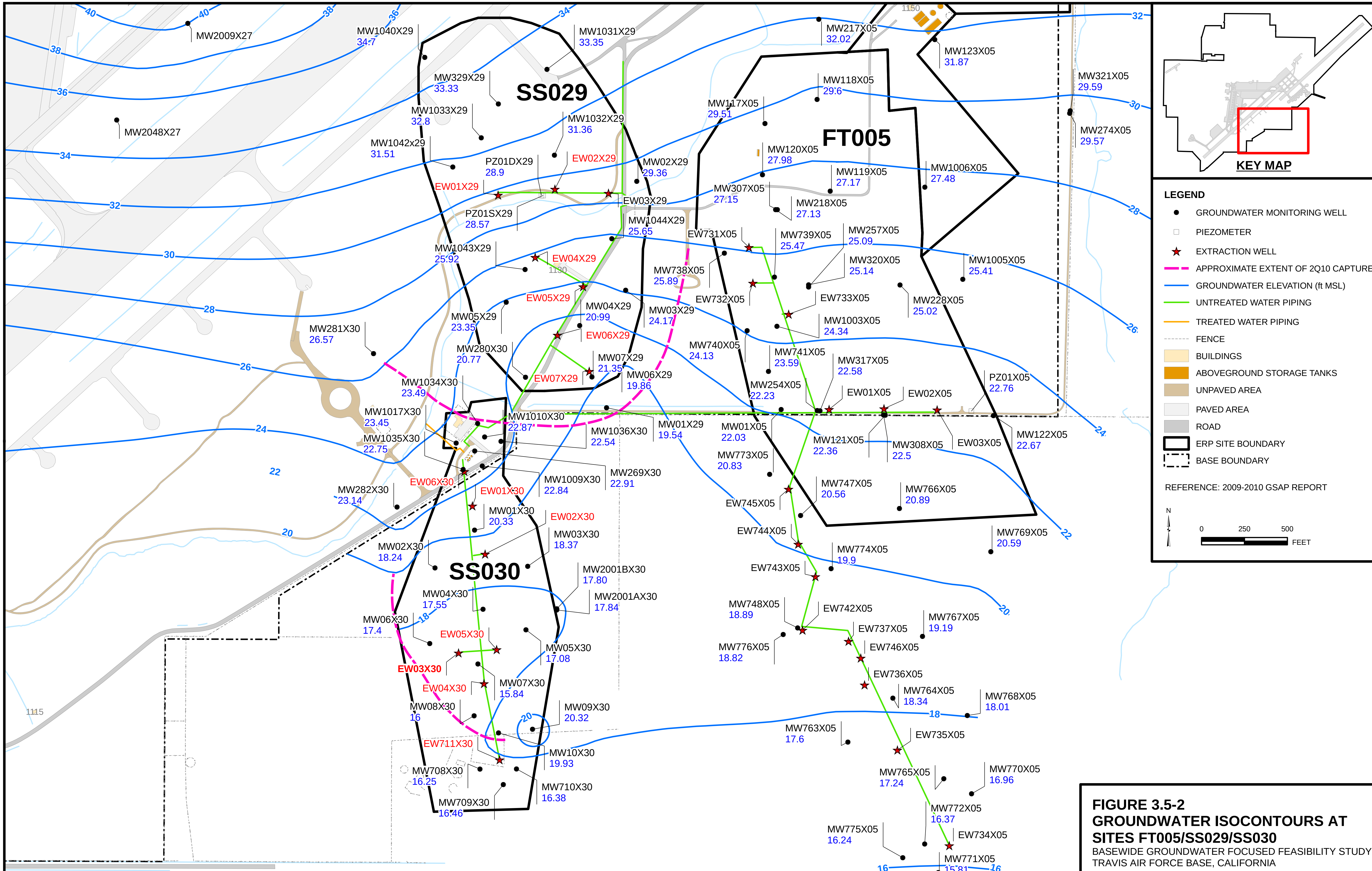


FIGURE 3.5-2
GROUNDWATER ISOCONTOURS AT SITES FT005/SS029/SS030
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIGURE_3_5-2_FT005_GW_2010.MXD MCLAY1 1/21/2011 11:15:37

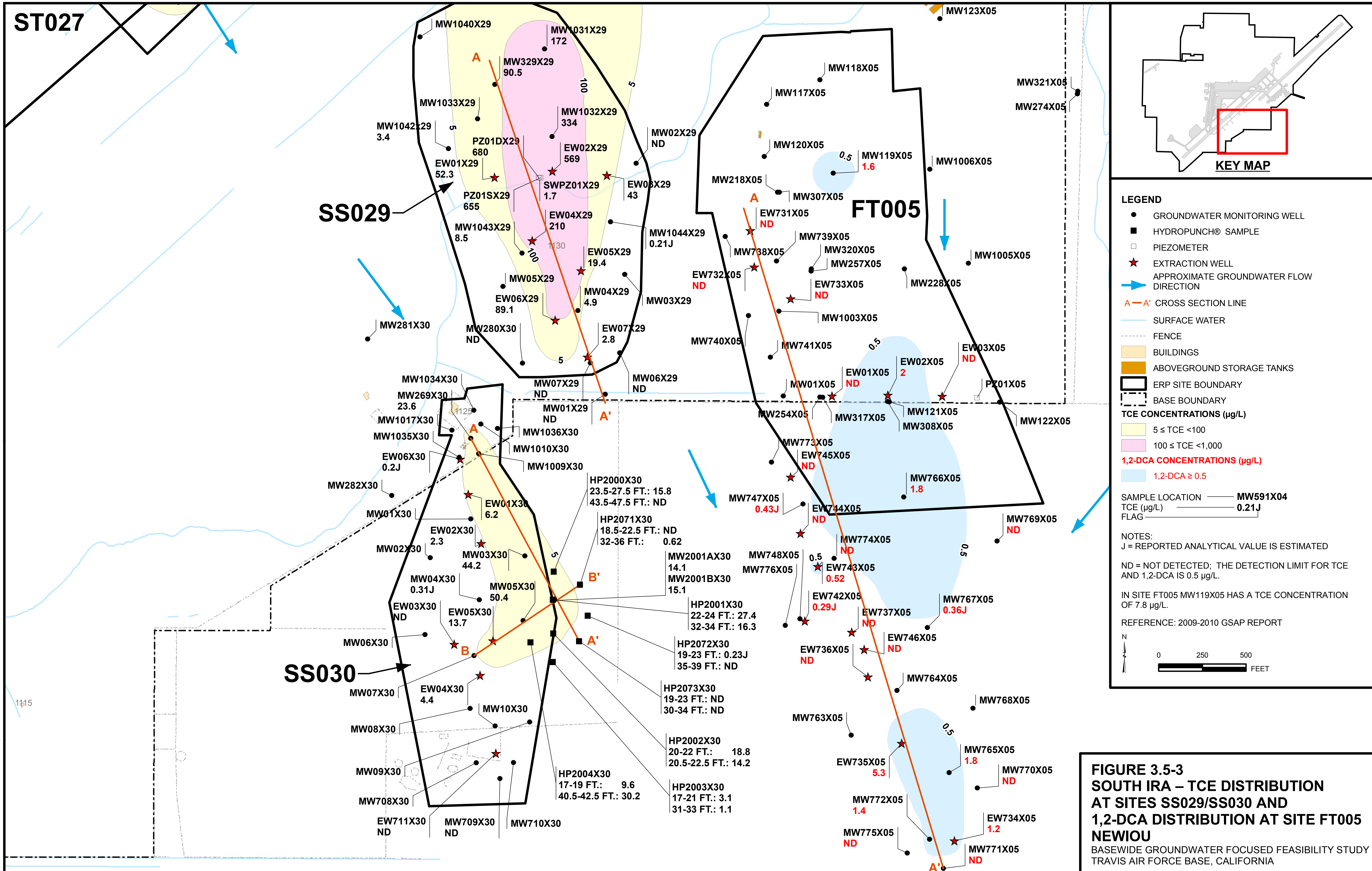
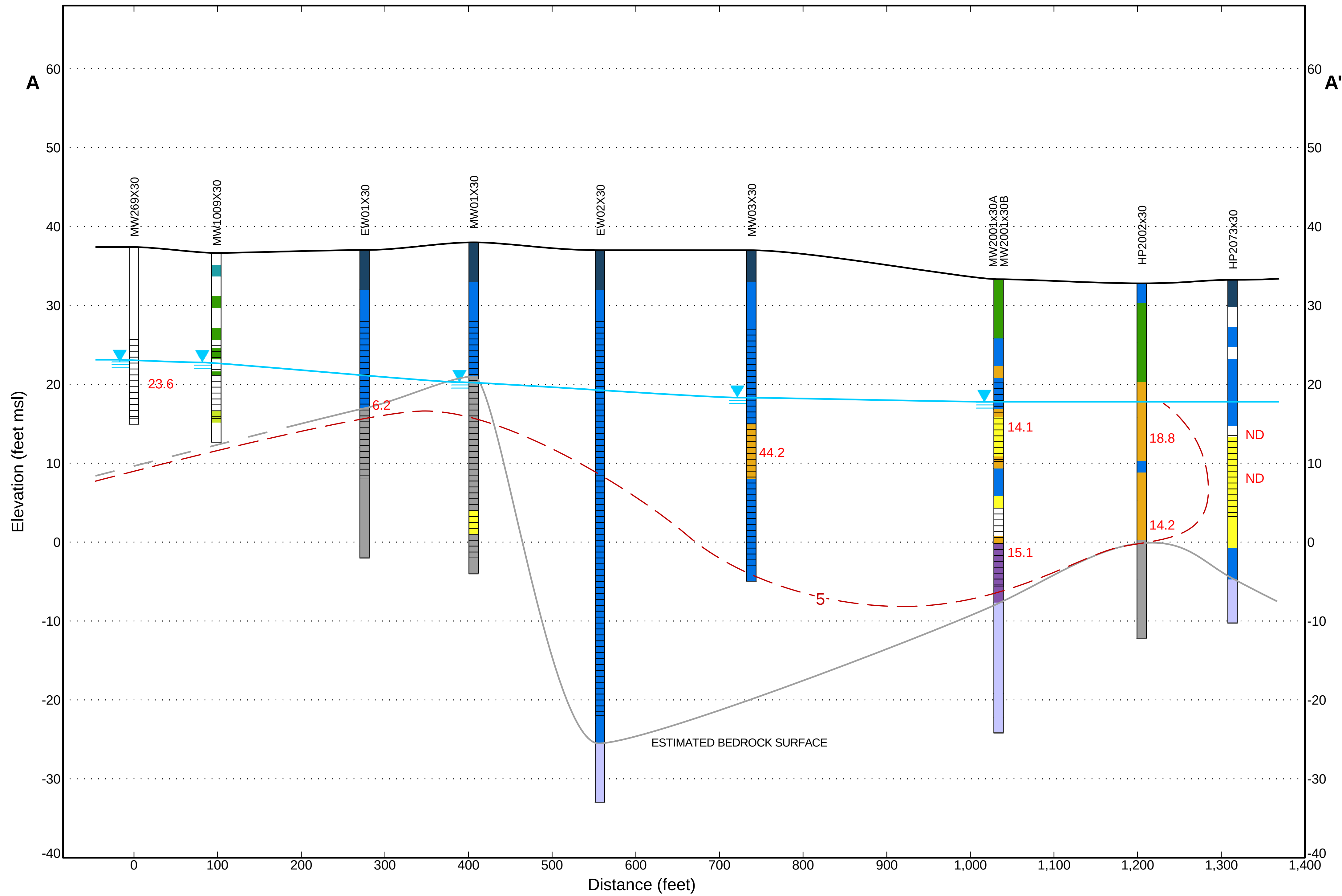


FIGURE 3.5-3
SOUTH IRA – TCE DISTRIBUTION AT SITES SS029/SS030 AND 1,2-DCA DISTRIBUTION AT SITE FT005 NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_5-3_DCA_FT005.MXD MSCHROCK 6/15/2011 03:42:37



SOIL AND LITHOLOGY

SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)

6.7 TCE CONCENTRATION (µg/L) DETECTED IN 2010

5 APPROXIMATE TCE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION

SCALE EXAGGERATION - 9.5:1 (H:V)

ND = NOT DETECTED; THE DETECTION LIMIT FOR TCE IS 0.5 µg/L

- NO SAMPLE/NO RECOVERY
- FILL/ASPHALT
- TOPSOIL/ORGANIC SOIL
- WELL GRADED GRAVEL (GW)
- POORLY GRADED GRAVEL (GP)
- SILTY GRAVEL (GM)
- CLAYEY GRAVEL (GC)
- WELL GRADED SAND (SW)
- SILTY SAND (SM)
- POORLY GRADED SAND (SP)
- CLAYEY SAND (SC)
- SILT (ML)
- ELASTIC SILT (MH)
- LEAN CLAY (CL)
- FAT CLAY (CH)
- SILTSTONE
- SANDSTONE
- SHALE
- ALLUVIUM (NO DATA)

FIGURE 3.5-4
SITE SS030 CROSS SECTION A–A'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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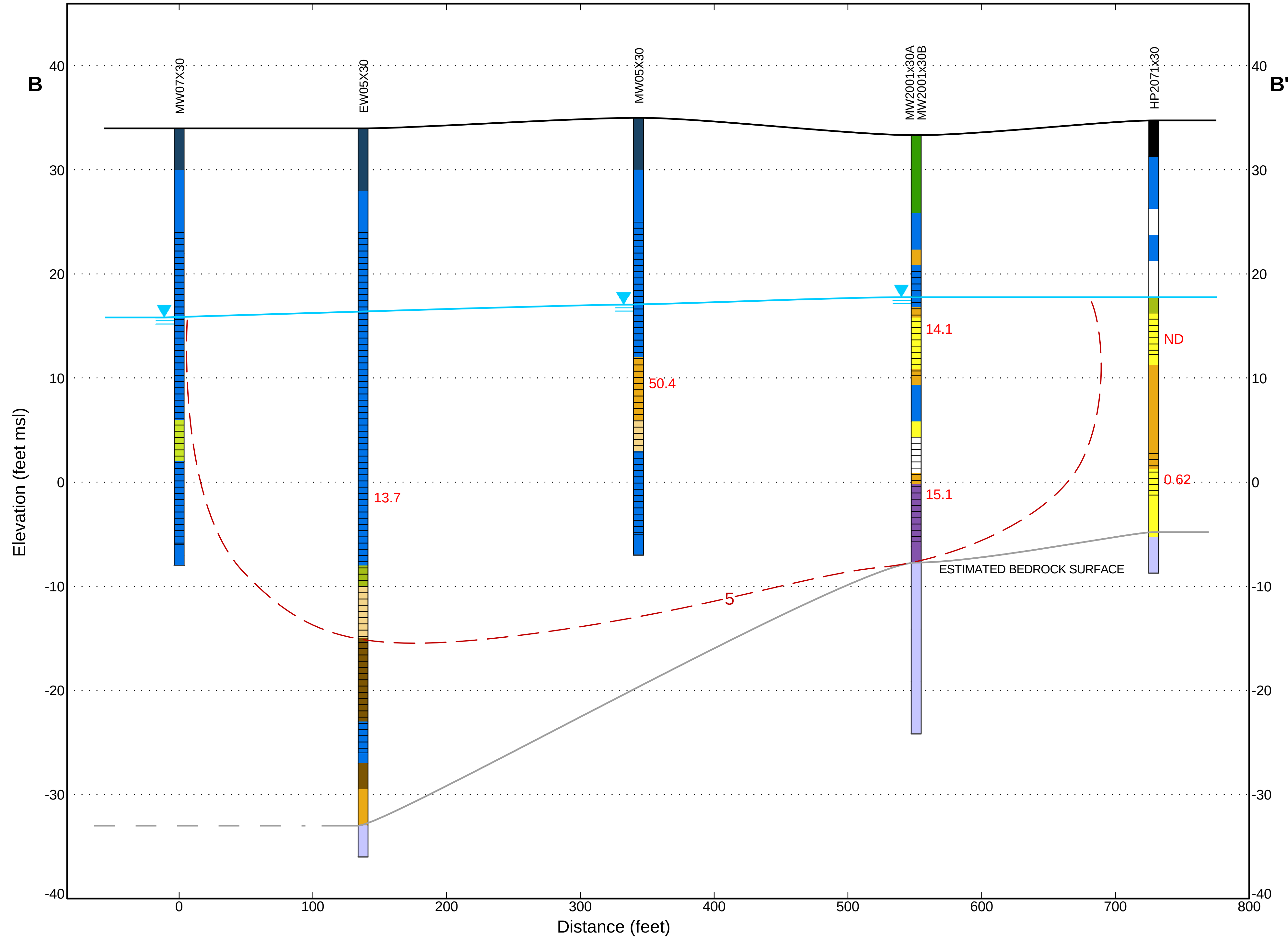
ES082009007SAC Figure_3.5-4.ai 04.11.2011 tdaus



SOIL AND LITHOLOGY

SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)

6.7 TCE CONCENTRATION (µg/L) DETECTED IN 2010

5 APPROXIMATE TCE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION

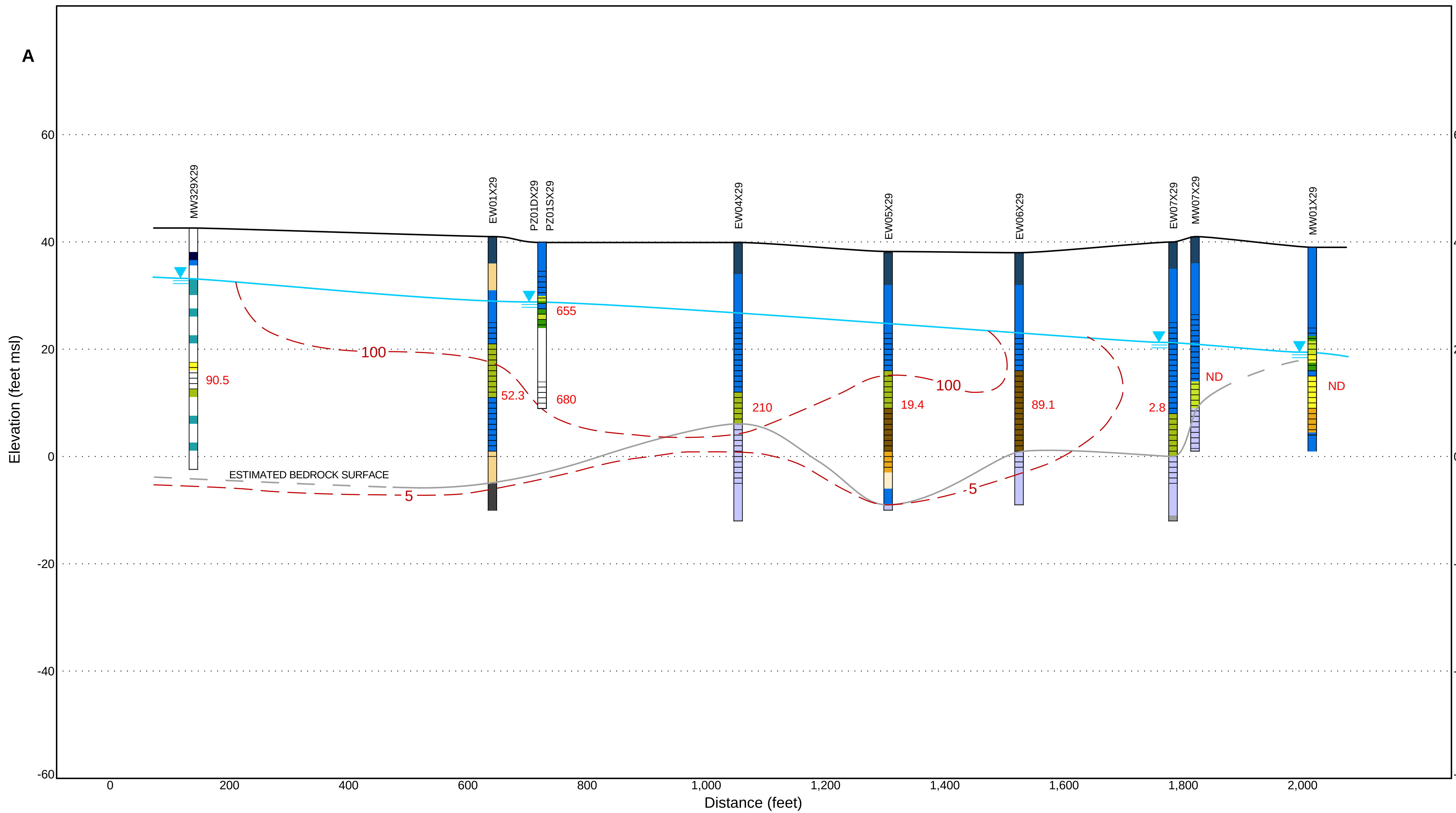
SCALE EXAGGERATION - 8:1 (H:V)

ND = NOT DETECTED; THE DETECTION LIMIT FOR TCE IS 0.5 µg/L

- NO SAMPLE/NO RECOVERY
- FILL/ASPHALT
- TOPSOIL/ORGANIC SOIL
- WELL GRADED GRAVEL (GW)
- POORLY GRADED GRAVEL (GP)
- SILTY GRAVEL (GM)
- CLAYEY GRAVEL (GC)
- WELL GRADED SAND (SW)
- SILTY SAND (SM)
- POORLY GRADED SAND (SP)
- CLAYEY SAND (SC)
- SILT (ML)
- ELASTIC SILT (MH)
- LEAN CLAY (CL)
- FAT CLAY (CH)
- SILTSTONE
- SANDSTONE
- SHALE
- ALLUVIUM (NO DATA)

FIGURE 3.5-5
SITE SS030 CROSS SECTION B–B'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL



SOIL AND LITHOLOGY

SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)

6.7 TCE CONCENTRATION (µg/L) DETECTED IN SECOND QUARTER 2010

— 5 — APPROXIMATE TCE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION

SCALE EXAGGERATION - 9:1 (H:V)

ND = NOT DETECTED; THE DETECTION LIMIT FOR TCE IS 0.5 µg/L

NO SAMPLE/NO RECOVERY
FILL/ASPHALT
TOPSOIL/ORGANIC SOIL
WELL GRADED GRAVEL (GW)
POORLY GRADED GRAVEL (GP)
SILTY GRAVEL (GM)
CLAYEY GRAVEL (GC)
WELL GRADED SAND (SW)
POORLY GRADED SAND (SP)
SILTY SAND (SM)
CLAYEY SAND (SC)
SILT (ML)
ELASTIC SILT (MH)
LEAN CLAY (CL)
FAT CLAY (CH)
SILTSTONE
SANDSTONE
SHALE
ALLUVIUM (NO DATA)

FIGURE 3.5-6
SITE SS029 CROSS SECTION A–A'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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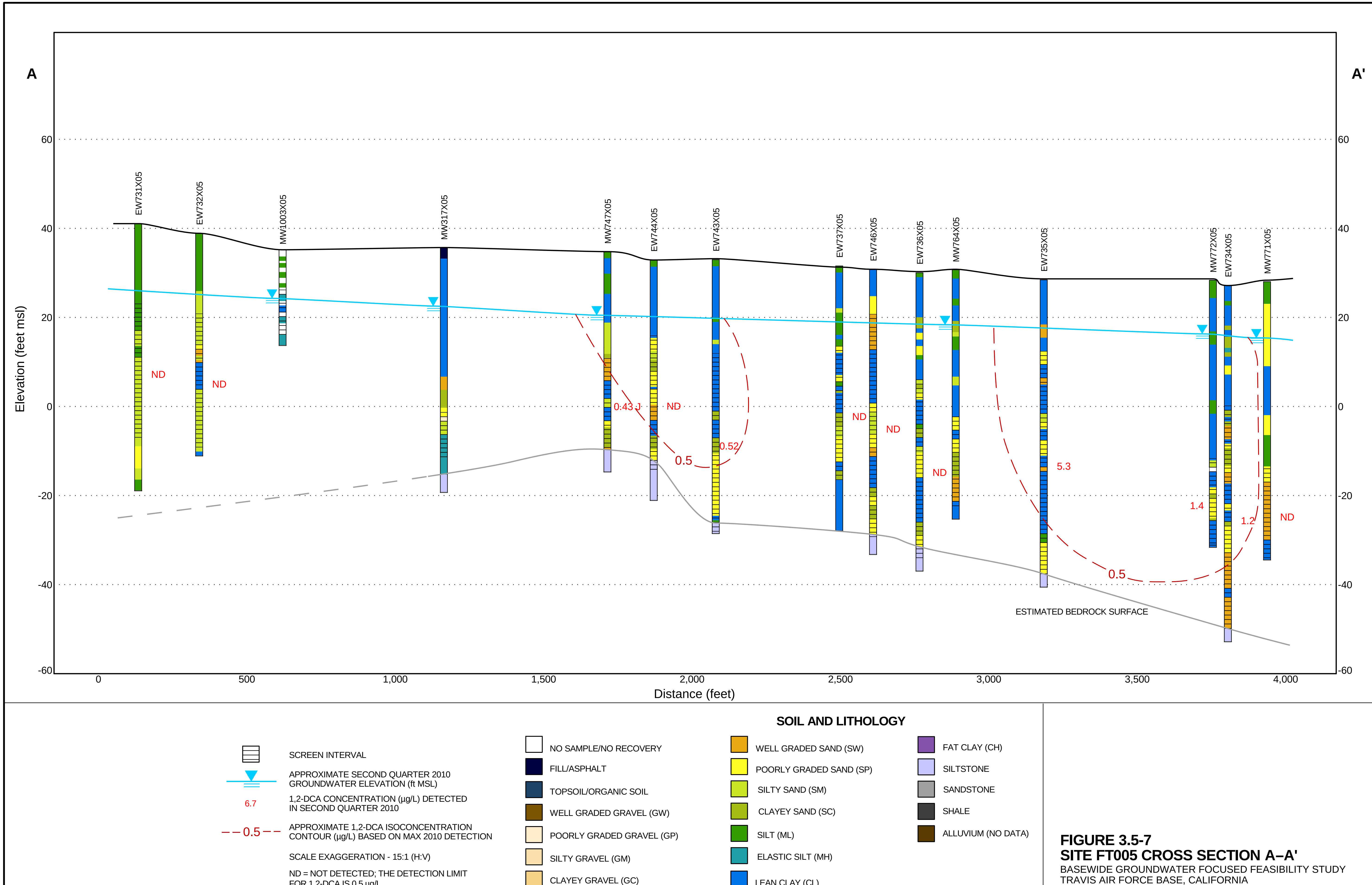

FIGURE 3.5-7
SITE FT005 CROSS SECTION A–A'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

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ES082009007SAC Figure_3.5-7.ai 04.11.2011 tdaus

3.6 Site ST027B Conceptual Site Model

This section provides the CSM for Site ST027B located in the central area of Travis AFB.

3.6.1 Site Description

Site ST027 is a 35-acre area located within the Travis AFB flightline. A site map is shown on Figure 3.6-1. The site is bounded by aircraft parking ramps and taxiways. Access to the site is restricted because of military security requirements.

The site has historically been used for fuel storage and aircraft and jet engine testing. However, jet engine testing is no longer conducted. The main current function of the site is to store fuel as part of the fuel hydrant system.

Historically, fourteen 50,000-gallon USTs were present at the site and used to store jet fuel (jet propulsion fuel, grade 4 [then later, grade 8]). These tanks were removed in 1997 and 1998. Although the tanks appeared intact, soil and groundwater samples indicated that fuel hydrocarbons had impacted the subsurface. Four (4) new aboveground storage tanks have been constructed at Site ST027 to replace the USTs. However, none of the aboveground storage tanks are located within Site ST027B. A small hazardous waste facility was in operation in the northeastern corner of the site between 1997 and 2004. A wash rack was also historically operated in the northeastern corner of the site.

Site ST027 has historically been managed as part of the POCO program at Travis AFB because petroleum hydrocarbons were believed to be the only contaminants present at this site. However, POCO investigations conducted in 2007 and 2008 discovered a small, previously unknown TCE plume located in the southwestern part of Site ST027, between the southern edge of the aircraft test pad and Taxiway November. This area of TCE contamination has been designated as Site ST027–Area B or Site ST027B. The TCE contamination probably originated from undocumented spills or dumping between the southern edge of the aircraft test pad and Taxiway November. Groundwater contamination within this portion of the site is now administered under the ERP. Petroleum fuel contamination found within the remainder of the site, now designated as Site ST027A, continues to be administered under the POCO program.

Ecological habitat quality at Site ST027B is marginal, because surface water bodies within this part of the Base consist of drainage swales that contain water for short periods of time and are mowed regularly during the winter as a part of flightline maintenance. In addition, all of Site ST027 is surrounded by parking ramps, taxiways, and runways, which act as a concrete and asphalt buffer zone for amphibians and reptiles, such as the California Tiger Salamander.

3.6.2 Geology

The subsurface at Site ST027B consists of Quaternary alluvial deposits underlain by weathered sandstone and shale, which have both been tentatively identified as part of the Markley Sandstone. The alluvial sediments above the sandstone bedrock are generally less than 30 feet thick and consist primarily of lean clay. The underlying sandstone is typically weathered and fissile in the top layers, becoming more competent with depth (Radian, 1996b). In the western part the site, the sandstone bedrock forms a subsurface ridge that trends and plunges south-southeast. The presence of the bedrock ridge strongly influences groundwater flow direction. The weathered nature of the Markley Sandstone has made identification of the bedrock contact uncertain.

The saturated zone is approximately 5 to 25 feet thick at Site ST027B, and contamination extends throughout the saturated zone to bedrock.

3.6.3 Groundwater

Groundwater flow beneath the western part of the site is variable. Flow is outward from a groundwater mound located near the aircraft test pad. This groundwater mound is caused by the subsurface ridge of Markley Sandstone. Groundwater flow in the eastern part of the site is to the east, away from the buried bedrock ridge, but becomes more southerly as it joins the regional gradient.

Groundwater characteristics at Site ST027B are summarized in the following list:

- Depth to groundwater is approximately 8 to 15 feet bgs.
- The horizontal direction of groundwater flow in the vicinity of the aircraft test pad is semi-radial (outward toward the south, southeast, and east from the center of the groundwater mound caused by the presence of the sandstone ridge).
- Horizontal hydraulic gradients are generally about 0.01 ft/ft in the vicinity of the mound and 0.004 ft/ft away from the mound.
- Pumping tests have not been performed at Site ST027B. However, using an average hydraulic conductivity of 10 feet/day (which is reasonable for Site ST027B, based on data from nearby sites), an effective porosity of 20 percent (typical for the fine-grained sediments encountered at the site), and a horizontal gradient of 0.007 ft/ft, the advective groundwater velocity would be approximately 0.35 foot per day or 125 ft/year.
- There are no long-term trends in groundwater elevations. The average seasonal fluctuation in groundwater elevations at this site is about 3 to 5 ft/year.

Groundwater elevation contours are shown on Figure 3.6-2.

3.6.4 Groundwater Contamination

TCE is the primary groundwater contaminant at Site ST027B. The current distribution of TCE is shown on Figure 3.6-3. The vertical distribution of TCE contamination is shown on Figures 3.6-4 and 3.6-5.

The maximum TCE concentration detected at the site is 474 µg/L during 4Q09 (CH2M HILL, 2011b). Other chlorinated VOCs detected at the site include 1,1-DCE; cis-1,2-DCE; trans-1,2-DCE; TCE; and vinyl chloride. Of these, only TCE; cis-1,2-DCE; and vinyl chloride were detected at concentrations exceeding IRGs in 2Q10. VOCs were detected at concentrations above the IRGs at wells MW791x27, MW792x27, MW794x27, and MW2009x27. TCE detected in monitoring well MW792x27 beyond the eastern edge of the site represents the distal part of the Site SS016 TCE plume and is not related to the ST027B TCE plume.

3.6.5 Status of Groundwater Interim Remedial Action

Previously unknown CERCLA groundwater contamination was discovered at the site after the NEWIOU Groundwater IROD was finalized. Therefore, Site ST027B is not included in the IROD as an ERP site, and no groundwater IRA was implemented. However, the site was previously managed under the Travis AFB POCO program.

Following the subdivision of Site ST027 into the subareas ST027A (POCO) and ST027B (ERP), two (2) new ST027B monitoring wells were installed in May 2009 (MW2009x27 and MW2010x27), and one (1) new monitoring well was installed in October 2009 (MW2048x27) to further characterize the chlorinated VOC plume. These wells were incorporated into the GSAP in 2009-2010. Site ST027B continues under a program of MNA assessment as an ERP site. Site ST027B is unique because it was historically managed entirely under the POCO Sites Program. Under this program, Human Health Risk Assessments (HHRAs) and Ecological Risk Assessments (ERAs) were not required. Therefore, an HHRA and ERA were not conducted for Site ST027 as they were for the other ERP groundwater sites discussed in this FFS.

With the discovery of CERCLA contaminants exceeding IRG concentrations within a portion of the site in 2007–2008 and the subsequent subdivision of Site ST027 into Sites ST027A (POCO) and Site ST027B (CERCLA/ERP), both an HHRA and ERA are now needed for Site ST027B. These risk assessments are provided in two (2) separate reports.

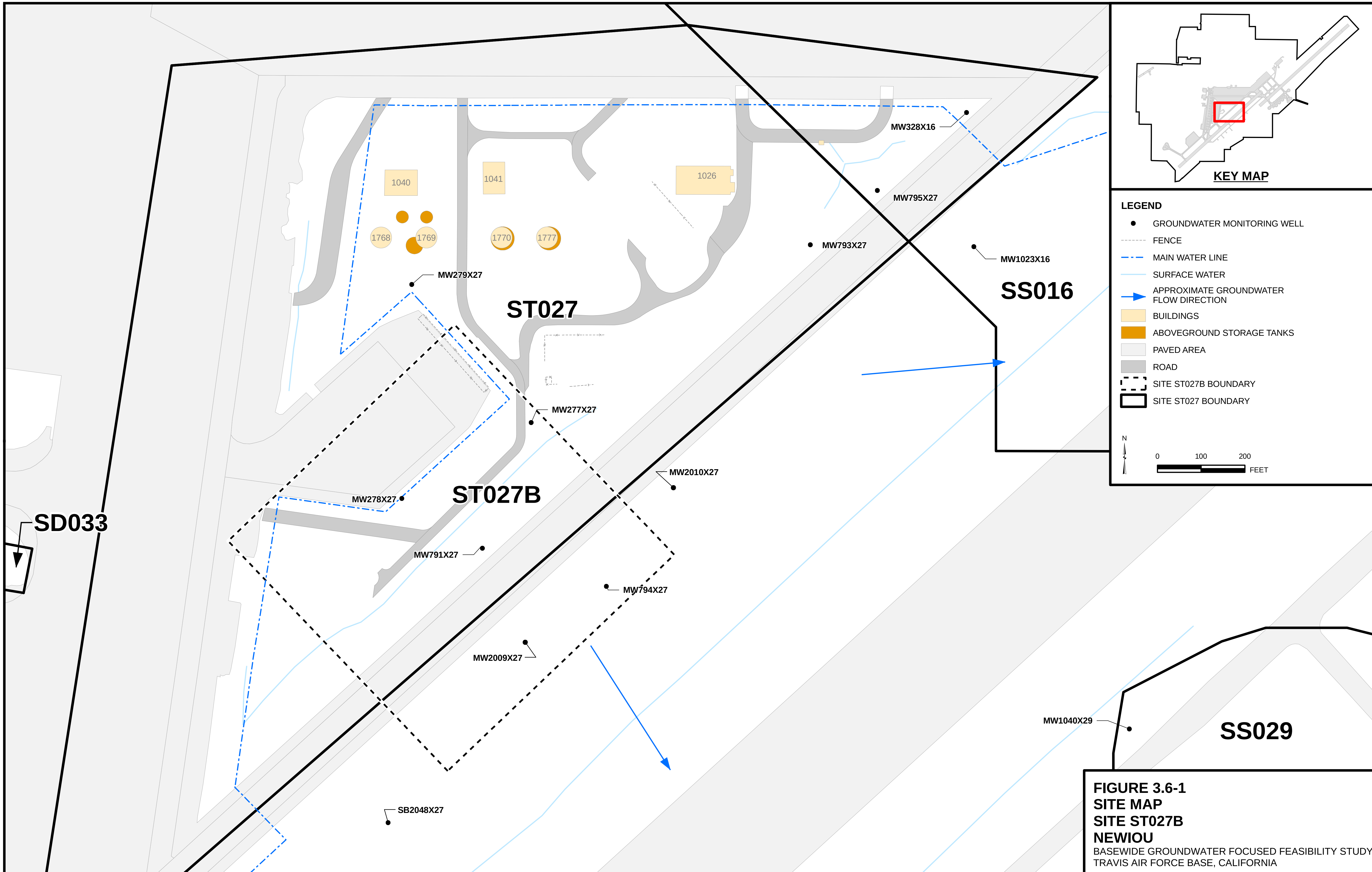


FIGURE 3.6-1
SITE MAP
SITE ST027B
NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_6-1_ST027B.MXD MCLAY1 1/21/2011 11:33:35

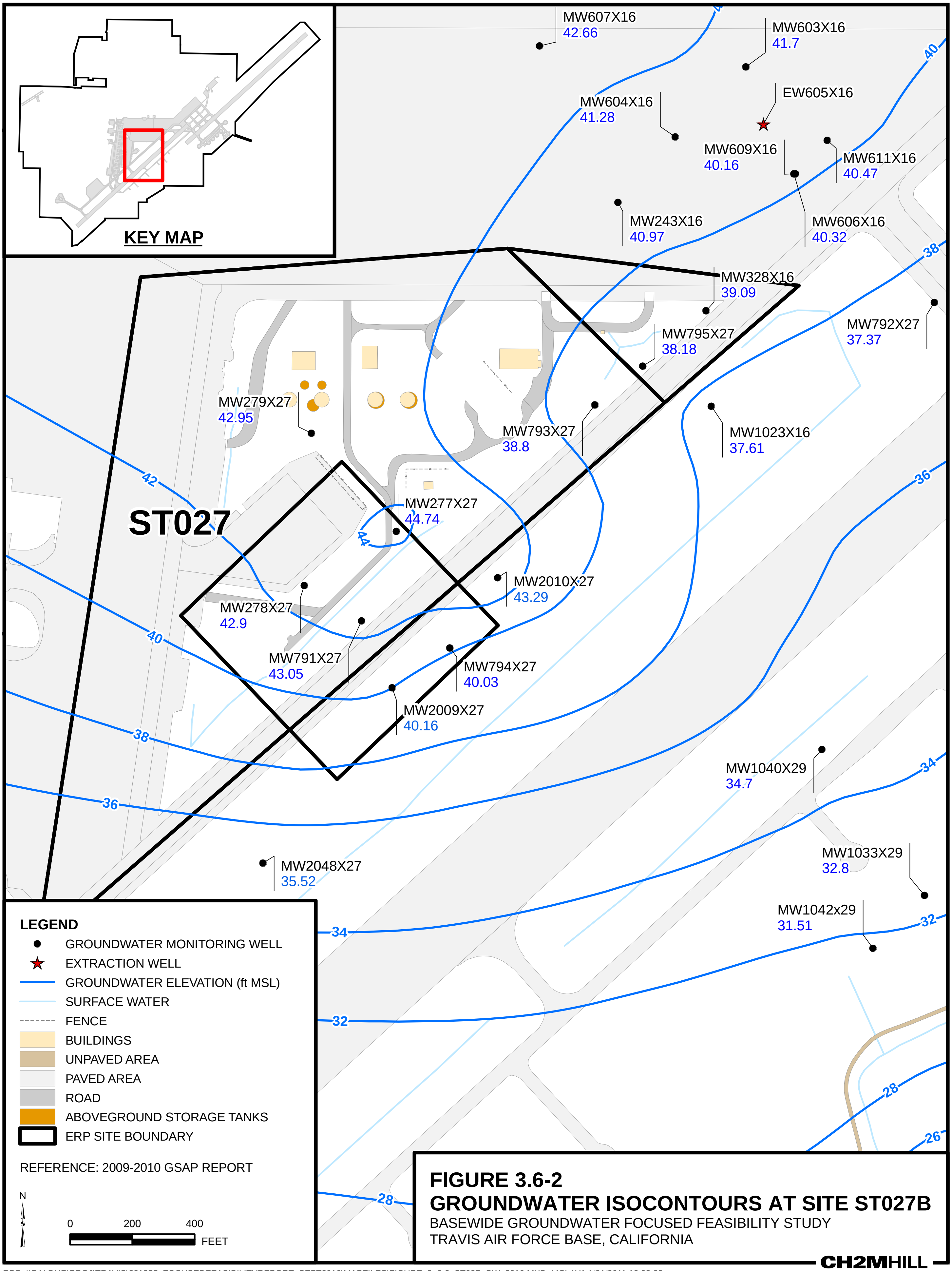


FIGURE 3.6-2
GROUNDWATER ISOCONTOURS AT SITE ST027B
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIGURE_3_6-2_ST027_GW_2010.MXD MCLAY1 1/21/2011 12:03:03

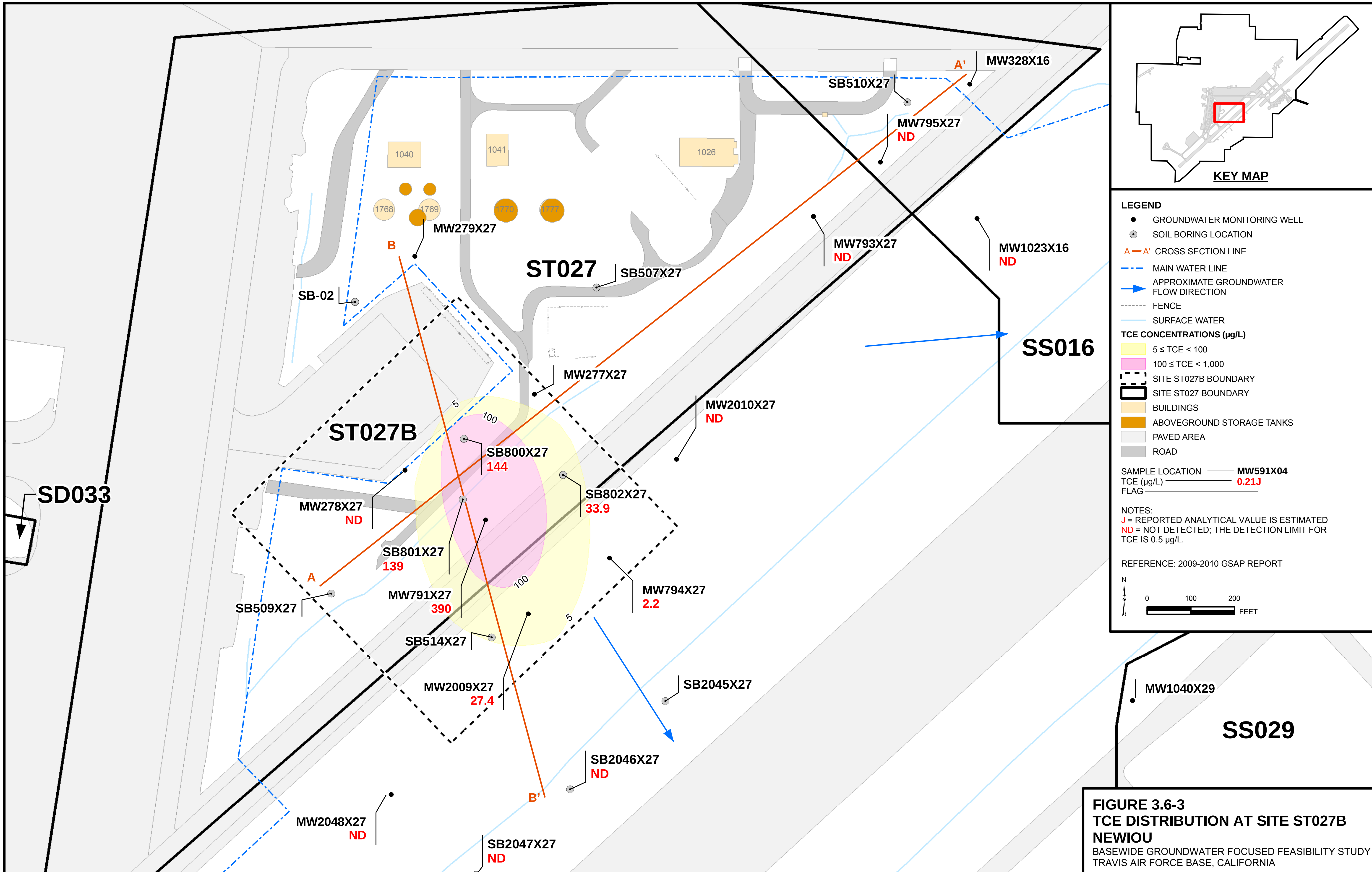
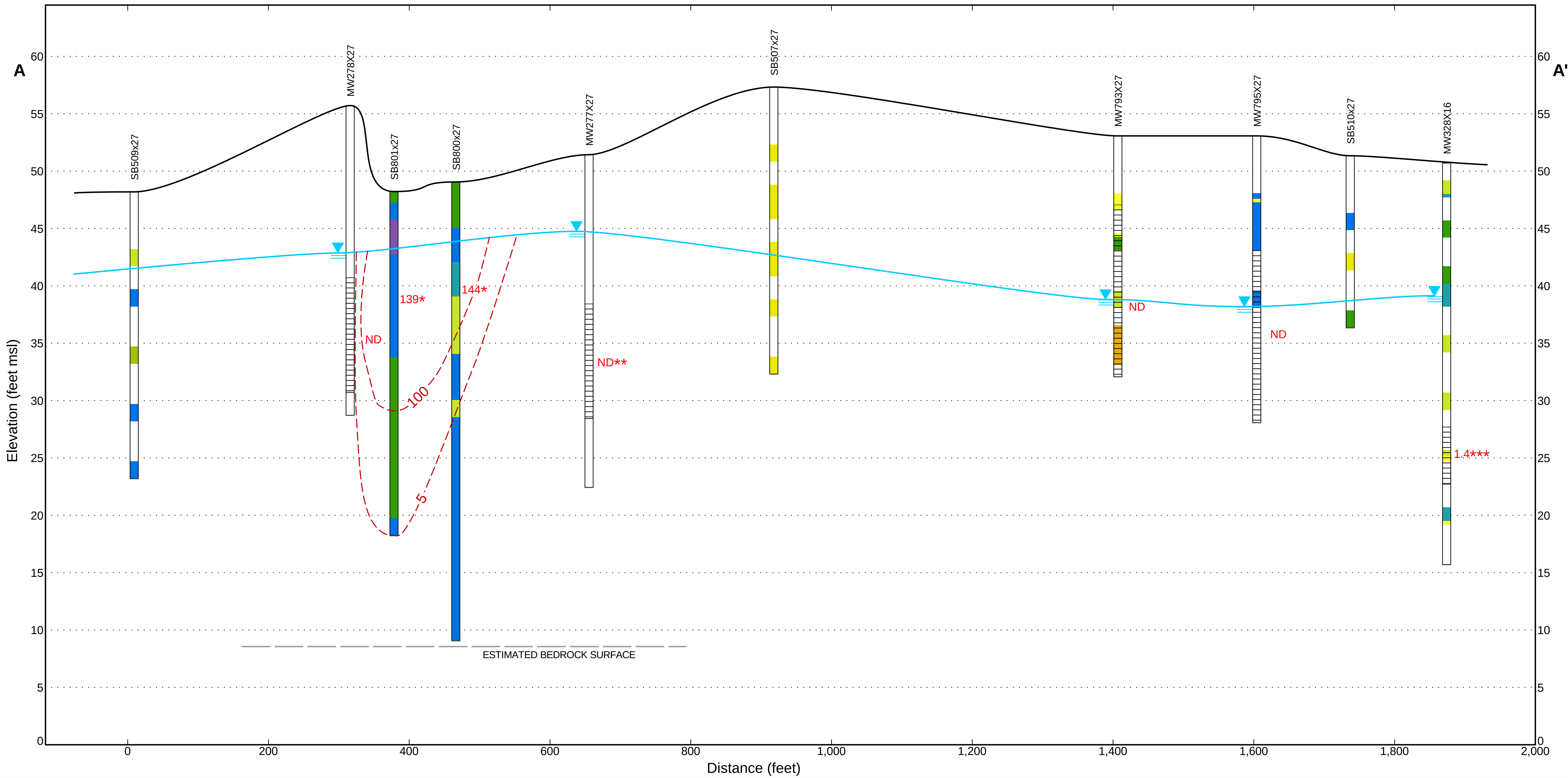


FIGURE 3.6-3
TCE DISTRIBUTION AT SITE ST027B
NEWIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

\\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\FIG3_6-3_TCE_ST027B.MXD MSCHROCK 4/14/2011 02:54:44



SCREEN INTERVAL

APPROXIMATE SECOND QUARTER 2010 GROUNDWATER ELEVATION (ft MSL)

6.7 TCE CONCENTRATION (µg/L) DETECTED IN 2010

— 5 — APPROXIMATE TCE ISOCONCENTRATION CONTOUR (µg/L) BASED ON MAX 2010 DETECTION

* HYDROPUNCH SAMPLES COLLECTED IN 2009

** SAMPLE COLLECTED SECOND QUARTER 2008

*** SAMPLE COLLECTED SECOND QUARTER 2009

SCALE EXAGGERATION - 16:1 (H:V)

ND = NOT DETECTED; THE DETECTION LIMIT FOR TCE IS 0.5 µg/L

SOIL AND LITHOLOGY

NO SAMPLE/NO RECOVERY	WELL GRADED SAND (SW)	FAT CLAY (CH)
FILL/ASPHALT	SILTY SAND (SM)	SILTSTONE
TOPSOIL/ORGANIC SOIL	POORLY GRADED SAND (SP)	SANDSTONE
WELL GRADED GRAVEL (GW)	CLAYEY SAND (SC)	SHALE
POORLY GRADED GRAVEL (GP)	SILT (ML)	ALLUVIUM (NO DATA)
SILTY GRAVEL (GM)	ELASTIC SILT (MH)	
CLAYEY GRAVEL (GC)	LEAN CLAY (CL)	

FIGURE 3.6-4
SITE ST027B CROSS SECTION A–A'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

\\YOSEMITE\PROJ\TRAVISAIRFORCEBASE\COMMONFILES\GINT FILES\FFS\GPJ\TRAVIS_2010_SAMPLING_EVENT.GPJ;
ES082009007SAC Figure_3.6-4.ai 04.11.2011 tdaus

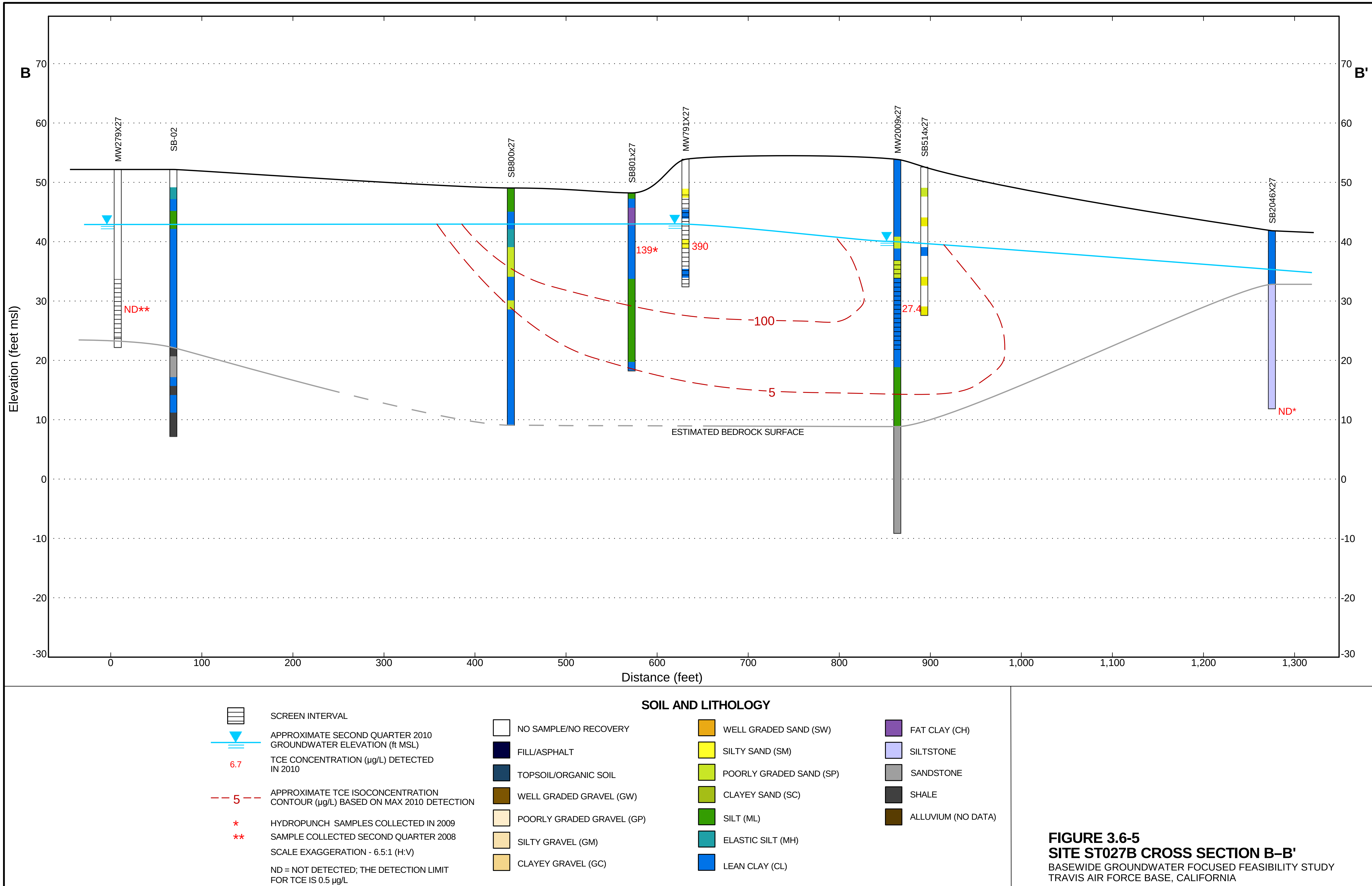


FIGURE 3.6-5
SITE ST027B CROSS SECTION B–B'
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

\\YOSEMITE\PROJ\TRAVISAIRFORCEBASE\COMMONFILES\GINT FILES\FFS\GPJ\TRAVIS_2010_SAMPLING_EVENT.GPJ;
ES082009007SAC Figure_3.6-5.ai 04.11.2011 tdaus

SECTION 4

Approach to the Focused Feasibility Study

This section describes the approach to developing the evaluations conducted in this FFS.

Previous sections of the FFS have described implementation of the current interim groundwater remedies at the Travis AFB ERP sites. This section describes the approach taken in the FFS to transition out of the period of interim remediation by identifying and evaluating potential final remedial alternatives for each site.

Final remedial actions will be formally selected in the pending Basewide Groundwater ROD.

4.1 Approach to Development of the FFS

The overall objective of this FFS is to develop and evaluate appropriate remedial alternatives for each of the contaminated groundwater sites at Travis AFB. To achieve this objective, the FFS includes evaluations that are typical in conducting a CERCLA FS (EPA, 1988). These evaluations are provided in the subsequent sections of this FFS and are summarized in the following list:

- **Section 5 – Preliminary Cleanup Goals**
  - Describes remedial action objectives
  - Identifies ARARs
  - Lists the numerical PCGs for groundwater
- **Section 6 – Identification and Screening of Technologies**
  - Identifies General Response Actions (GRAs), technologies, and technology process options to achieve the remedial action objectives
  - Screens the groundwater technologies and process options against the criteria of effectiveness, technical implementability, and relative cost
  - Identifies representative process options for the various technologies
- **Section 7 – Assembly and Screening of Alternatives**
  - Assembles potential remedial alternatives from representative technology process options
  - Screens the assembled alternatives against the criteria of effectiveness, implementability, and cost

- **Section 8 – Detailed Analysis of Alternatives**
  - Conducts detailed evaluations of the potential remedial alternatives against seven (7) CERCLA FS evaluation criteria:
    - 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

    The additional CERCLA criteria of State Acceptance and Community Acceptance are evaluated in the Proposed Plan and ROD stages.
- **Section 9 – Comparative Analysis of Alternatives**
  - Performs comparative analyses of the potential remedial alternatives against the seven (7) evaluation criteria

4.2 Focusing Criteria

In addition to the standard CERCLA FS evaluations, this *focused* FS will use "focusing criteria" to assist in the identification and screening of appropriate remedial technologies and support the subsequent assembly and screening of alternatives. These focusing criteria include considerations of the following factors:

- Past completion of the CERCLA process at Travis AFB
- Existing groundwater IRA performance
- Ongoing IRA optimization actions, studies, and demonstration projects
- Preference for sustainable remediation technologies

Further discussion of these focusing criteria and considerations is provided in the following subsections.

4.2.1 Past and Future Completion of the CERCLA Process

Travis AFB has successfully followed the CERCLA process to implement IRAs at each of the ERP sites with groundwater contamination. In the majority of cases, these interim actions have operated successfully during a period of interim remediation since the late 1990s to early 2000s (CH2M HILL, 2003a, 2008a). Further discussion of the IRAs is provided in Sections 2 and 3.

At Site ST027, groundwater contamination has historically been managed as part of the POCO program because petroleum fuel hydrocarbons were believed to be the only contaminants present. However, an investigation conducted in 2007 resulted in the discovery of TCE and several other chlorinated VOCs in the southwestern portion of the site. The site was subsequently subdivided as Site ST027A (fuels contamination only) and Site ST027B (CERCLA contamination). Site ST027A continues to be managed under the POCO program. Site ST027B is included in this FFS as a site managed under the ERP.

The following list provides summary descriptions of the how the six (6)-step CERCLA process was followed to implement the IRAs and how it will be followed to transition from the current IRAs to final remedial actions:

- **Preliminary Assessment/Site Inspection**
  - Already completed. Between approximately 1983 and early 1994, early IRP investigations, data gathering, and work planning efforts were conducted to preliminarily assess the nature of environmental contamination at sites within each of the OUs at Travis AFB. Further PA/SI is not required.
- **Remedial Investigation**
  - Operable Unit RIs – Formal OU-specific RIs have already been completed (Radian, 1996b [WIOU]; Radian, 1995 [NOU]; Weston, 1995 [EIOU]; CH2M HILL, 1997 [WABOU]).
  - Data Gaps Investigations – During 2009-2011, data gaps investigations have, or will be, conducted to reduce uncertainties in the current distribution of contamination, support optimization of the existing groundwater IRAs, and support the development of final groundwater remedial actions.
- **Feasibility Study**
  - Operable Unit FSs – Formal OU-specific FSs have already been completed to develop and evaluate interim remedial alternatives for the ERP sites within each OU (Radian, 1996a [NEWIOU]; CH2M HILL, 1998a [WABOU]).
  - Basewide Focused Feasibility Study – The purpose of this FFS is to supplement the FSs by developing and evaluating appropriate final remedial alternatives to be implemented at all Travis AFB ERP sites after the period of interim remediation is concluded.
- **Remedy Selection**
  - Interim Remedy Selection – Formal OU-specific IRODs have already been completed and interim remedial alternatives selected for the ERP sites within each OU (Travis AFB, 1998 [NEWIOU]; Travis AFB, 1999 [WABOU]).
  - Final Remedy Selection – A final groundwater remedial action for all Travis AFB ERP sites will be proposed and submitted for public review and comment in a pending Basewide Groundwater Proposed Plan. Following a period of public review, the final remedial actions will be formally selected in the Basewide Groundwater ROD.

    To the extent practical and appropriate, the components of the existing IRAs will be incorporated into the development of final remedial alternatives. Actions taken to optimize the current interim remedies, successful technology demonstration projects, and sustainable interim remedy components will also be incorporated into remedial alternative development where appropriate.

- **Remedial Design/Remedial Action**
  - Interim RD/RA – IRAs have already been designed and implemented.
  - Final RD/RA – After finalization of the Basewide Groundwater ROD, the final groundwater remedial actions will be designed and implemented.
- **Performance Monitoring/Five-year Reviews**
  - Basewide performance monitoring of the current IRAs are conducted under the GSAP. Performance monitoring of the final remedial actions will also be conducted and reported under the GSAP. Groundwater treatment plant O&M activities will continue to be regularly reported to the regulatory agencies in monthly data sheets and in annual O&M reports.
  - Two (2) five-year reviews of the current IRAs have already been completed (CH2M HILL, 2003a, 2008a). The next five-year review for Travis AFB is scheduled for 2013.

4.2.2 Existing Groundwater IRA Performance

One of the "focusing criteria" is the performance of the existing groundwater IRAs at Travis AFB. The ERP at Travis AFB is mature and has been successfully remediating groundwater contamination since the late-1990s. A considerable amount of practical knowledge has been gained from operating the current groundwater IRAs over the last decade. The performance of the IRAs has been documented in two (2) five-year reviews (CH2M HILL, 2003a, 2008a) and in the NAAR (CH2M HILL, 2010a). The results of routine groundwater monitoring are provided in annual GSAP reports. Groundwater treatment plant O&M activities are regularly reported in monthly data sheets and in annual O&M reports.

Additional descriptions of the site-specific IRAs are provided in Sections 2 and 3.

4.2.2.1 Five-year Reviews

Two (2) five-year reviews concluded that the IRAs are largely achieving the IRA objectives specified in the NEWIOU and WABOU groundwater IRODs. However, the second five-year review also found that optimization of the IRA was needed at some sites to improve remedial performance and effectiveness beyond the IRA objectives. Therefore, during 2008-2010, the Air Force implemented optimization activities at Site SS015, at the OSA within Site SS016, Site SS030, Site SD036, Site SD037, and Site DP039. Optimization of the IRA at Site LF007C will take place in 2011.

4.2.2.2 MNA Assessments

Following almost a decade of data collection after implementation of the groundwater IRAs, assessments of MNA performance were conducted for the sites where MNA was the IRA, or part of the IRA. These assessments are provided in the NAAR (CH2M HILL, 2010a).
The evaluations documented in the NAAR found that the data are sufficient to conclude that MNA can be an effective remedy, or is an important part of the remedy, at Sites FT004, LF006, LF007B, LF007D, SS015, SD031, SD033, SD037, and DP039.

4.2.3 Ongoing IRA Optimizations, Studies, and Demonstration Projects

Optimization of the current groundwater IRAs has, or will be, taken at several sites during 2009 through 2011 to improve their performance. A bioreactor demonstration project is also ongoing at Site DP039. These optimization activities and demonstration projects include the following:

- **Site LF007C –** Modified the existing solar-powered GET system to better address off-base groundwater contamination. An expanded GET system may be required to more effectively achieve the off-base remediation objective. Additional investigation is planned during 2011 to evaluate the scope of potential optimization measures.
- **Site SS015 –** Conducted supplemental injections of EVO to more aggressively remediate the source area plume and enhance natural attenuation processes in the remainder of the plume. Performance monitoring data obtained during the MNA assessment period indicated that MNA was probably not capable of achieving the IRA objective. Contaminant concentrations were increasing in some of the site monitoring wells. Therefore, the Air Force conducted an optimization of the IRA as described in Section 3.4.2.8 (EVO injection into the plume source area and an expansion of the performance monitoring well network).
- **Site SS016 –** A combination of optimization actions within the OSA source area to improve the overall effectiveness of the IRA:
  - Discontinued inefficient and energy-intensive 2-Phase® extraction and ThOx soil vapor treatment. Long-term operation of this system had removed contaminant mass, but concentrations were still the highest encountered at Travis AFB. The system had limited effectiveness at reducing plume concentrations and had relatively high O&M costs.
  - Converted inefficient and energy-intensive UV/Ox groundwater treatment process at the CGWTP to LGAC. Evaluations of influent concentrations indicated that contaminant concentration had decreased to levels that warranted changing the treatment process.
  - Construction of an in situ bioreactor with solar-powered groundwater pumps. A part of the bioreactor construction required the excavation and removal of a large quantity of solvent-contaminated soil. Operation of the bioreactor provides supplemental treatment of source area solvent contamination using a sustainable remediation approach.
- **Site SS030 –** Modified operation of the existing GET system to better address migration of off-base groundwater contamination. Included conversion of SBBGWTP from air stripper treatment to the more technically appropriate and cost-effective LGAC technology, given the reduced influent VOC concentrations.
- **Sites SD036 and SD037 –** Injected EVO to more aggressively remediate the source area plumes and enhance attenuation processes in the remainder of the plumes. Performance monitoring data obtained during the period of interim remediation indicated that interim objectives at both sites were being achieved. However, the Air Force optimized the two (2) IRAs by injecting EVO into their plume source areas and expanding their performance monitoring well networks.

- **Site DP039 –** Includes a demonstration project and optimization actions:
  - Discontinued DPE, excavated highly contaminated source area soil, and conducted a bioreactor demonstration project. The DPE system had removed contaminant mass during its interim operation period, but solvent concentrations were still relatively high and had reached asymptotic levels. The system also had relatively high O&M costs. A part of the bioreactor construction required the excavation and removal of a large quantity of solvent-contaminated soil. Operation of the bioreactor provides supplemental treatment of source area solvent contamination using a sustainable remediation approach.
  - Established a phytoremediation study area in the center of the downgradient plume. A study of the capacity of planted trees to remediate groundwater began in 1998. A 2010 evaluation concluded that the trees can significantly contribute toward remediation of the contaminated groundwater.
  - Optimized the existing IRA by injecting EVO in a wall configuration to intercept and treat the leading edge of the 500-part-per-billion portion of the solvent plume. Performance monitoring data obtained during the period of interim remediation indicated that MNA was probably not capable of achieving the IRA objectives beyond the phytoremediation study area. Contaminant concentrations were increasing in some of the site monitoring wells. Therefore, the Air Force built an EVO biobarrier and expanded the performance monitoring well network.

4.2.4 Sustainability

Sustainability in remedial action systems is emerging as a significant consideration for evaluating environmental cleanup methods. Using sustainability as a factor in developing the final groundwater remedial alternatives at Travis AFB now warrants much more consideration than it did at the time of the NEWIOU FS and WABOU FS (Radian, 1996a; CH2M HILL, 1998a). Sustainable groundwater technologies, once considered innovative, have matured since the selection of Travis AFB IRAs. The uncertainty that was once associated with these types of remediation technologies is now much reduced.

Policy statements have been issued by Presidential Executive Order, the Department of Defense (DOD), and EPA stating that environmental cleanup programs should fully consider "green" practices to achieve cleanup objectives. These statements of policy are included in the following references:

- *Federal Leadership in Environmental, Energy, and Economic Performance* (Executive Order 13514, 2009)
- *Consideration of Green and Sustainable Remediation Practices in the Defense Environmental Restoration Program* (DOD, 2009)
- *Principles for Greener Cleanups* (EPA, 2009)
- *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites* (EPA, 2008)
- *Superfund Green Remediation Strategy* (EPA, 2010)

The fundamental goal of a "green" remedial action is to ensure protectiveness of human health and the environment while decreasing the environmental footprint of the cleanup action itself. In the context of this FFS, "green" is used interchangeably with the terms "green cleanup," "greener cleanup," and "green and sustainable remediation," when referring to groundwater remedial alternatives that reduce energy demand, reduce greenhouse gas emissions, conserve water and other resources, and minimize the environmental impact of the final remedial action. Each of the "green" remedial alternative components developed in this FFS satisfy the following basic requirements:

- Protect human health and the environment
- Comply with all laws and regulations
- Consider the anticipated land use of the site and avoid potential adverse impacts to the military mission of Travis AFB

The groundwater remedial alternatives described in the subsequent sections of this FFS considered sustainable technologies in their development.

4.3 Approach to Technology Identification and Screening

The focusing criteria described in Section 4.2 and the site/contaminant conditions described in Section 3 form the basis for identifying appropriate groundwater remediation technologies in this FFS. A typical FS will usually review the universe of possible remedial action technologies. However, most of the possible technologies have already been screened in the NEWIOU FS (Radian, 1996a) and WABOU FS (CH2M HILL, 1998a), and this approach does not take into account the experience gained from the IRAs at Travis AFB. The FFS took a second look at technologies that were considered to be innovative but unproven at the time of the initial technology screenings, but have become more accepted as a result of advances and demonstrations at other sites.

Potential remedial technologies were screened against the primary CERCLA FS criteria of effectiveness, technical implementability, and relative cost.

4.4 Approach to Alternative Development and Screening

The alternatives in this FFS were developed and screened following CERCLA guidance (EPA, 1988) and in consideration of the focusing criteria (i.e., existing groundwater IRA performance, current IRA optimization actions, the performance of demonstration projects and treatability studies, and a preference for use of sustainable technologies). The current site and contaminant conditions were also important in the alternative development process. If appropriate, components of the existing IRAs were incorporated into the development of remedial alternatives.

4.5 Approach to Detailed Alternatives Analysis

In accordance with CERCLA guidance (EPA, 1988), the first seven (7) of nine (9) evaluation criteria were considered in the detailed analysis of alternatives provided in Section 8. All nine (9) evaluation criteria are as follows:

1. Overall Protection of Human Health and the Environment
2. Compliance with ARARs
3. Long-term Effectiveness and Permanence
4. Reduction of Toxicity, Mobility, or Volume through Treatment
5. Short-term Effectiveness
6. Implementability
7. Cost
8. State Acceptance
9. Community Acceptance

The final two (2) criteria, State Acceptance and Community Acceptance, will be evaluated following receipt of comments on the Proposed Plan and ROD. These two (2) criteria will not be further discussed in this FFS report.

The following subsections provide summary descriptions of the first seven (7) evaluation criteria.

4.5.1 Criterion 1 – Overall Protection of Human Health and the Environment

This evaluation criterion assesses how each alternative provides and maintains adequate protection of human health and the environment. Alternatives are assessed to determine whether they can adequately protect human health and the environment from unacceptable risks posed by contaminants present at the site, in both the short and long term. This criterion is also used to evaluate how risks would be eliminated, reduced, or controlled through treatment, engineering, institutional controls, or other remedial activities.

4.5.2 Criterion 2 – Compliance with ARARs

This evaluation criterion is used to determine if each alternative would comply with federal and state ARARs, or if there is sufficient justification to invoke a specific ARAR. Other information, such as advisories, criteria, or guidance, is considered where appropriate during the ARARs analysis. Potential ARARs for the remedial alternatives are divided into action-specific, location-specific, and chemical-specific requirements and are described in Section 5.

4.5.3 Criterion 3 – Long-term Effectiveness and Permanence

This evaluation criterion addresses the long-term effectiveness and permanence of maintaining the protection of human health and the environment after implementing the remedial alternative. The primary components of this criterion are the magnitude of residual risk remaining at the site after remedial objectives have been met and the extent and effectiveness of controls that may be required to manage the risk posed by residual and/or untreated wastes. The components addressed for each alternative are described in more detail in the following subsections.

4.5.3.1 Magnitude of Residual Risk

The magnitude of residual risk at the end of remedial activities is measured by numerical standards such as cancer risk levels, or the volume or concentration of contaminants remaining at the site. The characteristics of the residuals remaining onsite are also evaluated, considering their volume, toxicity, mobility, and propensity to bioaccumulate.

4.5.3.2 Adequacy and Reliability of Controls

The adequacy and reliability of controls that are used to either manage residual or untreated materials that remain at the site after attaining preliminary remedial goals are evaluated. This criterion includes an assessment of containment systems and institutional controls to evaluate the degree of confidence that they adequately handle potential problems and provide sufficient protection. The criterion also addresses long-term reliability, the need for long-term management and monitoring of the site, and the potential need to replace technical components of the alternative.

4.5.4 Criterion 4 – Reduction of Toxicity, Mobility, or Volume through Treatment

This evaluation criterion addresses the anticipated performance of the alternative's treatment technologies in permanently and significantly reducing the toxicity, mobility, and/or volume of hazardous materials at the site through treatment. The NCP prefers remedial actions where treatment is used to reduce the principal threats at a site through destruction of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of the total volume of contaminated media. The evaluation of each alternative for reduction of toxicity, mobility, or volume of contaminants present at a given site through treatment is provided in Table 4-1.

4.5.5 Criterion 5 – Short-term Effectiveness

This evaluation criterion considers the effect of each remedial alternative on the protection of human health and the environment during the construction and implementation process. The short-term effectiveness evaluation only addresses protection prior to meeting the RAOs. The factors evaluated during the analysis of each alternative include protection of the community during the remedial action, protection of workers during the remedial action, environmental impacts, and the time until remedial action objectives are achieved.

Although not stipulated in CERCLA FS guidance (EPA, 1988), evaluation of the sustainability aspects of an alternative are included under this criterion.

4.5.6 Criterion 6 – Implementability

This criterion evaluates the technical feasibility and administrative feasibility (i.e., the ease or difficulty) of implementing each alternative and the availability of required services and materials during its implementation. The factors evaluated during the analysis of each alternative include the following:

- **Technical Feasibility –** The ability to construct and operate the technology, the reliability of the technology, and the ease of undertaking additional remedial action
- **Administrative Feasibility –** Coordination with other agencies

- **Availability of Services and Materials –** Availability of treatment, storage capacity, and disposal services; the availability of necessary equipment and specialists; and the availability of prospective technologies.

4.5.7 Criterion 7 – Cost

This criterion evaluates the direct cost and O&M cost of each alternative. The assessment against this criterion is based on the estimated present worth of these costs for each alternative. Present worth is used to estimate expenditures such as construction and O&M that occur over different lengths of time (i.e., the site-specific time to achieve cleanup goals). This allows costs for remedial alternatives to be compared by discounting all costs to the year that the alternative is implemented.

The present worth of a project represents the amount of money which, if invested in the initial year of the remedy and disbursed as needed, would be sufficient to cover all costs associated with the remedial action. As stated in the FS guidance (EPA, 1988), these estimated costs are expected to provide an accuracy of plus 50 percent to minus 30 percent.

4.6 Approach to the Comparative Analysis of Alternatives

Comparative analyses were conducted between the remedial alternative developed for each site and the current interim remedy. The comparative analyses were conducted using the same seven (7) evaluation criteria that were used for the detailed analyses.

TABLE 4-1
Reduction of Toxicity, Mobility, or Volume through Treatment Criterion
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Analysis Factor	Considerations
Treatment process and remedy	Does the treatment process employed address the principal threats? Are there special requirements for the treatment process?
Amount of hazardous material destroyed or treated	What portion of contaminated material is destroyed? What portion of the contaminant is treated?
Reduction in toxicity, mobility, or volume	To what extent is the total mass of toxic contaminants reduced? To what extent is the mobility of toxic contaminants reduced? To what extent is the volume of toxic contaminants reduced?
Irreversibility of treatment	To what extent are the effects of treatment irreversible?
Type and quantity of treatment residual	What residuals remain? What are their quantities and characteristics? What risk do treatment residuals pose?
Statutory preference for treatment as a principal element	Are principal threats within the scope of the action? Is treatment used to reduce inherent hazards posed by principal threats at the site?

SECTION 5

Preliminary Cleanup Goals

This section describes RAOs, provides an analysis of ARARs, and describes the derivation of PCGs for contaminated groundwater sites at Travis AFB.

The general and specific RAOs developed in this section are used in concert with analyses of ARARs to establish the numerical PCGs. These PCGs serve as the performance criteria for remedial alternative designs and provide a benchmark to measure the protectiveness of remedial action alternatives. The final cleanup levels to be achieved through remedial action will be defined in the pending Basewide Groundwater ROD.

5.1 Remedial Action Objectives

RAOs are narrative statements that define the extent to which sites require cleanup to meet the underlying objectives of protecting human health and the environment. The NCP specifies that RAOs are to be developed to address the following:

- **COCs –** The primary COCs are chlorinated VOCs and organochlorine pesticides. A listing of all the groundwater COCs at Travis AFB is provided in Table 5-4.
- **Media of concern –** The FFS addresses the groundwater medium.
- **Potential exposure pathways –** Travis AFB is an active military reservation, adjacent to agricultural lands. Potential dermal, ingestion, and inhalation exposure pathways exist for the following receptors: on-base industrial worker, on-base resident, and off-base agricultural worker. There are no ecological receptors of contaminated groundwater at Travis AFB.
- **PCGs –** PCGs for groundwater at Travis AFB are listed in Table 5-4.

5.1.1 Remedial Action Objectives for Protection of Human Health

- Prevent human ingestion and direct dermal contact of groundwater containing contaminant concentrations above the State and federal MCLs. The more stringent of a State or federal chemical-specific MCL is the controlling cleanup standard.
- Prevent inhalation of chlorinated VOCs volatilizing from groundwater to indoor air. Vapor intrusion exposure is considered significant when VOC concentrations exceed risk-based concentrations, cumulative risks are greater than EPA's risk management range of 10^{-6} to 10^{-4} or hazard indices exceed the threshold of 1.

5.1.2 Remedial Action Objectives for Environmental Protection

- Restore the groundwater aquifer to concentrations not exceeding the chemical-specific State or federal MCLs. The more stringent State or federal MCL for each contaminant is the controlling cleanup standard.

- Maintain existing water quality and prevent migration of groundwater contamination above the more stringent State or federal MCLs beyond existing boundaries.
- Ensure existing contaminant conditions do not change so as to threaten sensitive environmental receptors such as State or federal protected wildlife populations and vegetation communities.

5.2 Analysis of ARARs

The review and application of ARARs in the development of remedial actions are required to ensure that compliance with applicable laws and regulations is achieved by the overall remedial action. The ARARs are a key consideration in the analysis of the remedial action alternatives developed in this FFS, because the alternatives must comply with ARARs to be further considered. Also, compliance with ARARs often has a significant effect on the cost and implementability of a particular alternative during both implementation and LTO.

5.2.1 General Discussion of ARARs

The following subsections provide brief descriptions of applicable requirements, relevant and appropriate requirements, substantive requirements, administrative requirements, and possible waivers to these requirements.

5.2.1.1 Applicable Requirements

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, remedial action, location, or other circumstance found at a CERCLA site. "Promulgated" means the standard is of general applicability and is legally enforceable (40 CFR Section 300.400(g)(4)). A requirement is applicable if the jurisdictional prerequisites of the environmental standard show a direct correspondence when objectively compared with the conditions at the 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 or relevant and appropriate.

5.2.1.2 Relevant and Appropriate Requirements

If a requirement is not applicable, it may be relevant and appropriate. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not applicable, address problems or situations sufficiently similar to the circumstances of the proposed response action and are well-suited to the conditions of the site. The criteria for determining relevance and appropriateness are listed in Title 40, CFR, Section 300.400(g)(2). 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 or relevant and appropriate.

5.2.1.3 To Be Considered

In addition to legally binding laws and regulations, many Federal and State environmental and public health programs also develop criteria, advisories, guidance, and proposed standards that are not legally binding, but that may provide useful information or recommended procedures. These materials, commonly referred to as "To Be Considered" (TBC), are not potential ARARs, but are evaluated for each Superfund site in developing potential performance standards for the CERCLA remedy as deemed appropriate by the lead agency. Chemical-specific TBC values such as health advisories and reference doses are often used in the absence of ARARs or where ARARs are not sufficiently protective to establish cleanup levels. Other TBC materials such as guidance and policy documents developed to implement regulations may be considered and used as appropriate where necessary to ensure protectiveness. If no ARARs address a particular situation, or if existing ARARs do not ensure protectiveness, TBC advisories, criteria, or guidelines can be used to set cleanup levels. Once a TBC is selected in a Record of Decision as a requirement, it becomes a binding performance standard with which the chosen remedy must comply.

5.2.1.4 Substantive Requirements

ARARs are concerned only with substantive, not administrative, requirements of a statute or regulation. The substantive portions of the regulation are those requirements that pertain directly to actions or conditions in the environment. Remedy performance criteria, location restrictions and monitoring requirements are typically considered substantive, as are the substantive requirements of permitting programs (EPA, 1992). Other examples of substantive requirements include quantitative health- or risk-based restrictions upon exposure to types of hazardous substances.

5.2.1.5 Administrative Requirements

Administrative requirements are the mechanisms that facilitate implementation of the substantive requirements. Approval by or consultation with administrative bodies, documentation, reporting, record keeping and financial responsibility requirements are typically considered administrative, not substantive, as are applications for permits and other administrative requirements for permits (EPA, 1992; 1991). Thus, in determining the extent to which onsite CERCLA response actions must comply with environmental laws, a distinction should be made between substantive requirements, which may be ARARs, and administrative requirements, which are not.

Furthermore, the ARARs provision in CERCLA applies to onsite actions. In this context, "onsite" is defined as the areal extent of contamination and areas in proximity to it necessary for the implementation of the remedy. According to CERCLA Section 121(e), a remedial response action that takes place entirely onsite is exempt from administrative portions of ARARs and may proceed without obtaining permits. This permit exemption applies to all administrative requirements, as well as to permits and associated fees. Actions taken offsite must comply with all applicable laws and regulations, including administrative requirements. Thus, actions such as offsite disposal of waste will comply with all laws and regulations applicable to the actions, but the laws and regulations governing offsite activities are not ARARs for the purpose of this FFS.

5.2.1.6 Waivers

CERCLA Section 121 provides that, under certain circumstances, an otherwise applicable or relevant and appropriate requirement may be waived in the ROD. These waivers apply only to the attainment of the ARAR; other statutory requirements, such as the requirement that remedies be protective of human health and the environment, cannot be waived. The waivers provided by CERCLA Section 121(d)(4) are listed below:

1. **Interim Remedy –** The remedial action selected is only part of a total remedial action that will attain such a level or standard of control when completed.
2. **Greater Risk to Human Health or the Environment –** Compliance with the requirement will result in greater risk to human health and the environment than alternative options.
3. **Technical Impracticability –** Compliance with the requirement is technically impracticable from an engineering perspective.
4. **Equivalent Standard of Performance –** The remedial action selected will attain a standard of performance equivalent to that required under the otherwise applicable standard, requirement, criteria, or limitation through use of another method or approach.
5. **Inconsistent Application of State Requirements –** With respect to a state standard, requirement, criterion, or limitation, the state has not consistently applied (or demonstrated the intention to consistently apply) the standard, requirement, criterion, or limitation in similar circumstances at other remedial actions.
6. **Fund Balancing –** The Fund Balancing waiver does not apply to DOD sites.

5.3 Types of ARARs

The Air Force has identified three (3) categories of ARARs for Superfund remedial actions:

- Chemical-specific
- Action-specific
- Location-specific

A description of each category of ARARs is provided in the following subsections.

5.3.1 Chemical-specific ARARs

Chemical-specific ARARs are 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 (1) cleanup level, the most stringent level is identified as an ARAR for this remedial action. Chemical-specific ARARs are presented in Table 5-1. Substantive provisions of the following requirements are identified as the most stringent of the potential federal and state groundwater ARARs for Travis AFB groundwater remedial actions:

- Federal MCLs listed in the Safe Drinking Water Act
- State primary MCLs identified in 22 CCR

The selected remedial alternative will be consistent with the State Water Resources Control Board (SWRCB) Resolution 88-63's classification of all groundwater in the state as a potential source of drinking water (if the water meets certain quality criteria) and the SFBWQCB's designation of the groundwater at Travis AFB as potential drinking water, and comply with state and federal MCLs. However, 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 background 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 remedy selection. However, the Air Force will accept SWRCB Resolution 92-49 as a TBC and will meet the intent of SWRCB Resolution 92-49 by conducting a Technical and Economic Feasibility Analysis (TEFA) in accordance with the resolution's direction: "...in applying any alternative cleanup levels less stringent than background, apply Section 2550.4 of Chapter 15 [of 23 CCR]."

5.3.1.1 Air Force's Position

The Air Force's position is that all remedial actions 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 U.S. Code [USC] Section 9621(a) 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)).

As noted by EPA in preamble guidance to the March 1990 final rule revising the NCP, CERCLA does not require the complete elimination of all risk or of all known or anticipated adverse effects, i.e., remedies under CERCLA are not required to entirely eliminate potential exposures…"Remedies at Superfund sites comply with the statutory mandates when the amount of exposure is reduced so that the risk posed by contaminants is very small, i.e. an acceptable level" (55 Fed. Reg. 8666 at 8716; see also 8752). And, addressing groundwater in particular and any need to clean it up beyond MCLs, EPA also noted that "…MCLs are within EPA's acceptable risk range, and MCLs are protective. MCLs represent the level of water quality that EPA believes is acceptable for over 200 million Americans to consume every day from public drinking water supplies. EPA decided that Superfund cleanup of drinking water should use the same standards as EPA's drinking water program" (55 Fed. Reg. 8750).

There is solid statutory support in CERCLA for EPA's position as it clearly states as an overarching mandate of CERCLA that the lead agency "…shall select appropriate remedial actions determined to be necessary…" and that "[S]uch remedial actions shall be relevant and appropriate under the circumstances presented by the release or threatened release…" (42 USC Section 9621(a) and (d)(1)). It is simply not necessary to achieve the primary mandate of protectiveness in CERCLA to cleanup groundwater beyond MCLs. Further, as the levels deemed safe by law for consumers to drink everyday for a lifetime are MCLs, any cleanup of groundwater whose designated beneficial use is as drinking water is neither relevant nor appropriate under the circumstances under CERCLA.

Accordingly, California nondegradation provisions (to include but not limited to, SWRCB Resolution 92-49 and the San Francisco Bay Basin Plan) based on achieving background or the lowest cleanup level that is technically and economically achievable, are neither risk-based, necessary, applicable, nor appropriate or relevant to returning contaminated groundwater to a drinking water level of service; and, therefore, they are not eligible for consideration as potential ARARs.

Regarding applicability, and without prejudice to the Air Force's position above, the California nondegradation provisions (e.g., Resolutions 68-16 and 92-49) are not applicable as they are directed towards 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 in the case of Resolution 68-16, apply only to current discharges as opposed to historic releases or further migration of such releases; or apply to specific, discrete regulated units that received hazardous waste after July 26, 1982, neither of which apply here.

State nondegradation provisions are not relevant and appropriate requirements because in addition to the discussions above: 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 WABOU and NEWIOU sites would be zero, such background provisions in California nondegradation provisions are similarly not relevant and appropriate; 40 CFR Sections 300.430(e)(2)(i)(C) and 300.400(g)(2)(viii) together require that a potential ARAR for groundwater reasonably relate, that is be relevant and appropriate, to the beneficial use of the groundwater being addressed and as discussed above, California nondegradation provisions requiring cleanup levels be set in effect at zero or the lowest level technically and economically feasible, are not reasonably related to any actual or potential use of the water or risks to users thereof; and the CCR revisions are designed for specific and discrete units that manage hazardous waste, such as landfills, surface impoundments, and other similar transfer, treatment, storage or disposal units; thus they are not reasonably related to the diffuse release sites at Travis AFB.

Regarding California nondegradation TEFA provisions, as they are an inherent part of the California nondegradation provisions and are designed to establish whether cleanup to background or other levels below MCLs are feasible, for the reasons discussed above they are not applicable, relevant and appropriate, or necessary. As such a process is used to establish whether cleanup beyond MCLs is feasible, and such cleanup levels are categorically excluded as an ARAR, they too are similarly excluded.

Based upon all the above, the only provisions of the California regulations that are potential ARARs are those that direct cleanup concentrations or levels not more stringent than federal and state MCLs. To the extent state MCLs are the same as federal, they are not more stringent, and thus not ARARs. If a state MCL is more stringent, then that is an ARAR under CERCLA – see 42 USC Section 9621(d)(2)(A)(ii).

5.3.2 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 are presented in Table 5-2. Location-specific ARARs identified for this FFS are federal requirements in the Endangered Species Act, Clean Water Act, and the Migratory Bird Treaty Act.

5.3.3 Action-specific ARARs

Action-specific ARARs are technology- or activity-based requirements or limitations that apply to particular remedial activities. Action-specific ARARs are presented in Table 5-3.

Selected remedial actions 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. Resolution 68-16 and the Underground Injection Control Program apply to injection or reinjection of the treatment reagent, or any other reagent. Compliance will be achieved by monitoring WABOU and NEWIOU groundwater for complete reaction of the treatment reagents and by reinjecting only in already-degraded portions of the groundwater, at existing high contaminant concentration areas. Compliance with the state beneficial-use designation of all state groundwater as potential drinking water will be achieved by implementing the best economically achievable treatment practice and by establishing attainment of drinking water standards as the cleanup objective.

5.4 Preliminary Cleanup Goals

Cleanup levels to be achieved through remedial action will be defined in the pending Basewide Groundwater ROD. The PCGs presented in this FFS provide the basis for review and input toward establishing the cleanup levels in the ROD.

PCGs are the chemical concentrations that achieve the levels of protection specified by the RAOs. They are identified after RAOs have been developed and potential ARARs have been analyzed. These chemical concentrations are then used to assist in evaluating the effectiveness of remedial action alternatives in complying with ARARs and achieving RAOs. PCGs provide a basis for delineating the extent of groundwater contamination to evaluate and compare remedial action alternatives.

The PCG for the contaminated groundwater sites at Travis AFB is the contaminant-specific MCL. For example, the most commonly detected contaminant in groundwater at Travis AFB ERP sites is TCE. The MCL for TCE is 5 µg/L. Accordingly, the PCG for TCE is also 5 µg/L. Other chemicals found in the groundwater at the various ERP sites and their respective PCG are summarized in Table 5-4. The extent of groundwater contamination exceeding the PCG at each of the ERP sites is shown on the figures provided in Section 3.

TABLE 5-1
Chemical-specific ARARs
Basewide Groundwater Focused Feasibility Study, Travis AFB, California

Item No.	Remedy Components	Requirement	Citation	Federal, or State Requirement	Description	ARAR Determination	Comments
1	Groundwater treatment systems	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 40 CFR 300.430(e)(2)(i)(C)	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 for groundwater plumes.
			22 CCR, Div. 4, Ch. 15, Articles 4, 4.5, and 5.5, Sections 64431 et seq., 64444	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.		
2	Groundwater treatment systems and treatment system effluent discharged to surface water	Policies and Procedures for Investigation and Cleanup and Abatement	SWRCB Resolution No. 92-49. (23 CCR 2900) Water Code Sections 13140, 13240, 13304, 13307	State	State Board Resolution No. 92-49 establishes policies and procedures for the oversight of investigation and cleanup and abatement activities resulting from discharges of waste which affect or threaten water quality. It requires cleanup of all waste discharged and restoration of affected water to background conditions (i.e., the water quality that existed before the discharge). Requires actions for cleanup and abatement to conform to Resolution No. 68-16, (Antidegradation Policy) water quality control plans and policies, and applicable provisions of California Code of Regulations, Title 23, Division 3, Chapter 15 (Discharges of Hazardous Waste to Land) as feasible.	TBC	Insofar as Resolution 92-49 establishes a process for the RWQCB to follow, it is not applicable to the AF. However, the Air Force will accept the Resolution as a TBC.
3	Treatment system effluent discharged to surface water	California Toxics Rule	40 CFR 131.38	Federal	Establishes criteria for priority toxic pollutants in the State of California for inland surface waters and enclosed bays and estuaries that apply to all waters assigned any aquatic life or human health use classifications in a Basin Plan. The criteria apply concurrently with any criteria adopted by the State, except when State regulations contain criteria which are more stringent for a particular parameter and use, or except as provided in specific exceptions	Applicable	These criteria are subject to the State's general rules of applicability in the same way and to the same extent as are other Federally-adopted and State-adopted numeric toxics criteria. They will be reflected in effluent limitations established for discharges of extracted groundwater or from groundwater treatment plants that are enforced through NPDES permits.

