Appendix A
Acronyms and Abbreviations

APPENDIX A

Acronyms and Abbreviations

°C	degree(s) Celsius
°F	degree(s) Fahrenheit
µg/L	microgram(s) per liter
AF332	Air Force Form 332
AFB	Air Force Base
ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
CAMU	Corrective Action Management Unit
CCR	California Code of Regulations
CDFG	California Department of Fish and Game
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
CGWTP	Central Groundwater Treatment Plant
CIP	community involvement plan
cm/sec	centimeter(s) per second
CO_2	carbon dioxide
COC	chemical of concern
cP	centipoises(s)
CRP	community relations plan
CSM	conceptual site model
DCA	dichloroethane
DCE	dichloroethene
DNAPL	dense nonaqueous phase liquid
DOD	Department of Defense
DPE	dual-phase extraction
DTSC	Department of Toxic Substances Control

EA	enhanced attenuation
EIAP	Environmental Impact Analysis Process
EIOU	East Industrial Operable Unit
EOS®	Edible Oil Substrate
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
ERD	enhanced reductive dechlorination
ERP	Environmental Restoration Program
ERPIMS	Environmental Restoration Program Information Management System
ESTCP	Environmental Security Technology Certification Program
EVO	emulsified vegetable oil
FFA	Federal Facilities Agreement
FFS	basewide groundwater focused feasibility study
FS	feasibility study
ft/day	feet per day
ft^2/day	square feet per day
ft/ft	feet per foot
ft/year	feet per year
FTA	Fire Training Area
g/kg	gram(s) per kilogram
g/mL	gram(s) per milliliter
GAC	granular activated carbon
GET	groundwater extraction and treatment
gpm	gallon(s) per minute
GRA	General Response Action
GSAP	Groundwater Sampling and Analysis Program
HHRA	human health risk assessment
ICG	interim cleanup goal
IRA	interim remedial action

IRG	interim remediation goal
IROD	Interim Record of Decision
IRP	Installation Restoration Program
ISCO	in situ chemical oxidation
ITRC	Interstate Technology and Regulatory Council
JP-4	jet-propulsion fuel, grade 4
LGAC	liquid-phase granular activated carbon
LNAPL	light nonaqueous phase liquid
LTO	long-term operation
LUC	land use control
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MNA	monitored natural attenuation
msl	mean sea level
MTBE	methyl tert-butyl ether
MW	monitoring well
NAAP	natural attenuation assessment plan
NAAR	natural attenuation assessment report
NAPL	nonaqueous phase liquid
NCP	National Contingency Plan
NEWIOU	North, East, West Industrial Operable Unit
NFRAP	No Further Response Action Planned
NGWTP	North Groundwater Treatment Plant
NOU	North Operable Unit
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	National Research Council
O&M	operations and maintenance
OSA	Oil Spill Area
OU	operable unit

OWS	oil-water separator
PA	preliminary assessment
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PCG	preliminary cleanup goal
POCO	petroleum-only contaminated
POL	petroleum, oil, and lubricants
PRB	permeable reactive biobarrier
QAPP	quality assurance project plan
RAO	remedial action objective
RD/RA	remedial design/remedial action
RI	remedial investigation
ROD	record of decision
RPO	Remedial Process Optimization
SBBGWTP	South Base Boundary Groundwater Treatment Plant
SI	site inspection
SOD	soil oxidant demand
SRNL	Savannah River National Laboratory
SSA	Solvent Spill Area
SSPORTS	Supervisor of Shipbuilding, Conversion and Repair
SVE	soil vapor extraction
SVOC	semivolatile organic compound
SWRCB	State Water Resources Control Board
TARA	Tower Area Removal Action
TBC	to be considered
TCE	trichloroethene
TEFA	technical and economic feasibility analysis
ThOx	thermal oxidation
TPH	total petroleum hydrocarbon
TPH-D	total petroleum hydrocarbon as diesel

TPH-G	total petroleum hydrocarbon as gasoline
USA	Underground Service Alert
USC	U.S. Code
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	underground storage tank
UV/Ox	ultraviolet oxidation
VGAC	vapor-phase granular activated carbon
VOC	volatile organic compound
WABOU	West/Annexes/Basewide Operable Unit
Water Board	San Francisco Bay Regional Water Quality Control Board
WIOU	West Industrial Operable Unit
WTTP	West Treatment and Transfer Plant
ZVI	zero-valent iron

Appendix B
References

APPENDIX B

References

Air Force Center for Engineering and the Environment (AFCEE). 2010. *Sustainable Remediation Tool, Version 2.1*. Microsoft Excel-based platform. May.

Block, P.R. and D. Robinson. 2004. Novel Activation Technologies for Sodium Persulfate in In Situ Chemical Oxidation. Proceedings of the Fourth International Conference on the Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California.

CH2M HILL. 2011a. *Technical Report, Sustainable Bioreactor Demonstration Site DP039. Travis Air Force Base, California*. Air Force Center for Engineering and the Environment. Final. April.

CH2M HILL. 2011b. *Groundwater Sampling and Analysis Program 2009-2010 Annual Report.* Prepared for Travis Air Force Base, California. Final. April.

CH2M HILL. 2010a. *Natural Attenuation Assessment Report*. Prepared for Travis Air Force Base, California. Final. July.

CH2M HILL. 2010b. *2009 Annual Remedial Process Optimization Report for the Central Groundwater Treatment Plant, North Groundwater Treatment Plant, and South Base Boundary Groundwater Treatment Plant*. Prepared for Travis Air Force Base, California. Final. July.

CH2M HILL. 2010c. *Site SS015 Remedial Process Optimization Work Plan*. Prepared for Travis Air Force Base, California. Draft. November.

CH2M HILL. 2010d. Site SS030 *Remedial Process Optimization Work Plan*. Prepared for Travis Air Force Base, California. Final. April.

CH2M HILL. 2010e. *Sites SD036 and SD037 Remedial Process Optimization Work Plan*. Prepared for Travis Air Force Base, California. Final. July.

CH2M HILL. 2010f. *Site DP039 Remedial Process Optimization Work Plan*. Prepared for Travis Air Force Base, California. Final. June.

CH2M HILL. 2010g. *Vapor Intrusion Assessment Report*. Prepared for Travis Air Force Base, California. Final. March.

CH2M HILL. 2010h. *Third Progress Report, Sustainable Bioreactor Demonstration, Site DP039.* Prepared for Travis Air Force Base, California. Final. October.

CH2M HILL. 2010i. *Technical Memorandum: June 2009 6-month Rebound Study Completion at Site LF008*. Prepared for Travis Air Force Base, California. Final. January.

CH2M HILL. 2010j. *First Project Report, Sustainable Bioreactor Demonstration, Site DP039.* Prepared for Travis Air Force Base, California. Final. April.

CH2M HILL. 2010k. *Second Project Report, Sustainable Bioreactor Demonstration, Site DP039.* Prepared for Travis Air Force Base, California. Final. April.

CH2M HILL. 2010l. *Technical Memorandum Site ST027 – Area B Characterization Results*. Prepared for Travis Air Force Base, California. Final. July.

CH2M HILL. 2009a. *Recommendation to Transfer ERP Site ST032 to the POCO Program*. Technical Memorandum. Prepared for Travis Air Force Base, California. Final. April.

CH2M HILL. 2009b. *Site LF007C Remedial Process Optimization Work Plan*. Prepared for Travis Air Force Base, California. Final. March.

CH2M HILL. 2009c. *Sustainable Bioreactor Demonstration Work Plan, Site DP039*. Prepared for Travis Air Force Base, California. Final. January.

CH2M HILL. 2008a. *Second Five-Year Review Report*. Prepared for Travis Air Force Base, California. Final. September.

CH2M HILL. 2008b. *Vapor Intrusion Assessment Work Plan*. Prepared for Travis Air Force Base, California. Final. June.

CH2M HILL. 2007. *DP039 Optimization Field Report*. Prepared for Travis Air Force Base, California. Final. May.

CH2M HILL. 2004a. *South Base Boundary Groundwater Treatment Plant Operations and Maintenance Manual, Revision 3.* Prepared for Travis Air Force Base, California. Final. February.

CH2M HILL. 2004b. *Practical Considerations for Selecting and Delivering Electron Donors for Biostimulation Projects.* Technical Memorandum. Prepared for Travis Air Force Base, California. March.

CH2M HILL. 2003a. *Groundwater Five-Year Review*. Prepared for Travis Air Force Base, California. Final. July.

CH2M HILL. 2003b. *Long-Term Operation Strategic Plan, Version 2*. Prepared for Travis Air Force Base, California. Final. July.

CH2M HILL. 2002a. *LF007 Soil Remedial Action Design Report and Post-Closure Maintenance Plan.* Installation Restoration Program. Prepared for Travis Air Force Base, California. Final. August.

CH2M HILL. 2002b. *DP039 Phase Two Vacuum Dewatering Treatability Study Report*. Prepared for Travis Air Force Base, California. Final. October.

CH2M HILL. 2001. *Consolidation of Site ST032 into the Southern Interim Remedial Action.* Technical Memorandum. Prepared for Travis Air Force Base, California. August.

CH2M HILL. 2000. *SS030 Remedial Design*. Technical Memorandum. Installation Restoration Program. Travis Air Force Base, California. Final. September.

CH2M HILL. 1999a. *West Industrial Operable Unit Interim Groundwater Remedial Design Report*. Installation Restoration Program. Travis Air Force Base, California. Final. September.

CH2M HILL. 1999b. *Summary of the Site SS015 Investigation Technical Memorandum.* Installation Restoration Program. Prepared for Travis Air Force Base, California. Draft. October.

CH2M HILL. 1998a. *West/Annexes/Basewide Operable Unit Feasibility Study, 60th Air Mobility Wing*. Prepared for Travis Air Force Base, California. Final. April.

CH2M HILL. 1998b. *Natural Attenuation Assessment Plan*. Prepared for Travis Air Force Base, California. Final. August.

CH2M HILL. 1997. *West/Annexes/Basewide Operable Unit Remedial Investigation Report.* Installation Restoration Program. Prepared for Travis Air Force Base, California. Final. May.

Cohen, R.M., A.H. Vincent, J.W. Mercer, C.R. Faust, and C.P. Spalding. 1994. *Methods for Monitoring Pump-and-Treat Performance.* Dynamic Corporation. Prepared under contract to EPA. June.

Department of Defense (DOD). 2009. *Consideration of Green and Sustainable Remediation Practices in the Defense Environmental Restoration Program.* Memorandum for Assistant Secretaries of the Army and Navy (Installations and the Environment), Acting Assistant Secretary of the Air Force (Installations, Environment and Logistics), and Director, Defense Logistics Agency (DES-E). Office of the Under Secretary of Defense. August.

Environmental Security Technology Certification Program (ESTCP). 2008. *In Situ Chemical Oxidation for Remediation of Contaminated Groundwater – Frequently Asked Questions*. Prepared in support of ESTCP Project ER-0623. ESTCP, Colorado School of Mines, Clarkson University, CH2M HILL, Naval Facilities Engineering Command – Southern Division. Draft. November.

Environmental Security Technology Certification Program (ESTCP). 2007. *Users Manual, Emulsified Oil Design Tool.* North Carolina State University, Solutions-Industrial and Environmental Services (IES), and CH2M HILL. Draft. December.

Executive Order. 2009. *Executive Order 13514 - Federal Leadership in Environmental, Energy, and Economic Performance*. Federal Register, Vol. 74, No. 194. October 8.

Feenstra, S., J.A. Cherry, and B.L. Parker. 1996. "Conceptual Models for the Behavior of Dense Nonaqueous Phase Liquids in the Subsurface." *Dense Chlorinated Solvents and Other DNAPLs in Groundwater*. Pankow and Cherry, eds. Waterloo Press. pp. 53-88.

Fetter, C.W. 1988. *Applied Hydrogeology*. 2nd ed. New York: Macmillan Publishing Company, Inc.

Freeze, R.A. and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Gelhar, L.W., C. Welty, and K.R. Rehfeldt. 1992. "A Critical Review of Data on Field-Scale Dispersion in Aquifers." *Water Resources Research*. Vol. 28, No. 7. July. pp. 1955-1974.

Hrapovic, L., B.E. Sleep, D.J. Major, and E.D. Hood. 2005. "Laboratory Study of Treatment of Trichloroethene by Chemical Oxidation Followed by Bioremediation." *Environmental Science and Technology*. Vol. 39, No. 8. pp. 2888–2897.

Interstate Technology and Regulatory Council (ITRC). 2007. *A Decision Flowchart for the Use of Monitored Natural Attenuation and Enhanced Attenuation at Sites with Chlorinated Organic Plumes*. March.

Interstate Technology and Regulatory Council (ITRC). 2005. *Technical and Regulatory Guidance for In Situ Chemical Oxidation of Contaminated Soil and Groundwater*. 2nd ed. Technical/Regulatory Guideline. January.

Kueper, B.H., W. Abbot, and G. Farguhar. 1989. "Experimental Observations of Multiphase Flow in Heterogeneous Porous Media." *Journal of Contaminant Hydrology*. Vol. 5, pp. 83-95.

MACTEC. 2002. *Demonstration of Columnar Wall Jet Grouting of a Permeable Reactive Treatment Wall, Travis Air Force Base Project Report*. Final. June.

Major, D.W. 2001. Successful Field Demonstration of Bioaugmentation to Degrade PCE and TCE to Ethene. *Proceedings of the Sixth International In situ and On-Site Bioremediation Symposium*. June 2001, San Diego. Columbus, Ohio: Battelle Press. Vol. 8. pp. 27-34.

Mayer, K. and W. Laudenslayer, Jr. 1988. *A Guide to Wildlife Habitats of California.* California Department of Fish and Game. Sacramento, California.

National Research Council (NRC). 2004. *Contaminants in the Subsurface: Source Zone Assessment and Remediation*. Washington D.C.: National Academies Press.

National Research Council (NRC). 1999. *Groundwater and Soil Cleanup: Improving Management of Persistent Contaminants*. National Academy Press. ISBN: 0-309-06549-6.

Olmstead, F. and G. Davis. 1961. *Geologic Features and Ground-Water Storage Capacity of the Sacramento Valley, California.* U.S. Geological Survey Water-Supply Paper 1497.

Parsons. 2010. *Technical Report, Phytostabilization at Travis Air Force Base, California*. Air Force Center for Engineering and the Environment, Restoration Branch, Technology Transfer Office, Brooks City-Base, Texas. Final. September.

Parsons. 2009. *Technical Memorandum for the Demonstration of Phytostabilization of Chlorinated Solvents from Groundwater at Travis Air Force Base, California*. Draft. April.

Parsons. 2005. *Interim Technical Report for the Demonstration of Phytoremediation of Contaminated Groundwater Using Tree Plantings at Travis Air Force Base, California; Addendum Report No. 3.* Air Force Center for Environmental Excellence, Environmental Service Division, Brooks City-Base, Texas. Final. September.

Parsons. 2004. *Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents*. Air Force Center for Environmental Excellence, Naval Facilities Engineering Service Center, Environmental Security Technology Certification Program, U.S. Army Corps of Engineers. Final. August.

Parsons. 2002. *Phase II Field Feasibility Test for In-Situ Bioremediation of Chlorinated Solvents via Vegetable Oil Injection at Site SS015*. Travis Air Force Base, California. Final. March.

Parsons. 2001. *Phase I Field Feasibility Test for In-Situ Bioremediation of Chlorinated Solvents via Vegetable Oil Injection at Site SS015.* Travis Air Force Base, California. Draft. June.

Radian. 1996a. *North/East/West Industrial Operable Unit Feasibility Study*. Installation Restoration Program. Travis Air Force Base, California. Final. September.

Radian. 1996b. *West Industrial Operable Unit Remedial Investigation*. Installation Restoration Program. Travis Air Force Base. Final. February.

Radian. 1995. *Remedial Investigation Report for the North Operable Unit*. Installation Restoration Program. Travis Air Force Base. Final. July.

Sale, T.C. 1998. Interphase Mass Transfer from Single Component DNAPLs. Ph.D. Dissertation. Colorado State University, Fort Collins.

Savannah River National Laboratory (SRNL). 2006. *Enhanced Attenuation: A Reference Guide on Approaches to Increase the Natural Treatment Capacity of a System*. U.S. Department of Energy. August.

Supervisor of Shipbuilding, Conversion and Repair (SSPORTS) Environmental Detachment. 1998. *Removal Summary Report for Underground Storage Tank Site P-18, Travis Air Force Base, California.* April.

Thomasson, H., F. Olmsted, and E. LeRoux. 1960. *Geology, Water Resources and Usable Ground-Water Storage Capacity of Part of Solano County, California*. Geological Survey Water-Supply Paper 1464.

Travis Air Force Base. 2011. *Annual Report on the Status of Land Use Controls on Restoration Sites in 2010*. Environmental Restoration Program. 60 Civil Engineer Asset Management Flight. Final. February.

Travis Air Force Base. 2008. *Memorandum for the Record – Institutional Land Use Controls at Travis Air Force Base Groundwater Sites*. 60 CES/CEOA, Travis Air Force Base, California. October.

Travis Air Force Base. 2006. *North/East/West Industrial Operable Unit Soil, Sediment, and Surface Water Record of Decision*. Final. May.

Travis Air Force Base. 2005. Category IV No Further Remedial Action Planned Consensus Statement, Environmental Restoration Program Site SS041 (Building 905), Travis Air Force Base, California. December.

Travis Air Force Base. 2002a. *Soil Record of Decision for the West/Annexes/Basewide Operable Unit.* Installation Restoration Program. Travis Air Force Base, California. Final. December.

Travis Air Force Base. 2002b. *Travis AFB General Plan.* Travis Air Force Base, California. Final.

Travis Air Force Base. 1999. *Groundwater Interim Record of Decision for the West/Annexes/ Basewide Operable Unit*. Installation Restoration Program. Travis Air Force Base, California. Final. June.

Travis Air Force Base. 1998. *Groundwater Interim Record of Decision for the North, East, and West Industrial Operable Unit*. Installation Restoration Program. Travis Air Force Base, California. Final. January.

Travis Air Force Base. 1995. *Category IV No Further Remedial Action Planned Consensus Statement, Environmental Restoration Program Site SS041 (Building 905), Travis Air Force Base, California*. Final. December.

Travis Air Force Base. 1990. *Federal Facilities Agreement*. September.

U.S. Census Bureau. 2006. *2006 Population Estimate for Vacaville City, California*. http://factfinder.census.gov/servlet/SAFFPopulation?_event=Search&_name=vacaville&_state=04000US06&_county=vacaville&_cityTown=vacaville&_zip=&_sse=on&_lang=en&pctxt=fph. Accessed on February 25, 2008.

U.S. Census Bureau. 2009a. July 1, 2009 Population Estimate for Solano County, California. www.census.gov/popest/counties/CO-EST2009-01.html. Accessed on April 20, 2011.

U.S. Census Bureau. 2009b. July 1, 2009 Population Estimate for Fairfield and Vacaville, California. www.census.gov/popest/cities/SUB-EST2009-04.html. Accessed on April 20, 2011.

U.S. Environmental Protection Agency (EPA). 2011. Thermal Treatment: In Situ. U.S. EPA Contaminated Site Cleanup Information (CLU-IN). http://www.clu-in.org/techfocus/default.focus/sec/Thermal_Treatment%3A_In_Situ/cat/Overview/.

U.S. Environmental Protection Agency (EPA). 2010. Superfund Green Remediation Strategy. Office of Solid Waste and Emergency Response and Office of Superfund Remediation and Technology Innovation. September.

U.S. Environmental Protection Agency (EPA). 2010. *Dense Nonaqueous Phase Liquids Treatment Technologies*. EPA Contaminated Site Cleanup Information. August.

U.S. Environmental Protection Agency (EPA). 2009. *Principles for Greener Cleanups*. Office of Solid Waste and Emergency Response. August.

U.S. Environmental Protection Agency (EPA). 2008. *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites.* Technology Primer. Office of Solid Waste and Emergency Response. EPA 542-R-08-002. April.

U.S. Environmental Protection Agency (EPA). 2006. *In Situ Chemical Oxidation*. Engineering Issue. Scott G. Huling, EPA/ORD/NRMRL/GWERD and Bruce E. Pivetz, Dynamic Corporation. July.

U.S. Environmental Protection Agency (EPA). 1992. *CERCLA/Superfund Orientation Manual*. EPA 542-R-92005, p. XII-5. October.

U.S. Environmental Protection Agency (EPA). 1991. *ARARs Q's & A's: General Policy, RCRA, CWA, SDWA, Post-ROD Information, and Contingent Waivers*. EPA 9234.2-01/FS-A, p. 4. July.

U.S. Environmental Protection Agency (EPA). 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*. Interim Final. October.

U.S. Fish and Wildlife Service (USFWS). 2002. Formal Consultation on the Proposed Groundwater Remedial Action at LF007C, Area C, Travis Air Force Base, Solano County, California. Reference Biological Opinion #1-1-02-F-0227. July.

URS Group, Inc. (URS). 2005. *North Groundwater Treatment Plant Operations and Maintenance Manual, Sites FT004, SD031, and LF007 Area C.* Travis Air Force Base, California. Final. April.

URS Group, Inc. (URS). 2004. Central Groundwater Treatment Plant Monthly Data Sheet, Report Number 5. November.

URS Group, Inc. (URS). 2002a. *Central Groundwater Treatment Plant Operations and Maintenance Manual*. Revision 1. Travis Air Force Base, California. Final. May.

URS Group, Inc. (URS). 2002b. *SS016 Groundwater Interim Remedial Action Report*. Installation Restoration Program. Travis Air Force Base, California. Final. June.

Weston, Roy F., Inc. (Weston). 1995. *East Industrial Operable Unit Remedial Investigation Report*. Travis Air Force Base, California. Final. October.

Weston, Roy F., Inc. (Weston). 1988. *Interim Technical Report No. 5 for the Integrated Installation Restoration Program Stage 2 for Travis Air Force Base*. September.

Wiedemeier, T.H., M.A. Swanson, D.E. Moutoux, E.K. Gordon, J.T. Wilson, B.H. Wilson, D.H. Kampbell, J.E. Hansen, P. Haas, and F.H. Chapelle. 1996. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater*. Air Force Center for Engineering and the Environment. November.

Appendix C
Lines of Evidence for MNA

APPENDIX C

Lines of Evidence for MNA

This appendix provides lines of evidence for the applicability of natural attenuation processes to remediate contaminated groundwater at Travis Air Force Base (AFB), California.

Interim remedial actions (IRAs) for the groundwater sites at Travis AFB have been implemented in accordance with the Groundwater Interim Records of Decision (IRODs) for the North, East, and West Industrial Operable Unit (NEWIOU) (Travis AFB, 1997) and the West/Annexes/Basewide Operable Unit (WABOU) (Travis AFB, 1999). The IRAs have been performing over the interim period leading up to the Basewide Groundwater Record of Decision (ROD).

The IRODs deferred formal selection of Monitored Natural Attenuation (MNA) as an interim remedy, at all or portions of Environmental Restoration Program (ERP) sites, until assessments of the viability of natural attenuation processes were conducted. Therefore, natural attenuation assessments were performed at the following sites over the interim period leading up to the Groundwater ROD: FT004, LF006, LF007B, LF007D, SS015, SD031, SD033, SD037, and DP039. However, at several sites (FT004, SD031, SD033, SD037, and DP039), MNA or MNA assessment was performed only in the downgradient portion of the plume while an active interim remedy (i.e., groundwater extraction and treatment [GET]) was performed in the source area and higher concentration portions of the plume.
At Site SS015, a treatability study was performed to evaluate the application of vegetable oil to enhance in situ biodegradation of chlorinated solvents. In effect, enhanced attenuation (EA) has been performed at Sites FT004, SS015, SD031, SD033, SD037, and DP039 over the interim period. The results of the assessment are presented in detail in the Final *Natural Attenuation Assessment Report (*NAAR) (CH2M HILL, 2010a). The key conclusions of the assessment are summarized in this appendix.

MNA can be defined as follows (U.S. Environmental Protection Agency [EPA], 1998):

> The term "monitored natural attenuation" refers to the reliance on natural attenuation processes (within the context of a carefully controlled and monitored clean-up approach) to achieve site-specific remedial objectives within a time frame that is reasonable compared to other methods. The "natural attenuation processes" that are at work in such a remedial approach include a variety 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 soil or groundwater. These in situ processes include biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants.

EA can be defined as follows (Interstate Technology Regulatory Council [ITRC], 2008):

> Any type of intervention that might be implemented in a source-plume system to increase the magnitude of attenuation by natural processes beyond that which occurs without intervention. Enhanced attenuation is the result of applying an enhancement that sustainably manipulates a natural attenuation process, leading to an increased reduction in mass flux of contaminants.

The enhancements that have been performed over the interim period at Travis AFB have resulted in a reduction of mass loading to the aquifer. At several sites (FT004, FT005, LF008, and SD031), it appears that the reduction in mass loading has been sufficient to allow for the active remedy to cease and that the attenuation capacity of the aquifer now exceeds the mass loading to the aquifer. At some sites (SS015, DP039, and the West Industrial Operable Unit [WIOU], which includes Sites SD033, SD034, SD036, SD037, SD043), additional enhancement is required to reduce mass loading to the aquifer in order for the attenuation capacity of the aquifer to match or exceed the mass loading to the aquifer.

C.1 Lines of Evidence for Attenuation at Travis AFB

During the period of interim remediation, portions of groundwater plumes unaffected by active remediation have been monitored for 8 to 10 years, to evaluate attenuation at Travis AFB. In accordance with the Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-17 (1997), the Air Force believes the data collected to date at Travis AFB are of sufficient quality and duration to determine whether attenuation is occurring at the Base.

Three (3) lines of evidence were considered in this evaluation: (1) historical groundwater data that demonstrate plume attenuation, (2) hydrogeologic and geochemical data that indicate whether physical or biological attenuation processes are dominant at the site, (3) flux data that indicate volatilization from groundwater to soil gas is occurring.

C.1.1 Plume Attenuation

The first line of evidence, plume attenuation, includes the following:

- An assessment of contaminant concentration trends at individual wells.
- Comparison of the historical to current extent of groundwater contamination at a site (whether or not the plume is stable, increasing, or decreasing in extent).
- An estimate of the distance the plume would be expected to have migrated over the interim monitoring period in the absence of natural attenuation mechanisms (for sites included in the NAAR, where active remedies have not made this estimation inappropriate).
- Calculation of point attenuation rates (for sites included in the NAAR, where active remedies have not made this calculation inappropriate). Point attenuation (or concentration vs. time attenuation) rates can be calculated for individual wells as described in "Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies" (EPA, 2002). The point attenuation rate can be used to evaluate

reduction in contaminant concentration over time at a single point and can further be used to estimate the time needed to reach Preliminary Cleanup Goals (PCGs) at that point.

- Calculation of bulk attenuation rates (for sites included in the NAAR, where active remedies have not made this calculation inappropriate). A bulk attenuation rate may be calculated for the entire plume. This analysis is performed using a concentration vs. distance plot, ideally using data from wells located along the axis of the plume (EPA, 2002). The bulk attenuation rate provides information on the reduction in dissolved contaminant concentration with distance from the source and can be used to demonstrate that contaminants are being attenuated within the groundwater flow system.
- Estimations of time to reach PCGs (refer to Section 5).

C.1.2 Hydrogeologic and Geochemical Data

The second line of evidence is available for sites that had MNA as a part of the IRA and for which geochemical data are therefore available. This line of evidence was evaluated by using geochemical parameters to screen for biodegradation potential of chlorinated contaminants. The screening evaluation involves scoring the site for biodegradation potential according to a procedure developed by the Air Force Center for Engineering and the Environment (AFCEE) (Wiedemeier et al., 1996).

C.1.3 Volatilization

The third line of evidence, that of volatilization from dissolved to vapor phase, was provided by evaluation of the Site DP039 phytostabilization study area performed in 2009 (Parsons Engineering Science, Inc. [Parsons], 2010). The phytostabilization study area consists of a tree stand planted in an area overlying the Site DP039 groundwater plume. Soil flux samples were collected in June and October 2009 within the tree stand and outside of the tree stand. Soil flux was found to be an important mechanism of trichloroethene (TCE) mass loss in the system, equal to if not greater than mass loss through leaf transpiration. Measured soil flux was greatest within the tree stand (on average, more than fifty [50] times greater than that measured outside the tree stand). However, measurable mass flux (ranging from 0.008 to 0.39 micrograms per square meter-hour [$\mu g/m^2$-hr]) was found to occur outside of the tree stand (Parsons, 2010).

The sediments in the vadose zone at Site DP039 are similar to the rest of Travis AFB (primarily low permeability silts and clays with discontinuous sand stringers); thus, it is reasonable to conclude that if soil flux (volatilization) occurs at Site DP039, it also occurs at the other groundwater sites at Travis AFB. The significant difference between the soil flux inside and outside of the tree stand at Site DP039 may be due to increased permeability of the vadose zone created by the root systems of the trees. Therefore, the lower soil flux values measured outside of the tree stand are considered conservative and representative for Travis AFB.

When evaluating the evidence for natural attenuation at each site, it is important to remember that there are two (2) mechanisms for natural attenuation: biological and physical. Biological attenuation occurs when microbial organisms destroy the contaminant by degrading or transforming it into another substance. 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 dissolved to vapor phase.

C.1.4 MNA Sites

MNA is a remedial alternative at Sites FT004, FT005, LF006, LF007B, LF007D, LF008, ST027B, and SD031. The following subsections present the lines of evidence indicating whether MNA is an appropriate remedy for these sites.

C.1.4.1 Sites FT004 and SD031

Sites FT004 and SD031 (Figure C-1; figures are located at the end of this appendix) are discussed together because the sites are adjacent, the downgradient portions of the groundwater plumes at these sites are co-mingled, and they share a common interim remedial approach. Over the interim period, Sites FT004 and SD031 have undergone EA. At Site FT004, the primary groundwater contaminant is TCE; at Site SD031, it is 1,1-dichloroethene (DCE). Groundwater extraction was performed in the Site FT004 and SD031 source areas to reduce mass loading. The NAAR concluded that the combination of groundwater extraction in the source areas and monitored attenuation in the downgradient portion of the plume was an effective remedy (CH2M HILL, 2010a). Lines of evidence supporting the selection of MNA as an appropriate remedy for Sites FT004 and SD031 are as follows:

- **Plume Attenuation.** The NAAR, which evaluated data collected through fourth quarter of 2008 (4Q08) presented substantial evidence for natural attenuation of contaminants at Sites FT004 and SD031, including the following:
  - TCE and 1,1-DCE concentrations have declined over the interim period in most of the MNA wells (most of these wells are beyond the influence of the GET system).
  - The TCE and 1,1-DCE plumes have reduced in size since the MNA assessment began (Figure C-2).
  - There is no indication of plume migration. In fact, the leading edge of the plume has been receding.
  - Advective transport of contaminants at the rate of groundwater flow is modified by natural attenuation (processes such as dispersion, diffusion, biodegradation) and the chemical retardation characteristics of the individual contaminants and the alluvium. Disregarding natural attenuation processes, and assuming that retardation slows the transport of TCE at this site to approximately 0.8 times the linear velocity of groundwater (based on the EPA online retardation factor calculator located at http://www.epa.gov/athens/learn2model/part-two/onsite/retard.html), then the portion of the plume beyond the capture of the GET system would be expected to have migrated approximately 600 feet (80 feet per year) over the 8 years of the MNA assessment period. However, the plume has receded, indicating that natural attenuation processes must be occurring at the site.

- In 4Q08, of the seventeen (17) monitoring wells in the MNA assessment network, there were only three (3) monitoring wells at which contaminants continue to exceed PCGs.
- A point attenuation rate constant was calculated for two (2) of the three (3) MNA wells with TCE concentrations exceeding the PCG in 4Q08 (wells MW574x31, MW590x04, and MW591x04): MW574x31 and MW590x04. An attenuation rate constant could not be calculated for well MW591x04, where TCE concentrations recently increased. At both monitoring wells MW574x31 and MW590x04, the only contaminant that continued to exceed PCGs was TCE. The attenuation rate constant calculated for well MW574x31 is approximately 0.058 per year, and the attenuation rate constant calculated for well MW590x04 is approximately 0.58 per year (Attachment C1). At these rates, TCE concentrations at well MW574x31 are expected to reach the PCG (5 micrograms per liter [µg/L]) in 2021, and TCE concentrations at well MW590x04 would be expected to reach the PCG in 2007. TCE concentrations at well MW590x04 were below the PCG in 2007, but slightly exceeded the PCG of 5 µg/L in 2008 (TCE was detected at a concentration of 5.3 µg/L in 2008).
- However, it should be noted that both wells MW574x31 and MW590x04 are located along the designed extent of hydraulic capture of the GET system. Therefore, attenuation rates at these wells were likely affected by the GET system. The rate of attenuation at these wells may decrease if groundwater extraction at the site ceases.
- Note that the bulk attenuation rate calculations for Sites FT004 and SD031 were not included in the NAAR. Because of the recent GET IRA, the current bulk attenuation rates would not be representative of natural attenuation conditions. The resulting bulk attenuation rate would be an overestimation of the attenuation rate expected in the absence of the active IRA and thus cannot be used to evaluate the current effectiveness of natural attenuation at the site.

The evaluation provided in the NAAR focused on the area specified for MNA assessment over the interim period (the downgradient portion of the plume, beyond the influence of the GET system); however, MNA for the entire plume is a remedial alternative in this FFS. A portion of the Site FT004 GET system and the entire Site SD031 GET system have been shut down for a rebound study since December 2007. The rest of the Site FT004 GET system was shut down in March 2009 to support the ongoing rebound evaluation. Groundwater monitoring data have been collected to monitor for rebound and to assess the attenuation capacity of the aquifer in the absence of active remediation. Data collected at these sites through 2Q10 are presented in detail in the *Groundwater Sampling and Analysis Program 2009–2010 Annual Report* (GSAP 2009–2010 Annual Report) (CH2M HILL, 2011). The following is a summary of the main conclusions presented in the GSAP 2009–2010 Annual Report:

- Since the SD031 GET system was taken offline for a rebound study in 2007, volatile organic compound (VOC) concentrations within Site SD031 have remained below 100 µg/L.
- At Site FT004, VOC concentrations in a small portion of the plume (near monitoring wells MW134x04 and MW266x04) remain above 100 µg/L (the IRAO). However, no significant rebound was observed over the reporting period. 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 (Attachment C2).

- Only two (2) Site FT004 monitoring wells have statistically significant increasing TCE concentration trends (according to the Mann-Kendall trend analysis): MW134x04 and MW591x04 (Attachment C3). These wells are located in the downgradient portion of the plume. The increasing trend at MW134x04 is very slight; the maximum TCE concentration detected is 1.3 µg/L (below the PCG). The TCE concentration detected at MW591x04 in 2010 (13.5 µg/L) is below the maximum concentration detected at this well (14.4 µg/L).
- On the basis of the data collected through 2Q10, MNA is a viable remedy for the residual groundwater contamination at Sites FT004 and SD031. Overall, contaminant concentrations are stable or declining in the Site FT004 and SD031 wells (Attachments C2 and C3). The monitoring network includes both shallow and deep monitoring wells; MNA appears to be effective throughout the entire thickness of the plume.

In addition to the trend evaluation of analytical data collected at the sites over the last 10 years, MNA remediation timeframes (RTFs) were estimated for Sites SD031 and FT004 using a model as described in Appendix D. The timeframe estimate ranged from approximately 15 years (Site SD031) to approximately 35 years (Site FT004). For comparison, a continuation of the existing IRA (GET/MNA) RTF was also estimated for Site FT004, which has higher VOC concentrations and a longer RTF than Site SD031. The timeframe estimated for continuation of GET/MNA at Site FT004 was the same as the MNA estimate (35 years). Pumping appears to be having minimal impact on the overall downward trend in plume concentrations. This is to be expected because asymptotic recovery rates are removing a small fraction of the total removal that includes multiple MNA mechanisms. Optimization of the GET may result in a slightly shorter RTF. However, from this analysis it does not appear that continuing GET at Site FT004 would result in a significantly shorter RTF.

- **Geochemical Parameters.** Geochemical parameters were collected from Sites FT004 and SD031 in 2000–2001 and in 2008 and were used to evaluate the biological degradation potential at these sites (documented in the NAAR [CH2M HILL, 2010a]). The data collected in 2000–2001, prior to the startup of the GET, indicated reducing conditions that were conducive to biodegradation of chlorinated VOCs. However, the data collected in 2008, while the GET was operational, indicated aerobic conditions unfavorable to biodegradation (CH2M HILL, 2010a). These results are not surprising, as operation of the GET introduces oxygen into the aquifer. During operation, the stability of the downgradient portion of the plume, beyond the influence of the GET system, was due primarily to physical attenuation. The GET system has since been shut down for a rebound study, and the aquifer may return to more reducing conditions. If that is the case, biological degradation may add to the attenuation capacity of the aquifer.
- **Volatilization.** Data to evaluate volatilization at Travis AFB were not collected to support the NAAR. However, as previously discussed, evidence that volatilization from dissolved to vapor phase occurs at Travis AFB was provided by an evaluation of the Site DP039 phytostabilization study area performed in 2009 (Parsons, 2010). Lithology

and depth to groundwater at Sites FT004 and SD031 are similar to Site DP039 and it is reasonable to conclude that volatilization also occurs at these sites.

Summary. The lack of rebound in VOC concentrations at Sites FT004 and SD031 after the GET systems were shut down indicate that the attenuation capacity of the aquifer exceeds any remaining source loading. Continuation of GET will not result in a significant reduction in RTF. This is to be expected because asymptotic recovery rates are removing a small fraction of the total removal that includes multiple MNA mechanisms. MNA is an appropriate remedy at these sites.

C.1.4.2 Site FT005

Over the majority of the interim period, Site FT005 (Figure C-3) has undergone GET, which is the IRA at this site. The primary contaminant at Site FT005 is 1,2-dichloroethane (DCA). At Site FT005, the IRAO of migration control has been achieved, and the objective of off-base groundwater remediation has nearly been achieved (Figure C-4). 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 in accordance with the recommendations in the *2008 Annual Remedial Process Optimization Report for the Central Groundwater Treatment Plant, North Groundwater Treatment Plant, and South Base Boundary Groundwater Treatment Plant* (2008 RPO Report) (CH2M HILL, 2009). In August 2010, in response to rebound in 1,2-DCA concentrations in some portions of the plume, three (3) of the fifteen (15) Site FT005 extraction wells (EW02x05, EW734x05, and EW735x05) were brought back online. Data collected at Site FT005 are presented in detail in the GSAP 2009–2010 Annual Report (CH2M HILL, 2011).

Lines of evidence supporting the selection of MNA as an appropriate remedy for Site FT005 are as follows:

- **Plume Attenuation:**
  - Through the rebound study, most Site FT005 monitoring wells and extraction wells continued to have decreasing or stable 1,2-DCA concentrations (Attachments C2 and C3).
  - In 2Q10, approximately 2.5 years after the rebound study began, 1,2-DCA was detected in only five (5) of the fifteen (15) extraction wells and four (4) of the eleven (11) monitoring wells sampled. The maximum 1,2-DCA concentration detected in 2Q10 was 5.3 µg/L at extraction well EW735x05. The PCG for 1,2-DCA is 0.5 µg/L.
  - The Mann-Kendall analysis and chemical time-series plot indicate an increasing 1,2-DCA concentration trend at extraction well EW735x05 (Attachments C2 and C3). No increasing trends are evident at the other Site FT005 extraction wells.
  - No increasing 1,2-DCA trends have been identified by the Mann-Kendal analysis at Site FT005 monitoring wells. However, the chemical time-series plots indicate that 1,2-DCA concentrations have recently increased at monitoring well MW772x05, to a maximum concentration of 1.4 µg/L, after an initial period of decreasing concentrations. This monitoring well is located near extraction well EW735x05, where an increasing trend was also identified.

  - In addition to EW735x05, some rebound was also evident at two (2) other extraction wells during 2Q10 (EW02x05 and EW734x05). Consequently, all three (3) extraction wells (EW02x05, EW734x05, and EW735x05) were restarted in August 2010.
  - Rebound in 1,2-DCA concentrations has been limited to a few wells, indicating that the GET system is reaching its limit of effectiveness.

  Because of the recent GET IRA, point attenuation rates and current bulk attenuation rates would not be representative of natural attenuation conditions (this would result in an overestimate of attenuation at the site) and were therefore not calculated. However, RTFs for both continued GET and for MNA were estimated for Site FT005 using models as described in Appendix D. The RTF estimate under continued GET was approximately 10 years. The RTF estimate for an MNA alternative was approximately 43 years. Note that both the GET and the MNA RTF estimates are conservative. Site-specific 1,2-DCA decay data were not available; therefore, the effect of decay was not included in either estimate. The RTF estimates are also determined by the very low PCG (0.5 μg/L), which is an order of magnitude lower than that of TCE (5.0 μg/L).

- **Geochemical Parameters.** Because MNA was not selected as a part of the IRA for Site FT005, geochemical parameter data to assess biodegradation potential have not been collected at this site.
- **Volatilization.** As previously discussed, evidence that volatilization from dissolved to vapor phase occurs at Travis AFB was provided by an evaluation of the Site DP039 phytostabilization study area performed in 2009 (Parsons, 2010). Lithology and depth to groundwater at Site FT005 are similar to Site DP039, and it is reasonable to conclude that volatilization also occurs at this site.
- **Impact on Adjacent Site SS030.** The current IRA of GET at Site FT005 has negatively impacted the hydraulic capture at adjacent Site SS030, causing a portion of the Site SS030 TCE plume to migrate eastward toward the Site FT005 extraction system. Since the Site FT005 GET was shut down for a rebound study, the extent of hydraulic capture at adjacent Site SS030 has improved (CH2M HILL, 2011). Implementation of MNA at Site FT005 would increase the effectiveness of the Site SS030 remedy. Regardless, operation of the Site SS030 GET system was modified during 2010 to compensate for the hydraulic interactions between the sites. The Air Force is continuing to monitor the effectiveness of these modifications.

Summary. The lack of rebound in 1,2-DCA concentrations evident throughout most of the plume following shutdown of the GET system indicate that the attenuation capacity of the aquifer exceeds any remaining source loading. Some rebound was observed in a few extraction wells and monitoring wells; however, the overall response of the groundwater plume over the course of the rebound study indicates the GET system is reaching its limit of effectiveness. MNA is an appropriate remedy at this site.

C.1.4.3 Site LF006

Over the interim period, Site LF006 (Figure C-1) has undergone MNA. The NAAR concluded that MNA is an effective remedy (CH2M HILL, 2010a). Lines of evidence supporting the selection of MNA as an appropriate remedy for Site LF006 are as follows:

- **Plume Attenuation.** The NAAR, which evaluated data collected through 4Q08, presented substantial evidence for natural attenuation of contaminants at Site LF006, including the following:
  - The TCE plume has reduced in size since the MNA assessment began (Figure C-5).
  - Detections of total petroleum hydrocarbons as gasoline (TPH-G) are sporadic and low (typically less than 10 µg/L).
  - Total petroleum hydrocarbons as diesel (TPH-D) has been detected at the site only once in the last several years (since 2004).
  - 1,1-DCE concentrations are currently below the PCG.
  - There is no indication of plume migration. In fact, the plume has been receding.
  - TCE concentrations have declined over the interim period in most of the MNA wells (Attachment C2).
  - Disregarding natural attenuation processes, and assuming that retardation slows the transport of TCE at this site to approximately 0.8 times the linear velocity of groundwater, then the plume would be expected to have migrated approximately 800 feet (approximately 80 feet per year) over the 10 years of the MNA assessment period. However, the plume has receded, indicating that natural attenuation processes must be occurring at this site.
  - Of the twelve (12) monitoring wells in the MNA assessment network, in 4Q08, there were only two (2) monitoring wells at which contaminants continue to exceed PCGs. A point attenuation rate constant was calculated for these two (2) MNA wells: MW208Dx06 and MW259x06. At both monitoring wells, the only contaminant that continued to exceed PCGs is TCE. The attenuation rate constant calculated for well MW208Dx06 is approximately 0.061 per year, and the attenuation rate constant calculated for well MW259x06 is approximately 0.035 per year (Attachment C1). At these rates, TCE concentrations at well MW208Dx06 would be expected to reach the PCG (5 µg/L) in 2009, and TCE concentrations at well MW259x06 would be expected to reach the PCG in 2014.
  - Little change in aquifer conditions between 1999 (when the initial MNA assessment was performed) and 2008 is evident. The aquifer remains aerobic and available carbon is low; physical attenuation processes (such as dispersion, dilution, sorption, and volatilization) remain the dominant mechanisms for reduction in plume size over time. These mechanisms are not anticipated to change in the near future, and thus the attenuation rates calculated provide reasonable estimates of time to reach PCGs.

- A bulk attenuation rate constant of approximately 0.75 per year was calculated for TCE at Site LF006, based on the 2008 distribution of TCE in groundwater at the site (Attachment C4). The positive bulk attenuation rate constant indicates that attenuation of TCE is occurring. The maximum TCE concentration detected at Site LF006 in 2008 was 8.8 J- µg/L, and no TCE source area remains at the site. The travel time for TCE to reach the PCG (5 µg/L) once it leaves the portion of the plume with the highest TCE concentrations (8.8 J- µg/L) is estimated to be approximately 0.75 year. The plume (exceeding the PCG) should extend approximately 63 feet from the portion of the plume with the highest TCE concentrations.

Since the attenuation evaluation in the NAAR was performed, additional groundwater data have been collected at Site LF006. Data collected at Site LF006 through 2Q10 are presented in detail in the GSAP 2009–2010 Annual Report (CH2M HILL, 2011). The following is a summary of the main conclusions presented in the GSAP 2009–2010 Annual Report:

- TCE shows significantly decreasing trends at several Site LF006 plume wells according to the Mann-Kendall trend analysis and time-series plots (Attachments C2 and C3). No monitoring wells have increasing TCE trends.
- The TCE plume has reduced in size, and TCE concentrations detected at the site no longer exceed the PCG.
- No contaminants exceeded PCGs over the 2009–2010 reporting period.

- **Geochemical Parameters.** Geochemical parameters were collected from Site LF006 in 1998–1999 and in 2008 and were used to evaluate the biological degradation potential at the site (documented in the NAAR [CH2M HILL, 2010a]). In both cases, the evaluations indicated aerobic conditions unfavorable to biodegradation and that physical attenuation is dominant at the site (CH2M HILL, 2010a). The mechanisms contributing to physical attenuation (such as dispersion, dilution, sorption, and volatilization) are not anticipated to change in the near future. Thus the attenuation capacity of the aquifer should continue to exceed the mass loading at the site, resulting in a continued decrease in contaminant concentrations and achievement of remedial action objectives (RAOs). In fact, contaminant concentrations did decrease below PCGs in the 2009–2010 reporting period.
- **Volatilization.** Data to evaluate volatilization at Travis AFB were not collected to support the NAAR. However, as previously discussed, evidence that volatilization from dissolved to vapor phase occurs at Travis AFB was provided by an evaluation of the Site DP039 phytostabilization study area performed in 2009 (Parsons, 2010). Lithology and depth to groundwater at Site LF006 are similar to Site DP039, and it is reasonable to conclude that volatilization also occurs at Site LF006.

Summary. The continuing decrease in contaminant concentrations at Site LF006 indicates that the attenuation capacity of the aquifer exceeds any remaining source loading. In 2009–2010, contaminant concentrations declined below PCGs. MNA is an appropriate remedy for Site LF006.

C.1.4.4 Sites LF007B and LF007D

Over the interim period, Sites LF007B and LF007D (both subareas of Site LF007 as shown on Figure C-1) have undergone MNA assessment. The NAAR concluded that MNA is an effective remedy at these sites (CH2M HILL, 2010a). Lines of evidence supporting the selection of MNA as an appropriate remedy for Sites LF007B and LF007D are as follows:

- **Plume Attenuation.** The NAAR, which evaluated data collected through 4Q08, presented substantial evidence for natural attenuation of contaminants at Sites LF007B and LF007D, including the following:
  - Groundwater contaminants have not been detected in groundwater at Site LF007B for several years. No groundwater plume currently exists at the site, and IRAOs have been achieved.
  - At Site LF007D, contaminants (1,4-dichlorobenzene [1,4-DCB] and benzene) exceed the PCG in only one (1) monitoring well (MW261x07). No other contaminants are detected in groundwater at Site LF007D at concentrations exceeding PCGs.
  - In the portion of Site LF007D where contaminants continue to exceed PCGs, geochemical parameters indicate that biodegradation of chlorinated solvents (1,4-DCB) is occurring.
  - In the portion of Site LF007D where contaminants are below PCGs, there was little evidence of biodegradation of chlorinated solvents. The plume may be exhibiting mixed behavior, with reducing, anaerobic conditions near the source area and aerobic conditions in the downgradient portion of the plume (Wiedemeier et al., 1996).
  - The 1,4-DCB plume has reduced in size since the MNA assessment began (Figure C-6). The historical extent of contamination is based on in situ and monitoring well data collected during the 1994-1995 Remedial Investigation (RI) (Radian, 1996).
  - Benzene detections are restricted to one (1) location, MW261x07. Benzene concentrations at this location are stable (Attachment C2).
  - There is no indication of plume migration. In fact, the plume has receded.
  - Disregarding natural attenuation processes, and assuming that retardation slows the transport of 1,4-DCB at this site to approximately 0.6 times the linear velocity of groundwater (based on the EPA online retardation factor calculator located at http://www.epa.gov/ATHENS/learn2model/part-two/onsite/retard.html; note that retardation coefficients are chemical specific and that the retardation coefficient of 1,4-DCB is greater than that of TCE), then the plume would be expected to have migrated approximately 900 feet (90 feet per year) over the 10 years of the MNA assessment period. However, the plume has receded, indicating that natural attenuation processes must be occurring at the site.
  - Of the twenty (20) monitoring wells in the MNA assessment network, in 4Q08, there was only one (1) monitoring well at which contaminants continued to exceed PCGs. Point attenuation rate constants were calculated for the one (1) MNA well at which

contaminants continue to exceed PCGs: MW261x07. At this monitoring well, two (2) contaminants continued to exceed PCGs: 1,4-DCB and benzene. Attenuation rate constants were calculated for both contaminants. The attenuation rate constant calculated for 1,4-DCB at well MW261x07 is approximately 0.054 per year. At this attenuation rate, the 1,4-DCB concentrations would be expected to reach the PCG (5 µg/L) in 2029 (Attachment C1).

- Benzene concentrations have declined very slightly over the last 10 years; an attenuation rate constant of approximately 0.0039 per year was calculated (Attachment C1). At this attenuation rate, benzene concentrations would be expected to continue to exceed the PCG (1 µg/L) for over 100 years at this location.
- Although the current anaerobic conditions in the immediate vicinity of well MW261x07 (evident in monitoring data collected at this well from the initial MNA assessment in 1999 through 2008) are conducive to biodegradation of chlorinated solvents (such as 1,4-DCB), aerobic conditions are more favorable for biodegradation of benzene. Once the degradation of 1,4-DCB is complete, conditions near well MW261x07 are expected to gradually become aerobic, like the rest of the site, and more conducive to benzene degradation. The benzene concentrations detected at this well only slightly exceed the PCG (ranging from 2.2 to 2.7 µg/L in 2008) and are restricted to the immediate vicinity of this well. In addition, this well is located in a capped landfill, and there are no receptors.
- A bulk attenuation rate was calculated only for 1,4-DCB because it is the only chemical that was detected at more than one (1) monitoring well at the site during 2008. A bulk attenuation constant could only be calculated for the Site LF007D area. Because no chemicals were detected in the Site LF007B area monitoring wells, a bulk attenuation rate constant could not be calculated for this area. A bulk attenuation rate constant of approximately 1.8 per year was calculated for 1,4-DCB at Site LF007D, based on the 2008 distribution of 1,4-DCB in groundwater at the site (Attachment C4). The data set is limited to the two (2) monitoring wells (MW261x07 and MWCx07) where 1,4-DCB was detected in 2008. The positive bulk attenuation rate constant indicates that attenuation of 1,4-DCB is occurring. The travel time for 1,4-DCB to reach the PCG (5 µg/L) once it leaves the source area (near well MW261x07) is estimated to be approximately 0.96 year. The plume (exceeding the PCG) should extend approximately 85 feet from the source area.

Since the attenuation evaluation in the NAAR was performed, additional groundwater data have been collected at Sites LF007B and LF007D. Data collected at these sites through 2Q10 are presented in detail in the GSAP 2009–2010 Annual Report (CH2M HILL, 2011). The following is a summary of the main conclusions presented in the GSAP 2009–2010 Annual Report:

- No contaminants were detected in Site LF007B wells sampled during the 2009–2010 reporting period at concentrations exceeding PCGs. Only acetone, a common lab contaminant, was detected at concentrations well below the PCG. Sample results indicate that MNA is an appropriate remedy for Site LF007B.
- Groundwater contamination at Site LF007D is restricted to a small area in the vicinity of MW261x04—the only location at which Site LF007D contaminants were

detected at concentrations exceeding PCGs over the 2009–2010 reporting period. MNA continues to be an effective remedy for Site LF007D.

- **Geochemical Parameters.** Geochemical parameters were collected from Sites LF007B and LF007D in 1997-1999 and in 2008 and were used to evaluate the biological degradation potential at the sites (documented in the NAAR [CH2M HILL, 2010a]). In both cases, the evaluations indicated aerobic conditions unfavorable to biodegradation except at source area well MW261x07. This is the only monitoring well where contaminants (1,4-DCB and benzene) continue to exceed PCGs. Although the current anaerobic conditions in the immediate vicinity of well MW261x07 (evident in monitoring data collected at this well from the initial MNA assessment in 1999 through 2008) are conducive to biodegradation of chlorinated solvents (such as 1,4-DCB), aerobic conditions are more favorable for biodegradation of benzene. Once the degradation of 1,4-DCB is complete, conditions near well MW261x07 are expected to gradually become aerobic, like the rest of the site, and more conducive to benzene degradation.
- **Volatilization.** As previously discussed, evidence that volatilization from dissolved to vapor phase occurs at Travis AFB was provided by an evaluation of the Site DP039 phytostabilization study area performed in 2009 (Parsons, 2010). Although depth to groundwater at Sites LF007B and LF007D are similar to Site DP039, there is a landfill cap overlying large portions of Site LF007D. The landfill cap likely reduces volatilization at Site LF007D. In addition, while benzene is volatile, 1,4-DCB has a relatively low volatility (much lower than TCE). Significant volatilization of 1,4-DCB is unlikely.

Summary. Contaminants no longer exceed PCGs at Site LF007B; therefore, the IRAO has been achieved, and MNA is an appropriate remedy at this site. At Site LF007D, contaminants continue to exceed the PCG in only one (1) monitoring well, which is located in a capped landfill. The Site LF007D plume is not migrating. MNA is an appropriate remedy for Site LF007D.

C.1.4.5 Site LF008

Over the majority of the interim period (2001 through 2008), Site LF008 (Figure C-7) has undergone GET, which is the IRA at this site. In December 2008, all three (3) extraction wells were shut down to perform a 6-month rebound study to assess the effectiveness of GET at Site LF008. Several factors indicated that GET had limited effectiveness at the site, including the following:

- Because of low permeability of the alluvial sediments, extraction rates are approximately 1 gallon per minute (gpm) for the wells at this site, for a total extraction rate averaging 3 to 4 gpm for the entire site.
- The strong adsorption of alpha-chlordane and other pesticides to natural organic carbon or fine-grained soil particles in the subsurface binds them to the sediments and inhibits both their removal as well as their migration.
- Over 7.5 years of operation, the GET had minimal impact on pesticide concentrations at Site LF008. During operation of the GET, pesticide concentrations were stable and the extent of groundwater contamination remained unchanged.

The rebound study, which was performed over a 6-month period, concluded that pesticide concentrations had not rebounded and that the GET system should remain shut down for a continued rebound evaluation through the remainder of the interim period (leading up to the Basewide Groundwater ROD). The results of the rebound study are presented in the technical memorandum *Rebound Study Completion at Site LF008* (CH2M HILL, 2010b). Since the results of the rebound study were reported, additional groundwater data have been collected at Site LF008. Data collected at Site LF008 through 2Q10 are presented in detail in the GSAP 2009–2010 Annual Report (CH2M HILL, 2011).

Because pesticides are not readily biodegraded and are not volatile, the primary line of evidence supporting the selection of MNA as an appropriate remedy for Site LF008 is plume attenuation. Plume attenuation at Site LF008 has been documented in the technical memorandum *Rebound Study Completion at Site LF008* (CH2M HILL, 2010b) and GSAP 2009–2010 Annual Report (CH2M HILL, 2011) and is summarized here:

- **Plume Attenuation:**
  - Alpha-chlordane is the primary contaminant. In 2Q10, alpha-chlordane was the only contaminant detected at concentrations exceeding PCGs. The PCG (0.1 µg/L) was exceeded at only two (2) extraction wells and two (2) plume wells. The maximum concentration detected was 0.34 J µg/L at monitoring well MW712x08. The Mann-Kendall analysis identified a trend of decreasing alpha-chlordane concentrations at this monitoring well (Attachment C3).
  - Over 7.5 years of operation, the GET had minimal impact on pesticide concentrations at Site LF008. During operation of the GET, pesticide concentrations were stable and the extent of groundwater contamination remained unchanged (Figure C-8). This is likely due to 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.
  - Through 2Q10, no significant rebound of alpha-chlordane or any other contaminant has been evident during the 18 months since the rebound study began. In fact, alpha-chlordane concentrations are slightly lower than those detected prior to the rebound study (Attachment C2).
  - A long-term decreasing alpha-chlordane concentration trend was identified by the Mann-Kendall analysis for extraction well EW721x08. No long-term concentration trends were identified by the Mann-Kendall analysis in the other extraction well data, although the chemical time-series plots indicate that alpha-chlordane concentrations have also recently decreased at EW719x08 and EW720x08 (Attachment C3).
  - Because of the recent GET IRA, point attenuation rates and current bulk attenuation rates would not be representative of natural attenuation conditions (this would result in an overestimate of attenuation at the site) and were therefore not calculated. The physical properties of pesticides result in very low subsurface mobility because of strong sorption of the chemical to the soil. For comparison, the K_{oc}, which describes how strongly a chemical sorbs to soil material, for TCE is 67 milliliters per gram (mL/g), whereas the K_{oc} for alpha-chlordane (the primary

contaminant at Site LF008) is 86,650 mL/g. Given the extreme K_{oc} of alpha-chlordane and presumed lack of biodegradation, the RTFs for both GET and MNA are assumed to be greater than 100 years (Appendix D).

Summary. The GET IRA has not been effective at further reductions of the very low concentrations of contaminants at Site LF008. GET effectiveness is limited by the low permeability of the Site LF008 lithology and the physical properties of the contaminants, which cause strong sorption to the soil. Neither of these factors can be overcome by optimization of the GET system. Since the GET system was shut down, the pesticide plume has remained stable; and alpha-chlordane concentrations have decreased slightly. Because of the extremely high K_{oc} (which limits mobility) and the nature of the lithology, the pesticide plume is not expected to migrate. MNA is an appropriate remedy for Site LF008.

C.1.4.6 Site ST027B

Site ST027 has historically been managed as part of the petroleum-only contaminated (POCO) program at Travis AFB because petroleum hydrocarbons were believed to be the only contaminants present at this site. However, investigations conducted in 2007 and 2008 under the POCO program resulted in the discovery of 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 (Figure C-9). This area of TCE contamination has been designated Site ST027B. While TCE and other chlorinated VOCs are present in Site ST027B at concentrations above PCGs, these VOCs had not been identified as chemicals of concern (COCs), because they were unknown during the previous RI and risk assessment. The updated risk assessment for VOCs (Appendix G of this FFS) did not identify any VOCs as COCs. However, because the presence of TCE may affect the beneficial use of groundwater, remediation alternatives for TCE are being evaluated in this FFS. No IRA had been established for this site because the presence of chlorinated VOCs at Site ST027B was such a recent discovery.

In 2008 and 2009, additional investigation was performed at Site ST027B to further characterize chlorinated VOCs present at the site. A preliminary natural attenuation assessment was also performed based on data collected during this investigation. Both are documented in the Final *Technical Memorandum Site ST027-Area B Characterization Results (*CH2M HILL, 2010c). Since the results of the site investigation were reported, additional groundwater data have been collected at Site ST027B. Data collected at Site ST027B through 2Q10 are presented in detail in the GSAP 2009–2010 Annual Report (CH2M HILL, 2011). The distribution of TCE in groundwater in 2Q10 is shown on Figure C-10.

Lines of evidence supporting the selection of MNA as an appropriate remedy for Site ST027B are as follows (CH2M HILL, 2011, 2010c):

- **Plume Attenuation.** Because the chlorinated VOC contamination (primarily TCE) was only recently discovered, the monitoring history at the site is short (3 years); however, monitoring over this time period indicates the following:
  - TCE concentrations at well MW791x27 (approximately 60 feet downgradient of the presumed source area) have remained relatively stable since the well was installed in 2007. Through 2Q10, TCE concentrations detected at this well have varied

between 280 and 474 µg/L, with no evident increasing or decreasing trend (Attachments C1 and C2).

- Cis-1,2-DCE concentrations also exceed PCGs at source area well MW791x27. Cis-1,2-DCE concentrations have remained relatively stable, varying between about 45 and 70 µg/L from 4Q07 through 2Q10.
- Downgradient monitoring well MW2009x27 (approximately 240 feet downgradient of well MW791x27) was installed in 2009. TCE is the only chlorinated VOC to exceed the PCG at this monitoring well. The monitoring history at this well is too short to assess trends; however, TCE concentrations detected at this well have been consistent to date (varying from 26.3 to 27.4 µg/L in 4Q09 and 2Q10). TCE concentrations detected in this downgradient monitoring well are an order of magnitude lower than those in well MW791x27.
- The only other Site ST027B monitoring well where chlorinated VOCs exceed the PCG is monitoring well MW794x27, located approximately 300 feet downgradient of well MW791x27. TCE concentrations at this downgradient well have remained stable, varying between 2.1 and 2.5 µg/L from 4Q07 through 2Q10.
- Disregarding natural attenuation processes, and assuming that retardation slows the transport of TCE at this site to approximately 0.8 times the linear velocity of groundwater, then TCE detected in MW791x27 (the plume hotspot) would be expected to migrate approximately 320 feet in period between 4Q09 and 2Q10. However, monitoring data indicate that no appreciable migration has occurred in the direction of downgradient wells MW794x27 and MW2009x27.
- Cis-1,2-DCE and vinyl chloride are degradation products of TCE. The presence of these degradation products in the source area and distal portions of the plume indicate that biodegradation of TCE is occurring.
- The monitoring history is insufficient to calculate point attenuation rate constants for Site ST027B. Available data indicate that TCE concentrations are stable, but decreasing TCE concentration trends, which could be used to calculate the point attenuation rate constant, have not been established.
- A bulk attenuation rate constant of approximately 1.1 per year was calculated for TCE at Site ST027B, based on concentrations of TCE detected in groundwater at the site in 2Q10 (Attachment C4). The positive bulk attenuation rate constant indicates that attenuation of TCE is occurring. The maximum TCE concentration detected at Site ST027B in 2Q10 was 390 µg/L in the source area. The travel time for TCE to reach the PCG (5 µg/L) once it leaves the source area is estimated to be approximately 3.8 years. The plume (exceeding the PCG) should extend approximately 396 feet from the source area. Note that the data set is limited to the two (2) monitoring wells (MW791x27 and MW2009x27) along the plume axis (well MW2009x27 is the furthest downgradient well).
- An RTF of 50 years for an MNA alternative was estimated for Site ST027B using a model as described in Appendix D.

- **Geochemical Parameters.** Geochemical parameters were collected from monitoring wells at Site ST027B in 4Q09 and were used to evaluate the biological degradation potential at the site (documented in the *Technical Memorandum Site ST027-Area B Characterization Results* [CH2M HILL, 2010c]). The evaluation of the geochemical parameters indicated limited evidence for biodegradation of chlorinated VOCs at Site ST027B. This conclusion is typical for the alluvium at Travis AFB. However, the fact that concentrations of cis-1,2-DCE and/or vinyl chloride in groundwater samples collected during the 2009 investigation from monitoring wells and soil borings were generally greater in the middle and distal parts of the plume than in the source area may indicate that reductive dechlorination is occurring downgradient of the source area (CH2M HILL, 2010c).
- **Volatilization.** As previously discussed, evidence that volatilization, from dissolved to vapor phase, occurs at Travis AFB was provided by an evaluation of the Site DP039 phytostabilization study area performed in 2009 (Parsons, 2010). Lithology and depth to groundwater at Site ST027B are similar to Site DP039, and it is reasonable to conclude that volatilization also occurs in the unpaved portions of Site ST027B.

Summary. Because the TCE plume at Site ST027B is a recent discovery, the monitoring history is short and concentration trends have not been established. Through 2Q10, TCE and daughter products cis-1,2-DCE and vinyl chloride concentrations have been stable. The presence of cis-1,2-DCE and vinyl chloride indicates that biodegradation is occurring, although the geochemical parameters indicate aquifer conditions are not particularly conducive to biodegradation. The stability of the plume over the monitoring period indicates that attenuation is occurring, and modeling indicates that the plume will gradually attenuate to reach PCGs. The location of the site on the flightline limits potential exposure to groundwater contaminants. MNA is an appropriate remedy for Site ST027B.

C.1.5 EA Sites

EA is a remedial alternative at Sites SS015, DP039, and the WIOU. The following subsections present the lines of evidence that indicate EA is an appropriate remedy for these sites.

C.1.5.1 Site SS015

Although MNA assessment was selected as the IRA at Site SS015, the initial Site SS015 MNA assessment was delayed because the site was subsequently selected for a treatability study of enhanced MNA using vegetable oil injection (Figure C-11). A limited treatability study was conducted at the site during 2000–2001, during which approximately 227 pounds of soybean oil was injected at the site in two (2) phases (June and December 2000). The treatability study was terminated early because of a military construction project at the site. Building 554 was constructed over a portion of the vegetable oil injection area. 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). Several monitoring wells were installed during 2010 at Site SS015 to better characterize the plume and groundwater flow directions.

The NAAR concluded that MNA alone may not be a sufficient remedy at this site because recent data indicated that the plume may be migrating eastward. However, the vegetable oil treatability study demonstrates that the biological component of natural attenuation can be effectively enhanced at this site (CH2M HILL, 2010a). Lines of evidence supporting the selection of EA as an appropriate remedy for Site SS105 are as follows (CH2M HILL, 2010a, 2011):

- **Plume Attenuation:**
  - Source area contaminant concentrations were affected by the vegetable oil treatability study. TCE and tetrachloroethene (PCE) concentrations decreased in source area well MW216x15 from 2004 to 2007, but rebounded from 2007 through 2010. Cis-1,2-DCE and vinyl chloride concentrations have increased several orders of magnitude at MW216x15 from 2007 to the present. Concentrations of both daughter products now exceed 1,000 µg/L at this well (Attachment C2).
  - 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 (2000–2001) enhanced biodegradation. The concentrations of daughter products are currently an order of magnitude higher than the concentration of parent compounds (CH2M HILL, 2011).
  - Increasing concentrations at well MW625x15 and rebound in TCE and PCE concentrations at source area well MW216x15 indicate that the vegetable oil injected in 2000–2001 has been largely consumed and no longer provides adequate substrate for microorganisms (CH2M HILL, 2011).
  - Disregarding natural attenuation processes, and assuming that retardation slows the transport of TCE at this site to approximately 0.8 times the linear velocity of groundwater, then the plume would be expected to have migrated approximately 2,400 feet (240 feet per year) over the last 10 years (CH2M HILL, 2010a). However, the horizontal extent of the plume, which was defined during the 2010 investigation (Figure C-12), is much less, approximately 375 feet, indicating that attenuation is occurring.
  - Point attenuation rates for site-specific monitoring wells could not be calculated for Site SS015 because contaminant concentrations have recently begun to increase in the two (2) wells with contaminant detections that have sufficient monitoring history to perform the calculation (MW216x15 and MW625x15).
  - Bulk attenuation rate constants for TCE, cis-1,2-DCE, and vinyl chloride (contaminants detected at multiple wells at the site) were calculated for Site SS015 in the NAAR. Since then, the extent of the groundwater plume has been better defined; therefore, these calculations were updated with data collected in 2Q10 (Attachment C4). Bulk attenuation rate constants of approximately 2.3 per year (TCE), 6.6 per year (cis-1,2-DCE), and 9 per year (vinyl chloride) were calculated at Site SS015. The positive bulk attenuation rate constants indicate that attenuation of TCE and daughter products cis-1,2-DCE and vinyl chloride is occurring at the site. The travel times for these chemicals to reach PCGs upon leaving the source area are estimated to be approximately 2 years (TCE) and 1 year (cis-1,2-DCE and vinyl

chloride). Based on these travel times, the VOC plume (exceeding PCGs) should extend approximately 495 feet from the source area at Site SS015.

- After several years of apparent stability (the northern, downgradient portion of the plume was previously not well defined), the plume appears to be migrating eastward, in the vicinity of well MW625x15, where contaminant concentrations have recently been increasing (CH2M HILL, 2011). Because most of the plume wells were installed in 2010, there are insufficient data to evaluate trends and plume migration in the northern (downgradient) portion of the plume.
- An RTF of 70 years for an EA alternative was estimated for Site SS015 as described in Appendix D. This estimate is based on using a remedial technology (such as emulsified vegetable oil [EVO] or in situ chemical oxidation [ISCO]) to actively treat the portion of the plume where VOC concentrations exceed 1,000 µg/L. The RTF is determined by the time required for the portion of the plume beyond the treatment area to attenuate and achieve PCGs.

- **Geochemical Parameters.** Geochemical parameters were collected from Site SS015 in 2008 and were used to evaluate the biological degradation potential at the site (documented in the NAAR [CH2M HILL, 2010a]). The results of the assessment indicated adequate evidence for biodegradation of chlorinated solvents at source area well MW216x15. The potential for biodegradation was enhanced by the vegetable oil injection performed downgradient of this well in 2000–2001. The only other monitoring well at the site at which contaminants were detected at concentrations exceeding PCGs in 2008 was downgradient well MW625x15. Results of the assessment indicated limited evidence for biodegradation of chlorinated solvents at this location. However, this well had a negative oxidation-reduction potential (ORP) and high dissolved iron, both indicators that groundwater passing through this area originated in the highly anaerobic zone created by the vegetable oil injection. Results for wells outside the treatability study area of influence indicated limited to insufficient evidence for biodegradation.
- **Volatilization.** As previously discussed, evidence that volatilization from dissolved to vapor phase occurs at Travis AFB was provided by an evaluation of the Site DP039 phytostabilization study area performed in 2009 (Parsons, 2010). Lithology and depth to groundwater at Site SS015 are similar to Site DP039, and it is reasonable to conclude that volatilization also occurs in the unpaved portions of Site SS015.

Summary. MNA alone is not a sufficient remedy at this site because recent data indicate that the plume is migrating and contaminant concentrations in the source area are rebounding. However, the vegetable oil treatability study performed in 2000–2001 demonstrates that the biological component of natural attenuation can be effectively enhanced at this site. In addition to biological attenuation, physical attenuation is also occurring at the site, as evidenced by the limited distance the plume has migrated over the last 10 years. Modeling indicates that if the source area (exceeding 1,000 µg/L) is effectively treated, the remaining plume beyond the treatment area will attenuate to reach PCGs. EA is an appropriate remedy for Site SS015.

C.1.5.2 Site DP039

Over the interim period, Site DP039 has undergone EA. Several IRAs and treatability studies have been performed in the source area and within the groundwater plume to reduce mass loading while an MNA assessment was performed in the distal portion of the plume. A summary of the implemented IRAs is presented in Table C-1.

The NAAR concluded that MNA alone in the distal area may not be adequate to prevent plume migration. In 2010, an EVO PRB was installed as an RPO to promote degradation of contaminants in groundwater and address contamination migrating in the middle portion of the Site DP039 plume, downgradient from the phytoremediation study area. Figure C-13 shows the locations of the IRAs and the EVO PRB.

TABLE C-1
Summary of Implemented IRAs at Site DP039
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Groundwater Plume	IRAO	Implemented IRA	Status of IRA
DP039 Source Area	Source control Migration control	GET	GET was replaced by source area excavation and installation of a bioreactor in 2008. A demonstration of phytoremediation has been ongoing since 1998. Injection of an EVO PRB as another optimization measure was conducted in 2010.
DP039 Distal Area	MNA assessment	Groundwater monitoring	Ongoing groundwater monitoring.

Note:
PRB = permeable reactive biobarrier

Lines of evidence supporting the selection of EA as an appropriate remedy for Site DP039 are as follows (CH2M HILL, 2010a, 2011):

- **Plume Attenuation:**
  - Contaminant concentrations are decreasing at source area monitoring well MW751x39 (Attachments C2 and C3). This well is located upgradient of the phytoremediation study area and downgradient of the GET/bioreactor area (beyond the influence of these IRAs), within the portion of the plume where TCE concentrations exceed 1,000 µg/L. The historical maximum TCE concentration detected at this well was 3,800 µg/L; the TCE concentration detected in 2Q10 was 1,230 µg/L. The declining TCE trend in this well indicates that, while the source area is controlled by the IRA (GET/bioreactor), attenuation is occurring in some portions of Site DP039
  - The southern edge of the Site DP039 plume has remained stable (below PCGs) over the interim period (wells MW759x39, MW761x39, and MW762x39).
  - However, increasing contaminant trends are evident in distal area well MW02x39, and downgradient wells MW758x39 and MW760x39 also display generally increasing TCE trends. (Attachments C2 and C3).

- In addition, the extent of the plume has not reduced in size as has been observed at most of the other MNA assessment sites (Figure C-14).
- The stability of the eastern portion of the plume is uncertain because there is not a long monitoring history in this area. In 2007, it was discovered that the TCE plume extends further eastward than anticipated (MW785x39 is located in this portion of the plume). However, after an initial period of increasing concentrations, TCE concentrations appear to have stabilized at monitoring well MW785x39.
- Disregarding natural attenuation processes, and assuming that retardation slows the transport of TCE at this site to approximately 0.8 times the linear velocity of groundwater, then the portion of the plume beyond the capture of the GET system would be expected to have migrated approximately 240 feet (approximately 30 feet per year) over the 8 years of the MNA assessment period. However, the southern edge of the plume has remained stable, indicating that natural attenuation processes must be occurring at this site (CH2M HILL, 2010a).
- Of the six (6) monitoring wells in the MNA assessment network, in 4Q08, there were only two (2) monitoring wells at which contaminants continued to exceed PCGs. A point attenuation rate was calculated for these two (2) MNA wells: MW751x39 and MW759x39. At both monitoring wells, the only contaminant that continued to exceed PCGs is TCE. Both of these monitoring wells are located beyond the designed extent of hydraulic capture of the GET and the area impacted by the bioreactor treatability study. Well MW751x39 is located upgradient of the phytoremediation study area, and well MW759x39 is located downgradient of the phytoremediation study area. Point attenuation rates calculated for these wells are not expected to be impacted by the GET IRA or the treatability studies. The attenuation rate constant calculated for well MW751x39 is approximately 0.092 per year, and the attenuation rate constant calculated for well MW759x39 is approximately 0.14 per year (Attachment C1). At these rates, TCE concentrations at well MW751x39 would be expected to reach the PCG (5 µg/L) in 2067, and TCE concentrations at well MW759x39 would be expected to reach the PCG in 2015. The long attenuation period for monitoring well MW751x39 is due to its location within the portion of the plume where TCE concentrations continue to exceed 1,000 µg/L. This well is not located in the portion of the distal plume where natural attenuation is being assessed as a potential remedy.
- Little change in aquifer conditions between 2001 (when the initial MNA assessment was performed) and 2008 is evident in the portions of the aquifer evaluated for MNA. Outside of the treatability study areas, the aquifer remains aerobic and available carbon is low; physical attenuation processes (such as dispersion, dilution, sorption, and volatilization) remain the dominant mechanisms for reduction in plume size over time. Enhancements to natural attenuation (the bioreactor treatability study and EVO PRB) are designed to increase biodegradation rates in targeted areas of the plume. However, outside of these areas, physical processes are expected to remain the dominant mechanisms for attenuation.
- Note that the bulk attenuation rate was not calculated for Site DP039 because, as a result of the recent GET IRA and ongoing bioreactor and phytoremediation

treatability studies, the current bulk attenuation rates would not be representative of natural attenuation conditions. The resulting bulk attenuation rate would be an overestimation of the attenuation rate expected in the absence of the treatability studies and thus cannot be used to evaluate the current effectiveness of natural attenuation at the site.

- An RTF of 65 years for an alternative including excavation, source area bioreactor, phytoremediation, EVO PRB, and EA was estimated for Site DP039 using a model as described in Appendix D. The RTF is determined by the time required for the portion of the plume beyond the treatment area (500 µg/L) to attenuate and achieve PCGs. A similar RTF of 70 years was estimated for the current IRA of GET/MNA.

- **Geochemical Parameters.** Geochemical parameters were collected from Site DP039 in 2000–2001 and 2008 and were used to evaluate the biological degradation potential at the site (documented in the NAAR [CH2M HILL, 2010a]). In both cases, the evaluations indicated aerobic conditions unfavorable to biodegradation and that physical attenuation is dominant at the site outside of the areas impacted by the bioreactor and EVO PRB (CH2M HILL, 2010a). The mechanisms contributing to physical attenuation (such as dispersion, dilution, sorption, and volatilization) are not anticipated to change in the near future. However, ongoing monitoring of the bioreactor indicates that reductive conditions have been established around the bioreactor and that biodegradation is occurring and TCE concentrations have significantly declined (CH2M HILL, 2010d). The bioreactor treatability study demonstrates that suitable bacterial populations are present and reductive dechlorination can occur at the site. Over time, the reductive conditions created by soluble organics released by the bioreactor are expected to migrate downgradient toward well MW751x39.

- **Volatilization.** As previously discussed, evidence that volatilization from dissolved to vapor phase occurs at Travis AFB was provided by an evaluation of the Site DP039 phytostabilization study area performed in 2009 (Parsons, 2010). The results of the study indicated that volatization was occurring at Site DP039.

Summary. MNA alone is not a sufficient remedy at this site because increasing concentration trends in some distal monitoring wells indicate that the plume is migrating in some areas. However, the edge of the plume has remained stable, despite elevated VOC concentrations (exceeding 1,000 µg/L) in the core of the plume, beyond the influence of the IRAs. Although there is limited evidence of biological degradation at the site outside the treatability study areas, physical attenuation is occurring at the site, as evidenced by the limited distance the plume has migrated over the last 10 years. Modeling indicates that if the source area is effectively treated (to 500 µg/L), the remainder of the plume will gradually attenuate to reach PCGs over a similar timeframe as the current IRA of GET/MNA. EA is an appropriate remedy for Site DP039.

C.1.5.3 WIOU (Sites SD033, SD034, SD036, SD037, and SD043)

Over the interim period, the WIOU (Sites SD033, SD034, SD036, SD037, and SD043 as shown on Figure C-15) has undergone EA. The primary groundwater contaminant in the WIOU is TCE. Groundwater extraction has been performed in the WIOU source areas to reduce mass loading. The NAAR concluded that the combination of groundwater extraction in the source areas and monitored attenuation in the downgradient portion of the plume was an effective remedy (CH2M HILL, 2010a). The GET system was taken offline in 2010 to support an RPO of EVO injection into remaining hot spots (where VOC concentrations continue to exceed 1,000 µg/L). Since the attenuation evaluation in the NAAR was performed, additional groundwater data have been collected in the WIOU. Data collected in the WIOU through 2Q10 are presented in detail in the GSAP 2009–2010 Annual Report (CH2M HILL, 2011).

Lines of evidence supporting the selection of EA as an appropriate remedy for the WIOU are as follows (CH2M HILL, 2010a, 2011):

- **Plume Attenuation:**
  - Over the interim period, TCE concentrations have been stable and low at all of the southern WIOU MNA wells. TCE has not been detected at most of these wells for several years.
  - The extent of the WIOU plume has decreased over time (Figure C-16).
  - Disregarding natural attenuation processes, and assuming that retardation slows the transport of TCE at this site to approximately 0.8 times the linear velocity of groundwater, then the portion of the plume beyond the capture of the GET system would be expected to have migrated approximately 560 feet (approximately 70 feet per year) over the 8 years of the MNA assessment period. However, the plume has receded, indicating that natural attenuation processes must be occurring at this site (CH2M HILL, 2010a).
  - Of the eleven (11) monitoring wells in the MNA assessment network, in 4Q08, only two (2) monitoring wells had chlorinated VOC concentrations exceeding PCGs. A point attenuation rate constant was calculated for these two (2) MNA wells: MW1208x37 and MW722x37. Both of these monitoring wells are located beyond the designed extent of hydraulic capture of the GET system, and point attenuation rates calculated for these wells are not expected to be impacted by the GET IRA. At both monitoring wells, the only contaminant that continued to exceed PCGs is TCE. The attenuation rate constant calculated for well MW1208x37 is approximately 0.019 per year, and the attenuation rate constant calculated for well MW722x37 is approximately 0.058 per year (Attachment C1). At these rates, TCE concentrations at well MW1208x37 would be expected to reach the PCG (5 µg/L) in 2024, and TCE concentrations at well MW722x37 would be expected to reach the PCG in 2029 (CH2M HILL, 2010a).
  - Little change in aquifer conditions between 2001 (when the initial MNA assessment was performed) and 2008 is evident. The aquifer remains aerobic and, with the exception of areas impacted by historical Site SS014 TPH releases, available carbon is low. Enhancements to natural attenuation (EVO injection) are designed to increase biodegradation rates in targeted areas of the plume. However, outside of these areas, physical processes are expected to remain the dominant mechanisms for attenuation. These mechanisms are not anticipated to change in the near future.
  - Note that the bulk attenuation rate was not calculated for the WIOU because, as a result of the ongoing GET IRA, the current bulk attenuation rates would not be representative of natural attenuation conditions. The resulting bulk attenuation rate would be an overestimation of the attenuation rate expected in the absence of the

active IRA and thus cannot be used to evaluate the current effectiveness of natural attenuation at the site.

- An RTF of 60 years was estimated for a WIOU EA alternative of discontinuing GET and using an alternate remedial technology (such as EVO or ISCO) in remaining hotspots (where VOCs exceed 1,000 µg/L). The RTF is determined by the time required for the remaining portion of the plume beyond the treatment area to attenuate and achieve PCGs. An RTF of 91 years was estimated for the current IRA of GET/MNA. These estimates were performed using models as described in Appendix D.

- **Geochemical Parameters.** Geochemical parameters were collected from the WIOU in 2000–2001 and 2008 and were used to evaluate the biological degradation potential at the site (documented in the NAAR [CH2M HILL, 2010a]). In both cases, only distal well MW05x14 received a score indicating adequate evidence for biodegradation of chlorinated solvents. This monitoring well has relatively high concentrations of TPH because it is also associated with POCO Site SS014. The presence of petroleum hydrocarbons provides a carbon source for microorganisms and subsequently enhances biodegradation of chlorinated solvents. All other wells showed limited, to inadequate, evidence for biodegradation of chlorinated solvents. The evaluations indicate generally aerobic conditions unfavorable to biodegradation and that physical attenuation is dominant at the WIOU (CH2M HILL, 2010a). The mechanisms contributing to physical attenuation (such as dispersion, dilution, sorption, and volatilization) are not anticipated to change in the near future. However, if the GET system remains shut down, less oxygen will be introduced to the aquifer, and aquifer conditions may become less aerobic and more favorable to biodegradation. In addition, the EVO injection is designed to increase biodegradation rates in targeted areas of the plume.

- **Volatilization.** As previously discussed, evidence that volatilization from dissolved to vapor phase occurs at Travis AFB was provided by an evaluation of the Site DP039 phytostabilization study area performed in 2009 (Parsons, 2010). Lithology and depth to groundwater in the WIOU are similar to Site DP039, and it is reasonable to conclude that volatilization also occurs in the unpaved portions of the WIOU.

Summary. Over the interim period, the WIOU has effectively undergone EA, with GET in the source area and MNA in the distal portion of the plume. Ongoing monitoring indicates the EA performed over the interim period has prevented plume migration and reduced the plume size. However, modeling indicates that if the source areas (exceeding 1,000 µg/L) are more aggressively treated (using an alternate remedial technology such as EVO or ISCO) the plume will attenuate to reach PCGs over a shorter timeframe then the current GET/MNA IRA. EA is an appropriate remedy at this site.

C.2 Evaluating MNA and EA Performance

Routine performance monitoring of the remedy selected for each site will be established in the remedial design. Performance monitoring will focus on contaminants that exceed PCGs but may also include collection of additional geochemical parameter data if the data are needed to evaluate the effect of enhancements (such as EVO or ISCO) on aquifer conditions.

Specific performance evaluation criteria for each site will be established in the remedial design. Options for evaluating MNA/EA performance include the following:

- **Point attenuation rate calculations.** The point attenuation rate can be used to evaluate reduction in contaminant concentration over time at a single point and can further be used to estimate the time needed to reach PCGs at that point.
- **Bulk attenuation rate calculations.** A bulk attenuation rate may be calculated for the entire plume. The bulk attenuation rate provides information on the reduction in dissolved contaminant concentration with distance from the source and can be used to demonstrate that contaminants are being attenuated within the groundwater flow system.
- **Comparisons of plume dissolved mass, center of mass, and spread of mass over time.** The total dissolved mass, center of mass, and the spread of mass for a groundwater plume can be estimated for discrete sampling events, allowing for an evaluation of plume behavior over time.

C.3 Performance Enhancement Measures

If the performance monitoring indicates MNA or EA are not performing as anticipated, the Air Force will evaluate and carry out performance enhancement measures to correct the deficiencies. Potential measures include the following, listed in ascending order of field effort:

- Increased monitoring
- Installation of additional monitoring wells
- Supplemental injection of a carbon source (such as EVO) or a chemical oxidant (such as permanganate) using existing wells
- Addition of supplemental 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 treatment zone
- Restart of the existing groundwater extraction system (not applicable to Sites LF006, LF007B, LF007D, SS015, and ST027B, which do not have existing groundwater extraction systems)
- Expansion of the existing groundwater extraction system (not applicable to Sites LF006, LF007B, LF007D, SS015, and ST027B)
- Installation of new GET systems at Sites LF006, LF007B, LF007D, SS015, and/or ST027B

The Air Force and the regulatory agencies will base the selection of the appropriate measure(s) upon the type and severity of the adverse outcome.

C.4 Triggers for Performance Enhancement Measures

Triggers for implementation of performance enhancement measures include the following:

- Increases in contaminant concentrations in downgradient wells
- Incomplete reductive dechlorination or transformation that stalls at cis-1,2-DCE or vinyl chloride
- Migration of contaminant plume/lack of plume stability

C.5 MNA and EA Performance Evaluation Schedule and Documentation

Routine groundwater monitoring at Travis AFB is performed on an ongoing basis through the GSAP. Upon remedy selection and implementation, the GSAP will monitor each site in accordance with the specifications of the remedy design document. The performance of the selected remedy will be evaluated for each site annually in the Annual GSAP Report. This annual report will provide the Air Force and the regulatory agencies with the timely data and interpretation required to determine whether the remedy is operating as designed or if performance enhancement measures may be necessary. In addition to the annual monitoring reports, Five-year Review Reports will be submitted in accordance with the EPA Comprehensive Five-year Review Guidance (EPA, 2001). The primary purpose of the Five-year Review Report is to verify that the selected remedies are protective of human health and the environment and are functioning as designed.

C.6 Works Cited

CH2M HILL. 2011. *Groundwater Sampling and Analysis Program 2009–2010 Annual Report.* Prepared for Travis Air Force Base, California. Final. April.

CH2M HILL. 2010a. *Natural Attenuation Assessment Report*. Travis Air Force Base, California. Final. July.

CH2M HILL. 2010b. *June 2009 6-month Rebound Study Completion at Site LF008.* Travis Air Force Base, California. Final. January.

CH2M HILL. 2010c. *Technical Memorandum Site ST027-Area B Characterization Results.* Travis Air Force Base, California. Final. July.

CH2M HILL. 2010d. *Third Progress Report Sustainable Bioreactor Demonstration Site DP039.* Travis Air Force Base, California. Draft. August.

CH2M HILL. 2009. *2008 Annual Remedial Process Optimization Report for the Central Groundwater Treatment Plant, North Groundwater Treatment Plant, and South Base Boundary Groundwater Treatment Plant.* Travis Air Force Base, California. Final. June.

Interstate Technology Regulatory Council (ITRC). 2008. *Enhanced Attenuation: Chlorinated Organics*. April.

Parsons Engineering Science, Inc. (Parsons). 2010. *Technical Report: Phytostabilization at Travis Air Force Base*. Draft. May.

Parsons Engineering Science, Inc. (Parsons). 2002. *Phase II Field Feasibility Test for In-situ Bioremediation of Chlorinated Solvents via Vegetable Oil Injection at Site SS015.* Final.

Radian Corporation (Radian). 1996. *North/East/West Industrial Operable Unit Remedial Investigation.* Travis Air Force Base, California. July.

Travis Air Force Base (AFB). 1999. *Groundwater Interim Record of Decision, West/Annexes/Basewide Operable Unit.* Travis Air Force Base, California. Final. June.

Travis Air Force Base (AFB). 1997. *Groundwater Interim Record of Decision for the North, East, and West, Industrial Operable Units*. Travis Air Force Base, California. Final. December.

U.S. Environmental Protection Agency (EPA). 2002. "Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies." November.

U.S. Environmental Protection Agency (EPA). 2001. *Comprehensive Five-Year Review Guidance*. Office of Solid Waste and Emergency Response (OSWER) Directive 9355.7-03B-P. EPA 540R-98-050, PB99-96314. October.

U.S. Environmental Protection Agency (EPA). 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater. September.

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

Wiedemeier, T.H., M.A. Swanson, D.E. Moutoux, E.K. Gordon, J.T. Wilson, B.H. Wilson, D.H. Kampbell, J.E. Hansen, P. Haas, and F.H. Chapelle. 1996. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater.* Prepared for the Air Force Center for Engineering and the Environment. November.

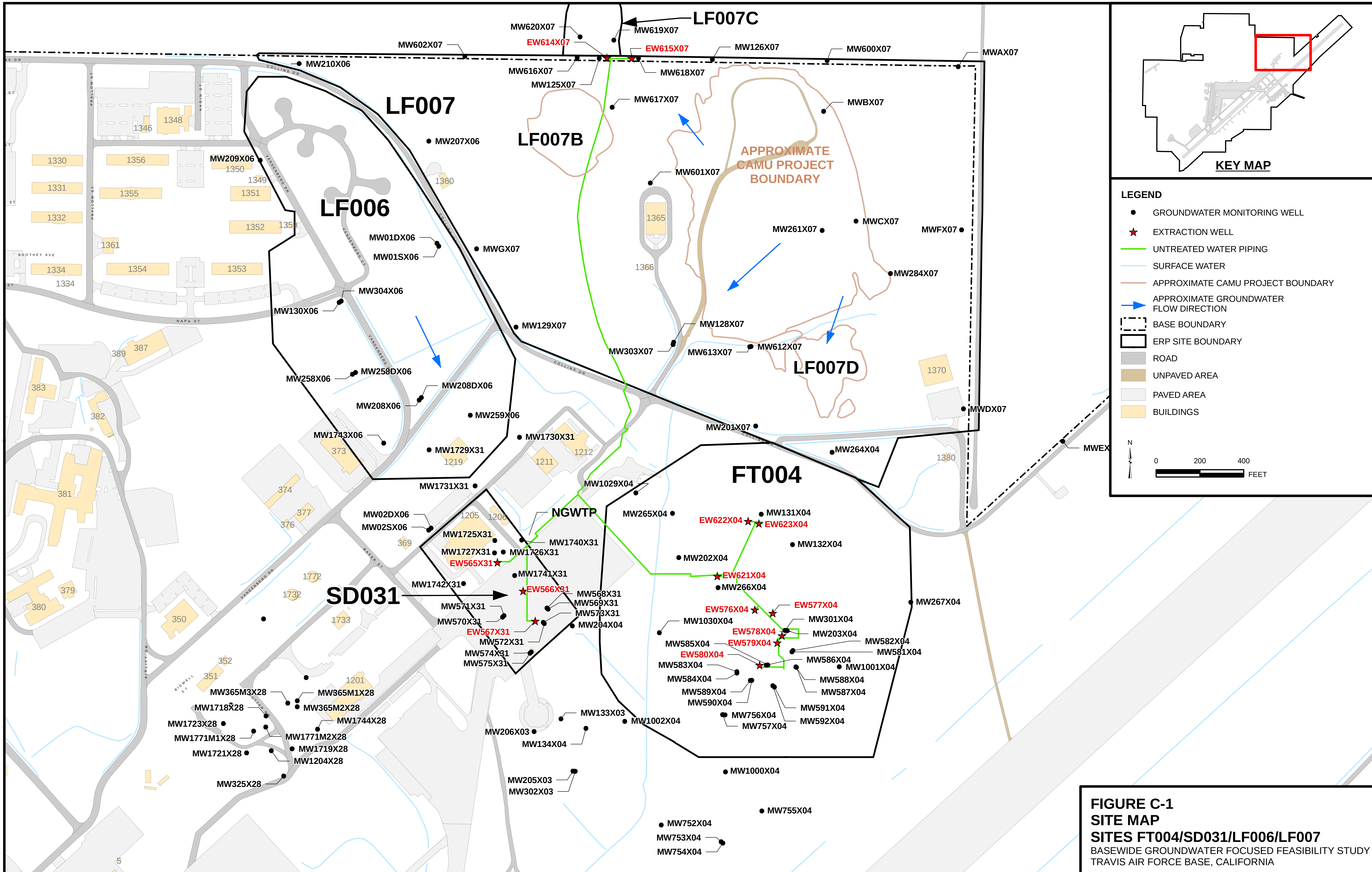
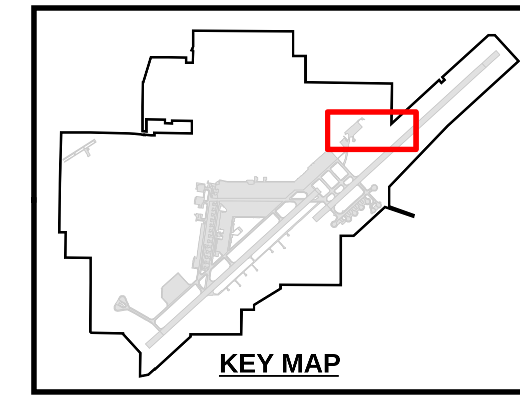
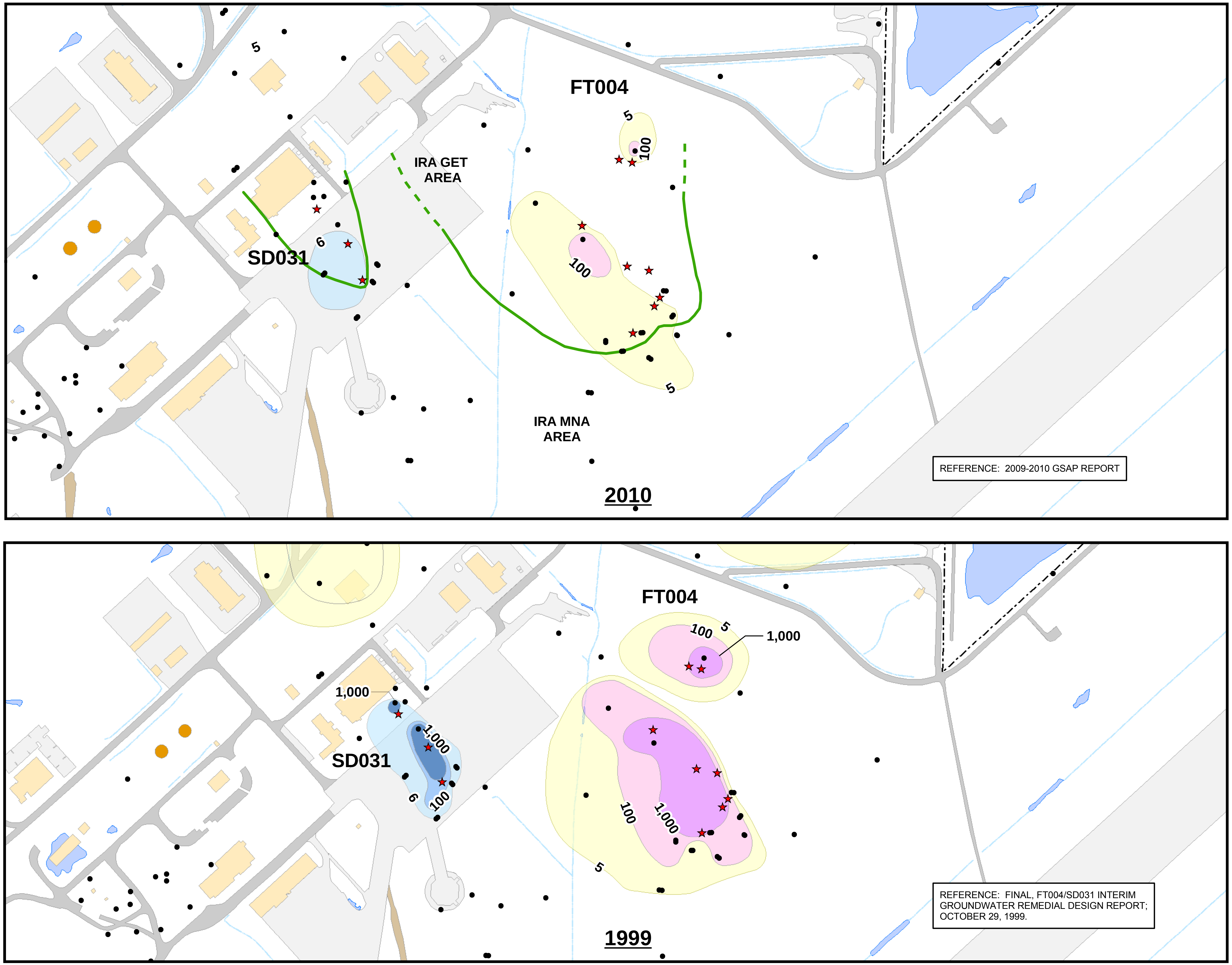


FIGURE C-1
SITE MAP
SITES FT004/SD031/LF006/LF007
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_C\FIGUREC-1_SITEMAPFT004_SD031_LF006_LF007.MXD MCLAY1 1/21/2011 11:45:29





LEGEND

- ● GROUNDWATER MONITORING WELL
- ★ EXTRACTION WELL

TCE CONCENTRATIONS (µg/L)

- 5 ≤ TCE <100
- 100 ≤ TCE <1,000
- TCE ≤ 1,000

1,1-DCE CONCENTRATIONS (µg/L)

- 6 ≤ 1,1-DCE < 100
- 100 ≤ 1,1-DCE < 1,000
- 1,1-DCE ≥ 1,000
- APPROXIMATE EXTENT OF HYDRAULIC CAPTURE (DASHED WHERE LESS CERTAIN)
- 5 APPROXIMATE ISOCONCENTRATION CONTOURS (µg/L)
- BASE BOUNDARY
- BUILDINGS
- ABOVEGROUND STORAGE TANKS
- UNPAVED AREA
- PAVED AREA
- ROAD
- SURFACE WATER

N

0 189 378 FEET

FIGURE C-2
SITES FT004/SD031
HISTORICAL AND CURRENT
GROUNDWATER CONTAMINATION

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_C\FIGUREC-2_GWCONTAMINATION_FT004_SD031.MXD MCLAY1 1/21/2011 13:12:00

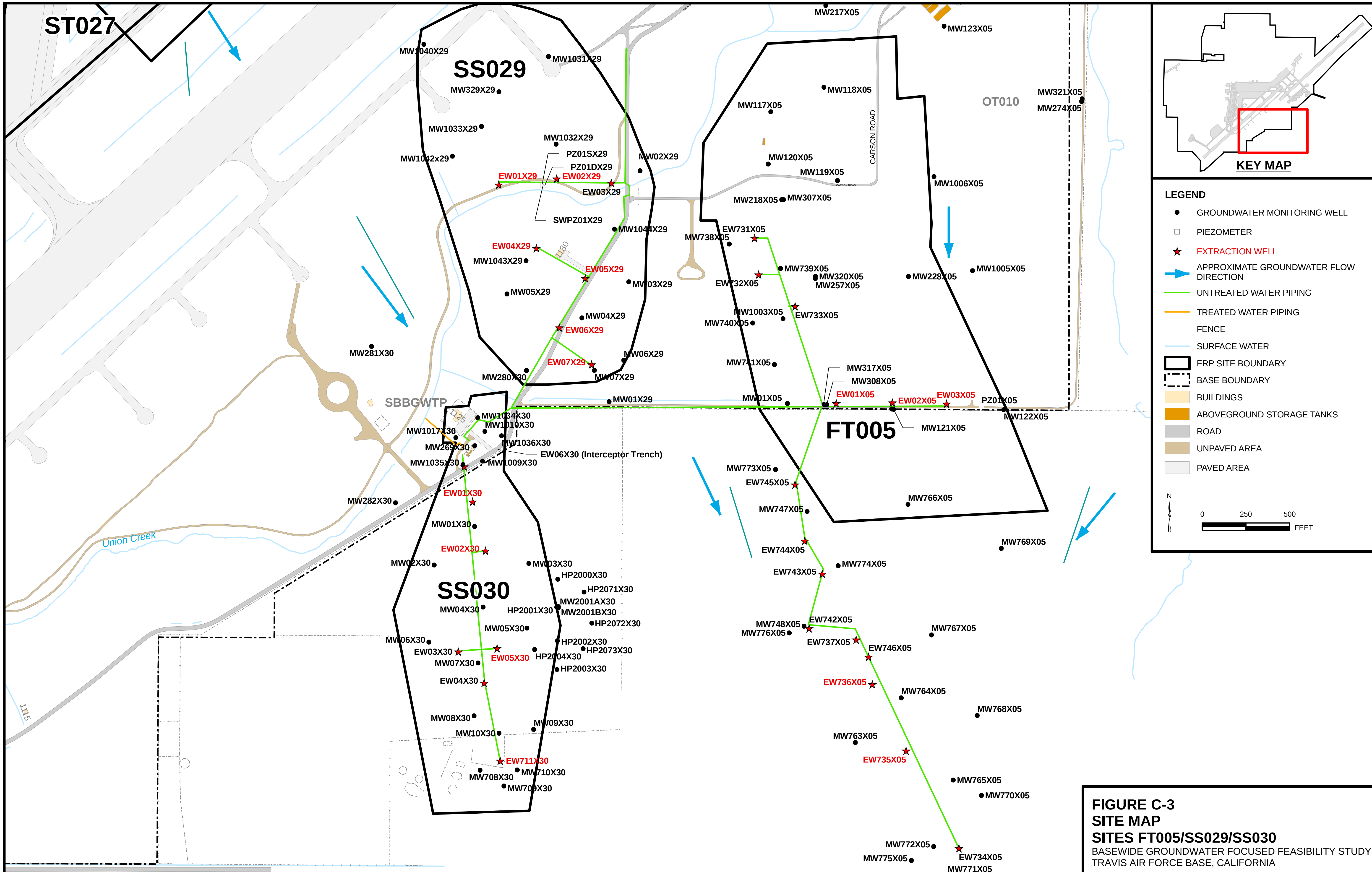


FIGURE C-3
SITE MAP
SITES FT005/SS029/SS030
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_C\FIGUREC-3_SITEMAP_FT005_SS029_SS030.MXD MCLAY1 1/21/2011 12:40:24

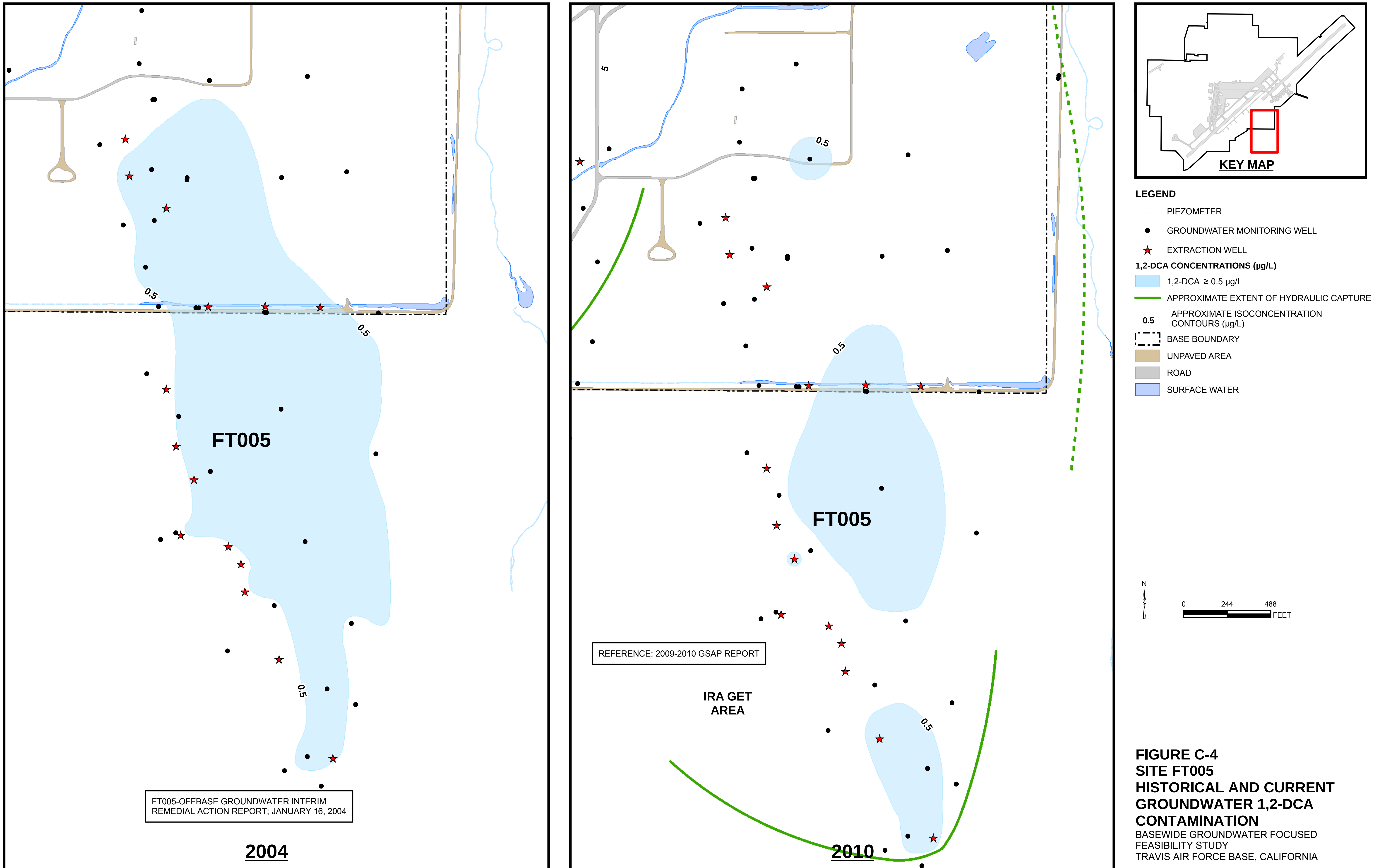
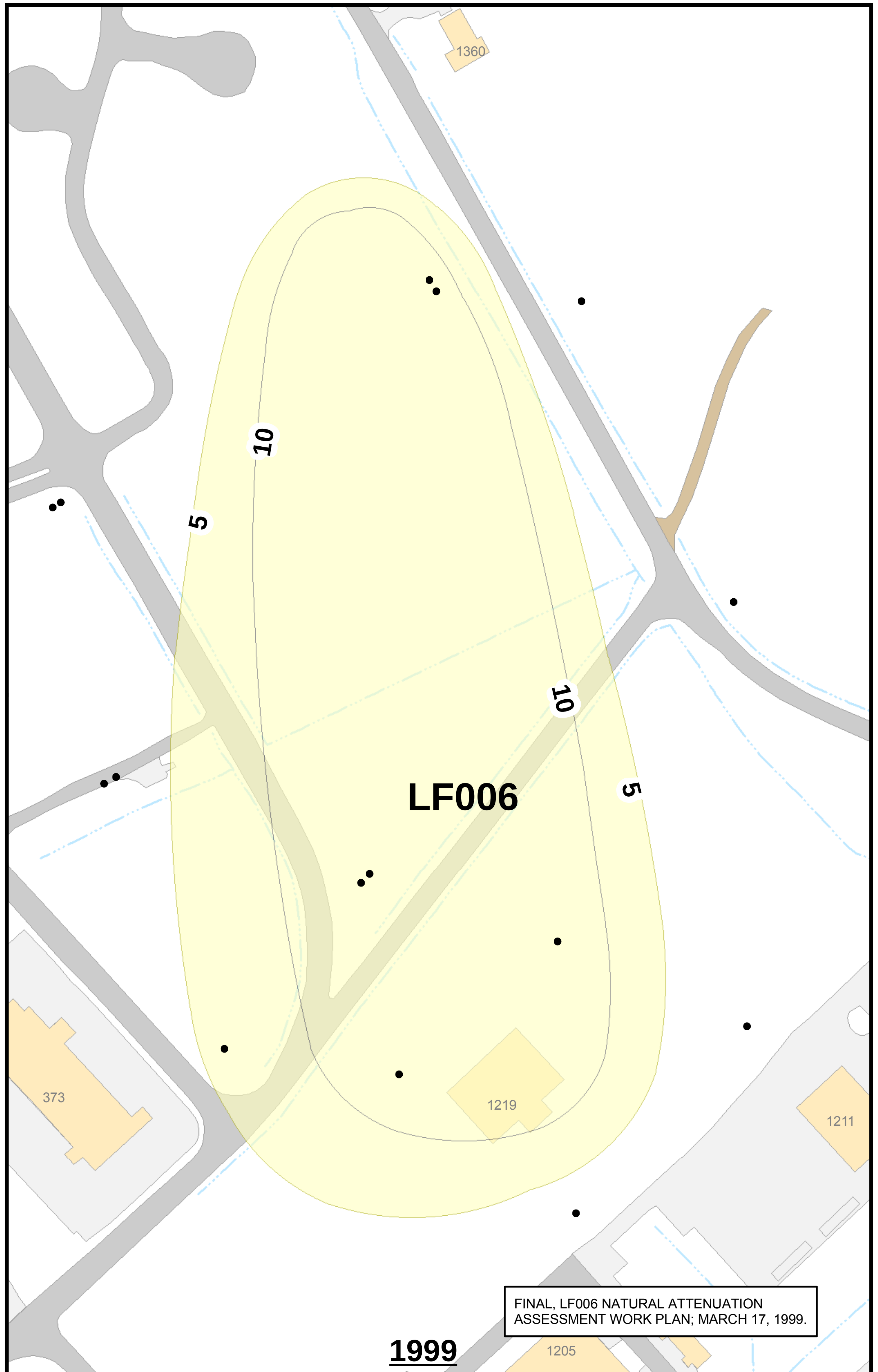
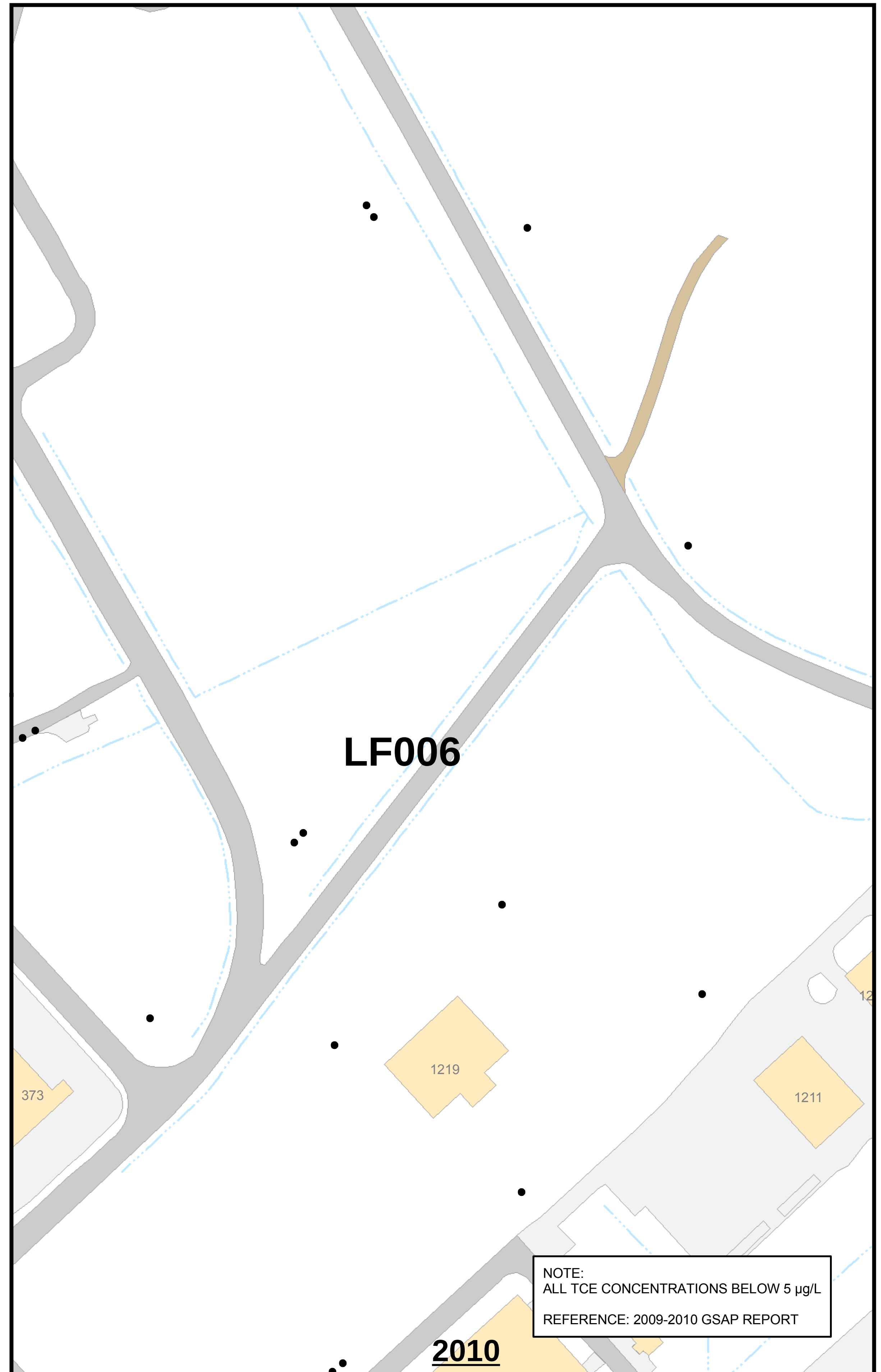


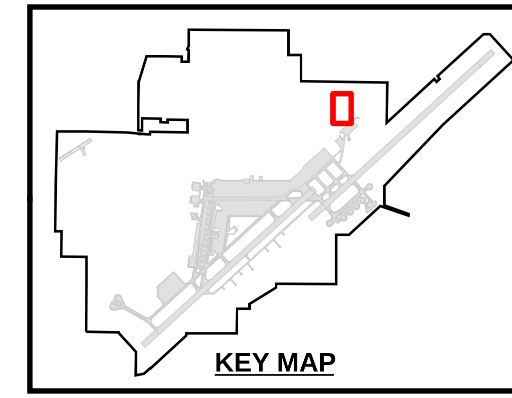
FIGURE C-4
SITE FT005
HISTORICAL AND CURRENT GROUNDWATER 1,2-DCA CONTAMINATION
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_C\FIGUREC-4_GWCONTAMINATION_FT005.MXD MCLAY1 1/21/2011 13:26:38







LEGEND

- GROUNDWATER MONITORING WELL
- SURFACE WATER
- 5 ≤ TCE <100
- 5 APPROXIMATE ISOCONCENTRATION CONTOURS (µg/L)
- BASE BOUNDARY
- BUILDINGS
- UNPAVED AREA
- PAVED AREA
- ROAD

N

0 82 164 FEET

FIGURE C-5
SITE LF006 HISTORICAL AND CURRENT TCE GROUNDWATER CONTAMINATION

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

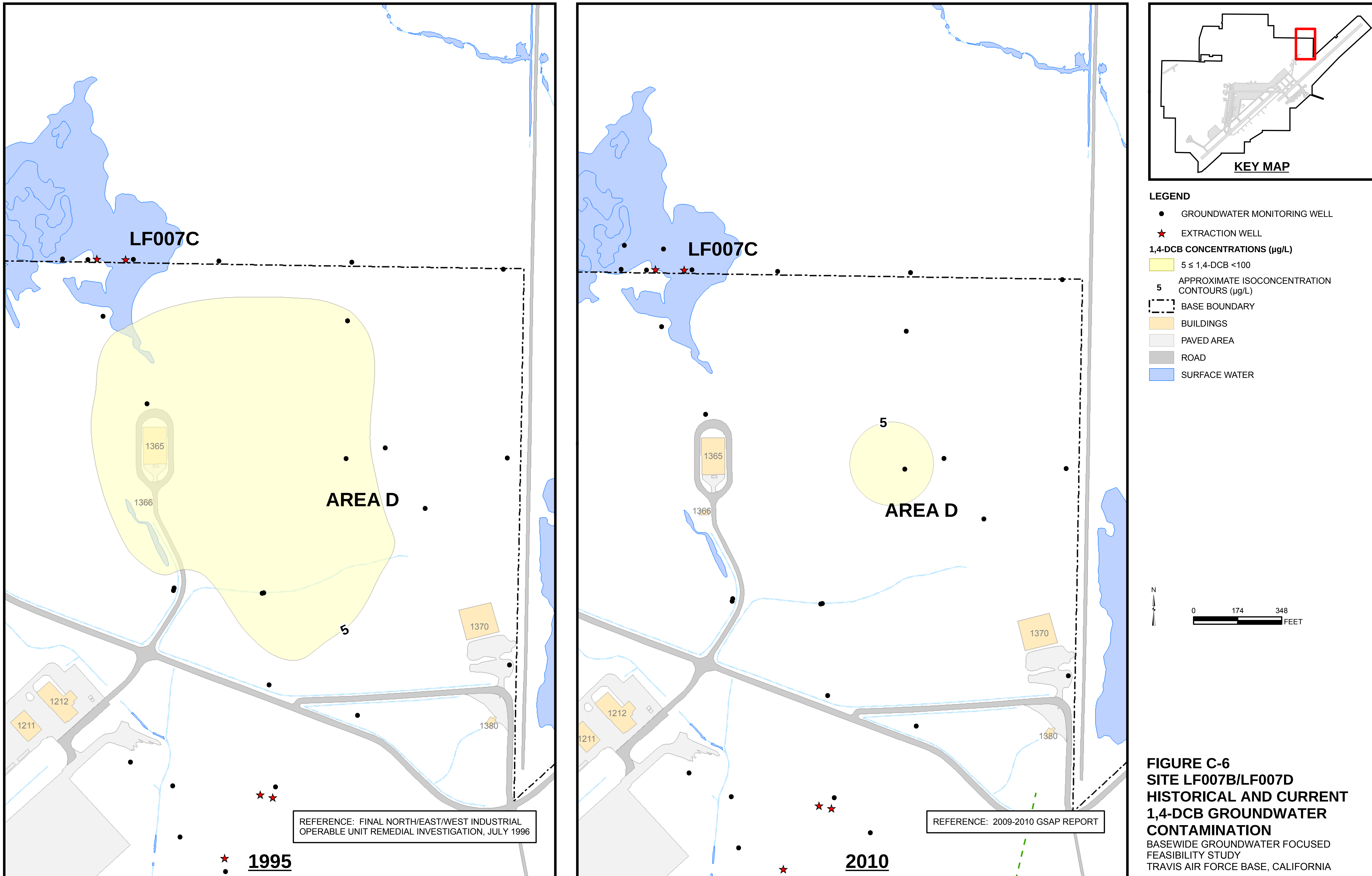


FIGURE C-6
SITE LF007B/LF007D
HISTORICAL AND CURRENT
1,4-DCB GROUNDWATER
CONTAMINATION
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

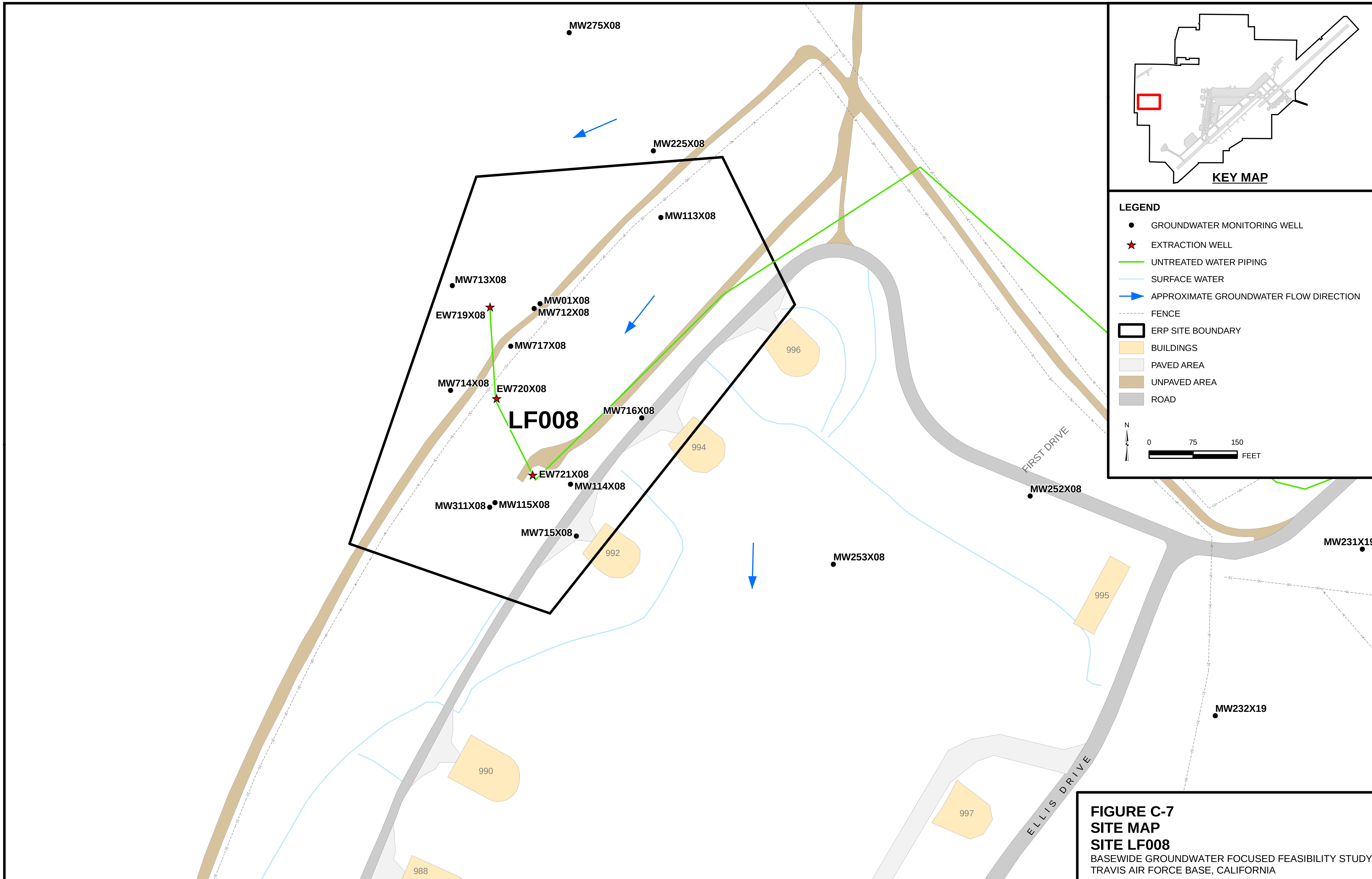


FIGURE C-7
SITE MAP
SITE LF008
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_C\FIGUREC-7_SITEMAP_LF008.MXD MCLAY1 1/21/2011 14:26:52

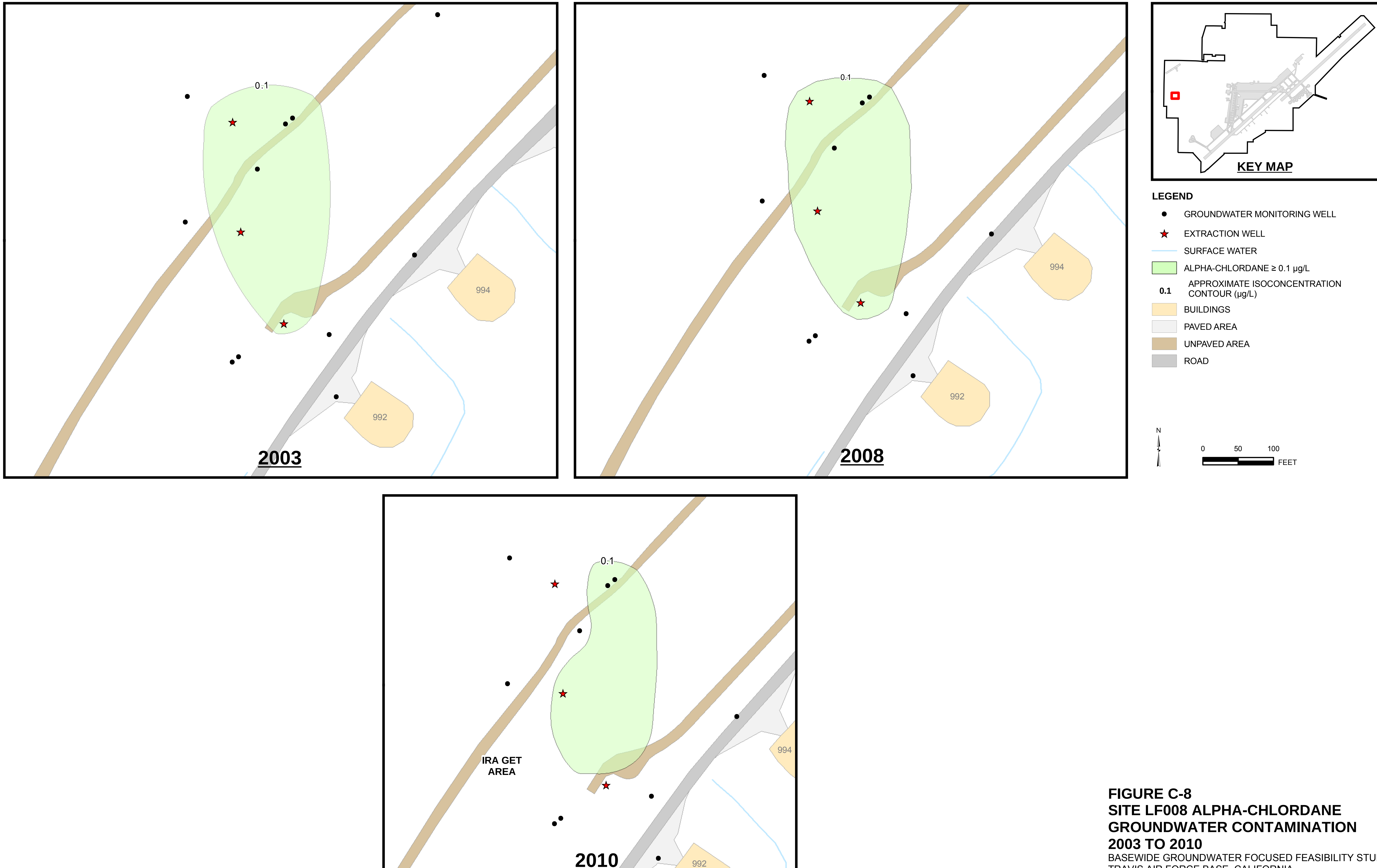


FIGURE C-8
SITE LF008 ALPHA-CHLORDANE GROUNDWATER CONTAMINATION 2003 TO 2010
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

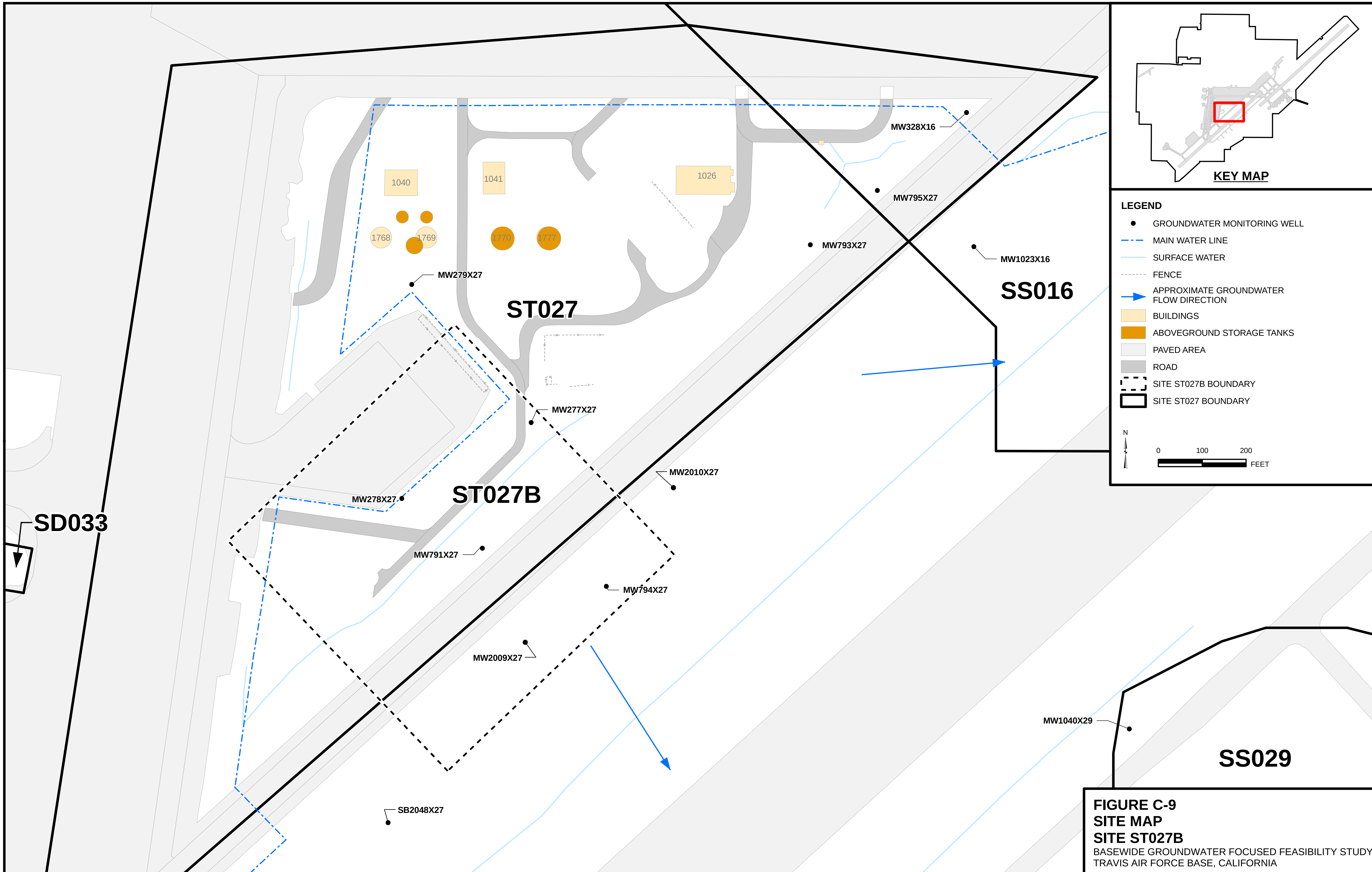


FIGURE C-9
SITE MAP
SITE ST027B
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_C\FIGUREC-9_SITEMAP_ST027B.MXD MCLAY1 1/21/2011 15:10:33

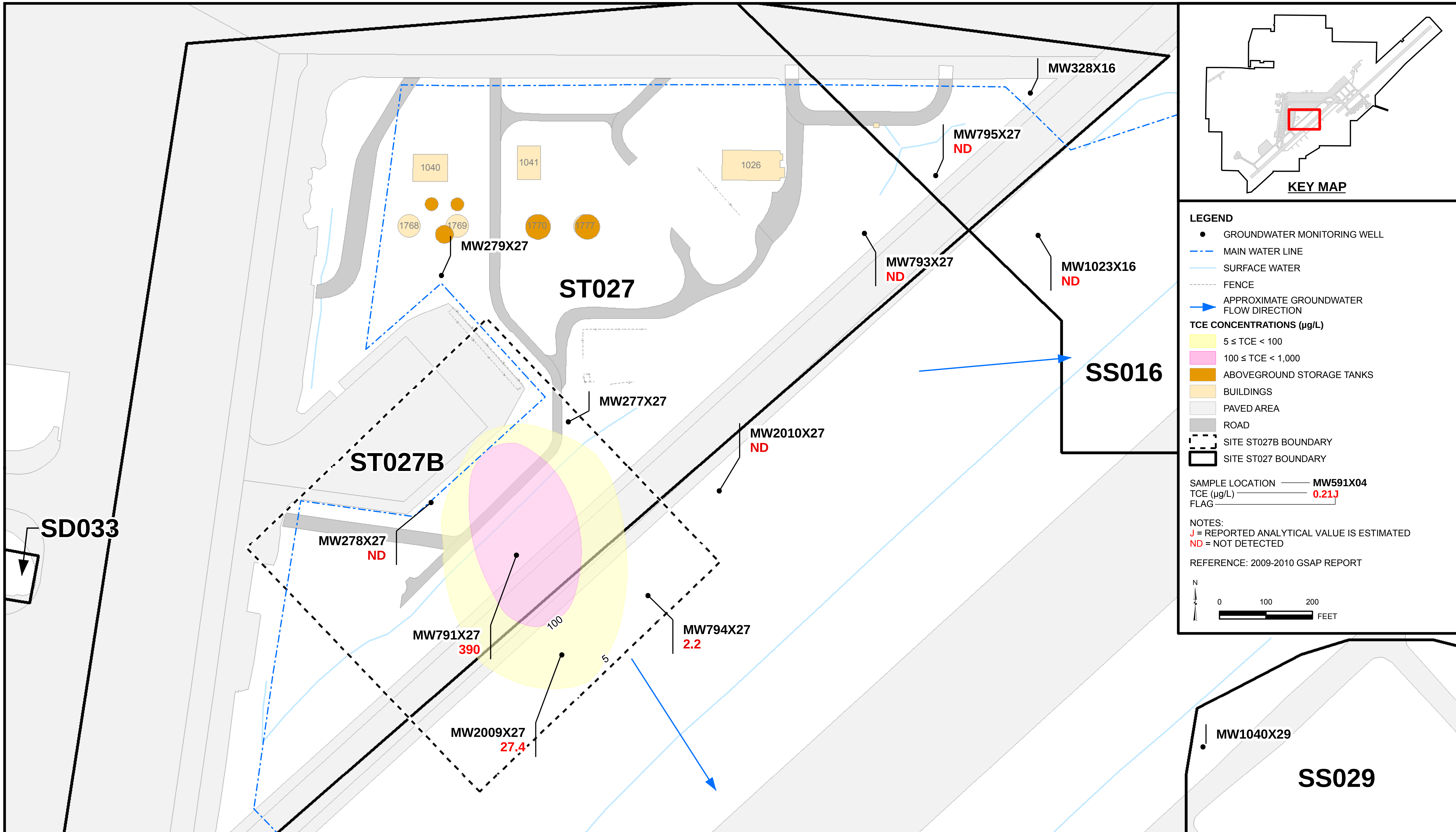


FIGURE C-10
CURRENT (2010) TCE DISTRIBUTION
AT SITE ST027B
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_C\FIGUREC-10_TCE_ST027B.MXD MCLAY1 1/21/2011 15:33:44

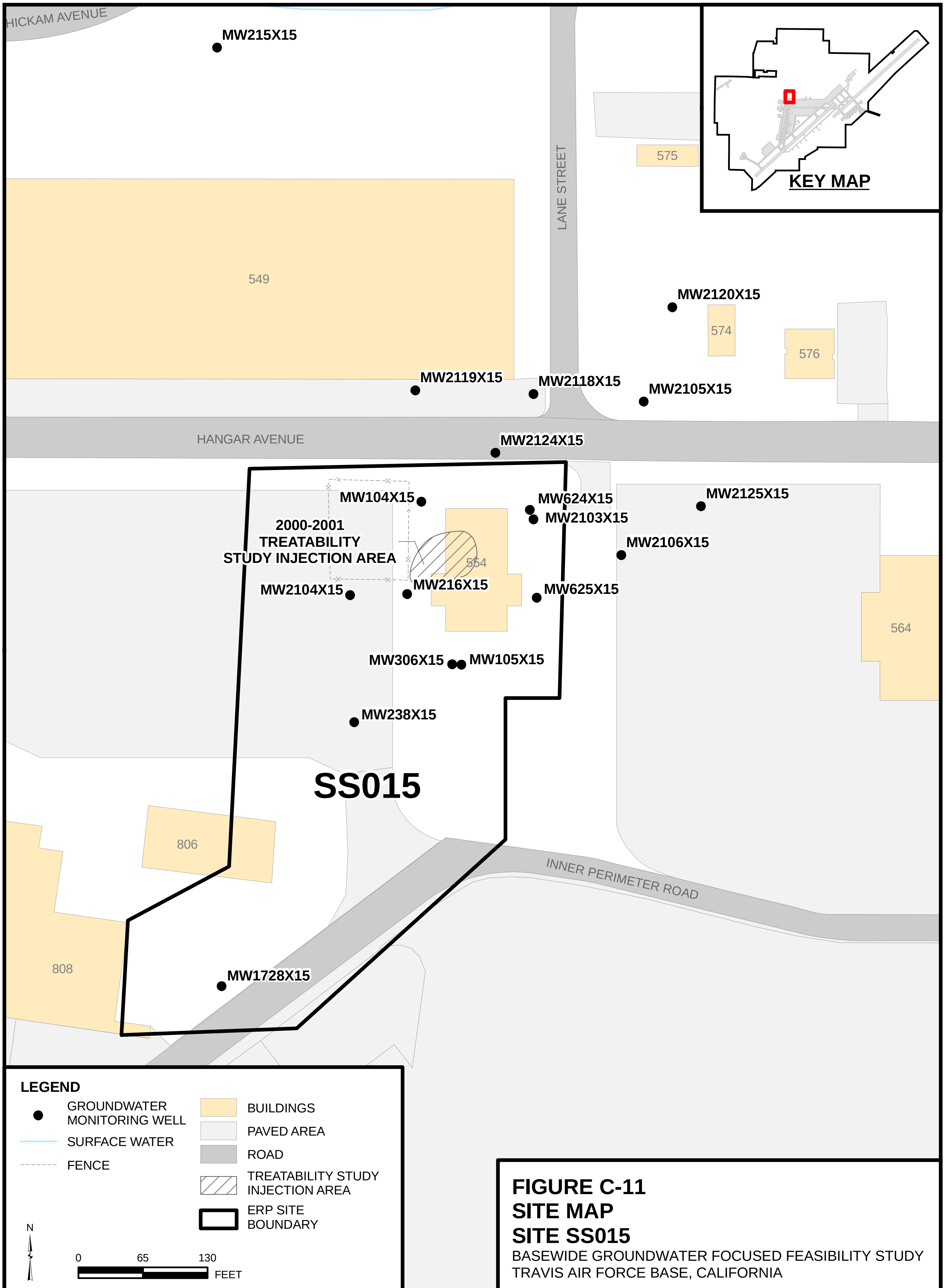
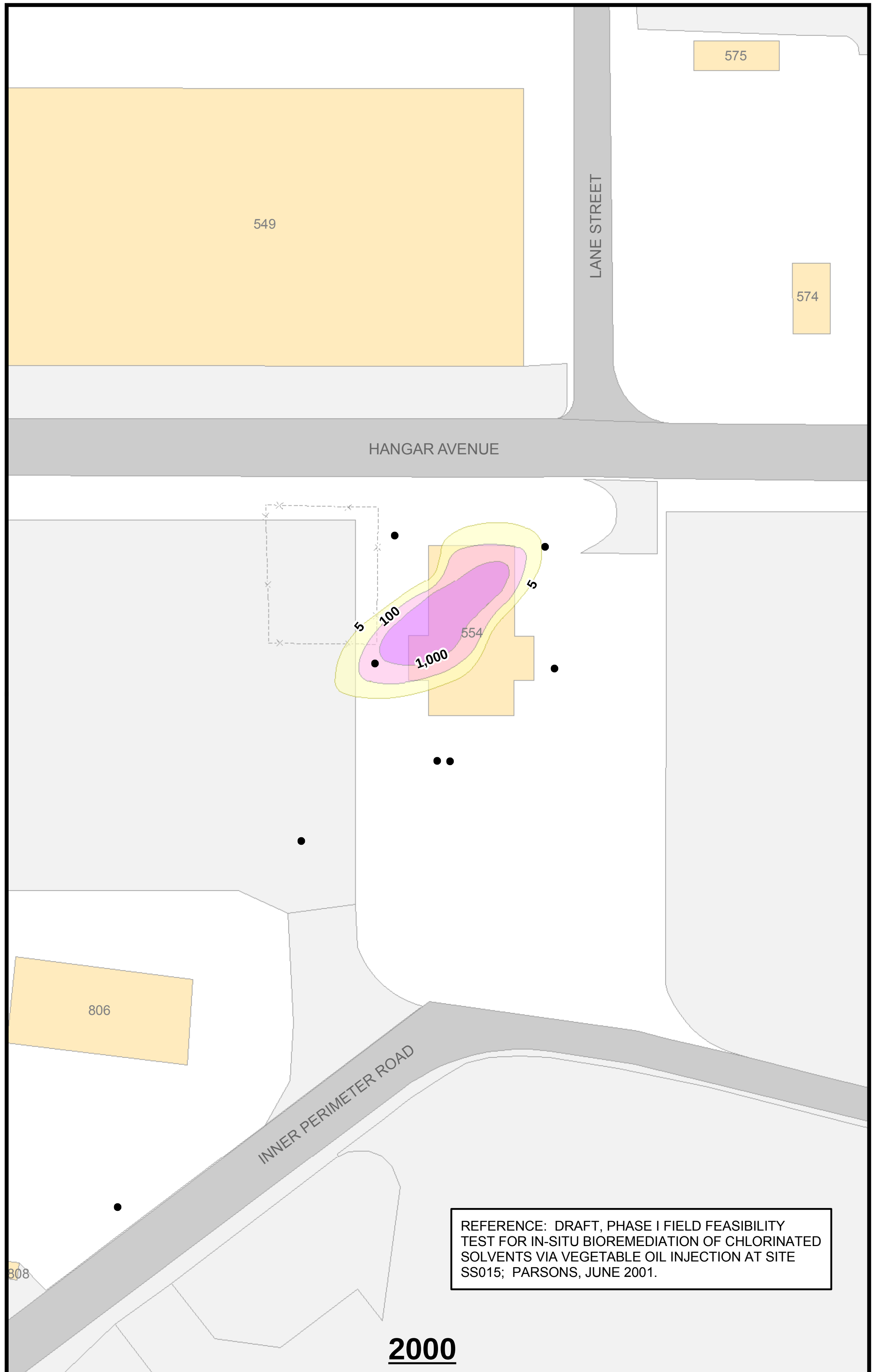
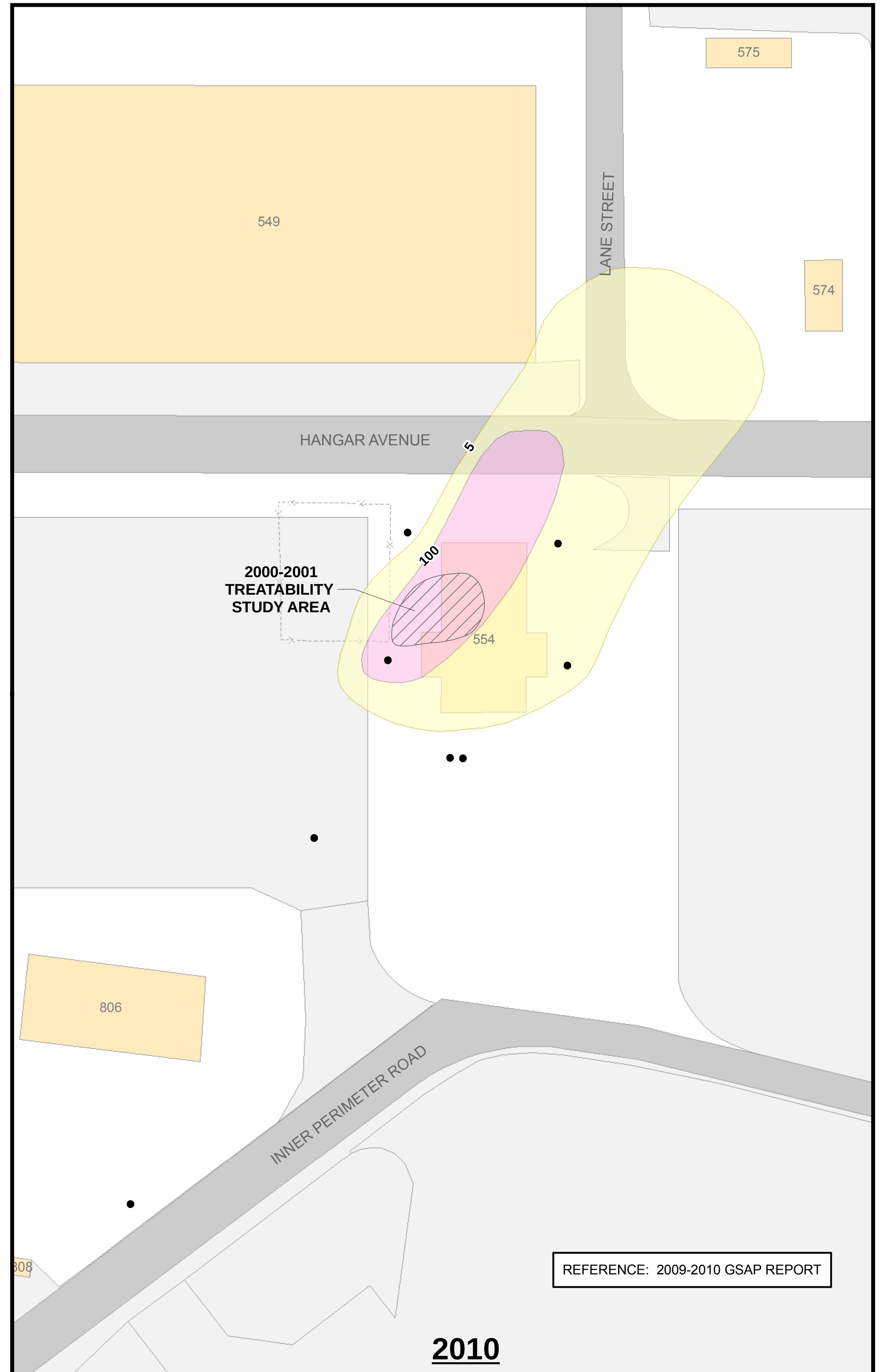


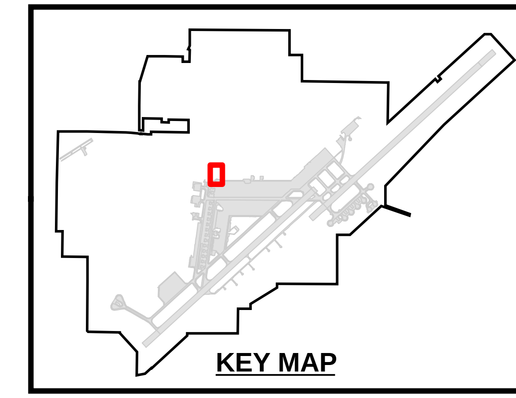
FIGURE C-11
SITE MAP
SITE SS015
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_C\FIGUREC-11_SITEMAP_SS015.MXD MCLAY1 1/21/2011 15:57:16







LEGEND

- GROUNDWATER MONITORING WELL

TCE CONCENTRATIONS (µg/L)

- 5 ≤ TCE <100
- 100 ≤ TCE <1,000
- TCE ≤ 1,000
- 5 APPROXIMATE ISOCONCENTRATION CONTOURS (µg/L)
- SURFACE WATER
- FENCE
- BUILDINGS
- ROAD
- PAVED AREA
- TREATABILITY STUDY AREA

N

0 50 100 FEET

FIGURE C-12
SITE SS015
HISTORICAL AND CURRENT TCE GROUNDWATER CONTAMINATION

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_C\FIGUREC-12_GWCONTAMINATION_SS015.MXD MCLAY1 1/21/2011 16:21:32

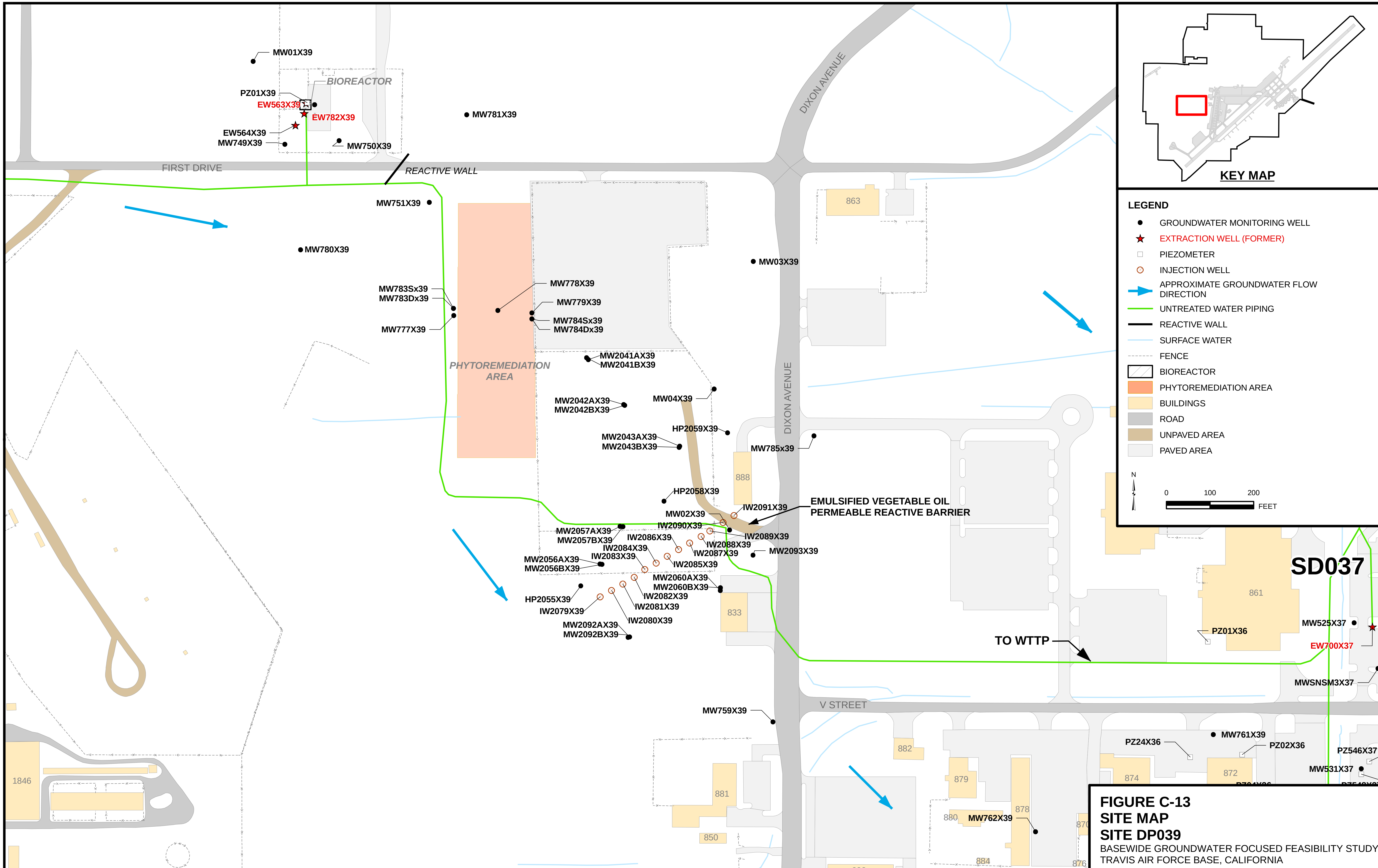


FIGURE C-13
SITE MAP
SITE DP039
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

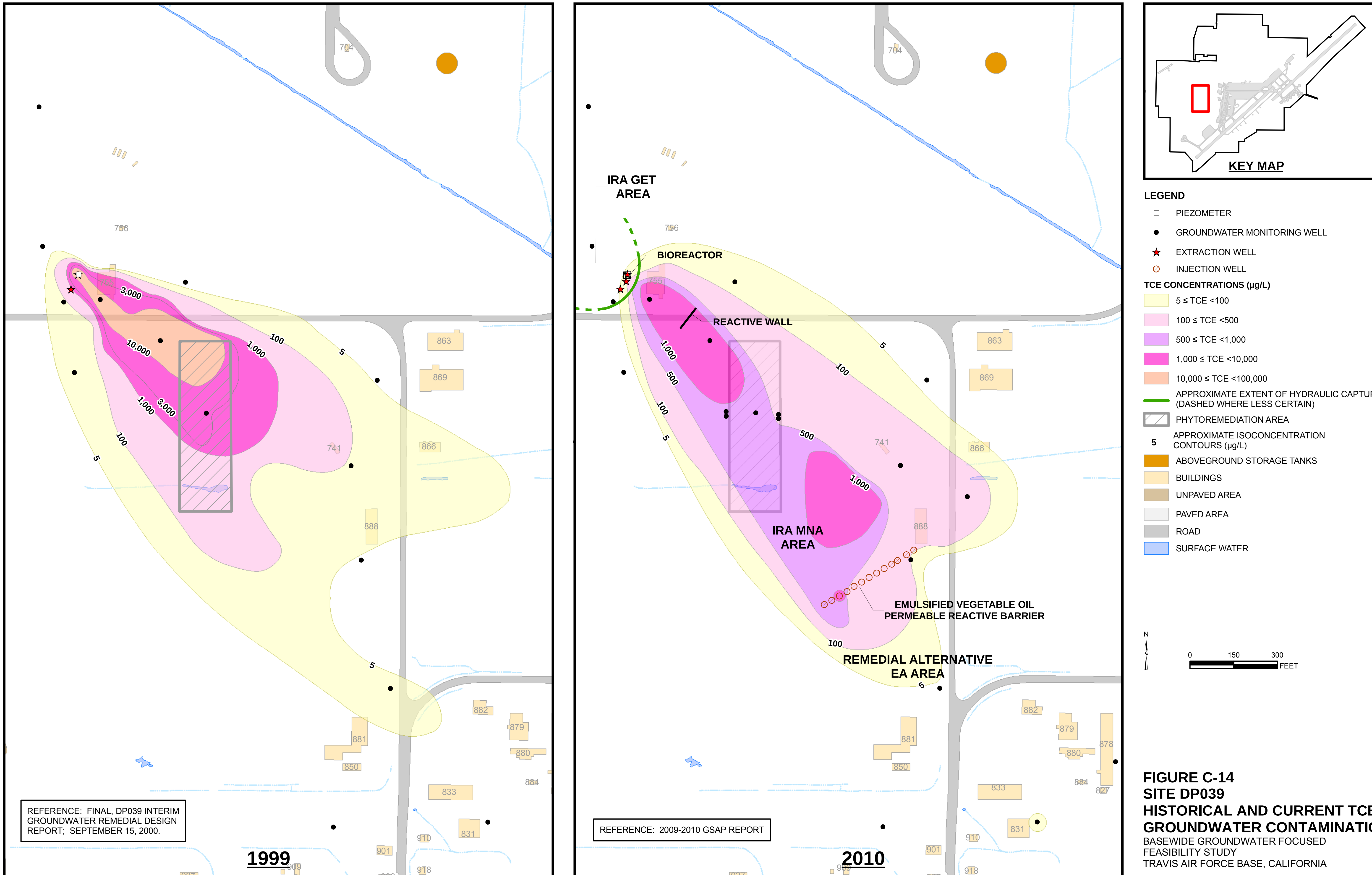


FIGURE C-14
SITE DP039
HISTORICAL AND CURRENT TCE GROUNDWATER CONTAMINATION
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

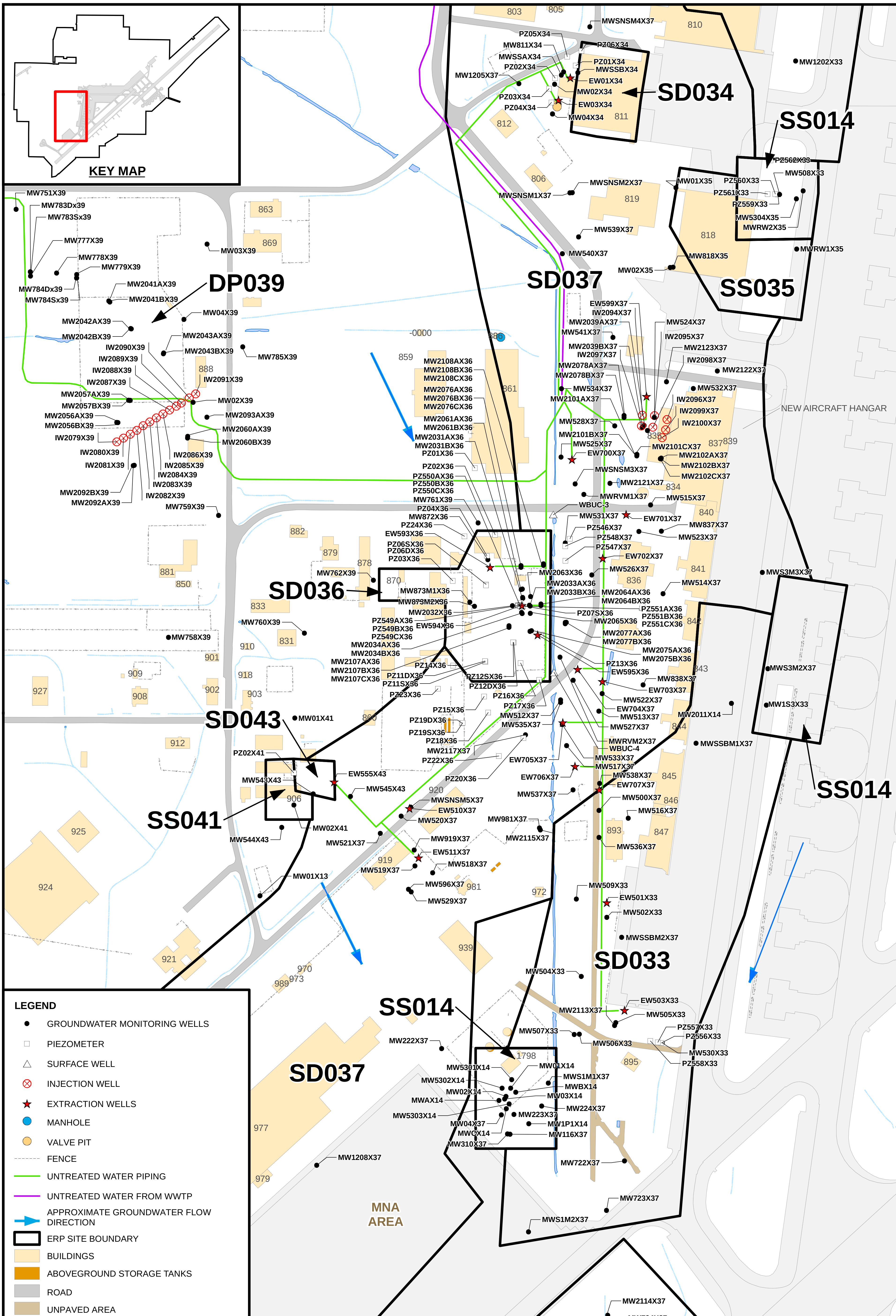
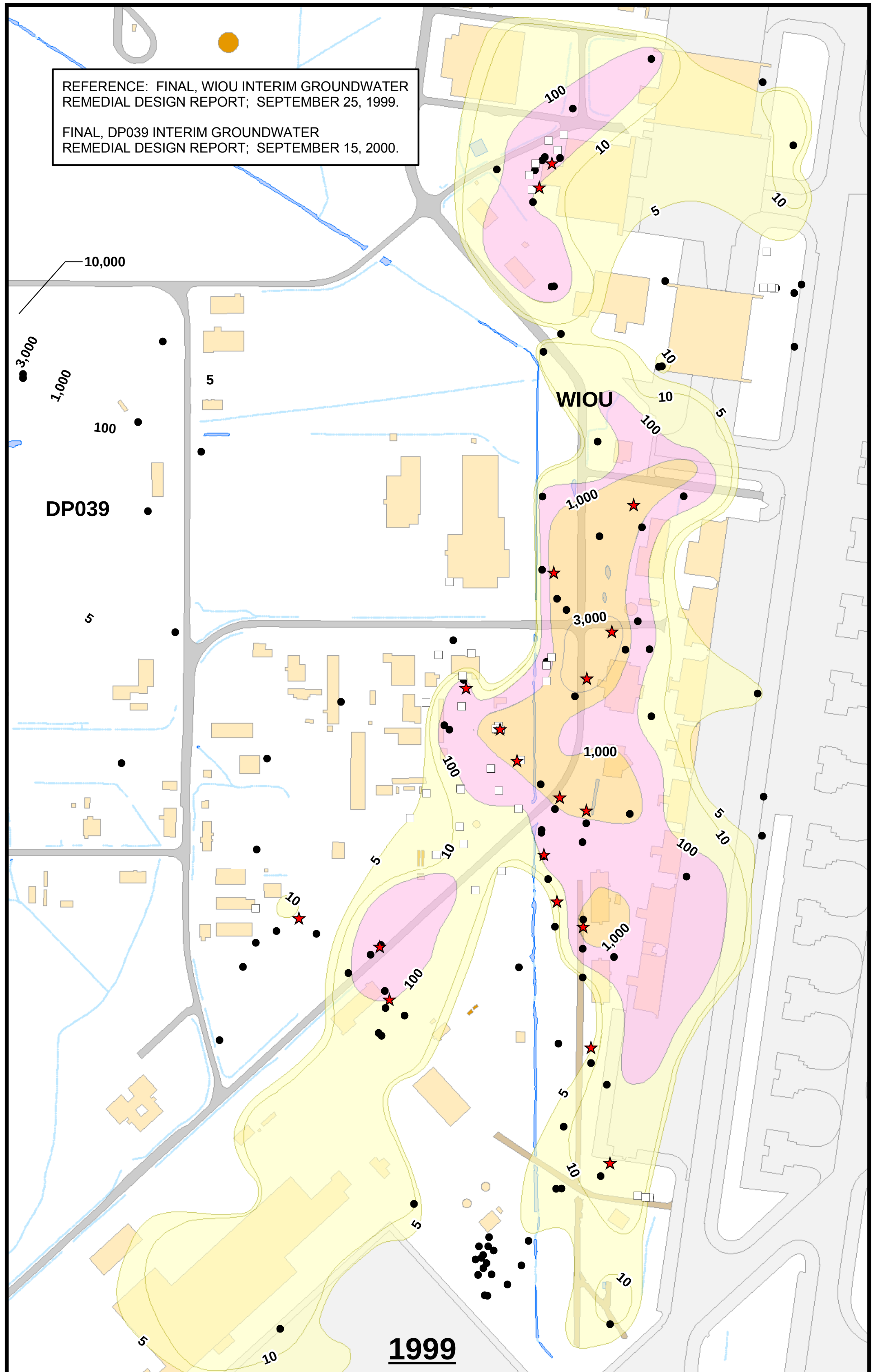
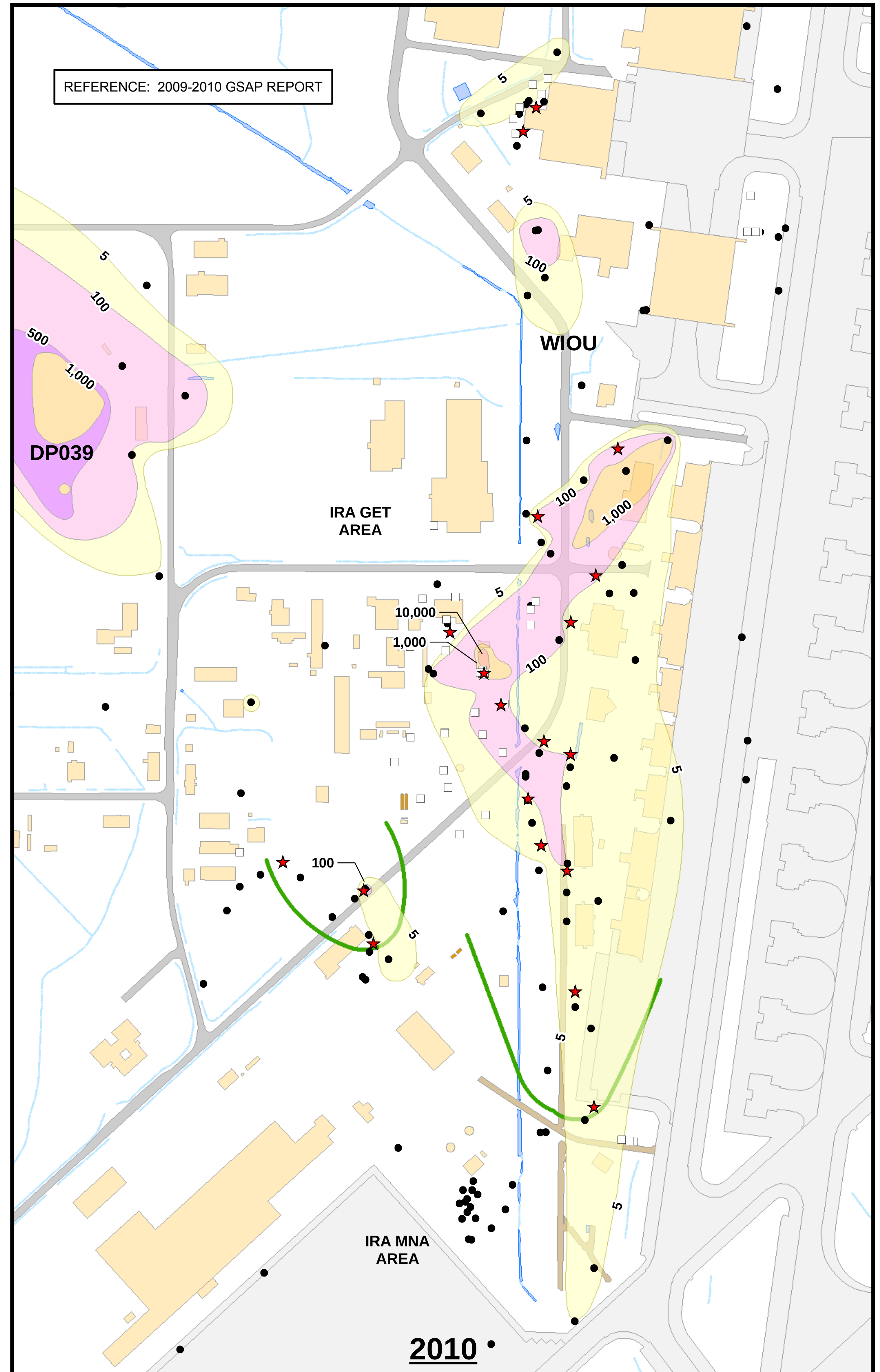


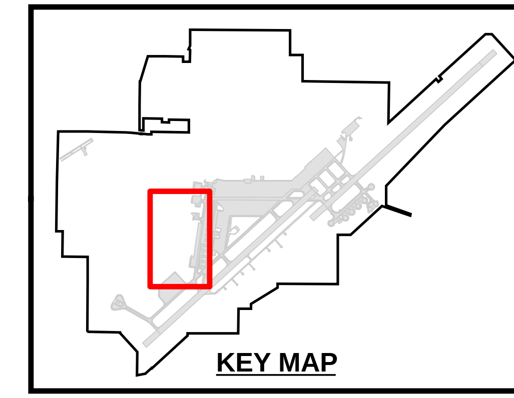
FIGURE C-15
SITE MAP
WIOU SITES
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_C\FIGUREC-15_SITEMAP_WIOU.MXD MCLAY1 1/21/2011 17:37:54







LEGEND

- PIEZOMETER
- GROUNDWATER MONITORING WELL
- EXTRACTION WELL

TCE CONCENTRATIONS (µg/L)

- 5 ≤ TCE <100
- 100 ≤ TCE < 500
- 500 ≤ TCE <1,000
- 1,000 ≤ TCE <10,000
- TCE ≥10,000
- APPROXIMATE EXTENT OF HYDRAULIC CAPTURE
- ABOVEGROUND STORAGE TANKS
- BUILDINGS
- UNPAVED AREA
- PAVED AREA
- ROAD
- SURFACE WATER

N

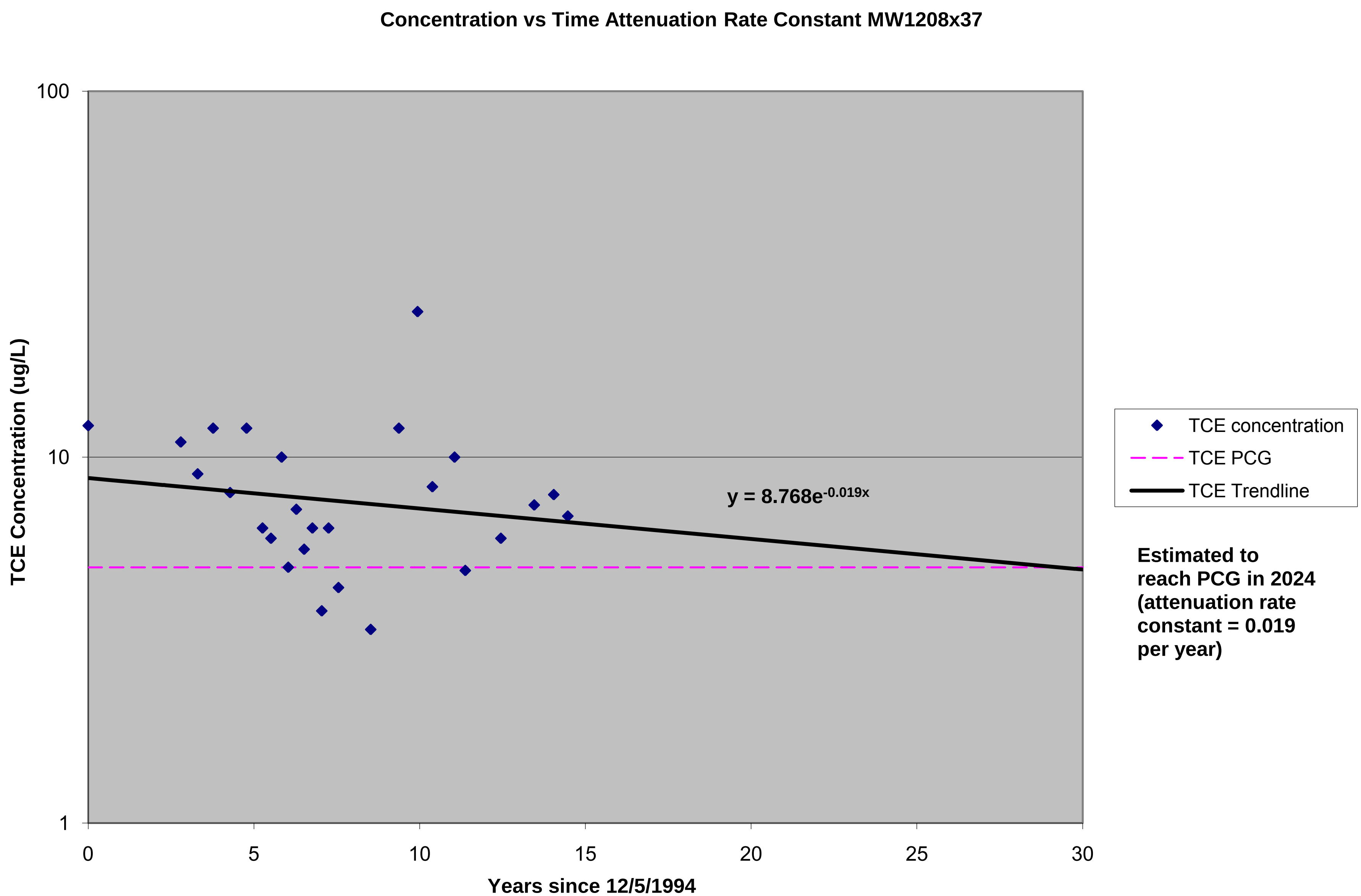
0 250 500 FEET

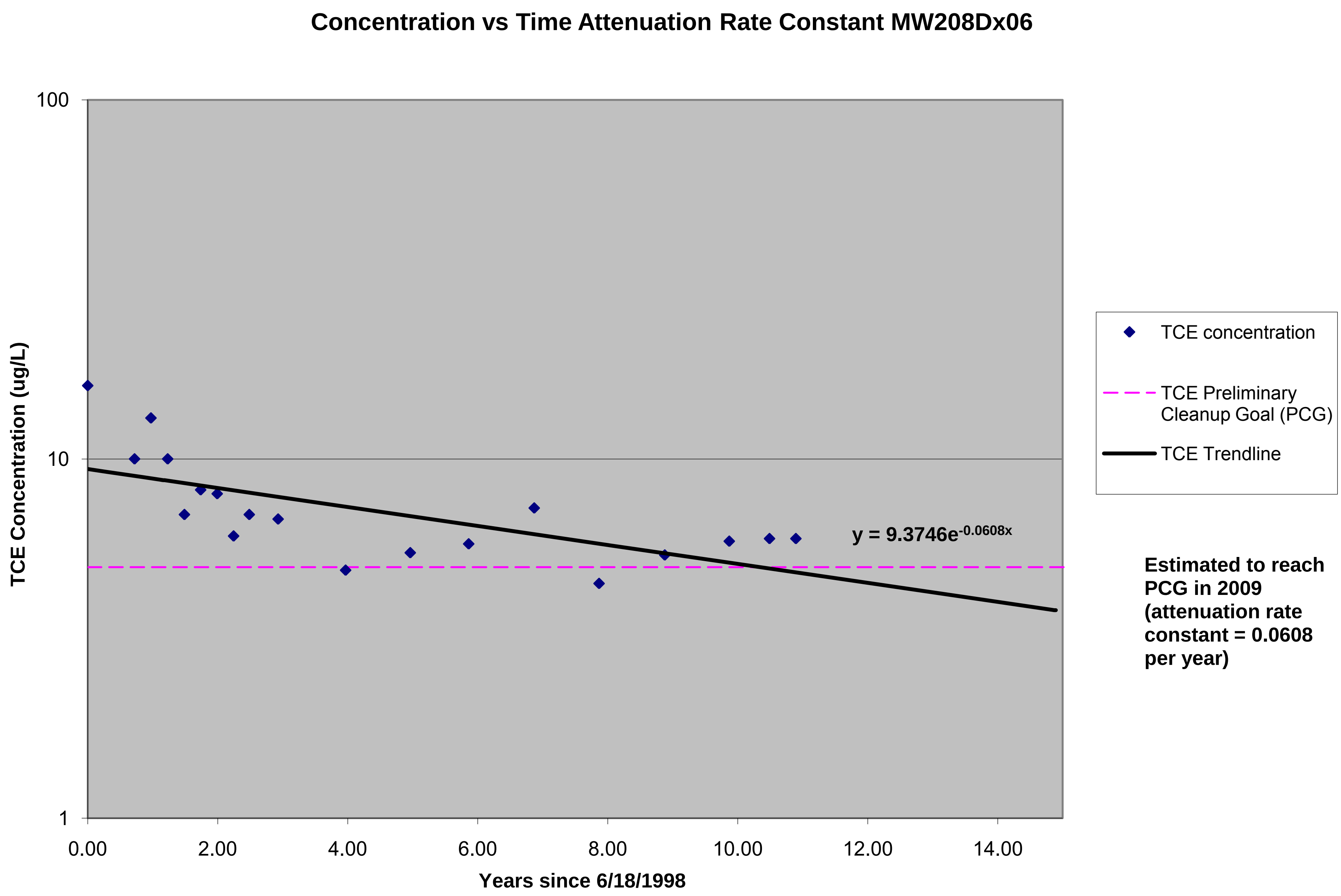
FIGURE C-16
WIOU SITES
HISTORICAL AND CURRENT TCE GROUNDWATER CONTAMINATION

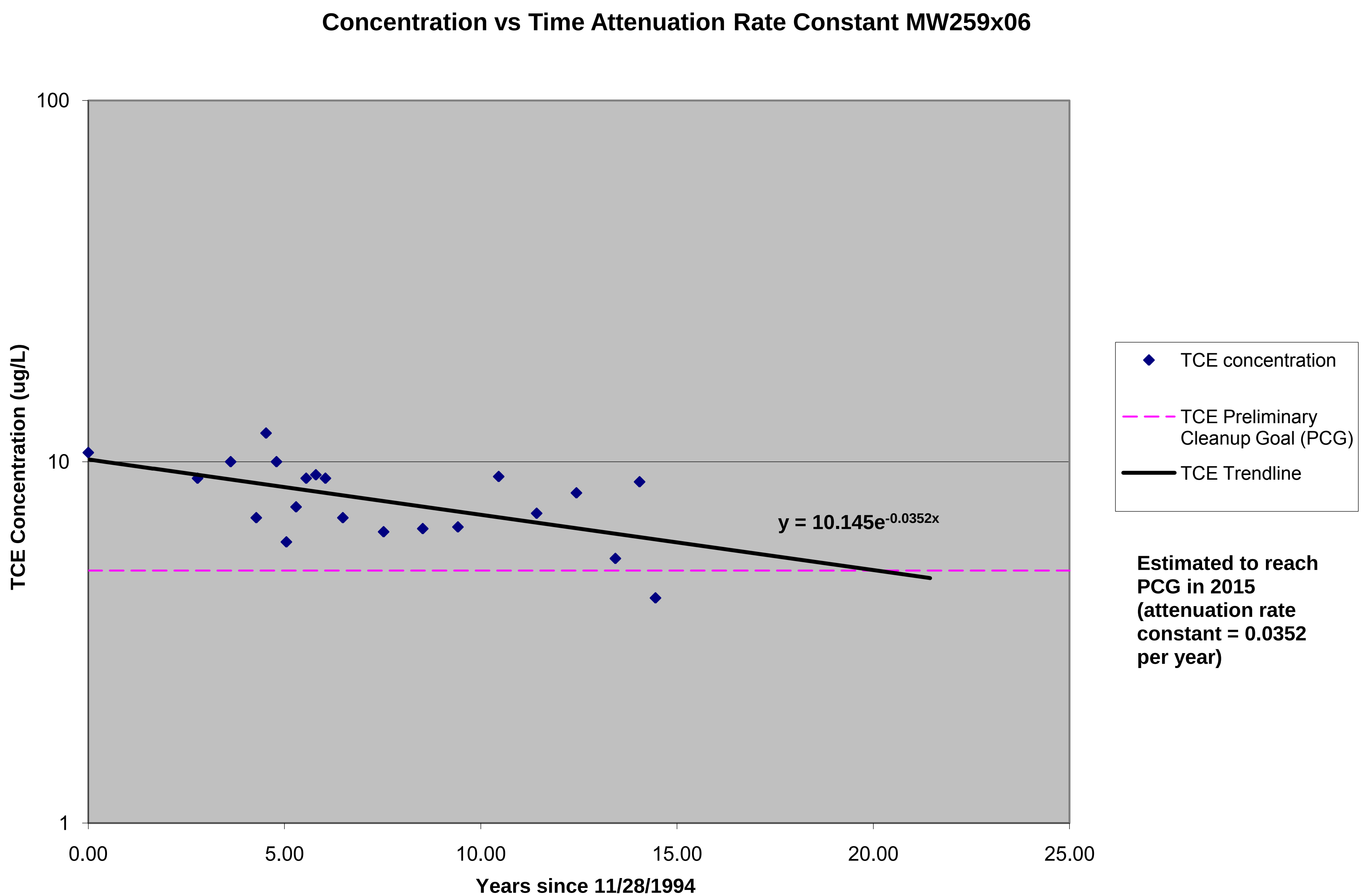
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

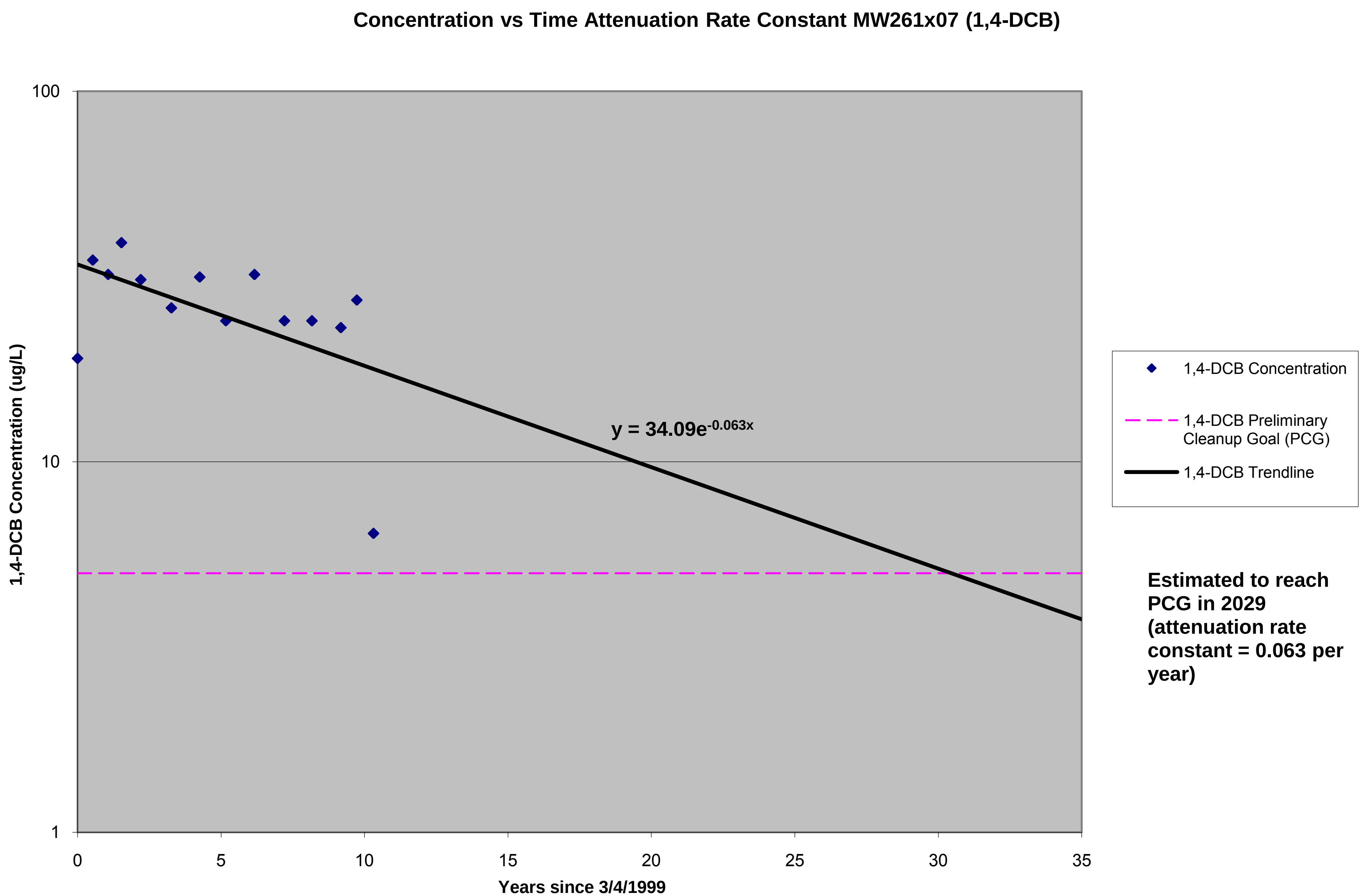
CH2MHILL

Attachment C1

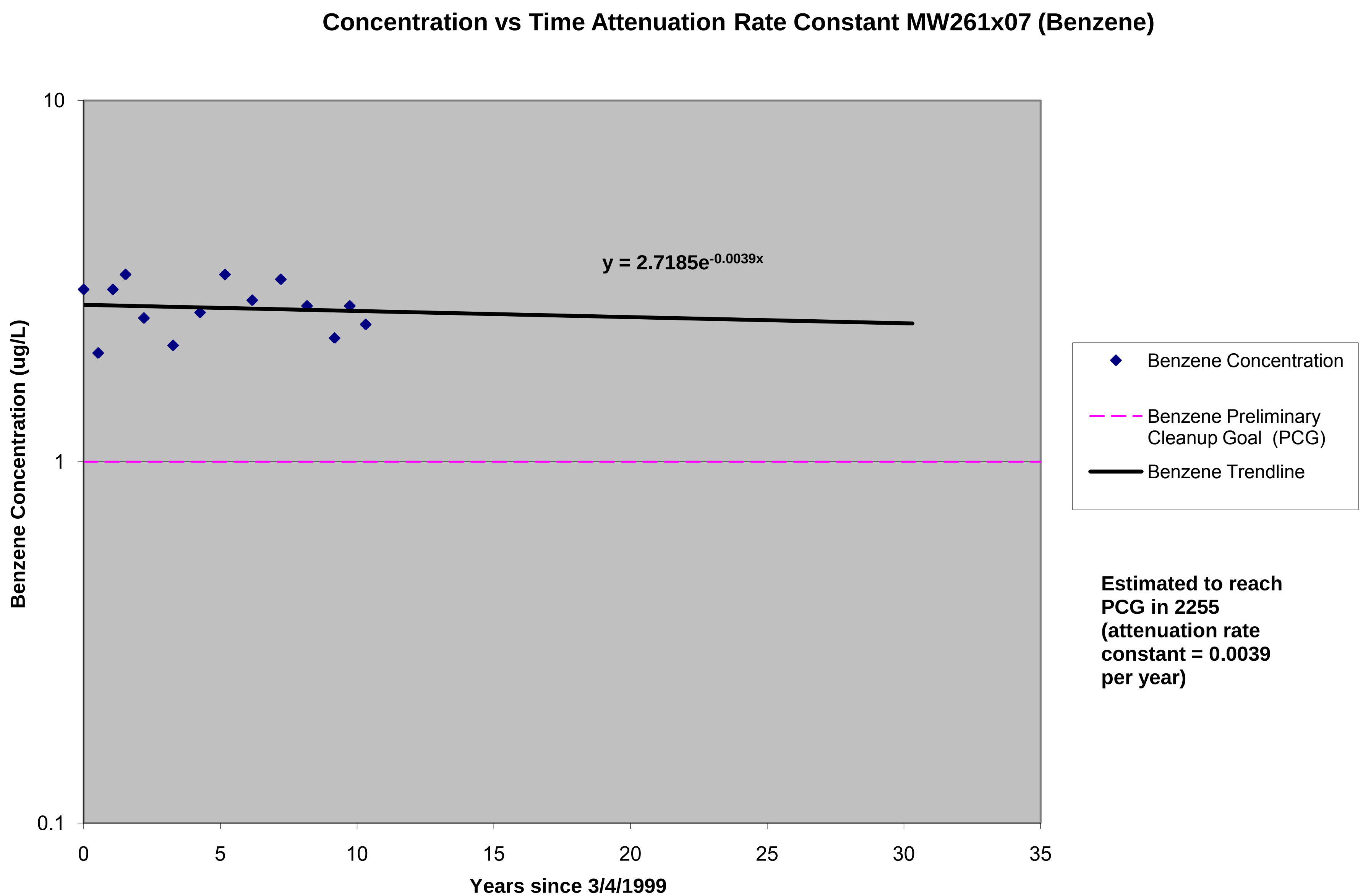

Concentration vs Time Attenuation Rate Constant MW1208x37
TCE Concentration (ug/L)
100
10
1
0
5
10
15
20
25
30
Years since 12/5/1994
y = 8.768e-0.019x
TCE concentration
TCE PCG
TCE Trendline
Estimated to reach PCG in 2024 (attenuation rate constant = 0.019 per year)


Concentration vs Time Attenuation Rate Constant MW208Dx06
100
10
1
TCE Concentration (ug/L)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
Years since 6/18/1998
y = 9.3746e^-0.0608x
TCE concentration
TCE Preliminary Cleanup Goal (PCG)
TCE Trendline
Estimated to reach PCG in 2009 (attenuation rate constant = 0.0608 per year)


Concentration vs Time Attenuation Rate Constant MW259x06
TCE Concentration (ug/L)
100
10
1
0.00
5.00
10.00
15.00
20.00
25.00
Years since 11/28/1994
y = 10.145e^-0.0352x
TCE concentration
TCE Preliminary Cleanup Goal (PCG)
TCE Trendline
Estimated to reach PCG in 2015 (attenuation rate constant = 0.0352 per year)

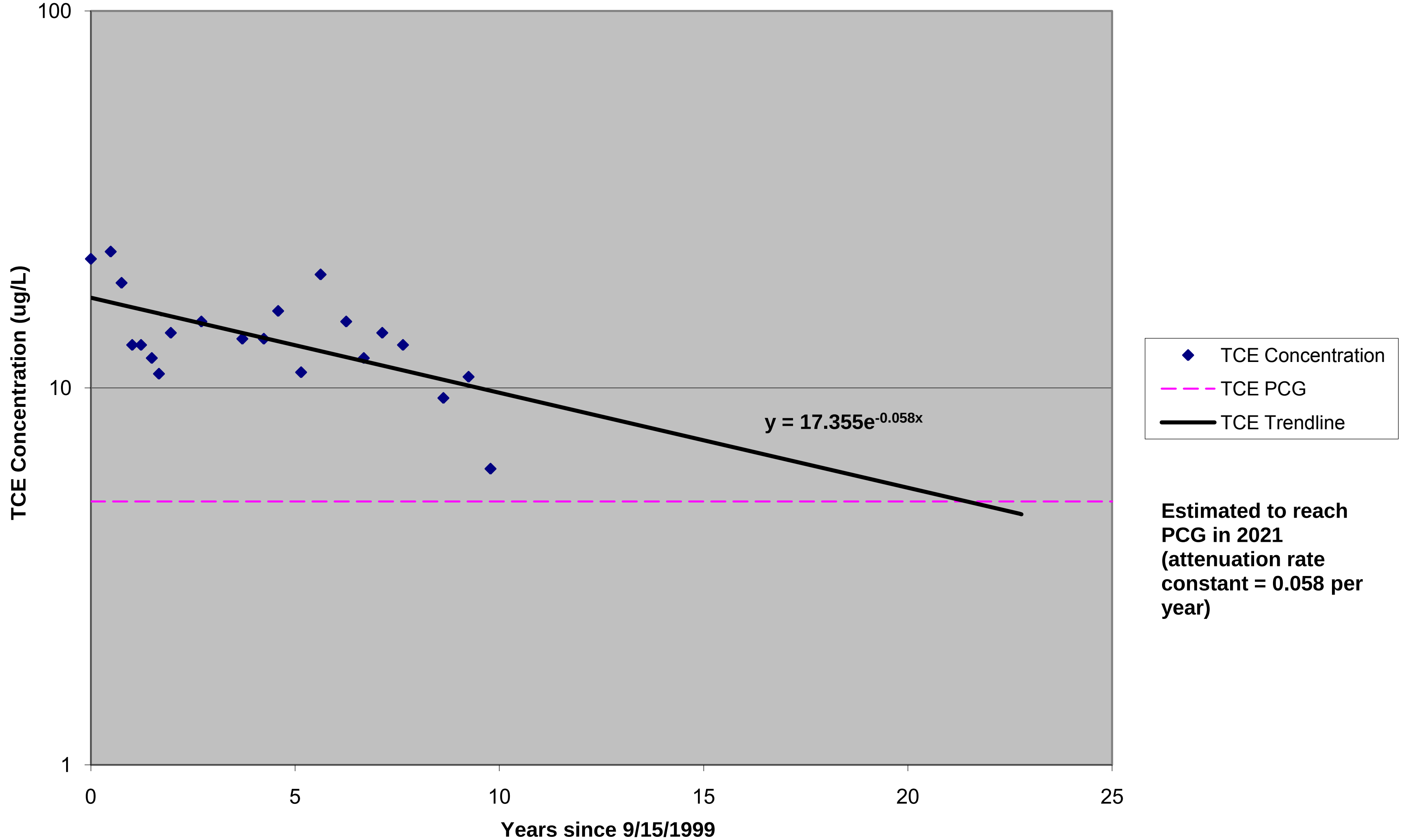


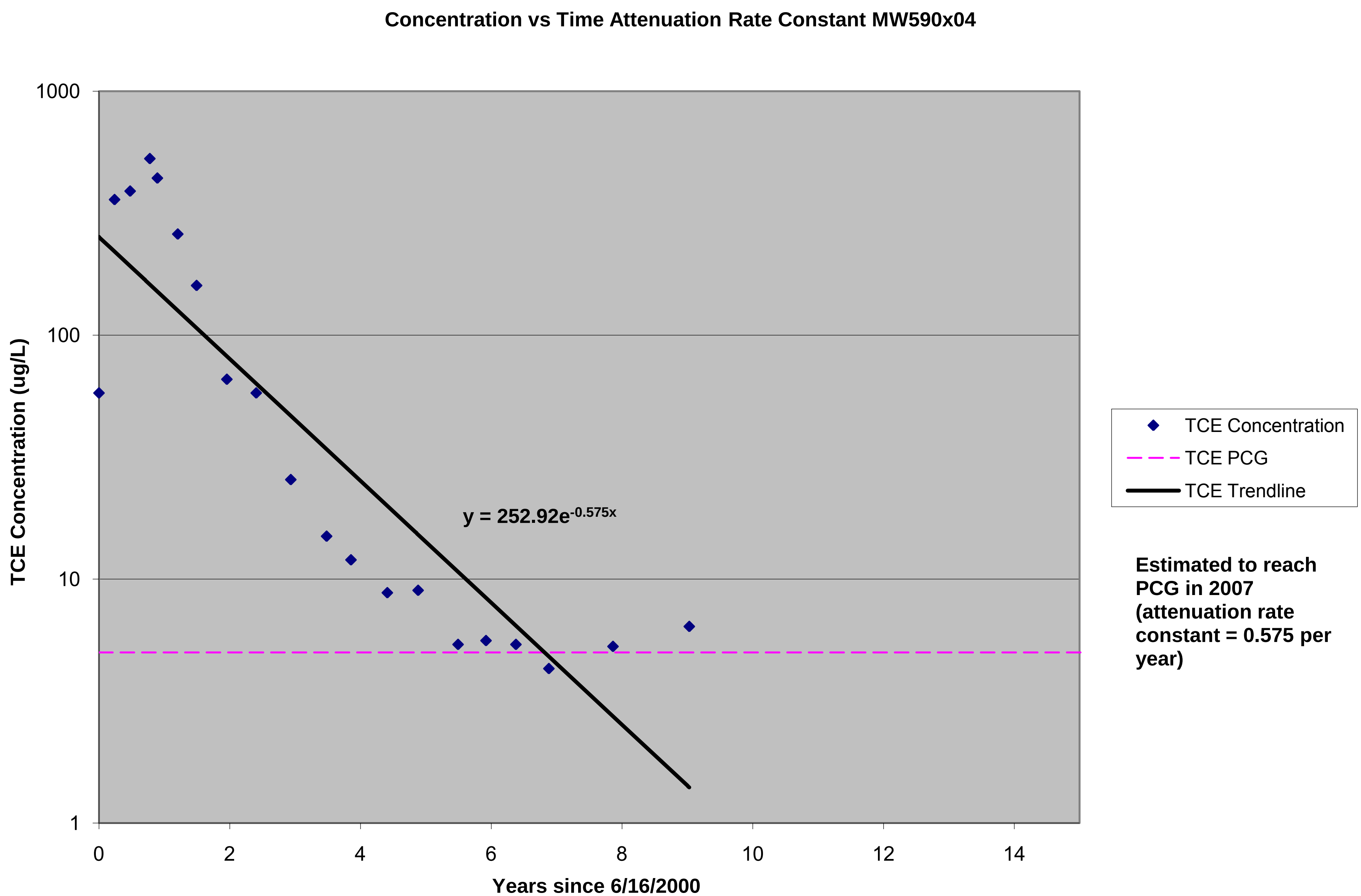
Concentration vs Time Attenuation Rate Constant MW261x07 (1,4-DCB)
100
10
1
1,4-DCB Concentration (ug/L)
y = 34.09e-0.063x
0
5
10
15
20
25
30
35
Years since 3/4/1999
1,4-DCB Concentration
1,4-DCB Preliminary Cleanup Goal (PCG)
1,4-DCB Trendline
Estimated to reach PCG in 2029 (attenuation rate constant = 0.063 per year)

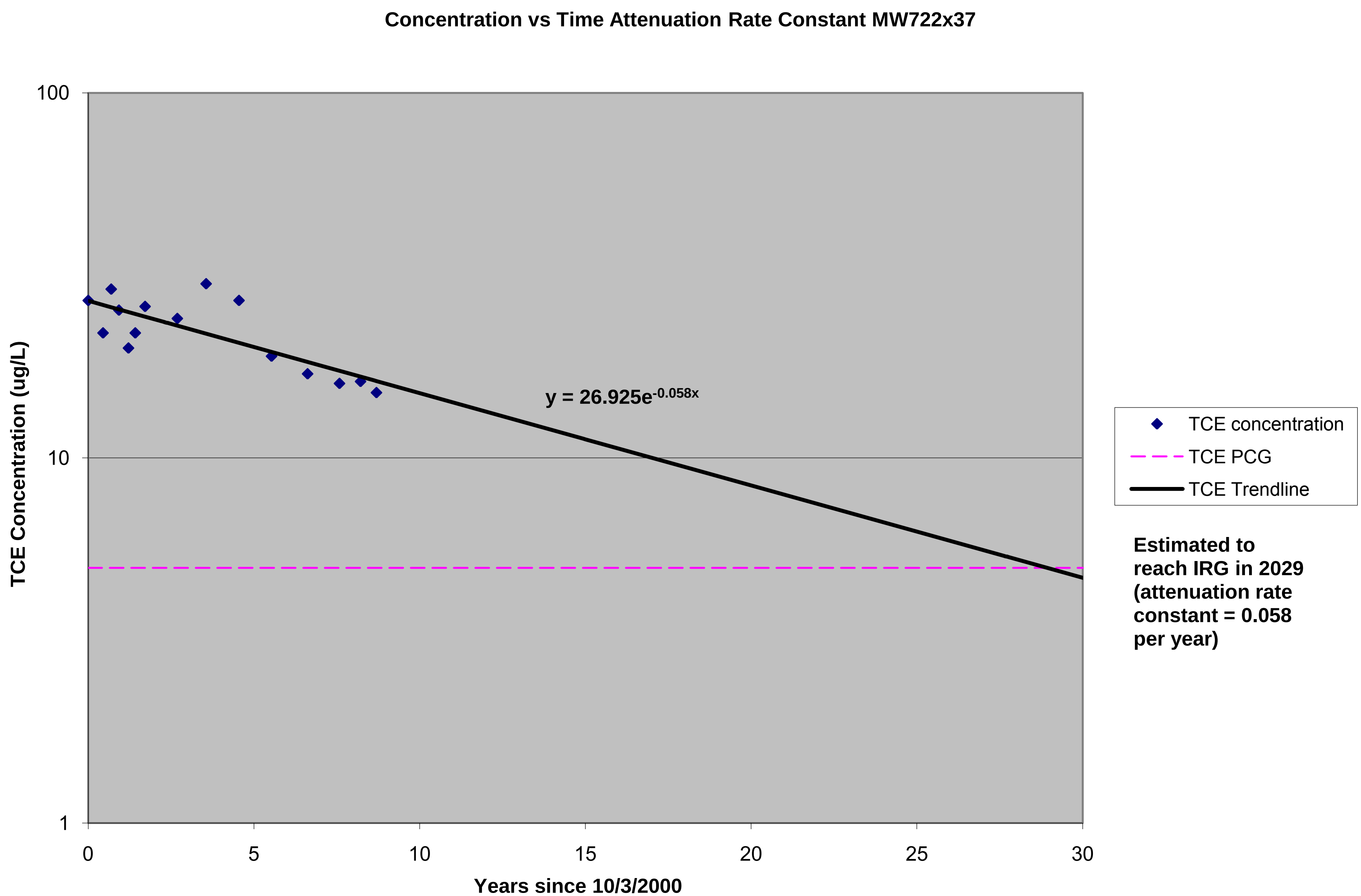


Concentration vs Time Attenuation Rate Constant MW261x07 (Benzene)
10
1
0.1
0
5
10
15
20
25
30
35
Years since 3/4/1999
Benzene Concentration (ug/L)
y = 2.7185e-0.0039x
Benzene Concentration
Benzene Preliminary Cleanup Goal (PCG)
Benzene Trendline
Estimated to reach PCG in 2255 (attenuation rate constant = 0.0039 per year)

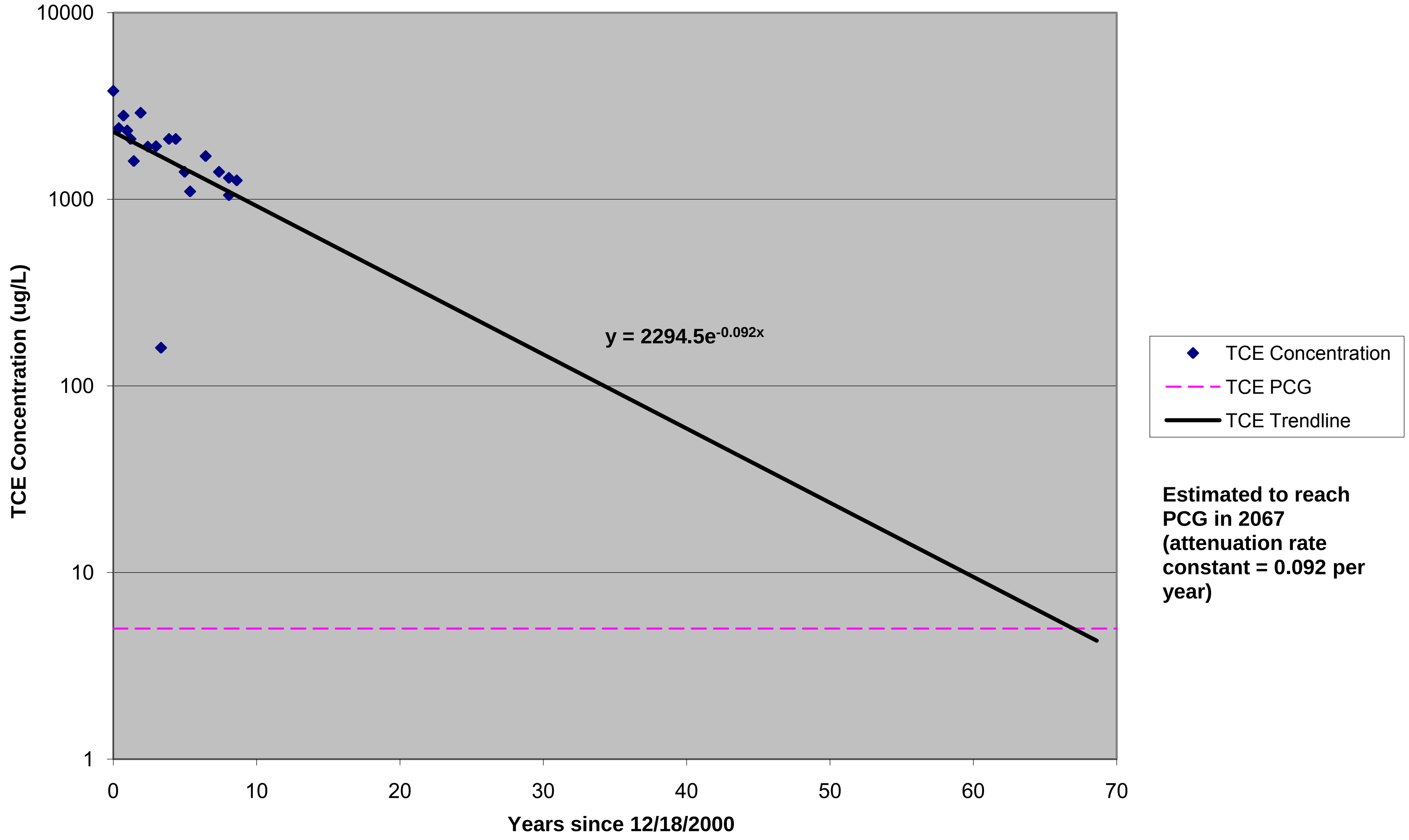
Concentration vs Time Attenuation Rate Constant MW574x31



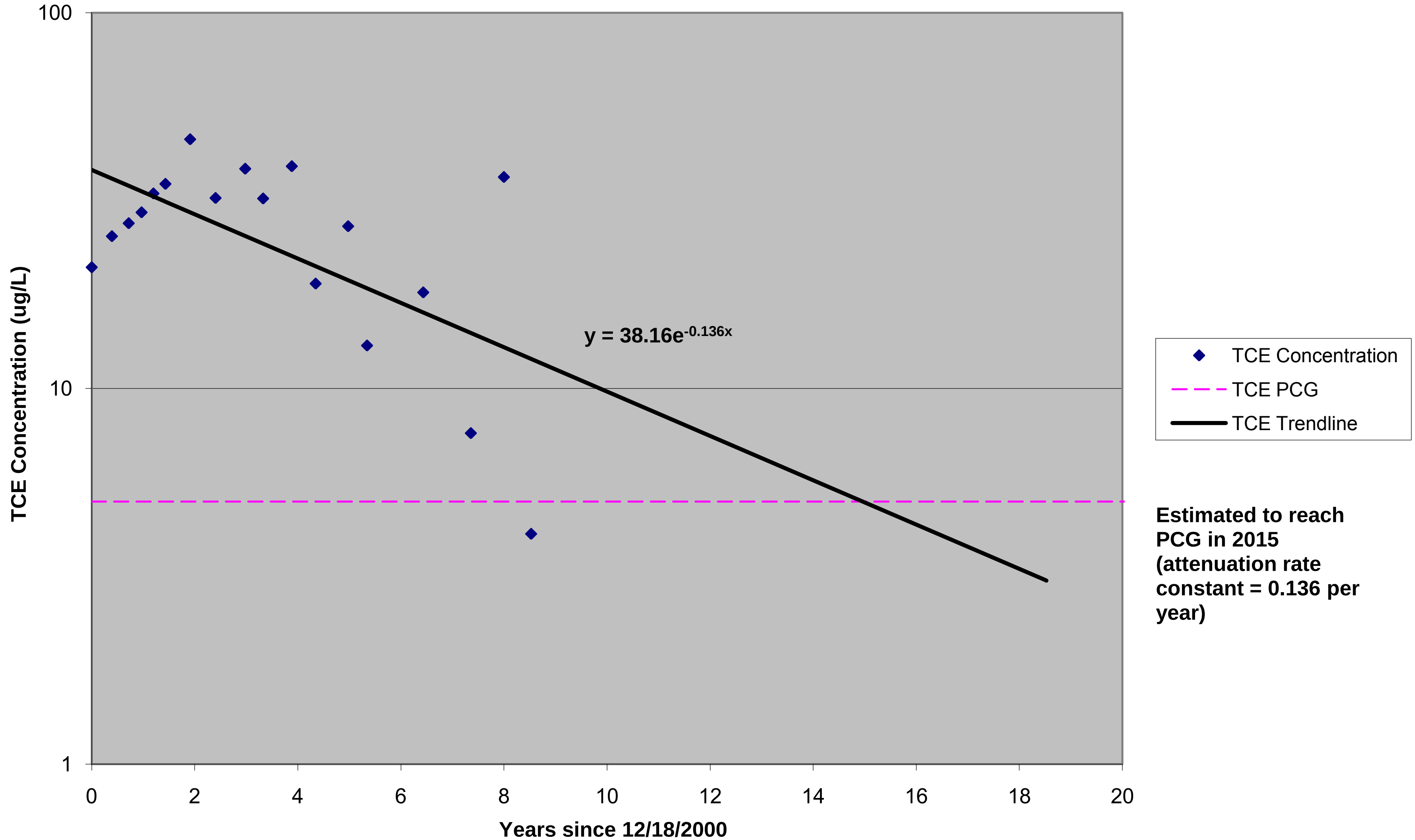

Concentration vs Time Attenuation Rate Constant MW590x04
TCE Concentration (ug/L)
1000
100
10
1
0
2
4
6
8
10
12
14
Years since 6/16/2000
y = 252.92e-0.575x
TCE Concentration
TCE PCG
TCE Trendline
Estimated to reach PCG in 2007 (attenuation rate constant = 0.575 per year)


Concentration vs Time Attenuation Rate Constant MW722x37
100
10
1
0
5
10
15
20
25
30
TCE Concentration (ug/L)
Years since 10/3/2000
y = 26.925e^-0.058x
TCE concentration
TCE PCG
TCE Trendline
Estimated to reach IRG in 2029 (attenuation rate constant = 0.058 per year)

Concentration vs Time Attenuation Rate Constant MW751x39

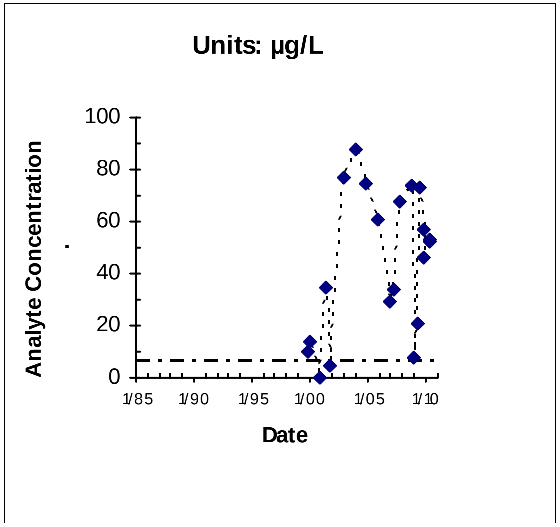


Concentration vs Time Attenuation Rate Constant MW759x39

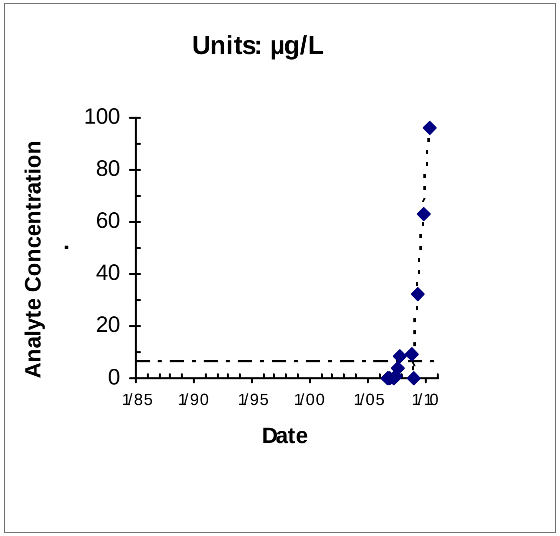


Attachment C2

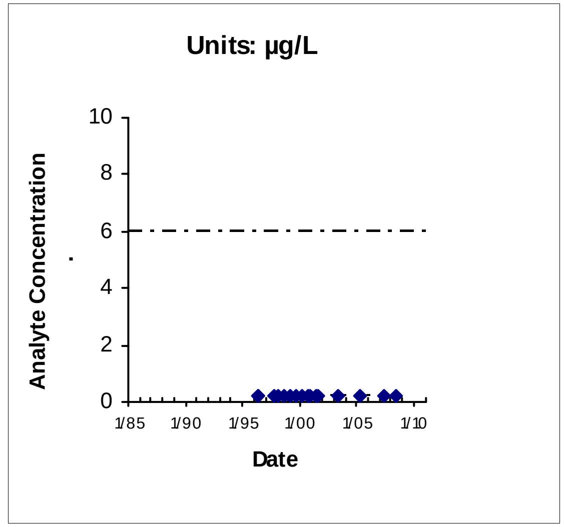
Attachment C2 contains chemical time-series plots excerpted from the final *Groundwater Sampling and Analysis Program 2009–2010 Annual Report,* Travis Air Force Base, California (CH2M HILL, 2011).



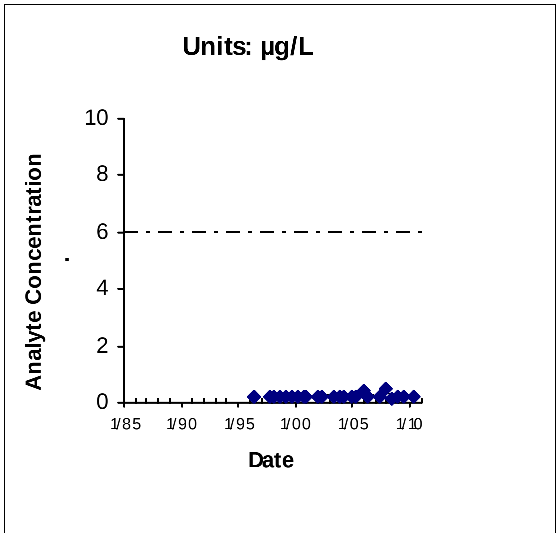
Location: EW563X39 Maximum: 87.8



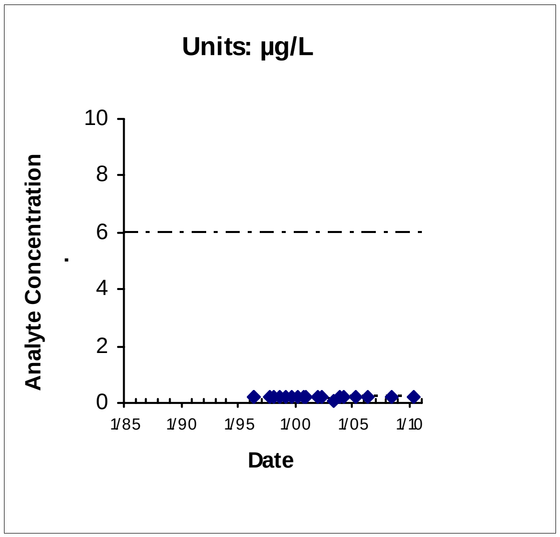
Location: EW782X39 Maximum: 96



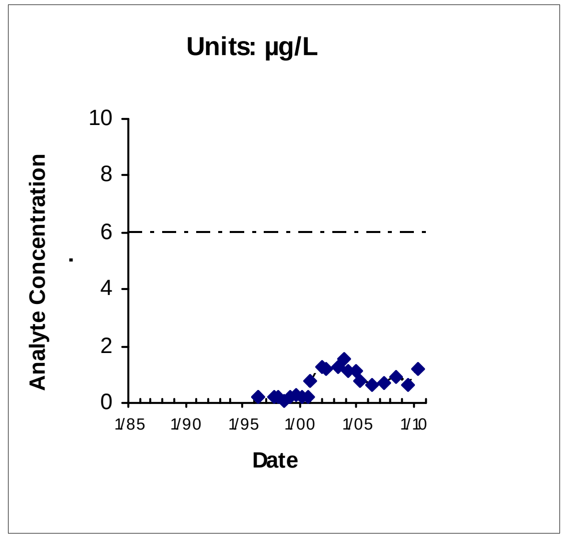
Location: MW01X39 Maximum: 0.23



Location: MW02X39 Maximum: 0.5



Location: MW03X39 Maximum: 0.23



Location: MW04X39 Maximum: 1.57

— - — - — IRG (6 µg/L)

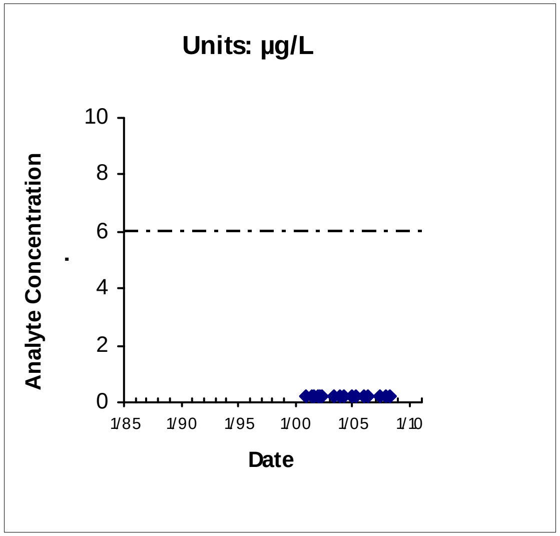
*Nondetects shown as the Method Detection Limit (0.23 µg/L)

FIGURE 4.8-6

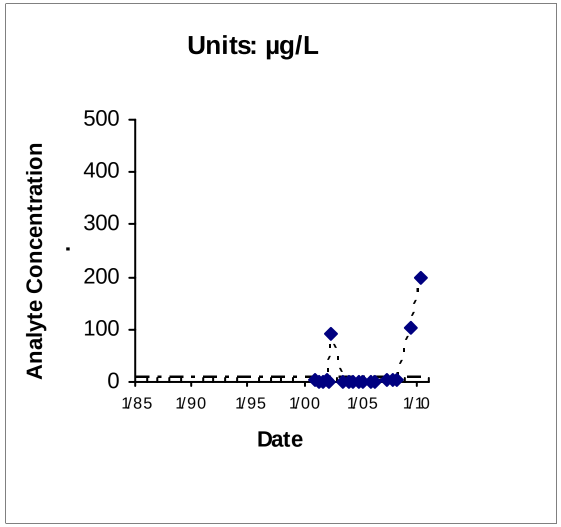
Site DP039

Cis-1,2-DCE

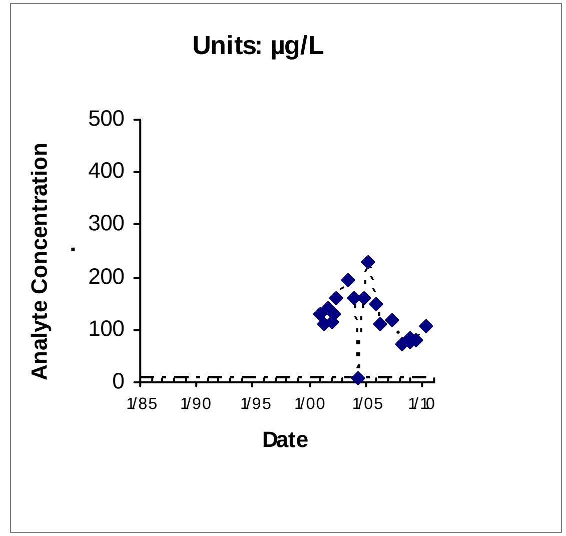
Chemical Time-series Plots



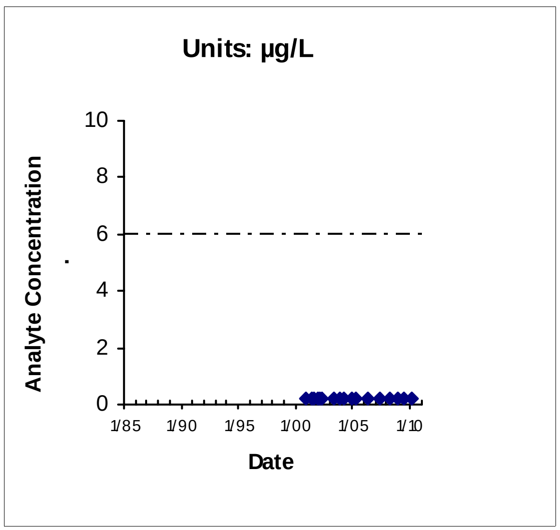
Location: MW749X39 Maximum: 0.23



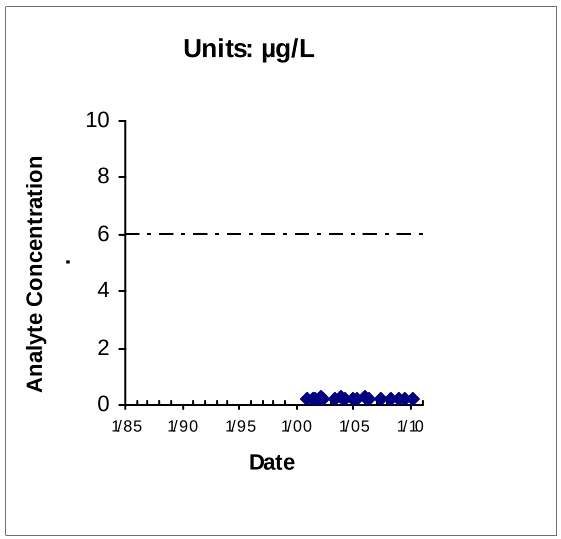
Location: MW750X39 Maximum: 198



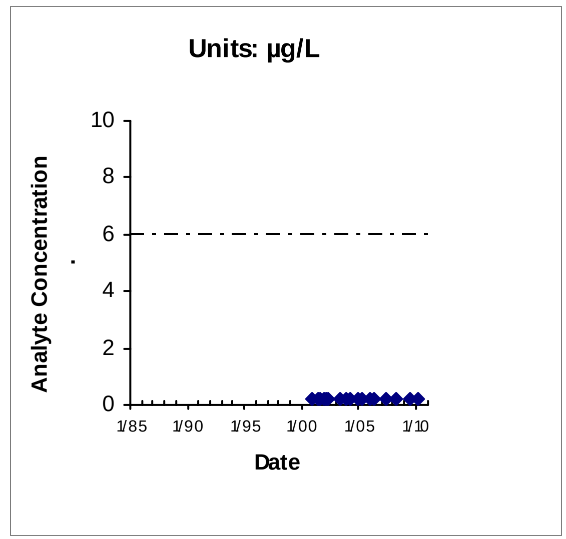
Location: MW751X39 Maximum: 230



Location: MW758X39 Maximum: 0.23



Location: MW759X39 Maximum: 0.31



Location: MW760X39 Maximum: 0.23

— - — - — IRG (6 µg/L)

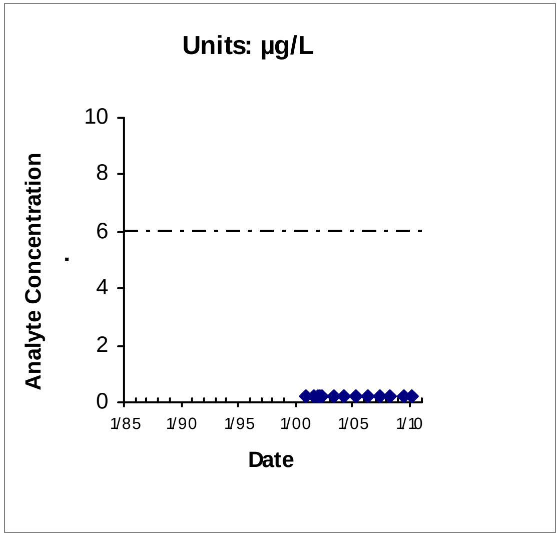
*Nondetects shown as the Method Detection Limit (0.23 µg/L)

FIGURE 4.8-6

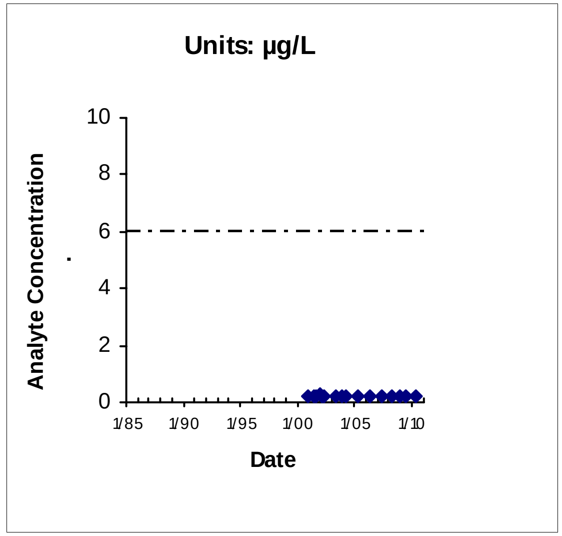
Site DP039

Cis-1,2-DCE

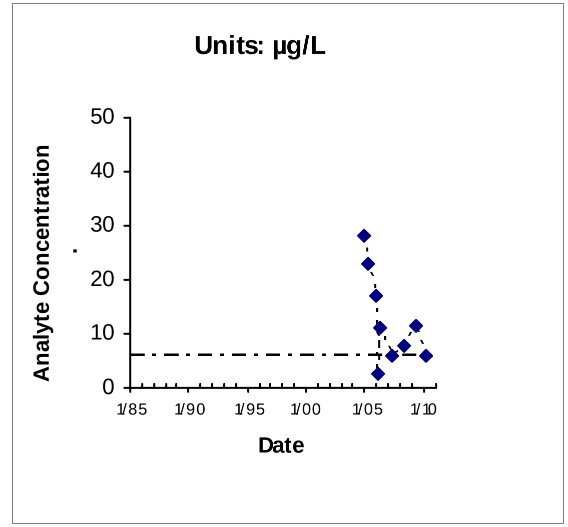
Chemical Time-series Plots



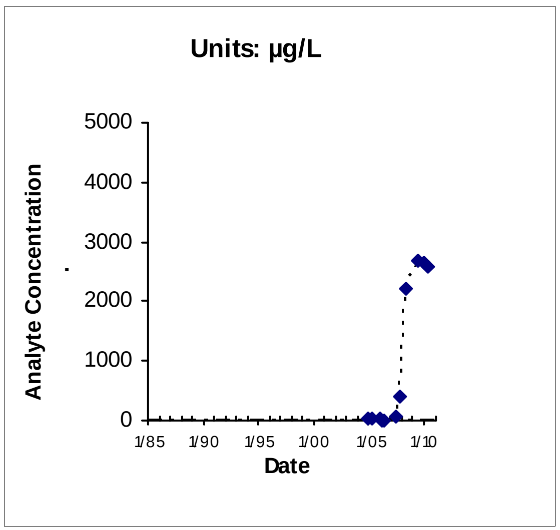
Location: MW761X39 Maximum: 0.23



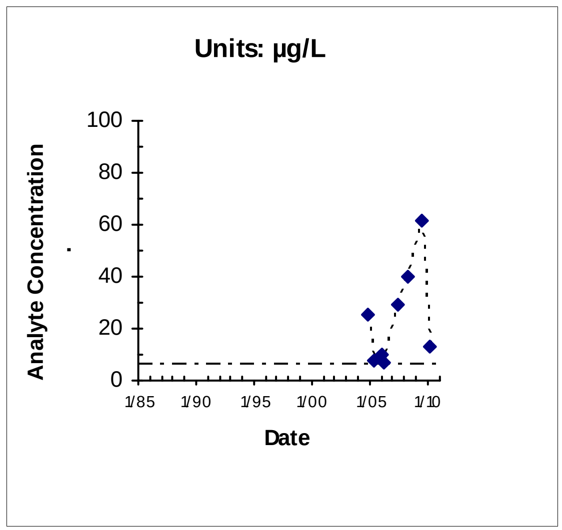
Location: MW762X39 Maximum: 0.3



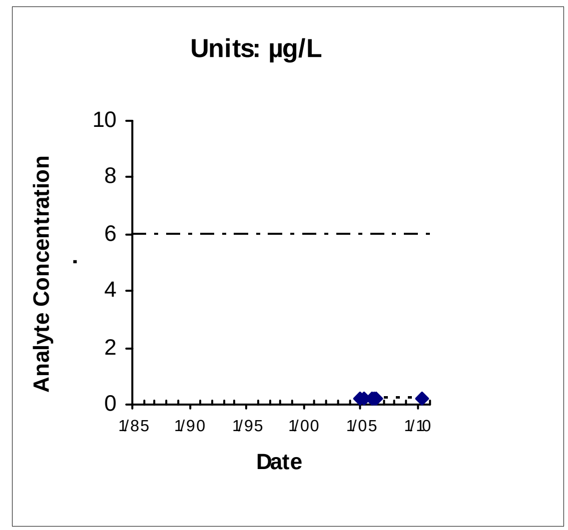
Location: MW777X39 Maximum: 28.3



Location: MW778X39 Maximum: 2690



Location: MW779X39 Maximum: 61.5



Location: MW780X39 Maximum: 0.23

— - — - — IRG (6 µg/L)

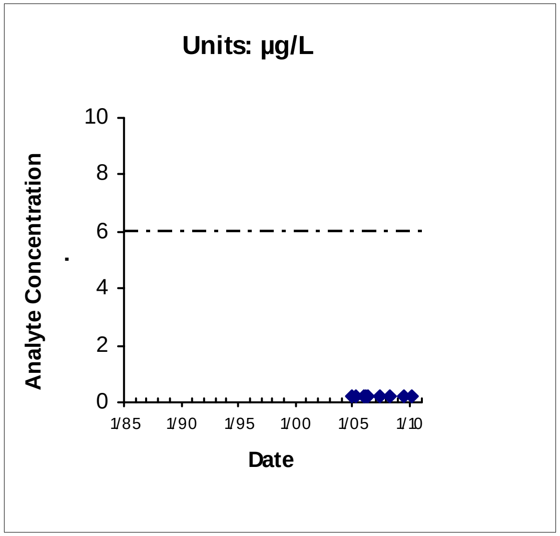
*Nondetects shown as the Method Detection Limit (0.23 µg/L)

FIGURE 4.8-6

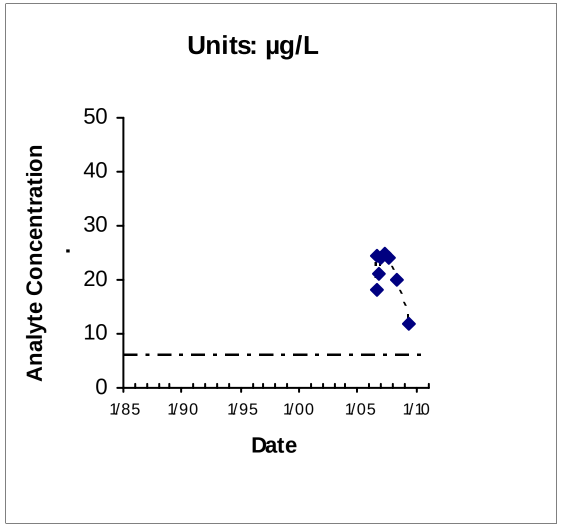
Site DP039

Cis-1,2-DCE

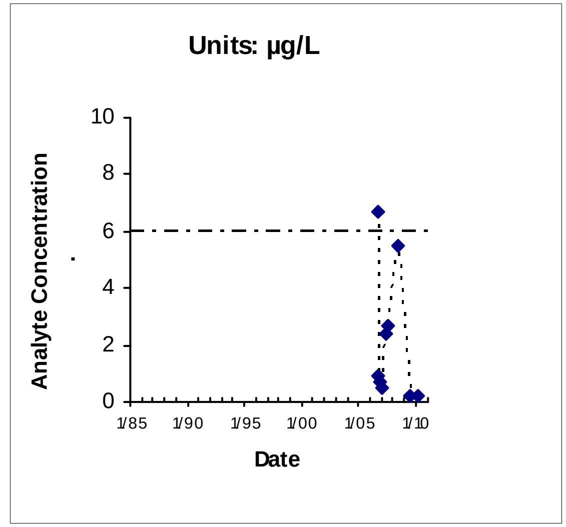
Chemical Time-series Plots



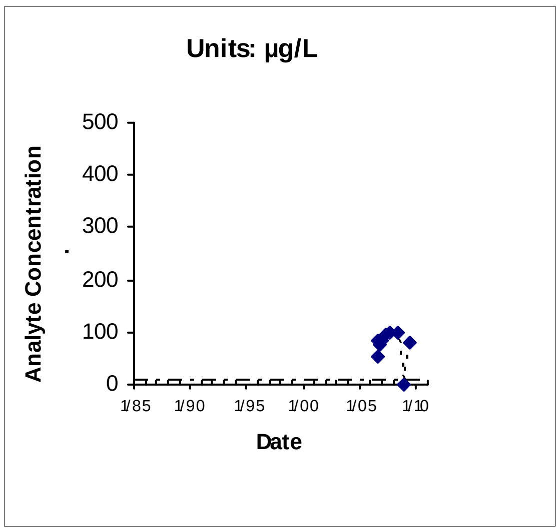
Location: MW781X39 Maximum: 0.24



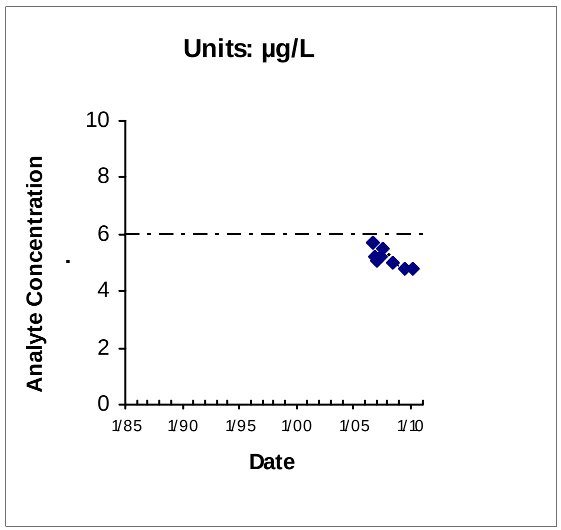
Location: MW783Sx39 Maximum: 25



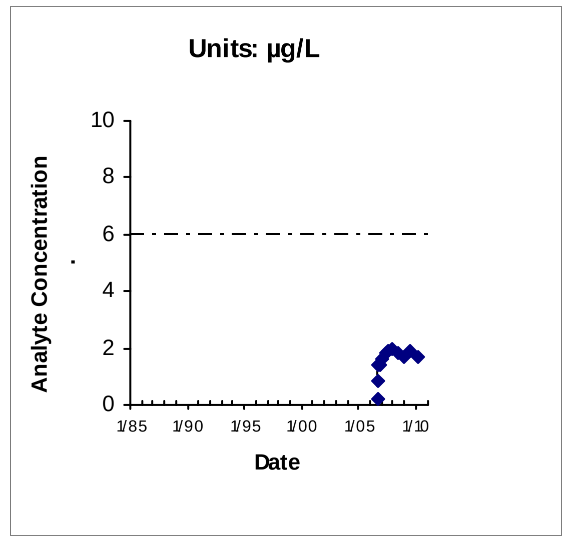
Location: MW783Dx39 Maximum: 6.71



Location: MW784Sx39 Maximum: 100



Location: MW784Dx39 Maximum: 5.73



Location: MW785X39 Maximum: 2

— - — - — IRG (6 µg/L)

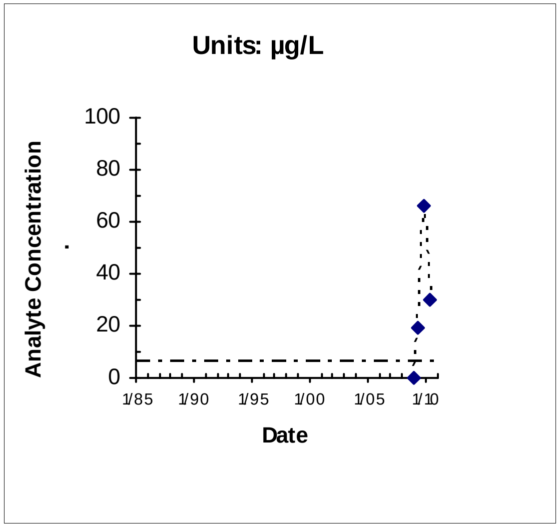
*Nondetects shown as the Method Detection Limit (0.23 µg/L)

FIGURE 4.8-6

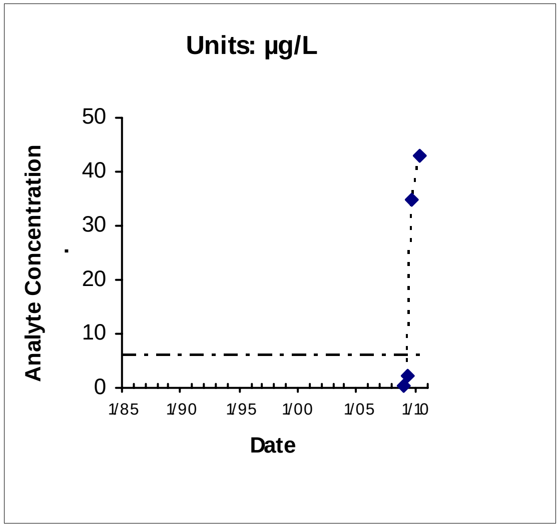
Site DP039

Cis-1,2-DCE

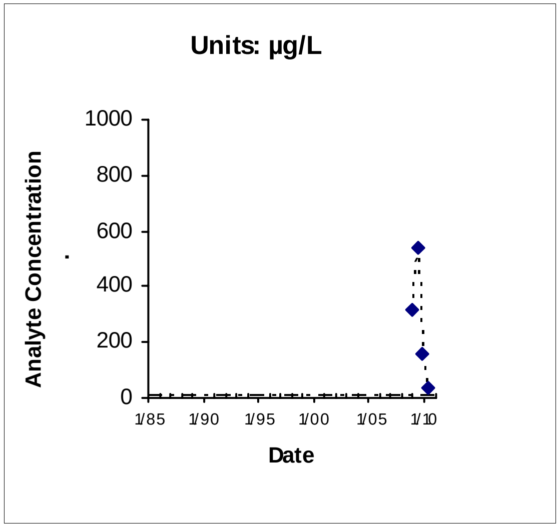
Chemical Time-series Plots



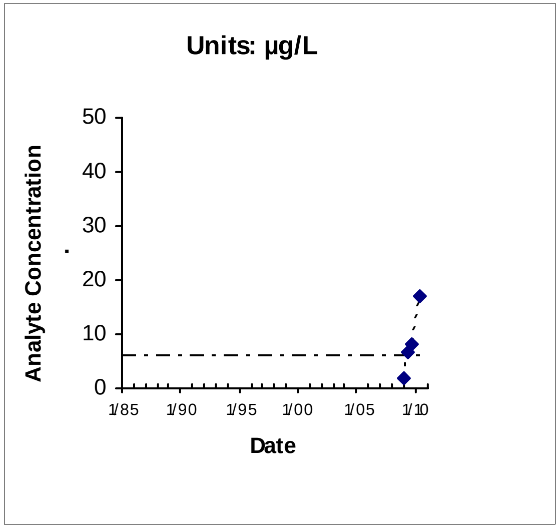
Location: MW787X39 Maximum: 66



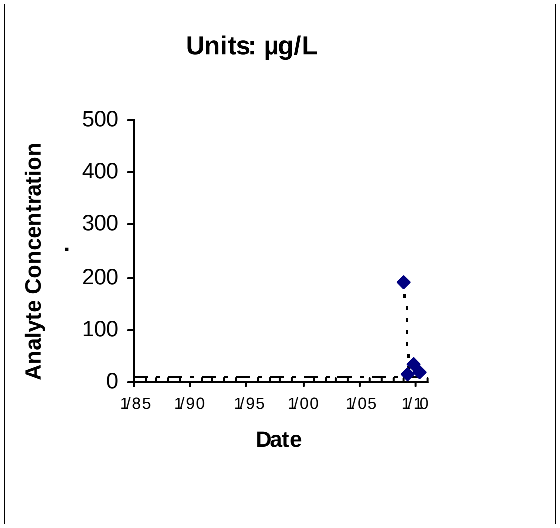
Location: MW788X39 Maximum: 43



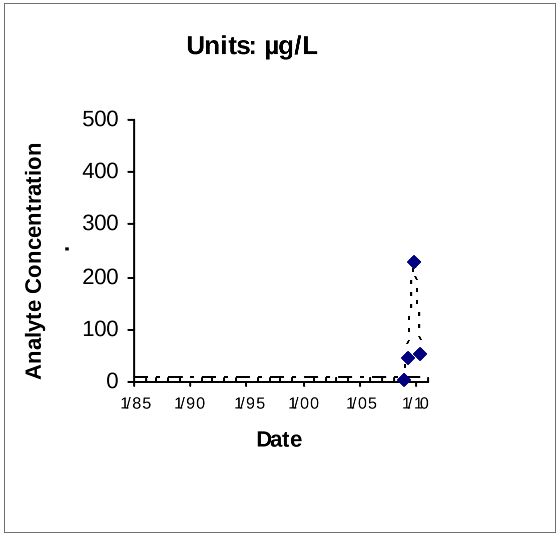
Location: MW791X39 Maximum: 540



Location: MW792X39 Maximum: 17



Location: MW793X39 Maximum: 190



Location: MW794X39 Maximum: 230

— - — - — IRG (6 µg/L)

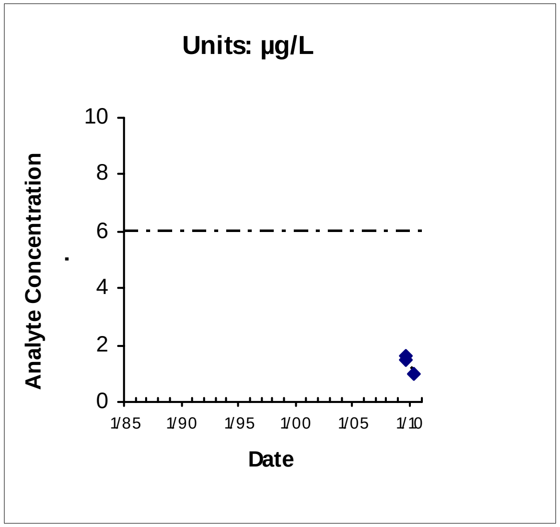
*Nondetects shown as the Method Detection Limit (0.23 µg/L)

FIGURE 4.8-6

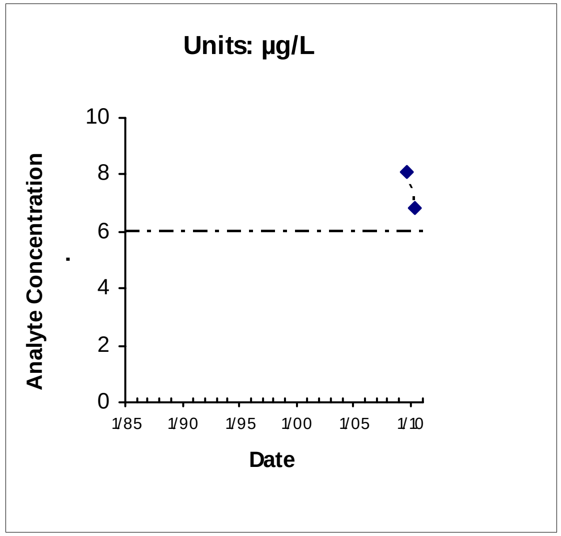
Site DP039

Cis-1,2-DCE

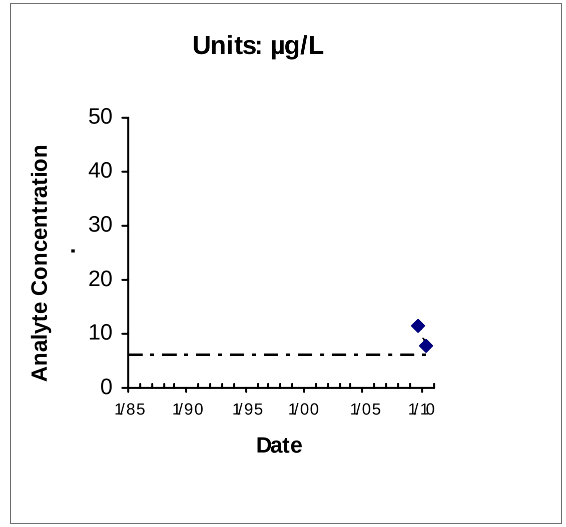
Chemical Time-series Plots



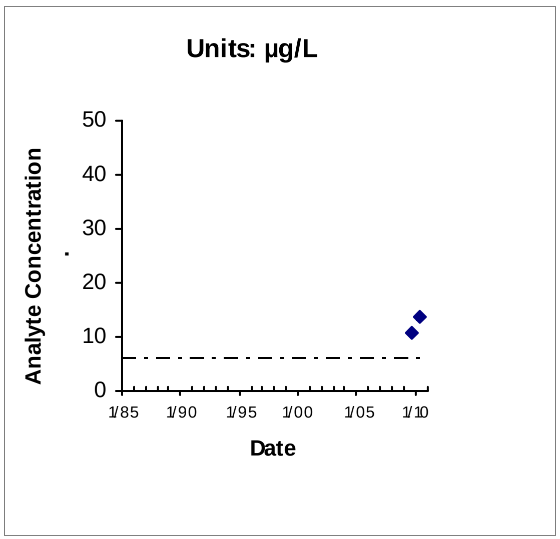
Location: MW2041Ax39 Maximum: 1.6



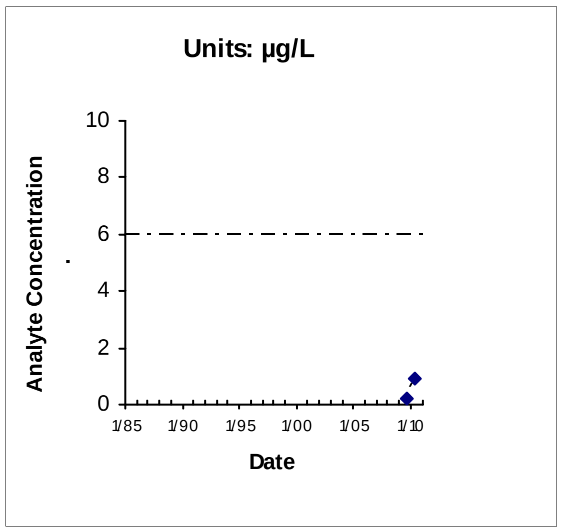
Location: MW2041Bx39 Maximum: 8.1



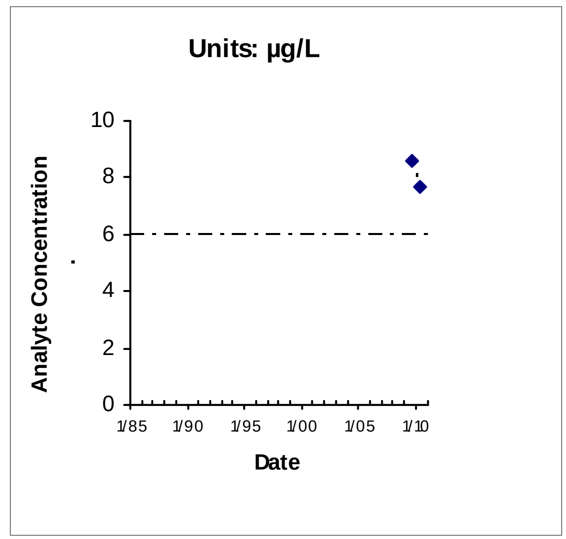
Location: MW2042Ax39 Maximum: 11.5



Location: MW2042Bx39 Maximum: 13.8



Location: MW2043Ax39 Maximum: 0.95



Location: MW2043Bx39 Maximum: 8.6

FIGURE 4.8-6

Site DP039

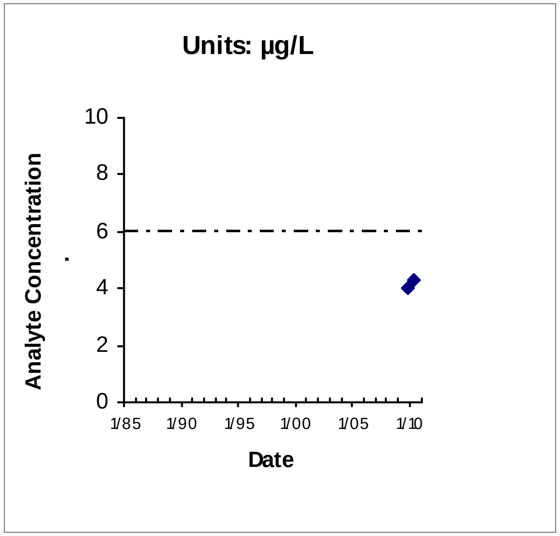
Cis-1,2-DCE

Chemical Time-series Plots

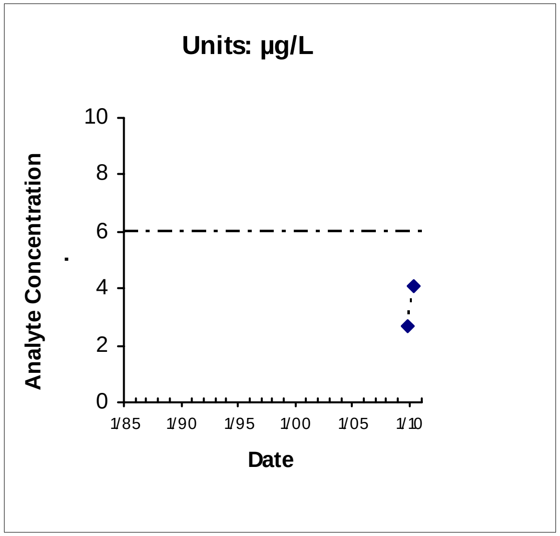
Page 6 of 7

— - — - — IRG (6 µg/L)

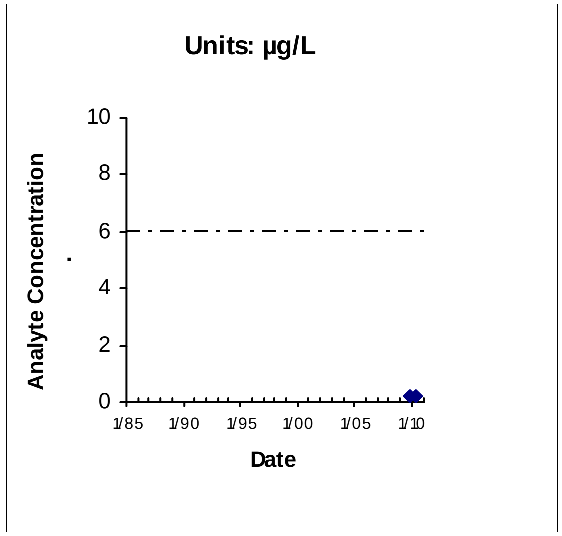
*Nondetects shown as the Method Detection Limit (0.23 µg/L)



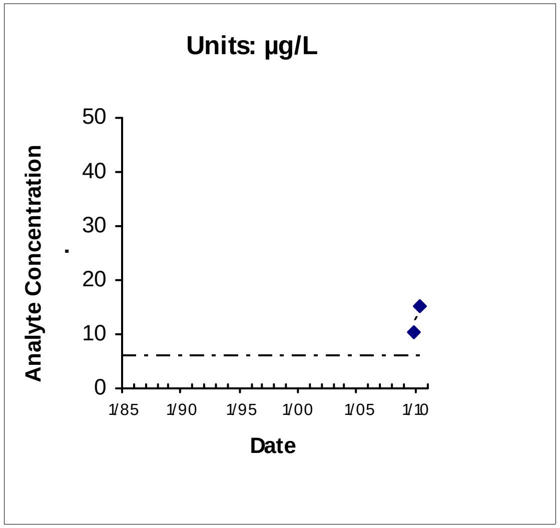
Location: MW2056Ax39 Maximum: 4.3



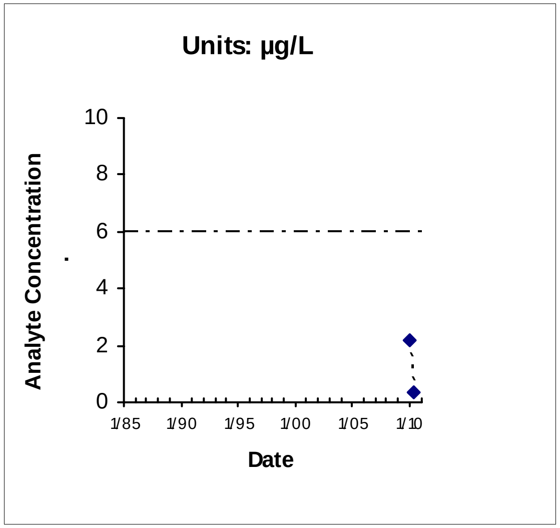
Location: MW2056Bx39 Maximum: 4.1



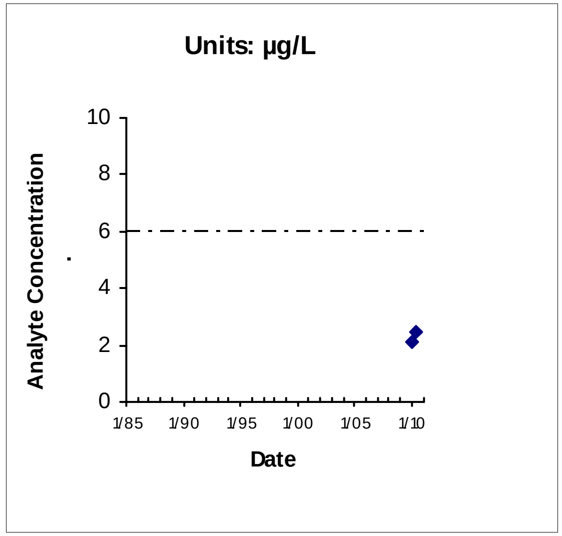
Location: MW2057Ax39 Maximum: 0.23



Location: MW2057Bx39 Maximum: 15.3



Location: MW2060Ax39 Maximum: 2.2



Location: MW2060Bx39 Maximum: 2.5

FIGURE 4.8-6

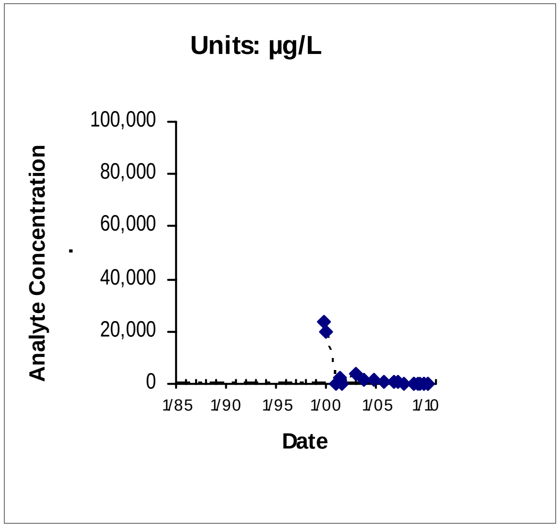
Site DP039

Cis-1,2-DCE

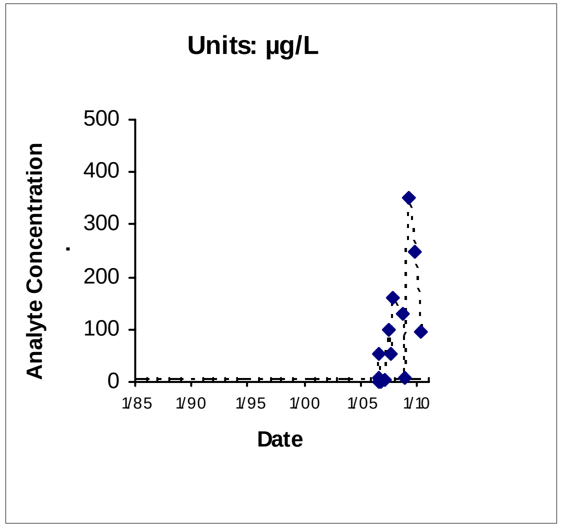
Chemical Time-series Plots

— - - — - - — IRG (6 µg/L)

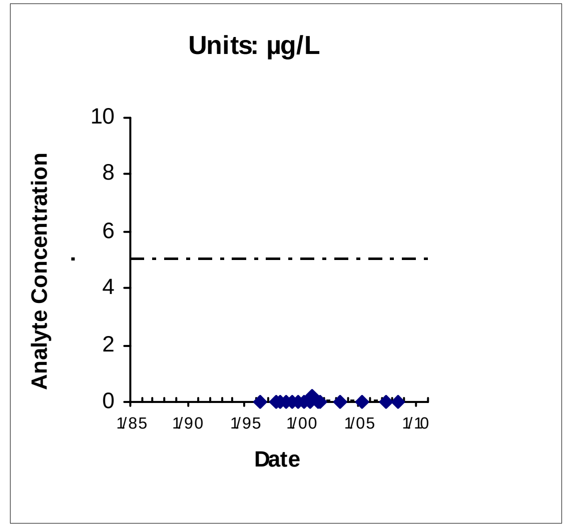
*Nondetects shown as the Method Detection Limit (0.23 µg/L)



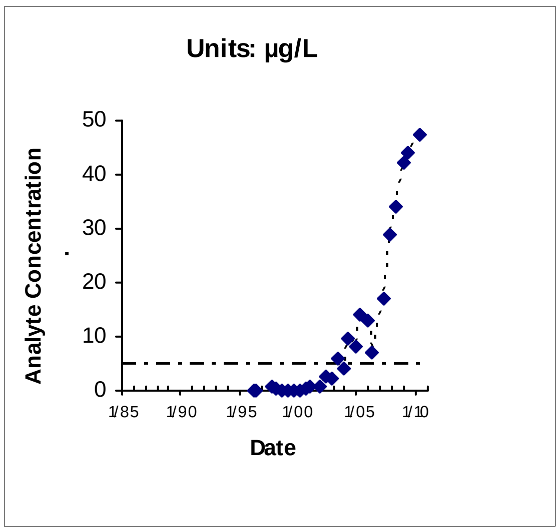
Location: EW563X39 Maximum: 24000



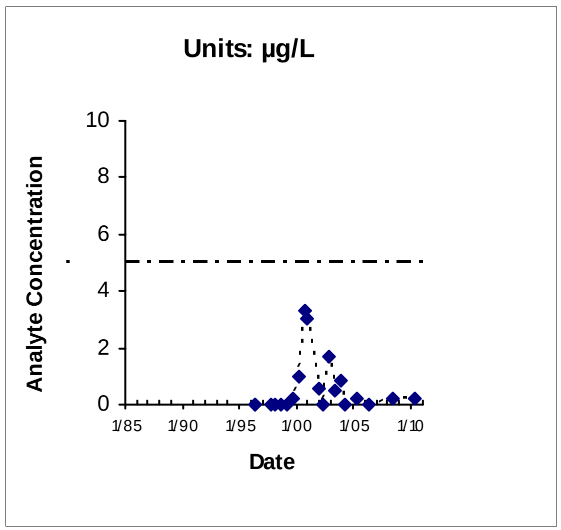
Location: EW782X39 Maximum: 350



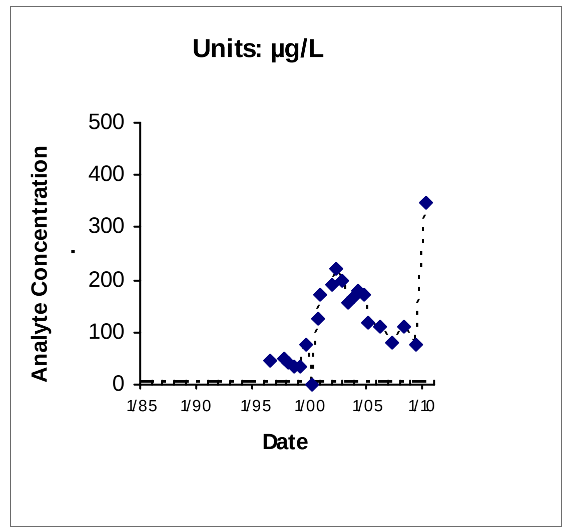
Location: MW01X39 Maximum: 0.2



Location: MW02X39 Maximum: 47.5



Location: MW03X39 Maximum: 3.3



Location: MW04X39 Maximum: 348

FIGURE 4.8-5

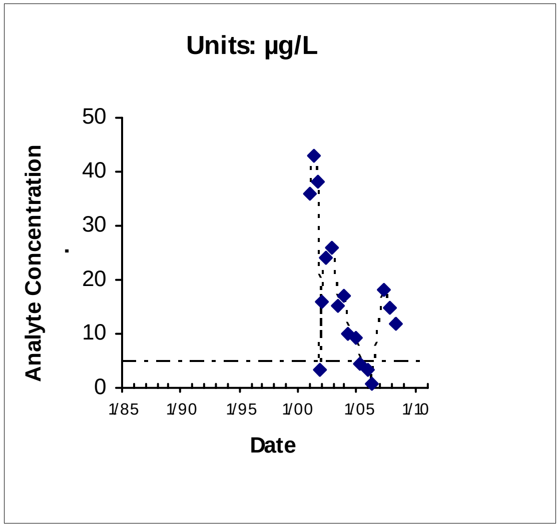
Site DP039

TCE

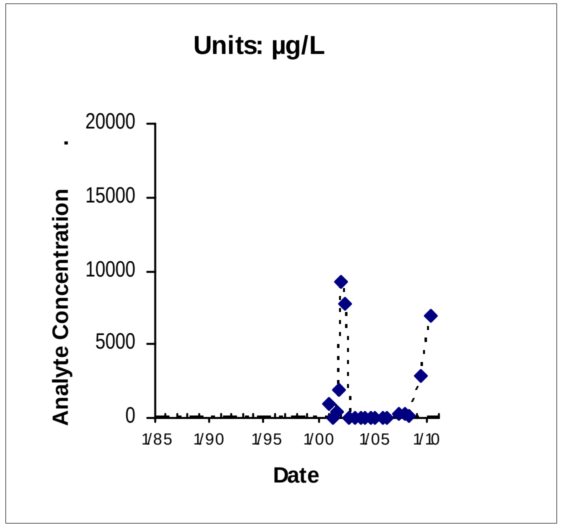
Chemical Time-series Plots

— - — - — IRG (5 µg/L)

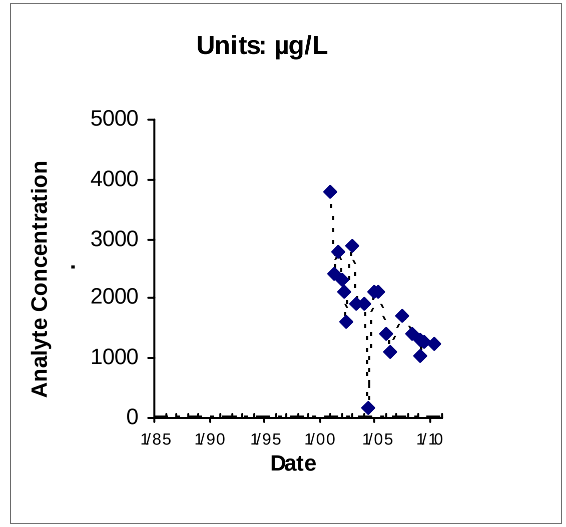
*Nondetects shown as the Method Detection Limit (0.03 µg/L)



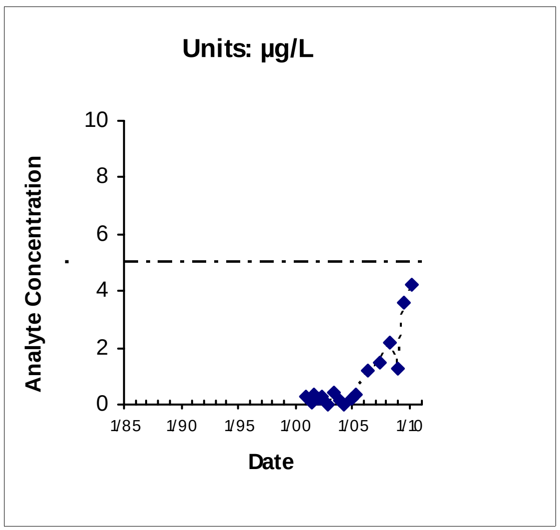
Location: MW749X39 Maximum: 43.1



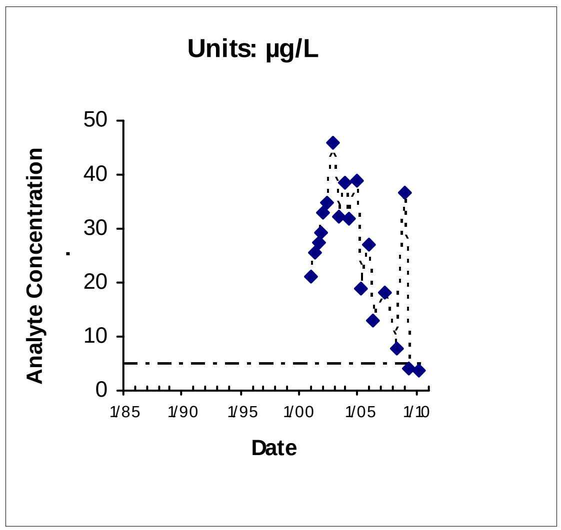
Location: MW750X39 Maximum: 9300



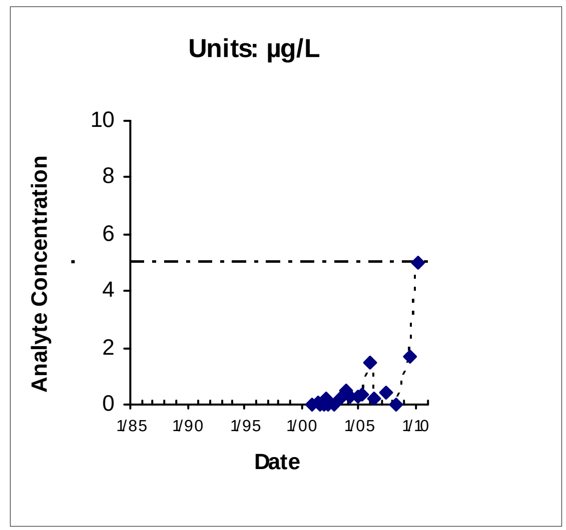
Location: MW751X39 Maximum: 3800



Location: MW758X39 Maximum: 4.2



Location: MW759X39 Maximum: 46



Location: MW760X39 Maximum: 5

— - — - — IRG (5 µg/L)

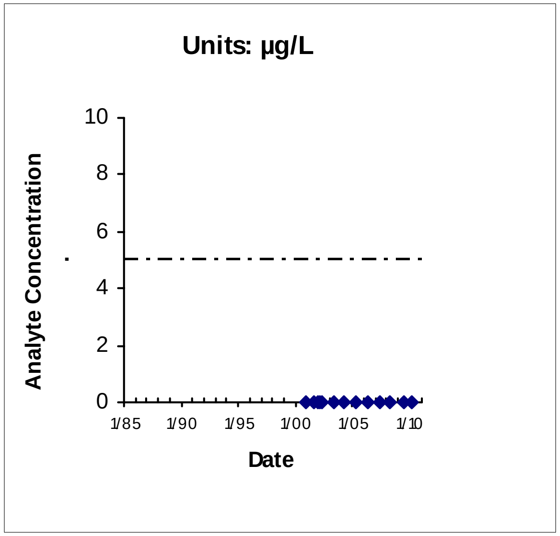
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.8-5

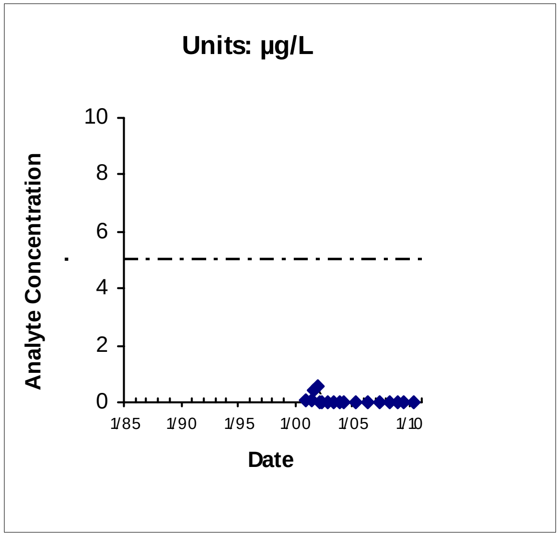
Site DP039

TCE

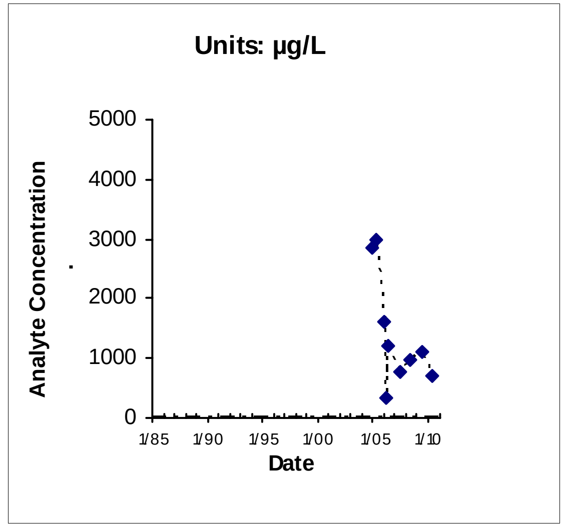
Chemical Time-series Plots



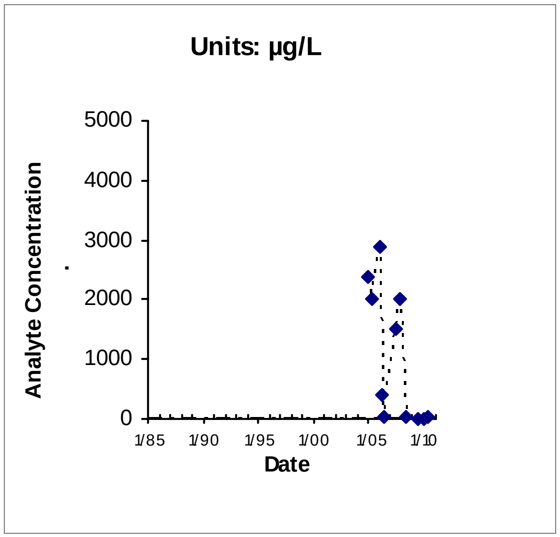
Location: MW761X39 Maximum: 0.03



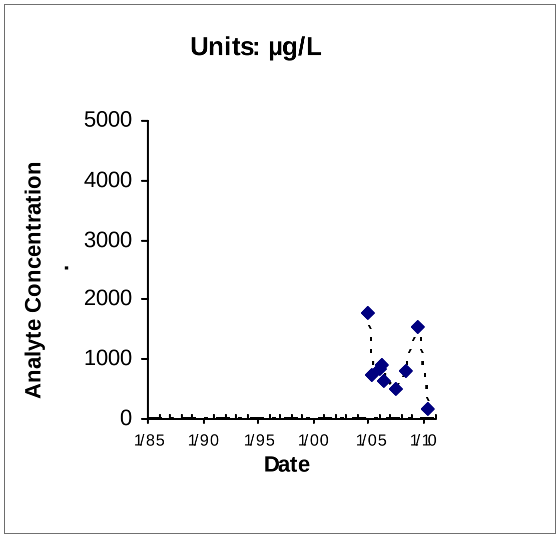
Location: MW762X39 Maximum: 0.54



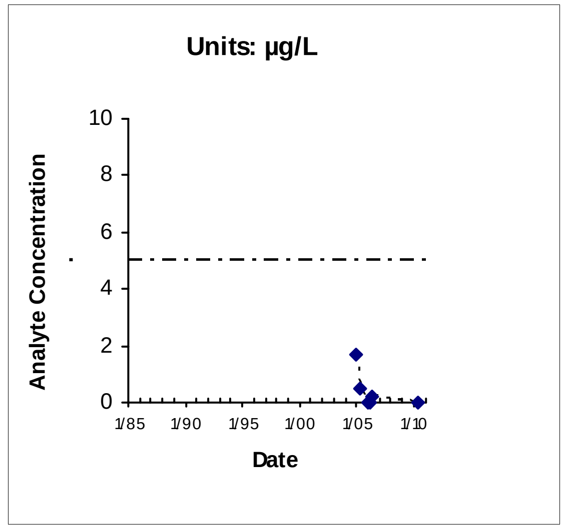
Location: MW777X39 Maximum: 3000



Location: MW778X39 Maximum: 2900



Location: MW779X39 Maximum: 1770



Location: MW780X39 Maximum: 1.67

— - — - — IRG (5 µg/L)

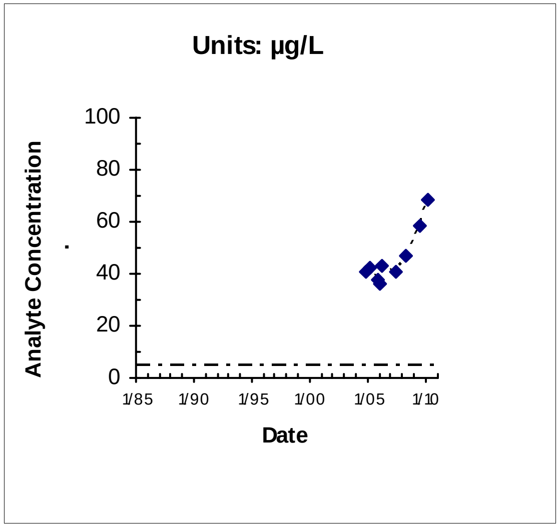
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.8-5

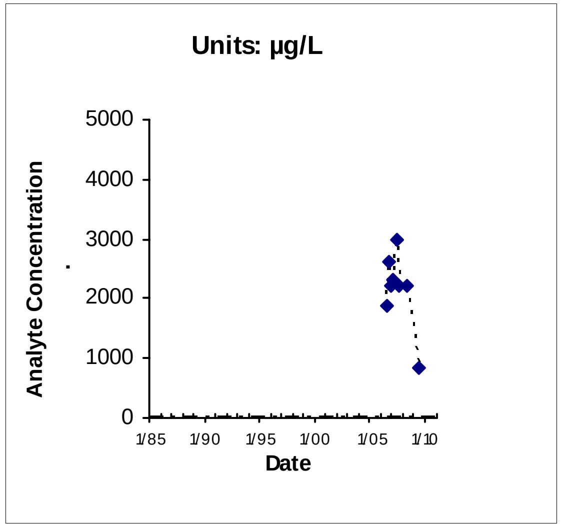
Site DP039

TCE

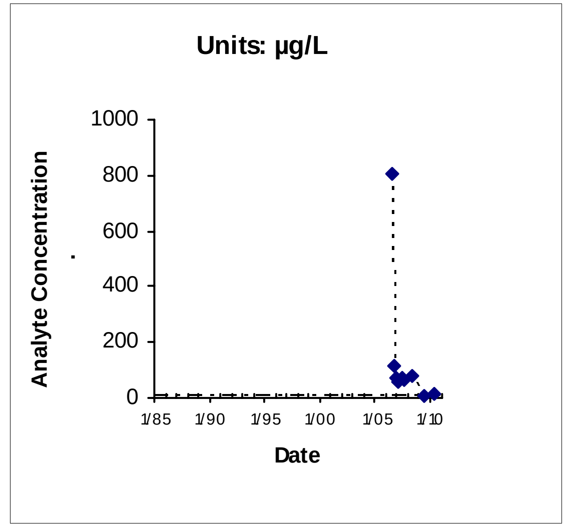
Chemical Time-series Plots



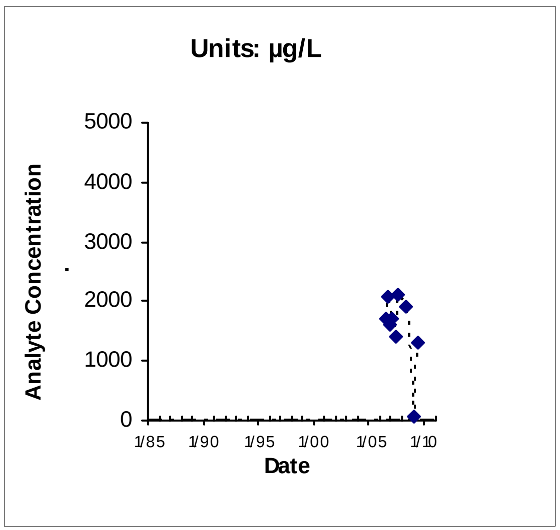
Location: MW781X39 Maximum: 68.5



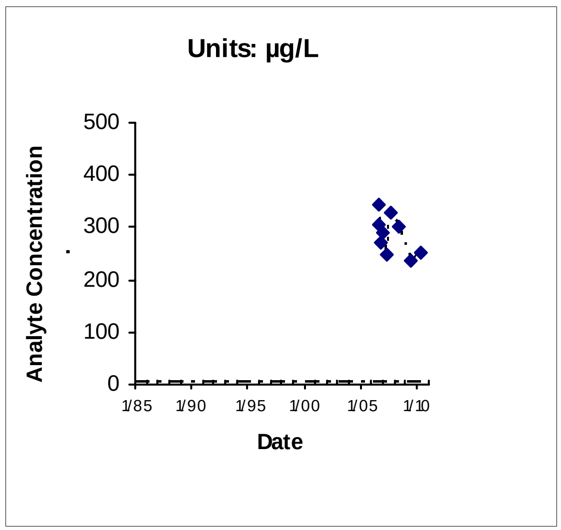
Location: MW783Sx39 Maximum: 3000



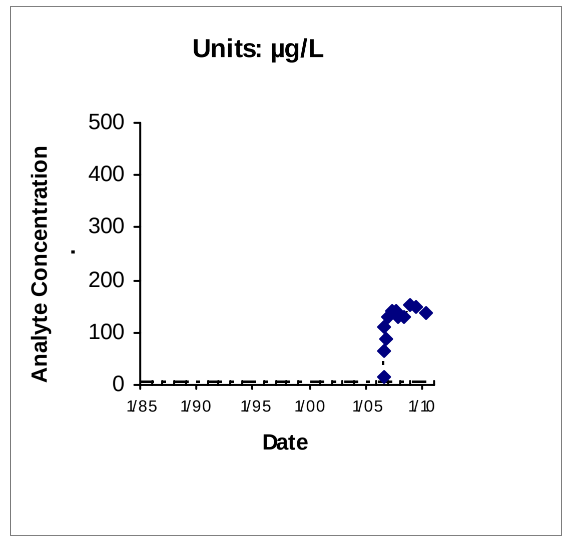
Location: MW783Dx39 Maximum: 807



Location: MW784Sx39 Maximum: 2100



Location: MW784Dx39 Maximum: 344



Location: MW785X39 Maximum: 151

— - — - — IRG (5 µg/L)

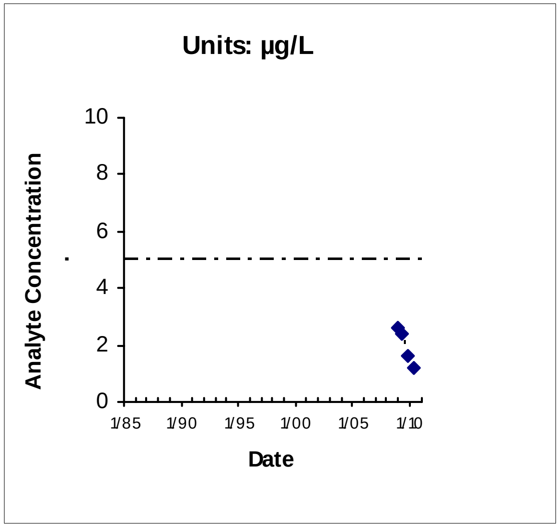
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.8-5

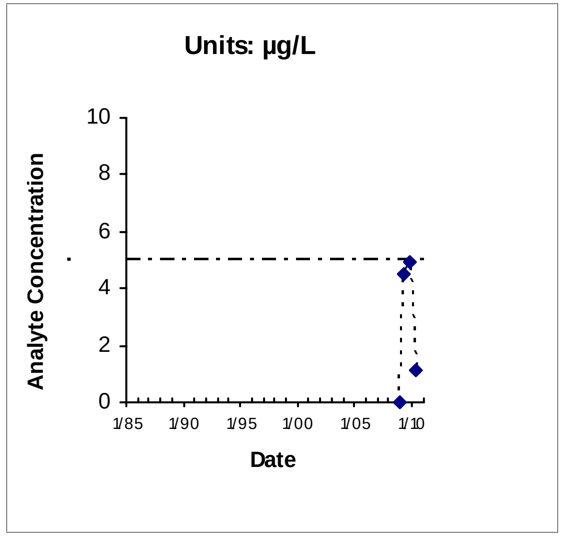
Site DP039

TCE

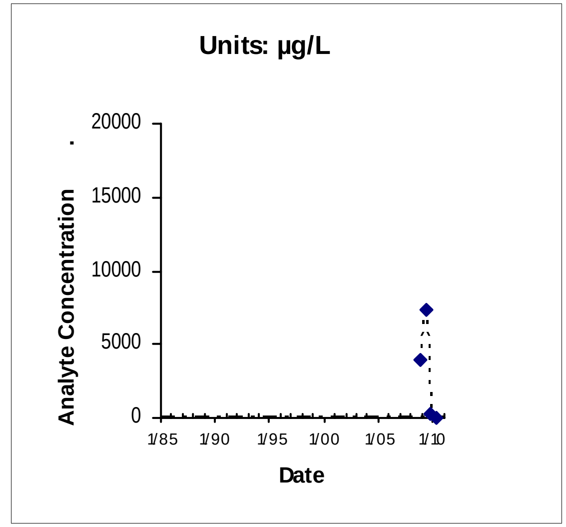
Chemical Time-series Plots



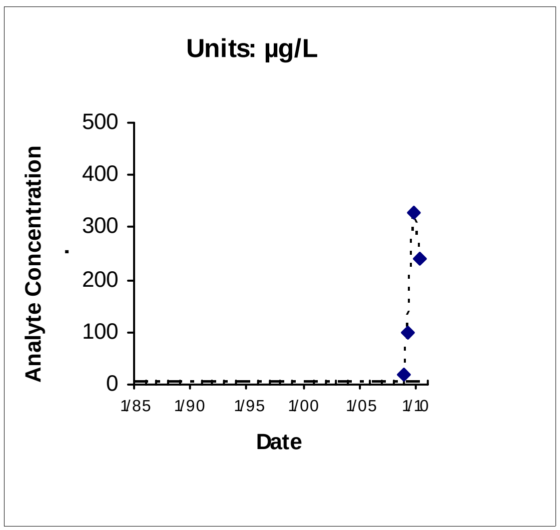
Location: MW787X39 Maximum: 2.6



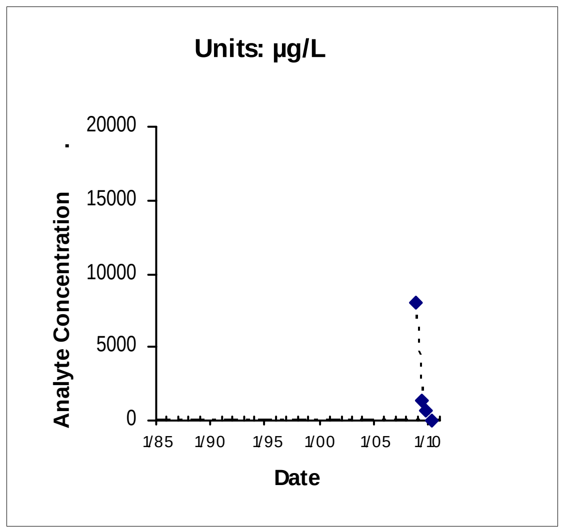
Location: MW788X39 Maximum: 4.9



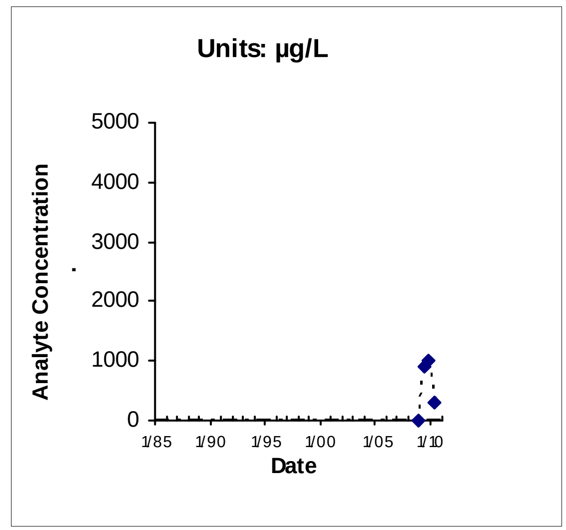
Location: MW791X39 Maximum: 7400



Location: MW792X39 Maximum: 330



Location: MW793X39 Maximum: 8000



Location: MW794X39 Maximum: 1000

— - — - — IRG (5 µg/L)

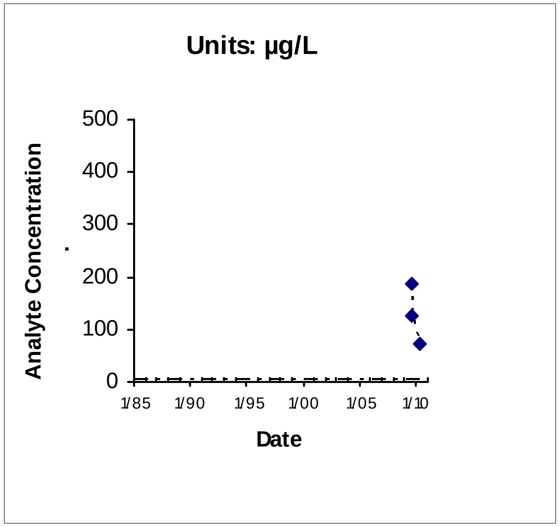
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.8-5

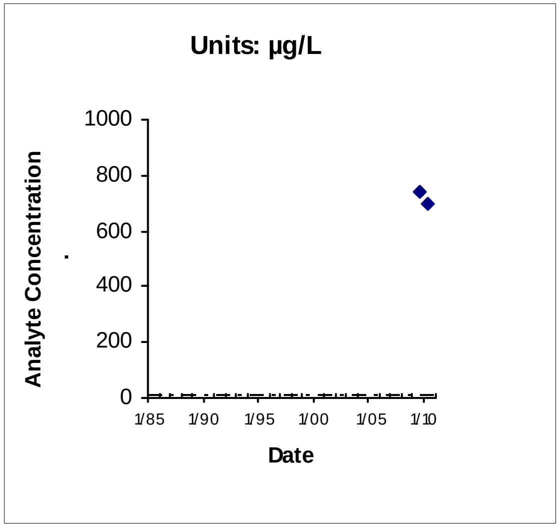
Site DP039

TCE

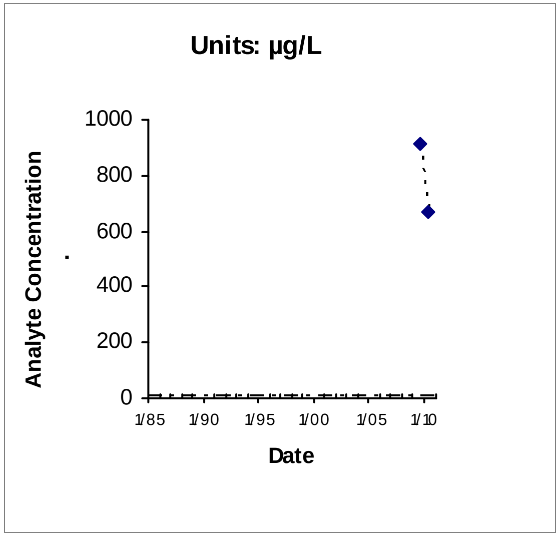
Chemical Time-series Plots



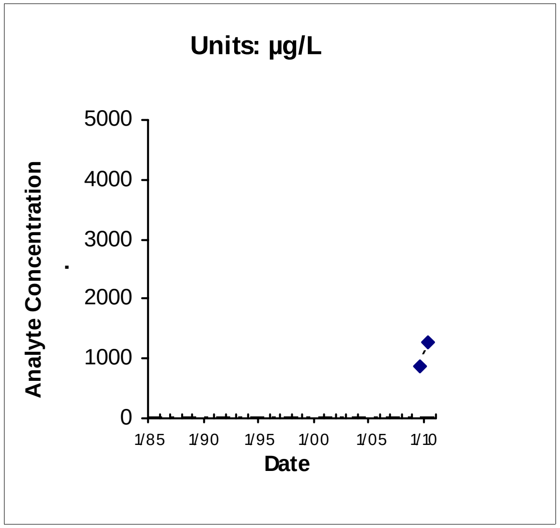
Location: MW2041Ax39 Maximum: 186



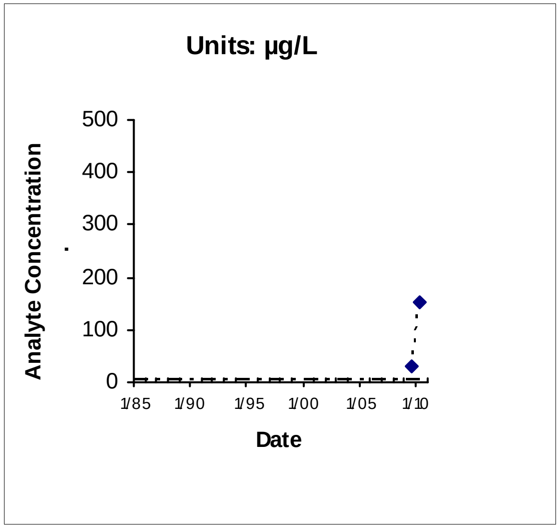
Location: MW2041Bx39 Maximum: 743



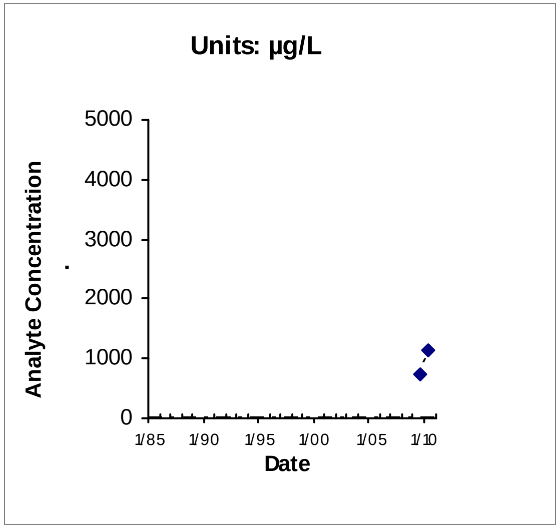
Location: MW2042Ax39 Maximum: 913



Location: MW2042Bx39 Maximum: 1260



Location: MW2043Ax39 Maximum: 151



Location: MW2043Bx39 Maximum: 1150

— - — - — IRG (5 µg/L)

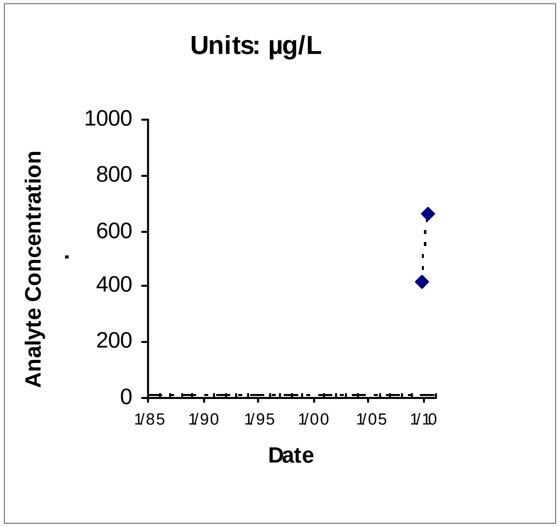
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.8-5

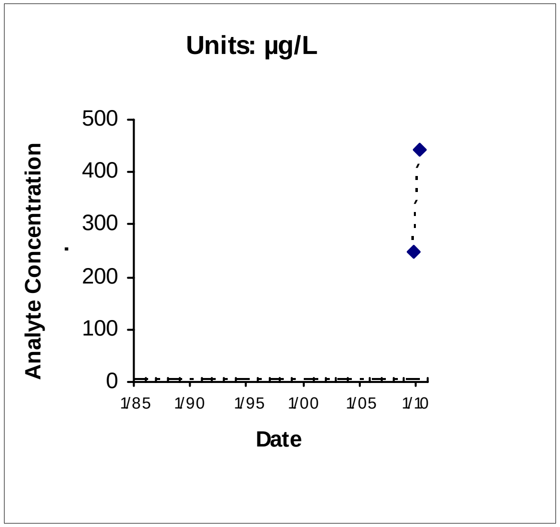
Site DP039

TCE

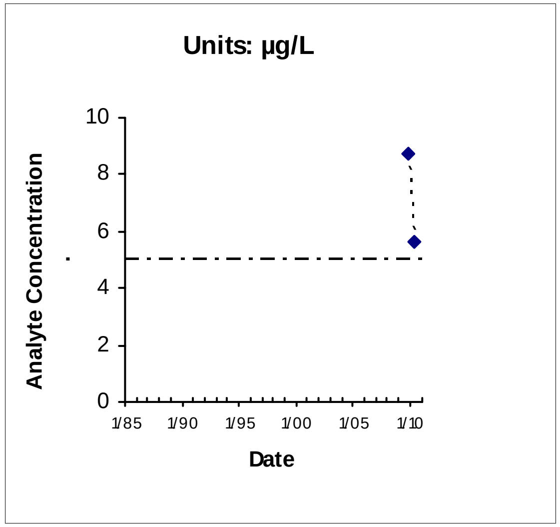
Chemical Time-series Plots



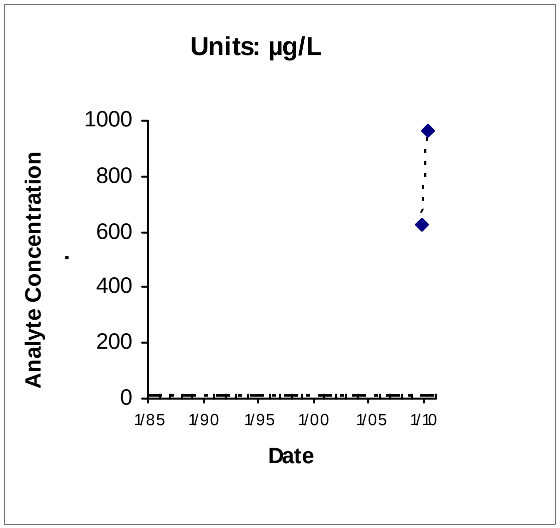
Location: MW2056Ax39 Maximum: 664



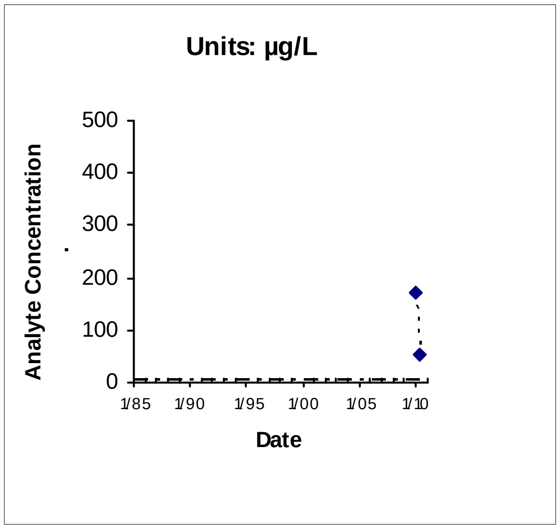
Location: MW2056Bx39 Maximum: 442



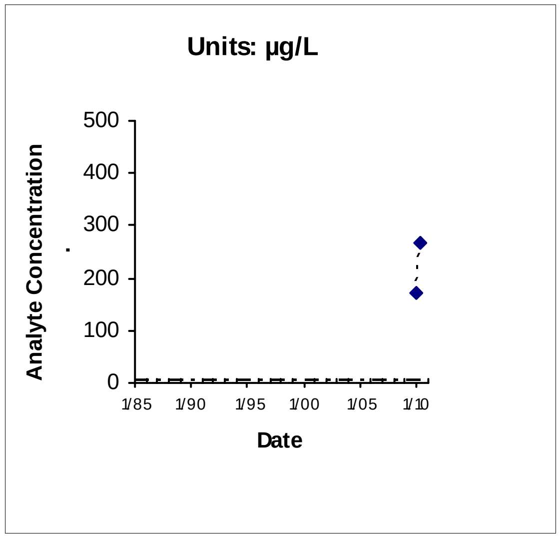
Location: MW2057Ax39 Maximum: 8.7



Location: MW2057Bx39 Maximum: 965



Location: MW2060Ax39 Maximum: 173



Location: MW2060Bx39 Maximum: 268

FIGURE 4.8-5

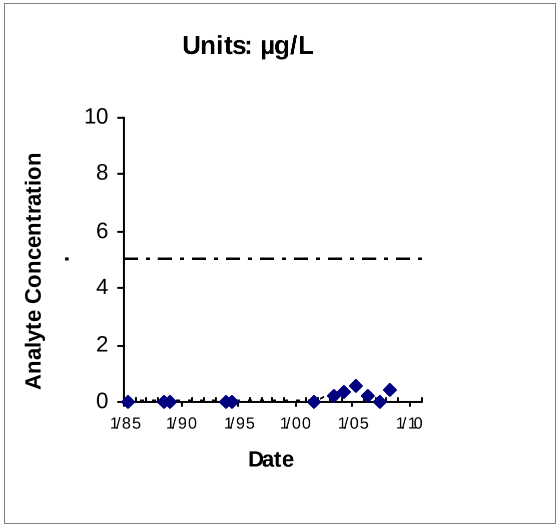
Site DP039

TCE

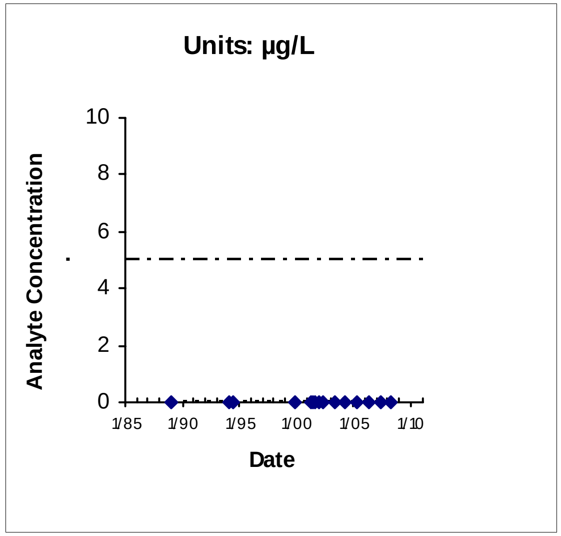
Chemical Time-series Plots

— - — - — IRG (5 µg/L)

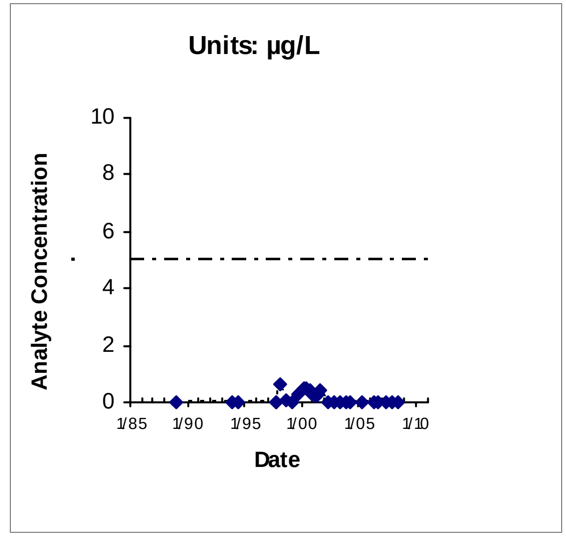
*Nondetects shown as the Method Detection Limit (0.03 µg/L)