TABLE 5-1
Chemical-specific ARARs
Basewide Groundwater Focused Feasibility Study, Travis AFB, California

Item No.	Remedy Components	Requirement	Citation	Federal, or State Requirement	Description	ARAR Determination	Comments
4	Groundwater treatment systems and treatment system effluent discharged to surface water	Water Quality Control Plan, San Francisco Bay Basin (Basin Plan) Ch. 2, Beneficial Uses Ch. 3, Water Quality Objectives	23 CCR 3912 Water Code Sections 13140 and 13240	State	The Porter-Cologne Water Quality Control Act establishes 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 (water quality objectives). The Basin Plan serves to protect the beneficial uses and water quality of the surface and groundwater in the San Francisco Bay Basin. Beneficial uses of Union Creek and downstream receiving waters include navigation, contact and non-contact recreation, fish spawning, warm freshwater habitat, and wildlife habitat Beneficial uses of groundwater in the Suisun-Fairfield Valley Basin are municipal and domestic water supply, industrial process water supply, industrial service water supply and agricultural water supply. Selected water quality objectives from the following lists potentially apply: Table 3-1, Water Quality Objectives for Coliform Bacteria Table 3-2, U.S. EPA Bacteriological Criteria for Water Contact Recreation Table 3-4, Freshwater Water Quality Objectives for Toxic Pollutants for Surface Waters Table 3-5, Water Quality Objectives for Municipal Supply Table 3-6, Water Quality Objectives for Agricultural Supply	TBC	Water quality objectives in Tables 3-1, 3-2, and 3-4 potentially apply to discharges to Union Creek. Water quality objectives based on State MCLs (if more stringent than Federal MCLs) and other risk-based water quality objectives in Tables 3-5 and 3-6 potentially apply to groundwater. The Air Force believes that beneficial use designations are not ARARs because they do not set a numerical standard. However, the Air Force accepts the beneficial use designations in the basin plan for purposes of determining cleanup levels.
5	Groundwater treatment systems and treatment system effluent discharged to surface water	Sources of Drinking Water Policy	SWRCB Resolution 88-63	State	Designates all ground and surface water of the state of California as potential drinking water with certain exceptions	TBC	Resolution 88-63 is not an applicable requirement because it applies only to RWQCBs. Nor is it relevant or appropriate in that it is procedural and does not establish substantive requirements for remediation. AF accepts the beneficial use designations in the basin plan for purposes of determining cleanup levels.

Notes:

AF = Air Force
AFB = Air Force Base
ARAR = Applicable or Relevant and Appropriate Requirement
BAAQMD = Bay Area Air Quality Management District
Basin Plan = Water Quality Control Plan for San Francisco Bay Region
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
Div. = Division
EPA = Environmental Protection Agency
gpd = gallon(s) per day
H&S = health and safety
IC = institutional control
ID = identification
LDR = land disposal restriction
MCL = Maximum Contaminant Level
MCLG = Maximum Contaminant Level Goal
NCP = National Contingency Plan
NWP = Nationwide permit
ppm = part(s) per million
RCRA = Resource Conservation and Recovery Act
ROD = Record of Decision
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 solids
TEFA = Technical and Economic Feasibility Analysis
TTLC = total threshold limit concentration
UIC = Underground Injection Control
U.S.C. = United States Code
UTS = universal treatment standard

TABLE 5-2
Location-specific ARARs
Basewide Groundwater Focused Feasibility Study, Travis AFB, California

Item No.	Location	Requirement	Citation	Federal, or State Requirement	Description	ARAR Determination	Comments
1	Critical habitat upon which endangered species or threatened species depend	Endangered Species Act	16 USC Section 1531(c)	Federal	Requires action to conserve endangered species and critical habitats upon which endangered species depend. Includes consultation with the Dept of Interior.	Applicable	Activities at remedial sites must be performed in such a manner as to identify the presence of and protect endangered or threatened plants and animals at the site. Species at Travis AFB include the California tiger salamander, vernal pool fairy shrimp, Contra Costa goldfields, and vernal pool tadpole shrimp.
2	Wildlife habitat	Migratory Bird Treaty Act	16 USC Section 703	Federal	Prohibits unlawful taking, possession, and sale of almost all species of native birds in the U.S	Applicable	Species at Travis AFB include burrowing owl, tri-colored blackbird, and Swainson 's hawk.

Notes:

AFB = Air Force Base
ARAR = Applicable or Relevant and Appropriate Requirement
USC = United States Code

TABLE 5-3
Action-specific ARARs
Basewide Groundwater Focused Feasibility Study, Travis AFB, California

Item No.	Remedy Component	Requirement	Citation	Federal or State Requirement	Description	ARAR Determination	Comments
1	Discharges to surface water	Effluent requirements for discharges to surface water	40 CFR Part 122	Federal	Establishes requirements to ensure that discharges to surface water do not contribute to a violation of surface water quality standards, including effluent limitations, monitoring and reporting requirements, and the requirement to comply with effluent requirements for discharges to surface water.	Applicable	Applicable at all sites where there will be discharge of extracted or treated groundwater to surface water via the storm water system or to Union Creek. The SWRCB is authorized to implement the NPDES program in the State of California. California Regional Water Quality Control Board, San Francisco Bay Region Order No. R2-2004-0055, NPDES NO. CAG912003, General Waste Discharge Requirements for Discharge or Reuse of Extracted and Treated Groundwater Resulting From the Cleanup of Groundwater Polluted by Volatile Organic Compounds, establishes substantive discharge standards. Only substantive portions of Part 122 are ARARs; reporting requirements are procedural and are not ARARs.
2	Contaminated groundwater containing hazardous waste; remediation waste	Definition of and criteria for identifying hazardous wastes	22 CCR, Div. 4.5, Ch. 11	State	Defines wastes that are subject to regulation as a RCRA or non-RCRA hazardous waste. Remediation waste (contaminated soil, extracted groundwater, spent carbon and other residuals from onsite groundwater treatment systems, recovered free product, etc.) must be classified using Air Force knowledge of the timing and nature of the release as well as waste toxicity characteristic testing. If, after good faith effort, the Air Force determines that the contaminated soil or groundwater contains a listed RCRA or non-RCRA hazardous waste or exhibits hazardous waste characteristics, 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 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 in Section 66261.24 are applicable for the characterization of remediation waste. Treated groundwater from onsite groundwater treatment systems will no longer be hazardous waste and will be subject to the facility's discharge permit limits. Spent carbon will be tested, as necessary, prior to offsite disposal or regeneration.
3	Remediation waste	Standards applicable to generators of hazardous waste	22 CCR, Div. 4.5, Ch. 12	State	These regulations apply to generators of hazardous waste. Travis AFB is a large quantity generator of hazardous waste and already subject to these requirements. Establishes standards for generators of RCRA and non-RCRA hazardous wastes, including those for hazardous waste determination, accumulation, identification numbers, manifesting, pre-transport, and record keeping and reporting requirements.	Applicable	Substantive requirements are applicable to waste generated (contaminated soil, extracted groundwater, spent carbon and other residuals from onsite groundwater treatment systems, recovered free product, etc.) as part of groundwater remedies if these wastes are hazardous.
4	Remediation waste	Hazardous waste land disposal restrictions	22 CCR, Div. 4.5, Ch. 18	State	Identifies hazardous wastes that are restricted from land disposal without prior treatment. Characteristic hazardous remediation wastes that are managed offsite are subject to the LDR UTS specified in Section 66268.48 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 prior to land disposal.	Applicable	LDR requirements are applicable to offsite disposal of remediation wastes if they contain RCRA-listed hazardous wastes, exhibit RCRA hazardous waste characteristics, or are specified non-RCRA hazardous wastes.

TABLE 5-3
Action-specific ARARs
Basewide Groundwater Focused Feasibility Study, Travis AFB, California

Item No.	Remedy Component	Requirement	Citation	Federal or State Requirement	Description	ARAR Determination	Comments
5	Institutional Controls	Institutional controls	22 CCR 67391.1(a), (b) and (e)(2) Calif. Civil Code Section 1471, a and b	State	Requires that if a remedy will result in hazardous substances remaining on a property at levels not suitable for unlimited use and unrestricted exposure, 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 a property transfer, requires the State to enter into restrictive land use covenants with land-owners and their successors under such circumstances, with exceptions for federal-to-federal property transfers.	Relevant and appropriate	If a remedy at property owned by the federal government will result in levels of hazardous substances remaining on the property at levels not suitable for unlimited use and unrestricted exposure, and it is not feasible, as is the case with these groundwater sites that may be subject to LUCs, to record a land use covenant, then the ROD will clearly define and include limitations on land use and other institutional control mechanisms to ensure that future land use will be compatible with the levels of hazardous substances remaining on the property..When this ARARs table appears in the ROD, this comment section will include the comment: "This ROD sets forth such land use controls in Section ____."
6	Groundwater treatment	Underground Injection Control Program	40 CFR Parts 144, 146, 147, Sections 144.13(c) 144.82-.83, 144.89; Sections 146.5 and 146.10; Section 147.251	Federal	Protects groundwater from contamination by subsurface emplacement of fluids. Wells for injection of treatment chemicals or treated groundwater into shallow wells are designated Class V wells according to Section 146.5. Section 144.82 prohibits the movement of fluid containing any contaminant into an underground source of drinking water if it would cause a violation of primary drinking water standards under 40 CFR Part 141, or other health-based standards, or may otherwise adversely affect the health of persons. Injection well closure must prohibit emplaced fluid movement. States and EPA Regions can establish more stringent requirements if needed to protect underground sources of drinking water. Section 144.83 specifies inventory requirements for the operation of the injection well. Section 144.89 contains well closure requirements. Section 146.10 contains well plugging and abandonment requirements. Section 147.251 states that EPA administers the UIC program in California for Class V wells.	Applicable	Substantive portions are applicable to the injection of oxidizing chemicals or any other treatment chemicals or reagents at applicable sites
7	Groundwater treatment	Statement of Policy with Respect to Maintaining High Quality of Waters in California (Non-degradation Policy	SWRCB Resolution No. 68-16 (23 CCR Section 2900)	State	Resolution No. 68-16 (anti-degradation policy) has been incorporated into all Regional Board Basin Plans, including the SF Bay Regional Water Board's Basin Plan. This resolution requires that the quality of waters of the State that is better than needed to protect all beneficial uses be maintained unless certain findings are made. Discharges to high quality waters must be treated using best practicable treatment or control necessary to prevent pollution or nuisance and to maintain the highest quality water. This resolution also requires cleanup to background quality or lowest concentrations technically and economically feasible to achieve. Beneficial uses, at minimum, must be protected.	Applicable	Resolution 68-16 is an ARAR for the injection or reinjection of oxidizing chemicals or any treatment chemicals or reagents into groundwater to treat contaminants.
8	Remediation waste	Hazardous waste container management requirements	22 CCR Division 4.5, Ch. 15, Article 9	State	Establishes requirements for managing hazardous waste containers, including maintaining containers in good condition, keeping containers closed, and minimum setback distances for containers of ignitable or reactive waste	Applicable	Applicable to hazardous waste generated during remediation activities, including waste generated by groundwater treatment systems.

TABLE 5-3
Action-specific ARARs
Basewide Groundwater Focused Feasibility Study, Travis AFB, California

Item No.	Remedy Component	Requirement	Citation	Federal or State Requirement	Description	ARAR Determination	Comments
9	Groundwater treatment systems	Hazardous waste incinerators	22 CCR Div. 4.5, Ch. 14, Article 15, Sections 66264.341, .342, .343, .345, .347, .351	State	Establishes the following requirements for hazardous waste incinerators: • Requires owner or operator of thermal treatment units to conduct sufficient waste analysis to verify that waste feed to the incinerator is within physical and chemical composition limits • Establishes treatment requirements for Principal Organic Hazardous Constituents (POHCs) in the waste feed. • Establishes construction, maintenance and performance standards for incinerators that burn hazardous waste. • Establishes operating conditions under which hazardous wastes may be burned. • Establishes operating requirements under which hazardous wastes may be burned. • Establishes inspection and monitoring requirements for incinerators.	Applicable	Applicable to operation of thermal treatment units that are treating hazardous waste and meet the definition of an incinerator (use controlled flame combustion and are not otherwise excluded).
10	Groundwater treatment systems	Hazardous waste miscellaneous units	22 CCR Div. 4.5, Ch. 14, Article 16	State	Establishes requirements for miscellaneous units that transfer, treat, store or dispose of hazardous waste, including performance standards; inspection, response, reporting, monitoring and corrective action standards; and maintenance standards.	Applicable	Applicable to sites where air strippers or other miscellaneous treatment units are used to treat hazardous waste. Section 66264.602 requirements related to response and reporting procedures are administrative requirements and are not ARARs.
11	Groundwater treatment systems and hazardous remediation waste	Corrective action temporary units	22 CCR 66264.553	State	Establishes requirements for Corrective Action Temporary Units for temporary storage or treatment of hazardous remediation waste in tanks and containers. Temporary units are subject to alternative design, operating, and closure standards set by DTSC. Temporary units may operate for up to one year with the opportunity for a one year extension.	Applicable	Applicable to groundwater treatment in tanks and storage of remediation waste in tanks and containers if temporary units are authorized as part of the remediation.
12	Groundwater treatment systems	Air emissions standards for hazardous waste process vents	22 CCR Div. 4.5, Ch. 14, Article 27, Sections 22264.1032-.1035	State	Establishes requirements for process vents associated with equipment storing or treating hazardous waste, including emission limits when process vents are used; standards for closed vent systems and control devices; test methods and procedures for closed vent systems; record keeping requirements and performance and design analysis/ parameters for closed vent systems.	Relevant and appropriate	Relevant and appropriate to alternatives where closed vent systems are used. This includes sites with remediation systems that have system vents, to include air strippers, UV oxidation, carbon treatment vessels and catalytic oxidation equipment.
13	Groundwater treatment systems	Air emissions standards for hazardous waste equipment leaks	22 CCR Div. 4.5, Ch. 14, Article 28, Sections 66264.1054, 66264.1063, 66264.1064	State	Establishes requirements for hazardous waste equipment leaks, including requirement that pressure relief devices in gas/vapor service shall be operated with no detectable emissions; leak detection monitoring requirements; and record keeping requirements for gas/vapors extraction systems.	Relevant and appropriate	Relevant and appropriate for actions where gas/vapor extraction systems are used
14a	Groundwater treatment systems	General requirements for sources requiring air permits	BAAQMD Rule 2-1 Section 308	State	Requires that fugitive emissions from equipment or facilities must comply with all applicable requirements.	Applicable	Applicable to actions where air strippers or other systems using pressurized components (UV oxidation, carbon adsorption, catalytic oxidation and ion exchange) may result in fugitive VOC emissions.
15b	Groundwater treatment systems	General requirements for sources requiring air permits	BAAQMD Rule 2-1 Section 316	State	Establishes maximum levels for toxic air contaminants, which, if exceeded, require a risk screening analysis	Applicable	Applicable to actions that have the potential to emit toxic air contaminants (e.g., TCE). Applicable to air stripping, UV oxidation, carbon adsorption, catalytic oxidation and ion exchange.

TABLE 5-3
Action-specific ARARs
Basewide Groundwater Focused Feasibility Study, Travis AFB, California

Item No.	Remedy Component	Requirement	Citation	Federal or State Requirement	Description	ARAR Determination	Comments
16c	Groundwater treatment systems	General requirements for sources requiring air permits	BAAQMD Rule 2-1 Section 501	State	Requires that continuous emission monitors meet certain requirements.	Applicable	Applicable to all sites or actions where air stripping, UV oxidation, carbon adsorption, catalytic oxidation and ion exchange technologies are used in the remedial action that require the use of continuous emission monitors.
17a	Groundwater treatment systems	New source review for sources requiring air permits	BAAQMD Rule 2-2 Section 112	State	Establishes exemptions for secondary pollutant emissions from abatement control equipment that complies with BACT or BARCT requirements.	Applicable	Applicable to actions where BARCT or BACT abatement devices are used (i.e., carbon adsorption is used together with catalytic oxidation or UV oxidation or ion exchange) but where secondary emissions from the abatement equipment still exist.
18b	Groundwater treatment systems	New source review for sources requiring air permits	BAAQMD Rule 2-2 Section 301	State	Establishes BACT requirement for new sources emitted in excess of 10 lbs/day of non-precursor organic compounds, precursor organic, compounds, NOx, SOx, PM10, CO_2.	Applicable	Applicable to actions with potential to discharge to air. Not applicable for permitting requirements or authority to construct. Applicable for determining the applicability of BACT to a new source. Remedial alternatives using air strippers must ensure BACT is used (i.e., catalytic oxidation with carbon adsorption) to control emissions in excess of levels specified in the rule.
19	Construction activities	Visible emissions	BAAQMD Rule 6-1, Sections 301, 302, 303, and 501	State	Establishes visible emissions limits of 20 percent opacity or Ringlemann 1 for all sources except specified engines, laboratory equipment, and brazing, soldering and welding equipment, which are limited to 40 percent opacity or Ringlemann 2. Sets requirements for sampling facilities and instruments.	Applicable	Applicable to sites where excavation or construction activities have the potential to release particulate matter into the air (i.e., dirt and dust), or at sites where portable soldering, brazing, welding equipment is used. Also applicable at sites where portable combustion engines of < 25 liters of displacement are used.

Notes:

AF = Air Force
AFB = Air Force Base
ARAR = Applicable or Relevant and Appropriate Requirement
BAAQMD = Bay Area Air Quality Management District
Basin Plan = Water Quality Control Plan for San Francisco Bay Region
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
Div. = Division
EPA = Environmental Protection Agency
gpd = gallon(s) per day
H&S = health and safety
IC = institutional control
ID = identification
LDR = land disposal restriction
MCL = Maximum Contaminant Level
MCLG = Maximum Contaminant Level Goal
NCP = National Contingency Plan
NWP = Nationwide permit
ppm = part(s) per million
RCRA = Resource Conservation and Recovery Act
ROD = Record of Decision
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 solids
TEFA = Technical and Economic Feasibility Analysis
TTLC = total threshold limit concentration
UIC = Underground Injection Control
U.S.C. = United States Code
UTS = universal treatment standard

TABLE 5-4
Summary of ERP Groundwater Sites, Chemicals of Concern, and Preliminary Cleanup Goals
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Operable Unit	Name/Description	Chemical of Concern	PCG* (µg/L)
FT004	EIOU	Fire Training Area 3	TCE	5
			cis-1,2-DCE	6
			1,2-DCA	0.5
			Chloroform	100
			Bromodichloromethane	100
			1,1-DCE	6
			Vinyl chloride	0.5
			1,4-DCB	5
			bis(2-Ethylhexyl)phthalate	4
			Nickel	100
FT005	EIOU	Fire Training Area 4	TCE	5
			1,2-DCA	0.5
			cis-1,2-DCE	6
			Chloroform	100
			Bromodichloromethane	100
			bis(2-Ethylhexyl)phthalate	4
			Nickel	100
LF006	NOU	Landfill 1	TCE	5
			1,1-DCE	6
			TPH-G	5
			TPH-D	100
LF007	NOU	Landfill 2	TCE	5
			Benzene	1
			1,4,-DCB	5
			Chlorobenzene	70
			bis(2-Ethylhexyl)phthalate	4
			Vinyl chloride	0.5
			1,1-DCE	6
			1,2-DCA	0.5
			1,2-Dichloropropane	5
LF008	WABOU	Landfill 3	Aldrin	0.023
			Alpha-chlordane	0.1
			Heptachlor	0.01
			Heptachlor epoxide	0.01

TABLE 5-4
Summary of ERP Groundwater Sites, Chemicals of Concern, and Preliminary Cleanup Goals
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Operable Unit	Name/Description	Chemical of Concern	PCG* (µg/L)
SS015	EIOU	Solvent Spill Area and Facility 552	TCE	5
			cis-1,2-DCE	6
			Vinyl chloride	0.5
			1,2-DCA	0.5
			PCE	5
			bis(2-Ethylhexyl)phthalate	4
			Nickel	100
SS016	EIOU	Oil Spill Area Facilities 11, 13/14, 20, 42/1941, and 139/144	TCE	5
			cis-1,2-DCE	6
			Vinyl chloride	0.5
			Benzene	1
			Chloroform	100
			1,4-DCB	5
			Bromodichloromethane	100
			1,2-DCA	0.5
			1,1-DCE	6
			PCE	5
			bis(2-Ethylhexyl)phthalate	4
			Nickel	100
ST027	EIOU	TF33, Facilities 1918, 1919, 1020, and 1040	Benzene	1
			TCE	5
			Toluene	150
			MTBE	13
			TPH-G	5
			TPH-D	100
SS029	EIOU	MW329x29 Area	TCE	5
			1,2-DCA	0.5
			cis-1,2-DCE	6
			Benzene	1
			Chloroform	100
			1,1-DCE	6
			Vinyl chloride	0.5
SS030	EIOU	MW269x30 Area	TCE	5
			Chloroform	100
			Bromodichloromethane	100
			1,2-DCA	0.5
			Nickel	100

TABLE 5-4
Summary of ERP Groundwater Sites, Chemicals of Concern, and Preliminary Cleanup Goals
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Operable Unit	Name/Description	Chemical of Concern	PCG* (µg/L)
SD031	EIOU	Facility 1205	TCE	5
			Benzene	1
			1,1-DCE	6
			cis-1,2-DCE	6
			Carbon tetrachloride	0.5
			Chloroform	100
			1,2-DCA	0.5
			Vinyl chloride	0.5
			Nickel	100
SD033	WIOU	Storm Sewer System 2 (former Storm Sewer System B – includes Facilities 810, 1917, and South Gate Area)	TCE	5
			1,1-DCE	6
			1,2-DCA	0.5
			cis-1,2-DCE	6
			TPH-G	5
			TPH-D	100
SD034	WIOU	Facility 811	LNAPL (PD-680)	NA
			TCE	5
			Vinyl chloride	0.5
			1,1-DCE	6
			Benzene	1
			cis-1,2-DCE	6
			PCE	5
			TPH-G	5
			TPH-D	100
			bis(2-Ethylhexyl)phthalate	4
SS035	WIOU	Facilities 818 and 819	TCE	5
			TPH-D	100
SD036	WIOU	Facilities 872, 873, and 876	Vinyl chloride	0.5
			TCE	5
			1,1-DCE	6
			cis-1,2-DCE	6
			1,2-DCA	0.5
			Benzene	1
			Bromodichloromethane	100
			PCE	5
			TPH-G	5
			TPH-D	100

TABLE 5-4
Summary of ERP Groundwater Sites, Chemicals of Concern, and Preliminary Cleanup Goals
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Operable Unit	Name/Description	Chemical of Concern	PCG* (µg/L)
SD037	WIOU	Sanitary Sewer (includes Facilities 837, 838, 981, 919, the Area G Ramp, and Ragsdale/V Area)	1,1-DCE	6
			1,2-DCA	0.5
			Benzene	1
			Bromodichloromethane	100
			Carbon tetrachloride	0.5
			Chloromethane	1.5
			PCE	5
			TCE	5
			Vinyl chloride	0.5
			cis-1,2-DCE	6
			TPH-G	100
			bis(2-Ethylhexyl)phthalate	4
			Naphthalene	20
			TPH-D	100
DP039	WABOU	Building 755	1,1-DCE	6
			1,2-DCA	0.5
			1,1,1-TCA	0.5
			1,1,2-TCA	0.5
			Acetone	5,110
			Bromodichloromethane	100
			Methylene chloride	5
			PCE	5
			TCE	5
SS041	WABOU	Building 905	Heptachlor epoxide	0.01
SD043	WABOU	Building 916	TCE	0.5

* The lesser of either the federal MCL or California MCL is adopted as the PCG. Section 5.4 describes the selection of PCGs in more detail.

Notes:

DCA = dichloroethane
DCB = dichlorobenzene
DCE = dichloroethene
EIOU = East Industrial Operable Unit
MTBE = methyl tert-butyl ether
NA = not applicable
NOU = North Operable Unit
PCE = tetrachloroethene
TCA = trichloroethane
TCE = trichloroethene
TPH-D = total petroleum hydrocarbon as diesel
TPH-G = total petroleum hydrocarbon as gasoline
WABOU = West/Annexes/Basewide Operable Unit
WIOU = West Industrial Operable Unit

Source: Table 1-2 of the final 2009-2010 Travis AFB GSAP Report

SECTION 6

Identification and Screening of Technologies

This section describes the GRAs, remedial technologies, and technology process options that can be used to achieve the RAOs described in Section 5. Technologies and process options are developed that are applicable to the site and contaminant conditions described in Section 3. A summary of the ERP sites, the groundwater IRA implemented at each site, the component IRA technology processes, IRA optimization actions, and the status and performance of the IRA is provided in Table 6-1. Descriptions of the technology processes are provided in Section 6.5.

Travis AFB has already followed the CERCLA process by completing four (4) OU-specific RIs, two (2) OU-specific FSs, and two (2) groundwater IRODs, as well as the successful long-term operation of interim remedies at each ERP site. The technology evaluations previously conducted in the NEWIOU FS (Radian, 1996a) and WABOU FS (CH2M HILL, 1998a) resulted in four (4) types of IRAs being implemented either individually, or in combination, at each ERP site in accordance with the final Groundwater IROD for the NEWIOU (Travis AFB, 1998) and the final Groundwater IROD for the WABOU (Travis AFB, 1999). These four (4) types of IRAs are as follows:

- GET
- MNA
- MNA assessment
- Free product removal

Travis AFB has successfully operated and monitored the performance of the site-specific GET systems, MNA, MNA assessments, and free product removal for approximately a decade. During the period of interim remediation, each IRA has been evaluated during two (2) five-year reviews (CH2M HILL, 2003a, 2008a). Conclusions regarding the MNA assessments are also documented in the NAAR (CH2M HILL, 2010a).

Travis AFB is now beginning the transition out of the period of interim remediation that utilizes the IRA technologies. Three (3) basic actions are possible at each site:

- Continue using the interim remedy technologies
- Modify the interim remedy technologies
- Discontinue the interim remedy technologies and select different technologies

To assess the appropriate action at each site, this section of the FFS re-evaluates the technology process options that compose the IRAs. The long-term performance of the existing IRA technologies, existing IRA optimization measures, successful demonstration projects, and treatability studies results are significant factors in this re-evaluation. Discussions on the performance of the IRAs are provided in Section 2.6 and a site-specific summary of IRA status and performance is provided in Table 6-1.

Additionally, green and sustainable remedial technology processes are now also a consideration in the re-evaluation. Some technology processes that were considered innovative and largely unproven at the time of the NEWOU FS and WABOU FS have matured and are now viable alternatives under the appropriate site-specific conditions.

6.1 General Response Actions

GRAs describe the broad range of actions that will satisfy the RAOs. GRAs may include no action, institutional actions, containment, removal, treatment, and disposal, or a combination of these (EPA, 1988). GRAs to satisfy the RAOs for contaminated groundwater at the Travis AFB ERP sites include the following:

- **No action –** No attempt is made to satisfy the RAOs, and no remedial measures are implemented. A No Action Alternative is required for consideration by the NCP.
- **Land Use Controls –** Actions using physical, legal, or administrative mechanisms to restrict the use of land and limit access to contaminated groundwater.
- **Containment –** Actions that result in contaminated groundwater being contained or controlled, thereby minimizing or eliminating the migration of contaminants and preventing direct exposure to contamination.
- **Removal –** Actions taken to physically remove contaminated groundwater or pure contaminant from an aquifer.
- **Treatment –** In situ or ex situ actions taken to reduce the toxicity, mobility, and/or volume of contaminants in groundwater. Includes actions that rely on natural processes to reduce toxicity, mobility, and/or volume of contaminants.
- **Disposal –** Actions taken to reuse or dispose of treated groundwater.

6.2 Screening of Remedial Technologies and Process Options

Except for No Action, each GRA can be achieved by several remedial technologies and technology process options. In this context, the following definitions apply:

- **Remedial technologies –** General categories of remedies under a GRA. For example, in situ chemical oxidation (ISCO) is one (1) of the remedial technologies under the GRA of in situ treatment.
- **Process options –** Specific categories of remedies within each remedial technology. The process options are used to implement each remedial technology. For example, the remedial technology of in situ biological treatment could be implemented using several types of treatment options, including carbon substrate injection, bioaugmentation, phytoremediation, and/or a bioreactor.

A universe of technology types and process options is available to implement the GRAs described in Section 6.1. The first step in the evaluation process involves screening the comprehensive list of technologies and process options against the criterion of Technical Implementability. A second screening of the surviving process options against the criteria of

Effectiveness, Implementability, and Relative Cost further reduces this list. The last step involves the selection of representative process options for each applicable technology type to simplify the subsequent development and evaluation of remedial alternatives.

6.2.1 Technical Implementability Screening

The first step in the evaluation process involves screening the comprehensive list of technologies and process options against the criterion of Technical Implementability. The purpose of initially considering this universe of possibilities is to ensure that applicable technologies and process options are not overlooked early in the FS process. This initial screening eliminates those technologies or process options that are not applicable or not workable for the contaminants and site characteristics found at Travis AFB.

6.2.2 Evaluation of Process Options

After the technical implementability screening, the surviving technologies and process options are evaluated in greater detail using the following criteria:

- Effectiveness
- Implementability
- Relative Cost

In terms of the Effectiveness criterion, specific process options are evaluated by the following:

- The potential effectiveness of process options to address the estimated areas or volumes of media and meet the remediation goals identified in the RAOs
- The potential impacts to human health and the environment during the construction and implementation phases
- How proven and reliable the process is with respect to the types of contamination and site conditions that will be encountered

Implementability refers to the administrative aspects of using a technology process, such as the ability to obtain necessary permits; the availability and capacity of treatment, storage, and disposal services; and the availability of necessary equipment and workers to implement the technology.

Cost plays a limited role in the screening of process options. Relative costs are used rather than detailed estimates. Each process option is evaluated on the basis of engineering judgment as to whether costs are high, medium, or low relative to the other process options in the same technology type.

Because of limited data on innovative technologies, their related process options were not evaluated on the same basis as the demonstrated technologies. Innovative technologies judged to be potentially effective, implementable, and cost-effective were retained through this level of evaluation.

6.2.3 Selection of Representative Process Options

Representative process options are selected to simplify the subsequent development and evaluation of remedial alternatives (EPA, 1988).

For this FFS, representative process options were selected by considering those that already exist at Travis AFB or are otherwise established, proven, reliable, and are consistent with the FFS focusing criteria described in Section 4 (e.g., compatible with site and contaminant conditions, sustainable). These processes were chosen to *represent* the options under a GRA and technology group. For example, in Table 6-1, EVO injection, phytoremediation, and bioreactor are selected as process options to represent the GRA of in situ treatment and the technology of in situ bioremediation.

More than one (1) representative process option may be selected for a technology type if the processes are sufficiently different in their performance that one would not adequately represent the other. The selection of representative process options provides more flexibility in the future, when the selected remedial action is designed. The specific process to be used at a particular site may not be selected until the remedial design phase (EPA, 1988).

Those process options not selected as representative are not eliminated from future consideration. For example, under the technology of in situ chemical treatment, chemical oxidant injection and ZVI PRB are not selected as representative processes, but this does not preclude them from being selected as part of the final remedial action in the pending Basewide Groundwater ROD.

6.3 Previous Technology Evaluations

Screening of technologies and process options took place during two (2) groundwater feasibility studies previously completed at Travis AFB.

6.3.1 Previous Technical Implementability Screening

An initial screening of Technical Implementability of groundwater technologies and process options was previously conducted during the NEWIOU FS (Radian, 1996a) and WABOU FS (CH2M HILL, 1998a). A summary of the Technical Implementability screening conducted in the NEWIOU FS is provided in Table 6-2. A similar summary of Technical Implementability screening conducted in the WABOU FS is provided in Table 6-3.

6.3.2 Previous Evaluation of Process Options

Following the Technical Implementability screening, evaluations of process options were conducted in the final NEWIOU FS (Radian, 1996a) and final WABOU FS (CH2M HILL, 1998a). A summary of the screening conducted against the criteria of Effectiveness, Implementability, and Relative Cost in the NEWIOU FS is provided in Table 6-4. A similar summary of criteria screening that was conducted in the WABOU FS is provided in Table 6-5.

6.3.3 Previous Selection of Representative Process Options

Following evaluations of Effectiveness, Implementability, and Relative Cost criteria in the final NEWIOU FS (Radian, 1996a) and final WABOU FS (CH2M HILL, 1998a), representative processes options were chosen to represent the range of process options.

A summary of the representative process options selected in the NEWIOU FS is provided in Table 6-4. A similar summary of representative process options selected in the WABOU FS is provided in Table 6-5.

6.3.4 Previous Implementation of Technologies

Following finalization of the NEWIOU FS (Radian, 1996a) and final WABOU FS (CH2M HILL, 1998a), site-specific IRAs were implemented at each ERP site in accordance with the final Groundwater IROD for the NEWIOU (Travis AFB, 1998) and final Groundwater IROD for the WABOU (Travis AFB, 1999).

Site-specific listings of the technology process options that have already been successfully implemented as components of the IRAs are provided in Table 6-1. Additional descriptions of the site-specific IRAs and their component technologies are provided in Sections 2 and 3. Descriptions of the technology processes are provided in Section 6.5.

In summary, the following remedial technologies and process options have been, or are currently being used, as components of the IRAs either individually, or in combination, at Travis AFB ERP sites:

- **GET:**
  - Vertical extraction wells
  - Horizontal extraction wells
  - DPE wells
  - 2-Phase® extraction well
  - Air stripping
  - UV/Ox
  - ThOx vapor treatment
  - LGAC groundwater treatment
  - Stormwater drainage system discharge
  - Groundwater monitoring
  - LUCs
- **MNA:**
  - Monitoring wells
  - Groundwater monitoring
  - LUCs
- **MNA assessment:**
  - Monitoring wells
  - Groundwater monitoring
  - LUCs
- **Free product removal:**
  - Passive skimming (Stoddard solvent)
  - LUCs

6.3.5 Technology Processes Used in IRA Optimizations

After approximately a decade of IRA implementation, groundwater contamination at multiple sites was reduced but remained at concentrations that exceeded the IRGs established by the NEWIOU Groundwater IROD (Travis AFB, 1998) and WABOU Groundwater IROD (Travis AFB, 1999). The IRAs at Sites LF007C, SS015, SS030, and DP039 were not functioning completely as intended by the two (2) IRODs. Also, although the IRAs at Sites SS016, SD036, and SD037 were meeting IRA objectives, additional measures were needed to improve the overall effectiveness of the interim remedies. Therefore, the Air Force took steps during 2010-2011 to optimize the IRAs and improve their performance.
The site-specific IRA optimizations and their respective technology components are summarized in the following list. Descriptions of the technology processes are provided in Section 6.5.

- **Site LF007C –** A portion of the Site LF007C plume is located off-base. Upon approval by the USFWS, optimization measures will be conducted in 2011 to improve the existing GET system performance. These measures will include additional characterization to improve understanding of off-base contaminant distribution, groundwater flow directions, and the needed GET system modifications. More complete descriptions of the optimization measures are provided in the *Site LF007C Remedial Process Optimization Work Plan* (CH2M HILL, 2009b). Existing IRA technology components at the site include the following:
  - LUCs
  - Groundwater monitoring
  - Easement
  - Vertical extraction wells
  - LGAC groundwater treatment
  - Stormwater drainage system discharge
  - Beneficial reuse (Duck Pond)

- **Site SS015 –** Increasing contaminant concentrations in some site monitoring wells indicate that the Site SS015 plume is migrating. During 2000-2001, soybean oil was injected into the aquifer during an in situ vegetable oil injection treatability study (Parsons, 2002; 2001). The findings of the treatability study were encouraging and indicated that bioremediation via reductive dechlorination was taking place. However, the treatability study was terminated early because of a military construction project at the site. The limited volume of oil injected during the treatability study may now be exhausted, as seen by recently increasing concentrations of TCE, cis-1,2-DCE, and vinyl chloride. During 2010, optimization actions included additional characterization to improve understanding of contaminant distribution and groundwater flow directions. These data supported a supplemental injection of EVO in the contaminant source zone. Further descriptions of the optimization measures are provided in the *Site SS015 Remedial Process Optimization Work Plan* (CH2M HILL, 2010c). Existing IRA technology components at the site previously installed for a MNA assessment include the following:
  - LUCs
  - Groundwater monitoring

Technology processes used during IRA optimization actions conducted in 2010 include the following:

– Vertical injection wells
– Carbon substrate injection (EVO)
– Groundwater monitoring

- **Site SS016 –** Although the overall IRA objectives at Site SS016 are largely being achieved, optimization actions were taken within the OSA source zone to improve the overall effectiveness of the existing GET system. Descriptions of the optimization measures are provided in the *Site SS016 Remedial Process Optimization Work Plan* (CH2M HILL, 2010c). Existing technology components at the site previously installed for the GET IRA include the following:

  – LUCs
  – Groundwater monitoring
  – Vertical extraction wells
  – Horizontal extraction wells – continuing in TARA
  – 2-Phase® extraction – discontinued
  – ThOx vapor treatment – discontinued
  – UV/Ox groundwater treatment – discontinued

  Technology processes used during IRA optimization actions conducted in 2010 include the following in lieu of the discontinued technology processes:

  – In situ bioreactor – includes OSA horizontal well to provide influent groundwater
  – LGAC groundwater treatment

- **Site SS030 –** A portion of the off-base Site SS030 plume appears to be migrating toward Site FT005 under the hydraulic influence of the adjacent Site FT005 GET system. Additional characterization of off-base contaminant distribution, groundwater flow directions, and GET system modifications was conducted during 2010-2011 to improve the IRA performance. Additional descriptions of the optimization measures are provided in the *Site SS030 Remedial Process Optimization Work Plan* (CH2M HILL, 2010d). Existing IRA technology components at the site include the following:

  – LUCs
  – Groundwater monitoring
  – Easement
  – Vertical extraction wells
  – LGAC groundwater treatment
  – Stormwater drainage system discharge

  No new technology processes are planned at the site, although additional extraction wells may be installed if required to maintain the effectiveness of the GET system.

- **Site SD036 –** Relatively high contaminant concentrations remain in the source area of the plume even after 10 years of IRA GET system operation. This area provides a continuing source of contamination into hydraulically downgradient portions of the plume. Therefore, optimization actions were taken during 2010. Operation of the GET system was discontinued, and additional characterization of contaminant distribution was performed. In situ treatment of the source zone was then conducted using enhanced bioremediation via injection of EVO. More complete descriptions of the optimization measures are provided in the *Sites SS036/SD037 Remedial Process Optimization Work Plan (*CH2M HILL, 2010e). Existing IRA technology components at the site include the following:

- LUCs
- Groundwater monitoring
- Vertical DPE wells – discontinued
- LGAC groundwater treatment – discontinued
- Stormwater drainage system discharge – discontinued

Technology processes used during IRA optimization actions conducted in 2010 include the following:

- Vertical injection wells
- Carbon substrate injection (EVO)
- Groundwater monitoring

- **Site SD037 –** Similar to Site SD036, relatively high contaminant concentrations remain in a localized portion of the Site SD037 plume. This source zone provides a continuing influx of contamination into hydraulically downgradient portions of the plume. During 2010, operation of the GET IRA was discontinued. Additional characterization of contaminant distribution and groundwater flow direction was conducted. Following this characterization, in situ treatment of the source area was conducted using EVO injection. Additional descriptions of the optimization measures are provided in the *Sites SD036/SD037 Remedial Process Optimization Work Plan (*CH2M HILL, 2010e). Existing IRA technology components at the site include the following:

  - LUCs
  - Groundwater monitoring
  - Vertical DPE wells – discontinued
  - LGAC – discontinued
  - Stormwater drainage system discharge – discontinued

  Technology processes used during IRA optimization actions conducted in 2010 include the following:

  - Vertical injection wells
  - Carbon substrate injection (EVO)
  - Groundwater monitoring

- **Site DP039 –** A portion of the Site DP039 plume appears to be migrating hydraulically downgradient. As a consequence, operation of the inefficient GET IRA within the contaminant source area was discontinued in December 2008 and an in situ bioreactor was installed in the source area. During 2010, additional characterization of contaminant distribution and groundwater flow direction was conducted. Subsequently, a PRB of injected EVO was installed during the summer of 2010. The performance of phytoremediation was also evaluated (Parsons, 2010). Additional descriptions of the optimization measures are provided in the *Site DP039 Remedial Process Optimization Work Plan* (CH2M HILL, 2010f). Existing IRA technology components at the site include the following:

- LUCs
- Groundwater monitoring
- Vertical DPE wells – discontinued
- LGAC – discontinued
- Stormwater drainage system discharge – discontinued
- Phytoremediation (previous treatability study and technology demonstration)
- Groundwater monitoring (MNA)

Technology processes used during IRA optimization actions conducted in 2010 include the following:

- In situ bioreactor
- Vertical injection wells
- Carbon substrate injection (EVO)
- Groundwater monitoring

6.4 Current Technology Evaluations

Travis AFB has successfully operated and monitored the long-term performance of site-specific IRA GET systems, MNA, MNA assessments, and free product removal for approximately a decade. Travis AFB is now beginning the transition out of the period of interim remediation.

One of the primary purposes of the FFS is to re-evaluate the various technologies that compose the IRAs and consider other technologies that have matured since the previous FSs were conducted.

The following subsections describe the current screening of technologies and process options following approximately a decade of interim remediation.

6.4.1 Current Technical Implementability Screening

Screening against the criterion of Technical Implementability was previously conducted in the NEWIOU FS (Radian, 1996a) and WABOU FS (CH2M HILL, 1998a). For the FFS, another iteration of Technical Implementability is provided in Table 6-6. This round of screening includes the technologies already implemented as components of the existing IRAs and other technologies that have matured since the NEWIOU FS and WABOU FS were conducted in the mid- to late-1990s.

Descriptions of the technology processes are provided in Section 6.5.

6.4.2 Current Evaluation of Process Options

This step evaluates technologies and process options against the criteria of Effectiveness, Implementability, and Relative Cost. The screening of GRAs, technologies, and process options is provided in Table 6-7. Tables 6-8, 6-9, and 6-10 graphically depict the site-specific evaluation of process options against the criteria of Effectiveness, Implementability, and Relative Cost. These tables also present the technology processes that have already been implemented at each site as a component of the IRA, as an optimization measure to the IRA, or as a technology demonstration that may be incorporated into an alternative.

Descriptions of the technology processes are provided in Section 6.5.

6.4.2.1 Effectiveness Criterion Screening

Overall, the technologies that best satisfy the Effectiveness criterion are those that already exist as components of the IRAs, are currently being evaluated as optimization actions to the IRAs, or are existing technology demonstrations. The screening of technology process options for each site against the criterion of Effectiveness are provided in Tables 6-7 and 6-8. Some key aspects of the Effectiveness screening are as follows:

- No action – Can potentially be effective, but no monitoring is conducted and no evaluations are conducted to determine effectiveness. Effective at Site SS041, because this site is already in NFRAP status.
- Base Civil Engineer Work Request – Effective for all on-base sites or the on-base portions of sites. Not applicable to the off-base portions of Sites FT005, LF007C, and SS030.
- Excavation permit – Effective for all on-base sites or the on-base portions of sites. Not applicable to the off-base portions of Sites FT005, LF007C, and SS030. Digging permits for off-base portions of these sites must follow Underground Service Alert (USA) procedures.
- Base General Plan – Effective for all sites.
- Easement purchase – Effective for off-base portions of Sites FT005, LF007C, and SS030. Not applicable to on-base sites or the on-base portions of sites.
- Vapor barrier – Effective for preventing vapor intrusion from groundwater into a new building. Recently constructed buildings at Sites SS015 and SD037 include vapor barriers with demonstrated effectiveness. Potential future buildings constructed in proximity to a chlorinated VOC groundwater plume will be required to have a vapor barrier in accordance with the requirements of the Base General Plan. At Site LF008, groundwater contamination is limited to low concentrations of non-volatile organochlorine pesticides. Therefore, installation of a vapor barrier for a hypothetical future building at this site would be unnecessary and ineffective.
- Passive venting – Effective for removing soil vapor that may accumulate under the subslab of a new building. Recently constructed buildings at Sites SS015 and SD037 include passive venting systems with demonstrated effectiveness. Potential future buildings constructed in proximity to a chlorinated VOC groundwater plume will be required to have a passive venting system in accordance with the requirements of the Base General Plan. At Site LF008, groundwater contamination is limited to low concentrations of non-volatile organochlorine pesticides. Therefore, installation of a passive venting system for a hypothetical future building at this site would be unnecessary and ineffective.

- Alternative water supply – Effective for replacing contaminated groundwater from an existing domestic well with potable water from another source. Applicable to the off-base portions of Sites FT005, LF007C, and SS030. GSAP monitoring has not found contamination in domestic wells located at these sites. Not applicable to on-base sites or portions of sites.

- Groundwater monitoring – Effective at all sites. Groundwater monitoring is used to track contaminant concentration and plume migration trends.

- Alternate water supply – Moderately effective at Sites FT005, LF007C, and SS030 as a component of a remedial system. Potential usage of contaminated groundwater by off-base residents is minimized by replacement with a potable water supply. Does not address the contaminants in groundwater.

- MNA – Effective. MNA has proven to be effective during the period of interim remediation for the plumes, or portions of plumes, at Sites FT004, LF006, LF007B, SD031, SD033, SD034, SS035, SD036, and SD037 (refer to Appendix C). The technology is effective in addressing large-volume and/or low-concentration plumes, or portions of plumes, but is less effective within higher concentration source areas.

  – MNA would not be fully effective at Site SS015, because this site still has a highly concentrated source area. Without an active remedy to address the large amount of contaminant mass in the Site SS015 source area, natural processes alone will not be capable of preventing plume migration and treating both the source area and the distal portion of the plume. As described above, MNA is more suited for a low concentration plume that does not have a source area.

  – MNA at Site LF007D has not been fully effective at reducing plume concentrations. The plume is stable, but benzene concentrations have not decreased significantly during the period of interim remediation. Groundwater contamination is currently limited to a small area within a closed and capped landfill in the vicinity of MW261x07. Within this area, PCGs are exceeded for 1,4-DCB (12.6 µg/L vs. PCG of 5 µg/L) and benzene (3 µg/L vs. PCG of 1 µg/L). Concentrations of 1,4-DCB have decreased during the period of interim remediation. However, benzene concentrations have remained relatively stable at about 3 µg/L.

- EA – Effective at Sites SS015, SD034, SD036, SD037, and DP039. Attenuation processes under EA can be more effective than relying solely on MNA. The same physical, chemical, and biological processes are used to degrade contamination. However, EA is used in conjunction with a source remediation action (e.g., extraction wells, EVO injection, bioreactor) to reduce the flow of contaminants into hydraulically downgradient portions of the plume. The source remediation action thereby enhances natural attenuation processes in the distal portions of the plume and provides for improved effectiveness. The technology is effective in addressing large volume and/or low concentration plumes, or portions of plumes. It is also potentially effective at addressing the distal portion of Site LF007C following expansion of the existing GET system and potentially effective at Sites FT004, SD031, SD033, and SD043 if implemented in conjunction with additional source area actions.

- Soil-bentonite slurry walls – Limited effectiveness. This is because the presence of any utilities across the wall's footprint can impede its installation and reduce its effectiveness. Also, the presence of fractured or weathered bedrock may allow contaminants to flow beneath the wall. Soil-bentonite slurry walls have potential limited effectiveness in containing a well defined, high concentration source area within a plume such as those found at Sites SS015, SD036, SD037, and DP039. The technology is not effective in addressing large volume and/or low concentration plumes.
- Interceptor trench – Potentially effective. An interceptor trench has potential effectiveness in containing a well defined, high-concentration source area within a plume such as those found at Sites SS015, SD036, and SD037. It is best used in a very shallow aquifer with a shallow impermeable bedrock beneath it. The technology is not effective in addressing large-volume and/or low-concentration plumes. An interceptor trench installed early during the interim remediation of the Site SS030 plume has become less efficient over time. Effectiveness is further limited by the dense silt and clay lithology encountered at most of the sites.
- Groundwater extraction systems, with site-specific technology components including vertical and horizontal extraction wells, DPE wells, and a 2-Phase® extraction well, have mostly proven effective during the period of interim remediation at Sites FT004, FT005, SS029, SS030, SD031, SD033, SD034, SS035, SD036, SD037, and DP039. The overall plume concentrations and the extent of groundwater contamination have been reduced using these process options (refer to Table 6-1, Section 2.6, and Figures 2-3 through 2-10).
  - Vertical extraction well – Effective. During the period of interim remediation, vertical extraction wells demonstrated effectiveness at Sites FT004, FT005, SS029, SS030, SD031, SD033, SD034, SS035, SD036, SD037, DP039, and SD043. Plume concentrations and the extent of groundwater contamination were reduced.
    - Vertical extraction wells continue to operate effectively in the non-source areas of the Site SS016 OSA plume.
    - Long-term operation vertical extraction wells at Site LF007C have not been effective at reducing concentrations of chlorinated VOCs. Optimization of the off-base GET system is planned. Access to the off-base portion of the plume has been restricted because of the presence of an environmentally-sensitive vernal pool.
    - Long-term operation of vertical extraction wells at Site LF008 has not been effective at reducing the concentrations of organochlorine pesticides. The concentrations are low, and the plume is stable. The inability of GET to avoid asymptotic conditions and achieve PCGs is probably due to the strong affinity of the pesticides to adsorb onto suspended soil particles.
  - Horizontal extraction well – Effective. During the period of interim remediation, horizontal extraction wells demonstrated effectiveness within the TARA portion of Site SS016. Plume concentrations and the extent of groundwater contamination have been reduced. Horizontal well screens are not likely to be as effective as vertical wells in layered lithologies with only thin permeable zones. Vertical well screens will usually intersect more of these permeable zones than a horizontal screen.

- DPE well – Similar to a vertical extraction well, it is effective at the start, but its effectiveness decreases over time as contaminant concentrations decrease. During the period of interim remediation, DPE extraction wells demonstrated effectiveness at Sites FT004, SD031, SD033, SD034, SS035, SD036, SD037, DP039, and SD043. Plume concentrations and the extent of groundwater contamination were reduced. Application of a partial vacuum also increased groundwater extraction rates from the low-permeability lithology present at the sites.
  - Long-term operation of DPE wells within the source areas of Sites SD036, SD037, and DP039 have become increasingly ineffective in the diffusion-dominated lithologies encountered at these sites.
  - At Site SS015, DPE extraction would likely be initially effective at removing contaminant mass, but would eventually be limited by the diffusion-dominated lithology present at the site.
- 2-Phase® extraction well – Similar effectiveness as for DPE wells. During the period of interim remediation, a 2-Phase® extraction well demonstrated moderate effectiveness within the OSA source area of Site SS016. Plume concentrations were reduced, and mass were removed. However, even after more than a decade of operation, the chlorinated VOC concentrations within the OSA source area are still the highest currently detected at Travis AFB.

- Passive skimming – Effective. Passive skimming is an effective process only at Site SD034. Floating product is not found at any other site.
- Bioslurping – Effective, but with decreasing effectiveness over time as the floating product layer becomes thinner. Bioslurping is an energy-intensive technology using simultaneous SVE, groundwater extraction, and free product extraction. The process is effective when large volumes of floating product are present. It becomes increasingly ineffective and inefficient as floating product thickness decreases. Floating product is found only at Site SD034 (Stoddard solvent).
- Carbon substrate injection – Effective. Sufficient evidence exists to evaluate carbon substrate injection (i.e., EVO) technology as potentially effective for in situ treatment of well defined high concentration and/or small-volume contaminant source areas such as those found at Sites SS015, SD036, SD037, and DP039. EVO has already been injected at these sites as optimization actions taken in 2010. The long-term effectiveness of EVO injection will continue to be evaluated during the period of interim remediation. The technology is not effective in addressing large-volume and/or low-concentration plumes. Potentially effective within the OSA source area of Site SS016, but effectiveness is limited by the low-permeability silt/clay lithology. Refer to Section 6.5 for more detailed discussion of the carbon substrate injection technology.
- PRB – Effective, if adequately keyed into bedrock or other low permeability lithology. An organic PRB (biobarrier) could potentially provide effective in situ treatment of chlorinated VOCs at Sites SS015, SS016, SS029, SD036, SD037, and DP039. The technologies are not effective in addressing large-volume and/or low-concentration plumes, but may provide a means to control plume migration by intercepting contamination flowing along the natural groundwater gradient. Additional

investigations will be conducted during 2011 to evaluate the technical implementability of this process option at Site SS029.

- Bioaugmentation – Effective. Bioaugmentation of native microbial populations with proprietary microbial consortia is potentially effective at improving reductive dechlorination processes with EVO treatment zones and/or bioreactors at Sites SS015, SS016, SD036, SD037, and DP039. However, the need for bioaugmentation will depend on the results of ongoing performance monitoring and the effectiveness of native microbes at degrading contaminants.

- Phytoremediation – Potentially effective. Phytoremediation has already demonstrated effectiveness at Site DP039. This process option is effective when the contamination is confined to the upper portion of a shallow aquifer. This process option could also be potentially effective for the conditions at the Site FT004 plume. The technology has more limited effectiveness in addressing large volume plumes that would require an excessive number of tree plantings. Vertically, effectiveness is limited by the depth of the root zone achieved by the trees when mature.

- Bioreactor – Potentially effective. Short-term operation of bioreactors at Sites SS016 and DP039 have generated sufficient amounts of evidence to demonstrate their potential effectiveness. The technology is effective in addressing a well defined, high-concentration source area within a plume. The technology is not effective in addressing large-volume and/or low-concentration plumes. The effectiveness of the bioreactors at both sites will continue to be evaluated during the period of interim remediation.

- Chemical oxidation – Effective under limited site-specific conditions. Sufficient evidence exists to evaluate chemical oxidation under the subsurface conditions at Travis AFB. The diffusion-dominated lithology, relatively short persistence time of the oxidant in the subsurface, and high soil oxidant demand (SOD) for a chemical oxidant technology are the main factors in assessing a limited effectiveness. Chemical oxidation could potentially be effective at treating permeable zones within high-concentration source areas, but would not function well in relatively impermeable silts and clays, like those found at Travis AFB. Repeated or continuous injection of oxidant would be required to maintain the treatment process. The technology is not effective in addressing large-volume and/or low-concentration plumes. Refer to Section 6.5 for more detailed discussion of the chemical oxidation technology.

- ZVI injection – Limited effectiveness. Injection of a ZVI mixture using the Ferox℠ or Z-Loy™ processes would likely have limited effectiveness in the dense silt and clay lithology typically encountered at Travis AFB. Obtaining an adequate distribution of ZVI in the complex layered lithology would be difficult and limit the effectiveness of the technology. In more permeable lithologies, the technology can be effective in addressing a well defined, high-concentration source area within a plume, but these conditions do not exist at candidate sites at Travis AFB (Sites SS015, SS016, SD036, SD037, and DP039). A 2-year study of an injected ZVI PRB was conducted at Site DP039 beginning in 1998 (MACTEC, 2002). The injected PRB was not successful and demonstrated the difficulty of obtaining an adequate distribution of a ZVI mixture in the lithology found at Travis AFB.

The technology is not effective in addressing large-volume and/or low-concentration plumes because of the excessive number of injection points required.

- ZVI PRB – Potentially effective. A ZVI PRB is potentially effective at treating the chlorinated VOCs typical of groundwater contamination at Travis AFB. Chemical dechlorination is achieved using ZVI to abiotically degrade contaminants in a permeable trench filled with a ZVI mixture (typically ZVI and sand). The PRB is oriented perpendicular to the direction of groundwater flow and intercepts contaminated groundwater flowing along the local hydraulic gradient. Effectiveness can be limited by the need to key the bottom of the PRB into competent bedrock or other low-permeability lithology. Also, effectiveness can be limited by the requirement to establish hydraulic conditions such that contaminants flow through the treatment zone and not over or around the PRB. The technology has a relatively high failure rate at other sites across the nation.

- Heating – Potentially effective. Heating technology process options are potentially effective within a well defined, high-concentration source area plume such as those found at Sites SS015, SS016, SD036, SD037, and DP039. There are potential adverse impacts to human health and subsurface infrastructure associated with the thermal processes. The technology processes are not effective in addressing large-volume and/or low-concentration plumes.

- Groundwater treatment systems, with site-specific technology components including LGAC, air stripping, ThOx, and UV/Ox have proven effective during the period of interim remediation at Sites FT004, FT005, SS029, SS030, SD031, SD033, SD034, SS035, SD036, SD037, and DP039. Contaminated groundwater has been effectively treated using one or more of these processes at the CGWTP, NGWTP, and SBBGWTP.

  - LGAC – Effective. Groundwater treatment using LGAC demonstrated its effectiveness during the period of interim remediation. During 2010, LGAC replaced the combination of UV/Ox and LGAC at the existing CGWTP, and air stripping at the NGWTP and SBBGWTP, because of decreased influent concentrations. Treatment of groundwater using LGAC is ongoing.

  - Air stripping – Effective. Groundwater treatment using air stripping demonstrated effectiveness during the period of interim remediation. During 2010, LGAC replaced air stripping at the existing NGWTP and SBBGWTP because of decreased influent concentrations.

  - ThOx – Effective. ThOx demonstrated effectiveness at treating soil vapor with high contaminant concentrations associated with 2-Phase® extraction at Site SS016. However, the process was discontinued in 2010 as part of the Site SS016 IRA optimization within the OSA (bioreactor installation).

  - UV/Ox – Effective. Groundwater treatment using UV/Ox demonstrated effectiveness at treating groundwater with high contaminant concentrations during the period of interim remediation. During 2010, LGAC fully replaced UV/Ox at the existing CGWTP because of decreased influent concentrations.

- Stormwater drainage system discharge – Effective. Treated groundwater has been effectively discharged from the CGWTP, NGWTP, and SBBGWTP into the stormwater drainage system for over a decade of interim remediation.
- Beneficial reuse – Effective. Beneficial reuse of treated groundwater has been effective at Sites LF007C, FT004, and SD031 during the period of interim remediation. Treated water was conveyed to the on-base recreational Duck Pond. Current restrictions on the use of environmental restoration funds limit other possible beneficial reuse opportunities.

6.4.2.2 Implementability Criterion Screening

Overall, the technologies that best satisfy the Implementability criterion are those that have already been incorporated as components of the IRAs and are technologies that have already been implemented as optimization actions to the IRAs or as technology demonstrations. The screening of technology process options for each site against the criterion of Implementability are provided in Tables 6-7 and 6-9. Some key aspects of the Implementability screening are as follows:

- No Action – Site SS041 is already in NFRAP status. No Action is not likely implementable at other sites with groundwater contamination exceeding PCGs.
- Base Civil Engineer Work Request – Implementable. Base Civil Engineer Work Requests are already implemented at Travis AFB. Applicable to all on-base sites or the on-base portions of sites.
- Excavation permit – Implementable. Excavation permitting is already implemented at Travis AFB. Applicable to all on-base sites or the on-base portions of sites.
- Base General Plan – Implementable. The Base General Plan has already been developed and published online. Applicable to all sites.
- Easement purchase – Implementable. Off-base easements have already been purchased at Sites FT005, LF007C, and SS030.
- Vapor barrier – Implementable. Vapor barriers have already been installed in two (2) new buildings located in proximity to a chlorinated VOC groundwater contaminant plume. Under the provisions of the Base General Plan, installation of a vapor barrier will be required for any future building constructed in proximity to a chlorinated groundwater plume.
- Passive venting – Implementable. Passive venting systems have already been installed in two (2) new buildings located in proximity to a chlorinated VOC groundwater contaminant plume. Under the provisions of the Base General Plan, installation of a passive venting system will be required for any future building constructed in proximity to a chlorinated VOC groundwater plume.
- Alternative water supply – Implementable, but not currently required to replace domestic wells located within Sites FT005, LF007C, and SS030. Groundwater monitoring has not detected plume contaminants in any off-base domestic well.

- Groundwater monitoring – Implementable. Groundwater monitoring has already been implemented at all ERP sites with groundwater contamination under the GSAP.
- Alternative water supply – An alternate water supply to off-base residents is potentially implementable at Sites LF007C, FT005, and SS030. However, the need to provide alternative water supplies is based on ability of the current GET IRAs to prevent contamination from impacting off-base domestic wells.
- MNA – Implementable. MNA well networks have already been implemented for the plumes, or portions of plumes, at Sites FT004, LF006, LF007B, SD031, SD033, SD034, SS035, SD036, SD037, and DP039.
- EA – Implementable. The EA technology process option will utilize the same monitoring well networks at sites where a source control action is also taken, including Sites SS015, SD036, SD037, and DP039.
- Soil-bentonite slurry walls – Sites SS015, SS016, SD036, and SD037 have well defined, high-concentration source areas where a soil-bentonite slurry wall might be applicable. However, this disruptive technology is not evaluated as technically or administratively implementable because of the subsurface infrastructure (e.g., sanitary sewer pipelines, stormwater drainage pipelines, electrical supply conduits), and aboveground infrastructure (buildings, asphalt and concrete paving, roadways).
- Interceptor trench – An interceptor trench has some limited technical implementability at Sites SS015, SS016, SD036, and SD037 where well defined, high-concentration source areas exist. However, overall, this disruptive technology is not evaluated as technically or administratively implementable because of the subsurface infrastructure (e.g., sanitary sewer pipelines, stormwater drainage pipelines, electrical supply conduits), and aboveground infrastructure (buildings, asphalt and concrete paving, roadways). The technology has already been implemented at Site SS030 where the site conditions are more amenable to the technology.
- Groundwater extraction systems, with site-specific technology components including vertical and horizontal extraction wells, DPE wells, and a 2-Phase® extraction well have already been implemented at Sites FT004, FT005, SS029, SS030, SD031, SD033, SD034, SS035, SD036, SD037, and DP039.
  - Vertical extraction well – Implementable. Already implemented at Sites FT004, FT005, SS029, SS030, SD031, SD033, SD034, SS035, SD036, SD037, and DP039. For Site SS015, potential installation of a GET system would entail installation of new vertical extraction wells.
  - Horizontal extraction well – Marginally implementable. Although these wells are already in place within the TARA and OSA portions of Site SS016, their construction is difficult to carry out beneath an active airfield .
  - DPE well – Implementable. Already implemented at Sites FT004, SD031, SD033, SD034, SS035, SD036, SD037, DP039, and SD043.
  - 2-Phase® extraction well – Implementable. Already implemented within the OSA portion of Site SS016.

- Passive skimming – Implementable. Passive skimming for free product removal of Stoddard solvent has already been implemented at Site SD034. Floating product is not found at any other site.
- Bioslurping – Moderately implementable at Site SD034.
- Carbon substrate injection – Implementable. Injection of carbon substrate (i.e., EVO) has already been implemented in the well defined, high concentration contaminant source areas within Sites SS015, SD036, SD037, and DP039. EVO has already been injected at these sites as optimization actions taken in 2010. The technology is technically implementable within well defined, high-concentration source areas of a plume, but not within large-volume and/or low-concentration plumes. Refer to Section 6.5 for more detailed discussion of the carbon substrate injection technology.
- PRB (biobarrier) – Implementable. Could potentially be implemented for in situ treatment of chlorinated VOCs at Sites SS029 and DP039. Additional evaluations of the technical implementability of the technologies at Site SS029 will be conducted during 2011. The process is not technically feasible for large plumes requiring excessively long and/or deep construction. Also, the technical and administrative implementability at other sites is limited because of subsurface infrastructure (e.g., sanitary sewer pipelines, stormwater drainage pipelines, electrical supply conduits), and aboveground infrastructure (buildings, asphalt and concrete paving, roadways, taxiways, runways, and aircraft parking ramps).
- Bioaugmentation – Implementable. Bioaugmentation of native microbial populations with proprietary microbial consortia is implementable at Sites SS015, SS016, SD036, SD037, and DP039. This technology could be readily implemented to improve reductive dechlorination processes within EVO treatment zones and/or bioreactors. The need for bioaugmentation would depend on the demonstrated effectiveness through ongoing performance monitoring of native microbes at degrading contaminants.
- Phytoremediation – Marginally implementable. Phytoremediation has already been studied at Site DP039. However, planted trees are also likely to create habitat for birds, which would pose hazards to aircraft. Therefore, the administrative implementability of phytoremediation at Site FT004, and other sites near the flightline, is limited because of the adverse impacts to the military mission of Travis AFB.
- Bioreactor – Implementable. Bioreactors have already been implemented as an IRA optimization action and a demonstration project at Sites SS016 and DP039, respectively.
- Chemical oxidation – Low implementability. There are potential adverse impacts to human health and subsurface infrastructure from exothermic chemical processes associated with several but not all chemical oxidants. Also, the field team needs special training and special equipment to inject these materials into the subsurface. Materials transportation and storage issues also limit implementability. The technology can be technically implementable for a well defined, high-concentration source area under different lithologic conditions, but not under the conditions at Travis AFB. The technology is not implementable for addressing large-volume and/or low-concentration plumes. Refer to Section 6.5 for more detailed discussion of the chemical oxidation technology.

- ZVI injection – Limited technical implementability. Injection of a ZVI mixture using Ferox℠ or Z-Loy™ processes has limited technical implementability in the dense silt and clay lithology typically encountered at Travis AFB, resulting in an unequal and potentially inadequate distribution of ZVI into all subsurface soil layers. Implementation of the process will require specialized training and equipment.

- ZVI PRB – Limited technical implementability primarily because of the need to key the bottom of the PRB into competent bedrock or other low-permeability lithology. Technical implementability is also limited by the requirement to establish hydraulic conditions such that contaminants flow through the treatment zone and not over or around the PRB. The technology has a relatively high failure rate at other sites across the nation. Implementation of the process will require specialized training and equipment.

- Heating – Heating technology process options have limited technical implementability for well defined, high-concentration source area plumes such those as found at Sites SS015, SS016, SD036, SD037, and DP039. Additionally, there are potential adverse impacts to human health and subsurface infrastructure associated with the thermal processes. Implementability is also constrained by the limitations of the electrical power grid at Travis AFB.

- Groundwater treatment technologies, including LGAC, air stripping, and UV/Ox have already been implemented at the CGWTP, NGWTP, and SBBGWTP during the period of interim remediation.

  - LGAC – Implementable. Already implemented at the CGWTP. During 2010, LGAC replaced air stripping at the NGWTP and UV/Ox technologies because of decreased influent concentrations.

  - Air stripping – Implementable. Already implemented at the NGWTP and SBBGWTP. Air stripping was replaced by LGAC in 2010 because of decreased influent concentrations.

  - ThOx – Implementable. ThOx has already been implemented for treating soil vapor. However, the treatment system was discontinued in 2010 as part of the Site SS016 IRA optimization (bioreactor installation).

  - UV/Ox – Implementable. UV/Ox treatment has already been implemented at the CGWTP. UV/Ox was replaced by LGAC in 2010 because of decreased influent concentrations.

- Stormwater drainage system discharge – Implementable. Discharge of treated groundwater into the stormwater drainage system has already been implemented over a decade of interim remediation.

- Beneficial reuse – Implementable. Beneficial reuse of treated groundwater has already been implemented at Sites LF007C, FT004, and SD031 during the period of interim remediation. Treated water was conveyed to the on-base recreational Duck Pond. Current restrictions on the use of environmental restoration funds limit other possible beneficial reuse opportunities.

6.4.2.3 Relative Cost Criterion Screening

Overall, the technologies that best satisfy the Relative Cost criterion are those that have already been installed as components of the IRAs, have already been implemented as optimization actions to the IRAs, or have already been conducted as technology demonstrations. The capital costs for these technologies have already been incurred, although it is possible that additional funding could be required to fully implement a technology that started off as a demonstration project or treatability study. Future measureable costs will mainly include O&M costs. The expended capital costs for those technologies that are eventually selected as final remedies or parts of the final remedies will be retained to calculate the total cost of remediation for future close-out reports once remedial actions have successfully achieved cleanup.

The screening of technology process options for each site against the criterion of Relative Cost is provided in Tables 6-7 and 6-10. Some key aspects of the Relative Cost screening are as follows:

- No Action – No associated costs.
- Base Civil Engineer Work Request – Low relative costs. The work request process has already been developed at Travis AFB.
- Excavation permit – Low relative costs. The excavation permitting process has already been developed at Travis AFB.
- Base General Plan – Low relative costs related to maintenance of the plan on the Travis AFB intranet. The Base General Plan has already been developed and published online.
- Easement purchase – Low to moderate relative costs. Easements have already been purchased within Sites FT005, LF007C, and SS030. Potential future easements would have low to moderate relative costs.
- Vapor barrier – Low to moderate capital cost, low O&M cost for a potential new building. Retrofitting an existing building would have a moderate to high relative cost.
- Passive venting – Low to moderate capital cost, low O&M cost for a potential new building. Retrofitting an existing building would have a moderate to high relative cost.
- Alternative water supply – Moderate to high capital cost, low to moderate O&M cost. Potential future costs will depend on the source of an alternative supply of potable water for off-base residents. The alternative sources could include a high cost for connection to a remote municipal supply, moderate costs for installation of a new domestic well, or moderate cost for construction of a wellhead treatment unit.
- Groundwater monitoring – Moderate relative costs. Costs for conducting groundwater monitoring under the existing GSAP are ongoing. Annual costs are relatively moderate.
- Alternative water supply – Moderate to high. Potential costs for providing off-base residents an alternate water supply will be moderate to high depending on the nature of the alternative water supply. Costs for providing bottled water for human consumption will be relatively low. Costs for installing a wellhead treatment unit (e.g., LGAC) can be

moderate. Costs for installing new water potable water conveyance pipelines can be high.

- MNA – Costs for implementing MNA will be relatively low. Monitoring well networks have already been installed as components of the IRAs. Monitoring plans have already been developed and MNA groundwater monitoring is already being conducted under the GSAP. MNA well networks have already been implemented for the plumes, or portions of plumes, at Sites FT004, LF006, LF007B, SD031, SD033, SD034, SS035, SD036, SD037, and DP039. The EA technology process option will utilize the same monitoring well networks at sites where a source control action is also taken, including Sites SS015, SD036, SD037, and DP039. Although MNA and EA technologies are similar, MNA differs in that monitoring is conducted in the absence of active source remediation.

- EA – Similar to MNA, costs for implementing EA will be relatively low. Monitoring well networks have already been installed as components of the IRAs. Monitoring plans have already been developed, and MNA groundwater monitoring is already being conducted under the GSAP. Monitoring well networks have already been installed at Sites SS015, SD036, SD037, and DP039. Although MNA and EA technologies are similar, MNA differs in that monitoring is conducted in the absence of active source remediation. Conversely, EA monitoring is performed in conjunction with a source remediation. Monitoring costs for EA include additional source remediation performance monitoring wells that are not present under the program of MNA. Therefore, the cost of EA is relatively greater than the cost of only MNA.

- Soil-bentonite slurry walls – Costs associated with this technology would be high because of constructability issues related to the subsurface infrastructure (e.g., sanitary sewer pipelines, stormwater drainage pipelines, electrical supply conduits), and aboveground infrastructure (buildings, asphalt and concrete paving, roadways).

- Interceptor trench – Costs associated with this technology would be high because of constructability issues related to shoring requirements, the subsurface infrastructure (e.g., sanitary sewer pipelines, stormwater drainage pipelines, electrical supply conduits), and aboveground infrastructure (buildings, asphalt and concrete paving, roadways). The technology has already been implemented at Site SS030 where the site conditions, including a low density of subsurface infrastructure and shallow bedrock, are amenable to the technology.

- The relative cost of GET systems at Sites FT004, FT005, SS029, SS030, SD031, SD033, SD034, SS035, SD036, SD037, and DP039 will be low to moderate. Costs for installation of site-specific technology components including vertical and horizontal extraction wells, DPE wells, and a 2-Phase® extraction well have already been incurred as part of the IRAs. Future costs will mainly be related to O&M of these existing process options. An additional factor is the relatively high cost of GET system operation within the diffusion-dominated source areas at Sites SS015, SS016, SD036, SD037, and DP039.

  - Vertical extraction well – Relatively low cost. Already installed at Sites FT004, FT005, SS029, SS030, SD031, SD033, SD034, SS035, SD036, SD037, and DP039.

    - For Site SS015, potential installation of a GET system would entail costs for installation of extraction wells and conveyance pipeline. Treatment would be conducted at the existing CGWTP, but additional costs will be required for modifications to incorporate the new Site SS015 wells (e.g., electrical supply, pump controls, valves, and fittings). A dense network of underground pipes (i.e., sanitary sewer, storm drains) and surface infrastructure (Building 554, paving) will increase conveyance system construction costs.

- For Site LF007C, expansion of the existing network of vertical extraction wells will be low to moderate.

– Horizontal extraction well – Relatively moderate cost, depending on the location of the installation. Already installed within the TARA and OSA portions of Site SS016.

– DPE well – Relatively low cost. Already installed at Sites FT004, SD031, SD033, SD034, SS035, SD036, SD037, DP039, and SD043.

– 2-Phase® extraction well – Relatively low cost. Already installed within the OSA portion of Site SS016.

- Passive skimming – Low relative cost. Costs for conducting passive skimming for free product removal of Stoddard solvent at Site SD034 will be relatively low. Passive skimmers have already been installed at the site. Future costs will mainly be for O&M of the existing skimmers. Floating product is not found at any other site.

- Bioslurping – Moderate to high relative costs. Potential costs for implementing a more aggressive free product removal technology at Site SD034 would be relatively high.

- Carbon substrate injection – Moderate relative cost. Costs for injection of carbon substrate (i.e., EVO) within the contaminant source areas at Sites SS015, SD036, SD037, and DP039 have already been incurred. EVO has already been injected at these sites as optimization actions taken in 2010. Supplemental carbon substrate injection costs will also be relatively moderate. The main capital cost factors are the areal extent of injection, injection well spacing, and the mass of substrate required to maintain an effective treatment zone. The technology is cost-effective within well defined, high-concentration source areas of a plume. The technology is not cost-effective for addressing large-volume and/or low-concentration plumes. Refer to Section 6.5 for more detailed discussion of the carbon substrate injection technology.

- PRB – Moderate to high relative costs. Potential costs for installation of a PRB (biobarrier) at Sites SS029 and DP039 would be relatively high. However, long-term O&M costs could potentially be relatively low. The main capital cost factors are the required the length and depth of the PRB. Capital costs could also become excessive because of constructability issues related shoring requirements, subsurface infrastructure (e.g., sanitary sewer pipelines, stormwater drainage pipelines, electrical supply conduits), and aboveground infrastructure (buildings, asphalt and concrete paving, roadways, taxiways, runways, and aircraft parking ramps).

- Bioaugmentation – Moderate to high relative costs. The costs for bioaugmentation of native microbial populations with proprietary microbial consortia will be relatively moderate to high. The main capital cost factors are the areal extent of the carbon substrate injection well network and the amount of consortia required to maintain an effective treatment zone. This process option would be used to improve reductive dechlorination processes within EVO treatment zones and/or bioreactors at Sites SS015, SS016, SD036, SD037, and DP039. The cost would depend on the ability of the consortia to survive under Travis AFB environmental conditions and their demonstrated improvement over native microbes at degrading contaminants.

- Phytoremediation – Moderate relative costs. Costs for installing phytoremediation technology at Site DP039 have already been incurred. Additional capital costs for expanding the DP039 phytoremediation footprint would be moderate.

- Bioreactor – Moderate relative costs. Costs for installation of bioreactors at Sites SS016 and DP039 have already been incurred. Costs of installation of a bioreactor at Site SS015 will be moderate. The main capital cost factors are the required the length, width, and depth of the bioreactor excavation, with depth being the most significant cost factor. Capital costs can also become excessive because of constructability issues related to shoring requirements, subsurface infrastructure (e.g., sanitary sewer pipelines, stormwater drainage pipelines, electrical supply conduits), and aboveground infrastructure (buildings, asphalt and concrete paving, roadways, taxiways, runways, and aircraft parking ramps). The technology is cost-effective for addressing a well defined, high-concentration source area within a plume. The technology is not cost-effective for addressing large-volume and/or low-concentration plumes.

- Chemical oxidation – High relative costs. The diffusion-dominated lithology, relatively short persistence time of oxidant in the subsurface, and the high SOD at Travis AFB are the main capital cost factors. As an example, for the same sized treatment zone, chemical oxidation is estimated to cost almost 13 times more than treatment using EVO. The main reason for this is the large mass of oxidant that will be required to overcome the natural demand imposed by the soil. The diffusion-dominated lithology and relatively short persistence time of the oxidant would also require multiple reinjections to maintain the treatment process over the long term. The technology could be cost-effective for a well defined, high-concentration source area under different lithologic conditions, but not under the conditions at Travis AFB. The technology is not cost-effective for addressing large-volume and/or low-concentration plumes. Refer to Section 6.5 for more detailed discussion of the chemical oxidation technology.

- ZVI injection – High relative cost. Costs for injection of a proprietary ZVI mixture using the Ferox℠ or Z-Loy™ processes within the source areas of Sites SS015, SS016, SD036, SD037, and DP039 would be high. The main capital cost factors are the areal extent of injection, injection well spacing, and the mass of ZVI mixture required to create an effective treatment zone. Obtaining an adequate distribution of ZVI in the interbedded silt and clay alluvial lithology at Travis AFB would be difficult and likely require an excessive number of injection points. The technology could be cost-effective for well defined, high-concentration source areas under different conditions, but not under the conditions at Travis AFB. The technology is not cost-effective for addressing large-volume and/or low-concentration plumes.

- ZVI PRB – High relative cost. The main capital cost factors are the required length and depth of the PRB. The capital cost of the ZVI media is relatively high. Capital costs could also become excessive because of constructability issues related to shoring requirements, subsurface infrastructure (e.g., sanitary sewer pipelines, stormwater drainage pipelines, electrical supply conduits), and aboveground infrastructure (buildings, asphalt and concrete paving, roadways, taxiways, runways, and aircraft parking ramps). Costs also increase for deep installations because of the need to key the bottom of the PRB into competent bedrock or other low-permeability lithology.

- Heating – High relative costs. Potential costs for implementing a heating technology process option would be high. The technology could be cost-effective within well defined, high-concentration source area plumes such as those found at Sites SS015, SS016, SD036, SD037, and DP039. Additionally, potential adverse impacts to human health and subsurface infrastructure associated with the thermal processes would require additional costs to mitigate. The technology processes are not cost-effective in addressing large-volume and/or low-concentration plumes.

- Costs for implementing groundwater treatment technologies, including LGAC, air stripping, and UV/Ox have already been incurred during the period of interim remediation. During 2010, LGAC replaced air stripping and UV/Ox technologies because of decreased influent concentrations at the existing treatment plants. Future costs will be relatively low to moderate and related to O&M of the existing treatment systems (e.g., activated carbon replacement prior to contaminant breakthrough).

  – LGAC – Low relative cost. Already implemented at the CGWTP. During 2010, LGAC replaced air stripping at the NGWTP and UV/Ox technologies because of decreased influent concentrations and cost-effectiveness.

  – Air stripping – Moderate relative cost. Already implemented at the NGWTP and SBBGWTP. Replaced by LGAC in 2010 because of decreased influent concentrations and decreased cost-effectiveness.

  – ThOx – High relative cost. ThOx has already been implemented for treating soil vapor. However, the treatment system was discontinued in 2010 as part of the Site SS016 IRA optimization (bioreactor installation) because of technical incompatibility.

  – UV/Ox – High relative costs. UV/Ox treatment has already been implemented at the CGWTP. Replaced by LGAC in 2010 because of decreased influent concentrations and decreased cost-effectiveness.

- Stormwater drainage system discharge – Low relative cost. Costs for discharge of treated groundwater into the stormwater drainage system have already been incurred. Future costs will be relatively low and related to O&M of the existing systems.

- Beneficial reuse – Moderate relative cost. Costs for beneficial reuse of treated groundwater have already been incurred for Sites LF007C, FT004, and SD031. Costs for an underground pipeline to convey treated water to the on-base recreational Duck Pond have already been realized. Current restrictions on the use of environmental restoration funds limit other possible beneficial reuse opportunities.

6.4.2.4 Consideration of Green and Sustainable Process Options

Sustainability in remedial action systems is emerging as a consideration for evaluating environmental cleanup methods. Although not an evaluation criterion specified in the FS guidance (EPA, 1988), using sustainability as a factor in identifying and screening technology processes now warrants much more consideration than it did at the time of the NEWIOU FS and WABOU FS (Radian, 1996a; CH2M HILL, 1998a). Sustainable technologies, once considered innovative, have matured since the selection of the IRA technologies. The uncertainty that was once associated with these types of remediation technologies is now much reduced. Travis AFB is currently collecting performance data on these processes. Additional discussion is provided in following paragraphs.

The fundamental goal of a "green" remedial action is to ensure protectiveness of human health and the environment while decreasing the environmental footprint of the cleanup action itself. In the context of this FFS, "green" is used interchangeably with the terms "green cleanup," "greener cleanup," and "green and sustainable remediation," when referring to remedial technology processes that reduce energy demand, reduce greenhouse gas emissions, conserve water and other resources, and minimize the environmental impact of the final remedial action. Each of the "green" remedial technologies identified in this FFS satisfies the following basic requirements:

- Protects human health and the environment
- Complies with all laws and regulations
- Considers the anticipated land use of the site and avoids potential adverse impacts to the military mission of Travis AFB

Site-specific green and sustainable technology process options are highlighted in Tables 6-8 through 6-11. In summary, these process options include the following:

- MNA
- EA
- Carbon substrate injection (e.g., food grade EVO)
- PRB (e.g., organic biobarrier)
- Bioaugmentation
- Phytoremediation
- Bioreactor
- ZVI injection
- ZVI PRB

Descriptions of these technology processes are provided in Section 6.5.

Several of the green process options listed above have already been implemented as optimizations to the current IRAs. After a decade of interim remediation, Travis AFB is evaluating permanently discontinuing operation of the IRA GET systems at Sites FT004, LF008, SS016 (OSA), SD031, SD034, SD036, SD037, and DP039 and replacing them with more green and sustainable technologies. Long-term and energy-intensive groundwater extraction had become increasingly inefficient and the rate of reduction in contaminant concentrations had decreased. Therefore, beginning in 2008, more green and sustainable technology processes for remediation of solvent plumes were implemented. The performance of these IRA optimization actions is being evaluated for the remainder of the period of interim remediation. The green and sustainable aspects of the IRA optimizations include the following:

- Bioreactors – IRA optimization has included installation of in situ bioreactors within the OSA source area at Site SS016 and the source area at Site DP039. At both sites, solar powered pumps are used to circulate contaminated groundwater through an organic mulch bioreactor. Operation of energy-intensive 2-Phase® and DPE GET systems have been discontinued while the performance of the bioreactors is evaluated.
- Carbon Substrate Injection – At Sites SD036 and SD037, optimization of source area IRA GET systems has involved replacing this energy intensive approach with an in situ treatment approach using injection of food grade EVO. The EVO provides nutrients for native bacterial populations to anaerobically degrade contaminants. At Site DP039, another IRA optimization involved a linear injection of EVO (i.e., a PRB) to intercept and treat groundwater contaminants flowing with the natural hydraulic gradient. The performance of the EVO injections is currently being evaluated.

  At Site SS015, EVO injection was conducted as an optimization action because an assessment of MNA concluded that natural processes were not fully effective at the site.
- Phytoremediation – A phytoremediation treatability study concluded that planted trees could be used as a component technology for groundwater remediation at Site DP039 (Parsons, 2010).
- Rebound Studies – At Sites FT004, FT005, LF008, SD031, SD033, SD036, SD037, and SD043 energy intensive IRA GET systems have been shut down, either fully or partly, for rebound studies. If successful, then natural physical, chemical, and biological processes could be employed to remediate the remaining plumes, or portions of plumes. Data from the rebound studies are currently being collected and evaluated.
- At Site LF007C, the existing GET IRA uses solar-powered pumps to extract contaminated groundwater. Potential expansion of the GET system would also utilize solar power. Treated groundwater from the site is beneficially reused by pumping it to the on-base recreational Duck Pond to maintain the pond’s water level (seasonal).

6.4.3 Current Selection of Representative Process Options

A site-specific summary of representative process options is provided in Table 6-11. The process options identified in this table are a composite of those that best satisfied the evaluation criteria of Effectiveness, Implementability, and Relative Cost at each of the ERP sites (refer to Tables 6-8 through 6-10). Descriptions of these technology processes are provided in Section 6.5.

An overall summary of the technology and process option criteria screening results and the selection of representative process options under the GRAs and technology groups is provided in Table 6-12. This table summarizes the process options that are either screened out by one (1) or more of the evaluation criteria, retained as potentially applicable in the future, or selected as being a representative process option. Representative process options are assembled into remedial alternatives in Section 7.

A brief summary of the representative process options is provided in the following list:

- No Action
- Land Use Controls – Administrative Mechanisms – Base Civil Engineer Work Request
- Land Use Controls – Administrative Mechanisms – Excavation Permit
- Land Use Controls – Administrative Mechanisms – Base General Plan
- Land Use Controls – Monitoring – Groundwater Monitoring
- Removal – Free Product Removal – Passive Skimming
- In Situ Treatment – In Situ Physical, Chemical, and Biological Degradation – MNA
- In Situ Treatment – In Situ Physical, Chemical, and Biological Degradation – EA
- In Situ Treatment – In Situ Biological Treatment – Carbon Substrate Injection
- In Situ Treatment – In Situ Biological Treatment – Phytoremediation
- In Situ Treatment – In Situ Biological Treatment – Bioreactor
- In Situ Treatment – In Situ Physical Treatment – Extraction Wells
- Ex Situ Treatment – Physical Treatment – LGAC
- Disposal – Treated Groundwater Discharge – Stormwater Drainage System

The selection of representative process options provides more flexibility in the future, when the selected remedial action is designed. The specific process to be used at a particular site may not be selected until the remedial design phase (EPA, 1988).

Those process options not selected as representative are not eliminated from future consideration. For example, under the technology of in situ chemical treatment, chemical oxidation and ZVI PRB are not selected as representative processes, but this does not preclude them from being selected as part of the final remedial action in the pending Basewide Groundwater ROD. The full range of process options is provided in Tables 6-7 through 6-10.

6.5 Technology and Process Options Descriptions

Descriptions of groundwater remedial technologies and process options are provided in the following sections to support the screening of process options against the criteria of Effectiveness, Implementability, and Relative Cost. Refer to Tables 6-7 through 6-10 for the screening against the individual criterion.

6.5.1 No Action

The No Action option serves as a baseline against which other potential remedial alternatives are compared. This action is required for consideration by the NCP. It is evaluated to determine the risks to public health and the environment, if no additional actions were taken. No additional attempt is made to satisfy the RAOs, and no remedial measures are implemented; therefore, effectiveness is limited.

6.5.2 Land Use Controls

LUCs are currently in place or may be required at contaminated groundwater sites until residual contamination in the groundwater is at levels that allow for unlimited use and unrestricted exposure. The RAO of LUCs is to prevent the exposure of human or ecological receptors to unacceptable risks from soil, groundwater, and soil gas. To meet this RAO, Travis AFB will restrict the land use to industrial uses, prohibit the development of on-base water supply wells and consumption of contaminated groundwater, and restrict soil excavation and other subsurface work where a worker might encounter contaminated groundwater or vapors. The RAO is accomplished by detailing these restrictions in designated areas set forth in the Base General Plan, administrative measures, and signage. The administrative measures are the Base Civil Engineer Work Request procedures, the Base dig permit procedures, and the EIAP. Signs warn site visitors that soil disturbance, excavation, and removal is controlled. The EIAP, work request, and Base dig permit procedures restrict development, soil disturbance, and relocation during the interim period before remedial actions are implemented. These measures are in accordance with specific provisions of 22 CCR Section 67391.1 that have been determined by the Air Force to currently be relevant and appropriate requirements. Subsections (a), (b) and (e)(2) of 22 CCR Section 67391.1 provide that if a remedy at property owned by the federal government will result in levels of hazardous substances remaining on the property at levels not suitable for unlimited use and unrestricted exposure, and it is not feasible, as is the case with the Travis AFB's groundwater sites subject to LUCs, to record a land use covenant, then the ROD is to clearly define and include limitations on land use and other institutional control mechanisms to ensure that future land use will be compatible with the levels of hazardous substances remaining on the property. These limitations and mechanisms will be set forth in the Proposed Plan and ROD; they include annotating these restrictions in the Travis AFB General Plan and continuing to follow the review and approval procedures for any well drilling and ground-disturbing activities at groundwater sites with LUCs.

Regarding contaminated plumes off the installation, Travis AFB will monitor and enforce the terms and restrictions of its access and environmental response easements to ensure the landowners do not engage in water development or soil disturbing activities that would interfere with the government's rights under the easements.

Travis AFB has effectively implemented LUCs during the period of interim remediation to reduce the possibility of human exposure to contaminated groundwater. The LUC process option is commonly implemented in conjunction with other response actions. Although easily implemented, LUCs alone may not necessarily achieve the RAOs.

Travis AFB actively enforces LUCs at all the ERP groundwater sites described in this FFS. Annual LUC reports are prepared to describe the status of the LUCs being enforced at each site. The most recent of these is the final *Annual Report on the Status of Land Use Controls on Restoration Sites in 2010* (Travis AFB, 2011). These existing LUCs are described in Section 5.6 (Land Use Restrictions) of the WABOU Groundwater IROD (Travis AFB, 1999) and Section 5.1.2 (Institutional Actions) of the NEWIOU Groundwater IROD (Travis AFB, 1998).

6.5.2.1 Administrative Measures

The Base uses the following tools/administrative measures to promote awareness of and enforce established environmental access restrictions.

Travis AFB General Plan. The Travis AFB General Plan is a long-range planning tool that provides a framework for selecting the locations of future facilities needed to carry out the Base mission (Travis AFB, 2002b). The Component Plan Overview section of the General Plan describes the specific LUCs for each site, the reasons for the controls, and the areas where the controls are applied. It is also Web-based and accessible to all Base personnel that are authorized to use the Travis AFB local area network. For a LUC to remain protective, Base personnel must have access to information concerning its existence, purpose, and maintenance requirements. The General Plan provides the important information management to ensure that LUC management takes place and that the LUC's presence is effectively communicated.

Base Civil Engineer Work Requests. Another tool for LUC enforcement is the Air Force Form 332 (AF332) or Base Civil Engineer Work Request. This form must be submitted and approved before the start of any building project at Travis AFB. One (1) step in the approval process for this form is a comparison of the building site with all constraints that are described in the General Plan. The AF332 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.

Excavation Permits. Travis AFB also uses the 60th Air Mobility Wing Form 55 or Excavation Permit to enforce the residential development and soil and sediment disturbance restrictions. The requester submits the permit to the Civil Engineer Squadron for any project that involves mechanical soil or sediment excavation, such as trench digging for underground utilities or soil excavation for building foundations. If constraints involving soil disturbance or worker safety exist at the excavation area, the permit describes the appropriate procedures that workers must implement before the start of excavation to prevent unknowing exposure to contamination.

Both AF332s and excavation permits are subject to an evaluation under the EIAP, conducted pursuant to the National Environmental Policy Act, as promulgated for the Air Force in 32 CFR 989, et. seq. An Air Force Form 813 initiates the EIAP. The proponent of a proposed action is required to submit the AF332 or excavation permit with the Form 813 so that the appropriate environmental analysis of the proposed action and alternatives to the proposed action is accomplished prior to any construction activities. The EIAP works to ensure proposed construction sites take into account the constraints that are described the General Plan. The EIAP also ensures that all environmental factors, such as LUCs, are considered in the selection of locations for construction projects.

Easement Purchase. Three (3) solvent plumes have migrated off-base; they are associated with Sites LF007C, FT005, and SS030 and lie beneath private property. To manage the groundwater IRAs for these sites, Travis AFB purchased long-term easements that grant access rights to the United States, its representatives, agents, and contractors for the purpose of conducting environment responses on the properties. The easements restrict the landowners from interfering or abridging the exercise of the government's rights under the easement. The United States would view any residential development and any well drilling on the properties covered by the easements as interfering with the government's easement and would take appropriate action to prevent interference with its rights under the easement.

Solano County Ordinance, Chapter 13.10, makes it a misdemeanor to construct a well without a Solano County permit and requires the permit requester to notify the County of all wells within a 100-foot radius of the proposed well site. Given the number of monitoring and extraction wells that the government is operating on the easements, this ordinance ensures that Travis AFB will be notified of a landowner's well drilling plans. Additionally, Travis AFB's wells are frequently monitored, and any landowner actions potentially interfering with the easements would be observed. The landowner would be contacted to rectify the situation. To date, no such activities have been observed, and there are no known drinking water wells that draw water from the plumes, as confirmed by the frequent presence of base and contractor personnel in the off-base area as part of conducting the interim remedies. The Air Force will purchase additional easements in the event the off-base plumes remain contaminated at the expiration of the terms of the existing easements.

Throughout their duration, the easements restrict development of new wells and incompatible use of the water below the property.

6.5.2.2 Engineered Controls

In addition to the administrative mechanisms of LUCs, Travis AFB implements, or may potentially implement, physical engineering controls.

Vapor Barriers and Passive Venting Systems. In accordance with the Base General Plan, all new buildings constructed in proximity to an underlying groundwater plume are required to use a vapor barrier and passive venting system. These physical controls prevent vapors that may emanate from contaminated groundwater from accumulating in the breathing spaces within a building.

Alternative Water Supply. Although not currently required for the off-base residents at Sites FT005, LF007C, and SS030, an alternate water supply is a possible process option in the future. If groundwater contamination that originates from Travis AFB is found in an off-base, privately owned domestic well in the future, then that well could be taken out of service and an alternative source of potable water provided to the landowner. The alternate source could include connection to a municipal water supply, installation of a new well in an uncontaminated portion of the aquifer, or construction of a wellhead treatment unit at an existing domestic well.

Groundwater contamination originating from Travis AFB has not been detected in any off-base domestic water supply well.

6.5.2.3 Groundwater Monitoring

Groundwater monitoring is conducted under the ongoing Travis AFB GSAP to evaluate contaminant concentrations and trends. Annual GSAP reports are issued to provide detailed analytical results and interpretations of the data.

6.5.3 Containment

Groundwater containment is used to minimize, reduce, or eliminate the migration of contaminants from source areas and at the distal portions of plumes. The containment action is typically used in conjunction with other technologies to achieve the RAOs. During the period of interim remediation, no physical barriers were used as a component of the IRAs. Hydraulic barriers using groundwater extraction wells were established to contain plume migration.

6.5.3.1 Physical Barriers

Physical containment can include the use of vertical barriers, such as engineered sheet metal walls or soil-bentonite (i.e., clay) slurry walls that are placed over or keyed into a confining layer or less permeable material such as low permeability clay or bedrock. These containment systems can be effectively installed to a depth of approximately 100 feet bgs depending on the nature of the subsurface materials. Subsurface environments that contain large rocks, cobbles, or fractured bedrock can greatly limit the implementability and increase the cost of these containment systems (NRC, 1999).

Sheet piles and/or soil-bentonite slurry walls are often used in conjunction with an in situ treatment technology to physically direct the flow of contaminated groundwater into a treatment zone (e.g., a ZVI PRB).

6.5.3.2 Hydraulic Barriers

Containment of contaminated groundwater can be achieved hydraulically through the use of groundwater extraction wells or by constructing a trench to physically intercept groundwater flow.

Groundwater Extraction Wells. Containment of contaminated groundwater can also be achieved hydraulically, through the use of groundwater extraction wells, to reverse the local groundwater gradient and prevent contaminant migration. Hydraulic containment groundwater extraction systems have been in successful operation at Travis AFB during the period of interim remediation. More information on the site-specific GET systems is provided in Sections 2 and 3.

Some removal of contaminants is inherent with groundwater extraction implemented for the purpose of hydraulic containment, but contaminant mass removal is not a primary objective of the action. Extraction wells installed for the purpose of hydraulic containment are typically located within the lower concentration distal portions of a plume (i.e., the toe of the plume) and not within the high-concentration areas, which would allow for higher rates of mass removal.

Interceptor Trench. An interceptor trench is another type of hydraulic barrier. This technology process typically involves excavating a trench perpendicular to the direction of contaminated groundwater flow and allowing groundwater to flow into the excavation. The trench is usually backfilled with coarse gravel. One (1) or more pumps are installed in the trench to remove the groundwater that is collected. An interceptor trench has been successfully employed as part of the IRA for Site SS030 to intercept the flow of contaminated groundwater before it can flow off-base.

6.5.4 Removal

The GRA of removal refers to the physical extraction of contaminated groundwater from the aquifer.

6.5.4.1 Groundwater Extraction

Contaminant removal using groundwater extraction wells is a conventional method of achieving RAOs when used in conjunction with treatment technologies. Multiple GET systems have been in successful operation at Travis AFB for several years. As with the containment GRA, extraction wells have been successfully employed under the GRA of removal during the period of interim remediation. More information on the site-specific IRA GET systems is provided in Sections 2 and 3.

Source Area Groundwater Extraction. Groundwater extraction is used to hydraulically isolate and remove contaminant mass from source areas, or other areas of the plume with relatively higher concentrations, so that there is no longer a continuing source of contaminant migration into downgradient areas of the plume. At Travis AFB, source areas are usually classified as those portions of the plume with contaminant concentrations greater than or equal to 1,000 µg/L. However, those portions of a plume with concentrations less than 1,000 µg/L, but with relatively higher concentrations than the remainder of the plume, can also be referred to as a source area.

Conventional vertical or dual-phase wells can be used to accomplish groundwater extraction. Conventional extraction wells typically use submersible electric pumps or eductor pumps to remove groundwater from the saturated zone. DPE wells use groundwater pumps and air vacuum pumps to simultaneously extract groundwater and soil vapor from the vadose zone, capillary fringe, and saturated zone. Pumping may be continuous or pulsed to remove contaminants after they have been given time to desorb from the aquifer material and equilibrate with groundwater. Horizontal groundwater extraction wells have been used within the OSA and TARA portions of the Site SS016 plume, but these types of wells cost considerably more than vertical wells and are difficult to install at the optimum depth interval in the aquifer.

Mass Removal Effectiveness. Groundwater extraction for the purpose of contaminant mass removal can be moderately effective in the long term and is implementable at most ERP sites, but has relatively high capital costs and high O&M costs. Installation of groundwater extraction wells, and associated conveyance pipelines, is not readily implementable at some Travis AFB sites (e.g., Site SS016) because of active airfield operations and the adverse impacts to the military mission of the Base.

Groundwater extraction systems installed for the purpose of mass removal are relatively energy intensive and tend to become less cost-effective over time as contaminant concentrations become diffusion-dominated because of the interbedded dense silt and clay lithology that dominates at most Travis AFB sites. This diffusion-dominated environment will usually result in a long period of operation to achieve the RAOs and an inefficient system for contaminant mass removal. While the process of extracting contaminated groundwater through extraction wells conceptually appears to be a simple process, the success of this technology at meeting RAOs depends on several complex factors. These factors can be loosely grouped into characteristics of the contaminated aquifer (physical factors) and characteristics of the particular contaminants present (chemical factors). While groundwater extraction is an effective strategy for containing large volumes of contaminated groundwater, its effectiveness is diminished by high contaminant concentrations, the presence of DNAPLs, or low permeability geologic materials. These conditions are typical at the Travis AFB ERP sites and generally do not support the long-term application of source area GET to efficiently achieve RAOs.

The process of extracting groundwater requires a three (3) dimensional framework of interconnected pores to allow the contaminant molecules to move from their original positions into an extraction well. The primary aquifer properties that determine how efficiently this occurs include the tortuosity of the flow path, the presence of dead-end pore space, the heterogeneity of the aquifer material, and the anisotropy in permeability produced by the layered nature of sediments.

Tortuosity is a measure of how directly a molecule can move to an extraction well. If flow paths are tortuous, interstitial groundwater velocities are often reduced, and the probability increases that contaminants will interact with the aquifer solids or enter dead-end pore space. The presence of dead-end pore space has a significant impact on the length of time required for a contaminated aquifer to reach a particular cleanup goal. Contamination present in the free-flowing pores is removed relatively rapidly by the process of liquid advection or aquifer flushing. Alternatively, contamination present in the dead-end pore space must first flow out of the dead-end pores by molecular diffusion before it can be flushed into the extraction wells by advection.

Because molecular diffusion is driven solely by concentration gradients, the movement of contaminants out of the dead-end pores will not occur until late in the remediation process, when groundwater concentrations in the flushed pores have declined significantly. The driving force for diffusion will also decrease as concentrations drop, resulting in a slow decline in groundwater contaminant concentrations near the end of the remedial action. This process is partially responsible for the "tailing" of groundwater contaminant concentrations often seen in the late stages of a remedial action.

Heterogeneity and anisotropy can also affect the progress of a remedial action. Both of these factors, inherent in layered sediments typical at Travis AFB, can impede the progress of contaminant movement to an extraction well. In addition, the shape of the capture zone created by an extraction well in heterogeneous, anisotropic sediments may differ considerably from what would be predicted by groundwater modeling. As a result, careful monitoring of the aquifer response to pumping is required to ensure that the desired aquifer target volume is indeed captured.

The main chemical factors that influence the success of groundwater extraction are the molecular diffusion coefficient of the contaminant, the affinity of a particular contaminant to interact (adsorb) with aquifer solids, and the solubility of the contaminant. The molecular diffusion coefficient is a measure of the rate at which contaminants in dead-end pore space will migrate into free-flowing pores, as described above.

Adsorption occurs when a contaminant molecule has a higher affinity for the organic matter on the aquifer mineral grains than for the water flowing through the pores. The extent to which contamination will adsorb to the organic material is directly proportional to the concentration of the contaminant in the aqueous phase (dissolved in water). The mass of contamination adsorbed to organic material will remain until the aqueous phase contaminant concentration drops to low levels. The subsequent removal of contaminant mass from the organic carbon phase can be slow and will increase the time required for remediation.

DNAPLs. If a contaminant in liquid form is denser than water and reaches the water table after a release, it can remain in the environment as a DNAPL. Also, DNAPLs are more likely to persist when the contaminant, such as TCE, has a low solubility coefficient. DNAPLs greatly increase the time required for remediation, because they dissolve very slowly in groundwater, and a small mass can sustain dissolved contaminant concentrations above regulatory standards for a long time.

Despite the many borings drilled and wells installed at Travis AFB, DNAPL of chlorinated VOCs has not been directly observed. The presence of DNAPL is inferred from high dissolved-phase concentrations (greater than 3,000 µg/L for TCE). Several Travis AFB sites (e.g., Sites SS016, SD036, and DP039) have dissolved-phase contaminant concentrations that suggest the presence of DNAPL. This DNAPL can act as a secondary source of groundwater contamination by remaining as a residual liquid within the soil pore spaces, or it can diffuse into low permeability soil. The diffused DNAPL can also act a residual source, even though the resultant aqueous-phase concentrations are lower than typically expected near a source zone. Therefore, a more conservative concentration of 1,000 µg/L is considered indicative of the presence of DNAPL (Travis AFB, 1998).

6.5.4.2 In Situ Thermal Removal

Different methods and combinations of techniques can be used to apply heat to contaminated soil and/or groundwater in situ. The heat can destroy or volatilize organic chemicals. As the chemicals change into gases, they become more mobile and can be extracted via collection wells for capture and cleanup in an ex situ treatment unit. Thermal methods can be particularly useful for DNAPLs or LNAPLs. Heat can be introduced to the subsurface by electrical resistance heating, radio frequency heating, dynamic underground stripping, thermal conduction, or injection of hot water, hot air, or steam (EPA, 2011).

The main advantage of in situ thermal methods is that they allow soil to be treated without being excavated and transported, potentially resulting in significant cost savings; however, in situ treatment generally requires longer time periods than ex situ treatment, and there is less certainty about the uniformity of treatment because of the variability in soil and aquifer characteristics and because the efficacy of the process is more difficult to verify (EPA, 2011).

A treatability study is typically required to demonstrate the effectiveness of in situ thermal treatment (EPA, 2011).

Electrical Resistance Heating. Electrical resistance heating uses arrays of electrodes installed around a central neutral electrode to create a concentrated flow of current toward the central point. Resistance to flow in the soils generates heat greater than 100°C, producing steam and readily mobile contaminants that are recovered via vacuum extraction and processed at the surface. Electrical resistance heating is an extremely rapid form of remediation with case studies of effective treatment of soil and groundwater in less than 40 days. Three (3)-phase heating and six (6)-phase soil heating are varieties of this technology (EPA, 2011).

Hot Air Injection. Injection of hot air can volatilize organic contaminants (e.g., fuel hydrocarbons) in soils or sediments. With deeper subsurface applications, hot air is introduced at high pressure through wells or soil fractures. In surface soils, hot air is usually applied in combination with soil mixing or tilling, either in situ or ex situ (EPA, 2011).

Hot Water Injection. Injection of hot water via injection wells heats the soil and groundwater and enhances contaminant release. Hot water injection also displaces fluids (including LNAPL and DNAPL free product) and decreases contaminant viscosity in the subsurface to accelerate remediation through enhanced recovery (EPA, 2011).

Steam Injection. Injection of steam heats the soil and groundwater and enhances the release of contaminants from the soil matrix by decreasing viscosity and accelerating volatilization. Steam injection may also destroy some contaminants. As steam is injected through a series of wells within and around a source area, the steam zone grows radially around each injection well. The steam front drives the contamination to a system of groundwater pumping wells in the saturated zone and SVE wells in the vadose zone (EPA, 2011).

Radio Frequency Heating. Radio frequency heating is an in situ process that uses electromagnetic energy to heat soil and enhance SVE. The technique heats a discrete volume of soil using rows of vertical electrodes embedded in soil or other media. Heated soil volumes are bounded by two (2) rows of ground electrodes with energy applied to a third row midway between the ground rows. The three (3) rows act as a buried triplate capacitor. When energy is applied to the electrode array, heating begins at the top center and proceeds vertically downward and laterally outward through the soil volume. The technique can heat soils to over 300°C (EPA, 2011).

Thermal Conduction. Thermal conduction, also referred to as electrical conductive heating or in situ thermal desorption, supplies heat to the soil through steel wells or with a blanket that covers the ground surface. As the contaminated area is heated, the contaminants are destroyed or evaporated. Steel wells are used when the contaminated soil is deep. The blanket is used where the contaminated soil is shallow. Typically, a carrier gas or vacuum system transports the volatilized water and organics to a treatment system (EPA, 2011).

Vitrification. Vitrification uses an electric current to melt contaminated soil at elevated temperatures (1,600 to 2,000°C or 2,900 to 3,650°F). Upon cooling, the vitrification product is a chemically stable, leach-resistant, glass and crystalline material similar to obsidian or basalt rock. The high temperature component of the process destroys or removes organic materials. Vitrification can be conducted in situ or ex situ (EPA, 2011).

6.5.4.3 Free Product Removal

Free product removal involves physically removing free-phase liquids floating on the groundwater table by using bailers or skimmers (active or passive), or a combination of both. Travis AFB has successfully used these methods during the period of interim remediation to remove free-phase Stoddard solvent floating on the groundwater table at Site SD034.

A more aggressive and energy intensive process to remove free product is bioslurping. With this process option, free product, groundwater, and soil vapor are simultaneously removed from the subsurface using an applied partial vacuum. Travis AFB has successfully used bioslurping to remove floating jet fuel at several sites managed under the POCO program.

6.5.5 Treatment

The treatment GRA includes the following in situ and ex situ treatment technologies to achieve RAOs:

- In situ physical, chemical, and biological degradation
- In situ biological treatment
- In situ chemical treatment
- Ex situ treatment

Additional descriptions of these technologies and their associated process options are provided in the following subsections.

6.5.5.1 In Situ Physical, Chemical, and Biological Degradation

In situ physical, chemical, and biological degradation refers to the use of naturally occurring physical, chemical, and/or biological processes to achieve RAOs. These attenuation processes can work without or with human intervention. For this FFS, the attenuation process operating without human intervention is called MNA. For an attenuation process operating in conjunction with a human intervention (i.e., an enhancement), the process is called EA. An enhancement is typically a source control GRA such as containment, removal, or in situ treatment.

Monitored Natural Attenuation. MNA is generally a long-term response action that continues until cleanup levels have been attained. It includes monitoring to track the direction and rate of movement of the plume and natural attenuation processes. In this context, natural attenuation is defined as any combination of physical, chemical, or biological processes that, under favorable conditions, act *without human intervention* to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. At Travis AFB, MNA assessments have been successfully implemented at multiple sites during the period of interim remediation. The results of these MNA assessments are provided in the NAAR (CH2M HILL, 2010a).

MNA can be effective by itself or when implemented with other actions. Although MNA might not be effective at reducing groundwater contaminant concentrations in the short term, it could serve as a subsequent remedy after a certain threshold of groundwater cleanup has been achieved through an active remedy.

MNA is relatively easy to implement because only groundwater sampling, analysis, and reporting are required to monitor the cleanup progress.

Travis AFB currently conducts extensive long-term monitoring of groundwater for the purpose of assessing MNA. Groundwater collection and analyses are conducted under the GSAP.

Enhanced Attenuation. EA is a plume remediation strategy to achieve groundwater restoration goals by providing a “bridge” between source zone treatment and MNA and/or between MNA and slightly more aggressive methods. EA provides an organized, scientific, and disciplined approach to implementing treatment technologies at appropriate sites and at appropriate times. Various remediation technologies can be designed to reduce the source flux and/or increase the attenuation capacity/rate in the plume to ensure that the plume will stabilize and shrink in a suitable timeframe (Interstate Technology and Regulatory Council [ITRC], 2007).

Under EA, an intervention is used to improve the capacity of the aquifer to remediate distal plume contamination using physical, chemical, and biological processes. The intervention can include source area removal (e.g., excavation, thermal, vapor extraction), source area destruction (e.g., chemical or biological oxidation or reduction), and source area containment (ITRC, 2007).

The same physical, chemical, and biological processes are used under MNA, except no source plume action is taken to reduce the ongoing flux of contamination from a source area into the distal portions of the plume.

At sites where a contaminant source is present, focused treatment is typically required. These treatment processes can rely on removal (e.g., groundwater extraction), destruction (e.g., chemical oxidation or biological reduction), or containment (e.g., slurry walls). The objective of any source treatment process is to reduce the flux of contaminants into downgradient portions of the plume. Then, the natural attenuation processes in non-source portions of the plume can more successfully address this reduced influx of contaminants (ITRC, 2007).

The groundwater IRAs already in operation at Travis AFB demonstrate the viability of this treatment strategy. During the period of interim remediation, groundwater extraction wells have been used to hydraulically contain the higher concentration portions of several plumes. Concurrent assessments of MNA have been conducted in the portions of the plumes hydraulically downgradient of the extraction wells. After the contaminant loading from the source areas of the plumes was contained by the extraction wells, the downgradient portions of the plumes exhibited stable or declining concentrations (CH2M HILL, 2010a).

6.5.5.2 In Situ Biological Treatment

In situ biological treatment, or bioremediation, is an established remediation methodology for chlorinated solvents such as those found at Travis AFB groundwater sites. There are a number of terms that are used to describe the various approaches to bioremediation. Intrinsic biodegradation is the biological component of natural attenuation, which also includes advection and dispersion, sorption/desorption, volatilization, and dilution. When enhanced through the addition of carbon substrates, known as electron donors, to accelerate attenuation of chlorinated solvents, the process is often called enhanced bioremediation, enhanced reductive dechlorination (ERD), or biostimulation (Parsons, 2004).

Bioaugmentation involves the injection of a microbial amendment composed of non-native organisms known to carry dechlorination of the target chlorinated compounds to completion (Parsons, 2004).

Bioremediation relies on the degradation of organic compounds using microorganisms. In situ treatment involves the use of the subsurface environment to treat contaminants and eliminate the need for aboveground treatment. Field and scientific research has shown that microorganisms, including bacteria, fungi, and algae, are capable of biodegrading a wide variety of natural and man-made organic and inorganic chemicals. In groundwater environments, bacteria are the primary microorganisms responsible for the biological transformation and/or destruction of chemicals.

In anaerobic-reducing environments, the main biodegradation mechanism for highly chlorinated compounds such as TCE is reductive dechlorination. Generalized degradation pathways for chlorinated ethenes (e.g., TCE) and ethanes are shown on Figure 6-1. This process involves the sequential replacement of chlorine atoms on the solvent molecule with hydrogen atoms. The more chlorine atoms a compound has, the more susceptible it is to reductive dechlorination and the faster reductive dechlorination occurs. The chlorinated compound serves as an electron acceptor in these degradation reactions, while simple organic carbon compounds (e.g., alcohols, fatty acids, sugars, petroleum hydrocarbons, and other natural organic carbon substances) serve as electron donors. The complete sequential dechlorination of TCE proceeds via 1,2-DCE and vinyl chloride to ethene.

The main advantages of bioremediation are as follows:

- Applicable to a wide range of chlorinated contaminants
- Compatible with slow contaminant release from a diffusion-dominated lithology because many injected substrates can persist for 2 or more years
- Simple amendment delivery systems
- Minimal waste disposal
- Moderate cost for localized source treatment
- Only basic worker safety measures required during handling of amendments

The main disadvantages of bioremediation are as follows:

- Possibility of incomplete degradation, which can create an accumulation of breakdown products, primarily cis-1,2-DCE and vinyl chloride
- Amendment distribution difficulties in a heterogeneous aquifer
- High cost for large area treatment

Carbon Substrate Injection. Reductive dechlorination is a natural biological process, but degradation rates are typically low. To increase the rate of degradation by several orders of magnitude, an electron donor enhancement is employed. This enhancement to reductive dechlorination (i.e., ERD) typically involves adding an electron donor to the aquifer via injection wells or in PRBs (biowalls and bioreactors). The electron donor then stimulates natural microorganisms to produce an anaerobic-reducing environment. A summary of common electron donors is provided in Table 6-13.

Electron Donors. Electron donors are simple to complex carbon substrates that are used by various microorganisms as a food source. As the carbon substrates are metabolized, they stimulate fermentative biodegradation processes that result in the generation of hydrogen. The hydrogen is typically the electron donor used by dehalorespiring bacteria, which use the chlorinated solvents as electron acceptors. This microbial activity is responsible for creating anaerobic-reducing conditions that degrade chlorinated VOCs (CH2M HILL, 2004b).

As electron donor compounds are degraded, suitable electron acceptors are needed to balance the electron charge within the microorganism. This electron transfer is known as respiration. Depending on the electron acceptor used, the process is termed aerobic oxidation or anaerobic oxidation. Direct oxidation involves the use of the target substrate (contaminant) as an electron donor, along with the reduction of an electron acceptor. Cometabolism involves the metabolism of a primary substrate other than the target contaminant as an electron donor, with subsequent degradation of the target contaminant. Like humans, aerobic microorganisms use oxygen as the terminal electron acceptor, while anaerobic microorganisms use other electron transfer substrates like iron, manganese, nitrate, sulfate, carbon dioxide, and many chlorinated compounds. Most, if not all, of these reactions occur within the microorganisms.

Soluble Substrates. Commonly used carbon substrates include electron donors that are food ingredients or food industry byproducts such as vegetable oils, fructose corn syrup, molasses, milk lactate, and cheese whey waste. These substrates have been specifically formulated for in situ injections and are sold as proprietary Edible Oil Substrate (EOS®) (i.e., EVO), Regenesis' Hydrogen Release Compounds (HRC®, HRC-X®) and 3D Microemulsion (3DMe®), and Aventus' EHC™. A listing of typical carbon substrates is provided in Table 6-13.

Substrate Selection. The most suitable electron donors are regulatory acceptable substrates, that can be injected and mixed into the target groundwater remediation zone and that donate sufficient electrons when degraded. A number of electron donors have been used either in laboratory microcosms (bench testing) or in the field for pilot testing or for full-scale application of bioremediation.

Several factors influence the selection and use of electron donors for ERD or bioaugmentation purposes. These factors include, but are not limited to, the following:

- Concentrations of the groundwater contaminants
- Concentrations of competing electron acceptors (nitrate, iron, manganese, sulfate, and carbon dioxide)
- Stoichiometry of the reaction (i.e., the proportions of elements that combine during chemical reactions)
- Subsurface conditions (permeability, hydraulic conductivity, temperature, and pH)
- Desired longevity of the substrate in the subsurface

Substrate Persistence. Long half-life substrates such as EVO, HRC®, HRC-X®, 3DMe®, and EHC™ may persist in the subsurface and remain effective for several years. Other potential substrates, such as fructose, lactate, and cheese whey, have relatively short half-lives and typically persist for less than 1 year.

A summary of potential electron donors and half-lives is provided in Table 6-13. These donors are grouped into short and long half-life compounds. Generally, donors with fewer carbon atoms are more soluble and have a short half-life. Short half-life donors include lactate, fructose, acetate, ethanol, methanol, molasses, and cheese whey. These short half-life donors are used for systems in which multiple dosing is necessary, such as a recirculation approach. These donors can also be used in highly permeable aquifers, where soluble donors can be mixed to create the reducing conditions required for ERD. The main drawback of these donors is the short half-life, which usually requires multiple injections to facilitate complete reductive dechlorination.

Long half-life donors include EVO, polylactate esters (HRC® and HRC-X®), EHC™, and chitin. Long half-life donors can be used for one (1)-time injection, where donors may last up to 3 years or more. The benefit of the long-lasting donors is that O&M is minimized. This, however, must be balanced by providing enough electron donors for the demand. These long half-life donors break down more slowly than do the short half-life donors, so fewer hydrogen ions are available at any given time for reductive dechlorination. However, if concentrations of contaminants are relatively low or contaminants are being slowly released from the soil matrix, then one (1) or two (2) injections of a long half-life donor may be all that is required.

In some cases, the short half-life donors are mixed with the long half-life donors (such as lactate and emulsified oil). Short half-life donors provide a rapid decrease of high concentrations of contaminants. Long half-life donors address contaminants that may desorb from aquifer material over time.

Formation of Breakdown Products. Incomplete (i.e., stalled) reductive dechlorination has the potential to create an accumulation of intermediate compounds such as cis-1,2-DCE and/or vinyl chloride. The California Primary MCLs for these compounds are 6 and 0.5 µg/L, respectively. Reductive dechlorination can stall at the formation of these breakdown products for two (2) basic reasons:

- Insufficient electron donor in the target groundwater treatment zone
- Limited microbial consortia populations that are responsible for the complete dechlorination of chlorinated contaminants

Vinyl chloride is the most toxic potential byproduct of incomplete ERD. Within the anaerobic treatment zone created by EVO injection, creation of vinyl chloride is expected as part of normal reductive dechlorination processes. Full degradation of vinyl chloride within the treatment zone is expected as those processes continue through completion to form ethane, ethene, and methane. Outside of the treatment zone, the aquifer at Travis AFB is aerobic. Vinyl chloride readily degrades under aerobic conditions, so any vinyl chloride that migrates beyond the treatment zone will degrade aerobically shortly after entering the downgradient portion of the aquifer. This rapid degradation of vinyl chloride has been observed at the Site DP039 bioreactor demonstration. An effective anaerobic treatment zone is typically propagated up to 30 feet from an EVO injection point. Outside of this induced anaerobic zone, the Travis AFB aquifer becomes increasingly aerobic. The average groundwater flow velocity at Travis AFB is approximately 60 feet per year. The vinyl chloride solute velocity is approximately 45 feet per year. Therefore, vinyl chloride originating from incomplete ERD within the treatment zone will take less than a year to migrate into naturally aerobic groundwater conditions.

Carbon substrates are readily available, produced in large quantities, and relatively inexpensive. For example, EVO is a food-grade product that requires no special handling requirements and poses no exposure risk to workers.

In 2000, a field treatability study of vegetable oil injection to degrade chlorinated VOCs was conducted at Travis AFB Site SS015. Two (2) phases of partially hydrogenated soybean oil injection were conducted. Phase I was conducted during June 2000 when approximately 62 gallons of oil were injected. During Phase II, conducted in December 2000, approximately 165 gallons were injected. Although the study was cut short because of a military construction project at the site, the results were promising and demonstrated that suitable bacterial populations were present and reductive dechlorination was occurring at the site (Parsons, 2002).

Carbon Substrate Injection. Enhanced in situ bioremediation using carbon substrate injection involves adding an organic carbon substrate to the aquifer via injection wells. The substrate is injected into the groundwater to stimulate natural anaerobic microorganisms to produce an anaerobic-reducing environment. The microbial activity is responsible for creating the anaerobic-reducing conditions that degrade chlorinated VOCs. Carbon substrate is readily available, produced in large quantities, and relatively inexpensive.

Carbon substrates can be delivered with a series of injection wells and distributed via natural groundwater flow or by using an active injection well/extraction well recirculation system. A recirculation system provides for containment of chlorinated VOCs and re-injection of any excess carbon substrates, but uses more energy than a simple injection system.

Permeable Reactive Barrier. A PRB is defined as an in situ method for remediating contaminated groundwater that combines a passive chemical or biological treatment zone with subsurface fluid flow management. Treatment media may include ZVI, chelators, sorbents, and microbes to address a wide variety of groundwater contaminants, such as chlorinated solvents, other organics, metals, inorganics, and radionuclides. The contaminants are concentrated and either degraded or retained in the barrier material, which may need to be replaced periodically.

Under the technology of in situ biological treatment, a PRB, or biobarrier, is a potential treatment process option. This option involves installing a network of substrate injection wells or placing a trench filled with reactive materials across the flow path of the contaminant plume. Reactive materials used to install a PRB using injection wells typically include emulsified soybean oil or other edible oils. Using an excavated trench approach typically involves the placement of woodchips, pecan shells, cotton seed, chitin, limestone, and other composting material as backfill. With either option, a system of monitoring wells is needed to monitor biological and water quality treatment parameters.

In situ bioremediation using a PRB is moderately difficult to implement and usually has moderate to high capital costs. A depth to bedrock greater than about 40 feet will usually preclude trenching and placement of the PRB backfill. Also, installing organic materials (e.g., mulch) below the groundwater table with a traditional excavator is difficult because the organic material tends to float as it is placed in the trench. Injection wells are a more implementable option in this circumstance.

Travis AFB is currently conducting a demonstration of the ERD process via injection of EVO in a PRB configuration at Site DP039. This PRB was installed during 2010, and the collection of performance monitoring data is ongoing.

The main benefits of a PRB are that it does not require extraction and subsequent discharge of treated groundwater, and it can be more cost effective than ex situ treatment. PRB capital costs tend to run between 50 to 75 percent of ex situ treatment costs.

Bioaugmentation. Bioaugmentation involves the injection of a specialized consortium of chlorinated solvent-degrading bacteria. At some sites, the activity of the naturally occurring microorganisms is significantly reduced or inhibited because of site geochemical conditions. Bioaugmentation may also be applicable if incomplete dechlorination of TCE occurs regardless of the electron donors that are used. At some sites, conversion of TCE to cis-1,2-DCE occurs, but further degradation does not occur, even after addition of electron donors and nutrients. Under these conditions, bioaugmentation with selected chlorinated solvent-degrading consortia known to be capable of complete dechlorination to ethene may be effective (Major, 2001).

Bioaugmentation cultures for use at sites with TCE include the KB-1™ culture available from SiREM and the Bio-Dechlor INOCULUM™ culture available from Regenesis.

Sites with low permeability lithology may require closely spaced injection points to ensure adequate distribution of solution.

Bioaugmentation of the ERD optimization actions at Sites SS015, SS016, SD036, SD037, and DP039 is a possible performance enhancement measure, if the populations of native bacteria prove to be incapable of completely degrading chlorinated VOCs into harmless compounds, such as ethene. Performance monitoring at each of these sites is ongoing during the period of interim remediation.

Bioaugmentation typically has a moderate to high cost, depending mostly on the required number of injection points and the quantity of microbial consortia.

Phytoremediation. Phytoremediation is a bioremediation technology process option that involves the use of plants to remove groundwater through uptake and consumption to contain or control the migration of contaminants. A study of phytoremediation using approximately 2.24 acres of planted eucalyptus trees has been completed at Site DP039 (Parsons, 2010).

Stabilization of groundwater contamination is achieved through a combination of phytovolatilization, phytodegradation, phytoextraction, and rhizodegradation. Summary descriptions of these processes are provided as follows (SRNL, 2006):

- **Phytovolatilization –** Chlorinated VOCs are taken up by plants and discharged into the atmosphere during transpiration.
- **Phytodegradation –** The process in which plants metabolically degrade contaminants to a nontoxic form in roots, stems, and leaves. The resulting metabolic products include trichloroethanol, trichloroacetic acid, and dichloroacetic acid. Mineralization products are probably incorporated into insoluble products such as the components of plant cell walls.
- **Phytoextraction –** Plants extract contaminants from soil and store them in plant tissues.

- **Rhizodegradation –** Plants promote a soil environment suitable for microbes that can degrade or sequester contaminants. Under rhizodegradation, plants modify the environment of the root zone by releasing root exudates and secondary plant metabolites. Root exudates are typically photosynthetic carbon, low molecular weight molecules, and high molecular weight organic acids. This complex mixture modifies and promotes the development of a microbial community in the rhizosphere. These secondary metabolites have a potential role in the development of naturally occurring contaminant-degrading enzymes.

Phytoremediation has some advantages over more intrusive methods. Planting trees on a site may be preferable to more expensive technology processes. Trees can live for a long time. After the root systems are established, they can provide relatively inexpensive remediation over the life of the tree. One (1) of the major advantages is the non-invasive nature of establishing trees on a site. Trees provide a sustainable remediation process and are aesthetically pleasing.

There are also some disadvantages to using trees for remediation. For example, soil and groundwater contaminant concentrations must not exceed plant tolerances or they will not survive. Although trees live a long time, the rate at which they remove contaminants may be lower than for more active treatment processes. One (1) of the greatest limitations to the use of trees for phytoremediation of groundwater is the potential for contaminants to flow beneath the trees where the depth of the contaminated aquifer exceeds the maximum root depth (SRNL, 2006). Finally, trees tend to attract birds which are a liability around an active airfield, because Bird Air Strike Hazards (BASH) result in unsafe flight conditions and adversely impact the Base mission.

Performance monitoring of the Site DP039 phytoremediation area is ongoing through the period of interim remediation.

Bioreactor. In situ bioreactors are a maturing remedial technology process. Installation of an in situ bioreactor involves excavation of contaminated soil in a known source area and backfilling of the excavation void with a mixture of organic mulch and gravel. Contaminated groundwater is then pumped from an extraction well located within the source area, conveyed by pipe to the bioreactor, applied to the top of the bioreactor mulch mixture, and then circulated through bioreactor and source area aquifer. Groundwater that is circulated through the bioreactor is loaded with dissolved organic carbon as it passes through the mulch mixture. This organic loading then creates the anaerobic conditions around the bioreactor to stimulate VOC degradation via ERD.

A bioreactor demonstration project has been under way at Site DP039 since December 2008. After almost 2 years of operation, the bioreactor's performance is promising with TCE degradation within the bioreactor treatment area of over 90 percent (CH2M HILL, 2010h). Another bioreactor within the OSA source area of Site SS016 was installed during October 2010. Performance data from the OSA bioreactor has just started to become available.

The bioreactor mulch mixture promotes the long-term generation of dissolved organic carbon and provides a permeable and well mixed environment for ERD processes. Additives such as iron and gypsum can promote the formation of reactive iron sulfides for enhancing abiotic reduction. The mulch and gravel in a bioreactor also provide a uniform media for surrounding groundwater contaminants with organic substrates and bacteria. This uniformity is more difficult to achieve by standard injections of edible oils and other substrates, particularly in heterogeneous formations. However, a bioreactor cannot be cost-effectively installed at depths greater than about 25 feet bgs because of the difficulties associated with deep excavation (e.g., shoring, dewatering). Also, a bioreactor is most applicable at sites with well defined source areas with limited areal extent. It is generally not cost effective or technically implementable to excavate relatively large source areas where the mechanism of contaminant release is uncertain. In these situations, a different approach must be taken, such as edible oil or chemical oxidant injection to reach the deeper and more widespread contamination.

Bioreactor installation includes an extraction well (or trench) with a pumping system to collect and recirculate groundwater between the bioreactor and source area aquifer. This recirculation distributes organic substrate below and downgradient of the bioreactor and increases the residence time for promoting more complete dechlorination. Solar-powered pumps are well suited for low-yield aquifers to provide a renewable energy source.

Bioreactors have several potential advantages over other technologies. The initial excavation of highly contaminated source area soil removes the worst contamination and reduces the potential for future leaching into groundwater. After installation in the excavation void, the bioreactor circulates organic-rich and reduced groundwater through both unsaturated and saturated soils and has the potential to treat both contaminated soils and groundwater in a source area. The recirculation of contaminated groundwater through the bioreactor increases the average treatment residence time resulting in more complete dechlorination of TCE daughter products. The mixed culture of *Dehalococcoides* bacteria required for complete dechlorination is much easier to maintain or augment within a small bioreactor than it is throughout a larger heterogeneous aquifer.

Some of the dissolved organic carbon and TCE daughter products will move downgradient of the bioreactor. However, the downgradient VOC plume is already contaminated at relatively high concentrations and the movement of lesser concentrations of daughter products into the downgradient plume will not impact the risk or size of the plume. The vinyl chloride daughter product is more mobile and toxic than its TCE parent compound. However, vinyl chloride is rapidly oxidized under the natural aerobic conditions found at Travis AFB. Therefore, if reductive dechlorination is incomplete, then vinyl chloride is not likely to further degrade downgradient water quality. Minimal vinyl chloride formation (< 2 µg/L) has been observed at the Site DP039 bioreactor.

6.5.5.3 In Situ Chemical Treatment

In situ chemical treatment can also potentially be used to treat contaminated groundwater at Travis AFB. The following subsection provides descriptions of these processes. Detailed descriptions of these technologies are available in multiple references (ITRC, 2005; EPA, 2006; Environmental Security Technology Certification Program, 2008).

Chemical Oxidation. ISCO, or chemox, involves the introduction of a strong oxidizing agent into a high contaminant concentration zone or suspected DNAPL zone to chemically destroy contaminants in the subsurface. The oxidizing agent is applied to the subsurface via injection wells or direct-push probes.

Chemical oxidation is a process in which the oxidation state of a substance is increased. In general, the oxidant is reduced by accepting electrons released from the transformation (i.e., oxidation) of reactive compounds. The main objective of chemical oxidation is to transform contaminants into other compounds that are harmless. For example, oxidation of TCE may produce reaction byproducts that include dichloroacetaldehyde and dichloroacetic acid, compounds with lower toxicity (EPA, 2006).

Using ISCO, numerous reactions potentially occur, including acid/base reactions, adsorption/desorption, dissolution, hydrolysis, ion exchange, oxidation/reduction, and precipitation. A wide array of reactants and conditions influence reaction rates and pathways, which vary from site to site. Many reaction intermediates are never identified (EPA, 2006).

The main advantages of ISCO remediation include the following:

- Rapid reactions – measurable contaminant reductions in weeks or months
- Applicable to a wide range of contaminants, particularly known sources with high concentrations
- Potentially feasible for aqueous and non-aqueous phases of contaminants
- Enhanced desorption and DNAPL dissolution
- Potential enhancement of post-oxidation microbial activity and natural attenuation
- Minimal waste generation
- Moderate cost for localized source treatment
- Compatible with post-treatment MNA

The main disadvantages of remediation using ISCO include the following:

- Unproductive oxidant consumption (e.g., by natural organic matter) resulting from natural oxidant demand – significant losses of oxidants may occur as they react with soil/bedrock material rather than contaminants
- Oxidant distribution difficulties in a heterogeneous aquifer – contamination in low permeability soil may not be readily contacted and destroyed by the oxidants
- Limited persistence because of fast reaction rates (i.e., short half-life)
- Possible rebound of dissolved contaminant concentrations in the weeks or months following chemical oxidation treatment because oxidants are short-lived and unable to address slow chemical desorption from the soil
- Possible need for multiple reinjections after short-lived oxidant is consumed
- Potential soil permeability reduction – can cause clogging of aquifer through precipitation of minerals in the pore spaces
- High cost for large-area treatment
- Additional worker safety measures required during handling of strong chemical oxidants

- Potential exothermic reactions and damage to subsurface utilities within the injection area.

The performance of ISCO remediation is primarily dependent on the contact achieved between the oxidant and the contaminants, which in turn is controlled by the distribution of contaminants and other site-specific conditions (e.g., lithology). Oxidation technologies have the potential for achieving significant mass destruction of organics in the subsurface; however, the results of field and laboratory work indicate that complete removal of contaminants may not be achieved with these technologies even under optimal conditions (National Research Council, 2004).

Oxidants. Several oxidants are commonly used for ISCO of groundwater contaminated with chlorinated VOCs. Hydrogen peroxide, Fenton's Reagent™, ozone, persulfate, and permanganate have shown promising results at a number of Superfund sites, leaving almost no mass remaining after treatment. Descriptions of the most commonly employed oxidants are provided in the following list (EPA, 2010):

- **Hydrogen peroxide.** While catalysts can be added to increase oxidation potential, hydrogen peroxide can be used alone to oxidize contaminants. Peroxide oxidation is an exothermic reaction that can generate sufficient heat to boil water. The generation of heat can assist in making contaminants more available for degradation, as well as allowing them to escape to the surface. With its high reaction and decomposition rates, hydrogen peroxide is not likely to address contaminants found in low permeability soil. Solid peroxides (e.g., calcium peroxide) in slurry form moderate the rate of dissolution and peroxide generation, thereby allowing a more uniform distribution.

- **Fenton's Reagent™ (catalyzed hydrogen peroxide).** Fenton's Reagent™ uses hydrogen peroxide in the presence of ferrous sulfate to generate hydroxyl radicals, which are powerful oxidants. The reaction is fast, releases oxygen and heat, and can be difficult to control. Because of the fast reaction, the area of influence around the injection point is small. In conventional application, the reaction needs to take place in an acidified environment, which generally requires the injection of an acid to lower the treatment zone pH to between 3 and 5. The reaction oxidizes the ferrous iron to ferric iron and causes it to precipitate, which can result in a loss of permeability in the soil near the injection point. Over time, the depletion of the ferrous ion can be rate-limiting for the process. Chelated iron can be used to preserve the iron in its ferrous state at neutral pH, thus eliminating the acid requirement. The byproducts of the reaction are relatively benign, and the heat of the reaction may cause favorable desorption or dissolution of contaminants and their subsequent destruction. It also may cause the movement of contaminants away from the treatment zone or allow them to escape to the atmosphere. There are safety concerns with handling Fenton's Reagent™ on the surface, and the potential exists for violent reactions in the subsurface. In many cases, there may be sufficient iron or other transition metals in the subsurface to eliminate the need to add ferrous sulfate.

- **Ozone.** One (1) of the stronger oxidants, ozone can be applied as a gas or dissolved in water. As a gas, ozone can degrade a number of chemicals directly in both the dissolved and pure forms, and it provides an oxygen-rich environment for contaminants that degrade under aerobic conditions. It also degrades in water to form radical species that are highly reactive and non-specific. Ozone may require longer injection times than other oxidants, and vapor control equipment may be needed at the surface. Because of its reactivity, ozone may not be appropriate for slow diffusion into low-permeability soil.

- **Persulfate.** Sodium persulfate is a strong oxidant with a higher oxidation potential than hydrogen peroxide and a potentially lower SOD than permanganate or peroxide. Persulfate reaction is slow unless placed in the presence of a catalyst, such as ferrous iron, or heated to produce sulfate free radicals that are highly reactive and capable of degrading many organic compounds. At temperatures above 40°C, persulfate becomes especially reactive and can degrade most organics (Block et al., 2004). Like Fenton's Reagent™, the ferrous iron catalyst (when used) will degrade with time and precipitate (EPA, 2006).
- **Permanganate.** Sodium or potassium permanganate is a non-specific oxidizer of contaminants with low standard oxidation potential and high SOD. It can be used over a wide range of pH values and does not require a catalyst. Permanganate tends to remain in the subsurface for a long time as compared with other oxidants (i.e., several months), allowing for more contaminant contact and the potential of reducing rebound. As permanganate oxidizes organic materials, manganese oxide forms as a dark brown to black precipitate. During the treatment of large bodies of NAPL with high concentrations of permanganate, this precipitate may form a coating that reduces contact between oxidant and NAPL. The extent to which this reduction negatively affects contaminant oxidation has not been quantified. Potassium permanganate has a much lower solubility than sodium permanganate and generally is applied at lower concentrations. Commercial-grade permanganates may contain elevated concentrations of heavy metals, and they may lower the pH of the treated zone (EPA, 2004). If bioremediation is planned as a polishing step, permanganate will have an adverse effect on microbial activity and may cause a change in microbe distribution. This effect is generally transitory. Also, there is some evidence that permanganates may be inhibitory to *Dehalococcoides ethenogenes,* the microbial species that completely dechlorinates PCE and TCE (Hrapovic et al., 2005).
- **Zero-valent Iron.** ZVI can be used to reduce concentrations of chlorinated compounds via abiotic reductive dechlorination. Several different commercially available substrates (e.g., Ferox℠, Z-Loy™) can be applied through means of injection, such as installed injection wells or direct push injection rods. Successful ZVI implementation requires direct contact with the chlorinated contaminant, either in the dissolved phase or in DNAPL. Injected ZVI will last typically longer than other ISCO reagents (e.g., ozone, permanganate), and typically requires reinjection after 5 to 7 years. Typical implementations of ZVI involve pneumatic fracturing of the subsurface to increase contact between the injected ZVI slurry and contaminant mass. Some formulations (Z-Loy™) of injectable ZVI include propylene glycol to prevent formation of iron hydroxides, iron oxides, and hydrogen gas prior to injection into the subsurface.

A summary comparison of the potential oxidants is provided in Table 6-14.

As with bioremediation substrates, chemical oxidants are typically delivered to the subsurface using a series of injection wells and distributed via natural groundwater flow or by using an active injection well/extraction well recirculation system. A recirculation system provides for containment of chlorinated VOCs and re-injection of any excess oxidant, but uses more energy than a simple injection system.

Soil Oxidant Demand. SOD refers to the consumption of the oxidant by naturally occurring reactive soil constituents. Total oxidant demand includes both the consumption by the soil constituents and the target contaminants.

A wide range of naturally occurring reactants, other than the target VOCs, also react with chemical oxidants and impose a background oxidant demand. This background oxidant demand reduces oxidant efficiency and is often greater than the demand imposed by the contaminants. The non-contaminant reactants mainly include organic matter and reduced chemical species (e.g., ferrous, manganous, and sulfidic species). A high background oxidant demand results in a required high mass of oxidant, reduced contaminant breakdown efficiency, and increased costs. A generalized summary of permanganate SOD ranges is provided in the following list:

- Low: SOD ≤ 3 gram (of permanganate) per kilogram (of soil) (g/kg)
- Medium: 3 g/kg < SOD ≤ 15 g/kg
- High: 15 g/kg < SOD < 30 g/kg (or greater, depending on soil characteristics)

Oxidant Persistence. Chemical oxidants are relatively short-lived after injection into an aquifer. A graphical depiction of typical oxidant decomposition rates is shown on Figure 6-2. In general terms, the relative persistence of the various oxidants is as follows:

permanganate > persulfate > ozone > peroxide

Decomposition rates for commonly used oxidants such as hydrogen peroxide, persulfate, ozone, and permanganate usually range from 5 to 10 percent per day, or greater. At these rates, even the most persistent chemical oxidant (permanganate) is entirely consumed within approximately 3 to 5 months. Reinjection of the oxidant is then required if untreated groundwater contamination remains.

Oxidant Selection. Selection of an oxidant depends on several basic conditions:

- **Geologic conditions**
  - In advection-dominated, high permeability aquifers, any oxidant could potentially work.
  - In diffusion-dominated, low permeability aquifers, longer lasting permanganate and persulfate could possibly work.
- **Groundwater velocity**
  - Slow – permanganate and persulfate are best.
  - Fast – any oxidant could possibly work.
- **Geochemistry**
  - Oxidant demand – permanganate and persulfate are best.
  - High dissolved metals – potential precipitation issue using permanganate and ozone.

Travis AFB Site Conditions. The following subsections briefly describe the geology and groundwater conditions relevant to the selection of an in situ groundwater treatment technology at Travis AFB. Additional discussion is provided in Section 3.

Geology. The large majority of surface deposits at Travis AFB are unconsolidated alluvial sediments ranging in thickness from 0 to about 70 feet. The alluvium has relatively low permeability and is composed primarily of silt and clay with minor amounts of sand. The sand units occur as small heterogeneous lenses that are laterally discontinuous. The alluvium is predominantly fluvial in origin; however, some colluvium eroded from bedrock uplands may also be present.

The alluvium was carried in several streams that have migrated laterally across the Base. Coarse sands and gravels are deposited in the streambed and immediately adjacent to the stream levee; finer silts and clays are deposited away from the stream during flood events. Consequently, the discontinuous sand lenses are usually elongated parallel to streams and are contained in an overall matrix of fine-grained silts and clays. These discontinuous permeable zones are preferential pathways that create anisotropic groundwater flow in the horizontal plane.

The alluvium is underlain by bedrock consisting of semi-consolidated to consolidated sedimentary units, primarily sandstone and shale. The top of the bedrock unit is weathered to varying degrees and varying thickness. Consequently, bedrock generally becomes increasingly competent with depth. The composition of the most weathered portions reflects the composition of the parent material (sand and silt) and therefore may have similar permeability to the overlying alluvium.

Groundwater Characteristics. Groundwater at Travis AFB is found under unconfined or semi-confined conditions and flows in a predominantly horizontal direction. The average groundwater flow velocity at Travis AFB is approximately 60 feet per year, but can vary depending on the site lithology.

The aquifer should be viewed as a single leaky and heterogeneous system of unconsolidated alluvium, as opposed to one with multiple and distinct aquifers. The sediments consist primarily of fine-grained silts and clays with interbedded sand lenses that do not correlate well from one location to another. The depth to bedrock is fairly shallow (i.e., a few feet to tens of feet); thus, the saturated thickness of the aquifer is small compared with the length of groundwater contaminant plumes. It is not usually possible to predict with confidence where the more permeable sand lenses may be encountered or interconnected.

ERD Study Projects. Travis AFB is currently evaluating the technical implementability of ERD via EVO injection within the contaminant source areas at Sites SS015, SD036, SD037, and DP039. From June through November 2010, EVO was injected into the aquifer at each of these sites. Quarterly performance monitoring of the EVO treatment will be conducted during the remainder of the period of interim remediation to obtain data necessary to demonstrate the viability of ERD at Travis AFB sites.

The performance of the Site DP039 bioreactor is also relevant to the demonstration of in situ bioremediation technology and ERD processes at Travis AFB. Operation of this bioreactor since December 2008 has demonstrated that complete reduction of TCE to methane using ERD is taking place under site-specific conditions (CH2M HILL, 2010h, 2010j, 2010k). TCE reductions of over 90 percent have been observed in the first 16 months of the bioreactor demonstration with minimal vinyl chloride formation. Although the means of inducing anaerobic degradation conditions in the aquifer differ between the bioreactor and EVO injection, the biotransformation processes within the treatment zones are the same.

Another in situ bioreactor was constructed at the OSA within Site SS016 in September 2010. Performance monitoring of this bioreactor is ongoing.

Soil Oxidant Demand Studies. SOD at Travis AFB is high. During April, July, and November 2010 site characterization efforts, soil samples for a screening-level analysis of permanganate SOD were collected at Sites SS015 and SD036. The screening analyses were conducted to provide information on the amount of permanganate that would be consumed by natural occurring reactive constituents. The April and July analytical results indicate that the SOD is high at both sites, with SOD greater than 30 g/kg. The November analyses indicated an even higher SOD with results greater than 60 g/kg. These SOD data strongly suggest that chemical oxidation is not workable under the lithologic conditions at Travis AFB. An excessive mass of oxidant would be required to overcome the natural consumption by the aquifer soil.

Sites SS015 and SD036 were selected for analysis of SOD because both sites are candidates for source zone remediation using ISCO processes. Additionally, the two (2) sample sites were used to address the natural heterogeneity of the aquifer materials and obtain representative results from non-contiguous locations.

Comparison of ERD and ISCO Technology Process Options. ERD using EVO as the injected substrate is the preferred process option for source zone treatment at Travis AFB. Both ERD and ISCO are applicable to the kind of chlorinated VOC, primarily TCE, groundwater contamination found at Travis AFB. The main characteristic that distinguishes the two (2) technologies is the greater compatibility of ERD with Travis AFB subsurface conditions. Summary comparisons of the attributes of EVO and ISCO technologies are provided in Table 6-15. Additional rationale is provided in the following discussion.

Establishing long-term contact between the contamination and the treatment amendment is the key criterion for success of an in situ treatment process. Amendments must first be delivered to the contaminated zone and then contact must be maintained with the contamination until it is degraded. The diffusion-dominated silt and clay lithology typically encountered at Travis AFB is more compatible with the long half-life organic substrates (e.g., EVO and HRC®) than relatively short-lived chemical oxidants. Contaminants will be released from these soil types slowly and require a longer lasting treatment process.

At Travis AFB, aquifer heterogeneity and low permeability make adequate distribution of relatively short-lived oxidant solutions difficult and limit their overall effectiveness. The persistence of the permanganate and persulfate is relatively short, on the order of months, before the oxidant is consumed and re-injection is required. Other potential oxidants, such as ozone and Fenton’s Reagent™, are less persistent in the subsurface, with typical half-lives of hours to days. The short-term persistence of oxidants is not compatible with the slow, diffusion-dominated release of contaminants from the silts and clays that are prevalent at the Base.

Treatment using ISCO would probably result in a quick reduction of VOC concentrations where it could be fully contacted with the contamination. This would be mostly within the permeable (i.e., sandy) zones of the aquifer. An effective oxidant could be delivered to sand seams, and VOC concentrations would quickly be reduced. However, rebound of dissolved contaminants is likely because of the diffusion of VOCs from the less permeable silts and clays surrounding the thin sandy zones. ISCO reagents would not persist long enough to address this rebounding contamination. Multiple reinjection of oxidant would be required to maintain the treatment process.

Another important drawback of ISCO at Travis AFB is the high oxidant demand of the soil. The bench scale studies described above indicate that naturally occurring compounds will compete with chlorinated VOCs for oxidant and will impose a significant background oxidant demand. Excessive quantities of oxidant would be required to overcome this natural oxidant consumption before the contamination could be effectively treated. The cost-effectiveness of ISCO would be greatly decreased even for a limited source zone treatment.

A combination of factors, including using short-lived chemical oxidants in the diffusion-dominated lithology at Travis AFB and the resultant likelihood of contaminant rebound, make ISCO a less effective technology than a bioremediation approach using EVO injection. This explains why ISCO has not been previously used in field demonstrations at Travis AFB.

Zero-valent Iron Slurry Injection. Injection of a ZVI slurry mixture can be used to reduce concentrations of chlorinated compounds via abiotic reductive dechlorination. Commercially available processes include the Ferox℠ process and Z-Loy™. Either process can be implemented using an area treatment configuration or as a PRB to intercept a migrating plume.

Ferox℠ is an in situ chemical treatment process that involves pneumatic fracturing of the subsurface followed by injection of a ZVI powder suspended in a slurry mixture. The Ferox℠ process can be effective at treating chlorinated VOCs if good distribution of the slurry is achieved. The use of ZVI for remediation of chlorinated VOCs is well documented. The mechanism for treatment was first identified by researchers at the University of Waterloo in 1989. The process appears to be abiotic reductive dechlorination of chlorinated VOCs, with the iron serving to lower the solution redox potential and being the electron source in the reductive dechlorination reaction. Reinstallation of the ZVI slurry is typically required after 5 to 7 years. Costs are moderate to high.

Z-Loy™ is another ZVI substrate engineered for injection, much like Ferox℠. Using Z-Loy™, a sub-micrometer ZVI powder is suspended in a propylene glycol solution to prevent premature reaction of the ZVI prior to injection. The process of remediation with Z-Loy™ is the same as that of Ferox℠ described above. Similar to the Ferox℠ process, in situ treatment costs with Z-Loy™ are relatively high.

Zero-valent Iron Permeable Reactive Barrier. In situ chemical treatment using a ZVI PRB has been used at hundreds of CERCLA sites to treat and contain groundwater containing chlorinated VOCs. This process is typically implemented by excavating a trench perpendicular to the direction of groundwater flow and placing a mixture of ZVI and sand in the trench. Once ZVI PRB is installed, contaminated groundwater flows through the wall under the natural hydraulic gradient and no pumping or other aboveground operations are required. The ZVI is permeable and creates geochemical conditions that rapidly degrade the contaminants. Innovative installation methods, such as jet grouting of the ZVI mixture, have previously been attempted at Travis AFB Site DP039 but were not successful.

Typical ZVI PRB installations use a funnel-and-gate configuration, a continuous wall configuration, or a more complex system of multiple gates and walls. In a funnel-and-gate scenario, relatively impermeable walls are used to physically direct the flow of groundwater into the reactive treatment zone. A funnel-and-gate system consists of low hydraulic conductivity (e.g., 1×10^{-6} cm/s) cutoff walls (i.e., the funnel) combined with a gate that contains the reactive material (i.e., the ZVI mixture). Contaminated groundwater then flows primarily through the high permeability gate component. The types of cutoff walls most likely to be used in current construction practice are slurry walls or sheet piles.

In some situations, the funnel component is not needed and a continuous reactive wall is used. The site and contaminant conditions dictate the approach required.

The reactive component of ZVI PRB typically consists of iron granules or other iron-bearing minerals for the treatment of chlorinated contaminants such as TCE, DCE, and vinyl chloride. As the iron is oxidized, a chlorine atom is removed from the compound by one (1) or more reductive dechlorination mechanisms, using electrons supplied by the oxidation of iron. The iron granules are dissolved by the process, but the metal disappears so slowly that the remediation barriers can be expected to remain effective for many years, possibly even decades.

The main advantages of a ZVI PRB include the following:

- An established technology with a record of good performance at other locations. Proven effectiveness at treating chlorinated VOCs.
- Limited O&M requirements. Low energy needs are related primarily to performance monitoring.
- Potential long-term effectiveness. May remain effective up to decades.

The main disadvantages of a ZVI PRB include the following:

- Not practical for large, diffuse VOC plumes that would require extensive trenching and a high volume of ZVI.
- Typically requires careful design to address hydraulic issues. Includes issues such as overtopping of the reactive wall because of groundwater mounding behind the gate component and contamination flowing around the funnel component of the system.
- The required depth and width of PRB may not be technically feasible or cost-effective. Trench excavation can usually be conducted to about 50 to 60 feet bgs using conventional earthmoving equipment and techniques. Deeper excavation may be possible using specialized equipment and/or excavation benching, but at greater cost.

- Costs increase with the length and depth of excavation for the reactive wall component and the volume of ZVI required. Costs for excavation of the funnel component also increase with length and depth, but to a lesser degree.
- Limited to a subsurface lithology that has a continuous aquitard or competent bedrock at a depth that is within the vertical limits of trenching equipment (50 to 60 feet bgs). The reactive wall and impermeable funnel walls are typically keyed into the aquitard or bedrock.
- Biological activity or chemical precipitation may limit the permeability of the passive treatment wall. The permeability of the reactive wall may decrease because of precipitation of metal salts.
- The PRB may lose its reactive capacity, requiring replacement of the reactive ZVI.
- Usually requires re-routing of surface and subsurface infrastructure during and after installation (e.g., roads, pipelines, electrical supply lines, communications wiring). The amount of infrastructure that must be re-routed impacts cost.
- A 2-year study of an injected ZVI PRB was conducted at Site DP039 beginning in 1998 (MACTEC, 2002). The injected PRB was not successful and demonstrated the difficulty of obtaining an adequate distribution of a ZVI mixture in the dense clay and silt lithology found at Travis AFB.

At Travis AFB, the depth to competent bedrock is typically at the limit or exceeding the reach of the type of conventional trenching equipment used to install a ZVI PRB. However, specialized excavators are available that can reach up to approximately 80 feet bgs. Also, contaminant plume geometry and concentrations limit the implementability of the technology because of the magnitude of the required trench excavation to capture and treat a large, diffuse plume. Adverse impacts to the military mission of Travis AFB because of large-scale and disruptive excavation activities are also a consideration at most sites.

A ZVI PRB is potentially applicable at Site SS029 where site and contaminant conditions may be amenable to the technology. At this site, the leading edge of the plume is relatively narrow and may be confined by the underlying geology to a zone that makes a funnel-and-gate system practical. The depth to competent bedrock across the site ranges from approximately 4 bgs in the western portion of the site to about 60 feet bgs in the northeastern portion.

The southern portion of the plume is under the hydraulic influence of the Site SS029 GET IRA, and the distribution of contamination may change if the GET system is turned off after installation of a PRB. Additional evaluations of the hydrogeology at Site SS029 would be needed to resolve this uncertainty.

The alluvial thickness in the likely vicinity of a funnel-and-gate system near the Base boundary is approximately 60 feet. The alluvium consists primarily of interbedded dense silts and clays with thin seams of fine to medium sand and laterally discontinuous seams of fine gravel. There are no cobbles or boulders requiring additional design considerations. The depth to bedrock is about 60 feet bgs, which is near the practical limit of excavation using conventional equipment, but still possible. Additional field investigation would be required to confirm the technical implementability and constructability of a ZVI PRB for Site SS029.

Costs for a ZVI PRB at Site SS029 would be moderate to high, depending primarily on the magnitude of excavation and volume of ZVI required.

6.5.5.4 Ex Situ Treatment

Several ex situ treatment processes have been used to treat contaminated groundwater and soil vapor extracted from the subsurface. These processes include the following:

- **Air stripping –** Air is bubbled through extracted groundwater in shallow trays. The VOCs partition into the airstream and are either vented to the atmosphere or captured on activated carbon.
- **LGAC –** Contaminants are adsorbed onto activated carbon by passing contaminated groundwater through a carbon column.
- **UV/Ox –** Ultraviolet light is used to promote the oxidation of groundwater contaminants. Ozone or hydrogen peroxide is typically used as part of the treatment process. It offers a cost effective means of permanently breaking down large amounts of highly concentrated contaminants, but the cost per pound of contaminant increases significantly as the influent volumes and concentrations drop.
- **ThOx –** Vapor phase VOCs are destroyed by heating the air stream and passing it through a natural gas combustion unit in contact with a catalyst bed.

At Travis AFB, LGAC treatment is currently used at the NGWTP, CGWTP, and SBBGWTP. The capital and O&M costs of these treatment systems are moderate compared with the energy-intensive treatment processes formerly used at each facility. The former and current treatment processes at each treatment plant are summarized in the following list:

- **NGWTP –** Formerly used air stripping treatment. Converted to a low-volume LGAC system to treat influent from Site LF007C in 2009.
- **CGWTP –** Formerly used a combination of ThOx for treatment of soil vapor and UV/Ox for treatment of groundwater. In 2010, converted to a LGAC system to treat groundwater from Site SS016. SVE and treatment were discontinued as part of IRA optimization.
- **SBBGWTP –** Converted from air stripping to LGAC treatment in 2010.

The various components of the discontinued treatment processes have been mothballed and remain available for future use should they become necessary (e.g., the ThOx unit at Site SS016).

6.5.6 Disposal

Treated groundwater at Travis AFB is typically discharged to the stormwater drainage system or directed to a beneficial reuse. Historically, water discharged from the CGWTP and NGWTP has been used for on-base landscape irrigation and for maintaining the water level in the Duck Pond. Effluent from the SBBGWTP is discharged to the main branch of Union Creek.

Travis AFB will continue to evaluate opportunities to beneficially reuse treated groundwater. However, administrative constraints on the use of environmental restoration funding do not currently allow for new approaches for beneficial reuse of treated groundwater.

TABLE 6-1
Summary of Site IRA Technologies and Status
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	IRA	IRA Technology Processes	IRA Optimization Actions	Summary of IRA Status and Performance
FT004	GET and MNA Assessment	Extraction wells LGAC Stormwater drainage system Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	Air stripping discontinued and replaced with LGAC treatment at NGWTP. GET system shut down for a rebound study in 2007.	The combination of GET in the Site FT004 source areas and MNA in the downgradient portions of the plume has been effective. Hydraulic capture of the source areas was achieved using GET. The effectiveness of GET is further demonstrated by declining VOC concentrations observed in the majority of site monitoring wells. Declining trends are observed in both shallow and deep monitoring wells, indicating both the horizontal and vertical extent of the target areas are being addressed. The Site FT004 GET system has been shut down for a rebound study for the remaining period of interim remediation because the source area VOC concentrations have declined. The maximum TCE concentrations during the 2010 GSAP were observed within two (2) localized and noncontiguous portions of the plume. These included 165 µg/L in MW266x04 and 130 µg/L in MW131x04. No other concentrations above 100 µg/L were observed at the site. MNA also appears to be a viable remedy at Site FT004. Overall, contaminant concentrations are stable or declining in the downgradient MNA assessment monitoring wells. The MNA network includes both shallow and deep monitoring wells. MNA appears to be effective throughout the entire thickness of the plume.
FT005	GET	Extraction wells Air stripping Stormwater drainage system Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Easement purchase Groundwater monitoring	Air stripping discontinued and replaced with LGAC treatment at SBBGWTP. GET system partially shut down for a rebound study in 2007.	The Site FT005 GET system has been effective. The existing GET system appears to have achieved hydraulic capture of the plume and is controlling off-base contaminant migration. A large portion of the plume has been remediated to non-detect concentrations. The extraction wells in the areas of the plume where IRA objectives have been achieved have been shut down for a rebound study for the remainder of the interim period of remediation.
LF006	MNA	Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	None	MNA appears to be a viable remedy at Site LF006. Data from monitoring wells indicate that groundwater contamination at Site LF006 is not migrating, and no contaminants were detected at a concentration exceeding the IRG.
LF007B	MNA Assessment	Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	None	MNA appears to be a viable remedy at Site LF007B. No contaminants were detected in Site LF007B wells sampled during the 2009-2010 GSAP events.
LF007C	GET	Extraction wells (solar-powered) Air stripping Stormwater drainage system Monitoring wells Base General Plan Easement purchase Groundwater monitoring	Air stripping discontinued and replaced with LGAC treatment at NGWTP. Pending in 2011 – additional site characterization and potential expansion of the GET system.	The migration control and off-base remediation IRA objectives for Site LF007C do not appear to be fully achieved. The existing GET system is not fully effective at hydraulically capturing and remediating the TCE plume. TCE continues to migrate off-base at concentrations above the TCE IRG of 5 µg/L. Optimization of the GET IRA is required. A data gaps investigation will be performed during 2011, pending USFWS approval of the request to reinitiate Section 7 consultation for activities within the vernal pool at the site, to define the extent of off-base contamination greater than the IRG, and to clarify groundwater flow directions. Based on the results of the investigation, optimization measures for the current GET system will be conducted.
LF007D	MNA Assessment	Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	None	MNA appears to be a viable remedy at Site LF007D. The plume is stable, but concentrations have not decreased significantly during the period of interim remediation. Groundwater contamination is currently limited to a small area in the vicinity of MW261x04. Within this area, PCGs are exceeded for 1,4-DCB (12.6 µg/L vs. PCG of 5 µg/L) and benzene (3 µg/L vs. PCG of 1 µg/L). Concentrations of 1,4-DCB have decreased during the period of interim remediation. However, long term benzene concentrations have remained relatively stable at about 3 µg/L. Contaminants do not appear to be migrating off-base to the north or east of the site.

TABLE 6-1
Summary of Site IRA Technologies and Status
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	IRA	IRA Technology Processes	IRA Optimization Actions	Summary of IRA Status and Performance
LF008	GET	Extraction wells LGAC Stormwater drainage system Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	GET system shut down for a rebound study in 2008.	The migration control IRA objective at Site LF008 was achieved by the GET system. Hydraulic capture of the source area was achieved. The distribution of contamination in monitoring wells also indicated hydraulic containment of the plume. The GET system had limited effectiveness at removing the residual organochlorine pesticide contamination. Concentrations are stable and not migrating. The GET system is currently shut down as part of a rebound study for the remainder of the period of interim remediation.
SS015	MNA Assessment	Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	Injection wells. Source area EVO injection in 2010. Additional monitoring wells.	Monitoring data indicated that MNA does not appear to be successfully addressing Site SS015 contamination. The plume appears to be migrating, and contaminant concentrations are increasing in some wells. The limited volume of EVO injected during a 2000-2001 vegetable oil injection treatability study appears to be exhausted. Optimization of the MNA IRA was required, and supplemental injection of EVO was conducted during 2010 to enhance natural attenuation processes. The performance of the EVO treatment is being evaluated.
SS016	GET	Extraction wells UV/Ox groundwater treatment ThOx vapor treatment Stormwater drainage system Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	UV/Ox and thermal oxidation treatment discontinued in 2010. Groundwater treatment replaced by LGAC at CGWTP. Source area excavation and bioreactor installation in 2010.	Hydraulic capture of the TARA source area has been achieved. Within the OSA source area, concentrations have decreased, but the extent of hydraulic capture is less certain. Declining TCE concentrations in shallow and deep monitoring wells downgradient of the OSA and TARA source areas indicate that the horizontal and vertical extents of the plume are being addressed by the existing GET system. However, even after several years of IRA operation, the highest TCE concentrations at Travis AFB are found at OSA source area horizontal extraction well EW003x16 (18,000 μg/L). Therefore, IRA optimization actions were taken during 2010. These actions included a data gaps investigation to more fully define the OSA source area. Based on the results of the data gaps investigation, operation of a 2-Phase® extraction/ThOx treatment was discontinued, the source area was excavated, and an in situ bioreactor was installed. The performance of the bioreactor is being evaluated. The portion of the commingled Site SS016 plume (OSA/TARA that is not hydraulically captured by the OSA and TARA source control GET systems) is eventually hydraulically captured by the downgradient Site SS029 GET system.
ST027B	MNA*	Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	None	Site ST027 has historically been managed as part of the POCO program at Travis AFB because petroleum hydrocarbons were believed to be the only contaminants present at this site. However, an investigation conducted in 2007 resulted in the discovery of TCE and several other chlorinated VOCs in groundwater in the southwestern part of the site. The site was subsequently subdivided into Site ST027A (fuels contamination only) and Site ST027B (CERCLA contaminants). A data gaps investigation was conducted during 2010 to characterize the VOC plume within Site ST027B and provide data to support risk assessments and remedy selection.
SS029	GET	Extraction wells Air stripping Stormwater drainage system Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	Air stripping discontinued and replaced with LGAC groundwater treatment at SBBGWTP.	The migration control IRA objective at Site SS029 has been achieved. The existing GET system has achieved hydraulic capture of the on-base plume and is effectively controlling potential off-base migration of the contaminant plume.

TABLE 6-1
Summary of Site IRA Technologies and Status
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	IRA	IRA Technology Processes	IRA Optimization Actions	Summary of IRA Status and Performance
SS030	GET	Extraction wells Air stripping Stormwater drainage system Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Easement purchase Groundwater monitoring	Air stripping discontinued and replaced with LGAC groundwater treatment at SBBGWTP. Increased groundwater extraction rates to improved hydraulic capture of the off-base plume.	The source control, migration control, and off-base remediation IRA objectives for the Site SS030 IRA have not been fully achieved. Contaminant concentrations are declining in all of the extraction wells and all but two (2) of the monitoring wells. The off-base plume is being captured on the southern and western sides of the plume. However, increasing TCE concentrations on the eastern side of the off-base plume indicate that contamination may be escaping hydraulic capture. The groundwater elevation contours derived from the 2Q10 GSAP sampling event indicate that the hydraulic capture in this eastern area of the plume has improved after several of the adjacent Site FT005 extraction wells were taken offline for a rebound study. Optimization of the GET IRA is required. Investigations will be performed during 2010-2011 to clarify groundwater flow directions and hydraulic capture. Based on the results of the investigation, optimization measures for the current GET system will be conducted as required.
SD031	GET and MNA Assessment	Extraction wells LGAC Stormwater drainage system Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	Air stripping discontinued and replaced with LGAC groundwater treatment at NGWTP. GET system shut down for a rebound study.	The combination of GET in the Site SD031 source areas and MNA in the downgradient portions of the plume has been effective. Hydraulic capture of the source areas was achieved using GET. The effectiveness of GET is further demonstrated by declining VOC concentrations observed in the majority of site monitoring wells. Declining trends are observed in both shallow and deep monitoring wells, indicating both the horizontal and vertical extent of the target areas are being addressed. The Site SD031 GET system has been shut down for a rebound study for the remaining period of interim remediation because VOC concentrations have declined. The maximum 1,1-DCE concentrations during the 2010 GSAP were observed within a localized portion of the plume. These included 78.8 μg/L in EW566x31 and 7.4 μg/L in EW567x31. MNA also appears to be a viable remedy at Site SD031. Overall, contaminant concentrations are stable or declining in the downgradient MNA assessment monitoring wells. The MNA network includes both shallow and deep monitoring wells. MNA appears to be effective throughout the entire thickness of the plume.
SD033	GET and MNA Assessment	Extraction wells UV/Ox groundwater treatment Stormwater drainage system Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	UV/Ox groundwater treatment discontinued in 2010 and replaced by LGAC at CGWTP. WIOU GET system, including Site SD033, shut down for a rebound study.	The GET system for WIOU Site SD033 achieved the migration control IRA objective. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 μg/L were captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume were addressed by the GET system. In the southern (downgradient) area of the site, MNA appears to be a viable remedy. Groundwater contamination in this area does not appear to be migrating.
SD034	GET and Passive Skimming	Extraction wells UV/Ox groundwater treatment VGAC vapor treatment Stormwater drainage system Passive skimmers Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2009-2010 and replaced by LGAC at CGWTP. WIOU GET system, including Site SD034, shut down for a rebound study.	The GET and passive skimming systems for WIOU Site SD034 are largely achieving the source control and migration control IRA objectives. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 μg/L are being captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume are being addressed by the existing GET system. Floating product removal of Stoddard solvent is achieving the source control IRA for the site. The extent of floating product continues to be limited to the original release area and is not migrating.

TABLE 6-1
Summary of Site IRA Technologies and Status
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	IRA	IRA Technology Processes	IRA Optimization Actions	Summary of IRA Status and Performance
SS035	GET	Extraction wells UV/Ox groundwater treatment VGAC vapor treatment Stormwater drainage system Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2010 and replaced by LGAC treatment at CGWTP. WIOU GET system, including Site SS035, shut down for a rebound study.	The GET system for the WIOU, including Site SS035, achieved the migration control IRA objective. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 µg/L were captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume are being addressed by the existing GET system.
SD036	GET and MNA Assessment	Extraction wells UV/Ox groundwater treatment VGAC vapor treatment Stormwater drainage system Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2009-2010 and replaced by LGAC treatment at CGWTP. WIOU GET system, including Site SD036, shut down for a rebound study in 2010. Source area EVO injection in 2010.	The GET system for WIOU Site SD036 is largely achieving the source control and migration control IRA objectives. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 µg/L were captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume are being addressed by the GET existing system. Although IRA objectives are largely being met, even after several years of IRA operation, TCE concentrations greater than 1,000 µg/L continue to be detected at the source area within Site SD036. Optimization of the GET IRA was required. Therefore, data gaps investigations were performed during 2010 to more fully define the extents of these source areas. Based on the results of the data gaps investigations, optimization measures included discontinuing the GET systems and injection of EVO within the plume source area. The performance of the EVO treatment is being evaluated. In the downgradient portions of the plume, MNA appears to be a viable remedy. Groundwater contamination in this area does not appear to be migrating.
SD037	GET and MNA Assessment	Extraction wells UV/Ox groundwater treatment VGAC vapor treatment Stormwater drainage system Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2009-2010 and replaced by LGAC treatment at CGWTP. WIOU GET system, including Site SD037, shut down for a rebound study in 2010. Source area EVO injection in 2010.	The GET system for WIOU Site SD037 is largely achieving the source control and migration control IRA objectives. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 µg/L were captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume are being addressed by the GET existing system. Although IRA objectives are largely being met, even after several years of IRA operation, TCE concentrations greater than 1,000 µg/L continue to be detected at the source area within Site SD037. Optimization of the GET IRA was required. Therefore, data gaps investigations were performed during 2010 to more fully define the extents of these source areas. Based on the results of the data gaps investigations, optimization measures included discontinuing the GET systems and injection of EVO within the source areas. The performance of the EVO treatment is being evaluated. In the southern (downgradient) area of the WIOU, MNA appears to be a viable remedy. Groundwater contamination in this area does not appear to be migrating.
DP039	GET and MNA	Extraction wells UV/Ox groundwater treatment VGAC vapor treatment Stormwater drainage system Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring Phytoremediation (demonstration project not specified in WABOU IROD)	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2009-2010 and replaced by LGAC treatment at CGWTP. GET system shut down in 2008. Source area in situ bioreactor installation in 2008. EVO PRB installed in 2010.	The Site DP039 source control IRA objective has been partly achieved. TCE concentrations in the historical contaminant release area (i.e., a former sump) are declining and a portion of the source area plume was hydraulically contained by the existing GET system. However, another portion of the source area plume is not hydraulically captured. This uncaptured portion of the plume, with TCE concentrations exceeding 1,000 µg/L, extends about 800 feet downgradient. This uncaptured portion of the source area plume underlies an ongoing demonstration of phytoremediation. The source area was excavated in December 2008 and an in situ bioreactor was installed in the former sump area as a technology demonstration. The performance of the bioreactor is being evaluated for the remainder of the period of interim remediation. A data gaps investigation was performed during 2010 to more fully define the extent of the downgradient source area with TCE concentrations greater than 500 µg/L. Based on the results of the data gaps investigations, an in situ PRB of EVO was installed hydraulically downgradient of an existing area of phytoremediation and upgradient of the portion of the plume undergoing MNA. The performance of the EVO PRB is being evaluated. Increasing TCE concentration trends at some monitoring wells in the distal portion of the plume indicate that MNA may not be fully effective if TCE concentrations in the untreated portion of the plume continue to exceed 1,000 µg/L and act as a continuing source of contamination into the downgradient portion of the plume.

TABLE 6-1
Summary of Site IRA Technologies and Status
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	IRA	IRA Technology Processes	IRA Optimization Actions	Summary of IRA Status and Performance
SS041	GET	Extraction wells UV/Ox groundwater treatment Stormwater drainage system Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	None	Site has been in NFRAP status. The NFRAP status is documented in a 14 December 2005 consensus statement (Travis AFB, 2005).
SD043	GET	Extraction wells UV/Ox groundwater treatment VGAC vapor treatment Stormwater drainage system Monitoring wells Base Civil Engineer Work Request Excavation permit Base General Plan Groundwater monitoring	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2009-2010 and replaced by LGAC treatment at CGWTP. WIOU GET system, including Site SD043, shut down for a rebound study in 2010.	The IRA GET system has effectively reduced plume size and concentrations. No contaminants were detected above IRGs during the 2010 GSAP.

* Historically managed under the POCO program and not addressed in either the Groundwater IROD for the NEWIOU or Groundwater IROD for the WABOU.

TABLE 6-2
Summary of Previous Technical Implementability Screening from NEWIOU Feasibility Study*
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option
No Action	None	None
Institutional Action	Access restrictions	Water use/water rights restrictions, fences, posting signs
		Land purchase/eminent domain
	Alternate water supply	Provide alternate water supply for agricultural users
	Monitoring	Groundwater monitoring
Containment	Vertical barrier	Slurry wall/grout curtain
		Sheet pile wall
		Pump and treat extraction wells and injection wells (hydraulic barrier)
	Horizontal barrier	Grout injection
Collection	Groundwater collectors	Vertical wells
		Horizontal wells
	Floating product recovery	Bioslurping
		Vertical well and skimmer pump
	Subsurface drains	Collection trenches (French drain)
Ex Situ Treatment	Biological treatment (aerobic)	Activated sludge
		Fixed film
	Biological treatment (anaerobic)	Fixed bed reactor
		Fluidized bed reactor
	Physical treatment	Air stripping
		Steam stripping
		Carbon adsorption
		Reverse osmosis
	Chemical treatment	Ion exchange
		pH adjustment and precipitation
		Chemical oxidation promoted with ultraviolet light (UV/Ox)
		Chemical dechlorination using zero valent metal

TABLE 6-2
Summary of Previous Technical Implementability Screening from NEWIOU Feasibility Study*
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option
Discharge	Onsite discharge	Direct discharge to storm drain
	Onsite use	Industrial use
		Irrigation
	Onsite discharge	Shallow aquifer injection
		Deep aquifer injection
	Offsite discharge	Discharge to publicly owned treatment works
In Situ Treatment	Chemical treatment	Chemical treatment using zero-valent metal to abiotically degrade contaminants in an intercepting trench
	Physical treatment	In situ air stripping; volatilize contaminants in well by percolating air within casing
	Biological treatment	Air sparging
	Thermal treatment	In situ steam stripping

* Source: Final NEWIOU FS, Table 3-1 (Radian, 1996a).

TABLE 6-3
Summary of Previous Technical Implementability Screening from WABOU Feasibility Study*
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option
No Action	None	None
Institutional Action	Access restrictions	Land use restrictions
		Land purchase
	Alternate water supply	Provide alternate water supply for agricultural users
	Monitoring	Groundwater monitoring
Natural Attenuation	Monitoring/Verification	Groundwater monitoring
Containment	Hydraulic barrier	Vertical extraction wells
		Horizontal extraction wells
		Extraction/injection wells
	Subsurface drains	Interceptor trenches
	Physical barrier	Soil-bentonite slurry wall
		Vibrating beam
		Grout curtain
		Sheet piling
	Horizontal barrier	Grout injection
Collection	Groundwater extraction	Vertical groundwater extraction wells
		Horizontal groundwater extraction wells
		DPE
		2-Phase® extraction
	Sparging	Air sparging
		Biosparging
Liquid-phase Treatment	Physical treatment	Phase separation by gravity
		Phase separation by floatation
		Media filtration
		LGAC
		Membrane osmosis
		Air stripping
		Steam stripping
		In-well aeration
		Coagulation/flocculation
		Freeze crystallization
		Electrodialysis
		Distillation

TABLE 6-3
Summary of Previous Technical Implementability Screening from WABOU Feasibility Study*
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option
Liquid-phase Treatment	In situ chemical treatment	Reactive wall
	Ex situ chemical treatment	Solvent extraction
		Precipitation
		Ion exchange
		Ultraviolet irradiation/ozone oxidation
		Ozone/hydrogen peroxide oxidation
		High energy electron irradiation
		Reductive dehalogenation
		Chemical reduction
		Hydrolysis
		Electrochemical processes
		Neutralization
	Ex situ biological treatment	Bioreactors
	In situ biological treatment	Anaerobic degradation
		Cometabolic degradation
		Phytoremediation
Vapor-phase Treatment	Ex situ physical treatment	Direct discharge
		VGAC
		Catalytic oxidation
		Synthetic resin adsorption
		Electron beam
		Photolytic destruction
		Incineration
		Packed bed thermal processor
		Biofilters
		Catalytic ozone decomposition
Discharge	Groundwater discharge	Discharge to treatment works
		Discharge to surface water
		Aquifer injection
		Irrigation reuse
		Deep well injection

* Source: Final WABOU FS, Figure 5-2 (CH2M HILL, 1998a).
Shaded cell indicates process option screened out on the basis of Technical Implementability.

TABLE 6-4
Summary of Previous Process Option Effectiveness, Implementability, and Relative Cost Screening from the NEWIOU Feasibility Study*
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option
No Action	None	None
Institutional Action	Access restrictions	**Water use/water rights restrictions, fences, posting signs**
		Land purchase/eminent domain
	Alternate water supply	Provide alternate water supply for agricultural users
	Monitoring	**Groundwater monitoring**
Containment	Vertical barrier	Slurry wall/grout curtain
		Sheet pile wall
		Pump and treat extraction wells and injection wells (hydraulic barrier)
	Horizontal barrier	Grout injection
Collection	Groundwater collectors	**Vertical wells**
		Horizontal wells
	Floating product recovery	**Bioslurping**
		Vertical well and skimmer pump
	Subsurface drains	Collection trenches (French drain)
Ex Situ Treatment	Biological treatment (aerobic)	Activated sludge
		Fixed film
	Biological treatment (anaerobic)	Fixed bed reactor
		Fluidized bed reactor
	Physical treatment	**Air stripping**
		Steam stripping
		Carbon adsorption
		Reverse osmosis
	Chemical treatment	**Ion exchange**
		pH adjustment and precipitation
		Chemical oxidation promoted with ultraviolet light (UV/Ox)
		Chemical dechlorination using zero valent metal

TABLE 6-4
Summary of Previous Process Option Effectiveness, Implementability, and Relative Cost Screening from the NEWIOU Feasibility Study*
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option
Discharge	Onsite discharge	**Direct discharge to storm drain**
	Onsite use	Industrial use
		Irrigation
	Offsite discharge	Discharge to Publicly Owned Treatment Works
In Situ Treatment	Chemical treatment	Chemical treatment using zero valent metal to abiotically degrade contaminants in an intercepting trench
	Physical treatment	In situ air stripping; volatilize contaminants in well by percolating air within casing
	Biological treatment	Air sparging
	Thermal treatment	In situ steam stripping

* Source: Final NEWIOU FS, Tables 3-1 and 3-5 (Radian, 1996a).

Shaded cell indicates process option screened out on the basis of Effectiveness, Implementability, and/or Relative Cost.
Boldface indicates a Representative Process Option.

TABLE 6-5
Summary of Previous Process Option Effectiveness, Implementability, and Relative Cost Screening from the WABOU Feasibility Study*
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option
No Action	None	None
Institutional Action	Access restrictions	**Land use restrictions**
		Land purchase
	Alternate water supply	Provide alternate water supply for agricultural users
	Monitoring	**Groundwater monitoring**
Natural Attenuation	Monitoring/verification	**Groundwater monitoring**
Containment	Hydraulic barrier	**Vertical extraction wells**
		Horizontal extraction wells
		Extraction/injection wells
	Subsurface drains	Interceptor trenches
	Physical barrier	Soil-bentonite slurry wall
		Vibrating beam
		Grout curtain
		Sheet piling
	Horizontal barrier	Grout injection
Collection	Groundwater extraction	**Vertical groundwater extraction wells**
		Horizontal groundwater extraction wells
		DPE
		2-Phase® extraction
	Sparging	**Air sparging**
Liquid-phase Treatment	Physical treatment	**LGAC**
		Membrane osmosis
		Air stripping
		In-well aeration
	In situ chemical treatment	Reactive wall
	Ex situ chemical treatment	Ion exchange
		Ultraviolet irradiation/ozone oxidation
		Ozone/hydrogen peroxide oxidation
		High energy electron irradiation
		Reductive dehalogenation

TABLE 6-5
Summary of Previous Process Option Effectiveness, Implementability, and Relative Cost Screening from the WABOU Feasibility Study*
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option
	Ex situ biological treatment	Bioreactors
	In situ biological treatment	Anaerobic degradation
		Cometabolic degradation
		Phytoremediation
Vapor-phase Treatment	Ex situ physical treatment	Direct discharge
		VGAC
		Catalytic oxidation
		Synthetic resin adsorption
		Electron beam
		Photolytic destruction
		Incineration
		Packed bed thermal processor
		Catalytic ozone decomposition
Discharge	Groundwater discharge	Discharge to treatment works
		Discharge to surface water
		Aquifer injection
		Irrigation reuse

* Source: Final WABOU FS, Figure 5-2 (CH2M HILL, 1998a).

Shaded cell indicates process option screened out on the basis of Effectiveness, Implementability, and/or Relative Cost.
Boldface indicates a Representative Process Option.

TABLE 6-6
Technical Implementability Screening of Groundwater Technologies
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Remedial Technology	Process Option	Description	Screening Comment
No Action	None	None	No action is taken.	Required for consideration by NCP. Applicable to Site SS041, which is already in NFRAP status.
Land Use Controls	Administrative mechanisms	Base Civil Engineer Work Requests	AF332 must be submitted and approved before the start of any building project at Travis AFB. The form provides a means for communicating any construction constraints to concerned parties, including issues related to contaminated groundwater.	Applicable to all sites. Described in the Travis AFB General Plan.
		Excavation permits	60th Air Mobility Wing Form 55 must be submitted and approved for any on-base activity that involves soil or sediment excavation. The permit describes the appropriate procedures that must be followed to prevent uncontrolled exposure to contamination.	Applicable to all sites. Described in the Travis AFB General Plan.
		County permits	Permits required for compliance with Solano County Ordinance 13.10. Permits are required to install a well within Solano County.	Applicable to off-base portions of Sites FT005, LF007C, and SS030. Permits obtained through Solano County are not under Air Force jurisdiction.
		Easement purchase	Privately owned land overlying an off-base groundwater plume is leased or purchased to provide Air Force access. The easement also restricts the installation of new wells by the land owner and other land usage that is incompatible with the contaminated groundwater underlying the easement.	Applicable. Off-base easements have already been purchased at Sites LF007C, FT005, and SS030.
	Engineered controls	Vapor barrier	A low-permeability barrier installed on the ground surface during building construction to minimize the intrusion of vapors emanated from a groundwater plume into a work space.	Applicable. Already required for construction of new structures in proximity to a groundwater plume. Described in the Travis AFB General Plan.
		Passive venting	A venting system is installed to prevent the accumulation of soil gas under a structure located in proximity to a groundwater plume.	Applicable. Already required for construction of new structures in proximity to a groundwater plume. Described in the Travis AFB General Plan.
		Alternate water supply	Alternative sources of potable water are provided to users in lieu of untreated groundwater from privately owned wells. The alternate sources could include connection to a municipal water supply, installing a new well in an uncontaminated portion of a property, or construction of a wellhead treatment unit.	Potentially applicable for the off-base plumes at Sites FT005, LF007C, and SS030.
	Access restrictions	Fencing	Fencing is erected around a source of contamination to prevent human exposure.	Screened out because process option is not applicable to groundwater contamination.
		Signs	Placards or signs are placed along the perimeter of a source of contamination to prevent human exposure.	Screened out because process option is not applicable to groundwater contamination.
	Monitoring	Groundwater monitoring	Short and long-term monitoring of groundwater is conducted to evaluate contaminant concentrations and trends.	Applicable. Comprehensive groundwater monitoring is already being conducted under the Travis AFB GSAP.
Containment	Physical barrier	Sheet piling	Sheet piles are driven into the subsurface to reduce or eliminate migration of contaminated groundwater.	Screened out because of limited technical implementability at sites with dense belowground and/or aboveground infrastructure (e.g., buildings, storm drains, sanitary sewers, communication and electrical power wiring).
		Soil-bentonite slurry wall	A trench is excavated and backfilled with a soil and bentonite (i.e., clay) slurry mixture to reduce or eliminate the migration of contaminated groundwater. The slurry creates a relatively low permeability barrier.	Potentially applicable at Site SS029 if used in conjunction with a PRB.
		Vibrating beam	Vibration force is used to advance a steel beam into the ground. A bentonite or cement slurry is injected as the beam is withdrawn.	Screened out because of limited technical implementability at sites with dense belowground and/or aboveground infrastructure (e.g., buildings, storm drains, sanitary sewers, communication and electrical power wiring).
		Grout curtain	Grout is pressure-injected around a source area of groundwater contamination using an overlapping pattern of drilled holes.	Screened out because of limited technical implementability at sites with dense belowground and/or aboveground infrastructure (e.g., buildings, storm drains, sanitary sewers, communication and electrical power wiring).
		Interceptor trench	A horizontal trench is excavated to intercept contaminated groundwater as it flows hydraulically downgradient. A pump removes accumulated water from the trench. The removed water is treated and discharged. Contaminated excess soil is disposed of at an off-base landfill.	Applicable. A horizontal interceptor trench has already been installed as part of the IRA at Site SS030.

TABLE 6-6
Technical Implementability Screening of Groundwater Technologies
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Remedial Technology	Process Option	Description	Screening Comment
Containment (continued)	Hydraulic barrier	Vertical extraction well	Pumps are installed in vertical extraction wells to remove contaminated groundwater and create a hydraulic barrier to contaminant migration. Dual-phase wells also use vacuum pumps or blowers to simultaneously extract soil vapor and enhance the rate of groundwater extraction. Extracted groundwater and soil vapor is conveyed to a treatment facility. Typically used in conjunction with a treatment technology.	Applicable. Vertical extraction wells have already been successfully installed and operated as part of the IRAs at Sites FT004, FT005, LF007C, LF008, SS016, SS029, SS030, SD031, SD033, SD034, SS035, SD036, SD037, DP039, and SD043.
		Horizontal extraction well	Horizontal wells are pumped to physically remove contaminants from the saturated zone. Typically used in conjunction with a treatment technology.	Applicable. Horizontal extraction wells have already been successfully installed and operated as part of the IRA at Site SS016.
		DPE well	Vacuum pumps or blowers are used to simultaneously extract soil vapor and enhance the rate of groundwater extraction. Extracted groundwater and soil vapor are conveyed to a treatment facility. Typically used in conjunction with a treatment technology.	Applicable. Dual-phase extraction wells have already been successfully installed and operated as part of the IRAs at Sites FT004, FT005, SD031, SD033, SD034, SS035, SD036, SD037, DP039, and SD043.
		2-Phase® extraction well	A proprietary process similar to DPE. Groundwater and soil vapor are removed using a single downhole pipe.	Applicable. A 2-Phase® extraction well has already been successfully installed and operated as part of the IRA at Site SS016.
Removal	Groundwater extraction	Extraction well	Pumps are installed in vertical or horizontal extraction wells to remove contaminated groundwater. Dual-phase wells also use vacuum pumps or blowers to simultaneously extract soil vapor. Extracted groundwater and soil vapor is conveyed to a treatment facility. Typically used in conjunction with a treatment technology.	Applicable. Source control extraction wells have already been successfully installed and operated as part of the IRAs at Sites FT004, SD031, SD034, SD036, SD037, and DP039.
	In situ thermal removal	Electrical resistance heating, hot air injection, hot water injection, steam injection, radio frequency heating, thermal conduction, and vitrification	Different methods are used to apply heat to the subsurface to mobilize/volatilize contaminants. Although the means to transmit heat into the subsurface varies with each process option, the end result of these technologies and the technical challenges that they face are identical.	Potentially applicable, although dense subsurface infrastructure at site source areas limit technical implementability.
	Free product removal	Passive skimming	Floating product in wells is physically removed by bailing or using skimmers (active or passive).	Applicable. Passive skimming of Stoddard solvent free product has already been conducted as part of the Site SD034 IRA.
		Bioslurping	A vacuum extraction technique to remove floating product from the groundwater table.	Potentially applicable. Bioslurping has already been used to remove floating jet fuel at POCO sites.
	Sparging	In-well aeration	Air is injected into wells to strip volatile chemicals from the groundwater in the well column.	Screened out because of the dense and low permeability silt/clay lithology typical at Travis AFB.
		Air sparging	Air is injected into the groundwater using a well or trench. Volatile chemicals are stripped from the water into the soil vapor and removed from the subsurface.	Screened out because of the dense and low permeability silt/clay lithology typical at Travis AFB.
In Situ Treatment	In situ physical, chemical, and biological degradation	MNA	Intrinsic physical, chemical, and biological processes are used to reduce the toxicity and volume of contamination. Groundwater sampling and analysis is conducted to track the direction and rate of movement of the plume and natural attenuation processes. Under MNA, no source remediation technology is used as with EA.	Applicable. Groundwater monitoring to assess the performance of MNA is already being conducted as a component of the site-specific IRAs at Sites FT004, LF006, LF007B, LF007D, SD031, SD031, SD034, SD036, SD037, and DP039.
		EA	Groundwater sampling and analysis is conducted to track the direction and rate of movement of a plume and attenuation processes after a source containment, removal, or treatment GRA is taken. Following implementation of the source control action, the contaminant mass loading to the portion of the aquifer being monitored for attenuation is reduced. Monitoring for EA is always conducted in association with a source control action.	Applicable. Similar to the monitoring requirements for MNA, except a source remediation action is also taken and monitoring is conducted within both the source area and distal portions of the plume.