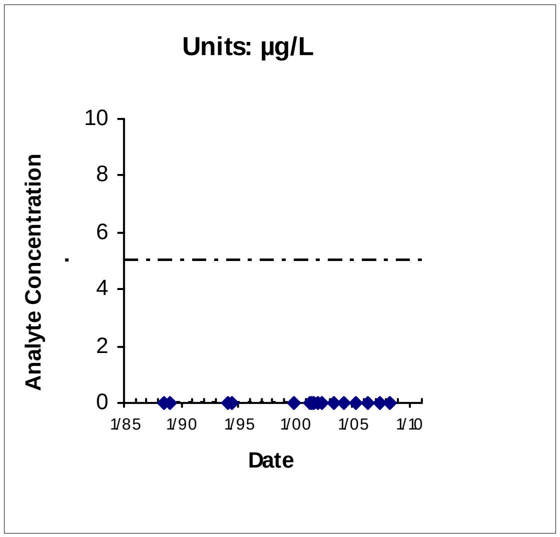
Location: MW133X03 Maximum: 0.58



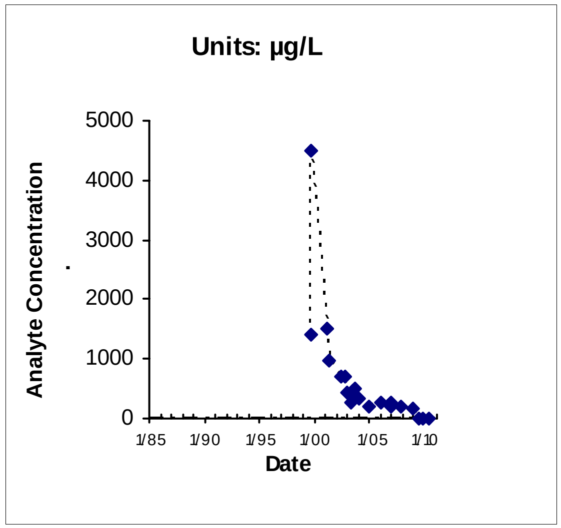
Location: MW205X03 Maximum: 0.03



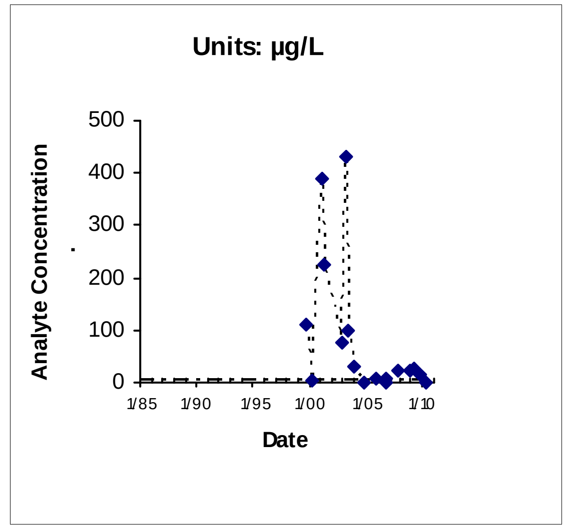
Location: MW206X03 Maximum: 0.6



Location: MW302X03 Maximum: 0.03



Location: EW576X04 Maximum: 4500



Location: EW577X04 Maximum: 430

— - — - — IRG (5 µg/L)

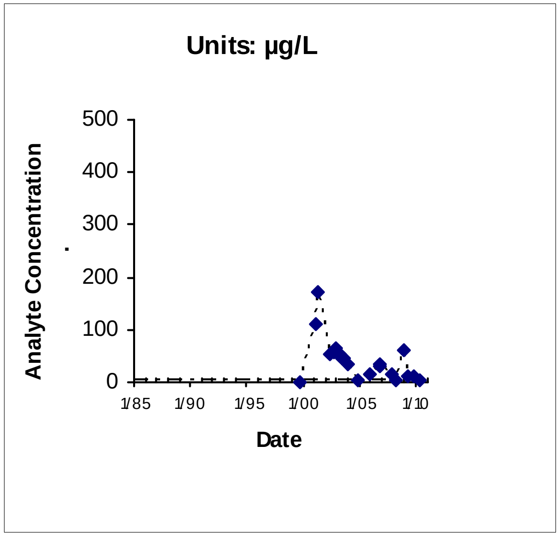
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.1-6

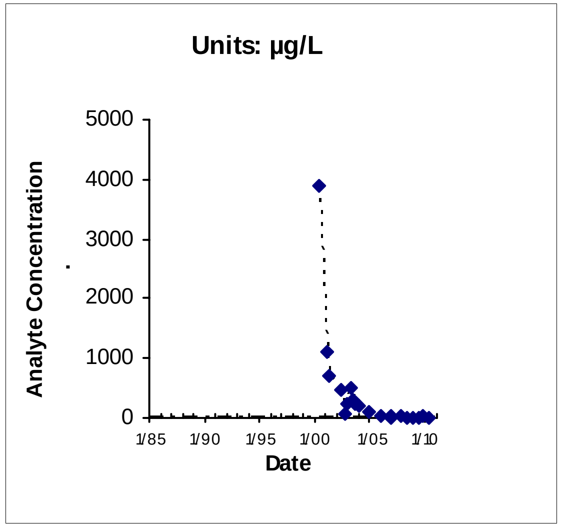
Sites FT004/SD031/LF007

TCE

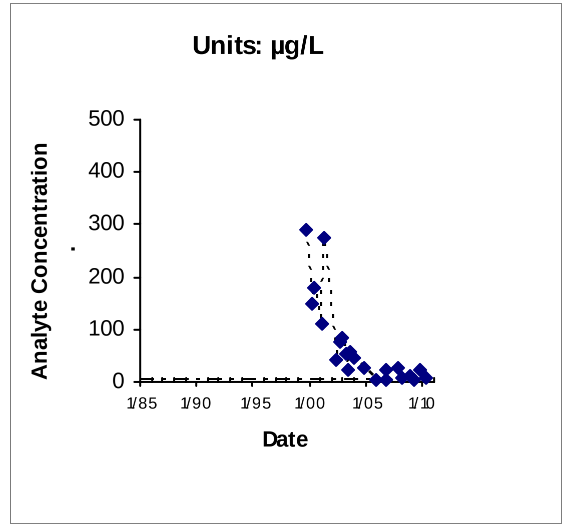
Chemical Time-series Plots



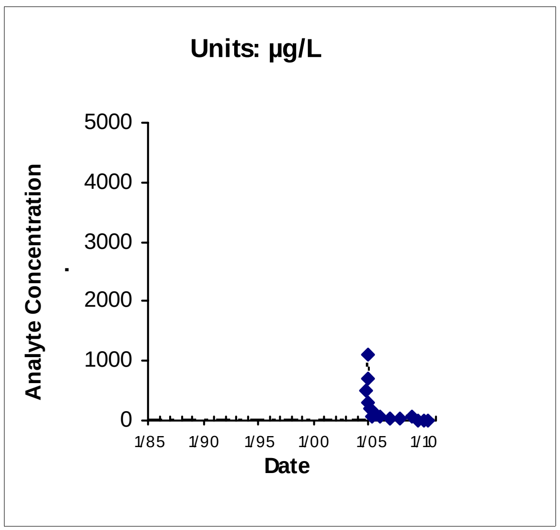
Location: EW578X04 Maximum: 170



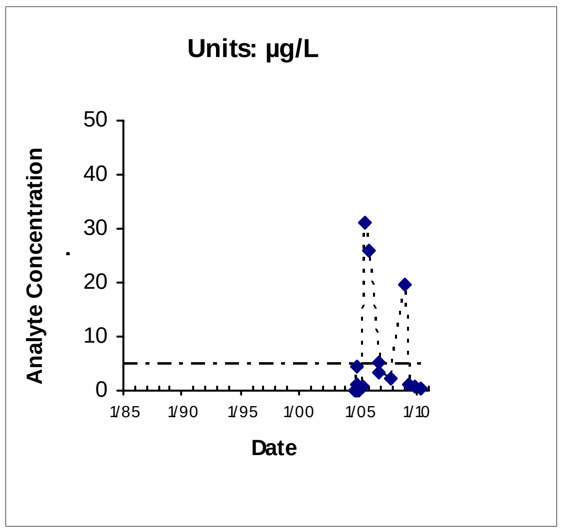
Location: EW579X04 Maximum: 3900



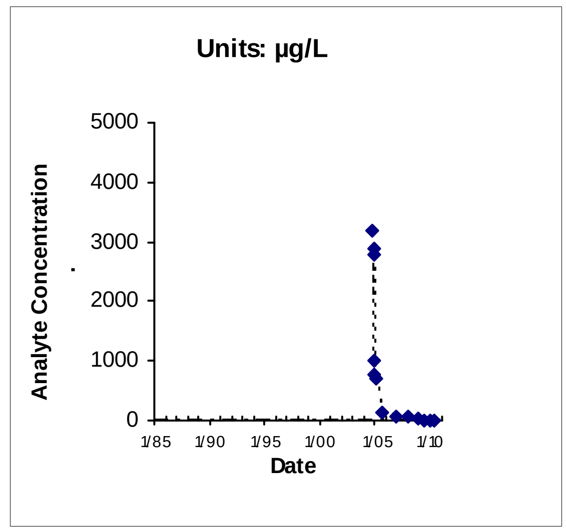
Location: EW580X04 Maximum: 290



Location: EW621X04 Maximum: 1100



Location: EW622X04 Maximum: 31



Location: EW623X04 Maximum: 3200

— - — - — IRG (5 µg/L)

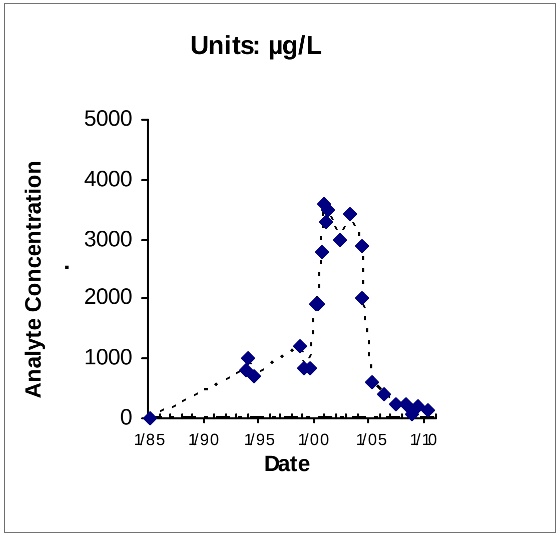
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.1-6

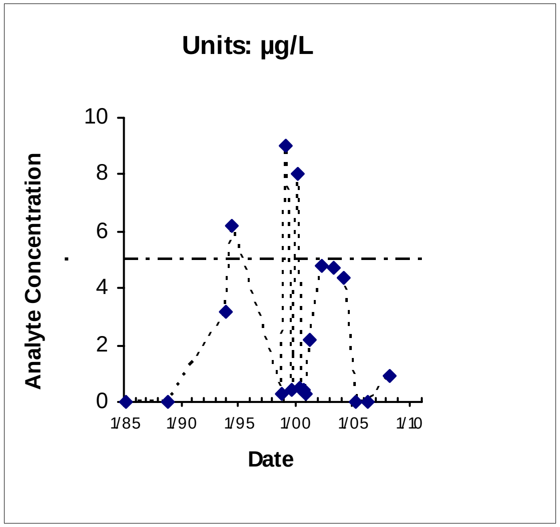
Sites FT004/SD031/LF007

TCE

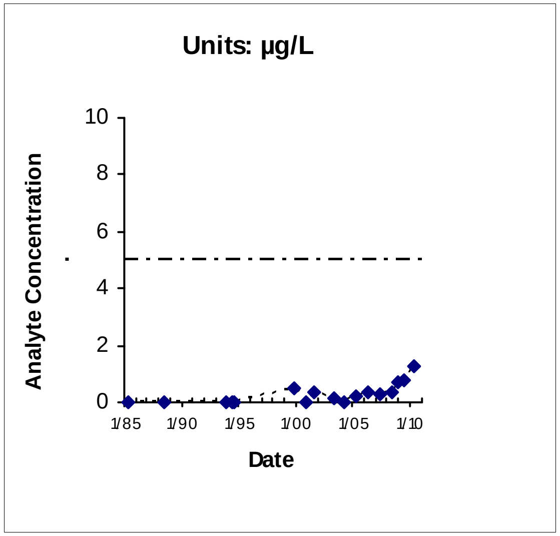
Chemical Time-series Plots



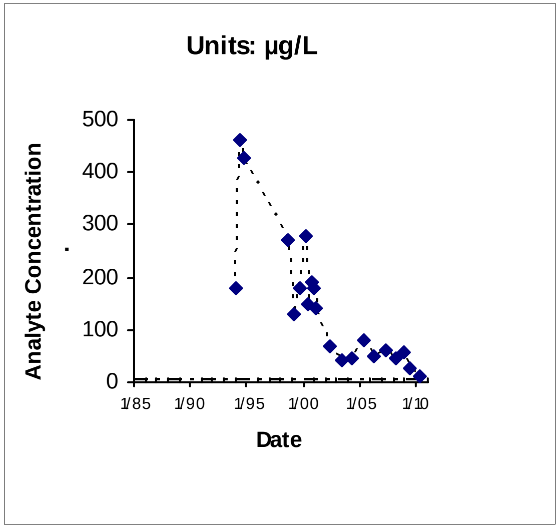
Location: MW131X04 Maximum: 3600



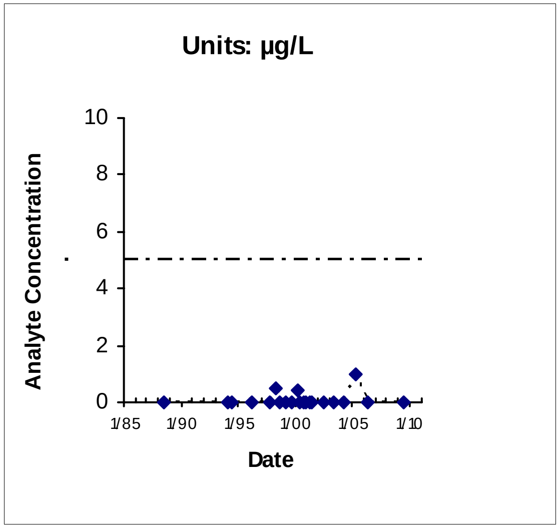
Location: MW132X04 Maximum: 9



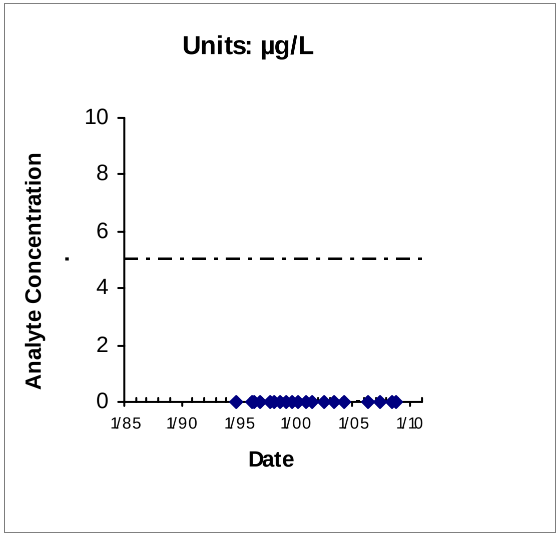
Location: MW134X04 Maximum: 1.3



Location: MW202X04 Maximum: 460



Location: MW203X04 Maximum: 0.96



Location: MW264X04 Maximum: 0.03

— - — - — IRG (5 µg/L)

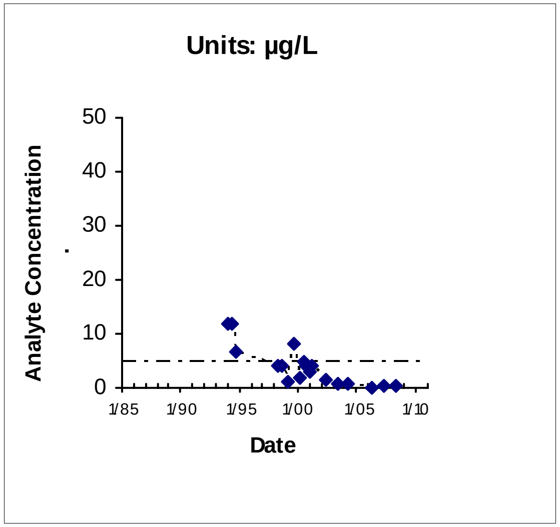
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.1-6

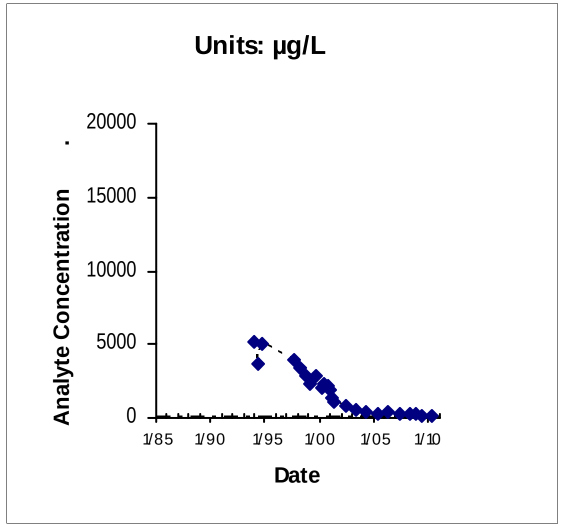
Sites FT004/SD031/LF007

TCE

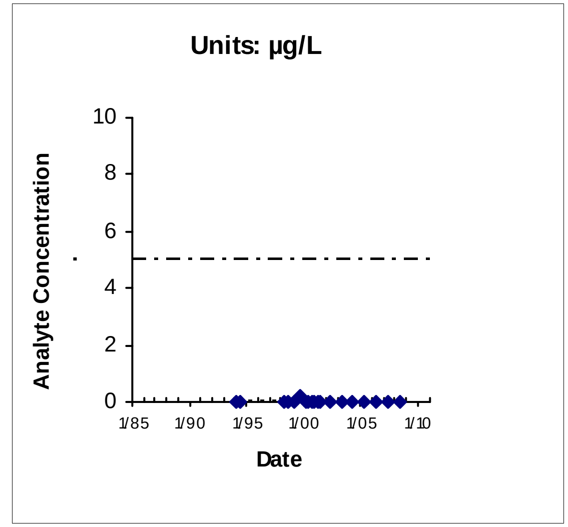
Chemical Time-series Plots



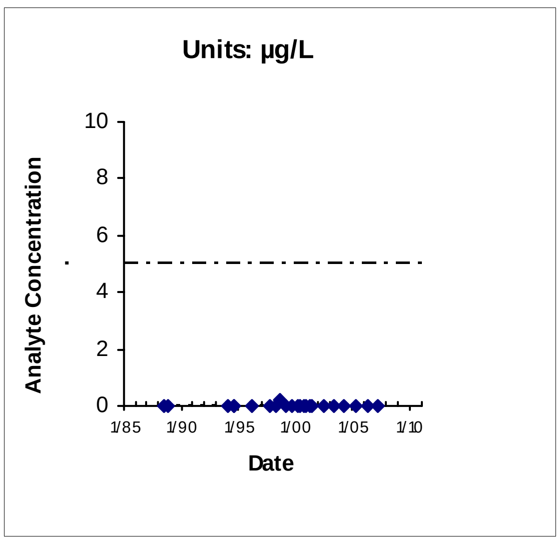
Location: MW265X04 Maximum: 12



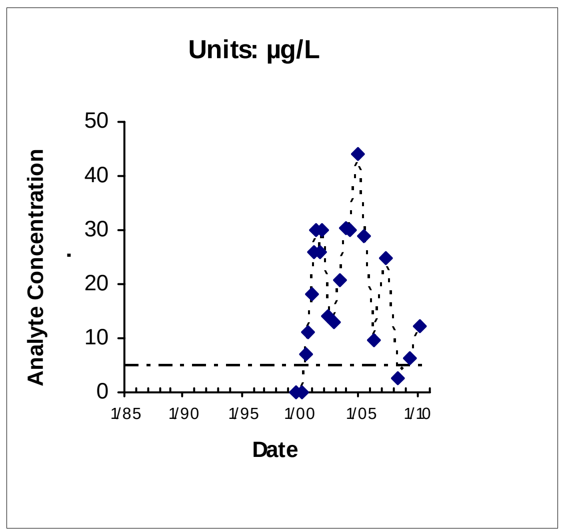
Location: MW266X04 Maximum: 5200



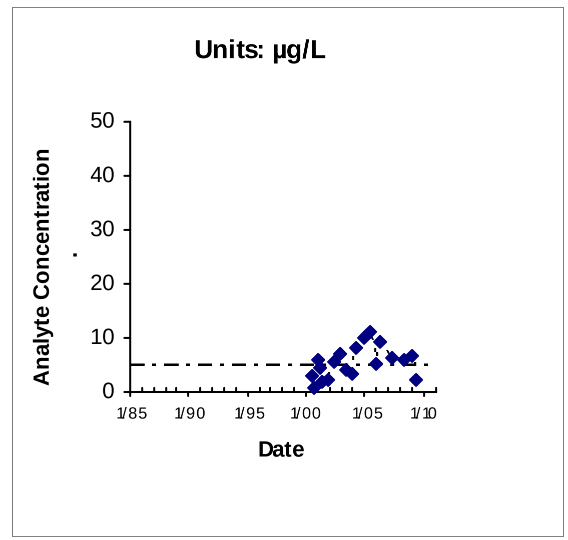
Location: MW267X04 Maximum: 0.2



Location: MW301X04 Maximum: 0.2



Location: MW581X04 Maximum: 44



Location: MW582X04 Maximum: 11

— - — - — IRG (5 µg/L)

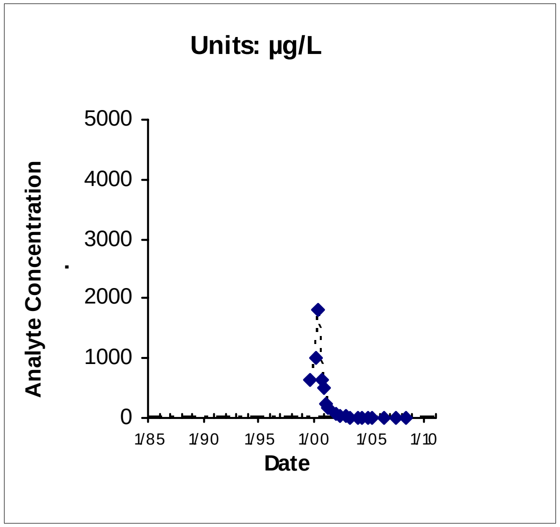
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.1-6

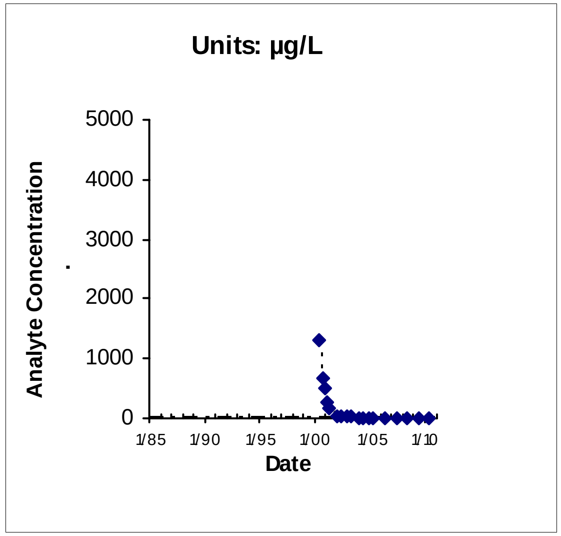
Sites FT004/SD031/LF007

TCE

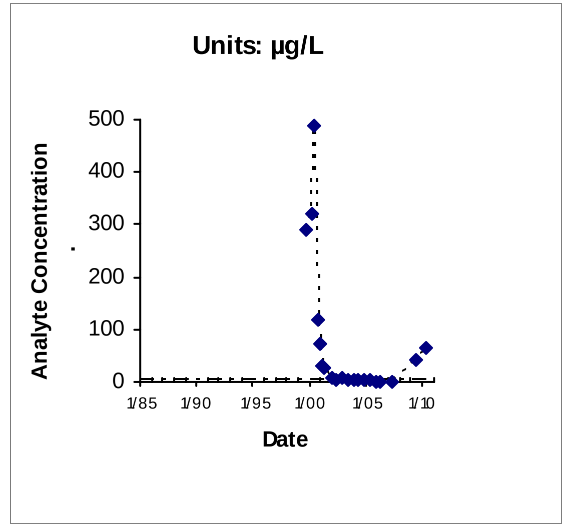
Chemical Time-series Plots



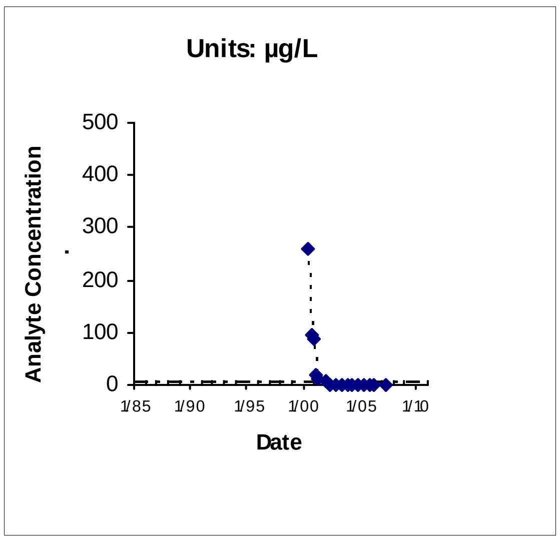
Location: MW583X04 Maximum: 1800



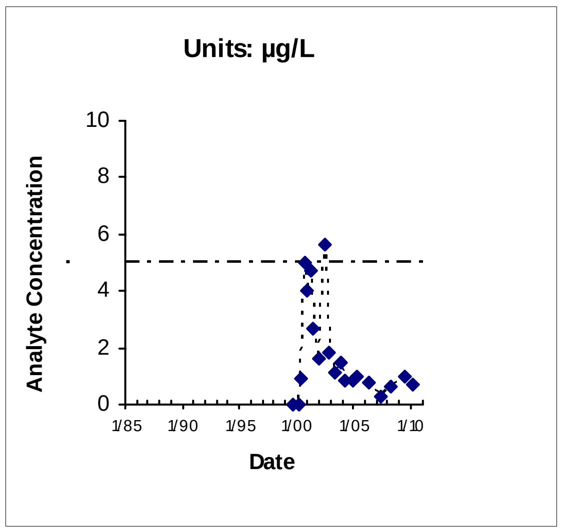
Location: MW584X04 Maximum: 1300



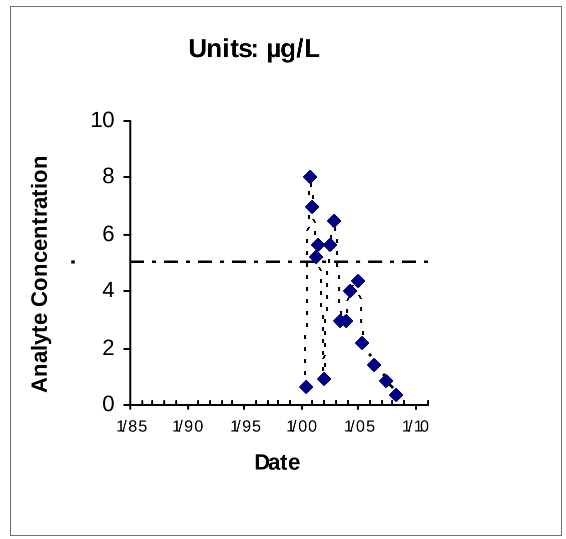
Location: MW585X04 Maximum: 490



Location: MW586X04 Maximum: 260



Location: MW587X04 Maximum: 5.6



Location: MW588X04 Maximum: 8

— - — - — IRG (5 µg/L)

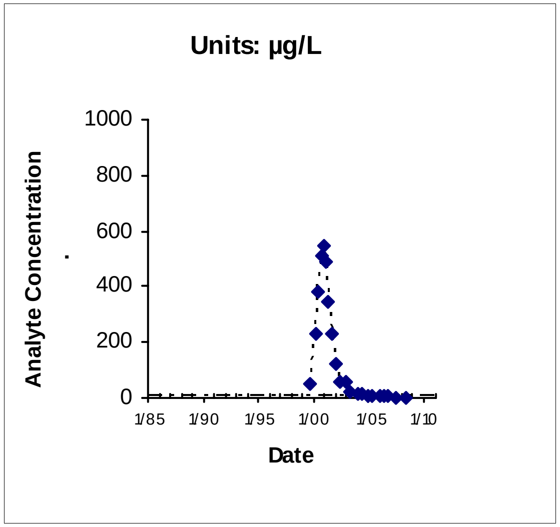
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.1-6

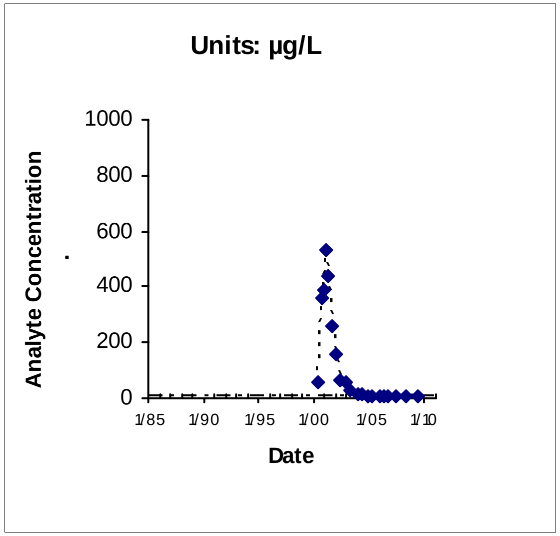
Sites FT004/SD031/LF007

TCE

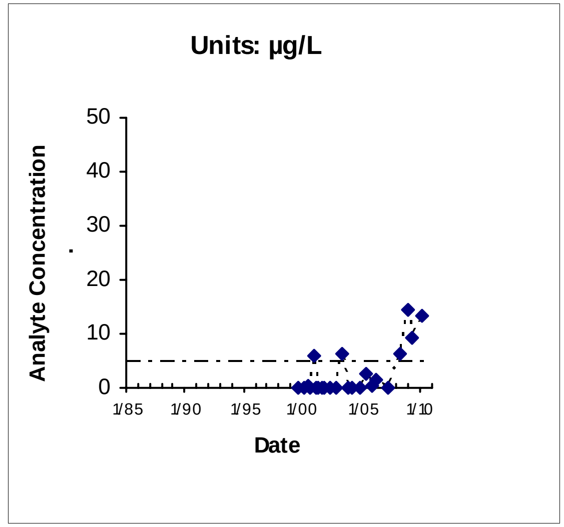
Chemical Time-series Plots



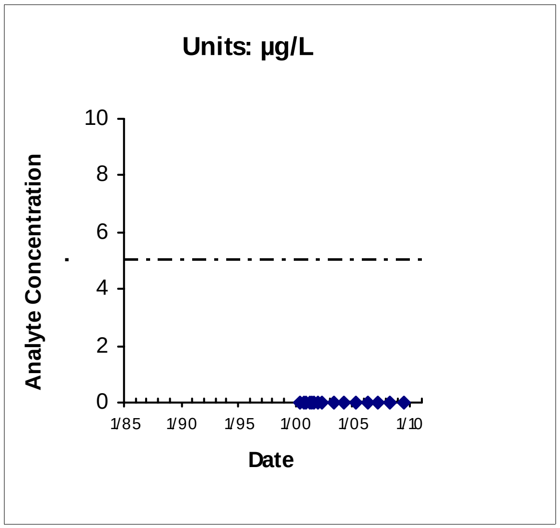
Location: MW589X04 Maximum: 550



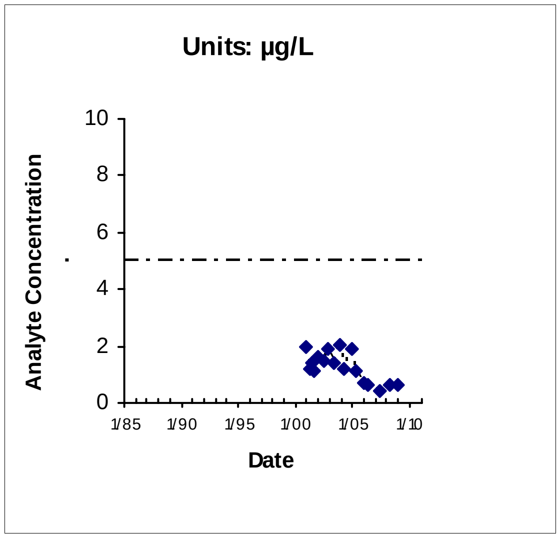
Location: MW590X04 Maximum: 530



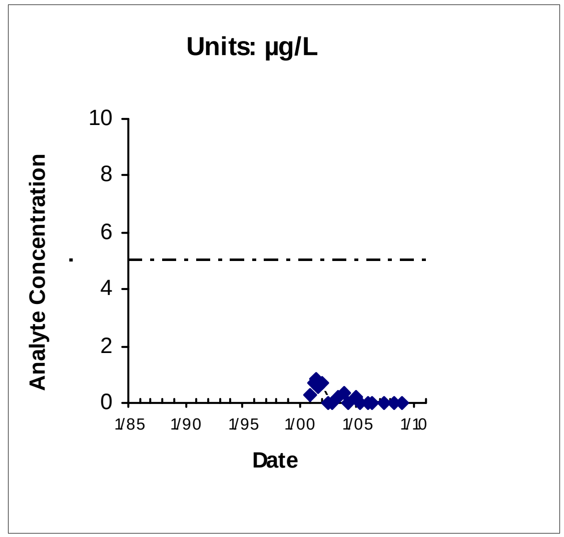
Location: MW591X04 Maximum: 14.4



Location: MW592X04 Maximum: 0.03



Location: MW752X04 Maximum: 2.01



Location: MW753X04 Maximum: 0.85

FIGURE 4.1-6

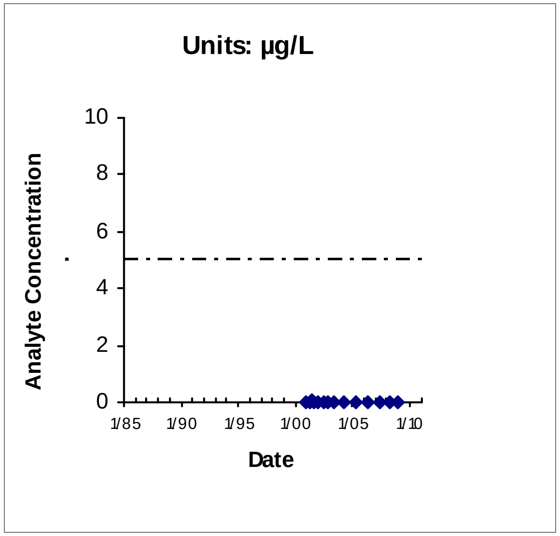
Sites FT004/SD031/LF007

TCE

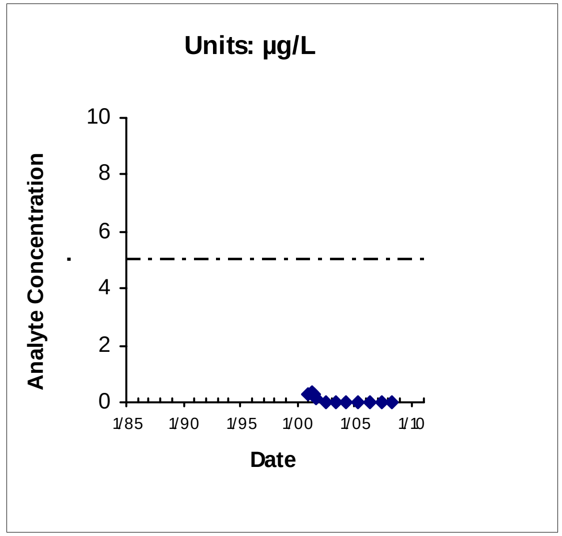
Chemical Time-series Plots

— - — - — IRG (5 µg/L)

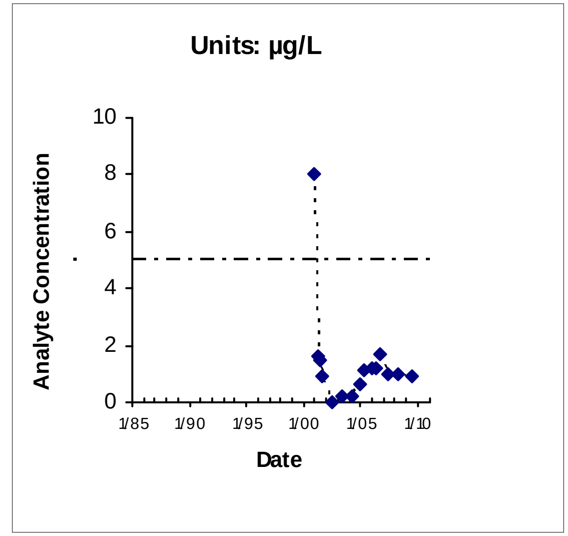
*Nondetects shown as the Method Detection Limit (0.03 µg/L)



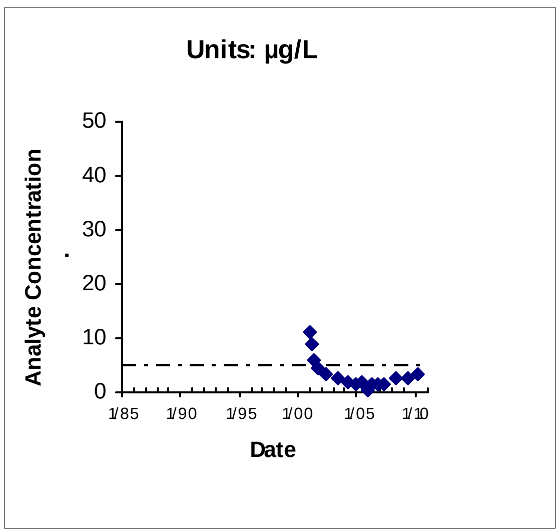
Location: MW754X04 Maximum: 0.1



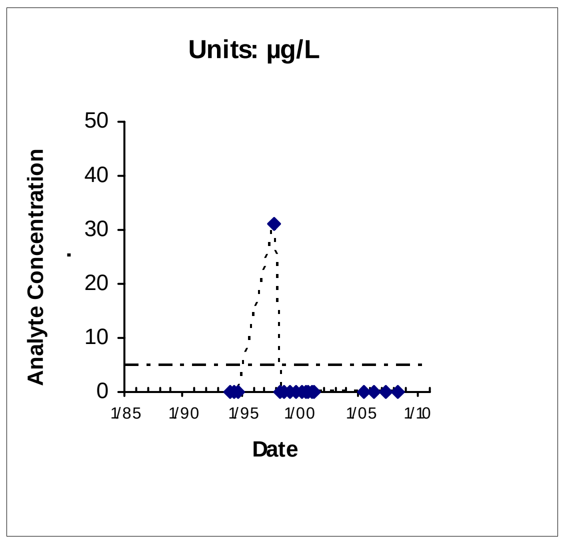
Location: MW755X04 Maximum: 0.35



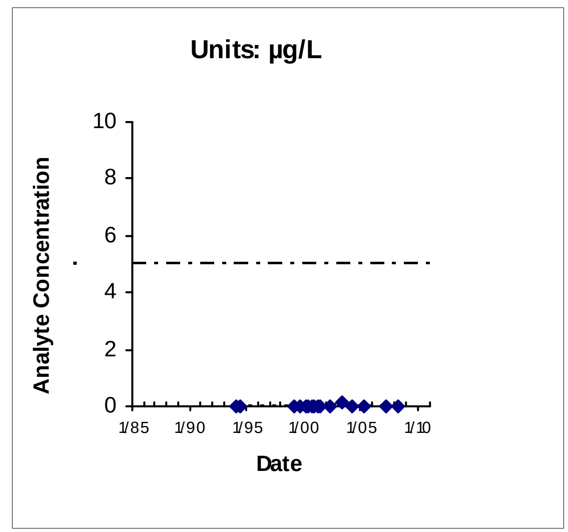
Location: MW756X04 Maximum: 8



Location: MW757X04 Maximum: 11



Location: MW1000X04 Maximum: 31



Location: MW1001X04 Maximum: 0.14

FIGURE 4.1-6

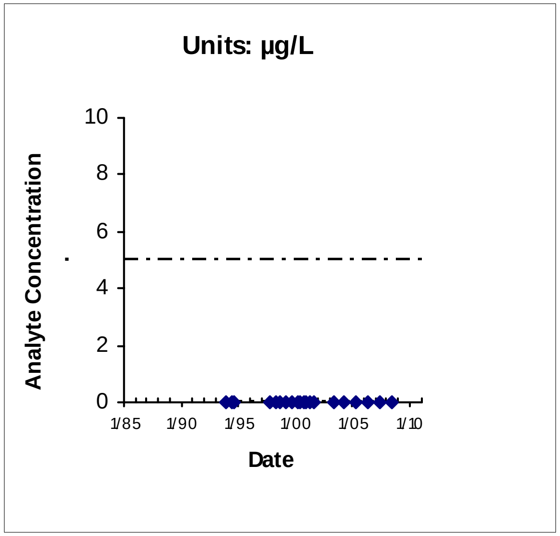
Sites FT004/SD031/LF007

TCE

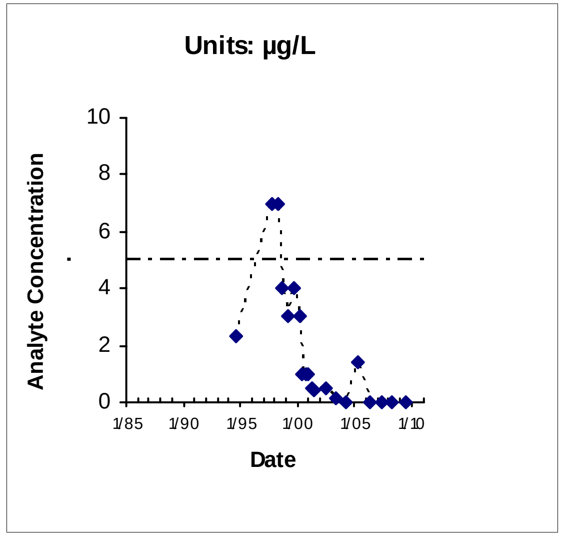
Chemical Time-series Plots

— - — - — IRG (5 µg/L)

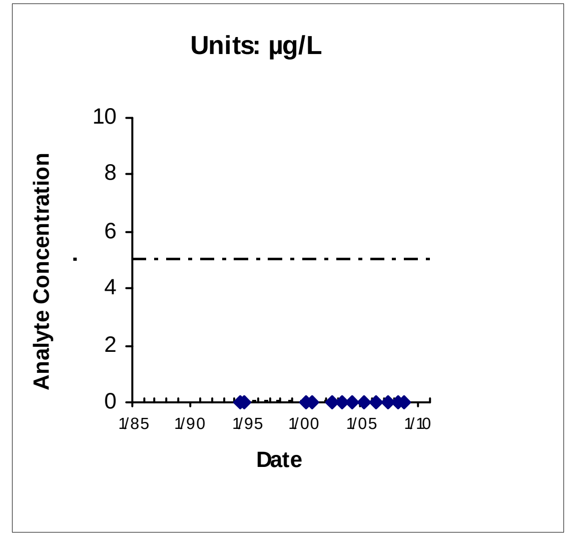
*Nondetects shown as the Method Detection Limit (0.03 µg/L)



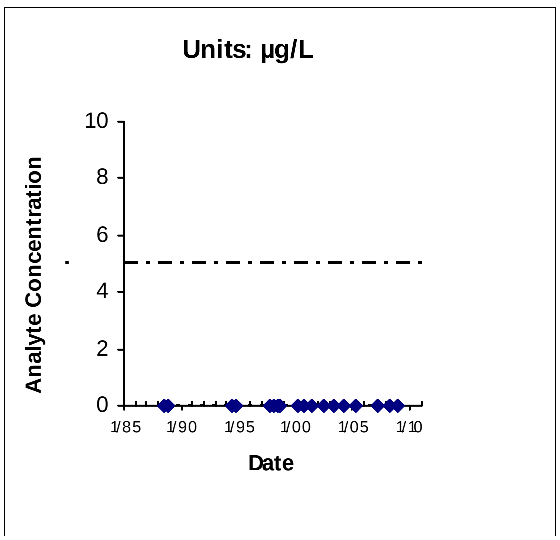
Location: MW1002X04 Maximum: 0.03



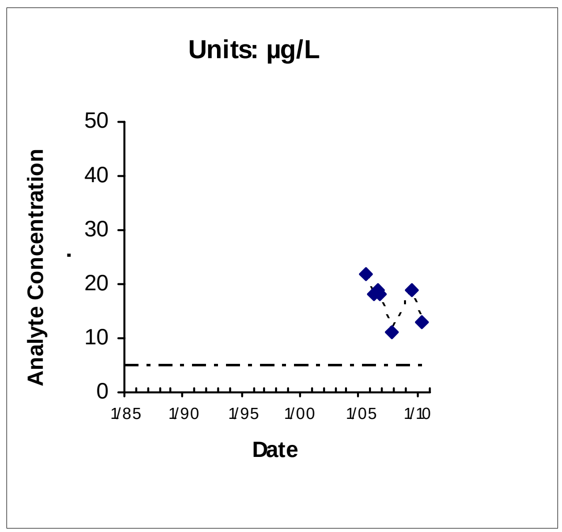
Location: MW1030X04 Maximum: 7



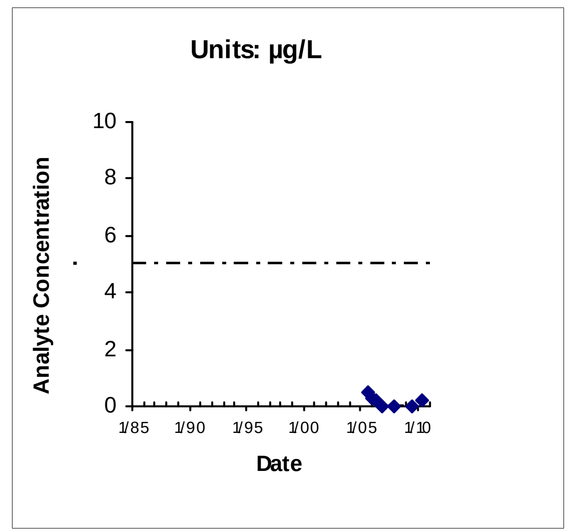
Location: MW207X06 Maximum: 0.03



Location: MW210X06 Maximum: 0.03



Location: EW614X07 Maximum: 22



Location: EW615X07 Maximum: 0.48

FIGURE 4.1-6

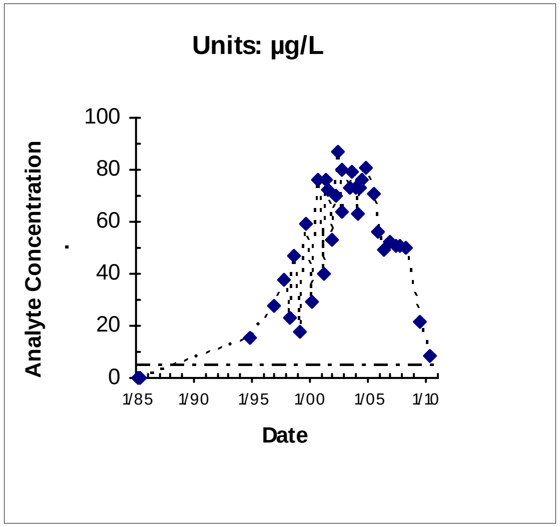
Sites FT004/SD031/LF007

TCE

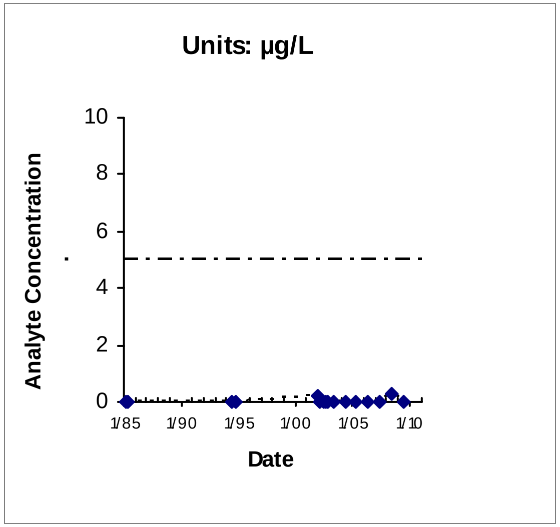
Chemical Time-series Plots

— - — - — IRG (5 µg/L)

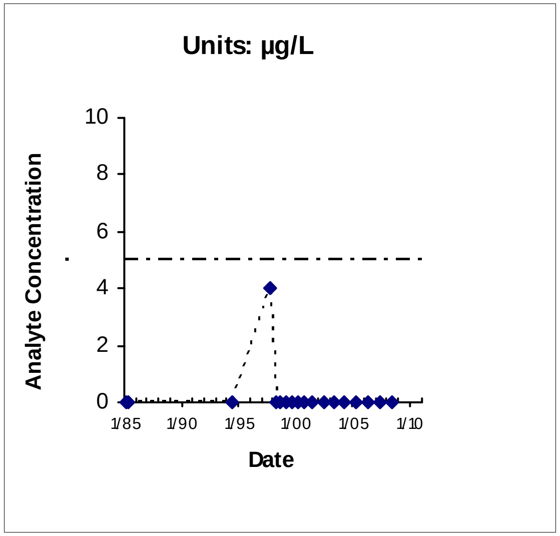
*Nondetects shown as the Method Detection Limit (0.03 µg/L)



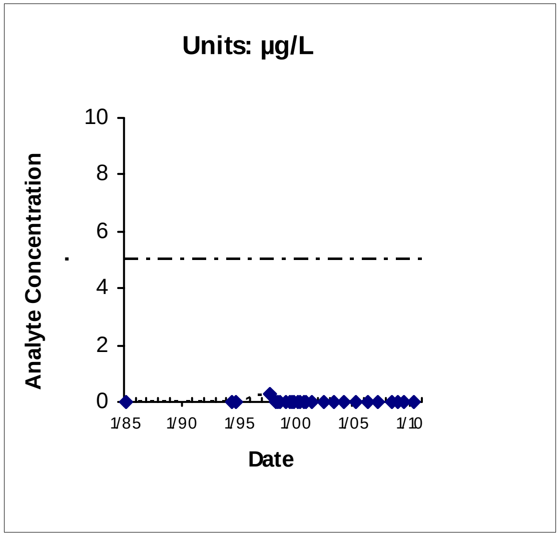
Location: MW125X07 Maximum: 87



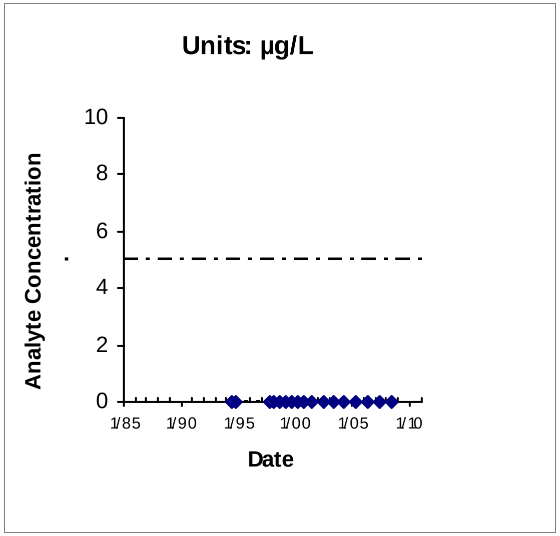
Location: MW126X07 Maximum: 0.25



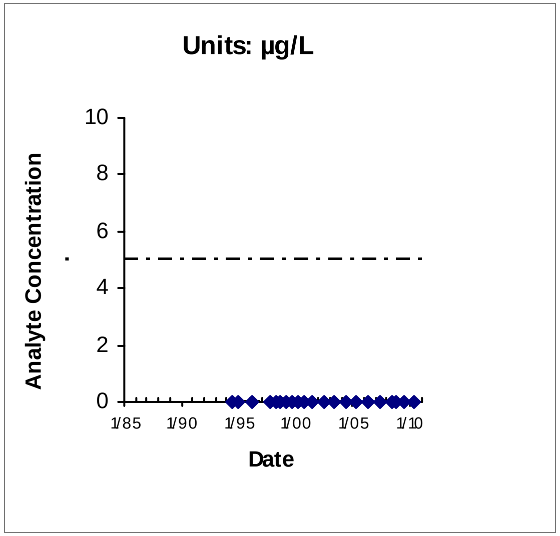
Location: MW128X07 Maximum: 4



Location: MW129X07 Maximum: 0.3



Location: MW201X07 Maximum: 0.03

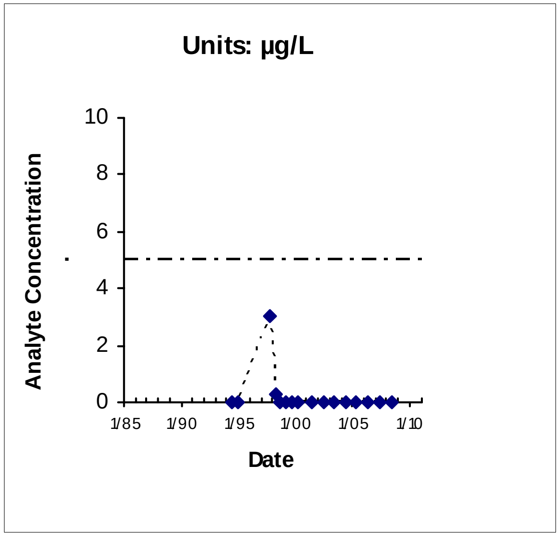


Location: MW261X07 Maximum: 0.03

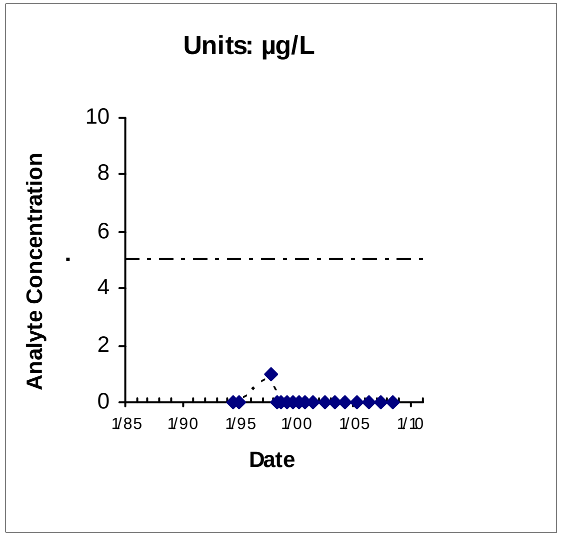
— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (0.03 µg/L)

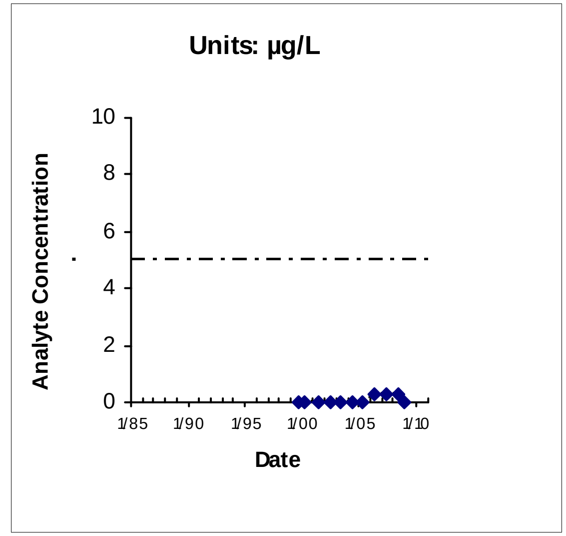
FIGURE 4.1-6
Sites FT004/SD031/LF007
TCE
Chemical Time-series Plots



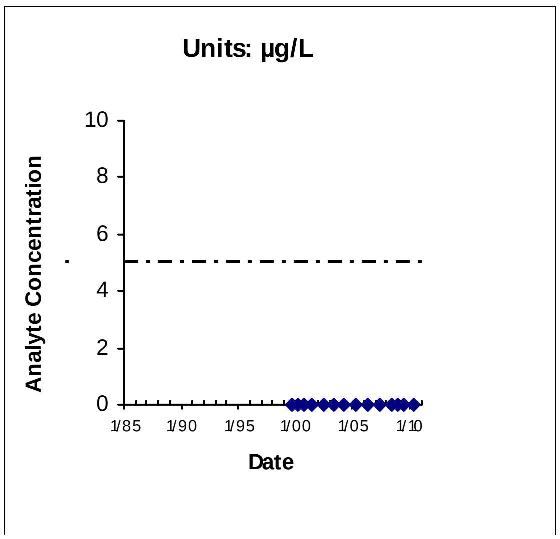
Location: MW284X07 Maximum: 3



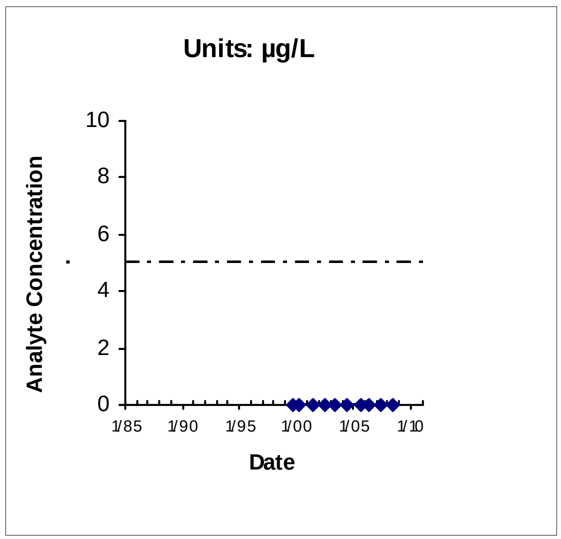
Location: MW303X07 Maximum: 1



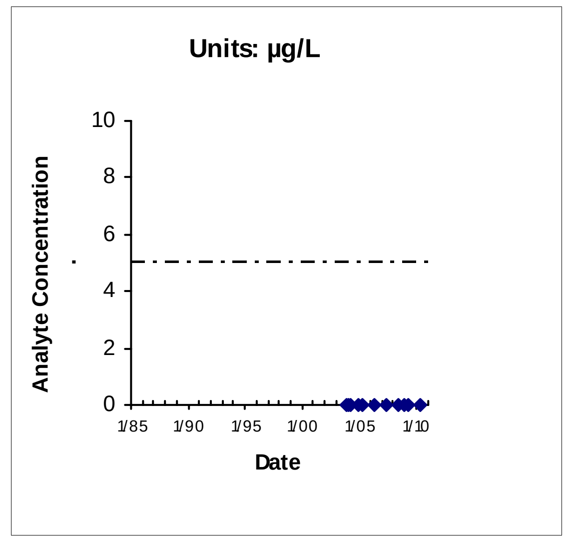
Location: MW600X07 Maximum: 0.3



Location: MW601X07 Maximum: 0.03



Location: MW602X07 Maximum: 0.03



Location: MW612X07 Maximum: 0.03

— - — - — IRG (5 µg/L)

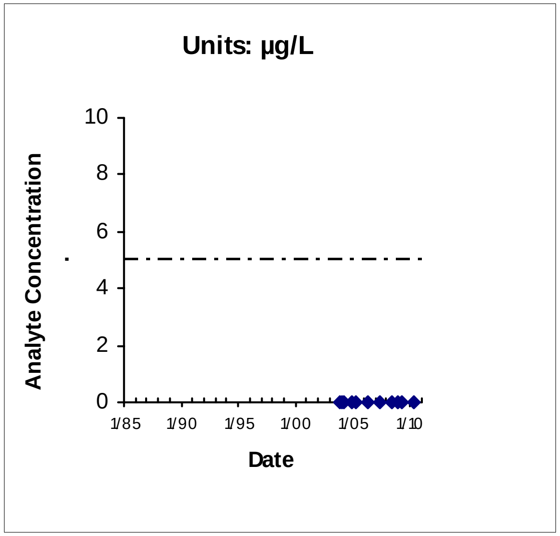
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.1-6

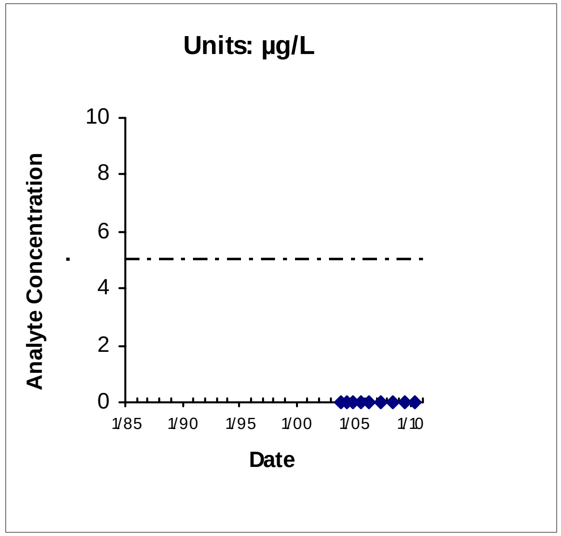
Sites FT004/SD031/LF007

TCE

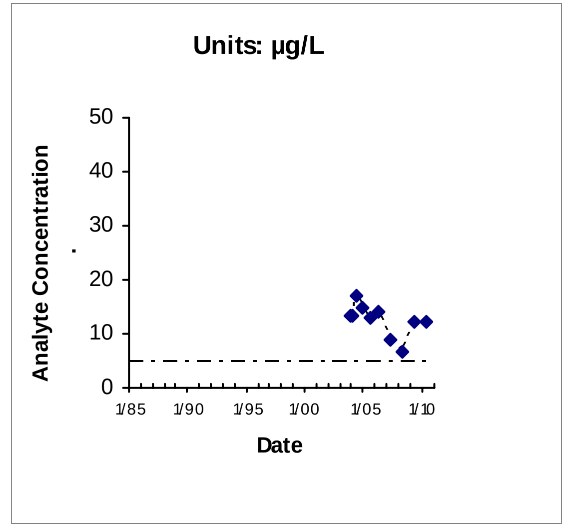
Chemical Time-series Plots



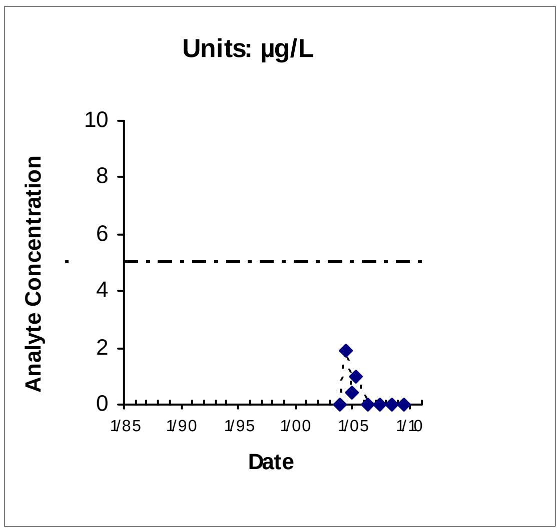
Location: MW613X07 Maximum: 0.03



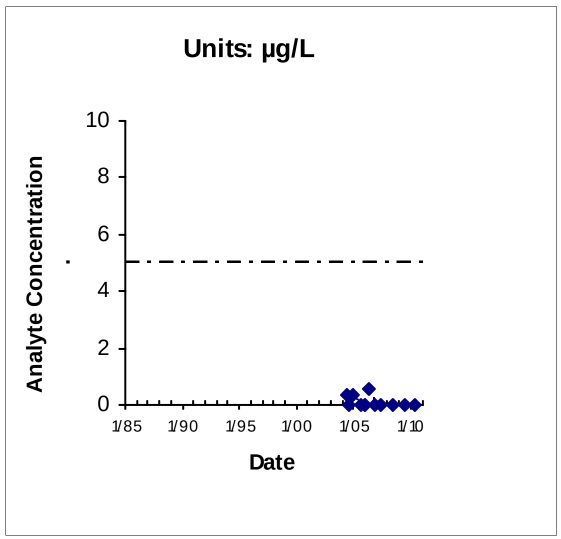
Location: MW616X07 Maximum: 0.03



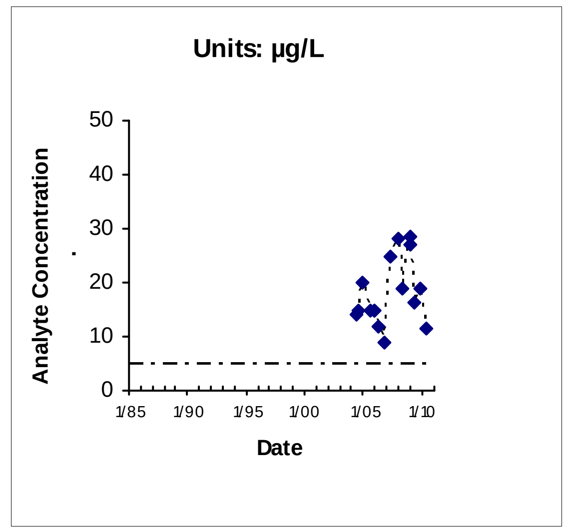
Location: MW617X07 Maximum: 17



Location: MW618X07 Maximum: 1.9



Location: MW619X07 Maximum: 0.56



Location: MW620X07 Maximum: 28.5

— - — - — IRG (5 µg/L)

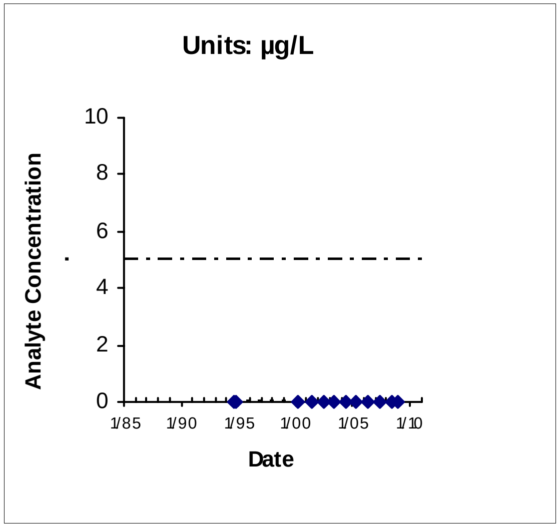
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.1-6

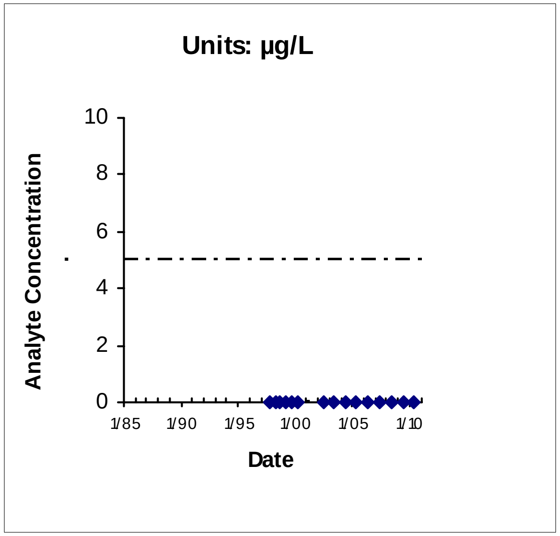
Sites FT004/SD031/LF007

TCE

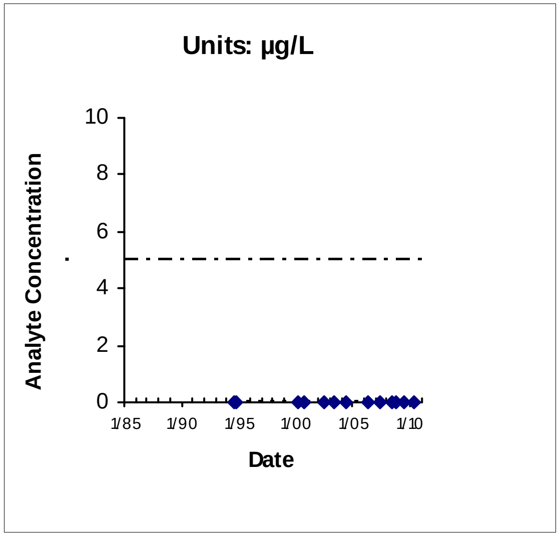
Chemical Time-series Plots



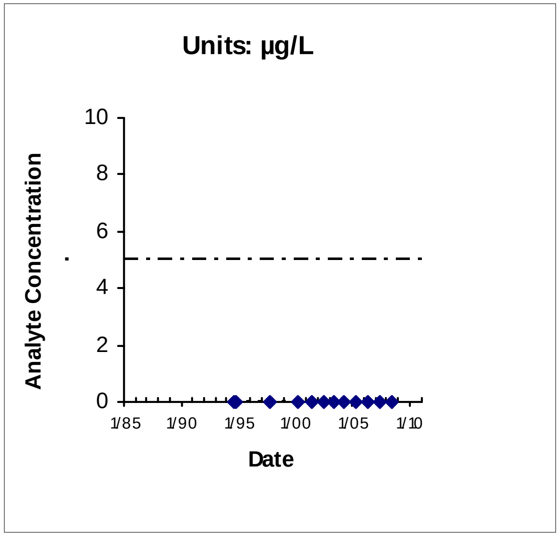
Location: MWAX07 Maximum: 0.03



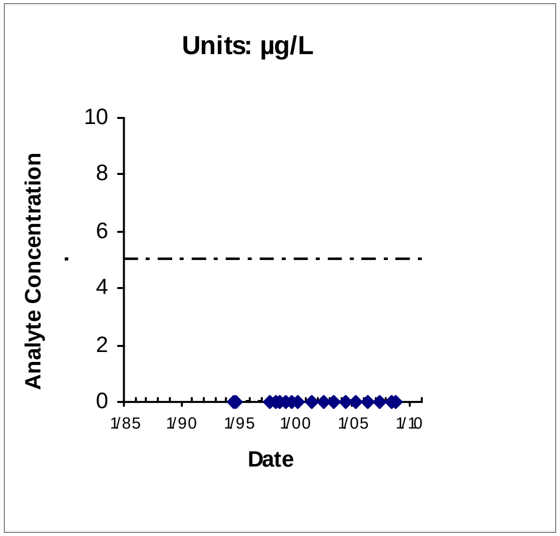
Location: MWBX07 Maximum: 0.03



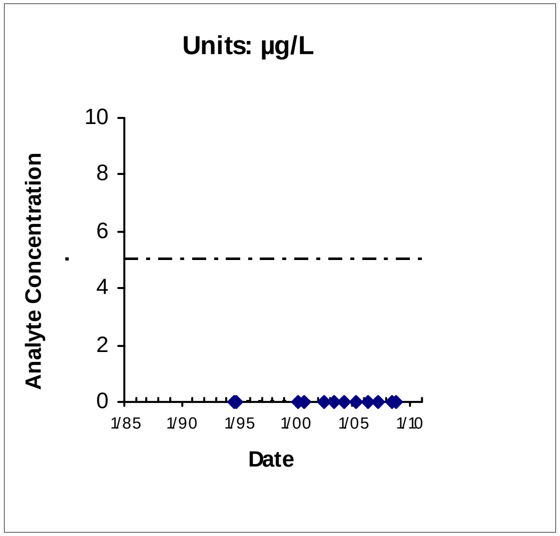
Location: MWCX07 Maximum: 0.03



Location: MWDX07 Maximum: 0.03



Location: MWFX07 Maximum: 0.03



Location: MWGX07 Maximum: 0.03

— - — - — IRG (5 µg/L)

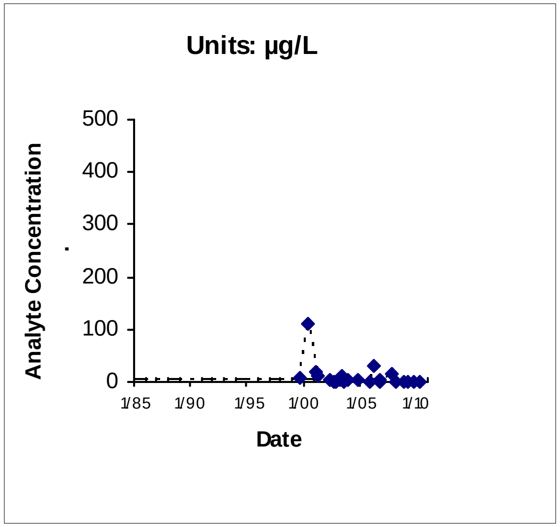
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.1-6

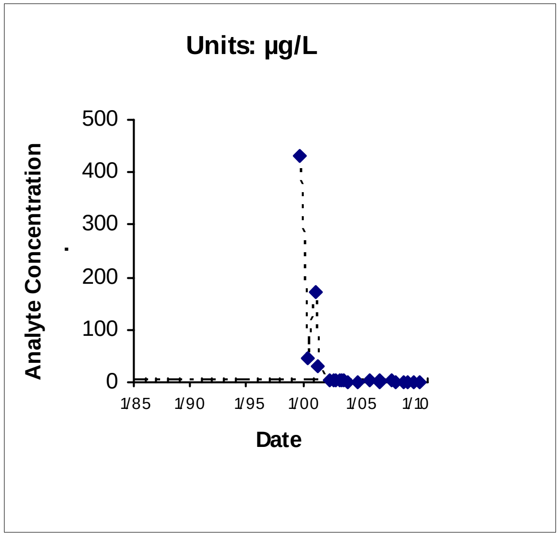
Sites FT004/SD031/LF007

TCE

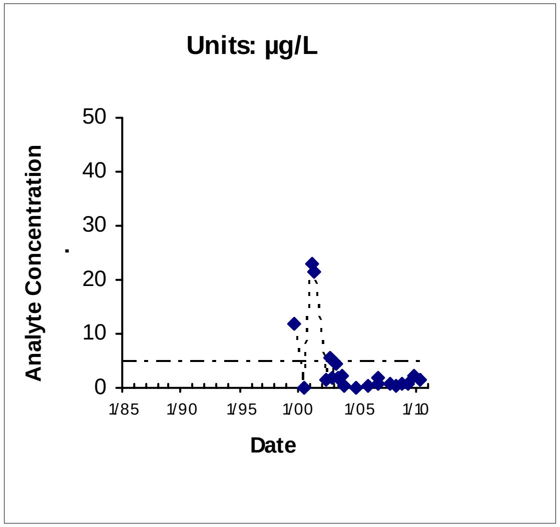
Chemical Time-series Plots



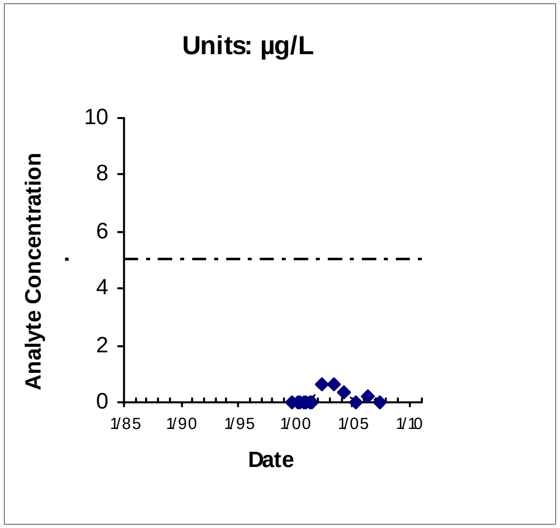
Location: EW565X31 Maximum: 110



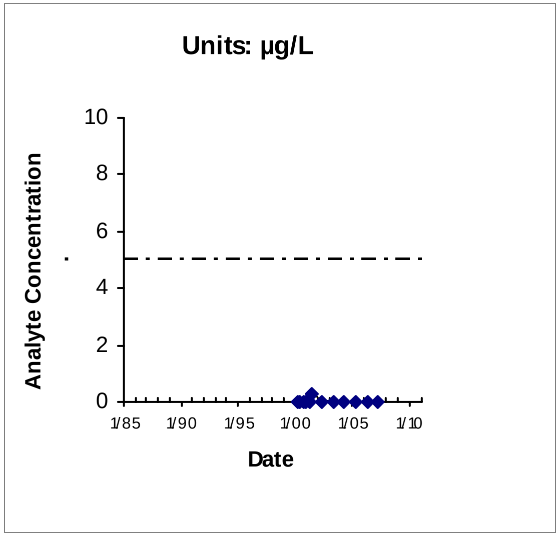
Location: EW566X31 Maximum: 430



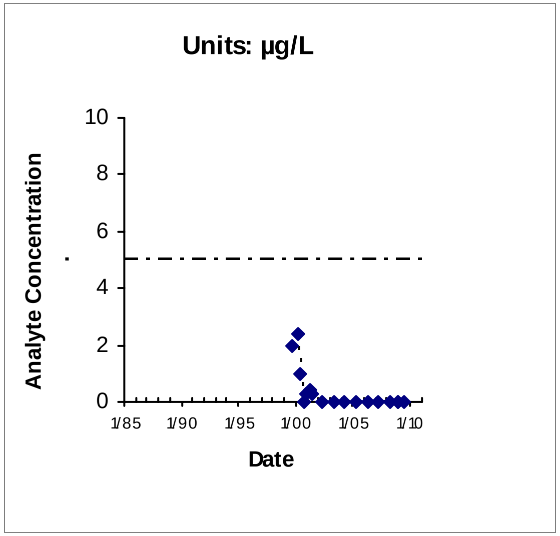
Location: EW567X31 Maximum: 23



Location: MW568X31 Maximum: 0.66



Location: MW569X31 Maximum: 0.25



Location: MW570X31 Maximum: 2.4

— - — - — IRG (5 µg/L)

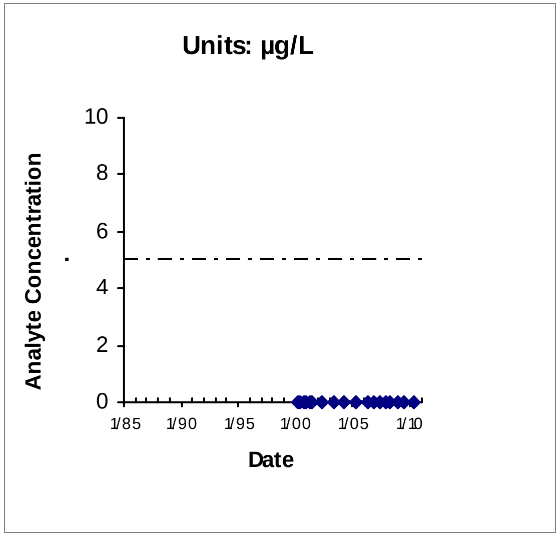
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.1-6

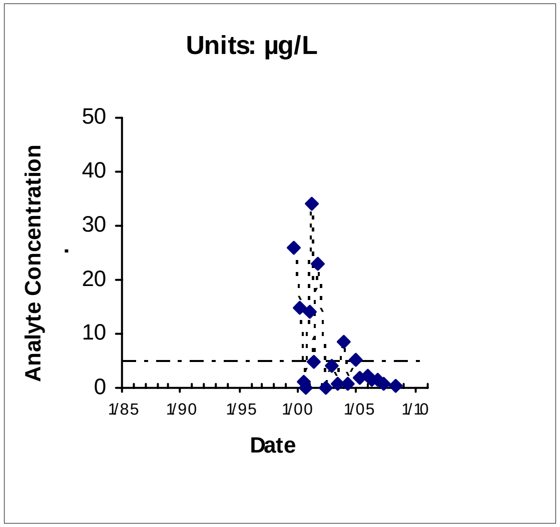
Sites FT004/SD031/LF007

TCE

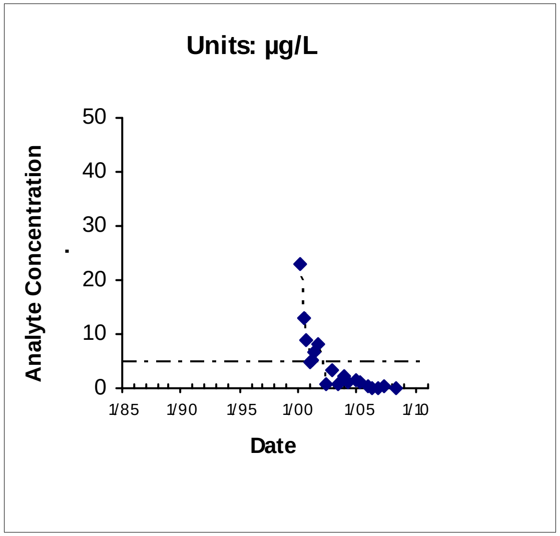
Chemical Time-series Plots



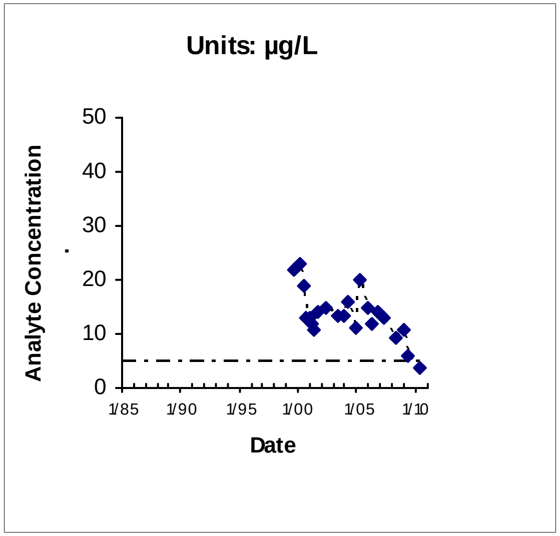
Location: MW571X31 Maximum: 0.03



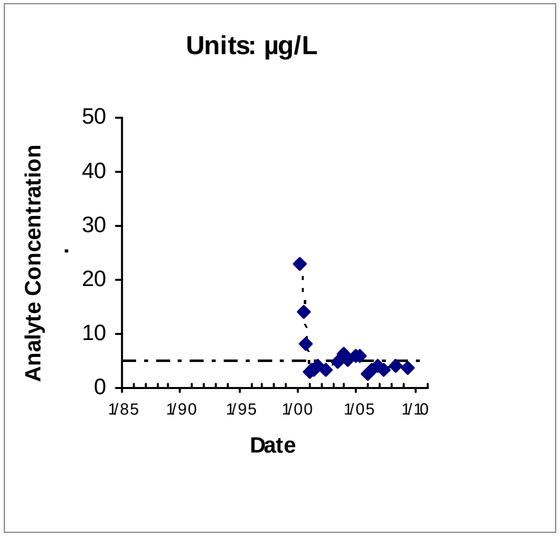
Location: MW572X31 Maximum: 34



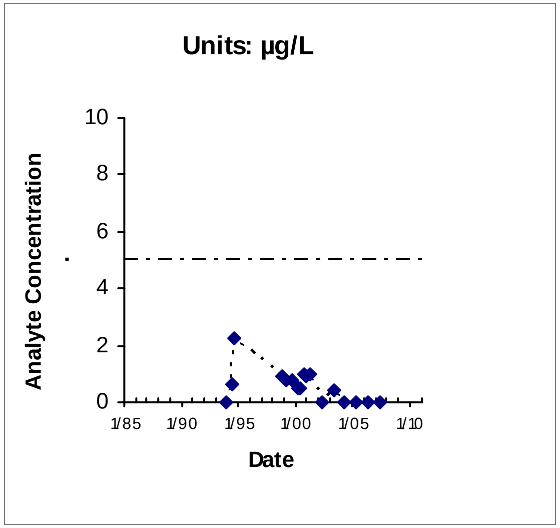
Location: MW573X31 Maximum: 23



Location: MW574X31 Maximum: 23



Location: MW575X31 Maximum: 23



Location: MW1725X31 Maximum: 2.28

— - — - — IRG (5 µg/L)

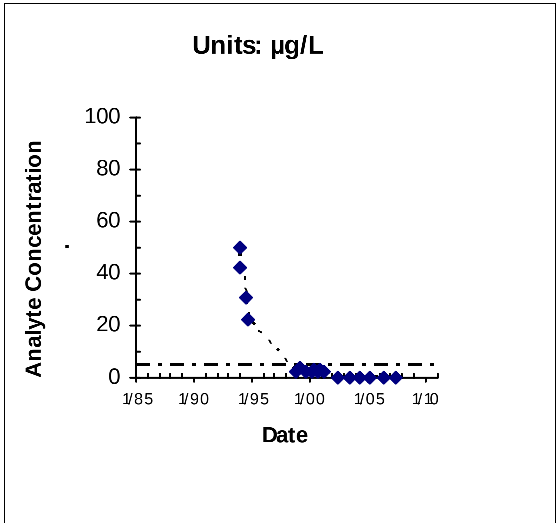
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.1-6

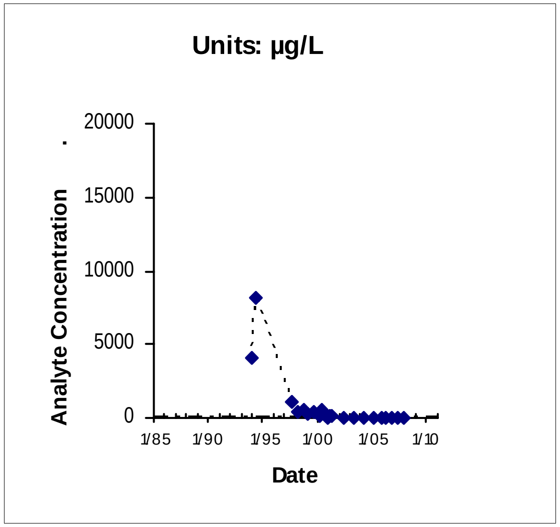
Sites FT004/SD031/LF007

TCE

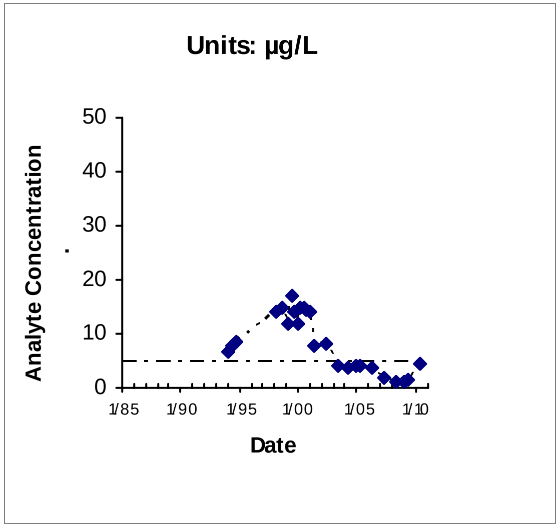
Chemical Time-series Plots



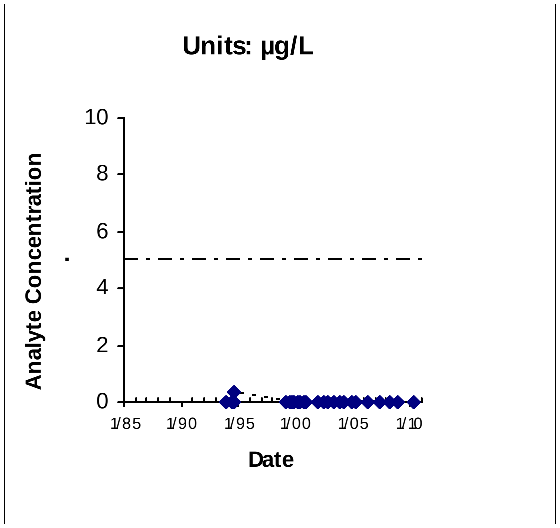
Location: MW1726X31 Maximum: 50



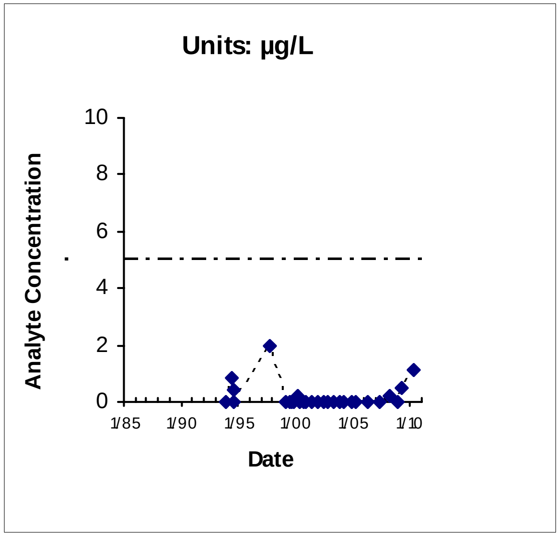
Location: MW1727X31 Maximum: 8100



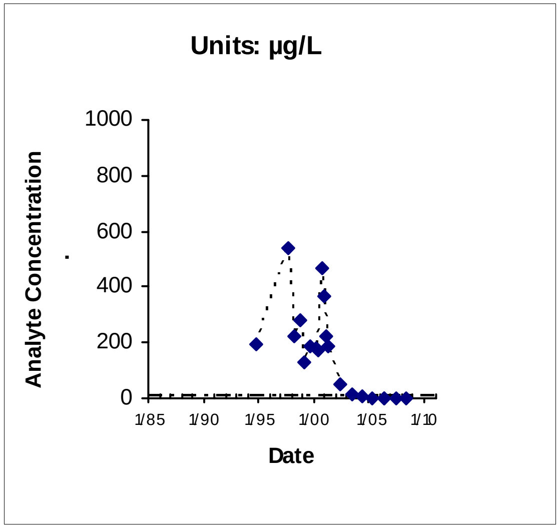
Location: MW1729X31 Maximum: 17



Location: MW1730X31 Maximum: 0.35



Location: MW1731X31 Maximum: 2



Location: MW1741X31 Maximum: 540

— - — - — IRG (5 µg/L)

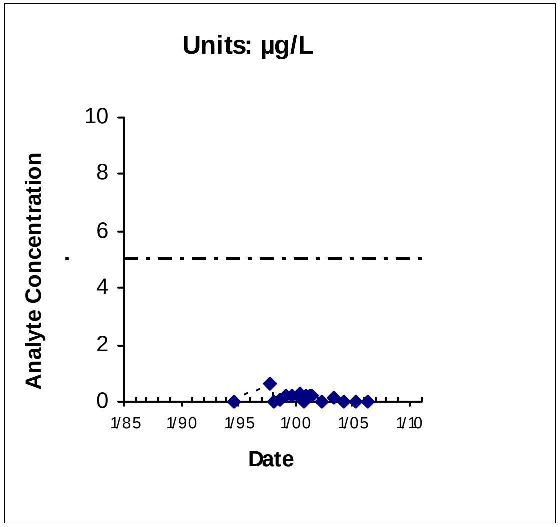
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.1-6

Sites FT004/SD031/LF007

TCE

Chemical Time-series Plots



Location: MW1742X31 Maximum: 0.6

— - — - — IRG (5 µg/L)

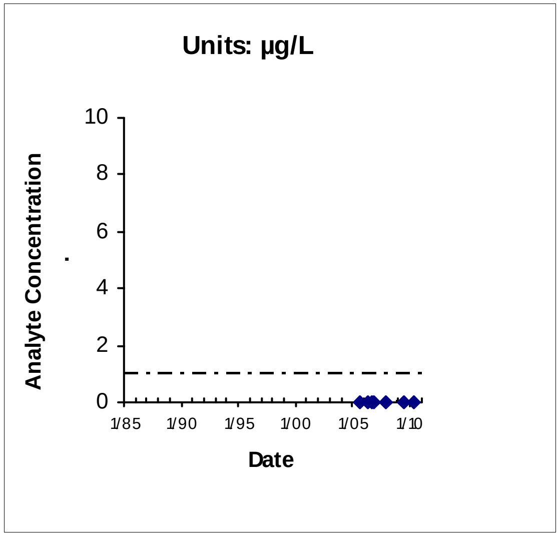
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.1-6

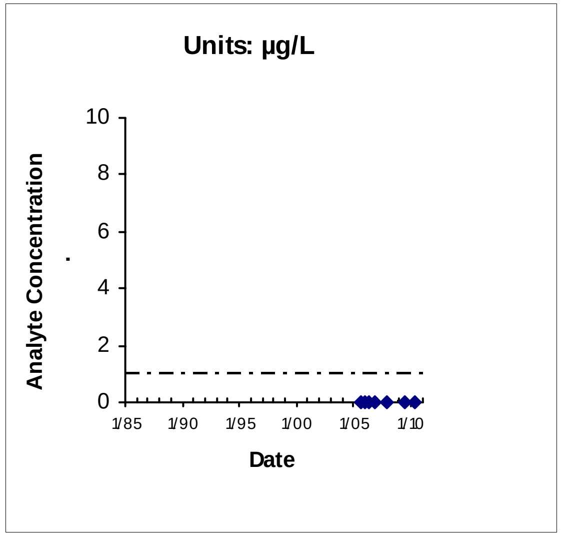
Sites FT004/SD031/LF007

TCE

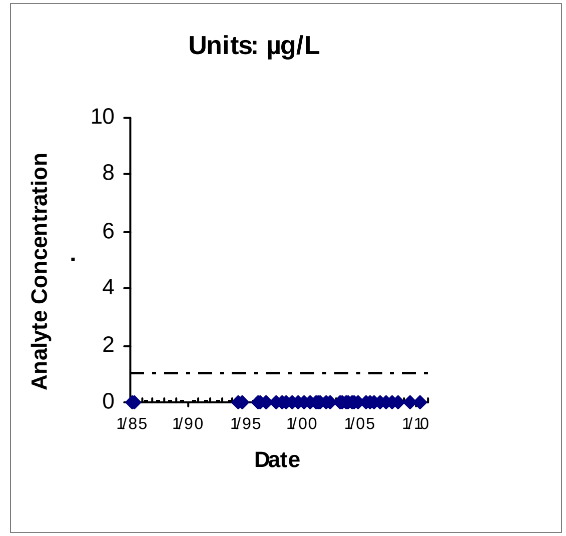
Chemical Time-series Plots



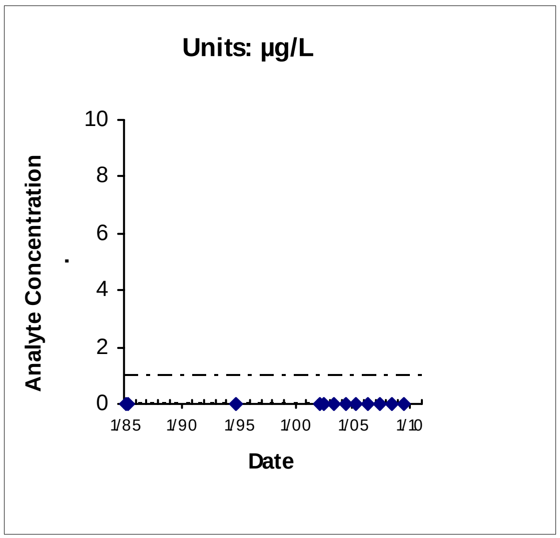
Location: EW614X07 Maximum: 0.0257



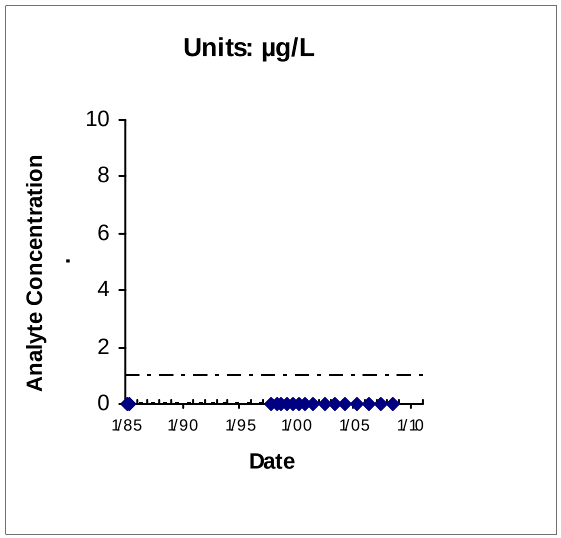
Location: EW615X07 Maximum: 0.0257



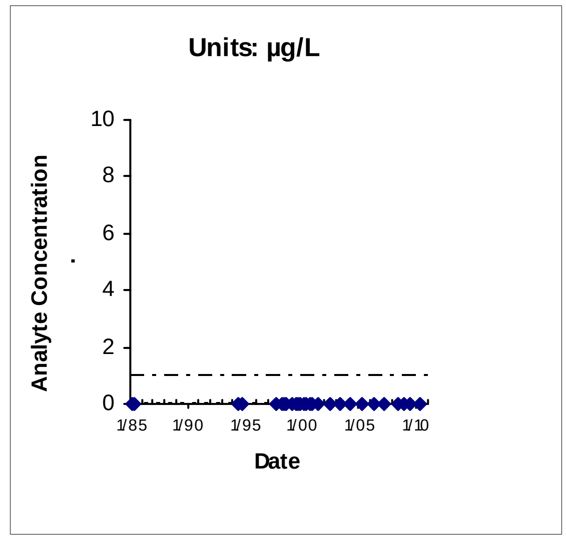
Location: MW125X07 Maximum: 0.0257



Location: MW126X07 Maximum: 0.0257



Location: MW128X07 Maximum: 0.0257



Location: MW129X07 Maximum: 0.0257

— - — - — IRG (1 µg/L)

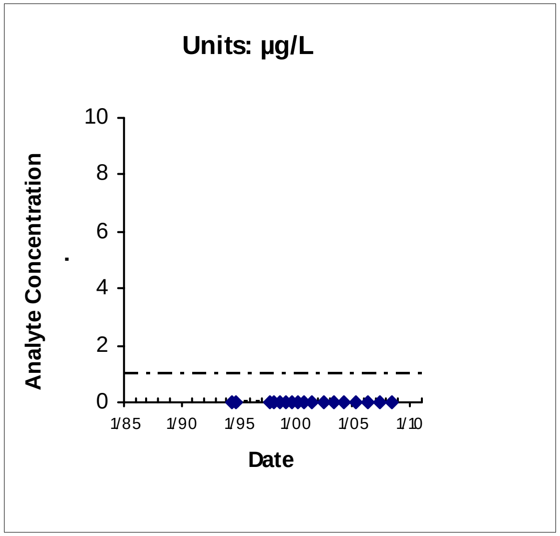
*Nondetects shown as the Method Detection Limit (0.0257 µg/L)

FIGURE 4.1-9

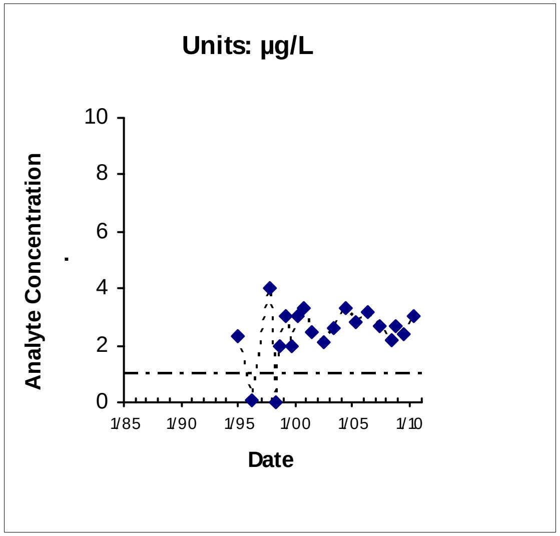
Site LF007

Benzene

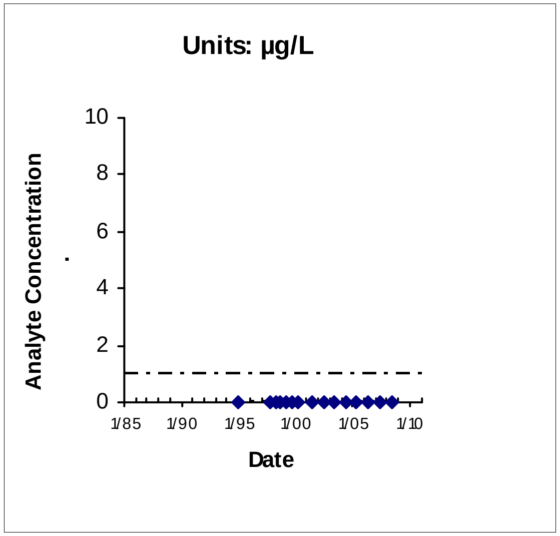
Chemical Time-series Plots



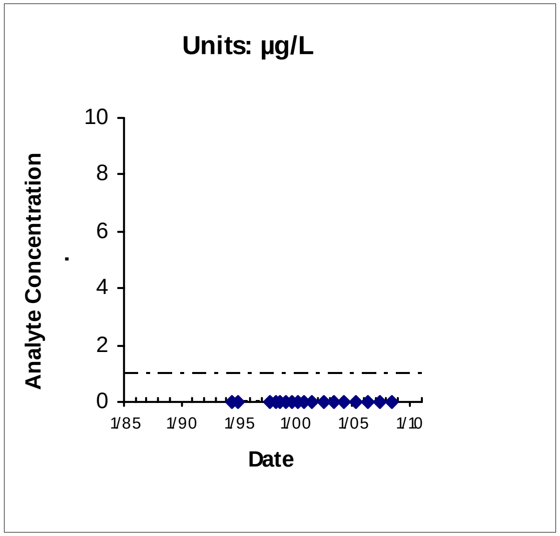
Location: MW201X07 Maximum: 0.0257



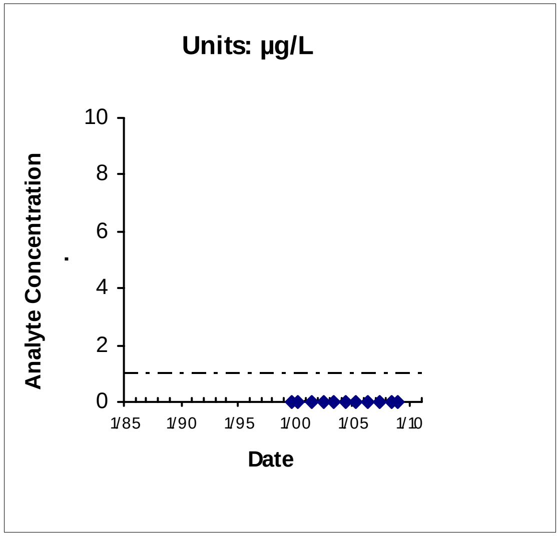
Location: MW261X07 Maximum: 4



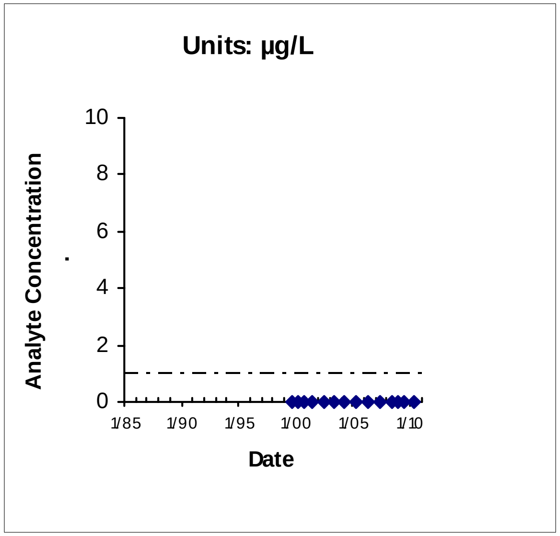
Location: MW284X07 Maximum: 0.0257



Location: MW303X07 Maximum: 0.0257



Location: MW600X07 Maximum: 0.0257



Location: MW601X07 Maximum: 0.0257

— - — - — IRG (1 µg/L)

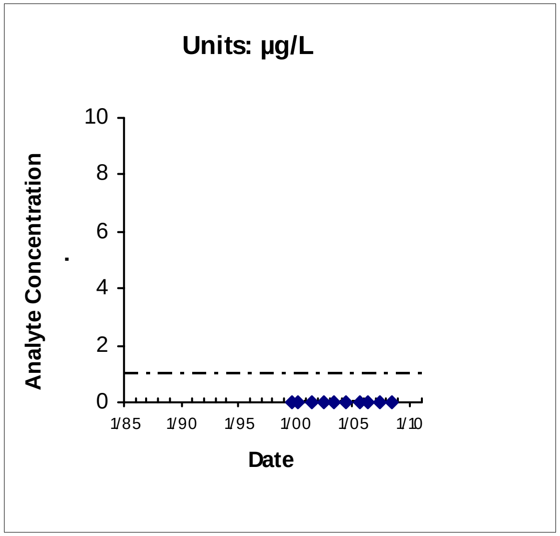
*Nondetects shown as the Method Detection Limit (0.0257 µg/L)

FIGURE 4.1-9

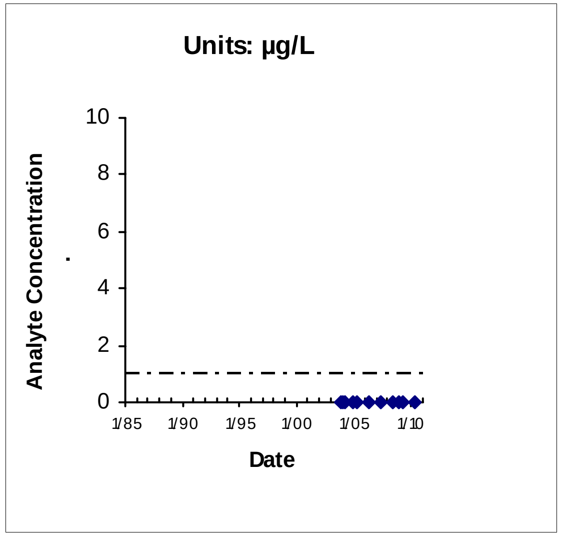
Site LF007

Benzene

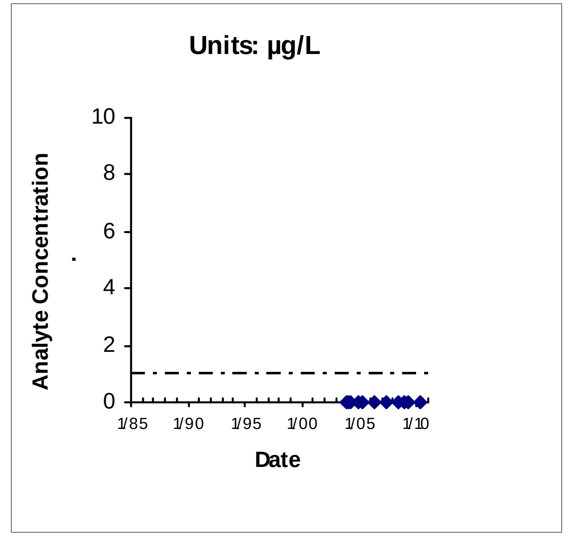
Chemical Time-series Plots



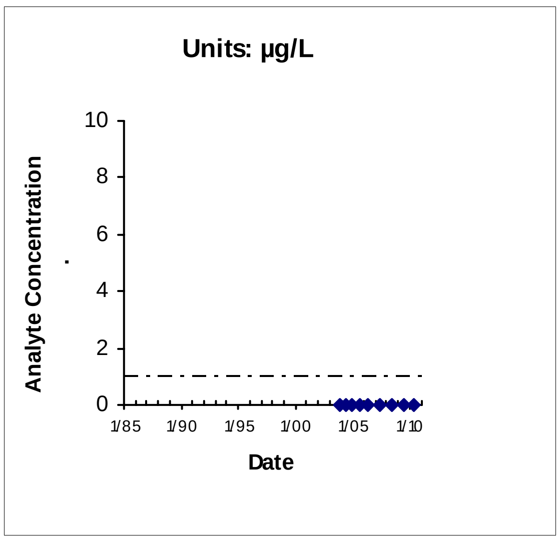
Location: MW602X07 Maximum: 0.0257



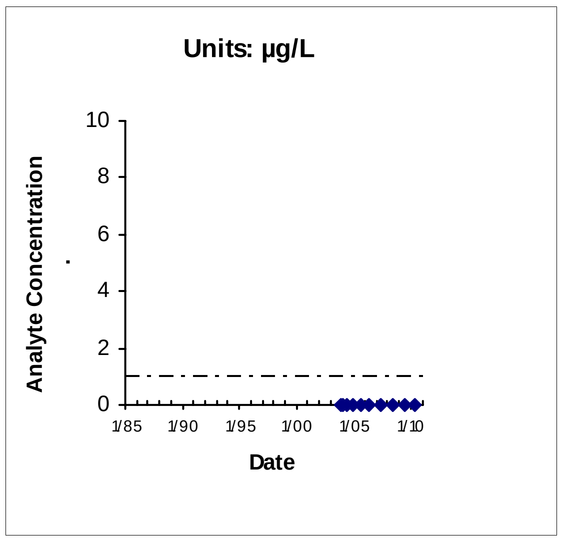
Location: MW612X07 Maximum: 0.0257



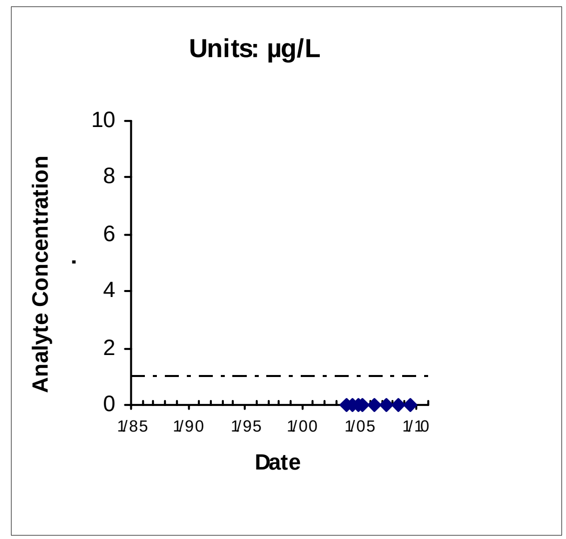
Location: MW613X07 Maximum: 0.0257



Location: MW616X07 Maximum: 0.0257



Location: MW617X07 Maximum: 0.0257



Location: MW618X07 Maximum: 0.0257

— - — - — IRG (1 µg/L)

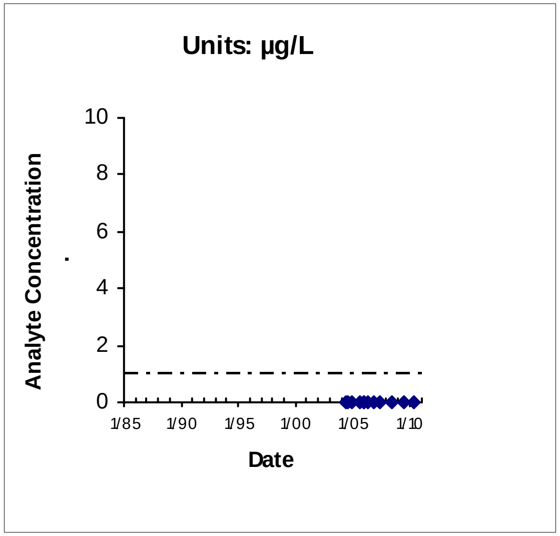
*Nondetects shown as the Method Detection Limit (0.0257 µg/L)

FIGURE 4.1-9

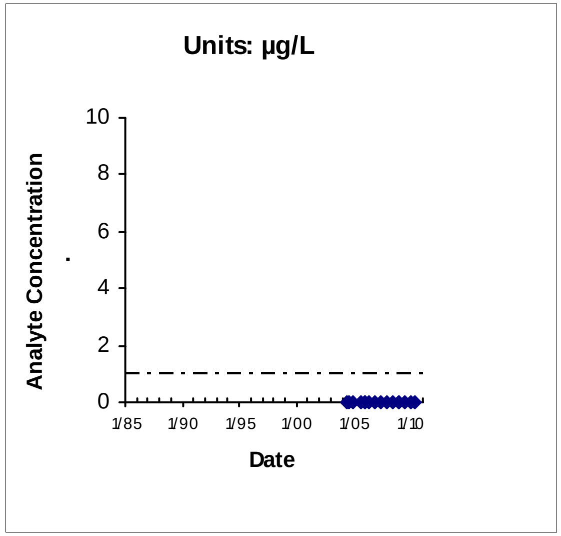
Site LF007

Benzene

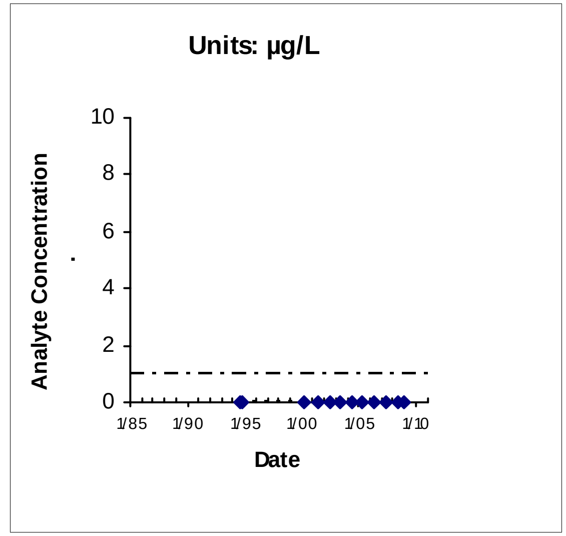
Chemical Time-series Plots



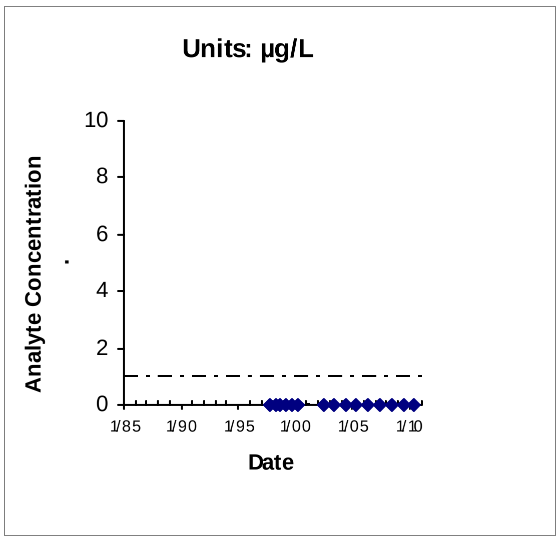
Location: MW619X07 Maximum: 0.0257



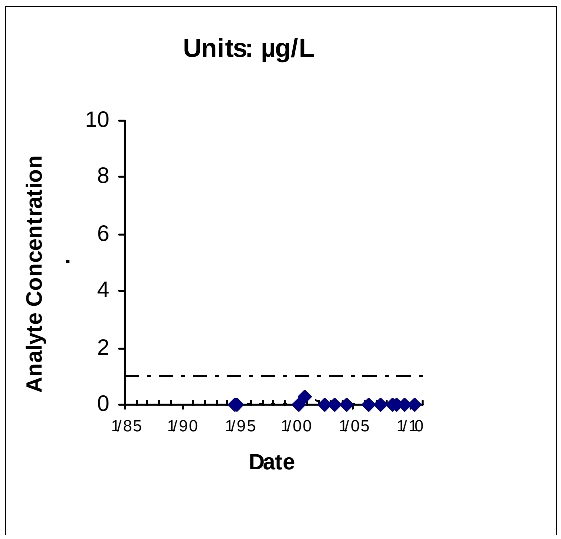
Location: MW620X07 Maximum: 0.0257



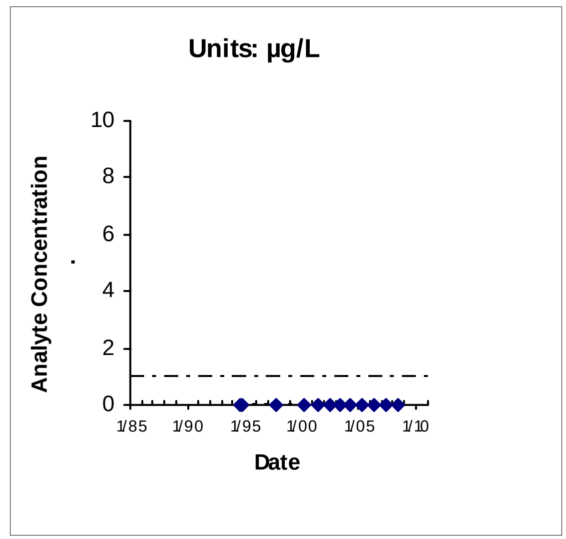
Location: MWAX07 Maximum: 0.0257



Location: MWBX07 Maximum: 0.0257



Location: MWCX07 Maximum: 0.3



Location: MWDX07 Maximum: 0.0257

— - — - — IRG (1 µg/L)

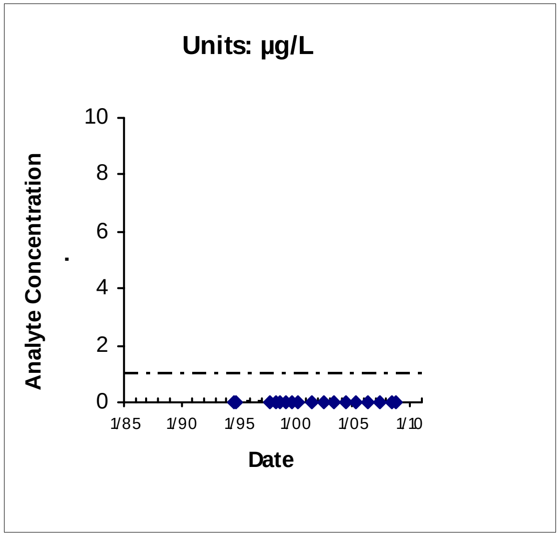
*Nondetects shown as the Method Detection Limit (0.0257 µg/L)

FIGURE 4.1-9

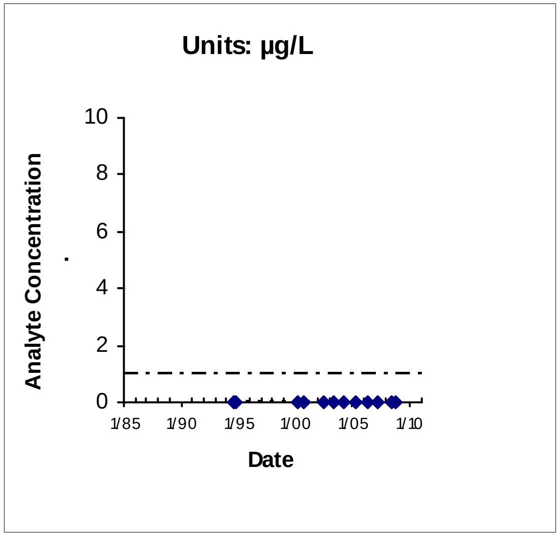
Site LF007

Benzene

Chemical Time-series Plots



Location: MWFX07 Maximum: 0.0257



Location: MWGX07 Maximum: 0.0257

— - — - — IRG (1 µg/L)

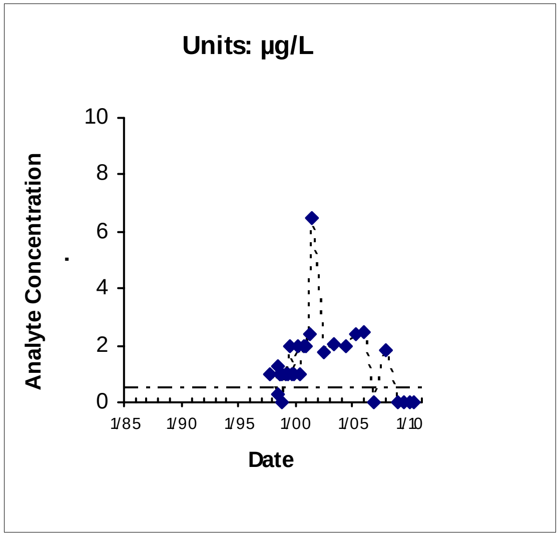
*Nondetects shown as the Method Detection Limit (0.0257 µg/L)

FIGURE 4.1-9

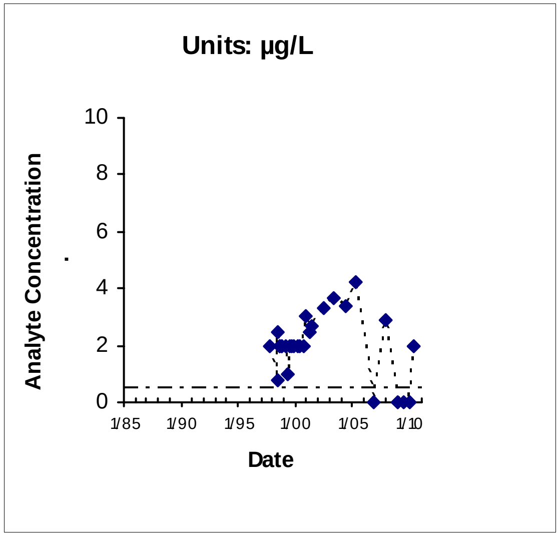
Site LF007

Benzene

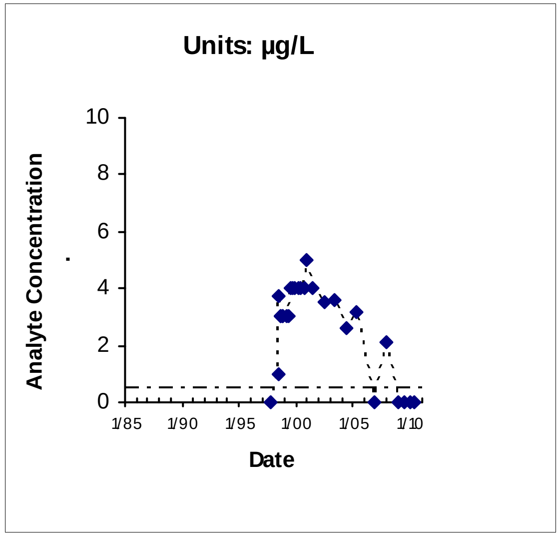
Chemical Time-series Plots



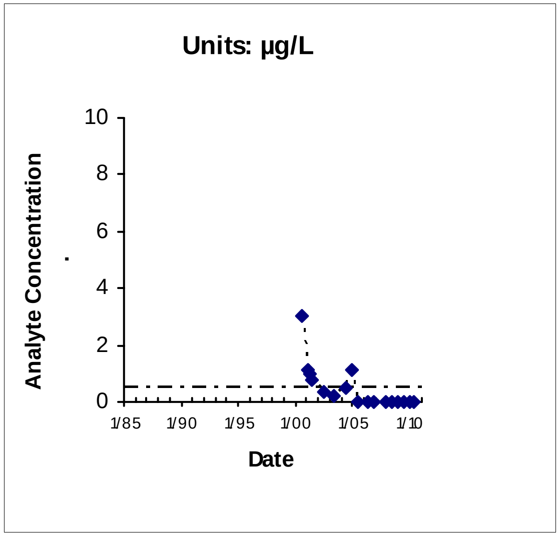
Location: EW01X05 Maximum: 6.5



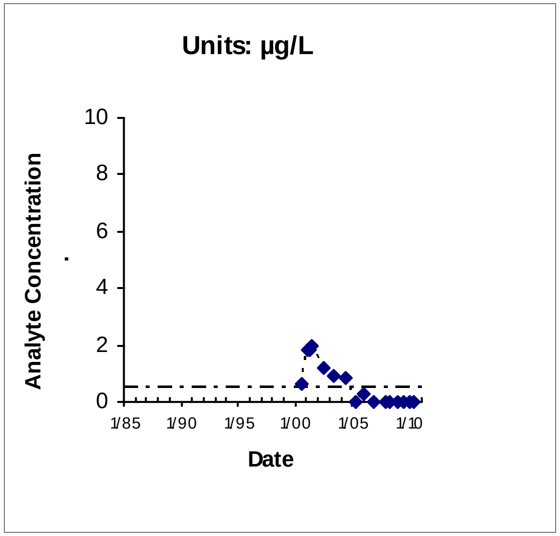
Location: EW02X05 Maximum: 4.2



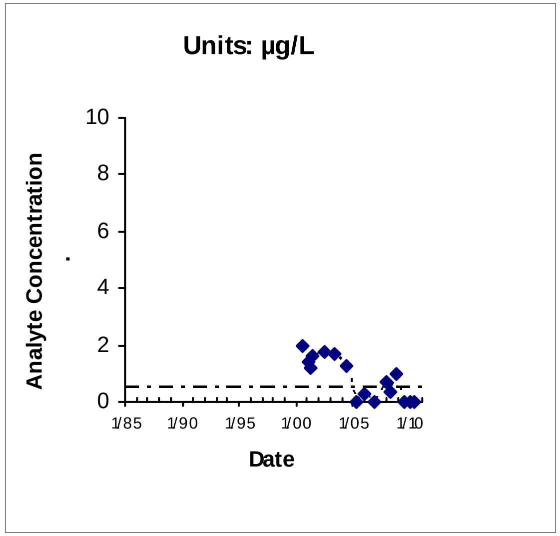
Location: EW03X05 Maximum: 5



Location: EW731X05 Maximum: 3



Location: EW732X05 Maximum: 2



Location: EW733X05 Maximum: 2

— - — - — IRG (0.5 µg/L)

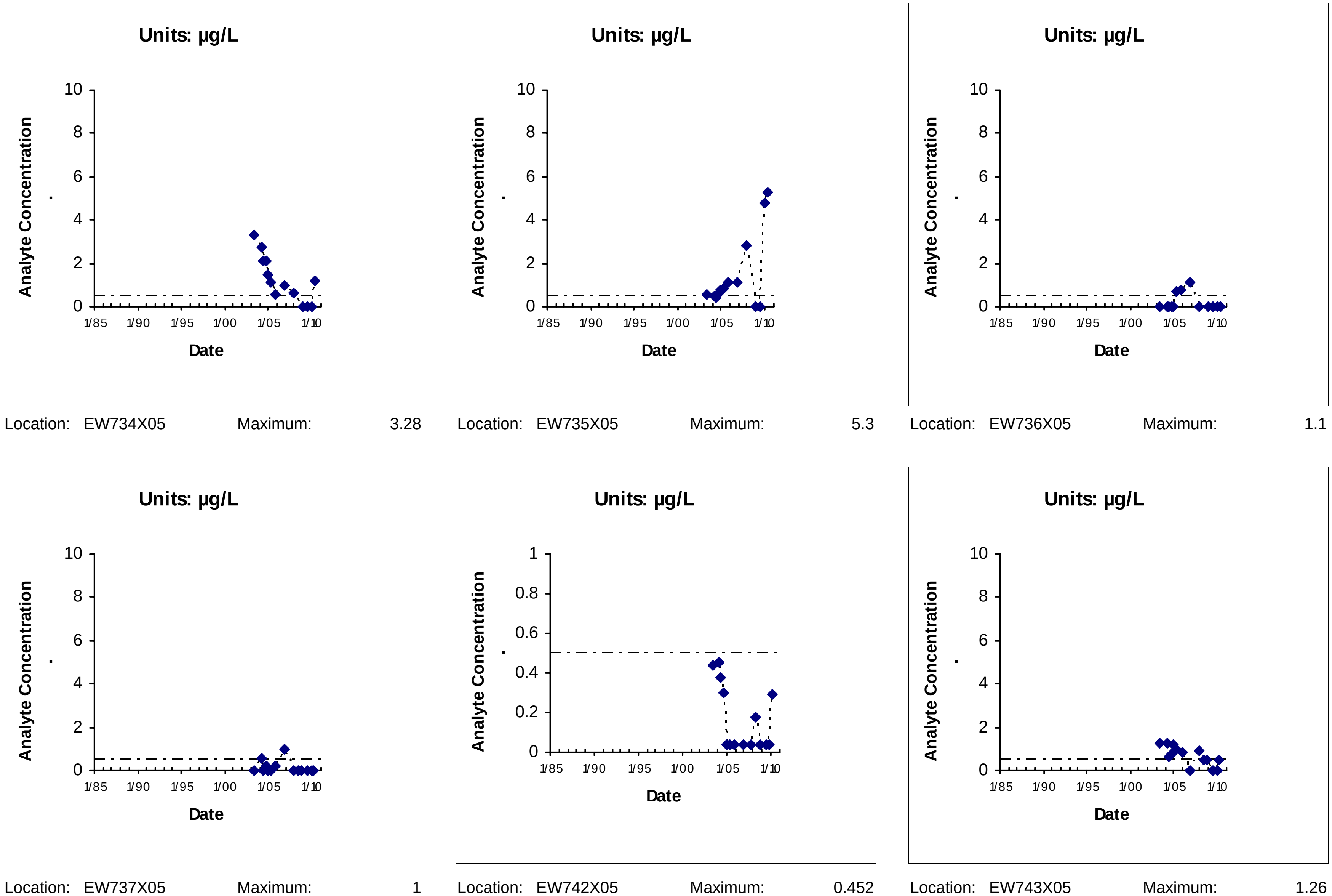
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)

FIGURE 4.3-9

Sites FT005/SS029/SS030

1,2-DCA

Chemical Time-series Plots



— - — - — IRG (0.5 µg/L)

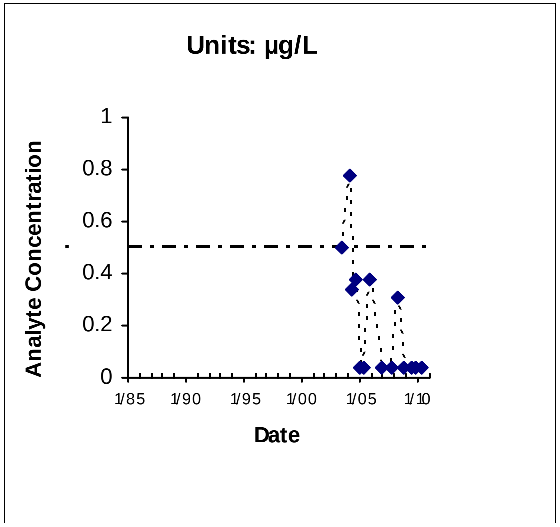
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)

FIGURE 4.3-9

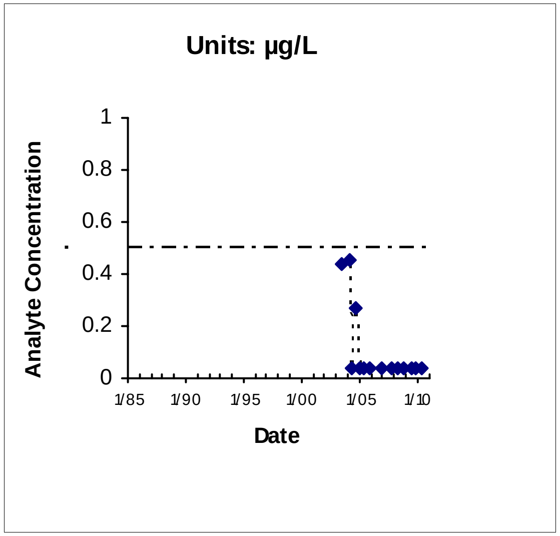
Sites FT005/SS029/SS030

1,2-DCA

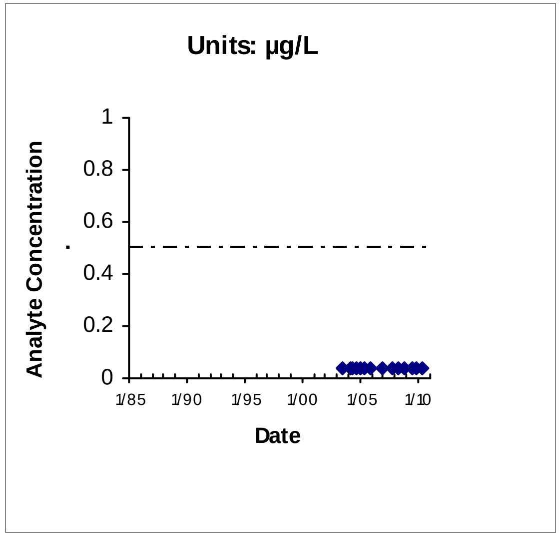
Chemical Time-series Plots



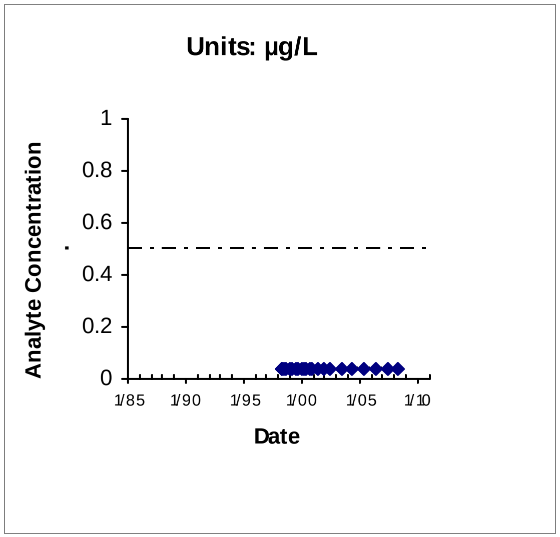
Location: EW744X05 Maximum: 0.779



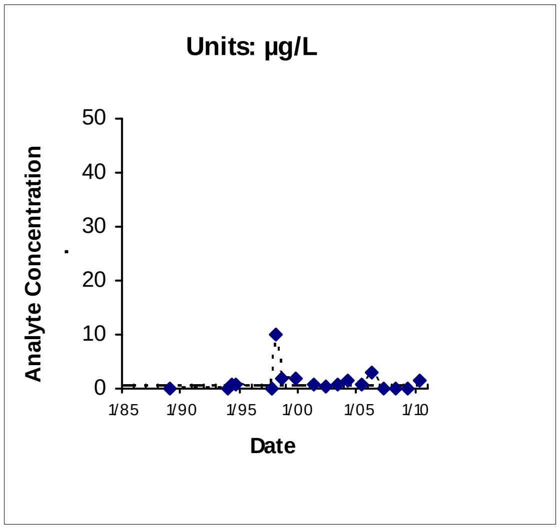
Location: EW745X05 Maximum: 0.456



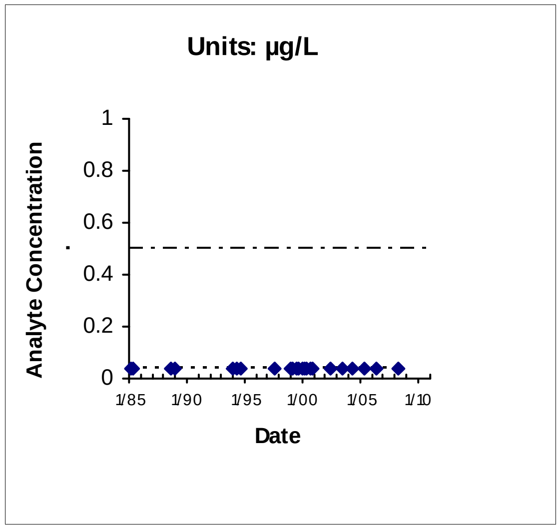
Location: EW746X05 Maximum: 0.0348



Location: MW01X05 Maximum: 0.0348



Location: MW119X05 Maximum: 10



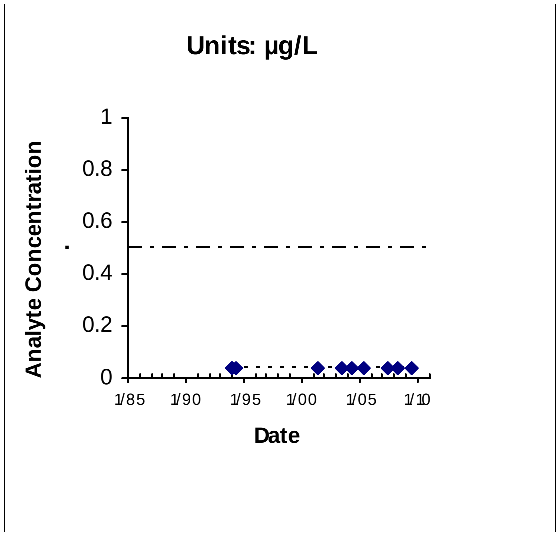
Location: MW122X05 Maximum: 0.0348

FIGURE 4.3-9

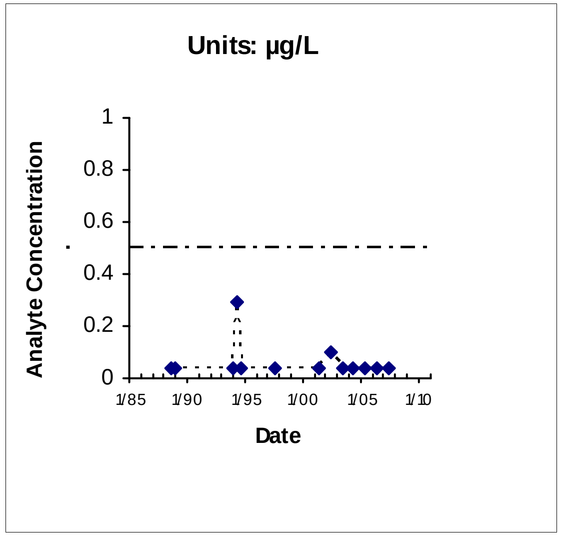
Sites FT005/SS029/SS030
1,2-DCA
Chemical Time-series Plots

— - — - — IRG (0.5 µg/L)

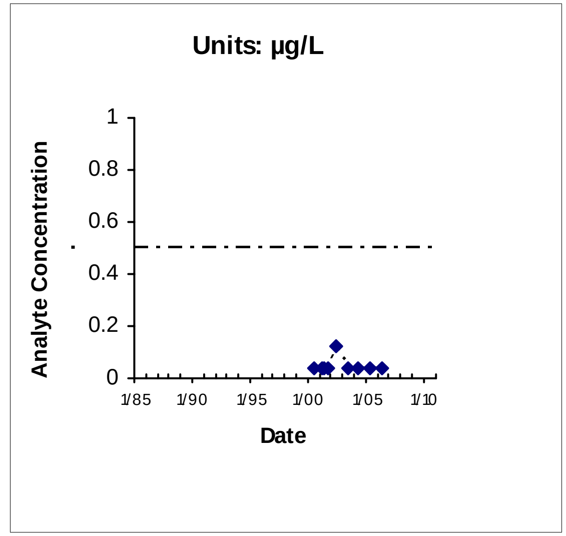
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)



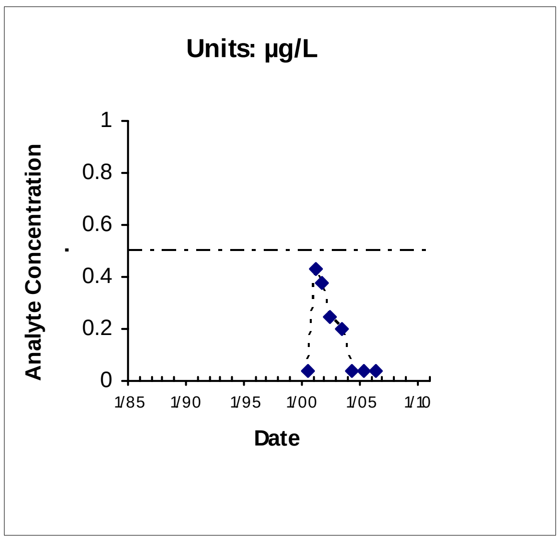
Location: MW217X05 Maximum: 0.0348



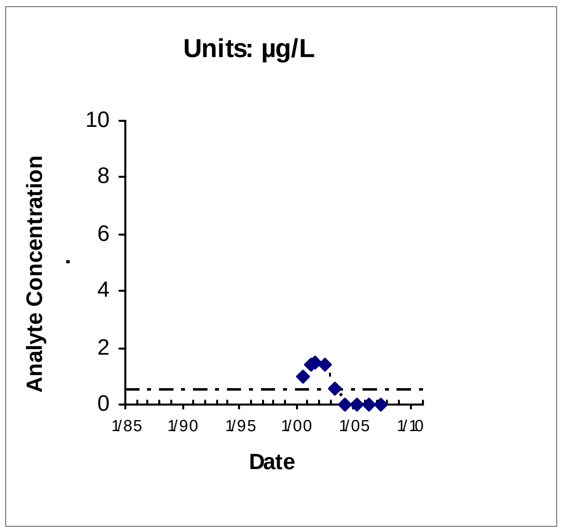
Location: MW228X05 Maximum: 0.29



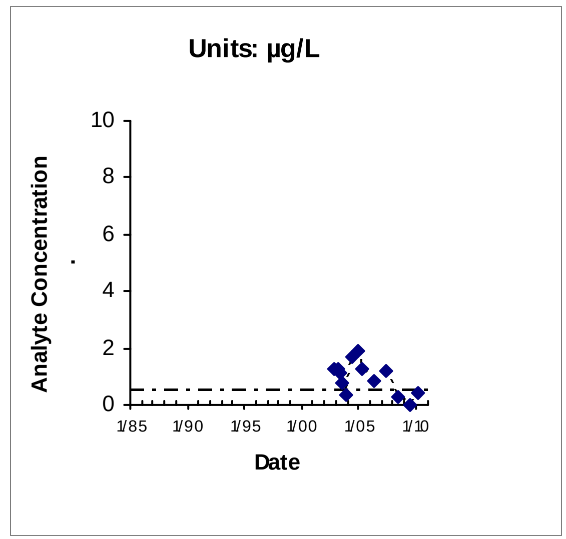
Location: MW738X05 Maximum: 0.12



Location: MW740X05 Maximum: 0.43



Location: MW741X05 Maximum: 1.5



Location: MW747X05 Maximum: 1.9

— - — - — IRG (0.5 µg/L)

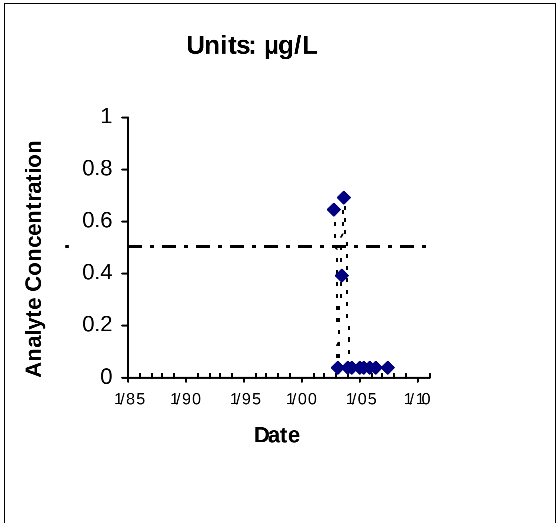
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)

FIGURE 4.3-9

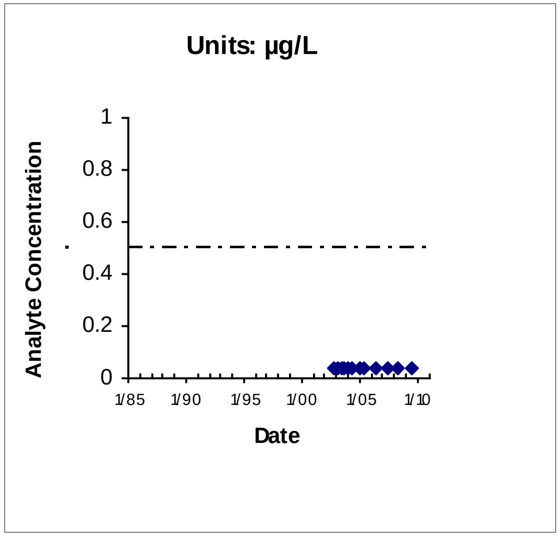
Sites FT005/SS029/SS030

1,2-DCA

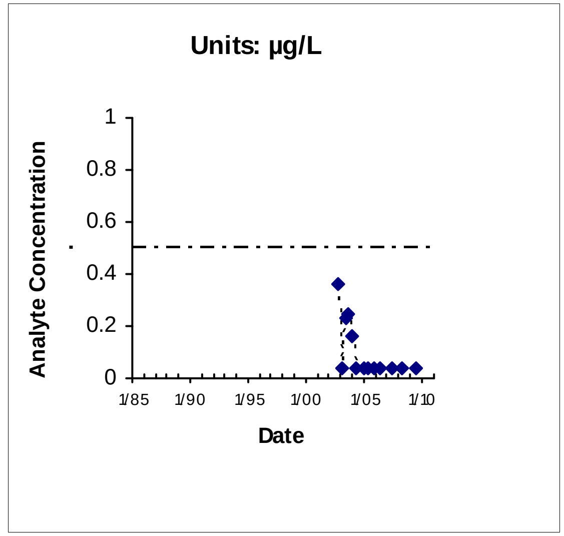
Chemical Time-series Plots



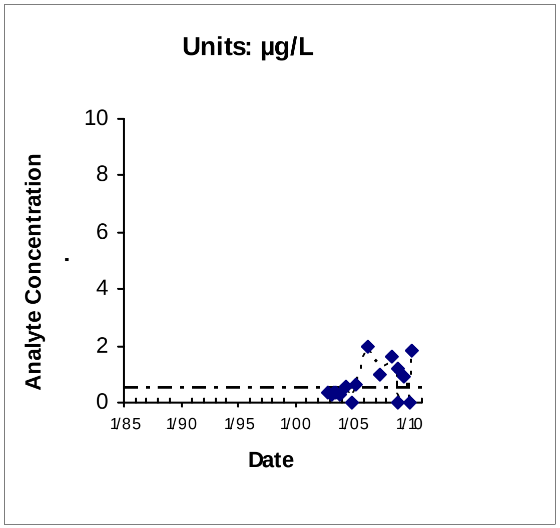
Location: MW748X05 Maximum: 0.69



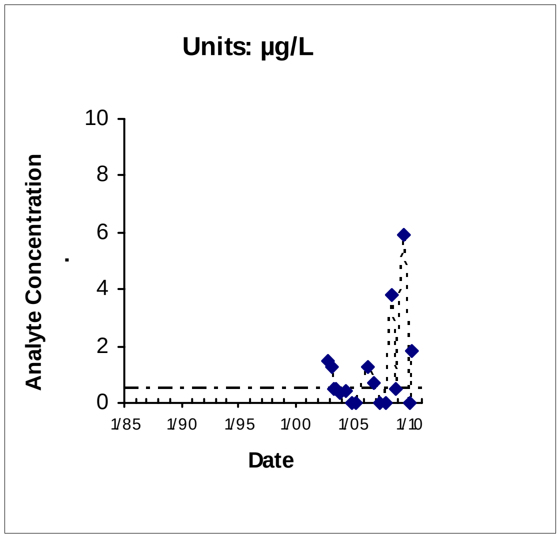
Location: MW763X05 Maximum: 0.0348



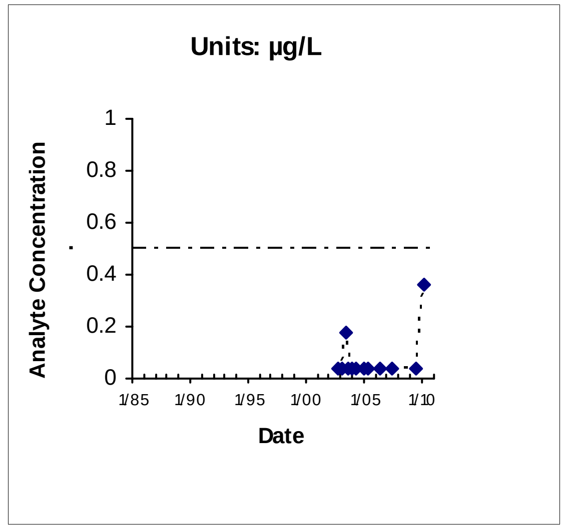
Location: MW764X05 Maximum: 0.36



Location: MW765X05 Maximum: 2



Location: MW766X05 Maximum: 5.9



Location: MW767X05 Maximum: 0.36

— - — - — IRG (0.5 µg/L)

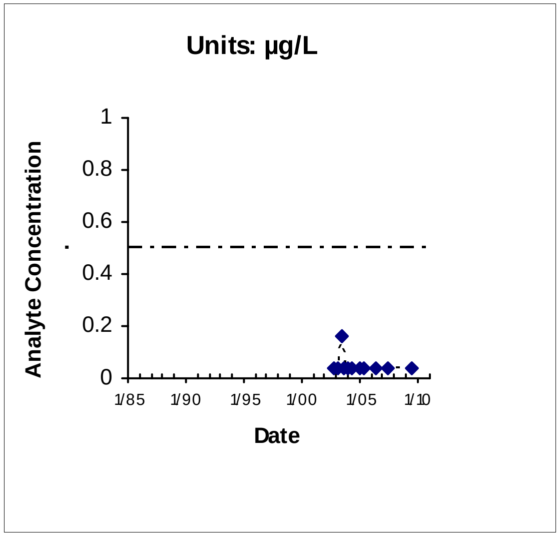
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)