TABLE 6-6
Technical Implementability Screening of Groundwater Technologies
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Remedial Technology	Process Option	Description	Screening Comment
In Situ Treatment (continued)	In situ biological treatment	Carbon substrate injection	A carbon substrate solution such as EVO, HRC®, lactate, or whey is injected into the subsurface as an electron donor to stimulate the anaerobic degradation of contaminants by native reducing bacteria. Chlorinated VOCs are broken down by reductive dechlorination processes. Can be used to remediate source areas by direct injection into the higher concentration areas of a plume; or the pattern of injected oil can form a PRB to intercept and treat contaminants as they migrate hydraulically downgradient.	Applicable. Carbon substrate injection using EVO has already been conducted at Sites SS015, SD036, SD037, and DP039 as IRA optimization measures in 2010.
		PRB – Biobarrier	Reactive organic materials are placed as backfill in a trench excavated across the path of contaminant migration to create a PRB. Contaminants are degraded as groundwater flows through the PRB.	Potentially applicable at Site SS029. Studies will be conducted in 2011 to further assess the technical feasibility of the process option.
		Bioaugmentation	Cultures of proprietary VOC-degrading microbes are injected into the contaminated aquifer along with electron donor solutions to enhance reductive dechlorination processes.	Potentially applicable at Sites SS015, SD036, SD037, and DP039 to supplement the populations of native bacteria with a proprietary consortia of non-native bacteria.
		Phytoremediation	Trees are planted to provide uptake of groundwater contaminants through the roots.	Applicable. A successful demonstration of phytoremediation has already been conducted at Site DP039.
		Bioreactor	Contaminated soil in a known source area is excavated, and the void backfilled with an organic mulch mixture. Contaminated groundwater from a source area extraction well is then recirculated through the bioreactor and source area aquifer.	Applicable. In situ bioreactors have already been installed at Sites SS016 and DP039 as IRA optimization measures.
		Cometabolic degradation	Chemical amendments such as dissolved methane and oxygen are added to the groundwater to stimulate cometabolism of chlorinated chemicals and biodegradation of other contaminants.	Screened out because the of the dense and low permeability silt/clay lithology typical at Travis AFB.
	In situ chemical treatment	Chemical oxidation	Commonly called ISCO or simply chemical oxidation (chemox). An oxidant solution such as hydrogen peroxide, Fenton's Reagent™, ozone, persulfate, or potassium permanganate is injected into the aquifer to oxidize organic contaminants to carbon dioxide and water.	Potentially applicable, although the dense silt/clay lithology and high SOD contraindicate use of the process option.
		ZVI Slurry Injection (Ferox℠ process, Z-Loy™ process)	Pneumatic fracturing is used to create macro-sized spaces in the subsurface. ZVI slurry is then injected into the macro spaces.	Potentially applicable, although the highly layered silt/clay alluvium will make adequate distribution of the slurry difficult.
		ZVI PRB	Chemical dechlorination is achieved using ZVI to abiotically degrade the VOCs in a permeable intercepting trench filled with a ZVI mixture.	Potentially applicable.
Ex Situ Treatment	Physical treatment	LGAC adsorption	Contaminants are adsorbed onto activated carbon by passing contaminated groundwater through a carbon column. The carbon vessel may be at a fixed treatment facility or on a temporary, transportable treatment unit.	Applicable. Groundwater treatment using LGAC adsorption is currently being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.
		Air stripping	Air is bubbled through extracted groundwater in shallow trays. The VOCs partition into the airstream and are either vented to the atmosphere or captured on activated carbon.	Potentially applicable. Groundwater treatment at the NGWTP and SBBGWTP using air stripping was discontinued in 2010 and replaced with LGAC adsorption treatment. The air stripping process can be resumed if necessary.
		Thermal oxidation	Vapor-phase VOCs are destroyed by heating the air stream and passing it through a natural gas combustion unit in contact with a catalyst bed.	Potentially applicable. Soil vapor treatment at the CGWTP using thermal oxidation was discontinued in 2010 when 2-Phase® extraction was discontinued. The thermal oxidation process can be resumed if necessary.

TABLE 6-6
Technical Implementability Screening of Groundwater Technologies
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Remedial Technology	Process Option	Description	Screening Comment
Ex Situ Treatment (continued)	Physical treatment	Membrane osmosis	A barrier membrane preferentially rejects certain dissolved and undissolved chemicals in a fluid mixture. Reverse osmosis is a typical example of this process option.	Screened out as not feasible. The equipment required to use this treatment process is incompatible with existing groundwater treatment plant infrastructure. Also, this process option is not particularly effective for VOC treatment and would result in the generation of a brine from the concentration of naturally occurring dissolved minerals. The disposal of this brine via truck or pipeline to an off-base treatment facility would not be feasible. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.
		Steam stripping	Similar to air stripping, but steam is injected into the stripping column. The higher temperature promotes transfer of VOCs from liquid to vapor phase.	Screened out as not feasible. Electrical utility lines in some parts of the base may be insufficient to meet power requirements for this process option. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.
		Electrodialysis	A membrane process that uses electrical potential to drive ionic contaminants across a membrane.	Screened out as not feasible. Process option is not applicable for the treatment of groundwater contaminants found at Travis AFB. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.
		Distillation	Distilling water to separate water from contaminants.	Screened out as not feasible. Process option is not applicable for the treatment of groundwater contaminants found at Travis AFB. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.
	Chemical treatment	UV/Ox	Ultraviolet light is used to promote the oxidation of groundwater contaminants. Ozone or hydrogen peroxide is typically used as part of the treatment process.	Potentially applicable. Groundwater treatment at the CGWTP using UV/Ox was discontinued in 2010 and replaced with LGAC adsorption treatment. The UV/Ox process can be resumed if necessary.
		Solvent extraction	Use of a water-soluble solvent into which the contaminants preferentially partition, which strips the contaminants from the water.	Screened out as not feasible. Process option is not applicable for the treatment of groundwater contaminants found at Travis AFB. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.
		Precipitation	The chemical equilibria of constituents is altered to reduce the solubility of heavy metals through the addition of a substance that reacts with the contaminant, changes the pH, or changes the temperature.	Screened out as not feasible. Process option is not applicable for the treatment of groundwater contaminants found at Travis AFB. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.
		Ion exchange	Contaminated water is passed through a resin bed capable of exchanging the ions in the solution with the ions on the resin.	Screened out as not feasible. Process option is not applicable for the treatment of groundwater contaminants found at Travis AFB. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.
		Ozone/hydrogen peroxide oxidation	VOCs in groundwater are chemically oxidized using ozone and hydrogen peroxide.	Screened out as not feasible. Without the use of ultraviolet radiation to promote contaminant degradation, this process option would require addition of extensive infrastructure to ensure attainment of NPDES requirements. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.
		High energy electron irradiation	An advanced oxidation process that uses high-energy electron irradiation of a thin aqueous stream to create highly reactive chemical species, which then react with and transform organic chemicals.	Screened out as not feasible. Electrical utility lines in some parts of the Base may be insufficient to meet power requirements for this process option. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.
		Reductive Dechlorination	Chemical dechlorination using zero valent metals to abiotically degrade contaminants. Metals may include iron, iron-nickel, or iron-palladium mixtures.	Screened out as not feasible. This ex situ process option would result in precipitation of dissolved minerals during groundwater treatment, which would block the flow of extracted water through the treatment canister. The use of a sequestering agent to keep minerals in solution has proved to have limited effectiveness at Travis AFB. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.

TABLE 6-6
Technical Implementability Screening of Groundwater Technologies
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Remedial Technology	Process Option	Description	Screening Comment
Ex Situ Treatment (continued)	Biological treatment	Activated sludge	Aerobic bacteria populations in a sludge degrade some organic chemicals. Limited effectiveness for chlorinated compounds.	Screened out as not feasible. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.
		Fixed film	Aerobic bacteria are used to degrade some organic chemicals. Limited effectiveness for chlorinated compounds.	Screened out as not feasible. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.
		Fixed bed reactor	Anaerobic processes are used to degrade chlorinated compounds.	Screened out as not feasible. This process option is incompatible with existing groundwater treatment plant infrastructure and may not be able to treat large volumes of VOC-contaminated groundwater. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.
		Fluidized bed reactor	Anaerobic processes are used to degrade chlorinated compounds.	Screened out as not feasible. This process option is incompatible with existing groundwater treatment plant infrastructure and may not be able to treat large volumes of VOC-contaminated groundwater. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.
		Reductive dechlorination	Anaerobic processes are used to degrade chlorinated compounds.	Screened out as not feasible. This process option is incompatible with existing groundwater treatment plant infrastructure and may not be able to treat large volumes of VOC-contaminated groundwater. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.
Disposal	Treated groundwater discharge	Stormwater drainage system	Treated groundwater is discharged to the Travis AFB stormwater drainage system (i.e., ditch, underground pipe network). Includes disposal in the Duck Pond component of the stormwater drainage system.	Applicable. Treated groundwater from the CGWTP, NGWTP, and SBBGWTP is already discharged to the stormwater drainage system as part of the existing IRAs.
		Beneficial reuse	Treated groundwater is used for landscape irrigation or to maintain the water level in recreation ponds.	Applicable. Treated groundwater from the NGWTP is already being beneficially reused through seasonal discharges to the on-base recreational Duck Pond.
		Aquifer reinjection	Treated groundwater is reinjected into the local aquifer.	Screened out as not feasible. This process option is incompatible with the tight clay soil beneath Travis AFB, which restricts water flow. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs. Most treated groundwater is discharged to the stormwater drainage system. Treated groundwater originating at Site LF007C is seasonally discharged to the on-base Duck Pond.
		Discharge to treatment works	Treated groundwater is discharged to the sanitary sewer system.	Screened out as not feasible. This process option requires connections to utility lines that are currently not available and would require a major upgrade to the off-base sanitary sewer infrastructure to treat the additional volume of water and the new VOC waste stream. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs. Most treated groundwater is discharged to the stormwater drainage system. Treated groundwater originating at Site LF007C is seasonally discharged to the on-base Duck Pond.
		Deep well injection	Treated groundwater is injected into a deep aquifer.	Screened out as not feasible. Travis AFB receives at least 10 percent of its potable water from deep wells north of the Base. The subsurface geological evaluation needed to verify that deep well injection would not have an adverse impact on this drinking water source would be extensive and impractical. Groundwater treatment using LGAC adsorption is already being used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs. Most treated groundwater is discharged to the stormwater drainage system. Treated groundwater originating at Site LF007C is seasonally discharged to the on-base Duck Pond.

Note:

Shaded cell indicates a process option screened out on the basis of Technical Implementability.

TABLE 6-7
Screening of Groundwater Remedial Technologies and Process Options
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comments
No Action	None	None	No action is taken.	Can be effective in protecting human health and ecological receptors given exposure duration and frequency.	Requires approval from regulatory agencies.	Low.	**Required by NCP.** Retained as a process option. Applicable to Site SS041, which is already in NFRAP status.
Land Use Controls	Administrative Mechanisms	Base Civil Engineer Work Requests	Air Force Form 332 must be submitted and approved before the start of any building project at Travis AFB. The form provides a means to communicating any construction constraints to concerned parties, including issues related to contaminated groundwater.	Effective at protecting human health with consistent implementation. Will not achieve RAOs without being used in conjunction with other technology. Does not address contaminants in groundwater.	Readily implementable. Base Civil Engineer Work Requests are already being implemented at Travis AFB.	Low capital, low O&M.	**Retained as a representative process option.** Applicable to all on-base sites.
		Excavation permit	60th Air Mobility Wing Form 55 must be submitted and approved for any on-base activity that involves soil or sediment excavation. The permit describes the appropriate procedures that must be followed to prevent uncontrolled exposure to contamination.	Effective at protecting human health with consistent implementation. Will not achieve RAOs without being used in conjunction with other technology. Does not address contaminants in groundwater.	Readily implementable. Excavation permitting is already being implemented at Travis AFB.	Low capital, low O&M.	**Retained as a representative process option.** Applicable to all on-base sites.
		Base General Plan	A Base plan that provides a framework for siting and constructing facilities required to support the Base mission. The Base General Plan shows all environmental constraints to facility construction, including LUCs at contaminated groundwater sites. The Base General Plan is currently Web-based and can only be accessed through the Travis AFB intranet.	Effective at protecting human health with consistent implementation. Will not achieve RAOs without being used in conjunction with other technology. Does not address contaminants in groundwater.	Implementable. The Base General Plan has already been developed and published online.	Low capital, low O&M	**Retained as a representative process option.** Applicable to all sites.
		Easement purchase	Privately-owned land overlying an off-base groundwater plume is leased or purchased to provide Air Force access. The easement also restricts the installation of new wells by the land owner and other land usage that is incompatible with the contaminated groundwater underlying the easement.	Moderately effective. Potential usage of contaminated groundwater by off-base residents is minimized by the easement. Does not address the contaminants in groundwater.	Implementable. Off-base easements have already been purchased at Sites LF007C, FT005, and SS030.	Low to moderate capital. Low O&M.	Retained as a process option. Applicable to all off-base portions of groundwater sites. Off-base easements have already been purchased at Sites FT005, LF007C, and SS030.

TABLE 6-7
Screening of Groundwater Remedial Technologies and Process Options
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comments
Land Use Controls (continued)	Engineered Controls	Vapor barrier	A low-permeability barrier installed on the ground surface during building construction to minimize the intrusion of vapors emanated from a groundwater plume into a work space.	Effective at protecting human health from vapor intrusion with consistent implementation. Will not achieve RAOs without being used in conjunction with other technology. Does not address contaminants in groundwater.	Implementable. Installation of a vapor barrier in a new building adjacent to a groundwater plume is already required under the Base General Plan.	Low to moderate capital. Low O&M.	Retained as a process option. Applicable to sites where vapor intrusion has already been confirmed in existing buildings or where soil permeability is high.
		Passive venting	A venting system is installed to prevent the accumulation of soil gas under a structure located in proximity to a groundwater plume.	Effective at protecting human health from vapor intrusion with consistent implementation. Will not achieve RAOs without being used in conjunction with other technology. Does not address contaminants in groundwater.	Implementable. Installation of a passive venting system in a new building adjacent to a groundwater plume is already required under the Base General Plan.	Low to moderate capital. Low O&M.	Retained as a process option. Applicable. Already required for construction of new structures in proximity to a groundwater plume.
		Alternative water supply	Alternative sources of potable water are provided to users in lieu of untreated groundwater from privately-owned wells. The alternate sources could include connection to a municipal water supply, installing a new well in an uncontaminated portion of a property, or construction of a wellhead treatment unit.	Moderately effective at Sites FT005, LF007C, and SS030 as a component of a remedial system. Potential usage of contaminated groundwater by off-base residents is minimized by replacement with a potable water supply. Does not address the contaminants in groundwater.	Potentially implementable for the off-base portions of plumes at Sites LF007C, FT005, and SS030. However, the current GET IRAs have prevented contamination from impacting off-base domestic wells.	Moderate to high capital, low to moderate O&M.	Retained as a potential process option. Potentially applicable for the off-base plumes at Sites FT005, LF007C, and SS030.
	Monitoring	Groundwater monitoring	Short and long-term monitoring of groundwater is conducted to evaluate contaminant concentrations and trends.	Effective at all sites with groundwater contamination as a component of a remedial system. Groundwater monitoring has long been effective at monitoring contaminant concentrations and trends.	Implementable, but requires coordination between federal, state, and local agencies and the property owner.	Low capital, low O&M.	**Retained as a representative process option.** Applicable to all sites. Comprehensive groundwater monitoring is already being conducted under the Travis AFB GSAP.
Containment	Physical barrier	Soil-bentonite slurry wall	A trench is excavated and backfilled with a soil and bentonite (i.e., clay) slurry mixture to reduce or eliminate the migration of contaminated groundwater. The slurry creates a relatively low permeability barrier.	Can be effective if placed over or keyed into a confining layer or less permeable soil. Often used to isolate high concentration areas or source areas. Routinely used in conjunction with PRBs (e.g., ZVI) in a funnel-and-gate configuration to improve effectiveness of the permeable barrier.	Moderate to difficult implementability. Can be installed to a depth of approximately 60 feet bgs with conventional construction equipment. The degree of difficulty depends primarily on the nature of the subsurface materials.	Moderate to high. The presence of surface water features may require mitigation of natural resources and increase cost. The presence of roads, fences, underground utilities, or other structures can increase the difficulty of construction and increase costs.	Retained as a potential process option. Potentially applicable process option in conjunction with a PRB at Site SS029.
		Interceptor trench	A horizontal trench is excavated to intercept contaminated groundwater as it flows hydraulically downgradient. A pump removes accumulated water from the trench. The removed water is treated and discharged. Contaminated excess soil is disposed of at an off-base landfill.	Effective if the trench is keyed into competent bedrock. Contaminated groundwater is physically removed from the subsurface.	Moderate to difficult implementability. Can be installed to a depth of approximately 50 feet bgs with conventional construction equipment. The degree of difficulty depends primarily on the dimensions of the trench and the nature of the subsurface materials.	Moderate to high, depending on the dimensions of the trench, shoring requirements, and the presence of adjacent structures and subsurface infrastructure.	Retained as a potential process option. A groundwater interceptor trench was successfully installed as a component of the IRA at Site SS030. However, current groundwater contamination is hydraulically downgradient of the trench.

TABLE 6-7
Screening of Groundwater Remedial Technologies and Process Options
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comments
Containment (continued)	Hydraulic barrier	Extraction wells	Pumps are installed in vertical or horizontal extraction wells to remove contaminated groundwater and create a hydraulic barrier to contaminant migration. Dual-phase wells also use vacuum pumps or blowers to simultaneously extract soil vapor and enhance the rate of groundwater extraction. Extracted groundwater and soil vapor are conveyed to a treatment facility. Typically used in conjunction with an ex situ treatment technology.	Effective. Pumping a sufficient volume of groundwater with extraction wells can provide effective hydraulic containment. Groundwater extraction technology has been effectively employed at Travis AFB for several years. Vertical extraction wells have been proven more effective than horizontal wells. Limited effectiveness in removing contaminant mass when implemented as a containment action. Mass removal is incidental to the pumping of groundwater necessary to achieve hydraulic control.	Readily Implementable. Groundwater extraction is already used extensively at Travis AFB to hydraulically control contaminant migration. However, long-term implementation is required to maintain hydraulic containment of the contaminant plume and prevent migration. The presence of roads, taxiways, runways, underground utilities, or other structures can increase the difficulty of construction.	Moderate to high. An extensive network of groundwater extraction wells and conveyance pipelines already exist at Travis AFB. Depending on the scope of additional extraction system capacity to support a containment function, the capital costs related to new well construction, pump installation, and multi-service conveyance trench construction could range from moderate to high. Long-term O&M requirements can also be moderate to high, depending on the amount of time that the hydraulic barrier would be in service.	Retained as a potential process option. Vertical extraction wells for hydraulic containment have already been successfully implemented as a component of the existing groundwater IRAs at Sites FT004, FT005, LF007C, LF008, SS016, SS029, SS030, SD031, SD033, SD034, SD036, SD037, DP039, and SD043. Horizontal extraction wells have already been implemented as a component of the IRA at Site SS016.
Removal	Groundwater extraction	Extraction wells	Pumps are installed in vertical or horizontal extraction wells to remove contaminated groundwater. Dual-phase wells also use vacuum pumps or blowers to simultaneously extract soil vapor. Extracted groundwater and soil vapor are conveyed to a treatment facility. Typically used in conjunction with a treatment technology.	Effective. Pumping a sufficient volume of groundwater with extraction wells can provide effective contaminant mass removal. Groundwater extraction technology has been effectively employed at Travis AFB for several years. Vertical extraction wells have been proven more effective than horizontal wells. Mass removal effectiveness decreases over time as plume concentrations decrease.	Readily implementable. Groundwater extraction is already used extensively at Travis AFB to remove contamination and hydraulically control contaminant migration. The presence of roads, taxiways, runways, underground utilities, or other structures can increase the difficulty of construction.	Moderate to high. An extensive network of groundwater extraction wells and conveyance pipelines already exist at Travis AFB and will reduce initial capital costs at some sites. Depending on the scope of installing additional extraction system capacity, the capital costs related to new well construction, pump installation, and multi-service conveyance trench construction could range from moderate to high. Long-term O&M requirements can also be moderate to high. Not cost-effective for removal of contaminant mass on lower concentration dissolved-phase VOC plumes.	**Retained as a representative process option.** Installation of vertical extraction wells for contaminant mass removal has already been implemented as a component of the existing groundwater IRAs at Sites FT005, LF007C, LF008, SS016, SS029, SS030, SD033, SD034, SD036, SD037, and DP039. Optimization of the existing groundwater IRA at Sites LF007C and SS030 is planned during 2011–2012. At Site LF007C, solar-powered extraction pumps will be used to provide a more sustainable approach. At Site SS030, operation of the existing GET system will be conducted to improve hydraulic capture and mass removal.
		In situ thermal removal	Different methods are used to apply heat to the subsurface to mobilize/volatilize contaminants. Although the means to transmit heat into the subsurface varies with each process option, the end results of these technologies and the technical challenges that they face are identical.	Potentially effective within a well defined, high-concentration source area plume such as those found at Sites SS015, SS016, SD036, SD037, and DP039. Potential adverse impacts to human health and subsurface infrastructure associated with the thermal processes. The technology processes are not effective in addressing large-volume and/or low-concentration plumes.	Limited technical implementability for well defined, high-concentration source area plumes such as those found at Sites SS015, SS016, SD036, SD037, and DP039. Potential adverse impacts to human health and subsurface infrastructure associated with the thermal processes.	High capital cost. Low to moderate O&M. Can be cost-effective within well defined, high-concentration source area plumes such as those found at Sites SS015, SS016, SD036, SD037, and DP039. Not cost-effective in addressing large-volume and/or low-concentration plumes or portions of plumes.	Screened out because of technical implementability and high relative cost. Also, heating processes are incompatible with the GET IRA installations as well as the carbon substrate injections and bioreactor installations that have already been implemented at Sites SS015, SS016, SD036, SD037, and DP039 as IRA optimization actions.

TABLE 6-7
Screening of Groundwater Remedial Technologies and Process Options
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comments
Removal (continued)	Free product removal	Passive skimming	Floating product in wells is physically removed by bailing or using skimmers (active or passive).	Moderately effective. Removal can require long-term effort. Overall effectiveness is primarily dependent on subsurface conditions (i.e., soil permeability, chemical properties of product).	Implementable. Intermittent free product removal has been conducted at Site SD034 (Stoddard solvent) for several years during the period of interim remediation.	Low capital. Low to moderate O&M.	**Retained as a representative process option.** Applicable to Site SD034. Passive skimming is already being intermittently conducted at Site SD034.
		Bioslurping	A vacuum extraction technique to remove floating product from the groundwater table.	Limited effectiveness when floating product thickness is thin. Bioslurping has already been used to remove floating jet fuel at POCO sites.	Implementable. Bioslurping has already been used to remove floating jet fuel at POCO sites.	Moderate to high capital cost, moderate to high O&M cost.	Screened out because of limited effectiveness at removing thin layers of floating product and high relative cost.
In Situ Treatment	In situ physical, chemical, and biological degradation	MNA	Groundwater sampling and analysis is conducted to track the direction and rate of movement of the plume and natural attenuation processes.	Effective at achieving RAOs. MNA assessments at multiple Travis AFB sites during the period of interim remediation have demonstrated that MNA can effectively remediate groundwater contamination.	Readily implemented. Extensive Basewide groundwater monitoring is already being conducted at Travis AFB to assess the performance of MNA.	Low to moderate because of long-term monitoring requirements.	**Retained as a representative process option.** Groundwater monitoring to assess MNA processes is already implemented under the GSAP. MNA assessment is a component of the groundwater IRA at Sites FT004, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, and SD043. Sustainable process option.
		EA	Groundwater sampling and analysis is conducted to track the direction and rate of movement of a plume and attenuation processes after a source remedial action is taken. Following implementation of the source control action, the contaminant mass loading to the portion of the aquifer being monitored for attenuation is greatly reduced.	Effective at achieving RAOs for entire plumes, or portions of plumes. Used in conjunction with a source remediation technology (e.g., excavation). Attenuation assessments at multiple Travis AFB sites have demonstrated that physical, chemical, and/or biological processes can effectively remediate groundwater contamination.	Readily implemented. Extensive Basewide groundwater monitoring is already being conducted at Travis AFB to assess the performance of attenuation processes.	Low to moderate because of long-term monitoring requirements. O&M costs relatively higher than for MNA because of source area monitoring requirement.	**Retained as a representative process option.** Groundwater monitoring to assess attenuation processes is already implemented under the GSAP. EA monitoring is applicable to Sites SS015, SD034, SD036, SD037, and DP039. Each of these sites will have a source area remediation component. Sustainable process option.
	In situ biological treatment	Carbon substrate injection	A carbon substrate solution such as EVO, HRC®, lactate, or whey is injected into the subsurface as an electron donor to stimulate the anaerobic degradation of contaminants by native reducing bacteria. Chlorinated VOCs are broken down by reductive dechlorination processes. Can be used to remediate source areas by direct injection into the higher concentration areas of a plume; or the pattern of injected oil can form a PRB to intercept and treat contaminants as they migrate hydraulically downgradient.	Effective in treatment of well defined source areas. The overall effectiveness is primarily dependent on subsurface conditions and successful delivery of substrate. Diffusion-dominated conditions present at Travis AFB require a long-lived electron donor for effectiveness. Short-lived substrates will not be effective in the long term without frequent reinjection. EVO and HRC® are long half-life substrates that persist for years. Lactate and whey are short half-life substrates that only persist for days to months.	Moderately difficult to implement. Low aquifer permeability requires more closely spaced wells to ensure adequate distribution of the injected solutions. Travis AFB has already implemented substrate injection using EVO as optimizations to the existing groundwater IRAs at Sites SS015, SD036, SD037, and DP039. The HRC® substrate is proprietary. EVO, lactate, and whey are readily available as commercial products.	Low to moderate depending on injection of large volumes of electron donor into contaminant source areas. Not cost-effective on lower concentration portions of VOC plumes. Short half-life substrates will require frequent reinjection at higher cost.	**Retained as a representative process option using EVO primarily because the substrate persistence is more compatible with diffusion-dominated conditions than the other short half-life organic substrates.** In 2000 and 2001, a field treatability study of edible oil injection to degrade TCE was successfully implemented at Site SS015. Optimization actions for the existing groundwater IRAs using anaerobic degradation via EVO injection was conducted in 2010 at Sites SS015, SD036, SD037, and DP039. Sustainable process option.

TABLE 6-7
Screening of Groundwater Remedial Technologies and Process Options
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comments
In Situ Treatment (continued)	In situ biological treatment	PRB – Biobarrier	Reactive organic materials are placed as backfill in a trench excavated across the path of contaminant migration to create a PRB. Contaminants are degraded as groundwater flows through the PRB.	Effective in treatment of chlorinated VOCs if placed over or keyed into a confining layer or less permeable soil.	Moderate to difficult implementability. Can be installed to a depth of approximately 60 feet bgs with conventional construction equipment. The degree of difficulty depends primarily on the nature of the subsurface materials and surface obstructions.	Moderate to high. Not cost-effective on lower concentration areas of VOC plumes. The presence of surface water features may require mitigation of natural resources and increase cost. The presence of roads, fences, underground utilities, or other structures can increase the difficulty of construction and increase costs.	Retained as a potential process option. Sustainable process option.
		Bioaugmentation	Cultures of proprietary VOC-degrading microbes are injected into the contaminated aquifer along with electron donor solutions to enhance reductive dechlorination processes. Used in conjunction with carbon substrate injection, biobarrier, and bioreactor process options.	Effective for treatment of chlorinated VOCs through enhancement of native microbial populations. Often used to address incomplete anaerobic degradation. For example, conversion of TCE to cis-1,2-DCE occurs with native bacterial populations, but further degradation does not occur, even after the addition of an electron donor. The addition of other microbial consortia is used to complete the degradation process.	Implementable. Low aquifer permeability may require closely spaced wells to ensure adequate distribution of the injected solutions. Bioaugmentation cultures such as KB-1™ are available from SiREM and the Bio-Dechlor INOCULUM™culture from Regenesis.	Moderate to high, depending on the number of injection wells needed and the quantity of microbial consortia needed for treatment. Not cost-effective on lower concentration areas of VOC plumes.	Retained as a potential process option. Sustainable process option.
		Phytoremediation	Trees are planted to provide uptake of groundwater contaminants through the roots.	Limited effectiveness in treating relatively high concentrations of chlorinated VOCs in source areas. The main limiting factor is the depth of the root zone into the plume of contamination.	Implementable. A successful demonstration of phytoremediation has already been conducted at Site DP039. Creation of flying bird habitat limits administrative implementability at sites near the Travis AFB flightline.	Low to moderate capital costs. Low O&M costs.	**Retained as a representative process option.** Sustainable process option.
		Bioreactor	Contaminated soil in a known source area is excavated and the void backfilled with an organic mulch mixture. Contaminated groundwater from a source area extraction well is then recirculated through the bioreactor and source area aquifer. The mulch provides a nutrient source for native reducing bacteria, which also consume chlorinated VOCs.	Potentially effective within well defined contaminant source areas. Effectiveness is under evaluation for the remainder of the period of interim remediation. Bioreactors are in operation at Sites SS016 and DP039. Performance data are being collected and evaluated. Performance results at Site DP039 are encouraging.	Implementable. Bioreactors have already been installed at Sites SS016 and DP039.	Estimated moderate capital costs. Low to moderate O&M costs. Not cost-effective on lower concentration dissolved-phase VOC plumes.	**Retained as a representative process option.** Sustainable process option. Sustainable components include solar panels to provide the extraction pumps electric power.

TABLE 6-7
Screening of Groundwater Remedial Technologies and Process Options
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comments
In Situ Treatment (continued)	In situ chemical treatment	Chemical oxidation	Commonly called ISCO or simply chemical oxidation (chemox). An oxidant solution such as hydrogen peroxide, Fenton's Reagent™, ozone, persulfate, or potassium permanganate is injected into the aquifer to oxidize organic contaminants to carbon dioxide and water.	Potentially effective in DNAPL source areas or high concentration source areas. Effectiveness will be limited in the layered and diffusion-dominated clay and silt lithologies present at Travis AFB. The oxidant will not persist long in the subsurface, typically only days to months. Contaminant concentrations will rebound after the oxidant is depleted within the permeable zones. Effectiveness will also be limited by the high SOD present at Travis AFB. An excessive mass of oxidant will be required to overcome the natural consumption of the aquifer.	Moderate to difficult implementability. Aquifer heterogeneity can make distribution of the short-lived oxidant solutions difficult. Low aquifer permeability may require closely spaced wells to ensure adequate distribution of the injected solution. High SOD will rapidly consume the oxidant. Additional oxidant injections will be required to maintain treatment process. Oxidants such as peroxide require stringent health and safety measures during handling.	High, relative to in situ bioremediation costs using EVO. Costs are primarily dependent on the high SOD encountered at Travis AFB. Costs also depend on the number of injection wells needed and the quantity and type of oxidant required. Chemical oxidation not cost-effective on lower concentration dissolved-phase VOC plumes. Short-lived oxidants will require frequent reinjection at higher cost.	Retained as a potential process option. Applicable to sites with small source areas and subsurface soil with more permeable layers.
		ZVI Injection (Ferox℠ process, Z-Loy™ process)	Pneumatic fracturing is used to create macro-sized spaces in the subsurface. A proprietary ZVI slurry is then injected into the macro spaces.	Effective at treating chlorinated VOCs if good distribution of ZVI slurry is achieved. Effectiveness will be limited by the highly layered silt/clay lithology present at Travis AFB. Injection may not create as uniform a treatment zone as with a PRB.	Difficult to implement over a large area. More applicable to small areas and high concentration source areas than diffuse low-concentration plumes. May require re-injection after 5 to 7 years. More difficult in proximity of surface and subsurface infrastructure (e.g., utilities). Can be used up to 80 feet bgs. Radius of influence on the order of approximately 7 feet necessitates many injection points for effective distribution.	High, depending primarily on the areal extent and depth of treatment required. Not cost-effective on lower concentration dissolved-phase VOC plumes. Relatively low radius of influence necessitates several injection points and increased quantities of ZVI for effective distribution in treatment areas.	Screened out primarily because of technical implementability concerns in the layered alluvium, uncertainty about creating a uniform treatment zone, and high relative cost. Additionally, some formulations of injectable ZVI slurries (Z-Loy™) contain propylene glycol, which gets injected along with the ZVI.
		ZVI PRB	Chemical dechlorination is achieved using ZVI to abiotically degrade the VOCs in a permeable intercepting trench filled with a ZVI mixture.	Effective. Iron media may foul after time, typically 10 to 30 years, and require replacement. Routinely used in conjunction with vertical and horizontal barrier technologies in a funnel-and-gate configuration to improve effectiveness of the permeable ZVI barrier.	Moderate to difficult implementability. Can be installed to a depth of approximately 60 feet bgs with conventional construction equipment. The degree of difficulty depends primarily on the depth of the PRB and the ability to key into bedrock.	Moderate to high, depending primarily on the depth of installation and volume of ZVI required.	Retained as a potential process option. Applicable only to the distal portion of the commingled Site SS016 and Site SS029 plumes. Sustainable process option.

TABLE 6-7
Screening of Groundwater Remedial Technologies and Process Options
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Relative Cost	Screening Comments
Ex Situ Treatment	Physical treatment	LGAC adsorption	Contaminants are adsorbed onto activated carbon by passing contaminated groundwater through a carbon column. The carbon vessel may be at a fixed treatment facility or on a temporary, transportable treatment unit.	Effective at removing VOCs. Typically used in conjunction with a removal technology.	Readily implementable. Treatment of contaminated groundwater using LGAC has been successfully implemented at Travis AFB for several years.	Moderate to high depending on the volume and contaminant concentrations in the groundwater requiring treatment. Carbon replacement costs are typically moderate at Travis AFB.	**Retained as a representative process option.** LGAC already used at the NGWTP, CGWTP, and SBBGWTP as a component of the existing groundwater IRAs for Sites LF007C, FT004, SD031, LF008, SS016, SD033, SD034, SD036, SD037, DP039, FT005, SS029, and SS030.
		Air stripping	Air is bubbled through extracted groundwater in shallow trays. The VOCs partition into the airstream and are either vented to the atmosphere or captured on activated carbon.	Effective at removing VOCs. Typically used in conjunction with a removal technology.	Readily implementable. Air stripping has already been successfully implemented at the NGWTP for Sites FT004, LF007C, and SD031 as a component of the existing groundwater IRAs. Also implemented as a component of the existing groundwater IRAs at the SBBGWTP for Sites FT005, SS029, and SS030.	Low to moderate, but energy-intensive compared with LGAC treatment.	Retained as a potential process option. Previously used to treat groundwater extracted from Sites FT005, SS029, and SS030 at the existing SBBGWTP. Also used at the NGWTP to treat groundwater extracted from Sites FT004, LF007C, and SD031.
	Chemical treatment	UV/Ox	Ultraviolet light is used to promote the oxidation of groundwater contaminants. Ozone or hydrogen peroxide is typically used as part of the treatment process.	Effective at removing VOCs. Typically used in conjunction with a removal technology.	Implementable. UV/Ox has already been successfully implemented as a component of the IRAs at the CGWTP for Sites LF008, SS016, SD033, SS035, SD036, SD037, DP039, and SD043.	Moderate capital, but energy-intensive compared with LGAC treatment.	Retained as a potential process option. Previously used to treat groundwater extracted from Sites LF008, SS016, SD033, SS035, SD036, SD037, DP039, and SD043.
	Thermal treatment	ThOx	Vapor-phase VOCs removed from groundwater are destroyed by heating the air stream and passing it through a natural gas combustion unit in contact with a catalyst bed.	Effective at removing vapor-phase VOCs. Typically used in conjunction with a removal technology.	Implementable. Thermal oxidation has already been successfully implemented as a component of the IRA at Site SS016.	Moderate capital, but energy-intensive compared with LGAC treatment.	Retained as a potential process option. Previously used to treat soil vapor extracted by the 2-Phase® extraction well at Site SS016.
Disposal	Treated groundwater discharge	Stormwater drainage system	Treated groundwater is discharged to the Travis AFB stormwater drainage system (i.e., ditch, underground pipe network). Includes disposal in the Duck Pond component of the stormwater drainage system.	Effective. Treated groundwater has been effectively discharged to the Travis AFB stormwater drainage system for several years.	Readily implementable. Treated groundwater from existing groundwater treatment plants is already being discharged to the Travis AFB stormwater drainage system, including NGWTP discharges to the Duck Pond.	Low.	**Retained as a representative process option.** Discharge of treated groundwater from the CGWTP, NGWTP, and SBBGWTP has already been implemented as a component of the existing groundwater IRAs.
		Beneficial reuse	Treated groundwater is used for landscape irrigation.	Effective. Treated groundwater has historically been reused for landscape irrigation at Travis AFB.	Readily implementable. However, reuse of treated groundwater requires maintaining a pumping and conveyance system from the treatment facility to the reuse area.	Low to moderate, primarily because of the costs associated with maintaining pumping and conveyance systems. Difficult to obtain Air Force environmental restoration funding for beneficial reuse purposes.	Potential process option. Beneficial reuse of treated groundwater has previously been implemented at the CGWTP and NGWTP. Treated groundwater from Site LF007C is currently conveyed to the on-base Duck Pond recreational area. Sustainable process option.

TABLE 6-7
Screening of Groundwater Remedial Technologies and Process Options
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Summary of GRAs, Technologies, retained Process Options, and **Representative Process Options (shown in bold)**:

- **No Action**

- Land Use Controls – Administrative Mechanisms – **Base Civil Engineer Work Request**
- Land Use Controls – Administrative Mechanisms – **Excavation permit**
- Land Use Controls – Administrative Mechanisms – **Base General Plan**
- Land Use Controls – Administrative Mechanisms – Easement purchase
- Land Use Controls – Engineered Controls – Vapor barrier
- Land Use Controls – Engineered Controls – Passive venting
- Land Use Controls – Engineered Controls – Alternative water supply
- Land Use Controls – Monitoring – **Groundwater monitoring**

- Containment – Physical Barrier – Soil-bentonite slurry wall
- Containment – Physical Barrier – Interceptor trench
- Containment – Hydraulic Barrier – Extraction wells

- Removal – Groundwater Extraction – Extraction well
- Removal – Free Product Removal – **Passive skimming**

- In Situ Treatment – In situ physical, chemical, and biological degradation – **MNA**
- In Situ Treatment – In situ physical, chemical, and biological degradation – **EA**
- In Situ Treatment – In situ biological treatment – **Carbon substrate injection**
- In Situ Treatment – In situ biological treatment – PRB (biobarrier)
- In Situ Treatment – In situ biological treatment – Bioaugmentation
- In Situ Treatment – In situ biological treatment – **Phytoremediation**
- In Situ Treatment – In situ biological treatment – **Bioreactor**
- In Situ Treatment – In situ chemical treatment – Chemical oxidation
- In Situ Treatment – In situ chemical treatment – ZVI PRB

- Ex Situ Treatment – Physical treatment – **LGAC**
- Ex Situ Treatment – Physical treatment – Air stripping
- Ex Situ Treatment – Chemical treatment – UV/Ox
- Ex Situ Treatment – Thermal treatment – ThOx

- Disposal – Treated groundwater discharge – **Stormwater drainage system**
- Disposal – Treated groundwater discharge – Beneficial reuse

TABLE 6-8
Summary of Effectiveness Criterion Screening – by Technology Process Option and Site
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Technology Process Option	Site																				
	FT004	FT005	LF006	LF007B	LF007C	LF007D	LF008	SS015	SS016	ST027B	SS029	SS030	SD031	SD033	SD034	SS035	SD036	SD037	DP039	SS041	SD043
No Action	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○
Base Civil Engineer Work Request	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	○	■
Excavation permit	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	○	■
Base General Plan	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Easement purchase	○	■	○	○	■	○	○	○	○	○	○	■	○	○	○	○	○	○	○	○	○
Vapor barrier	◙	◙	◙	◙	◙	◙	○	■	◙	◙	◙	◙	◙	◙	◙	◙	◙	■	◙	○	◙
Passive venting	◙	◙	◙	◙	◙	◙	○	■	◙	◙	◙	◙	◙	◙	◙	◙	◙	■	◙	○	◙
Alternative water supply	○	◙	○	○	◙	○	○	○	○	○	○	◙	○	○	○	○	○	○	○	○	○
Groundwater monitoring	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	○	■
MNA	■	■	■	■	□	■	■	○	○	■	○	○	■	■	□	■	◙	◙	◙	○	■
EA	□	□	○	○	◙	□	□	■	○	□	○	□	◙	◙	■	□	■	■	■	○	◙
Soil-bentonite slurry wall	○	○	○	○	○	○	○	□	□	○	○	○	○	○	○	○	□	□	□	○	○
Interceptor trench	○	○	○	○	○	○	○	□	□	○	○	□	○	○	○	○	□	□	□	○	○
Vertical extraction well	◙	◙	○	○	■	□	□	◙	■	□	■	■	◙	◙	◙	□	◙	◙	◙	○	◙
Horizontal extraction well	□	□	○	○	□	□	□	□	■	□	□	□	□	□	□	□	□	□	□	○	□
DPE well	□	□	○	○	□	○	○	◙	□	□	□	□	□	□	□	□	◙	◙	◙	○	□
2-Phase® extraction well	□	□	○	○	□	○	○	◙	◙	□	□	□	□	□	□	□	◙	◙	◙	○	□
Passive skimming	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○	○	○	○	○
Bioslurping	○	○	○	○	○	○	○	○	○	○	○	○	○	○	◙	○	○	○	○	○	○
Carbon substrate injection	□	□	○	○	○	○	○	■	◙	□	○	○	□	○	□	○	■	■	■	○	○

TABLE 6-8
Summary of Effectiveness Criterion Screening – by Technology Process Option and Site
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Technology Process Option	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
PRB (biobarrier)	□	□	○	○	□	○	○	◙	◙	○	◙	□	□	○	□	□	◙	◙	◙	○	□
Bioaugmentation	□	□	○	○	○	○	○	◙	◙	○	◙	□	□	○	○	○	◙	◙	◙	○	○
Phytoremediation	◙	○	○	○	○	○	○	□	□	□	○	□	□	○	○	○	□	□	■ (shaded)	○	□
Bioreactor	□	○	○	○	○	○	○	◙	■ (shaded)	○	○	○	○	○	○	○	□	□	■ (shaded)	○	○
Chemical oxidation	○	○	○	○	○	○	□	□	□	○	○	○	○	○	○	○	□	□	□	○	○
ZVI injection	○	○	○	○	○	○	○	□	□	○	○	○	○	○	○	○	□	□	□ (shaded)	○	○
ZVI PRB	○	○	○	○	○	○	○	◙	◙	○	○	○	○	○	○	○	◙	◙	◙	○	○
Heating	○	○	○	○	○	○	○	◙	◙	○	○	○	○	○	○	○	◙	◙	◙	○	○
LGAC	◙ (shaded)	◙ (shaded)	○	○	■ (shaded)	○	□ (shaded)	◙	■ (shaded)	□	■ (shaded)	■ (shaded)	◙ (shaded)	◙ (shaded)	◙ (shaded)	□ (shaded)	◙ (shaded)	◙ (shaded)	◙ (shaded)	○	□ (shaded)
Air stripping	◙ (shaded)	◙ (shaded)	○	○	◙	○	○	◙	◙	□	◙ (shaded)	◙ (shaded)	◙ (shaded)	◙	◙	□	◙	◙	◙	○	◙
ThOx	○	○	○	○	○	○	○	○	◙ (shaded)	○	○	○	□	□	□	□	□	□	□	○	□
UV/Ox	□	□	○	○	□	○	□	◙	◙ (shaded)	○	□	□	□	□ (shaded)	□ (shaded)	□ (shaded)	◙ (shaded)	◙ (shaded)	◙ (shaded)	○	□ (shaded)
Stormwater drainage system	◙ (shaded)	◙ (shaded)	○	○	■ (shaded)	○	□ (shaded)	◙	■ (shaded)	□	■ (shaded)	■ (shaded)	◙ (shaded)	◙ (shaded)	◙ (shaded)	□ (shaded)	◙ (shaded)	◙ (shaded)	◙ (shaded)	○	□ (shaded)
Beneficial reuse	◙ (shaded)	□	○	○	■ (shaded)	○	□	□	□	□	□	□	◙ (shaded)	□	□	□	□	□	□	○	□

Notes:
■ Process option better satisfies Effectiveness criterion
◙ Process option moderately satisfies Effectiveness criterion
□ Process option poorly satisfies Effectiveness criterion
○ Process option not applicable or does not satisfy Effectiveness criterion

Shaded indicates a process option that has already been implemented as a component of the IRA, including demonstration projects, optimization measures, and actions taken in compliance with the requirements of the Base General Plan.
Bolded technology process options are considered to have aspects of green and sustainable remediation.

TABLE 6-9
Summary of Implementability Criterion Screening – by Technology Process Option and Site
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Technology Process Option	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
No Action	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○
Base Civil Engineer Work Request	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	○	■
Excavation permit	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	○	■
Base General Plan	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Easement purchase	○	■	○	○	■	○	○	○	○	○	○	■	○	○	○	○	○	○	○	○	○
Vapor barrier	◙	◙	◙	◙	◙	◙	○	■	◙	◙	◙	◙	◙	◙	◙	◙	◙	■	◙	○	◙
Passive venting	◙	◙	◙	◙	◙	◙	○	■	◙	◙	◙	◙	◙	◙	◙	◙	◙	■	◙	○	◙
Alternative water supply	○	◙	○	○	◙	○	○	○	○	○	○	◙	○	○	○	○	○	○	○	○	○
Groundwater monitoring	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	○	■
Alternate water supply	○	◙	○	○	◙	○	○	○	○	○	○	◙	○	○	○	○	○	○	○	○	○
MNA	■	■	■	■	◙	■	■	◙	○	■	○	◙	■	■	◙	■	◙	◙	◙	○	■
EA	◙	◙	○	○	□	○	○	■	□	◙	○	□	◙	◙	■	◙	■	■	■	○	◙
Soil-bentonite slurry wall	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Interceptor trench	○	○	○	○	○	○	○	□	○	○	□	■	○	○	○	○	□	□	□	○	○
Vertical extraction wells	■	■	○	□	■	□	■	◙	■	□	■	■	■	■	■	■	■	■	■	○	■
Horizontal extraction well	□	□	○	○	□	○	○	□	■	○	□	□	□	□	□	□	□	□	□	○	□
DPE well	◙	□	○	○	□	○	○	□	◙	○	□	□	◙	□	◙	□	◙	◙	◙	○	○
2-Phase® extraction well	□	□	○	○	□	○	○	□	◙	○	□	□	◙	□	◙	□	◙	◙	◙	○	○
Passive skimming	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○	○	○	○	○
Bioslurping	○	○	○	○	○	○	○	○	○	○	○	○	○	○	◙	○	○	○	○	○	○

TABLE 6-9
Summary of Implementability Criterion Screening – by Technology Process Option and Site
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Technology Process Option	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
Carbon substrate injection	□	□	○	□	□	□	○	■	□	□	○	○	□	○	□	○	■	■	■	○	○
PRB (biobarrier)	□	○	○	○	□	○	○	□	□	□	◙	□	□	○	□	○	□	□	◙	○	○
Bioaugmentation	□	□	○	□	□	□	○	■	□	□	○	○	□	○	□	○	■	■	■	○	○
Phytoremediation	□	○	○	○	○	○	○	○	○	○	○	○	□	○	○	○	○	○	■	○	○
Bioreactor	○	○	○	○	○	○	○	◙	■	○	○	○	○	○	○	○	□	□	■	○	○
Chemical oxidation	□	□	○	□	□	□	□	□	□	□	○	○	□	○	□	○	□	□	□	○	○
ZVI injection	□	□	○	□	□	□	○	□	□	□	○	○	□	○	□	○	□	□	□	○	○
ZVI PRB	□	○	○	○	□	○	○	□	□	□	□	○	○	○	○	○	□	□	□	○	○
Heating	○	○	○	○	○	○	○	□	□	○	○	○	□	○	○	○	□	□	□	○	○
LGAC	■	■	○	□	■	○	■	◙	■	□	■	■	■	■	■	■	■	■	■	○	■
Air stripping	◙	◙	○	○	◙	○	○	◙	◙	□	◙	◙	◙	◙	◙	□	◙	◙	◙	○	◙
ThOx	○	○	○	○	○	○	○	○	◙	○	○	○	□	□	□	□	□	□	□	○	□
UV/Ox	□	□	○	○	□	○	□	◙	◙	○	□	□	□	□	□	□	◙	◙	◙	○	□
Stormwater drainage system	◙	◙	○	○	■	○	□	◙	■	□	■	■	◙	◙	◙	□	◙	◙	◙	○	□
Beneficial reuse	◙	□	○	○	■	○	□	□	□	□	□	□	◙	□	□	□	□	□	□	○	□

Notes:

■ Process option better satisfies Implementability criterion
◙ Process option moderately satisfies Implementability criterion
□ Process option poorly satisfies Implementability criterion
○ Process option not applicable or does not satisfy Implementability criterion

Shaded indicates a process option that has already been implemented as a component of the IRA, including demonstration projects, optimization measures, and actions taken in compliance with the requirements of the Base General Plan.
Bolded technology process options are considered to have aspects of green and sustainable remediation.

TABLE 6-10
Summary of Relative Cost Criterion Screening – by Technology Process Option and Site
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Technology Process Option	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
No Action	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○
Base Civil Engineer Work Request	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	○	■
Excavation permit	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	○	■
Base General Plan	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Easement purchase	○	◙	○	○	◙	○	○	○	○	○	○	◙	○	○	○	○	○	○	○	○	○
Vapor barrier	◙	◙	◙	◙	◙	◙	○	■	◙	◙	◙	◙	◙	◙	◙	◙	◙	■	◙	○	◙
Passive venting	◙	◙	◙	◙	◙	◙	○	■	◙	◙	◙	◙	◙	◙	◙	◙	◙	■	◙	○	◙
Alternative water supply	○	◙	○	○	◙	○	○	○	○	○	○	◙	○	○	○	○	○	○	○	○	○
Groundwater monitoring	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	○	■
MNA	■	■	■	■	○	■	■	◙	○	■	○	○	■	■	◙	■	◙	◙	◙	○	■
EA	◙	◙	○	○	□	□	□	■	○	□	□	□	◙	◙	■	◙	■	■	■	○	◙
Soil-bentonite slurry wall	○	○	○	○	○	○	○	□	□	○	○	○	○	○	○	○	□	□	□	○	○
Interceptor trench	○	○	○	○	○	○	○	□	□	○	○	■	○	○	○	○	□	□	□	○	○
Vertical extraction well	◙	◙	○	□	■	□	◙	◙	◙	□	■	■	◙	◙	◙	◙	◙	◙	◙	○	◙
Horizontal extraction well	□	□	○	○	□	○	○	□	■	○	□	□	□	□	□	□	□	□	□	○	□
DPE well	◙	□	○	○	□	○	○	□	◙	○	□	□	◙	□	◙	□	◙	◙	◙	○	○
2-Phase® extraction well	□	□	○	○	□	○	○	□	◙	○	□	□	◙	□	◙	□	◙	◙	◙	○	○
Passive skimming	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○	○	○	○	○
Bioslurping	○	○	○	○	○	○	○	○	○	○	○	○	○	○	□	○	○	○	○	○	○
Carbon substrate injection	□	□	○	□	□	□	○	■	□	□	○	○	□	○	□	○	■	■	■	○	○

TABLE 6-10
Summary of Relative Cost Criterion Screening – by Technology Process Option and Site
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Technology Process Option	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
PRB (biobarrier)	□	○	○	○	□	○	○	□	□	□	◙	□	□	○	□	○	□	□	◙	○	○
Bioaugmentation	□	□	○	□	□	□	○	◙	□	□	○	○	□	○	□	○	◙	◙	◙	○	○
Phytoremediation	◙	○	□	□	□	□	○	□	□	□	□	□	□	□	□	□	□	□	■	○	□
Bioreactor	□	○	○	○	○	○	○	◙	■	○	○	○	○	○	○	○	□	□	■	○	○
Chemical oxidation	○	○	○	○	○	○	□	□	□	○	○	○	○	○	○	○	□	□	□	○	○
ZVI injection	○	○	○	○	○	○	○	□	□	○	○	○	○	○	○	○	□	□	□	○	○
ZVI PRB	□	○	○	○	□	○	○	□	□	□	□	○	○	○	○	○	□	□	□	○	○
Heating	○	○	○	○	○	○	○	□	□	○	○	○	□	○	○	○	□	□	□	○	○
LGAC	■	■	○	□	■	○	■	◙	■	□	■	■	■	■	■	■	■	■	■	○	■
Air stripping	◙	◙	○	○	◙	○	○	◙	◙	□	◙	◙	◙	◙	◙	□	◙	◙	◙	○	◙
ThOx	○	○	○	○	○	○	○	○	◙	○	○	○	□	□	□	□	□	□	□	○	□
UV/Ox	□	□	○	○	□	○	□	◙	◙	○	□	□	□	□	□	□	◙	◙	◙	○	□
Stormwater drainage system	◙	◙	○	○	■	○	□	◙	■	□	■	■	◙	◙	◙	□	◙	◙	◙	○	□
Beneficial reuse	◙	□	○	○	■	○	□	□	□	□	□	□	◙	□	□	□	□	□	□	○	□

Notes:
■ Process option better satisfies Relative Cost criterion
◙ Process option moderately satisfies Relative Cost criterion
□ Process option poorly satisfies Relative Cost criterion
○ Process option not applicable or does not satisfy Relative Cost criterion

Shaded indicates a process option that has already been implemented as a component of the IRA, including demonstration projects, optimization measures, and actions taken in compliance with the requirements of the Base General Plan.
Bolded technology process options are considered to have aspects of green and sustainable remediation.

TABLE 6-11
Summary of Representative Process Options – by Site
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Technology Process Option	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
No Action																				●	
Base Civil Engineer Work Request	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●
Excavation permit	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●
Base General Plan	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Groundwater monitoring	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●
MNA	●	●	●	●		●	●			●			●	●		●					●
EA								●							●		●	●	●		
Interceptor trench																					
Vertical extraction well					●				●		●	●									
Horizontal extraction well									●												
Passive skimming															●						
Carbon substrate injection								●									●	●	●		
Phytoremediation																			●		
Bioreactor									●										●		
LGAC					●				●		●	●									
Stormwater drainage system					●				●		●	●									
Beneficial reuse					●																

Notes:
● Representative Process Option that best satisfies the evaluation criteria of Effectiveness, Implementability, and Relative Cost at each site.

Shaded indicates a process option that has already been implemented as a component of the IRA at a site, including demonstration projects and optimization measures. After a approximately a decade of interim remediation, some existing process options best satisfy the evaluation criteria. Other existing process options do not satisfy the criteria as well as other listed processes and are not selected as being representative.
Bolded technology process options are considered to have aspects of green and sustainable remediation.

TABLE 6-12
Summary of General Response Actions, Technologies, and Process Options Screening
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

General Response Action	Technology	Process Option	Effectiveness, Implementability, and Relative Cost Screening Summary
No Action	None	None	Required for consideration by NCP
Land Use Controls	Administrative mechanisms	**Base Civil Engineer Work Request**	**Representative process option**
		Excavation permit	**Representative process option**
		Base General Plan	**Representative process option**
		Easement purchase	Potentially applicable
	Engineered controls	Vapor barrier	Potentially applicable
		Passive venting	Potentially applicable
		Alternative water supply	Potentially applicable
	Monitoring	**Groundwater monitoring**	**Representative process option**
Containment	Physical barrier	Soil-bentonite slurry wall	Potentially applicable
		Interceptor trench	Potentially applicable
	Hydraulic barrier	Extraction wells	Potentially applicable
Removal	Groundwater extraction	Extraction wells	**Representative process option**
		In situ thermal removal	Screened out
	Free product removal	**Passive skimming**	**Representative process option**
		Bioslurping	Screened out
In Situ Treatment	In situ physical, chemical, and biological degradation	**MNA**	**Representative process option**
		EA	**Representative process option**
	In situ biological treatment	**Carbon substrate injection**	**Representative process option**
		PRB (biobarrier)	Potentially applicable
		Bioaugmentation	Potentially applicable
		Phytoremediation	**Representative process option**
		Bioreactor	**Representative process option**
	In situ chemical treatment	Chemical oxidation	Potentially applicable
		ZVI injection	Screened out
		ZVI PRB	Potentially applicable
Ex Situ Treatment	Physical treatment	**LGAC adsorption**	**Representative process option**
		Air stripping	Potentially applicable
	Chemical treatment	UV/Ox	Potentially applicable
	Thermal treatment	Thermal oxidation	Potentially applicable
Disposal	Treated groundwater discharge	**Stormwater drainage system**	**Representative process option**
		Beneficial reuse	Potentially applicable

Note:

Boldface process options are selected as being representative of the technology type. Process options not selected as representative are not eliminated from future consideration.

TABLE 6-13
Summary of Electron Donors for Enhanced Reductive Dechlorination
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Electron Donor	Chemical Formula	Half-life (days)	Solubility	Viscosity (cP at 20°C)	Comments
Short Half-life					
Lactate	$C_3H_5O_3$	20 to 45	Soluble	38	One of the most commonly used soluble donors; density greater than water; therefore, must be injected in dilute concentrations.
Acetate	$C_2H_3O_2$	15 to 40	0.7 g/mL	0.732	Very soluble, making it a good donor for recirculation systems. Issues with transportation and handling because of its properties.
Ethanol	C_2H_60	15 to 25	Miscible	1.2	Completely miscible in water, making ethanol along with methanol one (1) of the most suitable donors for recirculation systems. Issues with transportation and handling because of its explosive properties.
Methanol	CH_4O	15 to 25	Miscible	0.61	Similar to ethanol.
Molasses	$C_{12}H_{22}O_{11}$	25 to 50	Soluble	5,000	Broad spectrum donor containing simple and complex sugars. Viscosity is a problem along with the potential to biofoul injection wells and well packs.
Whey (cheese)	–	30 to 50	Soluble		Contains complex sugars and other simple carbon compounds that provide electrons over a longer period than the first four (4) donors on this list.
Long Half-life					
EOS® – EVO	$C_{18}H_{32}O_2$	100 to 365	Slightly soluble	Similar to cream	Emulsified soybean oil. Complex unsaturated alkanes that degrade to release electrons over a long period. Slow release of electrons may not be sufficient to meet demand for solvent attenuation.
HRC®	$C_{39}H_{56}O_{39}$	85 to 200	Slightly soluble	20,000	Proprietary slow release polylactate ester releases lactate to aquifer. Viscosity like that of molasses in cold temperatures. Release of electrons may not be sufficient to meet demand for solvent attenuation.
HRC-X® (extended release formula)	–	365 to 1,000	Slightly soluble	200,000	Similar to HRC® but lasts longer. Release of electrons may not be sufficient to meet demand for solvent attenuation.
Chitin	–	100 to 250	Slightly soluble	10–5,000	Structure similar to cellulose. Breaks down slowly to produce electrons over time. Release of electrons may not be sufficient to meet demand for solvent attenuation.
EHC™	–	100 to 250	Slightly soluble	10–5,000	Structure similar to cellulose. Breaks down slowly to produce electrons over time. Release of electrons may not be sufficient to meet demand for solvent attenuation.

Notes:

HRC® and HRC-X® are registered products of Regenesis.
EHC™ is a registered product of Adventus.

cP = centipoises(s)
g/mL = gram(s) per milliliter

TABLE 6-14
Summary Comparison of Typical Oxidants
Basewide Groundwater Focused Feasibility Study,Travis Air Force Base, California

Oxidant	Characteristics	Advantages	Disadvantages
Hydrogen peroxide	H_2O_2 solution Fenton's Reagent™ is produced by adding an iron catalyst to a hydrogen peroxide solution to form free radical $OH^{\bullet}$ Complex chemistry involving numerous reactive intermediates and mechanisms	Readily available from industrial applications (but should be diluted to < 15% [wt.]) High oxidation potential Wide range of contaminant applicability	Subsurface heterogeneity can result in uneven distribution Strict health and safety procedures required for high-pressure injection Exothermic reactions Short half-life Porosity of the subsurface may be reduced because of the formation of metal oxide precipitates Requires closely spaced injection points A patented process is used to inject Fenton's Reagent™ Multiple injections may be required to address rebound effects in diffusion-dominated environments
Persulfate	$Na_2S_2O_8$ salt or solution Activated via heat, metal catalyst, or base to form free radical $SO_4^{\bullet}$ Available as sodium, ammonium, or potassium salt	High oxidation potential Wide range of contaminant applicability Fewer health and safety issues than peroxide	Subsurface heterogeneity can result in uneven distribution Emerging oxidant with less experience base Similar half-life to permanganate; typically persists for hours to weeks Multiple injections may be required to address rebound effects in diffusion-dominated environments
Ozone	Gas – O_3 Degrades to dissolved oxygen Reacts with water to produce hydroxyl radical $HO_2^{\bullet}$ Generated onsite from air or oxygen	High oxidation potential Wide range of contaminant applicability Onsite generation for continuous application	Subsurface heterogeneity can result in uneven distribution Unstable; short half-life; typically persists for only minutes to hours Requires closely spaced injection points Relatively expensive Multiple injections may be required to address rebound effects in diffusion-dominated environments

TABLE 6-14
Summary Comparison of Typical Oxidants
Basewide Groundwater Focused Feasibility Study,Travis Air Force Base, California

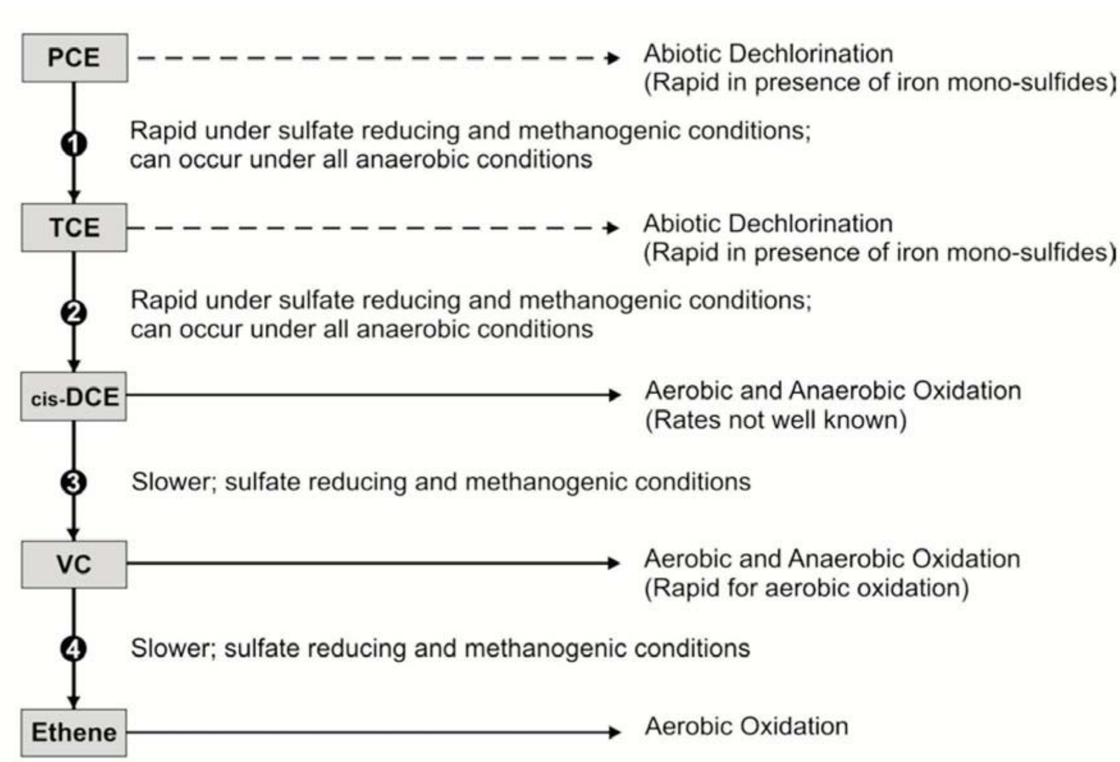
Oxidant	Characteristics	Advantages	Disadvantages
Permanganate	$KMnO_4$ salt – max. solubility ~4% $NaMnO_4$ liquid – 40% solution Mined from ore and contains impurities Supplied in grades based on purity and flow properties More fully developed process than other oxidants	More stable than other typical oxidants; can persist for 3 months or more Better stability allows for use of recirculation loops to improve efficiency of distribution Better diffusion into clay and rock Low gas/heat generation Effective over wide pH range	Subsurface heterogeneity can result in uneven distribution Strict health and safety procedures required for high-pressure injection Lower oxidation potential Narrower range of contaminant applicability Metal impurities Porosity of the subsurface may be reduced because of the formation of metal oxide precipitates (soil pore clogging resulting from MnO_2 formation) Multiple injections may be required to address rebound effects in diffusion-dominated environments
ZVI	Sub-micrometer zero valent metal powder suspension Variable concentrations of ZVI; higher concentrations for source areas (i.e, NAPL) Some formulations of ZVI slurry include propylene glycol (Z-Loy™); others water (Ferox℠)	Some formulations (not all) persistent in subsurface once injected, on the order of years Rapid abiotic destruction of chlorinated contaminants	Reduced permeability in subsurface due to filling pore space with solids Some formulations (not all) contain propylene glycol which would be injected along with the ZVI Byproducts of ZVI injections include iron hydroxides, iron oxides, and hydrogen gas Relatively high cost of ZVI slurry

TABLE 6-15
Summary Comparison of EVO and ISCO Technology Processes
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

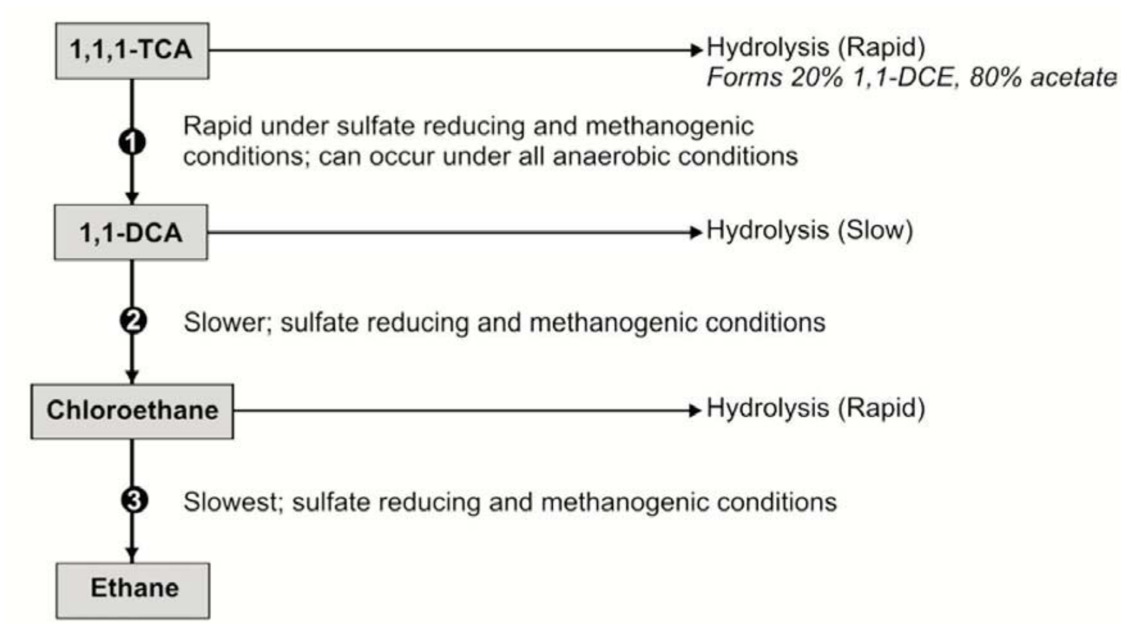
Attribute	ISCO	EVO	Comments
Treatment process	Direct chemical oxidation of contaminants to non-toxic compounds.	Provides nutrients to bacteria, which then create anaerobic conditions to degrade contaminants.	Both processes are potentially effective. The key factor is establishing and maintaining contact between the treatment compound and the contaminants.
Persistence of treatment process	Short-term persistence, typically on the order of weeks to months before oxidant is depleted and reinjection is required to maintain the treatment process.	Long-term persistence, typically on the order of years. Reinjection frequency approximately 3 to 5 years.	Treatment using ISCO is potentially fast in a permeable lithology, but short-lived. Conversely, treatment using EVO is slower, but longer-lived.
Compatibility with aquifer chemistry	Limited compatibility. Soil at Travis AFB has a high oxidant demand that requires closely spaced injection points, a large amount of initial oxidant injection, and frequent reinjection to maintain active treatment processes.	More compatible, but natural aerobic conditions in the aquifer will initially inhibit the creation of conditions amenable to reductive dechlorination. Time will be required to develop the requisite anaerobic conditions.	A 2000–2001 vegetable oil injection treatability study at Site SS015 and ongoing bioreactor studies at Sites SS016 and DP039 provide sufficient evidence that reductive dechlorination is a viable treatment process for the aquifer conditions at Travis AFB.
Compatibility with aquifer lithology	Mostly incompatible with the diffusion-dominated clay and silt lithology typically encountered at Travis AFB. Treatment using ISCO will rapidly destroy contaminants within the sandy permeable zones. However, the majority of the contamination in the silts and clays will not come in contact with the oxidant and will not be destroyed before the oxidant is depleted.	More compatible with diffusion-dominated clay and silt lithology. Contaminants will slowly diffuse out of the silts and clays as the longer term reductive dechlorination treatment proceeds. Long lasting EVO will continue to foster anaerobic conditions and maintain the treatment process for up to several years.	The alluvial aquifer at Travis AFB is diffusion-dominated and typically characterized by low permeability interbedded silts, clays, and sands. The more permeable sand seams are heterogeneous and typically occur as thin, laterally discontinuous lenses.
Potential for rebound of contamination following treatment	High potential for rebound after initial injection. After the oxidant within the permeable sandy zones is depleted, contaminant concentrations in the soil and groundwater will re-establish at equilibrium concentrations. Multiple reinjection of the oxidant will be required to maintain the treatment process.	Lower potential for rebound after initial injection. Although slower than ISCO, the reductive dechlorination treatment process can be maintained for years. This timeframe is more compatible with the slow release of contaminants from the fine-grained soils as equilibrium concentrations are maintained between the soil and groundwater.	The remediation timeframe is limited by how quickly contamination diffuses out of the clay and silt and into the sandy, more permeable zones. EVO lasts longer than ISCO. This long-term persistence is more compatible with the lengthy contaminant diffusion time.

TABLE 6-15
Summary Comparison of EVO and ISCO Technology Processes
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Attribute	ISCO	EVO	Comments
Compatibility with contamination types	Compatible with remediation of chlorinated VOCs, primarily TCE and related compounds. Can also be effective at destroying DNAPL source zones if good contact between the oxidant and the DNAPL in a sandy zone is established.	Compatible with remediation of chlorinated VOCs, primarily TCE and related compounds. Will not directly remediate DNAPL. Will remediate dissolved-phase contamination originating from a DNAPL source.	The presence of localized DNAPL is indicated by localized high dissolved-phase concentrations at Site SD036.
Potential formation of breakdown products	Byproducts typically are inorganics, such as selenium and arsenic. Breakdown products do not usually persist outside the treatment zone.	Incomplete reductive dechlorination typically results in formation of cis-1,2-DCE and vinyl chloride. Reduced metals such as manganese and iron are also potential byproducts. Vinyl chloride is more mobile than the TCE parent compound and can potentially migrate outside the anaerobic treatment zone. However, in the naturally aerobic aquifer at Travis AFB, the vinyl chloride will rapidly degrade.	ERD in and around the Site DP039 bioreactor has resulted in TCE reductions of more than 90 percent with minimal vinyl chloride formation or accumulation. The aerobic conditions surrounding the bioreactor appear to be providing an environment for aerobic biodegradation of vinyl chloride. The bioreactor within the OSA at Site SS016 was installed in October 2010. Performance data will be collected throughout the period of interim remediation.
Worker health and safety issues	Stringent for pressurized injection of strong oxidizers, such as peroxide. Worker protection measures will be required during transportation and handling. Less stringent measures will be required for permanganate-based oxidant solutions.	Minimal. EVO is a food-grade product that will not require special handling procedures to ensure worker safety.	Special handling procedures for strong oxidants decrease productivity and increase project risk and costs.
Relative Cost	Relatively high cost for Travis AFB driven by the high natural oxidant demand and multiple injections required. For a hypothetical site, similar to Site SD036, ISCO treatment using a permanganate solution would cost approximately $853,600.	Moderate cost for Travis AFB because of lower permeability soils. Cost could increase if EVO injection requires closer spacing of injection wells to distribute organic substrate. For the same hypothetical site, similar to Site SD036, EVO treatment would cost approximately $66,000.	Costs are primarily dependent on the number of injection points and quantity of treatment compound. In situ treatment is not cost-effective in lower concentration portions of plumes. The relatively high ISCO treatment cost is primarily driven by the high natural oxidant demand encountered at Travis AFB.



REACTION SEQUENCE AND RELATIVE RATES OF DEGRADATION FOR CHLORINATED ETHENES



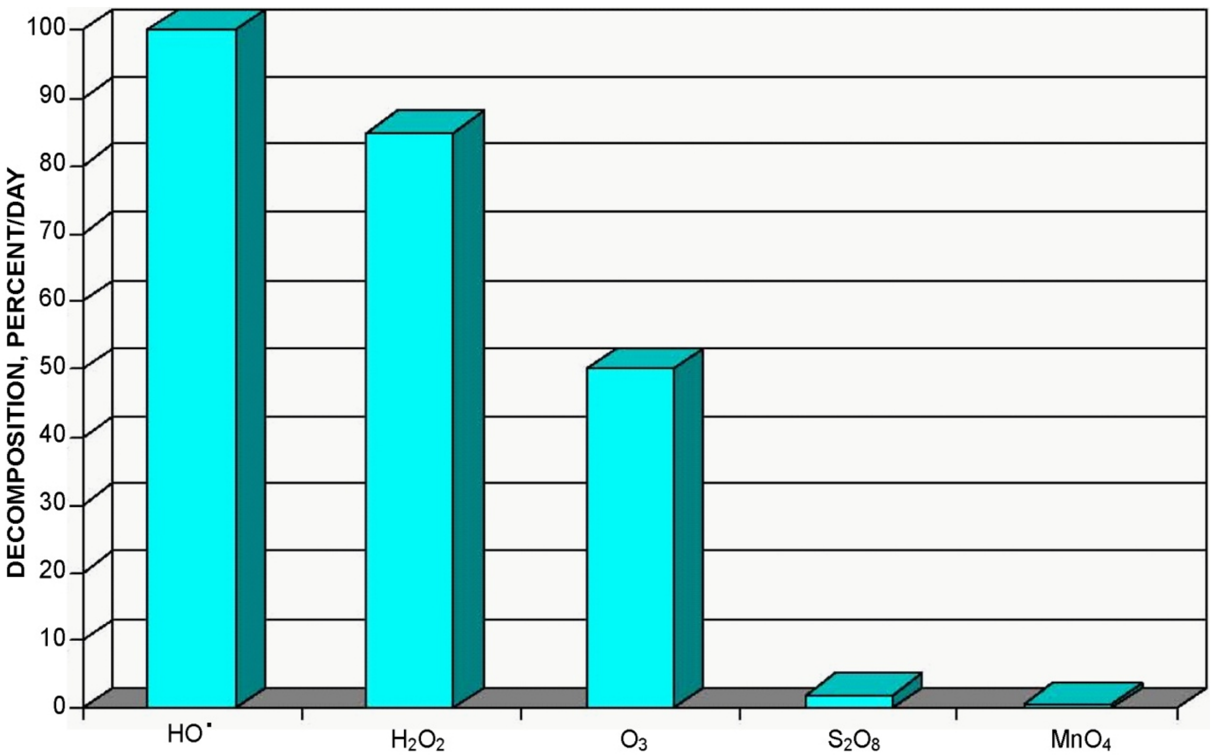
REACTION SEQUENCE AND RELATIVE RATES OF DEGRADATION FOR CHLORINATED ETHANES

SOURCE: AFCEE, 2004

FIGURE 6-1
REACTION SEQUENCES AND RELATIVE RATES OF DEGRADATION
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

ES011811013517RDD_6-1

CH2MHILL®



Source: Presentation by Richard Brown at 2003 AFCEE Technology Transfer Workshop

FIGURE 6-2
Typical Oxidant Decomposition Rates

SECTION 7

Assembly and Screening of Alternatives

This section describes the assembly of the representative process options developed in Section 6 into site-specific remedial alternatives. The assembled alternatives are then screened against the criteria of Effectiveness, Implementability, and Cost.

The alternatives developed in this section address the entirety of a site-specific plume. This is accomplished by assembling representative process options that are applicable to the site and contaminant conditions that exist within the various portions of the plume. At some sites, only one (1) technology process may be required to achieve RAOs. For example, GET may be capable of remediating the entirety of a plume without need of another process.

For other sites, individual technology process options might address contamination within one (1) portion of a plume but not another portion. For example, an in situ bioreactor can be effective, implementable, and cost-effective in a highly contaminated shallow source area but will fail against the three (3) evaluation criteria in the low-concentration distal portion of the same plume. For sites with these characteristics, an alternative is assembled from process options to address both the source and distal portions of the plume.

7.1 Summary of Previous Alternative Development

The following subsections summarize the development of groundwater remedial alternatives previously conducted for ERP sites within the NEWIOU and WABOU.

Interim remediation of the NEWIOU and WABOU contaminated groundwater sites is currently being conducted under the two (2) IRODs. These IRAs were implemented to quickly begin remediation of groundwater contamination, reduce the levels of contamination and potential risk, and collect some of the data necessary for the selection of final cleanup levels and technically and economically feasible long-term actions. The use of an IROD allowed groundwater IRAs to proceed without having final designated cleanup levels, as will be required for the pending ROD.

7.1.1 Interim Alternatives Developed in the NEWIOU Feasibility Study

The NEWIOU FS developed and evaluated interim remedial alternatives for 15 ERP sites and plume areas within the NEWIOU (Radian, 1996a). Descriptions of these alternatives are also provided in Section 4.1 of the final Groundwater IROD for the NEWIOU (Travis AFB, 1998). The alternatives developed and evaluated for NEWIOU sites include the following:

- Alternative 1 – No Action
- Alternative 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
- Alternative 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain

- Alternative 4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
- Alternative 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
- Alternative 6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
- Alternative 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
- Alternative 8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain
- Alternative 9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation

7.1.2 Interim Alternatives Selected in the NEWIOU Interim Record of Decision

Following evaluations of the nine (9) alternatives in the NEWIOU FS (Radian, 1996a), two (2) interim remedial alternatives were selected for the NEWIOU sites in the final Groundwater IROD for the NEWIOU (Travis AFB, 1998). A site-specific summary of the alternatives is provided in Table 7-1. In brief, the alternatives selected in the IROD include the following:

- Alternative 2 – Natural Attenuation/Monitoring
- Alternative 3 – Extraction, Treatment, and Discharge (i.e., GET)

At most sites, the formal selection of Alternative 2 – MNA was deferred pending the completion of MNA assessments during the period of interim remediation to evaluate the feasibility of implementing MNA for all or part of several contaminant plumes. At NEWIOU Site LF006, MNA was the selected IRA.

Alternative 3 uses groundwater extraction and treatment processes (i.e., GET) to hydraulically capture areas of groundwater contamination and remove contaminant mass.

7.1.3 Interim Alternatives Developed in the WABOU Feasibility Study

The WABOU FS developed and evaluated interim remedial alternatives for four (4) ERP sites within the WABOU (CH2M HILL, 1998a). Descriptions of these alternatives are provided in Section 4.2 and Table 4-1 of the final Groundwater IROD for the WABOU (Travis AFB, 1999). The alternatives developed and evaluated for WABOU sites include the following:

- Alternative G1 – No Action
- Alternative G2 – MNA
- Alternative G3 – Containment/Treatment/Discharge
- Alternative G4 – Extraction/Treatment/Discharge
- Alternative G5 – Source Area and Groundwater Extraction/Treatment/MNA
- Alternative G6 – Source Area Extraction/Treatment/MNA

TABLE 7-1
Summary of Selected Interim Remedial Alternatives for NEWIOU ERP Sites
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Selected Interim Remedial Alternative in NEWIOU IROD			
	Alternative 2 Natural Attenuation/ Monitoring	Alternative 3 Extraction, Treatment, and Discharge (GET)		
		Source Control	Migration Control	Off-base Remediation
FT004		●		
FT005			●	●
LF006	●			
LF007B	○			
LF007C	○[a]		●[b]	●[c]
LF007D	○			
SS015	○			
SS016	○	●[d]	●[e]	
SS029			●	
SS030		●	●	●
SD031		●		
SD033	○[f]		●[g]	
SD034		●[h]	●[i]	
SS035	○			
SD036		●	●	
SD037	○[j]	●[k]	●[l]	

[a] On-base portion of plume
[b] Plume at Base boundary
[c] Off-base portion of plume
[d] OSA portion of plume
[e] Southern portion of plume
[f] South Gate Area, Facility 1917, and Facility 810 plumes
[g] Storm sewer
[h] Bioslurp/free product removal
[i] Coordinated with Site SD037
[j] Portions of plume near Facilities 919, 977, 981, and Area G Ramp
[k] Portions of plume near Facilities 837, 838, and Ragsdale/V Area
[l] Remainder of plume

Notes:

● = Interim remedial alternative selected for the site.
○ = MNA Assessment. Selection of MNA deferred until completion of the NAAR.

Source: Table 5-3 of the final Groundwater IROD for the NEWIOU (Travis AFB, 1998).

7.1.4 Interim Alternatives Selected in the WABOU Interim Record of Decision

Following evaluations of the six (6) alternatives in the WABOU FS (CH2M HILL, 1998a), the Groundwater IROD for the WABOU (Travis AFB, 1999) selected three (3) interim remedial alternatives. A site-specific summary of the alternatives is provided in Table 7-2. In brief, the alternatives selected in the IROD include the following:

- Alternative G3 – Containment/Treatment/Discharge (i.e., GET)
- Alternative G4 – Extraction/Treatment/Discharge (i.e., GET)
- Alternative G5 – Source Area and Groundwater Extraction/Treatment/MNA (i.e., GET and MNA)

TABLE 7-2
Summary of Selected Interim Remedial Alternatives for WABOU ERP Sites
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Selected Interim Remedial Alternative in WABOU IROD		
Site	Alternative G3 Containment/Treatment/ Discharge (GET)	Alternative G4 Extraction/Treatment/ Discharge (GET)	Alternative G5 Source Area and Groundwater Extraction/Treatment/MNA (GET and MNA)
LF008		●	
DP039	●		●
SS041	●		
SD043	●		

Note:
● = Interim remedial alternative selected for the site.
Source: Section 5.0 of the final Groundwater IROD for the WABOU (Travis AFB, 1999).

Each of the WABOU alternatives includes a GET component. Similar to the NEWIOU Alternative 3, WABOU Alternatives G3 and G4 are GET actions to prevent the migration of groundwater contamination into hydraulically downgradient areas.

At Site DP039, Alternative 3 is combined with Alternative G5, a vacuum-enhanced version of GET to hydraulically contain and remove relatively high concentrations of VOCs from the vadose zone and groundwater at the source of contamination. These GET actions are also combined with a program of MNA to address the relatively lower levels of contamination within the distal portion of the plume.

7.2 Summary of Previously Selected Interim Remedial Alternatives

The following subsections provide summaries of the IRAs previously developed in the two (2) FSs and then formally selected the two (2) groundwater IRODs.

7.2.1 Summary of Interim Remedial Alternatives for NEWIOU Sites

A site-specific summary of the interim remedial alternatives developed in the NEWIOU FS (Radian, 1996a) and then selected in the Groundwater IROD for the NEWIOU (Travis AFB,

1998) is provided in Table 7-3. This table summarizes the alternatives developed in the NEWIOU FS, the alternatives evaluated for each site in the NEWIOU FS, and those alternatives subsequently selected in the Groundwater IROD for the NEWIOU for each site.

7.2.2 Summary of Interim Remedial Alternatives for WABOU Sites

A site-specific summary of the interim remedial alternatives developed in the WABOU FS (CH2M HILL, 1998a) and then selected in the Groundwater IROD for the WABOU (Travis AFB, 1999) is provided in Table 7-4. This table summarizes the alternatives developed in the WABOU FS, the alternatives evaluated for each site in the WABOU FS, and those alternatives subsequently selected in the Groundwater IROD for the WABOU for each site.

7.2.3 Summary of Interim Remedial Action Performance and Optimization Actions

A summary of the IRAs implemented at the ERP sites is provided in Table 7-5. This table summarizes the alternative selected for each site in the NEWIOU and WABOU IRODs, the IRA objectives, IRA performance and status, IRA optimization actions, and the post-optimization actions that have been taken to-date at each site.

7.2.4 Remedial Alternative Terminology Differences

Different terminologies are used to describe the remedial alternatives previously developed in the two (2) FS and two (2) IRODs. A listing of the alternative designations used in the IRODs for each NEWIOU and WABOU site is summarized in Table 7-6.

Although the terminology previously used in the IRODs is different between the NEWIOU and WABOU, the basic technology approach used at each site can be represented by one (1) consistent terminology in the current FFS. This equivalent alternative terminology is summarized in Table 7-6. This terminology is also used in the development of current remedial alternatives in this section of the FFS.

A summary of the technology process options that compose each of the alternatives is provided in Table 6-1.

7.3 Current Alternative Development

This section describes the assembly of the representative process options developed in Section 6 into current remedial alternatives for each site.

Travis AFB has successfully operated and monitored the performance of the site-specific groundwater IRAs within the NEWIOU and WABOU for approximately a decade. Travis AFB is now beginning the transition out of the period of interim remediation. The long-term performance of the existing IRAs, existing IRA optimization measures, successful demonstration projects, and treatability studies results are factors in the development of alternatives in the FFS. Summaries of the performance of the existing IRAs and optimization actions are provided in Table 7-5.

The *representative* process options developed in Section 6 and assembled into remedial alternatives in this section include the following:

- **No Action**
- Land Use Controls – Administrative Mechanisms – **Base Civil Engineer Work Request**
- Land Use Controls – Administrative Mechanisms – **Excavation Permit**
- Land Use Controls – Administrative Mechanisms – **Base General Plan**
- Land Use Controls – Monitoring – **Groundwater Monitoring**
- Removal – Groundwater Extraction – **Extraction Wells**
- Removal – Free Product Removal – **Passive Skimming**
- In Situ Treatment – In Situ Physical, Chemical, and Biological Degradation – **MNA**
- In Situ Treatment – In Situ Physical, Chemical, and Biological Degradation – **EA**
- In Situ Treatment – In Situ Biological Treatment – **Carbon Substrate Injection**
- In Situ Treatment – In Situ Biological Treatment – **Phytoremediation**
- In Situ Treatment – In Situ Biological Treatment – **Bioreactor**
- Ex Situ Treatment – Physical Treatment – **LGAC Adsorption**
- Disposal – Treated Groundwater Discharge – **Stormwater Drainage System**

The listed r*epresentative* process options are selected from those technology process options that best satisfied the Effectiveness, Implementability, and Relative Cost screening criteria (refer to Section 6).

7.4 Assembly of Groundwater Remedial Alternatives

A site-specific listing of representative process options and the assembled alternatives applicable to each ERP site is provided in Tables 7-7 and 7-8. The assembled alternatives are briefly summarized in the following list:

- Alternative 1 – No Action, Base General Plan

- Alternative 2 – MNA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring

- Alternative 3 – Vertical Extraction Well, LGAC Adsorption, Stormwater Drainage System, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring (for the off-base portions of Sites LF007C and SS030, the non-representative LUC process option of Easement purchase is also applicable)

- Alternative 4 – Bioreactor, Vertical Extraction Well and Horizontal Extraction Wells, LGAC Adsorption, Stormwater Drainage System, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring

- Alternative 5 – Carbon Substrate Injection, EA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring

- Alternative 6 – Bioreactor, Carbon Substrate Injection, Phytoremediation, EA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring

- Alternative 7 – Passive Skimming, EA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring

TABLE 7-3
Summary of Historical NEWIOU Groundwater Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Alternatives Developed in the NEWIOU FS[a]	Remedial Alternatives Evaluated for the Site in the NEWIOU FS[a]	Remedial Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]
FT004	1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain 9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation	1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	3 – Extraction, Treatment, and Discharge (GET)
FT005		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	3 – Extraction, Treatment, and Discharge (GET)
LF006		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA
LF007B		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA Assessment

TABLE 7-3
Summary of Historical NEWIOU Groundwater Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Alternatives Developed in the NEWIOU FS[a]	Remedial Alternatives Evaluated for the Site in the NEWIOU FS[a]	Remedial Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]
LF007C	1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain 9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation	1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA Assessment (on-base plume) 3 – Extraction, Treatment, and Discharge (GET) (Base boundary and off-base plume)
LF007D		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA Assessment
SS015		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA Assessment
SS016		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	3 – Extraction, Treatment, and Discharge (GET)

TABLE 7-3
Summary of Historical NEWIOU Groundwater Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

<table>
<tr><th>Site</th><th>Alternatives Developed in the NEWIOU FS[a]</th><th>Remedial Alternatives Evaluated for the Site in the NEWIOU FS[a]</th><th>Remedial Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]</th></tr>
<tr><td>SS029</td><td rowspan="4">1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain
9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>3 – Extraction, Treatment, and Discharge (GET)</td></tr>
<tr><td>SS030</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment
3 – Extraction, Treatment, and Discharge (GET)</td></tr>
<tr><td>SD031</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain Oxidation</td><td>2 – MNA Assessment
3 – Extraction, Treatment, and Discharge (GET)</td></tr>
<tr><td>SD033</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment
(South Gate Area, Facility 1917, and Facility 810 plumes)
3 – Extraction, Treatment, and Discharge (GET)
(storm sewer)</td></tr>
</table>

TABLE 7-3
Summary of Historical NEWIOU Groundwater Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

<table>
<tr><th>Site</th><th>Alternatives Developed in the NEWIOU FS[a]</th><th>Remedial Alternatives Evaluated for the Site in the NEWIOU FS[a]</th><th>Remedial Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]</th></tr>
<tr><td>SD034</td><td rowspan="4">1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain
9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation</td><td>3 – Extraction, Treatment, and Discharge (GET)
(Bioslurp/free product removal and coordination with Site SD037 alternative)</td></tr>
<tr><td>SS035</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment</td></tr>
<tr><td>SD036</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>3 – Extraction, Treatment, and Discharge (GET)</td></tr>
<tr><td>SD037</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment
(portions of plume near Facilities 919, 977, 981, and Area G Ramp)
3 – Extraction, Treatment, and Discharge (GET)
(portions of plume near Facilities 837, 838, and Ragsdale/V Area and the remainder of plume)</td></tr>
</table>

[a] Source: Final NEWIOU FS (Radian, 1996a).
[b] Source: Final Groundwater IROD for the NEWIOU (Travis AFB, 1998).
[c] Historically managed under the POCO program and not addressed in either the Groundwater IROD for the NEWIOU or Groundwater IROD for the WABOU.

TABLE 7-4
Summary of Historical WABOU Groundwater Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

<table>
<tr><th>Site</th><th>Alternatives Developed in WABOU FS[a]</th><th>Alternatives Evaluated in the WABOU FS[a]</th><th>Alternatives Selected in the WABOU Proposed Plan/IROD[b]</th></tr>
<tr><td>LF008</td><td rowspan="4">Alternative G1 – No Action
Alternative G2 – Monitored Natural Attenuation
Alternative G3 – Containment/Treatment/Discharge (GET)
Alternative G4 – Extraction/Treatment/Discharge (GET)
Alternative G5 – Source Area and Groundwater Extraction/Treatment/Monitored Natural Attenuation
Alternative G6 – Source Area Extraction/Treatment/Monitored Natural Attenuation</td><td>G1 – No Action
G2 – Natural Attenuation
G3 – Containment, Treatment, Discharge
G4 – Extraction, Treatment, Discharge</td><td>G4 – Extraction, Treatment, Discharge (GET)</td></tr>
<tr><td>DP039</td><td>G1 – No Action
G2 – Natural Attenuation
G3 – Containment, Treatment, Discharge (GET)
G4 – Extraction, Treatment, Discharge (GET)
G5 – Source Area Extraction, Treatment, Natural Attenuation
G6 – Source Area Containment, Treatment, Natural Attenuation</td><td>G3 – Containment, Treatment, Discharge (GET)
G5 – Source Area and Groundwater Extraction, Treatment, MNA</td></tr>
<tr><td>SS041</td><td>G1 – No Action
G2 – Natural Attenuation
G3 – Containment, Treatment, Discharge (GET)</td><td>G3 – Containment, Treatment, Discharge (GET)</td></tr>
<tr><td>SD043</td><td>G1 – No Action
G2 – Natural Attenuation
G3 – Containment, Treatment, Discharge (GET)</td><td>G3 – Containment, Treatment, Discharge (GET)</td></tr>
</table>

[a] Source: Final WABOU FS (CH2M HILL, 1998a).
[b] Source: Final Groundwater IROD for the WABOU (Travis AFB, 1999).

TABLE 7-5
Summary of Interim Remedial Action Performance and Status
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Remedial Alternative Selected in the Proposed Plan and IROD	Implemented IRA (FFS terminology)	IRA Objectives	IRA Performance and Status	IRA Optimization Actions	Post-IRA Optimization Actions
FT004 (NEWIOU)	Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 2 – MNA Assessment Alternative 3 – GET	Assess viability of natural physical, chemical, and biological processes to remediate plume GET for source control	The combination of GET in the Site FT004 source areas and MNA in the downgradient portions of the plume has been effective. Hydraulic capture of the source areas was achieved using GET. The effectiveness of GET is further demonstrated by declining VOC concentrations observed in the majority of site monitoring wells. Declining trends are observed in both shallow and deep monitoring wells, indicating both the horizontal and vertical extent of the target areas are being addressed. The Site FT004 GET system has been shut down for a rebound study for the remaining period of interim remediation because the source area VOC concentrations have declined. The maximum TCE concentrations during the 2010 GSAP were observed within two (2) localized and noncontiguous portions of the plume. These included 165 μg/L in MW266x04 and 130 μg/L in MW131x04. No other concentrations above 100 μg/L were observed at the site. MNA also appears to be a viable remedy at Site FT004. Overall, contaminant concentrations are stable or declining in the downgradient MNA assessment monitoring wells. The MNA network includes both shallow and deep monitoring wells. MNA appears to be effective throughout the entire thickness of the plume.	Air stripping discontinued and replaced with LGAC treatment at NGWTP. GET system shut down for a rebound study in 2007.	Monitoring to evaluate rebound study is ongoing.
FT005 (NEWIOU)	Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 3 – GET	GET for migration control GET for off-base remediation	The Site FT005 GET system has been effective. The existing GET system appears to have achieved hydraulic capture of the plume and is controlling off-base contaminant migration. A large portion of the plume has been remediated to non-detect concentrations. The extraction wells in the areas of the plume where IRA objectives have been achieved have been shut down for a rebound study for the remainder of the interim period of remediation.	Air stripping discontinued and replaced with LGAC treatment at SBBGWTP. GET system partially shut down for a rebound study in 2007.	Monitoring to evaluate rebound study is ongoing.
LF006 (NEWIOU)	Alternative 2 – MNA	Alternative 2 – MNA	Use natural physical, chemical, and biological processes to remediate plume	MNA appears to be a viable remedy at Site LF006. Data from monitoring wells indicate that groundwater contamination at Site LF006 is not migrating, and no contaminants were detected at a concentration exceeding the IRG.	None	Monitoring to evaluate natural attenuation processes is continuing.
LF007B (NEWIOU)	Alternative 2 – MNA Assessment	Alternative 2 – MNA Assessment	Assess viability of natural physical, chemical, and biological processes to remediate plume	MNA appears to be a viable remedy at Site LF007B. No contaminants were detected in Site LF007B wells sampled during the 2009-2010 GSAP events.	None	Monitoring to evaluate MNA processes is continuing.
LF007C (NEWIOU)	Alternative 2 – MNA Assessment[a] Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 2 – MNA Assessment Alternative 3 – GET	GET for migration control[b] GET for off-base remediation[c]	The migration control and off-base remediation IRA objectives for Site LF007C do not appear to be fully achieved. The existing GET system is not fully effective at hydraulically capturing and remediating the TCE plume. TCE continues to migrate off-base at concentrations above the TCE IRG of 5 μg/L. Optimization of the GET IRA is required. A data gaps investigation will be performed during 2011, pending USFWS approval of the request to reinitiate Section 7 consultation for activities within the vernal pool at the site, to define the extent of off-base contamination greater than the IRG, and to clarify groundwater flow directions. Based on the results of the investigation, optimization measures for the current GET system will be conducted.	Air stripping discontinued and replaced with LGAC treatment at NGWTP. Pending in 2011 – additional site characterization and potential expansion of the GET system.	Continuing to resolve site access limitations because of the presence of a vernal pool and associated access restrictions imposed by USFWS. Most of the site is located on off-base private property.
LF007D (NEWIOU)	Alternative 2 – MNA Assessment	Alternative 2 – MNA Assessment	Assess viability of natural physical, chemical, and biological processes to remediate plume	MNA appears to be a viable remedy at Site LF007D. The plume is stable, but concentrations have not decreased significantly during the period of interim remediation. Groundwater contamination is currently limited to a small area in the vicinity of MW261x04. Within this area, PCGs are exceeded for 1,4-DCB (12.6 μg/L vs. PCG of 5 μg/L) and benzene (3 μg/L vs. PCG of 1 μg/L). Concentrations of 1,4-DCB have decreased during the period of interim remediation. However, long-term benzene concentrations have remained relatively stable at about 3 μg/L. Contaminants do not appear to be migrating off-base to the north or east of the site.	None	Monitoring to evaluate natural attenuation processes is continuing.

TABLE 7-5
Summary of Interim Remedial Action Performance and Status
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Remedial Alternative Selected in the Proposed Plan and IROD	Implemented IRA (FFS terminology)	IRA Objectives	IRA Performance and Status	IRA Optimization Actions	Post-IRA Optimization Actions
LF008	Alternative G4 Extraction/Treatment/ Discharge (GET)	Alternative G4 – GET	GET for migration control	The migration control IRA objective at Site LF008 was achieved by the GET system. Hydraulic capture of the source area was achieved. The distribution of contamination in monitoring wells also indicated hydraulic containment of the plume. The GET system had limited effectiveness at removing the residual organochlorine pesticide contamination. Concentrations are stable and not migrating. The GET system is currently shut down as part of a rebound study for the remainder of the period of interim remediation.	GET system shut down for a rebound study in 2008.	Monitoring to evaluate rebound study is ongoing.
SS015 (NEWIOU)	Alternative 2 – MNA Assessment	Alternative 2 – MNA Assessment	Assess viability of natural physical, chemical, and biological processes to remediate plume	Monitoring data indicated that MNA does not appear to be successfully addressing Site SS015 contamination. The plume appears to be migrating, and contaminant concentrations are increasing in some wells. The limited volume of EVO injected during a 2000-2001 vegetable oil injection treatability study appears to be exhausted. Optimization of the MNA IRA was required, and supplemental injection of EVO was conducted during 2010 to enhance natural attenuation processes. The performance of the EVO treatment is being evaluated.	Data gaps investigation in 2010. Installation of injection wells in 2010. Source area EVO injection in 2010. Installation of additional monitoring wells in 2010.	Performance monitoring and evaluation of the 2010 EVO injection in the site source area is ongoing.
SS016 (NEWIOU)	Alternative 2 – MNA Assessment Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 3 – GET	GET for source control[d] GET for migration control[e]	Hydraulic capture of the TARA source area has been achieved. Within the OSA source area, concentrations have decreased, but the extent of hydraulic capture is less certain. Declining TCE concentrations in shallow and deep monitoring wells downgradient of the OSA and TARA source areas indicate that the horizontal and vertical extents of the plume are being addressed by the existing GET system. However, even after several years of IRA operation, the highest TCE concentrations at Travis AFB are found at OSA source area horizontal extraction well EW003x16 (18,000 µg/L). Therefore, IRA optimization actions were taken during 2010. These actions included a data gaps investigation to more fully define the OSA source area. Based on the results of the data gaps investigation, operation of a 2-Phase® extraction/ThOx treatment was discontinued, and an in situ bioreactor was installed. The performance of the bioreactor is being evaluated. The portion of the commingled Site SS016 plume (OSA/TARA that is not hydraulically captured by the OSA and TARA source control GET systems) is eventually hydraulically captured by the downgradient Site SS029 GET system.	2-Phase® extraction within OSA source area discontinued in 2010. UV/Ox and Th/Ox treatment discontinued in 2010. Groundwater treatment replaced by LGAC at CGWTP. Data gaps investigation within OSA source area conducted in 2010. OSA source area bioreactor installation in 2010.	Performance monitoring and evaluation of the 2010 bioreactor installation in the OSA source area is ongoing. Site access is limited. The site is adjacent to, or within, an active area of military flightline operations (i.e., parking apron, taxiways, and runways).
ST027B (NEWIOU)	Historically managed under the POCO program. Site not addressed in either NEWIOU or WABOU Proposed Plan/ IROD.	MNA (POCO)	Assess viability of natural physical, chemical, and biological processes to remediate plume	Site ST027 has historically been managed as part of the POCO program at Travis AFB because petroleum hydrocarbons were believed to be the only contaminants present at this site. However, an investigation conducted in 2007 resulted in the discovery of TCE and several other chlorinated VOCs in groundwater in the southwestern part of the site. The site was subsequently subdivided into Site ST027A (fuels contamination only) and Site ST027B (CERCLA contaminants). A data gaps investigation was conducted during 2010 to characterize the VOC plume within Site ST027B and provide data to support risk assessments and remedy selection.	Data gaps investigation within Site ST027B conducted during 2010.	Monitoring to evaluate natural attenuation processes is continuing. Site is bounded by military flightline operations.
SS029 (NEWIOU)	Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 3 – GET	GET for migration control	The migration control IRA objective at Site SS029 has been achieved. The existing GET system has achieved hydraulic capture of the on-base plume and is effectively controlling potential off-base migration of the contaminant plume.	Air stripping discontinued and replaced with LGAC groundwater treatment at SBBGWTP. Additional site characterization will be conducted during 2011 to assess the technical implementability of installing a PRB to intercept the distal end of the plume.	Monitoring to evaluate GET system performance is continuing. A large portion of the site is within an area of military flightline operations.

TABLE 7-5
Summary of Interim Remedial Action Performance and Status
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Remedial Alternative Selected in the Proposed Plan and IROD	Implemented IRA (FFS terminology)	IRA Objectives	IRA Performance and Status	IRA Optimization Actions	Post-IRA Optimization Actions
SS030 (NEWIOU)	Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 3 – GET	GET for source control GET for migration control GET for off-base remediation	The source control, migration control, and off-base remediation IRA objectives for the Site SS030 IRA have not been fully achieved. Contaminant concentrations are declining in all of the extraction wells and all but two (2) of the monitoring wells. The off-base plume is being captured on the southern and western sides of the plume. However, increasing TCE concentrations on the eastern side of the off-base plume indicate that contamination may be escaping hydraulic capture. The groundwater elevation contours derived from the 2Q10 GSAP sampling event indicate that the hydraulic capture in this eastern area of the plume has improved after several of the adjacent Site FT005 extraction wells were taken offline for a rebound study. Optimization of the GET IRA is required. Investigations will be performed during 2010-2011 to clarify groundwater flow directions and hydraulic capture. Based on the results of the investigation, optimization measures for the current GET system will be conducted as required.	Air stripping discontinued and replaced with LGAC groundwater treatment at SBBGWTP. Increased groundwater extraction rates to improve hydraulic capture of the off-base plume.	Monitoring to evaluate GET system performance is continuing. Most of the site is located on off-base private property.
SD031 (NEWIOU)	Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 2 – MNA Assessment Alternative 3 – GET	Assess viability of natural physical, chemical, and biological processes to remediate plume GET for source control	The combination of GET in the Site SD031 source areas and MNA in the downgradient portions of the plume has been effective. Hydraulic capture of the source areas was achieved using GET. The effectiveness of GET is further demonstrated by declining VOC concentrations observed in the majority of site monitoring wells. Declining trends are observed in both shallow and deep monitoring wells, indicating both the horizontal and vertical extent of the target areas are being addressed. The Site SD031 GET system has been shut down for a rebound study for the remaining period of interim remediation because VOC concentrations have declined. The maximum 1,1-DCE concentrations during the 2010 GSAP were observed within a localized portion of the plume. These included 78.8 µg/L in EW566x31 and 7.4 µg/L in EW567x31. MNA also appears to be a viable remedy at Site SD031. Overall, contaminant concentrations are stable or declining in the downgradient MNA assessment monitoring wells. The MNA network includes both shallow and deep monitoring wells. MNA appears to be effective throughout the entire thickness of the plume.	Air stripping discontinued and replaced with LGAC groundwater treatment at NGWTP. GET system shut down for a rebound study.	Monitoring to evaluate natural attenuation processes is continuing. Monitoring to evaluate rebound study is ongoing.
SD033 (NEWIOU)	Alternative 2 – MNA Assessment[f] Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 2 – MNA Assessment Alternative 3 – GET	Assess viability of natural physical, chemical, and biological processes to remediate plume GET for migration control[g]	The GET system for WIOU Site SD033 achieved the migration control IRA objective. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 µg/L were captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume were addressed by the GET system. In the southern (downgradient) area of the site, MNA appears to be a viable remedy. Groundwater contamination in this area does not appear to be migrating.	UV/Ox groundwater treatment discontinued in 2010 and replaced by LGAC at CGWTP. WIOU GET system, including Site SD033, shut down for a rebound study.	Monitoring to evaluate natural attenuation processes is continuing. Monitoring to evaluate rebound study is ongoing. The site is a component of the overall WIOU plume.
SD034 (NEWIOU)	Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 3 – GET	GET for source control[h] GET for migration control[i]	The GET and passive skimming systems for WIOU Site SD034 are largely achieving the source control and migration control IRA objectives. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 µg/L are being captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume are being addressed by the existing GET system. Floating product removal of Stoddard solvent is achieving the source control IRA for the site. The extent of floating product continues to be limited to the original release area and is not migrating.	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2009-2010 and replaced by LGAC at CGWTP. WIOU GET system, including Site SD034, shut down for a rebound study.	Passive skimming operations are continuing. Monitoring to evaluate rebound study is ongoing. The site is a component of the overall WIOU plume.
SS035 (NEWIOU)	Alternative 2 – MNA Assessment	Alternative 2 – MNA Assessment	Assess viability of natural physical, chemical, and biological processes to remediate plume	The GET system for the WIOU, including Site SS035, achieved the migration control IRA objective. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 µg/L were captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume are being addressed by the existing GET system.	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2010 and replaced by LGAC treatment at CGWTP. WIOU GET system, including Site SS035, shut down for a rebound study.	Monitoring to evaluate natural attenuation processes is continuing. The site is a component of the overall WIOU plume

TABLE 7-5
Summary of Interim Remedial Action Performance and Status
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Remedial Alternative Selected in the Proposed Plan and IROD	Implemented IRA (FFS terminology)	IRA Objectives	IRA Performance and Status	IRA Optimization Actions	Post-IRA Optimization Actions
SD036 (NEWIOU)	Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 3 – GET	GET for source control GET for migration control	The GET system for WIOU Site SD036 is largely achieving the source control and migration control IRA objectives. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 µg/L were captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume are being addressed by the GET existing system. Although IRA objectives are largely being met, even after several years of IRA operation, TCE concentrations greater than 1,000 µg/L continue to be detected at the source area within Site SD036. Optimization of the GET IRA was required. Therefore, data gaps investigations were performed during 2010 to more fully define the extents of these source areas. Based on the results of the data gaps investigations, optimization measures included discontinuing the GET systems and injection of EVO within the plume source area. The performance of the EVO treatment is being evaluated. In the downgradient portions of the plume, MNA appears to be a viable remedy. Groundwater contamination in this area does not appear to be migrating.	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2009-2010 and replaced by LGAC treatment at CGWTP. WIOU GET system, including Site SD036, shut down for a rebound study in 2010. Data gaps investigation conducted during 2010. Source area EVO injection in 2010.	Performance monitoring and evaluation of the 2010 EVO injection in the site source area is ongoing. Monitoring to evaluate rebound study is ongoing. The site is a component of the overall WIOU plume.
SD037 (NEWIOU)	Alternative 2 – MNA Assessment[j] Alternative 3 – Extraction, Treatment, and Discharge (GET)	Alternative 2 – MNA Assessment Alternative 3 – GET	GET for source control[k] GET for migration control[l]	The GET system for WIOU Site SD037 is largely achieving the source control and migration control IRA objectives. Estimates of the extent of hydraulic capture indicate that VOC concentrations above 100 µg/L were captured by the existing GET system. Decreasing trends of VOC concentrations are observed throughout the commingled WIOU plume. The decreasing trend is observed in both shallow and deep monitoring wells, indicating that the horizontal and the vertical extents of the plume are being addressed by the GET existing system. Although IRA objectives are largely being met, even after several years of IRA operation, TCE concentrations greater than 1,000 µg/L continue to be detected at the source area within Site SD037. Optimization of the GET IRA was required. Therefore, data gaps investigations were performed during 2010 to more fully define the extents of these source areas. Based on the results of the data gaps investigations, optimization measures included discontinuing the GET systems and injection of EVO within the source areas. The performance of the EVO treatment is being evaluated. In the southern (downgradient) area of the WIOU, MNA appears to be a viable remedy. Groundwater contamination in this area does not appear to be migrating.	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2009-2010 and replaced by LGAC treatment at CGWTP. WIOU GET system, including Site SD037, shut down for a rebound study in 2010. Data gaps investigation conducted during 2010. Source area EVO injection in 2010.	Performance monitoring and evaluation of the 2010 EVO injection in the site source area is ongoing. Monitoring to evaluate natural attenuation processes is continuing. Monitoring to evaluate rebound study is ongoing. The site is a component of the overall WIOU plume.
DP039 (WABOU)	Alternative G3 – Containment/Treatment/Discharge (GET) Alternative G5 – Source Area and Groundwater Extraction/ Treatment/MNA (GET and MNA)	Alternative G3 – GET Alternative G5 – GET and MNA	GET for migration control GET for source control MNA to assess the viability of natural physical, chemical, and biological processes to remediate plume	The Site DP039 source control IRA objective has been partly achieved. TCE concentrations in the historical contaminant release area (i.e., a former sump) are declining and a portion of the source area plume was hydraulically contained by the existing GET system. However, another portion of the source area plume is not hydraulically captured. This uncaptured portion of the plume, with TCE concentrations exceeding 1,000 µg/L, extends about 800 feet downgradient. This uncaptured portion of the source area plume underlies an ongoing demonstration of phytoremediation. In December 2008, an in situ bioreactor was installed in the former sump area as a technology demonstration. The performance of the bioreactor is being evaluated for the remainder of the period of interim remediation. A data gaps investigation was performed during 2010 to more fully define the extent of the downgradient source area with TCE concentrations greater than 500 µg/L. Based on the results of the data gaps investigations, an in situ PRB of EVO was installed hydraulically downgradient of an existing area of phytoremediation and upgradient of the portion of the plume undergoing MNA. The performance of the EVO PRB is being evaluated. Increasing TCE concentration trends at some monitoring wells in the distal portion of the plume indicate that MNA may not be fully effective if TCE concentrations in the untreated portion of the plume continue to exceed 1,000 µg/L and act as a continuing source of contamination into the downgradient portion of the plume.	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2009-2010 and replaced by LGAC treatment at SBBGWTP. GET system shut down in 2008. Source area in situ bioreactor installation conducted in 2008 as a technology demonstration project. Data gaps investigation conducted during 2010. EVO PRB installed in 2010.	Performance monitoring and evaluations of the 2010 bioreactor and EVO PRB installations are ongoing. Monitoring to evaluate natural attenuation processes is continuing. A phytoremediation treatability study conducted at the site concluded that planted trees can contribute to remediation of the plume. Monitoring within the area of phytoremediation is continuing.
SS041 (WABOU)	Alternative G3 – Containment/ Treatment/Discharge (GET)	Alternative G3 – GET	GET for migration control	Site SS041 has been in NFRAP status. The NFRAP status is documented in a 14 December 2005 consensus statement (Travis AFB, 2005).	None	

TABLE 7-5
Summary of Interim Remedial Action Performance and Status
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Remedial Alternative Selected in the Proposed Plan and IROD	Implemented IRA (FFS terminology)	IRA Objectives	IRA Performance and Status	IRA Optimization Actions	Post-IRA Optimization Actions
SD043 (WABOU)	Alternative G3 – Containment/ Treatment/Discharge (GET)	Alternative G3 – GET	GET for migration control	The IRA GET system has effectively reduced plume size and concentrations. No contaminants were detected above IRGs during the 2010 GSAP.	UV/Ox groundwater treatment and VGAC vapor treatment discontinued in 2009-2010 and replaced by LGAC treatment at CGWTP. WIOU GET system, including Site SD043, shut down for a rebound study in 2010.	Monitoring to evaluate rebound study is ongoing. The site is a component of the overall WIOU plume.

[a] On-base portion of plume
[b] Plume at Base boundary
[c] Off-base portion of plume
[d] OSA portion of plume
[e] Southern portion of plume
[f] South Gate Area, Facility 1917, and Facility 810 plumes
[g] Storm sewer
[h] Bioslurp/free product removal
[i] Coordinated with Site SD037
[j] Portions of plume near Facilities 919, 977, 981, and Area G Ramp
[k] Portions of plume near Facilities 837, 838, and Ragsdale/V Area
[l] Remainder of plume

TABLE 7-6
Comparison of Previous and Current Remedial Alternative Terminologies
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	NEWIOU IROD Remedial Alternative Terminology[a]	WABOU IROD Remedial Alternative Terminology[b]	Equivalent FFS Terminology
FT004	3 – Extraction, Treatment, and Discharge	–	3 – GET
FT005	3 – Extraction, Treatment, and Discharge	–	3 – GET
LF006	2 – MNA	–	2 – MNA
LF007B	2 – MNA Assessment	–	2 – MNA Assessment
LF007C	2 – MNA Assessment 3 – Extraction, Treatment, and Discharge	–	2 – MNA Assessment 3 – GET
LF007D	2 – MNA Assessment	–	2 – MNA Assessment
LF008	–	G4 – Extraction/Treatment/Discharge	G4 – GET
SS015	2 – MNA Assessment	–	2 – MNA Assessment
SS016	2 – MNA Assessment 3 – Extraction, Treatment, and Discharge	–	2 – MNA Assessment 3 – GET
ST027B	MNA (POCO)	–	MNA
SS029	3 – Extraction, Treatment, and Discharge	–	3 – GET
SS030	3 – Extraction, Treatment, and Discharge	–	3 – GET
SD031	3 – Extraction, Treatment, and Discharge	–	3 – GET
SD033	2 – MNA Assessment 3 – Extraction, Treatment, and Discharge	–	2 – MNA Assessment 3 – GET
SD034	3 – Extraction, Treatment, and Discharge	–	3 – GET
SS035	2 – MNA Assessment	–	2 – MNA Assessment
SD036	3 – Extraction, Treatment, and Discharge	–	3 – GET
SD037	2 – MNA Assessment 3 – Extraction, Treatment, and Discharge	–	2 – MNA Assessment 3 – GET
DP039	–	G3 – Containment/Treatment/Discharge G5 – Source Area and Groundwater Extraction/Treatment/MNA	G3 – GET G5 – GET and MNA
SS041	–	G3 – Containment/Treatment/Discharge	G3 – GET
SD043	–	G3 – Containment/Treatment/Discharge	G3 – GET

[a] Final Groundwater IROD for the NEWIOU (Travis AFB, 1998)
[b] Final Groundwater IROD for the WABOU (Travis AFB, 1999)

TABLE 7-7
Summary of Alternatives Assembled from Representative Process Options
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Representative Process Option	Site																				
	FT004	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
No Action																				●	
Base Civil Engineer Work Request	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●
Excavation Permit	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●
Base General Plan*	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Groundwater Monitoring	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●
MNA	●	●	●	●		●	●			●			●	●		●					●
EA								●							●		●	●	●		
Vertical Extraction Well					●				●		●	●									
Horizontal Extraction Well									●												
Passive Skimming															●						
Carbon Substrate Injection								●									●	●	●		
Phytoremediation																			●		
Bioreactor									●										●		
LGAC Adsorption					●				●		●	●									
Stormwater Drainage System					●				●		●	●									

* In accordance with the Base General Plan, the non-representative LUC process options of Vapor Barrier and Passive Venting are potentially applicable to all sites. These vapor intrusion mitigation measures are applicable to address future building construction in proximity to a groundwater contaminant plume.

Notes:

● Representative Process Option that best satisfies the evaluation criteria of Effectiveness, Implementability, and Relative Cost at each site.

Shaded indicates a process option that has already been implemented as a component of the IRA at a site, including demonstration projects and optimization measures. After approximately a decade of interim remediation, some existing process options best satisfy the evaluation criteria of Effectiveness, Implementability, and Cost. Other existing process options currently do not satisfy the criteria as well as other processes and are not selected as being representative.

Bolded technology process options are considered to have aspects of green and sustainable remediation.

Assembly of alternatives:

Alternative 1 – No Action, Base General Plan: Site SS041
Alternative 2 – MNA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring: Sites FT004, FT005, LF006, LF007B, ST027B, SD031, SD033, SS035, and SD043.The off-base portion of Site FT005 also includes the non-representative LUC process option of an off-base easement.
Alternative 3 – Vertical Extraction Wells, LGAC Adsorption, Stormwater Drainage System, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring: Sites LF007C, SS029, and SS030.The off-base portion of Sites LF007C and SS030 also includes the non-representative LUC process option of off-base easement.
Alternative 4 – Bioreactor, Horizontal and Vertical Extraction Wells, LGAC Adsorption, Stormwater Drainage System, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring: Site SS016
Alternative 5 – Carbon Substrate Injection, EA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring: Sites SS015, SD036, and SD037
Alternative 6 – Bioreactor, Carbon Substrate Injection, Phytoremediation, EA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring: Site DP039
Alternative 7 – Passive Skimming, EA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring: Site SD034

TABLE 7-8
Assembly of Remedial Alternatives from Representative Process Options
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

GRA	Remedial Technology	Representative Process Option	Alternative 1	2	3	4	5	6	7
No Action	None	None	•						
Land Use Controls	Administrative mechanisms	Base Civil Engineer Work Request		•	•	•	•	•	•
		Excavation Permit		•	•	•	•	•	•
		Base General Plan	•	•	•	•	•	•	•
	Monitoring	Groundwater Monitoring		•	•	•	•	•	•
Removal	Groundwater extraction	Extraction Wells			•	•			
	Free product removal	Passive Skimming							•
In Situ Treatment	In situ physical, chemical, and biological degradation	MNA		•					
		EA					•	•	•
	In situ biological treatment	Carbon Substrate Injection					•	•	
		Phytoremediation						•	
		Bioreactor				•		•	
Ex Situ Treatment	Physical treatment	LGAC Adsorption			•	•			
Disposal	Treated groundwater discharge	Stormwater Drainage System			•	•			

* In accordance with the Base General Plan, the non-representative LUC process options of Vapor Barrier and Passive Venting are potentially applicable to all sites. These vapor intrusion mitigation measures are applicable to address future building construction in proximity to a groundwater contaminant plume.

Notes:

Summary of assembled groundwater alternatives and applicable sites:

Alternative 1 – No Action, Base General Plan* (Site SS041)

Alternative 2 – MNA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring (Sites FT004, FT005, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, SS035, and SD043). The off-base portion of Site FT005 also includes the non-representative LUC process option of an off-base easement.

Alternative 3 – Extraction Wells, LGAC Adsorption, Stormwater Drainage System, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring (Sites LF007C, SS029, and SS030). The off-base portions of Sites LF007C and SS030 also include the non-representative LUC process option of an off-base easement.

Alternative 4 – Bioreactor, Extraction Wells, LGAC Adsorption, Stormwater Drainage System, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring (Site SS016)

Alternative 5 – Carbon Substrate Injection, EA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring (Sites SS015, SD036, and SD037)

Alternative 6 – Bioreactor, Phytoremediation, Carbon Substrate Injection, EA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring (Site DP039)

Alternative 7 – Passive Skimming, EA, Base Civil Engineer Work Request, Excavation Permit, Base General Plan, Groundwater Monitoring (Site SD034)

Most of the listed alternatives have long and unwieldy names when mechanically described in terms of their component process options. To shorten and simplify the naming of the alternatives, the following conventions are used:

- GET – For Alternatives 3 and 4, GET refers to the combination of groundwater extraction, treatment, and discharge process options.
  - Groundwater Extraction – For the groundwater extraction component, horizontal and/or vertical extraction well process options may be used either singly or in combination at a site.
  - Treatment – The CGWTP, NGWTP, and SBBGWTP currently all use LGAC as the treatment process option for multiple sites.
  - Discharge – Treated groundwater effluent from the CGWTP, NGWTP, and SBBGWTP is discharged to the stormwater drainage system.
- Carbon Substrate Injection – For Alternatives 5 and 6, this process option is implemented using an area treatment configuration of EVO injection points or as a linear configuration of EVO injection points to create a PRB. The configuration does affect the treatment process, so the adopted naming conventions are simply EVO or EVO PRB.
- Representative process options that compose the administrative mechanisms of LUCs, including Base Civil Engineer Work Requests, Excavation Permits, and the Base General Plan are components of all the alternatives and are omitted from the alternative names for brevity. Subsequent use of the term LUCs refers to the combination of administrative mechanisms, engineered controls, and monitoring that are applicable to each site. The term LUCs is omitted from the alternative names for brevity. The representative process options that compose the administrative mechanisms of LUCs are summarized as follows:
  - Base Civil Engineer Work Requests (AF332) is applicable to all on-base sites or on-base portions of sites, except Site SS041 (NFRAP status).
  - Excavation permits using 60th Air Mobility Wing Form 55 is applicable to all on-base sites or on-base portions of sites, except Site SS041 (NFRAP status).
  - The provisions of the Base General Plan are applicable to all sites. Accordingly, LUCs potentially include the non-representative process options of Vapor Barrier and Passive Venting. These process options are potentially applicable to all sites as vapor intrusion mitigation measures for future new building construction in proximity to a groundwater contaminant plume.
  - The administrative mechanism of an easement purchase is not a representative process option because it is applicable only to the off-base portions of Sites FT005, LF007C, and SS030. Therefore, this process option is not included in the naming of Alternative 3.

- Groundwater Monitoring – Groundwater monitoring is another LUC process option and is also omitted from the alternative names for brevity. Groundwater monitoring will continue to be conducted under the GSAP to track the movement of the contaminants and to verify that contaminant concentrations are being remediated. The GSAP will be modified to incorporate any new groundwater wells installed as part of the alternative implementation. Additions to the existing well networks may be required at some sites to implement the remedial alternative. Table 7-9 summarizes the existing well network at each of the sites and whether additional monitoring, extraction, or injection wells were assumed necessary at the site to support implementation of the remedial alternative.

After applying these naming conventions, the simplified alternative names are as follows:

- Alternative 1 – No Action
- Alternative 2 – MNA
- Alternative 3 – GET
- Alternative 4 – Bioreactor and GET
- Alternative 5 – EVO and EA
- Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA
- Alternative 7 – Passive Skimming and EA

More complete descriptions of the implementation of the alternatives at individual sites are provided in the following subsections.

7.4.1 Alternative 1 – No Action

The No Action alternative serves as a baseline against which other potential remedial alternatives are compared. This action is required for consideration by the NCP. It is evaluated to determine the risks to public health and the environment if no additional actions were taken. No additional attempt is made to satisfy the RAOs and no remedial measures are implemented; therefore, effectiveness is limited.

Site SS041 is an ERP site that had pesticide contaminants in its surface soil and groundwater. A 2003 soil remedial action had cleaned up the surface soil and achieved residential cleanup levels. An interim groundwater remedial action cleaned up the Site SS041 groundwater contaminant (heptachlor epoxide) to below its interim cleanup goal (0.01 µg/L) and its practical quantitation limit (0.01 µg/L). Since these were the only two media of concern at the site, Site SS041 was placed into NFRAP status. The NFRAP status is documented in a 14 December 2005 consensus statement that was signed by the representatives of the lead and regulatory agencies (Travis AFB, 2005). This site will be documented in the upcoming Basewide Groundwater ROD. Any potential future action at Site SS041 is unlikely but would be conducted in accordance with the requirements of the Base General Plan. Excavation permits will be obtained if additional activities are conducted that disturb the subsurface soil.

TABLE 7-9
Adequacy of Well Networks to Support Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Number of Wells in Current Monitoring Network	Remedial Alternative	Number of Additional Wells Needed to Implement Remedial Alternative	Reason
FT004	Extraction Wells: 8 Monitoring Wells: 36	2	None	The existing monitoring network provides sufficient plume, upgradient, downgradient, and crossgradient monitoring wells to implement Remedial Alternative 2.
LF006	Monitoring Wells: 15	2	None	The existing monitoring network provides sufficient plume, upgradient, downgradient, and crossgradient monitoring wells to implement Remedial Alternative 2.
LF007B and LF007D	Monitoring Wells: 17	2	None	The existing monitoring network provides sufficient plume, upgradient, downgradient, and crossgradient monitoring wells to implement Remedial Alternative 2.
SD031	Extraction Wells: 3 Monitoring Wells: 19	2	None	The existing monitoring network provides sufficient plume, upgradient, downgradient, and crossgradient monitoring wells to implement Remedial Alternative 2.
SD033	Extraction Wells: 2 Monitoring Wells: 18	2	None	The existing monitoring network provides sufficient plume, upgradient, downgradient, and crossgradient monitoring wells to implement Remedial Alternative 2.
FT005	Extraction Wells: 15 Monitoring Wells: 45	2	None	The existing monitoring network provides sufficient plume, upgradient, downgradient, and crossgradient monitoring wells to implement Remedial Alternative 2.
LF008	Extraction Wells: 3 Monitoring Wells: 15	2	None	The existing monitoring network provides sufficient plume, upgradient, downgradient, and crossgradient monitoring wells to implement Remedial Alternative 2.
ST027B	Monitoring Wells: 11	2	None	The existing monitoring network provides sufficient plume, upgradient, downgradient, and crossgradient monitoring wells to implement Remedial Alternative 2.
SD043	Extraction Wells: 1 Monitoring Wells: 3	2	None	VOC concentrations are currently below PCGs at this site. The existing monitoring network is sufficient to implement Remedial Alternative 2.
LF007C	Extraction Wells: 2 Monitoring Wells: 8	3	Extraction Wells: 2 Monitoring Wells: 2	The off-base extent of contamination is uncertain; additional site investigation is pending. For cost estimating purposes, it is assumed that two (2) additional extraction wells and two additional monitoring wells will be needed to implement Remedial Alternative 2.
SS029	Extraction Wells: 7 Monitoring Wells: 17	3	None	The existing network provides sufficient extraction wells and plume, upgradient, downgradient, and crossgradient monitoring wells to implement Remedial Alternative 3.

TABLE 7-9
Adequacy of Well Networks to Support Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Number of Wells in Current Monitoring Network	Remedial Alternative	Number of Additional Wells Needed to Implement Remedial Alternative	Reason
SS030	Extraction Wells: 7 Monitoring Wells: 25	3	Extraction Wells: 1	One (1) additional extraction well may be needed to enhance the existing GET system. For cost estimating purposes, it was assumed that one (1) additional extraction well will be installed to support Remedial Alternative 3. The existing monitoring network provides sufficient plume, upgradient, downgradient, and crossgradient monitoring wells to implement Remedial Alternative 3.
SS016	Extraction Wells: 5 Monitoring Wells: 69	4	Monitoring Wells: 1	One (1) additional monitoring well is needed to monitor the bioreactor to support implementation of Remedial Alternative 4. Outside of the bioreactor area, the existing network provides sufficient extraction wells, plume, upgradient, downgradient, and crossgradient monitoring wells to implement Remedial Alternative 4.
SS015	Monitoring Wells: 18	5	Injection Wells: 2 Monitoring Wells: 2	The current configuration of site monitoring wells is not sufficient to support implementation of Remedial Alternative 5. Installation of two (2) injection wells and two (2) monitoring wells in the source area is needed to implement and monitor the effects of EVO.
SD036	Extraction Wells: 3 Monitoring Wells: 63	5	Injection Wells: 8	The current configuration of site monitoring wells is not sufficient to support implementation of Remedial Alternative 5. Installation of eight (8) injection wells in the source area is needed to implement EVO.
SD037	Extraction Wells: 11 Monitoring Wells: 85	5	Injection Wells: 7 Monitoring Wells: 6	The current configuration of site monitoring wells is not sufficient to support implementation of Remedial Alternative 5. Installation of seven (7) injection wells and six (6) monitoring wells in the source area is needed to implement and monitor the effects of EVO.
DP039	Extraction Wells: 3 Monitoring Wells: 44	6	Injection Wells: 13 Monitoring Wells: 3	The current configuration of site monitoring wells is not sufficient to support implementation of Remedial Alternative 6. Installation of 13 injection wells and three (3) monitoring wells in the source area is needed to implement and monitor the effects of the biobarrier.
SD034	Extraction Wells: 2 Monitoring Wells: 11	7	None	The existing network provides sufficient extraction wells and plume, upgradient, downgradient, and crossgradient monitoring wells to implement Remedial Alternative 7.

7.4.2 Alternative 2 – Monitored Natural Attenuation

Alternative 2 – MNA is potentially applicable to all Travis AFB ERP sites, either for the contaminant conditions that currently exist or for future contaminant conditions following a period of active remediation using another alternative.

Under Alternative 2, natural physical, chemical, and/or biological processes will be used to achieve RAOs.

LUCs, including Base Civil Engineer Work Requests, excavation permits, and the requirements of the Base General Plan, will continue to be enforced. The existing off-base easement at Site FT005 will continue to be maintained.

The provisions of the Base General Plan related to vapor intrusion mitigation will continue to be enforced. Installation of a vapor barrier and passive venting system will be required for future new building construction in proximity to a groundwater contaminant plume.

Groundwater monitoring will be continued under the GSAP.

Alternative 2 is applicable to the current physical and contaminant conditions at the following sites:

- **Sites FT004/SD031 –** MNA assessment provided in NAAR and Appendix C; plume is stable
- **Site FT005 –** IRA GET system has effectively reduced plume size and concentrations
- **Site LF006 –** MNA assessment provided in NAAR; plume concentrations decreasing
- **Site LF007B –** MNA assessment provided in NAAR; no plume concentrations have been detected above PCGs for several years
- **Site LF007D –** MNA assessment provided in NAAR and Appendix C; plume concentrations stable or decreasing
- **Site LF008 –** Source removal action completed; plume is stable
- **Site ST027B –** Former POCO site; geographically isolated plume
- **Site SD033 –** MNA assessment provided in NAAR; plume concentrations decreasing in portion of plume not addressed by IRA GET system
- **Site SS035 –** Component site of the WIOU plume; plume concentrations decreasing in portion of plume not addressed by IRA GET system
- **Site SD043 –** IRA GET system has effectively reduced plume size and concentrations

At several of the listed sites, implementation of Alternative 2 – MNA follows approximately a decade of interim remediation using GET. This is the situation at Sites FT004, SD031, FT005, LF008, SD033, and SD043. The IRA GET systems at these sites still exist. Active remediation using these systems can be readily resumed under Alternative 3 – GET if natural attenuation processes do not perform as successfully as the long-term MNA assessment data indicate.

For Sites LF006, LF007B, and LF007D, MNA or MNA assessment was the IRA specified in the NEWIOU IROD. After approximately a decade of interim remediation, the NAAR concluded that natural attenuation of the plumes was effective. A status summary for each of these sites is provided in the following list:

- **Site LF006 –** Natural attenuation processes have already reduced contaminant concentrations to less than the PCGs. No other action is likely to be required at this site. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of achieving the final cleanup concentrations that will be established in the Basewide Groundwater ROD.

- **Site LF007B –** Natural attenuation processes have already reduced contaminant concentrations to less than the PCGs. No other action is likely to be required at this site. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of achieving the final cleanup concentrations that will be established in the Basewide Groundwater ROD.

- **Site LF007D –** Low concentrations of benzene (3 µg/L vs. PCG of 1 µg/L) and 1,4-dichlorobenzene (12.6 µg/L vs. PCG of 5 µg/L) were detected in the 2010 GSAP. Concentrations of 1,4-dichlorobenzene have been decreasing over time. Concentrations of benzene have remained stable. The plume size is small and limited to the vicinity of monitoring well MW261x07 (refer to Figure 3.2-12). Use of an active treatment technology, such as GET, is not warranted under these conditions. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of achieving the final cleanup concentrations that will be established in the Basewide Groundwater ROD.

Site ST027B was formerly managed under the POCO program. A portion of the site with CERCLA contamination is designated as Site ST027B. The site is located within the flightline and is bounded by aircraft parking ramps and taxiways. The maximum concentration of TCE during the 2010 GSAP was 390 µg/L (refer to Figure 3.6-3). Use of an active treatment technology is unlikely to be needed under these conditions and would have implementability problems because of the proximity to airfield operations. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of achieving the final cleanup concentrations that will be established in the Basewide Groundwater ROD.

Alternative 2 – MNA would likely not be effective at addressing the *current* contaminant conditions at Sites LF007C, SS016, SS029, and SS030. However, MNA is potentially applicable to *future* contaminant conditions after the current contaminant concentrations have been reduced by several years of active remediation. At that time, continued progress toward RAOs may be achieved by transitioning from the active remedy to an effective but lower cost program of MNA.

7.4.2.1 Implementation of Alternative 2 at Sites FT004, LF006, LF007B, LF007D, SD031, SD033, and SS035

At Sites FT004, LF006, LF007B, LF007D, SD031, SD033, and SS035, assessments of MNA were conducted during the period of interim remediation. A summary of these assessments is provided in Table 7-10. The MNA assessments concluded that the existing groundwater IRAs had effectively reduced the size and concentrations of VOCs in the plumes and that the plumes are stable (CH2M HILL, 2011b). Additional discussion on the effectiveness of MNA as part, or all, of the remedial alternative at the listed sites is provided in Appendix C. Detailed descriptions of groundwater sampling results and contaminant trends at each of the sites are provided in the 2009-2010 Annual GSAP Report (CH2M HILL, 2011b).

Implementation of Alternative 2 at Site FT004. Alternative 2 could be fully implemented at Site FT004 after discontinuing operation of the GET system that was active during the period of interim remediation.

The groundwater IRA at Site FT004 comprises two (2) main components:

- GET in the northern portion of the plume with relatively high TCE contaminant concentrations. Extracted groundwater was treated at the NGWTP.
- MNA assessment in the lower concentration southern portion of the plume.

The GET system in the northern portion of the plume has been largely effective at reducing groundwater contamination. TCE contamination is not migrating, and the plume is stable. Additional discussion regarding the site groundwater contamination is provided in Appendix C.

The Site FT004 GET system was shut down for a rebound study beginning in December 2007 because of low influent VOC concentrations at the NGWTP and poor cost effectiveness. Through 2010, no significant rebound of TCE contamination has been observed. In fact, VOC concentrations continued to decline in most Site FT004 extraction wells and monitoring wells, indicating that the attenuation capacity of the aquifer exceeds the mass loading from residual contamination in the source area (CH2M HILL, 2011b).

The data indicate that MNA is a viable remedy for the residual groundwater contamination at Site FT004. Overall, contaminant concentrations are stable or declining in the Site FT004 wells. No VOCs were detected at concentrations exceeding PCGs in the downgradient wells during the 2010 GSAP. The monitoring network includes both shallow and deep monitoring wells; MNA appears to be effective throughout the entire thickness of the plume.

The Site FT004 GET system will continue to be shut down for the remainder of the interim period. Routine monitoring of the Site FT004 plume will continue to assess plume stability and identify long-term trends. If increasing trends are observed, then the Air Force will evaluate turning back on all or part of the GET system.

In the southern portion of the Site FT004 plume, the NAAR concluded that MNA has also been successful and is an appropriate remedy to address the remaining contamination (CH2M HILL, 2010a).

TABLE 7-10
Summary of MNA Assessments
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Interim Remedy	Has the Plume Been Stable Over the Interim Period?	Dominant Natural Attenuation Mechanism	Summary
FT004	MNA assessment in distal portion of plume	Yes. The plume has receded.	Physical	EA is an appropriate remedy for the distal portion of the plume.
LF006	MNA for entire site	Yes. The plume has receded.	Physical	MNA is an appropriate remedy for the entire plume.
LF007B	MNA assessment for entire subarea	Yes. COCs are no longer detected in groundwater.	Physical	MNA is an appropriate remedy for the entire plume.
LF007D	MNA assessment for entire subarea	Yes. The plume has receded.	Biological in source area, physical in distal areas	MNA is an appropriate remedy for the entire plume.
SS015	MNA assessment for entire site	The plume was stable for several years but now appears to be migrating. The long period of plume stability is due to vegetable oil injection performed in 2000-2001 (enhanced MNA).	Biological (enhanced by vegetable oil injection)	EA is an appropriate remedy for the site.
SD031	MNA assessment in distal portion of plume	Yes. The plume has receded.	Physical	EA is an appropriate remedy for the distal portion of the plume.
SD033	MNA assessment in distal portion of plume	Yes. The plume has receded.	Physical	EA is an appropriate remedy for the distal portion of the plume.
SD037	MNA assessment in distal portion of plume	Yes. The plume has receded.	Physical	EA is an appropriate remedy for the distal portion of the plume.
DP039	MNA assessment in distal portion of plume	Uncertain. The southern toe of the plume has remained stable over the interim period. Increasing contaminant trends in some distal areas of the plume indicate that natural processes alone may not be sufficient to prevent plume migration.	Physical	EA is an appropriate remedy for the distal portion of the plume. The existing bioreactor, phytoremediation area, and EVO biobarrier will provide enhanced biodegradation of the source area plume.
LF007D	MNA assessment for entire subarea	Yes. The plume has receded.	Biological in source area, physical in distal areas	MNA is an appropriate remedy for the entire plume.

Source: CH2M HILL, 2010a.

Note: The distal portion of the plume is defined as the portion of the plume beyond the influence of the source area treatment.

To fully implement MNA at this site, the monitoring requirements for both monitoring and extraction wells would be revised as appropriate. For instance, it is likely that monitoring wells would be used in place of some of the extraction wells that are currently being monitored for rebound. However, for the purposes of the FFS, it is assumed that the same number of wells (i.e., ten [10]) currently sampled at the site would continue to be sampled under Alternative 2.

Implementation of Alternative 2 at Site LF006. Implementation of Alternative 2 at Site LF006 would simply be a continuation of the ongoing MNA IRA.

The MNA interim remedy has been successful. Long-term groundwater monitoring at Site LF006 indicates that the already low TCE concentrations are decreasing in all of the site wells. During the interim period of remediation, the plume has reduced in size, groundwater contamination is not migrating, and no contaminants exceeded the PCG during the 2010 GSAP event (CH2M HILL, 2011b).

Implementation of Alternative 2 at Sites LF007B and LF007D. At Sites LF007B and LF007D, implementation of Alternative 2 represents a continuation of the MNA assessments conducted during the period of interim remediation.

The data indicate that MNA is an effective remedy at Sites LF007B and LF007D. The plumes are not migrating, and contaminant concentrations are stable or decreasing (CH2M HILL, 2010a, 2011b). During the 2010 GSAP event, no Site LF007B COCs were detected in the Site LF007B monitoring wells. Within Site LF007D, groundwater contamination is restricted to a small area in the vicinity of MW261x07. Groundwater contamination greater than PCGs was not detected in any other site monitoring well.

Implementation of Alternative 2 at Site SD031. Similar to Site FT004, Alternative 2 could be fully implemented at Site SD031 after discontinuing operation of the GET system that was active during the period of interim remediation.

The groundwater IRA at Site SD031 comprises two (2) main components:

- GET in the northern portion of the plume with relatively high 1,1-DCE contaminant concentrations. Extracted groundwater was treated at the NGWTP.
- MNA assessment in the lower concentration southern portion of the plume.

The GET system in the northern portion of the plume has been largely effective at reducing groundwater contamination. 1,1-DCE contamination is not migrating, and the plume is stable. No portion of the plume contains concentrations of 1,1-DCE greater than 100 µg/L. The concentrations of 1,1-DCE exceed the PCG in three (3) wells, including monitoring well MW571x31 (9.1 µg/L), extraction well EW566x31 (98.7 µg/L), and extraction well EW567x31 (21.4 µg/L) (CH2M HILL, 2010a, 2011b).

Along with Site FT004, the Site SD031 GET system has been shut down for a rebound study since December 2007 because of low influent VOC concentrations at the NGWTP and poor cost effectiveness. Through 2010, no significant rebound of 1,1-DCE contamination has been observed. In fact, VOC concentrations continued to decline in most Site SD031 extraction wells and monitoring wells, indicating that the attenuation capacity of the aquifer exceeds the mass loading from residual contamination in the source area (CH2M HILL, 2011b).

The data indicate that MNA is a viable remedy for the residual groundwater contamination at Site SD031. Overall, contaminant concentrations are stable or declining in the site wells. No VOCs were detected at concentrations exceeding PCGs in the downgradient wells during the 2010 GSAP. The monitoring network includes both shallow and deep monitoring wells; MNA appears to be effective throughout the entire thickness of the plume.

The Site SD031 GET system will continue to be shut down for the remainder of the interim period. Routine monitoring of the plume will continue to assess plume stability and identify long-term trends. If increasing trends are observed, then the Air Force will evaluate turning back on all or part of the GET system.

To fully implement MNA at this site, the monitoring requirements for both monitoring and extraction wells would be revised as appropriate. For instance, it is likely that monitoring wells would be used in place of some of the extraction wells that are currently being monitored for rebound. However, for the purposes of the FFS, it is assumed that the same number of wells (i.e., six [6]) currently sampled at the site would continue to be sampled under Alternative 2.

Implementation of Alternative 2 at Site SD033. Implementation of Alternative 2 at Site SD033 represents a continuation of the MNA assessment conducted in the distal portion of the plume during the period of interim remediation. Alternative 2 would be fully implemented at Site SD033 after discontinuing operation of the GET system that was active during the period of interim remediation.

The groundwater IRA at Site SD033 comprises two (2) main components:

- GET in the northern portion of the plume with relatively high TCE contaminant concentrations. Extracted groundwater was treated at the CGWTP.
- MNA assessment in the lower concentration southern portion of the plume.

Site SD033 is one (1) site in the collection of sites that compose the WIOU. The GET system in the northern portion of the WIOU, including Site SD033, has been largely effective at reducing groundwater contamination. Chlorinated VOC contamination is not migrating, and the plume is stable. Trends of decreasing contamination are observed throughout the WIOU and Site SD033. These decreasing trends are observed in both shallow and deep wells, indicating that the vertical, as well as the horizontal, extent of the plume is being addressed by the GET IRA (CH2M HILL, 2011b).

The WIOU GET system was shut down in the second quarter of 2010 because of unrelated construction activities impacting operations at the CGWTP. The WIOU GET system, including Site SD033, will continue to be shut down for a rebound study during the remainder of the period of interim remediation.

Also during the interim period, an MNA assessment was conducted within the distal portion of the Site SD033 plume. The assessment concluded that MNA was an appropriate remedy for this portion of the plume. There is no evidence of plume migration, and the already low TCE concentrations have been stable. Overall, the extent of TCE contamination has decreased over time (CH2M HILL, 2010a). During the 2010 GSAP event, TCE concentrations exceeding the PCG were detected in only two (2) site monitoring wells.

Following implementation of Alternative 2, operation of the Site SD033 IRA GET system would be discontinued. The existing site monitoring wells would be incorporated into the implementation of MNA within the overall WIOU plume area.

Implementation of Alternative 2 at Site SS035. Implementation of Alternative 2 at Site SS035 represents a continuation of the MNA assessment conducted in the distal portion of the plume during the period of interim remediation. Site SS035 is a component of the overall WIOU plume.

7.4.2.2 Implementation of Alternative 2 at Site FT005

Under Alternative 2, MNA would be implemented at Site FT005. Operations of the existing GET system would be discontinued. The GET system has been generally effective at reducing groundwater contamination, but cost effectiveness has decreased as plume concentrations have been reduced.

In December 2007, a portion of the Site FT005 GET system was shut down for a rebound study. The remainder of the GET system was shut down in August 2009. During the second quarter of 2010, site wells were sampled to evaluate potential rebound of contaminant concentrations. Rebound of 1,2-DCA concentrations was evident in extraction wells EW02x05, EW734x05, and EW735x05. These extraction wells were restarted in August 2010 and will remain under evaluation during the remainder of the period of interim remediation. Additional discussion of the rebound study results at Site FT005 is provided in Appendix C.

If the results of the rebound study indicate that MNA will be ineffective, then operation of all, or part, of the Site FT005 GET system will be continued to achieve RAOs.

7.4.2.3 Implementation of Alternative 2 at Site LF008

Alternative 2 would be implemented at Site LF008 after discontinuing operation of the GET system that was active during the period of interim remediation.

The existing Site LF008 GET system IRA was shut down for a rebound study in December 2008 after approximately 8 years of groundwater extraction. The findings of this study are documented in the *Technical Memorandum: Rebound Study Completion at Site LF008* (CH2M HILL, 2010i). In summary, the findings of the rebound study included the following:

- The existing GET system IRA has limited effectiveness at removing the remaining organochlorine pesticide contamination.
- Pesticide concentrations in the site monitoring wells remained consistent during the rebound period.
- The dilute residual pesticide plume is stable, and contaminants are not migrating in the absence of active groundwater extraction.
- The LF008 GET system will remain shut down to continue the rebound evaluation during the interim period of remediation.

These findings are consistent with those of the 2010 GSAP (CH2M HILL, 2011b).

7.4.2.4 Implementation of Alternative 2 at Site ST027B

Alternative 2 would be implemented at Site ST027B. A data gaps investigation and natural attenuation assessment completed in 2010 found that chlorinated VOC concentrations in the ST027B plume are less than 500 µg/L, the chlorinated VOC plume is limited in extent, and the plume is stable and is not migrating. This conclusion was reached after reviewing the soil gas data as a line of evidence. The Gore-sorber soil gas detector is a tool that can collect a large amount of data in a cost effective manner. The installation of ST027B monitoring wells was based on these soil gas data, and it was determined that the Gore-sorber soil gas data correlated well with the solvent detections in the groundwater. The plume has existed since the mid-1980s, after the use of TCE was banned by EPA. The site is surrounded by either low soil gas concentrations or a lack of detections. Therefore, it is clear that the plume is stable.

In addition, the natural attenuation assessment identified some evidence that reductive dechlorination of TCE is occurring (CH2M HILL, 2010l). Lines of evidence supporting MNA of chlorinated VOCs at Site ST027B are summarized in Section C.1.4.6 of Appendix C. Finally, this groundwater treatment approach does not require pumps, piping, and other engineered infrastructure, which would be extremely difficult, if not impossible, to build and maintain within an active air facility with considerable security and safety restrictions. Based on these considerations, MNA is a viable remedy for ST027B. The existing site monitoring wells would be incorporated into the implementation of MNA within the overall plume area.

Site ST027 was formerly managed under the POCO program. An IRA was not specified in the NEWIOU Groundwater IROD because CERCLA contamination was not detected until after the IROD was finalized. The Site ST027B portion of the site is contaminated with TCE and is now managed under the ERP (beginning in 2009). The Site ST027A portion of the plume, with only petroleum fuel contamination, continues to be managed under the POCO program.

7.4.2.5 Implementation of Alternative 2 at Site SD043

Alternative 2 would be implemented at Site SD043 after discontinuing operation of the GET system that has been active during the period of interim remediation.

The Site SD043 GET system was shut down during 2009, and a rebound study is being conducted for the remaining period of interim remediation. Given the current low concentrations of TCE at the site, this rebound study is expected to support the selection of MNA.

7.4.3 Alternative 3 – GET

Alternative 3 entails active groundwater remediation using the GET systems previously installed as part of the IRA at each applicable site. Contaminated groundwater would be extracted using horizontal and/or vertical extraction wells, treated at the NGWTP (Site LF007C) and SBBGWTP (Sites SS029 and SS030), and the treated water discharged to the stormwater drainage system.

LUCs, including Base Civil Engineer Work Requests, excavation permits, the requirements of the Base General Plan, and maintenance of the existing easements at Sites LF007C and SS030 will continue to be enforced.

The provisions of the Base General Plan related to vapor intrusion mitigation will continue to be enforced. Installation of a vapor barrier and passive venting system will be required for future new building construction in proximity to a groundwater contaminant plume.

Groundwater monitoring will be continued under the GSAP.

Alternative 3 is applicable to the physical and contaminant conditions at the following sites:

- **Site LF007C –** off-base TCE plume, existing IRA GET system
- **Site SS029 –** TCE plume near the Base boundary, existing IRA GET system
- **Site SS030 –** off-base TCE plume, existing IRA GET system

After a period of active remediation under Alternative 3, continued progress toward RAOs at Sites LF007C, SS029, and SS030 may be achieved by transitioning from the active GET remedy to an effective but lower cost program of MNA under Alternative 2.

In the future, Alternative 3 is also potentially applicable to sites currently found applicable to Alternative 2 – MNA; Alternative 4- Bioreactor and GET; Alternative 5 – EVO and EA; Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA; and Alternative 7 – Passive Skimming and EA. If one (1) or more of these alternatives ultimately prove incapable of achieving RAOs, then Alternative 3 can be implemented. The sites where Alternative 3 may be potentially applicable under future conditions are summarized in the following list:

- **Sites FT004, FT005, LF008, SD031, SD033, and SD043 –** IRA GET systems exist at these sites. Under potential future conditions, active remediation using these systems can be resumed under Alternative 3 if natural attenuation processes do not perform successfully under Alternative 2.

- **Sites LF006, LF007B, and LF007D –** No IRA GET systems exist at these sites. However, Alternative 3 – GET may be implemented in the future if MNA processes under Alternative 2 ultimately prove incapable of achieving RAOs. New GET systems would be required at each site.

- **Site ST027B –** Alternative 3 – GET may be implemented in the future at this site if MNA processes under Alternative 2 ultimately prove incapable of achieving RAOs. A new GET system would be required. Proximity to active airfield operations will pose difficulties in constructing such a GET system.

- **Site SS016 –** If the combination of an in situ bioreactor and GET under Alternative 4 proves incapable of achieving RAOs, then Alternative 3 can be implemented in the future. The existing IRA GET system could be expanded.

- **Sites SS015, SD036, and SD037 –** If source area EVO injection combined with EA under Alternative 5 proves incapable of achieving RAOs, then Alternative 3 can be implemented in the future. Operation of the IRA GET systems at Sites SD036 and SD037 could be resumed. A new GET system would be required at Site SS015.

- **Site DP039 –** If the Alternative 6 combination of an in situ bioreactor, phytoremediation, EVO PRB, and EA ultimately proves incapable of achieving RAOs, then Alternative 3 can be implemented in the future. The existing IRA GET system could be expanded.

- **Site SD034 –** If the combination of passive skimming and EA under Alternative 7 proves incapable of achieving RAOs, then Alternative 3 can be implemented in the future. Operation of the IRA GET system can be resumed.

7.4.3.1 Implementation of Alternative 3 at Site LF007C

Under Alternative 3, operation of the optimized GET system at Site LF007C would continue until RAOs are achieved. A conceptual design of Alternative 3 at Site LF007C is shown on Figure 7-1.

The existing solar-powered GET system at Site LF007C has not been fully effective at reducing groundwater contamination in the off-base portion of the plume. Concentrations of TCE in on-base and off-base monitoring wells continue to exceed the PCG. Groundwater flow directions are also uncertain (CH2M HILL, 2008a).

During 2011, the Site LF007C IRA GET system will be optimized to improve overall effectiveness. A data gaps investigation will be conducted to more fully characterize the off-base portion of the plume. Following evaluation of the characterization data, additional extraction wells may be installed to improve hydraulic capture and removal of TCE from the off-base portion of the plume. These IRA enhancements will be incorporated into Alternative 3.

During the times of year when a vernal pool at the site is dry, extracted groundwater would be conveyed to a small skid-mounted treatment unit and treated using LGAC. The LGAC unit would be located at the NGWTP, but treatment of groundwater using the NGWTP air stripper would be discontinued. The Air Force would beneficially reuse the treated water by pumping it to the Duck Pond via the existing conveyance system.

During the wet season, GET is discontinued in accordance with USFWS requirements (USFWS, 2002).

7.4.3.2 Implementation of Alternative 3 at Site SS029

Under Alternative 3, operation of the existing GET system at Site SS029 would continue until RAOs are achieved. A conceptual design of Alternative 3 at Site SS029 is shown on Figure 7-2.

The GET system at Site SS029 has been effective at controlling the migration of groundwater contamination (CH2M HILL, 2008a, 2011b). No changes to the current GET system are required. Extracted groundwater would continue to be conveyed to the existing SBBGWTP for treatment using LGAC. The treated water would then be discharged to the Main Branch of Union Creek at the existing outfall.

7.4.3.3 Implementation of Alternative 3 at Site SS030

Under Alternative 3, optimized groundwater extraction, treatment at the SBBGWTP, and discharge of treated water into the stormwater drainage system would continue at Site SS030 until RAOs are achieved. A conceptual design of Alternative 3 at Site SS030 is shown on Figure 7-2.

The GET system at Site SS030 has been effective at reducing groundwater contamination. However, the extraction system has not fully controlled migration of the off-base plume (CH2M HILL, 2008a).

It is likely that the Site FT005 extraction well system drew the Site SS030 plume to the east of its extraction well network. In response, operation of the Site SS030 GET system was modified in 2010 to improve the hydraulic capture of the off-base plume. Groundwater extraction flow rates were increased to reverse the local hydraulic gradient. The effect of increased extraction rates will be monitored during 2011 to assess whether hydraulic capture of the plume has been achieved.

If the modified operation of the Site SS030 extraction wells does not work and the eastern boundary of the Site SS030 plume remains unclear, then the Base will investigate the eastern side of the plume to verify its boundaries. Following evaluation of the characterization data, operation of the existing extraction wells may be modified and/or additional extraction wells may be installed to more fully achieve hydraulic capture of the off-base portion of the plume. All IRA optimizations will be incorporated into Alternative 3.

If required, a data gaps investigation will be conducted to verify the boundaries of the off-base portion of the plume. Following evaluation of the characterization data, operation of the existing extraction wells may be modified and/or additional extraction wells may be installed to more fully achieve hydraulic capture of the off-base portion of the plume. All IRA optimizations will be incorporated into Alternative 3.

Extracted groundwater will continue to be conveyed to the existing SBBGWTP for treatment using LGAC. The treated water will then be discharged to the Main Branch of Union Creek at the existing outfall.

7.4.4 Alternative 4 – Bioreactor and GET

Alternative 4 combines two (2) technology processes to remediate the Site SS016 plume.

LUCs, including Base Civil Engineer Work Requests, excavation permits, and the requirements of the Base General Plan, will continue to be enforced.

The provisions of the Base General Plan related to vapor intrusion mitigation will continue to be enforced. Installation of a vapor barrier and passive venting system will be required for future new building construction in proximity to a groundwater contaminant plume.

Groundwater monitoring will be continued under the GSAP.

A conceptual design of Alternative 4 at Site SS016 is shown on Figures 7-3 and 7-4. The primary components of the Alternative 4 include the following:

- Bioreactor
- GET

In 2010, a bioreactor was constructed at Site SS016 within the OSA source area as an optimization of the existing IRA. The bioreactor uses ERD processes to break down chlorinated VOCs within the source area. Contaminated groundwater from existing horizontal extraction well EW003x16 currently recirculates through the bioreactor using a solar-powered pump. As a result of these actions, the continuing source of TCE contamination into the hydraulically downgradient portions of the Site SS016 plume will be greatly reduced. Residual contamination from the OSA source area will be addressed by existing vertical groundwater extraction wells EW605x16 and EW610x16. The location of the bioreactor is shown on Figure 7-5. A conceptual cross section of a bioreactor is shown on Figure 7-6. Performance data for the bioreactor will continue to be evaluated for the remainder of the period of interim remediation.

Groundwater extraction within the TARA portion of Site SS016 would continue under Alternative 4 using the two (2) existing horizontal extraction wells (EW001x16 and EW002x16).

Extracted groundwater would be treated using LGAC at the CGWTP and then discharged into the stormwater drainage system.

After a period of active remediation under Alternative 4, continued progress toward RAOs may be achieved by transitioning from the combination of a bioreactor and GET to an effective but lower cost program of MNA under Alternative 2.

7.4.5 Alternative 5 – EVO and EA

Alternative 5 combines in situ bioremediation with monitored EA. Under this alternative, EVO is injected into the higher concentration source area of a plume to anaerobically degrade chlorinated VOCs through ERD processes. After injection of EVO within the source area, the continuing source of TCE contamination into the hydraulically downgradient portions of the plume is greatly reduced. The physical, chemical, and biological mechanisms of attenuation in these downgradient areas will then be enhanced.

LUCs, including Base Civil Engineer Work Requests, excavation permits, and the requirements of the Base General Plan, will continue to be enforced.

The existing vapor intrusion mitigation measures for Building 554 (Site SS015) and Building 837 (Site SD037) will continue to be maintained. Installation of a vapor barrier and passive venting system will be required for future new building construction in proximity to a groundwater contaminant plume.

Groundwater monitoring under the GSAP will be continued.

Alternative 5 is applicable to the physical and contaminant conditions at the following sites:

- Site SS015
- Site SD036
- Site SD037

Site-specific EVO injection conceptual designs are shown on Figures 7-6 (Site SS015), 7-8 (Site SD036), and 7-9 (Site SD037).

The primary components of Alternative 5 include the following:

- **EVO Injection –** Edible oil substrates are injected into the higher concentration source areas to facilitate anaerobic degradation of chlorinated VOCs. These areas are a continuing source of contamination into the hydraulically downgradient portions of the plume.

- **EA –** Physical, chemical, and/or biological processes will reduce the mass, toxicity, volume, or concentration of contaminants in the remaining portions of the plume.

During 2010, the existing groundwater IRAs at Sites SS015, SD036, and SD037 were optimized. Additional source area characterization was conducted, and EVO was injected into the source area plume at each site. Performance data for the source area EVO injections and attenuation process in the distal portions of the plumes currently under rebound studies will continue to be evaluated for the remainder of the period of interim remediation. Successful IRA optimization actions would be incorporated into Alternative 5 at each of the sites.

Following implementation of Alternative 5, the Site SD036 and Site SD037 GET IRAs would be discontinued. The overall WIOU GET system, including the system components at Site SD036 and SD037, was shut down in the second quarter of 2010 for a rebound study. The WIOU GET system will continue to be shut down for the remainder of the period of interim remediation. Rebound study data will continue to be evaluated for the remainder of the period of interim remediation.

Groundwater monitoring for EA would be continued within the non-source areas of the overall WIOU plume, including the distal portions of Sites SD036 and SD037. At Site SS015, monitoring for natural attenuation of contaminants would also be continued under Alternative 5. Performance data for attenuation processes in the distal portions of the plumes will continue to be evaluated for the remainder of the period of interim remediation.

The IRA GET systems at Sites SD036 and SD037 still exist. Active remediation using these systems can be readily resumed if ERD processes using source area EVO injection do not perform as expected. At Site SS015, the IRA was MNA Assessment, and no IRA GET system was constructed. If necessary, implementing GET at this site would require the design and construction of a groundwater extraction system and modifications to the CGWTP to accommodate the new system components.

7.4.5.1 Implementation of Alternative 5 at Site SS015

Under Alternative 5, EVO is injected into the higher concentration source areas of the Site SS015 plume, and monitoring wells are incorporated into an EA monitoring program within the overall plume area. A conceptual design of Alternative 5 at Site SS015 is shown on Figure 7-6.

At Site SS015, an assessment of natural attenuation was conducted during the period of interim remediation. This assessment concluded that natural processes, enhanced by the vegetable oil injection treatability study conducted during 2000-2001, have been largely effective at degrading TCE contamination (CH2M HILL, 2010a; Parsons, 2002). However, 2010 GSAP data indicate that natural attenuation alone may not be a sufficient remedy because the plume is migrating. A summary of the findings of the 2009-2010 GSAP Annual Report (CH2M HILL, 2011b) and supplemental discussion of Site SS015 groundwater contamination are provided in Appendix C.

7.4.5.2 Implementation of Alternative 5 at Site SD036

At Site SD036, Alternative 5 would be implemented by EVO injection within the source area to degrade TCE and other chlorinated VOC contamination using ERD processes. The purpose of this action would be to reduce the continuing source of TCE contamination into the hydraulically downgradient portions of the plume. The physical, chemical, and biological processes of attenuation in these downgradient areas would then be enhanced.

The site monitoring wells would be incorporated into a program of EA within the overall plume area. A conceptual design of Alternative 5 at Site SD036 is shown on Figure 7-8.

During 2010, the existing groundwater IRA at Site SD036 was optimized. Additional source area characterization was conducted, and EVO was injected into the source area plume at the site. Performance monitoring of the EVO injection is ongoing. This IRA optimization action would be incorporated into Alternative 5 at the site.

Following implementation of Alternative 5, the Site SD036 GET IRA would be discontinued. The overall WIOU GET system, including the system components at Site SD036, was shut down in the second quarter of 2010 for a rebound study. The Site SD036 GET system will continue to be shut down for the remainder of the period of interim remediation.

Groundwater monitoring for natural attenuation would be continued within the non-source areas of the overall WIOU plume, including the distal portions of Site SD036. Additional discussion of natural attenuation processes within the WIOU is provided in Appendix C.

7.4.5.3 Implementation of Alternative 5 at Site SD037

Similar to Site SD036, Alternative 5 would be implemented at Site SD037 by EVO injection within the source area to degrade TCE and other chlorinated VOC contamination using ERD processes. This action would reduce the continuing source of TCE contamination into the hydraulically downgradient portions of the plume. This would also enhance the physical, chemical, and biological processes of attenuation in these downgradient areas. The site monitoring wells would be incorporated into a natural attenuation program within the overall plume area. A conceptual design of Alternative 5 at Site SD037 is shown on Figure 7-9.

During 2010, the existing groundwater IRA at Site SD037 was optimized. Additional source area characterization was conducted, and EVO was injected into the source area plume (i.e., hot spot) in the vicinity of Building 837. Performance monitoring of the EVO injection is ongoing. This IRA optimization action would be incorporated into Alternative 5 at the site.

Following implementation of Alternative 5, the Site SD037 GET IRA would be discontinued. The overall WIOU GET system, including the system components at Site SD037, was shut down in the second quarter of 2010 for a rebound study. The Site SD037 GET system will continue to be shut down for the remainder of the period of interim remediation.

Groundwater monitoring for MNA will continue within the non-source areas of the overall WIOU plume, including the distal portions of Site SD037.

During the period of interim remediation, an MNA assessment was conducted within the distal portion of the Site SD037 plume. The assessment concluded that MNA was an appropriate remedy for this portion of the plume. There is no evidence of plume migration, and already low TCE concentrations have been stable. Overall, the extent of TCE contamination has decreased over time (CH2M HILL, 2010a). Additional discussion of Site SD037 groundwater contamination is also provided in Appendix C.

7.4.6 Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA

Alternative 6 combines three (3) in situ bioremediation technology processes and monitored EA to achieve RAOs at Site DP039.

LUCs, including Base Civil Engineer Work Requests, excavation permits, and the requirements of the Base General Plan, will continue to be enforced.

The provisions of the Base General Plan related to vapor intrusion mitigation will continue to be enforced. Installation of a vapor barrier and passive venting system will be required for future new building construction in proximity to a groundwater contaminant plume.

Groundwater monitoring will be continued under the GSAP.

A conceptual design of the implementation of Alternative 6 is shown on Figure 7-10. The primary alternative components include the following:

- **In Situ Bioremediation**
  - **Bioreactor –** The bioreactor installed in December 2008 as a technology demonstration project actively treats the source area plume by recirculating extracted groundwater through an organic mulch mixture to reduce contaminant mass and volume via ERD processes. The location of the bioreactor is shown on Figure 7-10. A conceptual cross section of the bioreactor is shown on Figure 7-5. Contaminated groundwater from a source area extraction well is pumped through a pipe system onto the mulch column. The water then trickles through the mulch column and into the aquifer before being captured and recirculated by an extraction well. A sustainable source of electric power to the extraction well pump is provided by solar panels (CH2M HILL, 2009c).
  - **Phytoremediation –** A downgradient phytoremediation zone supplements the treatment of the source area plume provided by the bioreactor. Source area contamination that is not treated by the bioreactor flows beneath a grove of engineer-planted eucalyptus trees. Phytoremediation would contribute to the overall effectiveness of the alternative by providing additional reduction of contaminant mass and volume outside of the source area (Parsons, 2009, 2010).
  - **EVO PRB –** As an optimization to the Site DP039 IRA, a PRB of edible oil (i.e., a biobarrier) was installed using injection wells in the portion of the aquifer downgradient of the bioreactor and phytoremediation zone during 2010. Injection of EVO across the leading edge of the 500-µg/L source area plume anaerobically degrades some of the higher concentrations of TCE and other chlorinated VOCs. This portion of the plume is a continuing source of contamination into the hydraulically downgradient area of EA. The injected EVO is expected to provide effective treatment for approximately 2 to 3 years. Supplemental injection of EVO could be conducted using the injection wells, if required, to maintain the treatment process.
- **EA –** Physical, chemical, and/or biological processes would remediate the residual contaminants in the distal portion of the Site DP039 plume. After the portion of the plume with higher concentrations is addressed by the combination of bioreactor, phytoremediation, and EVO PRB, the effectiveness of attenuation in the lower concentration distal portions of the plume would be enhanced because contaminant migration originating from the source area would be greatly reduced. The existing site monitoring wells would be incorporated into the implementation of EA.

Following implementation of Alternative 6, operation of the Site DP039 IRA GET system would be permanently discontinued.

Performance data for the bioreactor, phytoremediation zone, EVO PRB, and area of EA will continue to be evaluated for the remainder of the period of interim remediation.

The IRA GET system at Site DP039 still exists. Active remediation using this system can be resumed if the combination of bioreactor, phytoremediation, EVO PRB, and EA do not perform as expected.

7.4.7 Alternative 7 – Passive Skimming and EA

Alternative 7 involves continuing the intermittent removal of free-phase Stoddard solvent from the Site SD034 source area using the existing network of vertical extraction wells previously installed as part of the IRA. In the distal portions of the plume, natural attenuation would be monitored to address dissolved-phase contamination.

LUCs, including Base Civil Engineer Work Requests, excavation permits, and the requirements of the Base General Plan, will continue to be enforced.

The provisions of the Base General Plan related to vapor intrusion mitigation will continue to be enforced. Installation of a vapor barrier and passive venting system will be required for future new building construction in proximity to a groundwater contaminant plume.

Groundwater monitoring will be continued under the GSAP.

Under Alternative 7, passive skimmers would be used to remove free product from Site SD034 source area wells if it is detected during routine monitoring events. From 1998 through 2004, active and passive skimmers were used at Site SD034 to remove floating Stoddard solvent from wells at the site. Since that time, passive skimmers have been periodically used as free product reappears in some of the source area wells. Through 2010, passive skimming has been conducted to remove floating Stoddard solvent from several of the source area wells. During the second quarter of 2010, floating product was found in two (2) site monitoring wells at thicknesses of 0.12 and 0.44 foot. Free-phase Stoddard solvent is limited to the source area and is not migrating (CH2M HILL, 2011b).

Dissolved-phase Stoddard solvent is also limited to the source area. Other petroleum fuel constituents at Site SD034 are commingled with chlorinated VOCs from the surrounding Site SD037 plume and have contributed to the ERD of chlorinated VOCs. The existing Site SD034 monitoring wells would be incorporated into the monitoring of EA within the overall WIOU plume.

The effectiveness of EA in the non-source areas of the plume would be enhanced by continuing to conduct passive skimming, if free-phase Stoddard solvent is detected in the site monitoring wells.

7.5 Screening of Alternatives

Screening of the assembled groundwater remedial alternatives against the criteria of Effectiveness, Implementability, and Cost is provided in Table 7-11. A site-specific summary of the alternative screening is provided in Table 7-12.

TABLE 7-11
Screening of Groundwater Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Alternative	Effectiveness	Implementability	Cost	Comment
1 – No Action	Possibly effective, but no monitoring is conducted and no evaluations are performed to assess reductions in the toxicity, mobility, or volume of contaminants.	Easy to implement, but unlikely to be accepted by regulatory agencies without extensive documentation.	None.	Required by NCP to be retained for detailed analysis.
2 – MNA	Effectiveness demonstrated at multiple Travis AFB sites as documented in the NAAR (CH2M HILL, 2010a) and also discussed in Appendix C. Reduces toxicity and volume of contaminants on a long-term basis through degradation, dispersion, and diffusion. Natural biodegradation processes play a limited role at Travis AFB. Applicable to large and/or diffuse plumes where in situ treatment and removal technologies cannot be effectively employed. Existing LUCs have been effective at protecting human health through consistent application of the on-base land restrictions that minimize unauthorized exposure to contaminants.	Already implemented as the interim remedy at Site LF006 and as a component of the interim remedy at Site DP039. MNA assessments have already been successfully conducted at Sites FT004, LF007B, LF007D, SS015, SD031, SD033, and SD037. LUCs are already enforced at Travis AFB.	Low capital, low maintenance.	Retained for detailed analysis. Applicable to current site and contaminant conditions at Sites FT004, FT005, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, and SD043. Alternative 2 is potentially applicable to *future* contaminant conditions at Sites LF007C, SS016, SS029, and SS030 after contaminant concentrations have been reduced by a more active remediation alternative. Continued progress toward RAOs may then be achieved by transitioning to an effective, but lower cost program of MNA.
3 – GET	Groundwater extraction using extraction wells has demonstrated effectiveness at removing contaminant mass. Also effectively limits the migration of the contaminated groundwater within large and/or diffuse plumes where in situ treatment technologies cannot be effectively employed. Reduces the toxicity and volume of contaminants on a long-term basis by extracting and treating the groundwater. LGAC treatment has demonstrated effectiveness at the NGWTP, CGWTP, and SBBGWTP. Existing LUCs have been effective at protecting human health through consistent application of the on-base land restrictions that minimize unauthorized exposure to contaminants.	Already implemented. GET has already been used extensively at Sites FT004, LF007C, LF008, SS016, SS029, SS030, SD031, SD033, SD034, SD036, SD037, DP039, and SD043 to remove contamination and hydraulically control contaminant migration. Air stripping and LGAC treatment processes have been effectively implemented at the NGWTP, CGWTP, and SBBGWTP during the period of interim remediation. Disposal of treated groundwater into the stormwater drainage system has also been effectively implemented. Treated groundwater is currently being beneficially reused at the NGWTP to supply water to the Duck Pond. LUCs are already enforced at Travis AFB.	Low to moderate capital because of existing infrastructure, moderate annual maintenance. An extensive groundwater extraction, treatment, and discharge network already exists at the NGWTP and SBBGWTP.	Retained for detailed analysis. Applicable to the current site and contaminant conditions at Sites LF007C, SS029, and SS030. Alternative 3 is potentially applicable to future site and contaminant conditions for those sites currently found applicable under Alternatives 2, 4, 5, 6, and 7. If one (1) or more of these alternatives prove incapable of achieving RAOs at a site, then Alternative 3 can be implemented in the future. These sites are as follows: Alternative 2 – MNA at Sites FT004, FT005, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, and SD043; Alternative 4 – Bioreactor and GET at Site SS016; Alternative 5 – EVO and EA at Sites SS015, SD036, and SD037; Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA at Site DP039; and Alternative 7 – Passive Skimming and EA at Site SD034.
4 – Bioreactor and GET	Installation of an in situ bioreactor includes excavation of soil within the contaminant source area. Soil excavation is a well established and effective technology. Conducting excavation for the bulk removal of highly contaminated soil is effective at permanently removing the continuing source of groundwater contamination. An in situ bioreactor can be effective at destroying groundwater contaminants via ERD. A demonstration of bioreactor effectiveness is in-progress at Site DP039. Results through 2010 are positive. A second bioreactor was installed during 2010 within the OSA source area of Site SS016, and effectiveness is under evaluation. GET has demonstrated effectiveness at removing contaminant mass and hydraulically controlling the migration of contaminated groundwater. Existing LUCs have been effective at protecting human health through consistent application of the on-base land restrictions that minimize unauthorized exposure to contaminants.	Already implemented. In situ bioreactors were successfully installed at Site DP039 in 2008 and Site SS016 in 2010. Shored excavations and bioreactor installations were successfully conducted at both sites without incident. Groundwater extraction wells have already been used extensively at Sites FT004, LF007C, LF008, SS016, SS029, SS030, SD031, SD033, SD034, SD036, SD037, SS041, and SD043 to remove contamination and hydraulically control contaminant migration. Air stripping and LGAC treatment processes have been effectively implemented at the NGWTP, CGWTP, and SBBGWTP during the period of interim remediation. Disposal of treated groundwater into the stormwater drainage system has also been effectively implemented. Treated groundwater is currently being beneficially reused at the NGWTP. LUCs are already successfully installed at Travis AFB.	Moderate to high capital, low annual maintenance. The presence of roads, fences, underground utilities, or other structures increases costs and the difficulty of construction.	Retained for detailed analysis. Applicable to site and contaminant conditions at Site SS016.
5 – EVO and EA	Effective at protecting human receptors by actively treating the source area portions of plume using ERD via injected edible oil to reduce contaminant mass and volume. After the source area is addressed, EA will be effective in the lower concentration distal portions of the plume because contaminant migration from the source area is greatly reduced and natural attenuation processes can work more effectively. The effectiveness of natural attenuation processes is documented in the NAAR (CH2M HILL, 2010a) and is also discussed in Appendix C. Existing LUCs have been effective at protecting human health through consistent application of the on-base land restrictions that minimize unauthorized exposure to contaminants.	Already implemented. Travis AFB has already implemented bioremediation using EVO injection as optimizations to the existing groundwater IRAs at Sites SS015, SD036, SD037, and DP039. MNA assessments have already been successfully conducted at Sites FT004, LF006, LF007B, LF007D, SS015, SD031, SD033, SD037, and DP039. The results of the MNA assessments are documented in the NAAR (CH2M HILL, 2010a) and also discussed in Appendix C. LUCs are already enforced at Travis AFB.	High short-term capital cost. Low aquifer permeability requires closely spaced wells to ensure adequate distribution of the injected solutions and increases costs. Low to moderate long-term maintenance cost.	Retained for detailed analysis. Applicable to site and contaminant conditions at Sites SS015, SD036, and SD037.

TABLE 7-11
Screening of Groundwater Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Alternative	Effectiveness	Implementability	Cost	Comment
6 – Bioreactor, Phytoremediation, EVO PRB, and EA	Installation of an in situ bioreactor includes excavation of soil within the contaminant source area. Excavation of highly contaminated soil within the source area is effective at permanently removing the continuing source of groundwater contamination. Effective at protecting human receptors by actively treating the source area portions of the plume using ERD via an injected EVO biobarrier and extraction wells recirculating groundwater through a bioreactor to reduce contaminant mass and volume. Phytoremediation will contribute to the overall effectiveness by additional reduction of contaminant mass and volume in the source area portion of the plume. After the source area is addressed by the combination of excavation, bioreactor, phytoremediation, and EVO PRB, EA will be effective in the lower concentration distal portions of the plume because contaminant migration from the source area is greatly reduced and natural attenuation processes can work more effectively. Existing LUCs have been effective at protecting human health through consistent application of the on-base land restrictions that minimize unauthorized exposure to contaminants.	Already implemented. Bioreactor installation has already been successfully implemented at Site DP039 in 2008 and Site SS016 in 2010. Shored excavations and bioreactor installations were successfully conducted at both sites without incident. In situ bioremediation using EVO injection has already been conducted as optimizations to the existing groundwater IRAs at Sites SS015, SD036, SD037, and DP039. A demonstration bioreactor is already in operation at the Site DP039 source area. Installation of a second bioreactor within the OSA source area of Site SS016 was successfully conducted in 2010. A successful phytoremediation treatability study has already taken place at Site DP039 (Parsons, 2002). MNA assessments have already been successfully conducted at Sites FT004, LF006, LF007B, LF007D, SS015, SD031, SD033, SD037, and DP039. The results of the MNA assessments are documented in the NAAR (CH2M HILL, 2010a) and also discussed in Appendix C. LUCs are already enforced at Travis AFB.	Moderate to high capital cost, low to moderate annual maintenance. Low aquifer permeability requires closely spaced wells to ensure adequate distribution of the injected solutions and increases costs. Solar panels provide the bioreactor extraction well pumps with a sustainable supply of electric power.	Retained for detailed analysis. Applicable to site and contaminant conditions at Site DP039.
7 – Passive Skimming and EA	Effective at protecting human receptors by removing floating product from the groundwater table using vertical wells. After the source area floating product is removed by skimming, EA will be more effective in the lower concentration distal portions of the plume because dissolved-phase contaminant migration from the floating product in the source area is greatly reduced and natural attenuation processes can work more effectively. Existing LUCs have been effective at protecting human health through consistent application of the on-base land restrictions that minimize unauthorized exposure to contaminants.	Already implemented. Travis AFB has already successfully implemented passive skimming at and Site SD034. MNA assessments have already been successfully conducted at Sites FT004, LF006, LF007B, LF007D, SS015, SD031, SD033, SD037, and DP039. The results of the MNA assessments are documented in the NAAR (CH2M HILL, 2010a) and also discussed in Appendix C. LUCs are already enforced at Travis AFB.	Low capital cost, low annual maintenance.	Retained for detailed analysis. Applicable to site and contaminant conditions at Site SD034. Floating product is not currently found at any other ERP site.

Note:

Remedial alternatives are assembled from the representative process options identified in Tables 7-7 and 7-8.

TABLE 7-12
Summary of Alternative Screening
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Remedial Alternative	Site																				
	FT004	FT005	LF006	LF007B	LF007C	LF007D	LF008	SS015	SS016	ST027B	SS029	SS030	SD031	SD033	SD034	SS035	SD036	SD037	DP039	SS041	SD043
1 – No Action	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○
2 – MNA	■	■	■	■	□	■	■	□	□	■	□	□	■	■	□	■	□	□	□	○	■
3 – GET	◙	◙	□	□	■	□	◙	◙	◙	□	■	■	◙	◙	◙	□	◙	◙	◙	○	◙
4 – Bioreactor and GET	□	□	○	○	○	□	○	□	■	□	○	○	□	○	○	○	□	□	◙	○	○
5 – EVO and EA	□	□	○	○	□	□	○	■	□	□	□	□	□	□	□	○	■	■	◙	○	○
6 – Bioreactor, Phytoremediation, EVO PRB, and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○
7 – Passive Skimming and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○	○	○	○	○

■ = Alternative that best satisfies the evaluation criteria of Effectiveness, Implementability, and Cost.
◙ = Alternative that moderately satisfies the evaluation criteria of Effectiveness, Implementability, and Cost.
□ = Alternative that poorly satisfies the evaluation criteria of Effectiveness, Implementability, and Cost.
○ = Alternative that is not applicable or does not satisfy the evaluation criteria of Effectiveness, Implementability, and Cost.