FIGURE 4.3-9

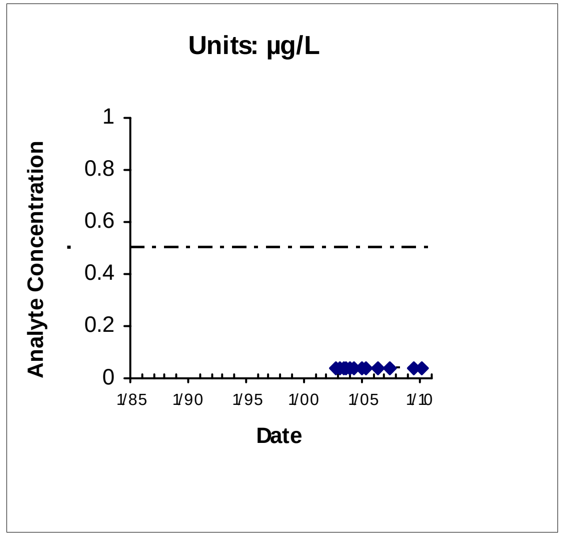
Sites FT005/SS029/SS030

1,2-DCA

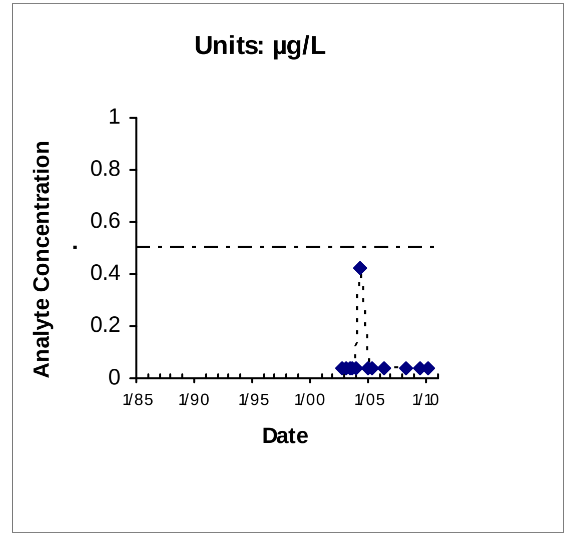
Chemical Time-series Plots



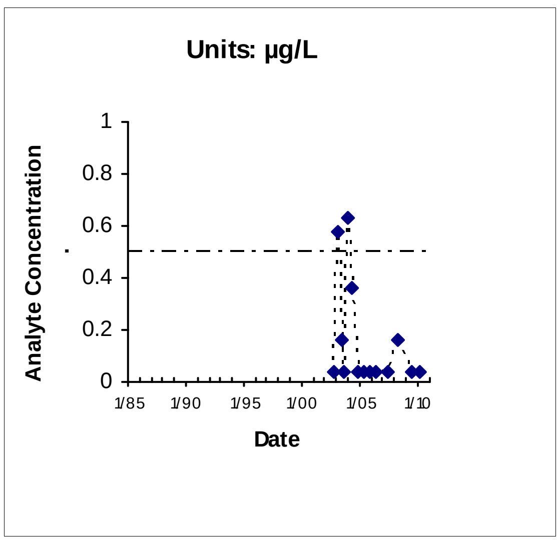
Location: MW768X05 Maximum: 0.16



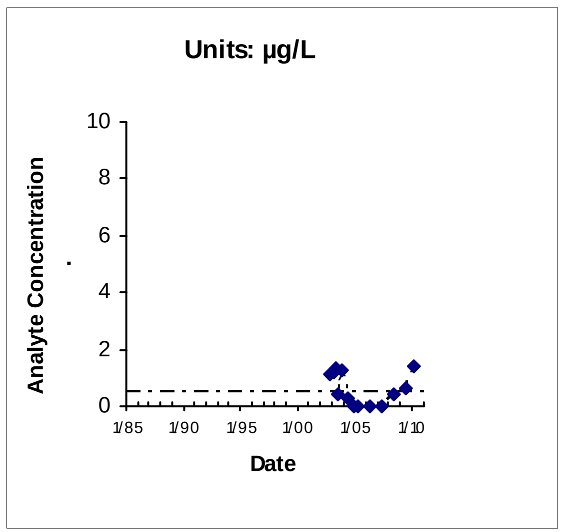
Location: MW769X05 Maximum: 0.0348



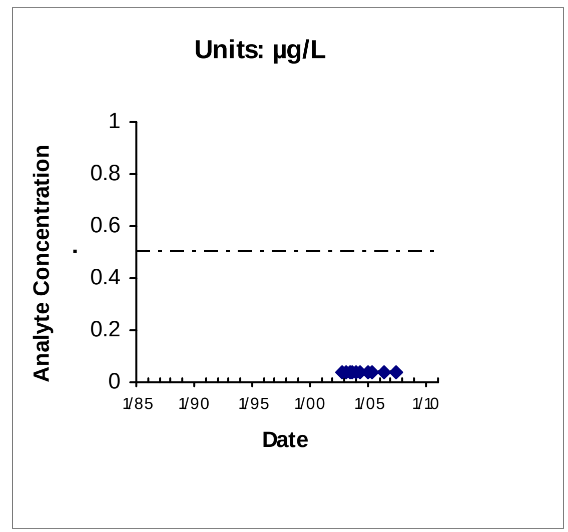
Location: MW770X05 Maximum: 0.42



Location: MW771X05 Maximum: 0.627



Location: MW772X05 Maximum: 1.4



Location: MW773X05 Maximum: 0.0348

FIGURE 4.3-9

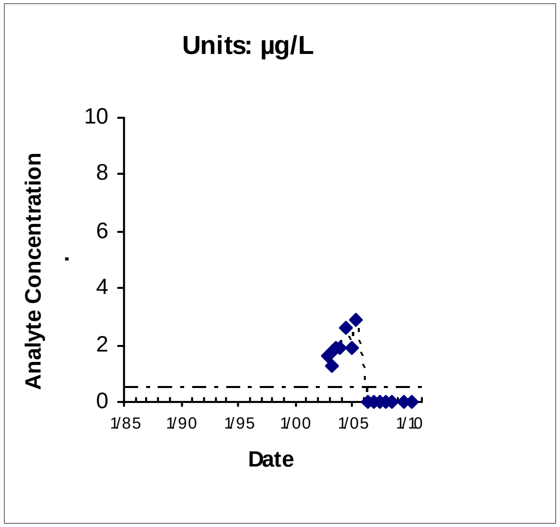
Sites FT005/SS029/SS030

1,2-DCA

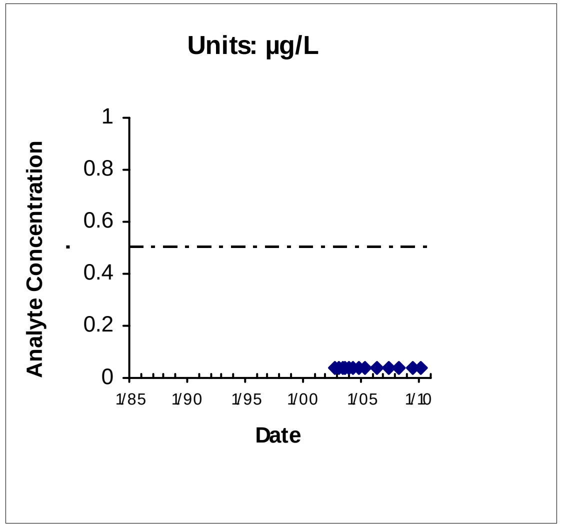
Chemical Time-series Plots

— - — - — IRG (0.5 µg/L)

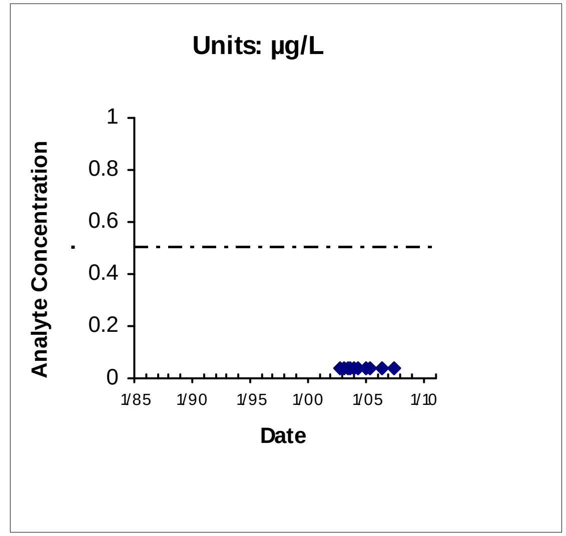
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)



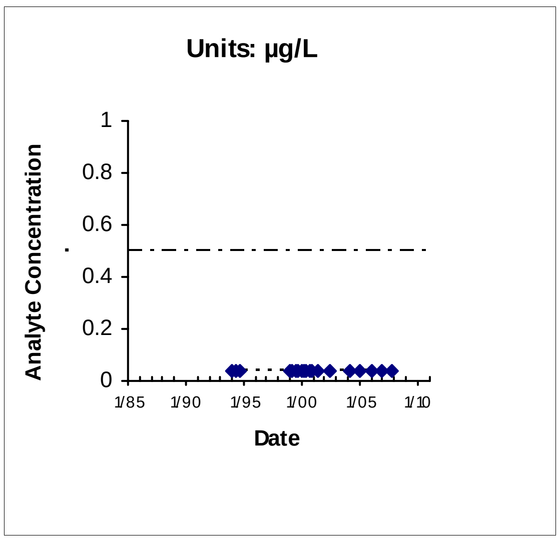
Location: MW774X05 Maximum: 2.9



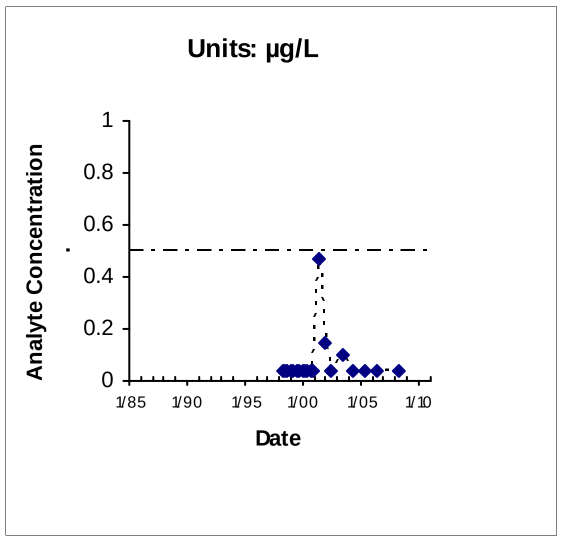
Location: MW775X05 Maximum: 0.0348



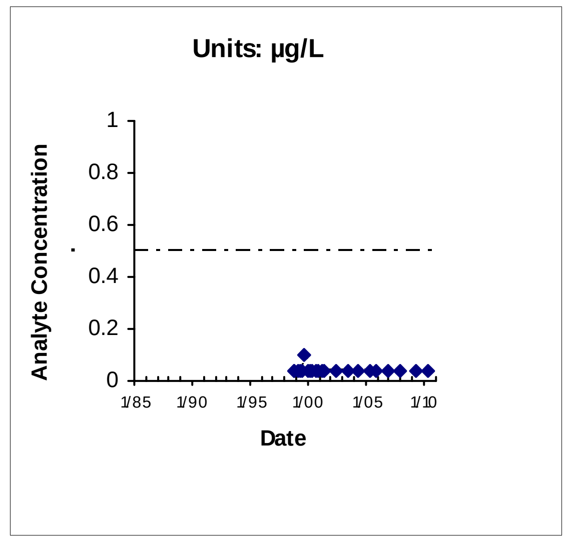
Location: MW776X05 Maximum: 0.0348



Location: MW1003X05 Maximum: 0.0348



Location: PZ01X05 Maximum: 0.47



Location: EW01X29 Maximum: 0.1

— - — - — IRG (0.5 µg/L)

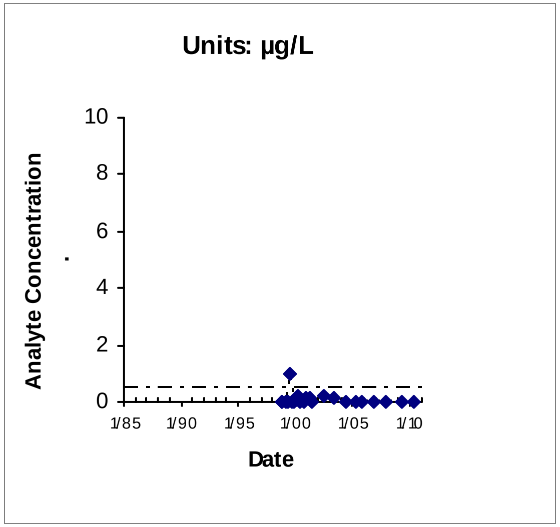
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)

FIGURE 4.3-9

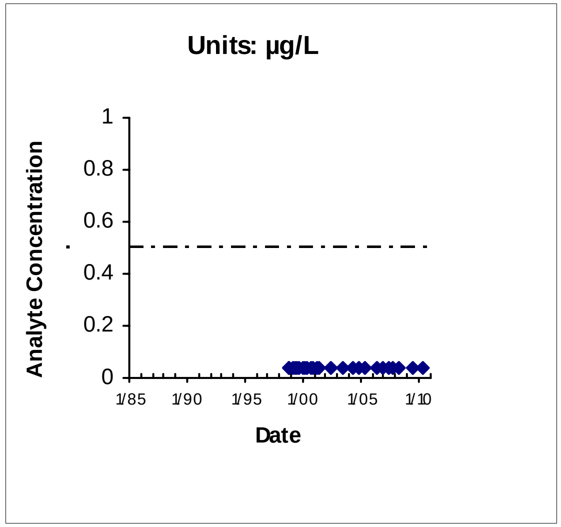
Sites FT005/SS029/SS030

1,2-DCA

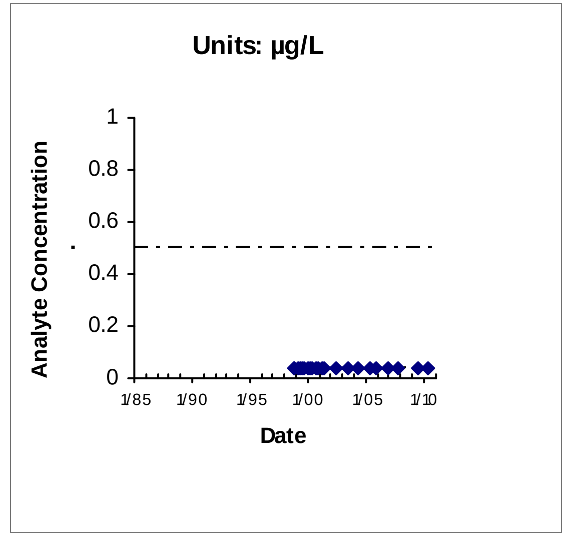
Chemical Time-series Plots



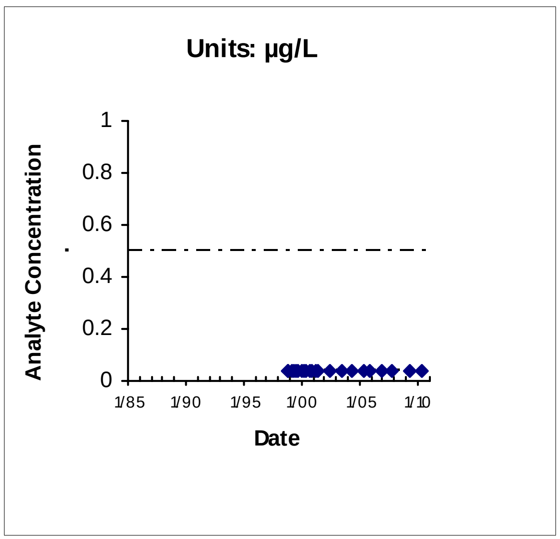
Location: EW02X29 Maximum: 1



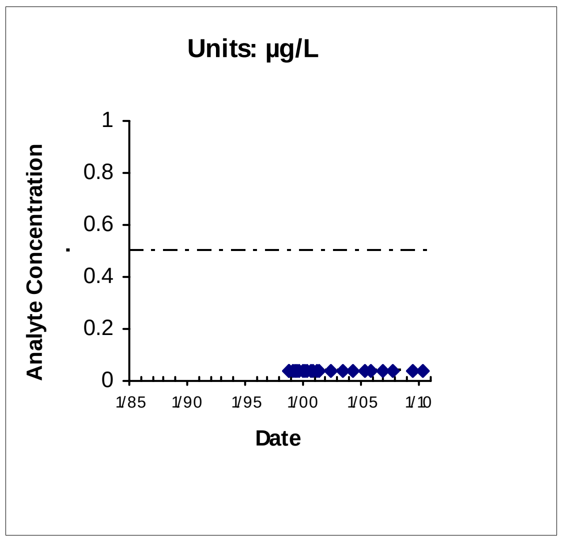
Location: EW03X29 Maximum: 0.0348



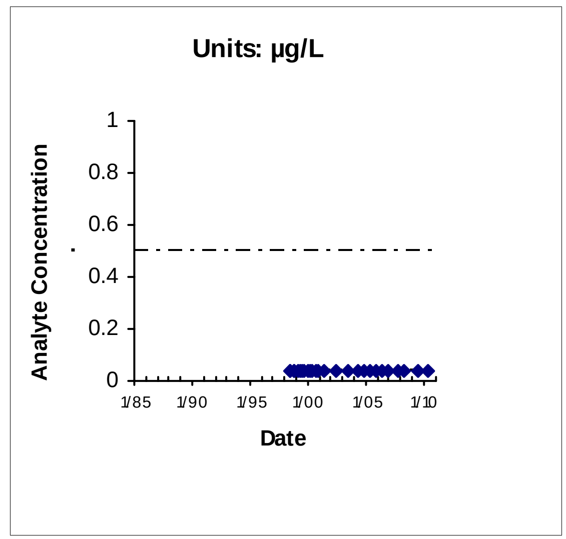
Location: EW04X29 Maximum: 0.0348



Location: EW05X29 Maximum: 0.0348



Location: EW06X29 Maximum: 0.0348



Location: EW07X29 Maximum: 0.0348

— - — - — IRG (0.5 µg/L)

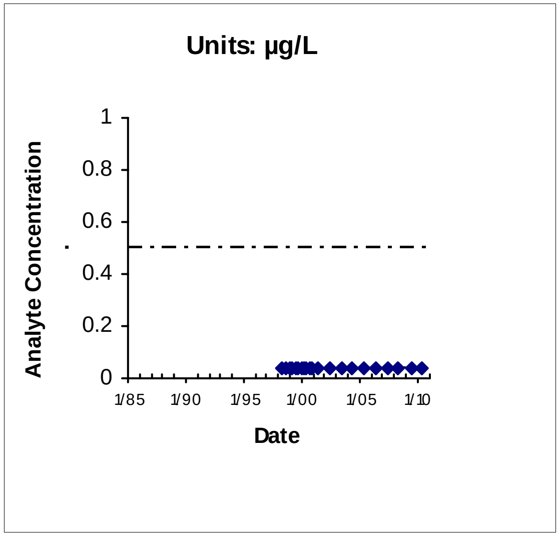
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)

FIGURE 4.3-9

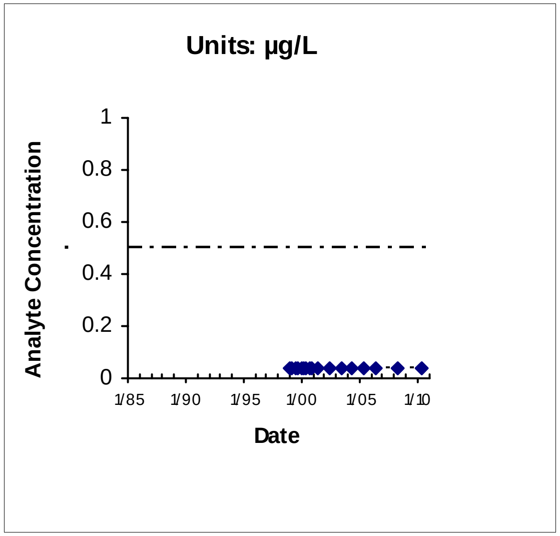
Sites FT005/SS029/SS030

1,2-DCA

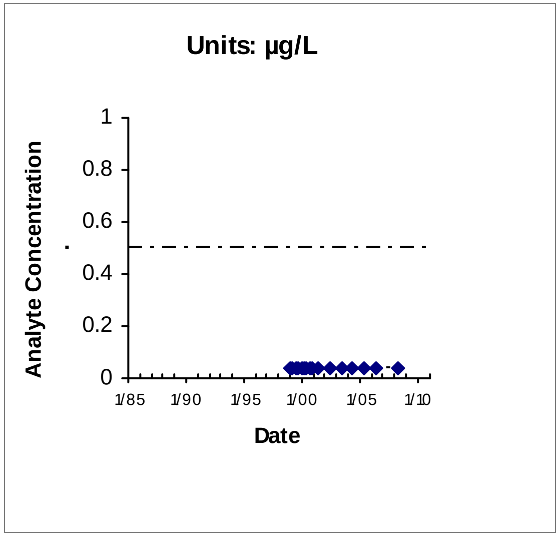
Chemical Time-series Plots



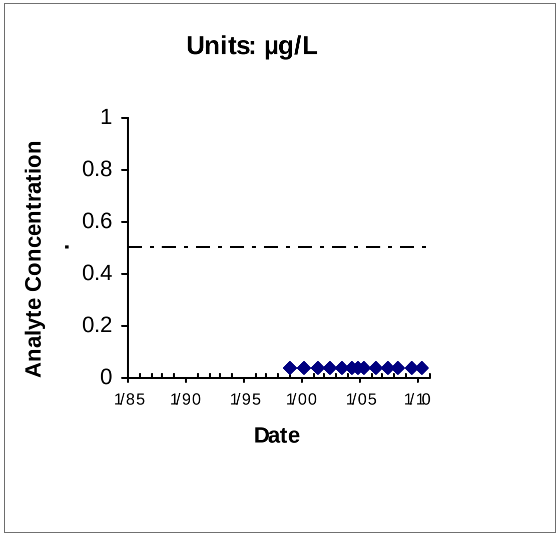
Location: MW01X29 Maximum: 0.0348



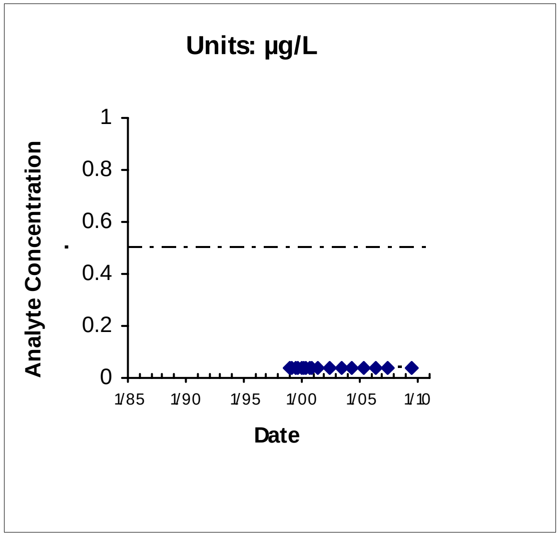
Location: MW02X29 Maximum: 0.0348



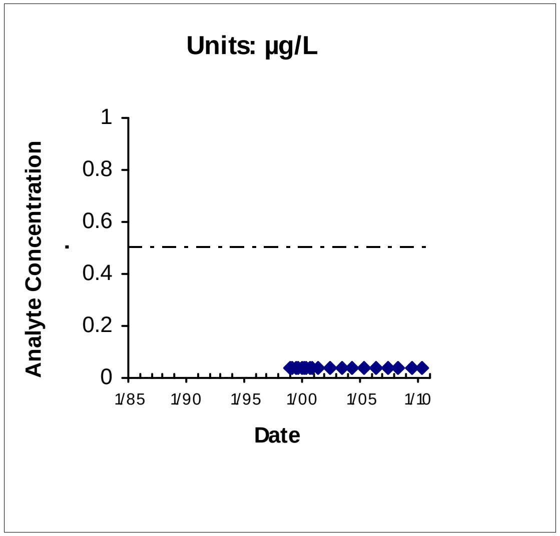
Location: MW03X29 Maximum: 0.0348



Location: MW04X29 Maximum: 0.0348



Location: MW05X29 Maximum: 0.0348



Location: MW06X29 Maximum: 0.0348

— - — - — IRG (0.5 µg/L)

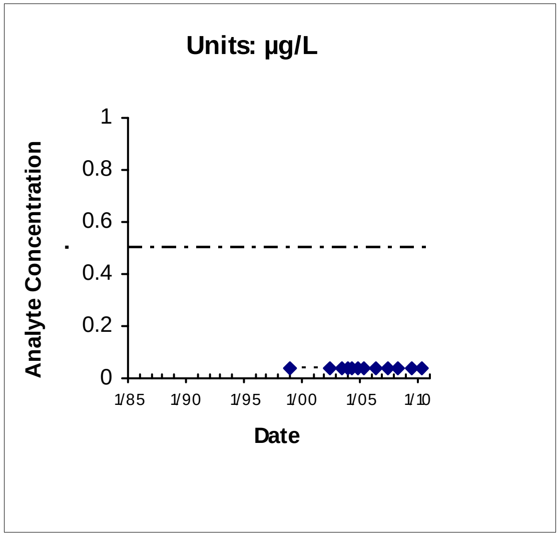
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)

FIGURE 4.3-9

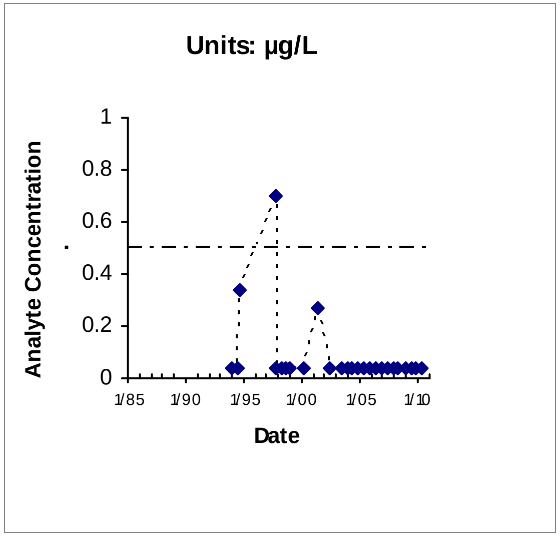
Sites FT005/SS029/SS030

1,2-DCA

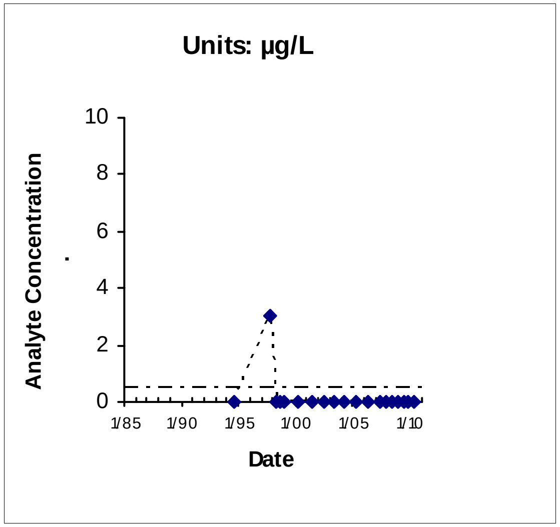
Chemical Time-series Plots



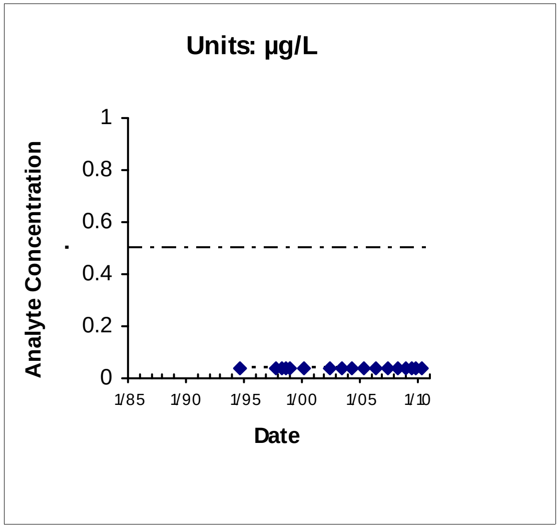
Location: MW07X29 Maximum: 0.0348



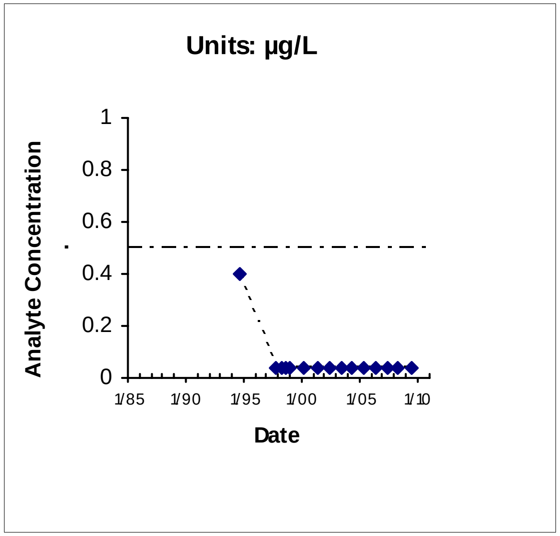
Location: MW329X29 Maximum: 0.7



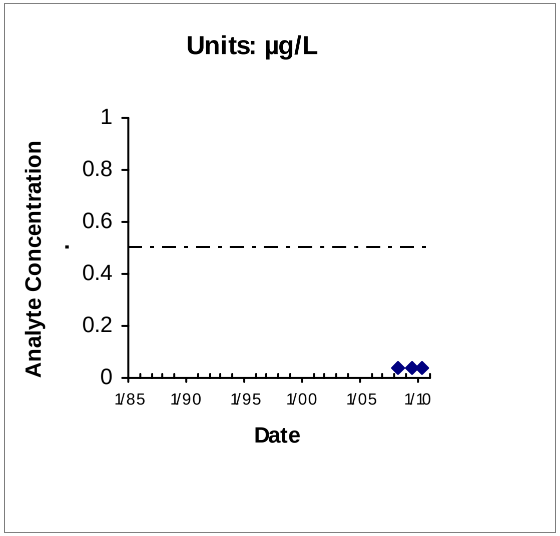
Location: MW1031X29 Maximum: 3



Location: MW1032X29 Maximum: 0.0348



Location: MW1033X29 Maximum: 0.4



Location: MW1042x29 Maximum: 0.0348

FIGURE 4.3-9

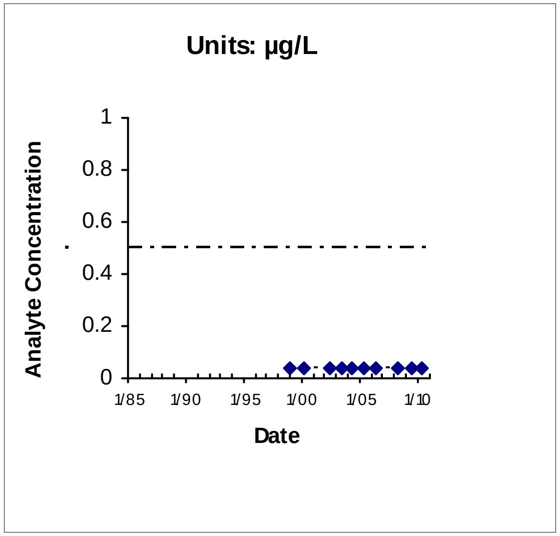
Sites FT005/SS029/SS030

1,2-DCA

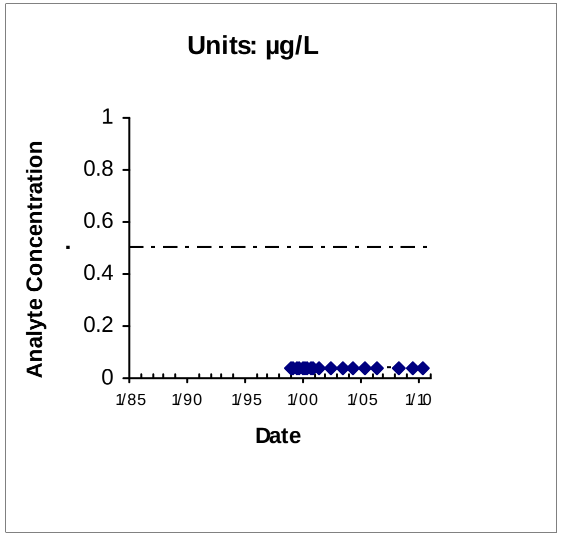
Chemical Time-series Plots

— - — - — IRG (0.5 µg/L)

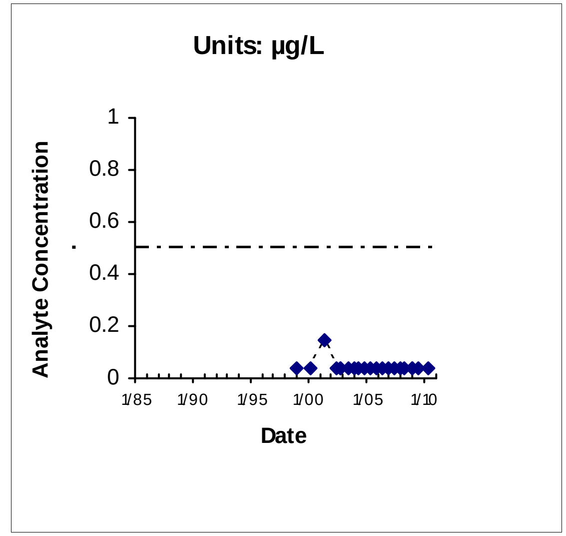
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)



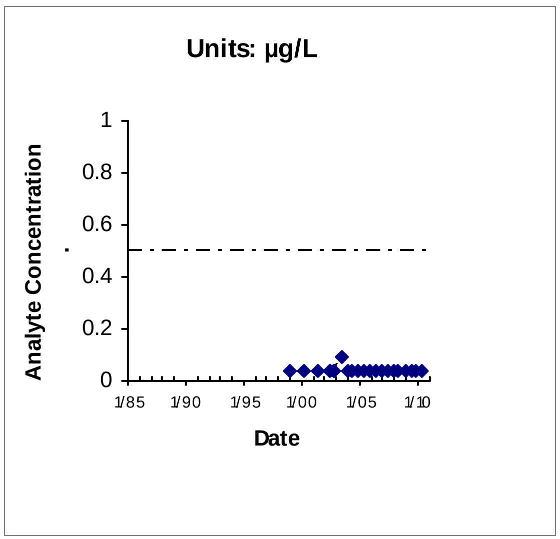
Location: MW1043X29 Maximum: 0.0348



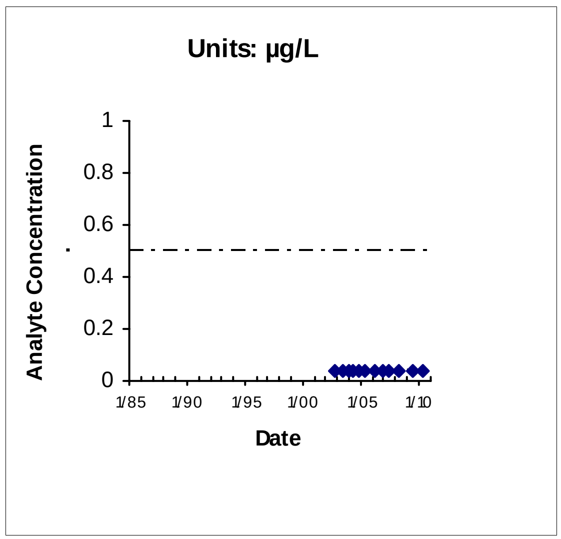
Location: MW1044X29 Maximum: 0.0348



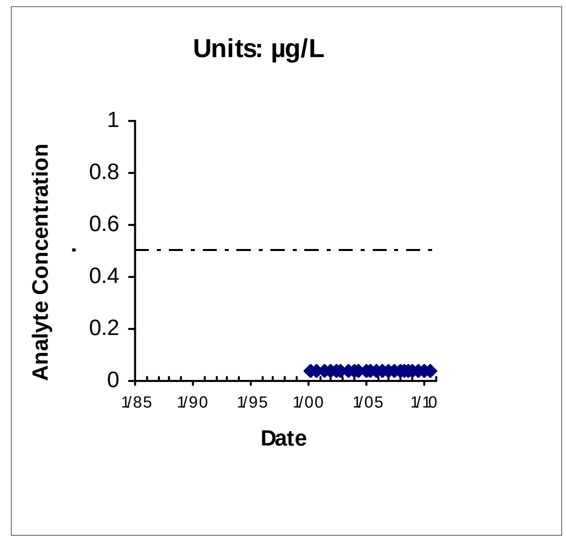
Location: PZ01DX29 Maximum: 0.15



Location: PZ01SX29 Maximum: 0.09



Location: SWPZ01X29 Maximum: 0.0348



Location: DWSET1X30 Maximum: 0.0348

— - — - — IRG (0.5 µg/L)

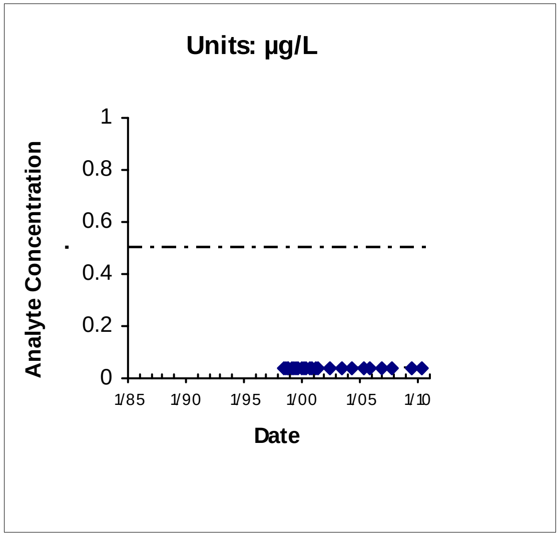
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)

FIGURE 4.3-9

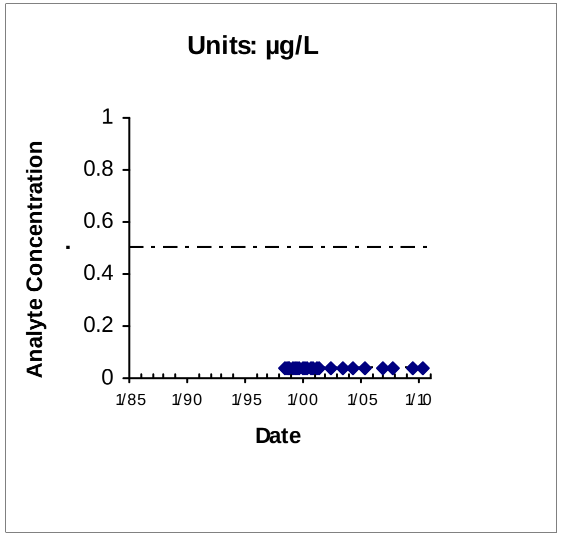
Sites FT005/SS029/SS030

1,2-DCA

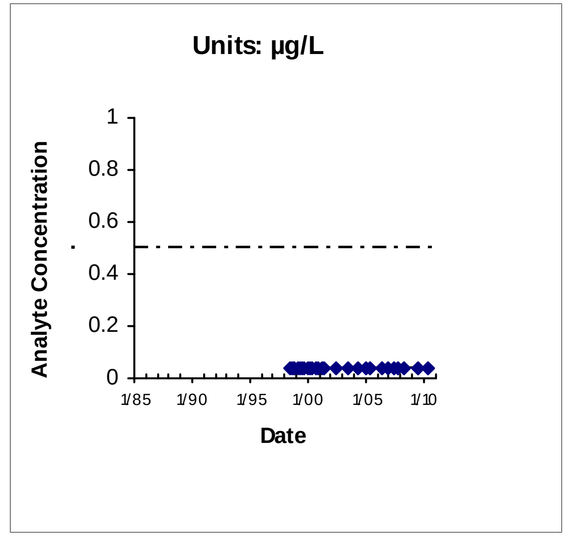
Chemical Time-series Plots



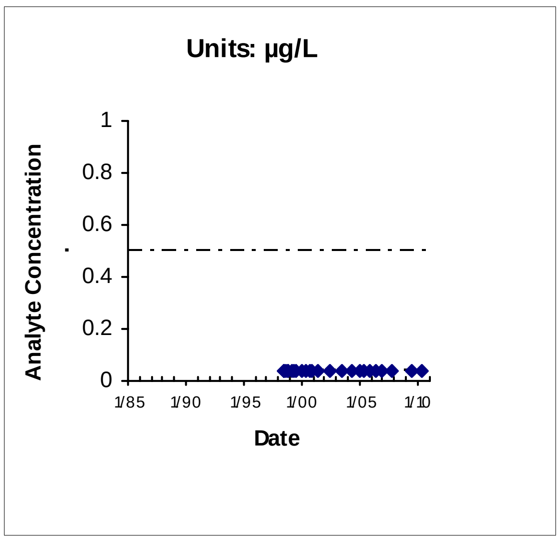
Location: EW01X30 Maximum: 0.0348



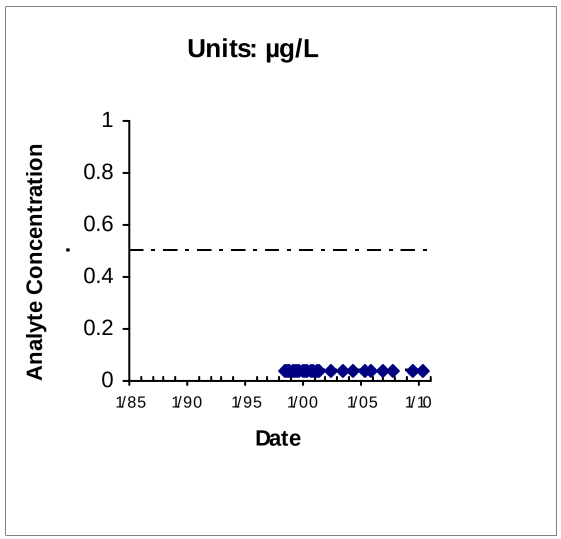
Location: EW02X30 Maximum: 0.0348



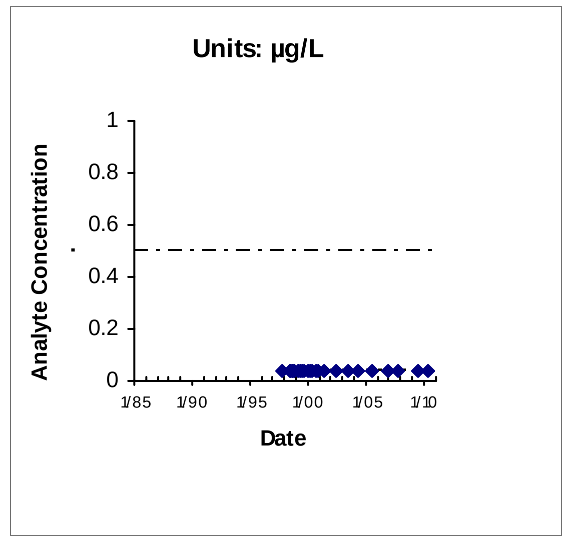
Location: EW03X30 Maximum: 0.0348



Location: EW04X30 Maximum: 0.0348



Location: EW05X30 Maximum: 0.0348



Location: EW06X30 Maximum: 0.0348

— - — - — IRG (0.5 µg/L)

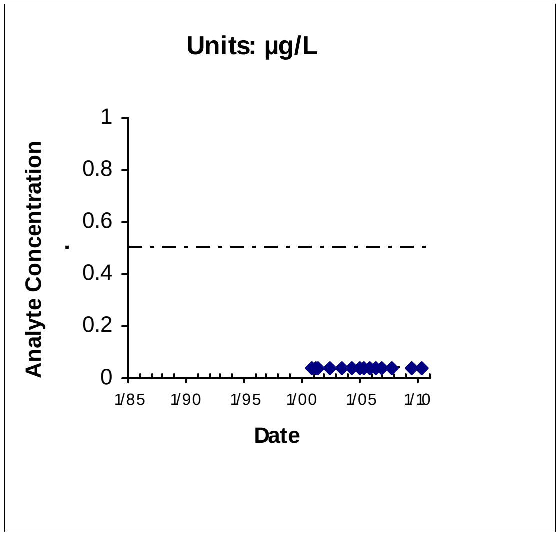
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)

FIGURE 4.3-9

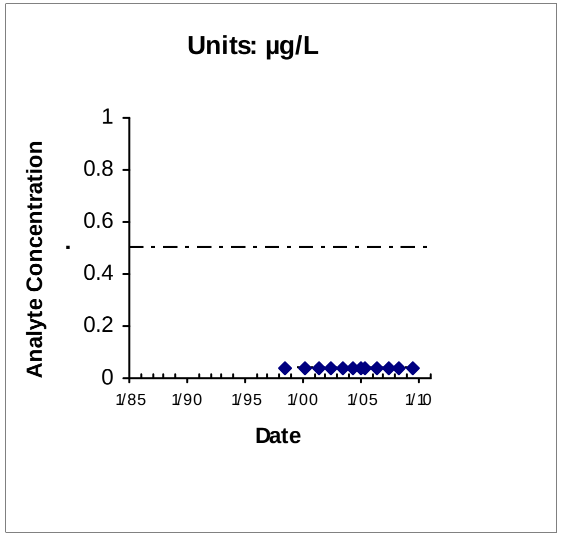
Sites FT005/SS029/SS030

1,2-DCA

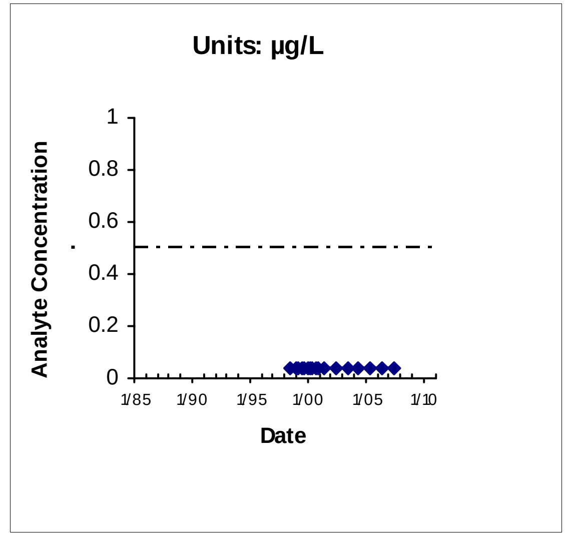
Chemical Time-series Plots



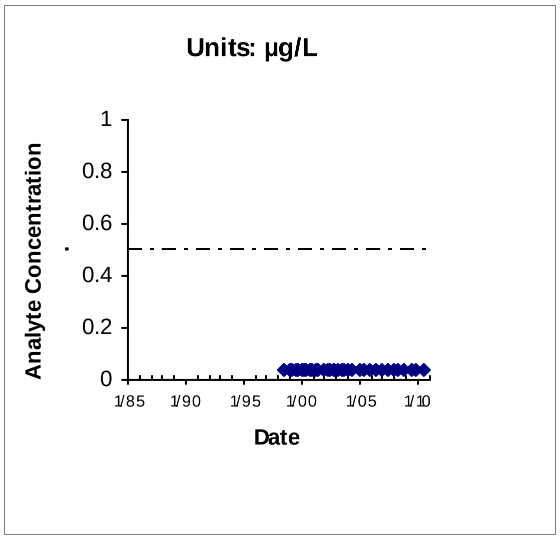
Location: EW711X30 Maximum: 0.0348



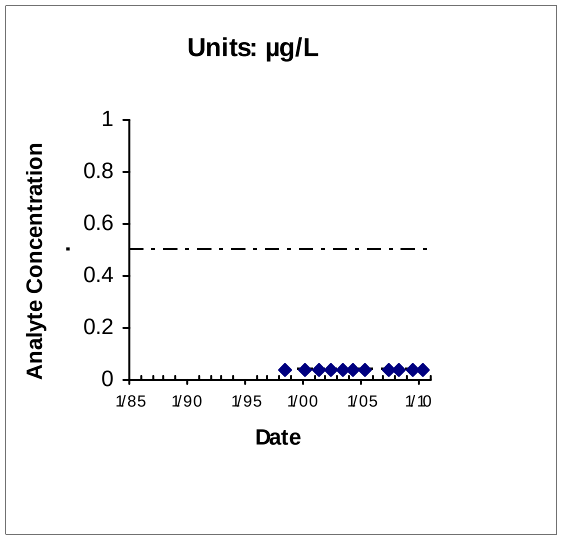
Location: MW01X30 Maximum: 0.0348



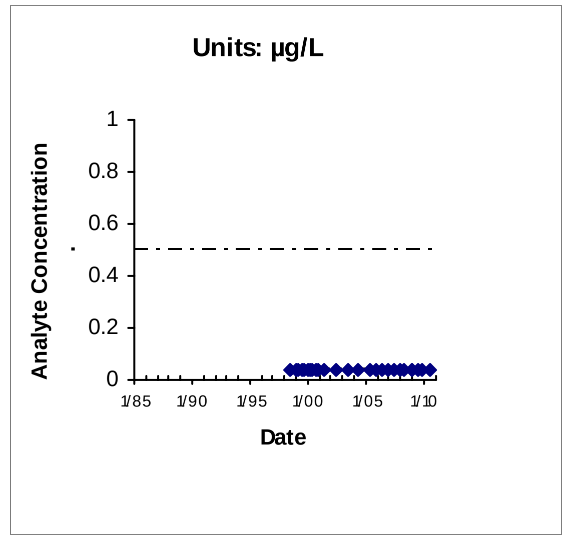
Location: MW02X30 Maximum: 0.0348



Location: MW03X30 Maximum: 0.0348



Location: MW04X30 Maximum: 0.0348



Location: MW05X30 Maximum: 0.0348

— - — - — IRG (0.5 µg/L)

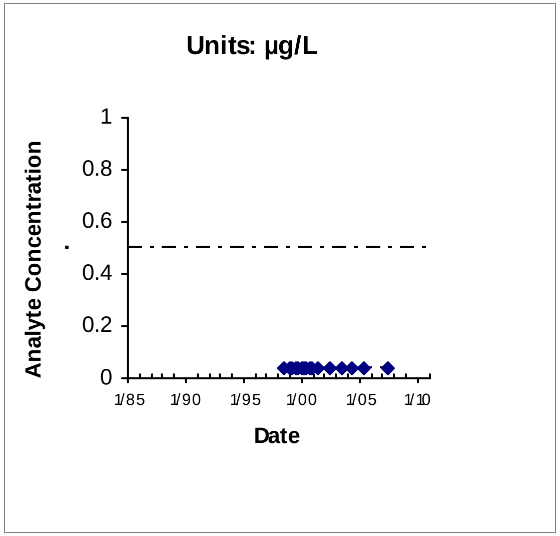
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)

FIGURE 4.3-9

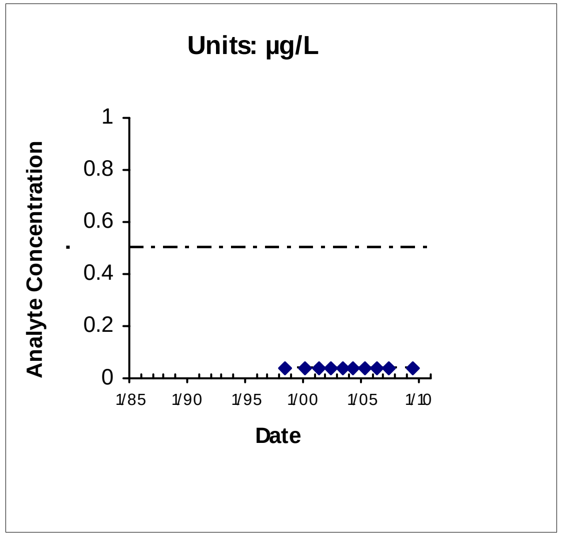
Sites FT005/SS029/SS030

1,2-DCA

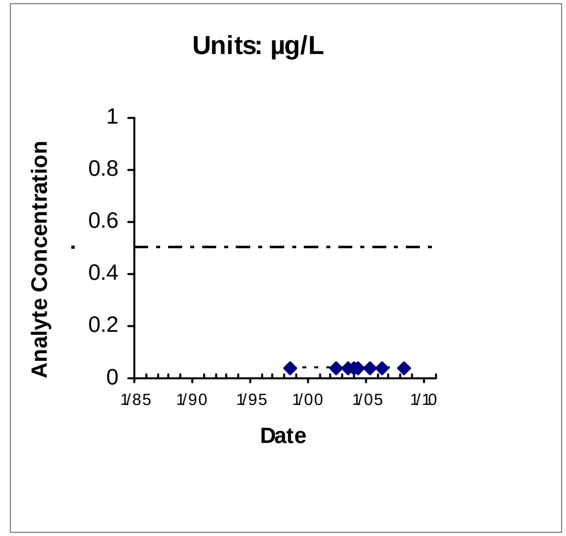
Chemical Time-series Plots



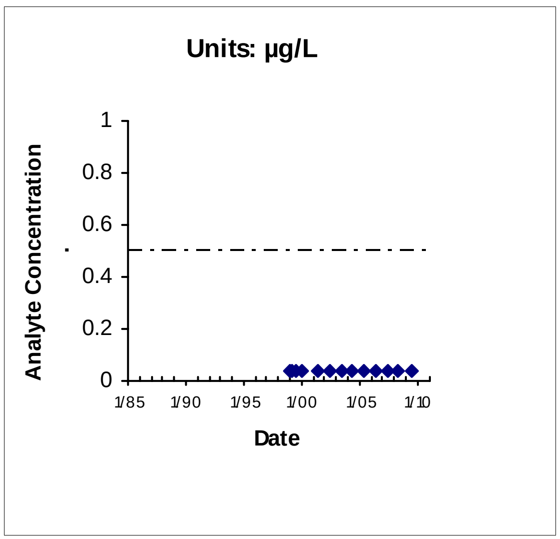
Location: MW06X30 Maximum: 0.0348



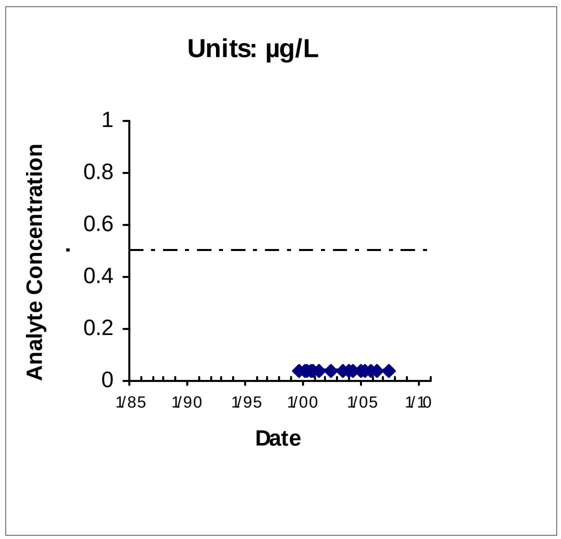
Location: MW07X30 Maximum: 0.0348



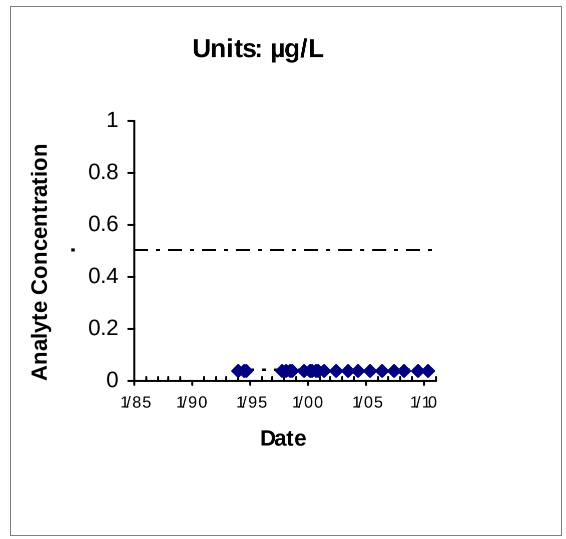
Location: MW08X30 Maximum: 0.0348



Location: MW09X30 Maximum: 0.0348



Location: MW10X30 Maximum: 0.0348



Location: MW269X30 Maximum: 0.0348

— - — - — IRG (0.5 µg/L)

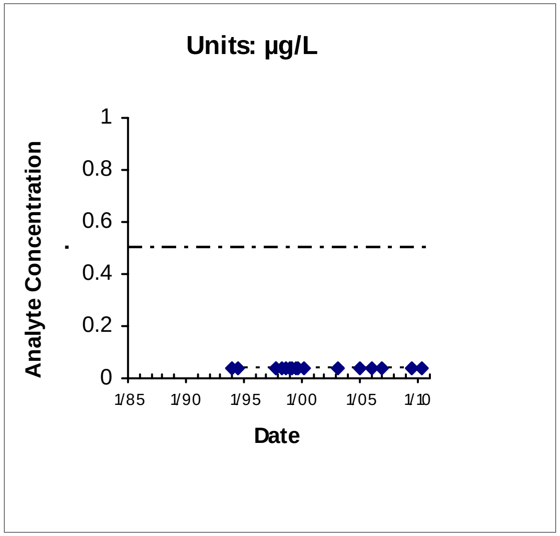
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)

FIGURE 4.3-9

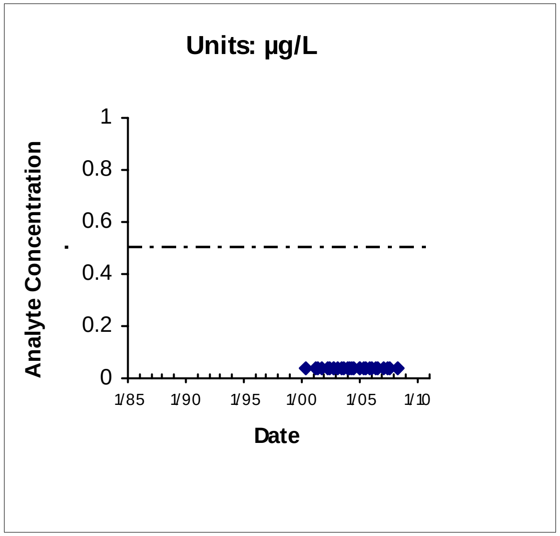
Sites FT005/SS029/SS030

1,2-DCA

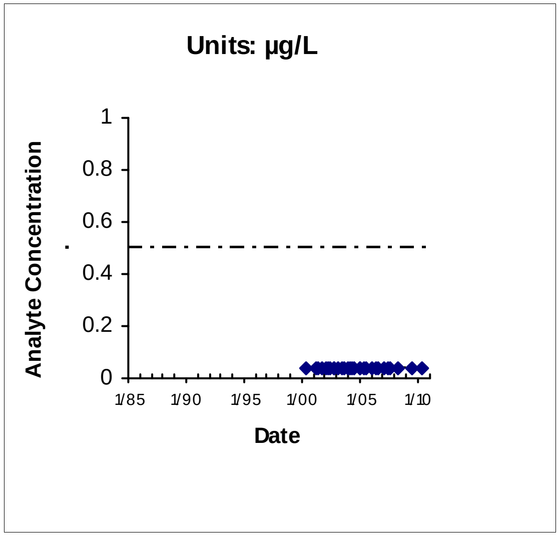
Chemical Time-series Plots



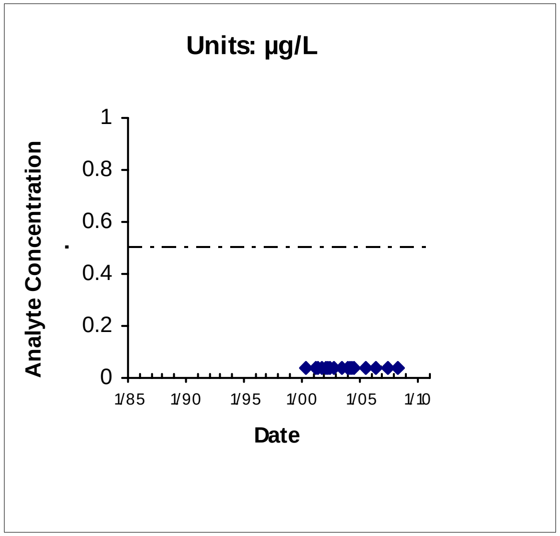
Location: MW280X30 Maximum: 0.0348



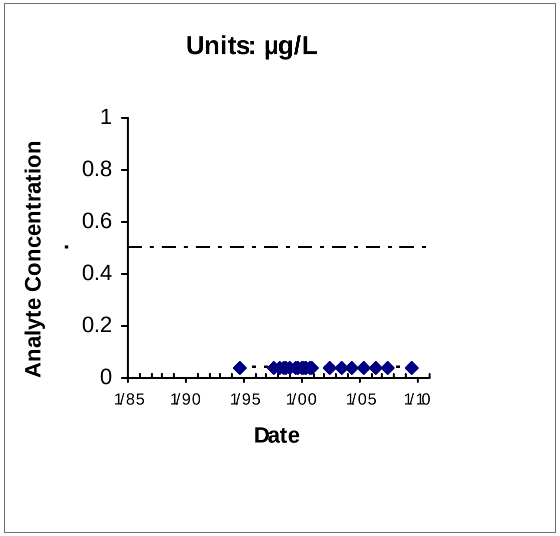
Location: MW708X30 Maximum: 0.0348



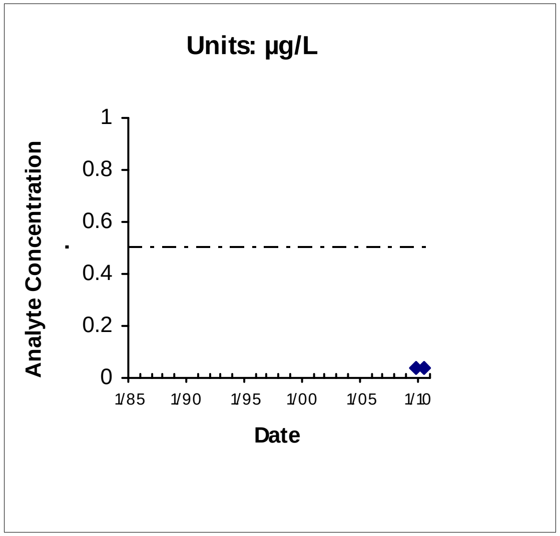
Location: MW709X30 Maximum: 0.0348



Location: MW710X30 Maximum: 0.0348



Location: MW1035X30 Maximum: 0.0348



Location: MW2001Ax30 Maximum: 0.0348

— - — - — IRG (0.5 µg/L)

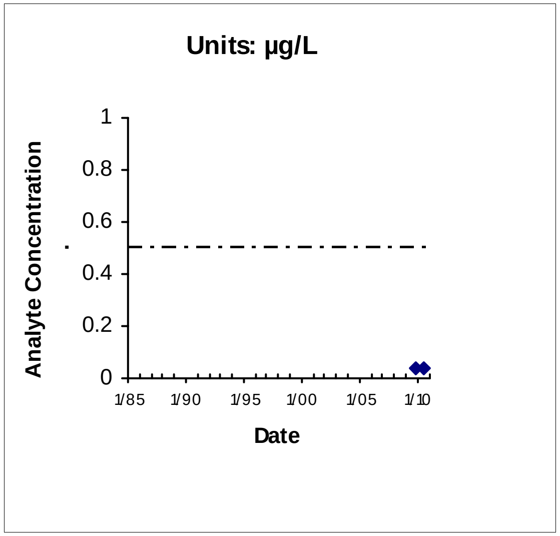
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)

FIGURE 4.3-9

Sites FT005/SS029/SS030

1,2-DCA

Chemical Time-series Plots



Location: MW2001Bx30 Maximum: 0.0348

— - — - — IRG (0.5 µg/L)

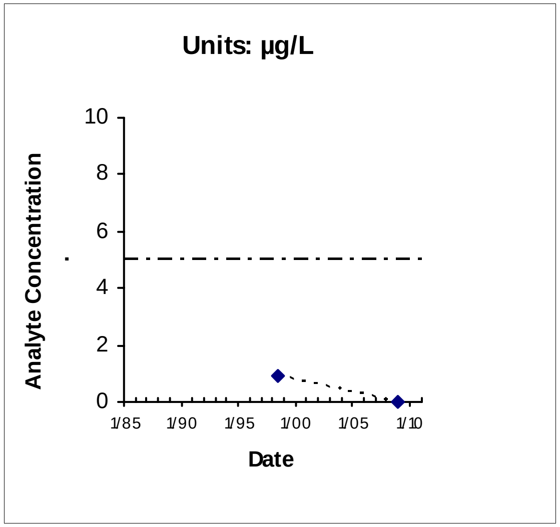
*Nondetects shown as the Method Detection Limit (0.0348 µg/L)

FIGURE 4.3-9

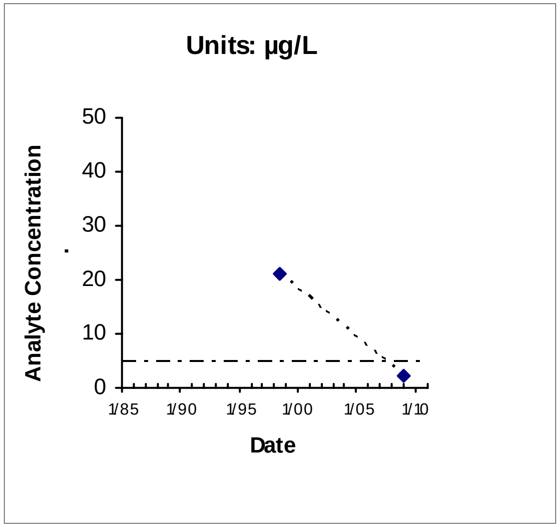
Sites FT005/SS029/SS030

1,2-DCA

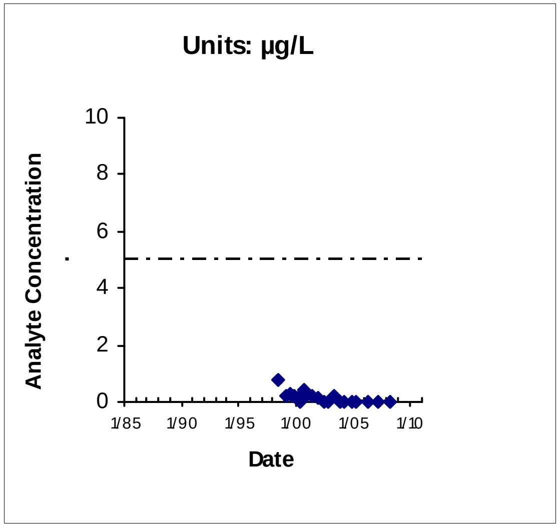
Chemical Time-series Plots



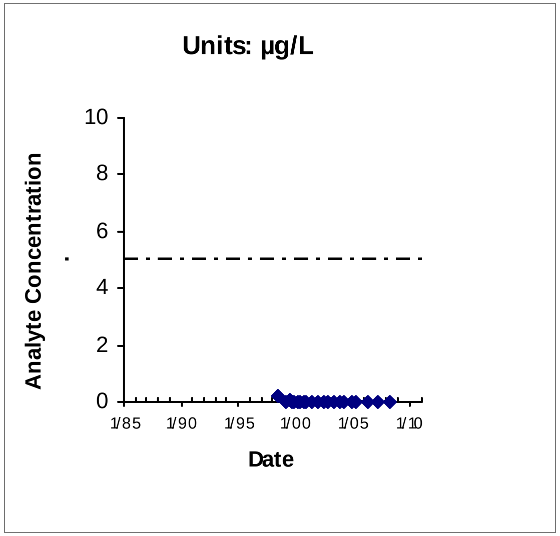
Location: MW01DX06 Maximum: 0.9



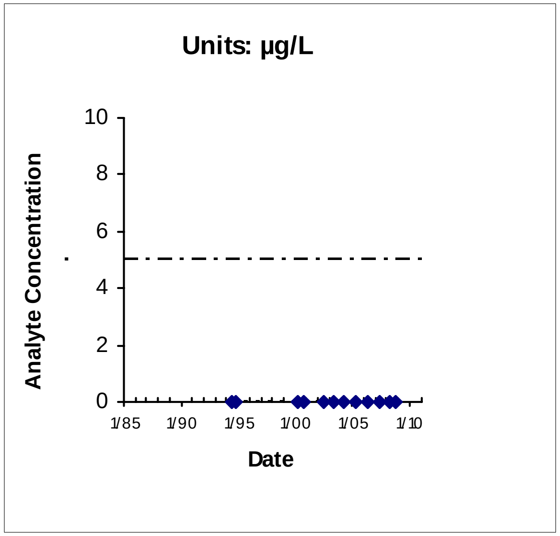
Location: MW01SX06 Maximum: 21



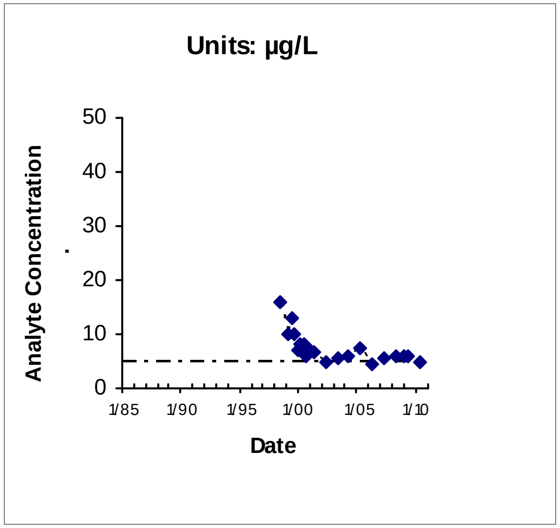
Location: MW02DX06 Maximum: 0.8



Location: MW02SX06 Maximum: 0.2



Location: MW207X06 Maximum: 0.03



Location: MW208DX06 Maximum: 16

— - — - — IRG (5 µg/L)

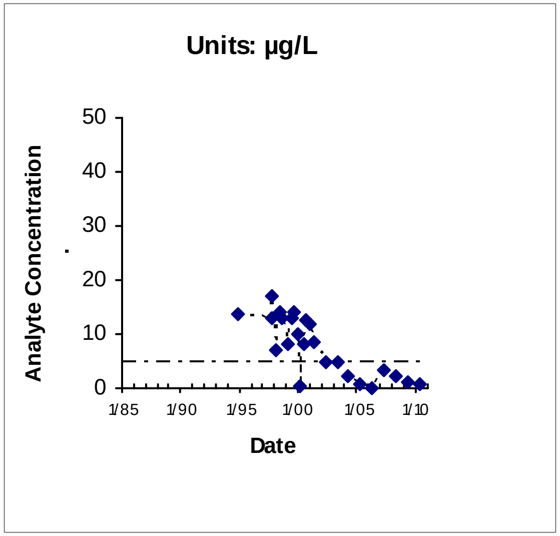
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.2-4

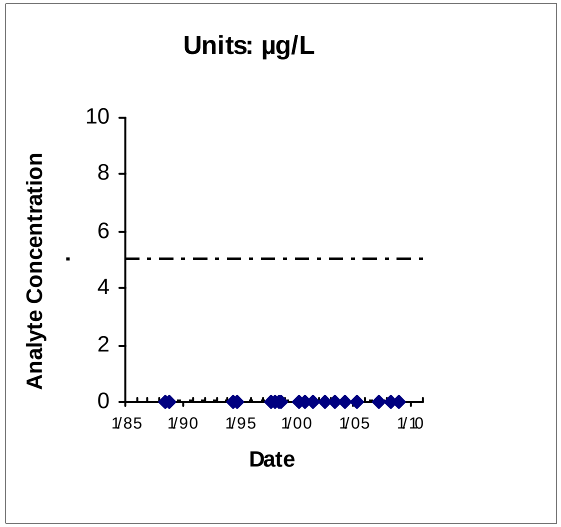
Site LF006

TCE

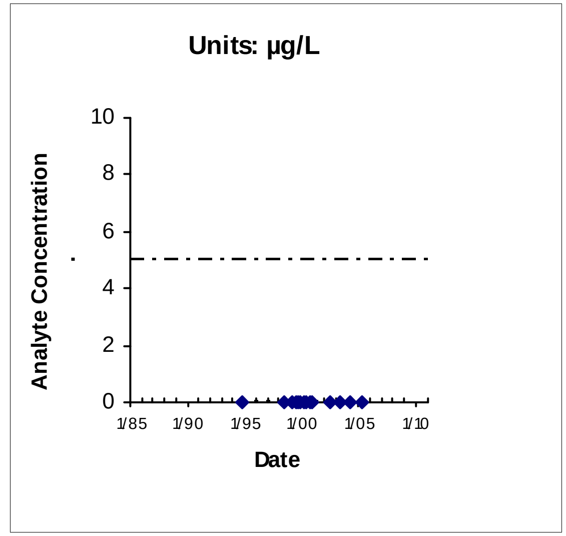
Chemical Time-series Plots



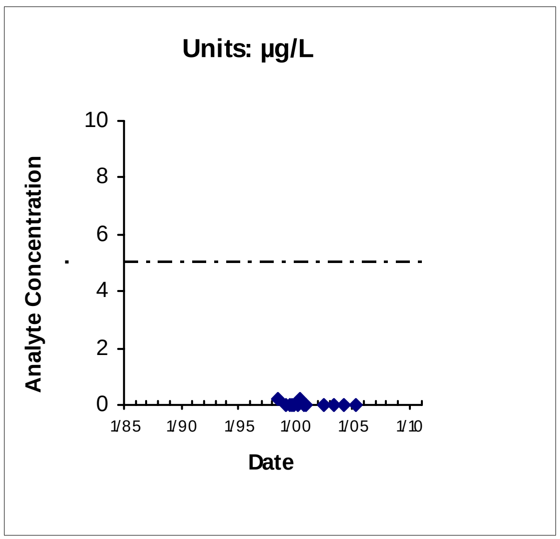
Location: MW208X06 Maximum: 17



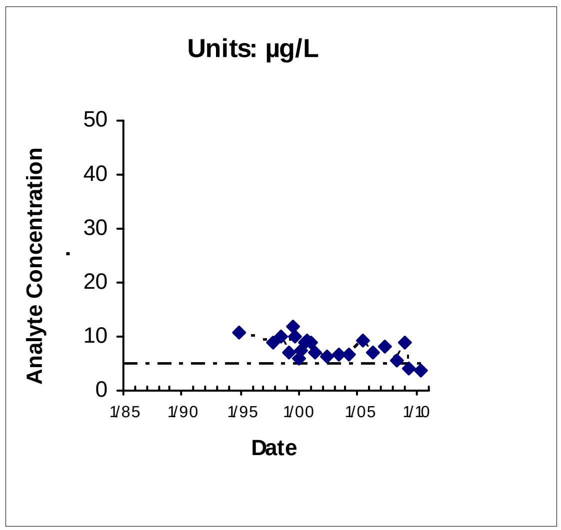
Location: MW210X06 Maximum: 0.03



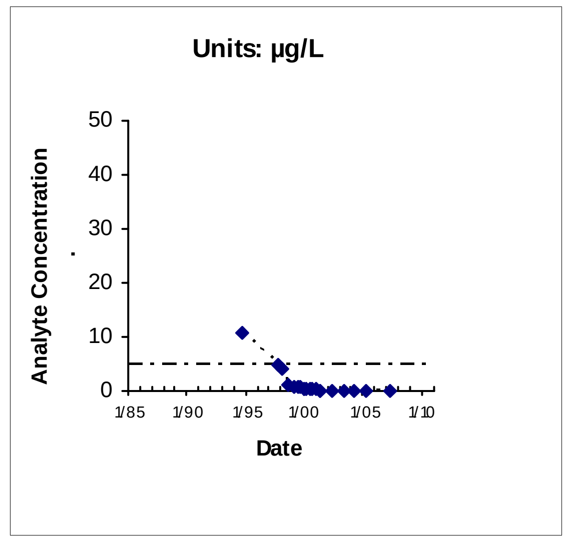
Location: MW258X06 Maximum: 0.03



Location: MW258DX06 Maximum: 0.2



Location: MW259X06 Maximum: 12



Location: MW1743X06 Maximum: 10.6

— - — - — IRG (5 µg/L)

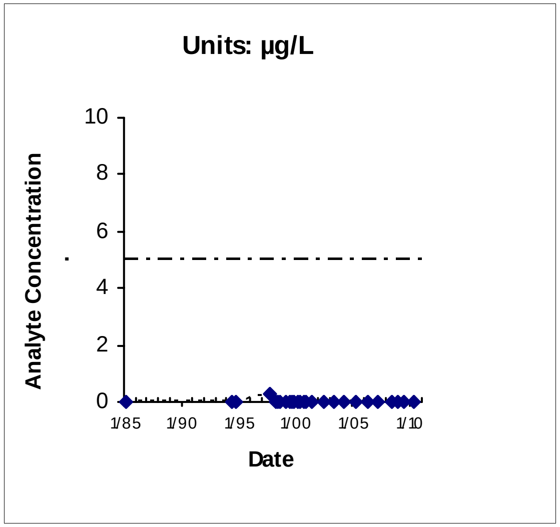
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.2-4

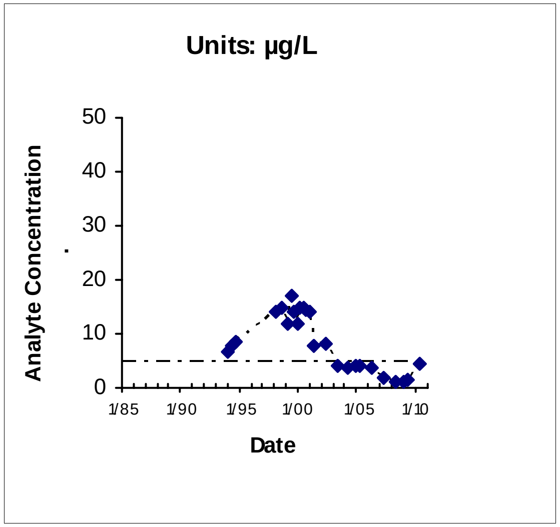
Site LF006

TCE

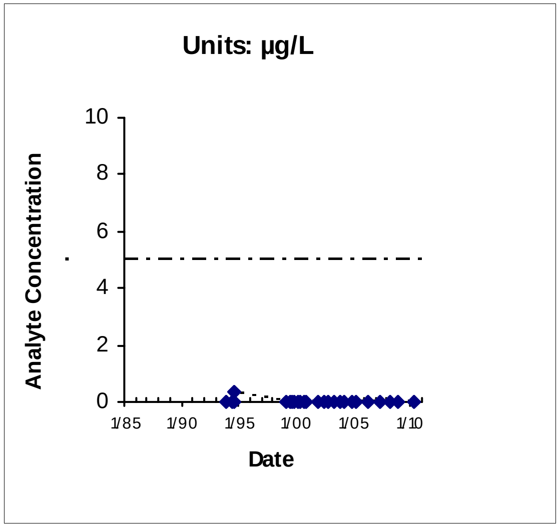
Chemical Time-series Plots



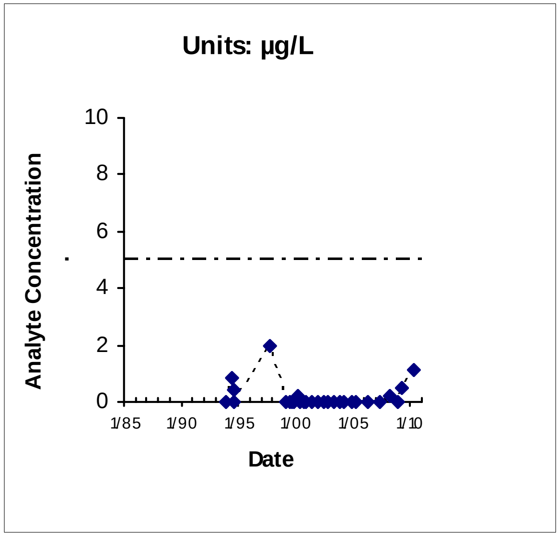
Location: MW129X07 Maximum: 0.3



Location: MW1729X31 Maximum: 17



Location: MW1730X31 Maximum: 0.35

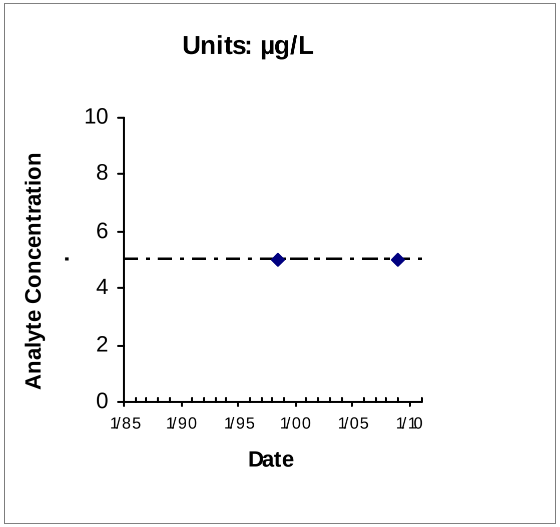


Location: MW1731X31 Maximum: 2

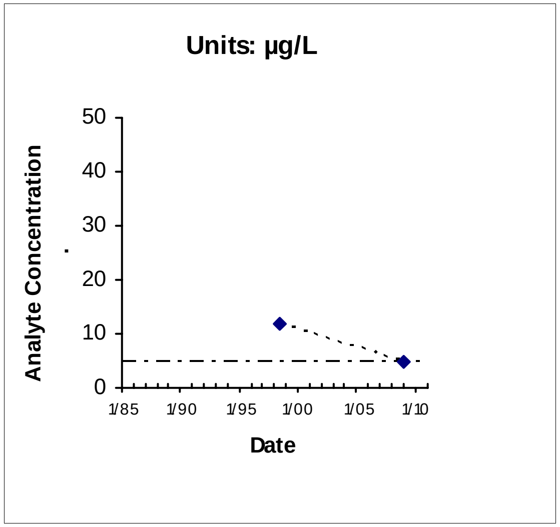
— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (0.03 µg/L)

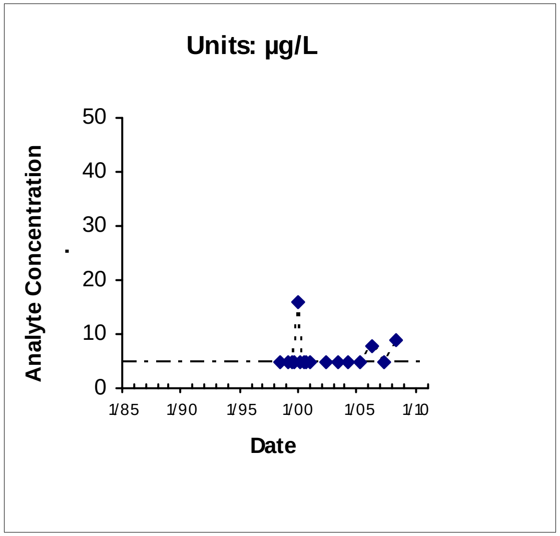
FIGURE 4.2-4
Site LF006
TCE
Chemical Time-series Plots
Page 3 of 3



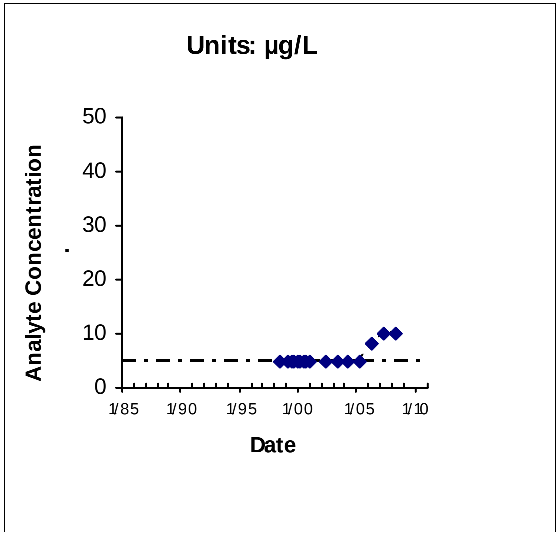
Location: MW01DX06 Maximum: 5



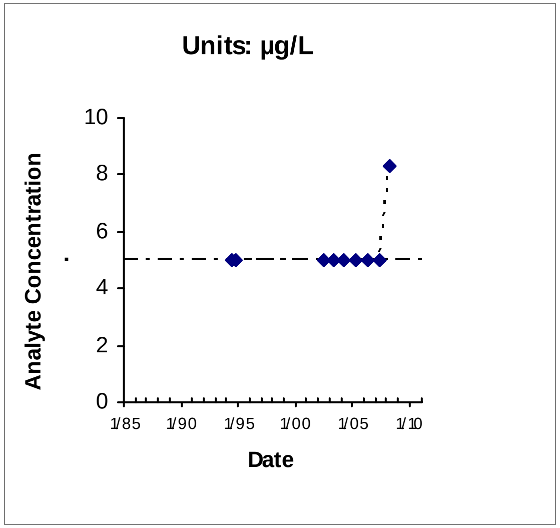
Location: MW01SX06 Maximum: 12



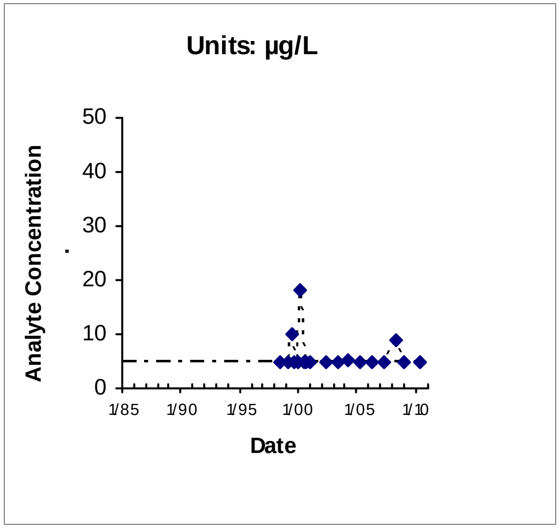
Location: MW02DX06 Maximum: 16



Location: MW02SX06 Maximum: 10



Location: MW207X06 Maximum: 8.3



Location: MW208DX06 Maximum: 18

— - — - — IRG (5 µg/L)

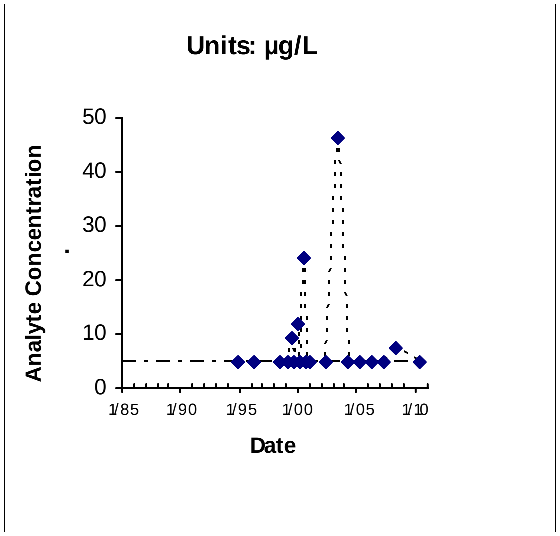
*Nondetects shown as the Method Detection Limit (5 µg/L)

FIGURE 4.2-5

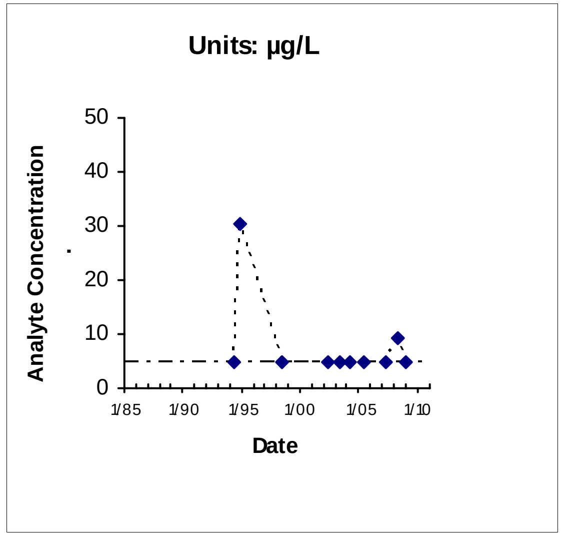
Site LF006

TPH-Gasoline

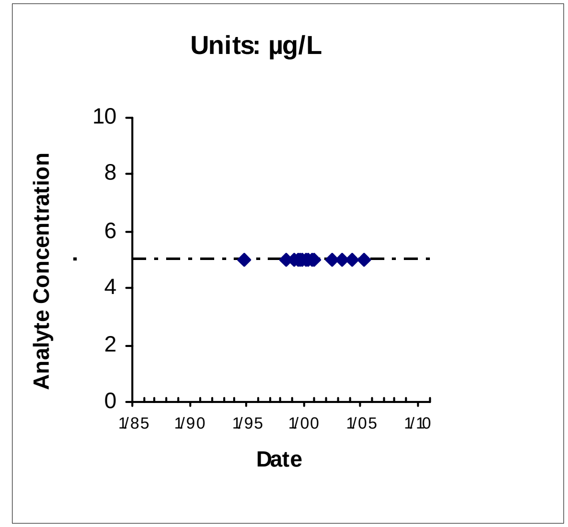
Chemical Time-series Plots



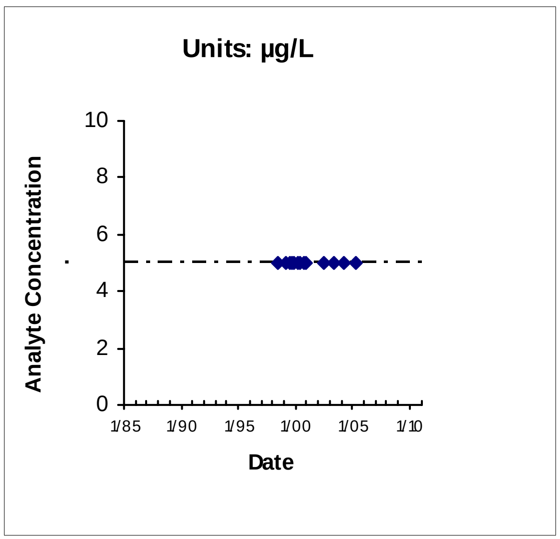
Location: MW208X06 Maximum: 46.2



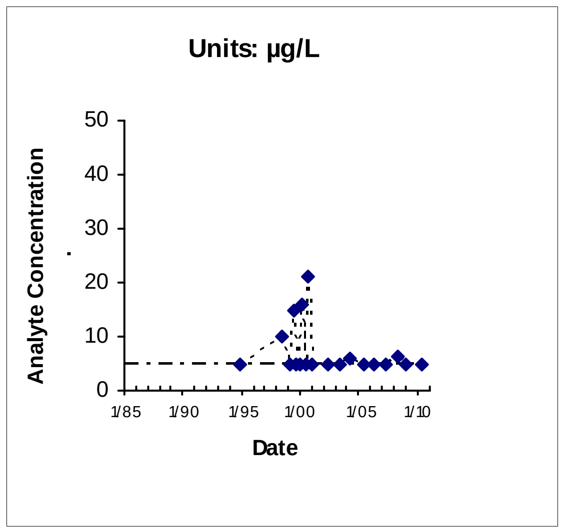
Location: MW210X06 Maximum: 30.3



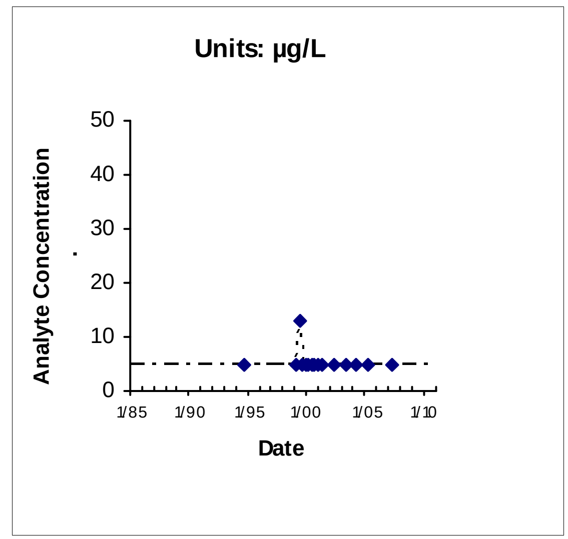
Location: MW258X06 Maximum: 5



Location: MW258DX06 Maximum: 5



Location: MW259X06 Maximum: 21



Location: MW1743X06 Maximum: 13

— - — - — IRG (5 µg/L)

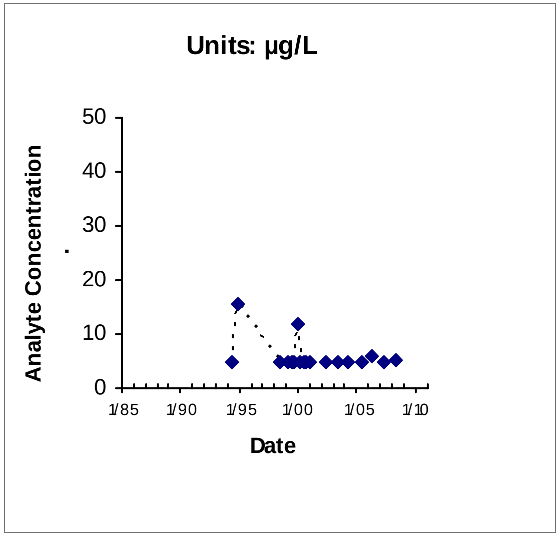
*Nondetects shown as the Method Detection Limit (5 µg/L)

FIGURE 4.2-5

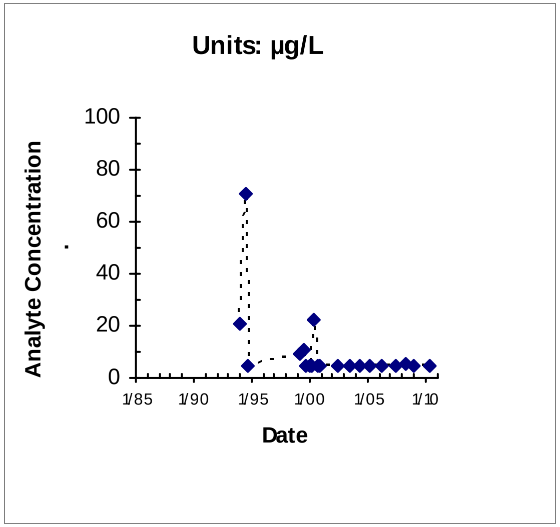
Site LF006

TPH-Gasoline

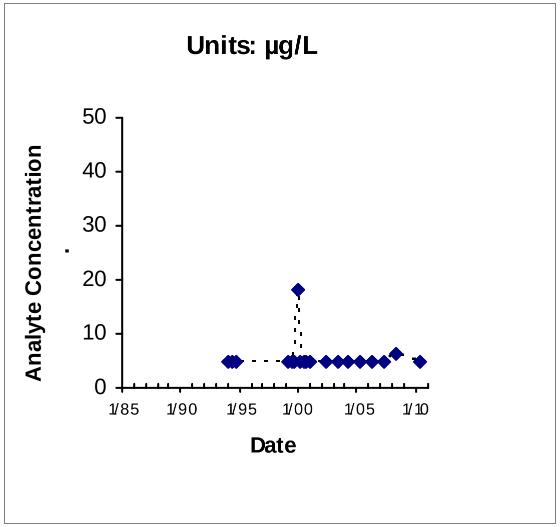
Chemical Time-series Plots



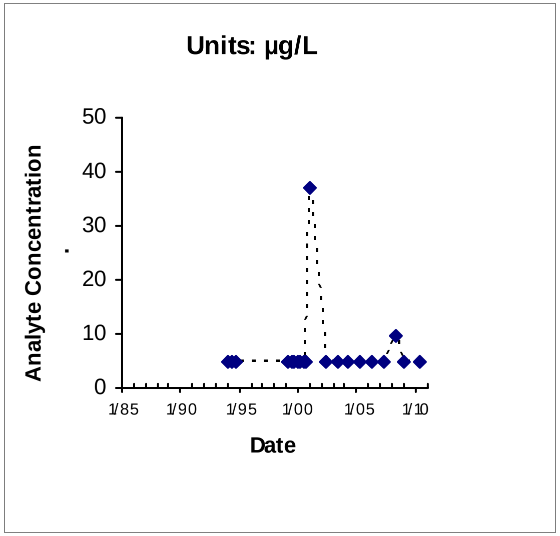
Location: MW129X07 Maximum: 15.5



Location: MW1729X31 Maximum: 71



Location: MW1730X31 Maximum: 18



Location: MW1731X31 Maximum: 37

— - — - — IRG (µg/L)

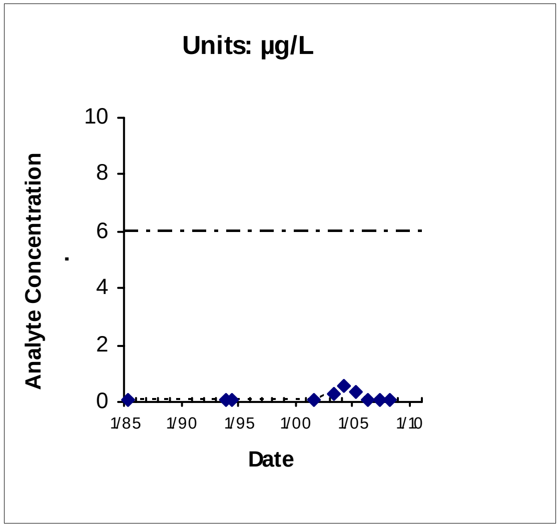
*Nondetects shown as the Method Detection Limit (5 µg/L)

FIGURE 4.2-5

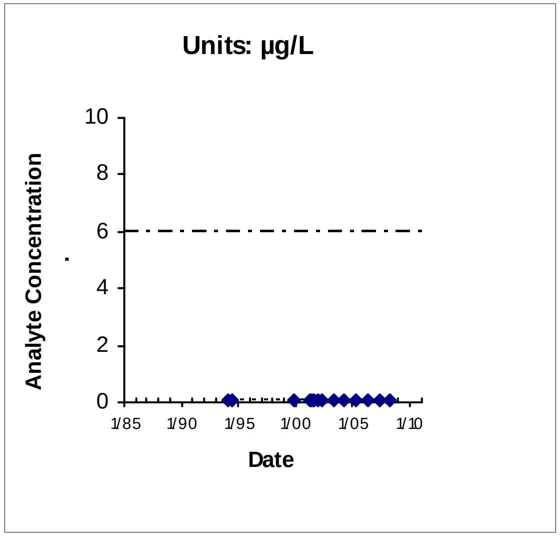
Site LF006

TPH-Gasoline

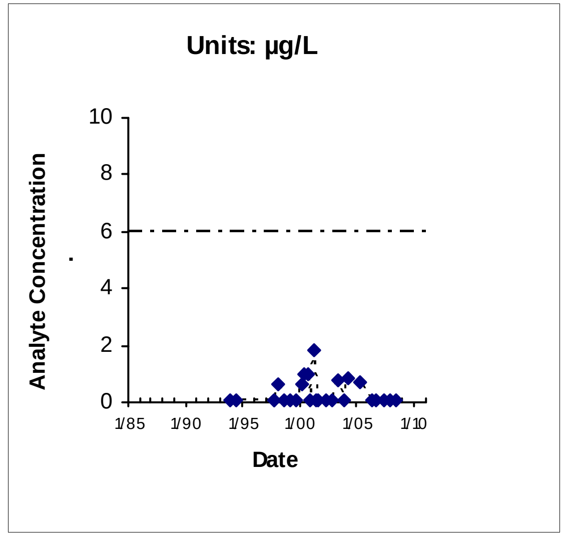
Chemical Time-series Plots



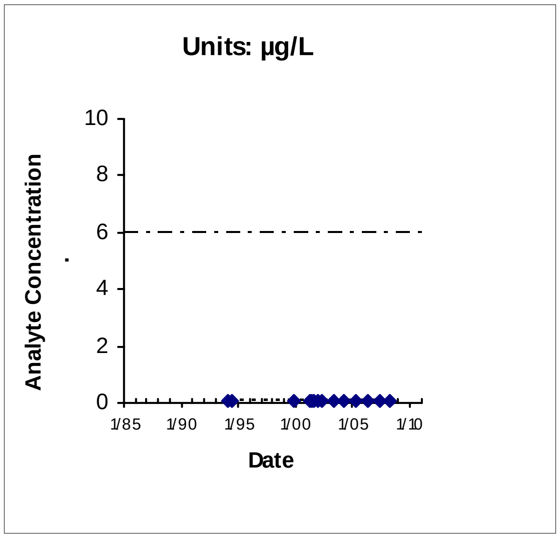
Location: MW133X03 Maximum: 0.55



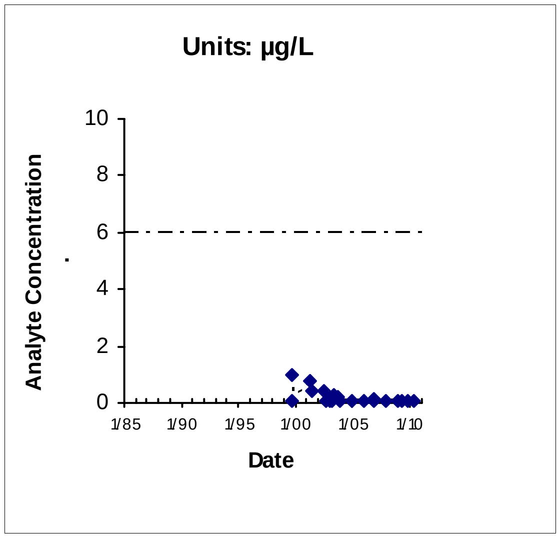
Location: MW205X03 Maximum: 0.0436



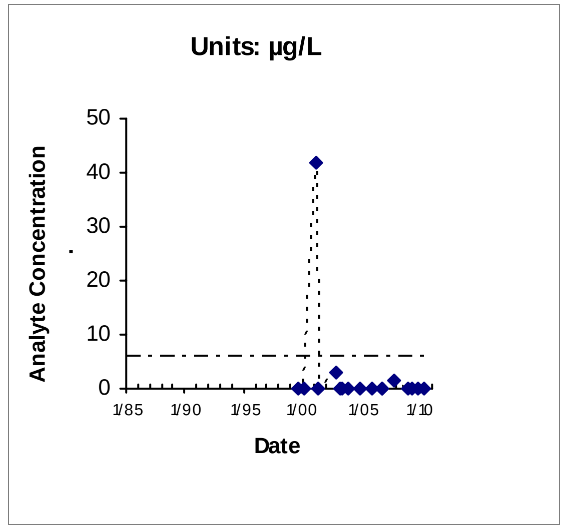
Location: MW206X03 Maximum: 1.8



Location: MW302X03 Maximum: 0.0436



Location: EW576X04 Maximum: 1



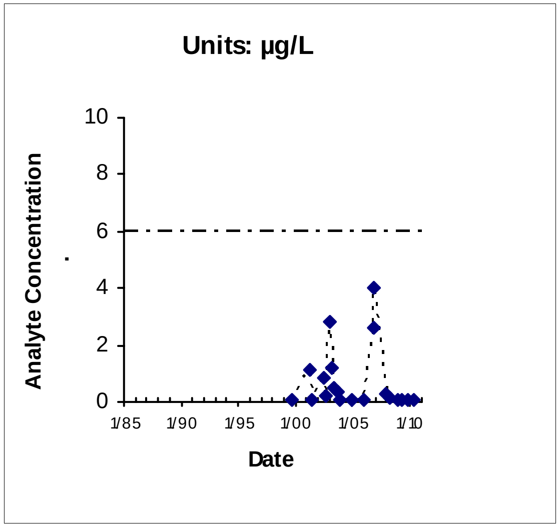
Location: EW577X04 Maximum: 42

FIGURE 4.1-7

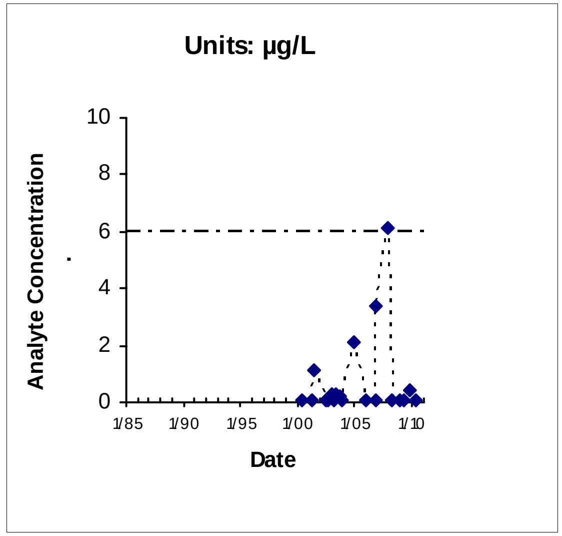
Sites FT004/SD031/LF007
1,1-DCE
Chemical Time-series Plots

— - — - — IRG (6 µg/L)

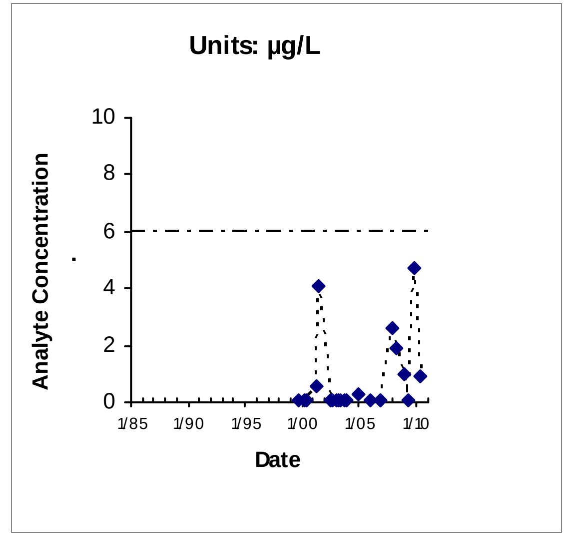
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)



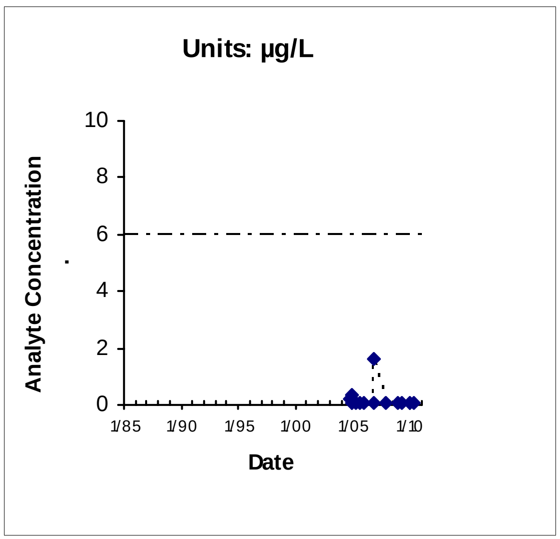
Location: EW578X04 Maximum: 4



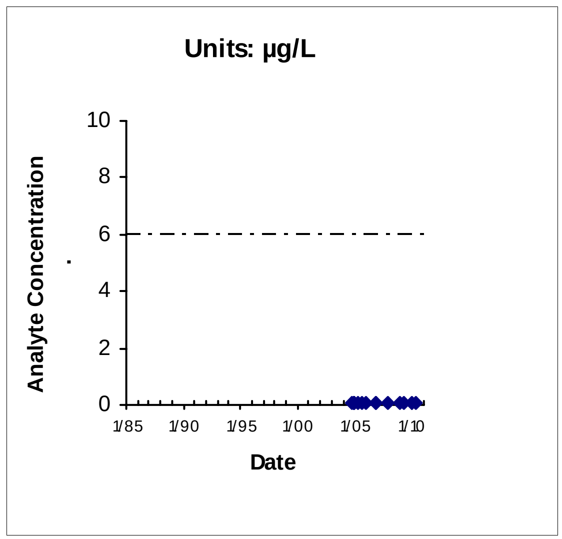
Location: EW579X04 Maximum: 6.1



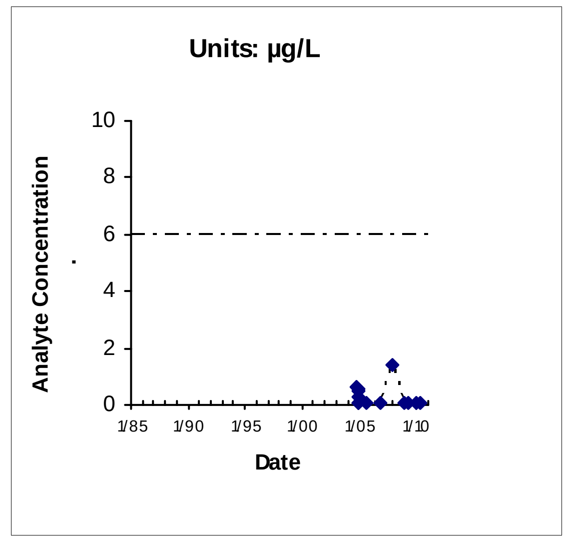
Location: EW580X04 Maximum: 4.7



Location: EW621X04 Maximum: 1.6



Location: EW622X04 Maximum: 0.0436



Location: EW623X04 Maximum: 1.4

— - — - — IRG (6 µg/L)

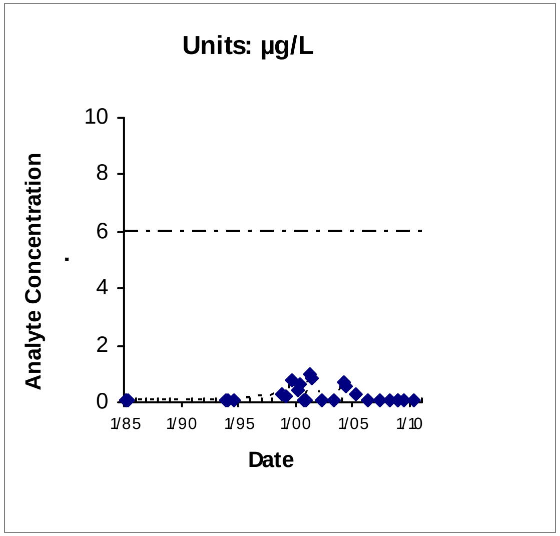
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)

FIGURE 4.1-7

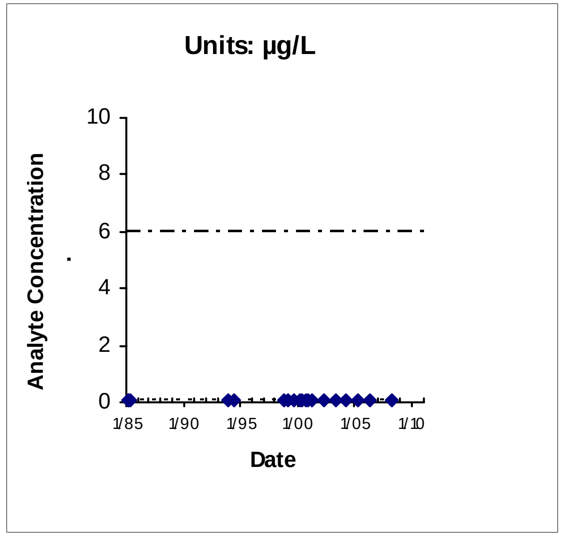
Sites FT004/SD031/LF007

1,1-DCE

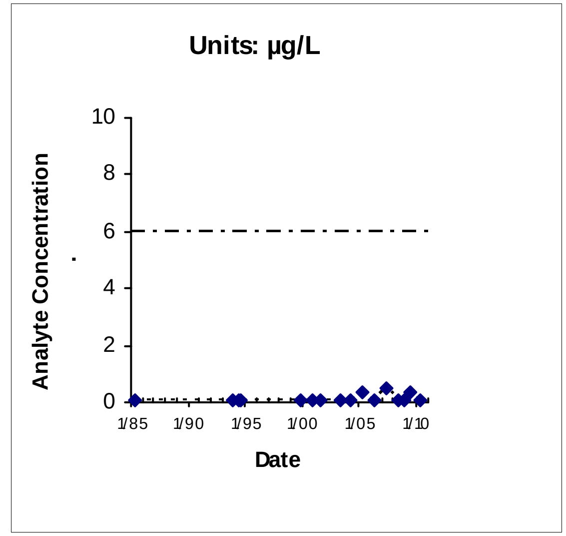
Chemical Time-series Plots



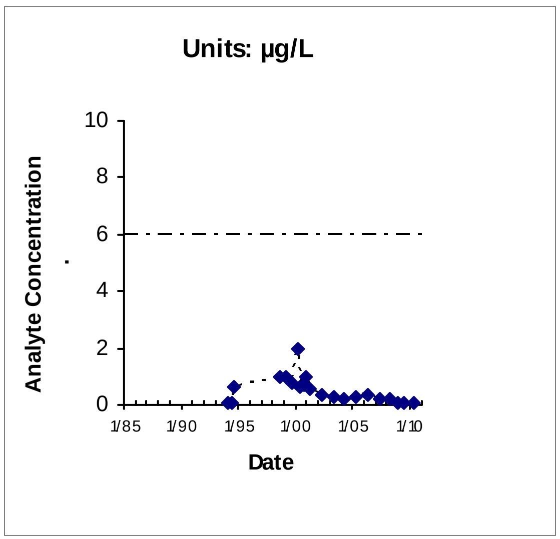
Location: MW131X04 Maximum: 0.98



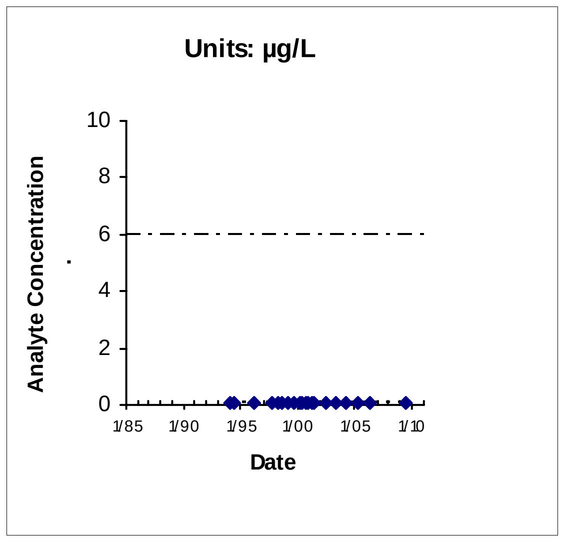
Location: MW132X04 Maximum: 0.0436



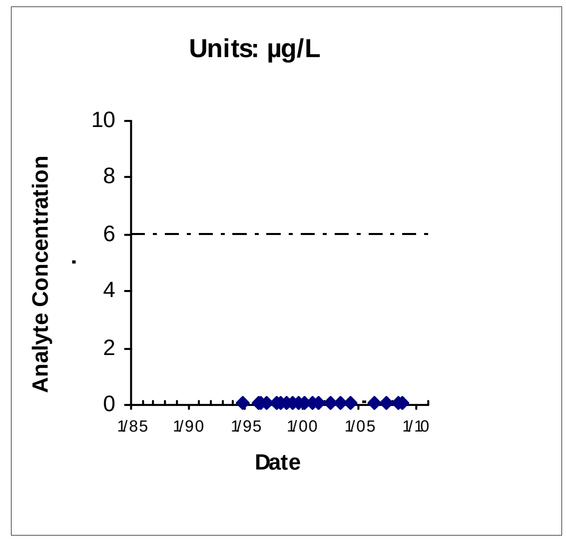
Location: MW134X04 Maximum: 0.52



Location: MW202X04 Maximum: 2



Location: MW203X04 Maximum: 0.0436



Location: MW264X04 Maximum: 0.0436

— - — - — IRG (6 µg/L)

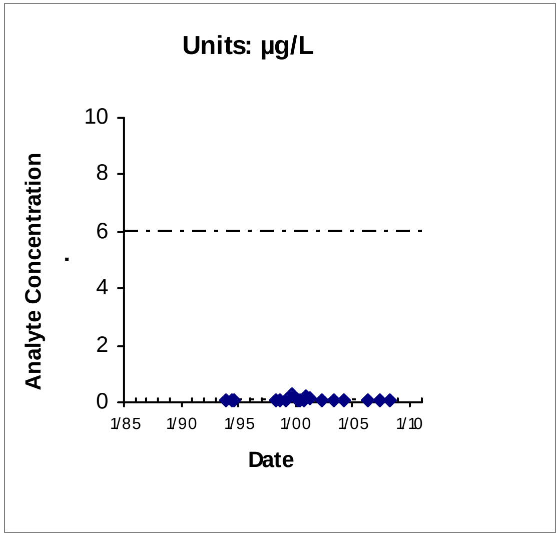
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)

FIGURE 4.1-7

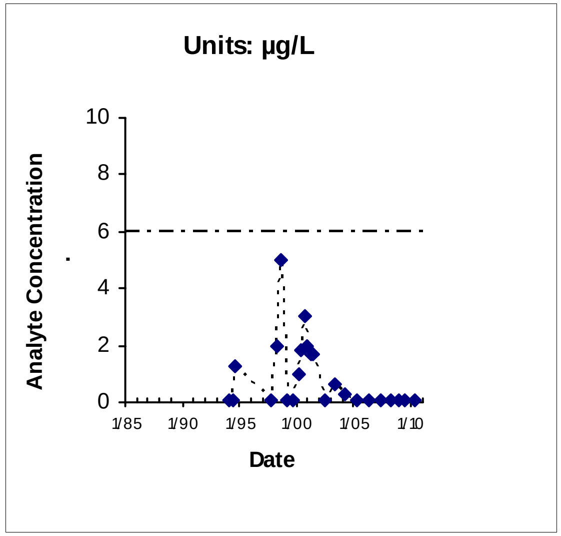
Sites FT004/SD031/LF007

1,1-DCE

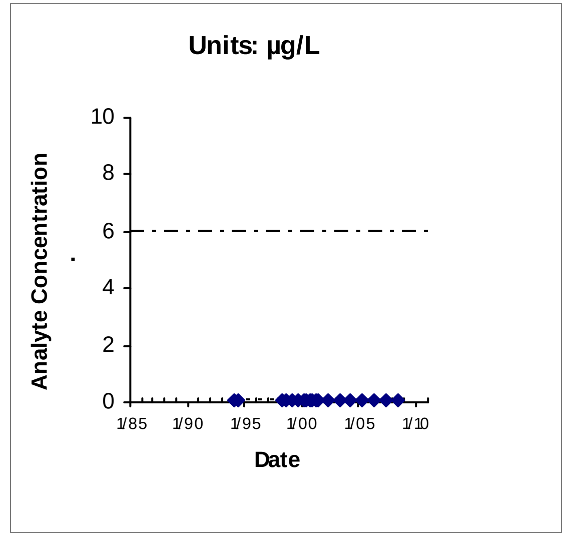
Chemical Time-series Plots



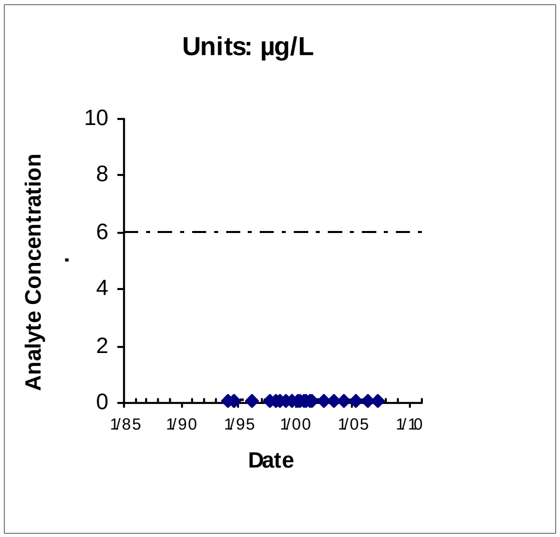
Location: MW265X04 Maximum: 0.3



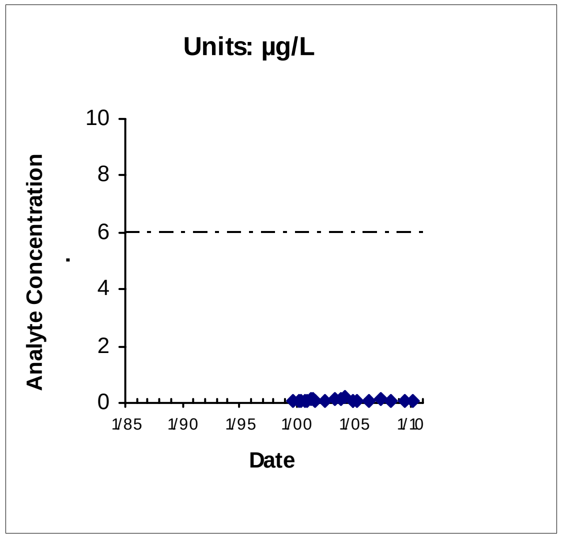
Location: MW266X04 Maximum: 5



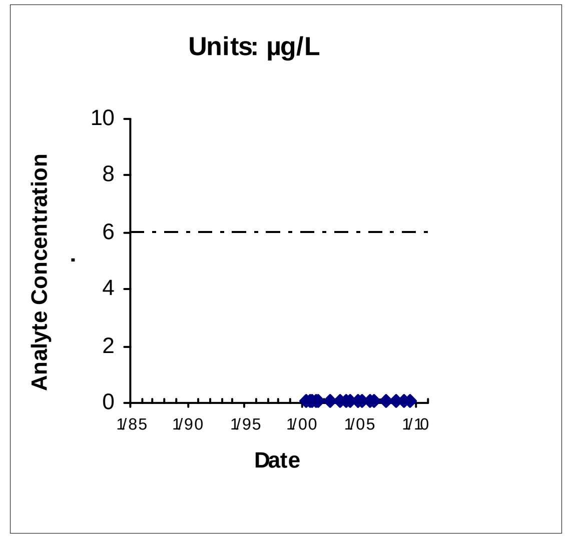
Location: MW267X04 Maximum: 0.1



Location: MW301X04 Maximum: 0.0436



Location: MW581X04 Maximum: 0.23



Location: MW582X04 Maximum: 0.0436

— - — - — IRG (6 µg/L)

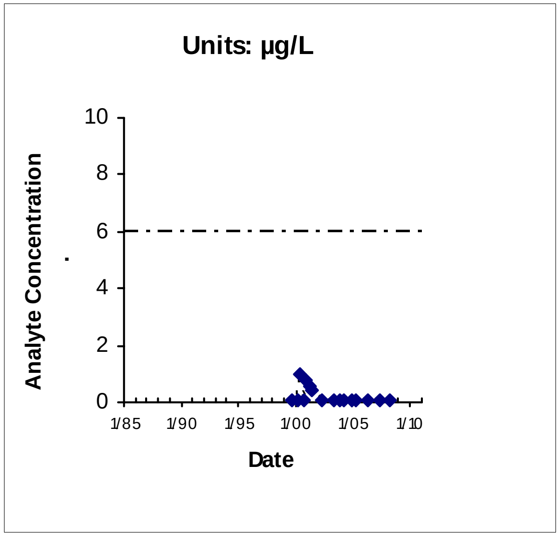
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)

FIGURE 4.1-7

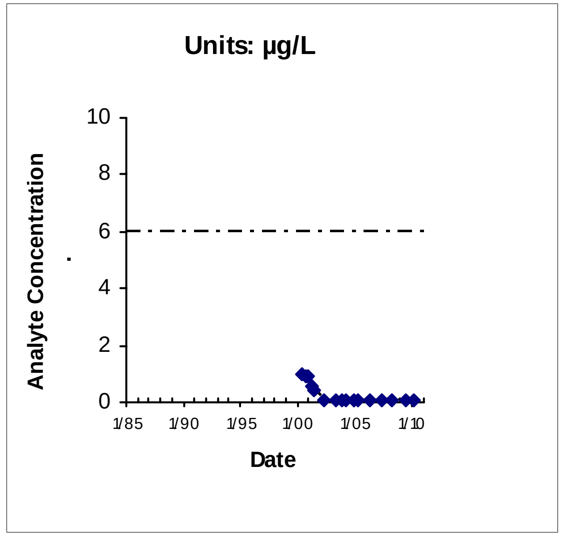
Sites FT004/SD031/LF007

1,1-DCE

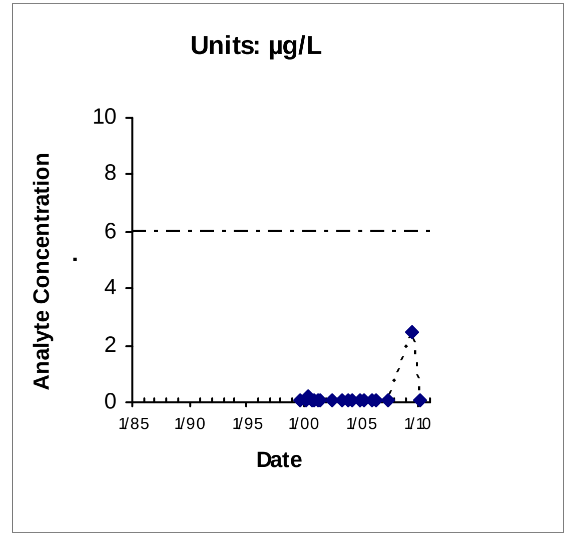
Chemical Time-series Plots



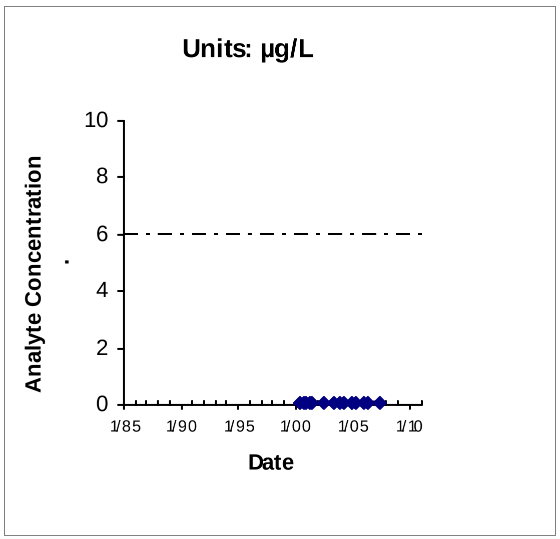
Location: MW583X04 Maximum: 1



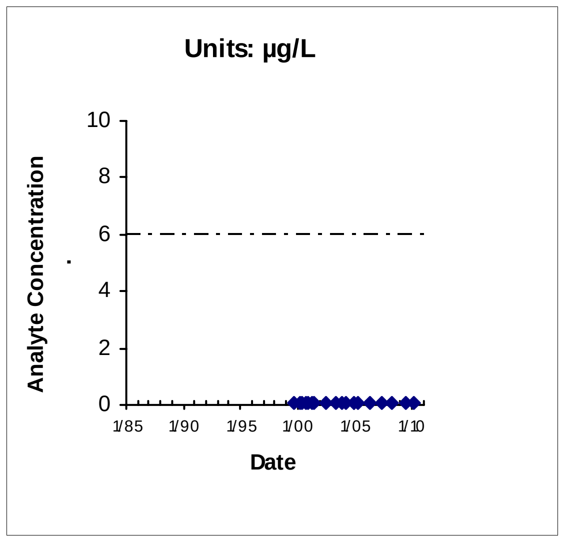
Location: MW584X04 Maximum: 1



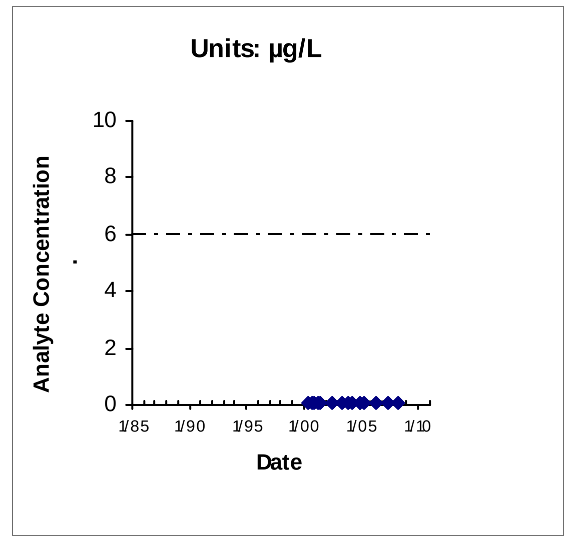
Location: MW585X04 Maximum: 2.5



Location: MW586X04 Maximum: 0.0436



Location: MW587X04 Maximum: 0.0436



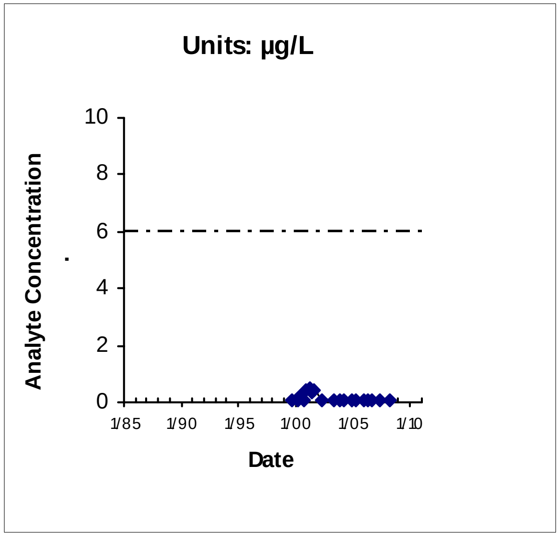
Location: MW588X04 Maximum: 0.0436

— - — - — IRG (6 µg/L)

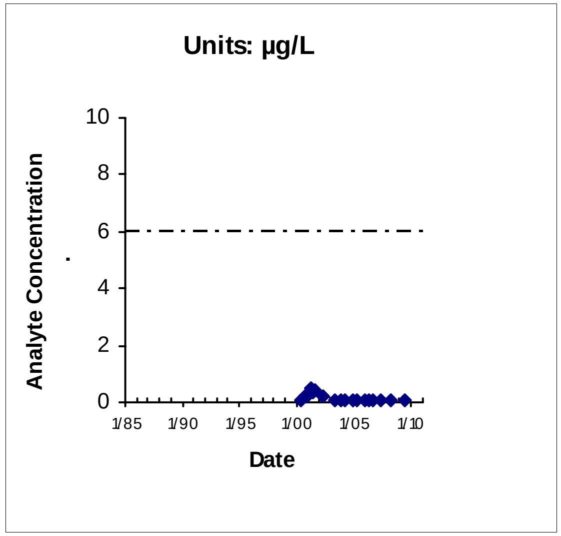
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)

FIGURE 4.1-7

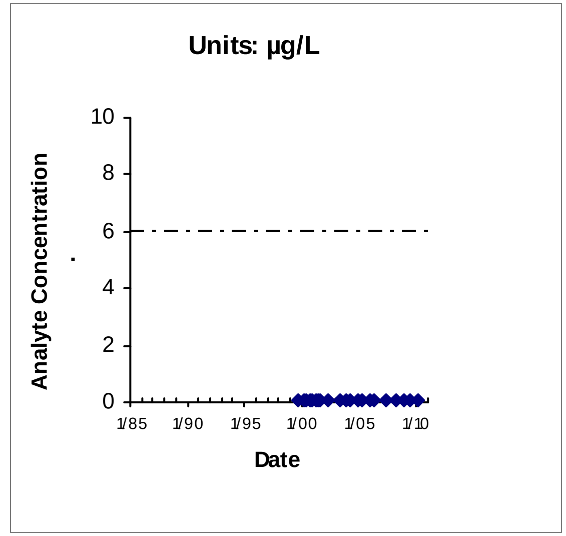
Sites FT004/SD031/LF007
1,1-DCE
Chemical Time-series Plots



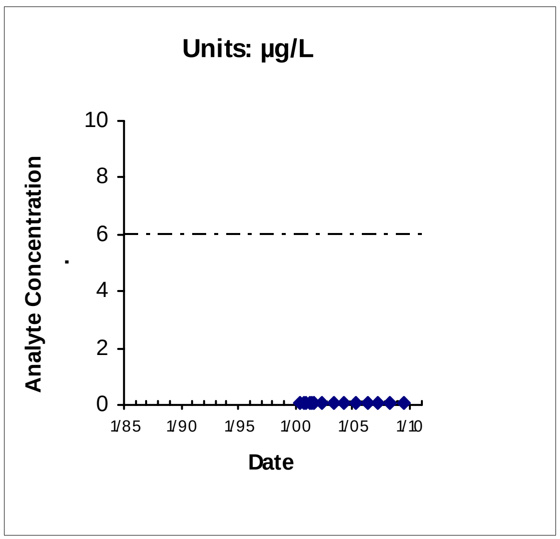
Location: MW589X04 Maximum: 0.48



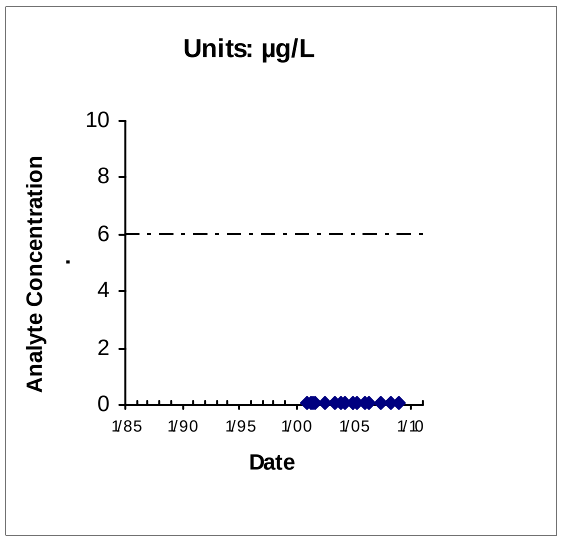
Location: MW590X04 Maximum: 0.49



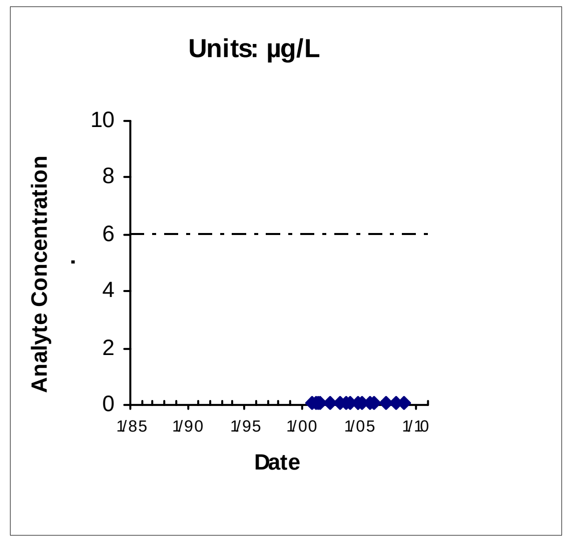
Location: MW591X04 Maximum: 0.0436



Location: MW592X04 Maximum: 0.0436



Location: MW752X04 Maximum: 0.0436



Location: MW753X04 Maximum: 0.0436

— - — - — IRG (6 µg/L)

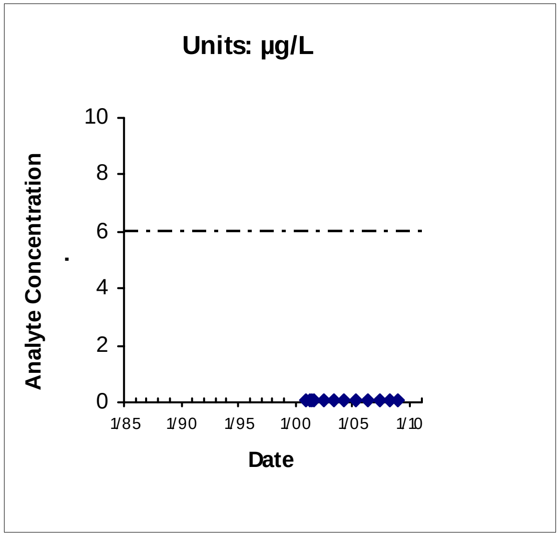
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)

FIGURE 4.1-7

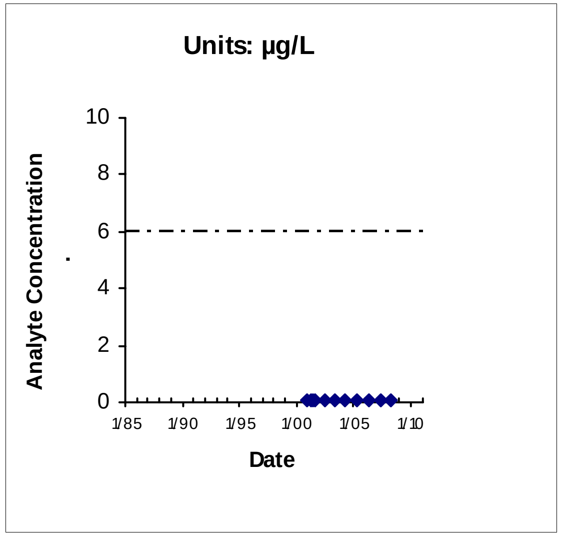
Sites FT004/SD031/LF007

1,1-DCE

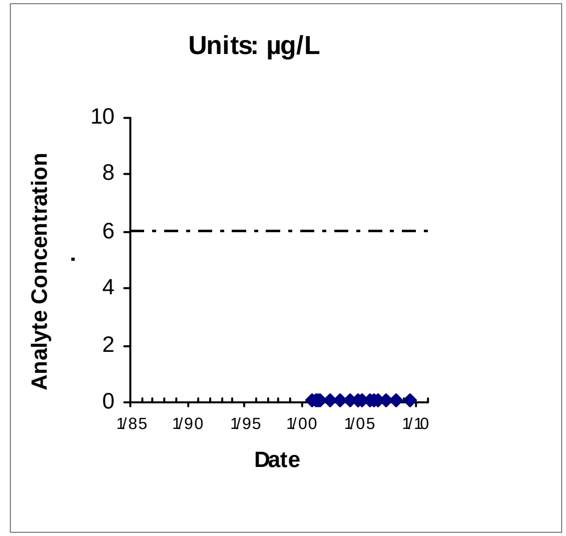
Chemical Time-series Plots



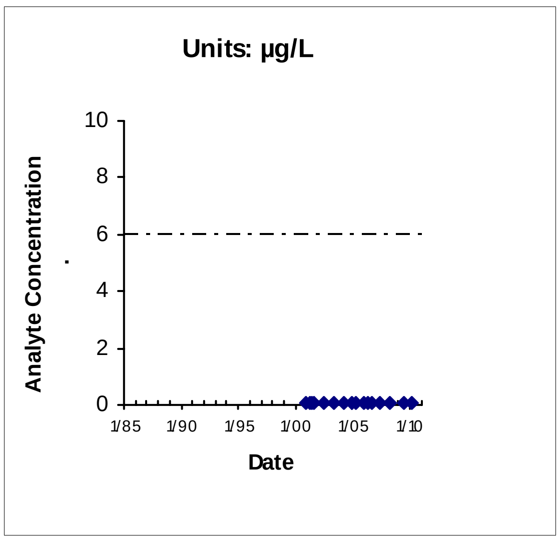
Location: MW754X04 Maximum: 0.0436



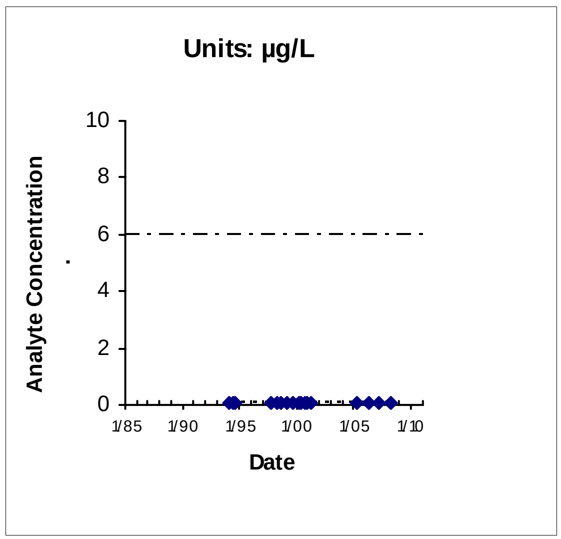
Location: MW755X04 Maximum: 0.0436



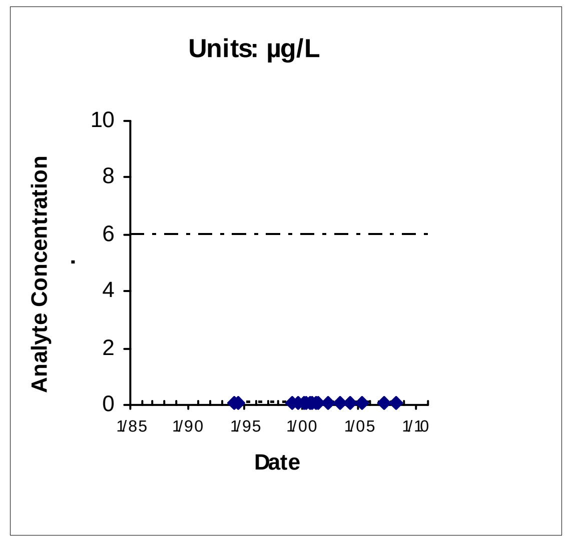
Location: MW756X04 Maximum: 0.0436



Location: MW757X04 Maximum: 0.0436



Location: MW1000X04 Maximum: 0.0436



Location: MW1001X04 Maximum: 0.0436

— - — - — IRG (6 µg/L)

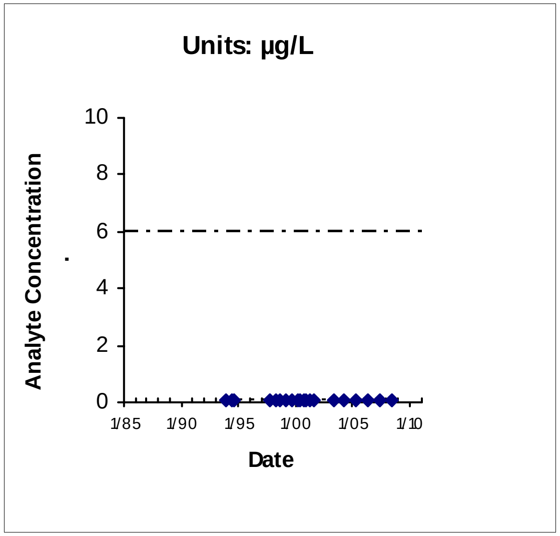
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)

FIGURE 4.1-7

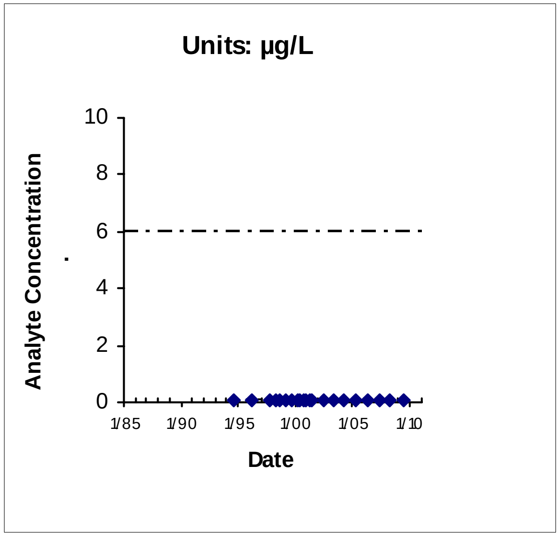
Sites FT004/SD031/LF007

1,1-DCE

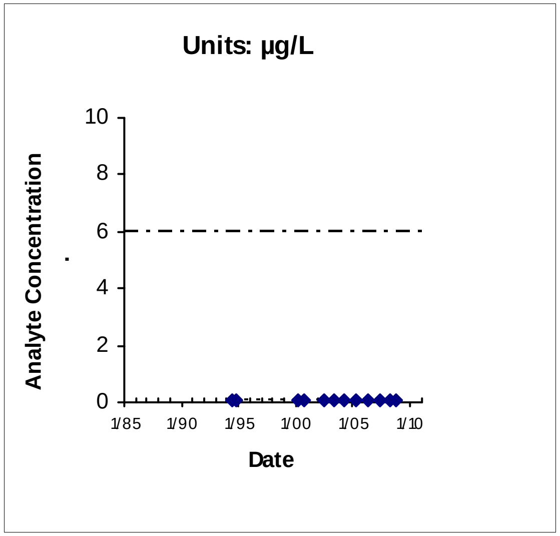
Chemical Time-series Plots



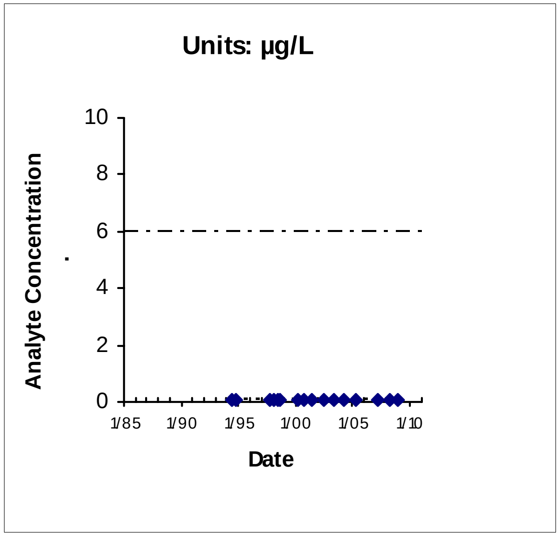
Location: MW1002X04 Maximum: 0.1



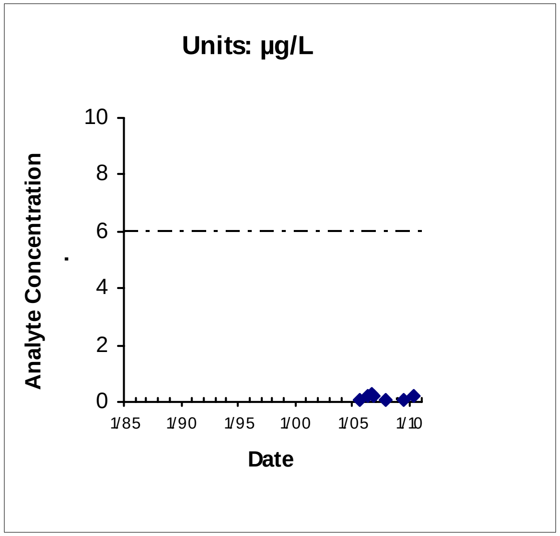
Location: MW1030X04 Maximum: 0.0436



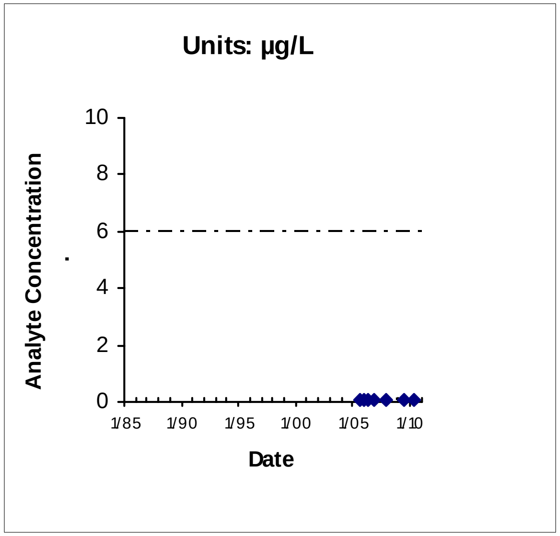
Location: MW207X06 Maximum: 0.0436



Location: MW210X06 Maximum: 0.0436



Location: EW614X07 Maximum: 0.25



Location: EW615X07 Maximum: 0.0436

— - — - — IRG (6 µg/L)

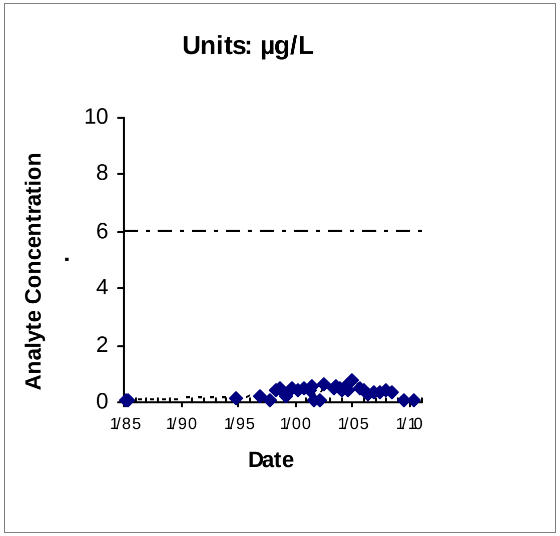
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)