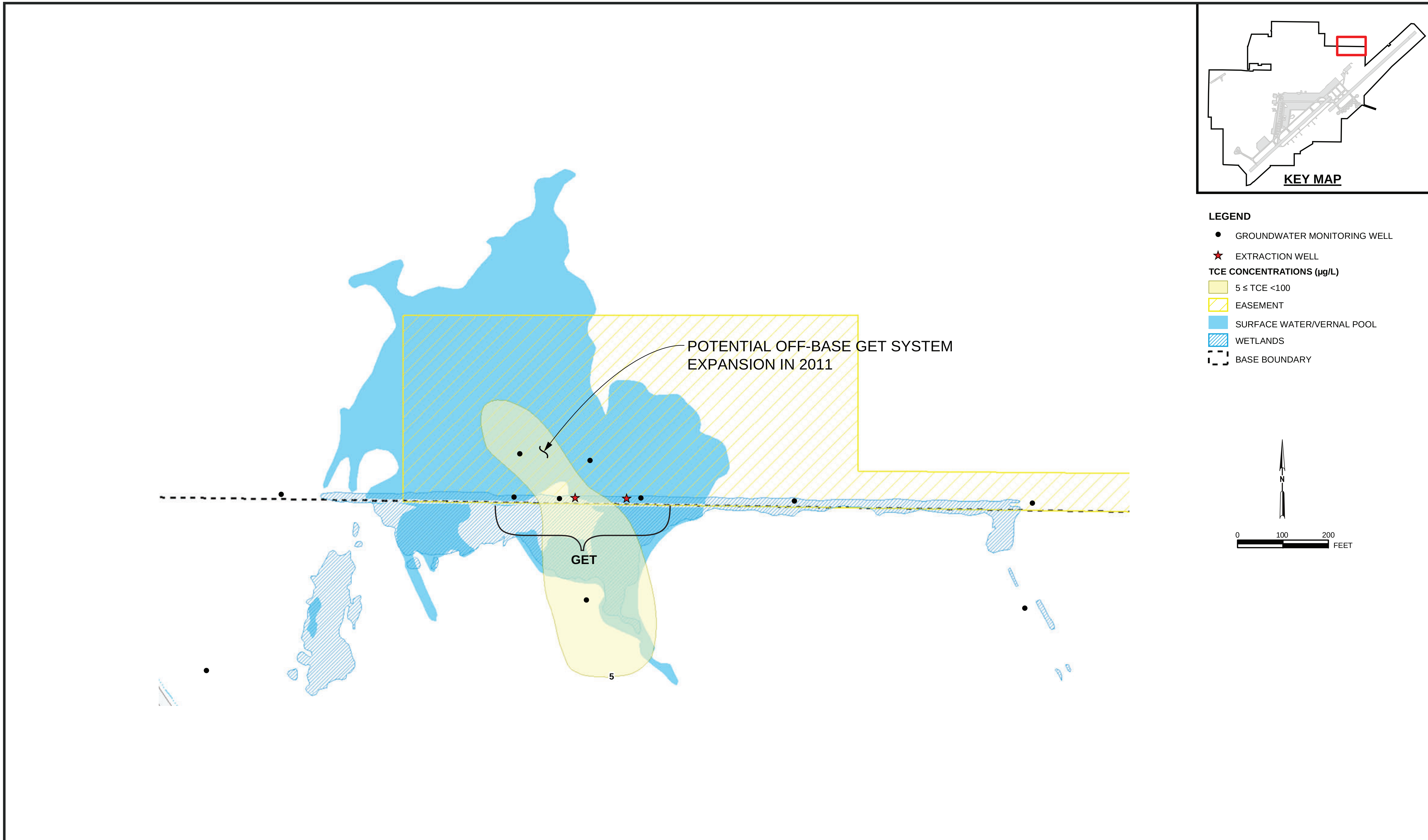


FIGURE 7-1
CONCEPTUAL DESIGN
ALTERNATIVE 3 – GET SITE LF007C
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

ES011811013517RDD_7-1

CH2MHILL

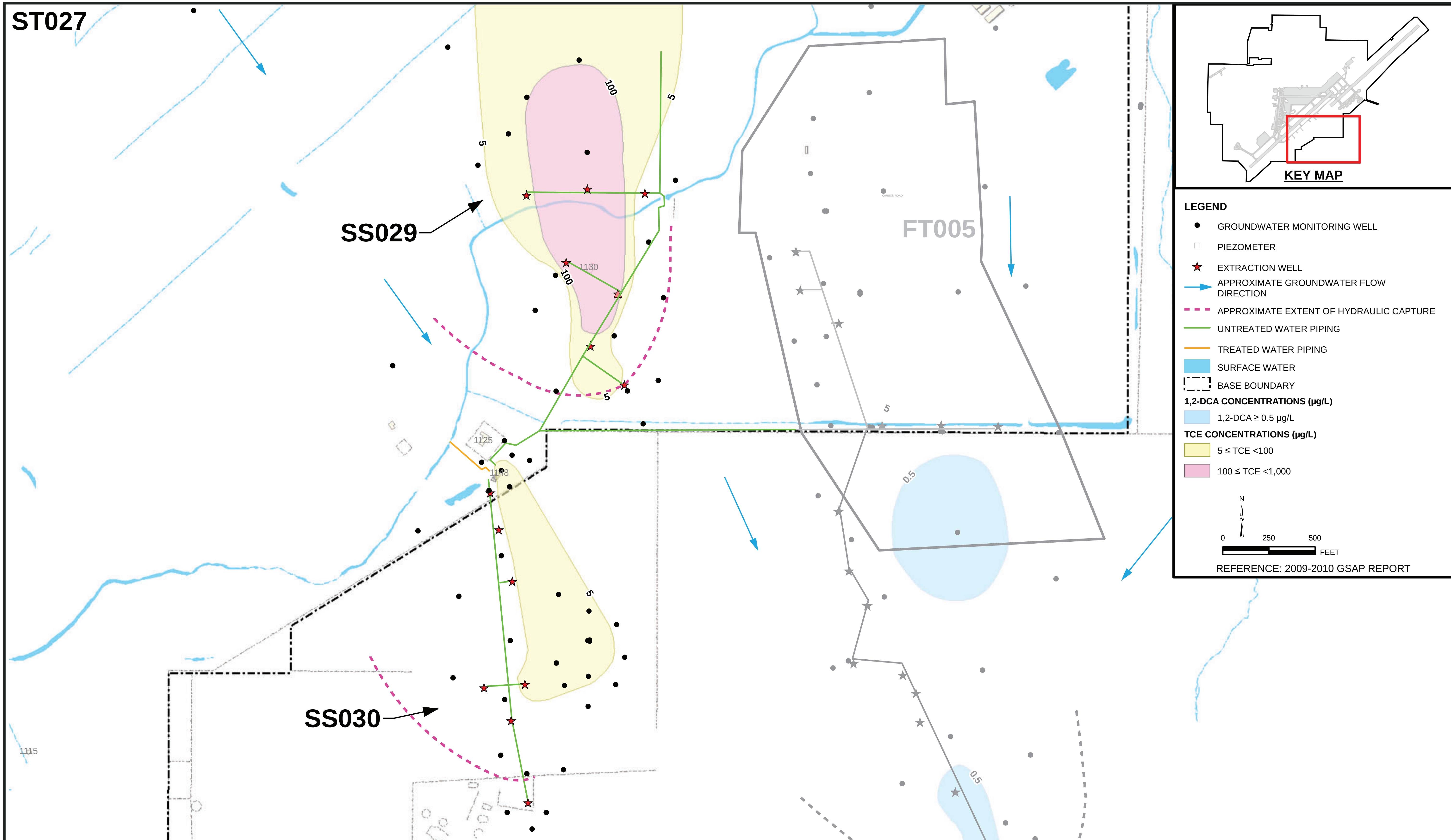


FIGURE 7-2
CONCEPTUAL DESIGN
ALTERNATIVE 3 – GET
SITES SS029 AND SS030
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

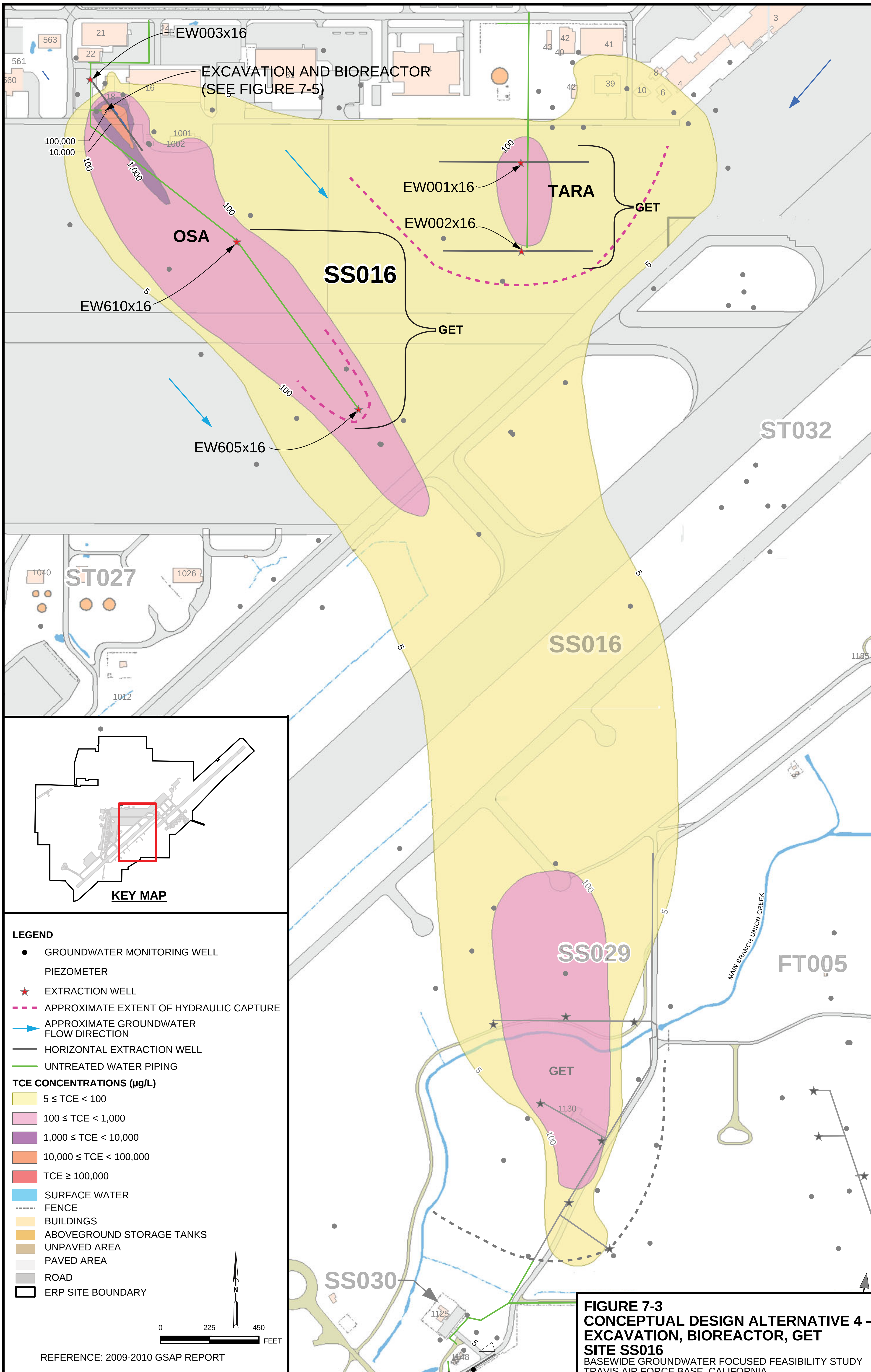


FIGURE 7-3
CONCEPTUAL DESIGN ALTERNATIVE 4 – EXCAVATION, BIOREACTOR, GET
SITE SS016
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA
CH2MHILL

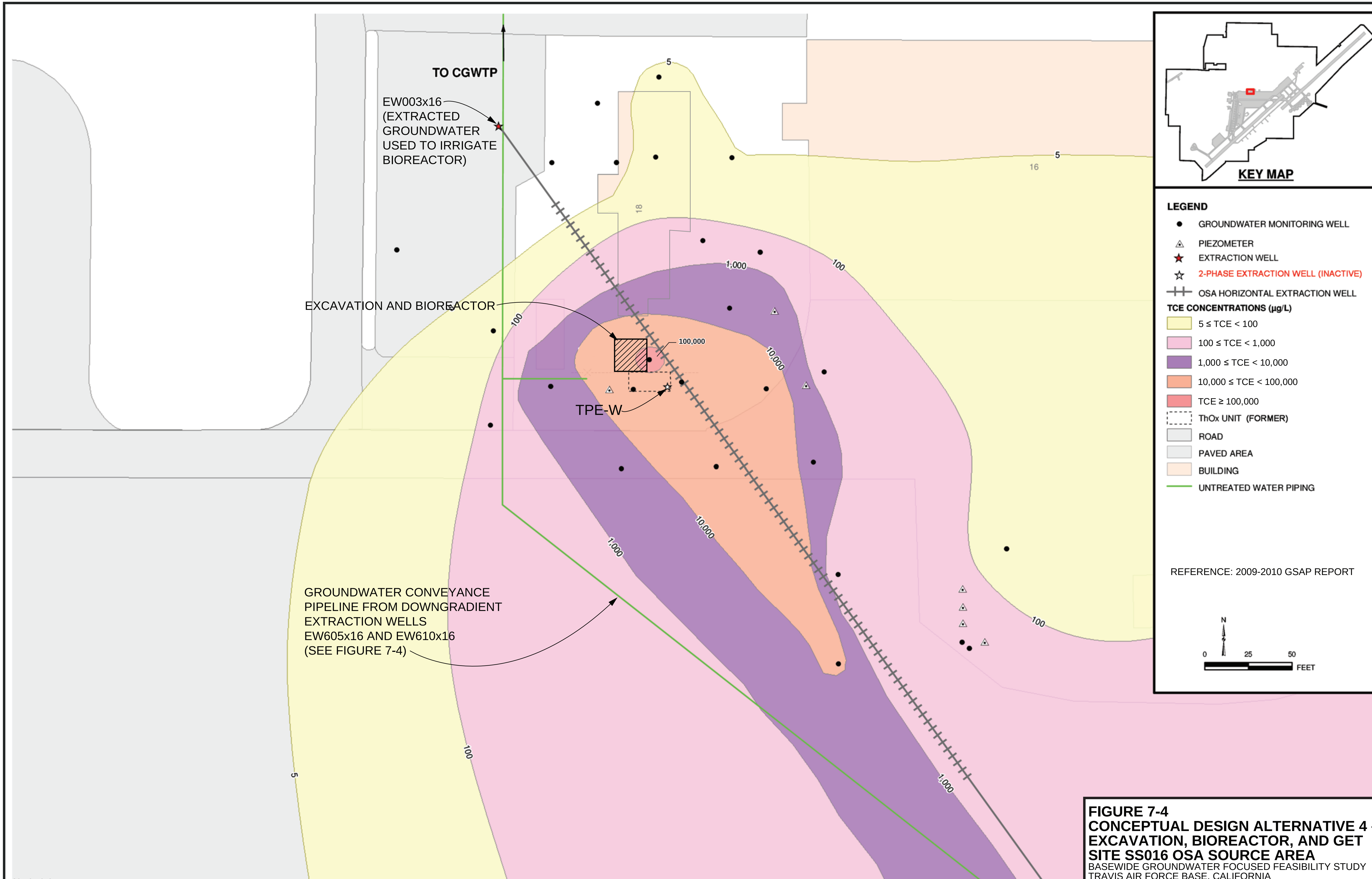
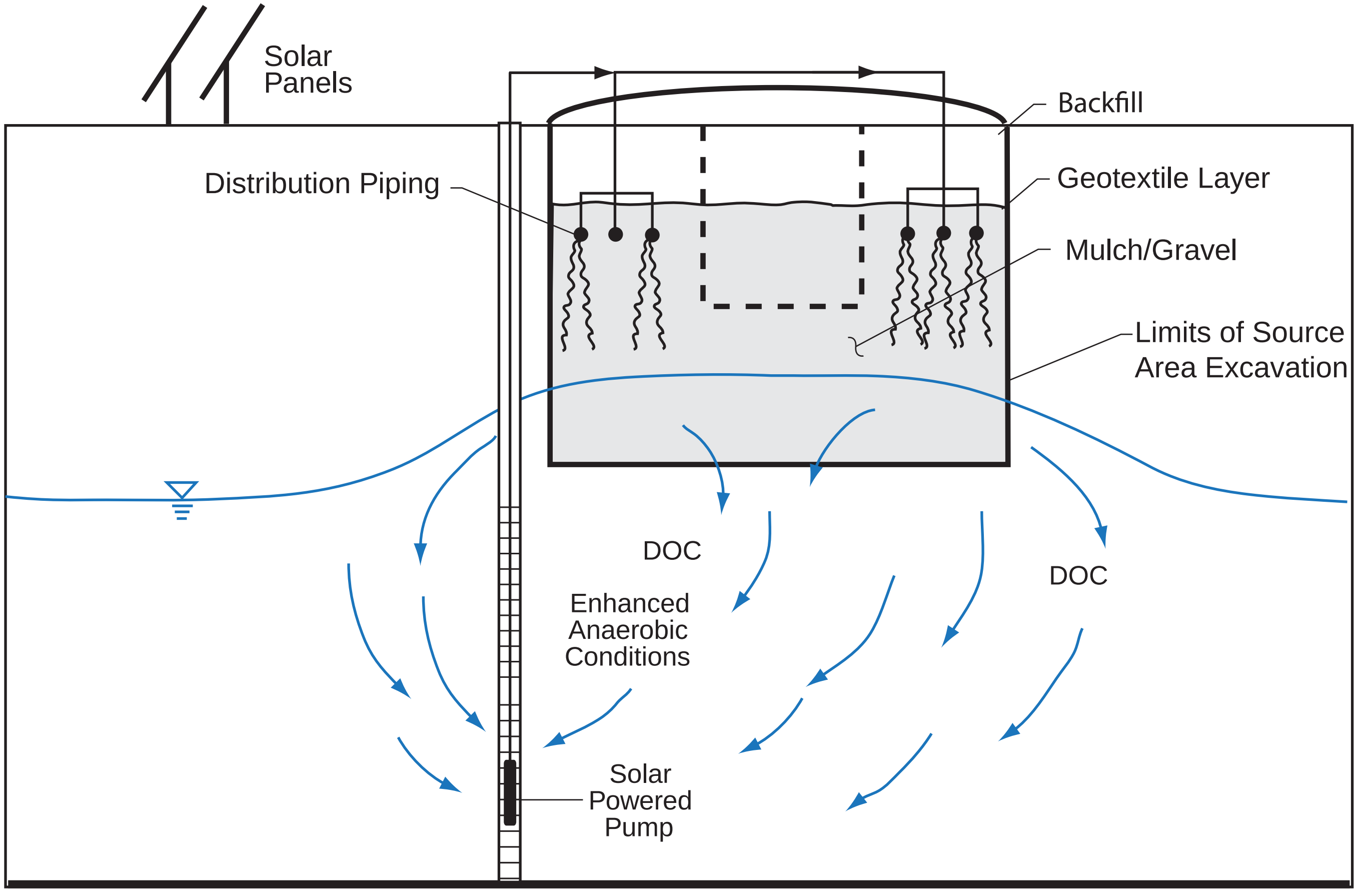


FIGURE 7-4
CONCEPTUAL DESIGN ALTERNATIVE 4 – EXCAVATION, BIOREACTOR, AND GET SITE SS016 OSA SOURCE AREA
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL



LEGEND

Groundwater Flow Direction

DOC Dissolved Organic Carbon

FIGURE 7-5
CONCEPTUAL DESIGN
ALTERNATIVES 4 AND 6
TYPICAL BIOREACTOR CROSS SECTION
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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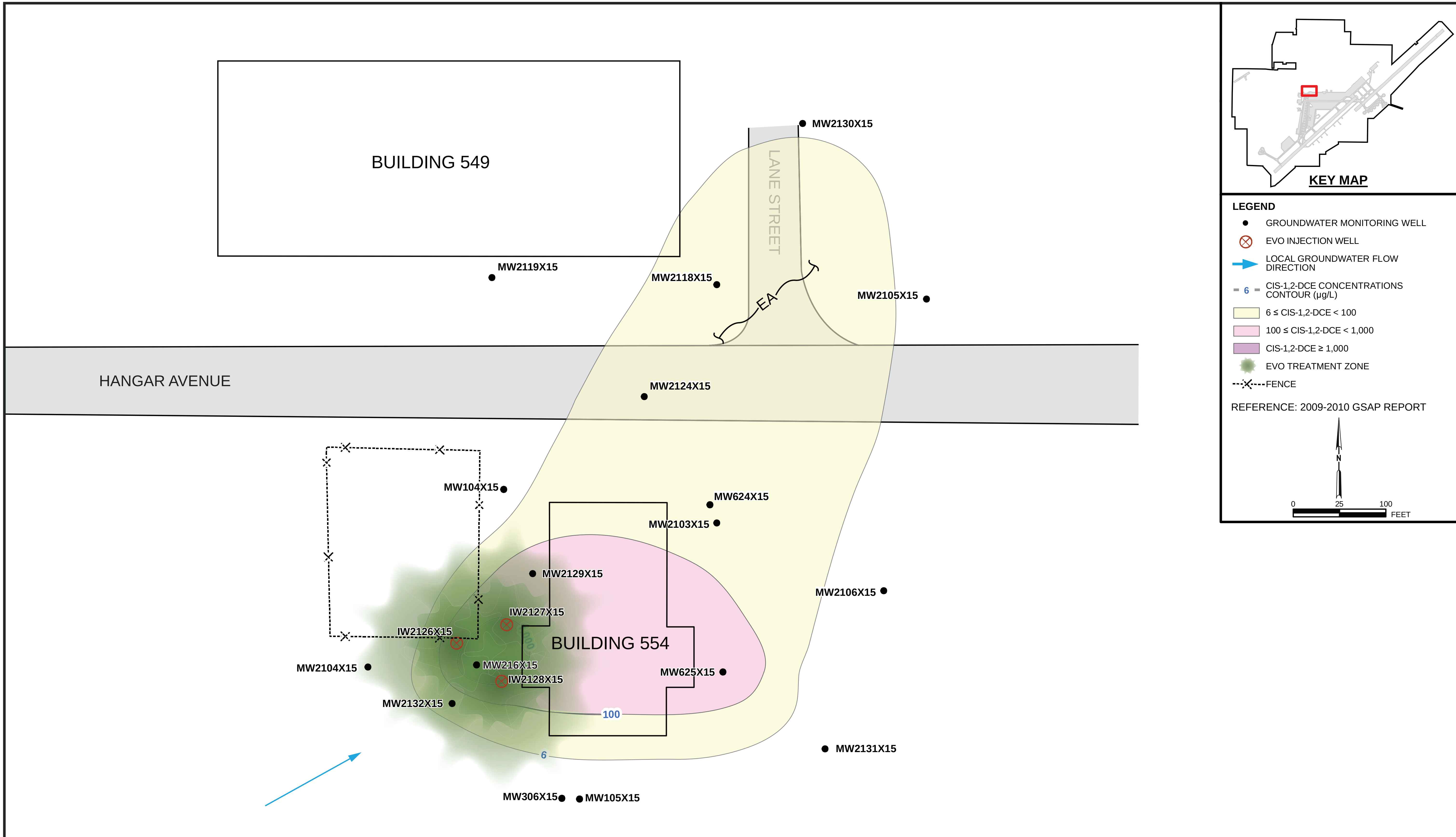

FIGURE 7-6
CONCEPTUAL DESIGN
ALTERNATIVE 5 – EVO AND EA
SITE SS015
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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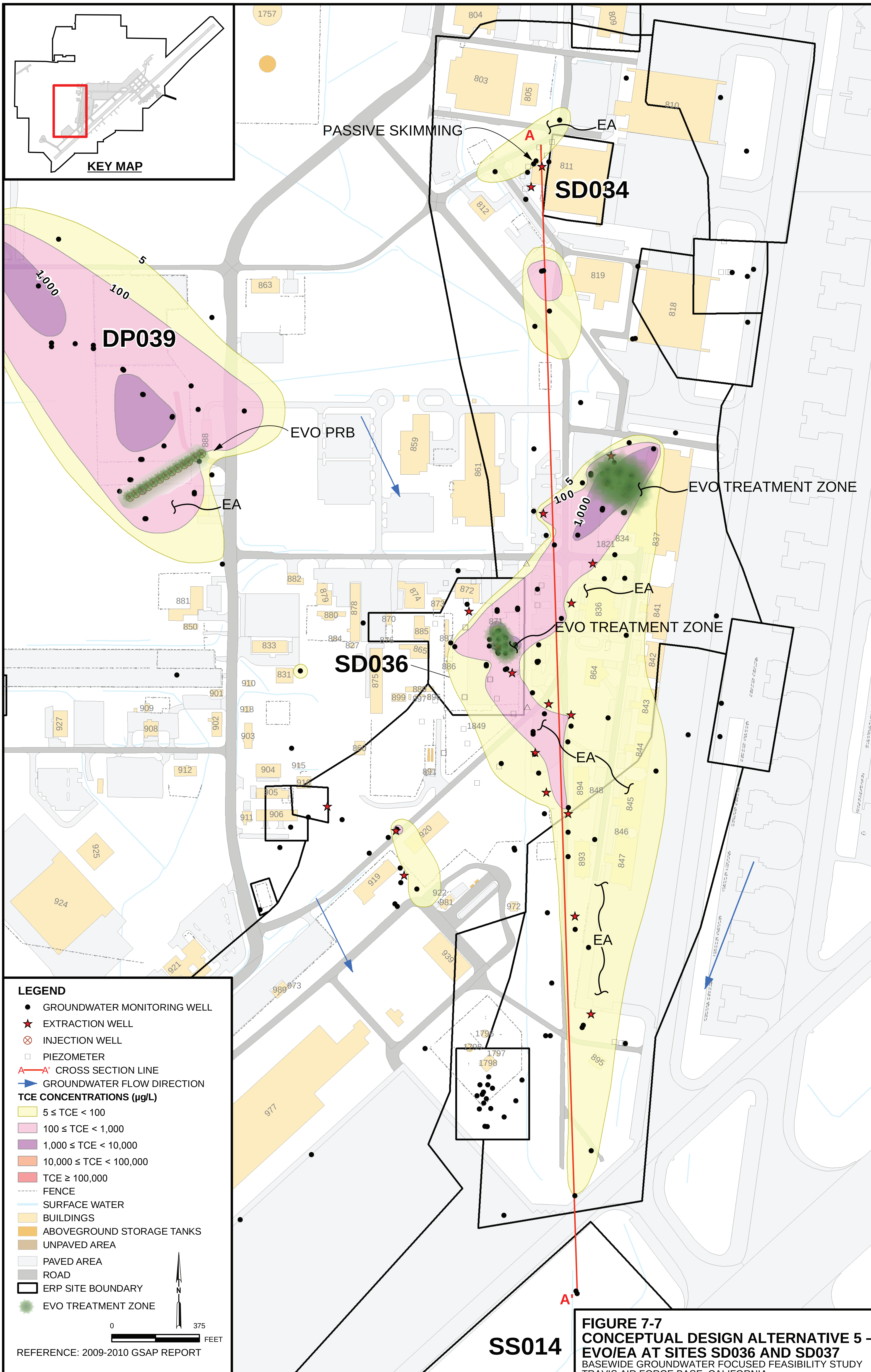
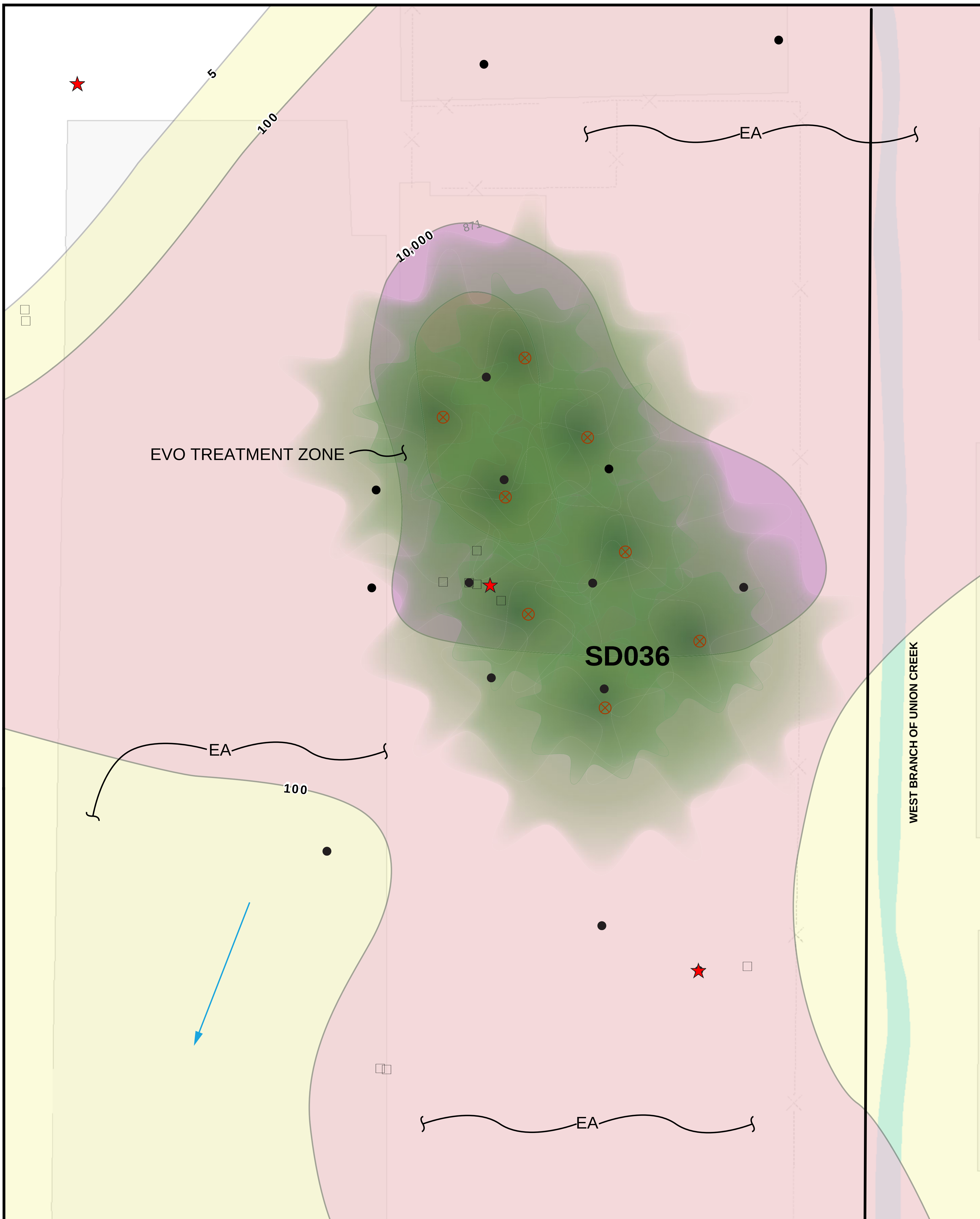


FIGURE 7-7
CONCEPTUAL DESIGN ALTERNATIVE 5 – EVO/EA AT SITES SD036 AND SD037
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA
CH2MHILL



LEGEND

- GROUNDWATER MONITORING WELL
- PIEZOMETER
- EXTRACTION WELL (INACTIVE)
- EVO INJECTION WELL
- EVO TREATMENT ZONE
- APPROXIMATE GROUNDWATER FLOW DIRECTION
- FENCE
- ROAD
- PAVED AREA
- BUILDING
- ERP SITE BOUNDARY

TCE CONCENTRATIONS (µg/L)

- 5 ≤ TCE <100
- 100 ≤ TCE <1,000
- 1,000 ≤ TCE <10,000
- TCE ≥ 10,000
- SURFACE WATER

REFERENCE: 2009-2010 GSAP REPORT

N

0 15 30 FEET

KEY MAP

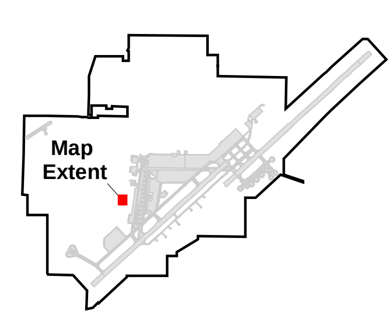


FIGURE 7-8
CONCEPTUAL DESIGN ALTERNATIVE 5 – EVO / EA SITE SD036
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

ES011811013517RDD_7-8

CH2MHILL

REFERENCE: 2009-2010 GSAP REPORT

FIGURE 7-9
CONCEPTUAL DESIGN
ALTERNATIVE 5 – EVO AND EA AT SITE SD037
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

ES011811013517RDD_7-9

CH2MHILL

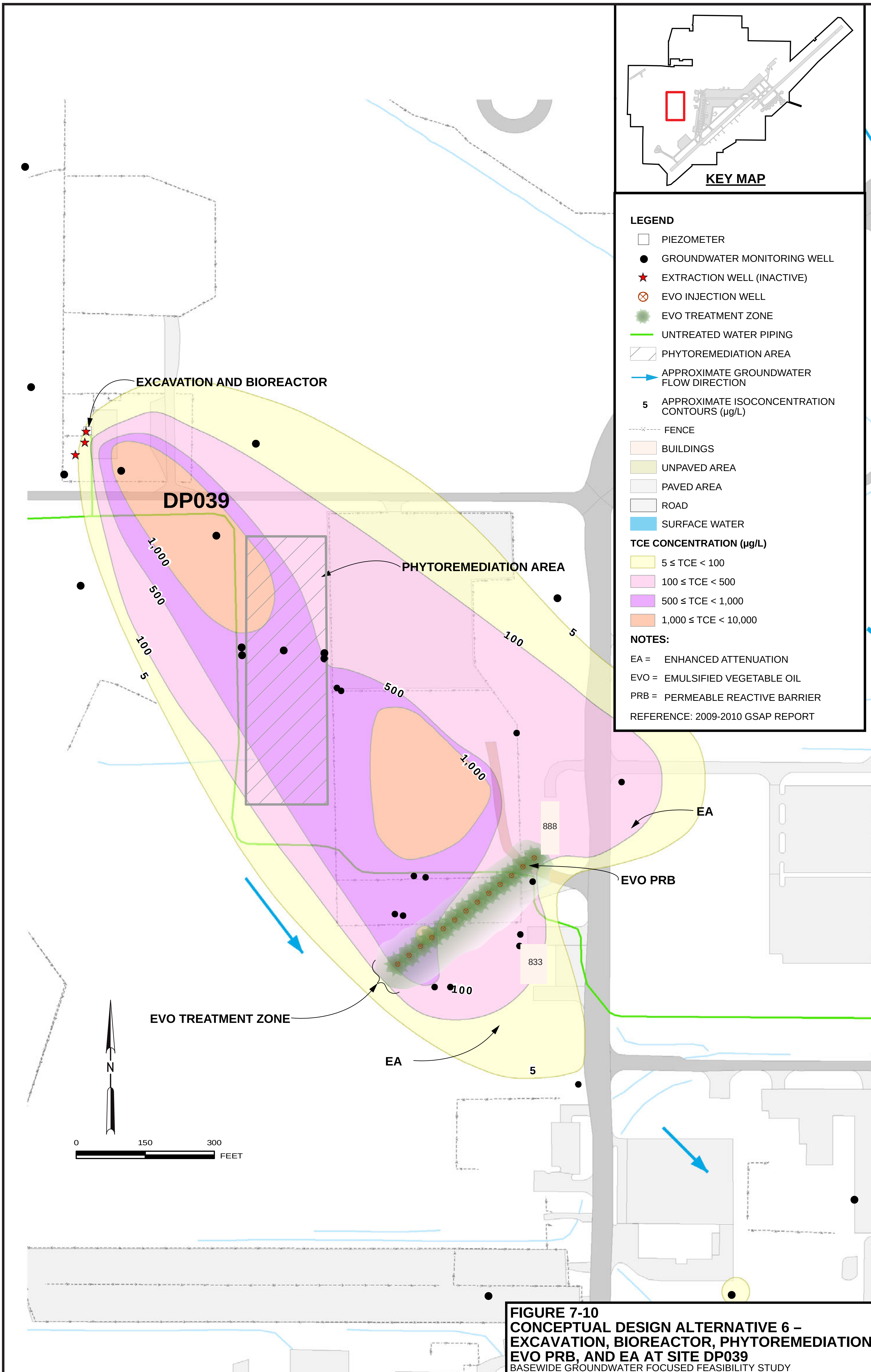


FIGURE 7-10
CONCEPTUAL DESIGN ALTERNATIVE 6 – EXCAVATION, BIOREACTOR, PHYTOREMEDIATION, EVO PRB, AND EA AT SITE DP039
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

ES011811013517RDD_7-10

SECTION 8

Detailed Analysis of Alternatives

This section of the FFS provides more detailed analyses of the groundwater remedial alternatives developed for the ERP sites in Section 7. A summary of the assembled alternatives and applicable sites is provided in Table 8-1.

TABLE 8-1
Summary of Assembled Remedial Alternatives and Applicable Sites
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Alternative[a,b]	Applicable Site
Alternative 1 – No Action	Site SS041
Alternative 2 – MNA	Sites FT004, FT005, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, SD043
Alternative 3 – GET[c]	Sites LF007C, SS029, SS030
Alternative 4 – Bioreactor and GET[c]	Site SS016
Alternative 5 – EVO and EA	Sites SS015[d], SD036[d], SD037[d]
Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA	Site DP039
Alternative 7 – Passive Skimming and EA	Site SD034

[a] Remedial alternatives assembled from representative process options.
[b] Groundwater monitoring and LUCs are components of all the alternatives except No Action.
[c] Includes extraction, conveyance, treatment, and discharge of groundwater.
[d] EVO injection within the source area portions of the plumes. EA implemented in the distal portions (i.e., non-source areas) of the plumes.

The CERCLA evaluation criteria at this stage of the FFS include the following:

- 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

The additional CERCLA criteria of State Acceptance and Community Acceptance are evaluated in the Proposed Plan and ROD stages.

Descriptions of the evaluation criteria are provided in Section 4.

Evaluations of the groundwater remedial alternatives against the seven (7) criteria are provided in the following subsections.

8.1 Alternative 1 – No Action

The No Action alternative serves as a baseline against which other potential remedial alternatives are compared. This action is required for consideration by the NCP. It is evaluated to determine the risks to public health and the environment if no additional actions were taken. No additional attempt is made to satisfy the RAOs, and no remedial measures are implemented.

Alternative 1 is applicable to Site SS041. This site is in NFRAP status. The NFRAP status is documented in a 14 December 2005 consensus statement that was signed by the representatives of the lead and regulatory agencies (Travis AFB, 2005).

8.1.1 Components of the Alternative

By definition, the No Action alternative has no components. For example, no groundwater monitoring is conducted, no LUCs are enforced, and no evaluations are performed.

8.1.2 Detailed Evaluation

The No Action alternative is potentially applicable to each of the Travis AFB ERP sites with groundwater contamination. The following subsections provide a detailed evaluation of this alternative.

8.1.2.1 Overall Protection of Human Health and the Environment

The No Action alternative provides no control of exposure to contaminated groundwater and no short-term reduction in risk to human health or improvement to groundwater quality. Migration of contaminants may eventually affect other groundwater resources. Over a long period, the risk may gradually decrease because of a combination of biological and chemical degradation of the contamination and physical dilution by dispersion and diffusion. However, any decreases in risks would be unknown because no monitoring or evaluations of risk would be conducted.

Travis AFB does not currently use groundwater for domestic or industrial purposes and has no plans to do so in the future. Therefore, the No Action alternative would not result in immediate threats to human health.

8.1.2.2 Compliance with ARARs

Chemical-specific ARARs related to PCGs may eventually be met. Although residual contamination is expected to gradually decrease over time, it will be unknown whether cleanup to PCGs is achieved because no groundwater sampling or evaluations will be performed. Thus, compliance will not be verified. Because the plumes could potentially migrate and degrade the aquifer, ARARs related to drinking water source protection may not be met. Location-specific and action-specific ARARs do not apply to the No Action alternative.

8.1.2.3 Long-term Effectiveness and Permanence

Untreated residual contamination in groundwater will pose a risk if the drinking water pathway becomes complete. No LUCs will be enforced to control exposure to groundwater contamination. Residual risk resulting from groundwater contamination is expected to gradually decrease over time through natural chemical, physical, and biological processes. However, this reduction will not be quantifiable or documented because no groundwater sampling or evaluations will be performed.

8.1.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 1 – No Action does not satisfy the reduction of toxicity, mobility, or volume of contaminants through treatment criterion. No treatment technologies are employed. Therefore, the alternative provides no measured reductions in toxicity, mobility, or volume of contaminants through treatment. Permanent or significant reductions in toxicity, mobility, or volume will occur gradually by natural processes. However, the reduction will not be quantifiable or documented because no groundwater sampling or evaluations will be performed. However, such reduction would be inherently irreversible. Because no treatment technologies will be employed, no treatment residuals will be generated.

8.1.2.5 Short-term Effectiveness

Because no remedial action will be taken under the No Action alternative, no short-term risks to the community or to workers will need to be addressed. Similarly, no environmental impact from construction activities will occur. Residual contamination is expected to decrease over time by natural processes. However, the actual reduction over time will not be measured or documented.

8.1.2.6 Implementability

No technology factors are evaluated (e.g., ability to construct or operate the technology, availability and reliability of the technology or specialists) under the No Action alternative. Similarly, no ability to monitor exposure pathways or evaluate risks in the future will exist, nor will a mechanism or need to coordinate with other agencies exist. Future remedial actions could be undertaken if desired.

8.1.2.7 Cost

The No Action alternative entails no capital or O&M costs.

8.2 Alternative 2 – Monitored Natural Attenuation

Alternative 2 – MNA is potentially applicable to all Travis AFB ERP sites, either for the contaminant conditions that currently exist or for future contaminant conditions following a period of active remediation using another alternative.

Under Alternative 2, contamination in the groundwater is reduced by natural processes. Groundwater monitoring is conducted to evaluate the effectiveness of these processes at achieving PCGs. This evaluation includes observing the distribution of contamination and evaluating the rate of contaminant reduction. Travis AFB will continue to enforce existing LUCs to minimize human exposure to contaminated groundwater while natural attenuation is taking place. Alternative 2 is applicable to the current physical and contaminant conditions at the following sites:

- **Site FT004 –** MNA assessment provided in NAAR; portion of plume assessed for MNA is stable
- **Site FT005 –** IRA GET system has effectively reduced plume size and concentrations
- **Site LF006 –** MNA assessment provided in NAAR; plume concentrations decreasing
- **Site LF007B –** MNA assessment provided in NAAR; plume concentrations decreasing
- **Site LF007D –** MNA assessment provided in NAAR; plume concentrations decreasing
- **Site LF008 –** source removal action completed; organochlorine pesticides plume is stable
- **Site ST027B –** former POCO site; low VOC concentrations; geographically isolated plume
- **Site SD031 –** IRA GET system has effectively reduced plume size and concentrations
- **Site SD033 –** MNA assessment provided in NAAR; plume concentrations decreasing
- **Site SD043 –** IRA GET system has effectively reduced plume size and concentrations

Detailed descriptions of the lines of evidence for the viability of natural attenuation processes to remediate groundwater at Travis AFB are provided in Appendix C.

The methodologies used to estimate the time required to achieve PCGs under Alternative 2 are provided in Appendix D.

8.2.1 Components of the Alternative

Under Alternative 2, groundwater contamination will be remediated by monitored natural physical, chemical, and biological processes at Sites FT004, FT005, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, and SD043.

Operation of the existing GET IRA systems at Sites FT004, FT005, LF008, SD031, SD033, and SD043 will be discontinued following implementation of Alternative 2. At the sites without GET IRA systems, including Sites LF006, LF007B, LF007D, and ST027B, groundwater monitoring to assess natural attenuation processes will be continued.

Travis AFB will continue to enforce existing LUCs to prevent unauthorized exposure to contaminated groundwater. Base Civil Engineer Work Requests, excavation permits, and the requirements of the Base General Plan will continue to be enforced. The existing off-base easement at Site FT005 will continue to be maintained.

The provisions of the Base General Plan related to vapor intrusion mitigation will continue to be enforced. Installation of a vapor barrier and passive venting system may be required for future new building construction in proximity to a groundwater contaminant plume.

Performance monitoring will continue to be conducted under the GSAP at each of the sites.

8.2.2 Detailed Evaluation

The following subsections provide a detailed evaluation of Alternative 2 against the evaluation criteria.

8.2.2.1 Overall Protection of Human Health and the Environment

Alternative 2 will provide effective protection of human health and the environment. Natural attenuation processes at Travis AFB have a demonstrated capacity to degrade chlorinated VOCs to non-chlorinated, environmentally acceptable end-products (CH2M HILL, 2010a). Chlorinated VOC concentrations have been shown to be reduced or eliminated in groundwater using MNA. Reductions in contaminant toxicity and mobility will be protective of human health and the environment.

At Site LF008, MNA of organochlorine pesticide under Alternative 2 will also provide overall protection of human health and the environment. Over approximately 7.5 years of operation, the interim GET system had minimal impact on pesticide concentrations. The pesticide concentrations were stable, and the extent of groundwater contamination remained unchanged. This is probably due to the strong adsorption of organochlorine pesticides to natural organic carbon and fine-grained soil particles and the low permeability of the saturated alluvium. In December 2008, the GET system was shut down for a rebound study. No significant rebound of organochlorine pesticides has been observed during the rebound study, and trend analyses show that concentrations are slowly decreasing even with the absence of active pumping.

LUCs enforced by Travis AFB during the period of MNA will provide administrative restrictions on groundwater use and thus provide protection of human health by controlling exposure to contaminants.

Groundwater monitoring will be used to detect and evaluate potential migration of contaminants to determine whether additional groundwater resources are impacted, and thus whether additional controls are necessary. Residual risk from groundwater contamination will decrease over time through chemical, physical, and/or biological processes.

8.2.2.2 Compliance with ARARs

Under Alternative 2, chemical-specific ARARs will be met.

The placement of existing groundwater monitoring wells already meets location-specific ARARs because they are not located in environmentally sensitive areas.

Action-specific ARARs that are relevant and appropriate to groundwater monitoring programs are also already being met and will continue to be met in the future.

8.2.2.3 Long-term Effectiveness and Permanence

Natural attenuation processes are effective, reliable, and permanent. The site conditions at Travis AFB have demonstrated the capacity to support chlorinated VOC degradation through a combination of physical and, to lesser degrees, chemical and biological mechanisms (CH2M HILL, 2010a). Additional discussion of the viability of natural attenuation processes to remediate groundwater at Travis AFB is provided in Appendix C.

Alternative 2 will be effective over the long term as chlorinated VOCs degrade to non-regulated compounds such as ethene and ethane. These processes are irreversible.

Residual contamination in groundwater will not pose a risk to human health as long as the existing LUCs continue to be enforced to minimize human exposure. Residual risk from groundwater contamination is expected to decrease through chemical, physical, and biological processes. The effectiveness of the natural attenuation processes will continue to be evaluated through the existing GSAP.

At Site LF008, natural attenuation processes will also provide long-term effectiveness and permanence during remediation of organochlorine pesticides. Residual contamination in groundwater will not pose a risk to human health as long as the existing LUCs continue to be enforced to minimize human exposure. Residual risk from groundwater contamination is expected to slowly decrease through natural processes.

8.2.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 2 will provide no measured reductions in toxicity, mobility, or volume of contaminants through treatment. No treatment technologies are employed. Permanent or significant reductions in toxicity, mobility, or volume will occur gradually by natural processes. These reductions will be quantified by groundwater sampling and analyses under the existing Travis AFB GSAP. The reductions will be inherently irreversible. Because no treatment technologies will be employed, no treatment residuals will be generated.
A summary of the performance of Alternative 2 against the criterion of reduction in toxicity, mobility, or volume of contaminants through treatment is provided in Table 8-2.

Alternative 2 will address the principal threats posed by groundwater contaminants at Sites FT004, FT005, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, and SD043 using natural attenuation processes. The plume areas that will be addressed by Alternative 2 are provided in Section 3 – Conceptual Site Models as follows:

- **Site FT004 –** Entirety of plume shown on Figure 3.2-4
- **Site FT005 –** Entirety of plume shown on Figure 3.5-3
- **Site LF006 –** Entirety of plume shown on Figure 3.2-6
- **Site LF007B –** No plume above PCGs. Natural attenuation processes have already reduced contaminant concentrations to less than the PCGs.
- **Site LF007D –** Entirety of plume in vicinity of monitoring well MW261x07
- **Site LF008** – Entirety of plume shown on Figure 3.4-33
- **Site ST027B –** Entirety of plume shown on Figure 3.6-3
- **Site SD031 –** Entirety of plume shown on Figure 3.2-5
- **Site SD033 –** Component of WIOU plume shown on Figure 3.4-7
- **Site SD043 –** Component of WIOU plume shown on Figure 3.4-7

Natural attenuation relies on intrinsic chemical, physical, and biological processes to reduce contaminants in groundwater over time. This alternative does not employ active treatment technologies. Rather, reductions in toxicity, mobility, and volume depend primarily on the rate of contaminant concentration reduction through naturally occurring processes. The degree of degradation will be monitored through the ongoing GSAP. Also, a study will be conducted from September through October 2011 to evaluate the contribution provided by aerobic biological processes.

During the period of interim remediation, natural attenuation processes demonstrated their capacity to reduce the toxicity, mass, and volume of contamination. The results of site-specific MNA assessments are documented in the NAAR (CH2M HILL, 2010a). Additional discussion of MNA is provided in Appendix C.

TABLE 8-2
Reduction of Toxicity, Mobility, or Volume through Treatment Under Alternative 2 – MNA
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Analysis Factor	Considerations
Treatment process and remedy	Alternative 2 – MNA relies on intrinsic treatment of chlorinated VOC contaminants via natural physical, chemical, and biological processes to address the principal threats from groundwater contamination. The effectiveness of these processes was demonstrated during a decade of interim MNA assessments. The results of those assessments are documented in the NAAR (CH2M HILL, 2010a) and summarized in Appendix C. Although Alternative 2 does not employ an active treatment process, toxic contaminants are destroyed and the total mass of contaminants is irreversibly reduced by natural degradation processes and the principal threats are reduced. Alternative 2 is applicable to the conditions at Sites FT004, FT005, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, and SD043. At these sites, the processes of natural attenuation are the most appropriate remedy because the plumes have relatively low contaminant concentrations and large areal extent. Alternative 2 – MNA is not generally applicable as a remedy for plumes with higher concentration source areas.
Amount of hazardous material destroyed or treated	Over approximately a decade of MNA assessments at Travis AFB, natural attenuation processes demonstrated the capacity to destroy chlorinated VOC contaminants down to concentrations less than PCGs. During the period of assessment, the chlorinated solvent plumes typically decreased in both size and concentration or the plumes were stable and not migrating. At Site LF007D, concentrations of 1,4-dichlorobenzene also decreased over time and benzene concentrations remained stable.
Reduction in toxicity, mobility, or volume	The physical, chemical, and biological processes of natural attenuation will eventually degrade chlorinated VOCs, such as TCE, to non-toxic compounds such as ethene and ethane. Over time, the total mass and volume of groundwater contamination will be fully reduced to concentrations less than the PCGs by these processes.
Irreversibility of treatment	The natural processes utilized under Alternative 2 – MNA are inherently irreversible.
Type and quantity of treatment residual	Under Alternative 2, no active treatment processes are employed. Therefore, no treatment residuals are generated.
Statutory preference for treatment as a principal element	Active treatment is not used under Alternative 2 – MNA. Therefore, the statutory preference for treatment as a principal element of the remedy is not satisfied. However, intrinsic treatment of contaminants through natural processes will address the principal threats from the contaminants.

8.2.2.5 Short-term Effectiveness

Natural attenuation is an effective means to reduce toxicity, mobility, volume, and mass over the long term. However, MNA will likely require a longer time to achieve RAOs than a more aggressive, more costly, less efficient, and less sustainable treatment alternative. At these sites, GET systems appear to have reached their limit of cost effective mass removal. Estimates of the time to achieve PCGs under Alternative 2 are summarized in Table 8-3.

Construction activities associated with the implementation of a MNA program are typically limited to installation of monitoring wells. This activity poses minimal risk to workers, the community, and the environment.

TABLE 8-3
Estimated Time to Achieve Preliminary Cleanup Goals for Alternative 2 – MNA[a]
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Estimated Cleanup Time[b] (years)	Comment
FT004	35	
FT005	43	Low PCG for 1,2-DCA
LF006	5	
LF007B	0	Contaminant concentrations already less than PCGs
LF007D	> 100	Stable (i.e., not decreasing) benzene concentrations over 10 years of MNA assessment
LF008	> 100	Stable concentrations of recalcitrant organochlorine pesticides
ST027B	50	
SD031	15	
SD033	60	Component site within WIOU plume
SD043	60	Component site within WIOU plume

[a] PCGs are described in Section 5.
[b] Remediation timeframe estimate is provided in Appendix D.

8.2.2.6 Implementability

Alternative 2 is readily implementable at Travis AFB. During the period of interim remediation, MNA assessments were successfully conducted at multiple sites (CH2M HILL, 2010a). No difficulties are anticipated in implementing MNA as a final groundwater remedy.

Remedial construction activities associated with the implementation of Alternative 2 are limited to the installation of monitoring wells. This action is easily implemented, with both equipment and technical specialists being readily available. No schedule delays or technical problems are anticipated with implementation of MNA, although Base activities and high security areas have to be considered when planning the placement of additional monitoring wells. Potential future remedial actions would not likely be adversely affected by MNA processes.

Groundwater monitoring is used to evaluate the effectiveness of natural attenuation. Engineering assessment and laboratory services are standard practices that are readily available.

Alternative 2 is also administratively implementable. Coordination with state and other federal agencies will only require their review of the GSAP monitoring plans and MNA evaluations. Also, Travis AFB is already enforcing LUCs to restrict activities that could result in human exposure to contaminated groundwater.

8.2.3 Cost

The annual and present value costs of implementing a program of MNA at the applicable sites are summarized in Table 8-4. More detailed descriptions of the basis of the cost estimate are provided in Appendix E.

The existing monitoring well networks at the sites are sufficient for implementing Alternative 2. No additional capital costs for new monitoring wells are required.

TABLE 8-4
Estimated Costs for Alternative 2 – MNA[a]
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Annual O&M Cost	Present Value[b]
FT004	$2,703	$59,641
FT005	$4,024	$101,633
LF006	$2,451	$11,909
LF007B	$817	N/A[c]
LF007D	$1,069	$21,806
LF008	$2,264	$46,182
ST027B	$2,451	$49,996
SD031	$2,451	$30,480
SD033	$2,063	$42,082
SD043	$1,288	$26,273

[a] More detailed cost estimates are provided in Appendix E.
[b] Remediation timeframe estimates are provided in Appendix D.
[c] PCGs are already achieved; therefore, the period of O&M is zero years and the Present Value calculation is not applicable.

8.2.3.1 Performance Enhancement Measures

This subsection briefly describes potential future remedy enhancements related to Alternative 2 – MNA.

GET System IRA Sites. At Sites FT004, FT005, LF008, SD031, SD033, and SD043, implementation of Alternative 2 – MNA follows approximately a decade of interim remediation using GET. The GET IRA systems at these sites were shut down for rebound studies during 2010. These contaminant plumes will continue to be monitored for the remainder of the period of interim remediation. Unless there is evidence of contaminant rebound, the GET systems will remain off. The IRA GET systems at these sites still exist. If rebound does occur or if plume migration is confirmed over a 2-year period, then the Air Force will evaluate resuming GET operations under Alternative 3.

At Site LF008, low concentrations of alpha-chlordane (0.34 J µg/L vs. PCG of 0.1 µg/L) were detected in the 2010 GSAP. Residual concentrations of alpha-chlordane in groundwater did not decrease but remained stable for over 7.5 years of GET operation, and the plume is not migrating. The GET system is currently turned off, and a rebound study is under evaluation. So far, the alpha-chlordane concentrations have not rebounded. Therefore, continued use of an active treatment technology is not warranted under these conditions and has a high cost relative to the current rebound study to assess MNA following long-term operation of the GET system. In addition, Site LF008 is located within an ammunition storage facility, which precludes for safety reasons the use of other more active remedies. The technology that best satisfies the evaluation criteria at Site LF008 is MNA.

MNA and MNA Assessment IRA Sites. For Sites LF006, LF007B, and LF007D, MNA or MNA assessment was the IRA specified in the NEWIOU IROD. After approximately a decade of interim remediation, the NAAR concluded that natural attenuation of the plumes was effective (refer to Appendix C). A status summary for each of these sites is provided in the following list:

- **Site LF006 –** Natural attenuation processes have already reduced contaminant concentrations to less than the PCGs. No other action is likely to be required at this site. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of achieving the final cleanup concentrations.
- **Site LF007B –** Natural attenuation processes have already reduced contaminant concentrations to less than the PCGs. No other action is likely to be required at this site. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of achieving the final cleanup concentrations.
- **Site LF007D –** Low concentrations of benzene (3 µg/L vs. PCG of 1 µg/L) and 1,4-dichlorobenzene (12.6 µg/L vs. PCG of 5 µg/L) were detected in the 2010 GSAP. Concentrations of 1,4-dichlorobenzene have been decreasing over time. Concentrations of benzene have remained stable. The plume size is small and limited to the vicinity of monitoring well MW261x07 (refer to Figure 3.2-12). The plume lies beneath a closed and capped landfill and is downgradient of an active Site LF007C GET system. Use of an active treatment technology is not warranted under these conditions, has a high cost relative to the current IRA of MNA assessment, and could potentially interfere with the performance of the Site LF007C cleanup. The technology that best satisfies the evaluation criteria at Site LF007D is MNA.

Former POCO Site. Site ST027B was formerly managed under the POCO program. A portion of the site with CERCLA contamination is designated as Site ST027B. The site is located within the flightline and is bounded by aircraft parking ramps and taxiways. The maximum concentration of TCE during the 2010 GSAP was 390 µg/L (refer to Figure 3.6-3). Use of an active treatment technology is unlikely to be needed under these conditions and would have implementability problems because of the proximity to airfield operations. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of achieving the final cleanup concentrations that will be established in the Basewide Groundwater ROD.

Future Remedy Transition. Alternative 2 – MNA would likely not be effective at addressing the *current* contaminant conditions at Sites LF007C, SS016, SS029, and SS030. The conditions at these sites are currently more applicable to Alternative 3 – GET. However, MNA is potentially applicable to *future* contaminant conditions after the current contaminant concentrations have been reduced by several years of groundwater extraction and treatment. At that time, continued progress toward RAOs may be achieved by transitioning from the active remedy to an effective but lower cost program of MNA. In the future, sites with an EA remedy component under Alternatives 5, 6, and 7 can readily be transitioned to a full-plume program of MNA under Alternative 2. At Sites SS015, SD034, SD036, SD037, and DP039, natural attenuation monitoring programs will already be implemented in the distal portions of the plumes. These monitoring programs can be expanded to address the entirety of the plume following successful remediation of the source areas.

8.3 Alternative 3 – GET

Alternative 3 entails active groundwater remediation using the GET systems previously installed as part of the IRA at each site. Alternative 3 is applicable to the physical and contaminant conditions at the following sites:

- **Site LF007C –** off-base TCE plume
- **Site SS029 –** TCE plume near the Base boundary
- **Site SS030 –** off-base TCE plume

The groundwater contaminant plumes where Alternative 3 will be implemented are shown on Figures 7-1 and 7-2.

The methodologies used to estimate the time required to achieve PCGs under Alternative 3 are provided in Appendix D.

8.3.1 Components of the Alternative

Under Alternative 3, extraction, treatment, and discharge of groundwater will be continued at Sites LF007C, SS029, and SS030 using the existing GET systems described in Sections 3.2 and 3.5.

Contaminated groundwater at each site will be extracted using existing vertical extraction wells and treated using LGAC at the existing NGWTP (Site LF007C) and SBBGWTP (Sites SS029 and SS030). The treated water from Sites SS029 and SS030 will be discharged to the main branch of Union Creek. Treated groundwater from Site LF007C will continue to be conveyed to the Duck Pond as a beneficial reuse.

Travis AFB will continue to enforce existing LUCs to prevent unauthorized exposure to contaminated groundwater. Base Civil Engineer Work Requests, excavation permits, the requirements of the Base General Plan, and maintenance of the existing easements at Sites LF007C and SS030 will continue to be enforced.

The provisions of the Base General Plan related to vapor intrusion mitigation will continue to be enforced. Installation of a vapor barrier and passive venting system may be required for future new building construction in proximity to a groundwater contaminant plume.

Performance monitoring will continue to be conducted under the GSAP.

8.3.2 Detailed Evaluation

The following subsections provide a detailed evaluation of Alternative 3 against the evaluation criteria.

8.3.2.1 Overall Protection of Human Health and the Environment

Alternative 3 will be protective of human health and the environment. GET has been proven an effective combination for remediation of chlorinated VOCs at Travis AFB. Migration of the Site LF007C, SS029, and SS030 contaminant plumes will be hydraulically controlled, and contaminant volume and mass will be reduced. Groundwater contamination will eventually be reduced to PCGs through extraction and treatment.

Risks to environmental receptors will also be low under Alternative 3 because the depth to groundwater is greater than 4 feet at each of the applicable sites. Also, discharges of treated groundwater from the NGWTP and SBBGWTP to the stormwater drainage system will meet or exceed regulatory standards.

Ongoing groundwater monitoring at Sites LF007C, SS029, and SS030 will be continued under the Travis AFB GSAP to evaluate the effectiveness of the GET systems. Existing Travis AFB LUCs will be enforced to minimize human exposure to contamination while GET is taking place.

8.3.2.2 Compliance with ARARs

Compliance with ARARs will be achieved under Alternative 3. Chemical-specific ARARs (i.e., PCGs) will be achieved within the plumes of contaminated groundwater undergoing GET at Sites LF007C and SS030. However, meeting chemical-specific ARARs at Site SS029 will require a longer period of time.

Treatment of contaminated groundwater will comply with action-specific and location-specific ARARs and satisfy chemical-specific ARARs for the discharge of treated water to the stormwater drainage system.

Compliance with ARARs at Sites LF007C and SS030. Continued operation of the Site LF007C and SS030 GET systems will likely require several more years of operation to achieve PCGs. Because PCGs will be achieved within a reasonable time at Site LF007C and SS030, this alternative is ARAR compliant. The site-specific GET systems will provide risk mitigation through contaminant mass removal and hydraulic containment of contaminants to control plume migration.

Compliance with ARARs at Site SS029. The GET system at Site SS029 is not expected to achieve chemical-specific ARARs for an extended amount of time. LTO of the system during the period of interim remediation has demonstrated that it can remove contaminant mass, hydraulically contain groundwater contamination, and prevent migration of the plume into off-base locations. However, meeting PCGs will be difficult to achieve. Increasing contaminant concentrations in the northern portion of the plume indicate that chlorinated VOCs from the hydraulically upgradient Site SS016 plume are migrating into the Site SS029 plume and providing a continuing source of contamination. Complying with chemical-specific ARARs at Site SS029 will therefore be largely dependent on the effectiveness of remedial action at Site SS016.

Within Site SS016, relatively high contaminant concentrations (including probable DNAPL), fine-grained lithology, a large plume area, and the presence of active military aircraft parking ramps, taxiways, and runways profoundly limit potential source area remedial actions that might reduce the time required to achieve PCGs. The remedial alternative for Site SS016 is described in Section 8.4.

8.3.2.3 Long-term Effectiveness and Permanence

Alternative 3 will provide effective, long-term treatment of the groundwater contamination at Sites LF007C, SS029, and SS030. GET is a well established combination of technologies for removing and treating chlorinated VOCs in groundwater, particularly sites with higher levels of contamination. These technologies have been successfully employed at multiple Travis AFB sites during the period of interim remediation to provide permanent reductions in contaminant mass.

Each of the technical components of this alternative are well established, so that the likelihood is high that RAOs will be met. Given sufficient time, pumping and treating will eventually achieve PCGs. The magnitude of the remaining risk would be low. Reviews will be conducted at 5-year intervals, so treatment system modifications can be made, if necessary, to address changing conditions. If performance monitoring data indicate that contamination is migrating past the extraction system, there would be time to modify the extraction system without presenting unacceptable risk of exposure. The magnitude of the risk of exposure would continue to be low because of the low velocity of contaminant migration.

Residual contamination will remain at each of the sites for a substantial period of time under Alternative 3. Travis AFB will continue to enforce institutional controls to prevent exposure to the groundwater within the plume. Long-term monitoring, together with five-year reviews, will also be conducted to ensure that the plume is being hydraulically captured and treated. Groundwater monitoring will be conducted for the life of the alternative.

At Site SS029, the long-term effectiveness and permanence of GET will depend on remedial action at Site SS016 reducing the mass flux of chlorinated VOCs into Site SS029. In the absence of a continuing source of contaminants, the Site SS029 GET system is otherwise capable of providing long-term and effective treatment.

8.3.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 3 – GET addresses the principal threats posed by groundwater contamination by use of extraction wells to physically remove contaminated groundwater from the aquifer. Reductions in toxicity, mobility, or volume of contaminants through treatment will be achieved by ex situ treatment of the extracted groundwater using activated carbon (LGAC) and the subsequent ex situ treatment of the spent carbon at an off-base facility. A summary of the performance of Alternative 3 against the criterion of reduction in toxicity, mobility, or volume of contaminants through treatment is provided in Table 8-5.

Implementation of Alternative 3 will reduce the toxicity, mobility, and volume of chlorinated VOCs at Sites LF007C, SS029, and SS030. Aboveground treatment using LGAC will reduce the toxicity of extracted groundwater. Contaminant mobility will be limited through hydraulic containment of the plumes. The volume and mass of contamination will be reduced over time as chlorinated VOCs are physically removed from the aquifer and transferred to activated carbon. Spent LGAC will be treated at an off-base vendor facility to destroy the sorbed contamination and regenerate the carbon for reuse.

During the period of interim remediation, GET systems demonstrated their capacity to reduce the mobility and volume of contamination. Plume contaminant concentrations and the extent of contamination was reduced. Continued operation of the Site LF007C and SS030 GET systems will likely require several more years of operation to achieve reductions of contaminant concentrations down to PCGs. However, the entire mass and volume of contaminants will eventually be treated, and the treatment will be irreversible.

A continuing source of contamination from hydraulically upgradient Site SS016 will likely limit the reduction in the volume of groundwater contaminants at Site SS029. The Site SS029 GET system will successfully intercept and remove contaminant mass originating from Site SS016. However, this migration will likely continue to supply contaminant mass to the Site SS029 plume for an extended time.

Ex situ LGAC treatment will not destroy the contaminants, but they will be concentrated on the carbon media. The carbon will periodically require regeneration at an off-base vendor facility where sorbed contaminants will be destroyed. Treatment residuals will not pose a risk to the public. This component of Alternative 3 satisfies the statutory preference for treatment as a principal element of the remedy.

TABLE 8-5
Reduction of Toxicity, Mobility, or Volume through Treatment Under Alternative 3 – GET
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Analysis Factor	Considerations
Treatment process and remedy	Alternative 3 – GET relies on physical removal of contaminated groundwater from the subsurface, adsorption of contaminants onto activated carbon, and off-base regeneration of the loaded carbon to address the principal threats from groundwater contamination. Adsorbed toxic contaminants are destroyed during regeneration of the carbon at an off-base vendor facility. The effectiveness of these processes was demonstrated during a decade of interim GET system operation. Under Alternative 3, the total mass of contaminants is irreversibly reduced by the combination of these processes and the principal threats are reduced. Alternative 3 is applicable to the conditions at Sites LF007C, SS029, and SS030. At these sites, groundwater plumes with low to moderate contaminant concentrations and/or large areal extent are present. The GET component of Alternative 3 is not generally applicable as a remedy within the source areas of plumes with high contaminant concentrations and residual DNAPL likely present. During the period of interim GET, source area groundwater extraction became increasingly ineffective and inefficient over time. Source area GET operation in the diffusion-dominated, low-permeability lithology found at Travis AFB reached asymptotic contaminant concentrations above PCGs.

TABLE 8-5
Reduction of Toxicity, Mobility, or Volume through Treatment Under Alternative 3 – GET
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Analysis Factor	Considerations
Amount of hazardous material destroyed or treated	A decade of GET system operation at Travis AFB has demonstrated the capacity of the remedy to hydraulically contain, remove, and ultimately destroy chlorinated VOC contaminants down to concentrations less than PCGs. The amount of chlorinated VOCs removed from the groundwater is documented in monthly O&M reports for the CGWTP, NGWTP, and SBBGWTP.
Reduction in toxicity, mobility, or volume	During the interim period, the chlorinated solvent plumes typically decreased in both size and concentration. This type of performance is expected to continue under Alternative 3. During 2010, progress towards meeting PCGs for chlorinated VOCs was sufficient to warrant shutting down the on-base GET systems and entering into a rebound studies. Off-base GET systems will remain in full or partial operation under Alternative 3 until PCGs are achieved or unless rebound studies indicate that continued GET system operation is unnecessary to achieve PCGs. Long-term operation of the interim GET systems effectively reduced the mobility and volume of groundwater contamination by hydraulically capturing the plumes and physically removing contaminants from the subsurface. The mass of chlorinated VOCs removed from the groundwater is documented in monthly O&M reports for the CGWTP, NGWTP, and SBBGWTP. This level of performance is expected to continue under Alternative 3.
Irreversibility of treatment	Contaminant concentrations under Alternative 3 could potentially increase (i.e., rebound) in the diffusion-dominated lithology found at Travis AFB if GET system operation is not maintained. Off-base vendor treatment of contaminants adsorbed to activated carbon is irreversible.
Type and quantity of treatment residual	No treatment residuals are generated under Alternative 3 – GET, except the contaminants adsorbed onto activated carbon at the treatment plants. Subsequent off-base vendor treatment of the loaded carbon provides for complete destruction of contaminants and no treatment residuals.
Statutory preference for treatment as a principal element	The component of Alternative 3 that provides for off-base carbon treatment satisfies the statutory preference for treatment as a principal element of the remedy. Contaminants that are removed from the aquifer by GET system operation are permanently and irreversibly destroyed by the regeneration of the carbon.

8.3.2.5 Short-term Effectiveness

Alternative 3 will provide short-term effectiveness. GET systems already exist for each of the sites. The IRA GET systems at Sites LF007C and SS030 will be optimized during 2011. These optimizations will be incorporated into system components under Alternative 3. The Site SS029 GET system is operating as intended and will not require optimization measures Estimates of the time to achieve PCGs under Alternative 3 are summarized in Table 8-6.

GET will be effective in the short term by hydraulically containing contaminants and preventing the spread of contamination. It will be less effective in the short term at achieving RAOs because time will be required to remove contaminant mass down to PCGs.

Existing LUCs will continue to be enforced by the Air Force to provide short-term and long-term protection from exposure to groundwater contamination. The community and the environment will be protected during the remediation by Air Force control of the groundwater resource and by treatment of the water to meet or exceed regulatory standards prior to discharge to surface water. Risks to workers will be minimized by these same measures and by following standard safety practices during O&M.

Implementation of Alternative 3 at Site LF007C includes a provision for sustainable remediation by using solar-powered groundwater extraction pumps. More detailed information is provided in Appendix F.

TABLE 8-6
Estimated Time to Achieve Preliminary Cleanup Goals for Alternative 3 – GET[a]
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Estimated Cleanup Time[b] (years)	Comment
LF007C	26	
SS029	62	Dependent on the effectiveness of remedial action at Site SS016
SS030	22	

[a] PCGs are described in Section 5.
[b] Remediation timeframe estimates are provided in Appendix D.

8.3.2.6 Implementability

Alternative 3 is readily implementable. GET systems already exist at Sites LF007C, SS029, and SS030. The IRA GET systems at Sites LF007C and SS030 will be optimized during 2011 and the optimization actions will be easily incorporated into the final remedial action at each site. The Air Force is already enforcing LUCs.

The ex situ treatment process of LGAC associated with Alternative 3 is proven and reliable, and replacement system components are readily available. No difficulties associated with additional future construction or operations are anticipated. If additional measures are necessary in the future, those actions could be easily undertaken. For example, additional or different treatment technologies could be added to the existing treatment trains with little difficulty.

Routine monitoring of treatment plant processes will continue under well established O&M procedures. Similarly, regular groundwater monitoring will continue to be conducted under the GSAP to verify plume capture and evaluate changes in chemical composition over time.

The regulatory agencies are already providing oversight of the ongoing groundwater IRAs at Sites LF007C, SS029, and SS030 and will continue to do so during implementation of Alternative 3 as the final remedial action at the sites.

8.3.2.7 Cost

The annual and present value costs of implementing Alternative 3 at Sites LF007C, SS029, and SS030 are summarized in Table 8-7. More detailed descriptions of the basis of the cost estimate are provided in Appendix E.

TABLE 8-7
Estimated Costs for Alternative 3 – GET[a]
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Capital Cost	Annual O&M Cost	Present Value[b]
LF007C	$121,023[c]	$15,258	$432,334
SS029	$0[d]	$20,503	$339,851
SS030	$17,532[e]	$20,503	$294,390

[a] More detailed cost estimates are provided in Appendix E.
[b] Remediation timeframe estimate is provided in Appendix D.
[c] Site LF007C estimated capital cost during 2011.
[d] Site SS029 GET system does not require additional capital cost expenditure.
[e] Potential capital costs for expansion of the Site SS030 GET system.

Site LF007C. Under Alternative 3, operation of the existing GET system at Site LF007C will be continued and potentially expanded. The current GET system employs two (2) solar-powered extraction wells. Groundwater from the extraction wells is treated at the NGWTP using LGAC. Depending on the results of a pending data gaps investigation in 2011, the current GET system may require expansion to more thoroughly address the off-base plume. The costs for a potential expansion are included in the estimated costs.

Sites SS029 and SS030. Operation of the existing GET systems at Sites SS029 and SS030 will continue under Alternative 3. Extracted groundwater from Sites SS029 and SS030 will continue to be treated at the SBBGWTP using LGAC. The existing GET systems are performing as intended and do not require additional capital costs for new wells or changes to the SBBGWTP treatment process.

Operation of the Site SS030 GET system will be optimized in 2011. Increased pumping rates implemented in 2010 appear to be improving the performance of the GET system at hydraulically capturing the plume. Additional monitoring will be conducted during 2011 to assess hydraulic capture of the plume. To account for a change in future off-base conditions, an additional Site SS030 extraction well is included in the cost estimate provided in Table 8-5.

8.3.2.8 Performance Enhancement Measures

This subsection briefy describes potential future remedy enhancements related to Alternative 3 – GET.

The Air Force will undertake site-specific performance enhancement measures if needed to address performance problems with the GET systems. Also, depending on the results of pending field investigations and evaluations at Site SS029, a more sustainable approach to remediation may be taken by construction of a ZVI PRB.

GET Systems. For all sites undergoing GET, if data indicate that contamination is escaping hydraulic capture by an extraction system, there would be time to modify the extraction system without an unacceptable risk of exposure. The magnitude of the risk of exposure would continue to be low because of the low velocity of groundwater contaminant migration.

PRB. At Site SS029, a PRB is a potential measure to replace the existing GET system. This would involve construction of a PRB in a funnel-and-gate or wall configuration to intercept and chemically treat groundwater contamination at the leading edge of the Site SS029 plume. Operation of the existing Site SS029 GET system would be discontinued.

The technical implementability of a Site SS029 PRB primarily depends on whether the site conditions are amenable to this in situ chemical treatment process. The main considerations include the distribution of the plume when the hydraulic containment GET system is turned off and the depth to competent bedrock. These two (2) variables and the system hydraulics will mainly govern the required dimensions of the funnel-and-gate system and the cost of construction. Geochemistry issues between the reactive materials and groundwater are also important considerations (e.g., wall clogging). Additional field investigations and hydraulic modeling are required to resolve the uncertainties. These investigations are planned during 2011.

Future Remedy Transition. In the future, Alternative 3 is also potentially applicable to sites currently found applicable to Alternative 2 – MNA; Alternative 4 – Bioreactor and GET; Alternative 5 – EVO and EA; Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA; and Alternative 7 – Passive Skimming and EA. If one (1) or more of these alternatives ultimately prove incapable of achieving RAOs, then Alternative 3 can be implemented. The sites where Alternative 3 may be potentially applicable under future conditions are summarized in the following list:

- **Sites FT004, FT005, LF008, SD031, SD033, and SD043 –** IRA GET systems exist at these sites. Under potential future conditions, active remediation using these systems can be resumed under Alternative 3 if natural attenuation processes do not perform successfully under Alternative 2.
- **Sites LF006, LF007B, and LF007D –** No IRA GET systems exist at these sites. However, Alternative 3 – GET may be implemented in the future if MNA processes under Alternative 2 ultimately prove incapable of achieving RAOs. New GET systems would be required at each site.
- **Site ST027B –** Alternative 3 – GET may be implemented in the future at this site if MNA processes under Alternative 2 ultimately prove incapable of achieving RAOs. A new GET system would be required. Proximity to active airfield operations will pose difficulties in constructing such a GET system.
- **Site SS016 –** If the combination of an in situ bioreactor and GET under Alternative 4 proves incapable of achieving RAOs, then Alternative 3 can be implemented in the future. The existing IRA GET system could be expanded.
- **Sites SS015, SD036, and SD037 –** If source area EVO injection combined with EA under Alternative 5 proves incapable of achieving RAOs, then Alternative 3 can be implemented in the future. Operation of the IRA GET systems at Sites SD036 and SD037 could be resumed. A new GET system would be required at Site SS015.
- **Site DP039 –** If the Alternative 6 combination of an in situ bioreactor, phytoremediation, an EVO PRB, and EA ultimately proves incapable of achieving RAOs, then Alternative 3 can be implemented in the future. The existing IRA GET system could be expanded.

- **Site SD034 –** If the combination of passive skimming and EA under Alternative 7 proves incapable of achieving RAOs, then Alternative 3 can be implemented in the future. Operation of the IRA GET system can be resumed.

8.4 Alternative 4 – Bioreactor and GET

Alternative 4 combines source removal through installation of an in situ bioreactor and conventional groundwater pump and treat actions to remediate the Site SS016 plume. The groundwater contaminant plume where Alternative 4 would be implemented is shown on Figures 7-3 and 7-4.

The methodologies used to estimate the time required to achieve PCGs under Alternative 4 are provided in Appendix D.

8.4.1 Components of the Alternative

As part of Site SS016 IRA optimization in 2010, an in situ bioreactor was installed within the OSA source area. Groundwater from existing horizontal extraction well EW003x16 was re-routed to circulate through the bioreactor using a solar-powered pump. The location of the bioreactor is shown on Figure 7-4. A conceptual cross section of the bioreactor is shown on Figure 7-5. The bioreactor uses ERD processes to break down chlorinated VOCs within the OSA source area.

As part of the bioreactor installation, operation of OSA 2-Phase® extraction well TPE-W was discontinued because soil vapor and groundwater extraction will oxygenate the aquifer in this portion of the plume, which is incompatible with the ERD processes used by the bioreactor. Energy intensive ThOx treatment of soil vapor extracted by TPE-W was also discontinued.

With the OSA source area installation of the bioreactor, the continuing source of TCE contamination into the hydraulically downgradient portions of the Site SS016 plume has been greatly reduced. The portion of the plume that is hydraulically downgradient of the OSA bioreactor will continue to be partly addressed by vertical groundwater extraction wells EW605x16 and EW610x16. The locations of these extraction wells are shown on Figure 7-3.

Groundwater extraction within the TARA portion of Site SS016 will continue under Alternative 4 using the two (2) existing horizontal extraction wells, EW001x16 and EW002x16. The locations of these extraction wells are shown on Figure 7-3.

The downgradient portion of the Site SS016 plume not hydraulically captured by the OSA component of the GET system (EW605x16, EW610x16) and TARA component of the GET system (EW001x16, EW002x16) will eventually be hydraulically captured by the Site SS029 GET system.

Groundwater removed by extraction wells EW605x16, EW610x16, EW001x16, and EW002x16 will continue to be treated using LGAC at the CGWTP. Treated groundwater will then be discharged into the stormwater drainage system.

Travis AFB will continue to enforce existing LUCs to prevent unauthorized exposure to contaminated groundwater. Base Civil Engineer Work Requests, excavation permits, and the requirements of the Base General Plan will continue to be enforced.

The provisions of the Base General Plan related to vapor intrusion mitigation will continue to be enforced. Installation of a vapor barrier and passive venting system may be required for future new building construction in proximity to a groundwater contaminant plume.

Performance monitoring will continue under the GSAP.

8.4.2 Detailed Evaluation

The following subsections provide a detailed evaluation of Alternative 4 against the evaluation criteria.

8.4.2.1 Overall Protection of Human Health and the Environment

Alternative 4 will be protective of human health and the environment. The components of the alternative will reduce the threat to groundwater quality. In the short term, installation of the OSA source area bioreactor in 2010 has effectively removed the highest concentrations of contamination present in the soil and groundwater. In the longer term, the in situ bioreactor will continue to reduce contaminant concentrations within the OSA source area via ERD processes. Continued operation of the OSA and TARA GET systems and the Site SS029 GET system will provide long-term hydraulic containment and removal of contaminants within the remaining portions of the plume.

Travis AFB will continue to enforce existing LUCs to minimize human exposure to contamination until RAOs are achieved.

Ongoing groundwater monitoring at Site SS016 will continue under the Travis AFB GSAP to evaluate the effectiveness of the bioreactor and GET systems.

8.4.2.2 Compliance with ARARs

Compliance with ARARs will eventually be achieved under Alternative 4. In the long term, chemical-specific ARARs (i.e., PCGs) are expected to be achieved within 62 years. The existing treatment processes will comply with action-specific and location-specific ARARs.

8.4.2.3 Long-term Effectiveness and Permanence

Alternative 4 will be permanent and effective in the long term. Installation of the OSA source area bioreactor has effectively and permanently removed high concentrations of contaminants, including suspected DNAPLs. The ERD treatment processes used by the OSA bioreactor are expected to permanently destroy the chlorinated VOCs within the treatment zone. Bioreactor operation at Site DP039 has effectively reduced TCE in the source area by more than 90 percent in the first 16 months of operation. The OSA and TARA GET system components of the alternative will hydraulically contain and remove remaining contamination by treating the extracted groundwater with LGAC. The likelihood is high that the RAOs will be met in the long term.

8.4.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 4 – Bioreactor and GET addresses the principal threats posed by groundwater contamination through a combination of two (2) technologies: an in situ bioreactor and GET. The bioreactor will treat the OSA source area using ERD processes. Under the GET component of the alternative, extraction wells will be used to physically remove contaminated groundwater from the aquifer, ex situ treatment of the extracted groundwater will be conducted using LGAC, and ex situ treatment of spent carbon will be conducted at an off-base facility. A summary of the performance of Alternative 4 against the criterion of reduction in toxicity, mobility, or volume of contaminants through treatment is provided in Table 8-8.

Implementation of Alternative 4 will reduce the toxicity, mobility, and volume of chlorinated VOCs through treatment at Site SS016. In situ biological treatment using the bioreactor will reduce the toxicity and volume of contaminants in the OSA source area with ERD processes. The bioreactor component of Alternative 4 satisfies the statutory preference for treatment as a principal element of the remedy.

The TARA portion of Site SS016 and the portion of the OSA plume downgradient of the bioreactor will be hydraulically captured by groundwater extraction wells. These extraction wells will also serve to reduce the mobility and volume of contaminants. Extracted groundwater will be conveyed to the CGWTP and treated using LGAC adsorption. Ex situ LGAC treatment will not destroy the contaminants, but they will be concentrated on the carbon media. The carbon will periodically require regeneration at an off-base vendor facility where sorbed contaminants will be destroyed. Treatment residuals will not pose a risk to the public. Therefore, this component of Alternative 4 also satisfies the statutory preference for treatment as a principal element of the remedy.

Alternative 4 will likely require many years to achieve RAOs within the entirety of the Site SS016 plume. However, installation of the bioreactor has greatly reduced the continuing source of TCE contamination into the hydraulically downgradient portions of the OSA plume. The remaining contamination will be hydraulically captured by the Site SS016 and Site SS029 GET systems.

Treatment residuals following complete degradation of chlorinated VOCs through the bioreactor ERD processes will include non-regulated end-products such as ethene and ethane. Incomplete ERD, resulting from stalling of these processes, has the potential to create intermediate treatment residuals such as cis-1,2-DCE and/or vinyl chloride. The PCGs for these compounds are 6 and 0.5 μg/L, respectively.

Vinyl chloride is the most toxic potential treatment residual resulting from incomplete ERD treatment. Within the anaerobic treatment zone created by the bioreactor, creation of vinyl chloride is expected as part of normal ERD processes. Based on results to date at Site DP039, full degradation of vinyl chloride within the treatment zone is expected as those processes continue through completion to form ethane, ethene, and methane. Outside of the treatment zone, the Site SS016 aquifer is aerobic. Vinyl chloride readily degrades under aerobic conditions, so any vinyl chloride that migrates beyond the ERD treatment zone will degrade aerobically shortly after entering the downgradient portion of the aquifer. Groundwater extraction wells are located downgradient of the bioreactor to provide hydraulic containment and contaminant removal of the OSA source area plume.

TABLE 8-8
Reduction of Toxicity, Mobility, or Volume through Treatment Under Alternative 4 – Bioreactor and GET
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Analysis Factor	Considerations
Treatment process and remedy	Alternative 4 – Bioreactor and GET uses two (2) primary remedy components, a bioreactor and GET. The first component, an in situ bioreactor will treat source area contamination within the OSA using the processes of ERD. The second remedy component will use GET for the physical removal of contaminated groundwater from the subsurface, adsorption of contaminants onto activated carbon at the CGWTP, and off-base regeneration of the loaded carbon. These two processes are used in combination to address the principal threats from groundwater contamination. Alternative 4 is applicable to the conditions at Site SS016. The OSA source area contains high contaminant concentrations and residual DNAPL is likely present. During the period of interim remediation, source area groundwater and vapor extraction using a 2-Phase® system became increasingly ineffective and inefficient over time. Source area GET operation in the diffusion-dominated, low-permeability lithology found at the OSA reached asymptotic contaminant concentrations above PCGs and, even after over a decade of operation, remained at the highest levels of contamination found at Travis AFB. An in situ bioreactor was installed within the OSA source area as an optimization measure in 2010 and 2-Phase® extraction was discontinued. The OSA and TARA GET components of the remedy effectively controlled contaminant migration and removed mass during the period of interim remediation and will be continued under Alternative 4. Treatment of extracted groundwater at the CGWTP using activated carbon will also be continued.
Amount of hazardous material destroyed or treated	A 25-feet wide by 25-feet long by 25-feet deep bioreactor will address the highest concentrations of chlorinated VOC contamination within the OSA source area. Over time, the ERD treatment zone created by the bioreactor is expected to propagate into the hydraulically downgradient portion of the aquifer approximately 30 feet, or less. After 2 years of monitoring of a similar bioreactor with the Site DP039 source area, the total VOC removal within the bioreactor was 99 percent. For the downgradient performance monitoring wells, total molar reduction of chlorinated VOCs was 95 percent. A similar level of performance is expected for the OSA bioreactor. A decade of GET system operation at Site SS016 has demonstrated the capacity of this component of Alternative 4 to hydraulically contain, remove, and ultimately destroy chlorinated VOCs. Adsorbed toxic contaminants are destroyed during regeneration of the carbon treatment medium at an off-base vendor facility. The amount of chlorinated VOCs removed from the groundwater at Site SS016 and subsequently destroyed at the vendor facility is documented in monthly O&M reports for the CGWTP. The combination of Alternative 4 remedy processes irreversibly reduces the total mass of contaminants and the principal threats are thereby also reduced.

TABLE 8-8
Reduction of Toxicity, Mobility, or Volume through Treatment Under Alternative 4 – Bioreactor and GET
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Analysis Factor	Considerations
Reduction in toxicity, mobility, or volume	Reductions in the toxicity, mobility, and volume of contamination will be achieved by the combination of ERD within the OSA source area and GET within the both the OSA and TARA source areas. The distal portion of the plume will eventually be captured by the hydraulically downgradient Site SS029 GET system. Within the highest concentration portion of the OSA, the processes of ERD facilitated by the bioreactor will eventually degrade chlorinated VOCs, such as TCE, to non-toxic compounds such as ethene and ethane. Over time, the total mass and volume of groundwater contamination within the ERD treatment zone will be fully reduced to concentrations less than the PCGs by these processes. Performance monitoring of the OSA bioreactor is ongoing. Long-term operation of the OSA and TARA components of the Site SS016 interim GET system have already effectively reduced the mobility and volume of groundwater contamination by hydraulically capturing portions of the plume, physically removing contaminants from the subsurface, and then treating the extracted groundwater at the CGWTP. The mass of chlorinated VOCs removed from the groundwater is documented in monthly O&M reports for the CGWTP.
Irreversibility of treatment	The ERD treatment process utilized by the bioreactor is inherently irreversible. Off-base vendor treatment of contaminants adsorbed to activated carbon is also irreversible. Contaminant concentrations under Alternative 4 could potentially increase (i.e., rebound) in the diffusion-dominated lithology found at Travis AFB if the bioreactor ERD treatment process is not maintained and GET system operation is not continued.
Type and quantity of treatment residual	Under the bioreactor component of Alternative 4, complete degradation of chlorinated VOCs via ERD treatment will include non-regulated end products such as ethene and ethane. Incomplete ERD, resulting from possible stalling of these processes, has the potential to create intermediate treatment residuals such as cis-1,2-DCE and/or vinyl chloride. Vinyl chloride is the most toxic potential treatment residual resulting from incomplete ERD treatment. Within the anaerobic treatment zone created by the bioreactor, creation of vinyl chloride is expected as part of normal ERD processes. However, based on results to-date at Site DP039, full degradation of vinyl chloride within the treatment zone is expected as those processes continue through completion to form ethane, ethene, and methane. Outside of the ERD treatment zone, the Site SS016 aquifer is aerobic. Vinyl chloride readily degrades under aerobic conditions, so any vinyl chloride that migrates beyond the treatment zone will degrade aerobically shortly after entering the downgradient portion of the aquifer and/or be hydraulically captured by the downgradient OSA component of the GET system. Performance monitoring of bioreactor performance and the potential generation of treatment residuals is ongoing. No treatment residuals are generated under the GET component of Alternative 4, except the contaminants adsorbed onto activated carbon at the treatment plants. Subsequent off-base vendor treatment of the loaded carbon provides for complete destruction of contaminants and no treatment residuals.

TABLE 8-8
Reduction of Toxicity, Mobility, or Volume through Treatment Under Alternative 4 – Bioreactor and GET
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Analysis Factor	Considerations
Statutory preference for treatment as a principal element	The statutory preference for treatment as a principal element of the remedy is satisfied by the bioreactor component of the alternative. The ERD treatment process utilized within the highest concentration OSA portion of the Site SS016 plume will address the principal threats from the contaminants. The component of Alternative 4 that provides for off-base carbon treatment also contributes toward satisfaction of the statutory preference for treatment. Contaminants that are removed from the aquifer by GET system operation are permanently and irreversibly destroyed by the regeneration of the carbon.

8.4.2.5 Short-term Effectiveness

Alternative 4 will provide short-term effectiveness. However, the in situ treatment processes and GET systems used under this alternative will require time to achieve RAOs and remove contaminant mass down to PCGs. The estimated time required to achieve PCGs under Alternative 4 is 62 years.

The community and the environment will be protected during remediation by the Air Force maintaining control of the groundwater resource through enforcement of LUCs. Risks to workers will be minimized by these same measures and by following standard safety practices during construction and O&M.

Implementation of Alternative 4 at Site SS016 includes a provision for sustainable remediation through an in situ bioreactor. By using this green technology, some of the existing components of the Site SS016 GET IRA will be permanently discontinued after implementation of Alternative 6. These components include a 2-phase® extraction well and vapor-phase treatment using ThOx. Groundwater treatment using LGAC at the CGWTP will be continued. More detailed information is provided in Appendix F.

8.4.2.6 Implementability

Alternative 4 is readily implementable. The components of the existing IRA within the OSA source area of Site SS016 have already been optimized during 2010. These optimizations include installation of a bioreactor. These optimization actions will be easily incorporated into the final remedial action described by this alternative. Similarly, the GET component of the alternative is already installed within the OSA and TARA portions of the plume. Extracted groundwater is already being successfully treated and discharged at the CGWTP.

Remedial construction activities associated with Alternative 4 have already been completed. Installation of a bioreactor within the OSA source area is complete. The GET system is installed. If modifications are required in the future, then specialized construction contractors and equipment are available. No schedule delays or technical problems are anticipated with the bioreactor or GET system. Potential future remedial actions would have to take the presence of these components of the alternative into consideration to prevent actions that might limit their effectiveness.

Potential expansion of remedial action at Site SS016, particularly the GET component, has limited implementability. Site SS016 is located within an area of active military airfield operations. Site access is restricted. The majority of the plume underlies active military aircraft parking ramps, taxiways, and runways. These physical considerations, combined with a large plume area, profoundly limit the implementability of actions that might reduce the time required to achieve PCGs (e.g., an expanded GET system).

Groundwater monitoring will be conducted under the GSAP to evaluate the effectiveness of the Alternative 4 components. Sampling and engineering evaluations will be conducted. Engineering and laboratory services are standard practices that are readily available.

Alternative 4 is also administratively implementable. Coordination with state and other federal agencies will continue following implementation of the alternative. Travis AFB is already implementing LUCs to restrict activities that could result in human exposure to contaminated groundwater. These existing LUCs will continue to be enforced by the Air Force to provide short-term and long-term protection from exposure to groundwater contamination.

8.4.2.7 Cost

At Site SS016, an in situ bioreactor was installed within the OSA source area as part of IRA optimization. These actions were completed in 2010 and are incorporated into the estimate of Alternative 4 costs. The actual capital costs of excavation and bioreactor installation are provided in Table 8-9. More detailed descriptions of the basis of the cost estimate are provided in Appendix E.

TABLE 8-9
Estimated Costs for Alternative 4 – Bioreactor and GET at Site SS016[a]
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Capital Cost	Annual O&M Cost	Present Value[b]
SS016	$0	$35,247	$1,116,162

[a] More detailed cost estimates are provided in Appendix E.
[b] Remediation timeframe estimate is provided in Appendix D.
[c] Actual capital cost incurred in 2010 was $306,116.

Operation of the existing OSA and TARA GET systems will continue under Alternative 4. Extracted groundwater will continue to be treated at the CGWTP using LGAC. The existing GET systems are performing as intended and do not require additional capital costs for new wells or changes to the CGWTP treatment process.

8.4.2.8 Performance Enhancement Measures

If performance monitoring identifies any unanticipated or adverse outcomes from the installation of the bioreactor, then the Air Force will evaluate and carry out performance enhancement measures to correct the deficiencies. The end result of these measures will either be a return of the bioreactor's ability to remediate contaminated groundwater, a transition to a more effective remedial alternative, or the application of an additional remedial alternative in a downgradient location.

Potential adverse outcomes could include the following:

- Incomplete reductive dechlorination or transformation that stalls at cis-1,2-DCE and/or vinyl chloride
- Increases in concentrations of VOCs immediately downgradient of the bioreactor treatment zone
- Migration of contaminant plume/lack of plume stability

Potential performance enhancement measures for one (1) or more of these outcomes include the following, listed in ascending order of field effort:

- Increased monitoring
- Installation of additional monitoring wells
- Sustaining high dissolved organic carbon levels in the bioreactor recirculation water (e.g., adding vegetable oil or high fructose corn syrup)
- Bioaugmentation of the water circulated through the bioreactor (i.e., supplement native microbes with a proprietary microbial consortium [e.g., KB-1®] if the native microbes prove incapable of complete degradation of TCE through vinyl chloride to non-toxic ethene)
- Expansion and restart of the OSA source area GET system
- Implementation of another remedial technology

The Air Force and the regulatory agencies will base the selection of the appropriate performance enhancement measure(s) on the type and severity of the adverse outcome.