FIGURE 4.1-7

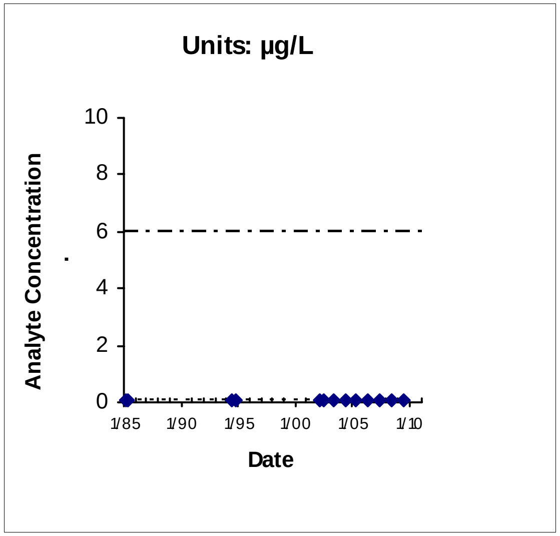
Sites FT004/SD031/LF007

1,1-DCE

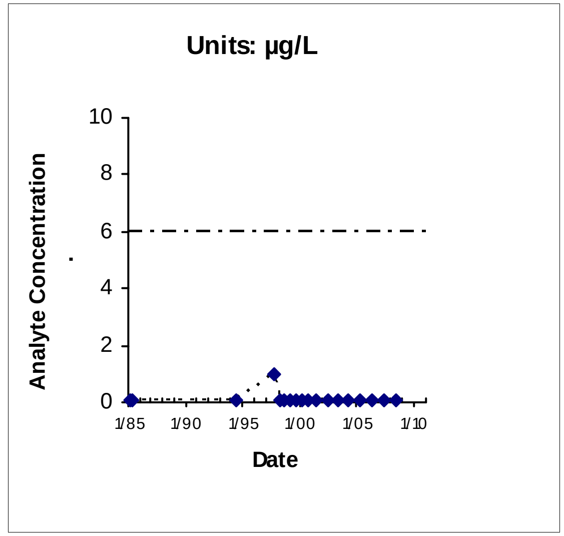
Chemical Time-series Plots



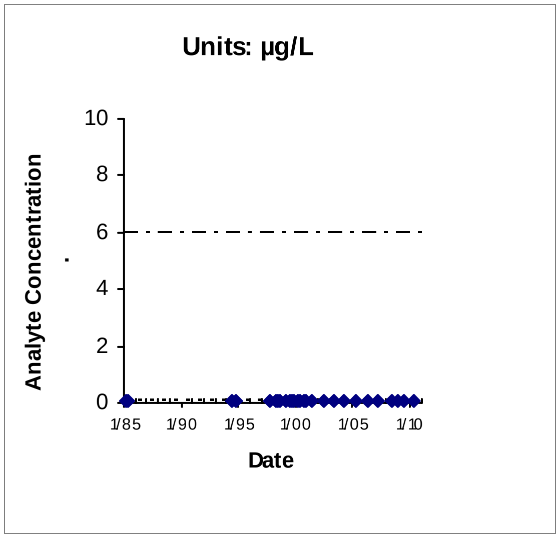
Location: MW125X07 Maximum: 0.75



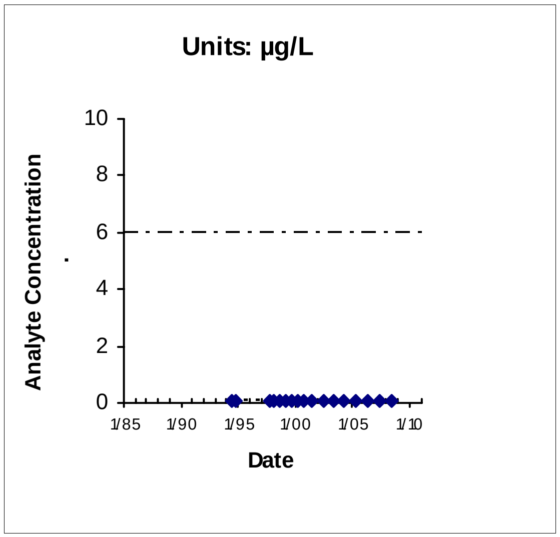
Location: MW126X07 Maximum: 0.0436



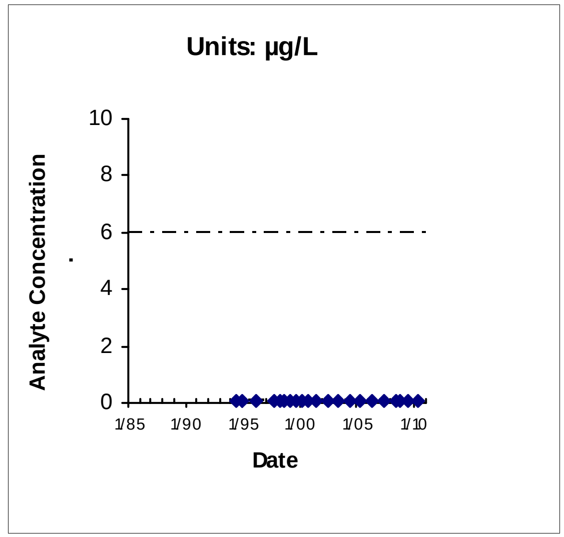
Location: MW128X07 Maximum: 1



Location: MW129X07 Maximum: 0.0436



Location: MW201X07 Maximum: 0.0436



Location: MW261X07 Maximum: 0.0436

— - — - — IRG (6 µg/L)

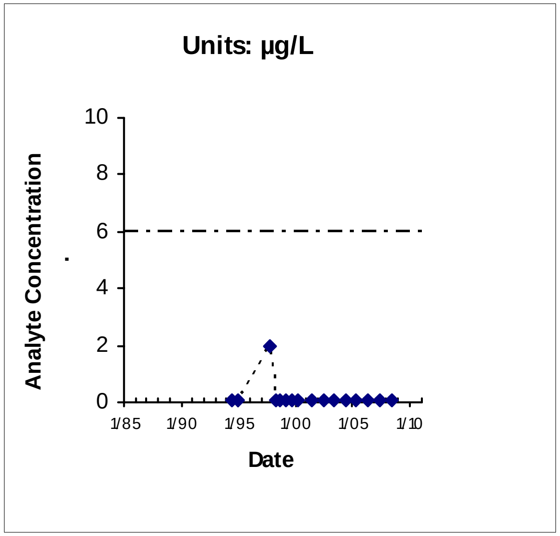
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)

FIGURE 4.1-7

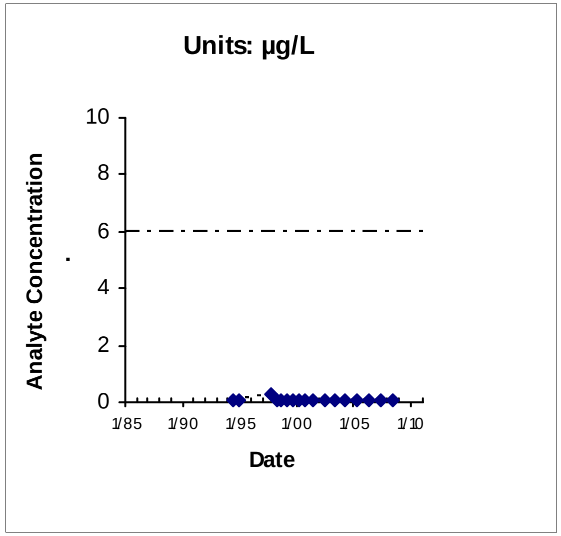
Sites FT004/SD031/LF007

1,1-DCE

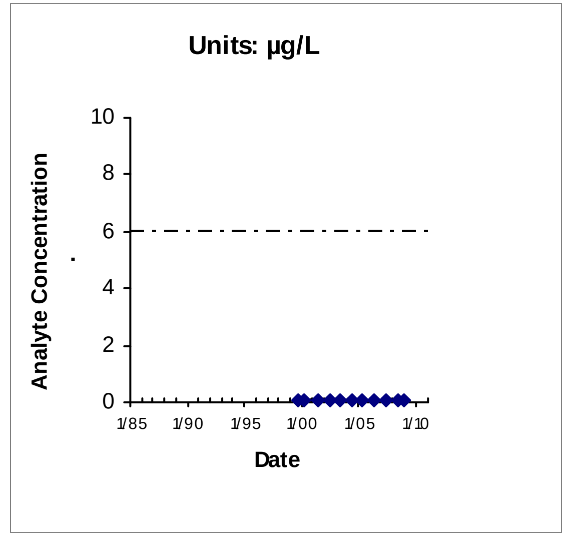
Chemical Time-series Plots



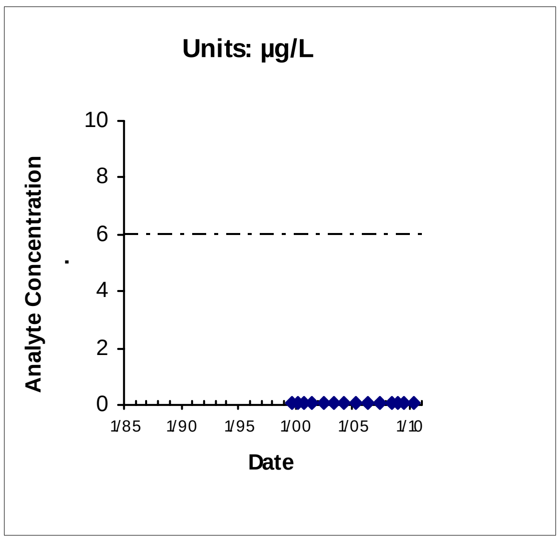
Location: MW284X07 Maximum: 2



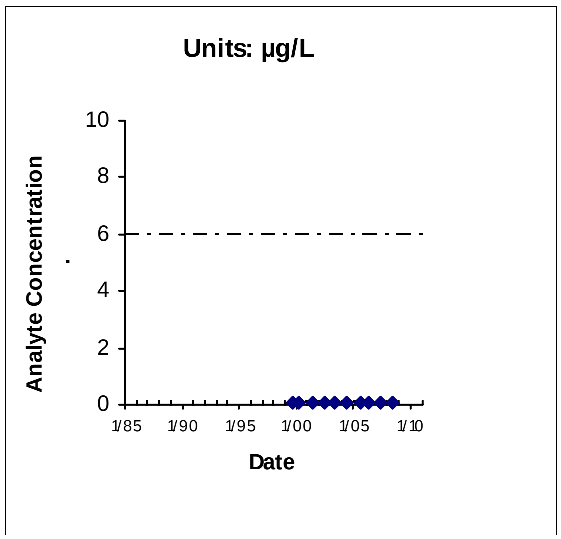
Location: MW303X07 Maximum: 0.3



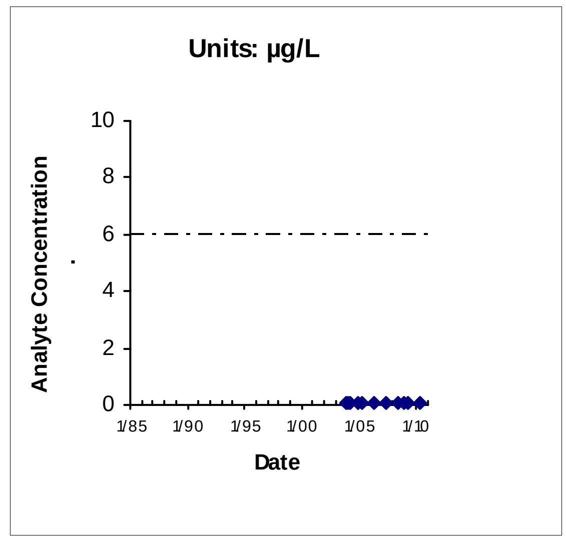
Location: MW600X07 Maximum: 0.0436



Location: MW601X07 Maximum: 0.0436



Location: MW602X07 Maximum: 0.0436



Location: MW612X07 Maximum: 0.0436

— - — - — IRG (6 µg/L)

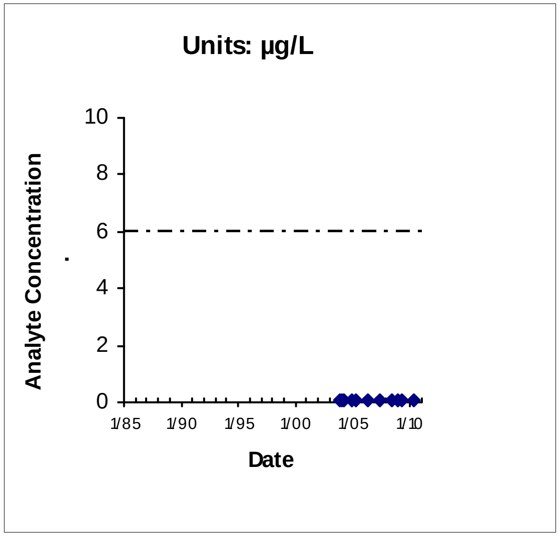
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)

FIGURE 4.1-7

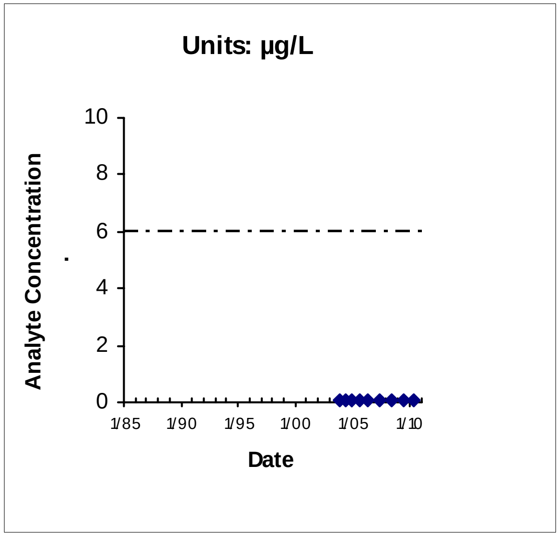
Sites FT004/SD031/LF007

1,1-DCE

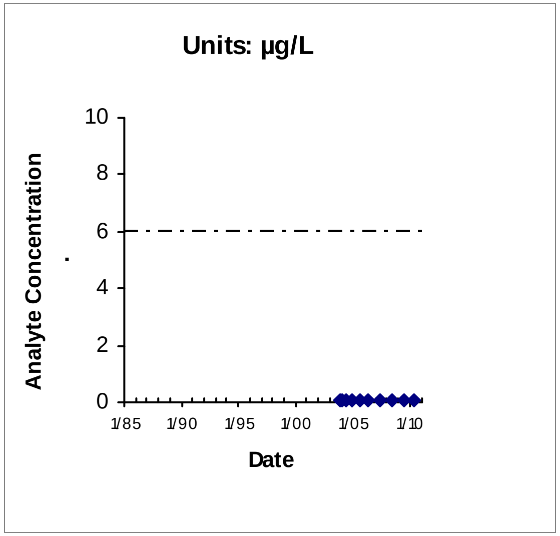
Chemical Time-series Plots



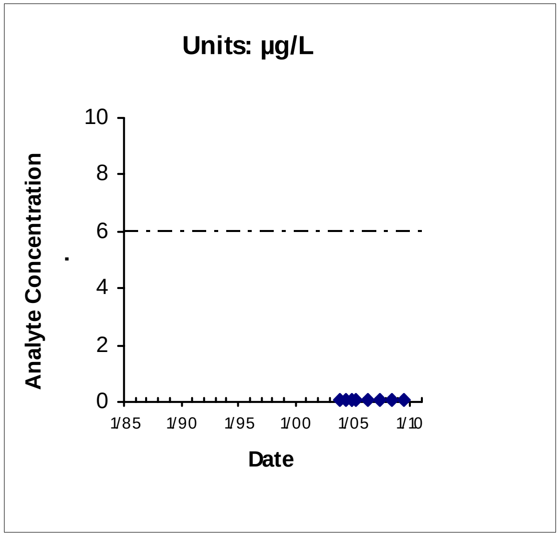
Location: MW613X07 Maximum: 0.0436



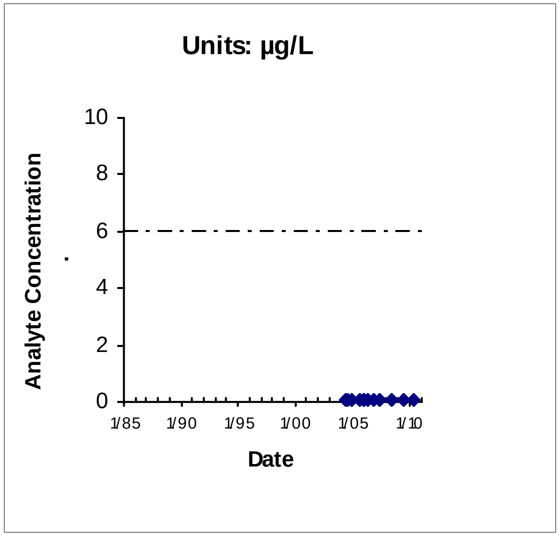
Location: MW616X07 Maximum: 0.0436



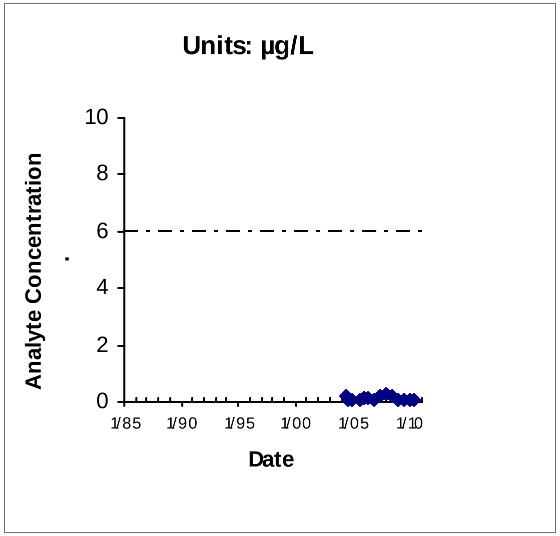
Location: MW617X07 Maximum: 0.0436



Location: MW618X07 Maximum: 0.0436



Location: MW619X07 Maximum: 0.0436



Location: MW620X07 Maximum: 0.25

— - — - — IRG (6 µg/L)

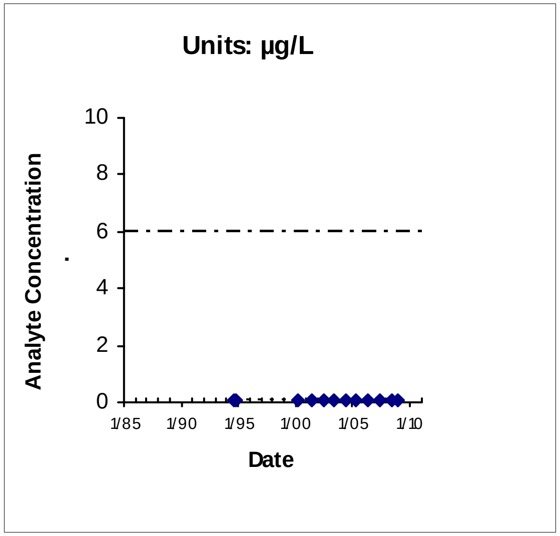
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)

FIGURE 4.1-7

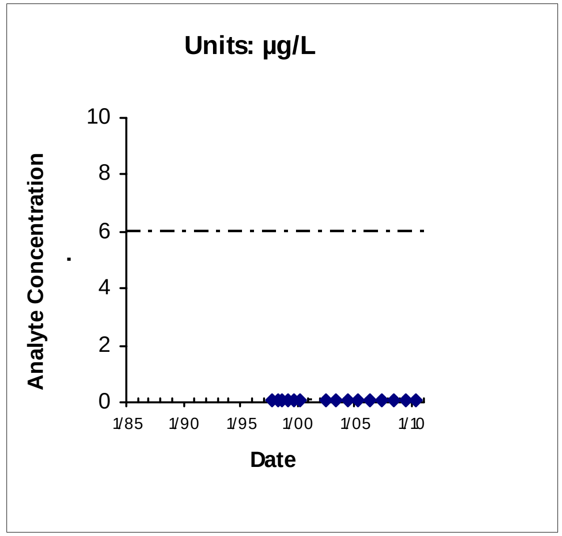
Sites FT004/SD031/LF007

1,1-DCE

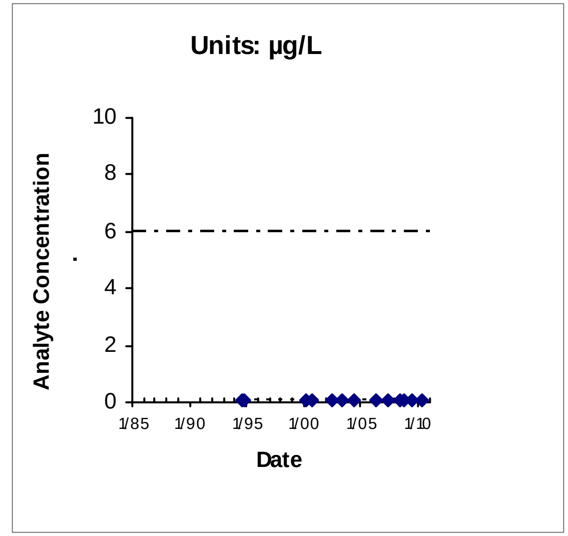
Chemical Time-series Plots



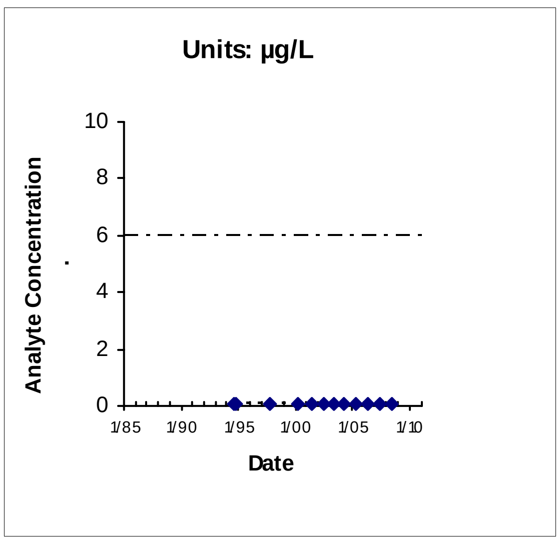
Location: MWAX07 Maximum: 0.0436



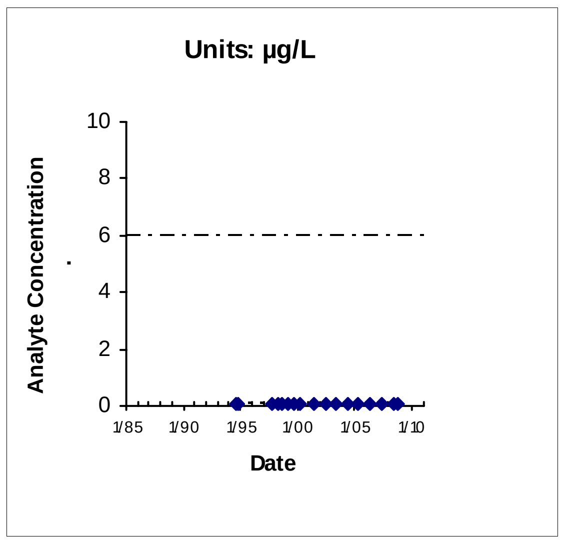
Location: MWBX07 Maximum: 0.0436



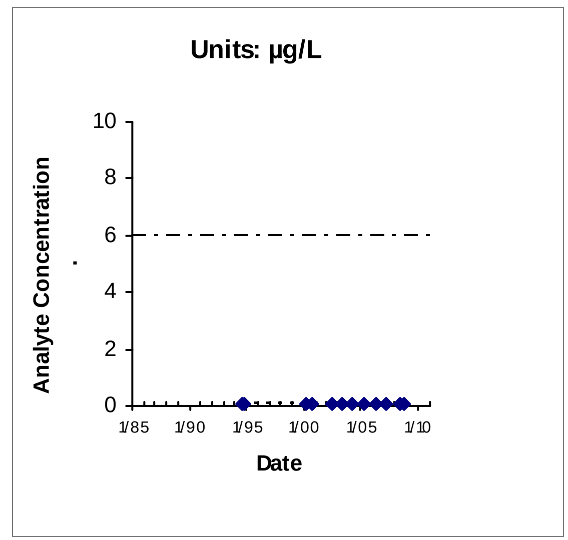
Location: MWCX07 Maximum: 0.0436



Location: MWDX07 Maximum: 0.0436



Location: MWFX07 Maximum: 0.0436



Location: MWGX07 Maximum: 0.0436

— - — - — IRG (6 µg/L)

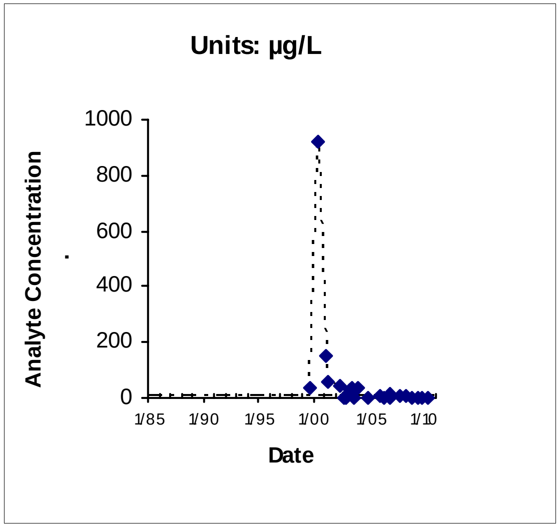
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)

FIGURE 4.1-7

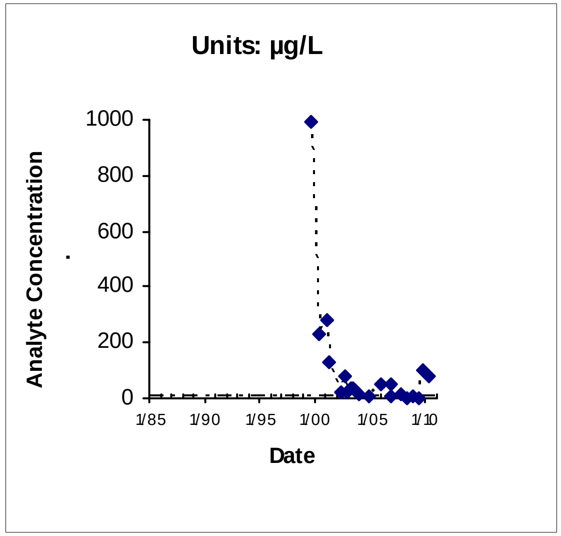
Sites FT004/SD031/LF007

1,1-DCE

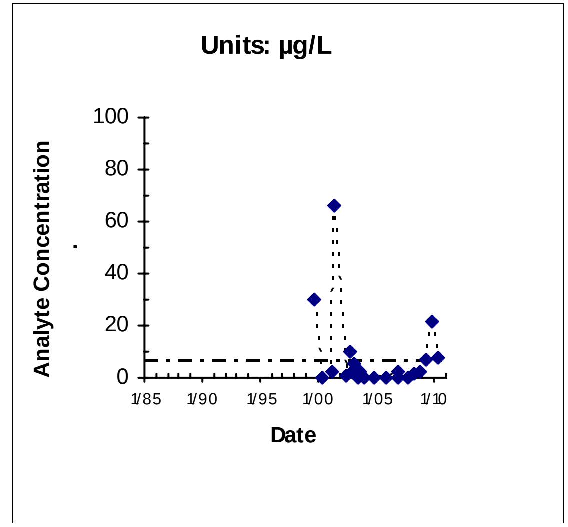
Chemical Time-series Plots



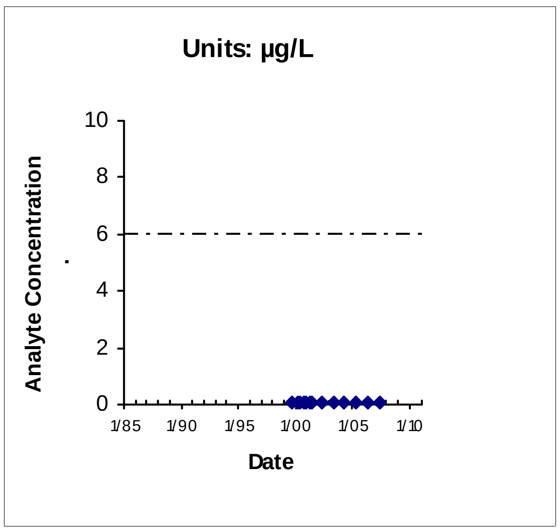
Location: EW565X31 Maximum: 920



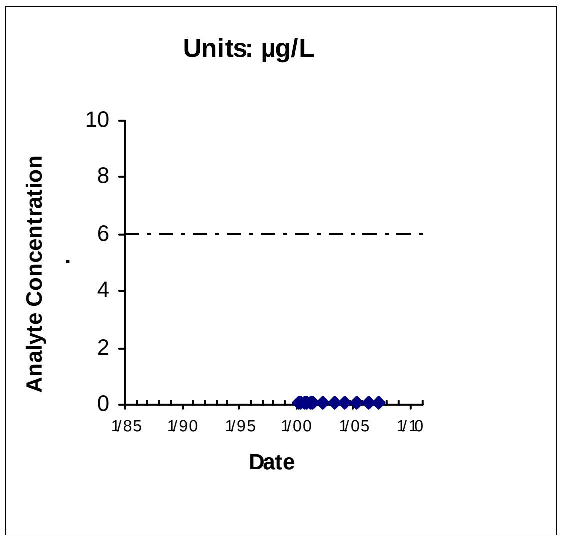
Location: EW566X31 Maximum: 990



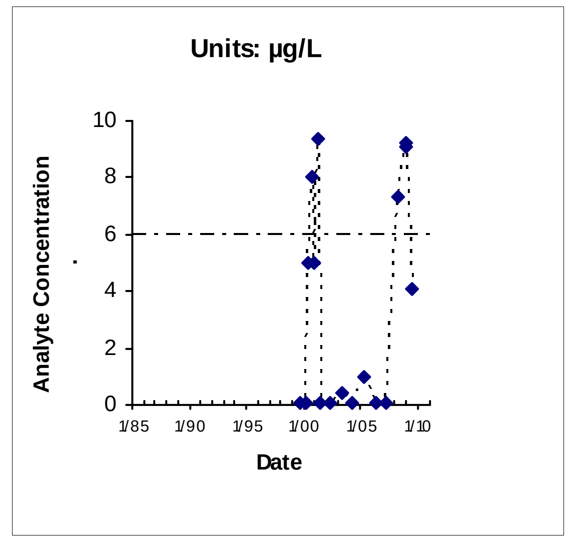
Location: EW567X31 Maximum: 66.2



Location: MW568X31 Maximum: 0.0436



Location: MW569X31 Maximum: 0.0436



Location: MW570X31 Maximum: 9.4

— - — - — IRG (6 µg/L)

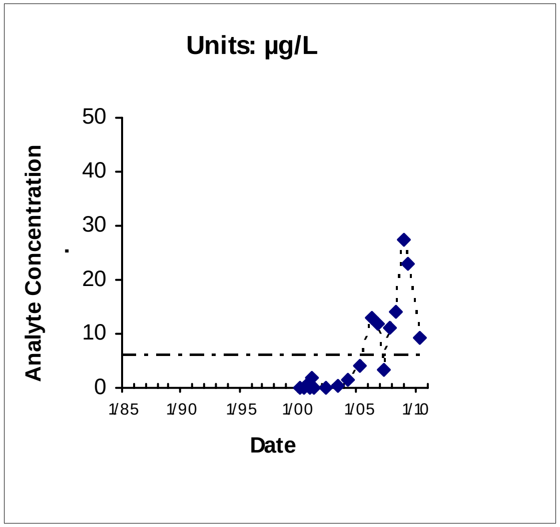
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)

FIGURE 4.1-7

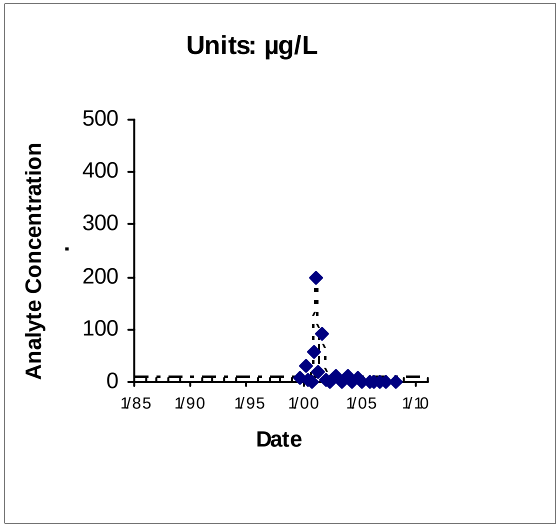
Sites FT004/SD031/LF007

1,1-DCE

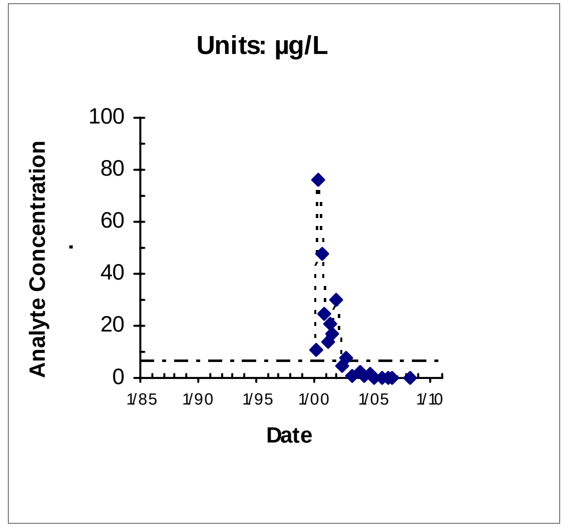
Chemical Time-series Plots



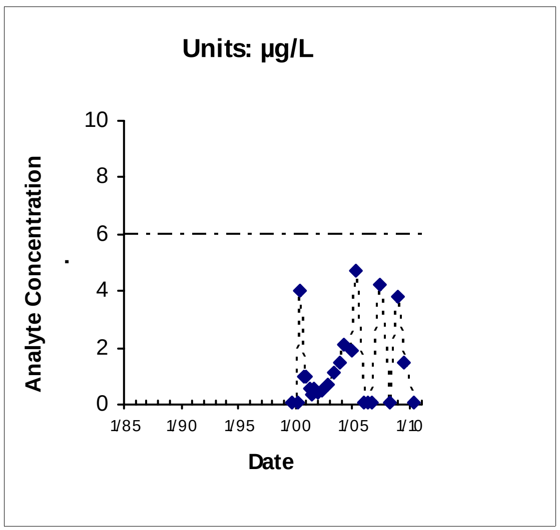
Location: MW571X31 Maximum: 27.4



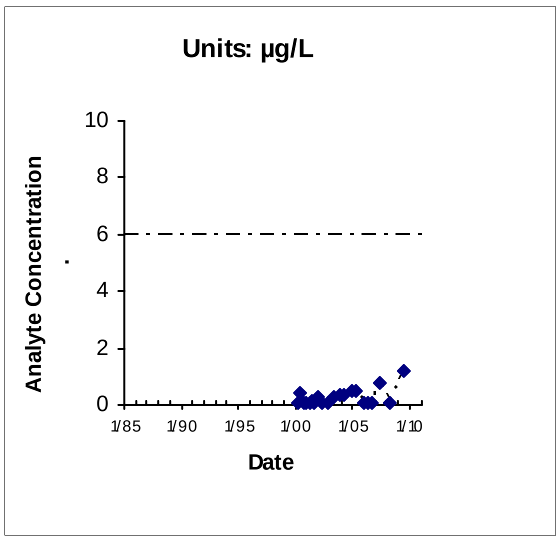
Location: MW572X31 Maximum: 200



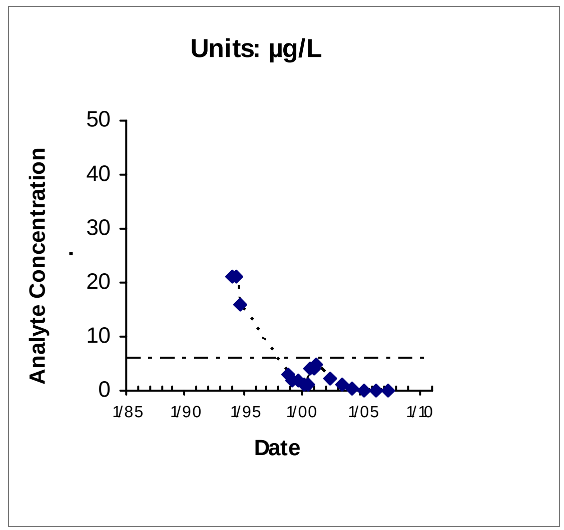
Location: MW573X31 Maximum: 76



Location: MW574X31 Maximum: 4.7



Location: MW575X31 Maximum: 1.2



Location: MW1725X31 Maximum: 21

FIGURE 4.1-7

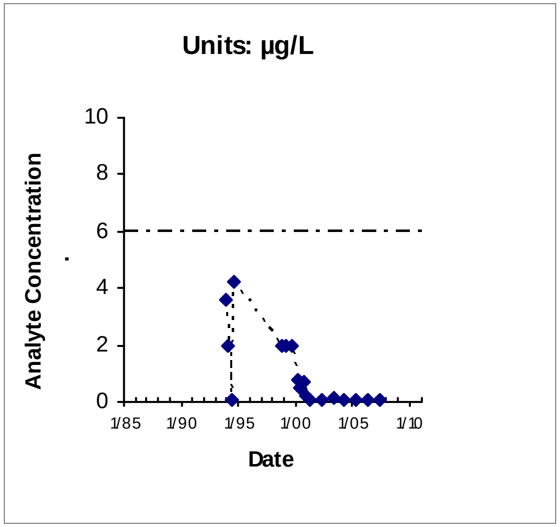
Sites FT004/SD031/LF007

1,1-DCE

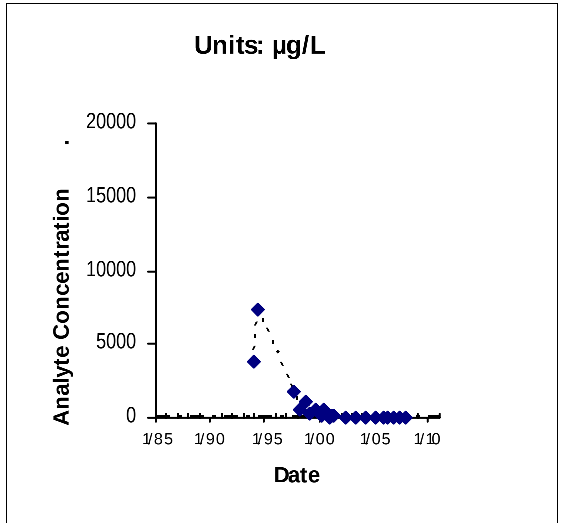
Chemical Time-series Plots

— - — - — IRG (6 µg/L)

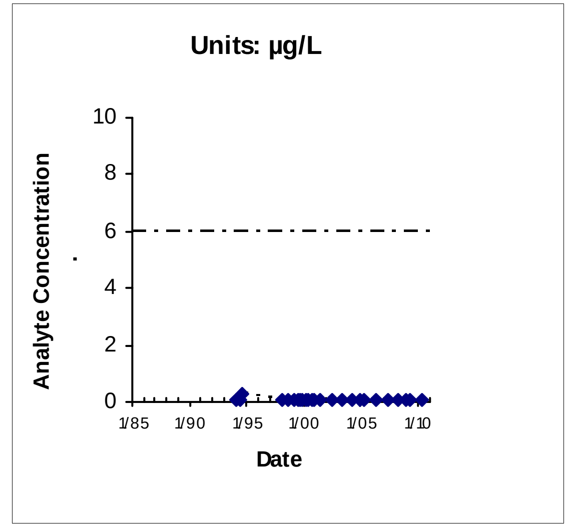
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)



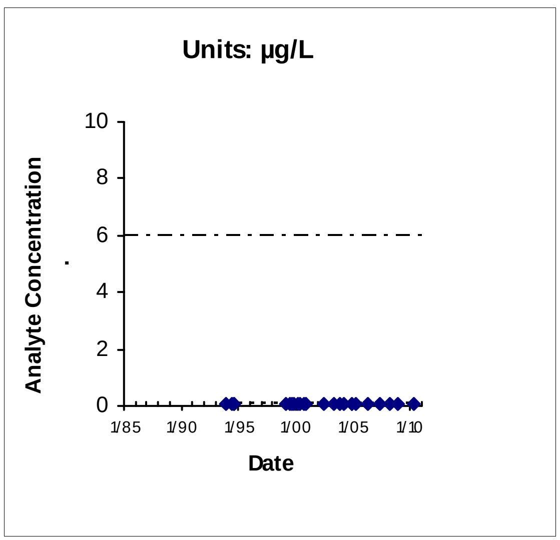
Location: MW1726X31 Maximum: 4.24



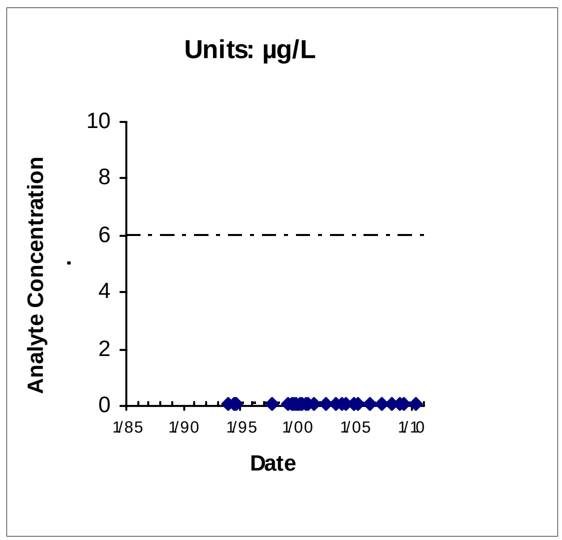
Location: MW1727X31 Maximum: 7300



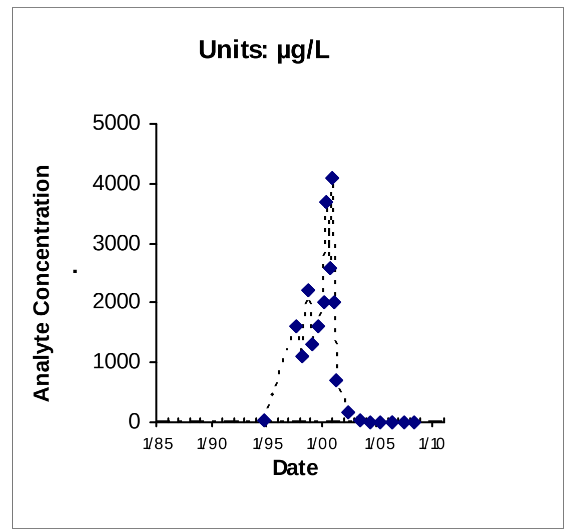
Location: MW1729X31 Maximum: 0.26



Location: MW1730X31 Maximum: 0.0436



Location: MW1731X31 Maximum: 0.0436



Location: MW1741X31 Maximum: 4100

— - — - — IRG (6 µg/L)

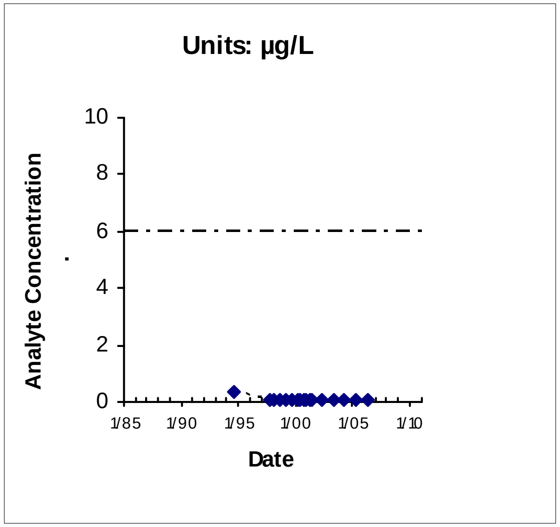
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)

FIGURE 4.1-7

Sites FT004/SD031/LF007

1,1-DCE

Chemical Time-series Plots



Location: MW1742X31 Maximum: 0.32

— - — - — IRG (6 µg/L)

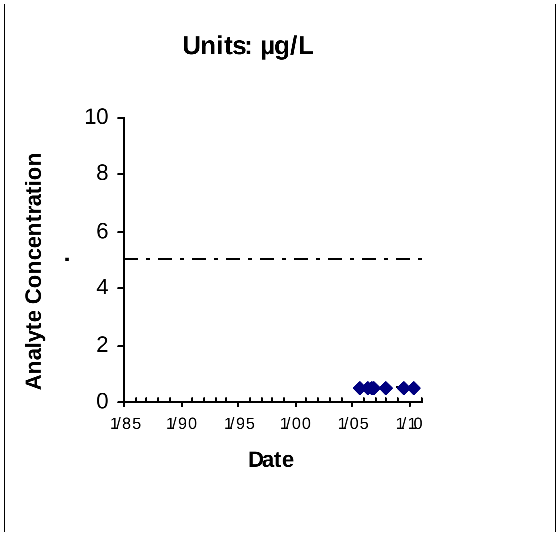
*Nondetects shown as the Method Detection Limit (0.0436 µg/L)

FIGURE 4.1-7

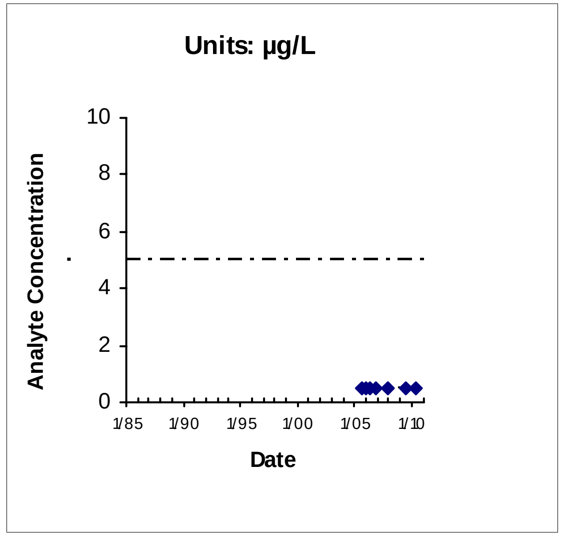
Sites FT004/SD031/LF007

1,1-DCE

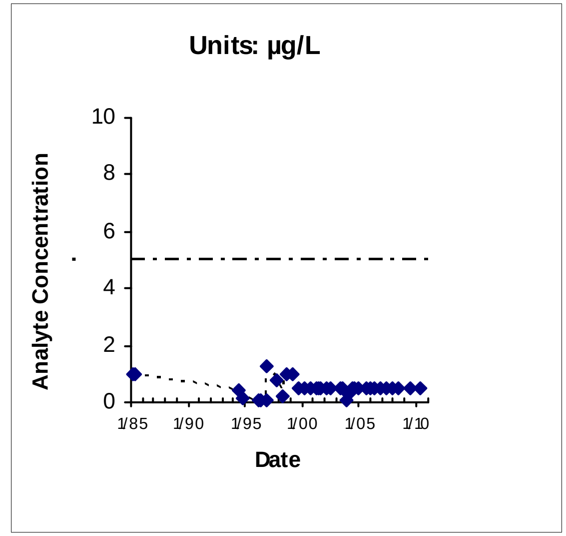
Chemical Time-series Plots



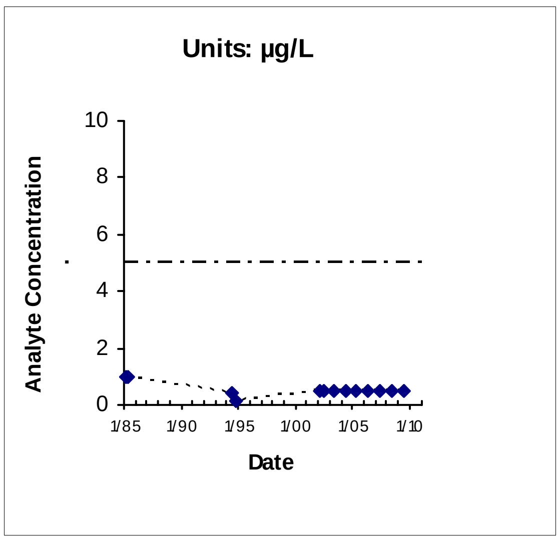
Location: EW614X07 Maximum: 0.5



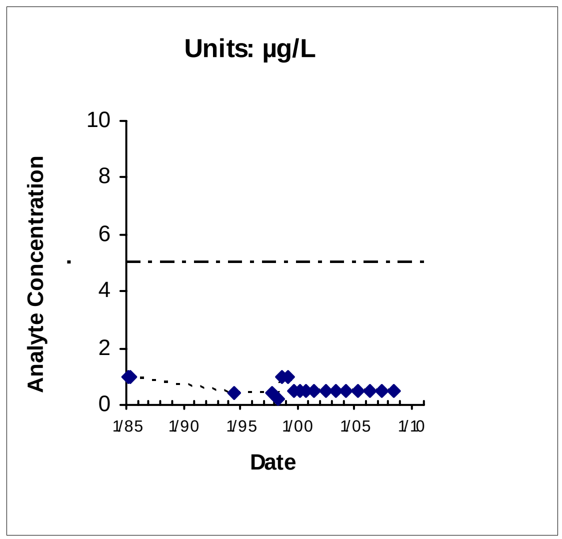
Location: EW615X07 Maximum: 0.5



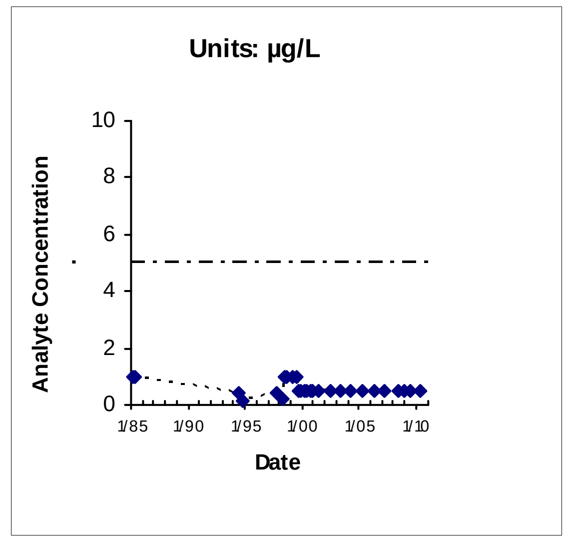
Location: MW125X07 Maximum: 1.27



Location: MW126X07 Maximum: 1



Location: MW128X07 Maximum: 1



Location: MW129X07 Maximum: 1

— - — - — IRG (5 µg/L)

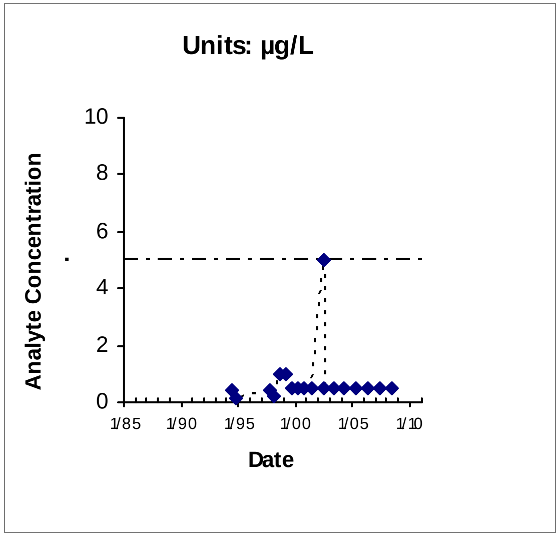
*Nondetects shown as the Method Detection Limit (µg/L)

FIGURE 4.1-8

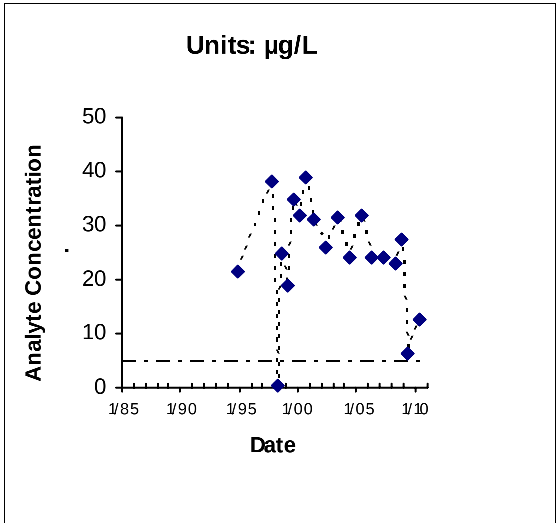
Site LF007

1,4-DCB

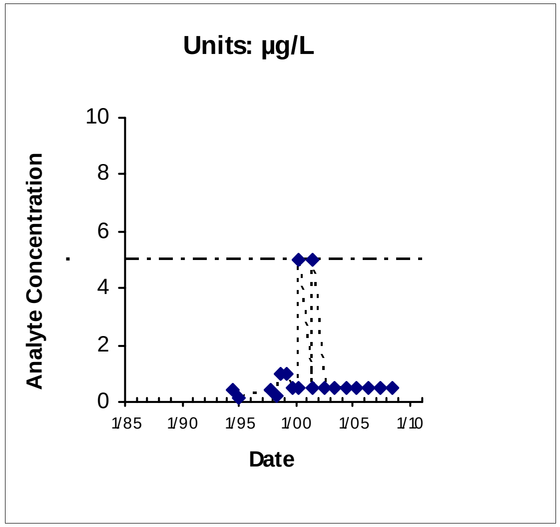
Chemical Time-series Plots



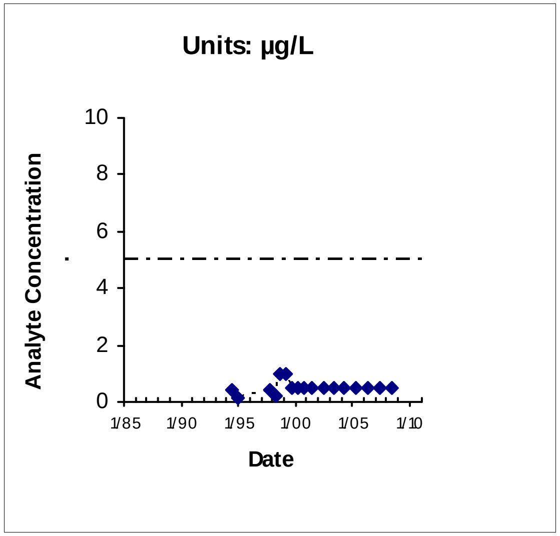
Location: MW201X07 Maximum: 5



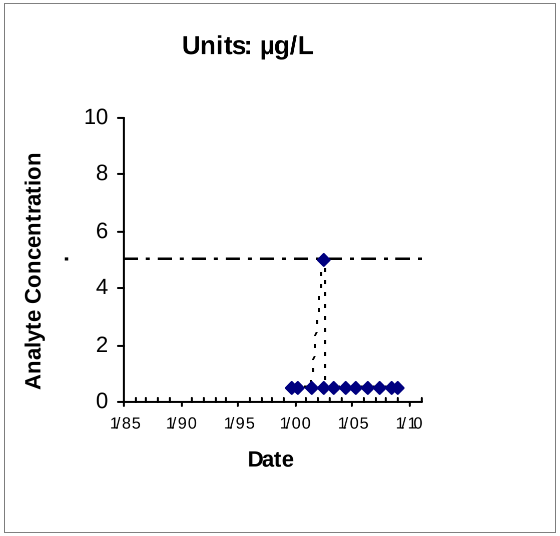
Location: MW261X07 Maximum: 39



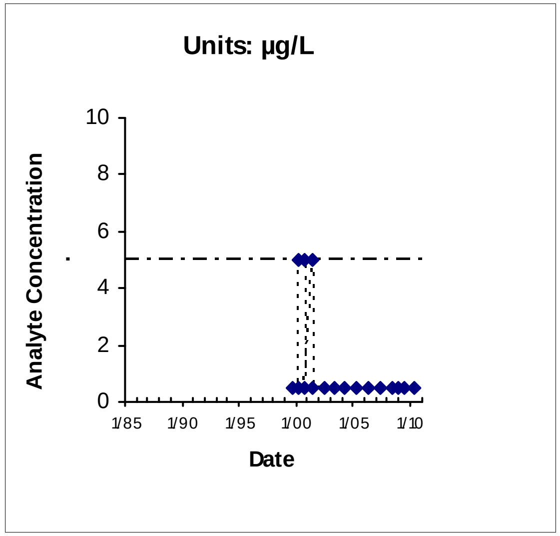
Location: MW284X07 Maximum: 5



Location: MW303X07 Maximum: 1



Location: MW600X07 Maximum: 5



Location: MW601X07 Maximum: 5

— - — - — IRG (5 µg/L)

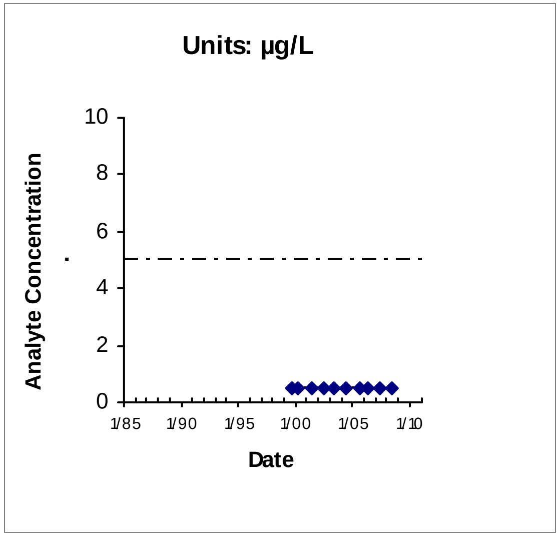
*Nondetects shown as the Method Detection Limit (µg/L)

FIGURE 4.1-8

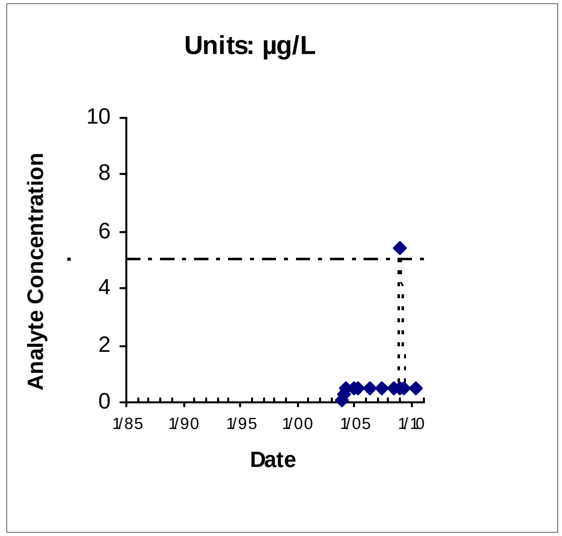
Site LF007

1,4-DCB

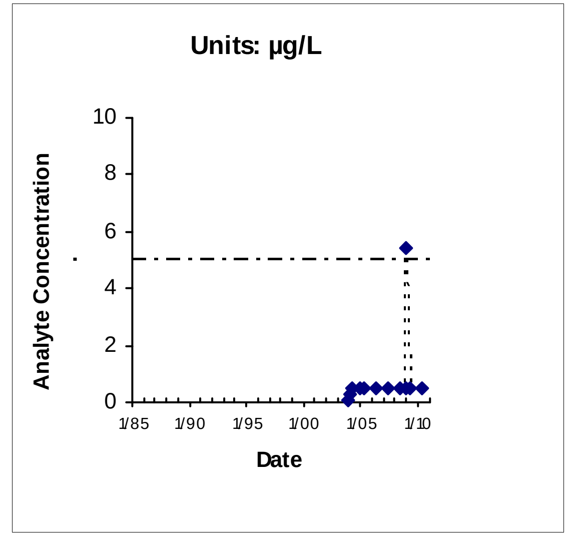
Chemical Time-series Plots



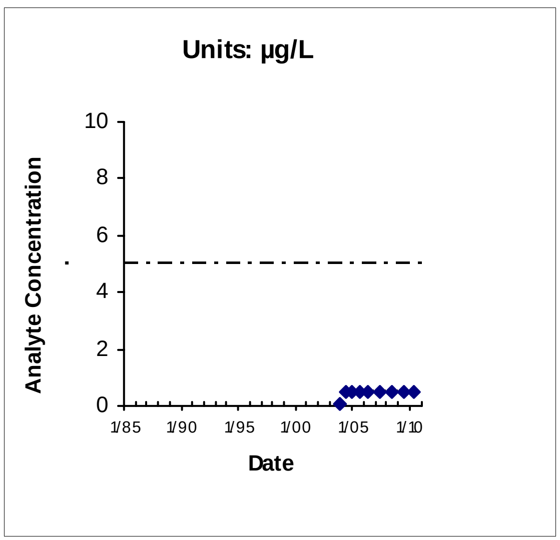
Location: MW602X07 Maximum: 0.5



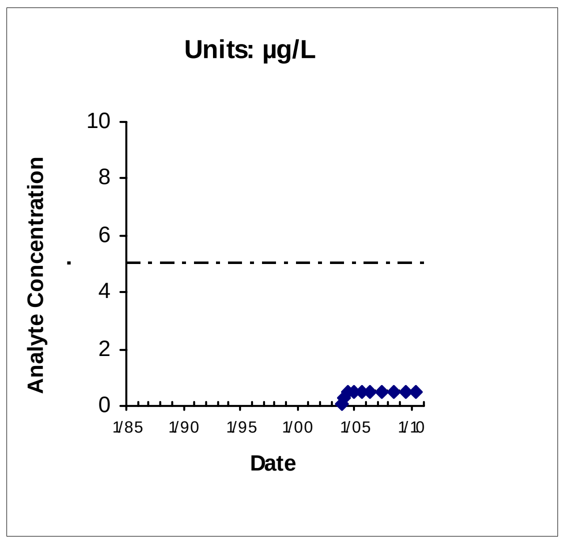
Location: MW612X07 Maximum: 5.4



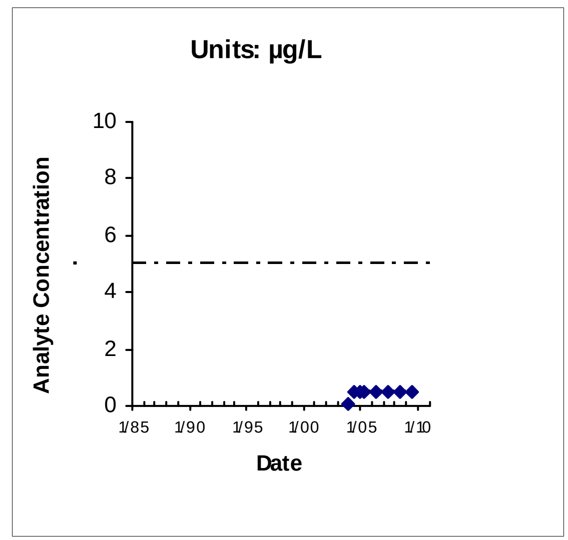
Location: MW613X07 Maximum: 5.4



Location: MW616X07 Maximum: 0.5



Location: MW617X07 Maximum: 0.5

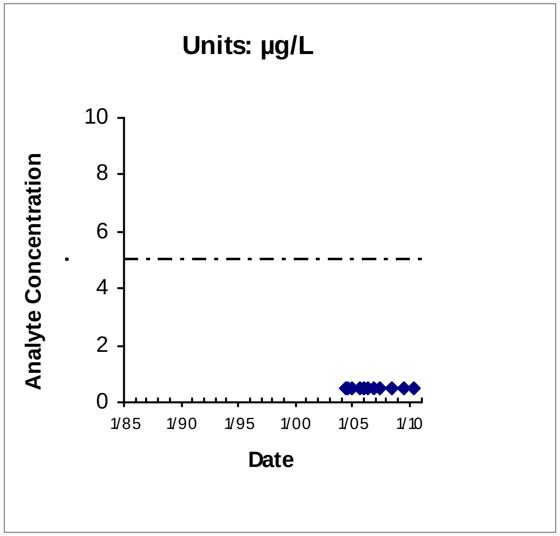


Location: MW618X07 Maximum: 0.5

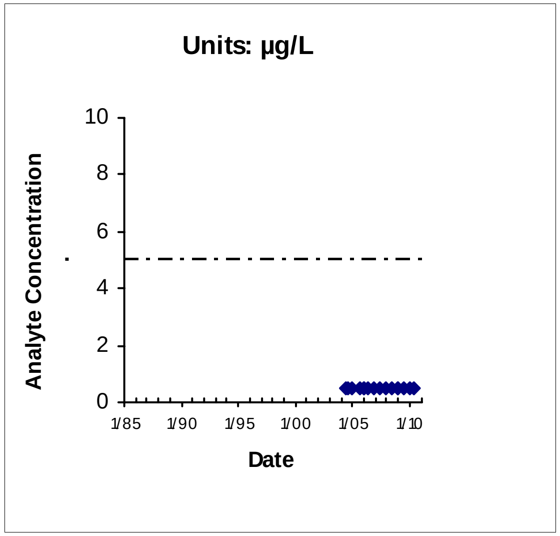
— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (µg/L)

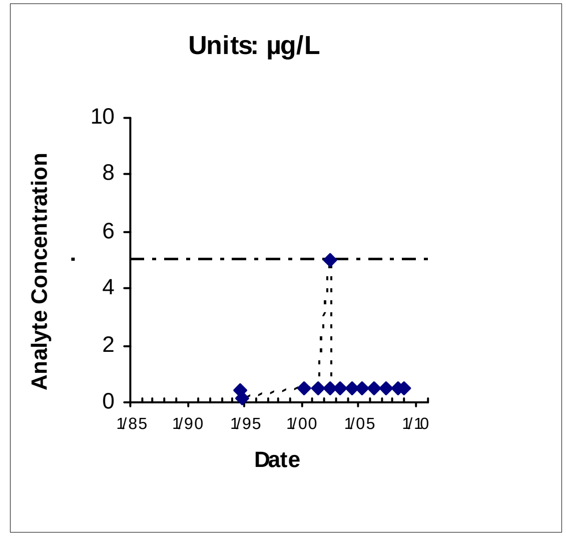
FIGURE 4.1-8
Site LF007
1,4-DCB
Chemical Time-series Plots



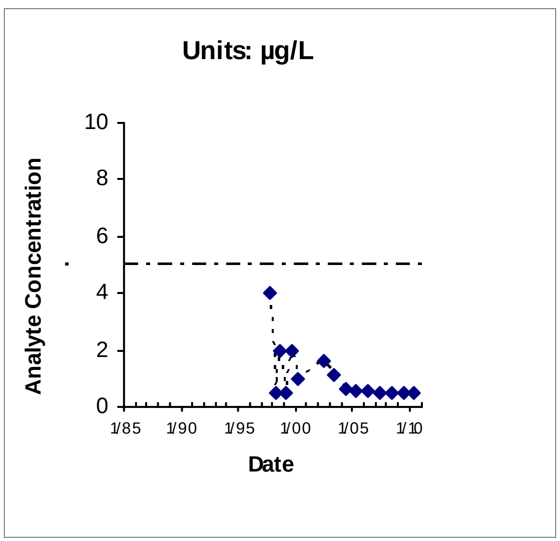
Location: MW619X07 Maximum: 0.5



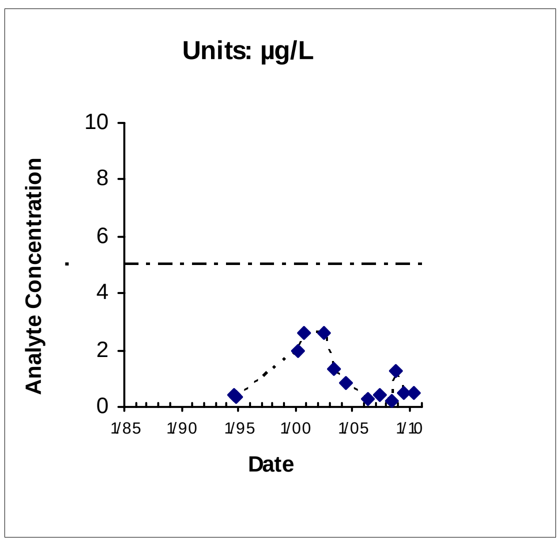
Location: MW620X07 Maximum: 0.5



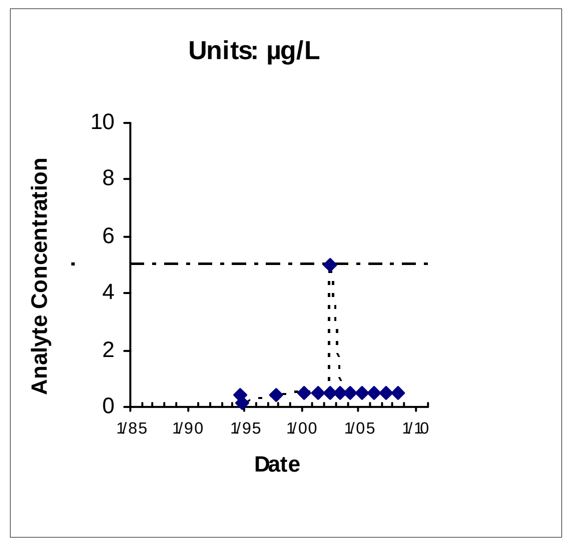
Location: MWAX07 Maximum: 5



Location: MWBX07 Maximum: 4



Location: MWCX07 Maximum: 2.6

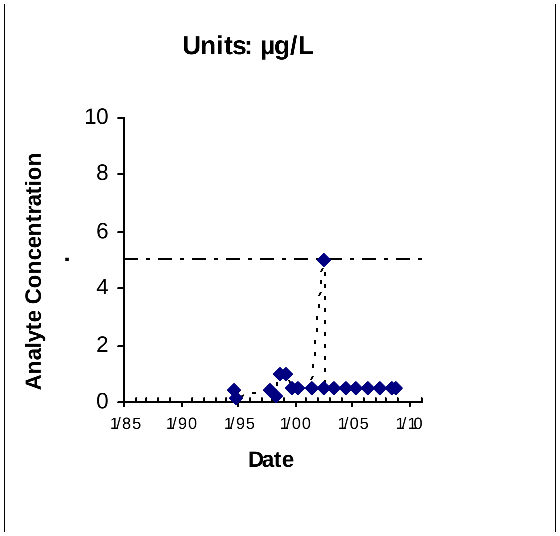


Location: MWDX07 Maximum: 5

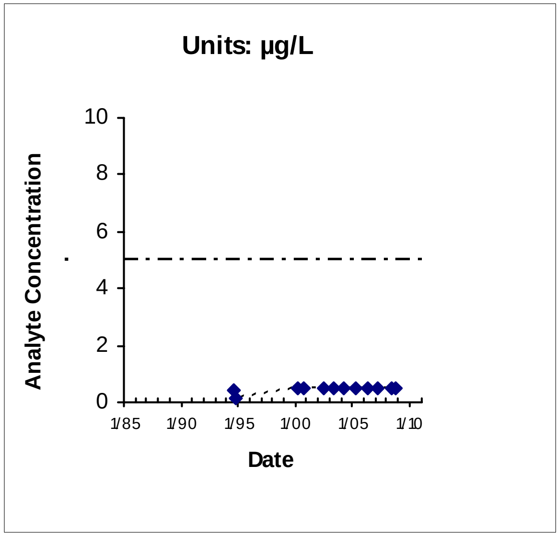
— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (µg/L)

FIGURE 4.1-8
Site LF007
1,4-DCB
Chemical Time-series Plots



Location: MWFX07 Maximum: 5



Location: MWGX07 Maximum: 0.5

— - — - — IRG (5 µg/L)

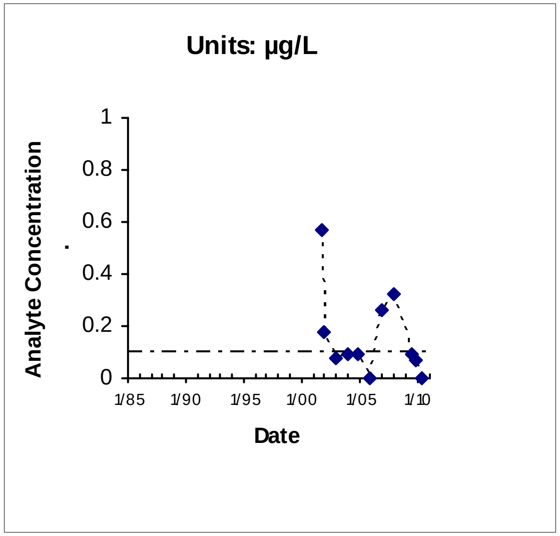
*Nondetects shown as the Method Detection Limit (µg/L)

FIGURE 4.1-8

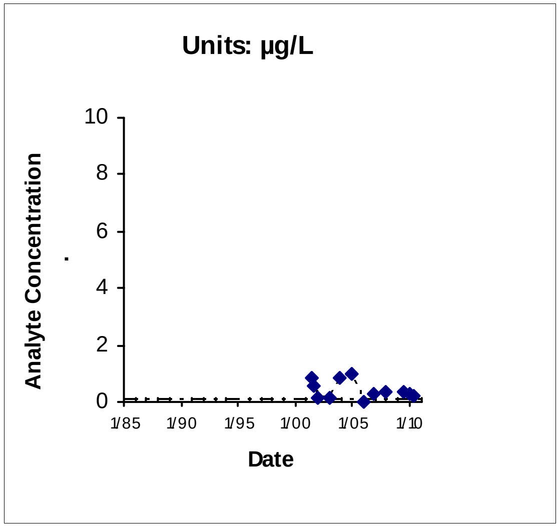
Site LF007

1,4-DCB

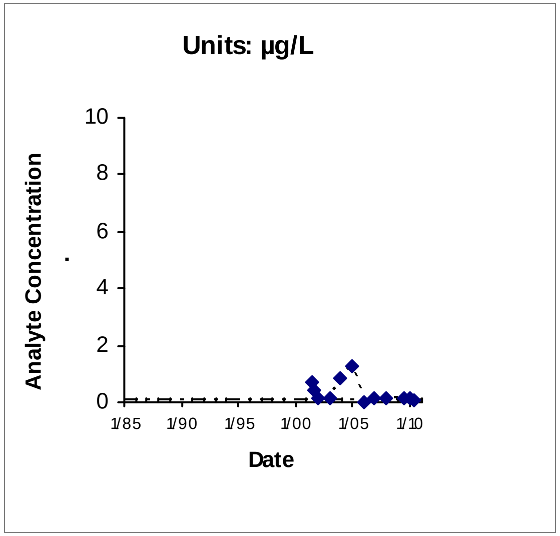
Chemical Time-series Plots



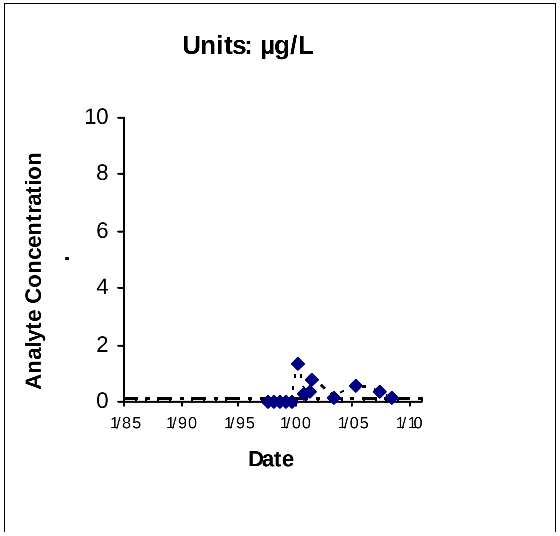
Location: EW719X08 Maximum: 0.571



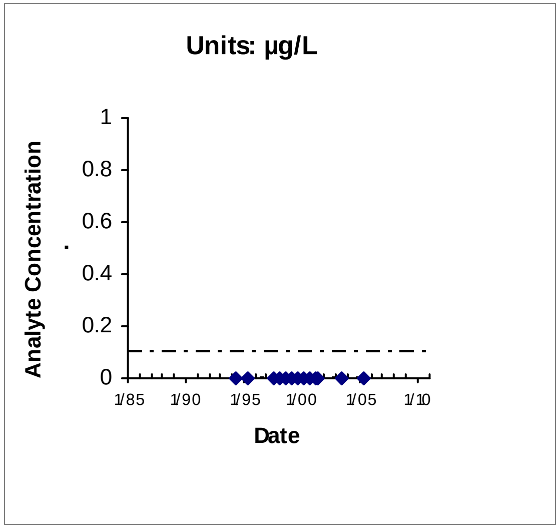
Location: EW720X08 Maximum: 1



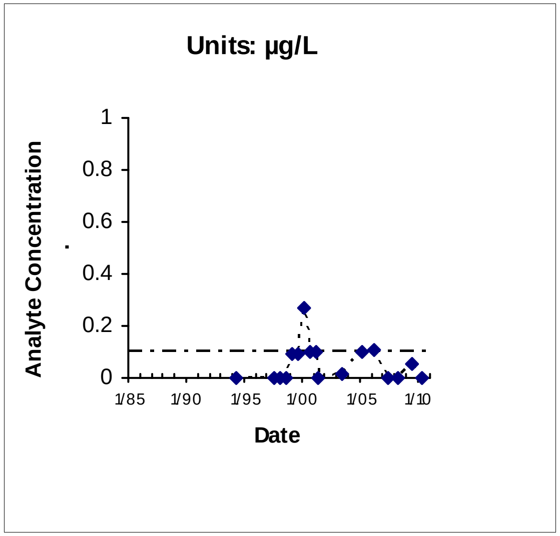
Location: EW721X08 Maximum: 1.3



Location: MW01X08 Maximum: 1.353



Location: MW113X08 Maximum: 0.000097



Location: MW114X08 Maximum: 0.2712

— - — - — IRG (0.1 µg/L)

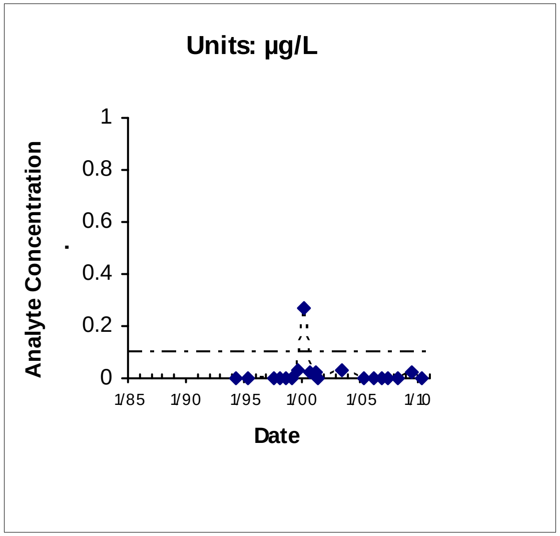
*Nondetects shown as the Method Detection Limit (0.000097 µg/L)

FIGURE 4.9-4

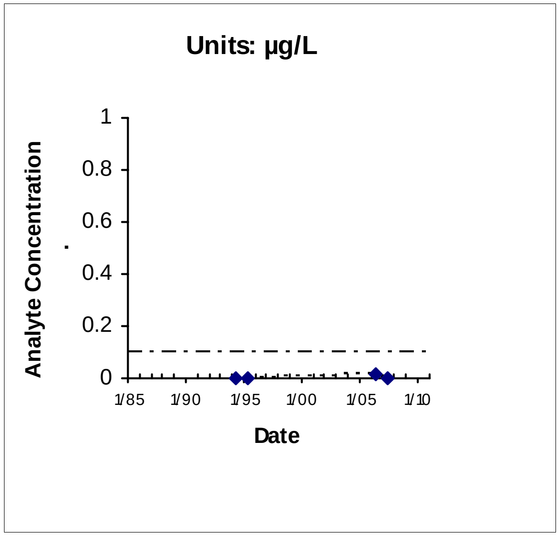
Site LF008

Alpha-chlordane

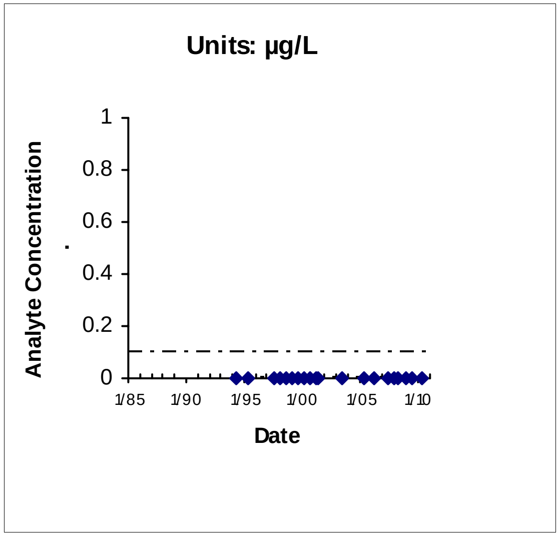
Chemical Time-series Plots



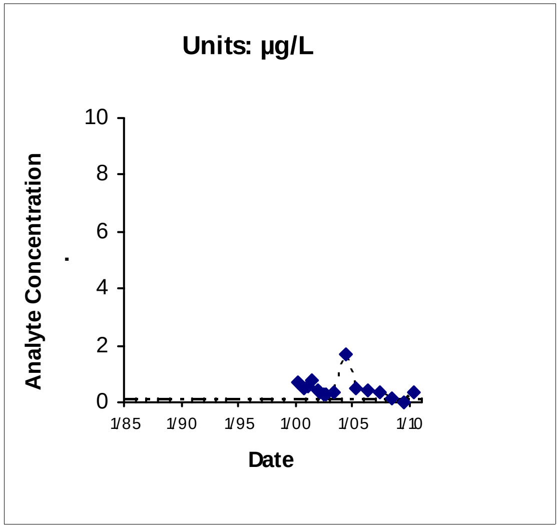
Location: MW115X08 Maximum: 0.2729



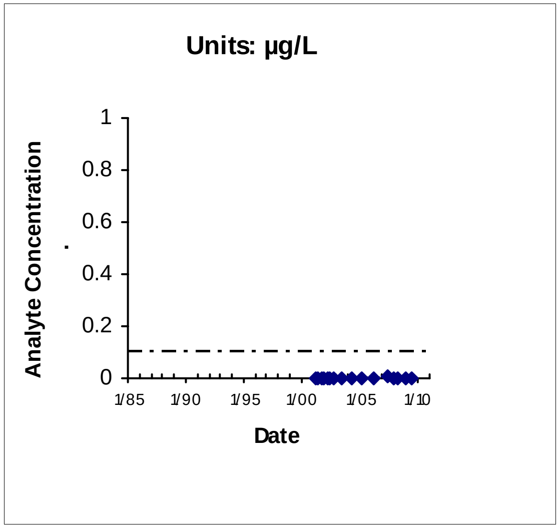
Location: MW253X08 Maximum: 0.013



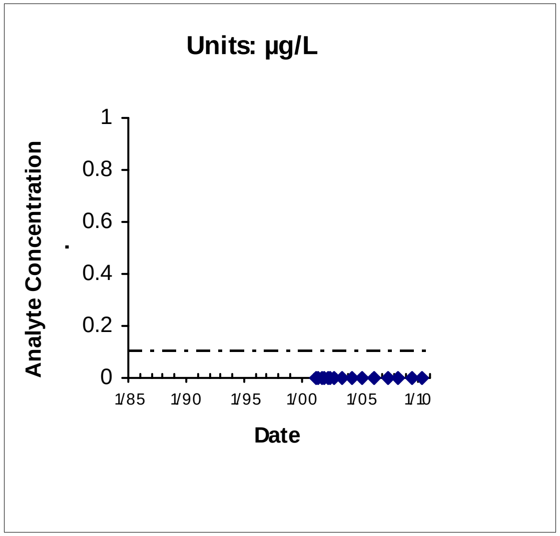
Location: MW311X08 Maximum: 0.000097



Location: MW712X08 Maximum: 1.7



Location: MW713X08 Maximum: 0.0076



Location: MW714X08 Maximum: 0.000097

— - — - — IRG (0.1 µg/L)

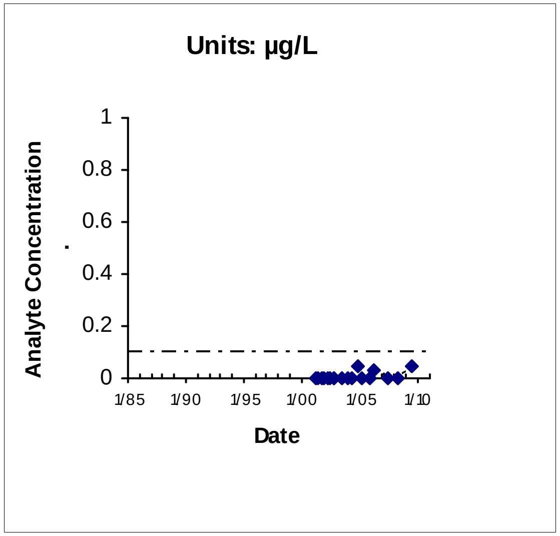
*Nondetects shown as the Method Detection Limit (0.000097 µg/L)

FIGURE 4.9-4

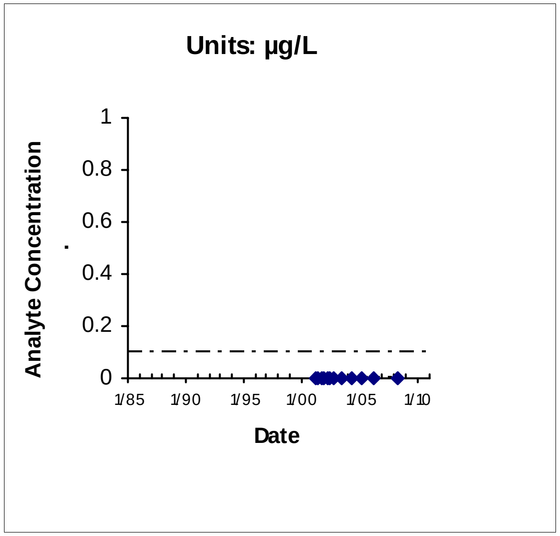
Site LF008

Alpha-chlordane

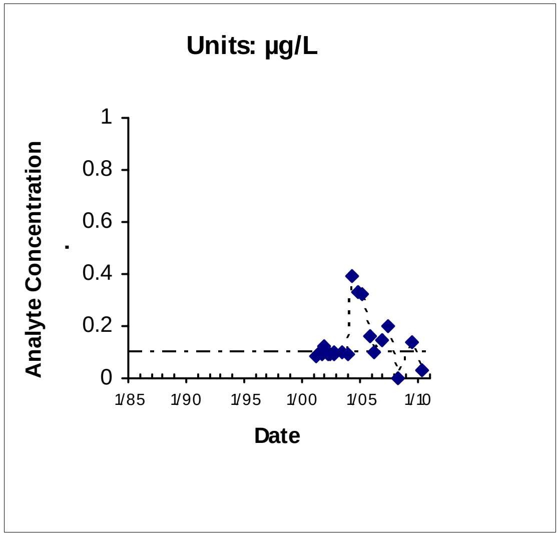
Chemical Time-series Plots



Location: MW715X08 Maximum: 0.047



Location: MW716X08 Maximum: 0.000097



Location: MW717X08 Maximum: 0.39

— - — - — IRG (0.1 µg/L)

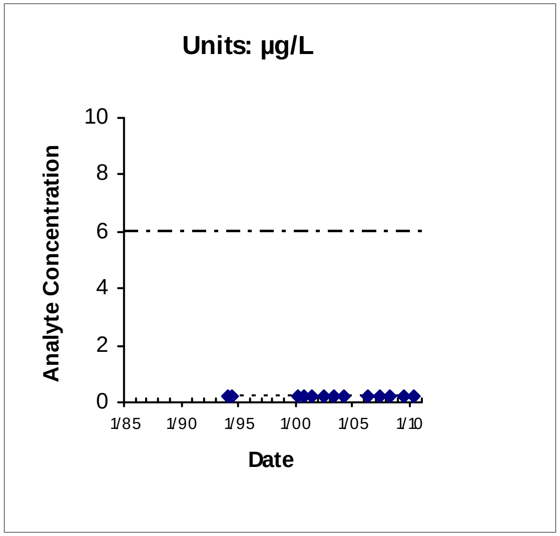
*Nondetects shown as the Method Detection Limit (0.000097 µg/L)

FIGURE 4.9-4

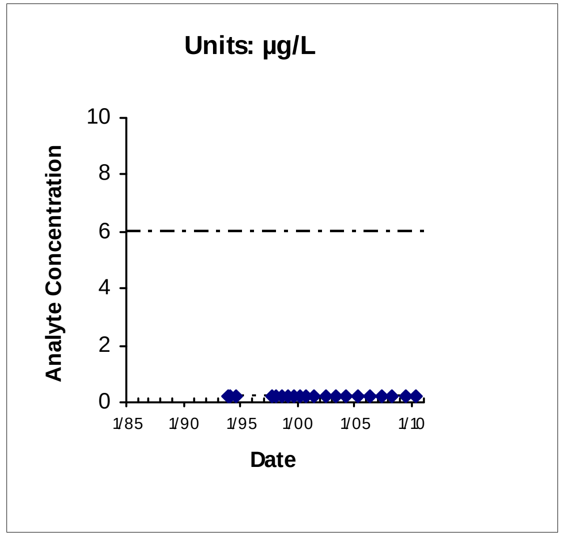
Site LF008

Alpha-chlordane

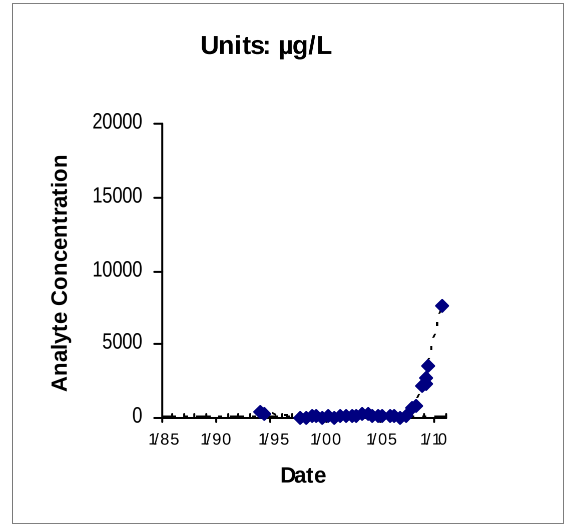
Chemical Time-series Plots



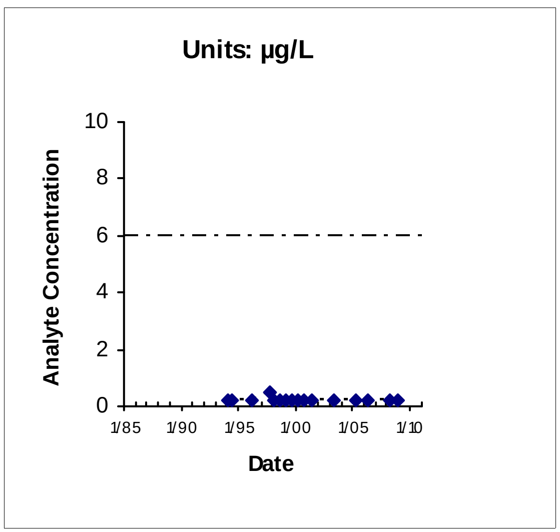
Location: MW104X15 Maximum: 0.23



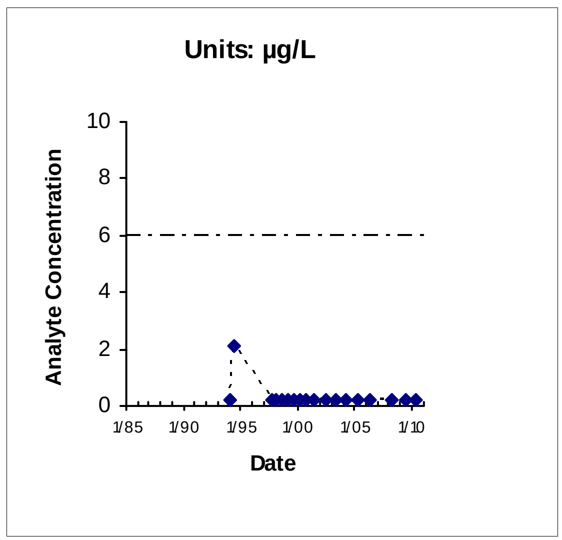
Location: MW105X15 Maximum: 0.23



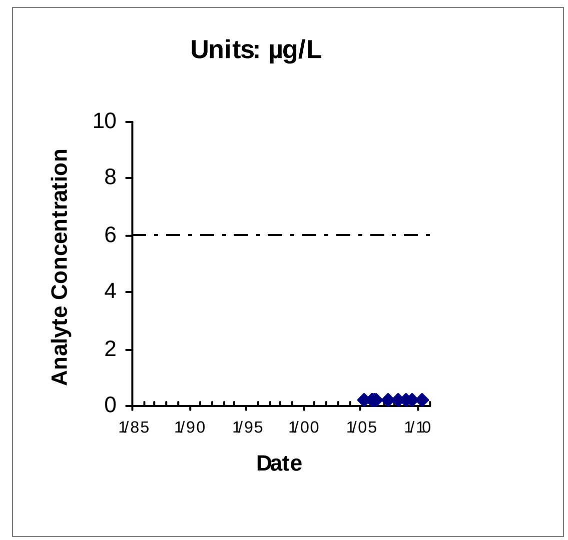
Location: MW216X15 Maximum: 7680



Location: MW238X15 Maximum: 0.5



Location: MW306X15 Maximum: 2.1



Location: MW624X15 Maximum: 0.23

— - — - — IRG (6 µg/L)

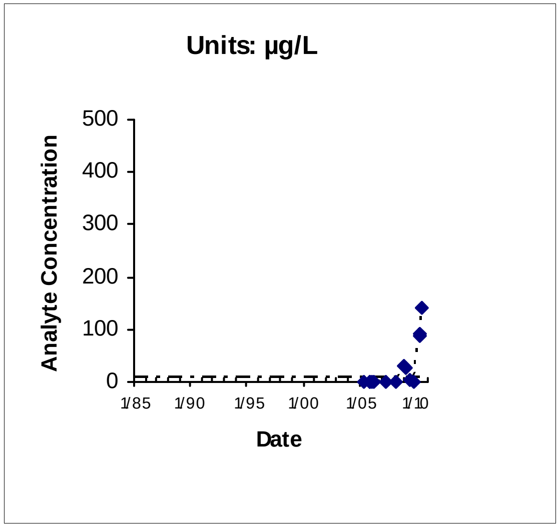
*Nondetects shown as the Method Detection Limit (0.23 µg/L)

FIGURE 4.7-11

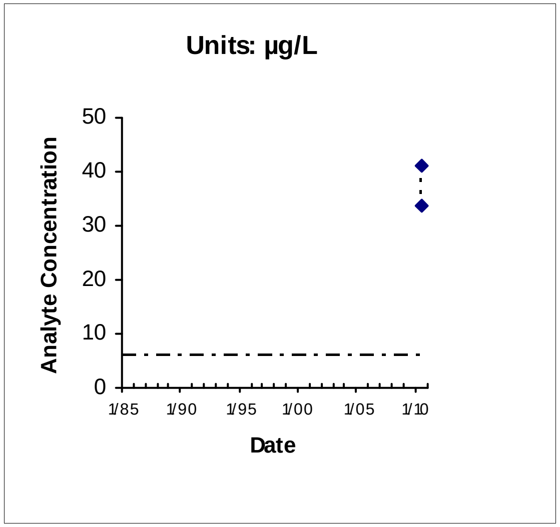
Site SS015

Cis-1,2-DCE

Chemical Time-series Plots



Location: MW625X15 Maximum: 143



Location: MW2124x15 Maximum: 41

— - — - — IRG (6 µg/L)

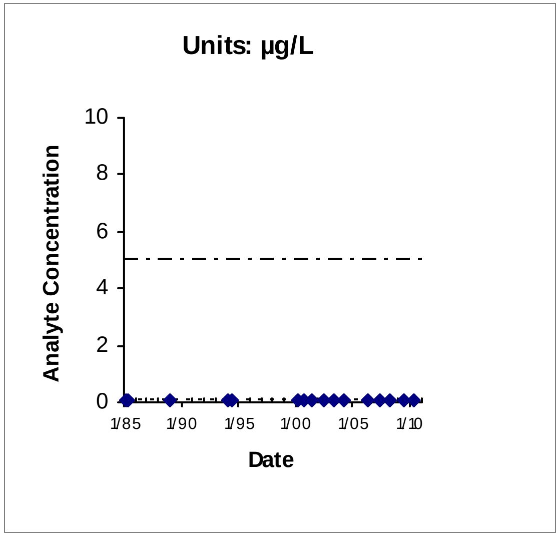
*Nondetects shown as the Method Detection Limit (0.23 µg/L)

FIGURE 4.7-11

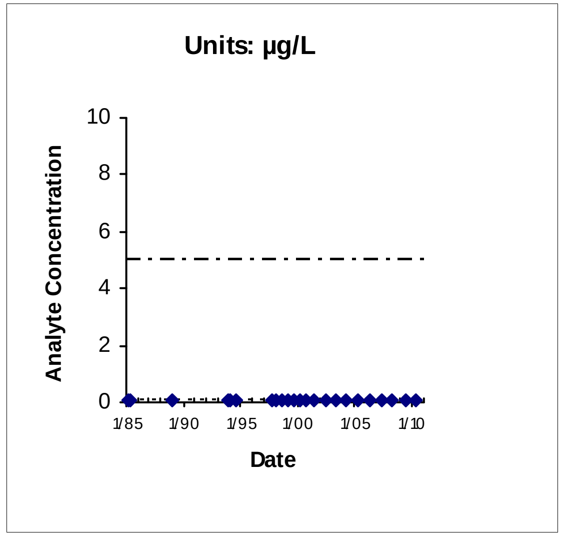
Site SS015

Cis-1,2-DCE

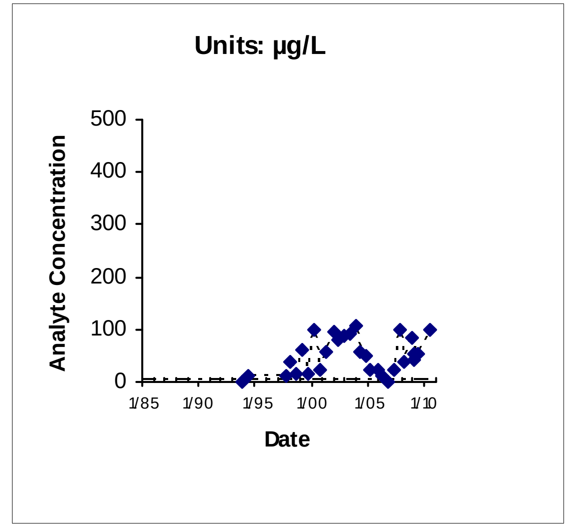
Chemical Time-series Plots



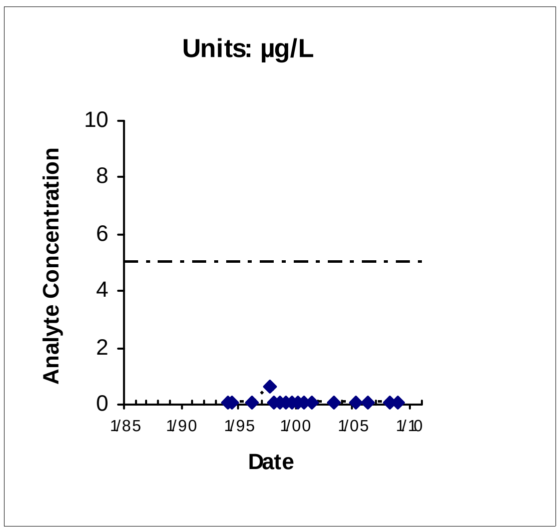
Location: MW104X15 Maximum: 0.0363



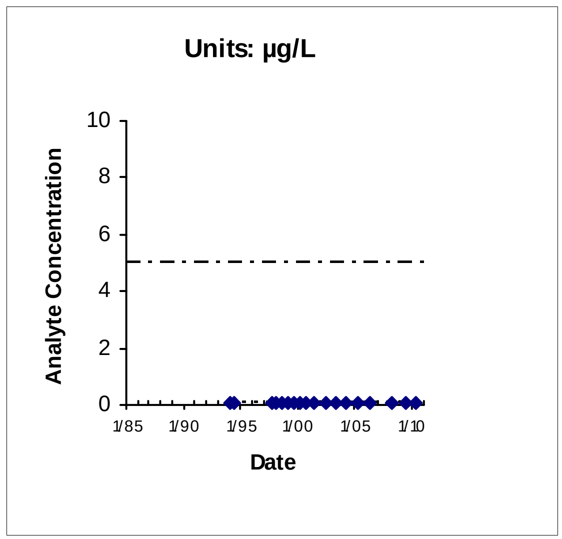
Location: MW105X15 Maximum: 0.0363



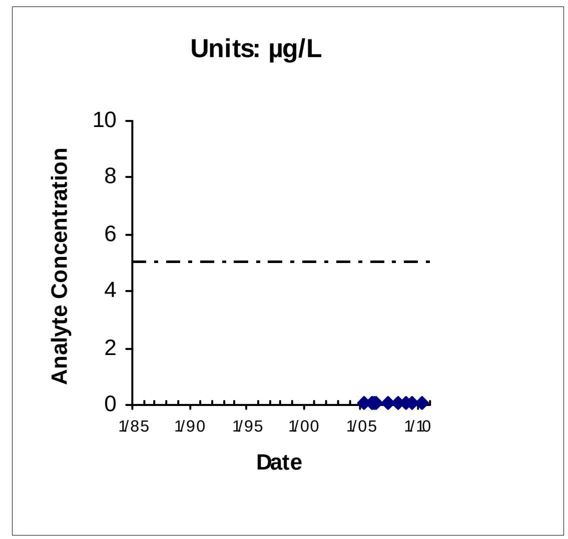
Location: MW216X15 Maximum: 105



Location: MW238X15 Maximum: 0.6



Location: MW306X15 Maximum: 0.0363



Location: MW624X15 Maximum: 0.0363

— - — - — IRG (5 µg/L)

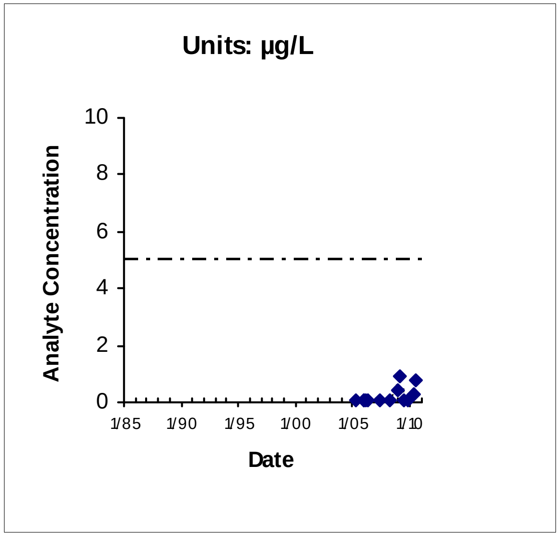
*Nondetects shown as the Method Detection Limit (0.0363 µg/L)

FIGURE 4.7-10

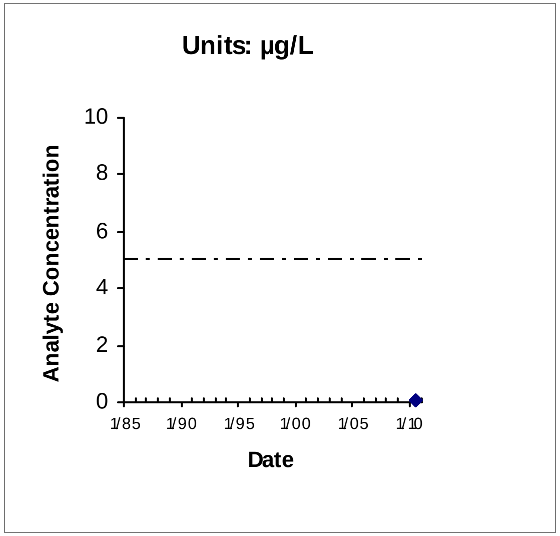
Site SS015

PCE

Chemical Time-series Plots



Location: MW625X15 Maximum: 0.91

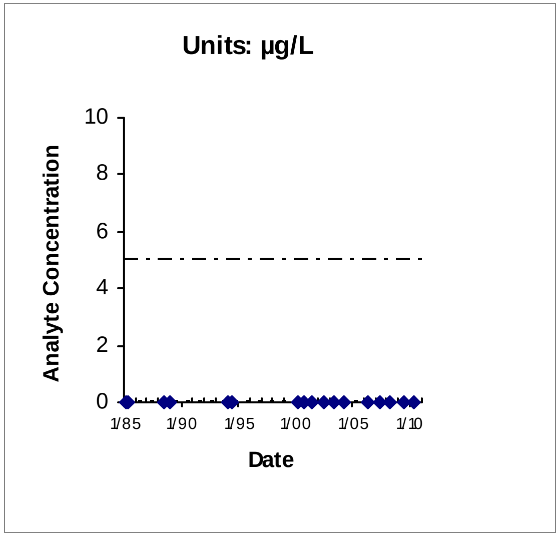


Location: MW2124x15 Maximum: 0.0363

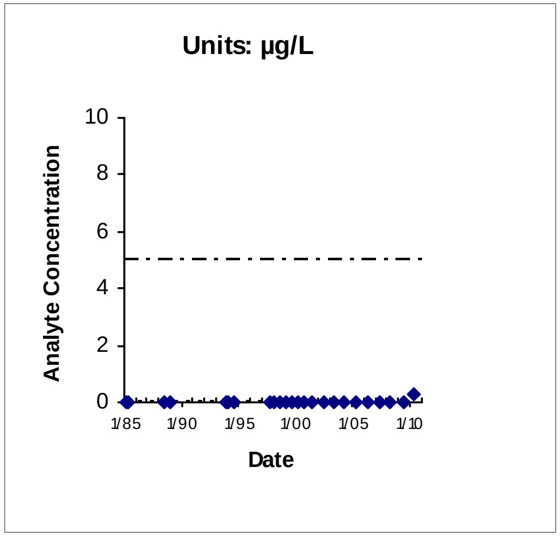
— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (0.0363 µg/L)

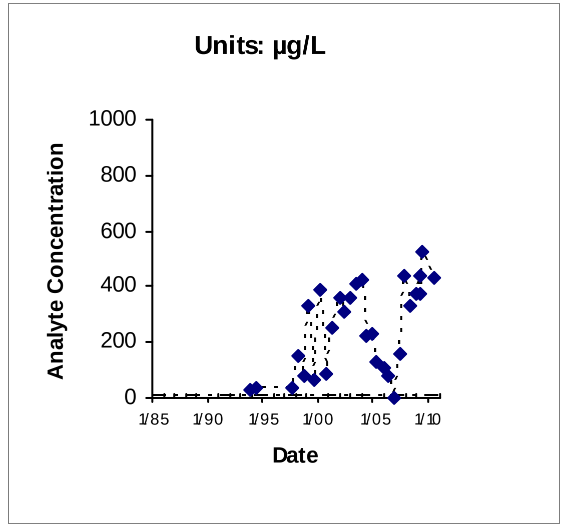
FIGURE 4.7-10
Site SS015
PCE
Chemical Time-series Plots



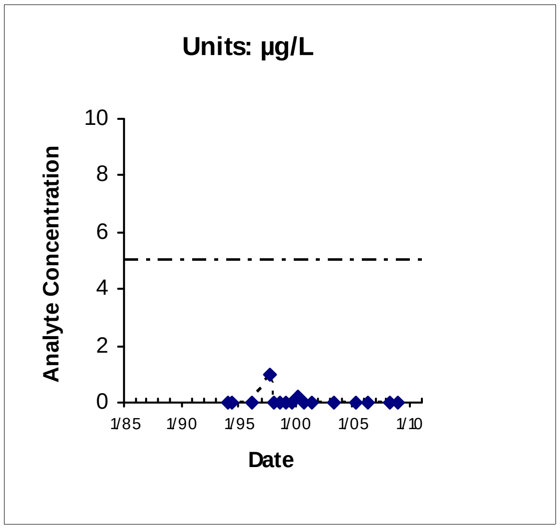
Location: MW104X15 Maximum: 0.03



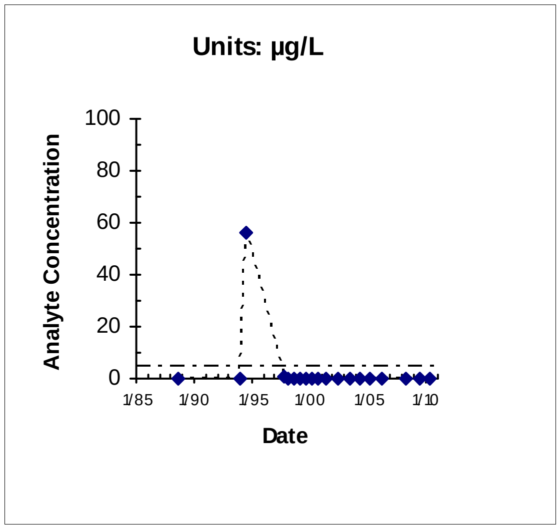
Location: MW105X15 Maximum: 0.25



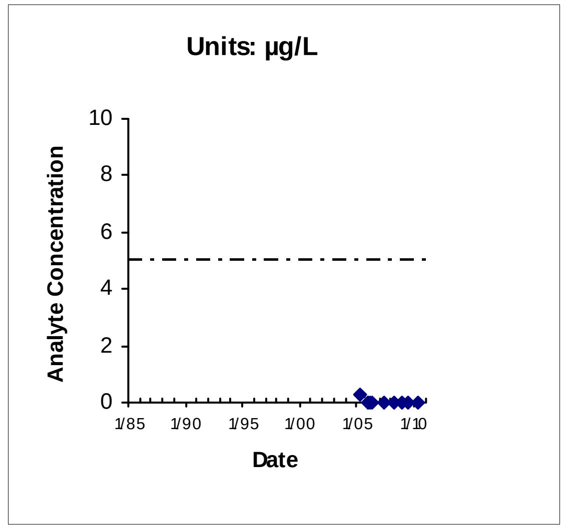
Location: MW216X15 Maximum: 525



Location: MW238X15 Maximum: 1



Location: MW306X15 Maximum: 56



Location: MW624X15 Maximum: 0.27

— - — - — IRG (5 µg/L)

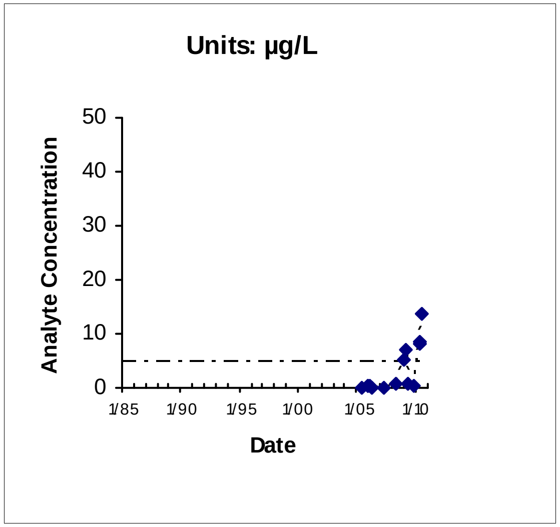
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.7-9

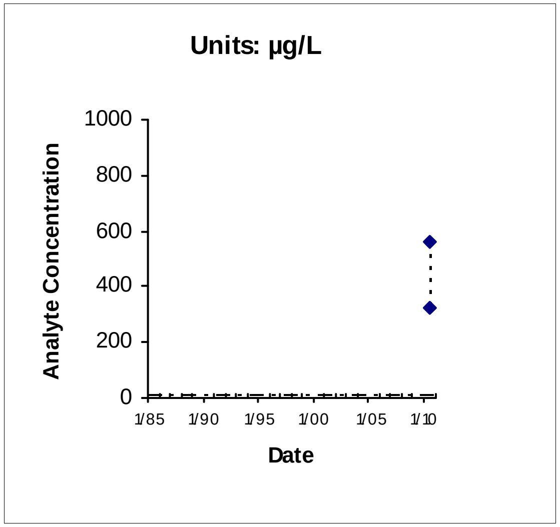
Site SS015

TCE

Chemical Time-series Plots



Location: MW625X15 Maximum: 13.6



Location: MW2124x15 Maximum: 563

— - — - — IRG (5 µg/L)

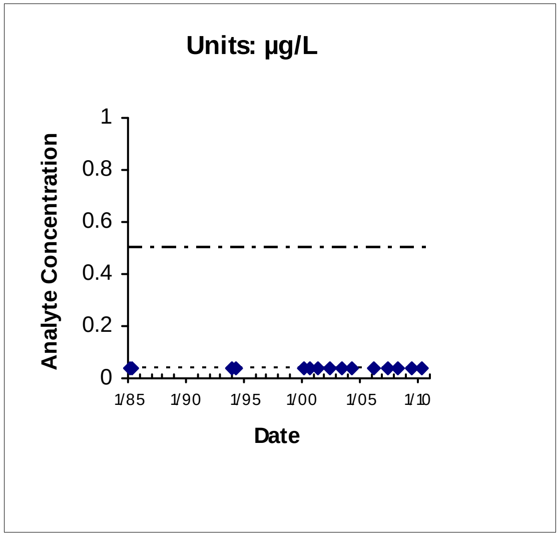
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.7-9

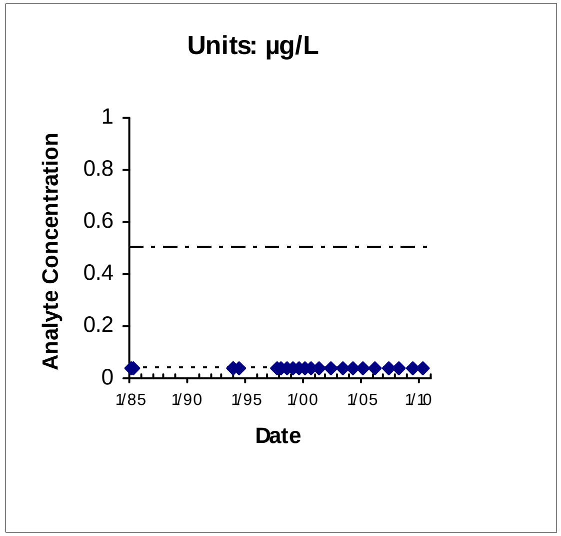
Site SS015

TCE

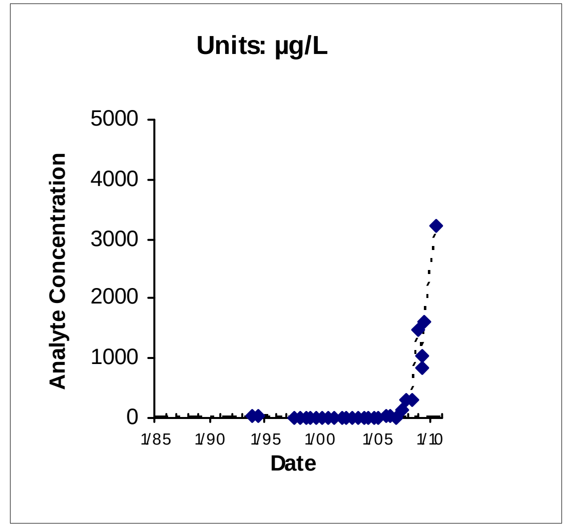
Chemical Time-series Plots



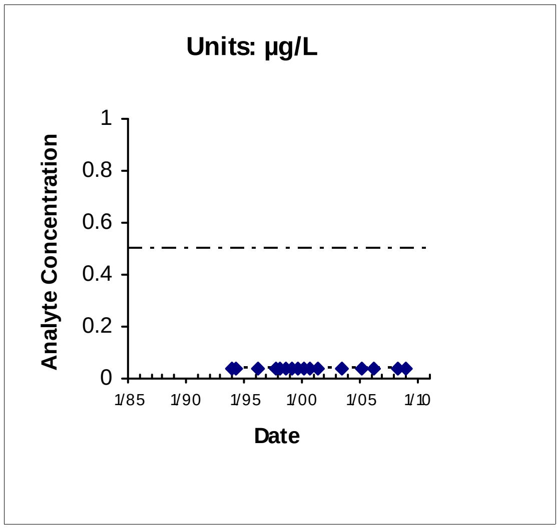
Location: MW104X15 Maximum: 0.04



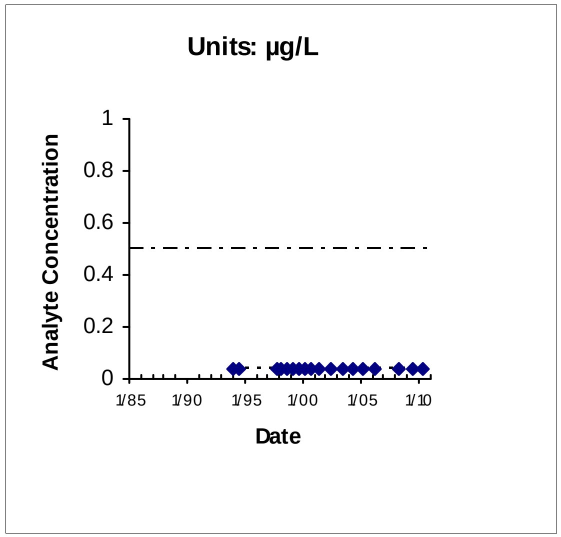
Location: MW105X15 Maximum: 0.04



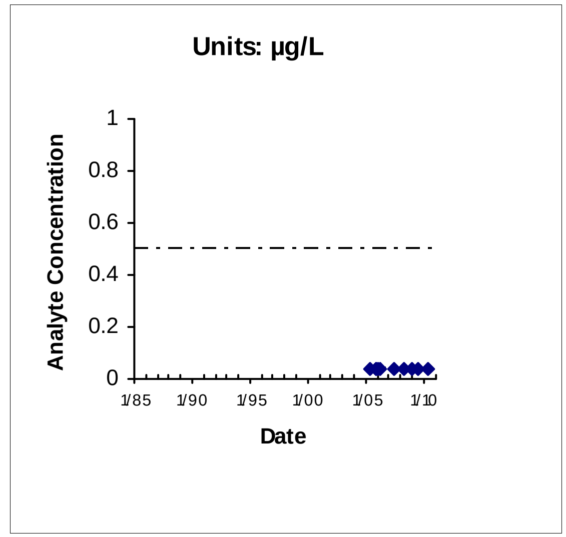
Location: MW216X15 Maximum: 3220



Location: MW238X15 Maximum: 0.04



Location: MW306X15 Maximum: 0.04



Location: MW624X15 Maximum: 0.04

— - - — - - — IRG (0.5 µg/L)

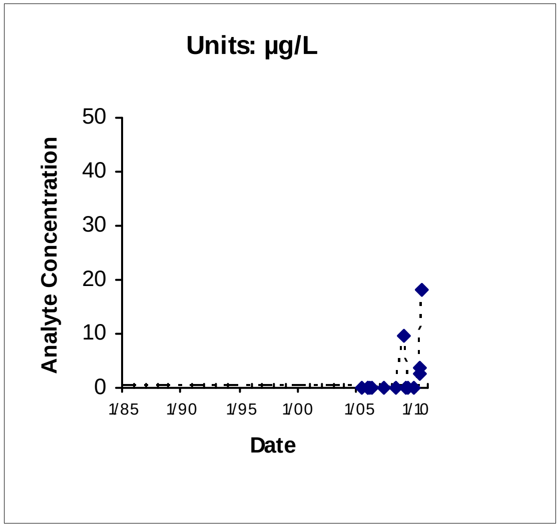
*Nondetects shown as the Method Detection Limit (0.04 µg/L)

FIGURE 4.7-12

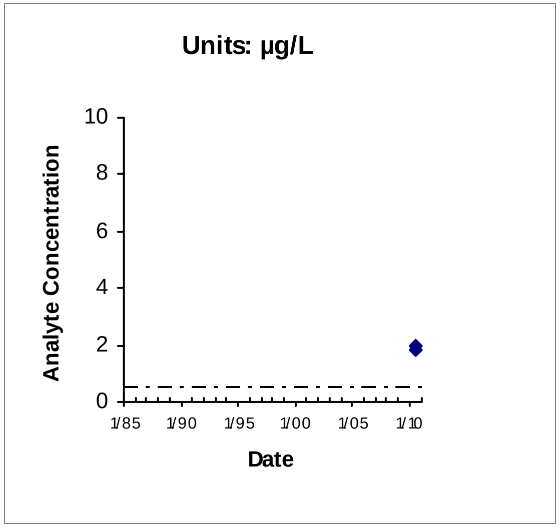
Site SS015

VC

Chemical Time-series Plots



Location: MW625X15 Maximum: 18.2



Location: MW2124x15 Maximum: 2

— - — - — IRG (0.5 µg/L)

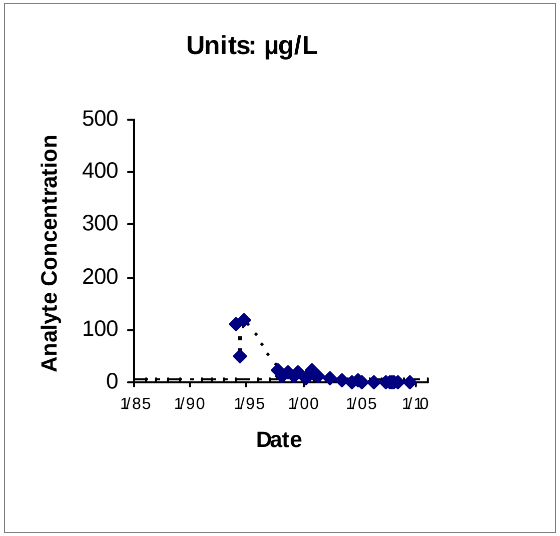
*Nondetects shown as the Method Detection Limit (0.04 µg/L)

FIGURE 4.7-12

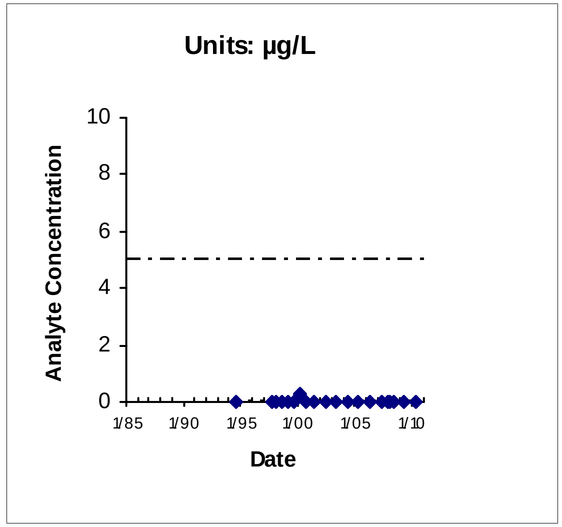
Site SS015

VC

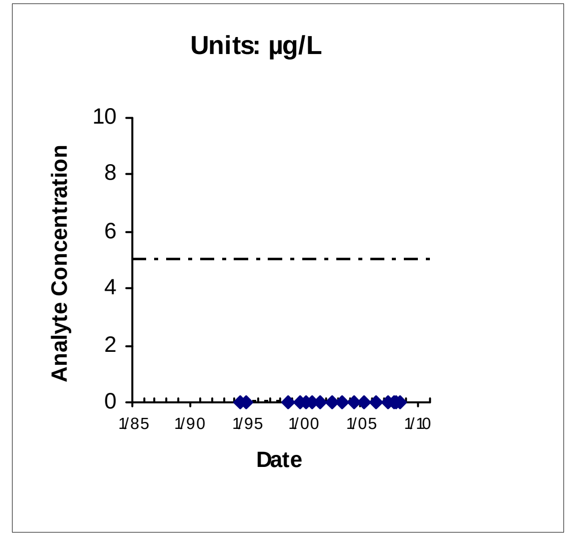
Chemical Time-series Plots



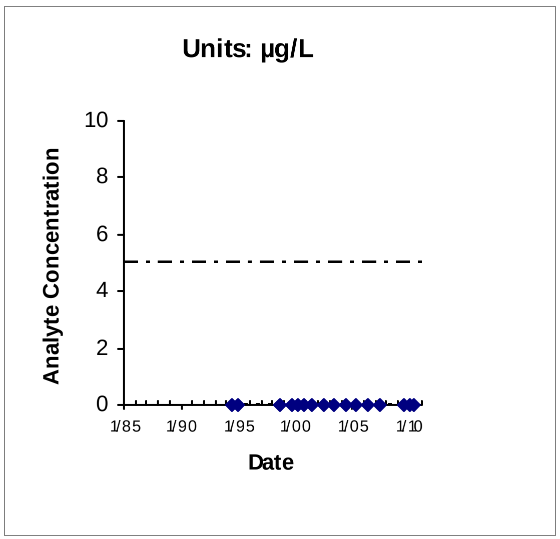
Location: MW328X16 Maximum: 120



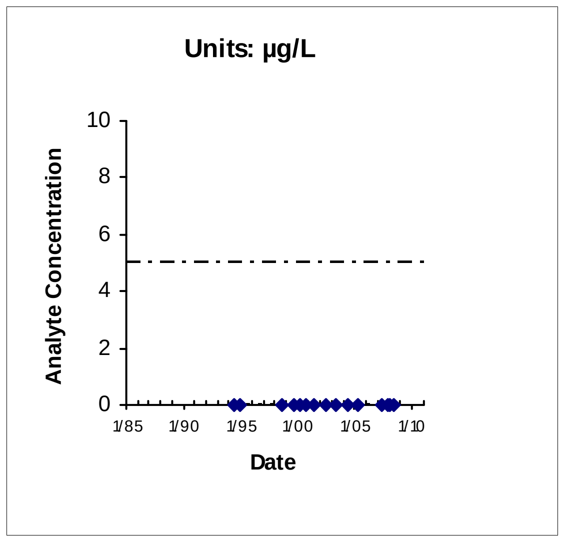
Location: MW1023X16 Maximum: 0.3



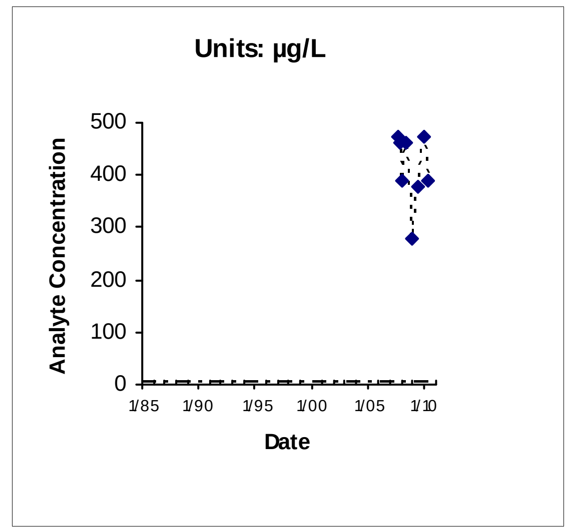
Location: MW277X27 Maximum: 0.03



Location: MW278X27 Maximum: 0.03



Location: MW279X27 Maximum: 0.03

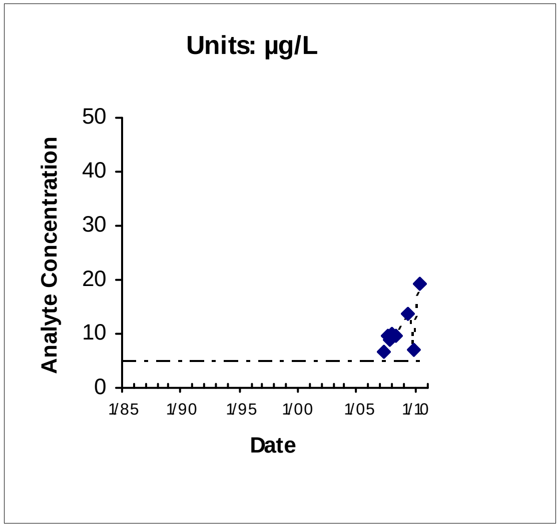


Location: MW791X27 Maximum: 474

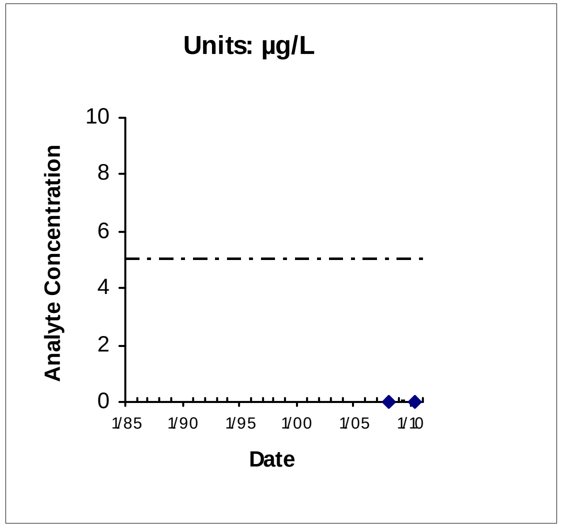
— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (0.03 µg/L)

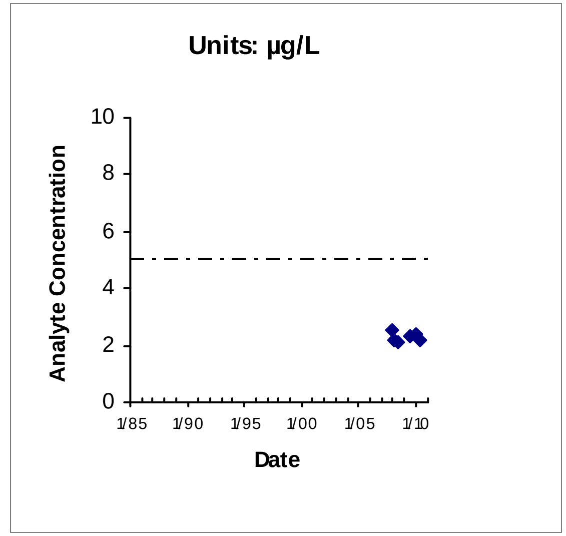
FIGURE 4.5-5
Site ST027
TCE
Chemical Time-series Plots



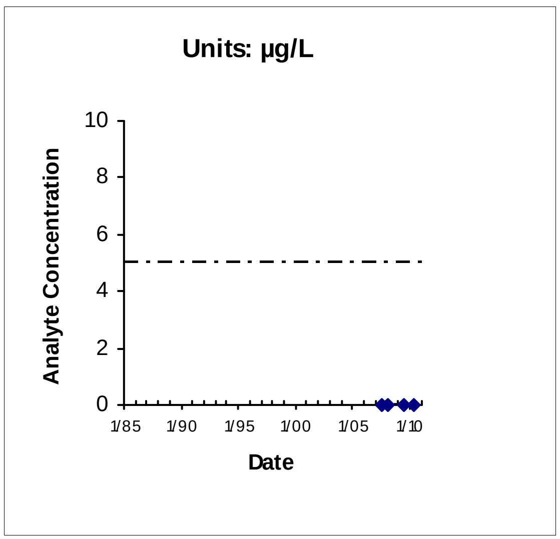
Location: MW792X27 Maximum: 19.1



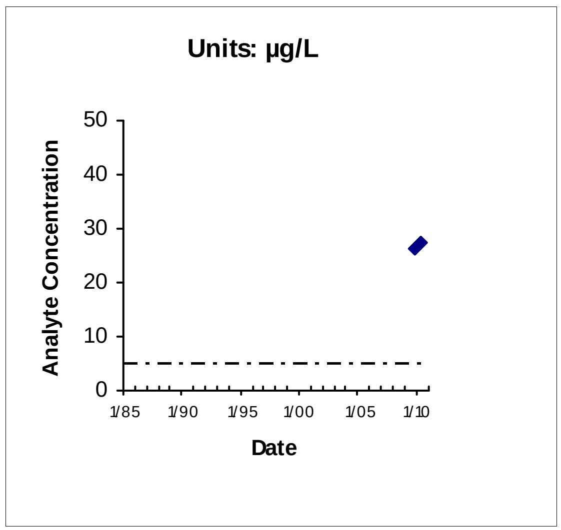
Location: MW793X27 Maximum: 0.03



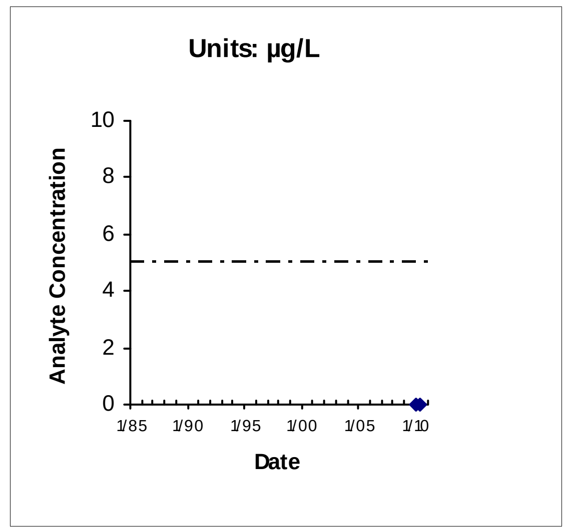
Location: MW794X27 Maximum: 2.52



Location: MW795X27 Maximum: 0.03



Location: MW2009x27 Maximum: 27.4



Location: MW2010x27 Maximum: 0.03

— - — - — IRG (5 µg/L)

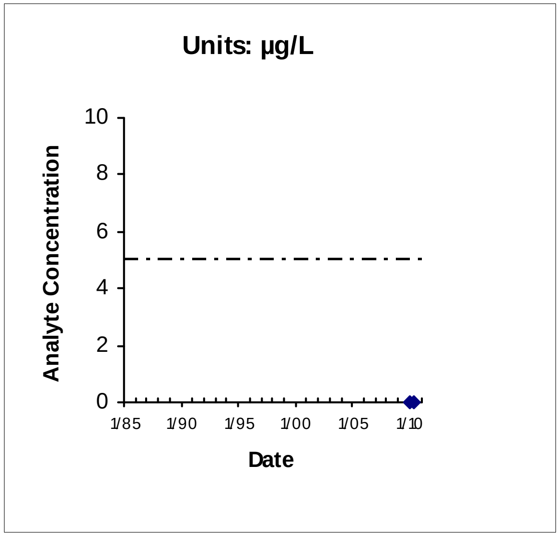
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.5-5

Site ST027

TCE

Chemical Time-series Plots

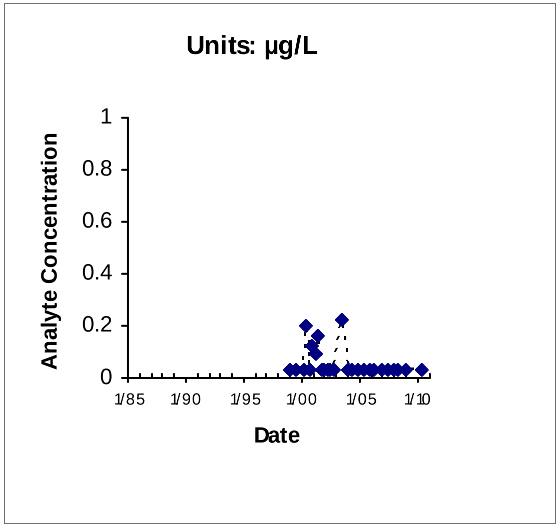


Location: MW2048x27 Maximum: 0.03

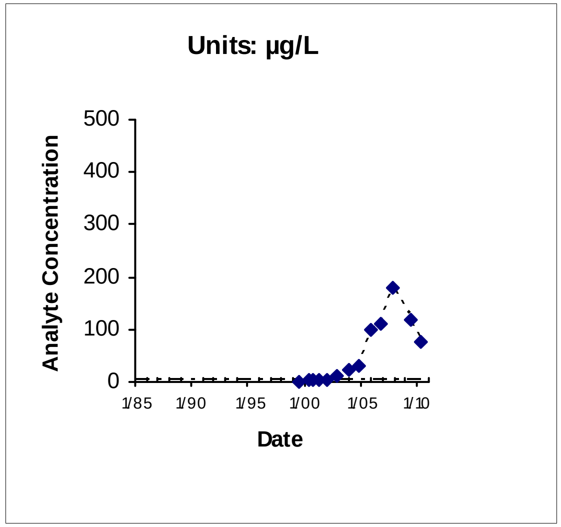
— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (0.03 µg/L)

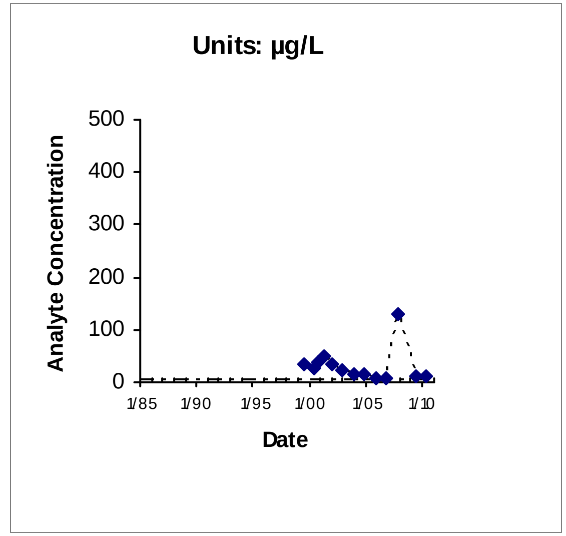
FIGURE 4.5-5
Site ST027
TCE
Chemical Time-series Plots



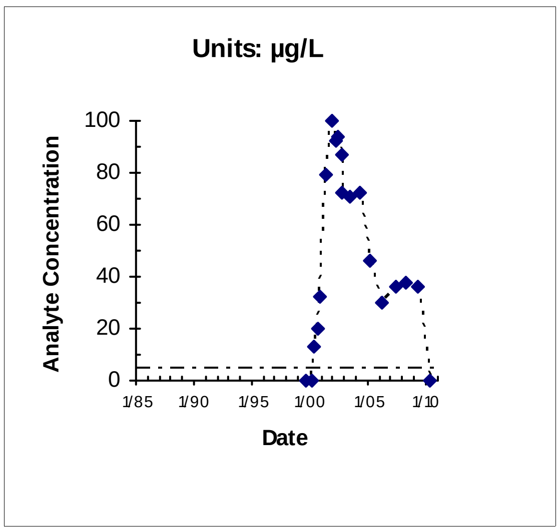
Location: MW05X14 Maximum: 0.22



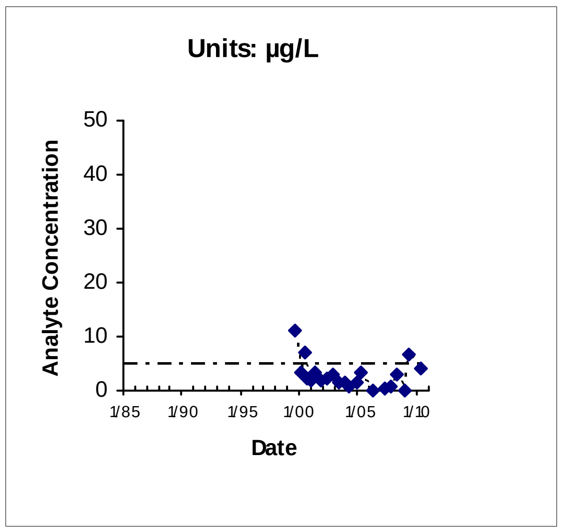
Location: EW501X33 Maximum: 180



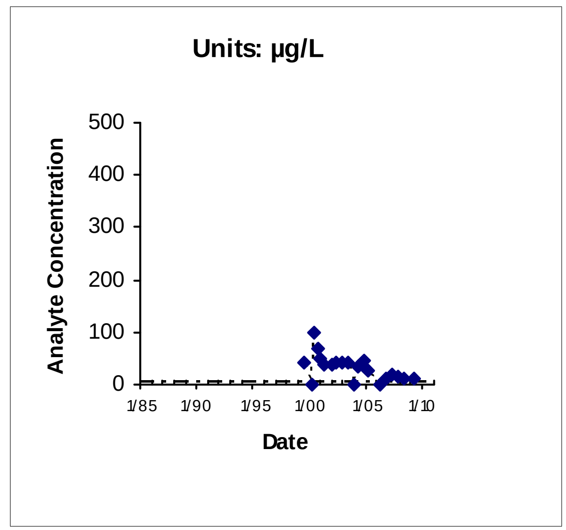
Location: EW503X33 Maximum: 130



Location: MW502X33 Maximum: 99.8



Location: MW504X33 Maximum: 11



Location: MW505X33 Maximum: 100

— - — - — IRG (5 µg/L)

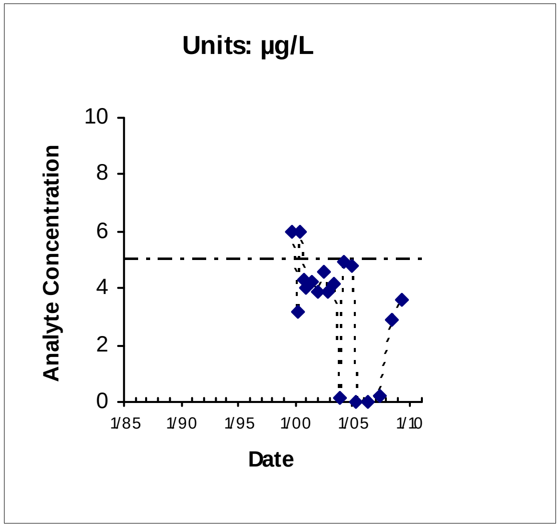
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

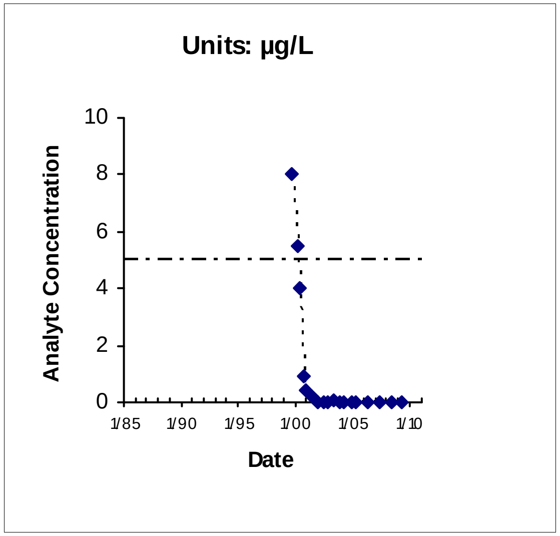
WIOU

TCE

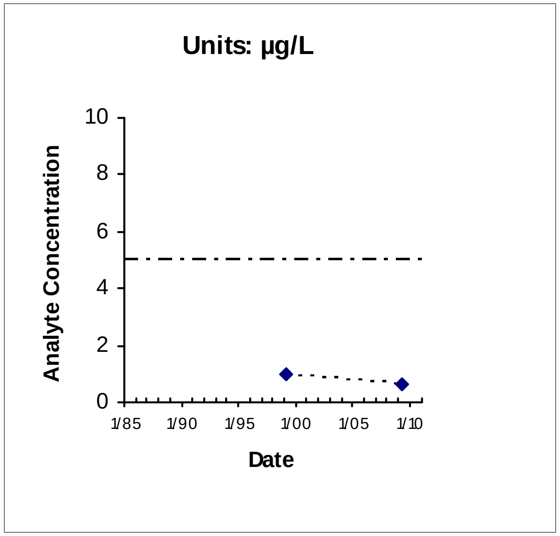
Chemical Time-series Plots



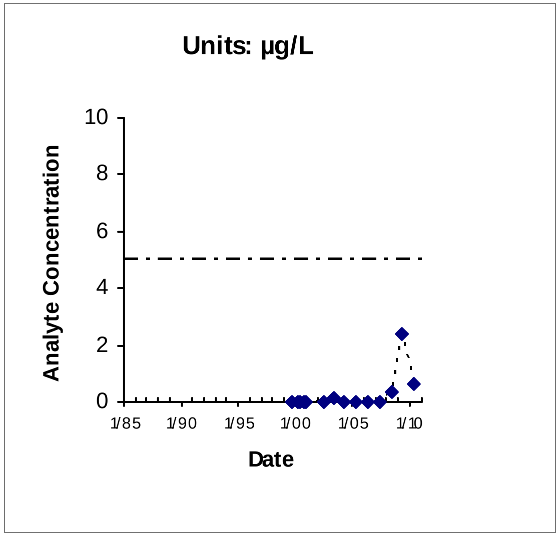
Location: MW506X33 Maximum: 6



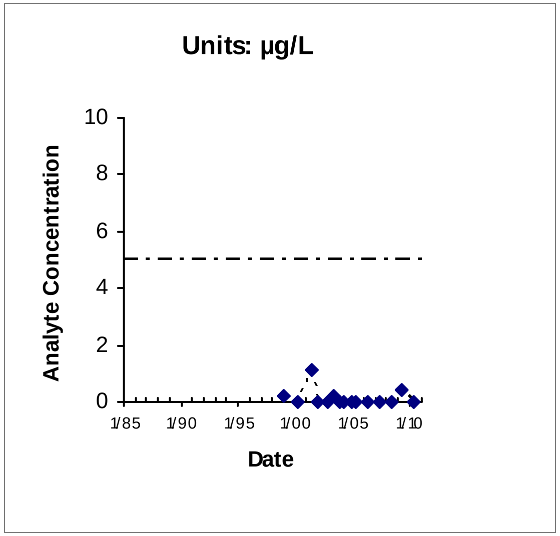
Location: MW507X33 Maximum: 8



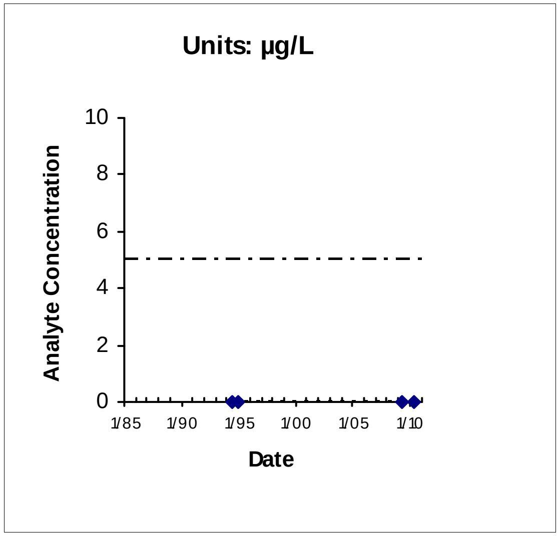
Location: MW508X33 Maximum: 1



Location: MW509X33 Maximum: 2.4



Location: MW530X33 Maximum: 1.1

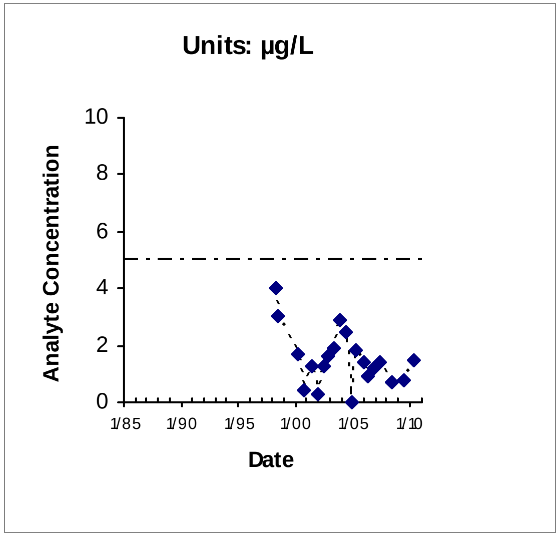


Location: MW1S3X33 Maximum: 0.03

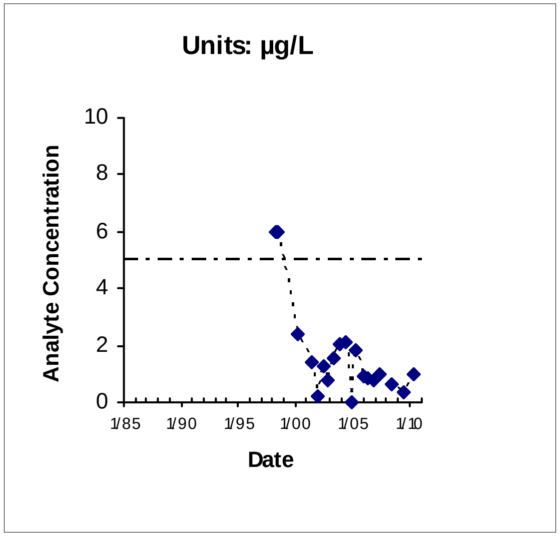
— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (0.03 µg/L)

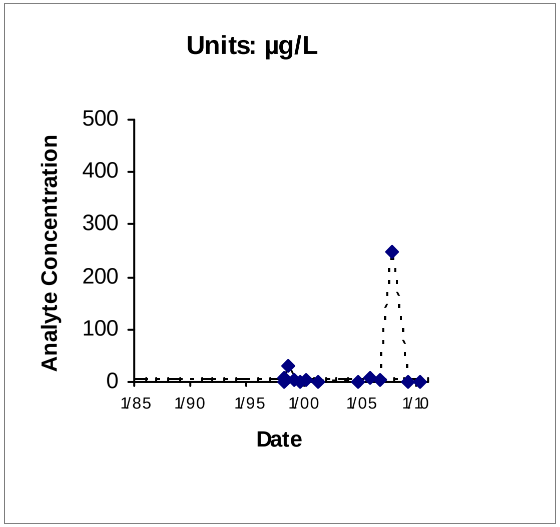
FIGURE 4.6-6
WIOU
TCE
Chemical Time-series Plots



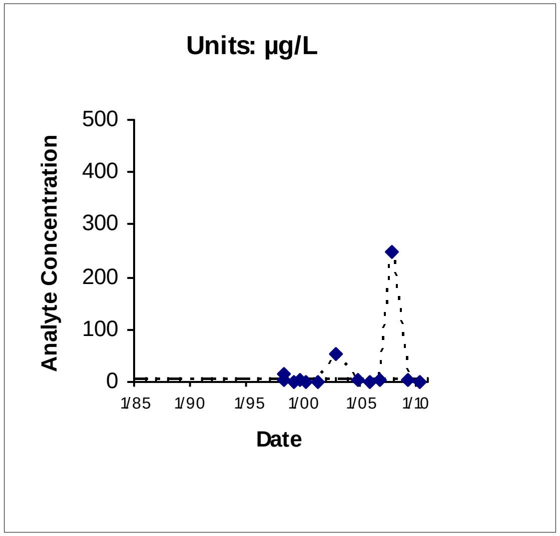
Location: WBUC-3 Maximum: 4



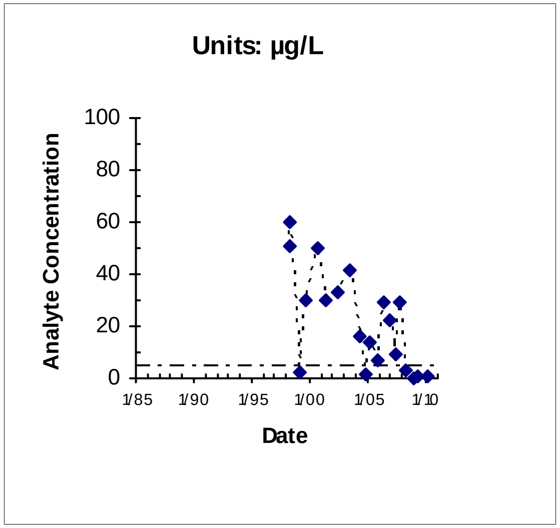
Location: WBUC-4 Maximum: 6



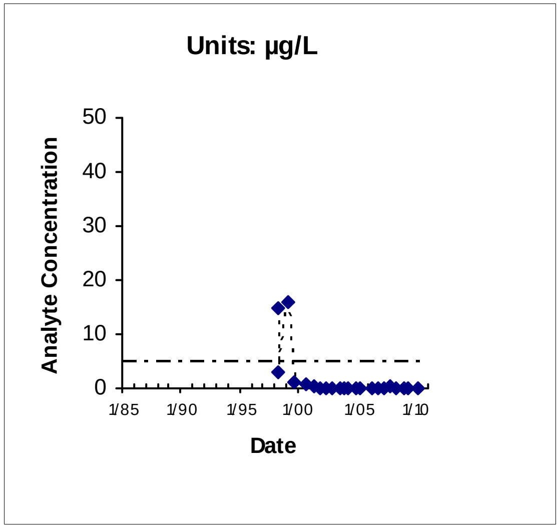
Location: EW01X34 Maximum: 250



Location: EW03X34 Maximum: 250



Location: MW02X34 Maximum: 60



Location: MW04X34 Maximum: 16

— - — - — IRG (5 µg/L)

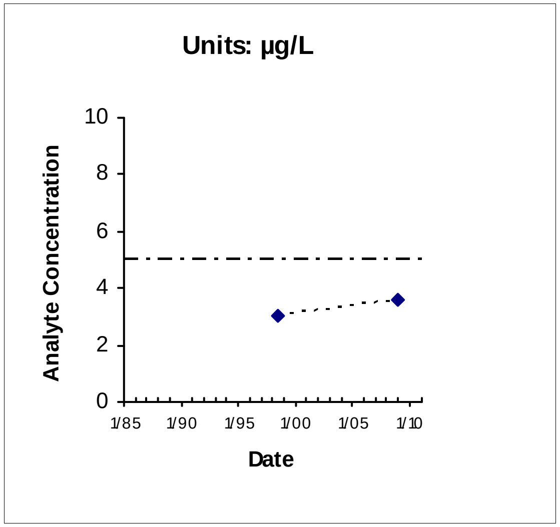
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

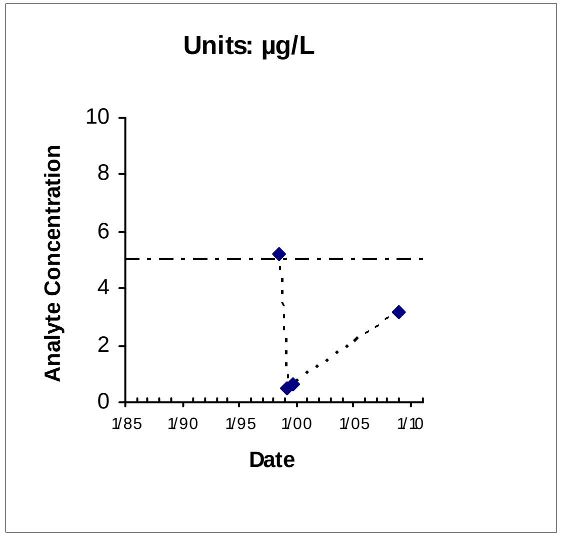
WIOU

TCE

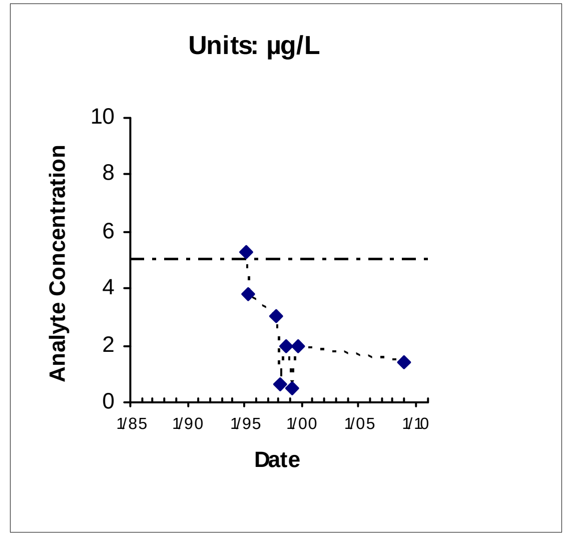
Chemical Time-series Plots



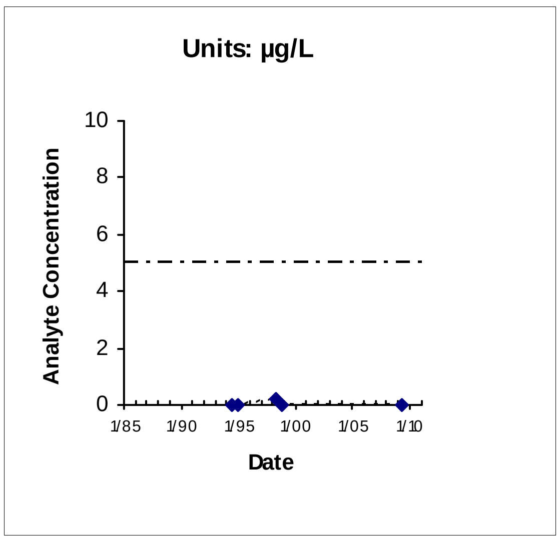
Location: MW01X35 Maximum: 3.6



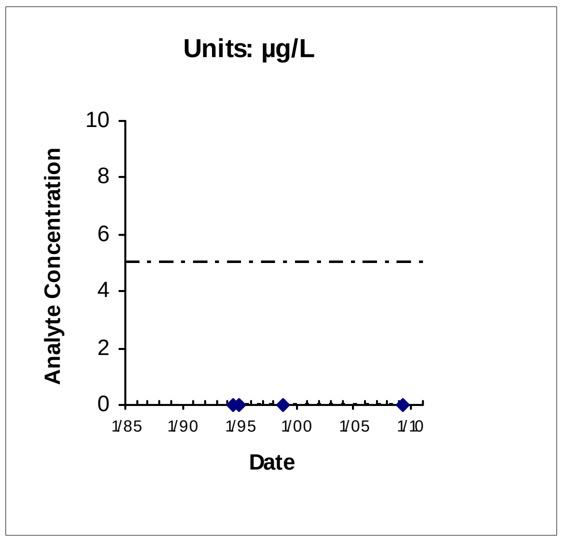
Location: MW02X35 Maximum: 5.2



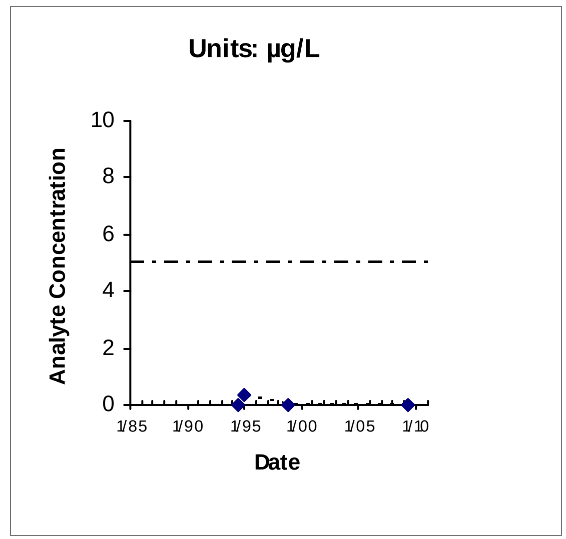
Location: MW818X35 Maximum: 5.3



Location: MW5304X35 Maximum: 0.2



Location: MWRW1X35 Maximum: 0.03



Location: MWRW2X35 Maximum: 0.376

— - — - — IRG (5 µg/L)

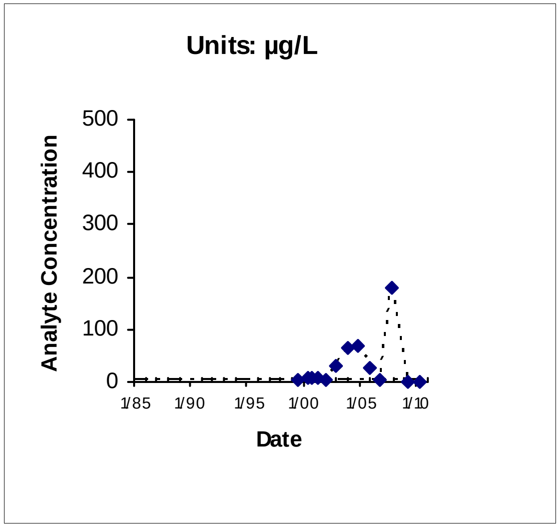
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

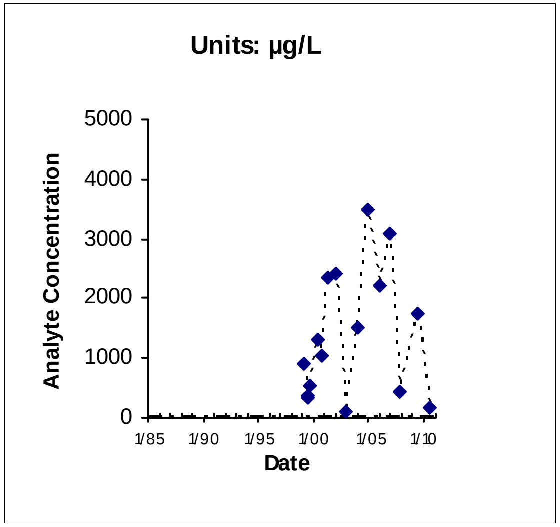
WIOU

TCE

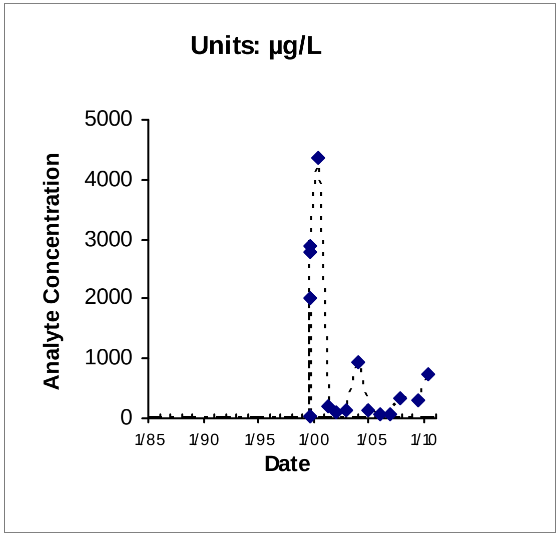
Chemical Time-series Plots



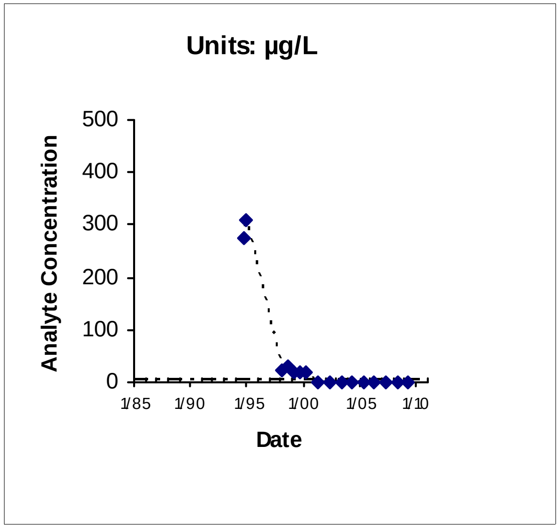
Location: EW593X36 Maximum: 180



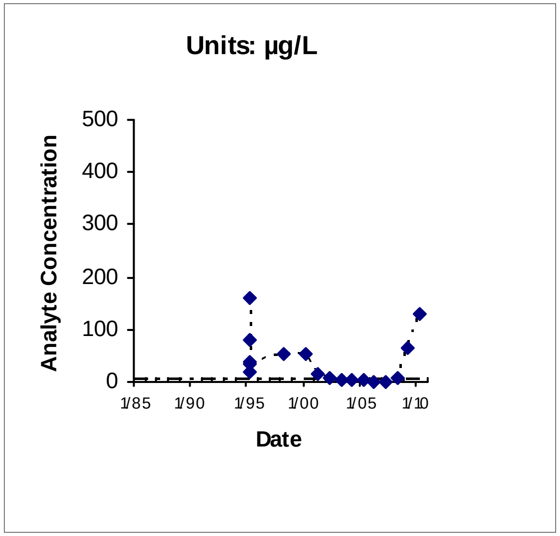
Location: EW594X36 Maximum: 3500



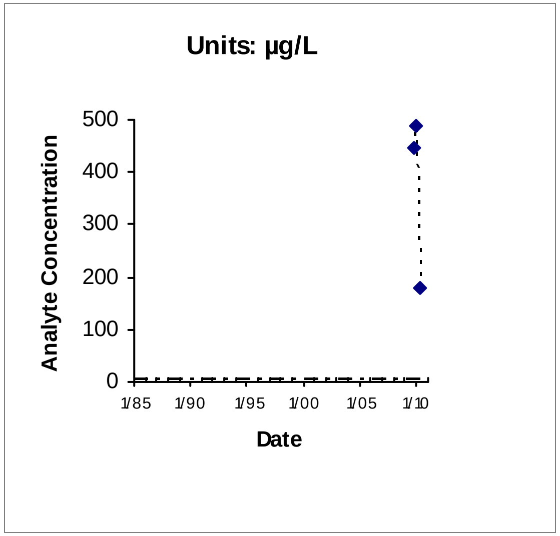
Location: EW595X36 Maximum: 4350



Location: MW872X36 Maximum: 308



Location: MW873M2X36 Maximum: 160



Location: MW2031Ax36 Maximum: 488

FIGURE 4.6-6

WIOU

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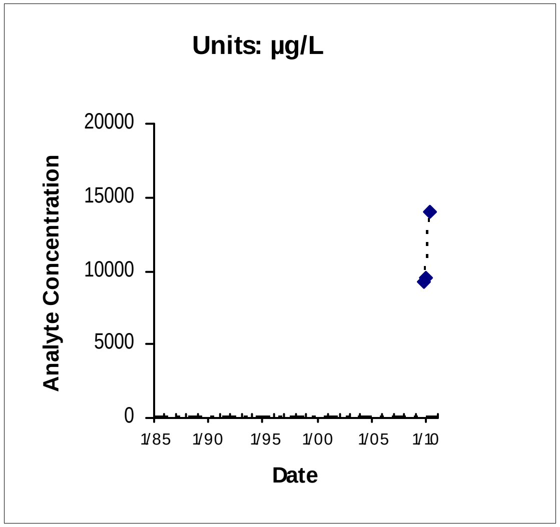
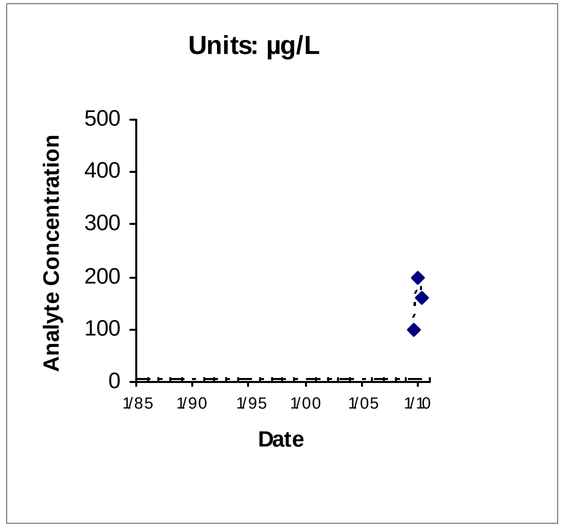
Chemical Time-series Plots

— - — - — IRG (5 µg/L)

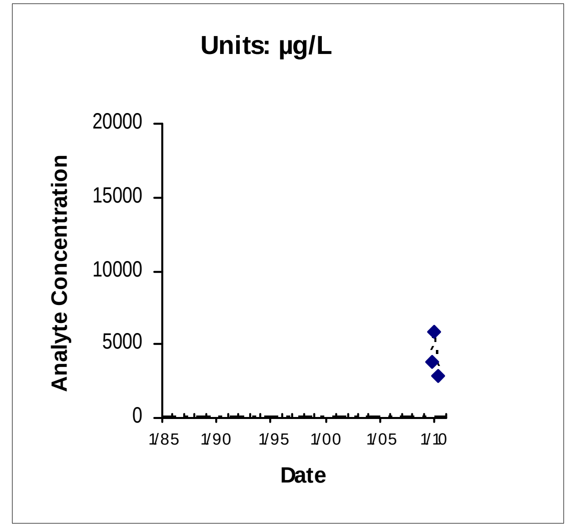
*Nondetects shown as the Method Detection Limit (0.03 µg/L)



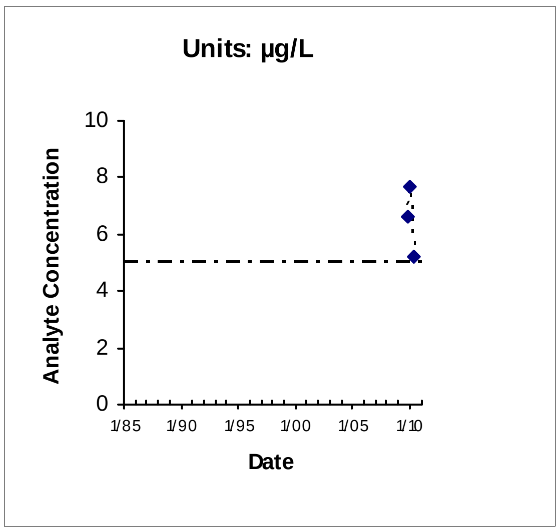
Location: MW2031Bx36 Maximum: 14000



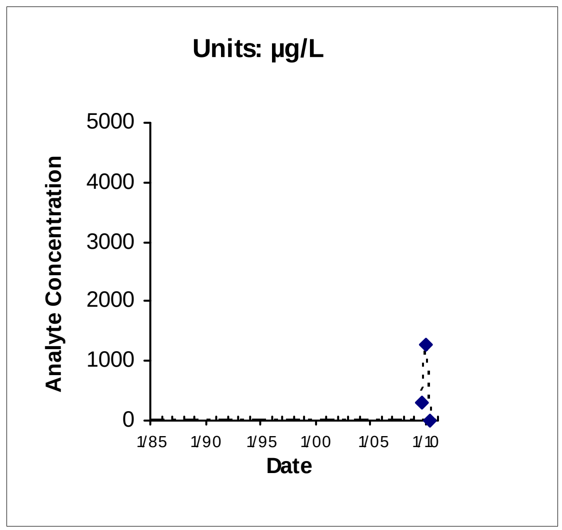
Location: MW2032x36 Maximum: 200



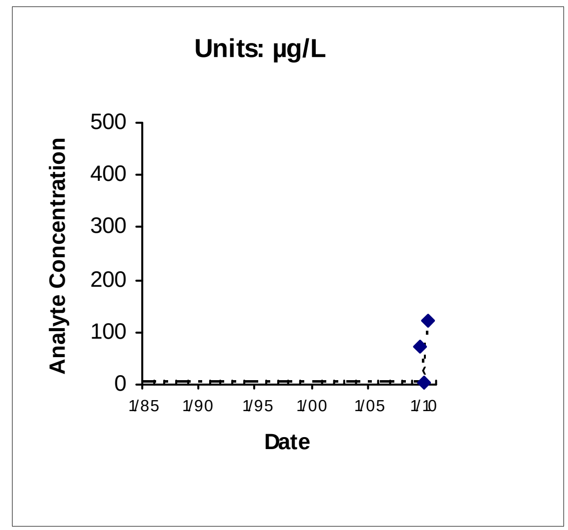
Location: MW2033Ax36 Maximum: 5890



Location: MW2033Bx36 Maximum: 7.7



Location: MW2034Ax36 Maximum: 1260



Location: MW2034Bx36 Maximum: 123

— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

WIOU

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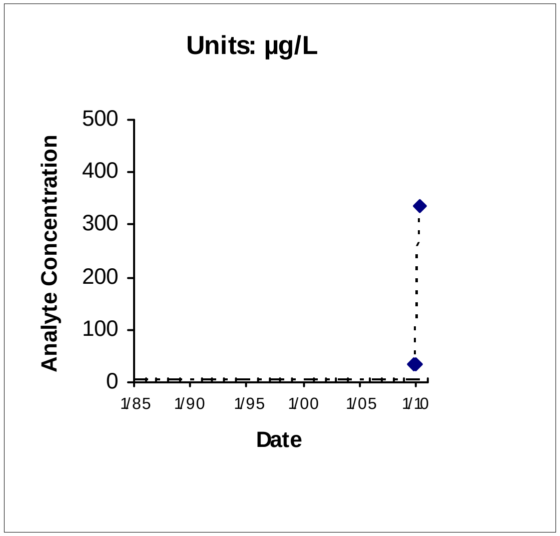
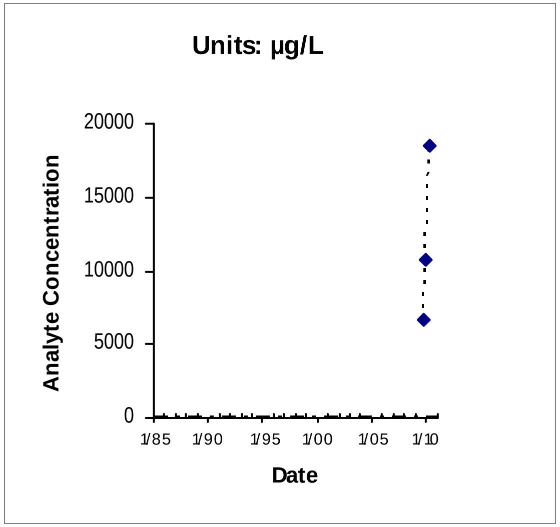
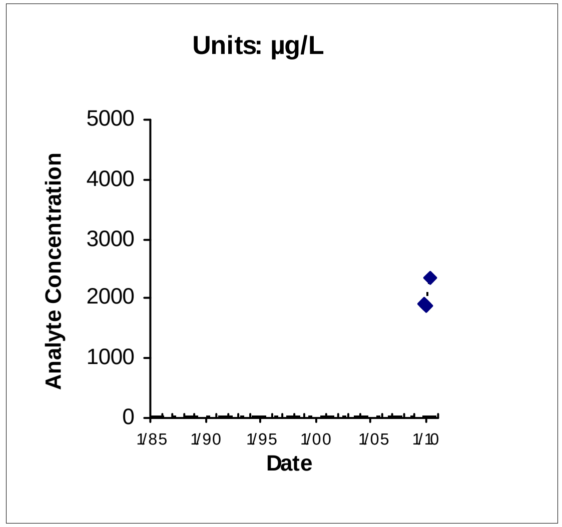
Chemical Time-series Plots



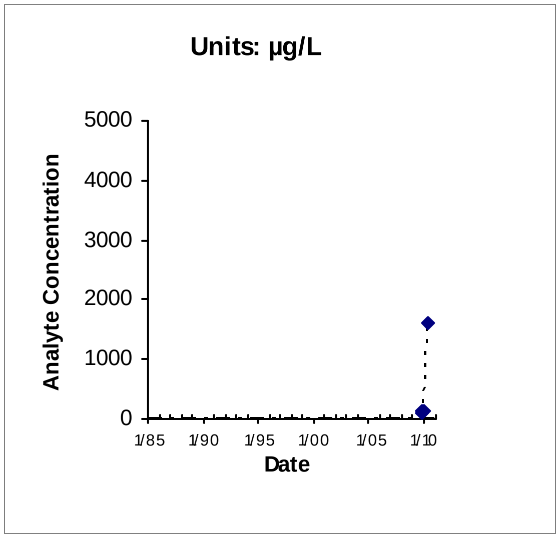
Location: MW2061Ax36 Maximum: 334



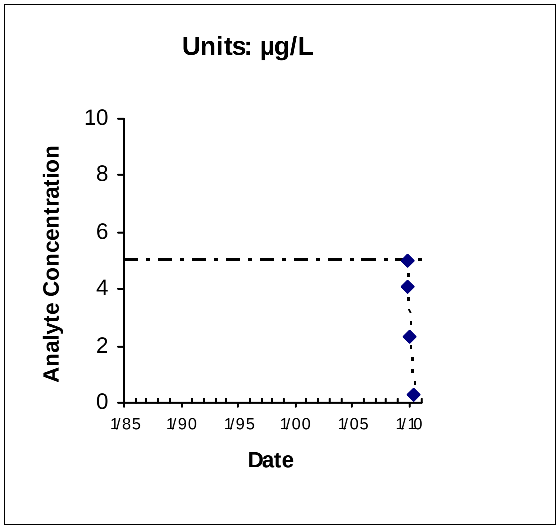
Location: MW2061Bx36 Maximum: 18500



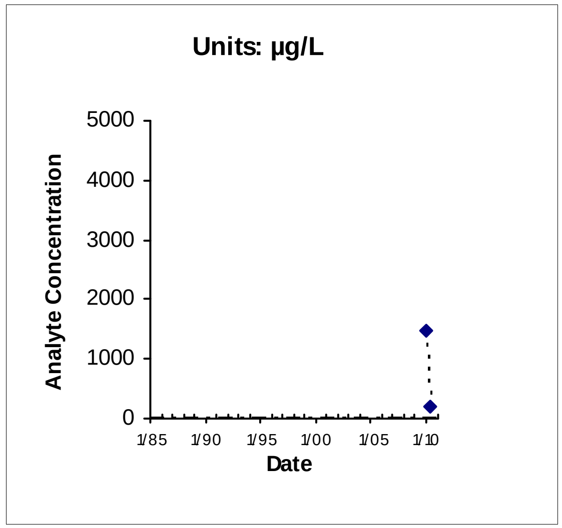
Location: MW2063x36 Maximum: 2360



Location: MW2064Ax36 Maximum: 1600



Location: MW2064Bx36 Maximum: 5



Location: MW2065x36 Maximum: 1470

— - — - — IRG (5 µg/L)

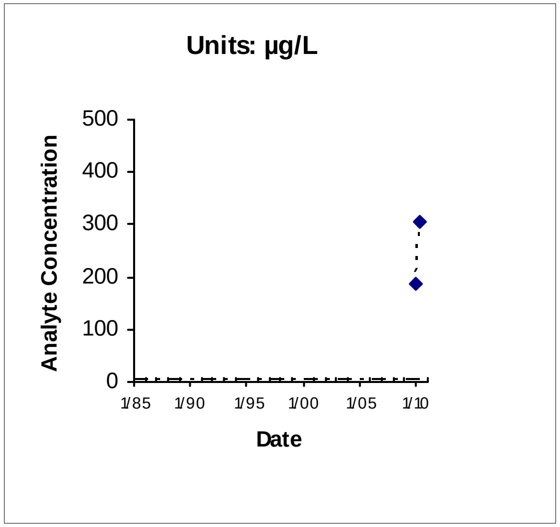
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

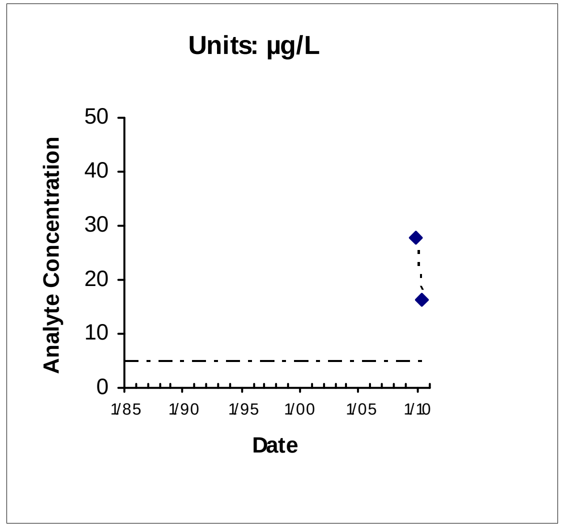
WIOU

TCE

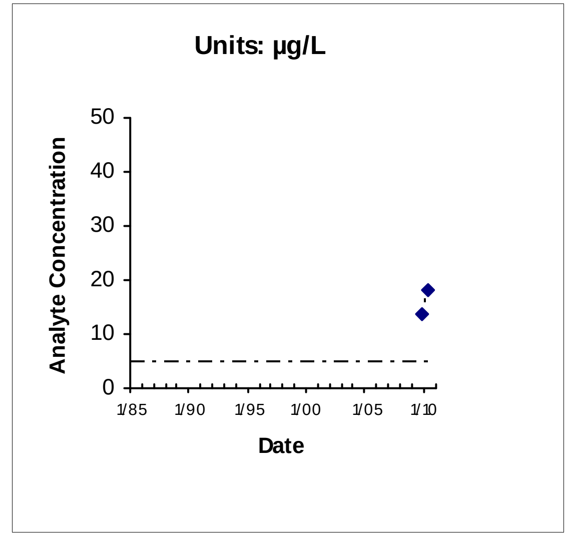
Chemical Time-series Plots



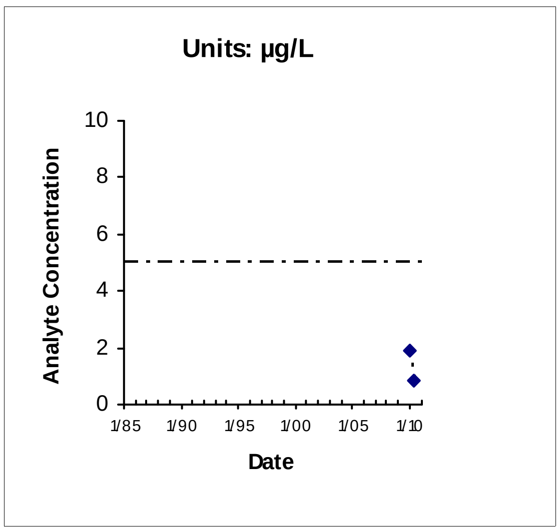
Location: MW2075Ax36 Maximum: 304



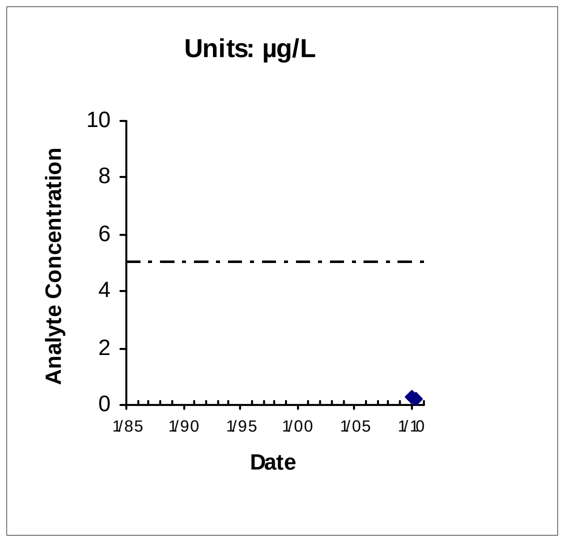
Location: MW2075Bx36 Maximum: 27.8



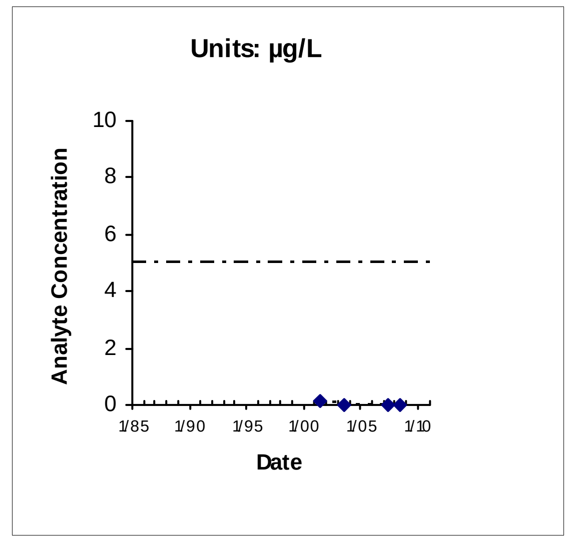
Location: MW2077Ax36 Maximum: 18.3



Location: MW2077Bx36 Maximum: 1.9



Location: MW2077Cx36 Maximum: 0.25

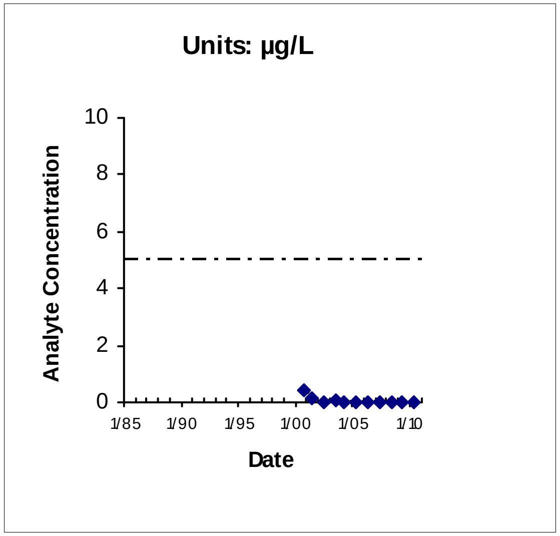


Location: PZ01X36 Maximum: 0.12

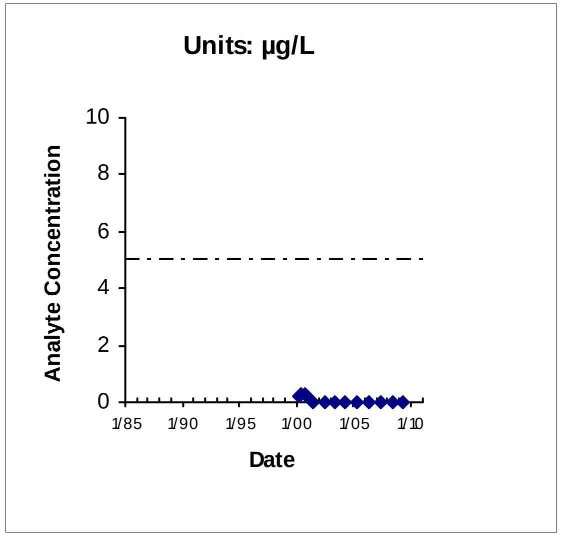
— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (0.03 µg/L)

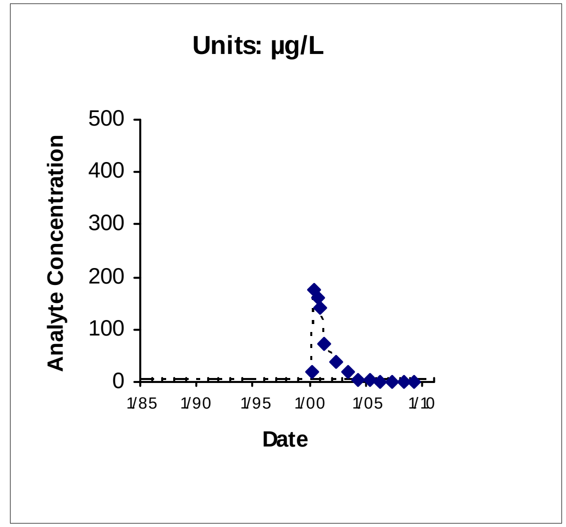
FIGURE 4.6-6
WIOU
TCE
Chemical Time-series Plots



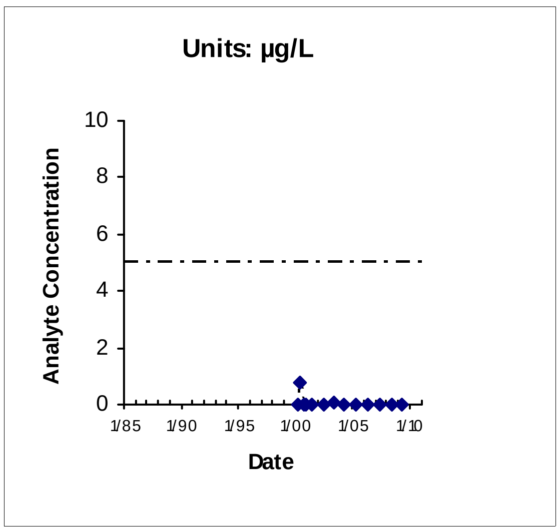
Location: PZ03X36 Maximum: 0.4



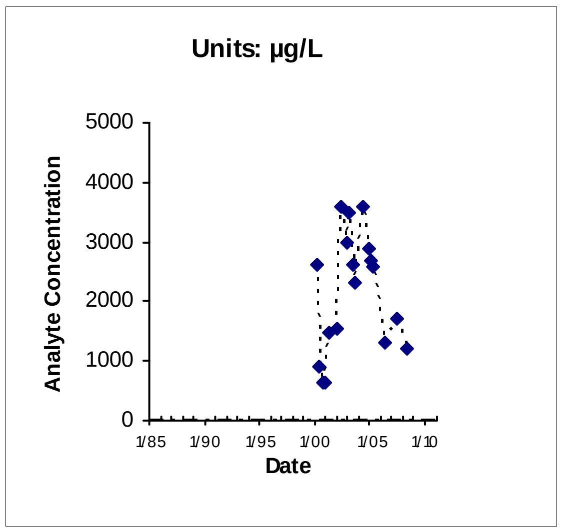
Location: PZ06DX36 Maximum: 0.3



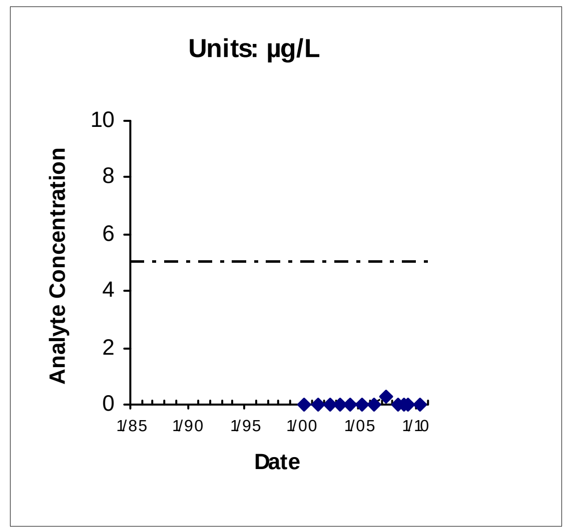
Location: PZ06SX36 Maximum: 176



Location: PZ07DX36 Maximum: 0.8



Location: PZ07SX36 Maximum: 3600

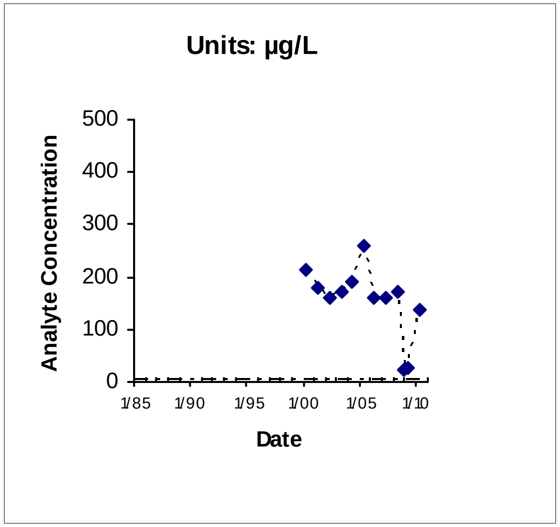


Location: PZ12DX36 Maximum: 0.25

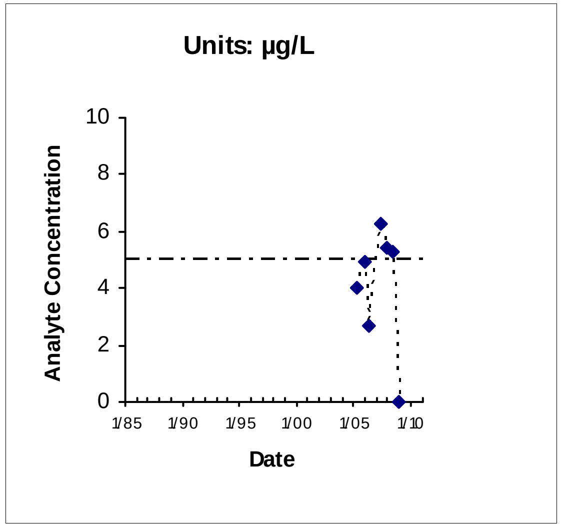
— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (0.03 µg/L)

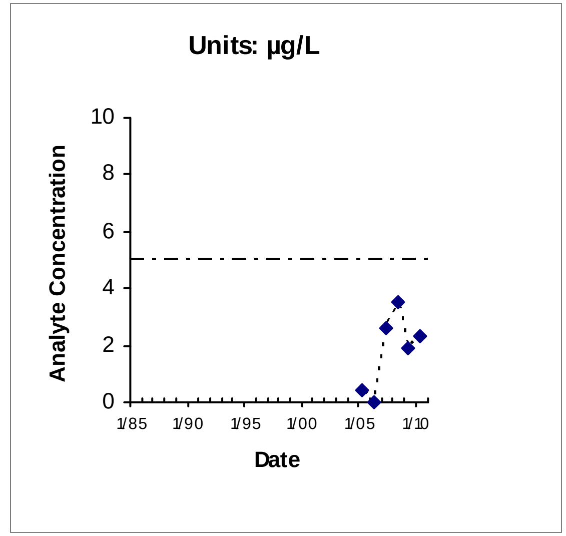
FIGURE 4.6-6
WIOU
TCE
Chemical Time-series Plots



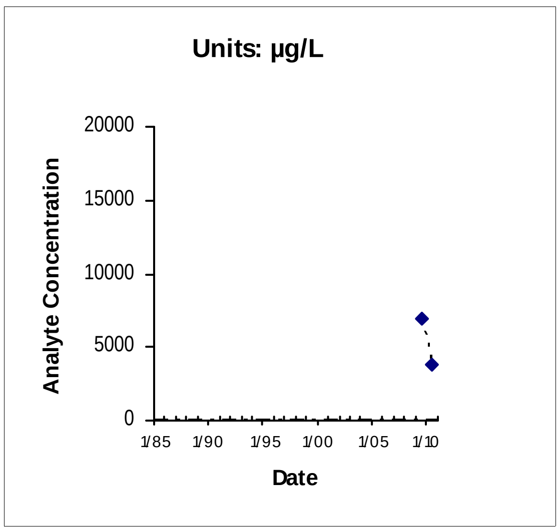
Location: PZ12SX36 Maximum: 260



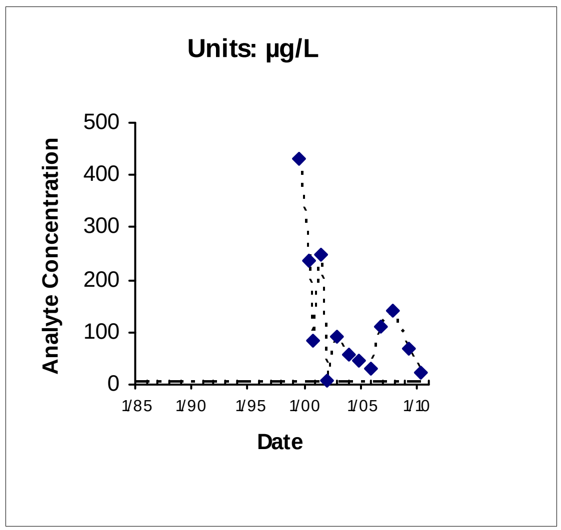
Location: PZ20x36 Maximum: 6.3



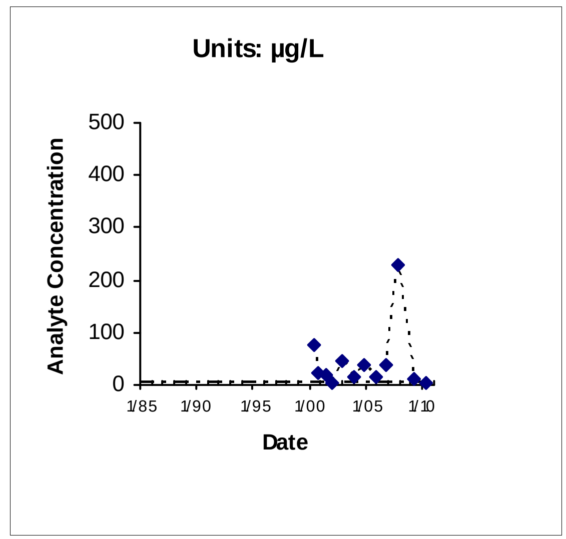
Location: PZ22x36 Maximum: 3.5



Location: PZ550Cx36 Maximum: 6980



Location: EW510X37 Maximum: 430



Location: EW511X37 Maximum: 230

— - — - — IRG (5 µg/L)

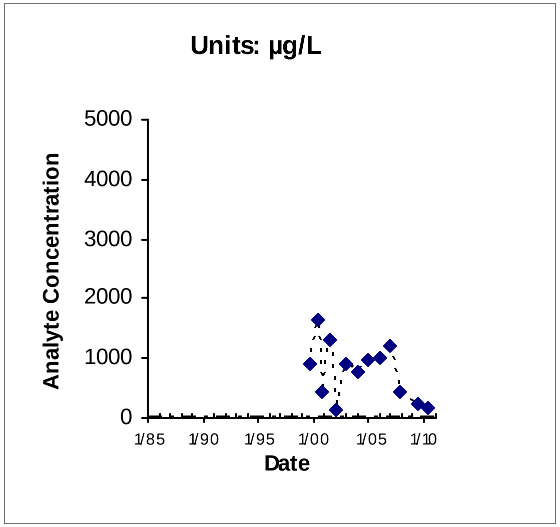
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

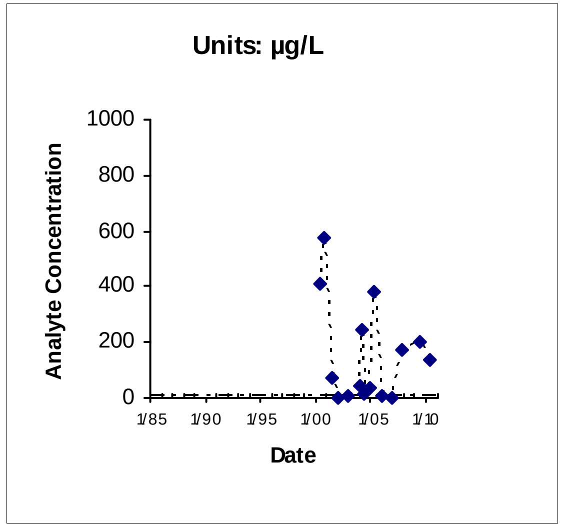
WIOU

TCE

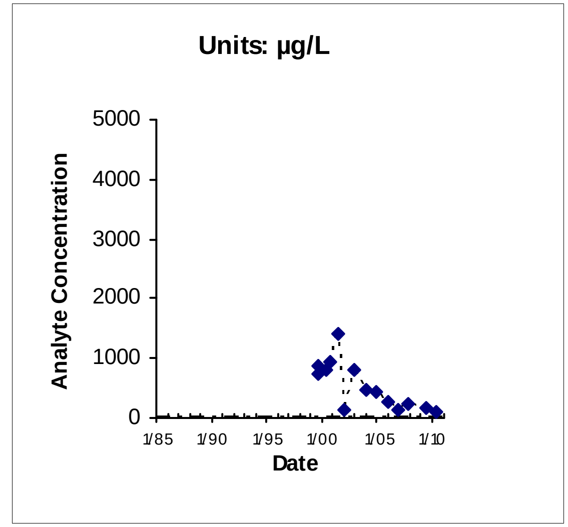
Chemical Time-series Plots



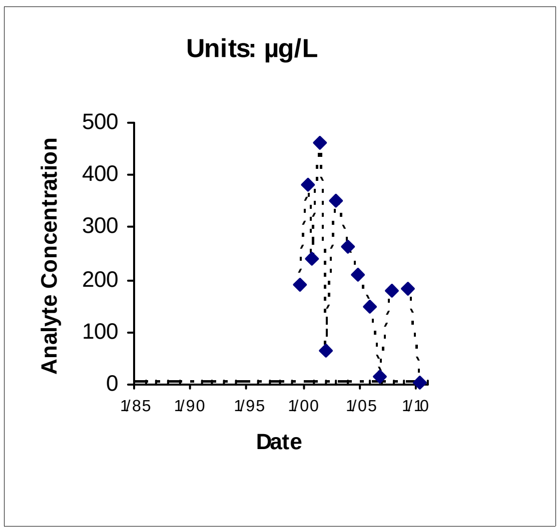
Location: EW599X37 Maximum: 1640



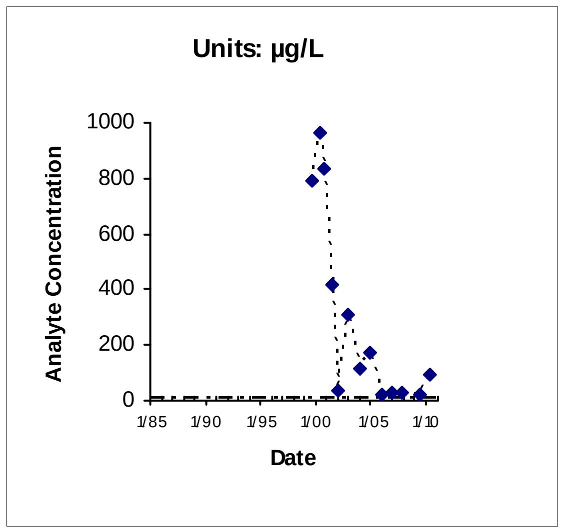
Location: EW700X37 Maximum: 577



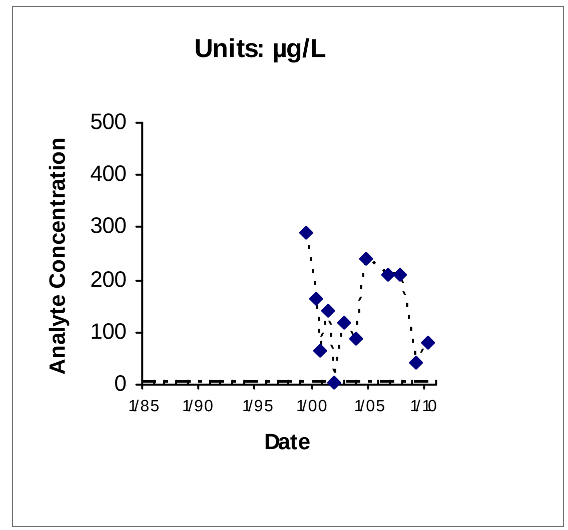
Location: EW701X37 Maximum: 1400



Location: EW702X37 Maximum: 460



Location: EW703X37 Maximum: 962



Location: EW704X37 Maximum: 290

— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

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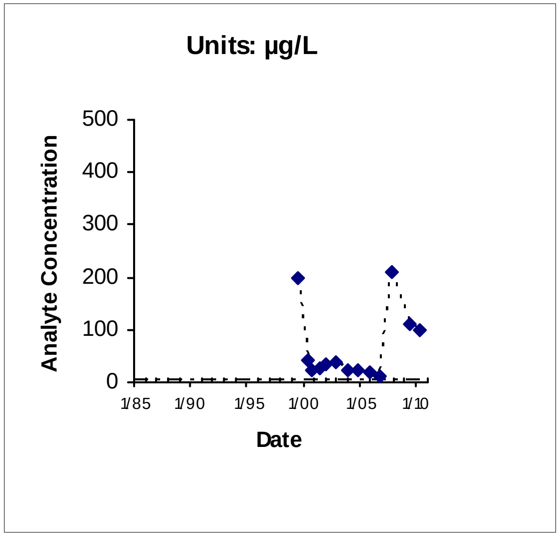
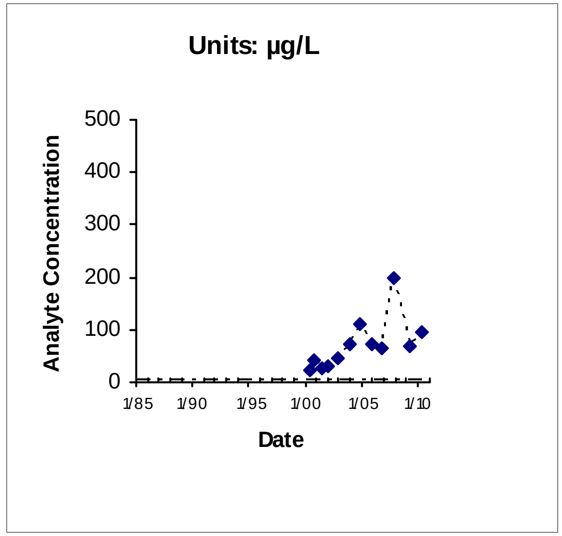
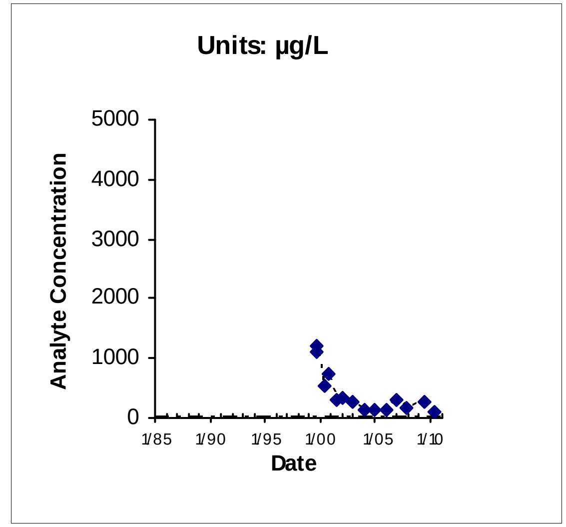
Chemical Time-series Plots



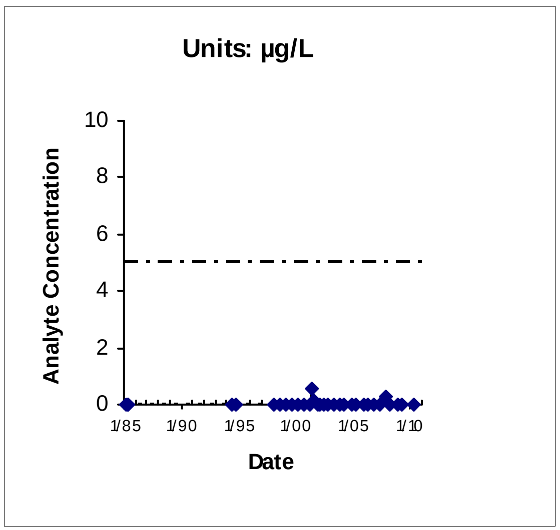
Location: EW705X37 Maximum: 210



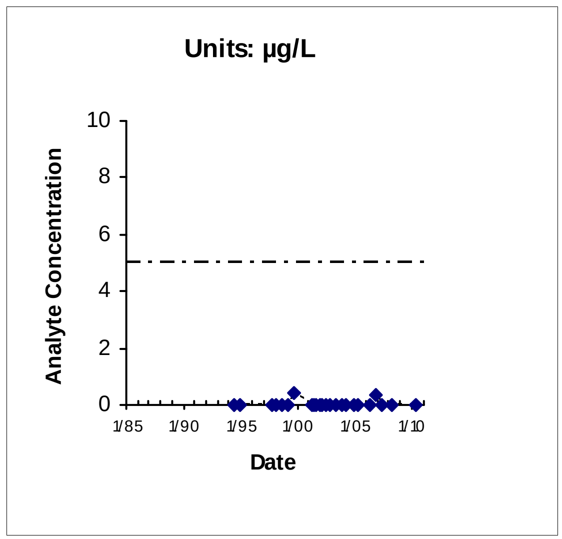
Location: EW706X37 Maximum: 200



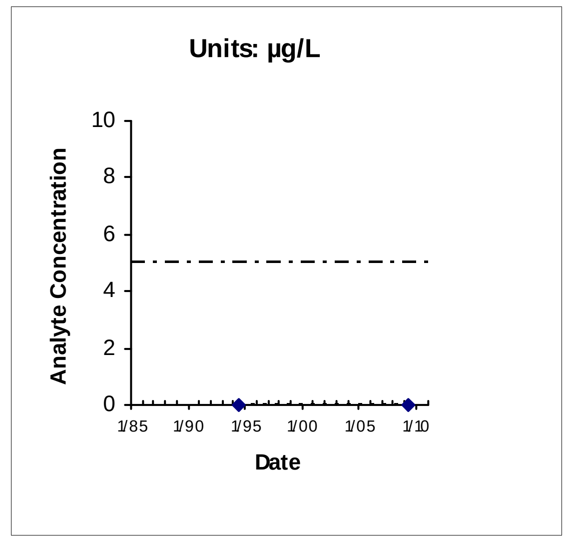
Location: EW707X37 Maximum: 1200



Location: MW116X37 Maximum: 0.56



Location: MW222X37 Maximum: 0.4



Location: MW223X37 Maximum: 0.03

— - — - — IRG (5 µg/L)

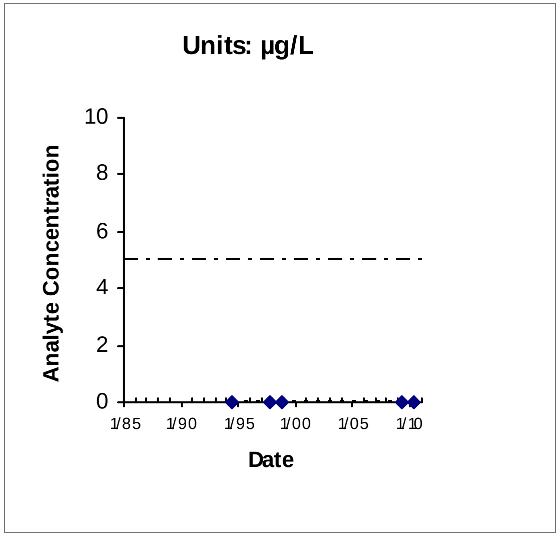
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

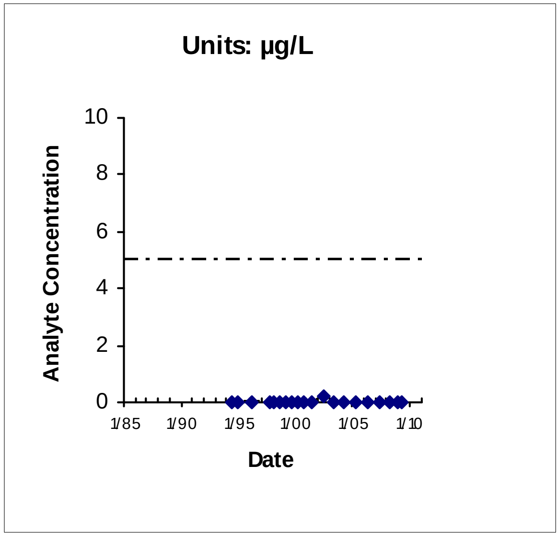
WIOU

TCE

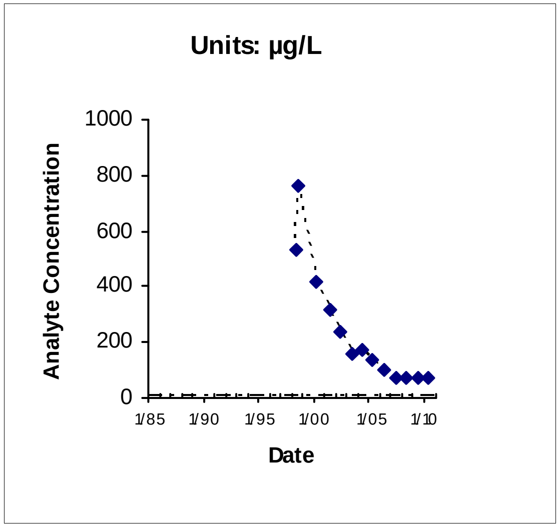
Chemical Time-series Plots



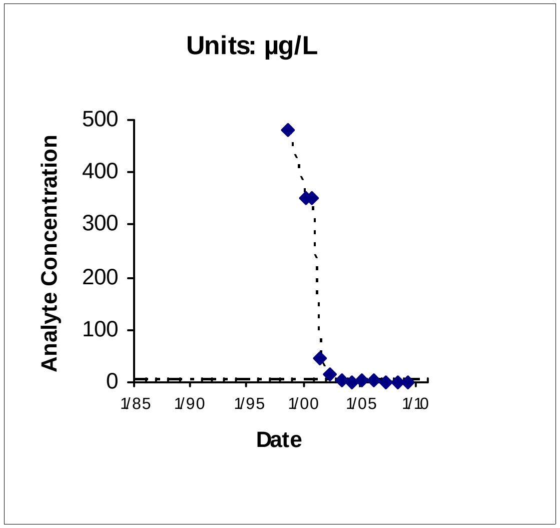
Location: MW224X37 Maximum: 0.03



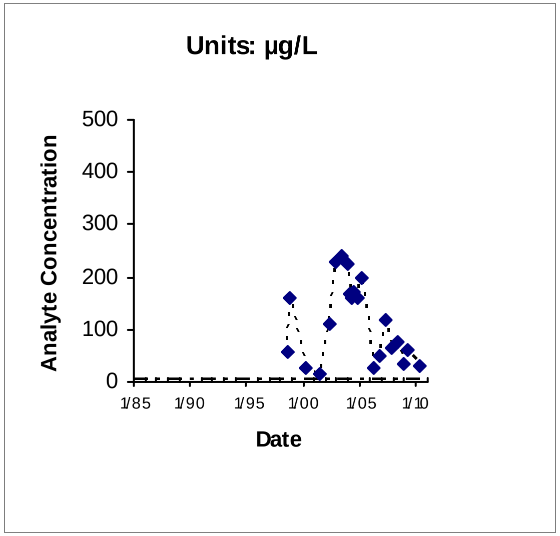
Location: MW310X37 Maximum: 0.18



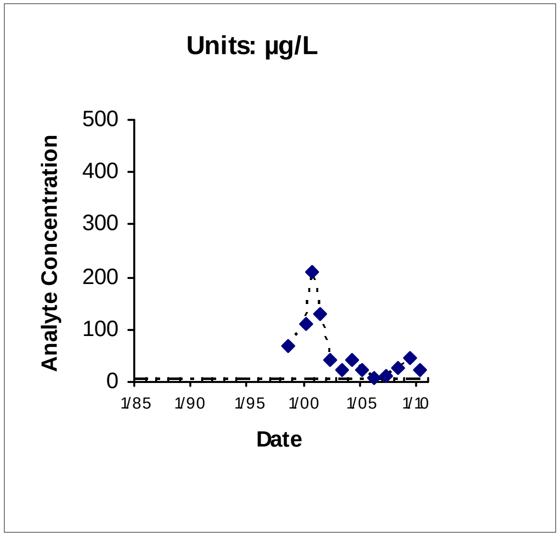
Location: MW500X37 Maximum: 760



Location: MW512X37 Maximum: 480



Location: MW513X37 Maximum: 242



Location: MW514X37 Maximum: 210

— - — - — IRG (5 µg/L)

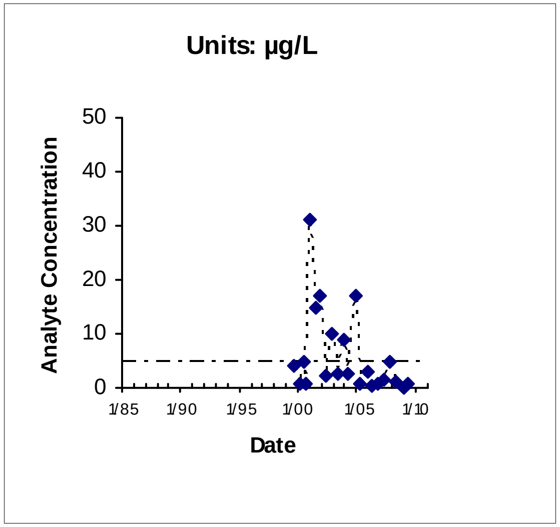
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

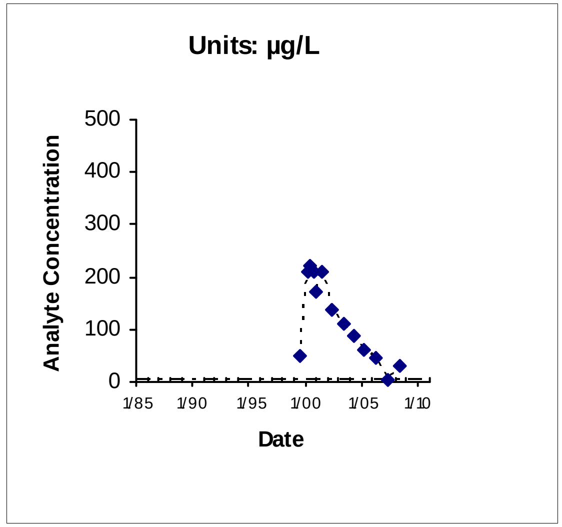
WIOU

TCE

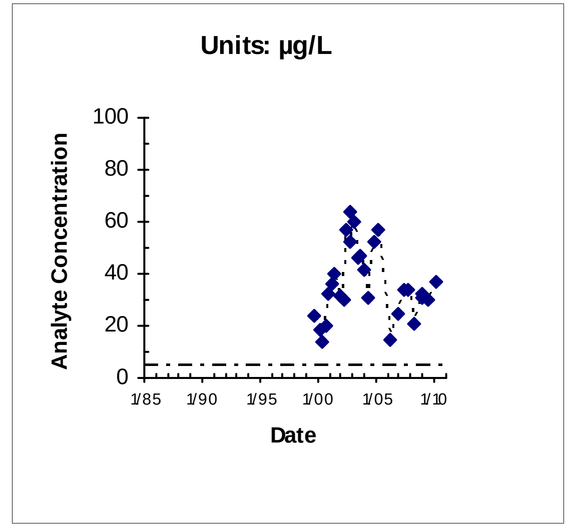
Chemical Time-series Plots



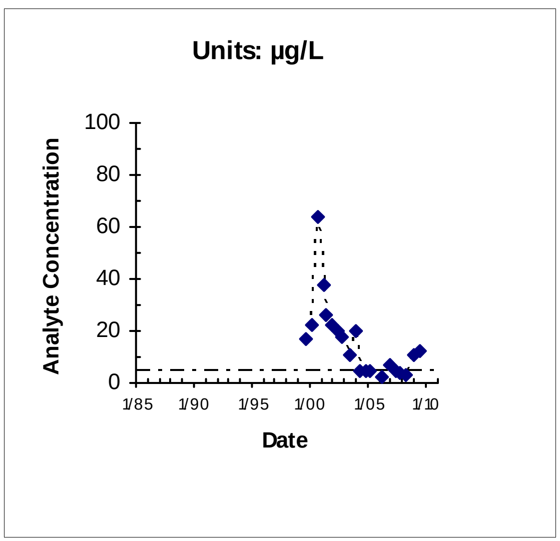
Location: MW516X37 Maximum: 31



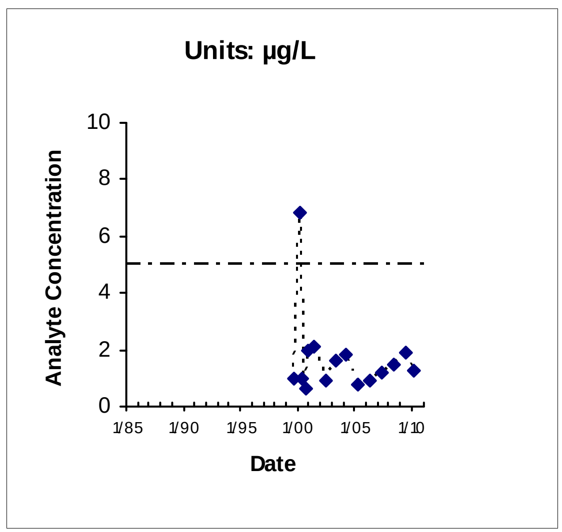
Location: MW517X37 Maximum: 220



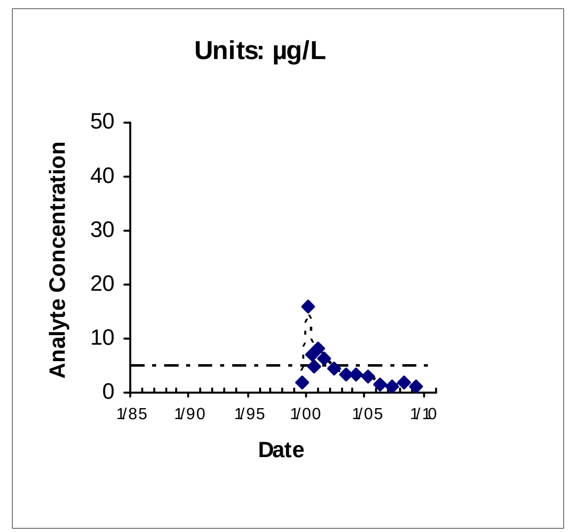
Location: MW518X37 Maximum: 64



Location: MW519X37 Maximum: 64



Location: MW520X37 Maximum: 6.8



Location: MW521X37 Maximum: 16.1

— - — - — IRG (5 µg/L)

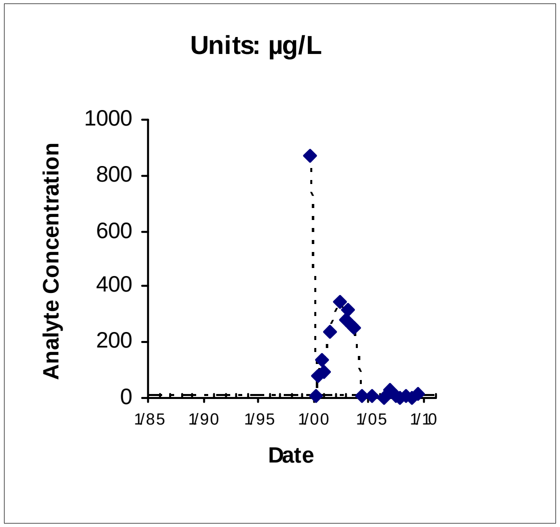
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

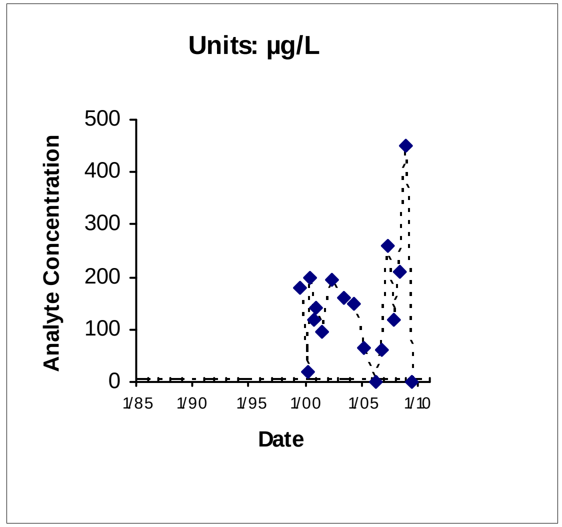
WIOU

TCE

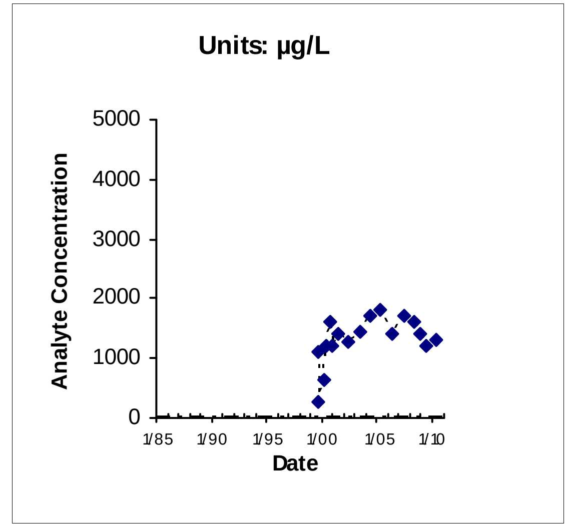
Chemical Time-series Plots



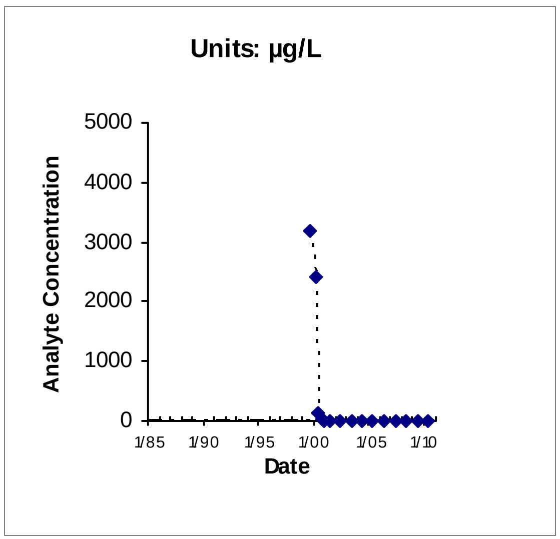
Location: MW522X37 Maximum: 870



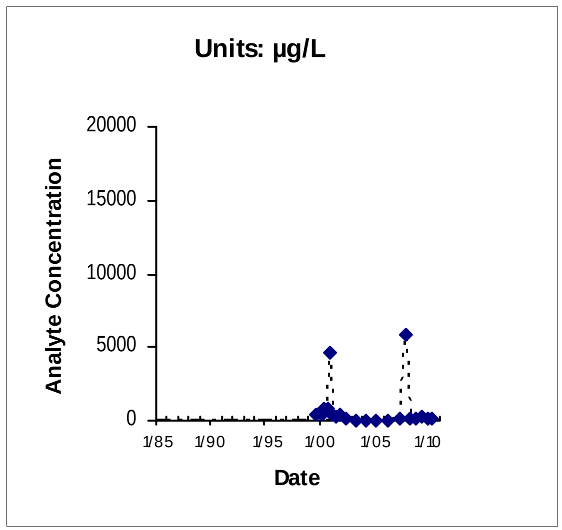
Location: MW523X37 Maximum: 452



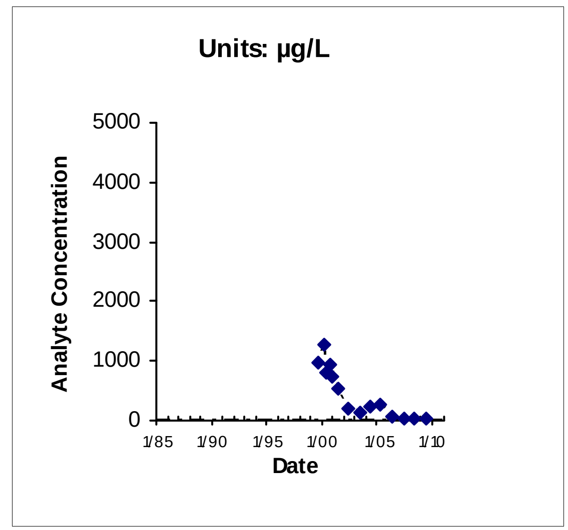
Location: MW524X37 Maximum: 1800



Location: MW525X37 Maximum: 3200



Location: MW526X37 Maximum: 5800



Location: MW527X37 Maximum: 1290

— - — - — IRG (5 µg/L)

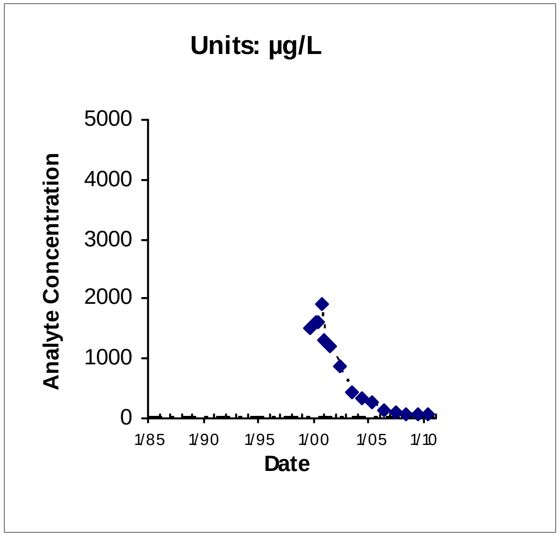
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

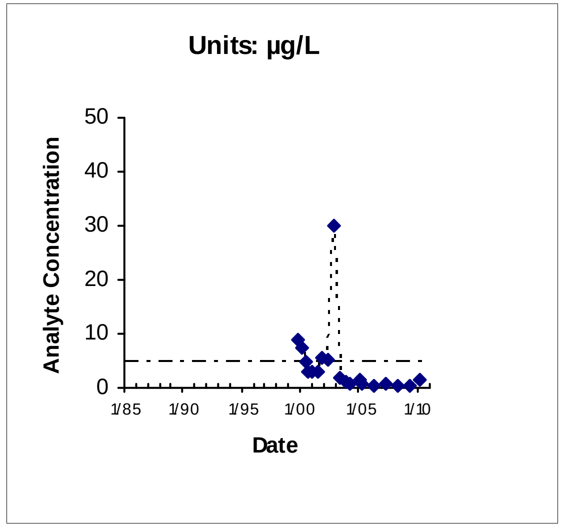
WIOU

TCE

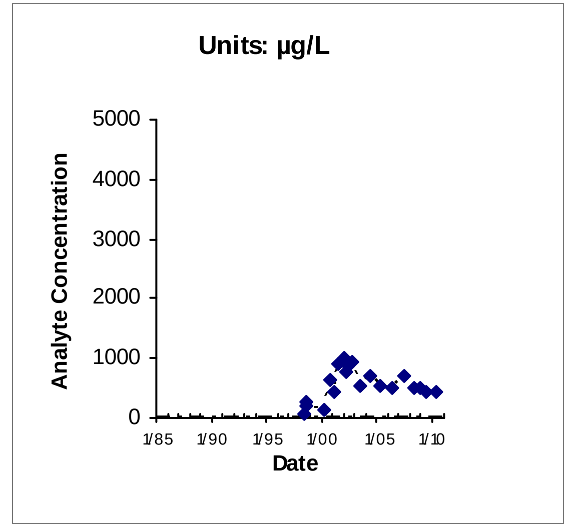
Chemical Time-series Plots



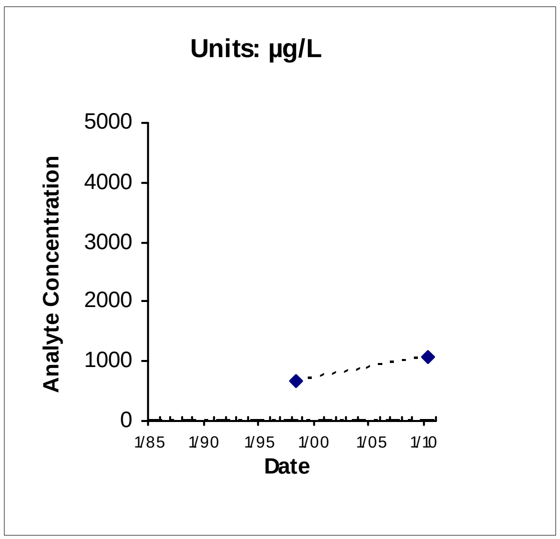
Location: MW528X37 Maximum: 1900



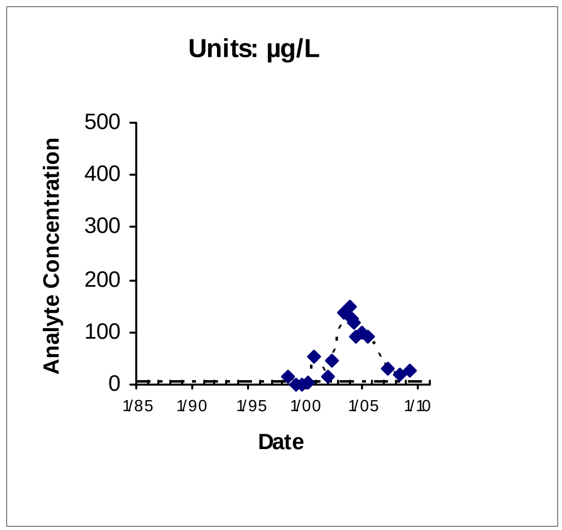
Location: MW529X37 Maximum: 30



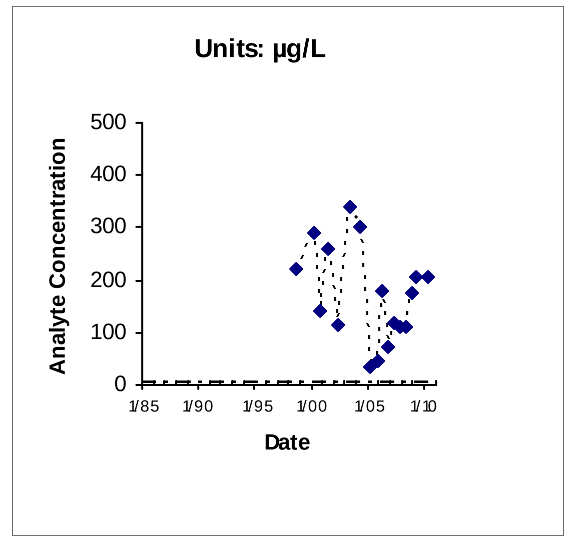
Location: MW531X37 Maximum: 1000



Location: MW532X37 Maximum: 1090



Location: MW533X37 Maximum: 150



Location: MW535X37 Maximum: 339

— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6
WIOU
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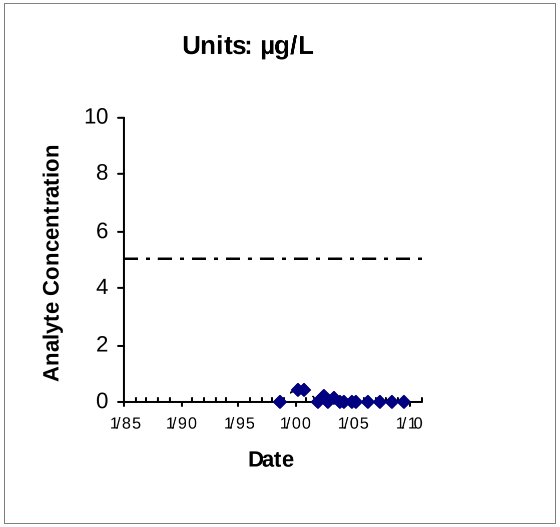
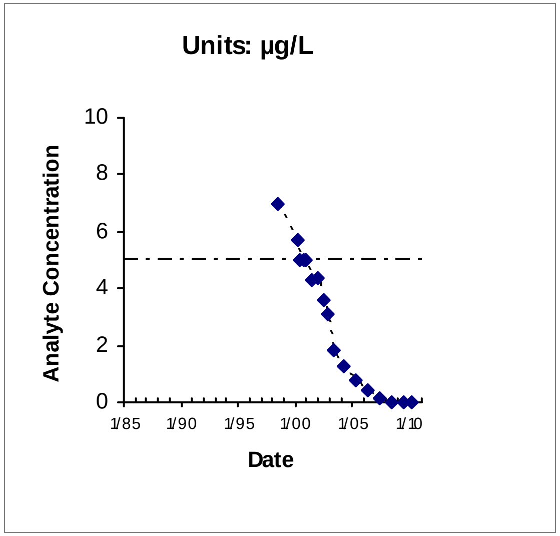
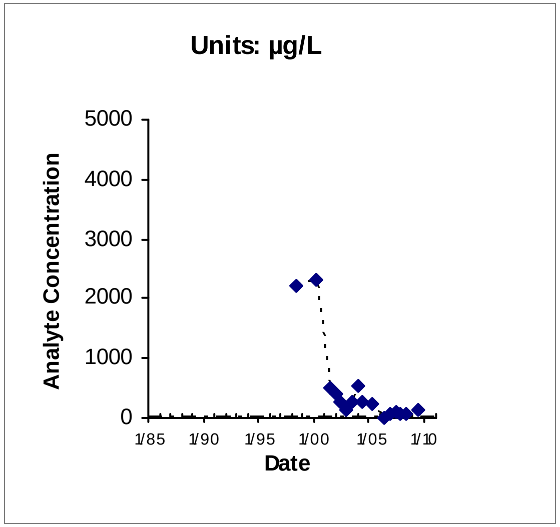
Chemical Time-series Plots



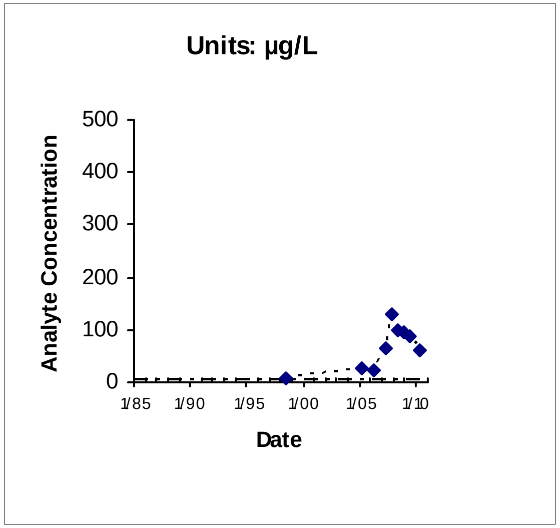
Location: MW536X37 Maximum: 0.4



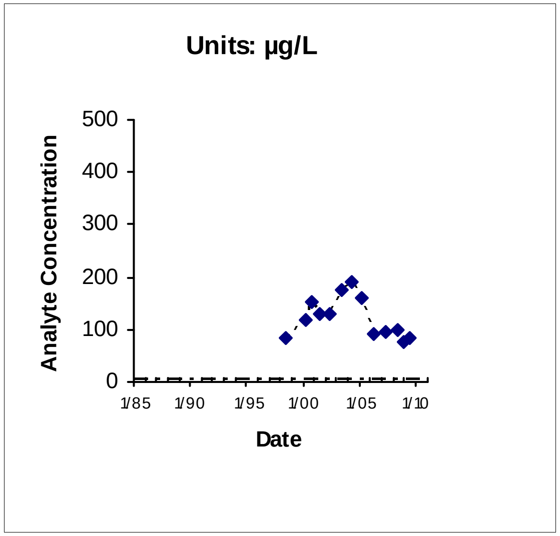
Location: MW537X37 Maximum: 7



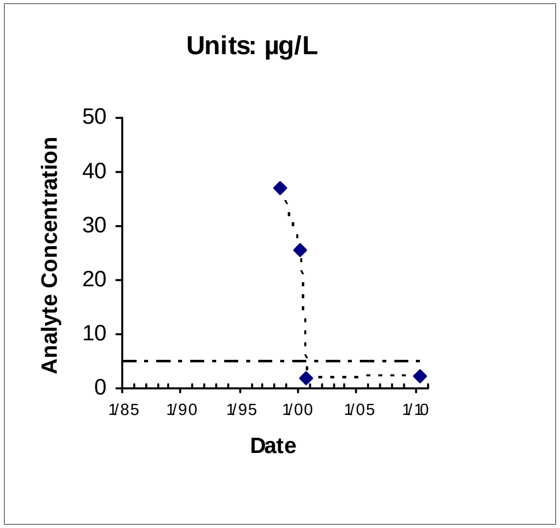
Location: MW538X37 Maximum: 2320



Location: MW539X37 Maximum: 130



Location: MW540X37 Maximum: 190



Location: MW541X37 Maximum: 37

— - — - — IRG (5 µg/L)

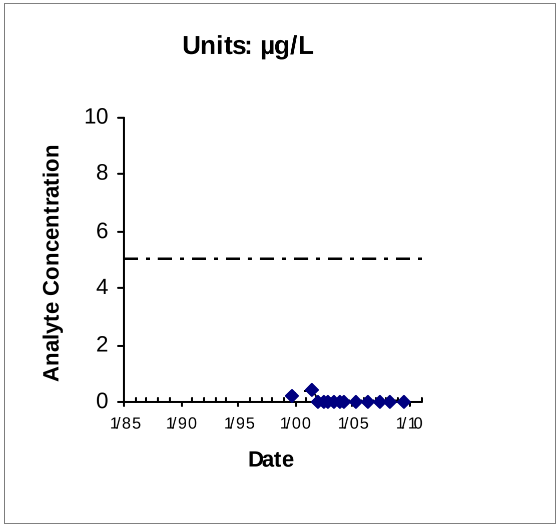
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

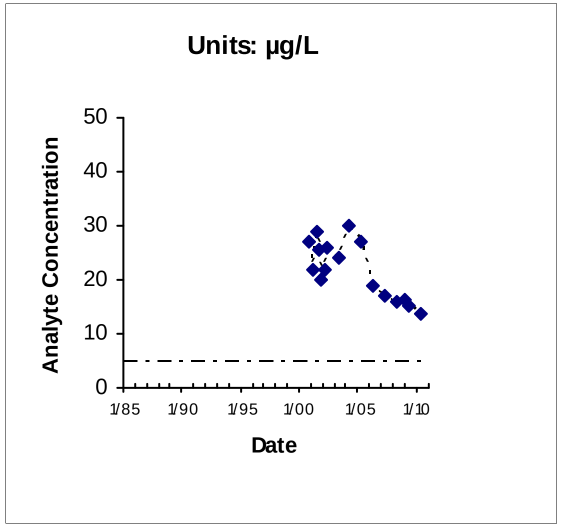
WIOU

TCE

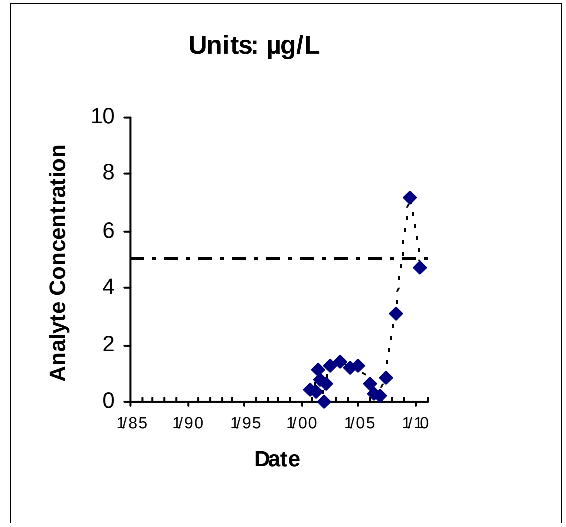
Chemical Time-series Plots



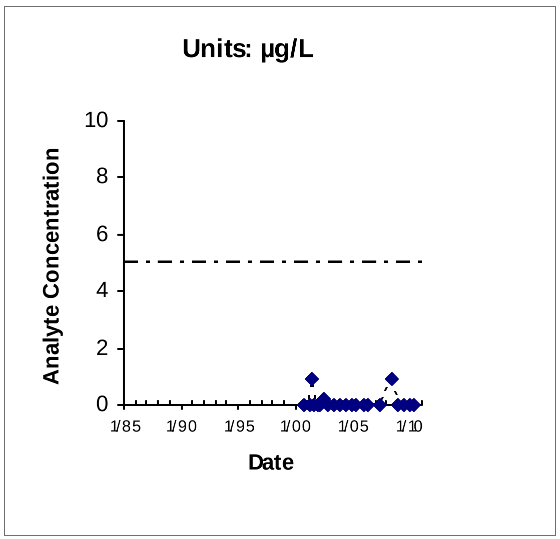
Location: MW596X37 Maximum: 0.43



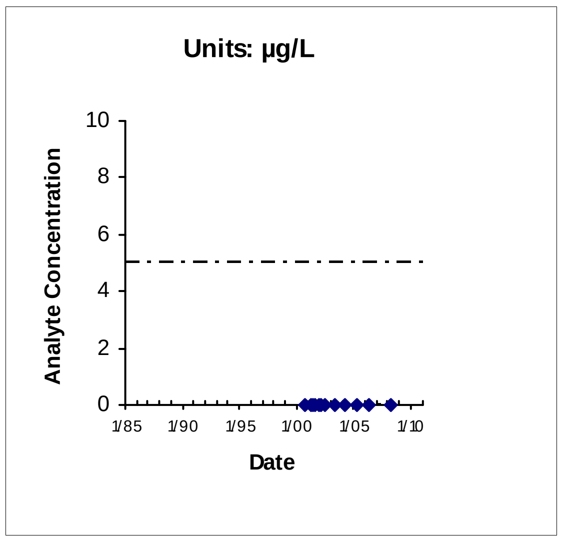
Location: MW722X37 Maximum: 30



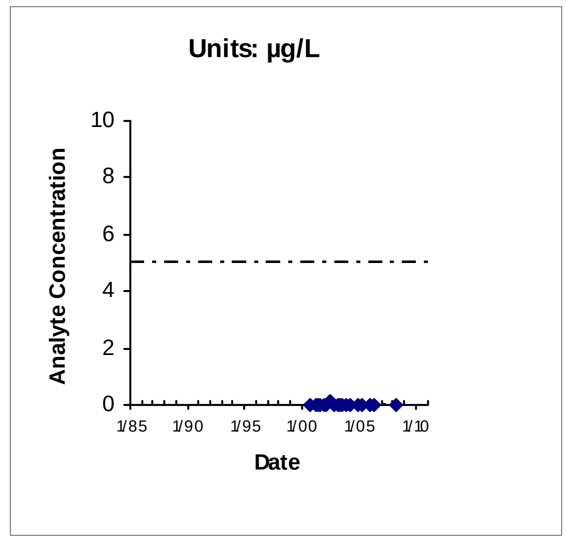
Location: MW723X37 Maximum: 7.2



Location: MW724X37 Maximum: 0.93



Location: MW729X37 Maximum: 0.03



Location: MW730X37 Maximum: 0.14

— - — - — IRG (5 µg/L)

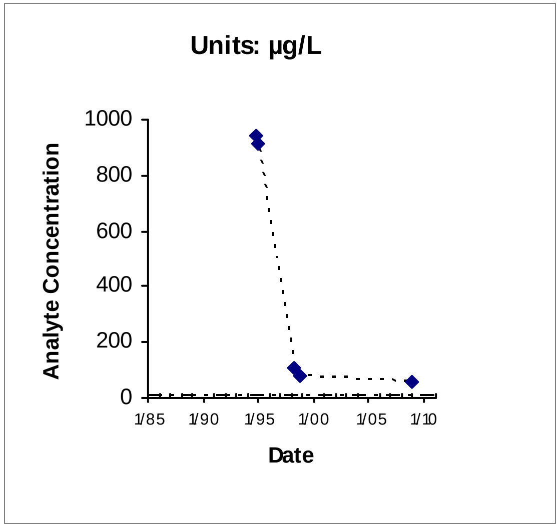
*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

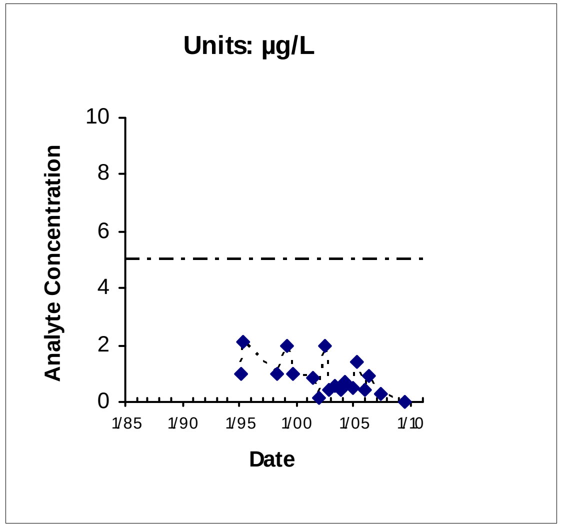
WIOU

TCE

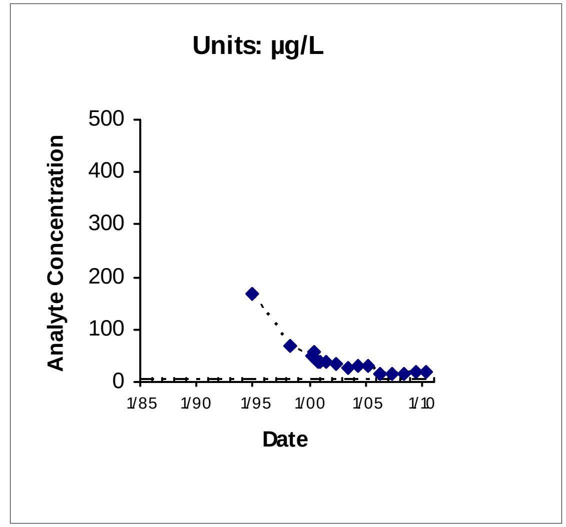
Chemical Time-series Plots



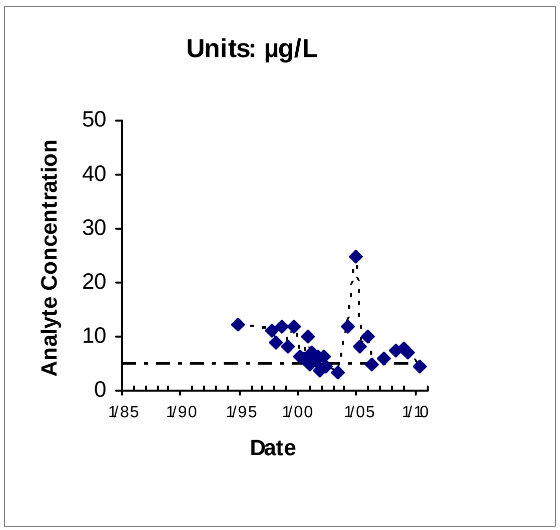
Location: MW810M1X37 Maximum: 941



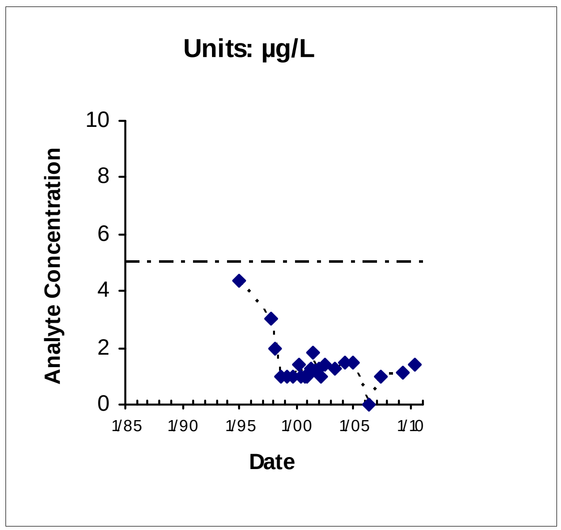
Location: MW981X37 Maximum: 2.12



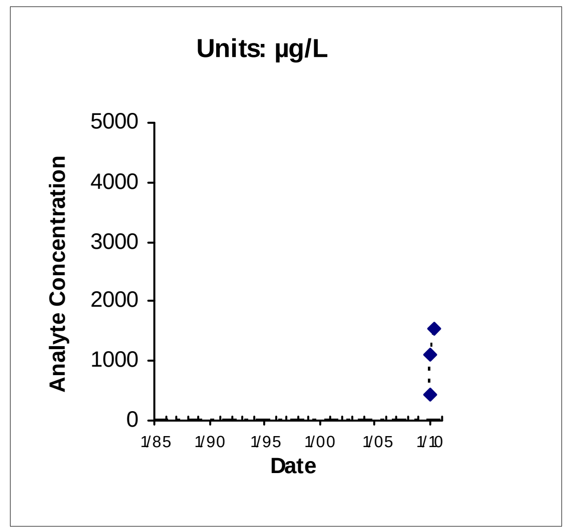
Location: MW1205X37 Maximum: 169



Location: MW1208X37 Maximum: 25



Location: MW1209X37 Maximum: 4.4



Location: MW2039Ax37 Maximum: 1550

FIGURE 4.6-6

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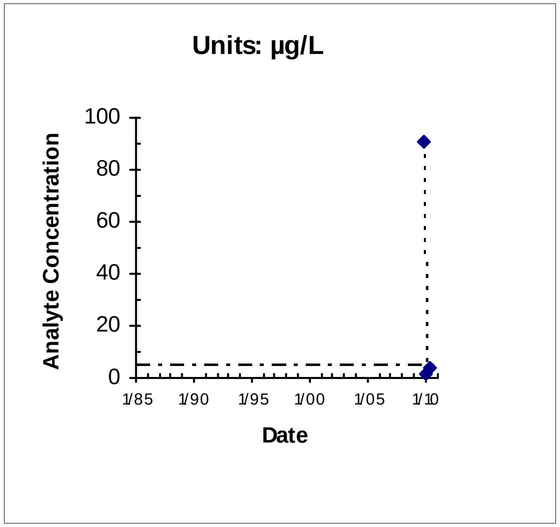
TCE

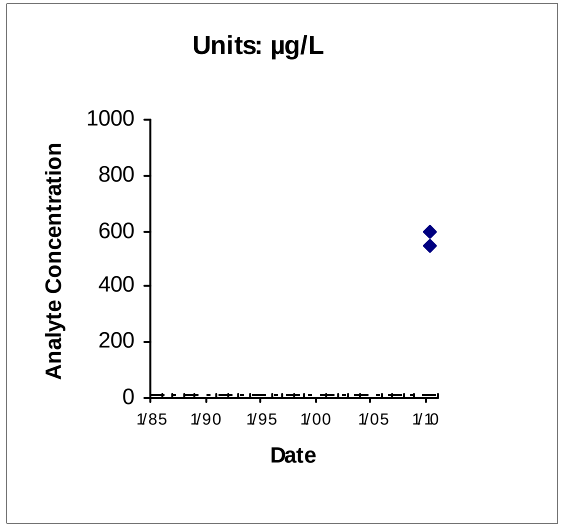
Chemical Time-series Plots

— - — - — IRG (5 µg/L)

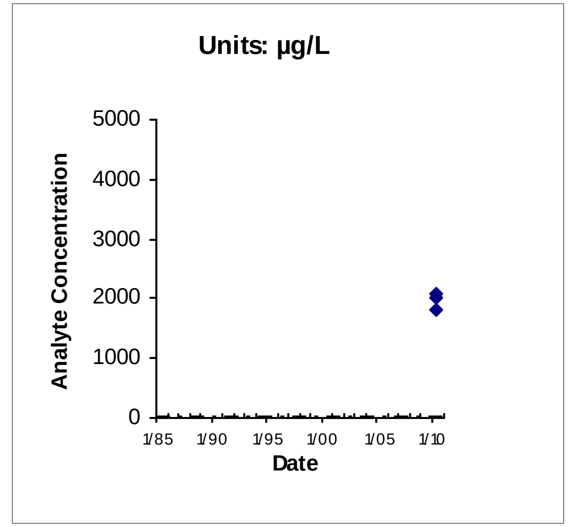
*Nondetects shown as the Method Detection Limit (0.03 µg/L)



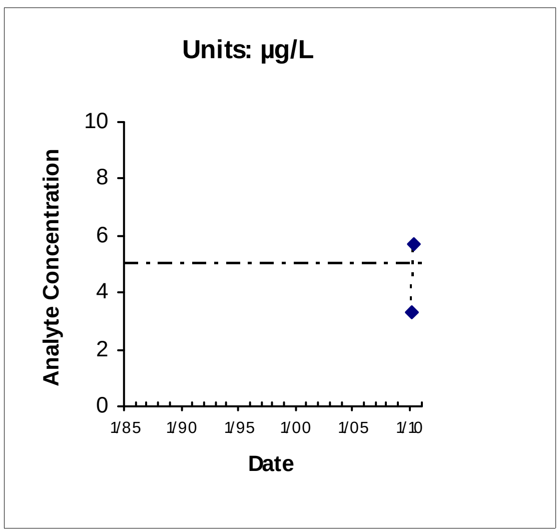
Location: MW2039Bx37 Maximum: 90.8



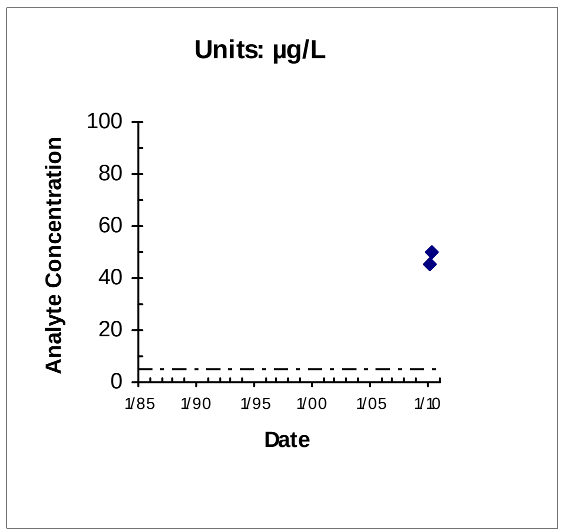
Location: MW2101Ax37 Maximum: 596



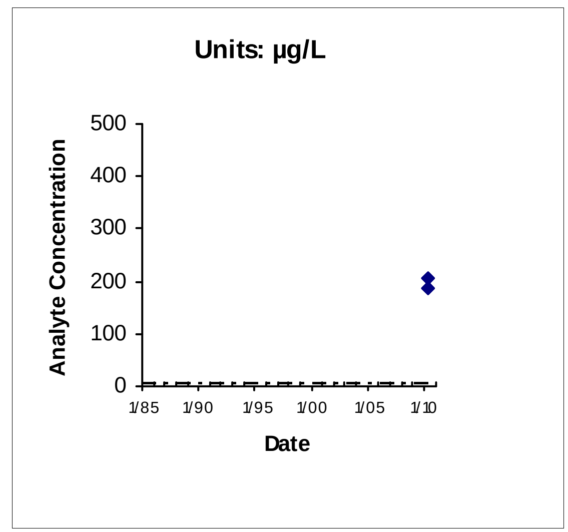
Location: MW2101Bx37 Maximum: 2070



Location: MW2101Cx37 Maximum: 5.7



Location: MW2102Ax37 Maximum: 50.1



Location: MW2102Bx37 Maximum: 208

FIGURE 4.6-6

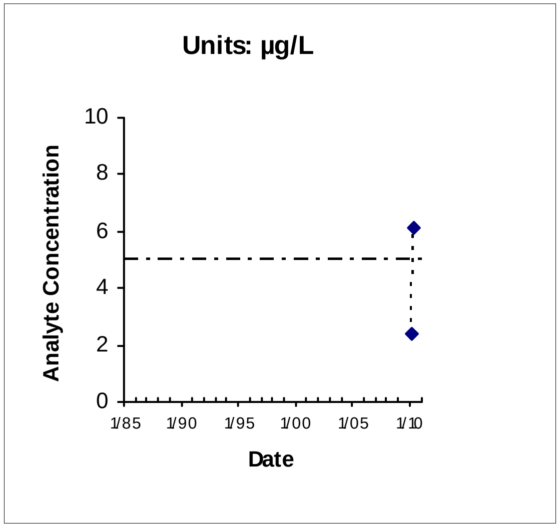
WIOU

TCE

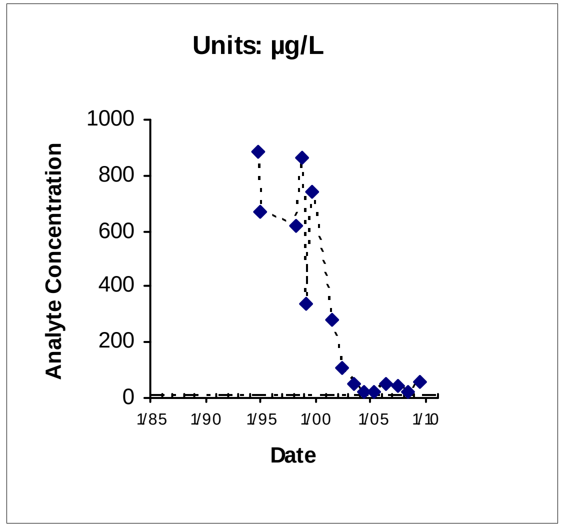
Chemical Time-series Plots

— - — - — IRG (5 µg/L)

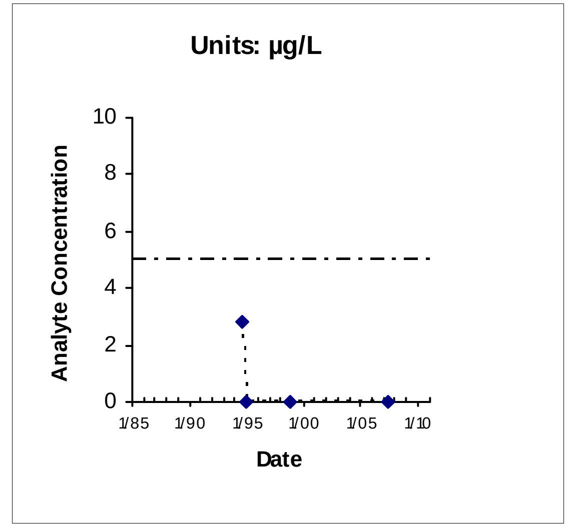
*Nondetects shown as the Method Detection Limit (0.03 µg/L)



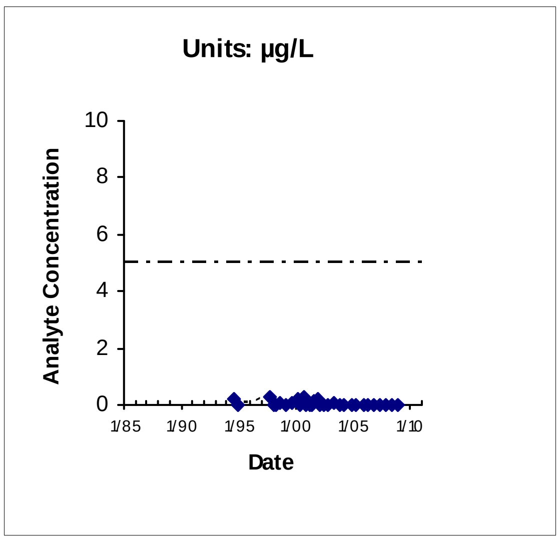
Location: MW2102Cx37 Maximum: 6.1



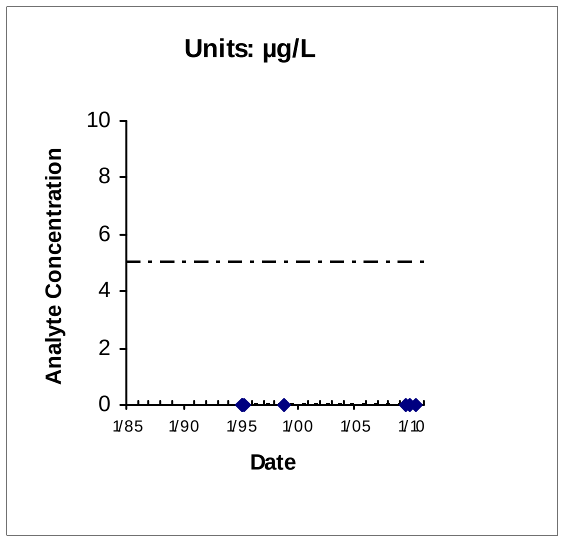
Location: MWRVM2X37 Maximum: 888



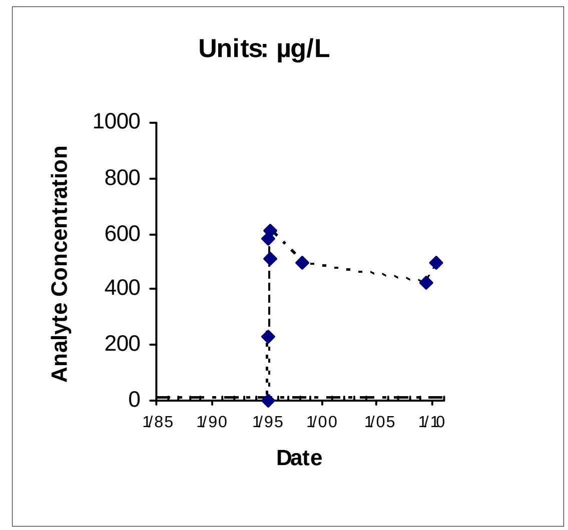
Location: MWS1M1X37 Maximum: 2.85



Location: MWS1M2X37 Maximum: 0.3



Location: MWS3M3X37 Maximum: 0.03



Location: MWSNSM1X37 Maximum: 608

— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

WIOU

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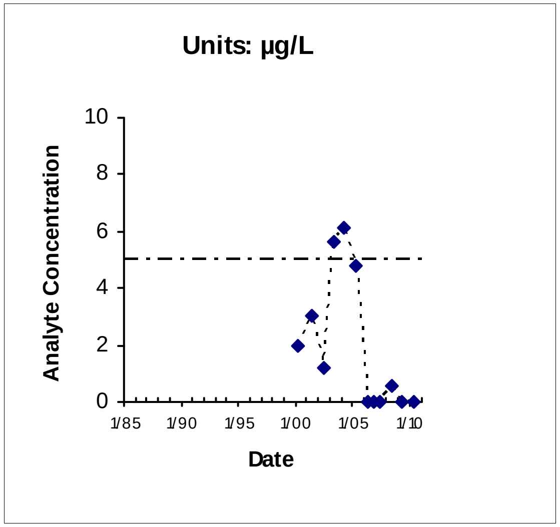
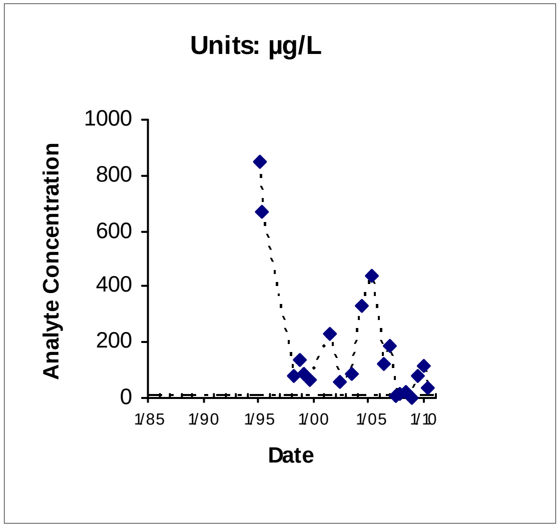
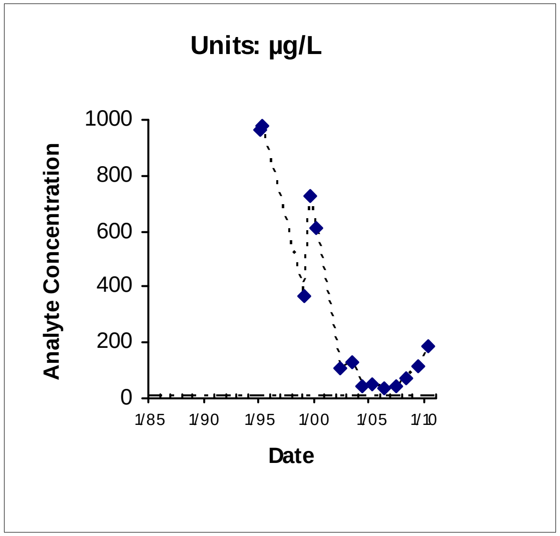
Chemical Time-series Plots



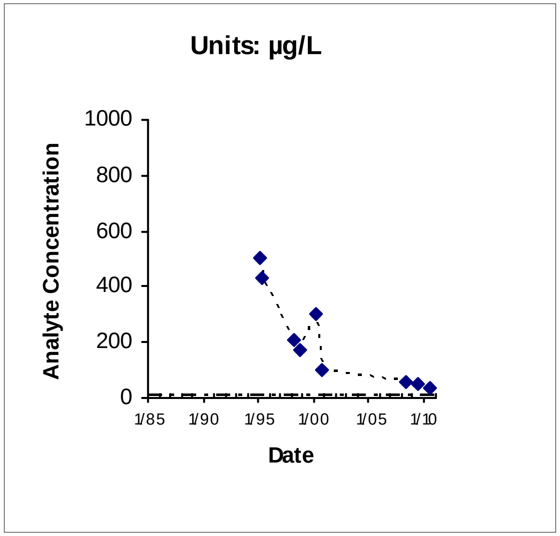
Location: MWSNSM3X37 Maximum: 6.1



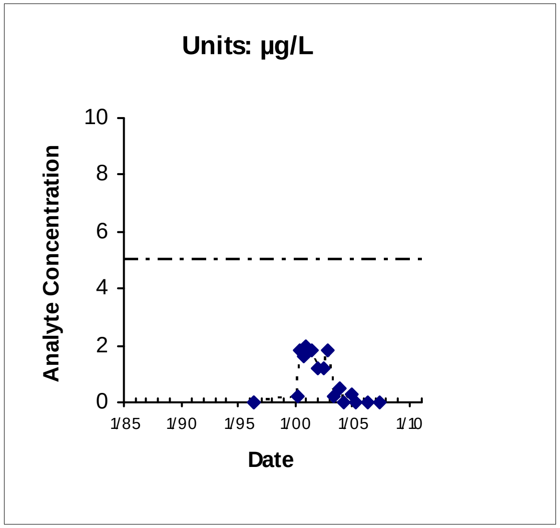
Location: MWSNSM4X37 Maximum: 851



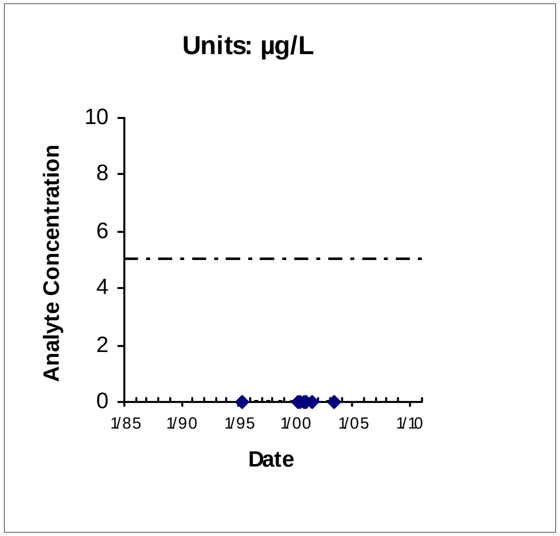
Location: MWSNSM5X37 Maximum: 979



Location: MWSSBM1X37 Maximum: 502



Location: MW02X41 Maximum: 2



Location: PZ02X41 Maximum: 0.03

— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

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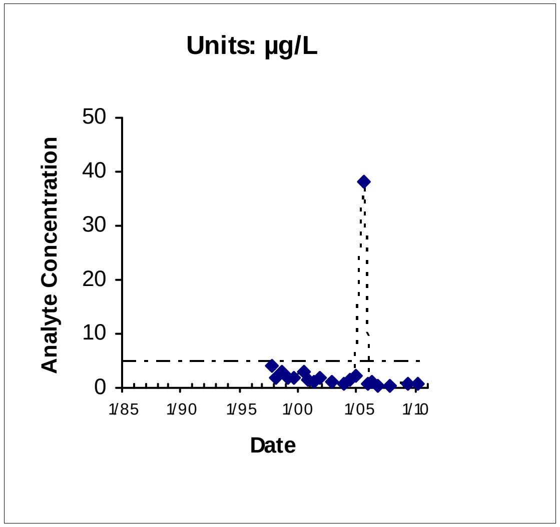
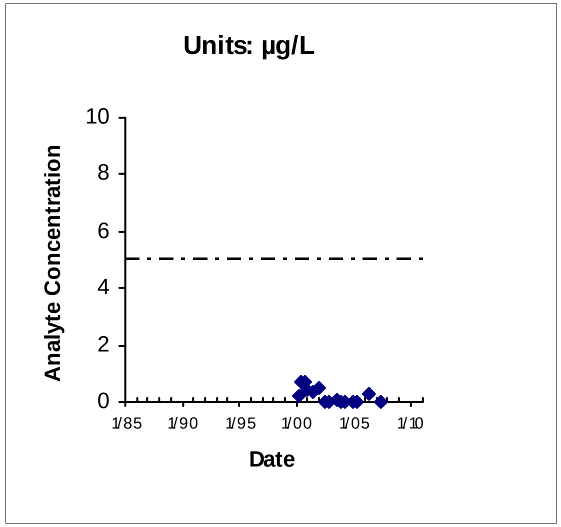
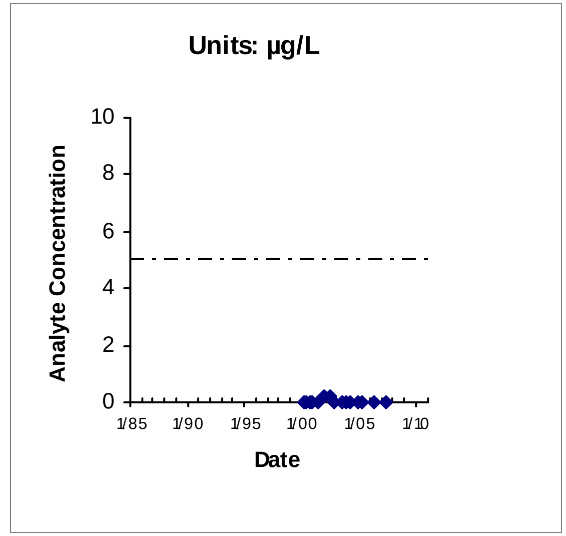
Chemical Time-series Plots



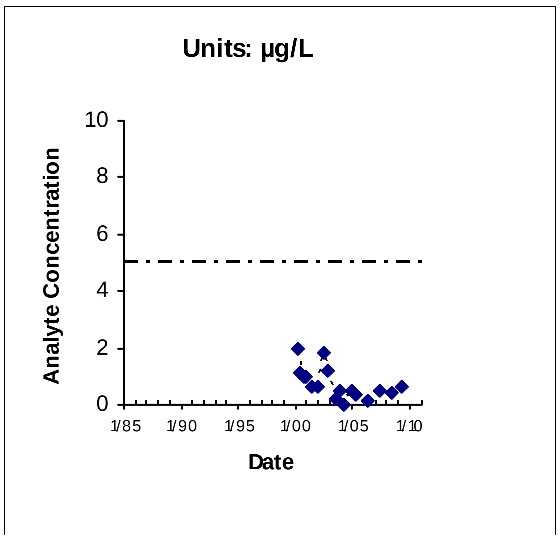
Location: EW555X43 Maximum: 38



Location: MW543X43 Maximum: 0.7



Location: MW544X43 Maximum: 0.21



Location: MW545X43 Maximum: 2

— - — - — IRG (5 µg/L)

*Nondetects shown as the Method Detection Limit (0.03 µg/L)

FIGURE 4.6-6

WIOU

TCE

Chemical Time-series Plots

Attachment C3

Attachment C3 contains Mann-Kendall trend analysis results excerpted from the final *Groundwater Sampling and Analysis Program 2009–2010 Annual Report,* Travis Air Force Base, California (CH2M HILL, 2011).

TABLE 4.8-3

Mann-Kendall Trend Analysis Results for Site DP039

Travis AFB 2009-2010 Annual GSAP Report

Location	Analyte	Count	S-Statistic	p-Value	Trend
Site: Site DP039					
EW563X39	1,1,1-TCA	20	-119	0.00	DECREASING
	1,1,2-TCA	20	-60	0.03	DECREASING
	1,1-DCE	20	-121	0.00	DECREASING
	TCE	20	-130	0.00	DECREASING
	Vinyl chloride	20	59	0.03	INCREASING
EW782X39	1,2-DCA	13	28	0.05	INCREASING
	Cis-1,2-DCE	13	58	0.00	INCREASING
	TCE	13	40	0.01	INCREASING
MW02X39	1,1-DCE	25	214	0.00	INCREASING
	TCE	26	281	0.00	INCREASING
MW04X39	1,1-DCE	22	86	0.01	INCREASING
	Cis-1,2-DCE	22	94	0.00	INCREASING
	Methyl tert-butyl ether (MTBE)	16	48	0.02	INCREASING
	TCE	22	62	0.04	INCREASING
MW751X39	1,1,1-TCA	19	-123	0.00	DECREASING
	1,1-DCE	19	-97	0.00	DECREASING
	TCE	20	-118	0.00	DECREASING
MW758X39	TCE	18	79	0.00	INCREASING
MW759X39	Cis-1,2-DCE	18	-45	0.05	DECREASING
MW760X39	TCE	18	85	0.00	INCREASING
MW762X39	TCE	17	-47	0.03	DECREASING
MW777X39	1,1,1-TCA	11	-38	0.00	DECREASING
	1,1,2-TCA	11	-27	0.02	DECREASING
	1,1-DCE	11	-27	0.02	DECREASING
	1,2-DCA	11	-24	0.04	DECREASING
	Cis-1,2-DCE	11	-33	0.01	DECREASING
	PCE	11	-30	0.01	DECREASING
	TCE	11	-35	0.00	DECREASING
MW778X39	1,1,1-TCA	11	-26	0.03	DECREASING
	Cis-1,2-DCE	11	33	0.01	INCREASING
	TCE	11	-33	0.01	DECREASING
	Vinyl chloride	11	34	0.00	INCREASING
MW781X39	TCE	9	22	0.01	INCREASING
MW783DX39	1,1-DCE	9	-21	0.03	DECREASING
	TCE	9	-22	0.01	DECREASING
MW784DX39	Cis-1,2-DCE	9	-25	0.01	DECREASING
MW785X39	1,1-DCE	12	56	0.00	INCREASING

Note: Grouped by Site and Location, sorted by Analyte

TABLE 4.8-3

Mann-Kendall Trend Analysis Results for Site DP039

Travis AFB 2009-2010 Annual GSAP Report

Location	Analyte	Count	S-Statistic	p-Value	Trend
Site: Site DP039					
MW785X39	Acetone	12	-30	0.02	DECREASING
	Cis-1,2-DCE	12	37	0.01	INCREASING
	TCE	12	42	0.00	INCREASING
MW787X39	TCE	4	-6	0.04	DECREASING
	Vinyl chloride	4	6	0.04	INCREASING
MW788X39	Cis-1,2-DCE	4	6	0.04	INCREASING
MW792X39	Cis-1,2-DCE	4	6	0.04	INCREASING
MW793X39	1,1-DCE	4	-6	0.04	DECREASING
	TCE	4	-6	0.04	DECREASING

Note: Grouped by Site and Location, sorted by Analyte

TABLE 4.1-3

Mann-Kendall Trend Analysis Results for Sites FT004/SD031/LF007

Travis AFB 2009-2010 Annual GSAP Report

Location	Analyte	Count	S-Statistic	p-Value	Trend
Site: Site FT004					
EW576X04	1,1-DCE	20	-72	0.01	DECREASING
	Cis-1,2-DCE	20	-94	0.00	DECREASING
	TCE	20	-163	0.00	DECREASING
	Vinyl chloride	20	54	0.04	INCREASING
EW577X04	Cis-1,2-DCE	17	49	0.02	INCREASING
	TCE	17	-49	0.02	DECREASING
	Vinyl chloride	17	58	0.01	INCREASING
EW578X04	Cis-1,2-DCE	20	75	0.01	INCREASING
	TCE	20	-89	0.00	DECREASING
EW579X04	TCE	20	-150	0.00	DECREASING
EW580X04	Chloroform	22	67	0.03	INCREASING
	TCE	22	-155	0.00	DECREASING
EW621X04	Cis-1,2-DCE	15	-76	0.00	DECREASING
	TCE	15	-88	0.00	DECREASING
EW623X04	1,2-DCA	13	-47	0.00	DECREASING
	Benzene	13	-47	0.00	DECREASING
	Chloroform	13	-48	0.00	DECREASING
	Cis-1,2-DCE	13	-65	0.00	DECREASING
	TCE	13	-70	0.00	DECREASING
MW134X04	TCE	17	83	0.00	INCREASING
MW202X04	1,1-DCE	21	-97	0.00	DECREASING
	Cis-1,2-DCE	21	-126	0.00	DECREASING
	TCE	21	-145	0.00	DECREASING
MW266X04	Cis-1,2-DCE	24	-119	0.00	DECREASING
	TCE	24	-261	0.00	DECREASING
MW581X04	Cis-1,2-DCE	19	70	0.01	INCREASING
MW584X04	1,1-DCE	16	-64	0.00	DECREASING
	Cis-1,2-DCE	16	-74	0.00	DECREASING
	TCE	18	-129	0.00	DECREASING
MW585X04	TCE	20	-111	0.00	DECREASING
MW587X04	Cis-1,2-DCE	18	-45	0.05	DECREASING
	TCE	20	-56	0.04	DECREASING
MW591X04	TCE	23	93	0.01	INCREASING
MW757X04	Cis-1,2-DCE	16	50	0.01	INCREASING
	PCE	16	38	0.05	INCREASING
	TCE	16	-50	0.01	DECREASING

Note: Grouped by Site and Location, sorted by Analyte

TABLE 4.1-3

Mann-Kendall Trend Analysis Results for Sites FT004/SD031/LF007

Travis AFB 2009-2010 Annual GSAP Report

Location	Analyte	Count	S-Statistic	p-Value	Trend
Site: Site LF007					
MW261X07	Chlorobenzene	19	69	0.01	INCREASING
MW612X07	1,2-Dichloropropane	11	-24	0.04	DECREASING
MW617X07	TCE	10	-21	0.04	DECREASING
MWBX07	1,4-DCB	15	-62	0.00	DECREASING
	Chlorobenzene	15	-49	0.01	DECREASING
MWCX07	Chlorobenzene	13	-34	0.02	DECREASING
Site: Site SD031					
EW565X31	1,1-DCE	22	-127	0.00	DECREASING
	Benzene	22	-94	0.00	DECREASING
	Cis-1,2-DCE	22	-127	0.00	DECREASING
	TCE	22	-106	0.00	DECREASING
EW566X31	1,1-DCE	21	-90	0.00	DECREASING
	Benzene	21	-84	0.01	DECREASING
	Cis-1,2-DCE	21	-150	0.00	DECREASING
	TCE	21	-151	0.00	DECREASING
EW567X31	Freon 113	6	15	0.00	INCREASING
MW571X31	1,1-DCE	18	103	0.00	INCREASING
	Freon 113	8	18	0.02	INCREASING
	PCE	18	96	0.00	INCREASING
MW574X31	Cis-1,2-DCE	22	111	0.00	INCREASING
	Freon 113	10	37	0.00	INCREASING
	TCE	22	-102	0.00	DECREASING
MW1729X31	Cis-1,2-DCE	25	-229	0.00	DECREASING
	TCE	25	-148	0.00	DECREASING
	TPH-Gasoline	20	-53	0.05	DECREASING

Note: Grouped by Site and Location, sorted by Analyte

Mann-Kendall Trend Analysis Results for Sites FT005/SS029/SS030

Travis AFB 2009-2010 Annual GSAP Report

Location	Analyte	Count	S-Statistic	p-Value	Trend
Site: Site FT005					
EW01X05	Cis-1,2-DCE	29	93	0.04	INCREASING
	TCE	29	171	0.00	INCREASING
EW731X05	1,2-DCA	17	-85	0.00	DECREASING
EW732X05	1,2-DCA	16	-73	0.00	DECREASING
EW733X05	1,2-DCA	16	-68	0.00	DECREASING
EW734X05	1,2-DCA	13	-56	0.00	DECREASING
EW735X05	1,2-DCA	13	34	0.02	INCREASING
EW742X05	1,2-DCA	14	-33	0.04	DECREASING
EW743X05	1,2-DCA	14	-48	0.00	DECREASING
EW744X05	1,2-DCA	14	-44	0.01	DECREASING
EW745X05	1,2-DCA	14	-32	0.05	DECREASING
MW119X05	Chloroform	20	56	0.04	INCREASING
	Cis-1,2-DCE	18	-138	0.00	DECREASING
	TCE	18	-131	0.00	DECREASING
MW774X05	1,2-DCA	15	-35	0.05	DECREASING
Site: Site SS029					
EW01X29	1,1-DCE	22	-73	0.02	DECREASING
	Cis-1,2-DCE	22	-89	0.01	DECREASING
	TCE	22	-76	0.02	DECREASING
EW02X29	1,1-DCE	22	100	0.00	INCREASING
	Cis-1,2-DCE	22	129	0.00	INCREASING
	TCE	22	143	0.00	INCREASING
EW04X29	Cis-1,2-DCE	22	-67	0.03	DECREASING
EW05X29	TCE	22	111	0.00	INCREASING
EW06X29	TCE	22	80	0.01	INCREASING
MW329X29	1,1-DCE	26	-81	0.04	DECREASING
	Benzene	26	-81	0.04	DECREASING
	Cis-1,2-DCE	26	-93	0.02	DECREASING
	TCE	28	-119	0.01	DECREASING
MW1031X29	Cis-1,2-DCE	19	136	0.00	INCREASING
	TCE	19	150	0.00	INCREASING
MW1032X29	Cis-1,2-DCE	17	54	0.01	INCREASING
	TCE	17	66	0.00	INCREASING
MW1044X29	TCE	18	-80	0.00	DECREASING
PZ01DX29	Cis-1,2-DCE	21	97	0.00	INCREASING
PZ01SX29	Cis-1,2-DCE	23	106	0.00	INCREASING
	TCE	23	101	0.00	INCREASING

Note: Grouped by Site and Location, sorted by Analyte

Location	Analyte	Count	S-Statistic	p-Value	Trend
Site: Site SS029					
SWPZ01X29	Chloroform	10	-22	0.03	DECREASING
Site: Site SS030					
EW01X30	TCE	24	-251	0.00	DECREASING
EW02X30	TCE	23	-210	0.00	DECREASING
EW03X30	TCE	27	-131	0.00	DECREASING
EW04X30	Chloroform	25	-75	0.04	DECREASING
	TCE	25	-226	0.00	DECREASING
EW05X30	TCE	24	-150	0.00	DECREASING
EW06X30	Cis-1,2-DCE	25	-124	0.00	DECREASING
	TCE	25	-202	0.00	DECREASING
EW711X30	TCE	14	-55	0.00	DECREASING
MW03X30	TCE	34	180	0.00	INCREASING
MW04X30	TCE	12	-51	0.00	DECREASING
MW05X30	TCE	26	206	0.00	INCREASING
MW269X30	TCE	22	-194	0.00	DECREASING

Note: Grouped by Site and Location, sorted by Analyte

TABLE 4.2-3

Mann-Kendall Trend Analysis Results for Site LF006

Travis AFB 2009-2010 Annual GSAP Report

Location	Analyte	Count	S-Statistic	p-Value	Trend
Site: Site LF006					
MW208DX06	Cis-1,2-DCE	20	-100	0.00	DECREASING
	TCE	20	-117	0.00	DECREASING
MW208X06	Cis-1,2-DCE	24	-152	0.00	DECREASING
	TCE	24	-172	0.00	DECREASING
MW259X06	Cis-1,2-DCE	22	-100	0.00	DECREASING
	TCE	22	-104	0.00	DECREASING
Site: Site SD031					
MW1729X31	Cis-1,2-DCE	25	-229	0.00	DECREASING
	TCE	25	-148	0.00	DECREASING
	TPH-Gasoline	20	-53	0.05	DECREASING

Note: Grouped by Site and Location, sorted by Analyte

TABLE 4.9-3

Mann-Kendall Trend Analysis Results for Site LF008

Travis AFB 2009-2010 Annual GSAP Report

Location	Analyte	Count	S-Statistic	p-Value	Trend
Site: Site LF008					
EW721X08	alpha-Chlordane	12	-26	0.04	DECREASING
MW712X08	alpha-Chlordane	16	-54	0.01	DECREASING

Note: Grouped by Site and Location, sorted by Analyte

TABLE 4.7-3

Mann-Kendall Trend Analysis Results for Site SS015

Travis AFB 2009-2010 Annual GSAP Report

Location	Analyte	Count	S-Statistic	p-Value	Trend
Site: Site SS015					
MW625X15	Cis-1,2-DCE	15	57	0.00	INCREASING
	Methyl tert-butyl ether (MTBE)	15	49	0.01	INCREASING
	PCE	15	42	0.02	INCREASING
	TCE	15	56	0.00	INCREASING
	Vinyl chloride	15	40	0.03	INCREASING

Note: Grouped by Site and Location, sorted by Analyte

TABLE 4.5-3

Mann-Kendall Trend Analysis Results for Site ST027

Travis AFB 2009-2010 Annual GSAP Report

Location	Analyte	Count	S-Statistic	p-Value	Trend
Site: Site ST027					
MW791X27	Benzene	10	22	0.03	INCREASING
MW792X27	TCE	16	56	0.01	INCREASING
MW2009X27	Cis-1,2-DCE	4	-6	0.04	DECREASING

Note: Grouped by Site and Location, sorted by Analyte

TABLE 4.6-3

Mann-Kendall Trend Analysis Results for the WIOU

Travis AFB 2009-2010 Annual GSAP Report

Location	Analyte	Count	S-Statistic	p-Value	Trend
Site: Site SS014					
MW05X14	Benzene	26	-243	0.00	DECREASING
	Ethylbenzene	20	-112	0.00	DECREASING
	TPH-Gasoline	20	-76	0.01	DECREASING
Site: Site SD033					
EW501X33	Cis-1,2-DCE	13	38	0.01	INCREASING
	PCE	13	53	0.00	INCREASING
	TCE	13	64	0.00	INCREASING
EW503X33	Cis-1,2-DCE	13	-33	0.03	DECREASING
	TCE	13	-34	0.02	DECREASING
MW502X33	PCE	18	-46	0.04	DECREASING
MW504X33	PCE	19	-76	0.00	DECREASING
	TCE	21	-69	0.02	DECREASING
MW509X33	TCE	14	36	0.03	INCREASING
WBUC-4	TCE	16	-51	0.01	DECREASING
Site: Site SD034					
EW01X34	Benzene	13	-44	0.00	DECREASING
	Cis-1,2-DCE	13	-49	0.00	DECREASING
	Methyl tert-butyl ether (MTBE)	10	-26	0.01	DECREASING
	Vinyl chloride	13	-39	0.01	DECREASING
EW03X34	Cis-1,2-DCE	13	-33	0.03	DECREASING
MW02X34	1,2-DCA	20	-52	0.05	DECREASING
	Benzene	20	-78	0.01	DECREASING
	Cis-1,2-DCE	20	-52	0.05	DECREASING
	Methyl tert-butyl ether (MTBE)	17	-97	0.00	DECREASING
	TCE	20	-105	0.00	DECREASING
	TPH-Gasoline	16	-60	0.00	DECREASING
MW04X34	Cis-1,2-DCE	20	-137	0.00	DECREASING
	PCE	20	-90	0.00	DECREASING
	TCE	22	-108	0.00	DECREASING
	TPH-Diesel	15	-47	0.01	DECREASING
	TPH-Gasoline	17	-44	0.04	DECREASING
Site: Site SD036					
EW593X36	Benzene	13	-33	0.03	DECREASING
	Cis-1,2-DCE	13	-62	0.00	DECREASING
	Vinyl chloride	13	-53	0.00	DECREASING
EW594X36	Benzene	14	-33	0.04	DECREASING
	Cis-1,2-DCE	16	-64	0.00	DECREASING

Note: Grouped by Site and Location, sorted by Analyte

Location	Analyte	Count	S-Statistic	p-Value	Trend
Site: Site SD036					
EW594X36	PCE	16	-64	0.00	DECREASING
	Vinyl chloride	16	-79	0.00	DECREASING
MW873M2X36	1,2-DCA	14	-41	0.01	DECREASING
	Cis-1,2-DCE	17	-48	0.03	DECREASING
	TCE	17	-52	0.02	DECREASING
MW2031BX36	Cis-1,2-DCE	4	6	0.04	INCREASING
	TCE	4	6	0.04	INCREASING
MW2061BX36	TCE	5	8	0.04	INCREASING
MW2063X36	Cis-1,2-DCE	6	11	0.03	INCREASING
	TCE	6	11	0.03	INCREASING
MW2064BX36	TCE	6	-15	0.00	DECREASING
PZ03X36	TCE	11	-25	0.03	DECREASING
PZ12SX36	1,2-DCA	12	-49	0.00	DECREASING
	TCE	12	-33	0.02	DECREASING
Site: Site SD037					
EW510X37	Cis-1,2-DCE	13	-34	0.02	DECREASING
	TCE	13	-28	0.05	DECREASING
EW511X37	Methyl tert-butyl ether (MTBE)	12	-28	0.03	DECREASING
	PCE	12	-28	0.03	DECREASING
	Vinyl chloride	12	-35	0.01	DECREASING
EW599X37	Vinyl chloride	13	-28	0.05	DECREASING
EW700X37	Benzene	15	-61	0.00	DECREASING
	PCE	15	41	0.02	INCREASING
EW701X37	PCE	14	-61	0.00	DECREASING
	TCE	14	-53	0.00	DECREASING
EW702X37	PCE	13	-54	0.00	DECREASING
	TCE	13	-36	0.02	DECREASING
EW703X37	TCE	13	-48	0.00	DECREASING
EW706X37	Cis-1,2-DCE	12	43	0.00	INCREASING
	TCE	12	40	0.00	INCREASING
EW707X37	Carbon tetrachloride	14	-59	0.00	DECREASING
	PCE	14	47	0.00	INCREASING
	TCE	14	-53	0.00	DECREASING
MW116X37	Methyl tert-butyl ether (MTBE)	24	-91	0.01	DECREASING
MW500X37	Carbon tetrachloride	13	-51	0.00	DECREASING
	Cis-1,2-DCE	13	-44	0.00	DECREASING
	Methyl tert-butyl ether (MTBE)	11	-34	0.00	DECREASING

Note: Grouped by Site and Location, sorted by Analyte

TABLE 4.6-3

Mann-Kendall Trend Analysis Results for the WIOU

Travis AFB 2009-2010 Annual GSAP Report

Location	Analyte	Count	S-Statistic	p-Value	Trend
Site: Site SD037					
MW500X37	TCE	13	-62	0.00	DECREASING
MW513X37	Cis-1,2-DCE	21	-95	0.00	DECREASING
MW514X37	Cis-1,2-DCE	13	-35	0.02	DECREASING
	Methyl tert-butyl ether (MTBE)	12	-46	0.00	DECREASING
	TCE	13	-32	0.03	DECREASING
MW518X37	Methyl tert-butyl ether (MTBE)	27	163	0.00	INCREASING
	PCE	28	176	0.00	INCREASING
MW524X37	Cis-1,2-DCE	17	95	0.00	INCREASING
	TCE	17	52	0.02	INCREASING
	Vinyl chloride	17	-48	0.03	DECREASING
MW525X37	1,1-DCE	15	-37	0.04	DECREASING
	Cis-1,2-DCE	15	-67	0.00	DECREASING
	TCE	15	-93	0.00	DECREASING
	Vinyl chloride	15	-49	0.01	DECREASING
MW526X37	Cis-1,2-DCE	20	99	0.00	INCREASING
	PCE	20	-84	0.00	DECREASING
	TCE	20	-55	0.04	DECREASING
MW528X37	TCE	15	-89	0.00	DECREASING
MW529X37	Cis-1,2-DCE	17	-116	0.00	DECREASING
	PCE	17	-83	0.00	DECREASING
	TCE	19	-114	0.00	DECREASING
MW531X37	Cis-1,2-DCE	20	78	0.01	INCREASING
MW535X37	Carbon tetrachloride	17	-57	0.01	DECREASING
MW537X37	TCE	17	-128	0.00	DECREASING
MW539X37	PCE	9	20	0.02	INCREASING
MW722X37	1,1-DCE	16	-57	0.01	DECREASING
	Cis-1,2-DCE	16	-75	0.00	DECREASING
	TCE	16	-66	0.00	DECREASING
MW723X37	TCE	17	46	0.03	INCREASING
MW1205X37	Cis-1,2-DCE	16	-74	0.00	DECREASING
	TCE	16	-94	0.00	DECREASING
MW1208X37	TCE	27	-95	0.03	DECREASING
MWS3M3X37	Benzene	14	-40	0.02	DECREASING
	Benzene	14	-40	0.02	DECREASING
	TPH-Diesel	10	28	0.01	INCREASING
	TPH-Diesel	10	28	0.01	INCREASING
	TPH-Gasoline	12	-28	0.03	DECREASING

Note: Grouped by Site and Location, sorted by Analyte

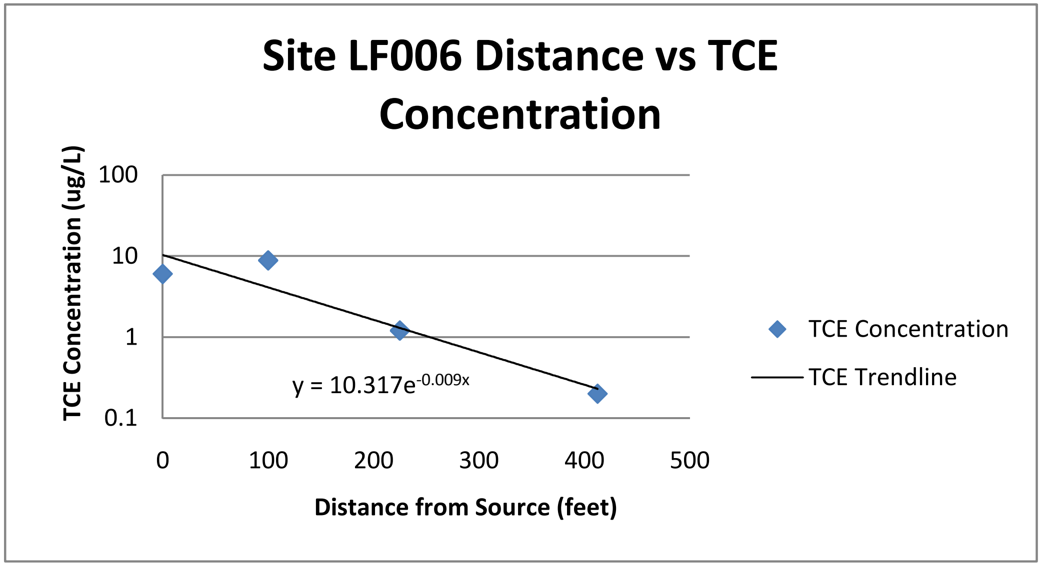
Location	Analyte	Count	S-Statistic	p-Value	Trend
Site: Site SD037					
MWS3M3X37	TPH-Gasoline	12	-28	0.03	DECREASING
MWSNSM3X37	Benzene	12	-26	0.04	DECREASING
	TCE	12	-28	0.03	DECREASING
MWSNSM4X37	Cis-1,2-DCE	20	-54	0.04	DECREASING
	TCE	20	-70	0.01	DECREASING
MWSNSM5X37	1,1-DCE	14	-36	0.03	DECREASING
	1,2-DCA	14	-32	0.05	DECREASING
	Cis-1,2-DCE	14	-45	0.01	DECREASING
	PCE	14	-53	0.00	DECREASING
	TCE	14	-41	0.01	DECREASING
	Vinyl chloride	14	-36	0.03	DECREASING
MWSSBM1X37	TCE	9	-32	0.00	DECREASING
Site: Site SD043					
EW555X43	Cis-1,2-DCE	20	-129	0.00	DECREASING
	PCE	20	-109	0.00	DECREASING
	TCE	20	-105	0.00	DECREASING

Note: Grouped by Site and Location, sorted by Analyte

Attachment C4

Well	Distance from source (ft)	TCE Concentration (ug/L)
MW208Dx06	0	6
MW259x06	100	8.8
MW1729x31	225	1.2
MW1731x31	412.5	0.2
MW02Dx06	587.5	ND

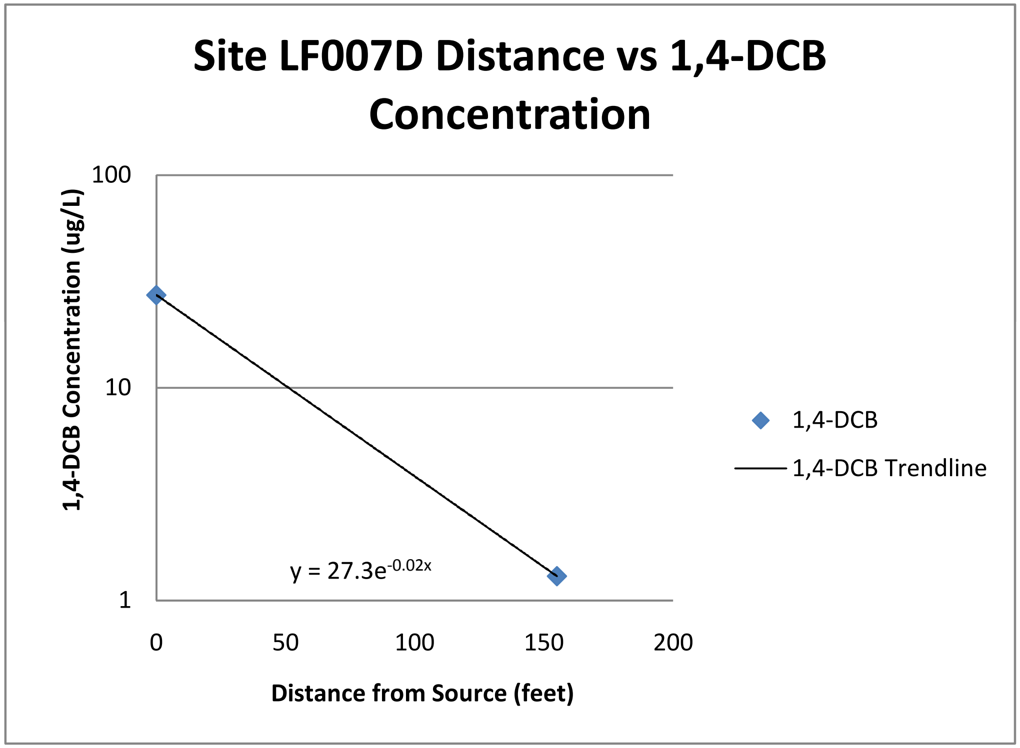
Seepage Velocity (ave linear flow velocity)=	100	ft/year
TCE Retardation Factor =	1.2	
Slope of TCE Trendline =	-0.009	per foot
Bulk Attenuation Rate Constant =	**0.75**	**per year**
Travel Time to Reach PCG (5 ug/L)=	**0.75**	**years**
Plume extent =	**63**	**feet**



LF007D

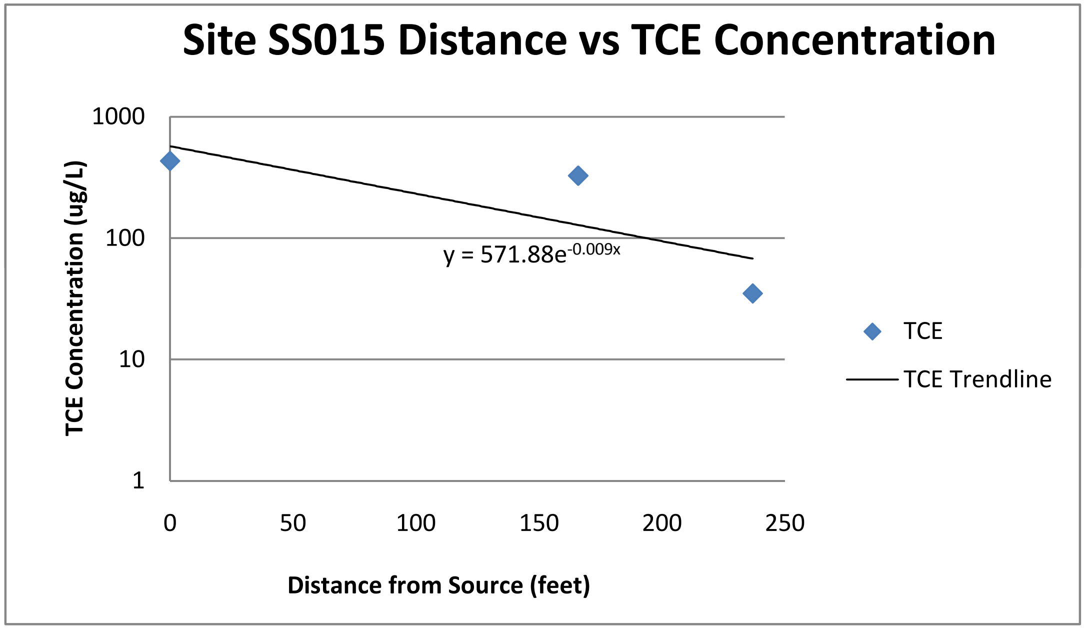
Well	**Distance from source (ft)**	**1,4-DCB Concentration (ug/L)**
MW261x07	0	27.3
MWCx07	155	1.3

Seepage Velocity (ave linear flow velocity)=	150	ft/year
1,4-DCB Retardation Factor =	1.7	
Slope of 1,4-DCB Trendline =	-0.02	per foot
Bulk Attenuation Rate Constant =	**1.8**	**per year**
Travel Time to Reach PCG (5 ug/L)=	**0.96**	**years**
Plume extent =	**85**	**feet**



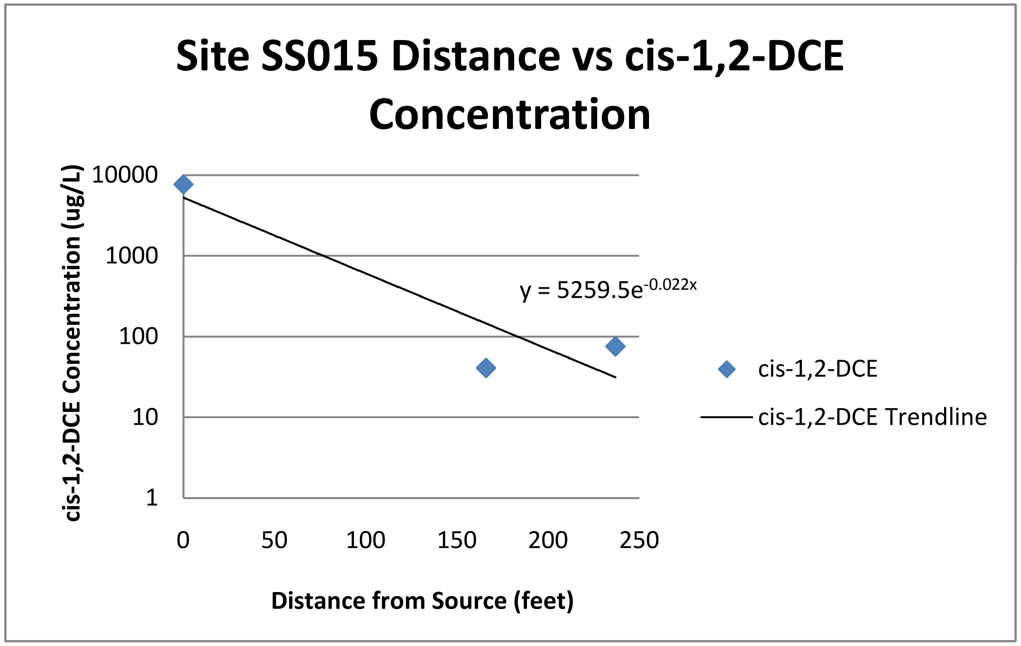
Well	Distance from source (ft)	TCE Concentration (ug/L)
MW216x15	0	432
MW2124x15	166	327
MW2118x15	237	35.1

Seepage Velocity (ave linear flow velocity)=	300	ft/year
TCE Retardation Factor =	1.2	
Slope of TCE Trendline =	-0.009	per foot
Bulk Attenuation Rate Constant =	**2.3**	**per year**
Travel Time to Reach PCG (5 ug/L)=	**1.98**	**years**
Plume extent =	**495**	**feet**



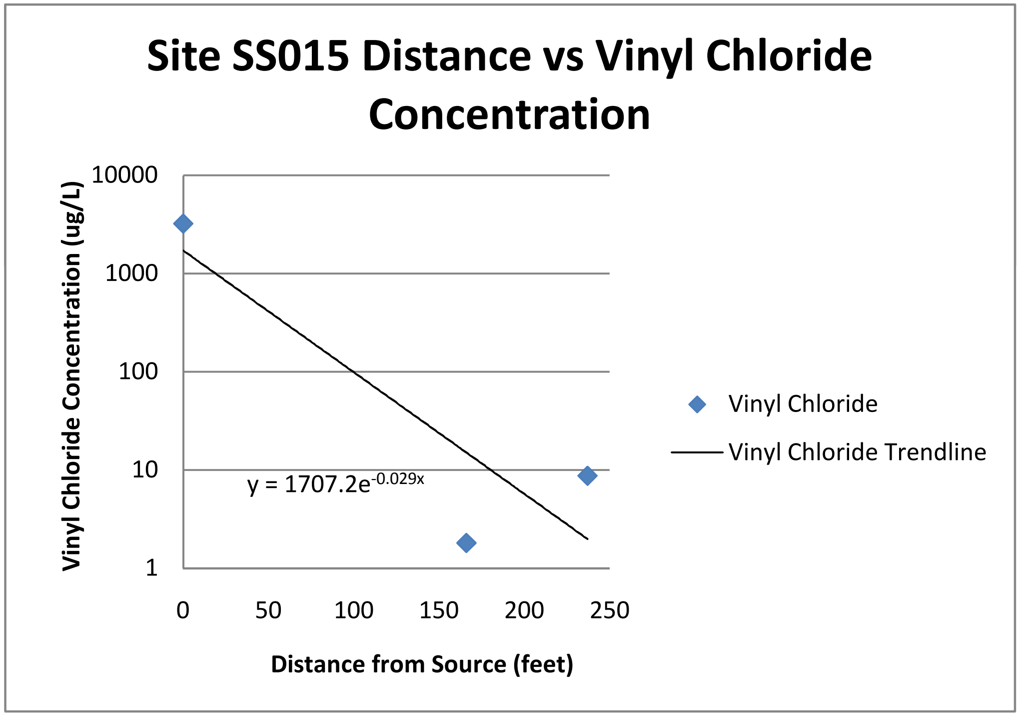
Well	Distance from source (ft)	cis-1,2-DCE Concentration (ug/L)
MW216x15	0	7680
MW2124x15	166	41
MW2118x15	237	75.7

Seepage Velocity (ave linear flow velocity)=	300	ft/year
cis-1,2-DCE Retardation Factor =	1	
Slope of cis-1,2-DCE Trendline =	-0.022	per foot
Bulk Attenuation Rate Constant =	**6.6**	**per year**
Travel Time to Reach PCG (6 ug/L)=	**1.08**	**years**
Plume extent =	**325**	**feet**



Well	Distance from source (ft)	vinyl chloride Concentration (ug/L)
MW216x15	0	3220
MW2124x15	166	1.8
MW2118x15	237	8.7

Seepage Velocity (ave linear flow velocity)=	300	ft/year
Vinyl Chloride Retardation Factor =	1	
Slope of Vinyl Chloride Trendline =	-0.029	per foot
Bulk Attenuation Rate Constant =	**9**	**per year**
Travel Time to Reach PCG (0.5 ug/L)=	**1.01**	**years**
Plume extent =	**302**	**feet**



Appendix D
Remediation Timeframe Estimates

APPENDIX D

Remediation Timeframe Estimates

D.1 Introduction

This appendix documents the application of screening-level solute transport models for multiple sites at Travis Air Force Base (AFB), California, in support of the overall goals of the Basewide Groundwater Focused Feasibility Study (FFS). Volatile organic compounds (VOCs) represent the most prevalent class of chemicals of concern (COCs). Of the VOCs present in groundwater at the Base, trichloroethene (TCE) is the most common COC, although 1,1-dichloroethene (DCE), 1,2-dichloroethane (DCA), cis-1,2-DCE, and alpha-chlordane are also COCs at individual sites. The following sites were evaluated on an individual basis in this FFS: FT004, FT005, LF006, LF007, LF008, SS015, SS016/SS029, ST027B, SS030, SD031, DP039, and the West Industrial Operable Unit (WIOU), which is considered in a single analysis given the commingled nature of the plumes in this area (WIOU: Sites SD033, SD034, SD036, SS037, SS041, and SD043) (Figure D-1; figures are located at the end of this appendix). This appendix documents a comparative analysis of estimated remediation timeframes (RTFs). RTF is defined herein as the time required after Calendar Year 2010 for site-specific COC concentrations in groundwater to drop below their respective preliminary cleanup goal (PCG). Table D-1 lists the PCG for the indicator COC at each site. In this analysis, the currently implemented interim remedial actions (IRAs) at each site are compared with the FFS remedial alternatives to support the detailed analysis of alternatives. Specific details of the remedial alternatives are provided below.