8.5 Alternative 5 – EVO and EA

Alternative 5 uses in situ bioremediation via EVO injection combined with EA to achieve RAOs. Alternative 5 is applicable to the physical and contaminant conditions at the following sites:

- **Site SS015**
- **Site SD036 –** component site within the WIOU plume
- **Site SD037 –** component site within the WIOU plume

The groundwater contaminant plumes where Alternative 5 would be implemented are shown on Figures 7-6 through 7-9.

The methodologies used to estimate the time required to achieve PCGs under Alternative 5 are provided in Appendix D.

8.5.1 Components of the Alternative

Under this Alternative 5, EVO is injected into the higher concentration source areas (i.e., VOC concentrations greater than or equal to 1,000 µg/L) of the plumes to anaerobically degrade chlorinated VOCs using ERD processes. After injection of substrate within the source area, the continuing source of TCE contamination into the hydraulically downgradient portions of the plume will be eliminated or greatly reduced. The mechanisms of natural attenuation in these downgradient areas will then be enhanced (i.e., EA). The primary components of Alternative 5 at Sites SS015, SD036, and SD037 are shown on Figures 7-6 through 7-9.

Additional descriptions of the lines of evidence for the viability of natural attenuation processes to remediate groundwater at Travis AFB are provided in Appendix C.

The existing WIOU GET system, including the extraction wells at Sites SD036 and SD037, was shut down in 2010 for a rebound study. The contaminant plumes will continue to be monitored for the remainder of the period of interim remediation. Unless there is evidence of contaminant rebound, the GET systems will remain off. If rebound does occur, then the Air Force will evaluate resuming all or part of the GET operations.

Travis AFB will continue to enforce existing LUCs to prevent unauthorized exposure to contaminated groundwater. Base Civil Engineer Work Requests, excavation permits, and the requirements of the Base General Plan will continue to be enforced.

The existing vapor intrusion mitigation measures for Building 554 (Site SS015) and Building 837 (Site SD037) will continue to be maintained. Installation of a vapor barrier and passive venting system may be required for future new building construction in proximity to a groundwater contaminant plume.

Performance monitoring will continue to be conducted under the GSAP.

8.5.2 Detailed Evaluation

The following subsections provide a detailed evaluation of Alternative 5 against the evaluation criteria.

8.5.2.1 Overall Protection of Human Health and the Environment

Alternative 5 will be protective of human health and the environment. The in situ bioremediation processes used under this alternative have a high likelihood of being effective at remediating chlorinated VOCs, such as those present at Sites SS015, SD036, and SD037. Contaminant volume and mass in the source areas will be reduced, and downgradient contaminant migration will be greatly reduced.

Ongoing groundwater monitoring will continue under the GSAP to evaluate the effectiveness of EVO injection and MNA. Existing LUCs will continue to be enforced to minimize human exposure to contamination until RAOs are achieved.

8.5.2.2 Compliance with ARARs

Compliance with ARARs will be achieved under Alternative 5. Chemical-specific ARARs (i.e., PCGs) will be achieved within the portions of the plumes undergoing in situ bioremediation. These treatment processes will comply with action-specific and location-specific ARARs.

Under Alternative 5, chemical-specific ARARs will eventually be met. The placement of existing groundwater monitoring wells already meets location-specific ARARs because they are not located in environmentally sensitive areas. Action-specific ARARs that are relevant and appropriate to groundwater monitoring programs are also already being met and will continue to be met in the future.

Alternative 5 does not involve discharge of treated groundwater to surface water. Therefore, action-specific, location-specific, and chemical-specific ARARs related to the treatment and discharges of contaminated groundwater do not apply.

8.5.2.3 Long-term Effectiveness and Permanence

Alternative 5 will be permanent and effective in the long term. In situ bioremediation is an established technology process for treating chlorinated VOCs in groundwater. This process has been successfully employed at numerous contaminated sites. Adequate distribution of EVO in the site source areas is the key to the overall effectiveness of the alternative.

Each of the technical components of this alternative is well established, so the likelihood is high that the RAOs will be met. Long-term monitoring of the alternative will be conducted under the GSAP.

8.5.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 5 – EVO and EA addresses the principal threats posed by groundwater contamination through a combination of two (2) technologies: ERD facilitated by EVO (i.e., carbon substrate) injection and enhanced natural attenuation. Injection of EVO in the site source area will treat chlorinated VOCs using ERD processes. Under the EA component of the alternative, natural attenuation processes will address the distal (i.e., non-source) portions of the plume. These natural processes will be enhanced by reducing the flux of contamination from the source area into the hydraulically downgradient portion of the plume. A summary of the performance of Alternative 5 against the criterion of reduction in toxicity, mobility, or volume of contaminants through treatment is provided in Table 8-10.

Implementation of Alternative 5 will reduce the toxicity, mobility, and volume of chlorinated VOCs at Sites SS015, SD036, and SD037. In situ biological treatment (ERD) using EVO injection will reduce the toxicity and volume of contaminants in the site source areas. Complete treatment of the chlorinated VOCs at the sites will result in non-regulated end-products such as ethene and ethane. The EVO component of Alternative 5 thereby satisfies the statutory preference for treatment as a principal element of the remedy.

After in situ bioremediation of the higher concentration sources areas, natural attenuation processes in the hydraulically downgradient portions of the plumes will be enhanced. The continuing sources of TCE contamination will be eliminated or greatly reduced. The ability of natural attenuation to reduce contaminant concentrations in the distal portions of the plumes will be improved.

The combination of in situ bioremediation and EA will likely require several years to achieve reductions of contaminant concentrations down to PCGs within the entirety of the site plumes.

Treatment residuals following complete degradation of chlorinated VOCs through the ERD processes will include non-regulated end-products such as ethene and ethane. Incomplete ERD, resulting from stalling of these processes, has the potential to create intermediate treatment residuals such as cis-1,2-DCE and/or vinyl chloride. The PCGs for these compounds are 6 and 0.5 µg/L, respectively.

Vinyl chloride is the most toxic potential treatment residual resulting from incomplete ERD. Within the anaerobic treatment zone created by EVO injection, creation of vinyl chloride is expected as part of normal ERD processes. Full degradation of vinyl chloride within the treatment zone is expected as those processes continue through completion to form ethane, ethene, and methane. Outside of the treatment zone, the aquifer is aerobic. Vinyl chloride readily degrades under aerobic conditions, so any vinyl chloride that migrates beyond the ERD treatment zone will degrade aerobically shortly after entering the downgradient portion of the aquifer.

TABLE 8-10
Reduction of Toxicity, Mobility, or Volume through Treatment Under Alternative 5 – EVO and EA
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Analysis Factor	Considerations
Treatment process and remedy	Alternative 5 – EVO and EA uses two (2) primary remedy components: injection of an EVO carbon substrate to facilitate ERD treatment within a plume source area and use of natural physical, chemical, and biological processes in the distal portions of the plume. These natural processes will be enhanced by reducing the flux of contamination from the source areas into the hydraulically downgradient portions of the plumes. The Alternative 5 remedy components are used in combination to address the principal threats from groundwater contamination. Alternative 5 is applicable to the conditions at Site SS015, SD036, and SD037. At these sites, source areas are present that contain high contaminant concentrations and residual DNAPL is likely present. During the period of interim remediation, source area groundwater and vapor extraction using dual-phase extraction became increasingly ineffective and inefficient over time. Source area GET operation in the diffusion-dominated, low-permeability lithology typically reached asymptotic contaminant concentrations and currently remains above PCGs even after over a decade of operation. Alternative 5 is not applicable as a remedy for large, low concentration plumes without a defined source area.
Amount of hazardous material destroyed or treated	Injection of EVO within the plume source areas will address the highest concentrations of chlorinated VOC contamination. At Travis AFB, the treatment area is typically defined as the portion of the plume within the 1,000 µg/L isocontour for the indicator chlorinated VOC, typically TCE. Over time, the treatment zone is expected to propagate into the hydraulically downgradient portion of the aquifer approximately 30 feet, or less. Performance monitoring of EVO injection demonstrations conducted in 2010 are ongoing. Within the portions of plumes outside of the ERD treatment zones, the physical, chemical, and biological processes of natural attenuation will address the remaining contamination. Over approximately a decade of MNA assessments at Travis AFB, natural attenuation processes demonstrated the capacity to destroy chlorinated VOC contaminants down to concentrations less than PCGs. During the period of assessment, the chlorinated solvent plumes typically decreased in both size and concentration or the plumes were stable and not migrating. The combination of Alternative 5 remedy processes irreversibly reduces the total mass of contaminants and the principal threats are thereby also reduced.

TABLE 8-10
Reduction of Toxicity, Mobility, or Volume through Treatment Under Alternative 5 – EVO and EA
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Analysis Factor	Considerations
Reduction in toxicity, mobility, or volume	Reductions in the toxicity, mobility, and volume of contamination will be achieved by the combination of ERD within the site source areas and natural attenuation processes within the distal portion of the plumes. Within the highest concentration portion of the plumes, the processes of ERD facilitated by EVO carbon substrate injection will eventually degrade chlorinated VOCs, such as TCE, to non-toxic compounds such as ethene and ethane. Over time, the total mass and volume of groundwater contamination within the ERD treatment zone (nominally defined by the 1,000 µg/L VOC isocontour) will be fully reduced to concentrations less than the PCGs. Performance monitoring of the EVO injection demonstration treatment areas at each site is ongoing. Within the distal portions of the plumes, the physical, chemical, and biological processes of natural attenuation will eventually degrade chlorinated VOCs, such as TCE, to non-toxic compounds such as ethene and ethane. Over time, the total mass and volume of groundwater contamination will be fully reduced to concentrations less than the PCGs by these processes.
Irreversibility of treatment	The ERD and natural attenuation treatment processes utilized under Alternative 5 are inherently irreversible. Contaminant concentrations under Alternative 5 could potentially increase (i.e., rebound) in the diffusion-dominated lithology found at Travis AFB if the ERD treatment process is not maintained through supplemental injections of EVO.
Type and quantity of treatment residual	Under the EVO injection component of Alternative 5, complete degradation of chlorinated VOCs via ERD treatment will include non-regulated end products such as ethene and ethane. Incomplete ERD, resulting from possible stalling of these processes, has the potential to create intermediate treatment residuals such as cis-1,2-DCE and/or vinyl chloride. Vinyl chloride is the most toxic potential treatment residual resulting from incomplete ERD treatment. Within the anaerobic treatment zone created by EVO injection, creation of vinyl chloride is expected as part of normal ERD processes. Full degradation of vinyl chloride within the treatment zone is expected as those processes continue through completion to form ethane, ethene, and methane. Outside of the ERD treatment zone, the aquifer is aerobic. Vinyl chloride readily degrades under aerobic conditions, so any vinyl chloride that migrates beyond the treatment zone will degrade aerobically shortly after entering the downgradient portion of the aquifer. Performance monitoring of ERD performance and the potential generation of treatment residuals is ongoing. For the EA component of Alternative 5, no active treatment processes are employed. Therefore, no treatment residuals are generated.
Statutory preference for treatment as a principal element	The statutory preference for treatment as a principal element of the remedy is satisfied by the EVO injection component of the alternative. The ERD treatment process utilized within the highest concentration portions of the Site SS015, SD036, and SD037 plumes will address the principal threats from the contaminants. Active treatment is not used under the EA component of Alternative 5. Therefore, the statutory preference for treatment as a principal element of the remedy is not satisfied by this part of the remedy. However, intrinsic treatment of contaminants through natural processes will contribute towards addressing the principal threats from the contaminants.

8.5.2.5 Short-term Effectiveness

Alternative 5 will provide short-term effectiveness. EVO injection at Sites SS015, SD036, and SD037 was successfully completed during 2010 without adverse impacts to workers or the community.

The in situ treatment and EA processes used under this alternative will require an extended time to achieve RAOs and reduce contaminant concentrations down to PCGs. Estimates of the time to achieve PCGs under Alternative 5 are summarized in Table 8-11. The community and the environment will be protected during remediation by the Air Force maintaining control of the groundwater resource. Risks to workers will be minimized by these same measures and by following standard safety practices during construction and O&M.

Implementation of Alternative 5 at Sites SS015, SD036, and SD037 includes a provision for sustainable remediation by using subsurface injection of food-grade vegetable oil. By using this green technology, the existing components of the Site SD036 and SD037 GET IRAs will be permanently discontinued after implementation of Alternative 6. These components include DPE wells, VGAC treatment at the WTTP, and granular activated carbon (GAC) groundwater treatment at the CGWTP.

TABLE 8-11
Estimated Time to Achieve Preliminary Cleanup Goals for Alternative 5 – EVO and EA
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Estimated Cleanup Time[b] (years)	Comment
SS015	70	
SD036	60	Component site within the WIOU plume
SD037	60	Component site within the WIOU plume

[a] PCGs are described in Section 5.
[b] Remediation timeframe estimates are provided in Appendix D.

8.5.2.6 Implementability

Alternative 5 is readily implementable. The existing IRAs at Sites SS015, SD036, and SD037 were optimized by source area EVO injection during 2010. These optimization actions will be easily incorporated into the final remedial action under this alternative.

Remedial construction activities associated with Alternative 5 have already been completed as optimizations to the existing IRAs. If modifications are required in the future, then specialized construction contractors and equipment are available. No schedule delays or technical problems are anticipated with supplemental injection of edible oil. Potential future remedial actions would have to take the presence of these in situ treatment processes into consideration to prevent field activities that might limit their effectiveness.

Groundwater monitoring will be used to evaluate the effectiveness of in situ bioremediation and natural attenuation processes. Engineering evaluations and laboratory services are standard practices that are readily available.

Alternative 5 is also administratively implementable. Coordination with state and other federal agencies will continue following implementation of the alternative. Travis AFB is already implementing LUCs to restrict activities that could result in human exposure to contaminated groundwater. These existing LUCs will continue to be enforced by the Air Force to provide short-term and long-term protection from exposure to groundwater contamination.

8.5.2.7 Cost

At Sites SS015, SD036, and SD037, EVO was injected into the plume source areas as part of IRA optimization. These actions were completed in 2010 and are incorporated into the estimate of Alternative 5 costs. The actual capital costs of EVO injection are provided in Table 8-12. More detailed descriptions of the basis of the cost estimate are provided in Appendix E.

TABLE 8-12
Estimated Costs for Alternative 5 – EVO and EA[a]
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Capital Cost	Annual O&M Cost	Present Value[b]
SS015	$0	$1,635	$358,474
SD036	$0	$1,635	$759,875
SD037	$0	$1,635	$1,298,581

[a] More detailed cost estimates are provided in Appendix E.
[b] Remediation timeframe estimate is provided in Appendix D.
[c] Site SS015 actual capital cost incurred in 2010 was $138,832.
[d] Site SD036 actual capital cost incurred in 2010 was $257,665.
[e] Site SD037 actual capital cost incurred in 2010 was $406,187.

8.5.2.8 Performance Enhancement Measures

If performance monitoring at Sites SS015, SD036, or SD037 identifies any unanticipated or adverse outcomes from the injection of EVO, then the Air Force will evaluate and carry out performance enhancement measures to correct the deficiencies. The end result of these measures will be a return of the EVO treatment zone's ability to remediate contaminated groundwater, a transition to a more effective remedial alternative, or the application of an additional remedial alternative in a downgradient location.

Potential outcomes could include the following:

- Increases in concentrations of VOCs immediately downgradient of the EVO treatment zone
- Decrease in the permeability of the EVO treatment zone, resulting in an upgradient pooling of contaminated groundwater
- Migration of contaminant plume/lack of plume stability
- Incomplete reductive dechlorination or transformation that stalls at cis-1,2-DCE or vinyl chloride

Potential performance enhancement measures for one (1) or more of these outcomes include the following, listed in ascending order of field effort:

- Increased monitoring
- Installation of additional monitoring wells
- Supplemental injection of EVO using existing wells
- Installation of additional injection wells
- Bioaugmentation (i.e., supplement native microbes with a proprietary microbial consortium [e.g., KB-1®] if the native microbes prove incapable of complete degradation of TCE through vinyl chloride to non-toxic ethene)
- Installation of recirculation loops to allow additional residence time of contaminants within the treatment zone
- Optimization and restart of the existing GET systems at Sites SD036 and SD037. Installing a new GET system at Site SS015.

Travis AFB will base the selection of the appropriate performance enhancement measure(s) on the type and severity of the adverse outcome.

8.6 Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA

Alternative 6 combines three (3) in situ bioremediation process options and enhanced natural attenuation to achieve RAOs at Site DP039. The groundwater contaminant plume where Alternative 6 would be implemented is shown on Figure 7-10.

8.6.1 Components of the Alternative

The primary components of Alternative 6 include the following:

- Bioreactor
- Phytoremediation
- EVO PRB
- EA

The combination of a bioreactor, a phytoremediation treatment zone, and EVO PRB would actively treat contaminated groundwater within the Site DP039 plume. In the distal portions of the plume, the mechanisms of natural attenuation would address the remaining groundwater contamination.

Travis AFB will continue to enforce existing LUCs to prevent unauthorized exposure to contaminated groundwater. Base Civil Engineer Work Requests, excavation permits, and the requirements of the Base General Plan will continue to be enforced.

The provisions of the Base General Plan related to vapor intrusion mitigation will continue to be enforced. Installation of a vapor barrier and passive venting system may be required for future new building construction in proximity to a groundwater contaminant plume.

Performance monitoring will continue to be conducted under the GSAP.

Additional descriptions of the lines of evidence for the viability of natural attenuation processes to remediate groundwater at Travis AFB are provided in Appendix C.

The methodologies used to estimate the time required to achieve PCGs under Alternative 6 are provided in Appendix D.

8.6.2 Detailed Evaluation

The following subsections provide a detailed evaluation of Alternative 6 against the evaluation criteria.

8.6.3 Overall Protection of Human Health and the Environment

Alternative 6 will be protective of human health and the environment. The combination of in situ bioremediation processes used under this alternative is expected to be effective at remediating chlorinated VOCs within the Site DP039 plume. Contaminant volume and mass in the source area has been reduced, and downgradient contaminant migration will be reduced.

Existing Travis AFB LUCs will be enforced to minimize human exposure to contamination while in situ treatment is taking place. Ongoing groundwater monitoring will be continued under the Travis AFB GSAP to verify the effectiveness of the alternative.

8.6.4 Compliance with ARARs

Compliance with ARARs will be achieved under Alternative 6. Chemical-specific ARARs at Site DP039 are expected to be achieved within approximately 58 years.

The placement of existing groundwater monitoring wells already meets location-specific ARARs, because they are not located in environmentally sensitive areas. Action-specific ARARs that are relevant and appropriate to groundwater monitoring programs are also already being met and will continue to be met in the future.

Alternative 5 does not involve discharge of treated groundwater to surface water. Therefore, action-specific, location-specific, and chemical-specific ARARs related to the treatment and discharges of contaminated groundwater do not apply.

8.6.5 Long-term Effectiveness and Permanence

The long-term effectiveness and permanence of Alternative 6 relies on the combination of established technology processes for treating chlorinated VOCs in groundwater at Site DP039. These Alternative 6 processes will be permanent and effective in the long term.

The combination of bioreactor, phytoremediation, EVO PRB, and EA under Alternative 6 will provide long-term, effective, and permanent remediation of the Site DP039 groundwater contamination. The various alternative components will effectively and permanently address the different portions of the plume. More discussions of the long-term effectiveness and permanence of the Alternative 6 components are provided in the following subsections.

8.6.5.1 Bioreactor Long-term Effectiveness and Permanence

From 2008 through 2010, the performance of the Site DP039 bioreactor has been evaluated, and several positive performance indicators have been identified during 16 months of operation. For example, TCE concentrations in monitoring well MW793x39, located about 40 feet downgradient of the center of the bioreactor, dropped from 8,000 to 58 µg/L. Decreases in TCE concentrations are also being observed in the other wells surrounding the bioreactor. More detailed information regarding the performance of the bioreactor is provided in the final *Third Progress Report, Sustainable Bioreactor Demonstration, Site DP039* (CH2M HILL, 2010h).

8.6.5.2 Phytoremediation Long-term Effectiveness and Permanence

Data obtained from a study of phytoremediation at Site DP039 indicate a good likelihood that the technology will contribute toward remediation of groundwater.

The long-term effectiveness of phytoremediation continues to be evaluated. The most recent findings are documented in the final *Phytostabilization at Travis Air Force Base, California* technical report (Parsons, 2010). A key finding in this report is that phytoremediation significantly reduced groundwater contaminant concentrations in the study area. The overall TCE removal rate within the phytoremediation study area was about 2 pounds per year. As the trees mature, future removal rates could increase to up to 15.4 pounds per year.

Although there are limitations to the phytoremediation process (e.g., limited effective depth below the groundwater table), it offers a beneficial component of the remedial action at Site DP039. It is a low impact, low maintenance, and sustainable process.

Optimization actions in the future could include the following:

- **Expand tree plantings –** Increasing the planted area to cover a larger portion of the plume and increase mass removal rates.
- **Install irrigation –** Solar-powered groundwater pumps could be installed in wells located hydraulically downgradient of the tree stand. These wells would extract contaminated groundwater from the deeper portions of the aquifer (i.e., below the tree root zone) and distribute it to the trees via a subsurface irrigation system (i.e., just below the transplanted root ball). This action would improve contaminant mass removal efficiency, avoid the use of potable water, stimulate root growth and increase the survival rate of the trees, and introduce another aspect of sustainable remediation.

8.6.5.3 EVO PRB Long-term Effectiveness and Permanence

The Site DP039 EVO PRB was installed in mid-2010 to demonstrate the long-term effectiveness of ERD via injection of EVO. Performance data will be collected for the remainder of the period of interim remediation.

The positive data obtained from operation of the bioreactor through 2010 indicate a good likelihood that ERD processes will have long-term effectiveness and permanence.

8.6.5.4 Enhanced Attenuation Long-term Effectiveness and Permanence

The EA component of Alternative 6 will be effective over the long term as chlorinated VOCs degrade to non-regulated compounds such as ethene and ethane. These processes are irreversible.

Natural attenuation processes are effective, reliable, and permanent. The site conditions at Travis AFB have demonstrated the capacity to support chlorinated VOC degradation through a combination of physical and, to lesser degrees, chemical and biological mechanisms (CH2M HILL, 2010a). Additional discussion of the viability of natural attenuation processes to remediate groundwater at Travis AFB is provided in Appendix C.

8.6.6 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA addresses the principal threats posed by groundwater contamination at Site DP039 through a combination of four (4) technology processes: (1) an in situ bioreactor will treat the source area using ERD processes, (2) an area of phytoremediation will use planted trees to provide biological treatment of a portion of the plume downgradient of the bioreactor, (3) injection of EVO in a PRB configuration will provide ERD treatment of chlorinated VOCs in the portion of the plume downgradient of the planted trees, and (4) EA will use natural attenuation processes to address the distal (i.e., non-source) portions of the plume downgradient of the other alternative components. These natural processes will be enhanced by reducing the flux of contamination from the source areas into the hydraulically downgradient portion of the plume. A summary of the performance of Alternative 6 against the criterion of reduction in toxicity, mobility, or volume of contaminants through treatment is provided in Table 8-13.

Implementation of Alternative 6 will reduce the toxicity, mobility, and volume of chlorinated VOCs at Site DP039. These reductions will result from the combination of alternative components, including ERD facilitated by the in situ bioreactor; phytovolatilization, phytodegradation, phytoextraction, and rhizodegradation within the area of planted trees; ERD facilitated by the EVO PRB; and enhanced natural attenuation. The bioreactor, phytoremediation, and EVO PRB components of Alternative 6 thereby satisfy the statutory preference for treatment as a principal element of the remedy.

The bioreactor, installed as a technology demonstration project in December 2008, will irreversibly reduce the toxicity and volume of contaminants in the source area using ERD processes. The portion of the plume located hydraulically downgradient of the bioreactor will be further irreversibly treated by an existing area of phytoremediation. Then, hydraulically downgradient of the phytoremediation area, the leading edge of the source plume will be intercepted by an existing EVO PRB and undergo additional irreversible in situ treatment via ERD processes. The remainder of the plume will be addressed by irreversible natural attenuation processes.

The existing area of phytoremediation is providing irreversible reductions in toxicity, mobility, and volume of contamination through a sustainable treatment process. In 2010, the trees demonstrated a mass removal rate of about 2 pounds of TCE per year. These reductions could increase up to 15.4 pounds of TCE per year as the trees mature. Optimization actions such as increasing the planting area and installing an irrigation system using contaminated groundwater would provide additional reductions.

In situ biological treatment using ERD processes within the treatment zones of the bioreactor and EVO PRB will reduce the toxicity and volume of contaminants. Treatment residuals following complete treatment of chlorinated VOCs will include non-regulated ethene and ethane. Incomplete ERD, resulting from stalling of these processes, has the potential to create intermediate treatment residuals such as cis-1,2-DCE and/or vinyl chloride. The PCGs for these compounds are 6 and 0.5 µg/L, respectively.

Vinyl chloride is the most toxic potential treatment residual of incomplete ERD. Within the anaerobic treatment zone created by EVO injection, creation of vinyl chloride is expected as part of normal ERD processes. During the first 16 months of operation, little vinyl chloride has been generated by the bioreactor. Full degradation of vinyl chloride within the treatment zone is expected as those processes continue through completion to form ethane, ethene, and methane. Outside of the treatment zone, the aquifer is aerobic. Vinyl chloride readily degrades under aerobic conditions, so any vinyl chloride that migrates beyond the ERD treatment zone will degrade aerobically shortly after entering the downgradient portion of the aquifer.

Natural attenuation of the distal portion of the Site DP039 plume will use intrinsic chemical, physical, and biological processes to irreversibly reduce contaminants in groundwater over time. Reductions in toxicity, mobility, and volume will depend primarily on the rate of contaminant concentration reduction through these natural processes. The degree of degradation will be monitored through the ongoing GSAP. Also, a study will be conducted during 2011 to evaluate the contribution provided by the biological processes of MNA.

During the period of interim remediation, natural attenuation processes demonstrated their capacity to reduce the toxicity, mass, and volume of contamination. The results of site-specific MNA assessments are documented in the NAAR (CH2M HILL, 2010a). Additional discussion of MNA is provided in Appendix C.

TABLE 8-13
Reduction of Toxicity, Mobility, or Volume through Treatment Under Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Analysis Factor	Considerations
Treatment process and remedy	Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA addresses the principal threats posed by groundwater contamination at Site DP039 through a combination of four (4) technology processes: (1) An in situ bioreactor will treat the source area using ERD processes, (2) An area of phytoremediation will use planted trees to provide biological treatment of a portion of the plume downgradient of the bioreactor, (3) Injection of EVO in a PRB configuration will provide ERD treatment of chlorinated VOCs in the portion of the plume downgradient of the planted trees, and (4) EA will use natural attenuation processes to address the distal (i.e., non-source) portions of the plume hydraulically downgradient of the other alternative components. Alternative 6 is applicable to the conditions at Site DP039. The source area contains high contaminant concentrations and residual DNAPL is likely present. During the period of interim remediation, source area groundwater and vapor extraction using dual-phase extraction became increasingly ineffective and inefficient over time. Source area GET operation in the diffusion-dominated, low-permeability lithology found at the site reached asymptotic contaminant concentrations above PCGs. An in situ bioreactor was installed within the site source area as a technology demonstration in 2008 and dual-phase extraction was discontinued. Performance monitoring of the ERD processes facilitated by the bioreactor is ongoing. An existing area of phytoremediation is another component of Alternative 6. Beginning in 1998, trees were planted downgradient of the source area to intercept and biologically treat contaminants flowing with the natural groundwater gradient. The performance of the trees is documented in the final Technical Report – Phytostabilization at Travis AFB, California (Parsons, 2010). The third component of the Site DP039 remedy is an EVO PRB. A demonstration of injected EVO in a linear configuration (i.e., PRB) began in 2010. Performance monitoring of the ERD processes facilitated by the EVP PRB is ongoing. The portion of the Site DP039 plume located hydraulically downgradient of the EVO PRB will be addressed by the physical, chemical, and biological processes of natural attenuation. These natural processes will be enhanced by reducing the flux of contamination from the source areas into the hydraulically downgradient portions of the plume.

TABLE 8-13
Reduction of Toxicity, Mobility, or Volume through Treatment Under Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Analysis Factor	Considerations
Amount of hazardous material destroyed or treated	The Site DP039 bioreactor will address the highest concentrations of chlorinated VOC contamination within the source area. Over time, the ERD treatment zone created by the bioreactor is expected to propagate into the hydraulically downgradient portion of the aquifer approximately 30 feet, or less. After 2 years of monitoring, the total VOC removal within the bioreactor was 99 percent. For the downgradient performance monitoring wells, total molar reduction of chlorinated VOCs was 95 percent. Performance monitoring of the bioreactor is ongoing. The existing area of phytoremediation is providing biological treatment of shallow contamination flowing with the natural movement of groundwater. In 2010, the trees demonstrated a mass removal rate of about 2 pounds of TCE per year. These reductions could increase up to 15.4 pounds of TCE per year as the trees mature. Performance monitoring of the area of phytoremediation is ongoing. Injection of an EVO PRB downgradient of the phytoremediation area will address the highest concentrations of chlorinated VOC contamination not treated by either the bioreactor or trees. At Travis AFB, a treatment area is typically defined as the portion of the plume within the 1,000 µg/L isocontour for the indicator chlorinated VOC, typically TCE. However, the EVO PRB was installed to intercept groundwater contamination at the 500 µg/L TCE isocontour. Over time, the PRB treatment zone is expected to propagate into the hydraulically downgradient portion of the aquifer approximately 30 feet, or less. Performance monitoring of EVO PRB is ongoing. Within the portions of plumes outside of the ERD treatment zones, the physical, chemical, and biological processes of natural attenuation will address the remaining contamination. Over approximately a decade of MNA assessments at Travis AFB, natural attenuation processes demonstrated the capacity to destroy chlorinated VOC contaminants down to concentrations less than PCGs. During the period of assessment, the chlorinated solvent plumes typically decreased in both size and concentration or the plumes were stable and not migrating. The combination of Alternative 6 remedy processes irreversibly reduces the total mass of contaminants and the principal threats are thereby also reduced.

TABLE 8-13
Reduction of Toxicity, Mobility, or Volume through Treatment Under Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Analysis Factor	Considerations
Reduction in toxicity, mobility, or volume	Reductions in the toxicity, mobility, and volume of contamination will be achieved by the combination of a bioreactor within the Site DP039 source area, phytoremediation downgradient of the bioreactor, and an EVO PRB downgradient of the phytoremediation area. The distal portion of the plume will be addressed by natural attenuation processes Within the source area, the processes of ERD facilitated by the bioreactor will eventually degrade chlorinated VOCs, such as TCE, to non-toxic compounds such as ethene and ethane. Over time, the total mass and volume of groundwater contamination within the ERD treatment zone will be fully reduced to concentrations less than the PCGs by these processes. Performance monitoring of the bioreactor is ongoing. The existing area of phytoremediation is providing irreversible reductions in toxicity, mobility, and volume of contamination in the shallow portion of the aquifer through a sustainable treatment process. In 2010, the trees demonstrated a mass removal rate of about 2 pounds of TCE per year. These reductions could increase up to 15.4 pounds of TCE per year as the trees mature. After portions of the source area are treated by the bioreactor and phytoremediation, remaining contamination will be intercepted at treated by the EVO PRB installed at the 500 µg/L TCE isocontour. The processes of ERD facilitated by EVO carbon substrate injection will eventually degrade the TCE, to non-toxic compounds such as ethene and ethane. Over time, the total mass and volume of groundwater contamination within the ERD treatment zone will be reduced. Within the distal portions of the plume, the physical, chemical, and biological processes of natural attenuation will eventually degrade chlorinated VOCs, such as TCE, to non-toxic compounds such as ethene and ethane. Over time, the total mass and volume of groundwater contamination will be fully reduced to concentrations less than the PCGs by the combination of processes comprising Alternative 6.
Irreversibility of treatment	The ERD, phytoremediation, and natural attenuation treatment processes utilized under Alternative 6 are inherently irreversible. Contaminant concentrations under Alternative 6 could potentially increase (i.e., rebound) in the diffusion-dominated lithology found at Travis AFB if the ERD treatment processes within the bioreactor and EVO PRB are not maintained.

TABLE 8-13
Reduction of Toxicity, Mobility, or Volume through Treatment Under Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Analysis Factor	Considerations
Type and quantity of treatment residual	Under the bioreactor and EVO PRB components of Alternative 6, complete degradation of chlorinated VOCs via ERD treatment will include non-regulated end products such as ethene and ethane. Incomplete ERD, resulting from possible stalling of these processes, has the potential to create intermediate treatment residuals such as cis-1,2-DCE and/or vinyl chloride. Vinyl chloride is the most toxic potential treatment residual resulting from incomplete ERD treatment. During 2 years of monitoring the bioreactor, only small amounts of vinyl chloride have been detected. Performance monitoring of the ERD processes related to the bioreactor and EVO PRB is ongoing. Within the anaerobic treatment zone created by the bioreactor and EVO PRB, creation of vinyl chloride is expected as part of normal ERD processes. Full degradation of vinyl chloride within the treatment zone is expected as those processes continue through completion to form ethane, ethene, and methane. Outside of the ERD treatment zone, the aquifer is aerobic. Vinyl chloride readily degrades under aerobic conditions, so any vinyl chloride that migrates beyond the treatment zone will degrade aerobically shortly after entering the downgradient portion of the aquifer. No unexpected treatment residuals resulting from phytoremediation were detected. Only small amounts of vinyl chloride have been detected within the tree stand. For the EA component of Alternative 6, no active treatment processes are employed. Therefore, no treatment residuals are generated.
Statutory preference for treatment as a principal element	The statutory preference for treatment as a principal element of the remedy is satisfied by the bioreactor, phytoremediation, and EVO PRB components of Alternative 6. These treatment processes are utilized within the highest concentration portion of the Site DP039 plume and will address the principal threats from the contaminants. Active treatment is not used under the EA component of Alternative 6. Therefore, the statutory preference for treatment as a principal element of the remedy is not satisfied by this part of the remedy. However, intrinsic treatment of contaminants through natural processes will contribute towards addressing the principal threats from the contaminants.

8.6.7 Short-term Effectiveness

Alternative 5 will provide short-term effectiveness. Installation of the Site DP039 source area bioreactor was completed in December 2008 without incident. Similarly, injection of the EVO PRB was successfully completed during 2010 without adverse impacts to workers or the community.

The in situ treatment and EA processes used under this alternative will require approximately 58 years to achieve RAOs and reduce contaminant concentrations down to PCGs. The community and the environment will be protected during remediation by the Air Force maintaining control of the groundwater resource. Risks to workers will be minimized by these same measures and by following standard safety practices during construction and O&M.

Implementation of Alternative 6 at Site DP039 includes several provisions for sustainable remediation, including the following:

- **In situ bioreactor –** Placement of organic mulch, extraction well submersible pump powered by solar panels.
- **Phytoremediation –** An area of planted trees. Potential sustainable optimization actions include expanding the planted area and installing a solar-power irrigation system using contaminated groundwater.
- **EVO PRB –** Subsurface injection of food-grade vegetable oil.

The existing components of the Site DP039 GET IRA will be permanently discontinued after implementation of Alternative 6. Through the use of green technologies, the energy-intensive GET system components, including DPE wells, VGAC treatment at the WTTP, and GAC groundwater treatment at the CGWTP, can be replaced. More detailed information is provided in Appendix F.

8.6.8 Implementability

Alternative 6 is readily implementable. The existing IRA at Site DP039 has already been optimized by installation of a demonstration bioreactor in December 2008 and by injection of an EVO PRB during 2010. The phytoremediation study area was planted in 1998 as part of a treatability study. These actions will be easily incorporated into the final remedial action under this alternative.

Remedial construction activities associated with Alternative 6 have already been completed as optimizations to the existing IRAs. If modifications are required in the future, then specialized construction contractors and equipment are available. No schedule delays or technical problems are anticipated with supplemental injection of edible oil at the bioreactor or PRB. Potential future remedial actions would have to take the presence of these in situ treatment processes into consideration to prevent field activities that might limit their effectiveness.

Groundwater monitoring will be used to evaluate the effectiveness of in situ bioremediation and natural attenuation processes. Engineering evaluation and laboratory services are standard practices that are readily available.

Alternative 6 is also administratively implementable. Coordination with state and other federal agencies will continue following implementation of the alternative. Travis AFB is already implementing LUCs to restrict activities that could result in human exposure to contaminated groundwater. These existing LUCs will continue to be enforced by the Air Force to provide short-term and long-term protection from exposure to groundwater contamination.

8.6.9 Cost

At Site DP039, installation of an in situ bioreactor was conducted as a technology demonstration project in 2008. In 2010, an EVO PRB was installed at the site as part of IRA optimization. Each of these actions is incorporated into the estimate of Alternative 6 costs. The actual capital costs of bioreactor installation and injection of the EVO PRB are provided in Table 8-14. Historical capital costs for the 1998 planting of trees for the phytoremediation component of the alternative are not included in the estimate. More detailed descriptions of the basis of the cost estimate are provided in Appendix E.

TABLE 8-14
Estimated Costs for Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA[a]
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Alternative Components	Capital Cost	Annual O&M Cost	Present Value[b]
Bioreactor[c]	$0	$680	$171,204
EVO PRB/Phytoremediation/EA[d]	$0	$1,949	$1,006,414
Total	**$0**	**$2,629**	**$1,177,618**

[a] More detailed cost estimates are provided in Appendix E.
[b] Remediation timeframe estimates are provided in Appendix D.
[c] Actual capital cost incurred in 2010 was $86,827.
[d] Actual capital cost incurred in 2010 was $204,851.
[e] Total capital cost incurred in 2010 was $297,073.

8.6.10 Performance Enhancement Measures

The following subsections describe the approach to implementing performance enhancement measures if the performance of the Site DP039 bioreactor and/or EVO PRB does not meet performance expectations.

8.6.10.1 Bioreactor Performance Enhancement Measures

If performance monitoring identifies any unanticipated or adverse outcomes from the installation of the bioreactor, then the Air Force will evaluate and carry out performance enhancement measures to correct the deficiencies. The end result of these measures will be a return of the bioreactor's ability to remediate contaminated groundwater, a transition to a more effective remedial alternative, or the application of an additional remedial alternative in a downgradient location.

Potential adverse outcomes could include the following:

- Incomplete reductive dechlorination or transformation that stalls at cis-1,2-DCE and/or vinyl chloride
- Increases in concentrations of VOCs immediately downgradient of the bioreactor treatment zone
- Migration of contaminant plume/lack of plume stability

Potential performance enhancement measures for one (1) or more of these outcomes include the following, listed in ascending order of field effort:

- Increased monitoring
- Installation of additional monitoring wells
- Boosting dissolved organic carbon levels in the bioreactor recirculation water (e.g., adding vegetable oil or high fructose corn syrup into the existing distribution manifold).

- Bioaugmentation of the water circulated through the bioreactor (i.e., supplement native microbes with a proprietary microbial consortium [e.g., KB-1®] if the native microbes prove incapable of complete degradation of TCE through cis-1,2-DCE to non-toxic ethene)
- Expansion and restart of the Site DP039 source area GET system
- Implementation of another remedial technology

The Air Force and the regulatory agencies will base the selection of the appropriate performance enhancement measure(s) on the type and severity of the adverse outcome.

8.6.10.2 EVO PRB Performance Enhancement Measures

Similarly, if performance monitoring identifies any unanticipated or adverse outcomes from installation of the EVO PRB, then the Air Force will evaluate and carry out performance enhancement measures to correct the deficiencies. The end result of these measures will either be a return of the PRB's ability to remediate contaminated groundwater, a transition to a more effective remedial alternative, or the application of an additional remedial alternative in a downgradient location.

Potential outcomes could include the following:

- Increases in concentrations of VOCs immediately downgradient of the EVO PRB treatment zone
- Decrease in the permeability of the EVO PRB treatment zone, resulting in an upgradient pooling of contaminated groundwater
- Migration of contaminant plume/lack of plume stability
- Incomplete reductive dechlorination or transformation that stalls at cis-1,2-DCE or vinyl chloride

Potential performance enhancement measures for one (1) or more of these outcomes include the following, listed in ascending order of field effort:

- Increased monitoring
- Installation of additional monitoring wells
- Supplemental injection of EVO using existing PRB injection wells
- Installation of additional PRB injection wells
- Bioaugmentation (i.e., supplement native microbes with a proprietary microbial consortium [e.g., KB-1®] if the native microbes prove incapable of complete degradation of TCE through cis-1,2-DCE to non-toxic ethene)
- Installation of recirculation loops to allow additional residence time of contaminants within the PRB treatment zone. The recirculation system could potentially be extended to include the area of phytoremediation located hydraulically upgradient of the PRB.
- Expansion of the Site DP039 GET system.

Travis AFB will base the selection of the appropriate performance enhancement measure(s) on the type and severity of the adverse outcome.

8.7 Alternative 7 – Passive Skimming and EA

Alternative 7 involves continuing the intermittent removal of free-phase Stoddard solvent from the Site SD034 source area. Natural attenuation processes will be used in the non-source portions of the plume. The groundwater contaminant plume where Alternative 7 would be implemented is shown on Figure 7-1.

8.7.1 Components of the Alternative

Under Alternative 7, passive skimmers will be used to remove Stoddard solvent free product using the existing network of vertical extraction wells previously installed as part of the IRAs at each site. In the distal portions of the plumes, EA will be monitored to address dissolved-phase contamination.

From 1998 through 2004, active and passive skimmers were used at Site SD034 to remove floating Stoddard solvent from wells at the site. Since that time, passive skimmers have been periodically used as free product reappears in some of the source area wells. Through 2010, passive skimming has been intermittently conducted to remove floating Stoddard solvent from several of the source area wells.

Travis AFB will continue to enforce existing LUCs to prevent unauthorized exposure to contaminated groundwater. Base Civil Engineer Work Requests, excavation permits, and the requirements of the Base General Plan will continue to be enforced.

The provisions of the Base General Plan related to vapor intrusion mitigation will continue to be enforced. Installation of a vapor barrier and passive venting system may be required for future new building construction in proximity to a groundwater contaminant plume.

Performance monitoring will continue to be conducted under the GSAP.

Additional discussion regarding the lines of evidence for the viability of natural attenuation processes to remediate groundwater at Travis AFB is provided in Appendix C.

The methodologies used to estimate the time required to achieve PCGs under Alternative 7 are provided in Appendix D.

8.7.2 Detailed Evaluation

Alternative 7 combines source removal via passive skimming with natural attenuation processes to achieve RAOs at Site SD034.

8.7.2.1 Overall Protection of Human Health and the Environment

Alternative 7 will be protective of human health and the environment. The passive skimming technology used under this alternative has a high likelihood of being effective at removing free-phase Stoddard solvent. Contaminant volume and mass in the source areas will be reduced, and downgradient migration of dissolved-phase contamination will be reduced. The effectiveness of natural attenuation in the non-source areas of the plume will be enhanced by reducing contaminant migration into hydraulically downgradient portions of the plume.

Free-phase and dissolved-phase Stoddard solvent is limited to the Site SD034 source area. Other petroleum fuel constituents at Site SD034 are commingled with chlorinated VOCs from the surrounding Site SD037 (WIOU) plume. The existing Site SD034 monitoring wells will be incorporated into the monitoring of natural attenuation within the overall WIOU plume.

Existing LUCs will continue to be enforced to minimize human exposure to contamination until RAOs are achieved. Ongoing groundwater monitoring will be continued under the GSAP to evaluate the effectiveness of free product removal and natural attenuation processes.

8.7.2.2 Compliance with ARARs

Compliance with ARARs at Site SD034 will be achieved under Alternative 7. Chemical-specific ARARs (i.e., PCGs) are expected to be achieved within approximately 60 years. These treatment processes will comply with action-specific and location-specific ARARs.

8.7.2.3 Long-term Effectiveness and Permanence

Skimming operations to remove intermittent occurrences of floating product are effective and permanent. An extended time may be required to physically remove the remaining free-phase Stoddard solvent.

Natural attenuation processes are effective, reliable, and permanent. The site conditions at Travis AFB have demonstrated the capacity to support chlorinated VOC degradation through a combination of physical and, to lesser degrees, chemical and biological mechanisms (CH2M HILL, 2010a). The presence of hydrocarbons (Stoddard solvent) enhances chlorinated VOC degradation. Additional discussion of the viability of natural attenuation processes to remediate groundwater at Travis AFB is provided in Appendix C.

Alternative 7 will be effective over the long term as chlorinated VOCs degrade to non-regulated compounds such as ethene and ethane. These processes are irreversible.

Residual contamination in groundwater will not pose a risk to human health, because the existing LUCs will continue to be enforced to minimize human exposure. Residual risk from groundwater contamination is expected to decrease through chemical, physical, and biological processes. The effectiveness of the natural attenuation processes will continue to be evaluated through the existing GSAP.

8.7.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 7 – Passive Skimming and EA addresses the principal threats posed by groundwater contamination through a combination of two (2) technology processes: passive skimming and enhanced natural attenuation. Passive skimming will address free-phase Stoddard solvent floating on the groundwater table. Under the EA component of the alternative, natural attenuation processes will address the distal (i.e., non-source) portions of the plume. These natural processes will be enhanced by reducing the flux of contamination from the source area into the hydraulically downgradient portion of the plume. A summary of the performance of Alternative 7 against the criterion of reduction in toxicity, mobility, or volume of contaminants through treatment is provided in Table 8-15.

The remaining volume of free-phase Stoddard solvent will slowly be removed by passive skimming operations. The Stoddard solvent is not mobile. After more than a decade, the free product is limited to a location near the release point. Off-base recycling of the Stoddard solvent free product will partially satisfy the statutory preference for treatment as a principal element of the remedy.

Natural attenuation relies on chemical, physical, and biological processes to reduce contaminants in groundwater over time. Reduction in toxicity, mobility, and volume depends primarily on the rate of contaminant concentration reduction through physical, chemical, and biological processes. The degree of degradation will be monitored through the ongoing GSAP. No treatment residuals will be generated because no treatment agents will be used to facilitate the natural attenuation processes.

TABLE 8-15
Reduction of Toxicity, Mobility, or Volume through Treatment Under Alternative 7 – Passive Skimming and EA
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Analysis Factor	Considerations
Treatment process and remedy	Alternative 7 – Passive Skimming and EA addresses the principal threats posed by groundwater contamination through a combination of two (2) technology processes: passive skimming and natural attenuation. Passive skimming will address free-phase Stoddard solvent floating on the groundwater table. Under the EA component of the alternative, natural attenuation processes will address the distal (i.e., non-source) portions of the plume. These natural processes will be enhanced by reducing the flux of contamination from the source area into the hydraulically downgradient portion of the plume. Alternative 7 is applicable to Site SD034. This is the only site at Travis AFB with free-phase Stoddard solvent floating on the groundwater table.
Amount of hazardous material destroyed or treated	The passive skimming component of Alternative 7 will address the Stoddard solvent floating on the groundwater table. The remaining volume of free-phase Stoddard solvent will slowly be removed by passive skimming operations. The Stoddard solvent is not mobile. After more than a decade, the free product is limited to a location near the release point. During 2010, floating Stoddard solvent was found in only two (2) of the site monitoring wells at thicknesses of 0.12 and 0.44 feet.
Reduction in toxicity, mobility, or volume	The passive skimming component of the alternative will be used to remove floating product from wells as it intermittently reoccurs. Within the portion of plume outside of the floating Stoddard solvent, the physical, chemical, and biological processes of natural attenuation will address the remaining contamination. Over approximately a decade of MNA assessments at Travis AFB, natural attenuation processes demonstrated the capacity to destroy chlorinated VOC contaminants down to concentrations less than PCGs. During the period of assessment, the chlorinated solvent plumes typically decreased in both size and concentration or the plumes were stable and not migrating. The combination of Alternative 7 remedy processes irreversibly reduces the total mass of contaminants and the principal threats are thereby also reduced.

TABLE 8-15
Reduction of Toxicity, Mobility, or Volume through Treatment Under Alternative 7 – Passive Skimming and EA
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Analysis Factor	Considerations
Irreversibility of treatment	Passive skimming will be conducted to remove floating product from wells as it intermittently reoccurs. In that sense, the skimming process is reversible. The natural processes utilized under Alternative 7 – MNA are inherently irreversible.
Type and quantity of treatment residual	Under Alternative 7, no active treatment processes are employed. Therefore, no treatment residuals are generated. Stoddard solvent not removed by a passive skimming event will accumulate and be removed in the next skimming operation if it appears in the site monitoring wells. No active treatment processes are employed under the EA component of the alternative. Therefore, no treatment residuals are generated.
Statutory preference for treatment as a principal element	Are principal threats within the scope of the action? Is treatment used to reduce inherent hazards posed by principal threats at the site? Active treatment is not used under Alternative 7 – Passive Skimming and EA. Therefore, the statutory preference for treatment as a principal element of the remedy is not satisfied. However, physical removal of Stoddard solvent and intrinsic treatment of contaminants through natural processes will address the principal threats from the contaminants. Off-base recycling of the Stoddard solvent free product will only partially satisfy the statutory preference for treatment .

8.7.2.5 Short-term Effectiveness

Alternative 7 will provide short-term effectiveness. Free product removal activities are standard practice and pose few risks to workers or the community.

Natural attenuation is an effective means to reduce toxicity, mobility, volume, and mass over the long term. However, natural attenuation processes will likely require a longer time to achieve RAOs than a more aggressive, more costly, less efficient, and less sustainable treatment alternative. The estimated time required to achieve PCGs under Alternative 7 is 60 years.

Alternative 7 has no construction activities associated with the implementation of a program of natural attenuation monitoring. If any were to arise, they would typically be limited to the installation of monitoring wells. This activity poses minimal risk to workers, the community, and the environment.

8.7.2.6 Implementability

Alternative 7 is readily implemented at Travis AFB. During the period of interim remediation, free product removal and MNA assessments were successfully conducted at multiple sites. The results of the MNA assessments are provided in the NAAR (CH2M HILL, 2010a) and in Appendix C. No difficulties are anticipated in implementing passive skimming or MNA as components of a final groundwater remedy.

Potential remedial construction activities associated with the implementation of Alternative 7 are limited to the installation of monitoring wells. This action is easily implemented, with both equipment and technical specialists being readily available. No schedule delays or technical problems are anticipated. Potential future remedial actions would not likely be adversely affected by either passive skimming or natural attenuation monitoring.

Groundwater monitoring will be used to evaluate the effectiveness of natural attenuation. Engineering evaluation and laboratory services are standard practices that are readily available.

Alternative 7 is also administratively implementable. Coordination with state and other federal agencies would be limited to their review of the GSAP monitoring plans and natural attenuation evaluations. Also, Travis AFB is already enforcing LUCs to restrict activities that could result in human exposure to contaminated groundwater.

8.7.2.7 Cost

There are no additional capital costs associated with implementation of Alternative 7 at Site SD034. No additional wells are required. More detailed descriptions of the basis of the cost estimate are provided in Appendix E. The annual cost of passive skimming operations is approximately $2,042. Sampling and analysis costs for assessing plume stability and natural attenuation processes is about $1,613 per year.

8.7.2.8 Performance Enhancement Measures

The GET IRA systems within the WIOU, including Site SD034, were shut down for rebound studies during 2010. The contaminant plumes will continue to be monitored for the remainder of the period of interim remediation. Unless there is evidence of contaminant rebound, the GET systems will remain off. If rebound does occur, then the Air Force will evaluate resuming GET operations.

SECTION 9

Comparative Analysis of Alternatives

This section of provides a comparative analysis of the groundwater remedial alternatives developed in Sections 7 and 8 with the groundwater IRAs the Air Force has already implemented at each of the ERP groundwater sites.

9.1 Summary of Existing IRAs and Remedial Alternatives

A summary of the implemented groundwater IRAs and the remedial alternatives developed for each site in this FFS is provided in Table 9-1. More detailed summaries of the IRAs and alternatives are provided in Tables 9-2 and 9-3. These tables provide comparisons among the alternatives previously developed in the historical NEWIOU FS (Radian, 1996a), WABOU FS (CH2M HILL, 1998a), and those alternatives developed in the current FFS.

TABLE 9-1
Summary Comparison of Implemented Interim Remedial Actions and Remedial Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Implemented Interim Remedial Action[a]	Focused Feasibility Study Remedial Alternative
FT004, SD031, SD033[b]	GET and MNA Assessment	2 – MNA
FT005, LF008, SS035[b], SD043	GET	2 – MNA
LF006, LF007B, LF007D, ST027B	MNA Assessment	2 – MNA
LF007C, SS029, SS030	GET	3 – GET
SS015	MNA Assessment	5 – EVO and EA
SS016	GET	4 – Bioreactor and GET
SD034[b]	GET, Passive Skimming, and MNA Assessment	7 – Passive Skimming and EA
SD036[b] SD037[b]	GET and MNA Assessment	5 – EVO and EA
DP039	GET and MNA	6 – Bioreactor, Phytoremediation, EVO PRB, and EA
SS041	GET	1 – No Action

[a] Groundwater IRAs selected by the final NEWIOU Groundwater IROD (Travis AFB, 1998) and final WABOU Groundwater IROD (Travis AFB, 1999).
[b] Component site of WIOU collection of site plumes.

9.2 Comparative Analyses

The following subsections provide comparisons of the IRAs already implemented at each Travis AFB ERP site with the remedial alternative developed in this FFS.

9.2.1 Overall Protection of Human Health and the Environment

Overall protection of human health and the environment serves as a threshold determination that must be met by any alternative for it to be selected as a remedy. Each of the groundwater alternatives, except for Alternative 1 – No Action, is protective of human health and the environment. Comparisons of the relative performance of the remedial alternatives at each site against the Overall Protection of Human Health and the Environment evaluation criterion is provided in Table 9-4.

Each alternative uses administrative mechanisms of LUCs to restrict unauthorized access to contaminated groundwater and provide for additional overall protection of human health. These common administrative LUCs include the Base Civil Engineer Work Request, excavation permits, and the requirements of the Base General Plan. These LUCs provide a similar level of support for the criterion under each alternative.

For the off-base plumes at Sites LF007C, FT005, and SS030, an additional administrative LUC is the purchase of an easement to provide the Air Force a means to manage and control the use of private property overlying a groundwater plume originating from within the boundaries of Travis AFB. These off-base easements provide a similar level of support for the criterion and have already been purchased.

In accordance with the Base General Plan, future buildings constructed in proximity of a groundwater plume may require installation of a vapor barrier and passive venting system. These vapor intrusion mitigation measures will further support achievement of the overall protection of human health and the environment criterion and are similar for all the alternatives.

9.2.1.1 Alternative 1 – No Action

Alternative 1 is included as a baseline for comparison when no remedial action is taken at a site. This alternative provides no overall protection to human health and the environment.

Alternative 1 is applicable to Site SS041. This site is already in NFRAP status in accordance with the consensus statement signed by representatives of the lead and regulatory agencies (Travis AFB, 2005).

9.2.1.2 Alternative 2 – MNA

In comparison to the IRAs at each site, Alternative 2 will provide continued overall protection of human health and the environment at Sites FT004, FT005, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, SS035, and SD043.

Alternative 2 provides a similar degree of protectiveness compared with the other alternatives that include active components. Natural attenuation processes have demonstrated effectiveness at remediating groundwater contamination at Travis AFB (refer to Appendix C).

TABLE 9-2
Comparison of Historical and Current NEWIOU Sites Alternative Development
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

<table>
<tr><th>Site</th><th>Alternatives Developed in the NEWIOU FS[a]</th><th>Alternatives Evaluated in the NEWIOU FS[a]</th><th>Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]</th><th>Alternatives Developed in the FFS</th><th>Alternatives Evaluated in the FFS</th><th>Preferred Alternative in the FFS</th></tr>
<tr><td>FT004</td><td rowspan="4">1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain
9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>3 – Extraction, Treatment, and Discharge (GET)</td><td rowspan="4">1 – No Action
2 – MNA
3 – GET
4 – Bioreactor and GET
5 – EVO and EA
6 – Bioreactor, Phytoremediation, EVO PRB, and EA
7 – Passive Skimming and EA</td><td>1 – No Action
2 – MNA
3 – GET</td><td>2 – MNA</td></tr>
<tr><td>FT005</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>3 – Extraction, Treatment, and Discharge (GET)</td><td>1 – No Action
2 – MNA
3 – GET</td><td>2 – MNA</td></tr>
<tr><td>LF006</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA</td><td>1 – No Action
2 – MNA
3 – GET</td><td>2 – MNA</td></tr>
<tr><td>LF007B</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment</td><td>1 – No Action
2 – MNA
3 – GET</td><td>2 – MNA</td></tr>
</table>

TABLE 9-2
Comparison of Historical and Current NEWIOU Sites Alternative Development
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Alternatives Developed in the NEWIOU FS[a]	Alternatives Evaluated in the NEWIOU FS[a]	Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]	Alternatives Developed in the FFS	Alternatives Evaluated in the FFS	Preferred Alternative in the FFS
LF007C	1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain 9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation	1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA Assessment (on-base plume) 3 – Extraction, Treatment, and Discharge (GET) (Base boundary and off-base plume)	1 – No Action 2 – MNA 3 – GET 4 – Bioreactor and GET 5 – EVO and EA 6 – Bioreactor, Phytoremediation, EVO PRB, and EA 7 – Passive Skimming and EA	1 – No Action 2 – MNA 3 – GET	3 – GET
LF007D		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA Assessment		1 – No Action 2 – MNA 3 – GET	2 – MNA
SS015		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	2 – MNA Assessment		1 – No Action 2 – MNA 3 – GET 4 – Bioreactor and GET 5 – EVO and EA	5 – EVO and EA
SS016		1 – No Action 2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation 3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain 7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain	3 – Extraction, Treatment, and Discharge (GET)		1 – No Action 2 – MNA 3 – GET 4 – Bioreactor and GET	4 – Bioreactor and GET

TABLE 9-2
Comparison of Historical and Current NEWIOU Sites Alternative Development
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

<table>
<tr><th>Site</th><th>Alternatives Developed in the NEWIOU FS[a]</th><th>Alternatives Evaluated in the NEWIOU FS[a]</th><th>Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]</th><th>Alternatives Developed in the FFS</th><th>Alternatives Evaluated in the FFS</th><th>Preferred Alternative in the FFS</th></tr>
<tr><td>ST027B[c]</td><td rowspan="5">1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain
9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation</td><td></td><td></td><td rowspan="5">1 – No Action
2 – MNA
3 – GET
4 – Bioreactor and GET
5 – EVO and EA
6 – Bioreactor, Phytoremediation, EVO PRB, and EA
7 – Passive Skimming and EA</td><td>1 – No Action
2 – MNA
3 – GET</td><td>2 – MNA</td></tr>
<tr><td>SS029</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>3 – Extraction, Treatment, and Discharge (GET)</td><td>1 – No Action
2 – MNA
3 – GET</td><td>3 – GET</td></tr>
<tr><td>SS030</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment
3 – Extraction, Treatment, and Discharge (GET)</td><td>1 – No Action
2 – MNA
3 – GET</td><td>3 – GET</td></tr>
<tr><td>SD031</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain Oxidation</td><td>2 – MNA Assessment
3 – Extraction, Treatment, and Discharge (GET)</td><td>1 – No Action
2 – MNA
3 – GET</td><td>2 – MNA</td></tr>
<tr><td>SD033</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment (South Gate Area, Facility 1917, and Facility 810 plumes)
3 – Extraction, Treatment, and Discharge (GET) (storm sewer)</td><td>1 – No Action
2 – MNA
3 – GET</td><td>2 – MNA</td></tr>
</table>

TABLE 9-2
Comparison of Historical and Current NEWIOU Sites Alternative Development
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

<table>
<tr><th>Site</th><th>Alternatives Developed in the NEWIOU FS[a]</th><th>Remedial Alternatives Evaluated for the Site in the NEWIOU FS[a]</th><th>Remedial Alternatives Selected in the NEWIOU Proposed Plan/IROD[b]</th><th>Alternatives Developed in the Basewide Groundwater FFS</th><th>Alternatives Evaluated in the FFS</th><th>Preferred Alternative in the FFS</th></tr>
<tr><td>SD034</td><td rowspan="4">1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain
9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
9 – Vertical Well Extraction, Bioslurping, Recovered Product Recycling, Off Gas Catalytic Oxidation</td><td>3 – Extraction, Treatment, and Discharge (GET)
(Bioslurp/free product removal and coordination with Site SD037 alternative)</td><td rowspan="4">1 – No Action
2 – MNA
3 – GET
4 – Bioreactor and GET
5 – EVO and EA
6 – Bioreactor, Phytoremediation, EVO PRB, and EA
7 – Passive Skimming and EA</td><td>1 – No Action
2 – MNA
3 – GET
7 – Passive Skimming and EA</td><td>7 – Passive Skimming and EA</td></tr>
<tr><td>SS035</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
4 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Activated Carbon, Discharge to Irrigation and/or Storm Drain
6 – Horizontal Well Extraction, UV/Ox, Activated Carbon, Discharge to Irrigation and/or Storm Drain
8 – Horizontal Well Extraction, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment</td><td>1 – No Action
2 – MNA
3 – GET</td><td>2 – MNA</td></tr>
<tr><td>SD036</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>3 – Extraction, Treatment, and Discharge (GET)</td><td>1 – No Action
2 – MNA
3 – GET
5 – EVO and EA</td><td>5 – EVO and EA</td></tr>
<tr><td>SD037</td><td>1 – No Action
2 – Institutional Action: Access Restrictions, Monitoring, Natural Attenuation
3 – Horizontal Well Extraction, Air Stripper/Catalytic Oxidation, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
5 – Horizontal Well Extraction, UV/Ox, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain
7 – Horizontal Well Extraction, Ion Exchange, Activated Carbon, Discharge to Irrigation and/or Storm Drain</td><td>2 – MNA Assessment
(portions of plume near Facilities 919, 977, 981, and Area G Ramp)
3 – Extraction, Treatment, and Discharge (GET)
(portions of plume near Facilities 837, 838, and Ragsdale/V Area and the remainder of plume)</td><td>1 – No Action
2 – MNA
3 – GET
5 – EVO and EA</td><td>5 – EVO and EA</td></tr>
</table>

[a] Source: Final NEWIOU FS (Radian, 1996a).
[b] Source: Final Groundwater IROD for the NEWIOU (Travis AFB, 1998).
[c] Historically managed under the POCO program and not addressed in either the Groundwater IROD for the NEWIOU or Groundwater IROD for the WABOU.

TABLE 9-3
Comparison of Historical and Current WABOU Sites Alternative Development
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Alternatives Developed in the WABOU FS[a]	Alternatives Evaluated in the WABOU FS[a]	Alternatives Selected in the WABOU Proposed Plan/IROD[b]	Alternatives Developed in the FFS	Alternatives Evaluated in the FFS	Preferred Alternative in the FFS
LF008	G1 – No Action G2 – MNA G3 – Containment/Treatment/Discharge (GET) G4 – Extraction/Treatment/Discharge (GET) G5 – Source Area and Groundwater Extraction/Treatment/MNA G6 – Source Area Extraction/Treatment/MNA	G1 – No Action G2 – Natural Attenuation G3 – Containment, Treatment, Discharge G4 – Extraction, Treatment, Discharge	G4 – Extraction, Treatment, Discharge (GET)	1 – No Action 2 – MNA 3 – GET 4 – Bioreactor and GET 5 – EVO and EA 6 – Bioreactor, Phytoremediation, EVO PRB, and EA 7 – Passive Skimming and EA	1 – No Action 2 – MNA 3 – GET	2 – MNA
DP039		G1 – No Action G2 – Natural Attenuation G3 – Containment, Treatment, Discharge (GET) G4 – Extraction, Treatment, Discharge (GET) G5 – Source Area Extraction, Treatment, Natural Attenuation G6 – Source Area Containment, Treatment, Natural Attenuation	G3 – Containment, Treatment, Discharge (GET) G5 – Source Area and Groundwater Extraction, Treatment, MNA (GET and MNA)		1 – No Action 2 – MNA 3 – GET 6 – Bioreactor, Phytoremediation, EVO PRB, and EA	6 – Bioreactor, Phytoremediation, EVO PRB, and EA
SS041		G1 – No Action G2 – Natural Attenuation G3 – Containment, Treatment, Discharge (GET)	G3 – Containment, Treatment, Discharge (GET)		1 – No Action 2 – MNA 3 – GET	1 – No Action[c]
SD043		G1 – No Action G2 – Natural Attenuation G3 – Containment, Treatment, Discharge (GET)	G3 – Containment, Treatment, Discharge (GET)		1 – No Action 2 – MNA 3 – GET	2 – MNA

[a] Source: Final WABOU FS (CH2M HILL, 1998a).
[b] Source: Final Groundwater IROD for the WABOU (Travis AFB, 1999).
[c] Site SS041 is currently in NFRAP status.

TABLE 9-4
Summary of Comparative Analysis of Alternative – Overall Protection of Human Health and the Environment
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Remedial Alternative	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
1 – No Action	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○
2 – MNA	■	■	■	■	□	■	■	□	□	■	□	□	■	■	□	■	□	□	□	○	■
3 – GET	■	■	■	■	■	■	◙	◙	◙	■	■	■	◙	◙	◙	■	◙	◙	◙	○	■
4 – Bioreactor and GET	○	○	○	○	○	○	○	□	■	○	○	○	○	○	○	○	○	○	◙	○	○
5 – EVO and EA	○	○	○	○	○	○	○	■	○	○	○	○	○	○	○	○	■	■	◙	○	○
6 – Bioreactor, Phytoremediation, EVO PRB, and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○
7 – Passive Skimming and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○	○	○	○	○

■ Alternative that best satisfies the Overall Protection of Human Health and the Environment criterion.
◙ Alternative that moderately satisfies the Overall Protection of Human Health and the Environment criterion.
□ Alternative that poorly satisfies the Overall Protection of Human Health and the Environment criterion.
○ Alternative that is not applicable or does not satisfy the Overall Protection of Human Health and the Environment criterion.

Overall protectiveness of human health and the environment will be maintained following implementation of Alternative 2. During the period of interim remediation, active GET systems successfully operated at Sites FT004, FT005, LF008, SD031, SD033, SS035, and SD043. These GET systems performed well and reduced plume concentrations and contaminant mass. However, over time, the energy-intensive GET systems became less efficient and cost-effective as plume concentrations decreased. As a consequence, these GET systems were shut down during 2010 and are being monitored under rebound studies for the remainder of the period of interim remediation. During 2010, contaminant rebound in portions of the Site FT005 plume resulted in partially resuming groundwater extraction at selected extraction wells. The Air Force will continue to evaluate data obtained during the rebound studies at each site for the remainder of the period of interim remediation.

At Sites LF006, LF007B, LF007D, and ST027B, no active IRA was implemented during the period of interim remediation. Groundwater contamination at each of these sites was monitored during a period of MNA assessment (CH2M HILL, 2010a). Groundwater monitoring and LUCs will continue under Alternative 2, and overall protectiveness will be maintained.

At Sites LF007C, SS015, SS016, SS029, SS030, SD034, SD036, SD037, and DP039, Alternative 2 would not provide the same degree of overall protectiveness as Alternatives 3, 4, 5, 6, and 7. A brief description of the key rationale is provided in following list:

- **Sites LF007C and SS030 –** The majority of the contaminant plume is located off-base. A more aggressive approach to plume remediation is warranted to maintain protectiveness (i.e., Alternative 3 – GET).
- **Site SS015 –** An assessment of MNA conducted during the period of interim remediation was not positive. More aggressive source area remediation is needed to maintain overall protectiveness (i.e., Alternative 5 – EVO and EA).
- **Site SS016 –** High source area concentrations indicate the presence of DNAPLs. Natural processes by themselves are considered inadequate to maintain overall protection of human health and the environment (i.e., Alternative 4 – Bioreactor and GET).
- **Site SS029 –** The contaminant plume is flowing with the natural hydraulic gradient towards the Base boundary. Natural attenuation processes would not prevent the plume from migrating off-base. A more aggressive approach is required (i.e., Alternative 3 – GET).
- **Site SD034 –** This is the only site at Travis AFB with free-phase Stoddard solvent floating on the groundwater table. The processes of MNA would not provide for overall protection of human health and the environment with this kind of contamination. An alternative that can directly address the floating product is needed (i.e., Alternative 7 – Passive Skimming and EA).
- **Sites SD036, SD037, and DP039 –** High source area concentrations indicate the presence of DNAPLs. Natural processes by themselves are considered inadequate to maintain overall protection of human health and the environment. An approach using source area treatment is needed (i.e., Alternative 5 – EVO and EA and Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA).

In the event that the natural attenuation processes under Alternative 2 ultimately prove incapable of maintaining overall protection of human health and the environment, then Alternative 3 – GET could be implemented at one (1) or more of the sites to maintain a comparable degree of overall protection.

GET System IRA Sites. At Sites FT004, FT005, LF008, SD031, SD033, SS035, and SD043, implementation of Alternative 2 – MNA follows approximately a decade of interim remediation using GET. The GET IRA systems at these sites were shut down for rebound studies during 2010. These contaminant plumes will continue to be monitored for the remainder of the period of interim remediation. Unless there is evidence of contaminant rebound, the GET systems will remain off. The IRA GET systems at these sites still exist. If rebound does occur or if plume migration is confirmed over a 2-year period, then the Air Force will evaluate resuming GET operations under Alternative 3 to maintain overall protection of human health and the environment.

MNA and MNA Assessment IRA Sites. For Sites LF006, LF007B, and LF007D, MNA or MNA assessment was the IRA specified in the NEWIOU IROD. After approximately a decade of interim remediation, the NAAR concluded that natural attenuation of the plumes was effective (refer to Appendix C). A status summary for each of these sites is provided in the following list:

- **Site LF006 –** Natural attenuation processes have already reduced contaminant concentrations to less than the PCGs. No other action is likely to be required at this site. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining overall protection of human health and the environment.
- **Site LF007B –** Natural attenuation processes have already reduced contaminant concentrations to less than the PCGs. No other action is likely to be required at this site. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining overall protection of human health and the environment.
- **Site LF007D –** Low concentrations of benzene (3 µg/L vs. PCG of 1 µg/L) and 1,4-dichlorobenzene (12.6 µg/L vs. PCG of 5 µg/L) were detected in the 2010 GSAP. Concentrations of 1,4-dichlorobenzene have been decreasing over time. Concentrations of benzene have remained stable. The plume size is small and limited to the vicinity of monitoring well MW261x07 (refer to Figure 3.2-12). Use of an active treatment technology, such as GET, is not warranted under these conditions. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining overall protection of human health and the environment.

Former POCO Site. Site ST027B was formerly managed under the POCO program. A portion of the site with CERCLA contamination is designated as Site ST027B. The site is located within the flightline and is bounded by aircraft parking ramps and taxiways. Use of an active treatment technology is unlikely to be needed under these conditions and would have implementability problems because of the proximity to airfield operations. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining overall protection of human health and the environment.

Alternative 2 – MNA would likely not be effective at addressing the *current* contaminant conditions at Sites LF007C, SS016, SS029, and SS030 and maintaining overall protection of human health and the environment. The conditions at these sites are currently more applicable to Alternative 3 – GET. However, MNA is potentially applicable to *future* contaminant conditions after the current contaminant concentrations have been reduced by several years of groundwater extraction and treatment. At that time, continued progress toward RAOs and maintaining overall protection of human health and the environment may be achieved by transitioning from the active remedy to a program of MNA. In the future, sites with an EA remedy component under Alternatives 5, 6, and 7 can readily be transitioned to a full-plume program of MNA under Alternative 2. At Sites SS015, SD034, SD036, SD037, and DP039, natural attenuation monitoring programs will already be implemented in the distal portions of the plumes. These monitoring programs can be expanded to address the entirety of the plume following successful remediation of the source areas.

9.2.1.3 Alternative 3 – GET

Under Alternative 3, the existing GET systems at Sites LF007C, SS029, and SS030 will continue operation. Alternative 3 will thereby continue to provide overall protection of human health and the environment.

During the period of interim remediation, Travis AFB successfully used GET to hydraulically control and remove contaminant mass from several sites, including Sites LF007C, SS029, and SS030. These GET systems performed well and reduced plume concentrations and contaminant mass (CH2M HILL, 2008a). The components of the Site LF007C, SS029, and SS030 GET systems will be retained and incorporated into Alternative 3 to maintain overall protectiveness.

Travis AFB will continue to enforce existing LUCs to prevent unauthorized exposure to contaminated groundwater. Performance monitoring will continue to be conducted under the GSAP.

In the future, Alternative 3 could be implemented to maintain overall protection of human health and the environment at the sites currently found applicable to Alternative 2 – MNA; Alternative 4 – Bioreactor and GET; Alternative 5 – EVO and EA; Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA; and Alternative 7 – Passive Skimming and EA. If one (1) or more of these alternatives ultimately prove incapable of maintaining overall protection of human health and the environment, then Alternative 3 can be implemented. The sites where Alternative 3 may be potentially applicable under future conditions are summarized in the following list:

- **Sites FT004, FT005, LF008, SD031, SD033, and SD043 –** IRA GET systems exist at these sites. Under potential future conditions, active remediation using these systems can be resumed under Alternative 3 if natural attenuation processes do not maintain protectiveness under Alternative 2. Resumed GET system operation will provide for a similar degree of overall protection of human health and the environment.
- **Sites LF006, LF007B, and LF007D –** No IRA GET systems exist at these sites. However, Alternative 3 – GET may be implemented in the future if MNA processes under Alternative 2 prove incapable of maintaining overall protection of human health and the environment. A new GET system would be required at each site. Implementing GET

system operation will provide a similar degree of overall protection of human health and the environment.

- **Site ST027B –** Alternative 3 – GET may be implemented in the future at this site if MNA processes under Alternative 2 ultimately prove incapable of maintaining overall protection of human health and the environment. A new GET system would be required. Implementing GET system operation will provide a similar degree of overall protection of human health and the environment.

- **Site SS016 –** If the combination of an in situ bioreactor and GET under Alternative 4 proves incapable of maintaining overall protection of human health and the environment, then Alternative 3 could be implemented in the future. The existing IRA GET system could be expanded. Performance data obtained during the period of interim remediation indicate that GET operations within contaminant source areas become increasingly inefficient over time because of the diffusion-dominated silt and clay lithology present at Travis AFB. Therefore, resuming source area extraction in the diffusion-dominated lithology present at the site will limit the overall protectiveness of a GET system. Contamination will be increasingly difficult to remove over time and will likely reach asymptotic concentrations.

- **Sites SS015, SD036, and SD037 –** If source area EVO injection combined with EA under Alternative 5 ultimately proves incapable of maintaining overall protection of human health and the environment, then Alternative 3 can be implemented in the future. Operation of the IRA GET systems at Sites SD036 and SD037 could be resumed. A new GET system would be required at Site SS015. Performance data obtained during the period of interim remediation indicate that GET operations within contaminant source areas become increasingly inefficient over time because of the diffusion-dominated silt and clay lithology present at Travis AFB. This will limit the overall protectiveness of a GET system in comparison with in situ source area ERD treatment under Alternative 5.

- **Site DP039 –** If the Alternative 6 combination of an in situ bioreactor, phytoremediation, an EVO PRB, and EA ultimately proves incapable of maintaining overall protection of human health and the environment, then Alternative 3 can be implemented in the future. The circumstances at Site DP039 are complex with the multiple alternative components. But if these components are not protective, then the existing IRA GET system could be expanded. Resuming GET system operation under this potential future condition would provide a similar degree of overall protection of human health and the environment.

- **Site SD034 –** If the combination of passive skimming and EA under Alternative 7 ultimately proves incapable of maintaining overall protection of human health and the environment, then Alternative 3 can be implemented in the future. Operation of the IRA GET system can be resumed and achieve a similar level of overall protectiveness.

9.2.1.4 Alternative 4 – Bioreactor and GET

In comparison with the current IRA GET system, Alternative 4 will continue to provide overall protection of human health and the environment at Site SS016.

Interim Remedial Action. During the period of interim remediation, a strategy of source area groundwater extraction was used at Site SS016. The GET system included the following components:

- 2-Phase® soil vapor and groundwater extraction within the OSA source area
- ThOx treatment of soil vapor
- Horizontal and vertical well groundwater extraction within the OSA source area
- Horizontal well groundwater extraction within the TARA source area
- UV/Ox treatment of extracted groundwater at the CGWTP

The Site SS016 IRA was optimized during 2010. The scope of the optimization included the following:

- Discontinuing 2-Phase® soil vapor and groundwater extraction within the OSA source area
- Discontinuing ThOx treatment of soil vapor
- Installing an in situ bioreactor within the OSA source area
- Modifying horizontal well groundwater extraction within the OSA source area to create a recirculation loop through the bioreactor
- Continuing vertical well groundwater extraction within the OSA source area
- Continuing horizontal well groundwater extraction within the TARA source area
- Replacing UV/Ox treatment of groundwater at the CGWTP with LGAC treatment

Prior to bioreactor installation, operation of OSA 2-Phase® extraction well TPE-W was discontinued because of limited effectiveness and high O&M costs. Also, soil vapor and groundwater extraction technologies oxygenate the aquifer and are incompatible with the anaerobic ERD processes used by the bioreactor. After discontinuing operation of TPE-W, soil vapor treatment became unnecessary, so the energy-intensive and costly treatment process was also discontinued.

An in situ bioreactor was installed within the OSA source area to treat the highest levels of contamination. Groundwater from existing horizontal extraction well EW003x16 was re-routed to circulate through the bioreactor using a solar-powered pump.

Extracted groundwater was formerly treated at the CGWTP using UV/Ox. This energy-intensive and relatively high-maintenance treatment process was replaced with LGAC.

Alternative 4. Several components of the optimized Site SS016 GET system will be retained and incorporated into Alternative 4 to maintain overall protectiveness. These retained components include the following:

- An in situ bioreactor
- Three (3) horizontal extraction wells
- Two (2) vertical extraction wells
- Groundwater treatment at the CGWTP

After installation of the bioreactor within the OSA source area, the continuing source of TCE contamination into the hydraulically downgradient portions of the Site SS016 plume was greatly reduced and protectiveness enhanced. The portion of the plume that is hydraulically downgradient of the OSA bioreactor will continue to be partly addressed by vertical groundwater extraction wells EW605x16 and EW610x16.

Groundwater extraction within the TARA portion of Site SS016 will be continued under Alternative 4 using the two (2) existing horizontal extraction wells, EW001x16 and EW002x16.

The downgradient portion of the Site SS016 plume not hydraulically captured by the OSA component of the GET system (EW605x16 and EW610x16) and the TARA component of the GET system (EW001x16 and EW002x16) will eventually be hydraulically captured by the Site SS029 GET system.

Groundwater removed by extraction wells EW605x16, EW610x16, EW001x16, and EW002x16 will continue to be treated using LGAC at the CGWTP. Treated groundwater will continue to be discharged into the stormwater drainage system.

Travis AFB will continue to enforce existing LUCs to prevent unauthorized exposure to contaminated groundwater. Performance monitoring will continue to be conducted under the GSAP.

Alternative 4 – Bioreactor and GET is applicable to the specific conditions at Site SS016. This site is adjacent to an area of active military airfield operations. Most of the plume underlies active aircraft parking aprons, taxiways, and runways. Under these site conditions, the degree of overall protection of human health and the environment afforded under Alternative 4 is considered greater than that achievable under Alternatives 1, 2, 3, 5, 6, and 7.

In the event that Alternative 4 ultimately proves incapable of maintaining overall protection of human health and the environment, then the Air Force will evaluate expanding the GET component of the alternative to improve protectiveness.

9.2.1.5 Alternative 5 – EVO and EA

Compared with the site-specific IRAs, Alternative 5 will provide improved overall protection of human health and the environment at Sites SS015, SD036, and SD037.

At each of the sites under Alternative 4, EVO injection in the contaminant source areas will reduce the highest concentrations of contamination via ERD processes. After source area treatment, the remainder of the plume will be remediated by natural attenuation processes.

Travis AFB will continue to enforce existing LUCs to prevent unauthorized exposure to contaminated groundwater. Performance monitoring will continue to be conducted under the GSAP.

Alternative 5 – EVO and EA is applicable to the specific conditions at Sites SS015, SD036, and SD037. Both of the two (2) alternative components are also components of Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA. Similar degrees of overall protection are provided by both alternatives.

In the event that Alternative 5 ultimately proves incapable of maintaining overall protection of human health and the environment, then the Air Force will evaluate installing a new GET system to maintain overall protectiveness.

9.2.1.6 Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA

Compared with the GET and MNA Assessment at Site DP039, Alternative 6 will provide improved overall protection of human health and the environment. Comparisons of the estimates of the time required to achieve PCGs under the current IRA and Alternative 6 are developed in Appendix D.

Interim Remedial Action. During the period of interim remediation, a strategy of source area groundwater extraction combined with MNA assessment was used at Site DP039. The GET system included the following components:

- Dual-phase soil vapor and groundwater extraction within the source area
- VGAC treatment of soil vapor at the WTTP
- UV/Ox treatment of extracted groundwater at the CGWTP
- Groundwater monitoring to assess the performance of MNA in the distal portion of the plume

In addition to these IRA components, a phytoremediation study was initiated in 1998 to evaluate the effectiveness of planted trees at removing chlorinated VOCs from the groundwater.

The Site DP039 IRA was optimized between 2008 and 2010. The scope of the optimization included the following:

- Discontinuing DPE within the source area
- Discontinuing VGAC treatment of soil vapor at the WTTP
- Discontinuing groundwater treatment at the CGWTP
- Excavating the source area and installing an in situ bioreactor
- Modifying groundwater extraction within the source area to create a recirculation loop through the bioreactor
- Installing an EVO PRB hydraulically downgradient of the area of phytoremediation
- Groundwater monitoring to evaluate natural attenuation processes in the distal portions of the plume.

Prior to bioreactor installation, DPE was discontinued because of limited effectiveness and high O&M costs. Also, soil vapor and groundwater extraction technologies oxygenate the aquifer and are incompatible with the anaerobic ERD processes used by the bioreactor. After discontinuing operation of the DPE wells, soil vapor treatment became unnecessary and the treatment at the WTTP was also discontinued.

An in situ bioreactor was installed within the Site DP039 source area. Groundwater from an existing extraction well was re-routed to circulate through the bioreactor using a solar-powered pump.

Alternative 6. Several components of the optimized Site DP039 IRA system will be retained and incorporated into Alternative 6 to maintain overall protectiveness. These retained components include the following:

- An in situ bioreactor
- Area of phytoremediation
- EVO PRB
- Network of monitoring wells used to evaluate natural attenuation processes

After installation of the source area bioreactor, the continuing source of TCE contamination into the hydraulically downgradient portions of the Site DP039 plume was greatly reduced and protectiveness enhanced. The portion of the plume that is hydraulically downgradient of the bioreactor will continue to be partly addressed by the area of phytoremediation and partly by the EVO PRB. The remainder of the plume will be remediated by natural attenuation processes enhanced by the source remediation components of the alternative.

In the event that Alternative 6 ultimately proves incapable of maintaining overall protection of human health and the environment, then the Air Force will evaluate installing a new GET system to maintain overall protectiveness. The existing network of underground conveyance pipes, power supply, and control wiring installed as part of the IRA could be modified for this GET system.

9.2.1.7 Alternative 7 – Passive Skimming and EA

Implementation of Alternative 7 will continue to provide overall protection of human health and the environment at Site SD034. Operation of the existing IRA GET system will be discontinued. The passive skimming and natural attenuation components of the IRA will be continued to maintain protectiveness. Comparisons of the estimates of the time required to achieve PCGs under the current IRA and Alternative 7 are developed in Appendix D.

The passive skimming technology used under the IRA and Alternative 7 has a high likelihood of being effective at removing free-phase Stoddard solvent. Contaminant volume and mass in the source areas will be reduced, and downgradient migration of dissolved-phase contamination will be reduced. The effectiveness of natural attenuation in the non-source areas of the plume will be enhanced by reducing contaminant migration into hydraulically downgradient portions of the plume.

Site SD034 is a component site of the overall WIOU plume. Free-phase and dissolved-phase Stoddard solvent is limited to the Site SD034 source area. Other petroleum fuel constituents at Site SD034 are commingled with chlorinated VOCs from the surrounding Site SD037 (WIOU) plume. The existing Site SD034 monitoring wells will be incorporated into the monitoring of natural attenuation processes within the overall WIOU plume. The remediation timeframe for Site SD034 and the overall WIOU plume under the FFS alternatives are improved in comparison with the existing IRAs because of the source remediation actions.

Existing LUCs will continue to be enforced to minimize human exposure to contamination until RAOs are achieved. Ongoing groundwater monitoring will be continued under the GSAP to evaluate the effectiveness of free product removal and natural attenuation processes.

In the event that Alternative 7 ultimately proves incapable of maintaining overall protection of human health and the environment, then the Air Force will evaluate installing a vacuum-enhanced free product removal system and an expanded GET system to maintain overall protectiveness.

9.2.2 Compliance with ARARs

Compliance with ARARs also serves as a threshold determination that must be met by any alternative for it to be selected as a remedy. Each of the groundwater alternatives, except for Alternative 1 – No Action, will comply with ARARs. Comparisons of the performance of the remedial alternatives at each site against the Compliance with ARARs evaluation criterion is provided in Table 9-5.

Each alternative uses administrative mechanisms of LUCs to restrict unauthorized access to contaminated groundwater and provide for additional compliance with ARARs. These common administrative LUCs include the Base Civil Engineer Work Request, excavation permits, and the requirements of the Base General Plan. These LUCs provide a similar level of support for the criterion under each alternative.

For the off-base plumes at Sites LF007C, FT005, and SS030, an additional administrative LUC is the purchase of an easement to provide the Air Force a means to manage and control the use of private property overlying a groundwater plume originating from within the boundaries of Travis AFB. These off-base easements provide a similar level of support for the criterion and have already been purchased. In accordance with the Base General Plan, future buildings constructed in proximity of a groundwater plume may require installation of a vapor barrier and passive venting system. These vapor intrusion mitigation measures will further support achievement of the compliance with ARARs criterion and are similar for all alternatives.

9.2.2.1 Alternative 1 – No Action

Under Alternative 1, groundwater contamination may eventually achieve chemical-specific ARARs. But because no monitoring will take place, there will be no act of compliance with ARARs. Compliance with ARARs is a threshold criterion. Because No Action does not satisfy this criterion, then No Action is not eligible for selection.

9.2.2.2 Alternative 2 – MNA

The processes of natural attenuation will eventually achieve compliance with chemical-specific ARARs. These processes have demonstrated effectiveness at remediating groundwater contamination at Travis AFB (refer to Appendix C). The potential installation of groundwater monitoring wells will meet location-specific ARARs. The existing well networks are adequate to monitor natural attenuation processes.

Action-specific ARARs specific to groundwater monitoring programs associated with corrective actions should be met with little difficulty.

In the event that the natural attenuation processes under Alternative 2 ultimately prove incapable of maintaining compliance with ARARs, then Alternative 3 – GET could be implemented at one (1) or more of the sites to maintain a similar degree of ARARs compliance.

TABLE 9-5
Summary of Comparative Analysis of Alternatives – Compliance with ARARs
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Remedial Alternative	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
1 – No Action	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○
2 – MNA	■	■	■	■	□	■	■	□	□	■	□	□	■	■	□	■	□	□	□	○	■
3 – GET	■	■	■	■	■	■	□	◙	◙	■	■	■	■	■	■	■	◙	◙	◙	○	■
4 – Bioreactor and GET	○	○	○	○	○	○	○	□	■	○	○	○	○	○	○	○	○	○	◙	○	○
5 – EVO and EA	○	○	○	○	○	○	○	■	○	○	○	○	○	○	○	○	■	■	◙	○	○
6 – Bioreactor, Phytoremediation, EVO PRB, and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○
7 – Passive Skimming and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○	○	○	○	○

■ Alternative that best satisfies the Compliance with ARARs criterion.
◙ Alternative that moderately satisfies the Compliance with ARARs criterion.
□ Alternative that poorly satisfies the Compliance with ARARs criterion.
○ Alternative that is not applicable or does not satisfy the Compliance with ARARs criterion.

GET System IRA Sites. At Sites FT004, FT005, LF008, SD031, SD033, SS035, and SD043, implementation of Alternative 2 – MNA follows approximately a decade of interim remediation using GET. The GET IRA systems at these sites were shut down for rebound studies during 2010. These contaminant plumes will continue to be monitored for the remainder of the period of interim remediation. Unless there is evidence of contaminant rebound, the GET systems will remain off. The IRA GET systems at these sites still exist. If rebound does occur or if plume migration is confirmed over a 2-year period, then the Air Force will evaluate resuming GET operations under Alternative 3 to maintain compliance with ARARs.

MNA and MNA Assessment IRA Sites. For Sites LF006, LF007B, and LF007D, MNA or MNA assessment was the IRA specified in the NEWIOU IROD. After approximately a decade of interim remediation, the NAAR concluded that natural attenuation of the plumes was effective (refer to Appendix C). A status summary for each of these sites is provided in the following list:

- **Site LF006 –** Natural attenuation processes have already reduced contaminant concentrations to less than the PCGs. No other action is likely to be required at this site. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining compliance with ARARs.
- **Site LF007B –** Natural attenuation processes have already reduced contaminant concentrations to less than the PCGs. No other action is likely to be required at this site. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining compliance with ARARs.
- **Site LF007D –** Low concentrations of benzene (3 µg/L vs. PCG of 1 µg/L) and 1,4-dichlorobenzene (12.6 µg/L vs. PCG of 5 µg/L) were detected in the 2010 GSAP. Concentrations of 1,4-dichlorobenzene have been decreasing over time. Concentrations of benzene have remained stable. The plume size is small and limited to the vicinity of monitoring well MW261x07 (refer to Figure 3.2-12). Use of an active treatment technology, such as GET, is not warranted under these conditions. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining compliance with ARARs.

Former POCO Site. Site ST027B was formerly managed under the POCO program. A portion of the site with CERCLA contamination is designated as Site ST027B. The site is located within the flightline and is bounded by aircraft parking ramps and taxiways. Use of an active treatment technology is unlikely to be needed under these conditions and would have implementability problems because of the proximity to airfield operations. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining compliance with ARARs.

Alternative 2 – MNA would likely not be effective at addressing the *current* contaminant conditions at Sites LF007C, SS016, SS029, and SS030 and achieving full compliance with ARARs. The conditions at these sites are currently more applicable to Alternative 3 – GET. However, MNA is potentially applicable to *future* contaminant conditions after the current contaminant concentrations have been reduced by several years of groundwater extraction and treatment. At that time, continued progress toward RAOs and maintaining compliance with ARARs may be achieved by transitioning from the active remedy to a program of MNA. In the future, sites with an EA remedy component under Alternatives 5, 6, and 7 can readily be transitioned to a full-plume program of MNA under Alternative 2. At Sites SS015, SD034, SD036, SD037, and DP039, natural attenuation monitoring programs will already be implemented in the distal portions of the plumes. These monitoring programs can be expanded to address the entirety of the plume following successful remediation of the source areas.

9.2.2.3 Alternative 3 – GET

Compliance with ARARs will be achieved under Alternative 3 at Sites LF007C, SS029, and SS030. Site-specific descriptions of ARARs compliance are provided in the following subsections.

Site LF007C. At Site LF007C, achieving chemical-specific ARARs under Alternative 3 may be achieved in less than the current estimate of 26 years after the current IRA GET system is optimized in 2011. The required scope of the GET system optimization is uncertain until additional site characterization is conducted and the number and location(s) of supplemental extraction and monitoring wells, if any, are determined. Until these uncertainties are resolved, the estimated remediation timeframe is conservatively assumed to be the same under the current IRA and under Alternative 3.

Compliance with location-specific and action-specific ARARs for optimization of the Site LF007C IRA GET system is currently being resolved with the USFWS. Compliance will be continued under Alternative 3.

The Site LF007C IRA GET system, including the NGWTP, already complies with action- and location-specific ARARs and with chemical-specific ARARs for the discharge of treated groundwater. These components will be continued under Alternative 3.

Site SS030. Chemical-specific ARARs under Alternative 3 are expected to be met within 22 years. The estimate is the same as for the IRA, because the GET systems use the same components of extraction, treatment, and discharge. Compliance with location-specific and action-specific ARARs are currently being achieved under the existing IRA and compliance will be continued under Alternative 3. The Site SS030 IRA GET system, including the SBBGWTP, already complies with action- and location-specific ARARs and with chemical-specific ARARs for the discharge of treated groundwater. These components will be continued under Alternative 3.