D.2 Modeling Objectives

The primary modeling objective was to provide a comparison of site-specific estimates of RTF between the currently implemented IRA and the remedial alternative in the FFS. However, it was not necessary to conduct a comparative analysis for all sites because the remedial alternative is consistent with the IRA. For these sites, the RTF estimate for the remedial alternative is the same as that for the IRA. These sites include LF006, LF007B, LF007C, LF007D, ST027B, and SS030.

D.3 Definitions of Groundwater Remedial Alternatives

The groundwater remedial alternatives are summarized as follows:

- Alternative 1 – No Action
- Alternative 2 – Monitored Natural Attenuation (MNA)
- Alternative 3 – Groundwater Extraction and Treatment (GET)
- Alternative 4 – Bioreactor and GET
- Alternative 5 – Emulsified Vegetable Oil (EVO) Injection and Enhanced Attenuation (EA)
- Alternative 6 – Bioreactor, Phytoremediation, EVO Permeable Reactive Biobarrier (PRB), and EA

To shorten and simplify the naming of the alternatives, the following conventions are used:

- GET – For Alternatives 3 and 4, the term GET is used to combine the sequence of groundwater extraction, treatment, and discharge process options.
- EA – For Alternatives 5 and 6, the term EA is used to distinguish attenuation processes that would occur within a groundwater plume following a source remediation action from attenuation processes that would occur solely from MNA (i.e., no source remediation action).

Remedial action objectives (RAOs) are described in Section 5 of the FFS.

D.3.1 Alternative 1 – No Action

This alternative serves as a baseline against which other potential remedial alternatives are compared and is required for consideration by the National Contingency Plan (NCP). It is evaluated to estimate risks to public health and the environment, assuming no additional remedial actions are implemented.

D.3.2 Alternative 2 – MNA

The effectiveness of this alternative would rely on natural physical, chemical, and biological processes to achieve the RAOs. Alternative 2 is applicable to the following sites: FT004, FT005, LF006, LF007B, LF007D, LF008, ST027B, SD031; and WIOU Sites SD033, SS035, and SD043.

D.3.3 Alternative 3 – GET

Implementation of this alternative would include active groundwater remediation using the GET systems previously installed as part of the IRA at each applicable site. The conceptual design of Alternative 3 is presented in Section 7 of the FFS. Contaminated groundwater would be extracted using vertical or horizontal extraction wells, treated at the Central Groundwater Treatment Plant (CGWTP), North Groundwater Treatment Plant (NGWTP), or South Base Boundary Groundwater Treatment Plant (SBBGWTP), and the treated water would be discharged to the stormwater drainage system. Existing Base land use controls would be enforced to minimize human exposure to groundwater contaminants. Alternative 3 is applicable to the following sites: LF007C, SS029, and SS030.

D.3.4 Alternative 4 – Bioreactor and GET

Implementation of this alternative would include combining two (2) technologies to remediate the Site SS016 plume, including an in situ bioreactor and GET. The conceptual design of Alternative 3 is presented in Section 7 of the FFS. Under this alternative, an in situ bioreactor would be installed in the OSA source area. The bioreactor would use enhanced reductive dechlorination (ERD) processes to help break down chlorinated VOCs within the OSA source area. These actions would seek to minimize the adverse effects associated with the original source of TCE, which contributed contaminant mass into the downgradient portions of Site SS016. Residual contamination from the OSA would be addressed through operation of EW605x16 and EW610x16. Contamination that is not hydraulically captured by these wells would flow downgradient toward the Site SS029 extraction system.

TABLE D-1
Summary of Remediation Timeframe Estimates
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	COC (PCG µg/L)	Remedial Alternative	RTF for Interim Remedial Action (years)	RTF for Remedial Alternative (years)	Comments
FT004	TCE (5)	Alternative 2	GET and MNA: 35	MNA: 35	The RTF for the IRA could be prolonged by stagnation zones between extraction wells when they are all operating. It is possible that an optimization of the GET (e.g., periodically cycling different pumping rates at selected extraction wells) could potentially reduce RTF.
FT005	1,2-DCA (0.5)	Alternative 2	GET: 10	MNA: 43	The plume was under pump and treat during the period of interim remediation. The data required to calculate a biodegradation rate are not available. Therefore, biodegradation effects were not included in the analysis. Observed concentrations at Site FT005 remain approximately an order of magnitude above the PCG.
LF006	TCE (5)	Alternative 2	MNA: [5]*	MNA: [5]*	The RTFs were estimated in the *Natural Attenuation Assessment Report* (NAAR) (CH2M HILL, 2010b).
LF007B	TCE (5)	Alternative 2	MNA: 0	MNA: 0	TCE concentrations are already below PCGs.
LF007C	TCE (5)	Alternative 3	GET: 26	GET: 26	The remedial alternative would be a continuation of the IRA.
LF007D	Benzene (1)	Alternative 2	MNA: [>100]*	MNA: [>100]*	Benzene concentrations have remained between 2 and 3 µg/L over the past 10 years at this site.
LF008	Alpha-chlordane	Alternative 2	GET: >100	MNA: >100	The RTF is driven by the low mobility of pesticides and lack of biodegradation mechanisms.
SS015	cis-1,2-DCE (6)	Alternative 5	MNA: N/A	EVO and EA: 70	The RTF for the IRA and the remedial alternative was indeterminate because concentrations of cis-1,2-DCE have been increasing. Given the uncertainty at this site, a point attenuation rate calculation was performed for estimation of the RTF for the remedial alternative.
SS016/SS029	TCE (5)	Alternative 4	GET: >100	Bioreactor and GET: 62	Under the IRA, the high residual TCE concentrations in the source area have not been removed.
ST027B	TCE (5)	Alternative 2	MNA: 50	MNA: 50	The remedial alternative is a continuation of the IRA.
SS030	TCE (5)	Alternative 3	GET: 22	GET: 22	The remedial alternative is a continuation of the IRA.
SD031	1,1-DCE (6)	Alternative 2	GET/MNA: 15	MNA: 15	Residual contamination exceeding the PCGs is not fully captured by the GET. The IRA RTF is considered to be equivalent to that of the remedial alternative. The effect of biodegradation was not included in the RTF estimate.
DP039	TCE (5)	Alternative 6	GET and MNA: 70	Bioreactor, Phytoremediation, EVO PRB, and EA: 58	The RTF under the remedial alternative considers the duration required for high TCE concentrations in the source area to migrate to the PRB and the natural attenuation timeframe for TCE exiting the PRB.
WIOU	TCE (5)	Alternative 5	GET and MNA: 91	EVO and EA: 60	Given the commingled nature of the TCE plumes in this area, sites in the WIOU are considered in one (1) analysis.

* Bracketed value indicates RTF presented in the NAAR (CH2M HILL, 2010b).

Groundwater extraction within the Tower Area Removal Action (TARA) portion of Site SS016 would be continued under Alternative 4 using the two (2) existing horizontal extraction wells. Extracted groundwater would be treated using liquid-phase granular activated carbon at the CGWTP. Treated groundwater would then be discharged into the stormwater drainage system.

D.3.5 Alternative 5 – EVO and EA

Implementation of this alternative would combine in situ bioremediation with EA. The conceptual design of Alternative 5 is presented in Section 7 of the FFS. Under this alternative, EVO would be injected into the source area of a plume to enhance anaerobic degradation of chlorinated VOCs. After injection of EVO within the source area, the continuing source of TCE contamination into the hydraulically downgradient portions of the plume would be reduced. The effects of the physical, chemical, and biological attenuation mechanisms in these downgradient areas would then be enhanced relative to those occurring with a higher concentration source in place. Land use controls would be enforced to prevent unauthorized exposure to contaminated groundwater. Alternative 5 is applicable to Site SS015 and the sites comprising a portion of the WIOU plume, including Sites SD036 and SD037.

D.3.6 Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA

Implementation of this alternative would combine three (3) in situ bioremediation technologies and EA to achieve RAOs at Site DP039. The primary alternative components are as follows:

- **In Situ Bioremediation**
  - **Bioreactor –** An existing bioreactor would be used to treat extracted groundwater in the Site DP039 source area. The existing bioreactor includes an organic mulch mixture to reduce contaminant mass and volume via ERD processes as extracted groundwater is recirculated back through the bioreactor. A sustainable source of electric power to the extraction well pump is currently provided by solar panels (CH2M HILL, 2010a).
  - **Phytoremediation –** An existing zone of phytoremediation would supplement the treatment of the source area plume provided by the bioreactor. Source area contamination that is not treated by the bioreactor would flow into a downgradient zone of planted eucalyptus trees. Phytoremediation would contribute to the overall effectiveness of the alternative by providing additional reduction of contaminant mass and volume in the source area (Parsons, 2010).
  - **PRB (via EVO Injection) –** As an optimization to the current Site DP039 IRA, a PRB of EVO would be injected into the aquifer downgradient of the bioreactor and phytoremediation zone. Injection of EVO across the leading edge of the 500-microgram-per-liter (μg/L) source area plume would anaerobically degrade TCE and other chlorinated VOCs. This portion of the plume would otherwise be a continuing source of contamination into the hydraulically downgradient area.
- **EA –** Physical, chemical, and biological processes would be relied upon to remediate the residual contaminants in the distal portion of the Site DP039 plume. After the source

area portion of the plume is addressed by the combination of bioreactor, phytoremediation, and PRB, the effectiveness of attenuation in the distal portions of the plume would be enhanced because the contaminant flux from the source area would be 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.

D.4 Contaminant Transport Modeling

In general, most sites underwent a GET, MNA, or EA analysis, or some combination thereof, depending on the IRA and the remedial alternative at each site (Table D-1). The GET analyses were performed to provide an estimate of the RTF for the zone(s) of capture from extraction wells. The MNA/EA analyses were performed to provide an estimate of the RTF associated with implementation of MNA/EA. Given the uncertainty in forecasting RTFs, estimates were limited to 100 years. The GET and MNA/EA analyses were performed independently using two (2) different modeling codes. The MNA/EA analyses were performed using HYDRUS-1D[1] version 4.14 (Šimůnek et al., 2008, 2009), and the GET analyses were performed using the Travis Basewide Groundwater Flow Model (TBGFM) (CH2M HILL, 1998, 2003, 2008), which uses the code MicroFEM version 4.10.14 (Hemker and de Boer, 2010). The generalized modeling approach for each type of analysis is presented below and is followed by a description of the site-specific models. These analyses were performed using the most recent data from 2009, except for Site SS015, which includes 2010 data from the newly installed wells at that site.

The following list summarizes some important points related to the modeling effort and the estimated RTFs:

- RTFs that were estimated for the EA analyses are independent of the remedial technology (in situ chemical oxidation or EVO injection).
- In most cases, the RTF is governed by the residual mass outside of the treatment area following implementation of the remedial alternative. Furthermore, the treatment area is relatively small compared to the overall plume.
- A dual-domain transport formulation was implemented in all MNA/EA simulations to more accurately represent the diffusion of chemicals into and out of lower permeability material.

D.4.1 GET Analysis Methodology

The GET analyses were performed using the TBGFM. The TBGFM was constructed using MicroFEM, which is a groundwater modeling program developed in the Netherlands. MicroFEM is a three-dimensional, finite-element groundwater modeling code that operates in a Windows® environment and can be used to solve groundwater flow problems for unconfined, semiconfined, and confined aquifer systems. The current version of the program (4.10.14) can simulate groundwater flow systems with up to 25 numerical layers

[1] http://www.pc-progress.com/en/Default.aspx?hydrus-1d (accessed August 4, 2010)

and 250,000 surface nodes. MicroFEM is capable of modeling saturated, single-density groundwater flow in layered systems.

The TBGFM is a steady-state model and was originally developed in 1998. The TBGFM was updated and recalibrated using the available data in 2003 and 2008 (CH2M HILL, 2003, 2008). The current analysis uses the 2008 TBGFM, but the pumping rates at extraction wells have been updated to reflect more recent conditions. The COC plume shapes have also been updated based on data collected in 2009 and 2010 (CH2M HILL, 2010c). The updated plume shapes are presented on Figure D-2.

The RTF analyses for the GET systems are based on flushing calculations. For each GET analysis, a particle was started at each model node within the target treatment area, tracked upgradient (i.e., in reverse), and stopped when they reached areas with COC concentrations below their respective PCG. The path that a particle takes in the model is called a flowline in this appendix. The model outputs a file containing information for each flowline, including the total time of travel along the flowline. This time of travel is an estimate of the duration for water with COC concentrations below the PCG to reach a given model node within the target treatment area. In other words, it is the time to flush one (1) pore volume of clean water to a given model node within the target treatment area.

The RTF is then calculated using the formula (van der Molen, 1973):

$$t = \frac{-\ln\left({}^{Ct}/_{Co}\right)}{\left({}^{f}/_{T} + k\right)} \qquad \text{(D-1)}$$

where:

Ct	=	COC-specific PCG
Co	=	initial (i.e., recent) COC concentration at a given model node
f	=	flushing efficiency
T	=	time to flush one (1) pore volume of clean water to a given model node within the hydraulic capture zone
k	=	first-order biodegradation rate constant
t	=	time required to reduce a *Co* to *Ct* at a given model node

The flushing efficiency (*f*) values typically vary between 0.2 to 0.6 and are heavily dependent on soil texture (van der Molen, 1973). Coarser-textured soils tend to have higher *f* values. Where possible, the *f* value was calibrated to match the historic COC concentration trend at a monitoring well within the capture zone to provide a site-specific value of *f*. This was done by taking the last observed COC concentration (i.e., *Co*) for a given well and then using Equation D-1 to forecast *Ct* values at different times with different values assumed for *f*. In cases where calibration to site-specific data was not possible, a value of 0.3 was used, except at Site FT005, where a value of 0.5 was used because the permeability tends to increase toward the southern portion of the Base. The *f* values of 0.3 and 0.5 correspond to clay soil and silt loam, respectively (van der Molen, 1973). First-order biodegradation was assumed to be occurring at all TCE sites, and the associated *k* value was estimated by forecasting TCE concentration trends that looked visually consistent with the historic TCE concentration trends measured at MW751x39. The process of estimating the *k* value is discussed in more detail below. Concentration data for other COCs were not available to estimate *k* values. Thus, to be conservative, first-order biodegradation of the other COCs was not assumed to be occurring at these sites.

D.4.2 MNA and EA Analysis Methodology

Two (2) approaches were used to estimate RTF under MNA and EA conditions. RTF estimates for sites, where MNA is the only IRA (e.g., Sites LF006, LF007B, and LF007D), were calculated in the NAAR (CH2M HILL, 2010b). These estimates were calculated for individual wells according to the approach described in Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies (EPA, 2002). This approach allows for evaluation of reduction in contaminant concentration over time and estimating an RTF at a well location if it is in the plume source area. In addition to the sites listed above, Site LF007C was also analyzed using this method because of uncertainties in the groundwater flow field. Site LF007C is discussed in more detail below.

Although RTF estimates were also calculated in the NAAR for sites where the IRA is MNA combined with a GET system, the nature of the calculation restricted the RTF estimation to the portion of the plume beyond the capture of the GET system in the distal portions of the plume. Extrapolating the attenuation rate for wells within the capture of the GET system would result in an underestimation of the remediation time if a given remedial alternative includes turning the GET system off. Therefore, a different approach (modeling) was used to estimate the RTF at these sites. The MNA and EA analysis used to estimate RTF for Sites FT004, FT005, SS015, ST027B, SD031, DP039, and the WIOU sites is described in the following subsections.

The screening-level transport models for the MNA and EA analyses were developed using a code named HYDRUS-1D version 4.14 (Šimůnek et al., 2008, 2009). This code was selected for the following reasons:

- Project scope required use of a model to compare the effectiveness of current and proposed remedial alternatives to compare RTF estimates.
- Given the project scope and limited knowledge of COC transport mechanisms, a screening-level model was considered appropriate.
- HYDRUS-1D provides more flexibility in how source terms are simulated, as compared with other screening-level solute transport codes (e.g., BIOSCREEN[2] and 3DADE[3]).
- HYDRUS-1D provides the option of simulating dual-domain transport processes. This provides the opportunity to consider back-diffusion of contaminant mass from less permeable mass storage zones in the subsurface, which tends to prolong RTFs.
- HYDRUS-1D is in the public domain, a product of more than 10 years of development, in wide use, and well documented.

[2] http://www.epa.gov/ada/download/models/bioscrn.pdf (accessed 11/29/2010)
[3] http://www.ars.usda.gov/Services/docs.htm?docid=8916 (accessed 11/29/2010)

HYDRUS-1D numerically solves the Richards equation for variably saturated flow in one (1) dimension (1D). For the current application, HYDRUS-1D was set up so that the modeled system remained fully saturated under a consistent hydraulic gradient along a 1D profile (see Figure D-2 for the location of all MNA and EA simulated groundwater flowlines). The 1D profile locations were defined with the aid of the TBGFM as follows. Groundwater particles were initiated at selected upgradient "source" locations at each site and allowed to track forward (i.e., downgradient). The flowlines generated from this exercise were evaluated to see if they traveled through areas with high COC concentrations and if their flow directions were consistent with the overall shapes of the COC plumes. In most cases, the flowlines provided an adequate basis for selecting a 1D flow profile for HYDRUS-1D; however, in some locations the flowlines were adjusted slightly within the COC plumes to better honor their overall shapes. Once the 1D profiles were established for each COC plume of interest, groundwater elevations at both the upgradient and downgradient ends of the 1D profile were pulled from the TBGFM and prescribed to each end of the 1D profiles in HYDRUS-1D.

HYDRUS-1D was set up to solve the advection-dispersion-biodegradation transport equation with dual-domain mass transfer to simulate COC transport along the 1D profile. The dual-domain transport formulation was implemented to more accurately account for transport processes with the goal of improving the predictive capabilities over what could have been achieved with a traditional single-domain transport formulation. With the dual-domain transport formulation, the transport equations account for 1D COC transport in the aqueous phase with first-order biodegradation and first-order COC mass transfer between the mobile and immobile zones in the subsurface. Additionally, the HYDRUS-1D models, as formulated for this particular application, include the assumption of steady-state groundwater flow conditions along the 1D profiles.

An attempt was made to make the simulated hydraulics of the HYDRUS-1D profile models consistent with the simulated hydraulics along the profile locations within the TBGFM. This was done to maximize the compatibility between the two (2) different models. Thus, the groundwater elevations along the HYDRUS-1D profile were calibrated to match those from the TBGFM. Once the hydraulics were calibrated to the TBGFM, COC concentration data were extracted from the COC plume maps (Figure D-2) and input into the model as the initial concentration profile. The initial concentration profiles in both the mobile and immobile domains were set equal. The HYDRUS-1D models were then run forward in time to estimate RTF for a given remedial alternative.

The following describes the parameterization of the HYDRUS-1D models:

- Saturated hydraulic conductivity (Ks) – This parameter is variable along the distance profile and was initially extracted from the TBGFM. Values were modified as necessary to calibrate groundwater elevations from the TBGFM groundwater elevation profile.
- Hydraulic gradient – This parameter is dependent on the locations of the profile endpoints and variable Ks values along the profiles. Prescribed heads at each endpoint of the profile were taken from the TBGFM.
- Mobile porosity = 0.15. This value was estimated based on professional judgment and is within the range of literature values (Payne et al., 2008).

- Bulk density = 1.65 grams per cubic centimeter (g/cm^3). This value was estimated based on professional judgment.
- Total porosity = 0.38. This value was calculated using Equation D-2:

$$\theta = 1 - \frac{\rho_b}{\rho_s} \quad \text{(D-2)}$$

where:

θ = total porosity
ρ_b = bulk density (1.65 g/cm^3)
ρ_s = particle density (2.65 g/cm^3)

- Immobile porosity = 0.23. This value was calculated as the difference between the total porosity and the mobile porosity.
- Longitudinal dispersivity – This value was estimated based on the relevant COC plume lengths (Figure D-2) and the Xu and Eckstein (1995) equation, as modified by Al-Suwaiyan (1996):

$$D = 3.28 \times 0.82 \times \left[\log_{10}\left(\frac{L_p}{3.28} \right) \right]^{2.446} \quad \text{(D-3)}$$

where:

D = longitudinal dispersivity, in units of feet
L_p = plume length, in units of feet

- Distribution coefficient (Kd) – Kd is the product of the fraction of organic carbon (f_{oc}) and soil organic carbon-water partitioning coefficient (K_{oc}). K_{oc} values were estimated from literature values and an f_{oc} value of 0.1 percent was used based on professional judgment. K_{oc} values used in the models are as follows: TCE = 67.7 milliliters per gram (mL/g), 1,2-DCA = 44 mL/g, 1,1-DCE = 35 mL/g, cis-1,2-DCE = 44 mL/g, alpha-chlordane = 86,650 mL/g (EPA, 2008).

The dual domain mass transfer (DDMT) coefficients were calculated on a site-specific basis using dimensional analysis via a Type I Damköhler Number (*DaI*), according to Equation D-4 as follows (Haggerty et al., 2004):

$$\mathrm{DaI} = \frac{\alpha \mathrm{L}}{\mathrm{V_s}} \quad \text{(D-4)}$$

The only exception is at site DP039, where the DDMT coefficient was calibrated to historical COC concentration data. When an advecting solute undergoes first-order mass transfer between the mobile and immobile domains, the *DaI* is approximately equal to the product of the DDMT coefficient (α) and solute plume length (L) divided by the solute velocity (V_s). The *DaI* can be generalized as the ratio of the mass transfer timescale to the advection timescale. As the magnitudes of these timescales approach consistent values (as *DaI* approaches unity), if sufficient solute mass resides in the immobile domain to cause back diffusion into the mobile domain, then one would expect to observe greater tailing in time-series solute concentration plots (i.e., chemographs) (Haggerty et al., 2004). Thus, to provide the most conservative estimate of α, the *DaI* was set equal to one (1) in each of the calculations, and solute plume lengths and solute velocities were computed based on available site data and the TBGFM.

A first-order biodegradation rate for all TCE plumes was estimated from concentration data at Site DP039. Figure D-3 shows the location of MW751x39, which was used to estimate a *k* value. This well was chosen because it is beyond the zone of capture of the extraction wells at the site and near the approximate plume centerline. This well has also been regularly sampled for approximately 10 years. The Site DP039 HYDRUS-1D model was used to estimate a TCE *k* value and a site-specific α value by forecasting TCE concentration trends that looked visually consistent with the historic TCE concentration trends at the two (2) wells. Figure D-4 shows the measured and forecasted TCE concentrations for MW751x39. Forecasted concentrations were estimated by assuming that the extraction wells at Site DP039 were shut off, and the current plume was allowed to migrate downgradient. The forecasted concentrations were created using a TCE *k* value equivalent to a biodegradation half-life of 9.5 years. Because similar site-specific data were not available to estimate *k* values for alpha-chlordane, 1,2-DCA, and 1,1-DCE (at Sites LF008, FT005, and SD031, respectively), biodegradation was not considered in the evaluations of these chemicals. Overall, these parameter values are consistent with site information and literature values for shallow materials underlying the site.

D.4.3 Site-specific Analyses

D.4.3.1 Site FT004

The IRA at Site FT004 is GET and MNA; the GET system was designed to hydraulically capture VOC contamination exceeding 100 µg/L. The remedial alternative for Site FT004 is Alternative 2 (i.e., MNA). In 2009, an assessment of MNA was conducted in the portion of the plume beyond the GET system hydraulic capture zone during the period of interim remediation (CH2M HILL, 2010b). The assessment indicated that the IRA had effectively reduced the size and concentrations of the TCE plume (CH2M HILL, 2010b). The Site FT004 GET is currently shut down for a rebound study.

Table D-1 shows a comparison of the IRA and the remedial alternative. The RTF estimates for the IRA and remedial alternative is discussed below.

Site FT004 IRA (GET and MNA) Analysis. The GET analysis of Site FT004 consists of two (2) separate analyses. The portions of the TCE plume within the 100-µg/L TCE contours (i.e., the target area of the IRA) were evaluated using a GET analysis with the aid of the TBGBFM, and the remainder of this plume was evaluated using an MNA analysis with HYDRUS-1D. The flushing efficiency for the GET analysis was calibrated using TCE chemographs for MW131x04 and MW266x04 and Equation D-1 to forecast TCE concentrations with future trends that are consistent with historical trends at the respective wells. Well locations are shown on Figure D-5. The calibrated flushing efficiency at Site FT004 is 0.3, which corresponds to the upper end of a clay soil; the calibration curves are presented on Figure D-6. Figure D-7 shows the flushing time distribution for the GET target volume. Based on the GET analysis, the RTF within the 100-µg/L contours is approximately 35 years.

The southern portion of the Site FT004 TCE plume outside of the 100-µg/L TCE contour was evaluated using HYDRUS-1D, given that TCE concentrations in this area would only decline via natural attenuation processes. The southern portion of the TCE plume is defined as beginning at the southernmost point of the southern 100-µg/L contour (Figure D-5). This starting point for the MNA analysis is conceptually a groundwater divide with the plume area north of this point being captured by the extraction system and the plume area south of this point escaping downgradient. Table D-2 presents the model parameters used for the Site FT004 HYDRUS-1D model, and Figure D-8 shows the forecasted TCE concentrations along the distance profile at the ends of three (3) different calendar years, including 2010, 2020, and 2035. Forecasted TCE concentration versus distance curves indicate that the RTF is approximately 25 years (i.e., around calendar year 2035) for the southern plume area not captured by the GET systems.

TABLE D-2
HYDRUS-1D Input Parameters for Site FT004
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Model	Profile Length (feet)	COC	Dispersivity (feet)	Kd (mL/g)	k (days^{-1})	α (days^{-1})	Aqueous Diffusivity (cm^2/s)
GET and MNA	13,020	TCE	20	0.067	2.0E-04	1.4E-04	9.1E-06
MNA only	13,020	TCE	24	0.067	2.0E-04	1.4E-04	9.1E-06

Notes:

α = dual-domain mass transfer coefficient
cm^2/s = square centimeter(s) per second
k = first-order biodegradation rate
Kd = soil distribution coefficient
mL/g = milliliter(s) per gram

The RTF of the entire plume is therefore determined by the portion of the plume with the longest RTF, which is 35 years in the GET capture zone of the TCE plume, as indicated in Table D-1.

Site FT004 Remedial Alternative (MNA) Analysis. The remedial alternative at Site FT004 is to discontinue operation of the GET and begin MNA, thus, the HYDRUS-1D model was used to estimate the RTF for the entire remaining TCE plume. Figure D-2 shows the simulated groundwater flowline for the MNA analysis at Site FT004. The similarity in groundwater elevation profiles between the HYDRUS-1D model and the TBGFM indicates that these models are hydraulically consistent along the 1D profile (see Figure D-9). Table D-2 presents the HYDRUS-1D model input parameters. Figure D-10 shows the results of the MNA analysis. The calendar year 2010 concentration profile shown on Figure D-10 is the model's initial condition and was generated using the plume shapes presented on Figure D-2 and observed TCE concentration data at the individual wells within the plumes. Thus, the initial concentration profile shows greater variability than the more generalized plume shapes shown on Figure D-2. Forecasted concentration versus distance curves show that the RTF under MNA only is approximately 35 years (i.e., around calendar year 2045).

Note that the estimated RTF is the same for the IRA and the remedial alternative. The GET analysis was performed assuming all currently existing extraction wells are pumping. It is possible that interference between extraction wells could result in stagnation zones within the three (3)-dimensional flow field, which could prolong the RTF in the GET analysis. Optimization of the GET system (periodically cycling different pumping rates at extraction wells) could potentially reduce the RTF under GET operation.

D.4.3.2 Site FT005

The IRA at Site FT005 is GET. The remedial alternative at Site FT005 is Alternative 2 (i.e., MNA). Under the remedial alternative, operation of the existing GET system would be discontinued. The GET system has been effective at reducing concentrations of 1,2-DCA, the primary COC, and is no longer required to achieve RAOs. The Site FT005 GET is currently undergoing a rebound study.

Table D-1 shows a comparison of the IRA and the remedial alternative. The RTF estimates for the IRA and remedial alternative is discussed below.

Site FT005 IRA (GET) Analysis. The TBGBFM was used along with a flushing analysis to estimate the RTF for Site FT005 under GET conditions. There were no appropriate wells at Site FT005 to calibrate the flushing efficiency for use in the GET analysis. Therefore, a literature value corresponding to a silt loam (0.5) was assumed. Figure D-11 shows the cumulative RTF distribution for the GET target area. The figure shows significant tailing of the flushing time distribution curve. The RTF is estimated to be approximately 10 years; however, modeling results suggest it could take up to 50 years to flush the entire Site FT005 target volume down to 1,2 DCA concentrations equal to the PCG.

Site FT005 Remedial Alternative (MNA) Analysis. The remedial alternative for Site FT005 is to discontinue operation of the GET and begin MNA. To perform the MNA analysis, a HYDRUS-1D model was developed to estimate the RTF. Figure D-2 shows the simulated groundwater flowline for the MNA analysis at Site FT005. The similarity in groundwater elevation profiles between the HYDRUS-1D model and the TBGFM indicates that these models are hydraulically consistent along the 1D profile (see Figure D-12). Table D-3 presents the HYDRUS-1D model parameters used for the Site FT005 HYDRUS-1D model. Figure D-13 shows the results of the MNA analysis. The calendar year 2010 concentration profile shown on Figure D-13 is the model's initial condition and was generated using the plume shapes presented on Figure D-2 and observed 1,2-DCA concentration data at the individual wells within the plumes. Thus, the initial concentration profile shows greater variability than the more generalized plume shapes shown on Figure D-2. Forecasted concentration versus distance curves show that the estimated RTF under MNA is approximately 43 years (i.e., around calendar year 2053).

TABLE D-3
HYDRUS-1D Input Parameters for Site FT005
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Model	Profile Length (feet)	COC	Dispersivity (feet)	Kd (mL/g)	*k* (days^{-1})	α (days^{-1})	Aqueous Diffusivity (cm^2/s)
MNA	3,600	1,2-DCA	22	0.044	N/A	4.9E-04	1.0E-05

Note:

N/A = not applicable because first-order biodegradation was not included for the FT005 analyses.

Site-specific 1,2-DCA concentration data were not sufficient to calculate an independent biodegradation rate; therefore, the effect of biodegradation was not included in the estimates. The RTF estimates are also driven by the very low PCG (0.5 µg/L), which is an order of magnitude lower than that of TCE (5.0 µg/L).

D.4.3.3 Site LF006

Implementation of Alternative 2 at Site LF006 would be a continuation of the ongoing IRA. Figure D-1 shows the location of Site LF006. Although total petroleum hydrocarbon as diesel (TPH-D) and total petroleum hydrocarbon as gasoline (TPH-G) have been detected sporadically at the site, TCE is the only COC that has been consistently detected at concentrations exceeding the PCG. An RTF estimate for Site LF006 was presented in the NAAR (CH2M HILL, 2010b) and is summarized below.

As of 4Q08, of the twelve (12) monitoring wells in the MNA assessment network, there were only two (2) monitoring wells, located near the source area, at which COCs continued to exceed the PCG. A first-order attenuation rate constant was calculated for these two (2) MNA wells: MW208Dx06 and MW259x06 (Figure D-14; Attachment D1). At both monitoring wells, the only COC that exceeded the PCG was TCE. The first-order attenuation rate constant calculated for wells MW208Dx06 and MW259x06 is approximately 0.061 and 0.035 per year, respectively (equivalent to TCE attenuation half-lives of approximately 11 and 20 years) (Attachment D1). At these rates, TCE concentrations at the site would be expected to reach the PCG by 2015 (using data from MW259x06, which would presumably take the longest to reach the PCG), which would be equivalent to an RTF of approximately 5 years. Little change in aquifer conditions has been evident over the 11 years this site has been undergoing MNA. The aquifer remains aerobic and available carbon is low; natural attenuation processes appear to be sufficient mechanisms for achieving RAOs within a reasonable timeframe.

D.4.3.4 Site LF007B

Implementation of Alternative 2 at Site LF007B would be a continuation of the ongoing IRA. No COCs exceed PCGs at Site LF007B; therefore, the RTF is 0 years. Figure D-1 shows the location of Site LF007B.

D.4.3.5 Site LF007C

Implementation of Alternative 3 at Site LF007C would be a continuation of the GET system under the IRA. Under Alternative 3, operation of the optimized GET system at Site LF007C would continue to operate until RAOs are achieved. The existing solar-powered GET system at Site LF007C has not been fully effective at reducing TCE concentrations in groundwater in the offbase portion of the TCE plume. Concentrations of TCE in on-base and off-base monitoring wells continue to exceed the PCG.

During 2011, the Site LF007C GET system would be optimized to improve overall effectiveness. A data gaps investigation would be conducted to more fully characterize the offbase portion of the TCE plume. Following evaluation of the characterization data, additional extraction wells might be installed to improve hydraulic capture and augment removal of TCE from the offbase portion of the TCE plume. These IRA enhancements would be incorporated into Alternative 3.

Groundwater flow directions are uncertain at Site LF007C (CH2M HILL, 2008). It appears that there may be a diverging flow field near the center of the TCE plume. The current version of the TBGFM does not indicate a diverging flow field. Given the uncertainty in the actual flow field, a GET analysis using the TBGFM was not conducted. Instead, a first-order attenuation trend line was fit to concentration data from well MW125x07, which is within the zone of capture of EW614x07 (Figure D-14). This analysis indicates that TCE concentrations at MW125x07, where the highest concentrations have been observed at Site LF007C, could drop below the PCG in approximately 26 years (i.e., around calendar year 2036) if observed TCE concentration trends continue (Figure D-15).

D.4.3.6 Site LF007D

Implementation of Alternative 2 at Site LF007D (Figure D-1) would include a continuation of the IRA of MNA. Benzene and 1,4-dichlorobenzene (DCB) are the only COCs that have been consistently detected at the site at concentrations exceeding the PCG. An RTF estimate for Site LF007D was presented in the NAAR (CH2M HILL, 2010b) and is summarized below.

As of 4Q08, MW261x07 was the only monitoring well at which COCs continued to exceed the PCGs. Figure D-14 shows the location of MW261x07. As such, first-order attenuation rate constants were calculated for this well for 1,4-DCB and benzene because concentrations of these COCs continue to exceed PCGs for groundwater. The first-order attenuation rate constant calculated for 1,4-DCB at well MW261x07 is approximately 0.054 per year (equivalent to a 1,4-DCB attenuation half-life of approximately 13 years). At this attenuation rate, the 1,4-DCB concentrations would be expected to reach the PCG (5 µg/L) in 2029, resulting in an RTF of approximately 19 years (Attachment D1).

Benzene concentrations have declined slightly over the last 10 years. The benzene concentration detected in 2010 was 3 µg/L. Following the same protocol for 1,4-DCB, a first-order attenuation rate constant of approximately 0.0039 per year was calculated for benzene at MW261x07 (equivalent to a benzene attenuation half-life of approximately 178 years). At this attenuation rate, benzene concentrations would be expected to continue to exceed the PCG (1 µg/L) for over 100 years at this location (Attachment D1). The overall RTF estimate for this site is therefore controlled by benzene concentrations, resulting in an RTF estimate for Site LF007D of over 100 years.

Although the current anaerobic conditions in the immediate vicinity of well MW261x07 (evident in monitoring data collected at this well from the initial MNA assessment in 1999 through 2008) are conducive to biodegradation of chlorinated solvents (such as 1,4-DCB), aerobic conditions are more favorable for biodegradation of benzene. Once the degradation of 1,4-DCB is complete, conditions near well MW261x07 could gradually become aerobic, like the rest of the site, and be more conducive to benzene degradation. The benzene concentrations detected at this well only slightly exceed the PCG (ranging from 2.2 to 2.7 µg/L in 2008) and are restricted to the immediate vicinity of this well. In addition, this well is located in a capped landfill, and there are no receptors.

D.4.3.7 Site LF008

The IRA at Site LF008 is GET. The remedial alternative at Site LF008 is Alternative 2 (i.e., MNA). Under the remedial alternative, operation of the existing GET system would be discontinued. The GET system is currently undergoing a rebound study.

The primary and most widespread COC at Site LF008 is the pesticide alpha-chlordane. The physical properties of this type of chemical result in low subsurface mobility because of strong sorption of the chemical to the soil. For comparison, the K_{oc}, which describes how strongly a chemical sorbs to soil material, for TCE is 67 mL/g, whereas the K_{oc} for alpha-chlordane is 86,650 mL/g (EPA, 2008). Given the extreme K_{oc} of alpha-chlordane and presumed lack of biodegradation, the RTFs for both GET and MNA are assumed to be greater than 100 years.

D.4.3.8 Site SS015

Figure D-16 shows the cis-1,2-DCE plume at Site SS015. Cis,1,2-DCE is the highest concentration COC at the site and thus is the focus of this analysis. The IRA at Site SS015 is MNA. The remedial alternative at Site SS015 is Alternative 5 (EVO and EA). At Site SS015, implementation of the proposed remedial alternative would consist of injection of EVO into the source area followed by monitoring.

Site SS015 IRA (MNA) Analysis. An RTF analysis for the IRA (MNA) was not performed for Site SS015 because MW216x15 exhibits increasing concentrations of chlorinated solvents. Thus, the IRA has not been an effective alternative and an associated RTF was not estimated.

Site SS015 Remedial Alternative (EVO and EA) Analysis. An EA analysis was not performed for Site SS015. The uncertainty in the geology, flow direction, and contaminant behavior complicate the estimation of an RTF. Groundwater locally flows to the north, opposite of the regional gradient (Figure D-16) for an unknown distance. Groundwater flow in this area eventually reverses direction and joins the regional flow field. However, the precise location of this reversal in flow direction is unknown, as is its impact on contaminant transport. Given the local complexities at this site, a HYDRUS-1D model was not constructed.

A point attenuation rate calculation was performed for Site SS015 using Equation D-5:

$$t = \frac{-\ln\left(C_t/C_0\right)}{k} \quad t \qquad \text{D-5}$$

where:

C_t = the PCG for cis-1,2-DCE of 6 µg/L
C_o = initial cis-1,2-DCE concentration after EVO injection
k = first-order attenuation rate constant
t = time required to reduce C_o to C_t

The following assumptions were made for this analysis:

- The treatment process (EVO injection) would be effective within the 1,000-µg/L contour, and thus the RTF would be goverened by the residual cis-1,2-DCE mass (i.e., in Equation D-5, C_o = 1,000 µg/L).
- Solute degradation is a first-order process, with a k value assumed to be equal to the biodegradation rate of TCE (2.0E-04 $days^{-1}$) estimated for Site DP039.

Given these assumptions, t was estimated to be approximately 70 years. To assess whether this RTF is reasonable, several years of additional plume monitoring would be required after the EVO injection(s).

D.4.3.9 Sites SS016 and SS029

The RTF estimate for Sites SS016 and SS029 are combined because VOC contamination (primarily TCE) is migrating from Site SS016 into Site SS029, resulting in a co-mingled plume. The current IRA at Site SS016 is GET. The remedial alternative for Site SS016 is Alternative 4, involving installation of an in situ bioreactor combined with the existing GET system. The remedial alternative at Site SS029 is Alternative 3 – GET, which is simply a continuation of the existing IRA.

Under Alternative 4, an in situ bioreactor would be installed in the OSA source area. The bioreactor would use ERD processes to help break down remaining chlorinated VOCs within the OSA. These actions would seek to minimize the adverse effects associated with the original source of TCE, which contributed contaminant mass into the downgradient portions of Site SS016. Residual contamination from the OSA would be partly addressed through operation of EW605x16 and EW610x16. Contamination that is not hydraulically captured by these wells would flow downgradient toward the Site SS029 extraction system.

Table D-1 shows a comparison of the IRA and the remedial alternative. The RTF estimates for the IRA and remedial alternative is discussed below.

Site SS016 and SS029 IRA (GET) Analysis. Because of the continuing source and high residual TCE concentrations at Site SS016, the TBGFM was not used to estimate the RTF for the Site SS016 and SS029 IRA. Instead, the RTF for the IRA was assumed to be greater than 100 years. If left in place, the high residual TCE concentrations at Site SS016 are expected to persist for several decades.

Site SS016 and SS029 Remedial Alternative, Bioreactor, and GET) Analysis. The remedial alternative would include installation of an in situ bioreactor with the OSA source area of Site SS016 and continuation of the Site SS016 and SS029 GET systems. It is assumed that the installation of the OSA bioreactor would remove high residual TCE contamination that is present. The TBGFM was used to perform the Site SS016 and SS029 remedial alternative analysis. For modeling purposes, the highest TCE concentrations in the northwestern portion of Site SS016 were not included in the GET analysis to account for the effects of the bioreactor. Figure D-17 shows the portion of the plume that was excluded in the GET analysis. The flushing efficiency for the GET analysis was calibrated using TCE chemographs for MW241x16, MW603x16, and MW611x16 and Equation D-1 to forecast TCE concentrations with future trends that are consistent with historical trends at the respective wells. Well locations are shown on Figure D-17. The calibrated flushing efficiency is 0.6, which corresponds to a sandy loam soil; the calibration curves are presented on Figure D-18. Figure D-19 shows the flushing time distribution for the GET target volume. Based on the GET analysis, the RTF is estimated to be approximately 62 years.

D.4.3.10 Site ST027B

Implementation of Alternative 2 at Site ST027B would be a continuation of the ongoing IRA (i.e., MNA). Site ST027B was formerly addressed under the Petroleum-only Contaminated sites program (CH2M HILL, 2010d). Figure D-2 shows the simulated groundwater flowline for the MNA analysis at ST027B. The similarity in groundwater elevation profiles between the HYDRUS-1D model and the TBGFM indicates that the HYDRUS-1D model is well calibrated (Figure D-20), and thus the hydraulics between the two (2) models are comparable. Table D-4 presents the model parameters used for the

Site ST027B HYDRUS-1D model. Figure D-21 shows the results of the MNA analysis. Forecasted TCE concentrations versus distance curves indicate that the estimated RTF under MNA is approximately 50 years (i.e., around calendar year 2060).

TABLE D-4
HYDRUS-1D Input Parameters for Site ST027B
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Model	Profile Length (feet)	COC	Dispersivity (feet)	Kd (mL/g)	*k* (days^{-1})	α (days^{-1})	Aqueous Diffusivity (cm^2/s)
MNA	8,120	TCE	19	0.067	2.0E-04	1.4E-04	9.1E-06

D.4.3.11 Site SS030

Implementation of Alternative 3 at Site SS030 will be a continuation of the existing GET system. The flushing efficiency for the GET analysis was calibrated using TCE chemographs for MW04x30 and Equation D-1 to forecast TCE concentrations with future trends that are consistent with historical trends at the respective wells. The well location is shown on Figure D-22. The calibrated flushing efficiency is 0.3, which corresponds to a clay soil; the calibration curve is presented on Figure D-23. Figure D-24 shows the flushing time distribution for the GET target volume. Based on the GET analysis, the RTF is approximately 22 years.

D.4.3.12 Site SD031

The IRA at Site SD031 is GET and MNA. The GET system was designed to capture VOC contamination exceeding 100 µg/L. The remedial alternative at Site SD031 is Alternative 2 (MNA).

Site SD031 IRA (GET and MNA) Analysis. A GET and MNA analysis was not performed for Site SD031 because the residual contamination at the site is not captured by the current extraction system. However, the extraction system has performed extremely well in reducing COC concentrations and plume area in the most contaminated areas of the site. The GET system has consequently been shut down for a rebound study. Because the system was not designed to achieve complete hydraulic capture of the 1,1-DCE plume, the remaining 1,1-DCE plume cannot be addressed by continuing GET. Therefore, MNA was the only remedial alternative evaluated at this site. The IRA RTF was assumed to be equal to that of the remedial alternative, which is 15 years.

Site SD031 Remedial Alternative (MNA) Analysis. Implementation of Alternative 2 at Site SD031 would consist of discontinuation of the GET and initiation of MNA. The COC at this site is 1,1-DCE. The MNA analysis was performed using HYDRUS-1D. Figure D-2 shows the simulated groundwater flowline for the MNA analysis at Site SD031. The similarity in groundwater elevation profiles between the HYDRUS-1D model and the TBGFM indicates that these models are hydraulically consistent along the 1D profile (see Figure D-25). Table D-5 presents the model parameters used for the Site SD031 HYDRUS-1D model. Figure D-26 shows the results of the MNA analysis. The calendar year 2010 concentration profile shown on Figure D-26 is the model's initial condition and was generated using the plume shapes presented on Figure D-2 and observed 1,1-DCE concentration data at the individual wells within the plumes. Thus the initial concentration profile shows greater variability than the more generalized plume shapes shown on Figure D-2. Forecasted 1,1-DCE concentration versus distance curves indicate that the estimated RTF under MNA is approximately 15 years (i.e., around calendar year 2025).

TABLE D-5
HYDRUS-1D Input Parameters for Site SD031
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Model	Profile Length (feet)	COC	Dispersivity (feet)	Kd (mL/g)	*k* ($days^{-1}$)	α ($days^{-1}$)	Aqueous Diffusivity (cm^2/s)
MNA	4,860	1,1-DCE	10.5	0.035	N/A	3.1E-03	1.0E-05

Note:
N/A = not applicable because first-order biodegradation was not included for the Site SD031 analysis.

Site-specific 1,1-DCE concentration data were not sufficient to calculate an independent biodegradation rate; therefore, the effect of biodegradation was not included in the estimate.

D.4.3.13 Site DP039

The IRA at Site DP039 is GET and MNA. The GET system was designed for source control, and the remainder of the TCE plume underwent MNA assessment over the interim period. The remedial alternative at Site DP039 is Alternative 6 (Bioreactor, Phytoremediation, EVO PRB, and EA). A conceptual design of the implementation of Alternative 6 is shown on Figure D-27.

Table D-1 shows a comparison of the IRA and the remedial alternative. The RTF estimates for the IRA and remedial alternative is discussed below.

Site DP039 IRA (GET and MNA) Analysis. The GET and MNA analysis at Site DP039 consists of two (2) separate analyses because only a portion of the TCE plume in the source area is captured by the extraction system. The portion of the TCE plume within the hydraulic capture zone was evaluated using the TBGFM, and the remainder of the TCE plume was evaluated using the HYDRUS-1D model. Figure D-28 shows the designed extent of hydraulic capture by the GET system (CH2M HILL, 2000). To be consistent with most of the other sites, the flushing efficiency (defined in Equation D-1) was set equal to 0.3 because there were no appropriate wells within the capture zone to independently calibrate a flushing efficiency. Figure D-29 shows the flushing time distribution for the GET target volume. Based on the GET analysis, the RTF within the zone of hydraulic capture was approximately 70 years (i.e., around calendar year 2080).

Because only a portion of the TCE plume was captured by the GET system, the portion of this plume beyond the capture zone was evaluated using the HYDRUS-1D model. Figure D-2 shows the simulated groundwater flowline for the Site DP039 MNA analysis. The starting point for the MNA analysis is conceptually a groundwater divide, with the TCE plume area north of this point being captured by the extraction system and the plume area south of this point migrating downgradient. The similarity in groundwater elevation profiles between the HYDRUS-1D model and the TBGFM indicates that the HYDRUS-1D model is well calibrated (Figure D-30), and thus the hydraulics between the two (2) models are comparable. Table D-6 shows the model parameters used in the MNA analysis when the GET system is operational. Figure D-31 shows the results of the MNA analysis. Forecasted TCE concentration versus distance curves indicate that the RTF is approximately 70 years for the TCE plume area not captured by the GET systems (i.e., around calendar year 2080). Thus the overall RTF for the IRA is determined by the portion of the plume undergoing MNA and is approximately 70 years (i.e., around calendar year 2080).

Site DP039 Remedial Alternative (EA) Analysis. The remedial alternative at Site DP039 would include replacing the GET system with a combination of excavating the source area, constructing a bioreactor, maintaining the phytoremediation area, installing an EVO PRB, and EA (Figure D-27). For modeling purposes, it was assumed that TCE concentrations exiting the PRB would be no greater than 500 μg/L.

Given the complexity of the Site DP039 remedial alternative, four (4) separate models were developed for the EA analysis. The first three (3) HYDRUS-1D models were used to forecast TCE concentrations from the downgradient edge of the bioreactor's zone of influence to the PRB (Figure D-32). The purpose of these models was to forecast the time-series TCE concentrations entering the PRB from upgradient. Three (3) models were required so that the effect of the phytoremediation area could be explicitly included. The first model simulated the portion of the TCE plume upgradient of the phytoremediation area; the second model simulated the portion of the TCE plume in the phytoremediation area; and the third model simulated the portion of the TCE plume between the downgradient edge of the phytoremediation area and the PRB (Figure D-32). These three (3) models were linked so that the time-series TCE concentrations exiting the upgradient model became the input to the downgradient model. Table D-6 presents the parameter values used for the HYDRUS-1D models simulating the EA analysis upgradient of the PRB.

The HYDRUS-1D model upgradient of the PRB simulated TCE conditions below the phytoremediation area, where in addition to the calibrated biodegradation halflife (9.5 years from MW751x39), TCE is also removed by trees at an estimated rate of 2 pounds per year (Parsons, 2010). Given the limitations of the one (1)-dimensional model approach, the additional mass of TCE removed by the trees was implemented in HYDRUS-1D by reducing the biodegradation halflife to below the initial value of 9.5 years, but only in the model transecting the phytoremediation area (Figure D-32). The reduced biodegradation halflife in this model was estimated to be 3.1 years, after accounting for the 2-pound-per-year removal of TCE in the phytoremediation area. The time-series TCE concentrations from the phytoremediation area model were then used as the input to the third model, which represented the area between the downgradient edge of the phytoremediation area and PRB (Figure D-32). Figure D-33 shows the forecasted time-series TCE concentration data entering the PRB.

The fourth HYDRUS-1D model was used to forecast time-series TCE concentrations in groundwater exiting the PRB and flowing downgradient of the treatment area. This is the portion of the TCE plume that would undergo EA. Once beyond the TCE plume, the flowline (i.e., profile) joins the larger DP039 flowline shown on Figure D-2. A time-variable concentration boundary condition was used at the upgradient boundary of this model to simulate the influx of TCE entering the PRB from upgradient of the PRB. The TCE concentration assigned at this boundary was based on the output from the observation node from the upgradient HYDRUS-1D model. Any TCE concentration in the observation node file greater than 500 µg/L was reduced to 500 µg/L because of the assumed effect of the PRB. Concentrations in the observation node file less than 500 µg/L were left unchanged. This is a conservative approach because, in reality, there would be some beneficial reduction in TCE concentrations less than 500 µg/L as well. Table D-6 presents the model parameters used for the HYDRUS-1D model simulating the EA analysis downgradient of the PRB. Figure D-34 shows the results of the EA analysis. Forecasted concentration versus distance curves indicate that the RTF under EA is approximately 58 years (i.e., around calendar year 2068). This RTF is controlled by the time that it takes for the forecasted TCE concentrations downgradient of the PRB to decrease below the PCG.

TABLE D-6
HYDRUS-1D Input Parameters for Site DP039
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Model	Profile Length (feet)	COC	Dispersivity (feet)	Kd (mL/g)	*k* ($days^{-1}$)	α ($days^{-1}$)	Aqueous Diffusivity (cm^2/s)
GET and MNA	9,100	TCE	29	0.067	2.0E-04	5E-05	9.1E-06
EA (upgradient of phytoremediation area)	210	TCE	11	0.067	2.0E-04	5E-05	9.1E-06
EA (phytoremediation area)	250	TCE	12.5	0.067	6.0E-04	5E-05	9.1E-06
EA (between phytoremediation area and PRB)	660	TCE	20	0.067	2.0E-04	5E-05	9.1E-06
EA (downgradient of PRB)	7,980	TCE	16	0.067	2.0E-04	5E-05	9.1E-06

D.4.3.14 WIOU

The WIOU plume comprises Sites SD033, SD034, SD036, SS037, SS041, and SD043 (Figure D-35). For the purposes of this evaluation, all sites within the WIOU were considered in one (1) analysis. The IRA for the WIOU is GET and MNA. The GET system was designed to capture VOC concentrations exceeding 100 µg/L. The remainder of the TCE plume underwent MNA assessment over the interim period. The proposed remedial alternative at the WIOU combines Alternatives 2 and 4. EVO would be injected into the source areas at Sites SD036 and SD037. The approach for the remainder of the WIOU would be EA.

Table D-1 shows a comparison of the IRA and the remedial alternative. The RTF estimates for the IRA and remedial alternative is discussed below.

WIOU IRA (GET and MNA) Analysis. The GET analysis was performed for the entire WIOU using the TBGFM. The flushing efficiency for the GET analysis was calibrated using TCE chemographs for MW512x37 and MW538 and Equation D-1 to forecast TCE concentrations with future trends that are consistent with historical trends at the respective wells. Well locations are shown on Figure D-36. The calibrated flushing efficiency is 0.5, which corresponds to a loam; the calibration curves are presented on Figure D-37. Figure D-38 shows the flushing time distribution for the GET target volume. Based on the GET analysis, the RTF at the WIOU is approximately 91 years (i.e., around calendar year 2101).

WIOU Remedial Alternative (EA) Analysis. The remedial alternative at the WIOU is to discontinue operation of the GET and begin EA. The EA would consist of EVO injection into the remaining Site SD036 and SD037 source areas to treat TCE concentrations exceeding 1,000 µg/L. For modeling purposes, it was assumed that the treatment process (EVO injection) would reduce concentrations within the source areas to 1,000 µg/L. Thus the WIOU EA analysis provides an estimate of the RTF for concentrations up to 1,000 µg/L.

HYDRUS-1D was used for the EA analysis. Figure D-2 shows the simulated groundwater flowline for the EA analysis at the WIOU. The similarity in groundwater elevation profiles between the HYDRUS-1D model and the TBGFM indicates that the HYDRUS-1D model is well calibrated (Figure D-39), and thus the hydraulics between the two (2) models are comparable. Table D-7 presents the model parameters used for the WIOU HYDRUS-1D model. Figure D-40 shows the results of the EA analysis. The calendar year 2010 concentration profile shown on Figure D-40 is the model's initial condition and was generated using the plume shapes presented on Figure D-2 and observed TCE concentration data at the individual wells within the plumes. Thus, the initial concentration profile shows greater variability than the more generalized plume shapes because the profile passes through multiple localized plumes and extraction systems. Forecasted concentration versus distance curves indicate that the RTF under EA is approximately 60 years (i.e., around calendar year 2070).

TABLE D-7
HYDRUS-1D Input Parameters for Site WIOU
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Model	Profile Length (feet)	COC	Dispersivity (feet)	Kd (mL/g)	*k* (days^{-1})	α (days^{-1})	Aqueous Diffusivity (cm^2/s)
EA	12,080	TCE	42	0.067	2.0E-04	1.3E-05	9.1E-06

D.5 Limitations

Mathematical models can only approximate processes of physical systems. Models are inherently inexact because the mathematical description of the physical system is imperfect and the understanding of interrelated physical processes is incomplete. The models described in this appendix are good tools that, when used carefully, can provide useful insight into transport processes within the physical system. However, such models are no substitute for continued monitoring of COC trends at available wells over the next several years to confirm the stage of plume evolution (i.e., advancing, stable, or retracting) and to continually refine the conceptual site model.

The RTFs provided in this appendix were taken directly from the model output for comparative purposes and do not reflect the level of precision implied in the estimate. While it is impossible to quantify the uncertainty associated with estimates of RTF, it would be appropriate to round up such estimates to the nearest decade or more for planning purposes.

D.6 Works Cited

Al-Suwaiyan, M., 1996. Discussion of "Use of Weighted Least-Squares Method in Evaluation of the Relationship Between Dispersivity and Scale," by M. Xu and Y. Eckstein. *Ground Water*. 34 (4): 578.

CH2M HILL. 2010a. *Third Project Report, Sustainable Bioreactor Demonstration, Site DP039.* Travis Air Force Base, California. Final. October.

CH2M HILL. 2010b. *Natural Attenuation Assessment Report*. Environmental Restoration Program. Travis Air Force Base, California. Final. July.

CH2M HILL. 2010c. *Groundwater Sampling and Analysis Program, 2008–2009 Annual Report.* Environmental Restoration Program. Travis Air Force Base, California. Final. April.

CH2M HILL. 2010d. *Technical Memorandum Site ST027 – Area B Characterization Results.* Environmental Restoration Program. Travis Air Force Base, California. Final. July.

CH2M HILL. 2008. *Second Five-year Review Report*. Environmental Restoration Program. Travis Air Force Base, California. Final. September.

CH2M HILL. 2003.*Groundwater Five-year Review*. Environmental Restoration Program. Travis Air Force Base, California. Final. July.

CH2M HILL. 2000. *DP039 Interim Groundwater Remedial Design Report, West/Annexes/ Basewide Operable Unit*. Final. September.

CH2M HILL. 1998. *Travis Basewide Groundwater Model*. Travis Air Force Base, California. March.

Haggerty R., C.F. Harvey, C.F. von Schwerin, and L.C. Meigs. 2004. "What Controls the Apparent Timescale of Solute Mass Transfer in Aquifers and Soils? A Comparison of Experimental Results." *Water Resources Research*. 40 W01510.

Hemker, C.J., and R.G. de Boer. 2010. MicroFEM version 4.10.14.

Parsons. 2010. *Phytostabilization at Travis Air Force Base, California*. Final. September.

Payne, F., J. Quinnan, and S. Potter. 2008. *Remediation Hydraulics.* CRC Press. Taylor & Francis Group, New York.

Šimůnek, J., M.T. van Genuchten, and M. Šejna. 2008. "Development and Applications of the HYDRUS and STANMOD Software Packages and Related Codes." *Vadose Zone J.* 7: 587-600.

Šimůnek, J., M. Šejna, H. Saito, M. Sakai, and M.T. van Genuchten. 2009. *The HYDRUS-1D Software Package for Simulating the One-Dimensional Movement of Water, Heat, and Multiple Solutes in a Variably-Saturated Media.* Version 4.08. Department of Environmental Sciences, University of California, Riverside.

U.S. Environmental Protection Agency (EPA). 2008. The Estimation Programs Interface (EPI) Suite.

U.S. Environmental Protection Agency (EPA). 2002. Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies. November.

van der Molen, W.H. 1973. *Salt Balance and Leaching Requirement*. In Drainage Principles and Applications vol. II, Theories of Field Drainage and Watershed Runoff. International Institute for Land Reclamation and Improvement, Wageningen, Netherlands.

Xu, M. and Y. Eckstein. 1995. "Use of Weighted Least-Squares Method in Evaluation of the Relationship Between Dispersivity and Scale." *Ground Water*. 33 (6): 905-908.

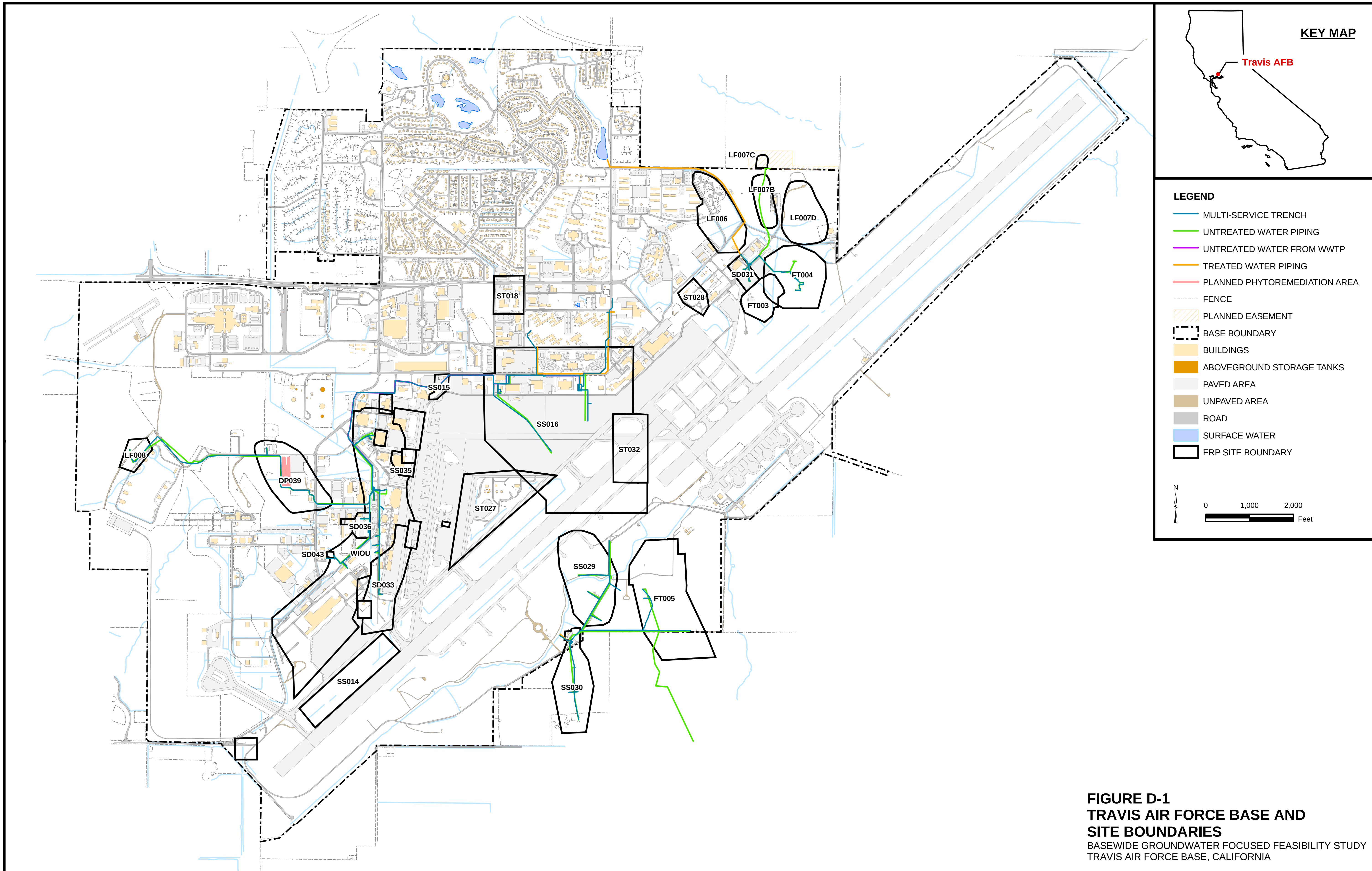


FIGURE D-1
TRAVIS AIR FORCE BASE AND SITE BOUNDARIES

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

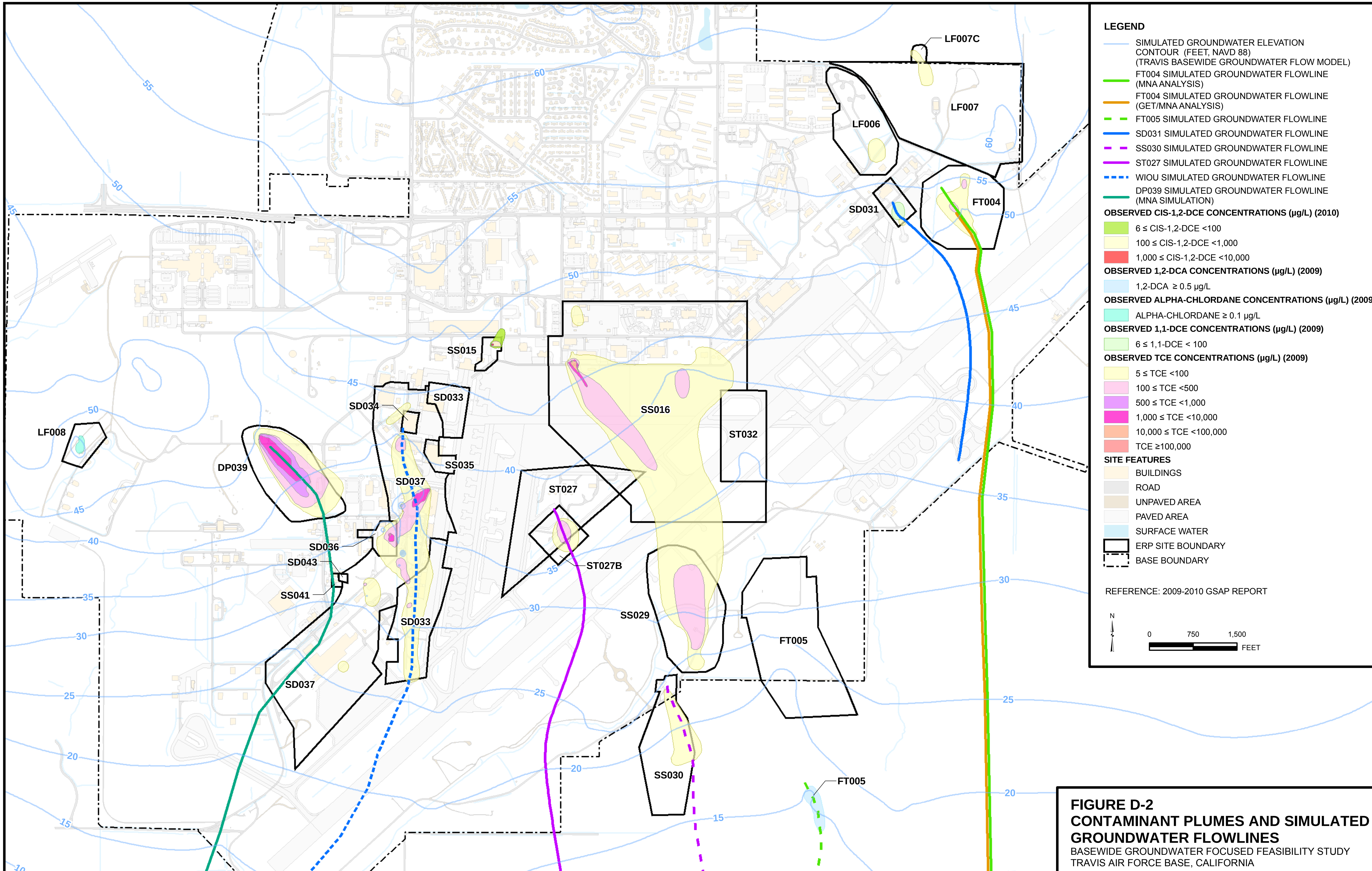


FIGURE D-2
CONTAMINANT PLUMES AND SIMULATED GROUNDWATER FLOWLINES
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_D\FIGD-2_PLUME_NETWORK_FFS.MXD MCLAY1 1/21/2011 19:15:29

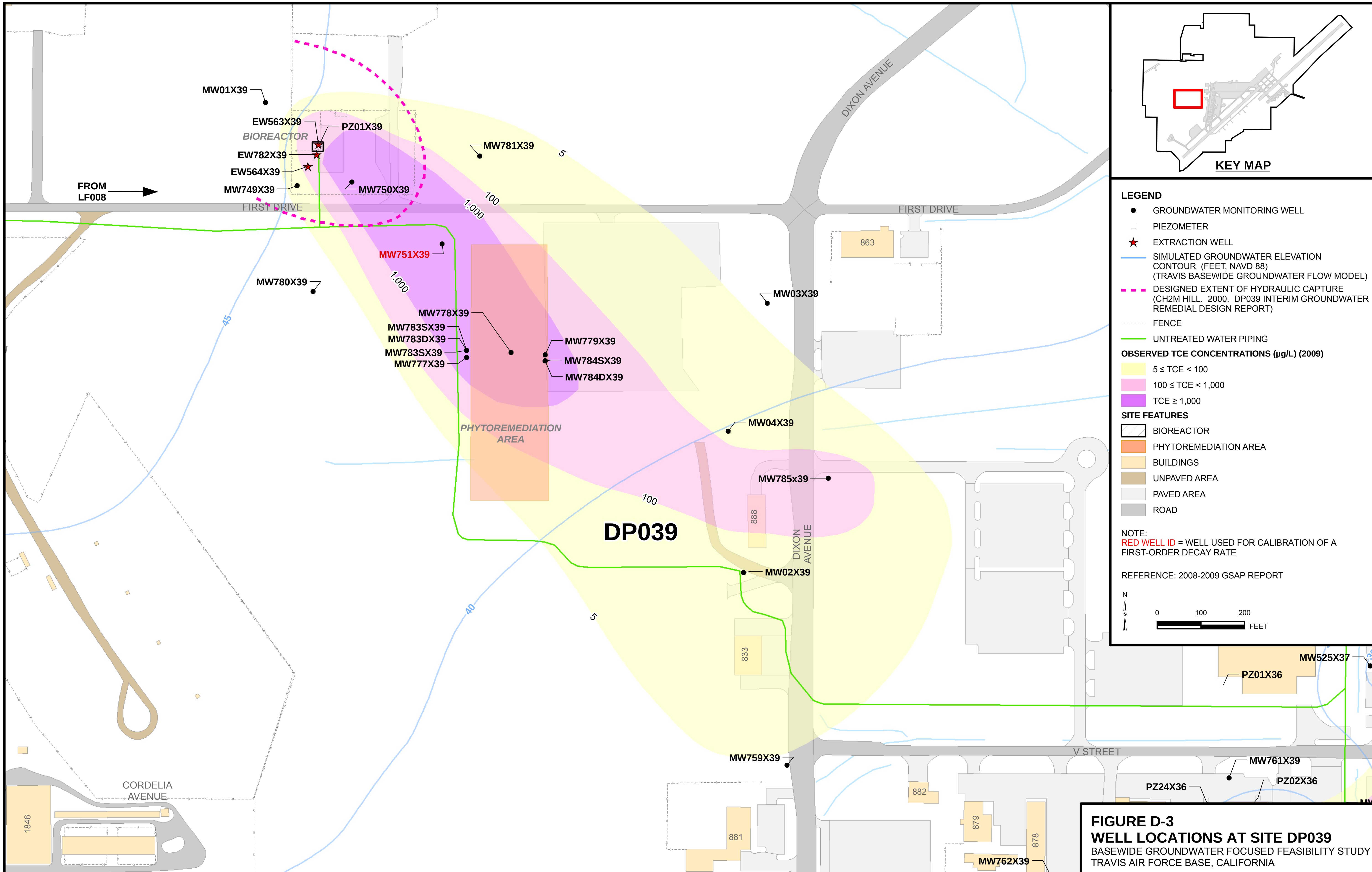
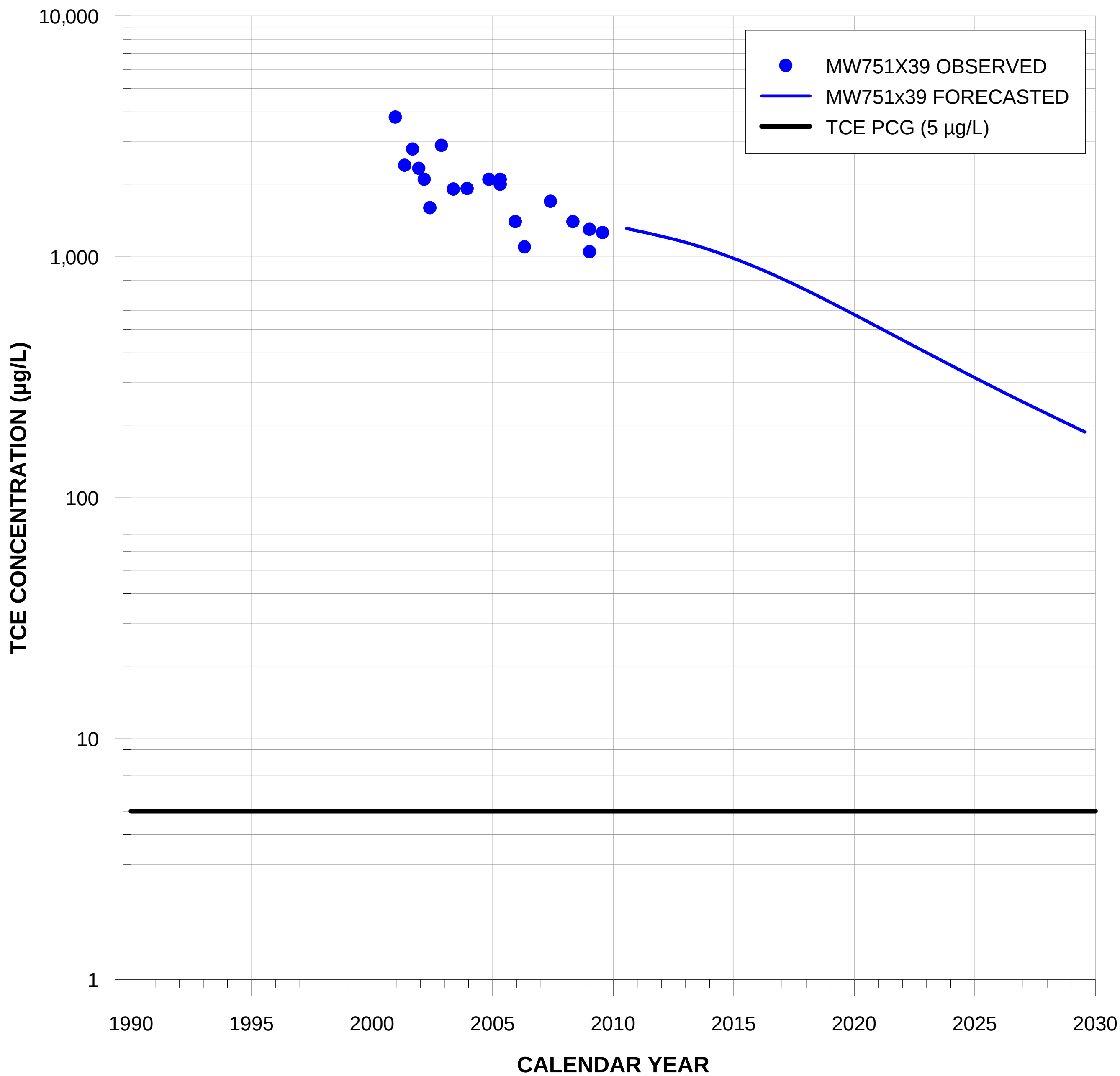


FIGURE D-3
WELL LOCATIONS AT SITE DP039
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_D\FIGD-3_WELLS_DP039.MXD MCLAY1 1/21/2011 20:04:50



NOTE
FORECASTED CONCENTRATIONS CALCULATED USING
A BIODEGRADATION HALF-LIFE OF 9.5 YEARS.

FIGURE D-4
HISTORICAL AND FORECASTED TCE CONCENTRATIONS AT MW751x39
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-4_DP039_Decay_Cal_TCE.grf

CH2MHILL

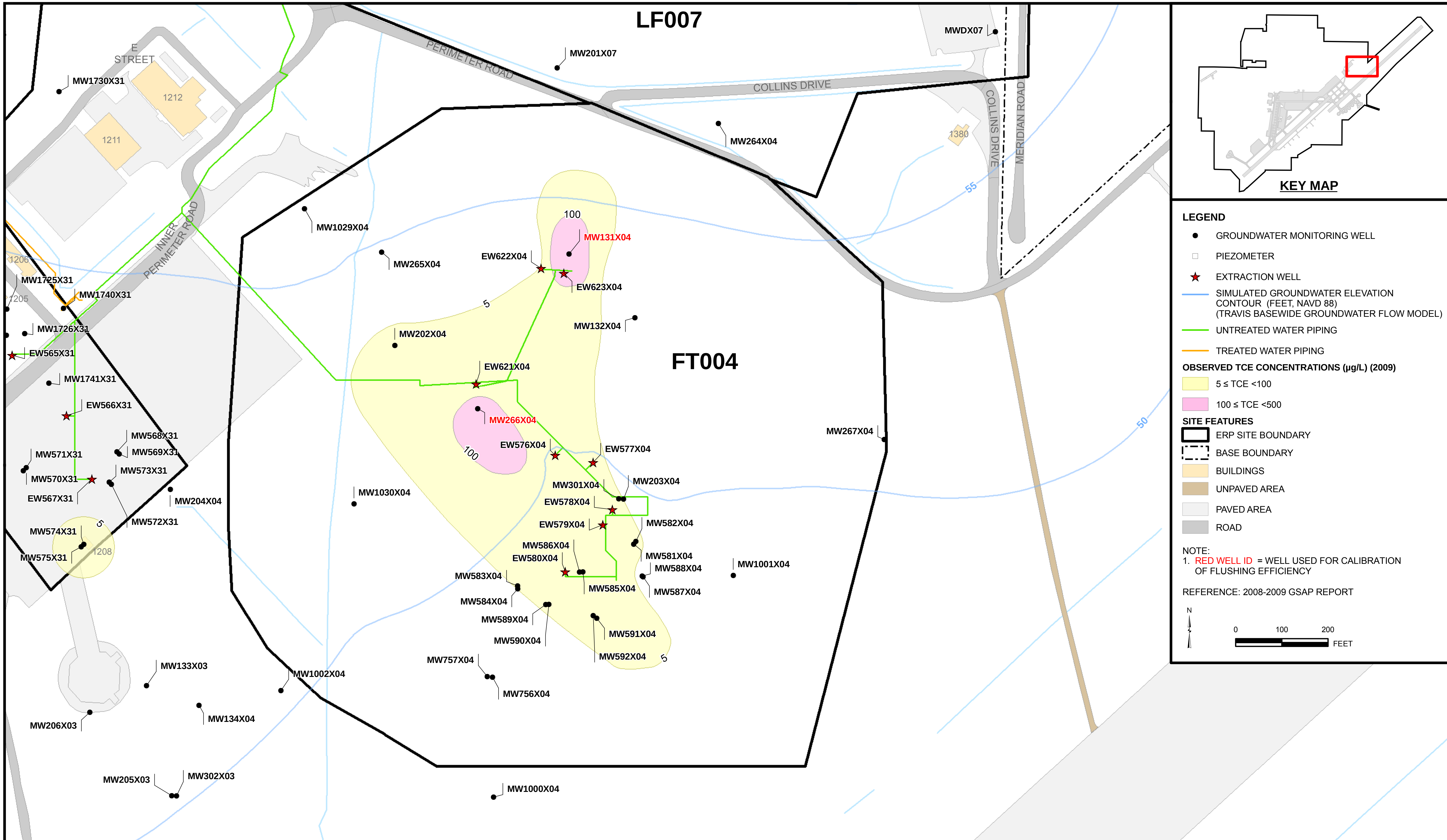
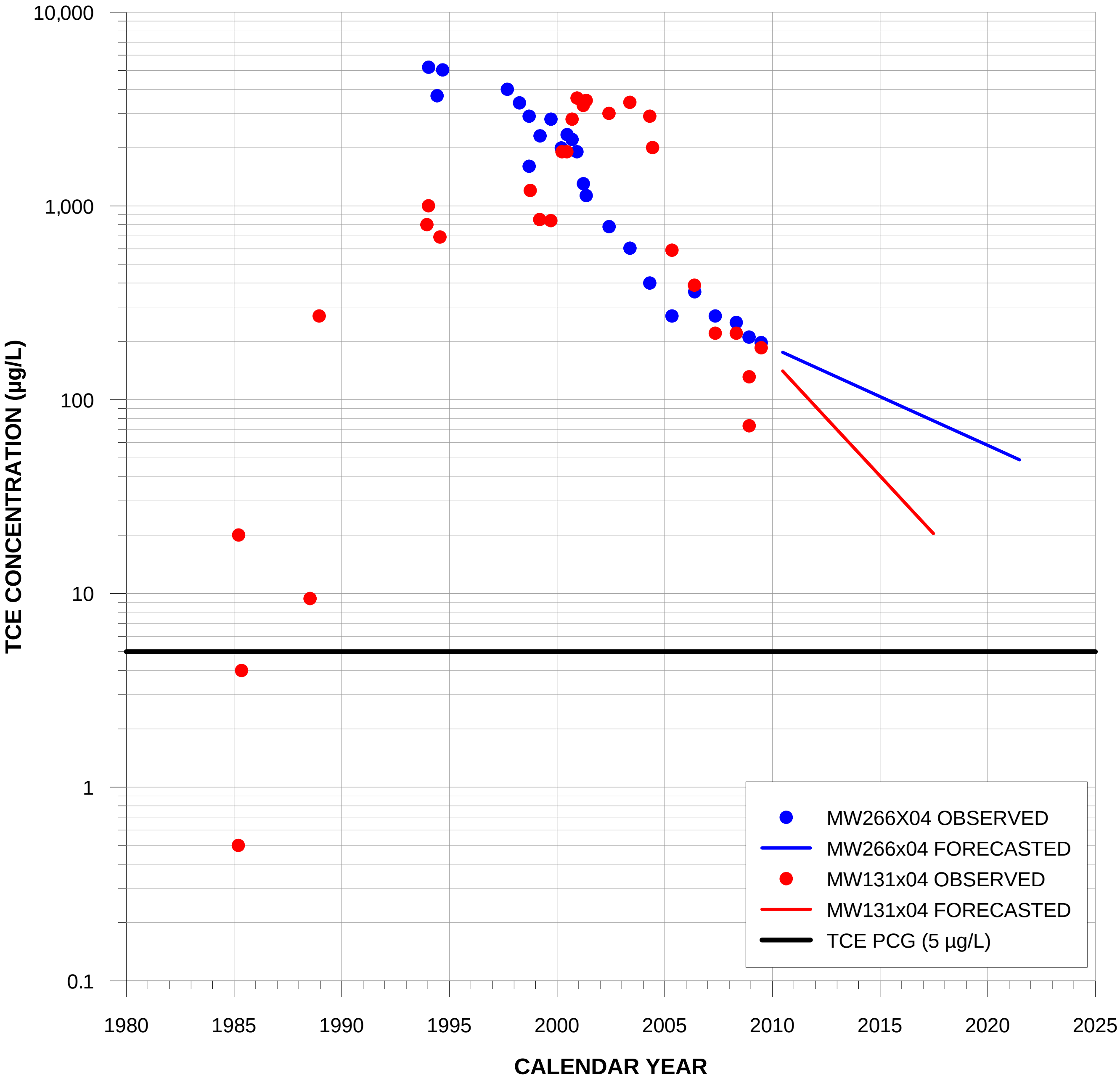


FIGURE D-5
WELL LOCATIONS AT SITE FT004
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_D\FIGD-5_WELLS_FT004.MXD MCLAY1 1/21/2011 20:23:41



NOTE
FORECASTED CONCENTRATIONS CALCULATED USING A FLUSHING EFFICIENCY OF 0.3.

FIGURE D-6
HISTORICAL AND FORECASTED TCE CONCENTRATIONS AT MW266x04 AND MW131x04
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-6_FT004_Flushing_Cal.grf

CH2MHILL

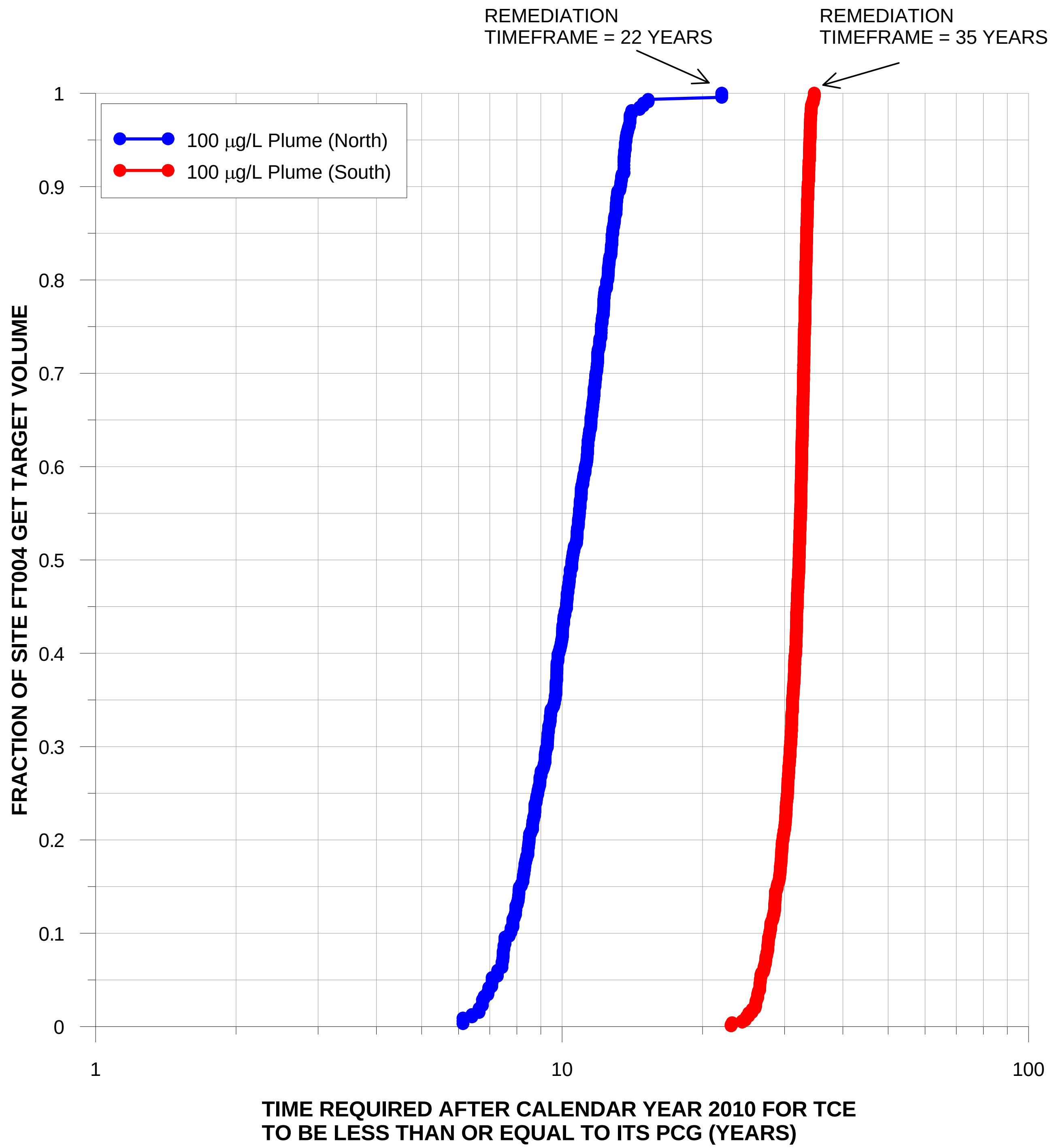
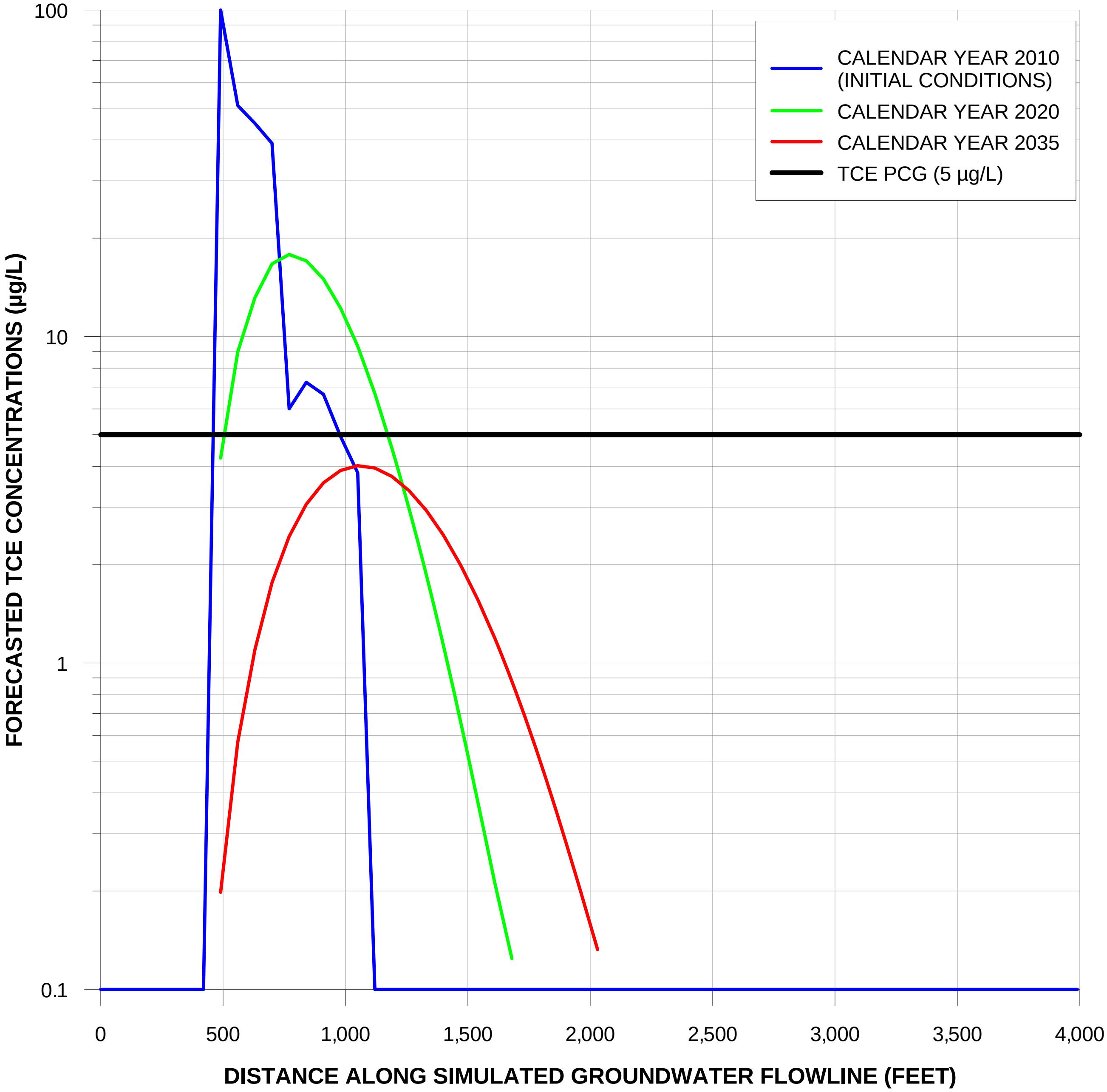


FIGURE D-7
FLUSHING TIME DISTRIBUTION FOR THE SITE FT004 GET TARGET VOLUME
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-7_FT004_GET_Cum_TTC.grf

CH2MHILL

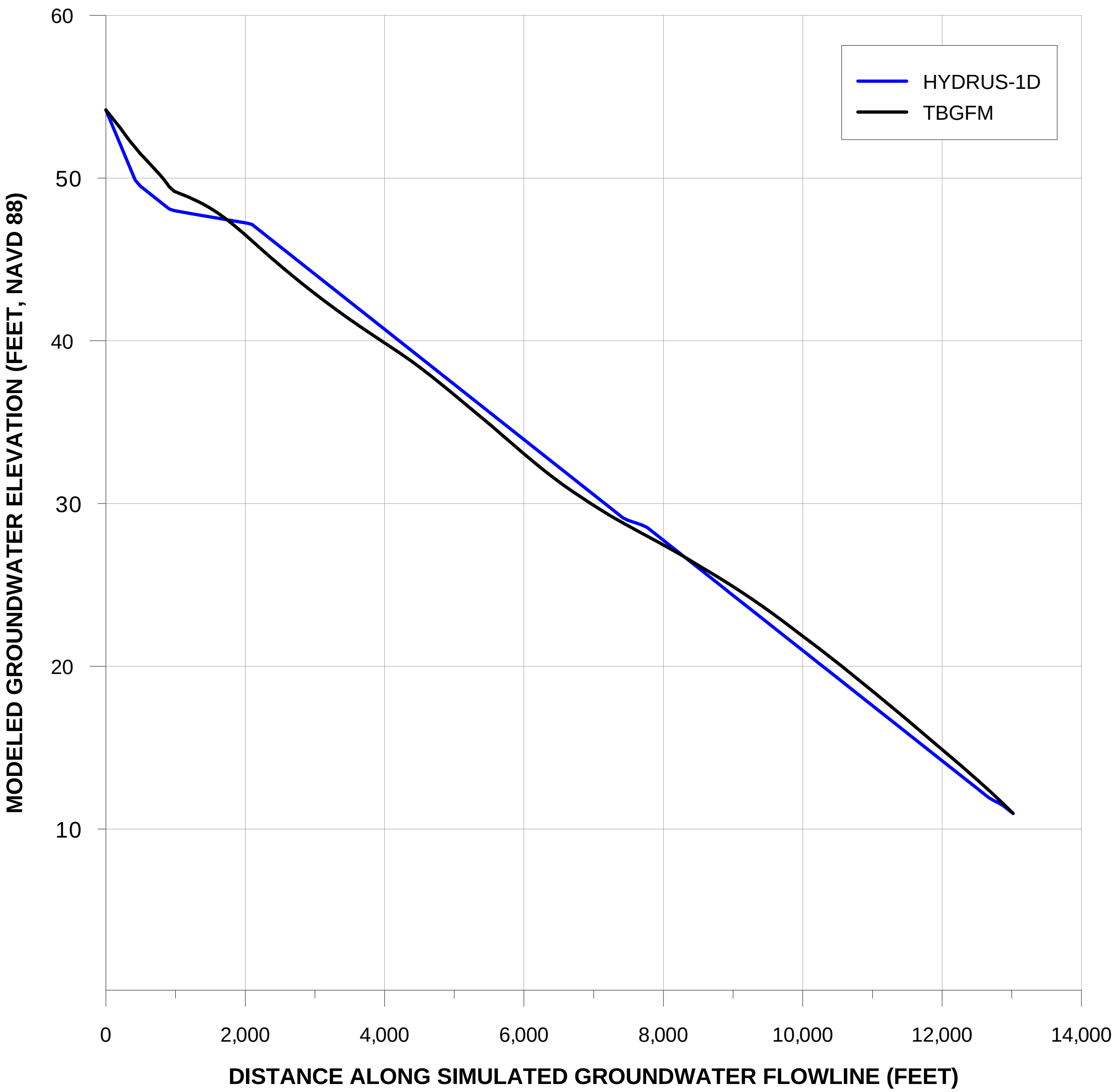


NOTE
SITE FT004 SIMULATED GROUNDWATER FLOWLINE SHOWN ON FIGURE D-2.

FIGURE D-8
FORECASTED SITE FT004 TCE CONCENTRATIONS UNDER INTERIM REMEDIAL ACTION CONDITIONS
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-8_FT004_Conc_vs_Distance_MNA_with_GET.grf

CH2MHILL

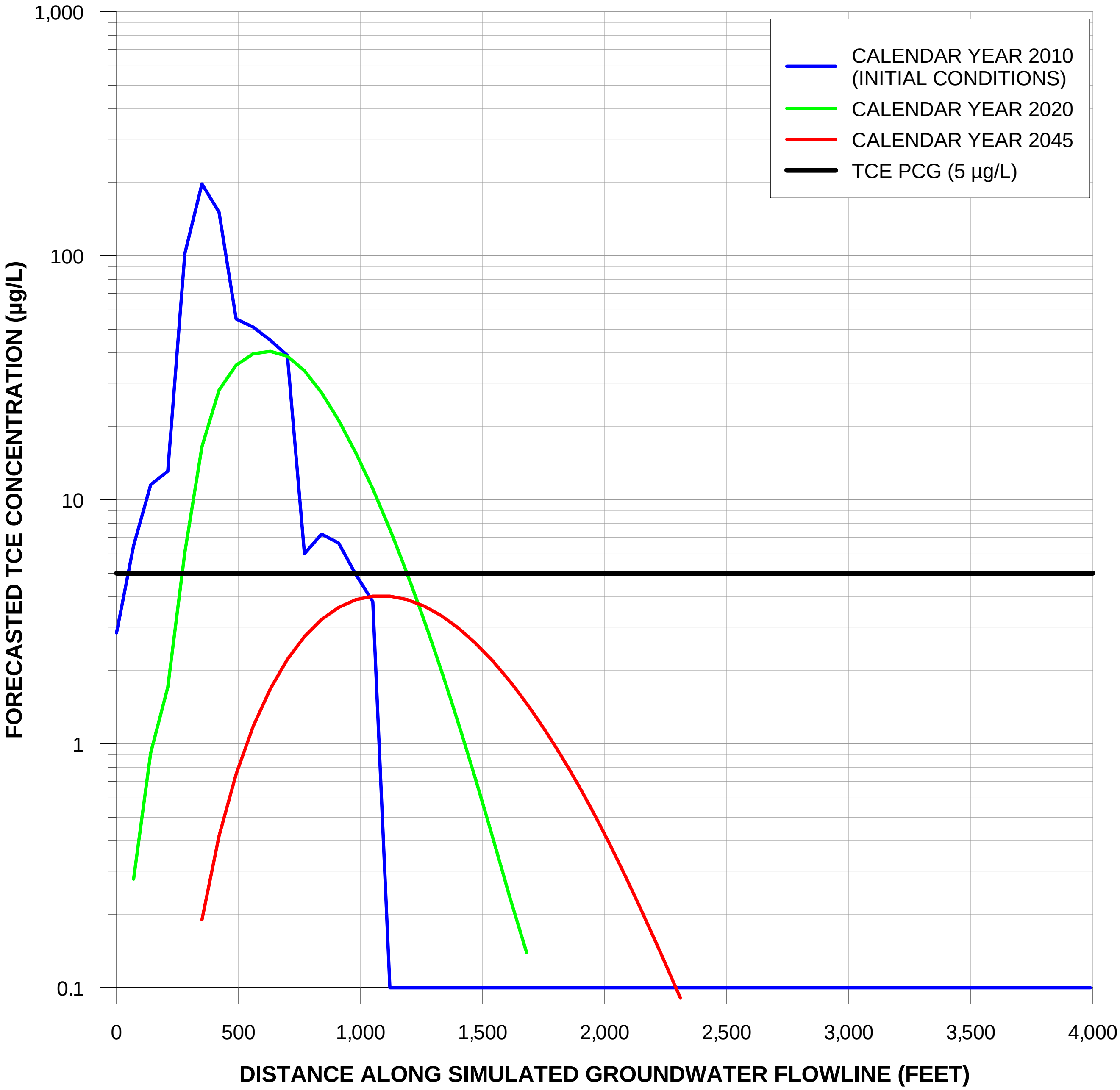


NOTES
1. SIMULATED GROUNDWATER FLOWLINE SHOWN ON FIGURE D-2.
2. TBGFM = TRAVIS BASEWIDE GROUNDWATER FLOW MODEL

FIGURE D-9
COMPARISON OF MODELED GROUNDWATER ELEVATIONS AT SITE FT004
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-9_FT004_Head_Comparison.grf

CH2MHILL



NOTE
SITE FT004 SIMULATED GROUNDWATER FLOWLINE SHOWN ON FIGURE D-2.

FIGURE D-10
FORECASTED SITE FT004 TCE CONCENTRATIONS UNDER REMEDIAL ALTERNATIVE CONDITIONS

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

FigureD-10_FT004_Conc_vs_Distance_MNA_with_GET.grf

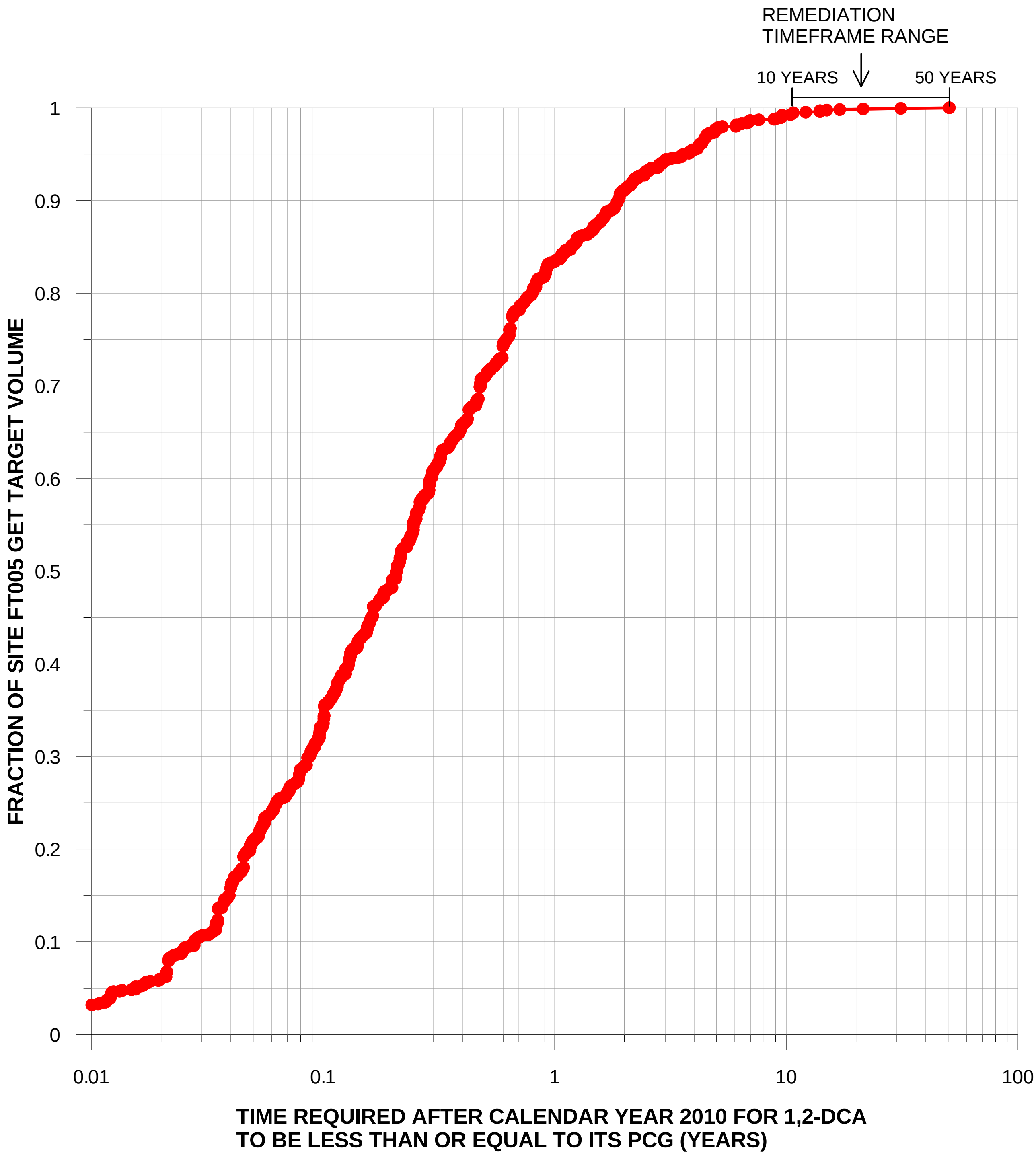
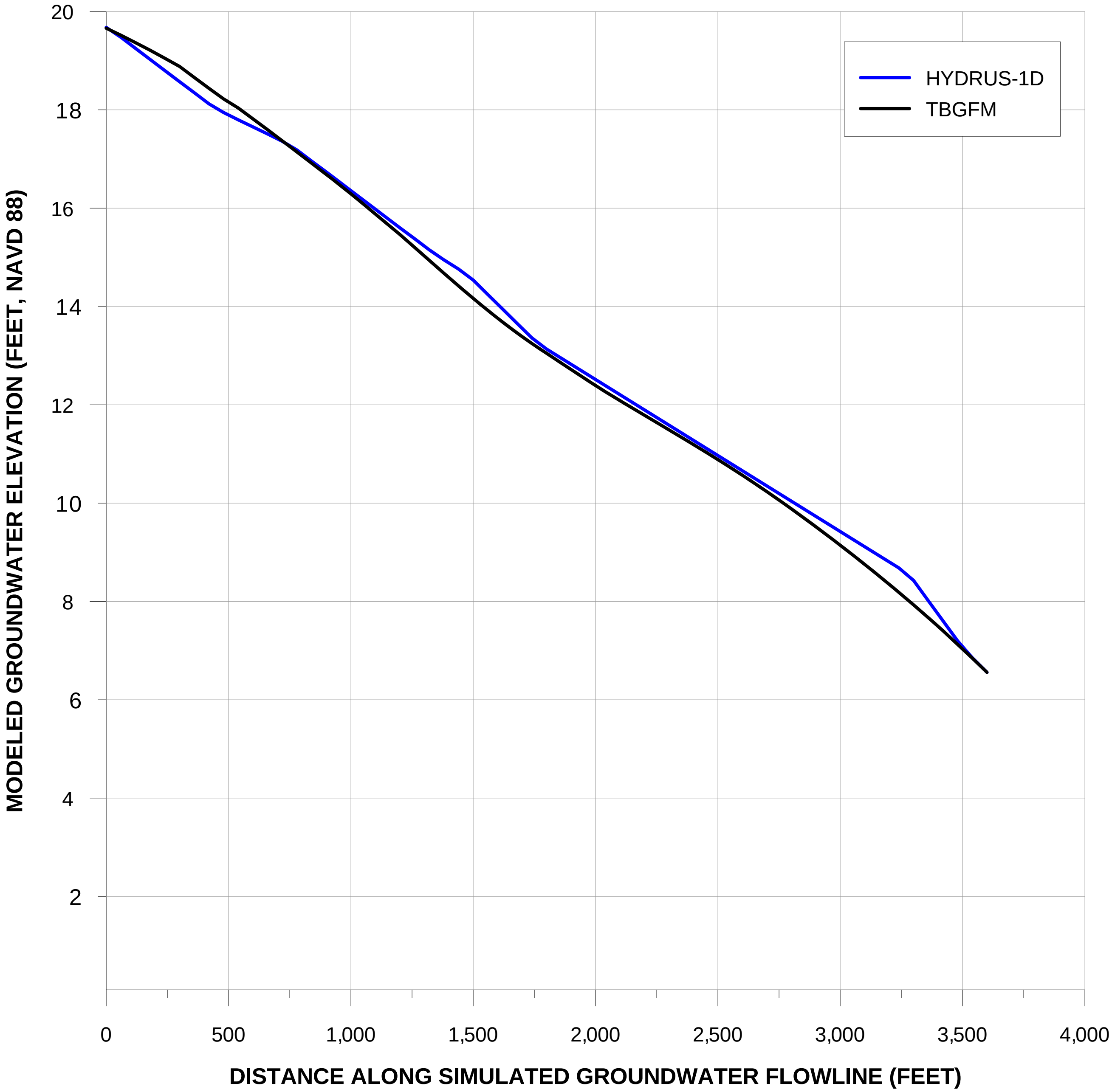


FIGURE D-11
FLUSHING TIME DISTRIBUTION FOR THE SITE FT005 GET TARGET VOLUME
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-11_FT005_GET_Cum_TTC.grf

CH2MHILL



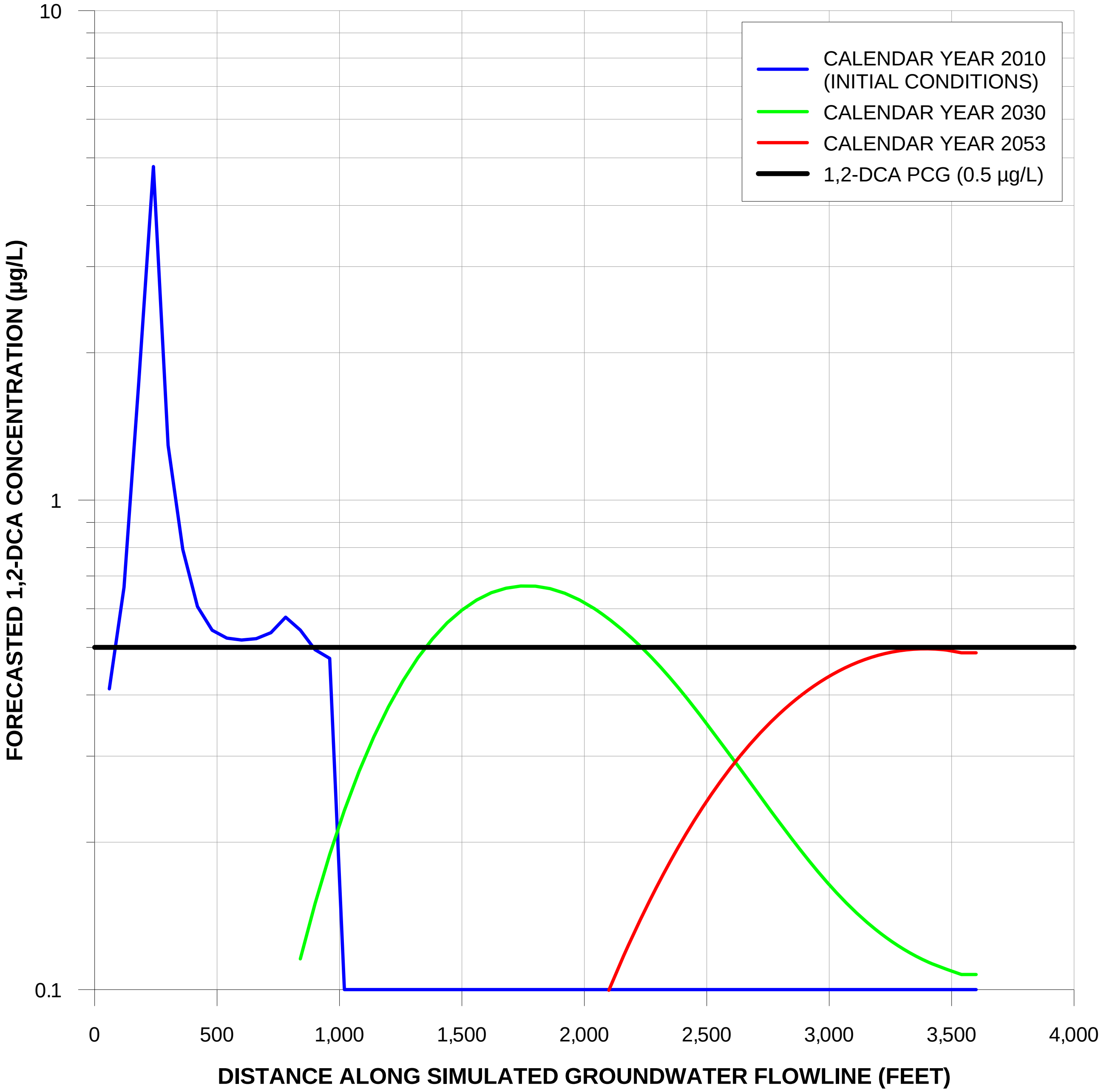
NOTES
1. SIMULATED GROUNDWATER FLOWLINE SHOWN ON FIGURE D-2.
2. TBGFM = TRAVIS BASEWIDE GROUNDWATER FLOW MODEL

FIGURE D-12
COMPARISON OF MODELED GROUNDWATER ELEVATIONS AT SITE FT005

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-12_FT005_Head_Comparison.grf

CH2MHILL



NOTE

SITE FT005 SIMULATED GROUNDWATER FLOWLINE SHOWN ON FIGURE D-2.

FIGURE D-13
FORECASTED SITE FT005 1,2-DCA CONCENTRATIONS UNDER REMEDIAL ALTERNATIVE CONDITIONS

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-13_FT005_Conc_vs_Distance.grf

CH2MHILL

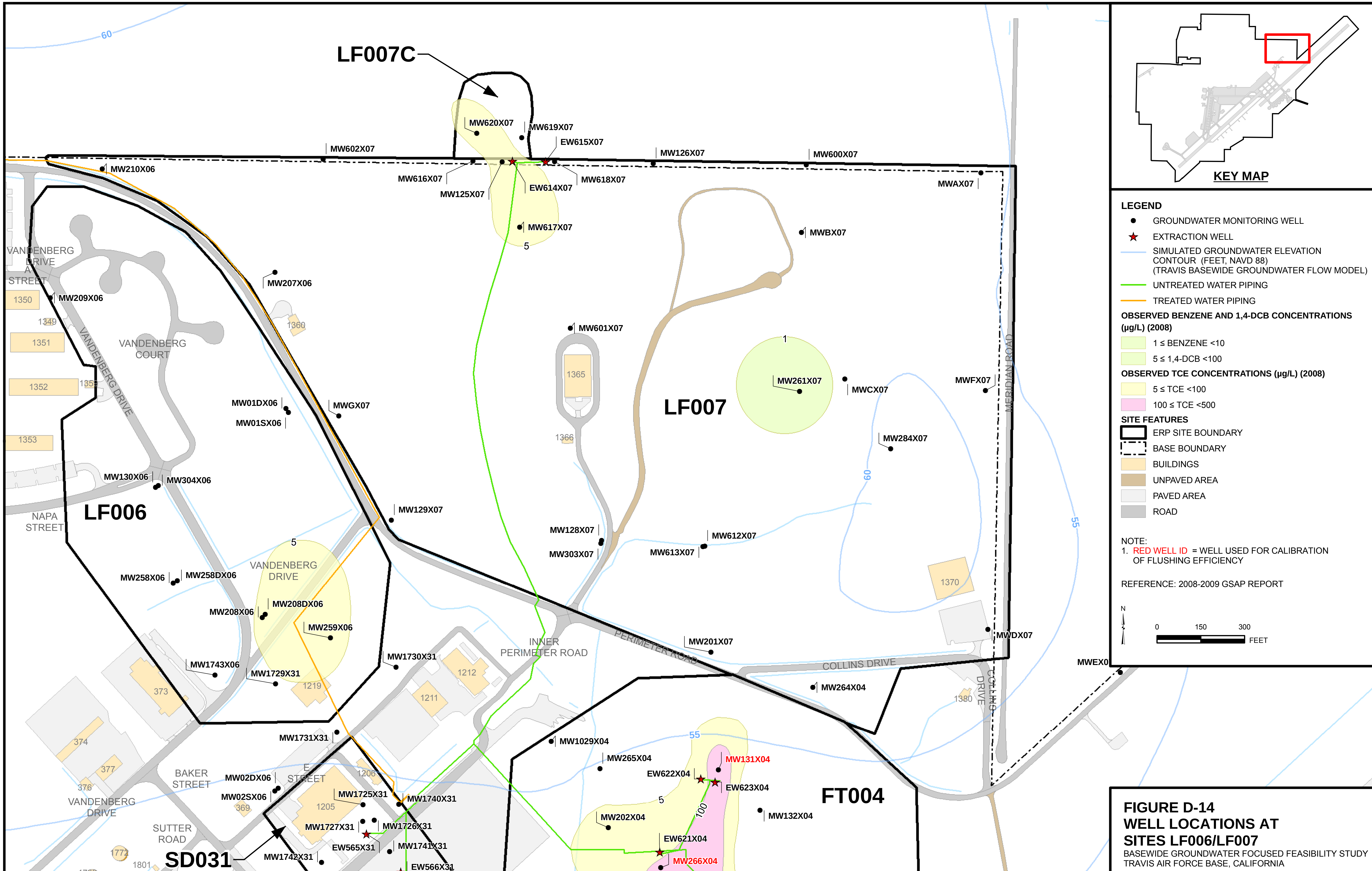


FIGURE D-14
WELL LOCATIONS AT SITES LF006/LF007
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_D\FIGD-14_WELLS_LF007.MXD MCLAY1 1/21/2011 21:15:32

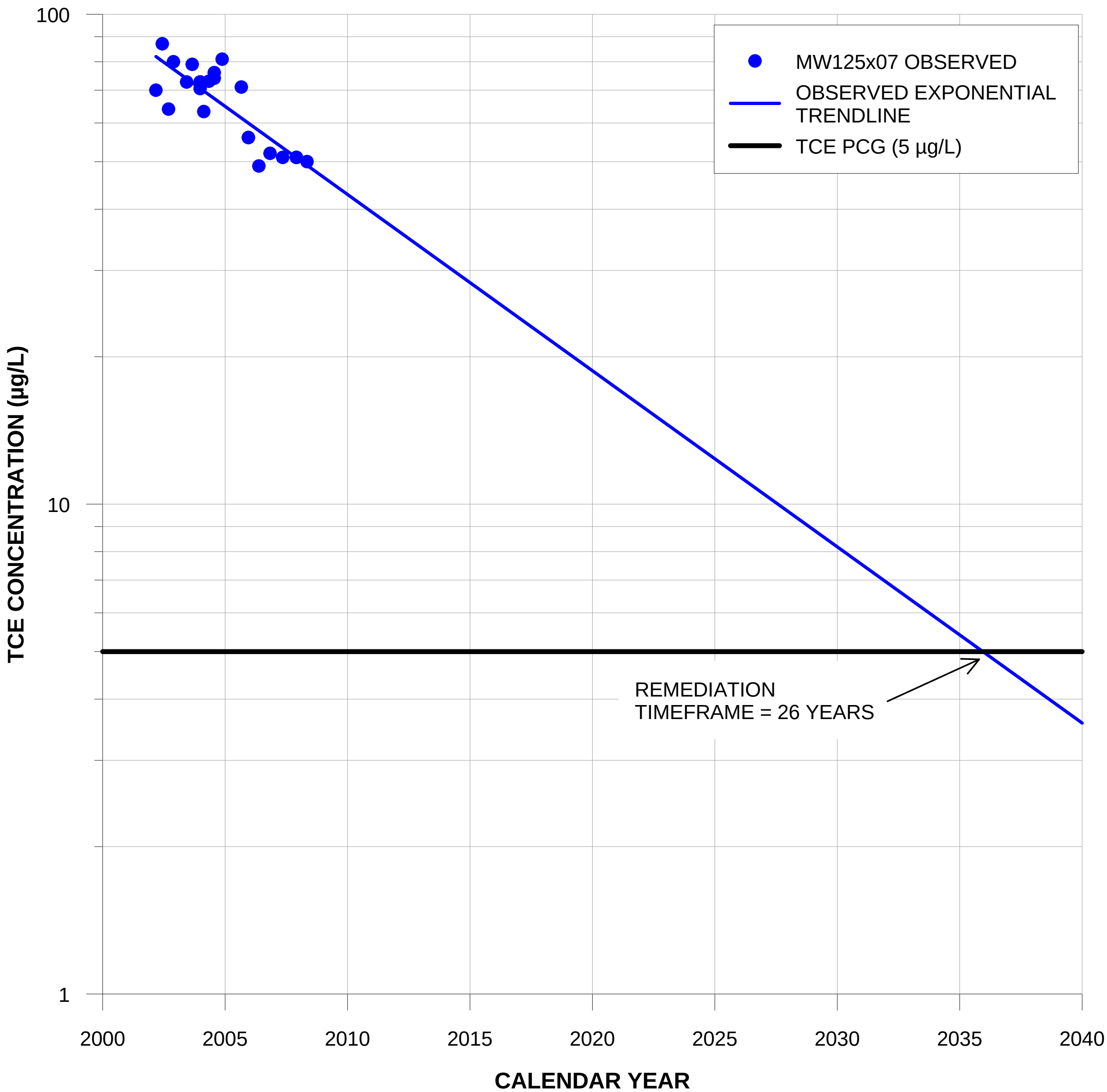


FIGURE D-15
MW125x07 TCE CONCENTRATION DATA AND OBSERVED TRENDLINE
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-15_LF007_Analysis_TCE.grf

CH2MHILL

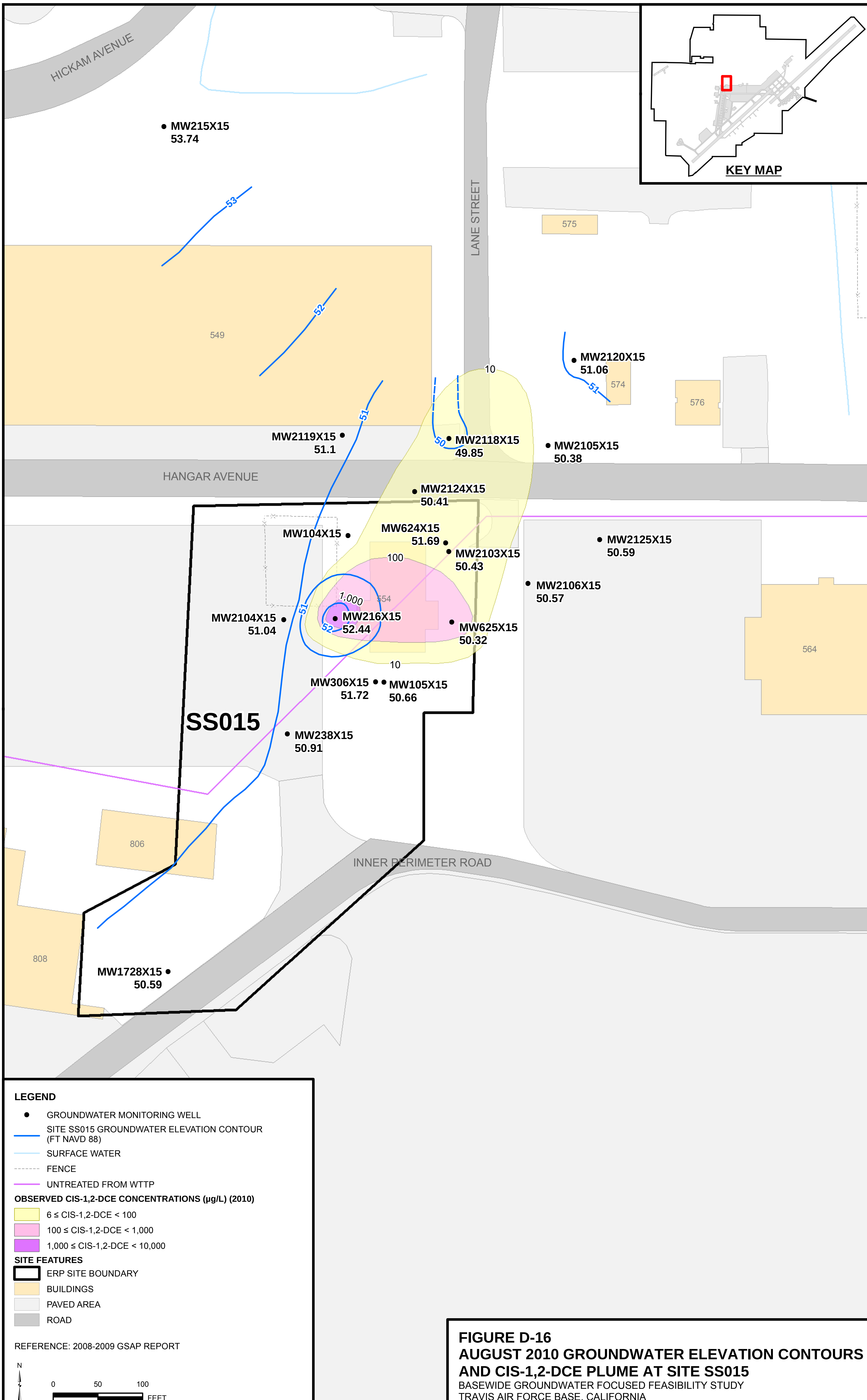


FIGURE D-16
AUGUST 2010 GROUNDWATER ELEVATION CONTOURS AND CIS-1,2-DCE PLUME AT SITE SS015
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_D\FIGD-16_AUG2010_GW_12DCE.MXD MCLAY1 1/21/2011 21:46:43

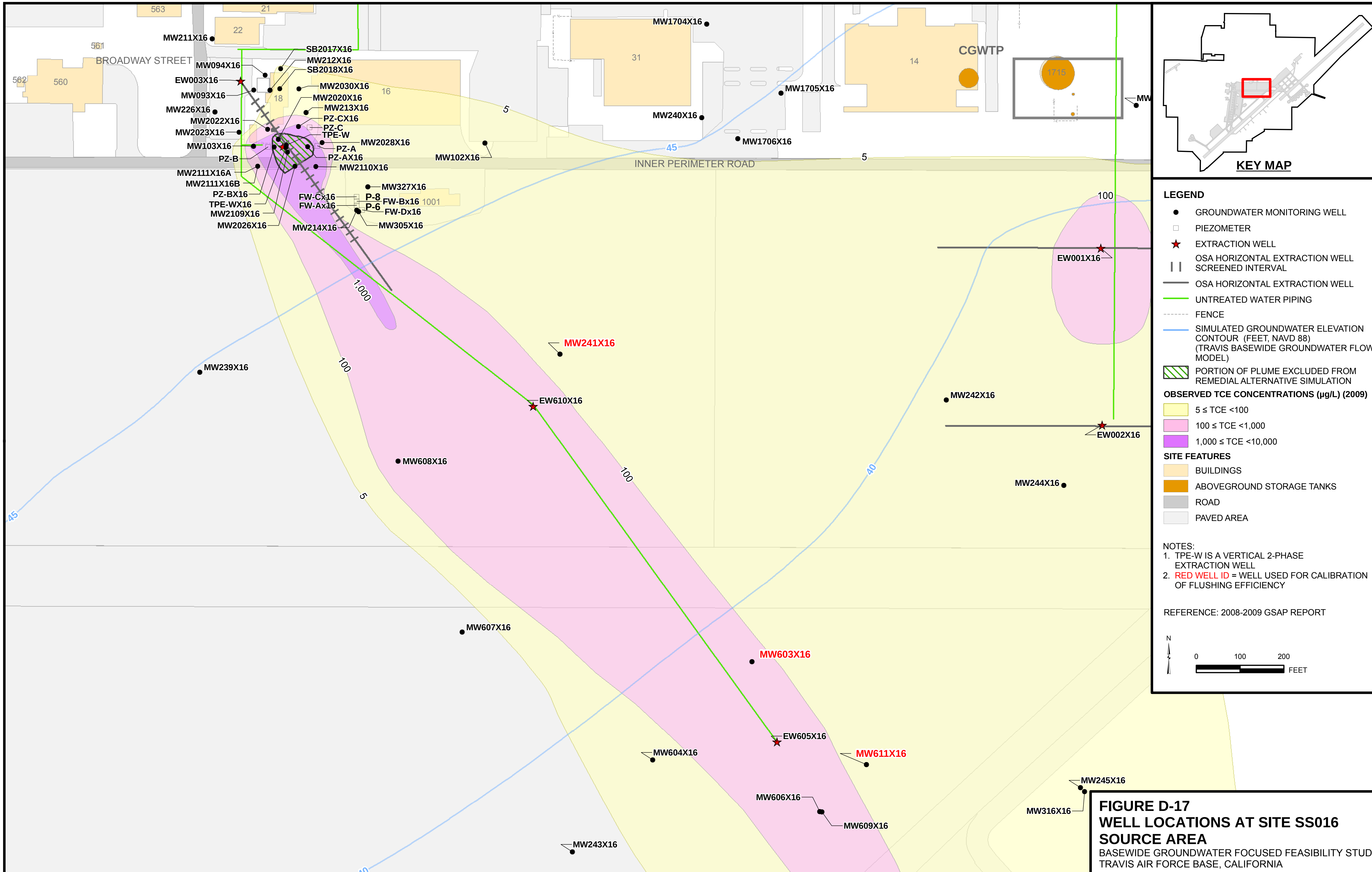
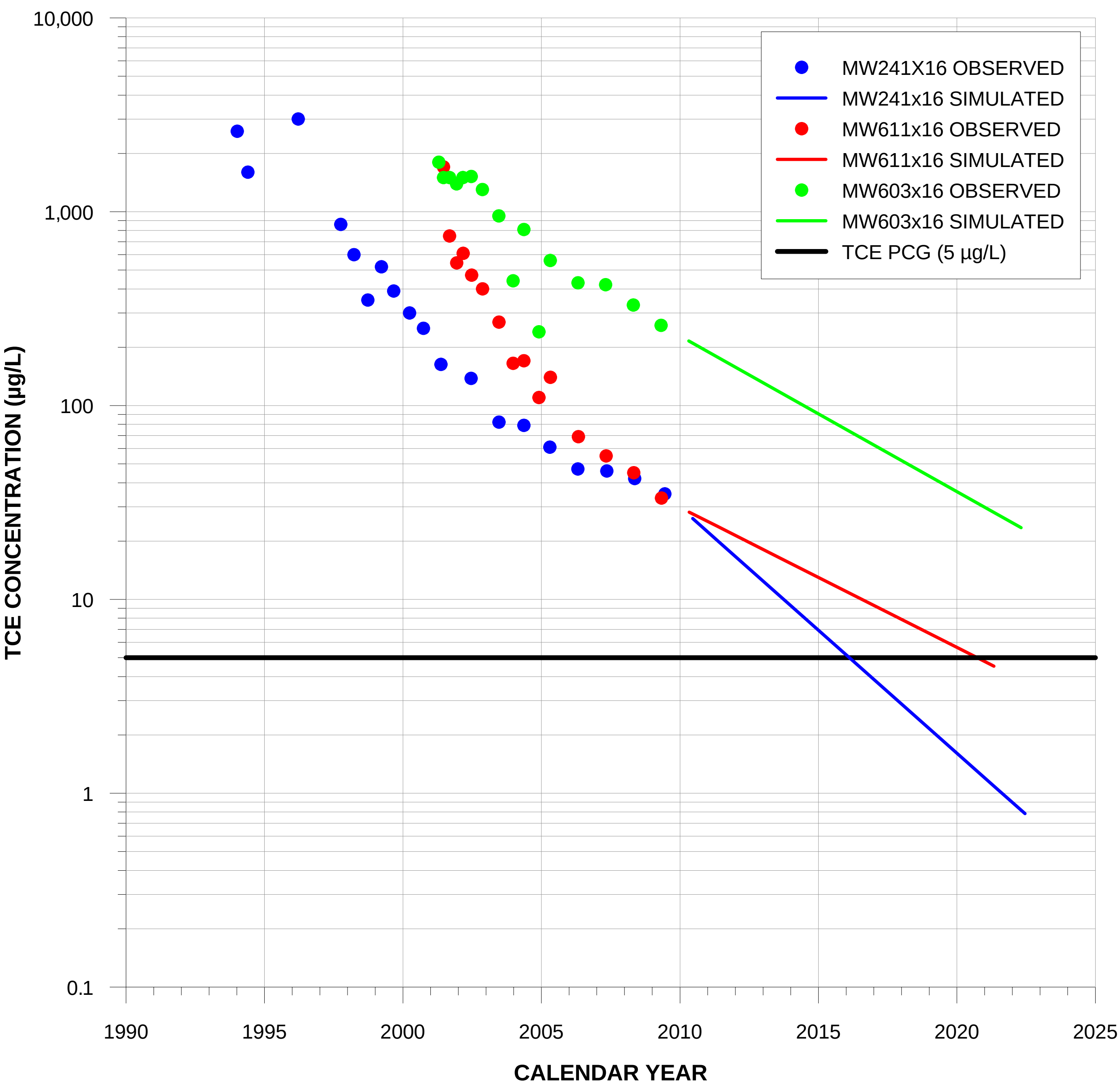


FIGURE D-17
WELL LOCATIONS AT SITE SS016 SOURCE AREA
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_D\FIGD-17_TCE_OSASOURCEAREA_SS016.MXD MCLAY1 1/21/2011 22:09:46



NOTE
FORECASTED CONCENTRATIONS CALCULATED
USING A FLUSHING EFFICIENCY OF 0.6.

FIGURE D-18
HISTORICAL AND FORECASTED TCE CONCENTRATIONS AT MW241x16, MW611x16, AND MW603x16
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-18_SS016_Flushing_Cal.grf

CH2MHILL

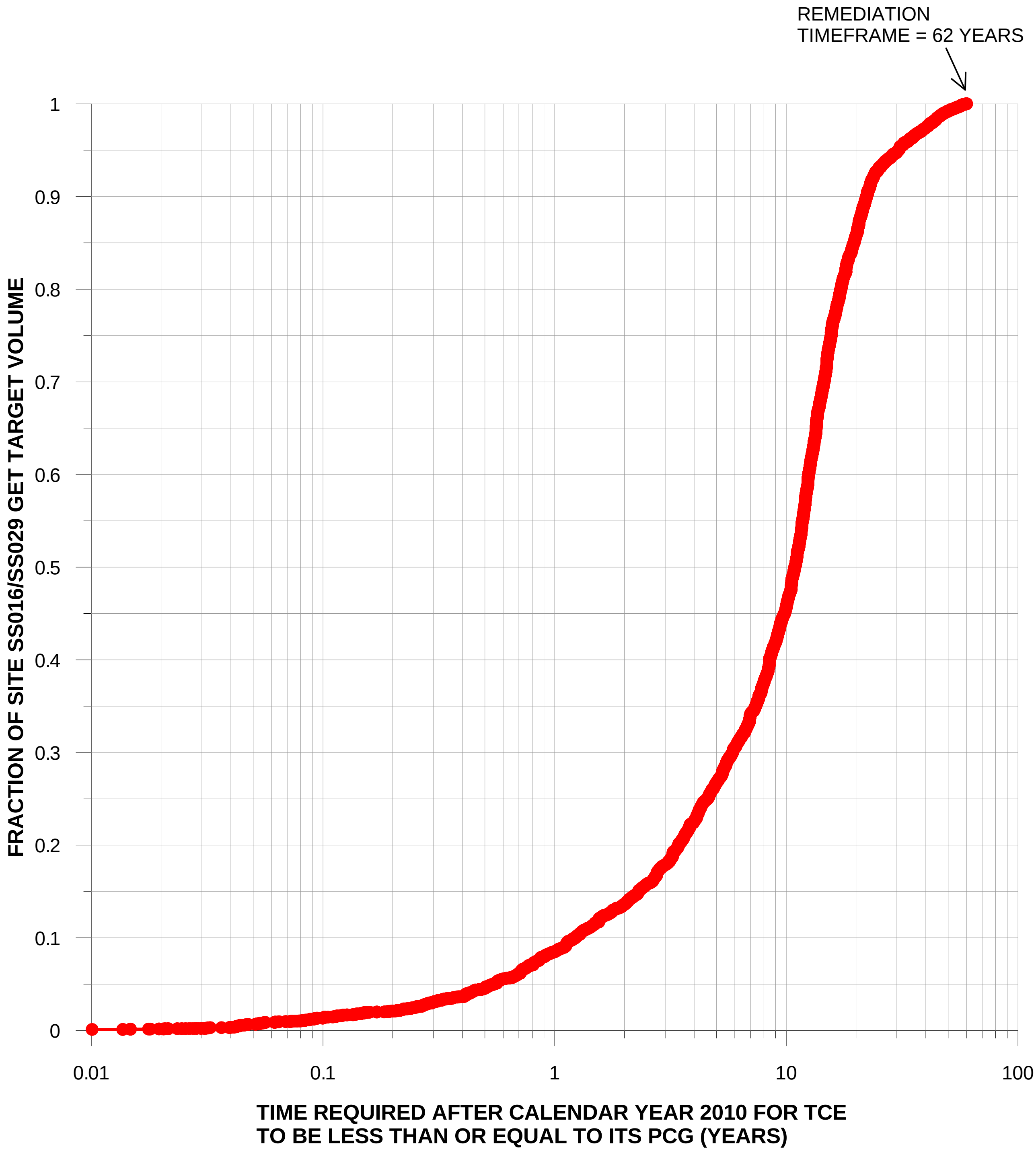
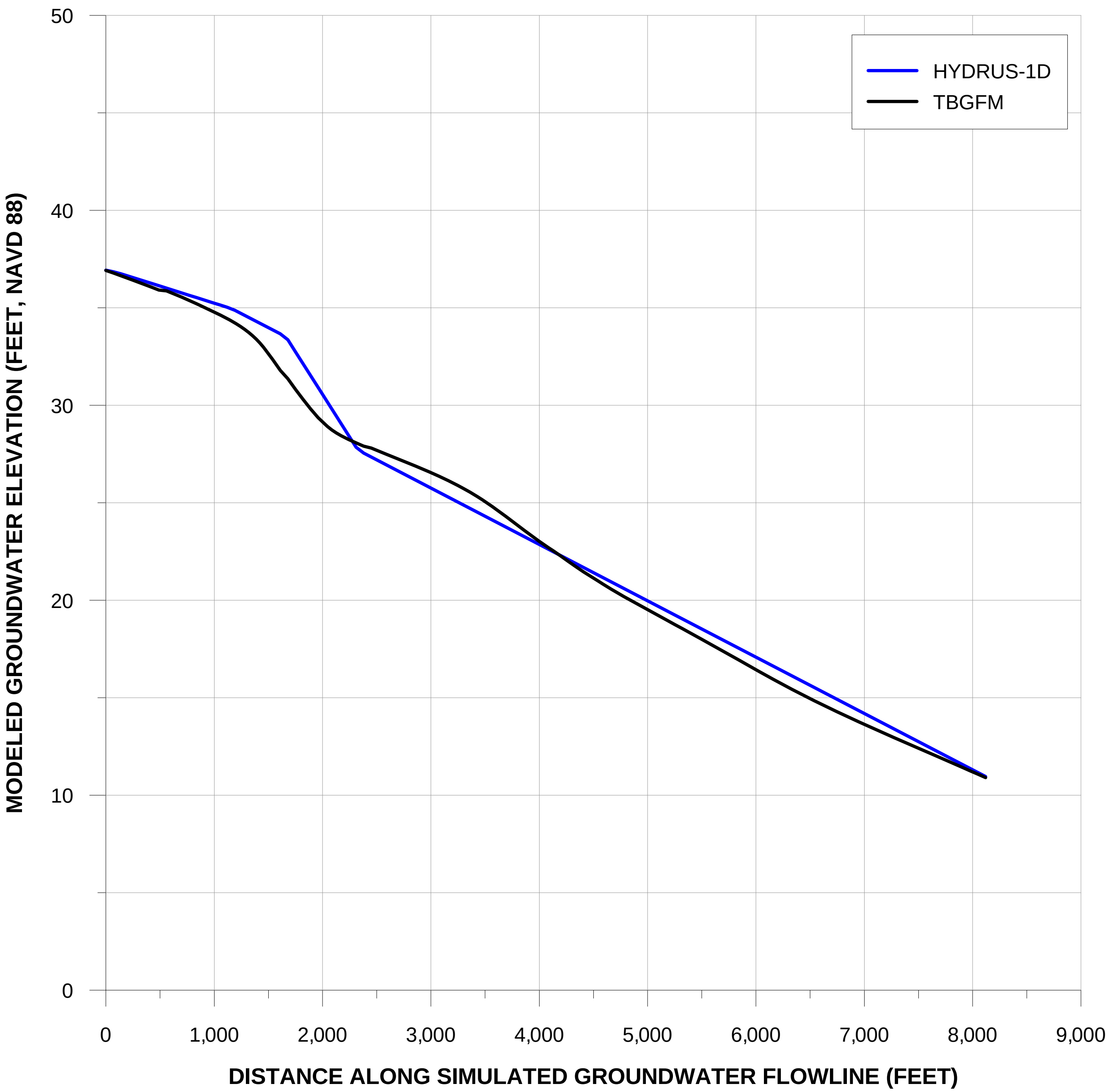


FIGURE D-19
FLUSHING TIME DISTRIBUTION FOR SITE SS016/SS029 GET TARGET VOLUME
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-19_SS016_GET_Cum_TTC.grf



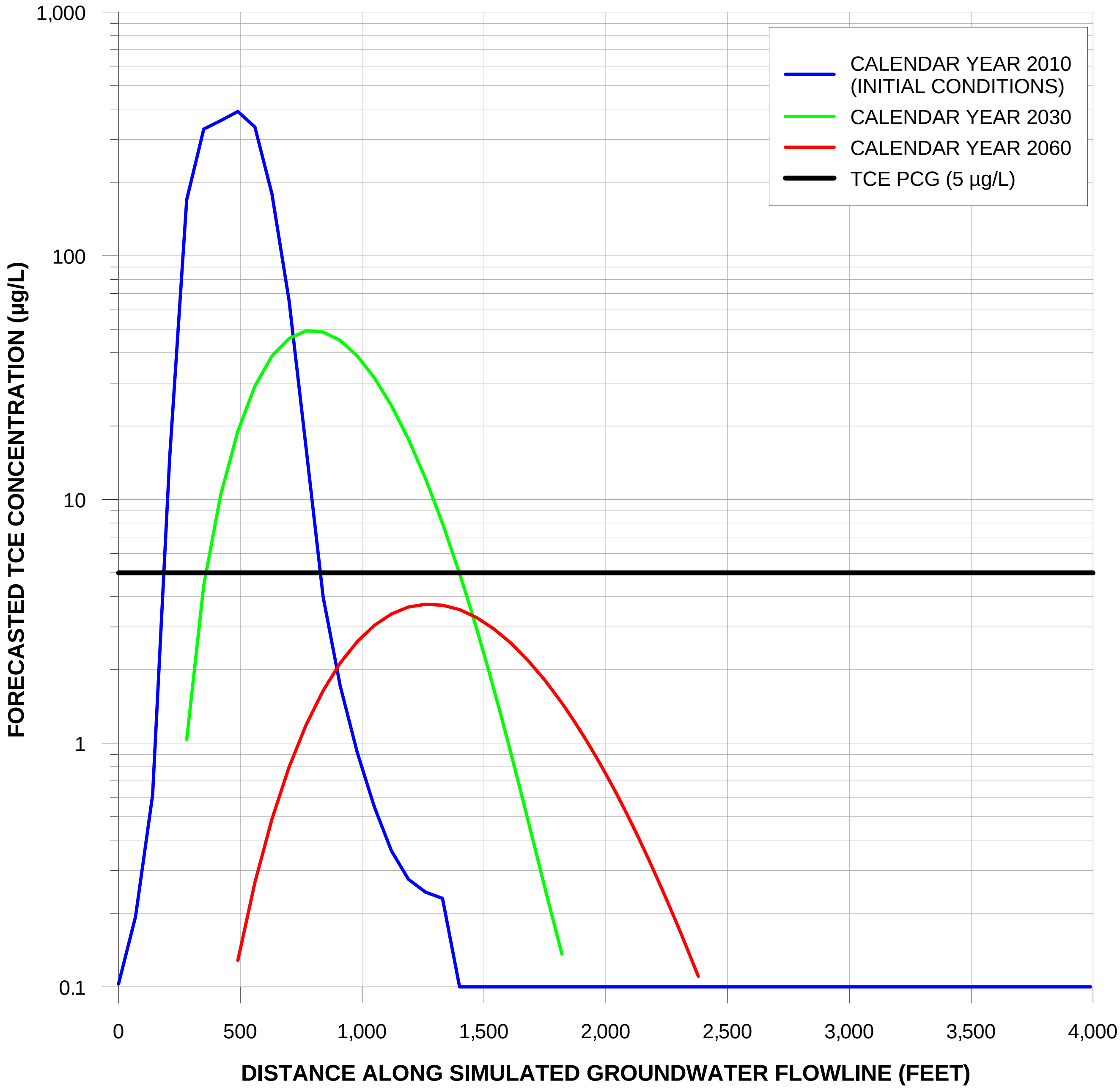
NOTES
1. SIMULATED GROUNDWATER FLOWLINE SHOWN ON FIGURE D-2.
2. TBGFM = TRAVIS BASEWIDE GROUNDWATER FLOW MODEL

FIGURE D-20
COMPARISON OF MODELED GROUNDWATER ELEVATIONS AT SITE ST027B

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-20_ST027B_Head_Comparison.grf

CH2MHILL



NOTE
SITE ST027B SIMULATED GROUNDWATER FLOWLINE SHOWN ON FIGURE D-2.