Site SS029. The estimated time to achieve chemical-specific ARARs at Site SS029 is approximately 62 years. This is because of contaminant migration from the hydraulically upgradient Site SS016 plume. Interim remediation of the Site SS029 plume has demonstrated that it can remove contaminant mass, hydraulically contain groundwater contamination, and prevent migration of the plume into off-base locations. However, chlorinated VOCs from the Site SS016 plume are migrating into the northern portion of the Site SS029 plume and providing a continuing source of contamination. Therefore, achieving chemical-specific ARARs at Site SS029 will require additional time and will be largely dependent on the effectiveness of remedial action at Site SS016.

Compliance with location-specific and action-specific ARARs are currently being achieved under the existing IRA, and compliance will be continued under Alternative 3. The Site SS029 IRA GET system, including the SBBGWTP, already complies with action- and location-specific ARARs and with chemical-specific ARARs for the discharge of treated groundwater. These components will be continued under Alternative 4.

In the future, Alternative 3 could be implemented to achieve the Compliance with ARARs criterion at the sites currently found applicable to Alternative 2 – MNA; Alternative 4 – Bioreactor and GET; Alternative 5 – EVO and EA; Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA; and Alternative 7 – Passive Skimming and EA. If one (1) or more of these alternatives ultimately prove incapable of maintaining compliance ARARs, then Alternative 3 could be implemented. The sites where Alternative 3 may be potentially applicable under future conditions are summarized in the following list:

- **Sites FT004, FT005, LF008, SD031, SD033, and SD043 –** IRA GET systems exist at these sites. Under potential future conditions, active remediation using these systems can be resumed under Alternative 3 if natural attenuation processes do not maintain compliance with ARARs under Alternative 2. Resumed GET system operation would provide for a similar degree of compliance with ARARs.

  At Site LF008, limited progress was observed in achieving compliance with chemical-specific ARARs during approximately a decade of GET system operation. Achieving chemical-specific ARARs following resumption of GET operation is expected to require a long period of remediation.

- **Sites LF006, LF007B, and LF007D –** No IRA GET systems exist at these sites. However, Alternative 3 – GET may be implemented in the future if MNA processes under Alternative 2 prove incapable of maintaining compliance with ARARs. A new GET system would be required at each site. Implementing GET system operation will provide a similar, or better, degree of compliance with ARARs.

- **Site ST027B –** Alternative 3 – GET may be implemented in the future at this site if MNA processes under Alternative 2 ultimately prove incapable of maintaining compliance with ARARs. A new GET system would be required. Implementing GET system operation will provide a similar degree of compliance with ARARs.

- **Site SS016 –** If the combination of an in situ bioreactor and GET under Alternative 4 proves incapable of maintaining compliance with ARARs, then Alternative 3 can be implemented in the future. The existing IRA GET system could be expanded. However, source area extraction in the diffusion-dominated lithology present at the site will moderately limit the capacity of a GET system to achieve compliance with chemical-specific ARARs. Contamination will be increasingly difficult to remove over time and will likely reach asymptotic concentrations.

- **Sites SS015, SD036, and SD037 –** If source area EVO injection combined with EA under Alternative 5 ultimately prove incapable of maintaining compliance with ARARs, then Alternative 3 can be implemented in the future. Operation of the IRA GET systems at Sites SD036 and SD037 could be resumed. A new GET system would be required at Site SS015. Performance data obtained during the period of interim remediation indicate that GET operations within contaminant source areas become increasingly inefficient over time because of the diffusion-dominated silt and clay lithology present at Travis AFB. This will moderately limit the capacity of a GET system to comply with ARARs in comparison with in situ source area ERD treatment under Alternative 5.

- **Site DP039 –** If the Alternative 6 combination of an in situ bioreactor, phytoremediation, an EVO PRB, and EA ultimately proves incapable of maintaining compliance with ARARs, then Alternative 3 can be implemented in the future. The circumstances at Site DP039 are complex with the multiple alternative components. But if these components are not compliant with ARARs, then the existing IRA GET system could be expanded. Resuming GET system operation under this potential future condition would provide a similar degree of overall compliance with ARARs.
- **Site SD034 –** If the combination of passive skimming and EA under Alternative 7 ultimately proves incapable of maintaining compliance with ARARs, then Alternative 3 can be implemented in the future. Operation of the IRA GET system can be resumed and achieve a similar level of compliance with ARARs.

9.2.2.4 Alternative 4 – Bioreactor and GET

Compliance with chemical-specific ARARs will eventually be achieved under Alternative 4 at Site SS016. The probable presence of residual DNAPLs will result in a long duration of remediation before the chemical-specific ARARs are achieved.

Compliance with location-specific and action-specific ARARs are currently being achieved under the existing IRA and compliance will be continued under Alternative 4. The Site SS016 IRA GET system, including the CGWTP, already complies with action- and location-specific ARARs and with chemical-specific ARARs for the discharge of treated groundwater. These components will be continued under Alternative 4.

9.2.2.5 Alternative 5 – EVO and EA

Compliance with chemical-specific ARARs will be achieved under Alternative 5 at Sites SS015, SD036, and SD037.

Compliance with location-specific and action-specific ARARs are currently being achieved under the existing IRAs, and compliance will be continued under Alternative 5. This alternative does not involve GET; therefore, chemical-specific ARARs for the discharge of treated groundwater applicable to the Site SD036 and SD037 IRAs do not apply.

The potential installation of groundwater monitoring wells will meet location-specific ARARs. The existing well networks are adequate to monitor natural attenuation processes.

Action-specific ARARs specific to groundwater monitoring programs associated with corrective actions should be met with little difficulty.

9.2.2.6 Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA

Compliance with chemical-specific ARARs will be achieved under Alternative 6 at Site DP039.

Compliance with location-specific and action-specific ARARs are currently being achieved under the existing IRA, and compliance will be continued under Alternative 6. The Site DP039 IRA GET system, including the WTTP and CGWTP, already complies with action- and location-specific ARARs and with chemical-specific ARARs for the discharge of treated soil vapor and groundwater. Compliance with these ARARs will not be applicable when the GET system is permanently shut down under Alternative 6.

The potential installation of groundwater monitoring wells will meet location-specific ARARs. The existing well networks are adequate to monitor natural attenuation processes.

Action-specific ARARs specific to groundwater monitoring programs associated with corrective actions should be met with little difficulty.

9.2.2.7 Alternative 7 – Passive Skimming and EA

Compliance with chemical-specific ARARs will be achieved under Alternative 7 at Site SD034. Compliance with location-specific and action-specific ARARs are currently being achieved under the existing IRA, and compliance will be continued under Alternative 7. The Site SD034 IRA GET system, including the WTTP and CGWTP, already complies with action- and location-specific ARARs and with chemical-specific ARARs for the discharge of treated soil vapor and groundwater. Compliance with these ARARs will not be applicable when the GET system is permanently shut down under Alternative 7.

The potential installation of groundwater monitoring wells will meet location-specific ARARs. The existing well networks are adequate to monitor natural attenuation processes.

Action-specific ARARs specific to groundwater monitoring programs associated with corrective actions should be met with little difficulty.

9.2.3 Long-term Effectiveness and Permanence

Long-term effectiveness and permanence is a measure of two (2) principal factors: (1) the magnitude of residual risk, and (2) the adequacy and reliability of controls used to manage treatment residuals. Each of the groundwater alternatives, except for Alternative 1 – No Action, will achieve some measure of long-term effectiveness and permanence. Comparisons of the relative performance of the remedial alternatives at each site against the Long-term Effectiveness and Permanence evaluation criterion is provided in Table 9-6.

Each alternative uses administrative mechanisms of LUCs to restrict unauthorized access to contaminated groundwater and provide for an additional measure of long-term effectiveness and permanence. These common administrative LUCs include the Base Civil Engineer Work Request, excavation permits, and the requirements of the Base General Plan. These LUCs provide a similar level of support for the criterion under each alternative.

For the off-base plumes at Sites LF007C, FT005, and SS030, an additional administrative LUC is the purchase of an easement to provide the Air Force a means to manage and control the use of private property overlying a groundwater plume originating from within the boundaries of Travis AFB. These off-base easements provide a similar level of support for the criterion and have already been purchased.

In accordance with the Base General Plan, future buildings constructed in proximity of a groundwater plume may require installation of a vapor barrier and passive venting system. These vapor intrusion mitigation measures will further support achievement of the long-term effectiveness and permanence criterion and are similar for all alternatives.

TABLE 9-6
Summary of Comparative Analysis of Alternatives – Long-term Effectiveness and Permanence
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Remedial Alternative	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
1 – No Action	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○
2 – MNA	■	■	■	■	□	■	■	□	□	■	□	□	■	■	□	■	□	□	□	○	■
3 – GET	■	■	■	■	■	■	■	◙	◙	■	■	■	■	■	■	○	◙	◙	◙	○	■
4 – Bioreactor and GET	○	○	○	○	○	○	○	□	■	○	○	○	○	○	○	○	○	○	◙	○	○
5 – EVO and EA	○	○	○	○	○	○	○	■	○	○	○	○	○	○	○	○	■	■	◙	○	○
6 – Bioreactor, Phytoremediation, EVO PRB, and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○
7 – Passive Skimming and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○	○	○	○	○

■ Alternative that best satisfies the Long-term Effectiveness and Permanence criterion.
◙ Alternative that moderately satisfies the Long-term Effectiveness and Permanence criterion.
□ Alternative that poorly satisfies the Long-term Effectiveness and Permanence criterion.
○ Alternative that is not applicable or does not satisfy the Long-term Effectiveness and Permanence criterion.

9.2.3.1 Alternative 1 – No Action

Alternative 1 is included as a baseline for comparison when no remedial action is taken at a site. This alternative provides no controls for exposure to contaminated groundwater and no long-term management measures. Untreated contamination may pose potential long-term residual risk.

9.2.3.2 Alternative 2 – MNA

Alternative 2 and the site-specific IRAs will provide similar degrees of long-term effectiveness and permanence at Sites FT004, FT005, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, SS035, and SD043.

Site FT004/SD031. A program of MNA for the entirety of the Site FT004 and SD031 plumes will have similar long-term effectiveness and permanence when compared with using a combination of GET within some portions of the plume and MNA in the remainder of the plumes. When all the current GET system wells are operational, stagnation points may limit the long-term effectiveness. Natural attenuation processes have demonstrated long-term effectiveness, permanence, and reliability at Travis AFB. Under either the IRA or Alternative 2, residual contamination will require continued long-term monitoring and enforcement of LUCs. Long-term O&M of the Site FT004 and SD031 IRA GET systems will not be required under Alternative 2.

Site FT005. Implementing Alternative 2 instead of active GET will result in a similar degree of long-term effectiveness and permanence. Natural attenuation processes have demonstrated long-term effectiveness, permanence, and reliability at Travis AFB. Under either the IRA or Alternative 2, residual contamination will require continued long-term monitoring and enforcement of LUCs. Long-term O&M of the Site FT005 IRA GET system will not be required under Alternative 2.

Sites LF006, LF007B, LF007D, and ST027B. Alternative 2 is simply a continuation of the programs of MNA assessment conducted at each site during the period of interim remediation. Both IRA and Alternative 2 will provide the same degree of long-term effectiveness and permanence.

Site LF008. LTO of a GET system has not decreased the concentrations of organochlorine pesticides that are strongly sorbed to the aquifer soil particles. Continued operation of the IRA GET system in comparison with Alternative 2 would not improve long-term effectiveness or permanence.

Sites SD033, SS035, and SD043. These are component sites of the large WIOU plume. A program of natural attenuation for the entirety of the plume will have similar long-term effectiveness and permanence when compared with using a combination of GET within some portions of the plume and MNA in the remainder of the plume. Natural attenuation processes have demonstrated long-term effectiveness, permanence, and reliability at Travis AFB. Under either the IRAs or Alternative 2, residual contamination will require continued long-term monitoring and enforcement of LUCs. Long-term O&M of the IRA GET systems will not be required under Alternative 2.

In the event that the natural attenuation processes under Alternative 2 ultimately prove incapable of maintaining long-term effectiveness and permanence, then Alternative 3 – GET could be implemented at one (1) or more of the sites to maintain a similar degree of compliance.

GET System IRA Sites. At Sites FT004, FT005, LF008, SD031, SD033, and SD043, implementation of Alternative 2 – MNA follows approximately a decade of interim remediation using GET. The GET IRA systems at these sites were shut down for rebound studies during 2010. These contaminant plumes will continue to be monitored for the remainder of the period of interim remediation. Unless there is evidence of contaminant rebound, the GET systems will remain off. The IRA GET systems at these sites still exist. If rebound does occur or if plume migration is confirmed over a 2-year period, then the Air Force will evaluate resuming GET operations under Alternative 3 to maintain compliance with the long-term effectiveness and permanence criterion.

MNA and MNA Assessment IRA Sites. For Sites LF006, LF007B, and LF007D, MNA or MNA assessment was the IRA specified in the NEWIOU IROD. After approximately a decade of interim remediation, the NAAR concluded that natural attenuation of the plumes was effective (refer to Appendix C). A status summary for each of these sites is provided in the following list:

- **Site LF006 –** Natural attenuation processes have already reduced contaminant concentrations to less than the PCGs. No other action is likely to be required at this site. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining compliance with the long-term effectiveness and permanence criterion.
- **Site LF007B –** Natural attenuation processes have already reduced contaminant concentrations to less than the PCGs. No other action is likely to be required at this site. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining compliance with the long-term effectiveness and permanence criterion.
- **Site LF007D –** Low concentrations of benzene (3 μg/L vs. PCG of 1 μg/L) and 1,4-dichlorobenzene (12.6 μg/L vs. PCG of 5 μg/L) were detected in the 2010 GSAP. Concentrations of 1,4-dichlorobenzene have been decreasing over time. Concentrations of benzene have remained stable. The plume size is small and limited to the vicinity of monitoring well MW261x07 (refer to Figure 3.2-12). Use of an active treatment technology, such as GET, is not warranted under these conditions. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining long-term effectiveness and permanence.

Former POCO Site. Site ST027B was formerly managed under the POCO program. A portion of the site with CERCLA contamination is designated as Site ST027B. The site is located within the flightline and is bounded by aircraft parking ramps and taxiways. Use of an active treatment technology is unlikely to be needed under these conditions and would have implementability problems because of the proximity to airfield operations. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining compliance with the long-term effectiveness and permanence criterion.

Alternative 2 – MNA would likely not be effective at addressing the *current* contaminant conditions at Sites LF007C, SS016, SS029, and SS030 and achieving full compliance with the long-term effectiveness and permanence criterion. The conditions at these sites are currently more applicable to Alternative 3 – GET. However, MNA is potentially applicable to *future* contaminant conditions after the current contaminant concentrations have been reduced by several years of groundwater extraction and treatment. At that time, continued progress toward RAOs and maintaining compliance with the long-term effectiveness and permanence criterion may be achieved by transitioning from the active remedy to a program of MNA. In the future, sites with an EA remedy component under Alternatives 5, 6, and 7 can readily be transitioned to a full-plume program of MNA under Alternative 2. At Sites SS015, SD034, SD036, SD037, and DP039, natural attenuation monitoring programs will already be implemented in the distal portions of the plumes. These monitoring programs can be expanded to address the entirety of the plume following successful remediation of the source areas.

9.2.3.3 Alternative 3 – GET

Under Alternative 3, the existing IRA GET systems at Sites LF007C, SS029, and SS030 will continue operation. Alternative 3 will thereby continue to provide the same degree of long-term effectiveness and permanence at each site.

During the period of interim remediation, Travis AFB successfully used GET to hydraulically control and permanently remove contaminant mass from several sites, including Sites LF007C, SS029, and SS030. The components of the Site LF007C, SS029, and SS030 GET systems will be retained and incorporated into Alternative 3 to maintain the long-term effectiveness and permanence of remedial action.

At Sites LF007C and SS030, the current GET IRAs will be optimized in 2011 to improve the long-term effectiveness of the site-specific systems. The Site SS029 GET system is operating as intended and does not currently require optimization.

Long-term O&M of the site-specific GET systems are required under both the IRA and Alternative 3.

In the future, Alternative 3 could be implemented to maintain compliance with the long-term effectiveness and permanence criterion at the sites currently found applicable to Alternative 2 – MNA; Alternative 4 – Bioreactor and GET; Alternative 5 – EVO and EA; Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA; and Alternative 7 – Passive Skimming and EA. If one (1) or more of these alternatives ultimately prove incapable of maintaining compliance with ARARs, then Alternative 3 could be implemented. The sites where Alternative 3 may be potentially applicable under future conditions are summarized in the following list:

- **Sites FT004, FT005, LF008, SD031, SD033, and SD043 –** IRA GET systems exist at these sites. Under potential future conditions, active remediation using these systems can be resumed under Alternative 3 if natural attenuation processes do not maintain compliance with the long-term effectiveness and permanence criterion under

Alternative 2. Resumed GET system operation would provide for a similar degree of compliance with ARARs.

At Site LF008, limited progress was observed in achieving PCGs during approximately a decade of GET system operation. Maintaining compliance with the long-term effectiveness and permanence criterion following resumption of GET operation is expected to require a long period of remediation.

- **Sites LF006, LF007B, and LF007D –** No IRA GET systems exist at these sites. However, Alternative 3 – GET may be implemented in the future if MNA processes under Alternative 2 prove incapable of maintaining compliance with the long-term effectiveness and permanence criterion. A new GET system would be required at each site. Implementing GET system operation will provide a similar, or better, degree of compliance.
- **Site ST027B –** Alternative 3 – GET may be implemented in the future at this site if MNA processes under Alternative 2 ultimately prove incapable of maintaining compliance with the long-term effectiveness and permanence criterion. A new GET system would be required. Implementing GET system operation will provide a similar degree of compliance.
- **Site SS016 –** If the combination of an in situ bioreactor and GET under Alternative 4 proves incapable of maintaining compliance with the long-term effectiveness and permanence criterion, then Alternative 3 can be implemented in the future. The existing IRA GET system could be expanded. However, source area extraction in the diffusion-dominated lithology present at the site will moderately limit the capacity of a GET system to achieve compliance. Contamination will be increasingly difficult to remove over time and will likely reach asymptotic concentrations above PCGs.
- **Sites SS015, SD036, and SD037 –** If source area EVO injection combined with EA under Alternative 5 ultimately prove incapable of maintaining compliance with the long-term effectiveness and permanence criterion, then Alternative 3 can be implemented in the future. Operation of the IRA GET systems at Sites SD036 and SD037 could be resumed. A new GET system would be required at Site SS015. Performance data obtained during the period of interim remediation indicate that GET operations within contaminant source areas become increasingly inefficient over time because of the diffusion-dominated silt and clay lithology present at Travis AFB. This will moderately limit the capacity of a GET system to comply with the long-term effectiveness and permanence criterion in comparison with in situ source area ERD treatment under Alternative 5.
- **Site DP039 –** If the Alternative 6 combination of an in situ bioreactor, phytoremediation, an EVO PRB, and EA ultimately proves incapable of maintaining compliance with the long-term effectiveness and permanence criterion, then Alternative 3 can be implemented in the future. The circumstances at Site DP039 are complex with the multiple alternative components. But if these components are not compliant with the long-term effectiveness and permanence criterion, then the existing IRA GET system could be expanded. Resuming GET system operation under this potential future condition would provide a similar degree of overall compliance.

- **Site SD034 –** If the combination of passive skimming and EA under Alternative 7 ultimately proves incapable of maintaining compliance with long-term effectiveness and permanence criterion, then Alternative 3 can be implemented in the future. Operation of the IRA GET system can be resumed and achieve a similar level of compliance.

9.2.3.4 Alternative 4 – Bioreactor and GET

Alternative 4 will provide a greater degree of long-term effectiveness and permanence at Site SS016 than the GET system installed during the period of interim remediation. Within the OSA of Site SS016, long-term 2-Phase® GET had not significantly reduced contaminant concentrations or risk. This was probably the result of a large mass of DNAPL and a lithology composed mostly of low-permeability clay that is unfavorable for efficient vapor and groundwater extraction. Therefore, in 2010, the IRA was optimized by discontinuing 2-Phase® GET in favor of an in situ bioreactor. Installation of the bioreactor has already effectively and permanently removed most of the DNAPL and highly contaminated soil from the source area. However, the probable presence of residual DNAPL limits the long-term effectiveness of the bioreactor. This residual contamination will likely continue to pose a long-term source of chlorinated VOCs into the hydraulically downgradient portions of the plume.

The bioreactor installed at the site as part of IRA optimization will provide long-term and permanent treatment of dissolved-phase contamination located outside the limits of the bioreactor treatment zone (within approximately 30 feet). Residual DNAPL, which was not removed during bioreactor installation, will be remediated as it dissolves into the groundwater and is then treated by ERD processes. Remaining contamination located outside of the bioreactor's treatment zone will be effectively removed in the long term by the hydraulically downgradient GET system.

Within the TARA portion of Site SS016, continued operation of the horizontal well GET IRA system will continue to provide effective long-term extraction and LGAC treatment at the CGWTP.

9.2.3.5 Alternative 5 – EVO and EA

Alternative 5 will provide a greater degree of long-term effectiveness and permanence at Sites SS015, SD036, and SD037 than the MNA assessment (Site SS015) and GET IRAs (Sites SD036 and SD037) implemented at the sites.

During 2010, the IRA at each of the sites was optimized by injecting EVO into the source areas. These injections are expected to provide long-term in situ treatment for approximately 5 years before re-injections are needed to maintain ERD processes. Permanent chlorinated VOC reductions of 85 to 95 percent can be expected in the EVO treatment zone.

Site SS015. Optimization of the IRA via EVO injection was conducted to reduce source area contaminant concentrations to improve the long-term effectiveness of natural attenuation processes in the distal portions of the plume. Groundwater monitoring conducted to assess MNA at Site SS015 indicated that contaminant concentrations were increasing in some of the site wells and that the plume was likely migrating. Residual contaminants from a 2000-2001 vegetable oil injection treatability study were increasing in concentrations above PCGs. Re-injection of the source area with EVO was conducted in 2010 as an optimization action to remediate the parent contaminants and the degradation products resulting from the previous treatability study.

Site SD036. This is a component site of the overall WIOU plume. LTO of the IRA GET system was discontinued in 2010 because of its limited effectiveness at reducing source area contaminant concentrations and risk. At Site SD036, this is due to the probable presence of DNAPL and a low-permeability clay lithology. Source area treatment with EVO injection was conducted to reduce the highest concentrations of contamination and thereby enhance the effectiveness of natural attenuation processes within the untreated portions of the plumes. Residual DNAPL, which is not directly treated by EVO injection, will be remediated as it dissolves into the groundwater and is then treated by ERD processes.

Site SD037. This is another component site of the overall WIOU plume. Similar to Site SD036, LTO of the IRA GET system was discontinued in 2010 because of its limited effectiveness at reducing source area contaminant concentrations and risk. At Site SD037, dissolved-phase groundwater contamination does not indicate DNAPL, but the lithology has similar low permeability. Source area treatment with EVO injection was conducted to reduce the highest concentrations of contamination and thereby enhance the effectiveness of natural attenuation processes within the untreated portions of the plumes.

Natural attenuation processes have demonstrated long-term effectiveness, permanence, and reliability at Travis AFB. Under either the IRAs or Alternative 5, residual contamination will require continued long-term monitoring and enforcement of LUCs.

9.2.3.6 Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA

Alternative 6 will provide a greater degree of long-term effectiveness and permanence at Site DP039 than the combination of GET and MNA assessment implemented at the site during the period of interim remediation. Under the IRA, the interim remediation strategy was focused on active GET remediation of the source plume with passive remediation of the hydraulically downgradient portions of the plume using MNA. Under Alternative 6, remediation of the source portion of the plume will be expanded using a combination of bioreactor operation, phytoremediation, and an EVO PRB. Monitoring of the distal portions of the plume for natural attenuation processes will be continued under either the IRA or Alternative 6.

Within the Site DP039 source area, long-term DPE during the period of interim remediation had reduced contaminant concentrations and mass, but concentrations had reached asymptotic levels above the PCGs. This was probably the result of a large mass of DNAPL and a lithology composed mostly of low-permeability clay that is unfavorable for efficient vapor and groundwater extraction. Therefore, in 2010, the IRA was optimized by discontinuing DPE in favor of installing a source area bioreactor. Installation of the bioreactor has already effectively and permanently removed most of the DNAPL and highly contaminated soil from the source area. However, the probable presence of residual DNAPL limits the long-term effectiveness of the bioreactor. This residual contamination will likely continue to pose a long-term source of chlorinated VOCs into the hydraulically downgradient portions of the plume.

The bioreactor installed as part of IRA optimization will provide long-term and permanent treatment of dissolved-phase contamination located outside the limits of the bioreactor treatment zone (within approximately 30 feet). After 16 months of treatment, average TCE concentrations in the treatment zone have decreased by nearly 95 percent. Residual DNAPL, which was not removed during bioreactor installation, will be remediated as it dissolves into the groundwater and is then treated by ERD processes. The remaining contamination located outside of the bioreactor's treatment zone will be effectively removed in the long term by the combination of phytoremediation, an EVO PRB, and natural attenuation processes.

Under either the IRA or Alternative 6, residual contamination will require continued long-term monitoring and enforcement of LUCs.

9.2.3.7 Alternative 7 – Passive Skimming and EA

Alternative 7 and the Site SD034 IRA will provide similar degrees of long-term effectiveness and permanence. Under Alternative 7, operation of the site GET system will be discontinued. Both the Alternative 7 and the implemented IRA will involve continued intermittent free product skimming and monitoring of natural attenuation processes.

Under either the IRA or Alternative 7, residual contamination will require continued long-term monitoring and enforcement of LUCs.

9.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Each of the groundwater treatment alternatives, including Alternative 1 – No Action, will achieve varying degrees of reduction in contaminant toxicity, mobility, and volume. Comparisons of the relative performance of the remedial alternatives at each site against the Reduction of Toxicity, Mobility, or Volume through Treatment evaluation criterion is provided in Table 9-7.

Each alternative uses administrative mechanisms of LUCs to restrict unauthorized access to contaminated groundwater and support achievement of the criterion. The common administrative LUCs include the Base Civil Engineer Work Request, excavation permits, and the requirements of the Base General Plan. These LUCs provide a similar level of support for the criterion under each alternative.

For the off-base plumes at Sites LF007C, FT005, and SS030, an additional administrative LUC is the purchase of an easement to provide the Air Force a means to manage and control the use of private property overlying a groundwater plume originating from within the boundaries of Travis AFB. These off-base easements provide a similar level of support for the criterion and have already been purchased.

In accordance with the Base General Plan, future buildings constructed in proximity of a groundwater plume may require installation of a vapor barrier and passive venting system. These vapor intrusion mitigation measures will further support achievement of the criterion and are similar for all alternatives.

Alternatives 1 – No Action and 2 – MNA will not achieve reduction through active treatment, although naturally occurring physical, chemical, and biological processes will be taking place to reduce the toxicity, mobility, and volume of contaminants.

TABLE 9-7
Summary of Comparative Analysis of Alternatives – Reduction of Toxicity, Mobility, or Volume through Treatment
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Remedial Alternative	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
1 – No Action	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○
2 – MNA	■	■	■	■	□	■	■	□	□	■	□	□	■	■	□	■	□	□	□	○	■
3 – GET	■	■	◙	◙	■	◙	◙	◙	◙	◙	■	■	◙	■	◙	○	◙	◙	◙	○	■
4 – Bioreactor and GET	○	○	○	○	○	○	○	□	■	○	○	○	○	○	○	○	□	□	◙	○	○
5 – EVO and EA	○	○	○	○	○	○	○	■	○	○	○	○	○	○	○	○	■	■	◙	○	○
6 – Bioreactor, Phytoremediation, EVO PRB, and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○
7 – Passive Skimming and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○	○	○	○	○

■ Alternative that best satisfies the Reduction of Toxicity, Mobility, or Volume through Treatment criterion.
◙ Alternative that moderately satisfies the Reduction of Toxicity, Mobility, or Volume through Treatment criterion.
□ Alternative that poorly satisfies the Reduction of Toxicity, Mobility, or Volume through Treatment criterion.
○ Alternative that is not applicable or does not satisfy the Reduction of Toxicity, Mobility, or Volume through Treatment criterion.

Under Alternative 3 – GET, reductions in contaminant toxicity, mobility, and volume will be achieved by first removing the contaminants from the groundwater and then transferring them to activated carbon. The mass of sorbed contaminants is later destroyed when the carbon is recycled at an off-base vendor facility.

The source area components of Alternative 4 – Bioreactor and GET, Alternative 5 – EVO and EA, and Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA provide for reductions through in situ biological treatment processes, primarily ERD.

Alternative 7 – Passive Skimming and EA provides for reductions in the volume of contamination through removal of floating product. However, no treatment process is employed.

9.2.4.1 Alternative 1 – No Action

Alternative 1 will provide no measured reductions in toxicity, mobility, or volume of contaminants through treatment. No treatment technologies are employed. Permanent or significant reductions in toxicity, mobility, or volume will occur gradually by natural processes. However, the reduction will not be quantifiable or documented because no groundwater sampling or evaluations will be performed. However, such reduction would be inherently irreversible. Because no treatment technologies will be employed, no treatment residuals will be generated.

9.2.4.2 Alternative 2 – MNA

Alternative 2 relies on natural chemical, biological, and physical processes (primarily volatilization) to reduce contaminant mass over time. As such, it is not an active "treatment" in the traditional sense of the word. However, it will address the principal threat and ultimately destroy the entire contaminant mass. This alternative carries the requirement that investigations be performed to verify that natural attenuation is occurring, and establish the rate at which toxicity, mobility, and volume are decreasing. A long-term monitoring program aimed at documenting the natural attenuation process over time is also a requirement of this alternative (i.e., GSAP). If natural attenuation is occurring, the destruction of contaminant mass will eventually be complete and irreversible with no treatment residuals.

During the period of interim remediation natural attenuation processes demonstrated their capacity to reduce the toxicity, mass, and volume of contamination. The results of site-specific MNA assessments are documented in the NAAR (CH2M HILL, 2010a). Additional discussion of MNA is provided in Appendix C.

A study will be conducted during 2011 to evaluate the contribution to MNA provided by aerobic biological processes.

9.2.4.3 Alternative 3 – GET

Under Alternative 3, continued pumping and treating at Sites LF007C, SS029, and SS030 will reduce contaminant mobility through containment, and reduce toxicity through capture and treatment. During the period of interim remediation, the GET IRAs at these and other sites at Travis AFB demonstrated effectiveness at satisfying the Reduction of Toxicity, Mobility, or Volume through Treatment criterion.

9.2.4.4 Alternative 4 – Bioreactor and GET

At Site SS016, Alternative 4 better satisfies the reduction of toxicity, mobility, or volume through treatment criterion than did GET operations during the period of interim remediation.

During the period of interim remediation, the IRA consisted of 2-Phase® GET within the OSA source area and GET for the remaining portions of the plume. However, even after approximately a decade of soil vapor and groundwater extraction, the highest contaminant concentrations at Travis AFB continued to be detected at Site SS016. Under Alternative 4, the treatment processes are changed to use a combination of ERD processes using a bioreactor and GET to better achieve permanent reductions in contaminant mass, toxicity, and mobility.

As an optimization of the IRA during 2010, approximately 37 pounds of chlorinated VOCs were permanently removed during installation of the OSA bioreactor. This mass estimate is based on soil waste stream samples collected during bioreactor installation and is probably quite conservative. Much more VOC mass was likely removed by volatilization. However, this component of removed mass cannot be quantified. In situ biological treatment using the bioreactor will further reduce the toxicity and volume of contaminants in the OSA source area using ERD processes. The portion of the OSA plume downgradient of the bioreactor will continue to be hydraulically captured by groundwater extraction wells. These extraction wells will continue to reduce the mobility and volume of contaminants. The entire mass and volume of contaminants will eventually be treated, and the treatment will be irreversible.

Under either Alternative 4 or the IRA, many years will be required to achieve PCGs within the entirety of the Site SS016 plume. However, following removal of highly contaminated soil within the OSA source area and installation of the bioreactor, the continuing source of TCE contamination into the hydraulically downgradient portions of the OSA plume will be greatly reduced. The remaining contamination will continue to be hydraulically captured by the Site SS016 and Site SS029 GET systems.

Complete degradation of chlorinated VOCs through the bioreactor ERD processes will result in non-regulated end-products such as ethene and ethane. Incomplete ERD, resulting from stalling of these processes, has the potential to create intermediate compounds such as cis-1,2-DCE and/or vinyl chloride. The PCGs for these compounds are 6 and 0.5 µg/L, respectively.

Vinyl chloride is the most toxic potential byproduct of incomplete ERD. Within the anaerobic treatment zone created by the bioreactor, creation of vinyl chloride is expected as part of normal ERD processes. Full degradation of vinyl chloride within the treatment zone is expected as those processes continue through completion to form ethane, ethene, and methane. There has been no accumulation of vinyl chloride at the Site DP039 bioreactor despite a 75 percent total molar reduction of chlorinated VOCs. Outside of the treatment zone, the Site SS016 aquifer is aerobic. Vinyl chloride readily degrades under aerobic conditions, so any vinyl chloride that migrates beyond the ERD treatment zone will degrade aerobically shortly after entering the downgradient portion of the aquifer.

9.2.4.5 Alternative 5 – EVO and EA

Implementation of Alternative 5 at Sites SS015, SD036, and SD037 better satisfies the reduction of toxicity, mobility, or volume through treatment criterion than did the combination of GET and MNA during the period of interim remediation.

Site SS015. Groundwater monitoring to assess MNA was conducted at this site during the period of interim remediation. The data indicate that natural attenuation processes, by themselves, will poorly satisfy the Reduction of Toxicity, Mobility, or Volume through Treatment criterion at this site. Residual contamination resulting from a limited 2000-2001 vegetable oil injection treatability study appears to be increasing. Therefore, in 2010, supplemental injection of EVO was conducted as an optimization action in the Site SS015 source area to actively treat the parent contamination and products of incomplete ERD. Natural attenuation processes in the distal portions of the plume will continue to be monitored.

Sites SD036 and SD037. During the period of interim remediation, the IRAs consisted of DPE GET within the source areas and MNA assessments for the remaining portions of the plumes. However, even after approximately a decade of soil vapor and groundwater extraction, high contaminant concentrations continue to be detected within the source areas. Under Alternative 5, the treatment processes are changed to use a combination of ERD processes and natural attenuation processes to better achieve permanent reductions in contaminant mass, toxicity, and mobility than was accomplished by the GET IRAs.

9.2.4.6 Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA

Implementation of Alternative 6 at Site DP039 better satisfies the reduction of toxicity, mobility, or volume through treatment criterion than did the combination of GET and MNA during the period of interim remediation.

During the period of interim remediation at Site DP039, the IRA consisted of active GET remediation of the source plume combined with MNA in the hydraulically downgradient portions of the plume. LTO of the GET system reduced contaminant concentrations and mass, but concentrations had reached asymptotic levels above the PCGs. This was probably the result of a large mass of DNAPL and a lithology composed mostly of low-permeability clay that is unfavorable for efficient vapor and groundwater extraction.

Under Alternative 6, the IRA GET system will be discontinued. Reductions of toxicity, mobility, and volume of the source portion of the plume will be improved using a combination of bioreactor operation, phytoremediation, and an EVO PRB. Monitoring of the distal portions of the plume for natural attenuation processes will be continued under either the IRA or Alternative 6.

Installation of the Site DP039 source area bioreactor in 2008 has already directly reduced the volume of high concentration contaminants, including potential DNAPLs. The bioreactor will further reduce the toxicity and volume of contaminants in the source area using ERD processes. The portion of the source plume located hydraulically downgradient of the bioreactor will be further remediated by an existing area of phytoremediation. Then, hydraulically downgradient of the phytoremediation area, the leading edge of the source plume will be intercepted by an existing EVO PRB and undergo additional in situ treatment via ERD processes. The remainder of the plume will be addressed by natural attenuation processes. The entire mass and volume of contaminants will eventually be treated to PCGs within about 65 years, and the treatment will be irreversible.

The existing area of phytoremediation is providing irreversible reductions in toxicity, mobility, and volume of contamination through a sustainable treatment process. In 2010, the trees demonstrated a mass removal rate of about 2 pounds of TCE per year. These reductions could increase up to 15.4 pounds of TCE per year as the trees mature. Optimization actions such as increasing the planting area and installing an irrigation system using contaminated groundwater would provide additional reductions.

In situ biological treatment using ERD processes within the treatment zones of the bioreactor and EVO PRB will reduce the toxicity and volume of contaminants in the site source areas. Complete treatment of the chlorinated VOCs within these treatment zones will result in non-regulated end-products such as ethene and ethane. After in situ treatment of the higher concentration sources areas, natural attenuation processes in the hydraulically downgradient portions of the Site DP039 plume will be enhanced. The continuing sources of TCE contamination will be eliminated or greatly reduced. As a result, the capacity of natural processes to reduce contaminant concentrations in the distal portions of the plumes will be improved.

Complete degradation of chlorinated VOCs through the bioreactor ERD processes will result in non-regulated end-products such as ethene and ethane. Incomplete ERD, resulting from stalling of these processes, has the potential to create intermediate compounds such as cis-1,2-DCE and/or vinyl chloride. There has been no accumulation of vinyl chloride at the Site DP039 bioreactor despite a 75 percent total molar reduction of chlorinated VOCs. Full degradation of vinyl chloride within the treatment zone is expected as those processes continue through completion to form ethane, ethene, and methane. Outside of the treatment zone, the aquifer is aerobic. Vinyl chloride readily degrades under aerobic conditions, so any vinyl chloride that migrates beyond the ERD treatment zone will degrade aerobically shortly after entering the downgradient portion of the aquifer.

9.2.4.7 Alternative 7 – Passive Skimming and EA

Alternative 7 and the Site SD034 IRA will provide similar reductions in contaminant toxicity, mobility, and volume. Under Alternative 7, operation of the site GET system will be discontinued. Both Alternative 7 and the implemented IRA will involve continued intermittent free product skimming and monitoring of natural attenuation processes.

Under either the IRA or Alternative 7, residual contamination above PCGs will require continued long-term monitoring and enforcement of LUCs.

9.2.5 Short-term Effectiveness

Short-term effectiveness is a measure of the protection afforded by each alternative during the construction and implementation process. Each of the groundwater alternatives, except for Alternative 1 – No Action, is effective in the short-term to some degree. Comparisons of the performance of the remedial alternatives at each site against the Short-term Effectiveness evaluation criterion are provided in Table 9-8.

TABLE 9-8
Summary of Comparative Analysis of Alternatives – Short-term Effectiveness
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Remedial Alternative	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
1 – No Action	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○
2 – MNA	■	◙	■	■	□	■	■	□	□	■	□	□	■	■	□	■	□	□	□	○	■
3 – GET	■	■	◙	◙	■	◙	◙	◙	◙	◙	■	■	■	■	■	○	◙	◙	◙	○	■
4 – Bioreactor and GET	○	○	○	○	○	○	○	□	■	○	○	○	○	○	○	○	○	○	◙	○	○
5 – EVO and EA	○	○	□	□	○	□	○	■	○	○	○	○	○	○	○	○	■	■	◙	○	○
6 – Bioreactor, Phytoremediation, EVO PRB, and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○
7 – Passive Skimming and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○	○	○	○	○

■ Alternative that best satisfies the Short-term Effectiveness criterion.
◙ Alternative that moderately satisfies the Short-term Effectiveness criterion.
□ Alternative that poorly satisfies the Short-term Effectiveness criterion.
○ Alternative that is not applicable or does not satisfy the Short-term Effectiveness criterion.

For this FFS, sustainable remediation considerations are also included under the short-term effectiveness criterion. A summary comparison of the key sustainability metrics (i.e., carbon dioxide generation and energy consumption) between each alternative and the IRA implemented at each site is provided in Table 9-10. Additional information regarding sustainability is provided in Appendix F.

Each alternative uses administrative mechanisms of LUCs to restrict unauthorized access to contaminated groundwater and support achievement of the criterion. The common administrative LUCs include the Base Civil Engineer Work Request, excavation permits, and the requirements of the Base General Plan. These LUCs provide a similar level of support for the short-term effectiveness criterion under each alternative.

For the off-base plumes at Sites LF007C, FT005, and SS030, an additional administrative LUC is the purchase of an easement to provide the Air Force a means to manage and control the use of private property overlying a groundwater plume originating from within the boundaries of Travis AFB. These off-base easements provide a similar level of support for the short-term effectiveness criterion and have already been purchased.

In accordance with the Base General Plan, future buildings constructed in proximity of a groundwater plume may require installation of a vapor barrier and passive venting system. These vapor intrusion mitigation measures will further support achievement of the criterion and are similar for all alternatives.

9.2.5.1 Alternative 1 – No Action

Alternative 1 is included as a baseline for comparison when no remedial action is taken at a site. This alternative provides no protection during construction and implementation because no actions are taken.

Because no remedial action will be taken under Alternative 1, no short-term risks to the community or to workers will need to be addressed. Similarly, no environmental impact from construction activities will occur. Residual contamination is expected to decrease over time by natural processes. However, the actual reduction over time will not be measured or documented.

9.2.5.2 Alternative 2 – MNA

Similar to the already implemented MNA assessments, Alternative 2 will continue to provide short-term effectiveness at Sites FT004, FT005, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, SS035, and SD043. However, MNA will likely require a longer time to achieve RAOs than a more aggressive, more costly, less efficient, and less sustainable treatment alternative. Comparisons of the estimates of the time required to achieve PCGs at each site under the current IRAs and Alternative 2 are developed in Appendix D and are summarized in Table 9-9. These estimates include varying degrees of uncertainty and precision. The key aspects of the remediation timeframe evaluations are provided in the following list:

- **Site FT004/SD031 –** A program of MNA for the entirety of the Site FT004/SD031 plume will not result in extending the remediation timeframe when compared with using a combination of GET within some portions of the plume and MNA in the remainder of the plume. When all the current GET system wells are operational, stagnation points may limit the system's performance. Modified operation of the GET system could potentially reduce the remediation timeframe.

- **Site FT005 –** Implementing a full program of MNA under Alternative 2 instead of active GET could result in an increase in the time required to achieve PCGs from 10 to 43 years. There are several reasons for this forecast increase:
  - The primary contaminant at the site is 1,2-DCA with a low PCG of 0.5 µg/L. Current groundwater concentrations are an order of magnitude above the PCG and will require an extended time to naturally attenuate to the PCG.
  - During the period of interim remediation, the IRA was GET. No 1,2-DCA biodegradation rate could be obtained during plume extraction.
  - In the absence of a biodegradation rate, none was assumed in the estimation of the remediation timeframe in Appendix D for Site FT005. Physical attenuation processes have been demonstrated to be the dominant mechanism at Travis AFB and the assumption of no significant contribution by biodegradation of 1,2-DCA is reasonable.
- **Sites LF006, LF007B, LF007D, and ST027B –** Alternative 2 is simply a continuation of the programs of MNA assessment conducted at each site during the period of interim remediation. Both the IRA and Alternative 2 result in the same time to achieve PCGs using natural attenuation processes. Implementation of the more aggressive Alternative 3 – GET or Alternative 5 – EVO and EA at these sites would likely reduce the time to achieve PCGs.
- **Site LF008 –** LTO of a GET system has not decreased the concentrations of intransigent organochlorine pesticides. Continued operation of the GET system would not improve overall short-term effectiveness or the required time to achieve PCGs.
- **Sites SD033, SS035, and SD043 –** These are component sites of the large WIOU plume. The remediation timeframe is collectively evaluated for all the sites included within the WIOU plume. Some sites, or portions of sites, within the overall WIOU plume may achieve PCGs before other portions.

TABLE 9-9
Comparison of Estimated Time to Achieve Preliminary Cleanup Goals[a]
Interim Remedial Action Compared with Alternative 2 – MNA
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Estimated Cleanup Time[b] (years)		Change from IRA to Alternative
	Interim Remedial Action	Alternative 2	
FT004	35	35	GET and MNA Assessment to MNA
FT005	10	43	GET to MNA
LF006	5	5	MNA Assessment to MNA
LF007B	0	0	MNA Assessment to MNA
LF007D	>100	>100	MNA Assessment to MNA
LF008	>100	>100	GET to MNA
ST027B	50	50	MNA to MNA
SD031	15	15	GET and MNA Assessment to MNA
SD033/SS035/SD043	91	60	GET and MNA Assessment to MNA[c]

[a] PCGs are described in Section 5.
[b] Remediation timeframe estimate is provided in Appendix D.
[c] Site components of the overall WIOU plume.

Construction activities associated with the implementation of an MNA program are typically limited to installation of monitoring wells. This activity poses minimal risk to workers, the community, and the environment. Each of the site-specific monitoring well networks has already been constructed as part of the IRAs. Potential future well installations pose minimal risk to workers, the community, and the environment.

The community and the environment will be protected during remediation by the Air Force maintaining control of the groundwater resource through enforcement of LUCs. Risks to workers will be minimized by these same measures and by following standard safety practices during construction and O&M.

Implementation of Alternative 2 at Sites FT004, FT005, LF008, SD031, SD033, SS035, and SD043 includes provisions for sustainable remediation. At each of these sites, an energy-intensive IRA GET system is replaced by a program of MNA. The carbon dioxide (CO_2) emissions were higher for the IRA activities compared with Alternative 2. In most cases, the IRA GET operations emitted 30-plus times the amount of CO_2 compared with MNA. The total energy reduction for Alternative 2 sites ranged from 95 to 97 percent compared with IRA GET systems. The footprints for CO_2 generation and energy consumption are summarized in Table 9-10. More detailed information is provided in Appendix F.

At Sites LF006, LF007B, LF007D, and ST207B, implementation of Alternative 2 is simply a continuation of the IRA MNA assessments. No improvements in sustainability metrics are realized.

TABLE 9-10
Summary Comparison of Key Sustainability Metrics – Site Alternatives Compared with Implemented IRAs
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Implemented Interim Remedial Action		Alternative		
Site	**Carbon Dioxide Generated (tons)**	**Energy Consumption (kWh)**	**Carbon Dioxide (tons)**	**Energy Consumption (kWh)**	**Change from IRA to Alternative**
FT004	48	205,600	1.3	5,600	GET and MNA Assessment to MNA
FT005	22	93,200	1.7	5,600	GET to MNA
LF006	0.12	500	0.12	500	MNA Assessment to MNA
LF008	124	596,000	3.9	16,000	GET to MNA
ST027B	2	8,100	2	8,100	MNA to MNA
SD031	18	77,300	0.6	2,300	GET and MNA Assessment to MNA
SD033	76	325,000	2.3	9,700	GET and MNA Assessment to MNA
SD043	68	285,000	2.3	9,700	GET and MNA Assessment to MNA
LF007C	30	124,200	30	124,200	GET to GET
SS029	310	1,416,000	310	1,416,000	GET to GET
SS030	79	333,600	79	333,600	GET to GET
SS016	284	1,216,000	332	702,000	GET to Bioreactor and GET
SS015	0.16	670	91	20,810	MNA Assessment to EVO and EA
SD036	73	319,700	137	33,110	GET and MNA Assessment to EVO and EA
SD037	144	625,000	134	29,300	GET and MNA Assessment to EVO and EA
DP039	86	341,000	257	98,300	GET and MNA Assessment to Bioreactor, Phytoremediation, EVO PRB, and EA
SD034	70	295,000	2.3	9,700	GET, Passive Skimming, and MNA Assessment to Passive Skimming and EA

In the event that the natural attenuation processes under Alternative 2 ultimately prove incapable of maintaining the short-term effectiveness criterion, then Alternative 3 – GET could be implemented at one (1) or more of the sites to maintain a similar degree of compliance.

GET System IRA Sites. At Sites FT004, FT005, LF008, SD031, SD033, and SD043, implementation of Alternative 2 – MNA follows approximately a decade of interim remediation using GET. The GET IRA systems at these sites were shut down for rebound studies during 2010. These contaminant plumes will continue to be monitored for the remainder of the period of interim remediation. Unless there is evidence of contaminant rebound, the GET systems will remain off. The IRA GET systems at these sites still exist. If rebound does occur or if plume migration is confirmed over a 2-year period, then the Air Force will evaluate resuming GET operations under Alternative 3 to maintain compliance with the short-term effectiveness criterion.

MNA and MNA Assessment IRA Sites. For Sites LF006, LF007B, and LF007D, MNA or MNA assessment was the IRA specified in the NEWIOU IROD. After approximately a decade of interim remediation, the NAAR concluded that natural attenuation of the plumes was effective (refer to Appendix C). A status summary for each of these sites is provided in the following list:

- **Site LF006 –** Natural attenuation processes have already reduced contaminant concentrations to less than the PCGs. No other action is likely to be required at this site. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining compliance with the short-term effectiveness criterion.
- **Site LF007B –** Natural attenuation processes have already reduced contaminant concentrations to less than the PCGs. No other action is likely to be required at this site. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining compliance with the short-term effectiveness criterion.
- **Site LF007D –** Low concentrations of benzene (3 µg/L vs. PCG of 1 µg/L) and 1,4-dichlorobenzene (12.6 µg/L vs. PCG of 5 µg/L) were detected in the 2010 GSAP. Concentrations of 1,4-dichlorobenzene have been decreasing over time. Concentrations of benzene have remained stable. The plume size is small and limited to the vicinity of monitoring well MW261x07 (refer to Figure 3.2-12). Use of an active treatment technology, such as GET, is not warranted under these conditions. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining the short-term effectiveness criterion.

Former POCO Site. Site ST027B was formerly managed under the POCO program. A portion of the site with CERCLA contamination is designated as Site ST027B. The site is located within the flightline and is bounded by aircraft parking ramps and taxiways. Use of an active treatment technology is unlikely to be needed under these conditions and would have implementability problems because of the proximity to airfield operations. However, Alternative 3 – GET may be implemented in the future if MNA processes ultimately prove incapable of maintaining compliance with the short-term effectiveness criterion.

Alternative 2 – MNA would likely not be effective at addressing the *current* contaminant conditions at Sites LF007C, SS016, SS029, and SS030 and achieving full compliance with the short-term effectiveness criterion. The conditions at these sites are currently more applicable to Alternative 3 – GET. However, MNA is potentially applicable to *future* contaminant conditions after the current contaminant concentrations have been reduced by several years of groundwater extraction and treatment. At that time, continued progress toward RAOs and maintaining compliance with the short-term effectiveness criterion may be achieved by transitioning from the active remedy to a program of MNA. In the future, sites with an EA remedy component under Alternatives 5, 6, and 7 can readily be transitioned to a full-plume program of MNA under Alternative 2. At Sites SS015, SD034, SD036, SD037, and DP039, natural attenuation monitoring programs will already be implemented in the distal portions of the plumes. These monitoring programs can be expanded to address the entirety of the plume following successful remediation of the source areas.

9.2.5.3 Alternative 3 – GET

Alternative 3 will continue to provide short-term effectiveness at Sites LF007C, SS029, and SS030. This alternative entails active groundwater remediation using the GET systems previously installed as part of the IRA at each site. A comparison of the estimated time required to achieve PCGs under Alternative 3 and the existing IRA at each site is provided in Table 9-11. The key aspects of the remediation timeframe evaluations are provided in the following list:

- **Site LF007 –** At Site LF007, achieving PCGs under Alternative 3 may be achieved in less than the current estimate of 26 years after the current IRA GET system is optimized in 2011. The required scope of the GET system optimization is uncertain until additional site characterization is conducted and the number and location(s) of supplemental extraction and monitoring wells, if any, are determined. Until these uncertainties are resolved, the estimated remediation timeframe is conservatively assumed to be the same under the current IRA and under Alternative 3.

- **Site SS030 –** PCGs under Alternative 3 are expected to be met within 22 years. The estimate is the same as for the IRA, because the GET systems use the same components of extraction, treatment, and discharge.

- **Site SS029 –** The estimated time to achieve PCGs at Site SS029 is approximately 62 years. This is because of contaminant migration from the hydraulically upgradient Site SS016 plume. Interim remediation of the Site SS029 plume has demonstrated that it can remove contaminant mass, hydraulically contain groundwater contamination, and prevent migration of the plume into off-base locations. However, chlorinated VOCs from the Site SS016 plume are migrating into the northern portion of the Site SS029 plume and providing a continuing source of contamination. Therefore, achieving PCGs at Site SS029 will require additional time and will be largely dependent on the effectiveness of remedial action at Site SS016.

TABLE 9-11
Comparison of Estimated Time to Achieve Preliminary Cleanup Goals[a]
Interim Remedial Action Compared with Alternative 3 – GET
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Estimated Cleanup Time[b] (years)		
Site	**Interim Remedial Action**	**Alternative 3**	**Change from IRA to Alternative**
LF007C	26	26	GET to GET
SS029	>100	62	GET to GET[c]
SS030	22	22	GET to GET

[a] PCGs are described in Section 5.
[b] Remediation timeframe estimate is provided in Appendix D.
[c] Reduction in remediation timeframe using GET because of interactions between Site SS029 and implementation of Alternative 4 at Site SS016.

Construction activities associated with the implementation of a GET system are typically limited to installation of extraction wells, monitoring wells, conveyance pipelines, and a treatment facility. These activities have already been conducted for each of the sites as part of the IRAs. Potential future GET system installations pose minimal risk to workers, the community, and the environment.

The community and the environment will be protected during remediation by the Air Force maintaining control of the groundwater resource through enforcement of LUCs. Risks to workers will be minimized by these same measures and by following standard safety practices during construction and O&M.

Implementation of Alternative 3 at Site LF007C includes a provision for sustainable remediation. Solar-powered pumps are currently being used in two (2) groundwater extraction wells. The current IRA GET system will be optimized in 2011 and may include additional extraction wells and expanded use of solar-powered pumps. However, the scope of the optimization action is currently uncertain, and the sustainability criteria cannot be more fully evaluated.

In the future, Alternative 3 could be implemented to maintain compliance with the short-term effectiveness criterion at the sites currently found applicable to Alternative 2 – MNA; Alternative 4 – Bioreactor and GET; Alternative 5 – EVO and EA; Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA; and Alternative 7 – Passive Skimming and EA. If one (1) or more of these alternatives ultimately prove incapable of maintaining compliance, then Alternative 3 could be implemented. The sites where Alternative 3 may be potentially applicable under future conditions are summarized in the following list:

- **Sites FT004, FT005, LF008, SD031, SD033, and SD043 –** IRA GET systems exist at these sites. Under potential future conditions, active remediation using these systems can be resumed under Alternative 3 if natural attenuation processes do not maintain compliance with the short-term effectiveness criterion under Alternative 2. Resumed GET system operation would provide for a similar degree of compliance with ARARs.

At Site LF008, limited progress was observed in achieving PCGs during approximately a decade of GET system operation. Maintaining compliance with the short-term effectiveness and permanence criterion following resumption of GET operation is also expected to require a long period of time.

- **Sites LF006, LF007B, and LF007D –** No IRA GET systems exist at these sites. However, Alternative 3 – GET may be implemented in the future if MNA processes under Alternative 2 prove incapable of maintaining compliance with the short-term effectiveness criterion. A new GET system would be required at each site. Implementing GET system operation will provide a similar degree of compliance.
- **Site ST027B –** Alternative 3 – GET may be implemented in the future at this site if MNA processes under Alternative 2 ultimately prove incapable of maintaining compliance with the short-term effectiveness criterion. A new GET system would be required. Implementing GET system operation will provide a similar degree of compliance.
- **Site SS016 –** If the combination of an in situ bioreactor and GET under Alternative 4 proves incapable of maintaining compliance with the short-term effectiveness criterion, then Alternative 3 can be implemented in the future. The existing IRA GET system could be expanded. However, source area extraction in the diffusion-dominated lithology present at the site will moderately limit the capacity of a GET system to achieve compliance. Contamination will be increasingly difficult to remove over time and will likely reach asymptotic concentrations above PCGs.
- **Sites SS015, SD036, and SD037 –** If source area EVO injection combined with EA under Alternative 5 ultimately prove incapable of maintaining compliance with the short-term effectiveness criterion, then Alternative 3 can be implemented in the future. Operation of the IRA GET systems at Sites SD036 and SD037 could be resumed. A new GET system would be required at Site SS015. Performance data obtained during the period of interim remediation indicate that GET operations within contaminant source areas become increasingly inefficient over time because of the diffusion-dominated silt and clay lithology present at Travis AFB.
- **Site DP039 –** If the Alternative 6 combination of an in situ bioreactor, phytoremediation, an EVO PRB, and EA ultimately proves incapable of maintaining compliance with the short-term effectiveness criterion, then Alternative 3 can be implemented in the future. The circumstances at Site DP039 are complex because of the multiple alternative components. But if these components prove to be non-compliant with the short-term effectiveness criterion, then the existing IRA GET system could be expanded. Resuming GET system operation under this potential future condition would provide a similar degree of overall compliance with the criterion.
- **Site SD034 –** If the combination of passive skimming and EA under Alternative 7 ultimately proves incapable of maintaining compliance with short-term effectiveness criterion, then Alternative 3 can be implemented in the future. Operation of the IRA GET system can be resumed and achieve a similar level of compliance with the criterion.

9.2.5.4 Alternative 4 – Bioreactor and GET

Alternative 4 at Site SS016 will provide short-term effectiveness similar to that provided under the site-specific IRAs. However, the in situ treatment processes and GET systems used under this alternative will require time to achieve RAOs and remove contaminant mass down to PCGs. A comparison of the estimated time required to achieve PCGs under Alternative 4 and the existing IRA is provided in Table 9-12.

TABLE 9-12
Comparison of Estimated Time to Achieve Preliminary Cleanup Goals[a]
Interim Remedial Action Compared with Alternative 4 – Bioreactor and GET
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Estimated Cleanup Time[b] (years)		
Site	**Interim Remedial Action**	**Alternative 4**	**Change from IRA to Alternative**
SS016	>100	62	GET to Bioreactor and GET

[a] PCGs are described in Section 5.
[b] Remediation timeframe estimate is provided in Appendix D.

The community and the environment will be protected during remediation by the Air Force maintaining control of the groundwater resource through enforcement of LUCs. Risks to workers will be minimized by these same measures and by following standard safety practices during construction and O&M.

Bioreactor installation and GET system installation have already been successfully completed at Site SS016. Potential future bioreactor modifications and GET system installations pose minimal risk to workers, the community, and the environment.

Implementation of Alternative 4 at Site SS016 includes a provision for sustainable remediation by using an in situ bioreactor. A solar-powered extraction pump will be used to circulate contaminated groundwater through the bioreactor. By using this green technology, some of the existing components of the Site SS016 GET IRA will be permanently discontinued. These components include a 2-Phase® extraction well and vapor-phase treatment using ThOx. The current groundwater treatment process of LGAC at the CGWTP will be continued. CO_2 emissions were 15 percent higher for the optimized IRA GET system compared with Alternative 4. The total energy reduction for Alternative 4 was 42 percent. The footprints for CO_2 generation and energy consumption are summarized in Table 9-10. More detailed information is provided in Appendix F.

9.2.5.5 Alternative 5 – EVO and EA

Implementation of Alternative 4 at Sites SS015, SD036, and SD037 will provide short-term effectiveness similar to that provided under the site-specific IRAs. However, the in situ treatment processes and natural attenuation processes used under this alternative will require time to achieve RAOs and remove contaminant mass down to PCGs. Comparisons of the estimates of the time required to achieve PCGs at each site under the current IRAs and Alternative 5 are developed in Appendix D and are summarized in Table 9-13. The key aspects of the remediation timeframe evaluations are provided in the following list:

- **Site SS015 –** Groundwater contaminant concentrations are increasing in some monitoring wells. This result indicates that MNA processes alone are not protective, and a remediation timeframe estimate cannot be evaluated with this increasing trend. Optimization of the IRA via EVO injection was conducted in 2010 to improve the overall protectiveness of the interim remedy.
- **Sites SD036 and SD037 –** These are component sites of the overall WIOU plume. Site-specific source area treatment with EVO injection will reduce the highest concentrations of contamination, enhance natural attenuation in the untreated portions of the plume, and improve overall protectiveness. An extended period of time will be required to achieve PCGs in the untreated portions of the plume via natural attenuation processes. However, the overall remediation timeframe will be reduced approximately 30 percent under the source area treatment component of Alternative 5 when compared with the time required under the current IRAs.

TABLE 9-13
Comparison of Estimated Time to Achieve Preliminary Cleanup Goals[a]
Interim Remedial Action Compared with Alternative 5 – EVO and EA
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Estimated Cleanup Time[b] (years)		
Site	**Interim Remedial Action**	**Alternative 5**	**Change from IRA to Alternative**
SS015	–[c]	70	MNA Assessment to EVO and EA
SD036	91	60	GET to EVO and EA[d]
SD037	91	60	GET and MNA Assessment to EVO and EA[d]

[a] PCGs are described in Section 5.
[b] Remediation timeframe estimate is provided in Appendix D.
[c] MNA not effective without enhancement. Groundwater contaminant concentrations are increasing.
[d] Sites SD036 and SD037 are components of the overall WIOU plume.

The community and the environment will be protected during remediation by the Air Force maintaining control of the groundwater resource through enforcement of LUCs. Risks to workers will be minimized by these same measures and by following standard safety practices during construction and O&M.

EVO injections have already been successfully completed at each of the sites. Potential future injection well installations and EVO injections pose minimal risk to workers, the community, and the environment.

Implementation of Alternative 5 at Sites SS015, SD036, and SD037 includes provisions for sustainable remediation by using in situ treatment though injection of EVO. By using this in situ treatment technology, some of the existing components of the Site SD036 and SD037 GET IRAs will be permanently discontinued. These discontinued components include energy-intensive DPE extraction wells, soil vapor treatment at the WTTP, and groundwater treatment at the CGWTP. The CO_2 emissions for Alternative 5 were either approximately the same (Site SD037) or 47 percent higher (Site SD036) than the IRA GET operations. The higher CO_2 emissions associated the Alternatives 5 are mainly due to the production of the substrate. The total energy reduction for Alternative 5 ranged from 95 to 97 percent for Sites SD037 and SD036, respectively. The footprints for carbon dioxide generation and energy consumption are summarized in Table 9-10. More detailed information is provided in Appendix F.

9.2.5.6 Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA

At Site DP039, Alternative 5 will provide short-term effectiveness similar to that provided by the existing IRA. A comparison of the estimated time required to achieve PCGs under Alternative 6 and the existing IRA is provided in Table 9-14.

TABLE 9-14
Comparison of Estimated Time to Achieve Preliminary Cleanup Goals[a]
Interim Remedial Action Compared with Alternative 6 – Excavation, Bioreactor, Phytoremediation, EVO PRB, and EA
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Estimated Cleanup Time[b] (years)		
Site	Interim Remedial Action	Alternative 6	Change from IRA to Alternative
DP039	70	58	GET and MNA Assessment to Bioreactor, Phytoremediation, EVO PRB, and EA

[a] PCGs are described in Section 5.
[b] Remediation timeframe estimate is provided in Appendix D.

Bioreactor installation, tree plantings, and EVO PRB injections have already been successfully completed. Potential future bioreactor modifications, tree plantings, injection well installations, and EVO injections pose minimal risk to workers, the community, and the environment.

The community and the environment will be protected during remediation by the Air Force maintaining control of the groundwater resource through enforcement of LUCs. Risks to workers will be minimized by these same measures and by following standard safety practices during construction and O&M.

Implementation of Alternative 6 at Site DP039 includes several provisions for sustainable remediation, including the following:

- **In situ bioreactor –** Placement of organic mulch, extraction well submersible pump powered by solar panels.
- **Phytoremediation –** An area of planted trees. Potential optimization actions include expanding the planted area and installing a solar-power irrigation system using contaminated groundwater.
- **EVO PRB –** subsurface injection of food-grade vegetable oil.

The existing components of the Site DP039 GET IRA will be permanently discontinued after implementation of Alternative 6. Through the use of these in situ treatment technologies, the energy-intensive GET system components, including DPE wells, VGAC treatment at the WTTP, and GAC groundwater treatment at the CGWTP will no longer be required. The CO_2 emissions were 75 percent higher for the GET system compared with Alternative 6. The higher CO_2 emissions associated with Alternative 6 are mainly due to the production of the substrate. The total energy reduction for Alternative 6 was 74 percent. The footprints for CO_2 generation and energy consumption are summarized in Table 9-10. More detailed information is provided in Appendix F.

9.2.5.7 Alternative 7 – Passive Skimming and EA

Implementation of Alternative 7 at Site SD034 will provide the same short-term effectiveness as the existing IRA. Free product removal activities are standard practice and pose few risks to workers or the community. A comparison of the estimated time required to achieve PCGs under Alternative 7 and the existing IRA is provided in Table 9-15.

TABLE 9-15
Comparison of Estimated Time to Achieve Preliminary Cleanup Goals[a]
Interim Remedial Action Compared with Alternative 7 – Passive Skimming and EA
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Estimated Cleanup Time[b] (years)		
Site	**Interim Remedial Action**	**Alternative 7**	**Change from IRA to Alternative**
SD034	91	60	GET, Passive Skimming, and MNA Assessment to Passive Skimming and EA[c]

[a] PCGs are described in Section 5.
[b] Remediation timeframe estimate is provided in Appendix D.
[c] Site SD034 is a component of the overall WIOU plume.

Natural attenuation is an effective means to reduce toxicity, mobility, volume, and mass over the long-term. However, natural attenuation processes will likely require a longer time to achieve RAOs than a more aggressive, more costly, less efficient, and less sustainable treatment alternative.

Alternative 7 has no construction activities associated with the implementation of a program of natural attenuation monitoring. If any were to arise, they typically would be limited to installation of monitoring wells. This activity poses minimal risk to workers, the community, and the environment.

Implementation of Alternative 7 at Site SD034 includes provisions for sustainable remediation. At this site, operation of the energy-intensive IRA GET system is discontinued and replaced by a program of MNA. The CO_2 emissions were 97 percent higher for the IRA GET system compared with Alternative 7. The total energy reduction for Alternative 7 was also 97 percent. The footprints for CO_2 generation and energy consumption are summarized in Table 9-10. More detailed information is provided in Appendix F.

9.2.6 Implementability

Implementability evaluates the technical and administrative difficulties associated with implementing each alternative. An important component of technical implementability is consideration of the reliability of the technology. Each of the groundwater alternatives assembled for the FFS, including Alternative 1 – No Action, are implementable. However, taking no action is an unreliable way to achieve cleanup goals. Comparisons of the performance of the remedial alternatives at each site against the Implementability evaluation criterion are provided in Table 9-16.

Each alternative uses administrative mechanisms of LUCs to restrict unauthorized access to contaminated groundwater and support achievement of the criterion. The common administrative LUCs include the Base Civil Engineer Work Request, excavation permits, and the requirements of the Base General Plan. Each of these components of LUCs are similarly implementable under each alternative.

For the off-base plumes at Sites LF007C, FT005, and SS030, an additional administrative LUC is the purchase of an easement to provide the Air Force a means to manage and control the use of private property overlying a groundwater plume originating from within the boundaries Travis AFB. These off-base easements have similar implementability and have already been purchased.

In accordance with the Base General Plan, future buildings constructed in proximity of a groundwater plume may require installation of a vapor barrier and passive venting system. These vapor intrusion mitigation measure have a similar degree of implementability under all of the alternatives.

9.2.6.1 Alternative 1 – No Action

Alternative 1 is included as a baseline for comparison when no remedial action is taken at a site.

No technology factors are evaluated (e.g., ability to construct or operate the technology, availability and reliability of the technology or specialists) under the No Action alternative. Similarly, no ability to monitor exposure pathways or evaluate risks in the future will exist, nor will a mechanism or need to coordinate with other agencies exist. Future remedial actions could be undertaken if desired.

9.2.6.2 Alternative 2 – MNA

In comparison with the site-specific IRAs, Alternative 2 is readily implemented at Travis AFB. Monitoring well networks have already been installed at Sites FT004, FT005, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, SS035, and SD043. During the period of interim remediation, MNA assessments were successfully conducted at multiple sites. No difficulties are anticipated in implementing Alternative 2.

Future remedial construction activities associated with the implementation of Alternative 2 would probably be limited to the installation of monitoring wells. This action is easily implemented, with both equipment and technical specialists being readily available. No schedule delays or technical problems are anticipated with implementation of Alternative 2. Potential future remedial actions would not likely be adversely affected by MNA processes.

TABLE 9-16
Summary of Comparative Analysis of Alternatives – Implementability
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Remedial Alternative	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
1 – No Action	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○
2 – MNA	■	■	■	■	□	■	■	□	□	■	□	□	■	■	□	■	□	□	□	○	■
3 – GET	■	■	◙	◙	■	◙	■	◙	◙	□	■	■	■	■	■	○	◙	◙	◙	○	■
4 – Bioreactor and GET	○	○	○	○	○	○	○	□	■	○	○	○	○	○	○	○	○	○	◙	○	○
5 – EVO and EA	○	○	○	○	○	○	○	■	○	□	○	○	○	○	○	○	■	■	◙	○	○
6 – Bioreactor, Phytoremediation, EVO PRB, and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○
7 – Passive Skimming and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○	○	○	○	○

■ Alternative that best satisfies the Implementability criterion.
◙ Alternative that moderately satisfies the Implementability criterion.
□ Alternative that poorly satisfies the Implementability criterion.
○ Alternative that is not applicable or does not satisfy the Implementability criterion.

Groundwater monitoring will be used to evaluate the effectiveness of natural attenuation. Sampling and engineering evaluations will be conducted. Engineering and laboratory services are standard practices that are readily available.

Alternative 2 is also administratively implementable. Coordination with state and other federal agencies would be limited to their continued review of the GSAP monitoring plans and MNA evaluations. Also, Travis AFB is already enforcing LUCs to restrict activities that could result in human exposure to contaminated groundwater.

In the event that the natural attenuation processes under Alternative 2 ultimately prove incapable of achieving RAOs, then Alternative 3 – GET could be implemented at one (1) or more of the sites.

GET System IRA Sites. At Sites FT004, FT005, LF008, SD031, SD033, and SD043, implementation of Alternative 2 – MNA follows approximately a decade of interim remediation using GET. The GET IRA systems at these sites were shut down for rebound studies during 2010. These contaminant plumes will continue to be monitored for the remainder of the period of interim remediation. Unless there is evidence of contaminant rebound, the GET systems will remain off. The IRA GET systems at these sites still exist and resuming GET under Alternative 3 would be readily implementable.

MNA and MNA Assessment IRA Sites. For Sites LF006, LF007B, and LF007D, MNA or MNA assessment was the IRA specified in the NEWIOU IROD. After approximately a decade of interim remediation, the NAAR concluded that natural attenuation of the plumes was effective (refer to Appendix C). A status summary for each of these sites is provided in the following list:

- **Site LF006 –** Natural attenuation processes have already reduced contaminant concentrations to less than the PCGs. No other action is likely to be required at this site. However, Alternative 3 – GET could be implemented in the future if MNA processes ultimately prove incapable of achieving RAOs.
- **Site LF007B –** Natural attenuation processes have already reduced contaminant concentrations to less than the PCGs. No other action is likely to be required at this site. However, Alternative 3 – GET could be implemented in the future if MNA processes ultimately prove incapable of achieving RAOs.
- **Site LF007D –** Low concentrations of benzene (3 µg/L vs. PCG of 1 µg/L) and 1,4-dichlorobenzene (12.6 µg/L vs. PCG of 5 µg/L) were detected in the 2010 GSAP. Concentrations of 1,4-dichlorobenzene have been decreasing over time. Concentrations of benzene have remained stable. The plume size is small and limited to the vicinity of monitoring well MW261x07. Use of an active treatment technology, such as GET, is not warranted under these conditions. However, Alternative 3 – GET could be implemented in the future if MNA processes ultimately prove incapable of achieving RAOs.

Former POCO Site. Site ST027B was formerly managed under the POCO program. A portion of the site with CERCLA contamination is designated as Site ST027B. The site is located within the flightline and is bounded by aircraft parking ramps and taxiways. Use of GET or another active treatment technology is unlikely to be needed under these conditions and would have implementability problems because of the proximity to airfield operations. Alternative 3 – GET has low implementability in comparison with Alternative 2 – MNA.

Alternative 2 – MNA would likely not be effective at addressing the *current* contaminant conditions at Sites LF007C, SS016, SS029, and SS030. The conditions at these sites are currently more applicable to Alternative 3 – GET. However, MNA is potentially implementable under *future* contaminant conditions after the current contaminant concentrations have been reduced by several years of groundwater extraction and treatment. At that time, continued progress toward RAOs may be achieved by transitioning from the active remedy to a program of MNA. In the future, sites with an EA remedy component under Alternatives 5, 6, and 7 can readily be transitioned to a full-plume program of MNA under Alternative 2. At Sites SS015, SD034, SD036, SD037, and DP039, natural attenuation monitoring programs will already be implemented in the distal portions of the plumes. These monitoring programs can be expanded to address the entirety of the plume following successful remediation of the source areas.

9.2.6.3 Alternative 3 – GET

Alternative 3 is readily implementable. Groundwater extraction and treatment systems already exist at Sites LF007C, SS029, and SS030. The IRA GET systems at Sites LF007C and SS030 will be optimized during 2011, and the optimization actions will be easily incorporated into the final remedial action at each site. The Air Force is already enforcing LUCs.

The ex situ treatment process of LGAC associated with Alternative 3 is proven and reliable, and replacement system components are readily available. No difficulties associated with additional future construction or operations are anticipated. If additional measures are necessary in the future, those actions could be easily undertaken. For example, additional or different treatment technologies could be added to the existing treatment trains with little difficulty.

Routine monitoring of treatment plant processes will continue under well established O&M procedures. Similarly, regular groundwater monitoring will continue to be conducted under the Travis AFB GSAP to verify plume capture and evaluate changes in chemical composition over time.

The regulatory agencies are already providing oversight of the ongoing groundwater IRAs at Sites LF007C, SS029, and SS030 and would continue to do so during implementation of Alternative 3.

In the future, Alternative 3 could be implementable at the sites currently found applicable to Alternative 2 – MNA; Alternative 4 – Bioreactor and GET; Alternative 5 – EVO and EA; Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA; and Alternative 7 – Passive Skimming and EA. The sites where Alternative 3 may be potentially applicable under future conditions are summarized in the following list:

- **Sites FT004, FT005, LF008, SD031, SD033, and SD043 –** IRA GET systems exist at these sites. Under potential future conditions, active remediation using these systems is readily implementable if MNA processes under Alternative 2 ultimately prove incapable of achieving RAOs.

- **Sites LF006, LF007B, and LF007D –** No IRA GET systems exist at these sites. However, Alternative 3 – GET could be implemented in the future if MNA processes under Alternative 2 ultimately prove incapable of achieving RAOs. A new GET system would be required at each site.
- **Site ST027B –** Alternative 3 – GET has limited implementability in the future. This site is bounded on all sides by active military airfield operations. A new GET system would be required, but the technical and administrative difficulties associated with installing such a system in proximity to aircraft parking aprons, taxiways, and runways would be considerable.
- **Site SS016 –** If the combination of an in situ bioreactor and GET under Alternative 4 proves incapable of achieving RAOs, then Alternative 3 could be implemented in the future. The existing IRA GET system could be expanded. Performance data obtained during the period of interim remediation indicate that GET operations within contaminant source areas become increasingly inefficient over time because of the diffusion-dominated silt and clay lithology present at Travis AFB. Therefore, resuming source area extraction in the diffusion-dominated lithology present at the site will limit the overall implementability of a GET system. Contamination will be increasingly difficult to remove over time and will likely reach asymptotic concentrations.
- **Sites SS015, SD036, and SD037 –** If source area EVO injection combined with EA under Alternative 5 ultimately prove incapable of achieving RAOs, then Alternative 3 can be implemented in the future. Operation of the IRA GET systems at Sites SD036 and SD037 could be resumed. A new GET system would be required at Site SS015. Performance data obtained during the period of interim remediation indicate that GET operations within contaminant source areas become increasingly inefficient over time because of the diffusion-dominated silt and clay lithology present at Travis AFB. This will limit the overall implementability of a GET system in comparison with in situ source area ERD treatment under Alternative 5.
- **Site DP039 –** If the Alternative 6 combination of an in situ bioreactor, phytoremediation, an EVO PRB, and EA ultimately proves incapable of achieving RAOs, then Alternative 3 can be implemented in the future. The circumstances at Site DP039 are complex because of the multiple alternative components. But, if these components prove incapable of making progress toward achieving the RAOs, then an expansion of the IRA GET system would be implementable.
- **Site SD034 –** If the combination of passive skimming and EA under Alternative 7 ultimately proves incapable of achieving RAOs, then Alternative 3 can be readily implemented in the future.

9.2.6.4 Alternative 4 – Bioreactor and GET

At Site SS016, Alternative 4 is similar in implementability as the existing IRA.
The components of the existing IRA within the OSA source area of Site SS016 have already been optimized during 2010. These optimizations included installation of a source area bioreactor. These optimization actions will be easily incorporated into this alternative. Similarly, the GET component of the alternative is already installed within the OSA and

TARA portions of the plume. Extracted groundwater is already being successfully treated and discharged at the CGWTP.

Remedial construction activities associated with Alternative 4 have already been completed. A source area bioreactor was installed in 2010. The GET system is also already installed. If modifications are required in the future, then specialized construction contractors and equipment are available. No schedule delays or technical problems are anticipated with the bioreactor or GET system. Potential future remedial actions would have to take the presence of these components of the alternative into consideration to prevent field activities that might limit their effectiveness.

Potential expansion of remedial action at Site SS016, particularly the GET component, has limited implementability. Site SS016 is located within an area of active military airfield operations. Site access is restricted. The majority of the plume underlies active military aircraft parking ramps, taxiways, and runways. These physical considerations, combined with a large plume area, profoundly limit the implementability of actions that might reduce the time required to achieve PCGs (e.g., an expanded GET system).

Groundwater monitoring will be conducted under the GSAP to evaluate the effectiveness of the Alternative 4 components. Engineering evaluation and laboratory services are standard practices that are readily available.

Alternative 4 is also administratively implementable. Coordination with state and other federal agencies will continue following implementation of the alternative. Travis AFB is already implementing LUCs to restrict activities that could result in human exposure to contaminated groundwater. These existing LUCs will continue to be enforced by the Air Force to provide short- and long-term protection from exposure to groundwater contamination.

9.2.6.5 Alternative 5 – EVO and EA

Alternative 5 is similar in implementability to the existing IRAs at Sites SS015, SD036, and SD037. The IRAs at each of these sites were optimized by source area EVO injection during 2010. These optimization actions will be easily incorporated into this alternative.

Remedial construction activities associated with Alternative 5 have already been completed as optimizations to the existing IRAs. If modifications are required in the future, then specialized construction contractors and equipment are available. No schedule delays or technical problems are anticipated with supplemental injection of edible oil. Potential future remedial actions would have to take the presence of these in situ treatment processes into consideration to prevent field activities that might limit their effectiveness.

Groundwater monitoring will be used to evaluate the effectiveness of in situ bioremediation and natural attenuation processes. Engineering evaluation and laboratory services are standard practices that are readily available.

Alternative 5 is also administratively implementable. Coordination with state and other federal agencies will continue following implementation of the alternative. Travis AFB is already implementing LUCs to restrict activities that could result in human exposure to contaminated groundwater. These existing LUCs will continue to be enforced by the Air Force to provide short- and long-term protection from exposure to groundwater contamination.

9.2.6.6 Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA

Alternative 6 is readily implementable in comparison with the existing Site DP39 IRA.

The existing IRA at Site DP039 has already been optimized by installation of a demonstration bioreactor in December 2008 and by injection of an EVO PRB during 2010. The area of phytoremediation was planted in 1998 as part of a treatability study. These optimization actions will be easily incorporated into this alternative.

Remedial construction activities associated with Alternative 6 have already been completed as optimizations to the existing IRAs. If modifications are required in the future, then specialized construction contractors and equipment are available. No schedule delays or technical problems are anticipated with supplemental injection of edible oil at the bioreactor or PRB. Potential future remedial actions would have to take the presence of these in situ treatment processes into consideration to prevent field activities that might limit their effectiveness.

Groundwater monitoring will be used to evaluate the effectiveness of in situ bioremediation and natural attenuation processes. Engineering evaluation and laboratory services are standard practices that are readily available.

Alternative 6 is also administratively implementable. Coordination with state and other federal agencies will continue following implementation of the alternative. Travis AFB is already implementing LUCs to restrict activities that could result in human exposure to contaminated groundwater. These existing LUCs will continue to be enforced by the Air Force to provide short- and long-term protection from exposure to groundwater contamination.

9.2.6.7 Alternative 7 – Passive Skimming and EA

Alternative 7 is readily implementable in comparison with the existing Site SD034 IRA.

During the period of interim remediation GET, free product removal, and MNA assessments were successfully conducted at Site SD034. No difficulties are anticipated in implementing passive skimming or MNA as components of a final groundwater remedy.

Potential remedial construction activities associated with the implementation of Alternative 7 are limited to the installation of monitoring wells. This action is easily implemented, with both equipment and technical specialists being readily available. No schedule delays or technical problems are anticipated. Potential future remedial actions would not likely be adversely affected by either passive skimming or natural attenuation monitoring.

Groundwater monitoring will continue to be used to evaluate the effectiveness of natural attenuation. Engineering evaluation and laboratory services are standard practices that are readily available.

Continuing passive skimming and natural attenuation monitoring under Alternative 7 is also administratively implementable. Coordination with state and other federal agencies would be limited to their review of the GSAP monitoring plans and natural attenuation evaluations. Also, Travis AFB is already enforcing LUCs to restrict activities that could result in human exposure to contaminated groundwater.

9.2.7 Costs

Comparisons of the estimated capital, O&M, and present value costs for the alternatives and implemented IRAs associated with each site are provided in the following summary tables. More detailed estimates are provided in Appendix E. Comparisons of the performance of the remedial alternatives at each site against the cost evaluation criterion is provided in Table 9-17.

Each alternative incurs the costs of implementing the administrative mechanisms of LUCs to restrict unauthorized access to contaminated groundwater and support achievement of the criterion. The common administrative LUCs cost components include the Base Civil Engineer Work Request, excavation permits, and the requirements of the Base General Plan. The cost of LUCs is similar under each alternative.

For the off-base plumes at Sites LF007C, FT005, and SS030, an additional cost component is for the purchase of an easement to provide the Air Force a means to manage and control the use of private property overlying a groundwater plume originating from within the boundaries of Travis AFB. The cost of an easement is similar for each off-base site and has already been incurred.

In accordance with the Base General Plan, future buildings constructed in proximity of a groundwater plume may require installation of a vapor barrier and passive venting system. These vapor intrusion mitigation measures will result in additional building costs, but are not cost components of the remedial alternatives.

The cost estimate summaries provided in this section include the capital and O&M costs of the selected remedial alternatives. The estimates may not include the full cost of final remedial action implementation. For example, the estimates do not reflect the administrative and management costs because these are considered costs common to all the alternatives. These estimates are not intended to be used to support procurement of project funding.

Cost estimates include completed, in-progress, and pending groundwater IRA optimization measures implemented from 2008 through 2011. These optimization measures include the following:

- **Site LF007C –** GET system expansion pending in 2011
- **Site SS015 –** source area treatment via EVO injection conducted in 2010
- **Site SS016 –** source area bioreactor installation conducted in 2010
- **Site SD036 –** source area treatment via EVO injection conducted in 2010
- **Site SD037 –** source area treatment via EVO injection conducted in 2010
- **Site DP039 –** source area bioreactor installation (2008) and EVO PRB installation (2010)

To the extent possible, the actual costs of the various optimization measures and other alternative components are used in developing the estimates. Subcontractor bid sheets and vendor quotes for pending work are the basis for some of the estimates.

The estimates do not include costs for some pre-existing components of the groundwater IRAs, treatability studies, and demonstration projects. This includes IRA components such as existing monitoring wells, extraction wells, and groundwater conveyance and treatment systems. The existing phytoremediation demonstration project at Site DP039 is also not included.

TABLE 9-17
Summary of Comparative Analysis of Alternatives – Cost
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Remedial Alternative	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
1 – No Action	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○
2 – MNA	■	■	■	■	□	■	■	□	□	■	□	□	■	■	□	■	□	□	□	○	■
3 – GET	■	■	□	□	■	□	□	◙	◙	□	■	■	■	■	■	○	◙	◙	◙	○	■
4 – Bioreactor and GET	○	○	○	○	○	○	○	□	■	○	○	○	○	○	○	○	○	○	◙	○	○
5 – EVO and EA	○	○	○	○	○	○	○	■	○	○	○	○	○	○	○	○	■	■	◙	○	○
6 – Bioreactor, Phytoremediation, EVO PRB, and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○
7 – Passive Skimming and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○	○	○	○	○

■ Alternative that best satisfies the Cost criterion.
◙ Alternative that moderately satisfies the Cost criterion.
□ Alternative that poorly satisfies the Cost criterion.
○ Alternative that is not applicable or does not satisfy the Cost criterion.

Present value costs are based on the remediation timeframe analysis conducted for each site (refer to Appendix D). The cleanup estimates include the time to reach PCGs by continuing the existing IRA and the time to reach PCGs under the site-specific FFS alternative. The remediation timeframe estimates were used to perform a present value calculation.

9.2.7.1 Alternative 1 – No Action

Alternative 1 is included as a baseline for comparison when no remedial action is taken at a site. No costs are associated with the No Action alternative.

9.2.7.2 Alternative 2 – MNA

A summary comparison of the costs associated with Alternative 2 and the implemented IRA at each applicable site is provided in Table 9-18.

9.2.7.3 Alternative 3 – GET

A summary comparison of the costs associated with Alternative 3 and the implemented IRA at Sites LF007C, SS029, and SS030 is provided in Table 9-19.

9.2.7.4 Alternative 4 – Bioreactor and GET

A summary comparison of the costs associated with Alternative 4 and the implemented IRA at Site SS016 is provided in Table 9-20.

9.2.7.5 Alternative 5 – EVO and EA

A summary comparison of the costs associated with Alternative 5 and the implemented IRA at Sites SS015, SD036, and SD037 is provided in Table 9-21.

9.2.7.6 Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA

A summary comparison of the costs associated with Alternative 6 and the implemented IRA at Site DP039 is provided in Table 9-22.

9.2.7.7 Alternative 7 – Passive Skimming and EA

A summary comparison of the costs associated with Alternative 2 and the implemented IRA at Site SD034 is provided in Table 9-23.

9.3 Summary of Comparative Analyses

A summary of the comparative analysis is provided in Table 9-24. This table presents an overall rating of the evaluation criteria for each site.

Similar comparison tables were previously provided for each site and remedial alternative for each evaluation criterion, including Table 9-4 (Overall Protection of Human Health and the Environment), Table 9-5 (Compliance with ARARs), Table 9-6 (Long-term Effectiveness and Permanence), Table 9-7 (Reduction of Toxicity, Mobility, or Volume through Treatment), Table 9-8 (Short-term Effectiveness), Table 9-16 (Implementability), and Table 9-17 (Cost).

TABLE 9-18
Summary of Compared Costs – Alternative 2 – MNA Costs Compared with Implemented IRA Costs
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Implemented Interim Remedial Action		Alternative 2		
Site	**Annual O&M**	**Present Value**	**Annual O&M**	**Present Value**	**Change from IRA to Alternative**
FT004	$4,088	$163,538	$2,703	$59,641	GET and MNA Assessment to MNA
FT005	$2,596	$94,273	$4,024	$101,633	GET to MNA
LF006	$2,451	$11,909	$2,451	$11,909	MNA Assessment to MNA
LF007B	$817	$0*	$817	$0*	MNA Assessment to MNA
LF007D	$1,069	$21,806	$1,069	$21,806	MNA Assessment to MNA
LF008	$2,264	$35,545	$2,264	$46,182	GET to MNA
ST027B	$2,451	$49,996	$2,451	$49,996	MNA to MNA
SD031	$2,970	$42,103	$2,451	$30,480	GET and MNA Assessment to MNA
SD033	$2,063	$65,778	$2,063	$42,082	GET and MNA Assessment to MNA
SD043	$1,461	$38,121	$1,288	$26,273	GET and MNA Assessment to MNA

*PCGs already achieved.

TABLE 9-19
Summary of Compared Costs – Alternative 3 – GET Costs Compared with Implemented IRA Costs
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Implemented Interim Remedial Action			Alternative 3			
Site	**Capital Cost**	**Annual O&M**	**Present Value**	**Capital Cost**	**Annual O&M**	**Present Value**	**Change from IRA to Alternative**
LF007C	$0	$15,258	$379,376	$121,023	$15,258	$432,334	GET to GET
SS029	$0	$20,503	$339,851	$0	$20,503	$339,851	GET to GET
SS030	$14,610	$20,503	$291,468	$17,532	$20,503	$294,390	GET to GET

TABLE 9-20
Summary of Compared Costs – Alternative 4 – Bioreactor and GET Costs Compared with Implemented IRA Costs
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Implemented Interim Remedial Action			Alternative 4			
Site	**Capital Cost**	**Annual O&M**	**Present Value**	**Capital Cost**	**Annual O&M**	**Present Value**	**Change from IRA to Alternative**
SS016	$0	$34,517	$761,718	$0	$35,247	$1,116,162	GET to Bioreactor and GET

TABLE 9-21
Summary of Compared Costs – Alternative 5 – EVO and EA Costs Compared with Implemented IRA Costs
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Implemented Interim Remedial Action			Alternative 5			
Site	**Capital Cost**	**Annual O&M**	**Present Value**	**Capital Cost**	**Annual O&M**	**Present Value**	**Change from IRA to Alternative**
SS015	$0	$2,703	$55,137	$0	$1,635	$358,474	MNA Assessment to EVO and EA
SD036	$0	$3,979	$100,106	$0	$1,635	$759,875	GET and MNA Assessment to EVO and EA
SD037	$0	$9,032	$275,751	$0	$1,635	$1,298,581	GET and MNA Assessment to EVO and EA

TABLE 9-22
Summary of Compared Costs – Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA Costs Compared with Implemented IRA Costs
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Implemented Interim Remedial Action			Alternative 6			
Site	**Capital Cost**	**Annual O&M**	**Present Value**	**Capital Cost**	**Annual O&M**	**Present Value**	**Change from IRA to Alternative**
DP039	$0	$2,212	$73,680	$0	$2,629	$1,177,618	GET and MNA Assessment to Bioreactor, Phytoremediation, EVO PRB, and EA

TABLE 9-23
Summary of Compared Costs – Alternative 7 – Passive Skimming and EA Costs Compared with Implemented IRA Costs
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Implemented Interim Remedial Action			Alternative 7			
Site	**Capital Cost**	**Annual O&M**	**Present Value**	**Capital Cost**	**Annual O&M**	**Present Value**	**Change from IRA to Alternative**
SD034	$0	$4,114	$108,288	$0	$3,655	$80,639	GET, Passive Skimming, and MNA Assessment to Passive Skimming and EA

TABLE 9-24
Summary of Comparative Analysis of Alternatives
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Site																				
Remedial Alternative	**FT004**	**FT005**	**LF006**	**LF007B**	**LF007C**	**LF007D**	**LF008**	**SS015**	**SS016**	**ST027B**	**SS029**	**SS030**	**SD031**	**SD033**	**SD034**	**SS035**	**SD036**	**SD037**	**DP039**	**SS041**	**SD043**
1 – No Action	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○
2 – MNA	■	■	■	■	□	■	■	□	□	■	□	□	■	■	□	■	□	□	□	□	■
3 – GET	◙	◙	□	□	■	□	◙	◙	◙	□	■	■	◙	◙	◙	□	◙	◙	◙	□	◙
4 – Bioreactor and GET	○	○	○	○	○	○	○	□	■	○	○	○	○	○	○	○	□	□	◙	○	○
5 – EVO and EA	○	○	○	○	○	○	○	■	○	○	○	○	○	○	○	○	■	■	◙	○	○
6 – Bioreactor, Phytoremediation, EVO PRB, and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○
7 – Passive Skimming and EA	○	○	○	○	○	○	○	○	○	○	○	○	○	○	■	○	○	○	○	○	○

■ Alternative that overall best satisfies the evaluation criteria.
◙ Alternative that overall moderately satisfies the evaluation criteria.
□ Alternative that overall poorly satisfies the evaluation criteria.
○ Alternative that is not applicable or does not satisfy the evaluation criteria.

All alternatives include components of LUCs and groundwater monitoring.