FIGURE D-21
FORECASTED SITE ST027B TCE CONCENTRATIONS UNDER REMEDIAL ALTERNATIVE CONDITIONS
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-21_ST027_Conc_vs_Distance.grf

CH2MHILL

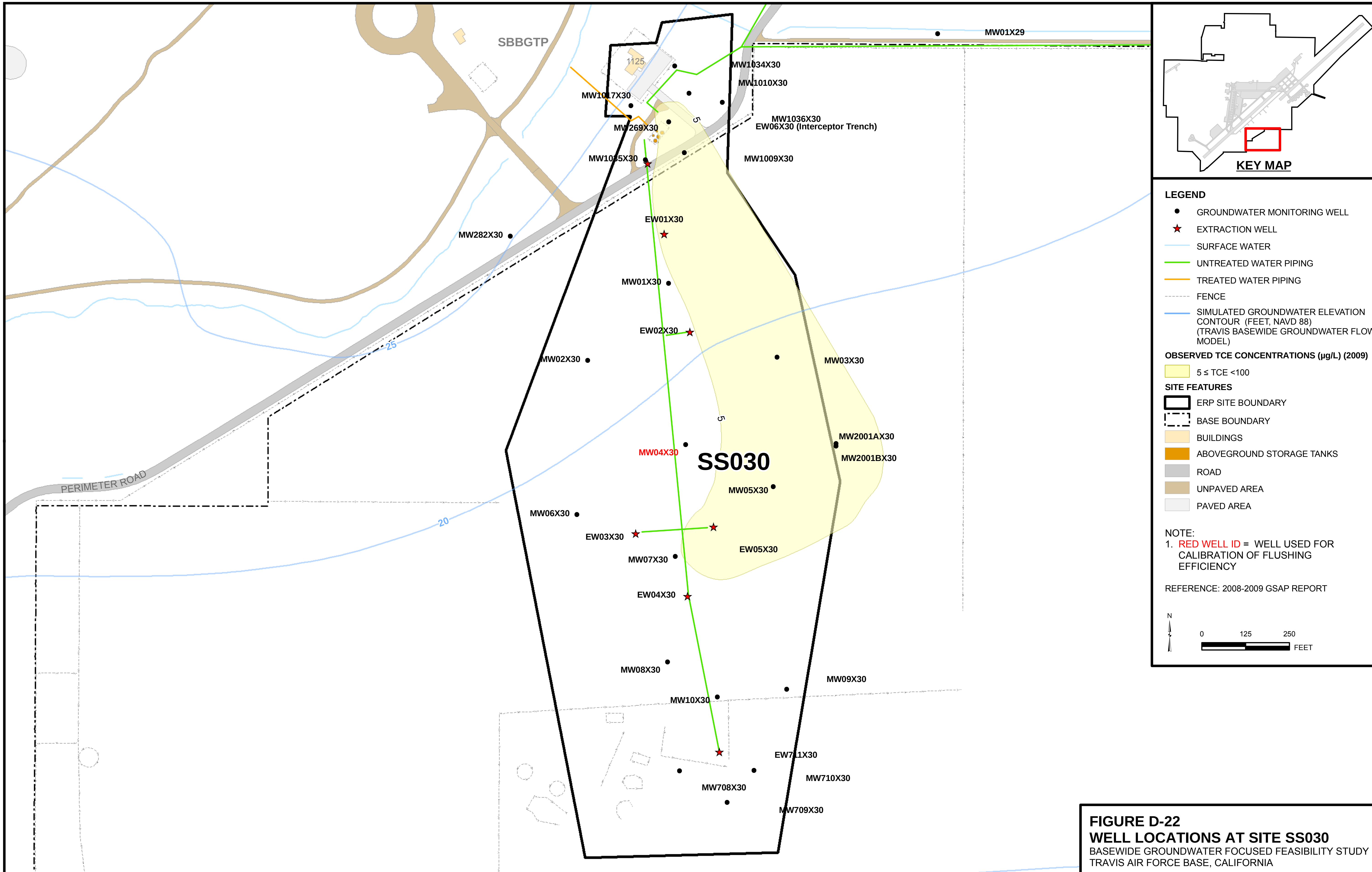
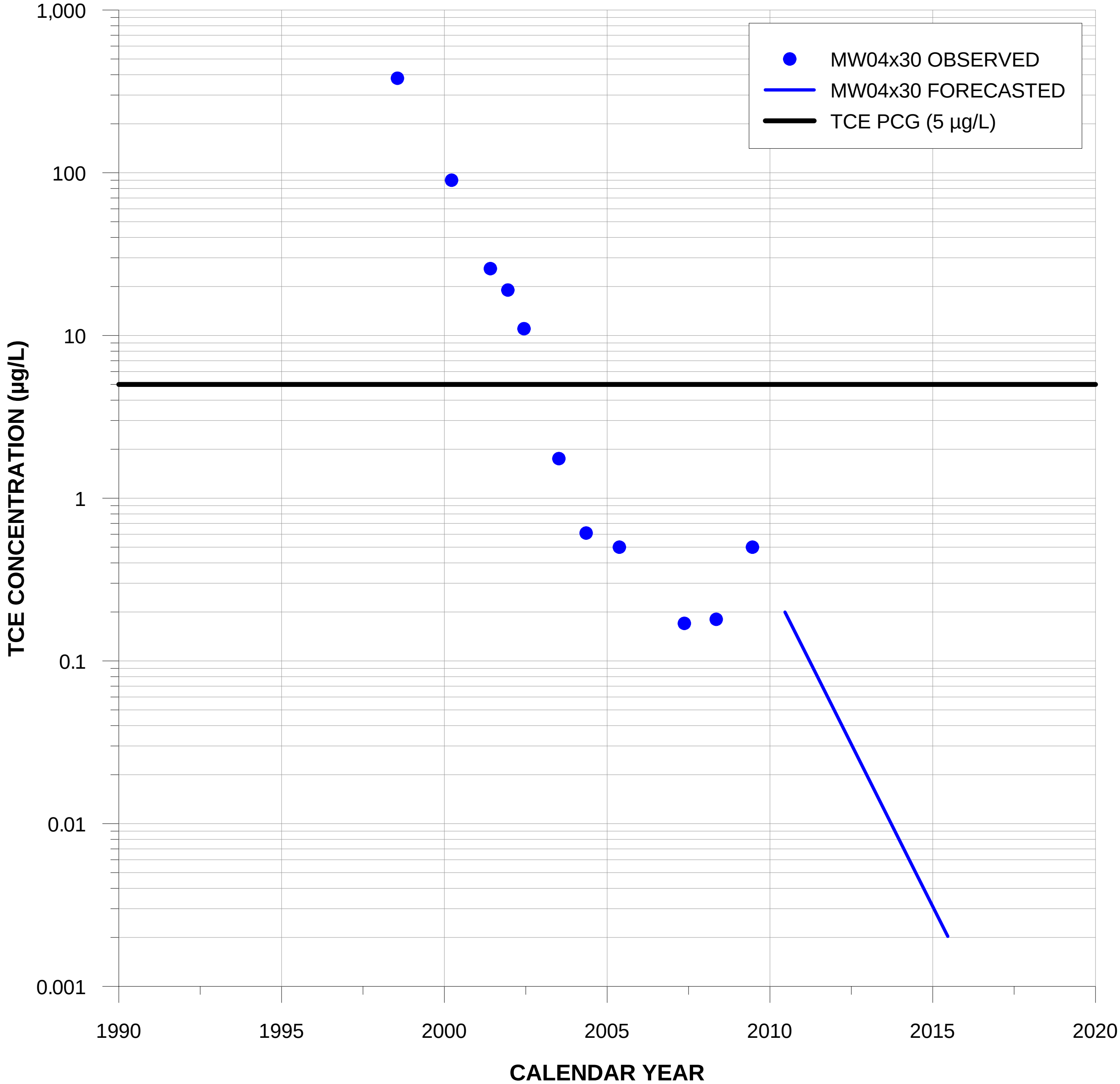


FIGURE D-22
WELL LOCATIONS AT SITE SS030
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_D\FIGD-22_WELLS_SS030.MXD MCLAY1 1/21/2011 22:27:41



NOTE
FORECASTED CONCENTRATIONS CALCULATED USING A FLUSHING EFFICIENCY OF 0.3.

FIGURE D-23
HISTORICAL AND FORECASTED TCE CONCENTRATIONS AT MW04x30
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-23_SS030_Flushing_Cal.grf

CH2MHILL

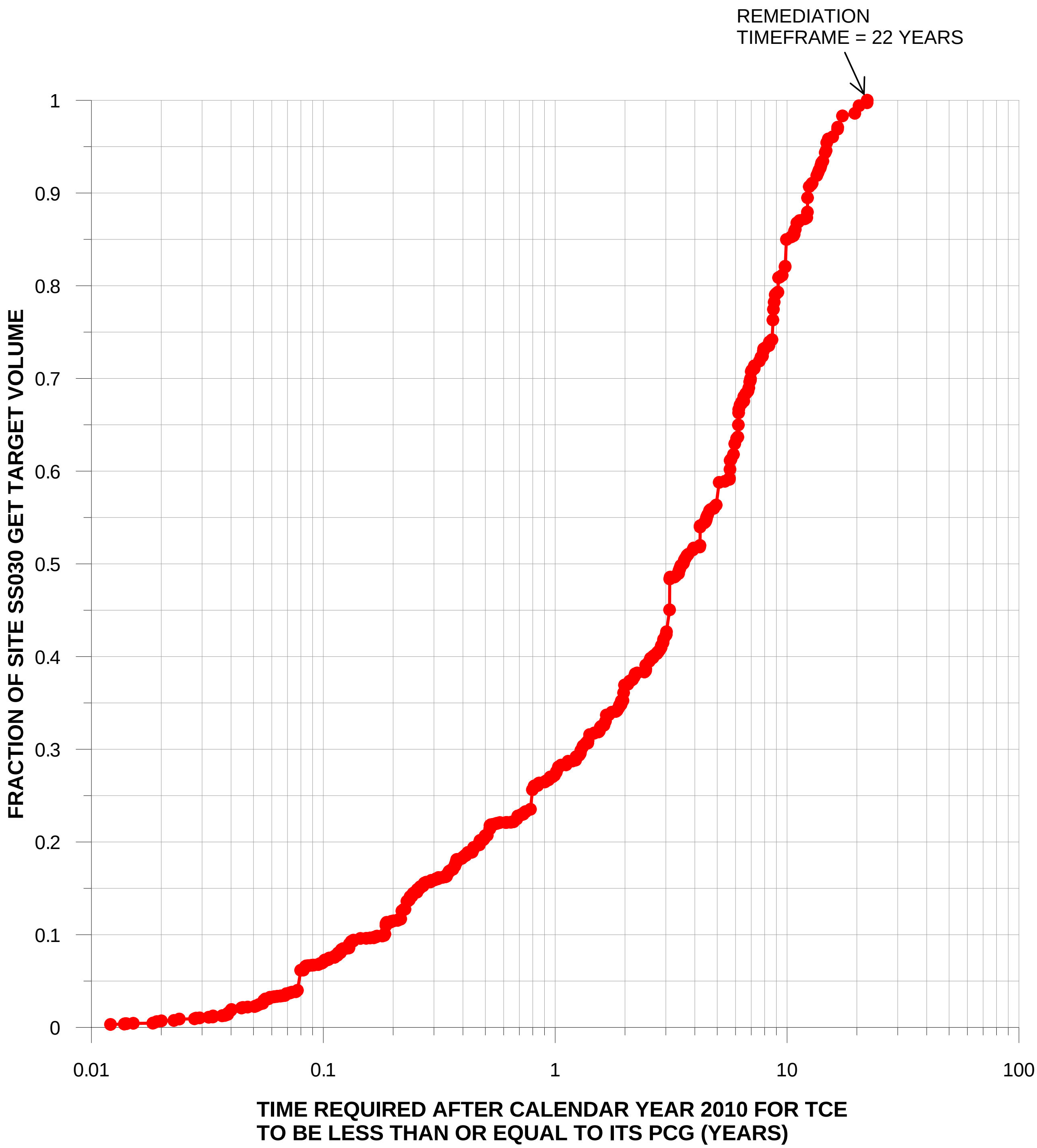
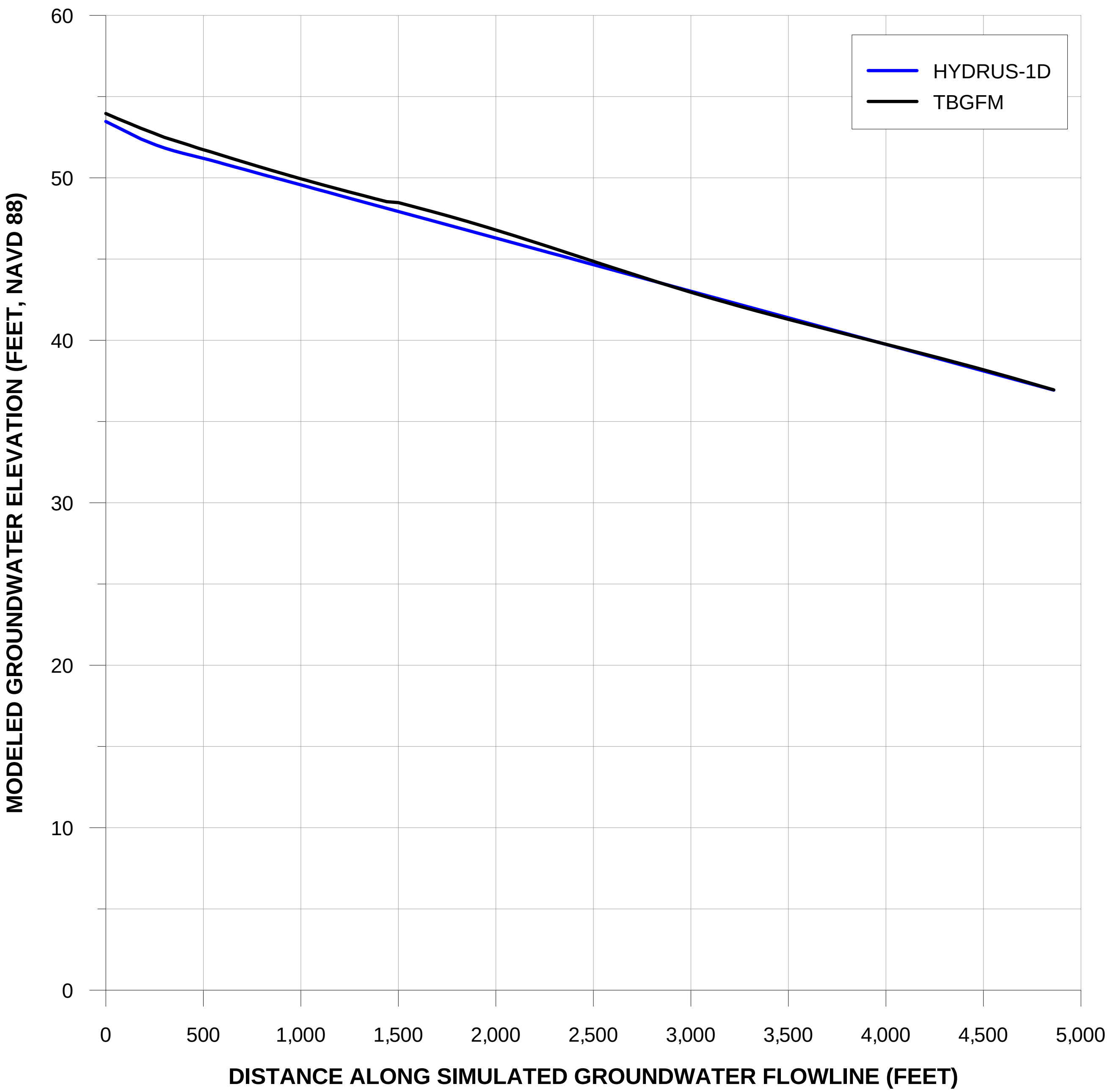


FIGURE D-24
FLUSHING TIME DISTRIBUTION FOR THE SITE SS030 GET TARGET VOLUME
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-24_SS030_GET_Cum_TTC.grf

CH2MHILL

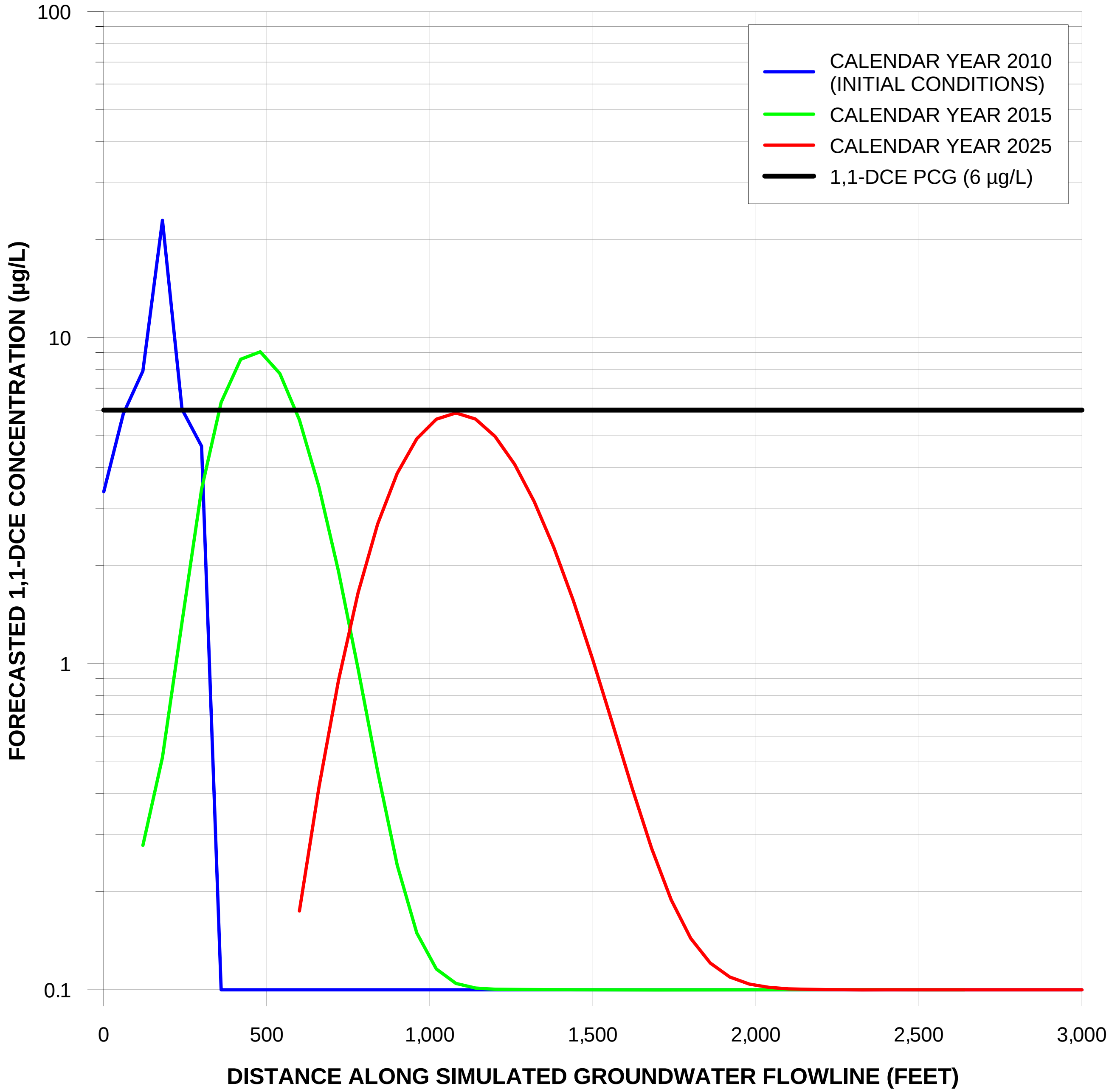


NOTES
1. SIMULATED GROUNDWATER FLOWLINE SHOWN ON FIGURE D-2.
2. TBGFM = TRAVIS BASEWIDE GROUNDWATER FLOW MODEL

FIGURE D-25
COMPARISON OF MODELED GROUNDWATER ELEVATIONS AT SITE SD031
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-25_SD031_Head_Comparison.grf

CH2MHILL



NOTE
SITE SD031 SIMULATED GROUNDWATER FLOWLINE SHOWN ON FIGURE D-2.

FIGURE D-26
FORECASTED SITE SD031 1,1-DCE CONCENTRATIONS UNDER REMEDIAL ALTERNATIVE CONDITIONS

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-26_SD031_Conc_vs_Distance.grf

CH2MHILL

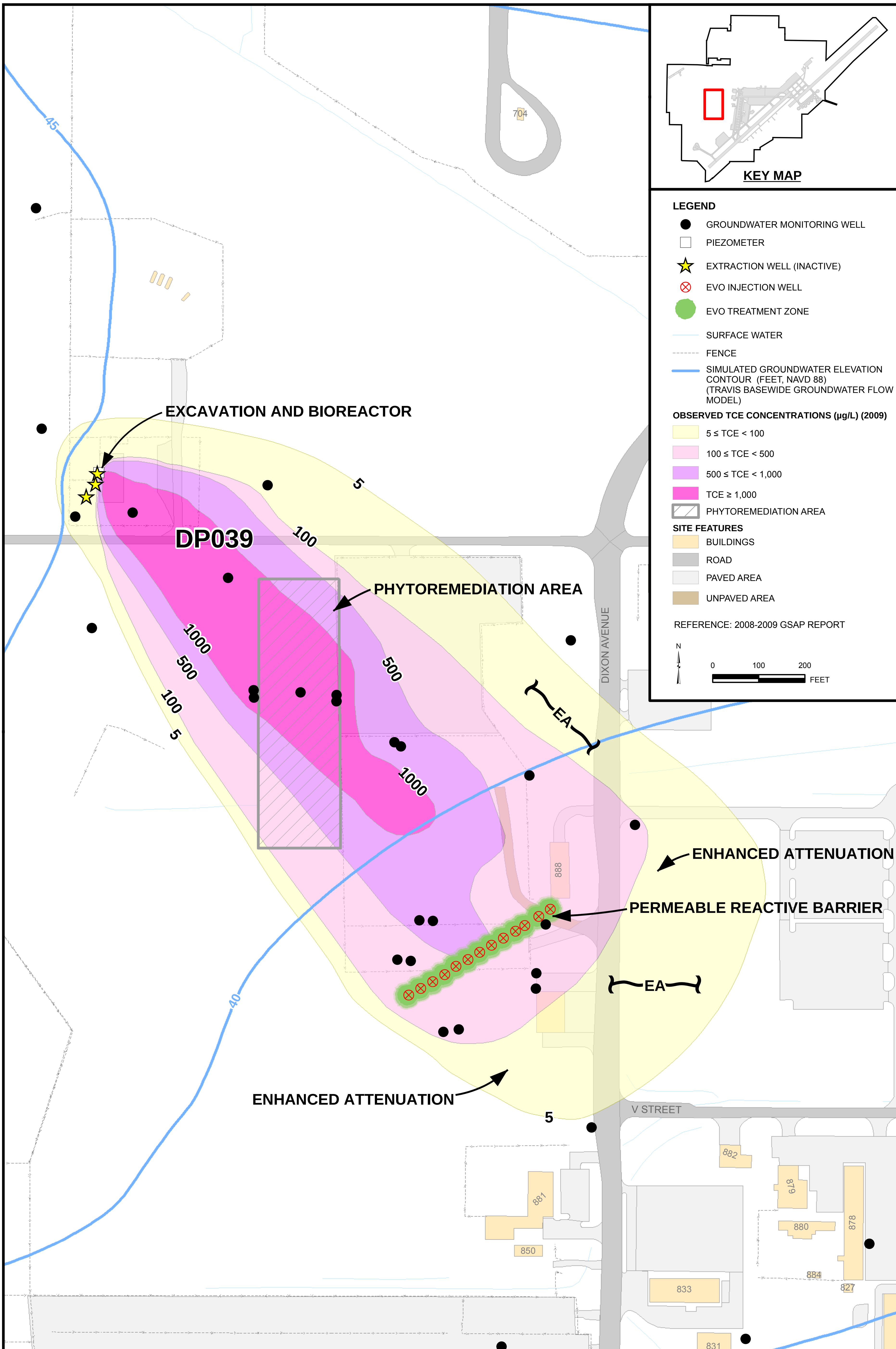


FIGURE D-27
SITE DP039 CONCEPTUAL DESIGN ALTERNATIVE 6
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_D\FIGD-27_TCE_CONCEPTUALDESIGN_DP039.MXD MCLAY1 1/22/2011 20:47:56

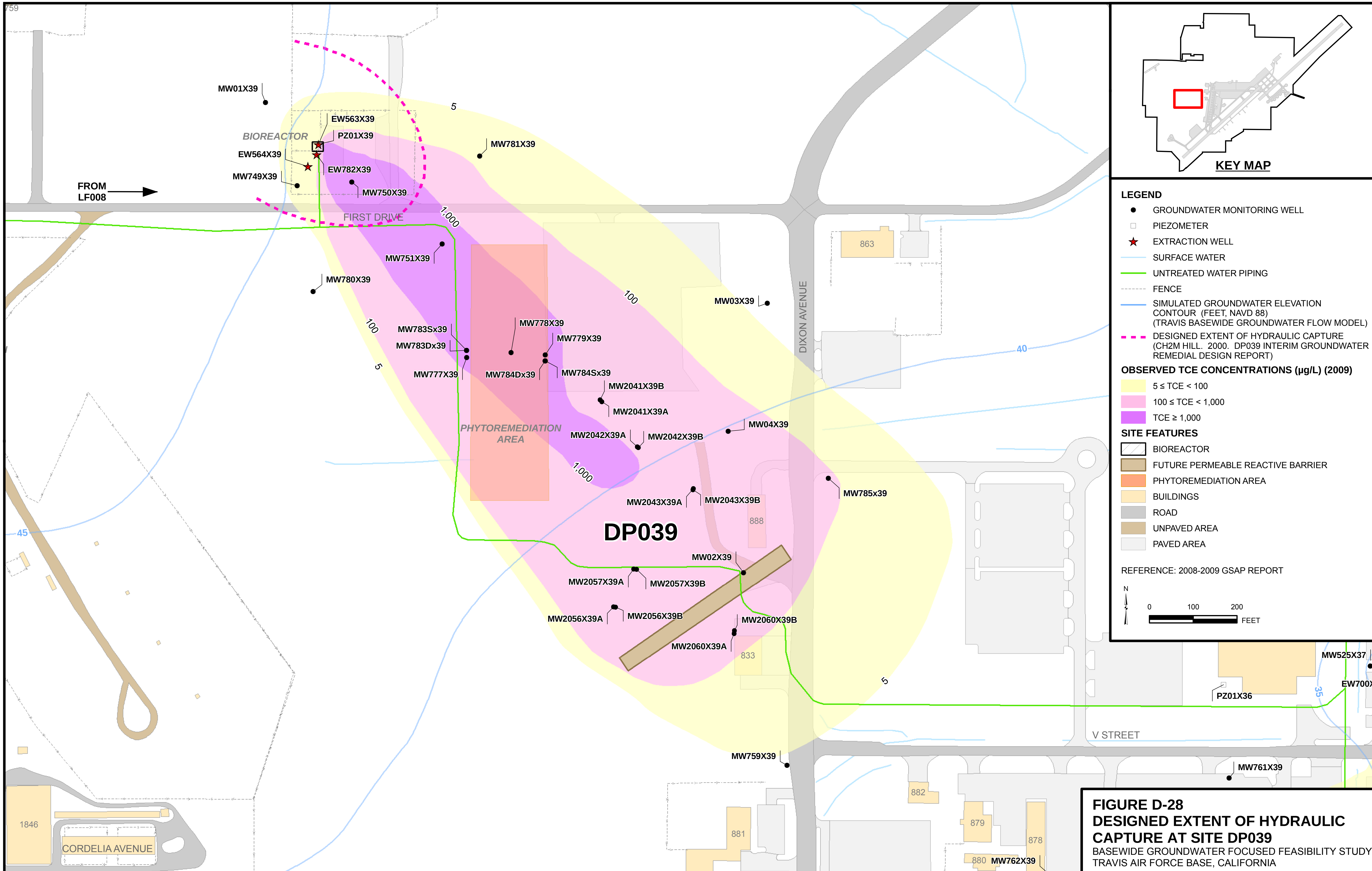


FIGURE D-28
DESIGNED EXTENT OF HYDRAULIC CAPTURE AT SITE DP039
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_D\FIGD-28_WELLS_DP039.MXD MCLAY1 1/21/2011 22:49:15

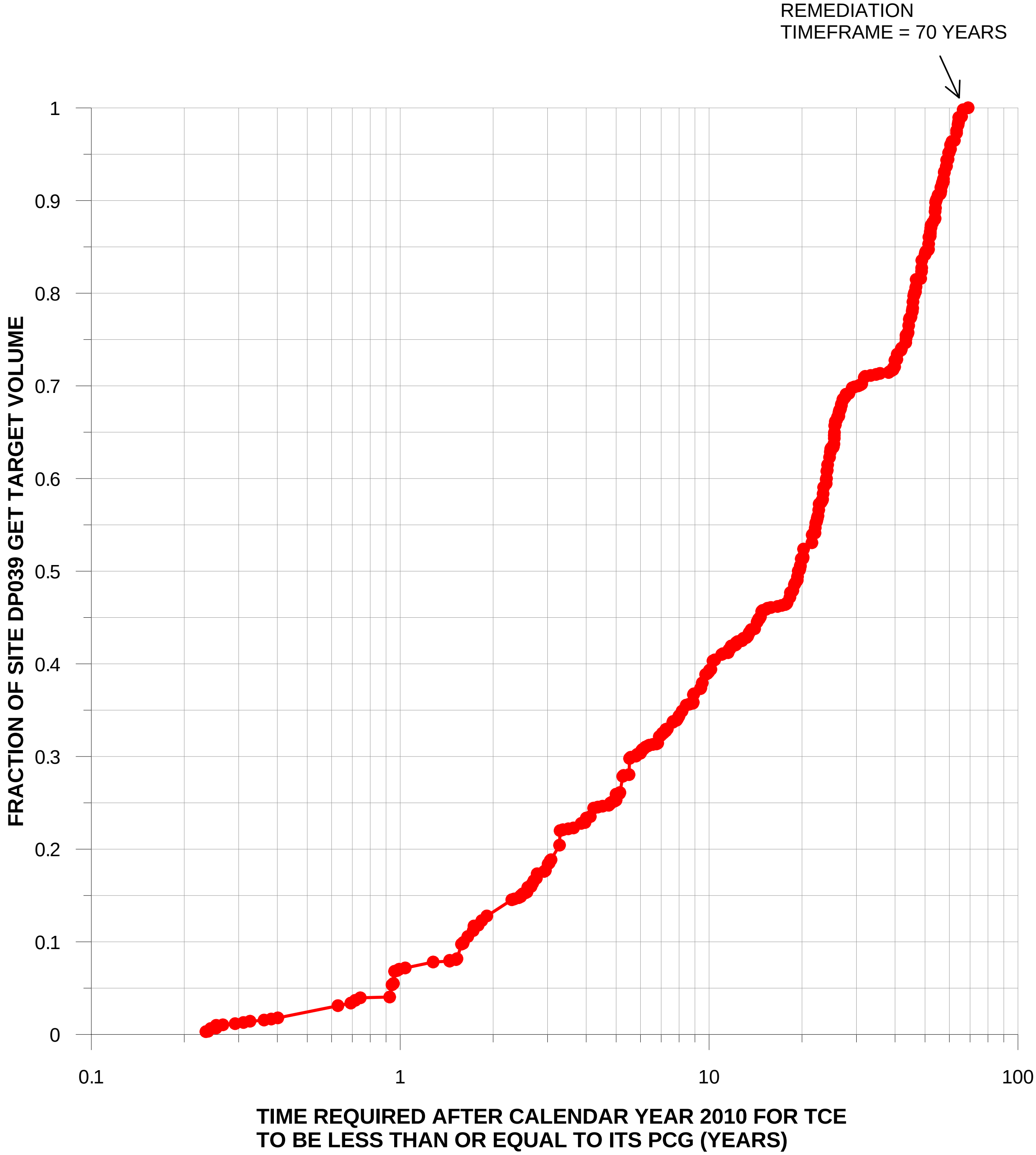
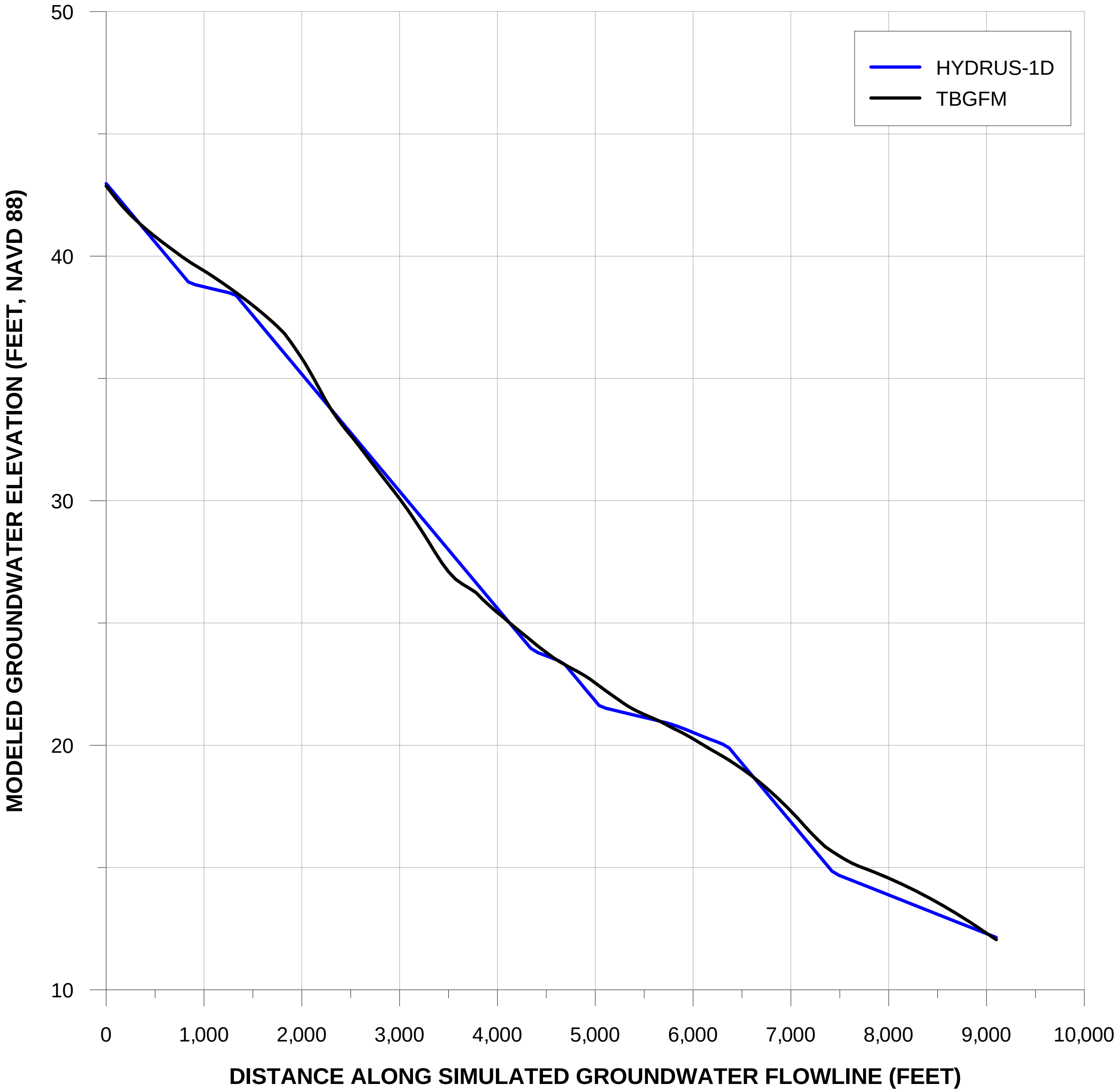


FIGURE D-29
FLUSHING TIME DISTRIBUTION FOR THE SITE DP039 GET TARGET VOLUME
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-29_DP039_GET_Cum_TTC.grf

CH2MHILL



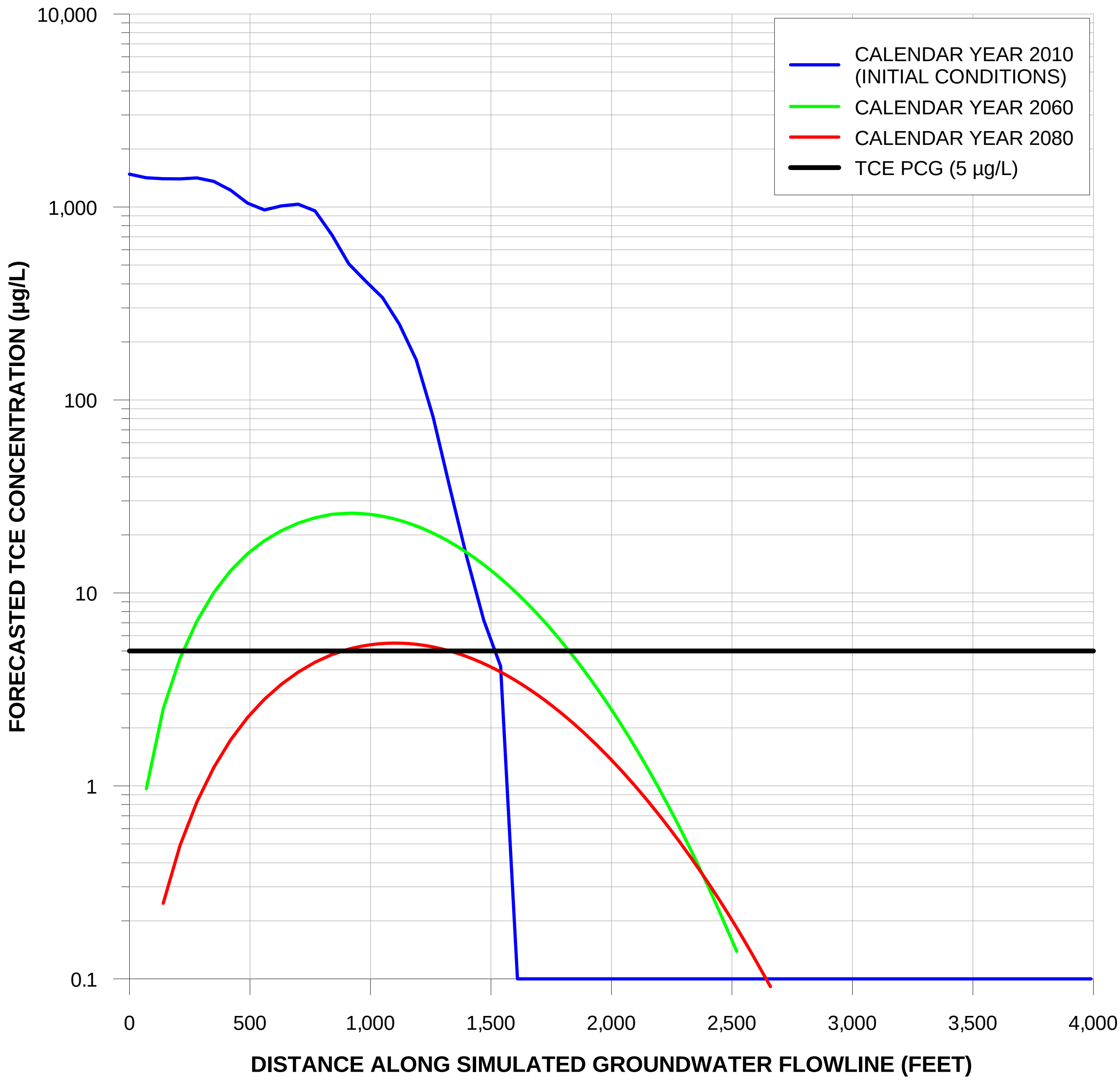
NOTES
1. SIMULATED GROUNDWATER FLOWLINE SHOWN ON FIGURE D-2.
2. TBGFM = TRAVIS BASEWIDE GROUNDWATER FLOW MODEL

FIGURE D-30
COMPARISON OF MODELED GROUNDWATER ELEVATIONS AT SITE DP039

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-30_DP039_Head_Comparison.grf

CH2MHILL



NOTE
SITE DP039 SIMULATED GROUNDWATER FLOWLINE SHOWN ON FIGURE D-2.

FIGURE D-31
FORECASTED SITE DP039 TCE CONCENTRATIONS UNDER INTERIM REMEDIAL ACTION CONDITIONS
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-31_DP039_GET_MNA.grf

CH2MHILL

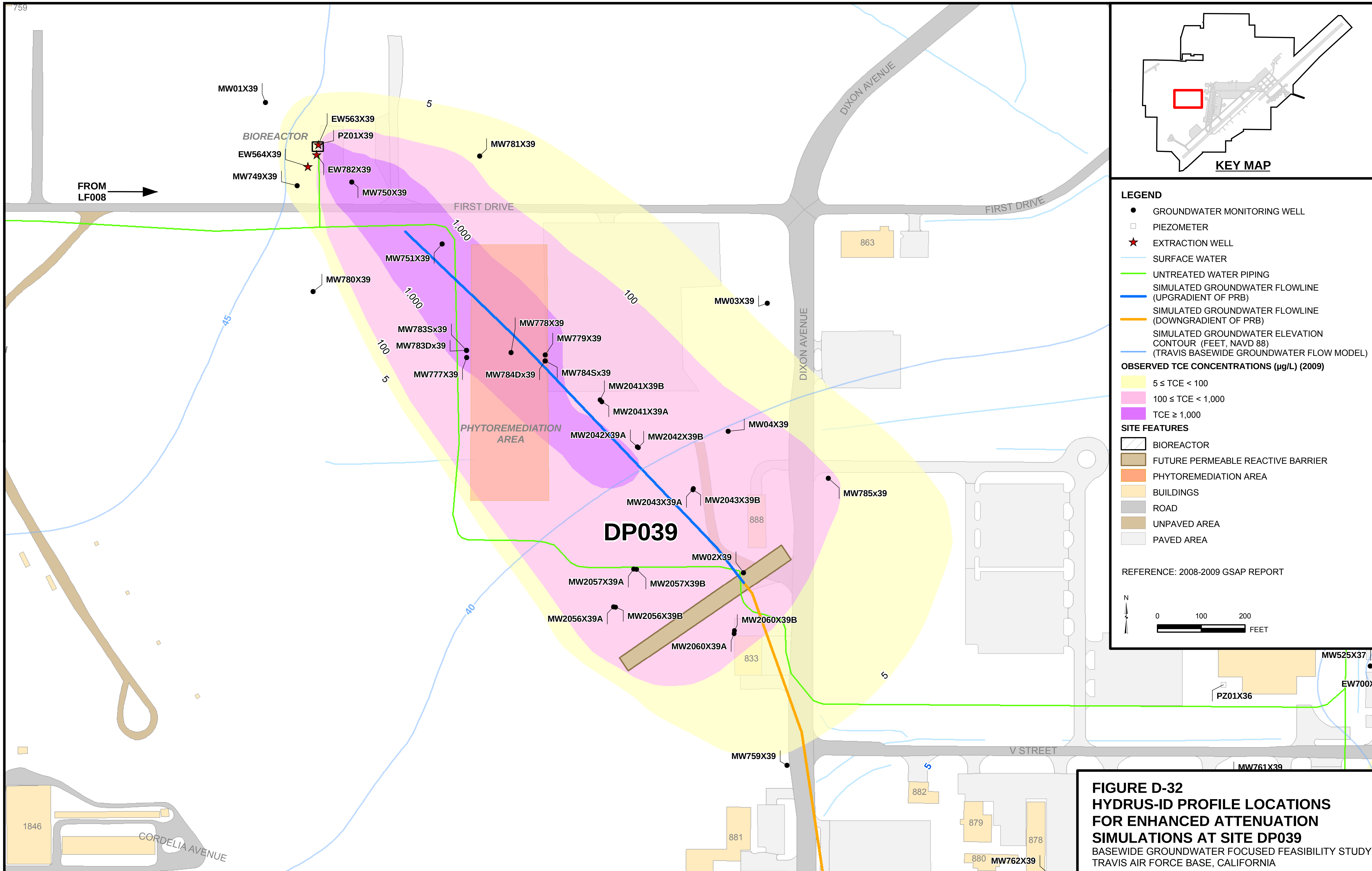


FIGURE D-32
HYDRUS-ID PROFILE LOCATIONS FOR ENHANCED ATTENUATION SIMULATIONS AT SITE DP039

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_D\FIGD-32_FLOW_DP039.MXD MCLAY1 1/22/2011 00:34:12

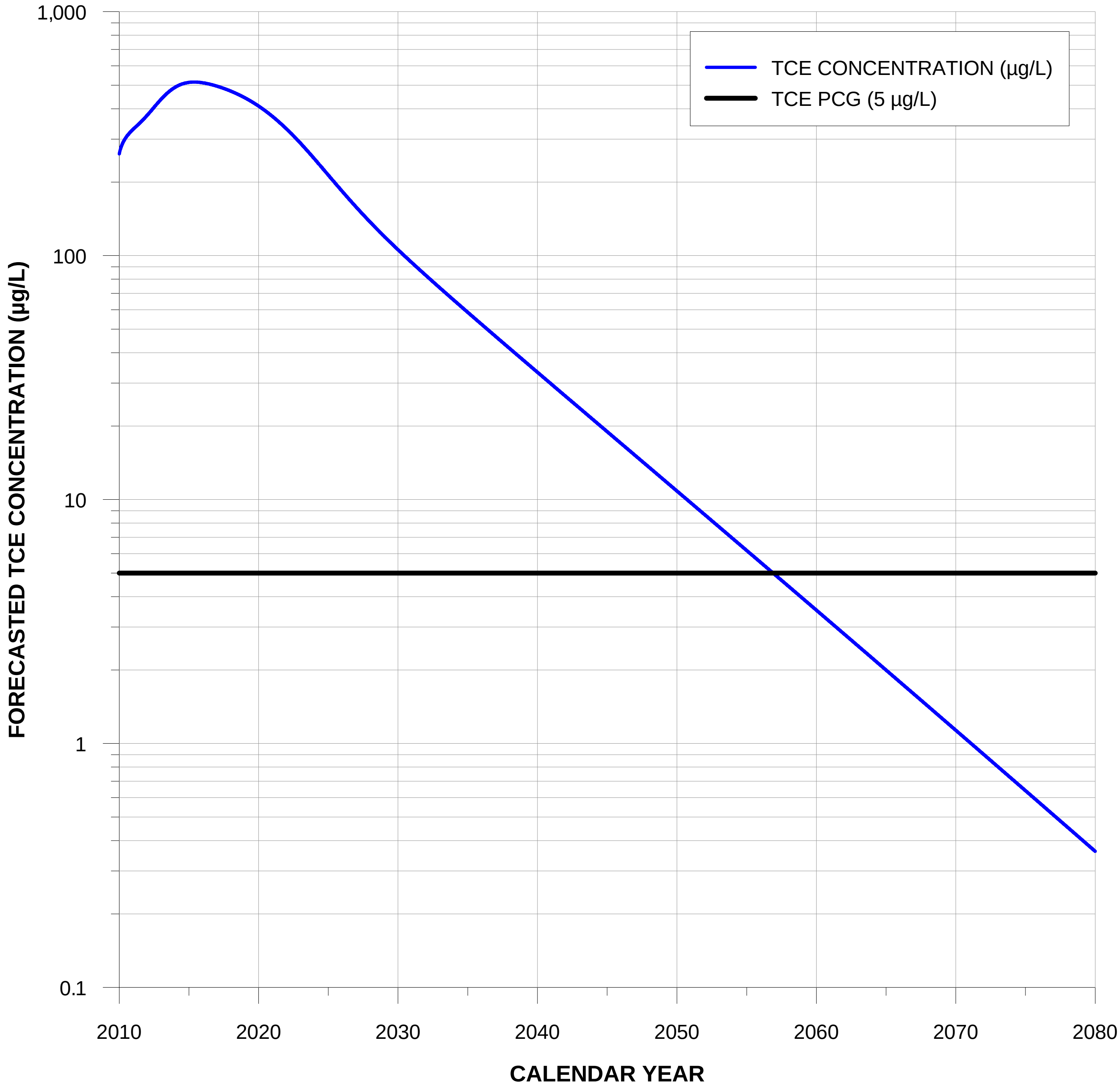
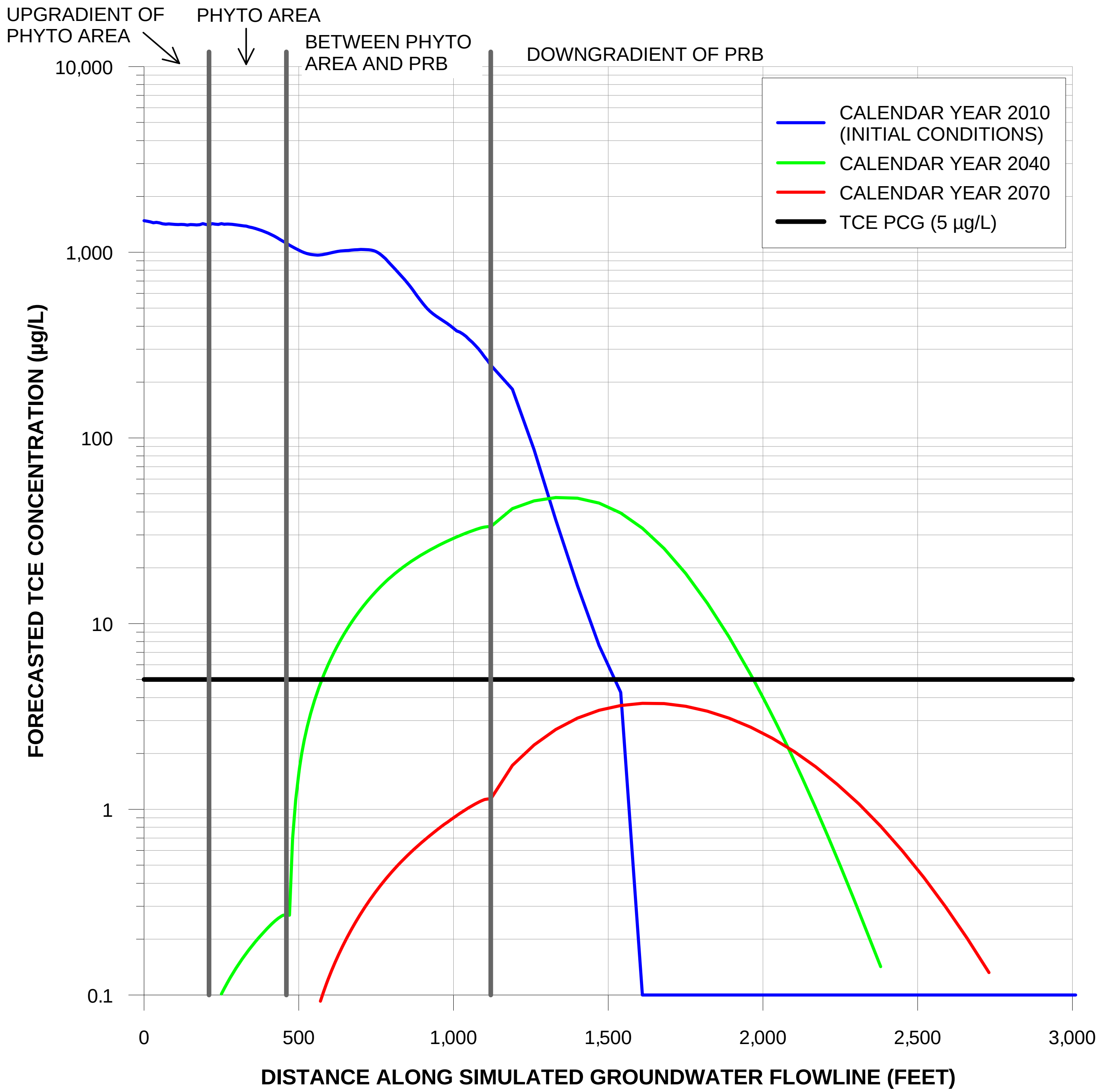


FIGURE D-33
FORECASTED TCE CONCENTRATION ENTERING THE SITE DP039 PERMEABLE REACTIVE BIOBARRIER
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-33_DP039_ObsNode_Output_v2_from_3_model_subsection.grf

CH2MHILL



NOTE
SITE DP039 SIMULATED GROUNDWATER FLOWLINE SHOWN ON FIGURE D-2 and D-32.

FIGURE D-34
FORECASTED SITE DP039 TCE CONCENTRATIONS UNDER REMEDIAL ALTERNATIVE CONDITIONS

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-34_DP039_MNA_PostRem_v2_from_3_model_subsections.grf

CH2MHILL

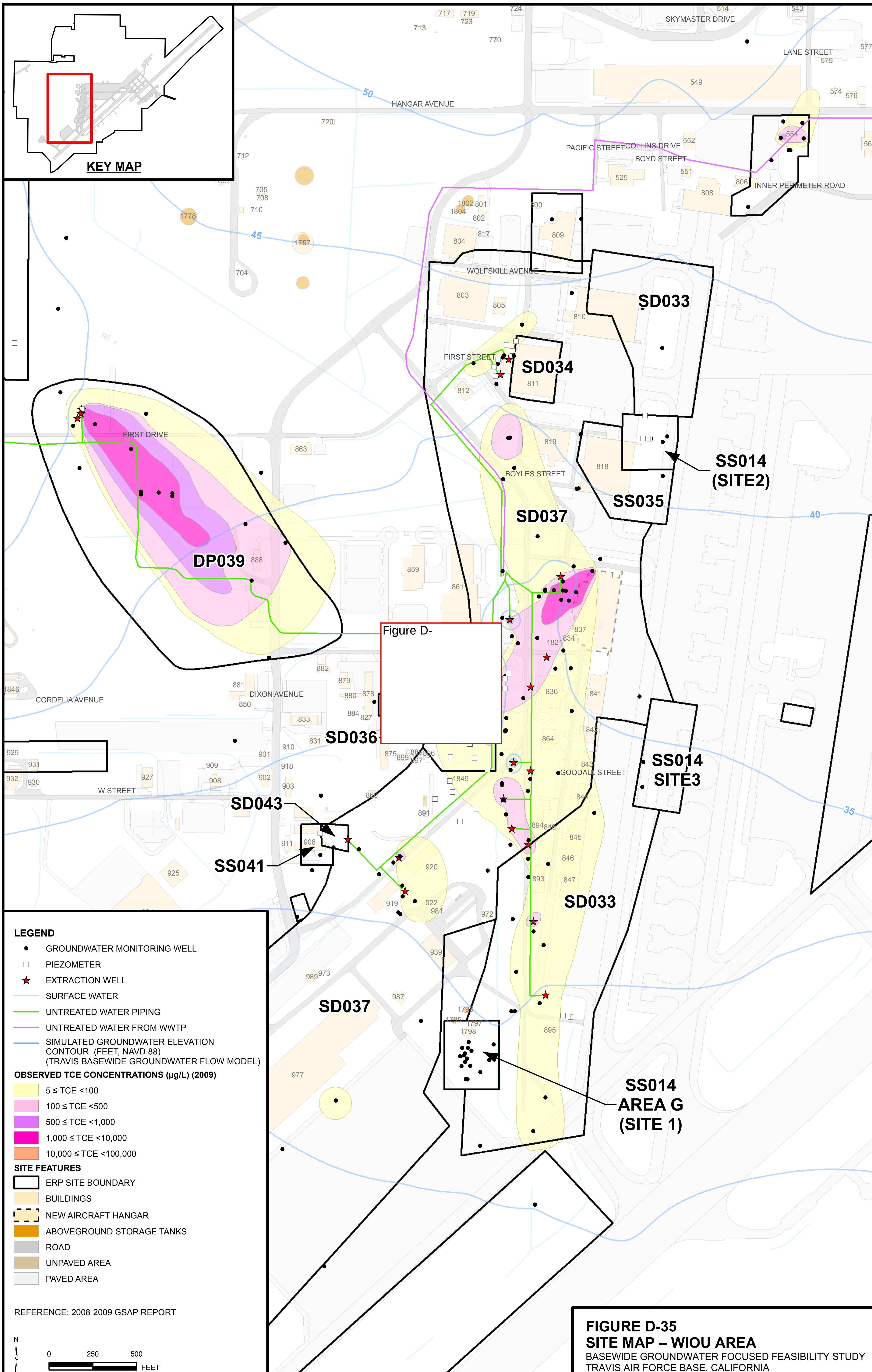


FIGURE D-35
SITE MAP – WIOU AREA
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_D\FIGD-35_WIOU_SITE.MXD MCLAY1 1/21/2011 23:19:21

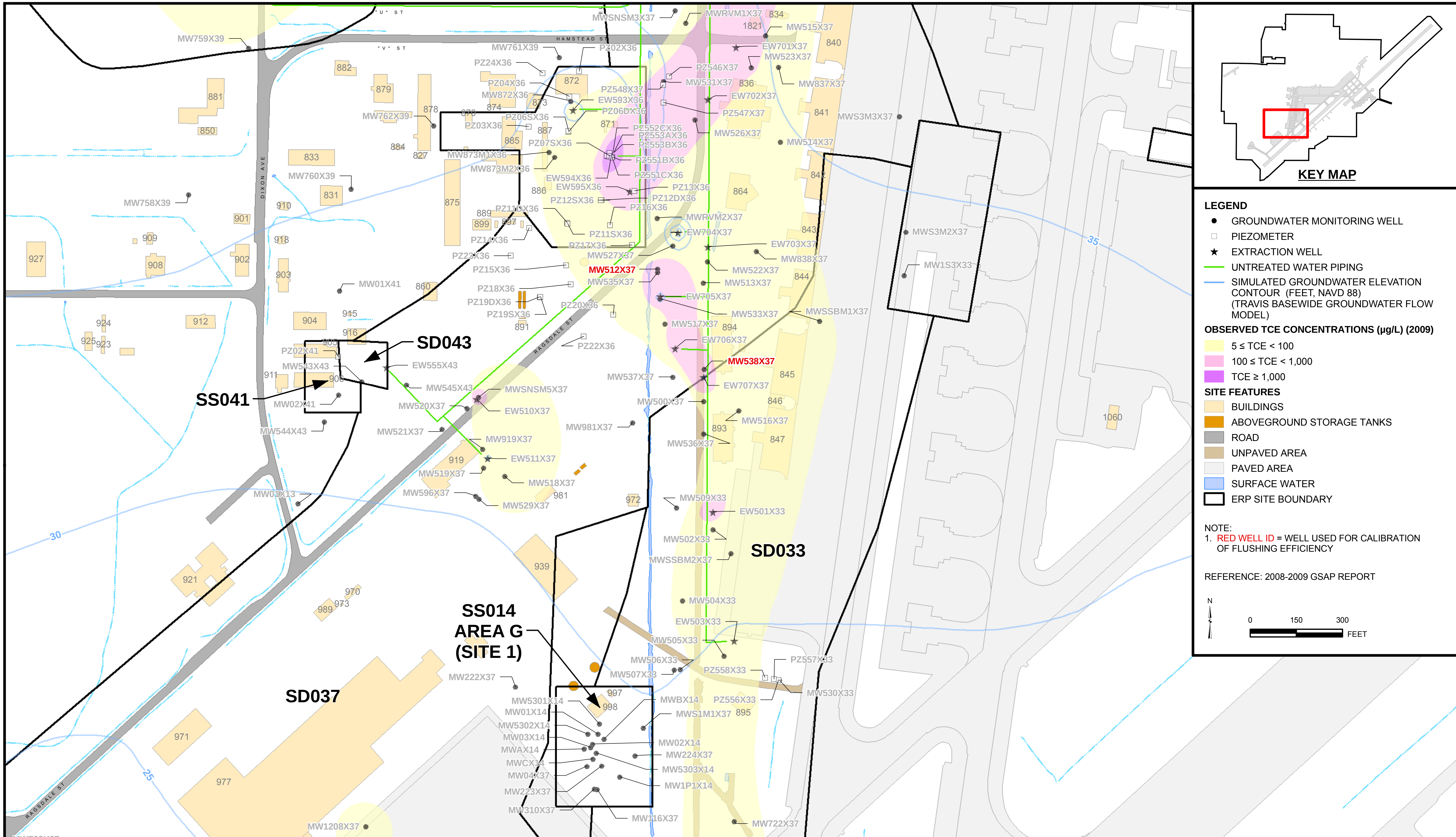
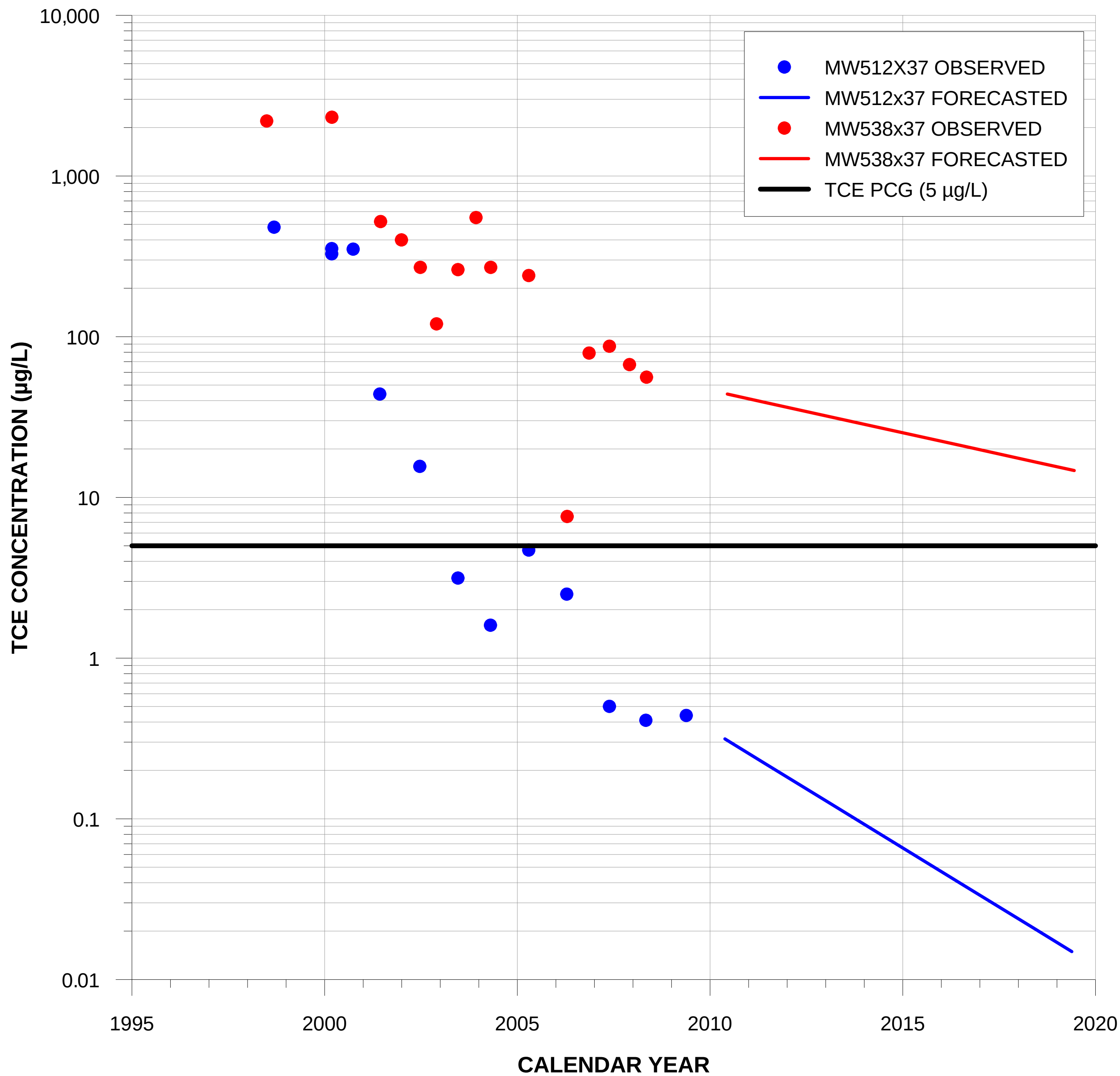


FIGURE D-36
WELL LOCATIONS AT WIOU
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA
CH2MHILL

RDD \\BALDUR\PROJ\TRAVIS\381355_FOCUSEDFEASIBILITYREPORT_SEPT2010\MAPFILES\APPENDIX_D\FIGD-36_WIOU_WELL.MXD MCLAY1 1/21/2011 23:33:43



NOTE
FORECASTED CONCENTRATIONS CALCULATED
USING A FLUSHING EFFICIENCY OF 0.5.

FIGURE D-37
HISTORICAL AND FORECASTED TCE CONCENTRATIONS AT MW512x37 AND MW538x37
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-37_WIOU_Flushing_Cal.grf

CH2MHILL

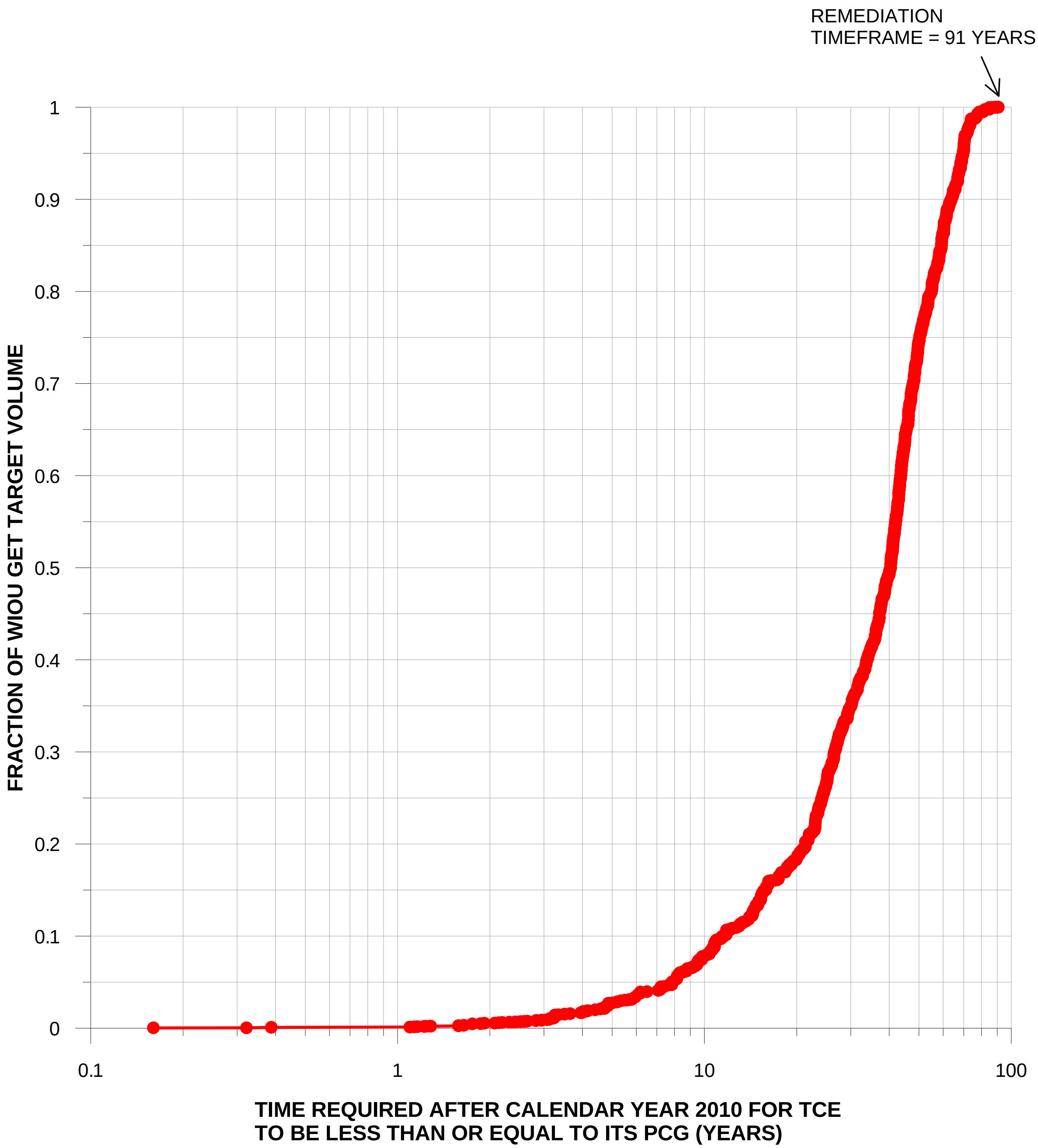
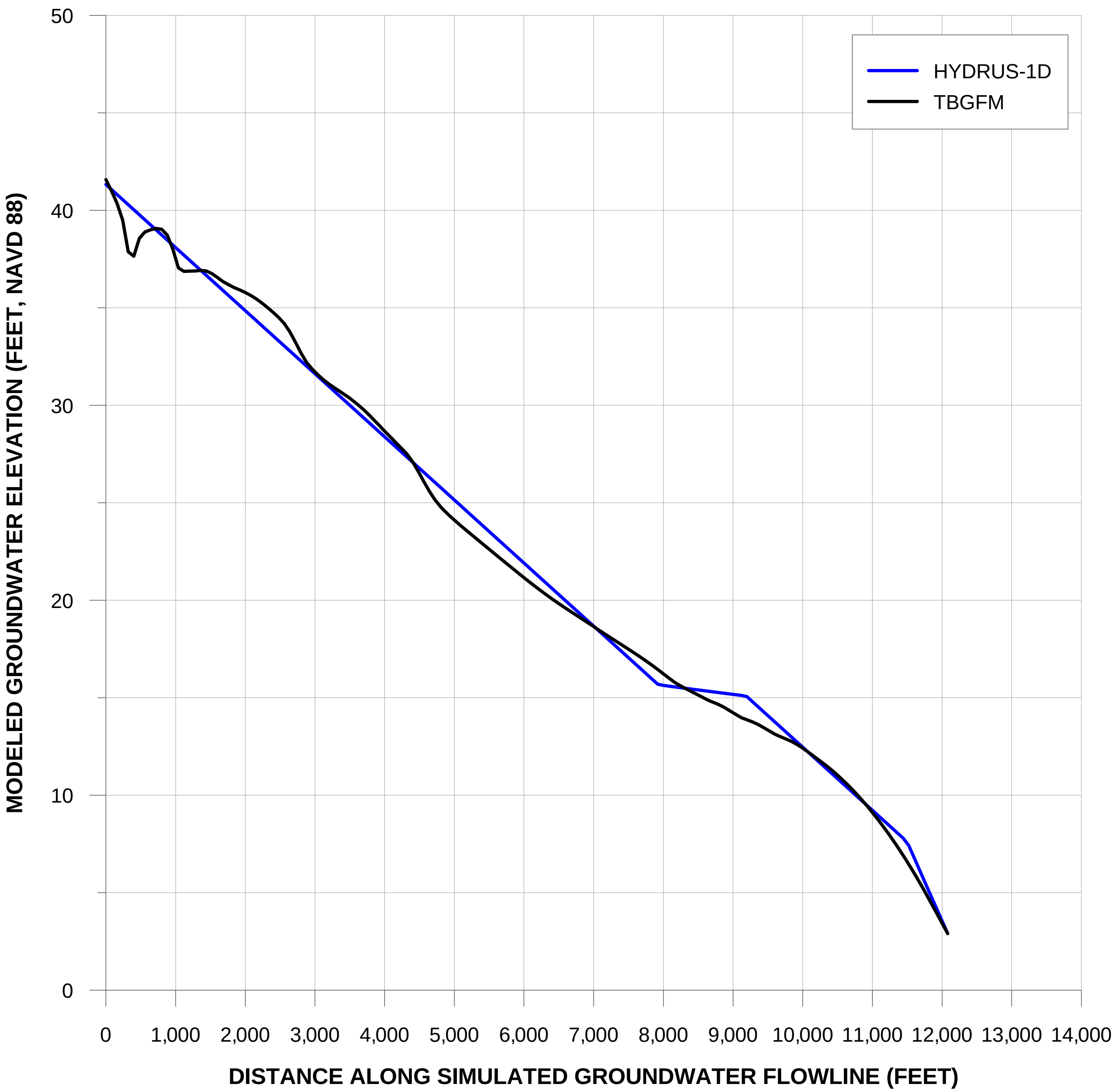


FIGURE D-38
FLUSHING TIME DISTRIBUTION FOR THE WIOU GET TARGET VOLUME
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-38_WIOU_GET_Cum_TTC.grf

CH2MHILL



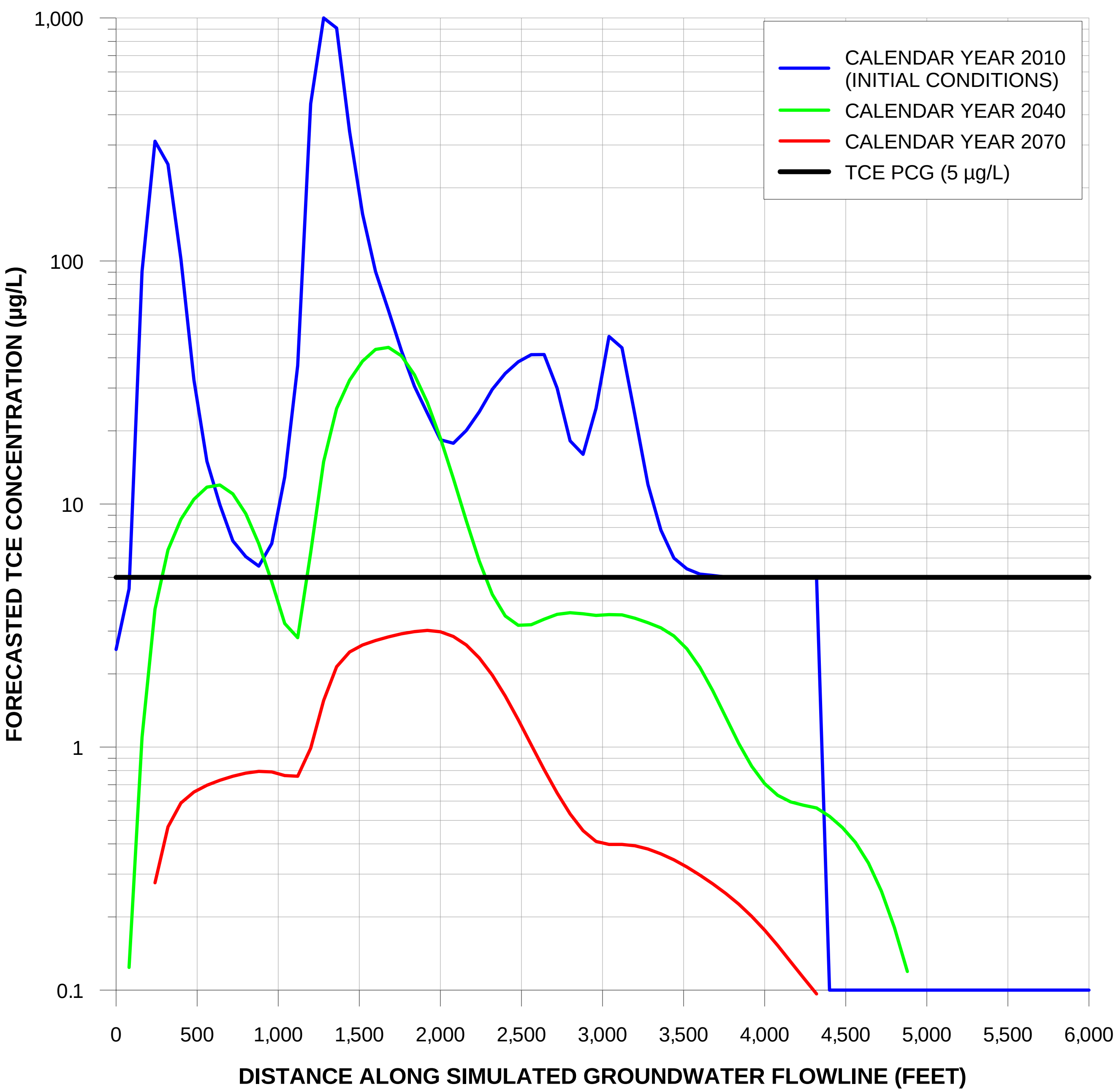
NOTES
1. SIMULATED GROUNDWATER FLOWLINE SHOWN ON FIGURE D-2.
2. TBGFM = TRAVIS BASEWIDE GROUNDWATER FLOW MODEL

FIGURE D-39
COMPARISON OF MODELED GROUNDWATER ELEVATIONS AT WIOU

BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

FigureD-39_WIOU_Head_Comparison.grf

CH2MHILL



NOTE
WIOU SIMULATED GROUNDWATER FLOWLINE SHOWN ON FIGURE D-2.

FigureD-40_WIOU_Conc_vs_Distance.grf

FIGURE D-40
FORECASTED WIOU TCE CONCENTRATIONS UNDER REMEDIAL ALTERNATIVE CONDITIONS
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

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Attachment D1

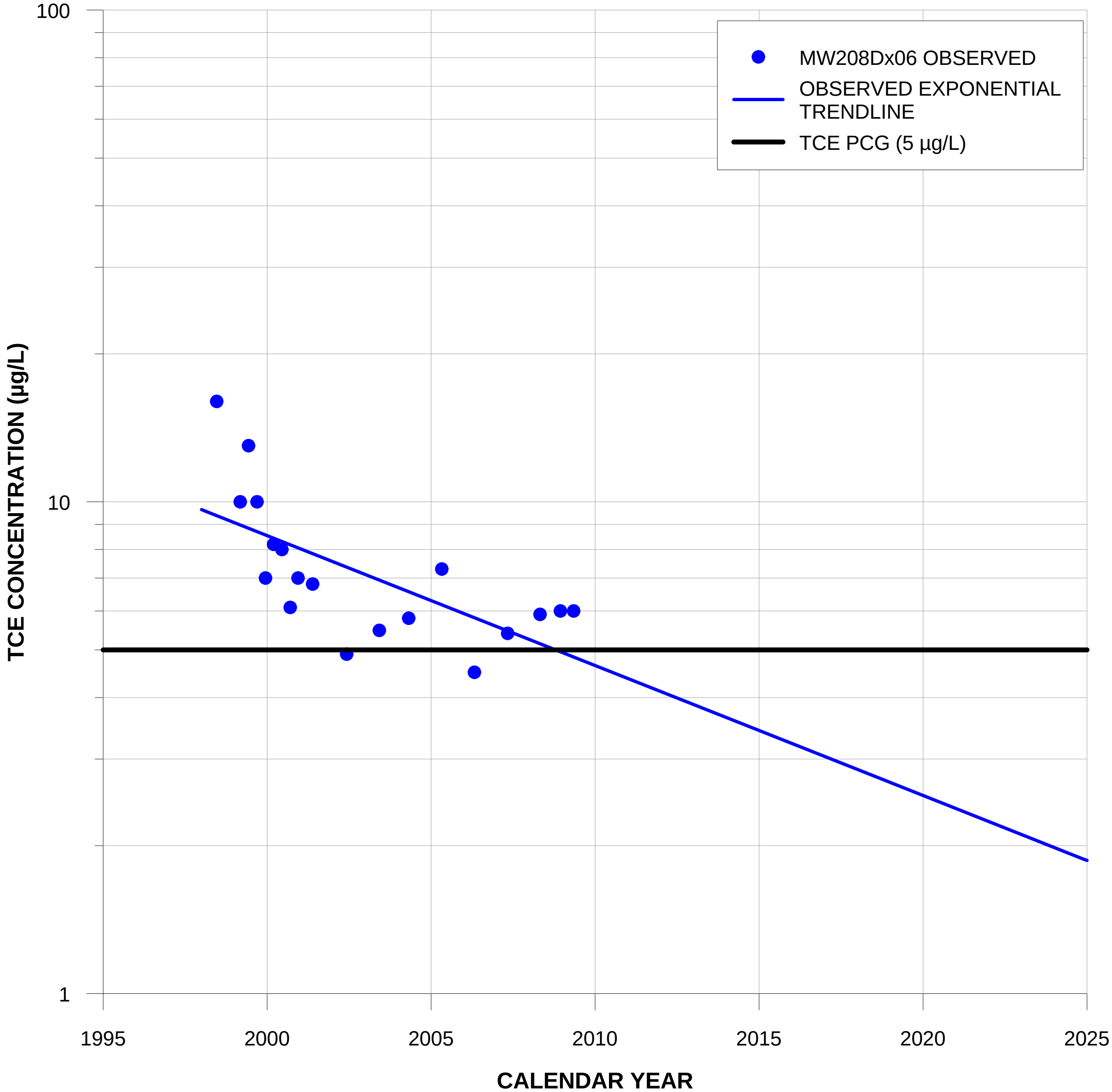

FIGURE D1-1
MW208Dx06 TCE CONCENTRATION DATA AND OBSERVED TRENDLINE
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

MW208Dx06_TCE.grf

CH2MHILL

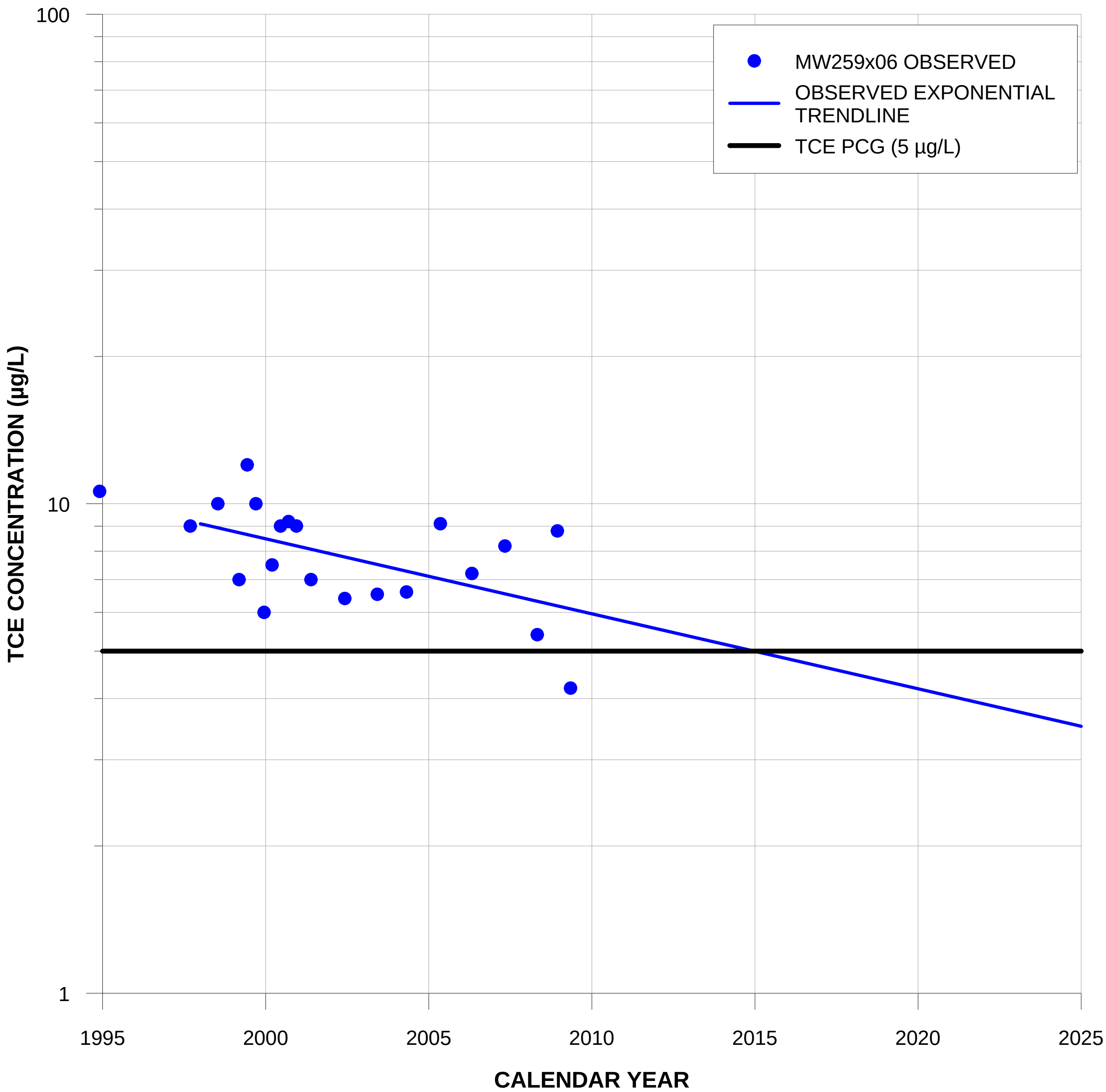

FIGURE D1-2
MW259x06 TCE CONCENTRATION DATA AND OBSERVED TRENDLINE
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

MW259x06_TCE.grf

CH2MHILL

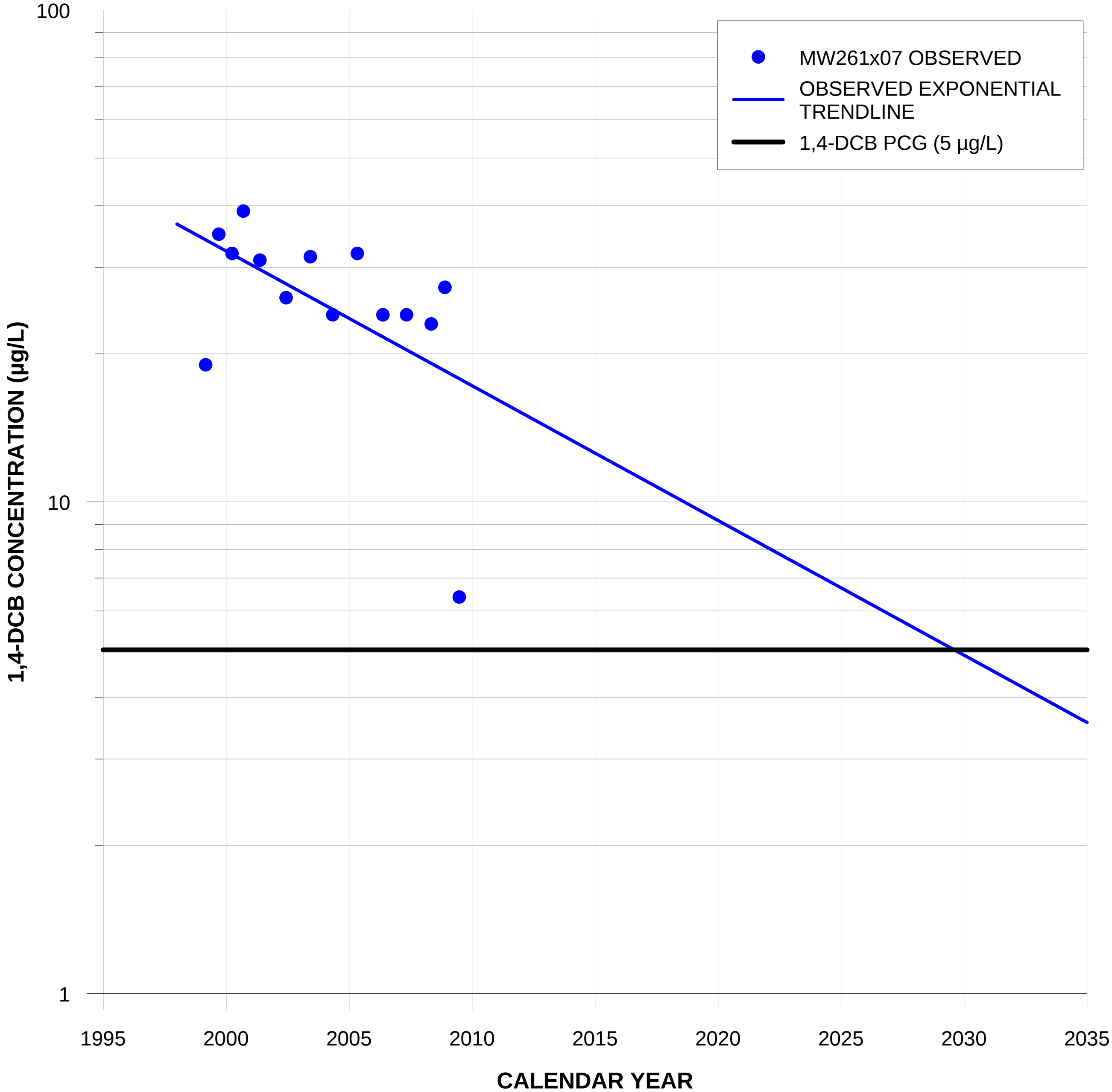

FIGURE D1-3
MW261x07 1,4-DCB CONCENTRATION DATA AND OBSERVED TRENDLINE
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

MW261x07_DCB.grf

CH2MHILL

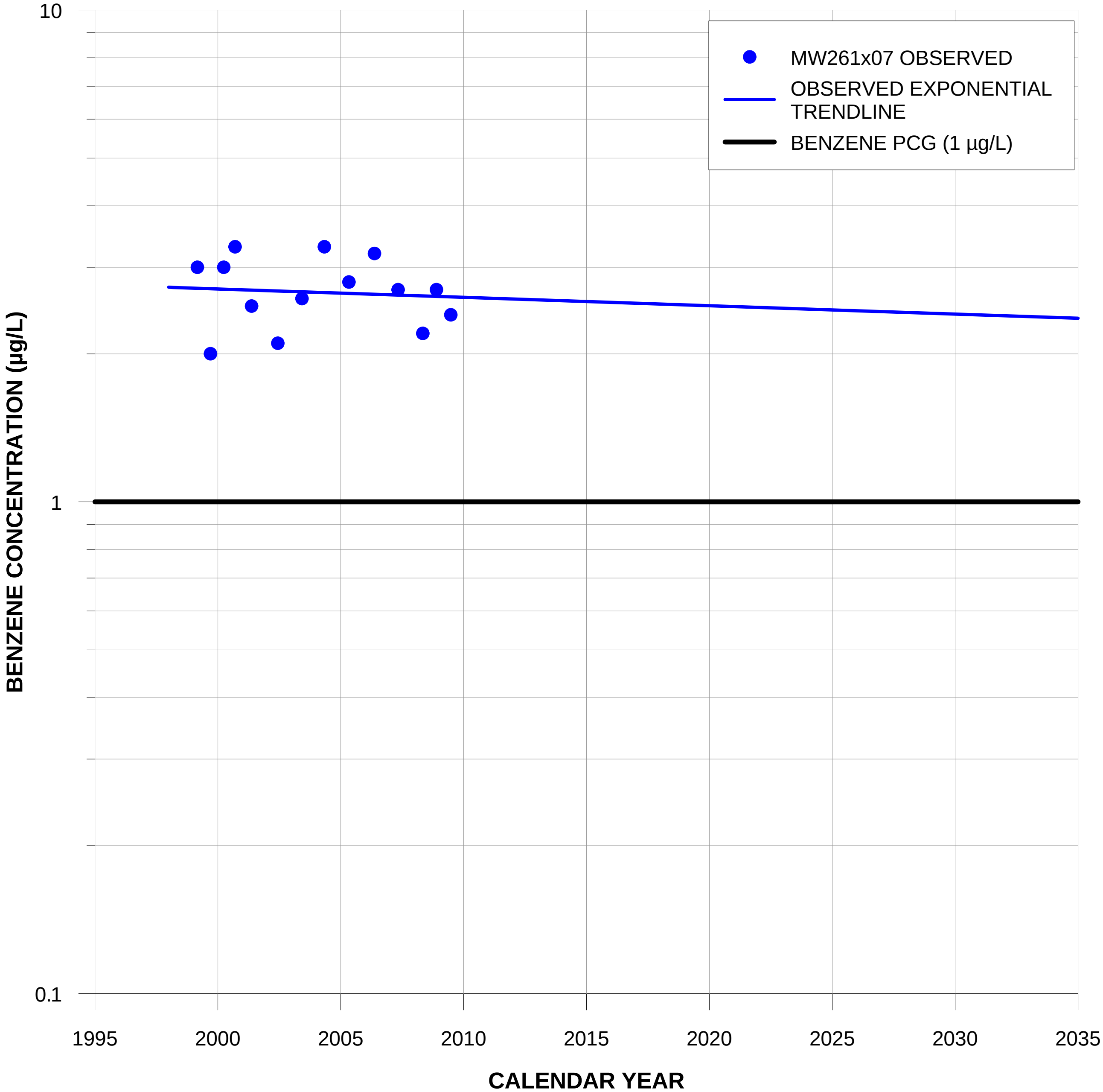

FIGURE D1-4
MW261x07 BENZENE CONCENTRATION DATA AND OBSERVED TRENDLINE
BASEWIDE GROUNDWATER FOCUSED FEASIBILITY STUDY
TRAVIS AIR FORCE BASE, CALIFORNIA

MW261x07_benzene.grf

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Appendix E
Cost Estimates

APPENDIX E

Cost Estimates

This appendix provides cost estimate summaries for the groundwater remedial alternatives described and evaluated in Section 8. A summary of the Basewide Groundwater Focused Feasibility Study (FFS) remedial alternatives and the applicable site(s) for each alternative is provided in Table E-1 (all tables are provided at the end of this appendix). An expanded summary of the sites, implemented IRAs, and alternatives is provided in Table E-2. A summary of the alternative cost estimates is provided in Table E-3.

Estimates provided in this appendix include the capital, and operation and maintenance (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 interim remedial action (IRA) optimization measures implemented from 2008 through 2011. These optimization measures include the following:

- **Site LF007C –** Groundwater Extraction and Treatment (GET) system expansion
- **Site SS015 –** source area treatment via emulsified vegetable oil (EVO) injection
- **Site SS016 –** source area excavation and bioreactor installation
- **Site SD036 –** source area treatment via EVO injection
- **Site SD037 –** source area treatment via EVO injection
- **Site DP039 –** source area excavation, bioreactor installation, and EVO permeable reactive biobarrier (PRB) installation

To the extent possible, the actual costs of the various optimization measures and 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 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.

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 maximum contaminant levels (MCLs) by continuing the existing IRA and the time to reach MCLs under the site-specific FFS alternative. The remediation timeframe estimates were used to perform a present value calculation (U.S. Environmental Protection Agency [EPA], 2000).

The present value for sites having remediation timeframe estimates greater than 50 years was calculated based on a 30-year project life. According to the EPA's *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*, "the period of analysis should not necessarily be limited to the commonly used assumption of 30 years" (EPA, 2000). A few sites had remediation timeframe estimates slightly over 30 years so the net present value for those sites were calculated based on their actual remediation timeframe estimates. However, some sites had remediation timeframe estimates well beyond even 50 years, so the net present value for those sites were calculated based on the past EPA guidance that recommended using 30 years for estimating present value analysis. The present value analysis uses discount rates from Appendix C of OMB Circular A-94 "Discount Rates for Cost-Effectiveness, Lease Purchase, and Related Analyses" because Travis Air Force Base (AFB) is a Superfund site.

Remedial Design (RD) costs were developed in one (1) of two (2) ways. For sites in which the remedial alternative includes EVO injections (Alternatives 5 and 6), the Emulsified Oil Design Tool (ESTCP, 2007) software was used to develop the costs. For sites in which the alternative did not include EVO injections, the RD costs were developed using the percentages on Exhibit 5-8 of *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (EPA, 2000). The RD costs for the following sites are expected to be negligible: Sites FT004, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, and SD043 under Alternative 2 – MNA; Site SS029 under Alternative 3 – GET; and Site SD034 under Alternative 7 – Passive Skimming and EA.

E.1 Alternative 1 – No Action

No costs are associated with 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 National Contingency Plan (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 remedial action objectives (RAOs), no remedial measures are implemented, and no costs are incurred.

E.2 Alternative 2 – MNA

Under Alternative 2, sites will undergo evaluations of natural physical, chemical, and/or biological processes until RAOs are achieved. Monitoring of the well networks at the sites will be conducted under the Travis AFB Groundwater Sampling and Analysis Program (GSAP).

Cost estimating data for implementation of Alternative 2 are provided in Tables E-4A to E-4K.

E.2.1 Applicable Sites

Alternative 2 is applicable to the following sites:

- Site FT004
- Site FT005
- Site LF006
- Site LF007B
- Site LF007D
- Site LF008
- Site ST027B
- Site SD031
- Site SD033
- Site SD043

E.2.2 Basis of Estimate

Routine sampling and monitoring of the existing well networks will continue under the Travis AFB GSAP. All costs associated with this alternative fall under O&M. Costs incurred during the 2010 GSAP were used in developing the Alternative 2 cost estimate.
The Alternative 2 estimates were completed based on the following assumptions:

- No additional capital costs for new monitoring wells will be required.
- 1 hour of field technician labor per well sampled.
- 1 hour of data management labor provided by an administrative assistant per well sampled.
- Cost for field sampling consumables such as gloves, tubing, and paper towels during the 2010 GSAP.
- Cost for field equipment and rentals to include truck, photoionization detector (PID), and pumps during the 2010 GSAP.
- Sample shipping and analysis costs are based on 2010 laboratory pricing guides.

E.2.3 Basis of Estimate at Sites SD033 and SD043

Under Alternative 2, the current GET IRA at Site SD033 and Site SD043 will be discontinued. Alternatively, groundwater monitoring will be conducted in the distal portions of the plume within the encompassing WIOU to assess EA processes.

The basis of the cost estimate for implementing Alternative 2 at Site SD033 and Site SD043 includes the following items and assumptions:

- No additional capital costs for new monitoring wells will be required.
- 1 hour of field technician labor will be required per well sampled.
- 1 hour of data management labor will be provided by an administrative assistant per well sampled.

- Cost for field sampling consumables such as gloves, tubing, and paper towels during the 2010 GSAP.
- Cost for field equipment and rentals to include truck, PID, and pumps during the 2010 GSAP.
- Sample shipping and analysis costs are based on 2010 laboratory pricing guides.

E.3 Alternative 3 – GET

Alternative 3 involves active groundwater remediation using existing GET systems installed as part of the IRA. Vertical extraction wells extract contaminated groundwater and convey the water to an on-base groundwater treatment plant. All Base groundwater treatment plants use liquid-phase granular activated carbon (LGAC) to address contamination. Treated groundwater is discharged to the Base stormwater drainage system. Alternative 3 cost estimates reflect actual prices per kilowatt-hour (kWh) and use historical averages for treatment plant energy usage under their current configuration. The cost estimates also use actual carbon replacement costs based on carbon usage rates as of FY2010.

Cost estimating data for implementation of Alternative 3 are provided in Tables E-5A to E-5C.

E.3.1 Applicable Sites

Alternative 3 is applicable to the following sites:

- Site LF007C
- Site SS029
- Site SS030

E.3.2 Basis of Estimate at Site LF007C

Under Alternative 3, operation of the existing GET IRA at Site LF007C will be continued and expanded. The IRA currently employs two (2) solar-powered extraction wells. Groundwater from the extraction wells is treated at the North Groundwater Treatment Plant (NGWTP) using LGAC. Site LF007C and the NGWTP will undergo an expansion to more thoroughly address the plume. The basis for the costs of expanding the GET system under Alternative 3 includes the following:

- Install two (2) additional extraction wells (consistent with remediation timeframe modeling).
- Install two (2) additional solar-powered extraction pumps, solar panels, batteries, controls, and appurtenances (consistent with remediation timeframe modeling).
- Install two (2) additional monitoring wells (consistent with remediation timeframe modeling).
- Each extraction well requires a pump replacement every 5 years.
- Conduct long-term O&M of four (4) solar-powered extraction wells (consistent with remediation timeframe modeling).

- Conduct long-term treatment of extracted groundwater by LGAC at the NGWTP. Replace two (2) 200-pound carbon vessels every 50 days.
- Complete demolition and removal of all groundwater treatment plant components at the NGWTP.
- Abandon four (4) extraction wells upon achieving PCGs.

E.3.3 Basis of Estimate for Sites SS029 and SS030

Operation of the existing GET IRA at Sites SS029 and SS030 will continue under Alternative 3. This IRA comprises a network of groundwater extraction wells and monitoring wells. Extracted groundwater from Sites SS029 and SS030 is treated at the South Base Boundary Groundwater Treatment Plant (SBBGWTP) using LGAC. The existing GET system is performing as intended and does not require changes. The basis for the cost estimate to continue operation of the existing Site SS029 and SS030 GET system under Alternative 3 includes the following assumptions:

- No additional monitoring wells will be required. One (1) additional extraction well at Site SS030 may be required.
- Install one (1) additional solar-powered extraction pump, solar panels, batteries, controls, and appurtenances.
- Site SS029 and SS030 GET systems (both sites have six [6] operating extraction wells) use the same amount of energy. Energy usage for these sites will be monitored by one (1) meter at the SBBGWTP.
- Long-term O&M of seven (7) extraction wells will be conducted at each site.
- A pump replacement will be required for each extraction well every 5 years.
- The energy usage rates will be based on data from August and September 2010 because the system was recently modified to use LGAC instead of an air stripper.
- Long-term treatment of extracted groundwater will be conducted by LGAC only at the SBBGWTP.
- Carbon changeout of two (2) 6,000-pound vessels will be done every 400 days (cost for changeout will be split evenly between Sites SS029 and SS030).

No demolition, removal, or abandonment costs were estimated because of the extended period required to treat contamination at Site SS029 (62 years). The SBBGWTP is expected to stay in operation until the PCGs are achieved, and the present value cost estimates are based on a maximum 30-year period. Present value costs will not be sensitive to potential costs incurred beyond that time.

E.4 Alternative 4 – Bioreactor and GET

The GET IRA at Site SS016 will be modified under Alternative 4. The 2-Phase® extraction and thermal oxidation treatment will be discontinued within the Oil Spill Area (OSA) portion of the site. Alternatively, an in situ bioreactor will be installed within the OSA source area. GET will continue in the portion of the OSA plume located hydraulically downgradient of the bioreactor.

Within the Tower Area Removal Action (TARA) portion of the Site SS016 plume, operation of the existing GET system will continue. Groundwater extracted from the TARA and OSA will still be conveyed to the CGWTP and treated using LGAC. Treated groundwater is discharged to the Base's storm drain system.

In summary, implementation of Alternative 4 at Site SS016 includes the following major cost components:

- **Bioreactor –** subsurface placement of mulch, gravel, and iron pyrite to create an in situ bioreactor
- **GET –** continue pumping groundwater from OSA extraction wells EW605x61 and EW 610x16 and TARA extraction wells EW01x16 and EW02x16 to be treated at the CGWTP

Cost estimating data for implementation of Alternative 4 are provided in Tables E-6A to E-6E.

E.4.1 Applicable Sites

Alternative 4 is applicable to Site SS016.

E.4.2 Basis of Bioreactor Estimate

The basis for the bioreactor capital costs at Site SS016 are the actual costs incurred during the 2010 IRA optimization. The following cost items are included:

- Prepare excavation locations with utility clearances to meet permit requirements.
- Remove all standing infrastructure that impedes excavations (e.g., fencing, wash rack structure).
- Remove approximately 490 cubic yards of contaminated soil from the OSA source area.
- Perform bioreactor installation work in Level B personal protective equipment (PPE) unless PID readings indicate that Level C is sufficient.
- Place biomulch in subsurface (mixture of gravel, mulch, EVO, and iron pyrite) and cap the biomulch with clay.
- Install bollards around the bioreactor.
- Remove surface drain connected to the storm drain system and install new drainage system.
- Install one (1) new monitoring well.

- Install solar-powered pump system in EW03x16 vault.
- Modify pipe system to convey extracted groundwater from EW03x16 to recirculate in the bioreactor.
- Construct bioreactor manifold system to distribute extracted groundwater evenly through the bioreactor.
- Provide design labor.
- Conduct long-term O&M.

E.4.3 Basis of GET System Estimate

The basis for the GET system cost estimate is as follows:

- Continue operating two (2) vertical OSA extraction wells and two (2) TARA horizontal extraction wells.
- Energy costs based on historical average energy usage of Site SS016 extraction wells.
- Treat extracted groundwater at the CGWTP with LGAC.
- Discharge treated groundwater into Base storm drain system.
- Actual cost to replace two (2) 20,000-pound carbon vessels.

No demolition, removal, or abandonment costs were calculated because of the extended period required to treat contamination at Site SS016 (62 years). Because the CGWTP is expected to stay in operation until PCGs are achieved, the present value cost estimates that are based on a 30-year period will not be sensitive to potential costs incurred in the future.

E.5 Alternative 5 – EVO and EA

Alternative 5 combines in situ bioremediation via EVO injection with Enhanced Attenuation (EA). EVO injections will be conducted within the plume's source area to anaerobically degrade the higher concentration chlorinated volatile organic compounds (VOCs). EA processes will be used within the remainder of the plume.

EA is similar to MNA because both rely on the same natural physical, chemical, and/or biological processes to break down contaminants. However, under Alternative 5, these natural processes are enhanced by implementing active source remediation to reduce contaminant mass flux from the source area into the distal portions of the plume. Conversely, under Alternative 2, no active remedial action is taken within the source area of the plume.

In summary, the primary cost components of Alternative 5 include the following:

- **EVO Injection –** inject EVO into higher concentration source areas to anaerobically degrade trichloroethene (TCE)
- **EA –** in conjunction with the EVO injection source action, use enhanced natural physical, chemical, and/or biological processes to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in the distal portions of the plume.

Cost estimating data for implementation of Alternative 5 are provided in Tables E-7A to E-7F.

E.5.1 Applicable Sites

Alternative 5 is applicable to the following sites:

- Site SS015
- Site SD036
- Site SD037

E.5.2 Basis of Estimate at Site SS015

Under Alternative 5, the current IRA program of MNA assessment at Site SS015 will be modified. EVO will be injected into the source area to actively remediate chlorinated VOCs while groundwater monitoring is conducted in the distal portions of the plume to assess EA processes.

The basis for Alternative 5 capital costs at Site SS015 are the actual costs incurred during the 2010 IRA optimization. The following cost items are included:

- Obtain permits and get utility clearance for additional well locations. Have wells surveyed upon completion.
- Install two (2) 2-inch-diameter monitoring wells (up to 30 feet bgs).
- Install five (5) 4-inch-diameter injection wells (up to 25 feet bgs).
- Investigation-derived waste (IDW) disposal costs based on Edible Oil Substrate (EOS®) injection tool design.
- Advance all borings using hollow-stem auger.
- Inject 1,560 pounds of EVO.
- Labor costs during injection process based on EOS® injection tool design.
- Design and engineering labor estimate based on EOS® injection tool design.
- 1 hour of field technician labor per well sampled.
- 1 hour of data management labor by an administrative assistant per well sampled.
- Field sampling consumables such as gloves, tubing, and paper towels.
- Field equipment and rentals to include truck, PID, and pumps.
- Sample shipping and analysis costs are based on 2010 laboratory pricing guides.
- Assumed similar scope and cost for injection system expansion (Post-Demonstration Optimization) as the work conducted during the 2010 technology demonstration. The expansion will serve to address any contamination beyond the boundary of the demonstration work.
- Expansion costs were escalated by 4 percent to adjust for potential inflation.

E.5.3 Basis of Estimate at Site SD036

Under Alternative 5, the current GET IRA at Site SD036 will be discontinued. Alternatively, EVO will be injected within the source area to actively remediate chlorinated VOCs. Groundwater monitoring will be conducted in the distal portions of the plume within the encompassing WIOU to assess EA processes.

The basis for Alternative 5 capital costs at Site SD036 are the actual costs incurred during the 2010 IRA optimization. The following cost items are included:

- Obtain permits and get utility clearance for eight (8) additional well locations. Have wells surveyed upon completion.
- Install eight (8) 4-inch-diameter injection wells (up to 70 feet bgs).
- Advance all borings using hollow-stem auger.
- Inject 10,856 pounds of EVO.
- Labor costs during injection process based on EOS injection tool design.
- Design and engineering labor estimate based on EOS injection tool design.
- 1 hour of field technician labor per well sampled.
- 1 hour of data management labor provided by an administrative assistant per well sampled.
- Field sampling consumables such as gloves, tubing, and paper towels.
- Field equipment and rentals to include truck, PID, and pumps.
- Sample shipping and analysis costs based on 2010 laboratory pricing guides.
- Assumed similar scope and cost for injection system expansion (Post-Demonstration Optimization) as the work conducted during the 2010 technology demonstration. The expansion will serve to address any contamination beyond the boundary of the demonstration work.
- Expansion costs were escalated by 4 percent to adjust for potential inflation.

E.5.4 Basis of Estimate at Site SD037

Under Alternative 5, the current source area GET IRA at Site SD037 will be discontinued. Alternatively, EVO will be injected within the source area (i.e., “hot spot”) in the vicinity of MW524x37 to actively remediate chlorinated VOCs. Groundwater monitoring will be conducted in the distal portions of the plume within the encompassing West Industrial Operable Unit (WIOU) to assess EA processes.

The basis for Alternative 5 capital costs at Site SD037 are the actual costs incurred during the 2010 IRA optimization. The following cost items are included:

- Obtain permits and get utility clearance for additional well locations. Have wells surveyed upon completion.
- Install six (6) 2-inch-diameter monitoring wells in two (2) locations (up to 60 feet bgs).

- Install seven (7) 4-inch-diameter injection wells (up to 60 feet bgs).
- Advance all borings using hollow-stem auger.
- Inject 36,400 pounds of EVO.
- Provide design and engineering labor.
- Labor costs during injection process based on EOS injection tool design.
- Design and engineering labor estimate based on EOS injection tool design.
- 1 hour of field technician labor per well sampled.
- 1 hour of data management labor an administrative assistant per well sampled.
- Field sampling consumables such as gloves, tubing, and paper towels.
- Field equipment and rentals to include truck, PID, and pumps.
- Sample shipping and analysis costs based on 2010 laboratory pricing guides.
- Assumed similar scope and cost for injection system expansion (Post-Demonstration Optimization) as the work conducted during the 2010 technology demonstration. The expansion will serve to address any contamination beyond the boundary of the demonstration work.
- Expansion costs were escalated by 4 percent to adjust for potential inflation.

E.6 Alternative 6 – Bioreactor, Phytoremediation, EVO PRB, and EA

Alternative 6 combines three (3) in situ bioremediation actions with EA. Under this alternative, a bioreactor and phytoremediation treatment zone will be coupled with an in situ EVO PRB. In the distal portion of the plume, EA processes will address residual contamination.

In summary, the primary cost components of Alternative 6 include the following:

- **Bioreactor –** install a bioreactor within the source area consisting of biomulch (an organic mixture of mulch, gravel, iron pyrites, and EVO).
- **Phytoremediation –** continue using an existing area of eucalyptus trees to treat some of the contaminated groundwater hydraulically downgradient of the bioreactor.
- **EVO PRB –** inject EVO hydraulically downgradient of the phytoremediation area to create a PRB aligned perpendicular to the direction of plume migration.
- **EA –** in conjunction with the EVO injection source action, enhanced natural physical, chemical, and/or biological processes will reduce the mass, toxicity, mobility, volume, or concentration of contaminants in the distal portions of the plume.

Cost estimating data for implementation of Alternative 6 are provided in Tables E-8A through E-8C.

E.6.1 Applicable Sites

Alternative 6 is applicable to Site DP039.

E.6.2 Basis of Bioreactor Estimate

A bioreactor will actively treat the Site DP039 source area plume by recirculating extracted groundwater through biomulch to reduce contaminant mass and volume via enhanced anaerobic degradation. To promote sustainability, the extraction well that circulates groundwater through the bioreactor uses solar panels as the energy source to operate the extraction well pump. The Alternative 6 cost estimate reflects actual costs to install the bioreactor that include the following:

- IDW disposal costs, including bin rentals.
- Materials and installation costs for the solar pumping system to recirculate extracted groundwater.
- Construction costs, including excavating approximately 300 cubic yards of soil and backfilling the excavation with biomulch and capping it with clay.
- Labor costs for construction oversight.
- Utility locating prior to excavation.
- Construct bioreactor manifold system to distributed extracted groundwater evenly through the bioreactor.
- Continue using the solar powered pumping system to circulate extracted groundwater through the bioreactor.
- Assumes replacement of a solar pump every 5 years.
- Recharge the bioreactor with a dose of 1,200 pounds of soybean oil every 4 years.

E.6.3 Basis of Phytoremediation Estimate

The intent of the phytoremediation zone is to supplement the treatment of the source area plume provided by the bioreactor. Source area contamination not treated by the bioreactor will flow into a downgradient zone of planted eucalyptus trees designed to absorb contaminated groundwater. Phytoremediation contributes to the overall effectiveness of Alternative 6 by providing additional reduction of contaminant mass and volume in the source area.

The phytoremediation zone is an existing component of Alternative 6. Capital and O&M costs are not included in the cost estimate.

E.6.4 Basis of EVO PRB Estimate

Injection of EVO across the leading edge of the 500-microgram per liter (µg/L) plume will anaerobically degrade the high concentrations of TCE. This portion of the plume is a continuing source of contamination into the hydraulically downgradient area of EA.

The following line items are actual costs and assumptions included in the EVO PRB cost estimate:

- Obtain permits and get utility clearance for sixteen (16) additional well locations. Have wells surveyed upon completion.
- Install thirteen (13) 4-inch-diameter injection wells and three (3) 2-inch-diameter monitoring well locations.
- Advance all borings using a hollow-stem auger.
- Inject 19,792 pounds of EVO to create the PRB.
- Labor costs during injection process based on EOS injection tool design.
- Design and engineering labor estimate based on EOS injection tool design.
- 1 hour of field technician labor per well sampled.
- 1 hour of data management labor by an administrative assistant per well sampled.
- Field sampling consumables such as gloves, tubing, and paper towels.
- Field equipment and rentals to include truck, PID, and pumps.
- Sample shipping and analysis costs based on 2010 laboratory pricing guides.

E.6.5 Basis of Enhanced Attenuation Estimate

In conjunction with the other remediation techniques, EA will use enhanced natural physical, chemical, and/or biological processes to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in the distal portions of the plume. The costs and assumptions associated with the EA portion of Alternative 6 include the following:

- No additional capital costs for new monitoring wells will be required.
- 1 hour of field technician labor per well sampled.
- 1 hour of data management labor provided by an administrative assistant per well sampled.
- Field sampling consumables such as gloves, tubing, and paper towels.
- Field equipment and rentals to include truck, PID, and pumps.
- Sample shipping and analysis costs are based on 2010 laboratory pricing guides.

E.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 plumes, EA will be employed to address dissolved-phase contamination.

Under Alternative 7, passive skimmers will be used to remove free product from source area wells if 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. During 2008, passive skimming was conducted to remove floating Stoddard solvent from several of the source area wells. Free-phase Stoddard solvent is limited to the source area and is not migrating.

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. The existing Site SD034 monitoring wells will be incorporated into the implementation of EA within the overall WIOU plume.

The effectiveness of EA processes in the non-source areas of the plume will be enhanced by continuing to conduct passive skimming if free-phase Stoddard solvent is detected in the site monitoring wells.

Cost estimating data for implementation of Alternative 7 are provided in Table E-9.

E.7.1 Applicable Sites

Alternative 7 is applicable to Site SD034.

E.7.2 Basis of Estimate

- No additional capital costs for new monitoring wells will be required.
- 1 hour of field technician labor per well sampled.
- 1 hour of data management labor provided by an administrative assistant per well sampled.
- Cost for field sampling consumables such as gloves, tubing, and paper towels during the 2010 GSAP.
- Cost for field equipment and rentals to include truck, PID, and pumps during the 2010 GSAP.
- Sample shipping and analysis costs are based on 2010 laboratory pricing guides.

E.8 Works Cited

Environmental Security Technology Certification Program (ESTCP). 2007. *Users Manual, Emulsified Oil Design Tool.* North Carolina State University, Solutions-Industrial and Environmental Services (IES), and CH2M HILL. Draft. December.

U.S. Environmental Protection Agency (EPA). 2000. *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study.* EPA 540-R-00-002. OSWER 9355.0-75. July.

TABLE E-1
Summary of Remedial Alternatives and Sites
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

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

* EVO injection within the source area portions of the Site SS015, SD036, and SD037 plumes. EA for the remainder of the plume.

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

Applicable Site	Implemented Interim Remedial Action[a]	FFS Remedial Alternative[b]	Comment
FT004	**GET and MNA Assessment**	**MNA** (Alternative 2)	Implementation of Alternative 2 at Site FT004 will result in discontinuation of GET and initiation of MNA. The existing Site FT004 GET IRA system is currently shut down for a rebound study.
FT005	**GET**	**MNA** (Alternative 2)	Implementation of Alternative 2 at Site FT005 will result in discontinuation of GET and initiation of MNA. The existing Site FT005 GET IRA system is currently shut down for a rebound study.
LF006	**MNA**	**MNA** (Alternative 2)	Implementation of Alternative 2 at Site LF006 will be a continuation of the MNA IRA.
LF007B	**MNA Assessment**	**MNA** (Alternative 2)	Implementation of Alternative 2 at Site LF007B will be a continuation of the MNA assessment IRA.
LF007C	**GET**	**GET** (Alternative 3)	Implementation of Alternative 3 at Site LF007C will be a continuation of the ongoing GET IRA. Optimization of existing Site LF007C GET system will be conducted in 2010 to more fully achieve IRA objectives.
LF007D	**MNA Assessment**	**MNA** (Alternative 2)	Implementation of Alternative 2 at Site LF007D will be a continuation of the ongoing MNA assessment IRA.
LF008	**GET**	**MNA** (Alternative 2)	Implementation of Alternative 2 at Site LF008 will result in discontinuation of GET and initiation of MNA. The existing GET IRA system is currently shut down for a rebound study.
SS015	**EVO and MNA Assessment** (Vegetable Oil Injection Treatability Study)	**EVO and EA** (Alternative 5)	Implementation of Alternative 5 at Site SS015 will be an optimization of the MNA assessment IRA. A vegetable oil injection treatability study was conducted in 2000-2001. Alternative 5 will optimize that past EVO injection to support EA at the site.

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

Applicable Site	Implemented Interim Remedial Action[a]	FFS Remedial Alternative[b]	Comment
SS016	**GET**	**Bioreactor and GET** (Alternative 4)	Implementation of Alternative 4 at Site 16 will result in source area excavation and installation of a bioreactor within the OSA source area. GET within the OSA source area plume using extraction wells EW605x16 and EW610x16 will be continued. Extracted groundwater will continue to be treated at the CGWTP using LGAC. 2-Phase® GET using OSA extraction well TPE-W and thermal oxidation treatment will be discontinued. Active groundwater extraction using OSA horizontal well EW003x16 will be discontinued. Groundwater from EW003x16 will be treated by circulation through the bioreactor. Within the TARA portion of the site, GET using horizontal wells EW605x16 and EW610x16 will be continued. Extracted groundwater will continue to be treated at the CGWTP using LGAC. The downgradient portion of the Site SS016 plume not hydraulically captured by OSA component of the GET system (EW605x16 and EW610x16) and TARA component of the GET system (EW001x16 and EW002x16) will be hydraulically captured by the Site SS029 GET system. Extracted groundwater will continue to be treated at the SBBGWTP.
ST027B	**MNA**	**MNA** (Alternative 2)	Implementation of Alternative 2 at Site ST027B will be a continuation of the ongoing program of MNA. Site ST027B was formerly addressed under the POCO program and is not addressed in either groundwater IROD.
SS029	**GET**	**GET** (Alternative 3)	Implementation of Alternative 3 at Site SS029 will be a continuation of the existing GET IRA near the southern Base boundary. Extracted groundwater will continue to be treated at the SBBGWTP.
SS030	**GET**	**GET** (Alternative 3)	Implementation of Alternative 3 at Site SS030 will be a continuation of the existing GET IRA. Optimization of the existing GET system will be conducted in 2010 to more fully achieve the IRA objective of off-base remediation. Extracted groundwater will continue to be treated at the SBBGWTP.
SD031	**GET and MNA Assessment**	**MNA** (Alternative 2)	Implementation of Alternative 2 at Site SD031 will result in discontinuation of GET and initiation of MNA. The existing Site SD031 GET IRA is currently shut down for a rebound study.

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

Applicable Site	Implemented Interim Remedial Action[a]	FFS Remedial Alternative[b]	Comment
DP039	**GET and MNA Assessment** (phytoremediation and bioreactor demonstration projects)	**Bioreactor, Phytoremediation, EVO PRB, and EA** (Alternative 6)	Implementation of Alternative 6 at Site DP039 will result in discontinuation of the source area GET component of the IRA. Highly contaminated source area soil will be excavated and an in situ bioreactor will be installed in lieu of the GET IRA. An existing phytoremediation demonstration project will also be incorporated into the remedial alternative. Additionally, EVO will be injected in a permeable wall configuration at the downgradient extent of the 500-µg/L TCE isocontour. The portion of the plume hydraulically downgradient of the zone of EVO injection will undergo a program of EA.
WIOU Sites			
SD033	**GET and MNA Assessment**	**MNA** (Alternative 2)	Implementation of Alternative 2 at Site SD033 will result in discontinuation of GET and initiation of MNA. The existing Site SD033 GET IRA is currently shut down for a rebound study. Site SD033 is one of several sites with commingled plumes comprising the WIOU. The SD033 plume will be incorporated into an overall program of MNA within the encompassing WIOU.
SD034	**GET and Passive Skimming**	**Passive Skimming and EA** (Alternative 7)	Implementation of Alternative 7 at Site SD034 will be a continuation of the ongoing Stoddard solvent free-product removal IRA. Site SD034 is one of several sites with commingled plumes comprising the WIOU. The portion of the plume not undergoing free-product removal will be incorporated into an overall program of EA within the encompassing WIOU.
SD036	**GET and MNA Assessment**	**EVO and EA** (Alternative 5)	Implementation of Alternative 5 at Site SD036 will result in discontinuation of GET. Alternatively, EVO will be injected within the source area of the plume. Site SD036 is one of several sites with commingled plumes comprising the WIOU. The portion of the plume not treated by EVO injection will be incorporated into an overall program of EA within the encompassing WIOU.

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

Applicable Site	Implemented Interim Remedial Action[a]	FFS Remedial Alternative[b]	Comment
SD037	**GET and MNA Assessment**	**EVO and EA** (Alternative 5)	Implementation of Alternative 5 at Site SD037 will result in discontinuation of GET. Alternatively, EVO will be injected within the source area of the plume in the vicinity of MW524x37. Site SD037 is one of several sites with commingled plumes comprising the WIOU. The portion of the plume not treated by EVO injection will be incorporated into an overall program of EA within the encompassing WIOU.
SD043	**GET**	**MNA** (Alternative 2)	Site SD043 is one of several sites with commingled plumes comprising the WIOU. Implementation of Alternative 2 will result in discontinuation of GET and initiation of MNA. The existing Site SD043 GET IRA is currently shut down for a rebound study.

[a] Groundwater IRAs taken under the final NEWIOU Groundwater IROD (Travis AFB, 1998) and final WABOU Groundwater (Travis AFB, 1999).
[b] FFS Groundwater Remedial Alternatives 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

Notes:

POCO = petroleum-only contaminated site
IROD = interim record of decision

TABLE E-3
Cost Estimate Summary
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Alternative											
1 – No Action		$0									
2 – MNA		**FT004**	**FT005**	**LF006**	**LF007B**	**LF007D**	**LF008**	**ST027B**	**SD031**	**SD033**	**SD043**
	Alternative Cost, Present Value	$163,538	$94,273	$11,909	$0	$21,806	$35,545	$49,996	$42,103	$65,778	$38,121
	Interim Cost, Present Value	$59,641	$101,633	$11,909	$0	$21,806	$46,182	$49,996	$30,480	$42,082	$26,273
3 – GET		**LF007C**	**SS030**	**SS029**							
	Alternative Cost, Present Value	$432,334	$294,390	$339,851							
	Interim Cost, Present Value	$379,376	$291,468	$339,851							
4 – Bioreactor and GET		**SS016**									
	Alternative Cost, Present Value	$1,116,162									
	Interim Cost, Present Value	$761,718									
5 – EVO and EA		**SS015**	**SD036**	**SD037**							
	Alternative Cost, Present Value	$358,474	$759,875	$1,298,581							
	Interim Cost, Present Value	$55,137	$100,106	$275,751							
6 – Bioreactor, Phytoremediation, EVO PRB, and EA		**DP039**									
	Alternative Cost, Present Value	$1,177,618									
	Interim Cost, Present Value	$73,680									
7 – Passive Skimming and MNA		**SD034**									
	Alternative Cost, Present Value	$80,639									
	Interim Cost, Present Value	$108,288									

TABLE E-4A

Alternative 2 – O&M Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Labor Hours Per Well	**Billing Rate/Technician**	**Total**
CCI Field Tech	1	$56.72	$56.72
	Labor Hours Per Well	**Billing Rate/Administrative**	
CCI Data management/field support	1	$56.72	$56.72
	Cost Per Well		
Other Direct Costs*	$75.00		$75.00
*ODC includes consumables, equipment rental, truck rental, and sample shipment.			**$188.44**

Site	Total Cost/Yr	Present Value Interim	Present Value Alternative
FT004	$2,703	$163,538	$59,641
FT005	$4,024	$94,273	$101,633
LF006	$2,451	$11,909	$11,909
LF007B	$817	$0	$0
LF007D	$1,069	$21,806	$21,806
LF008	$2,264	$35,545	$46,182
ST027B	$2,451	$49,996	$49,996
SD031	$2,451	$42,103	$30,480
SD033	$2,063	$65,778	$42,082
SD043	$1,288	$38,121	$26,273

TABLE E-4B

Alternative 2 – Site FT004 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Interim Action **GET/MNA**

Extraction Well	Average Flow (gpm)	Average Energy (kWh)/mo	Cost ($)/kwh	Estimated Cost ($)/mo	Estimated Cost ($)/yr
EW576x04	2.2	206	0.07	14.42	173.04
EW577x04	1.8	206	0.07	14.42	173.04
EW578x04	0.7	206	0.07	14.42	173.04
EW579x04	1.0	206	0.07	14.42	173.04
EW580x04	1.3	206	0.07	14.42	173.04
EW621x04	3.2	206	0.07	14.42	173.04
EW622x04	1.8	206	0.07	14.42	173.04
EW623x04	1.1	206	0.07	14.42	173.04
Total	13.1	1,648		115.36	$1,384

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	Total Cost ($)/Yr
10	3	$188	$63	$2,703

Total Cost/yr of Interim **$4,088**

Pump Replacement	Interval	Equipment Cost	Labor Cost	Total
	5 years	$1,700	$454	$2,154

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-35	$143,080	$4,088	22.0646	$90,200
Periodic	5	$17,232	$17,232	0.8753	$15,083
Periodic	10	$17,232	$17,232	0.7661	$13,201
Periodic	15	$17,232	$17,232	0.6706	$11,556
Periodic	20	$17,232	$17,232	0.5869	$10,113
Periodic	25	$17,232	$17,232	0.5137	$8,852
Periodic	30	$17,232	$17,232	0.4497	$7,749
Periodic	35	$17,232	$17,232	0.3936	$6,783
		$263,704			$163,538

TABLE E-4B

Alternative 2 – Site FT004 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Selected Alternative 2

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	Total Cost ($)/Yr
10	3	$188	$63	$2,703

Total Cost/yr Alternative **$2,703**

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-35	$94,605	$2,703	22.0646	$59,641
		$94,605			$59,641

TABLE E-4C

Alternative 2 – Site FT005 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Interim Action **GET**

Extraction Well	Average Flow (gpm)	Average Energy (kWh)/mo	Cost ($)/kwh	Estimated Cost ($)/mo	Estimated Cost ($)/yr
EW01x05	1.4	206	0.07	14.42	173.04
EW02x05	2.1	206	0.07	14.42	173.04
EW03x05	3.2	206	0.07	14.42	173.04
EW731x05	0.8	206	0.07	14.42	173.04
EW732x05	2.2	206	0.07	14.42	173.04
EW733x05	0.7	206	0.07	14.42	173.04
EW734x05	11.0	206	0.07	14.42	173.04
EW735x05	4.5	206	0.07	14.42	173.04
EW736x05	3.3	206	0.07	14.42	173.04
EW737x05	3.5	206	0.07	14.42	173.04
EW742x05	5.3	206	0.07	14.42	173.04
EW743x05	0.5	206	0.07	14.42	173.04
EW744x05	1.0	206	0.07	14.42	173.04
EW745x05	7.5	206	0.07	14.42	173.04
EW746x05	4.4	206	0.07	14.42	173.04
Total	51.4	3,090		216.3	$2,596

Pump Replacement	Interval	Equipment Cost	Labor Cost	Total
	5 years	$1,700	$454	$2,154

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-21	$54,516	$2,596	15.8856	$41,239
Periodic	5	$32,310	$32,310	0.8753	$28,281
Periodic	10	$32,310	$32,310	0.7661	$24,753
		$119,136			$94,273

TABLE E-4C

Alternative 2 – Site FT005 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Selected Alternative 2

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	Total Cost ($)/Yr
15	4	$188	$63	$4,024

Total Cost/yr Alternative **$4,024**

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-43	$94,605	$4,024	25.2568	$101,633
		$94,605			$101,633

TABLE E-4D

Alternative 2 – Site LF006 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Interim Action **MNA**

Selected Alternative **2**

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	TPH-G Analysis	TPH-D Analysis	Total Cost/Yr
6	2	$188	$63	$63	$73	$2,451

Total Cost/yr Interim	**$2,451**
Total Cost/yr Alternative	**$2,451**

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (1.6%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-5	$12,255	$2,451	4.8589	$11,909
		$12,255			$11,909

TABLE E-4E

Alternative 2 – Site LF007B Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Interim Action **MNA**

Selected Alternative **2**

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	Total Cost/Yr
3	1	$188	$63	$817

Total Cost/yr Interim	**$817**
Total Cost/yr Alternative	**$817**

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (0%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	0	$0	$817		$0
		$0			$0

TABLE E-4F

Alternative 2 – Site LF007D Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Interim Action **MNA**

Selected Alternative **2**

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	Total Cost/Yr
4	1	$188	$63	$1,069

Total Cost/yr Interim	**$1,069**
Total Cost/yr Alternative	**$1,069**

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$32,070	$1,069	20.3983	$21,806
		$32,070			$21,806

TABLE E-4G

Alternative 2 – Site LF008 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Interim Action **GET**

Extraction Well	Average Flow (gpm)	Average Energy (kWh)/mo	Cost ($)/kwh	Estimated Cost ($)/mo	Estimated Cost ($)/yr
EW719x08	1.0	206	0.07	14.42	173.04
EW720x08	1.0	206	0.07	14.42	173.04
EW721x08	1.0	206	0.07	14.42	173.04
Total	3.0	618		43.26	$519

Pump Replacement	Interval	Equipment Cost	Labor Cost	Total
	5 years	$1,700	$454	$2,154

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$15,570	$519	20.3983	$10,587
Periodic	5	$6,462	$6,462	0.8753	$5,656
Periodic	10	$6,462	$6,462	0.7661	$4,951
Periodic	15	$6,462	$6,462	0.6706	$4,333
Periodic	20	$6,462	$6,462	0.5869	$3,793
Periodic	25	$6,462	$6,462	0.5137	$3,320
Periodic	30	$6,462	$6,462	0.4497	$2,906
		$54,342			$35,545

Selected Alternative **2**

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	Pesticide Analysis	Total Cost/Yr
8	1	$188	$84	$2,264

Total Cost/yr Alternative **$2,264**

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$67,920	$2,264	20.3983	$46,182
		$67,920			$46,182

TABLE E-4H

Alternative 2 – Site LF007D Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Interim Action **MNA**

Selected Alternative **2**

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	TPH-G Analysis	TPH-D Analysis	Total Cost/Yr
6	2	$188	$63	$63	$73	$2,451

Total Cost/yr Interim	**$2,451**
Total Cost/yr Alternative	**$2,451**

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$73,530	$2,451	20.3983	$49,996
		$73,530			$49,996

TABLE E-4I

Alternative 2 – Site SD031 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Interim Action **GET/MNA**

Extraction Well	Average Flow (gpm)	Average Energy (kWh)/mo	Cost ($)/kwh	Estimated Cost ($)/mo	Estimated Cost ($)/yr
EW565x31	2.0	206	0.07	14.42	173.04
EW566x31	1.5	206	0.07	14.42	173.04
EW567x31	1.1	206	0.07	14.42	173.04
Total	4.6	618		43.26	$519

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	TPH-G Analysis	TPH-D Analysis	Total Cost/Yr
6	2	$188	$63	$63	$73	$2,451

Total Cost/yr Interim **$2,970**

Pump Replacement

Interval	Equipment Cost	Labor Cost	Total
5 years	$1,700	$454	$2,154

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.2%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-10	$29,700	$2,970	8.9048	$26,447
Periodic	5	$6,462	$6,462	0.8969	$5,796
Periodic	10	$6,462	$6,462	0.8044	$5,198
Periodic	15	$6,462	$6,462	0.7215	$4,662
		$42,624			$42,103

TABLE E-4I

Alternative 2 – Site SD031 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Selected Alternative 2

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	TPH-G Analysis	TPH-D Analysis	Total Cost/Yr
6	2	$188	$63	$63	$73	$2,451

Total Cost/yr Alternative **$2,451**

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.45%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-15	$24,510	$2,451	12.4357	$30,480
		$24,510			$30,480

TABLE E-4J

Alternative 2 – Site SD033 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Interim Action **GET/MNA**

Extraction Well	Average Flow (gpm)	Average Energy (kWh)/mo	Cost ($)/kwh	Estimated Cost ($)/mo	Estimated Cost ($)/yr
EW501x33	1.0	206	0.07	14.42	173.04
EW503x33	1.5	206	0.07	14.42	173.04
Total	2.5	412		28.84	$346

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	TPH-G Analysis	TPH-D Analysis
5	2	$188	$63	$63	$73
					Total Cost/Yr
Total Cost/yr Interim	**$2,409**				$2,063

Pump Replacement	Interval	Equipment Cost	Labor Cost	Total
	5 years	$1,700	$454	$2,154

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$72,270	$2,409	20.3983	$49,140
Periodic	5	$4,308	$4,308	0.8753	$3,771
Periodic	10	$4,308	$4,308	0.7661	$3,300
Periodic	15	$4,308	$4,308	0.6706	$2,889
Periodic	20	$4,308	$4,308	0.5869	$2,528
Periodic	25	$4,308	$4,308	0.5137	$2,213
Periodic	30	$4,308	$4,308	0.4497	$1,937
		$98,118			$65,778

TABLE E-4J

Alternative 2 – Site SD033 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Selected Alternative **2**

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	TPH-G Analysis	TPH-D Analysis
5	2	$188	$63	$63	$73
					Total Cost/Yr
Total Cost/yr Alternative	**$2,063**				$2,063

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$61,890	$2,063	20.3983	$42,082
		$61,890			$42,082

TABLE E-4K

Alternative 2 – Site SD043 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Interim Action **GET/MNA**

Extraction Well	Average Flow (gpm)	Average Energy (kWh)/mo	Cost ($)/kwh	Estimated Cost ($)/mo	Estimated Cost ($)/yr
EW555x43	0.7	206	0.07	14.42	173.04
Total	0.7	206		14.42	$173

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	TPH-G Analysis	TPH-D Analysis	Total Cost/Yr
3	2	$188	$63	$63	$73	$1,288

Total Cost/yr Interim **$1,461**

Pump Replacement	Interval	Equipment Cost	Labor Cost	Total
	5 years	$1,700	$454	$2,154

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$43,830	$1,461	20.3983	$29,802
Periodic	5	$2,154	$2,154	0.8753	$1,885
Periodic	10	$2,154	$2,154	0.7661	$1,650
Periodic	15	$2,154	$2,154	0.6706	$1,444
Periodic	20	$2,154	$2,154	0.5869	$1,264
Periodic	25	$2,154	$2,154	0.5137	$1,107
Periodic	30	$2,154	$2,154	0.4497	$969
		$56,754			$38,121

TABLE E-4K

Alternative 2 – Site SD043 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Selected Alternative 2

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	TPH-G Analysis	TPH-D Analysis	Total Cost/Yr
3	2	$188	$63	$63	$73	$1,288

Total Cost/yr Alternative **$1,288**

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$38,640	$1,288	20.3983	$26,273
		$38,640			$26,273

TABLE E-5A

Alternative 3 – Site SS030 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Interim Action - GET

Selected Alternative - 3

CAPITAL COSTS

	Unit	Unit Cost	Quantity	Line Item Cost	Total Cost	Comments
Extraction Well Installation						
IDW costs	EA	$1,500.00	1	$1,500.00		Bin rental and IDW disposal
Additional Cost	DAY	$200.00	2	$400.00		Consumables, H&S, equipment rental
Labor	DAY	$529.10	2	$1,058.20		One (1) person on site for 13 hr/day at a $40.7 bill rate
Well Installation	FT	$114.00	40	$4,560.00		Seven (7) wells total 265'-includes installation and completion
Auto Mileage	DAY	$45.00	2	$90.00		Mileage to and from Travis - approx 90 miles
Development	HR	$150.00	8	$1,200.00		Development costs per hr
					$5,100.00	
Mobilization/Demobilization	EA	$1,000.00	1	1,000.00	$1,000.00	One (1) mob/demob
Valut Installation and Plumbing	EA	$8,510.00	1	8,510.00	$8,510.00	Cost from Cornerstone including vault, plumbing, pump
Remedial Design	EA	$2,922.00	1	2,922.00	$2,922.00	
					$17,532.00	

Extraction Well	Average Flow	Average Energy/Mo (kwh)	Cost/kwh	Estimated Cost/Mo	Estimated Cost/Yr
EW01x30	7.73	1,723	$0.07	$120.61	$1,447.32
EW02x30	3.79	1,723	$0.07	$120.61	$1,447.32
EW03x30	1.2	1,723	$0.07	$120.61	$1,447.32
EW04x30	21.5	1,723	$0.07	$120.61	$1,447.32
EW05x30	11.6	1,723	$0.07	$120.61	$1,447.32
EW06x30	dry				
EW711x30	11.1	1,723	$0.07	$120.61	$1,447.32
Total	56.92				**$8,683.92**

Carbon Changeout

Total Flow from EWs	Frequency	SBBGWTP Cost/Change out	SBBGWTP Carbon Cost/yr	Carbon Cost/Yr SS030
57	400 days	$22,922	$20,916	**$10,458**

EW Energy Cost/Yr **$8,684**

Labor

Field Tech Hr/Mo	Cost per Field Tech Hr	Labor Cost/Mo	Labor Cost/Yr
2	$57	$113	**$1,361**

Total O&M Cost/Yr **$20,503**

Periodic Costs

Item	Interval	Cost	Labor Cost	Total
Pump Replacement	5 years	$1,700	$454	**$2,154**
Motor Control Center Repairs	5 years	$2,000	$0	**$2,000**

TABLE E-5A

Alternative 3 – Site SS030 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Present Value Analysis - Time to Cleanup: 22 yrs

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$17,532	$17,532	1	$17,532
Annual O&M	1-22	$304,370	$13,835	16.433	$227,351
Periodic	5	$17,078	$17,078	0.8753	$14,948
Periodic	10	$17,078	$17,078	0.7661	$13,083
Periodic	15	$17,078	$17,078	0.6706	$11,453
Periodic	20	$17,078	$17,078	0.5869	$10,023
		$390,214			$294,390

TABLE E-5B

Alternative 3 – Site SS029 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Interim Action

Selected Alternative - 3

Extraction Well	Average Flow	Average Energy/Mo (kwh)	Cost/kwh	Estimated Cost/Mo	Estimated Cost/yr
EW01x29	1.12	1,723	$0.07	$120.61	$1,447.32
EW02x29	6.34	1,723	$0.07	$120.61	$1,447.32
EW03x29	offline				
EW04x29	9.22	1,723	$0.07	$120.61	$1,447.32
EW05x29	0.96	1,723	$0.07	$120.61	$1,447.32
EW06x29	14.3	1,723	$0.07	$120.61	$1,447.32
EW07x29	16.4	1,723	$0.07	$120.61	$1,447.32
	48.34				**$8,683.92**

Carbon Changeout

Total Flow from EWs w/ Alternative	Frequency	SBBGWTP Cost/Change out	SBBGWTP Carbon Cost/Yr	Carbon Cost/Yr SS029
49	400 days	$22,922	$20,916.33	**$10,458**

EW Energy Cost/Yr **$8,684**

Labor

Field Tech Hr/Mo	Cost/Field Tech Hr	Labor Cost/Mo	Labor Cost/Yr
2	$56.72	$113.44	**$1,361**

Total O&M Cost/Yr **$20,503**

Periodic Costs

Item	Interval	Equipment Cost	Labor Cost	Total
Pump Replacement	5 years	$1,700	$454	**$2,154**
Motor Control Center Repairs	5 years	$2,000	$0	**$2,000**

TABLE E-5B

Alternative 3 – Site SS029 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Present Value Analysis - Time to Cleanup: 62yrs

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$415,050	$13,835	20.3983	$282,210
Periodic	5	$14,924	$14,924	0.8753	$13,063
Periodic	10	$14,924	$14,924	0.7661	$11,433
Periodic	15	$14,924	$14,924	0.6706	$10,008
Periodic	20	$14,924	$14,924	0.5869	$8,759
Periodic	25	$14,924	$14,924	0.5137	$7,666
Periodic	30	$14,924	$14,924	0.4497	$6,711
		$504,594			$339,851

TABLE E-5C
Alternative 3 – Site LF007C Cost Estimate
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Interim Action - GET
Selected Alternative - 3

CAPITAL COSTS

	Unit	Unit Cost	Quantity	Line Item Cost	Total Cost	Comments
Remedial Design	EA	$15,785.54	1	$15,785.54	$15,785.54	Includes planning, engineering, permitting, costing, and other design costs
Extraction Well Installation						
IDW costs	EA	$1,500.00	1	$1,500.00		Bin rental and IDW disposal
Additional Cost	DAY	$200.00	4	$800.00		Consumables, H&S, equipment rental
Labor	DAY	$529.10	4	$2,116.40		One (1) person on site for 13 hr/day at a $40.7 bill rate
Well Installation	FT	$114.00	50	$5,700.00		50' of wells
Auto Mileage	DAY	$45.00	4	$180.00		Mileage to and from Travis - approx 90 miles
Development	HR	$150.00	16	$2,400.00		Development costs per hr
					$12,696.40	
Performance Monitoring Well Installation						
IDW costs	EA	$1,500.00	1	$1,500.00		Bin rental and IDW disposal
Additional Cost	DAY	$200.00	1	$200.00		Consumables, H&S, equipment rental
Labor	DAY	$529.10	1	$529.10		One (1) person on site for 13 hr/day at a $40.7 bill rate
Well Installation	FT	$48.00	50	$2,400.00		50' of wells
Auto Mileage	DAY	$45.00	1	$45.00		Mileage to and from Travis - approx 90 miles
Development	HR	$150.00	16	$2,400.00		Development costs per hr
					$7,074.10	
Mobilization/Demobilization	EA	$1,000.00	2		$2,000.00	Two (2) mob/demob (installation and abandonment)
Solar Equipment						
Mount	EA	$325.00	1	$325.00		Sierra Solar Systems
85 Watt Modules	EA	$305.00	4	$1,220.00		Sierra Solar Systems
Solar Pump	EA	$2,122.00	2	$4,244.00		Sierra Solar Systems
Control Box	EA	$81.00	1	$81.00		Sierra Solar Systems
Vault	EA	$2,640.00	2	$5,280.00		
					$11,150.00	
					$32,920.50	
Demolition and Removal of Treatment Plant						
Dismantle Equipment	EA	$30,000.00	1	$30,000.00		
Truck Materials to Landfill	EA	$30,000.00	1	$30,000.00		Includes trucking and landfill costs
Well Abandonment	FT	$41.00	200	$8,200.00		Overdrilling and grout included
Additional Cost	DAY	$500.00	4	$2,000.00		Consumables, H&S, equipment rental
Labor	DAY	$529.10	4	$2,116.40		One (1) person on site for 13 hr/day at a $40.7 bill rate
					$72,316.40	
					$121,022.44	

O&M COSTS

Extraction Wells	Average Flow	Average Energy/Mo (kwh)	Cost/kWh	Estimated Cost/Mo	Estimated Cost/Yr
EW614x07	0.8	472	$0.07	$33.04	$396
EW615x07	0.8	472	$0.07	$33.04	$396
To be installed					$396
To be installed					$396
	1.6				**$1,585**

Carbon Usage Rates	
4.0431	#GAC/Day
0.1404	#GAC/1000 gal
Total Carbon in NGWTP vessels	400#
Lifecylce of carbon	100 Days
Cost to Replace	$495/vessel
# of Vessels	2
Total Cost/100 Days	$990
Total Cost/yr	$3,614

Carbon Changeout	Interval	Cost per changeout	Cost/yr
	50 Days	$1,500	**$10,950**

Labor

Field Tech Hr/Mo	Cost/Field Tech Hr	Labor Cost/Mo	Labor Cost/Yr
4	$56.72	$226.88	**$2,723**

Total O&M Cost/Yr **$15,257.52**

Periodic Costs

Item	Interval	Equipment Cost	Labor Cost	Total
Pump Replacement	5 years	$1,700	$454	**$2,154**
Motor Control Center Repairs	5 years	$2,000	$0	**$2,000**

Present Value Analysis - Time to Cleanup: 26yrs

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$48,706	$48,706	1	$48,706
Annual O&M	1-26	$396,696	$15,258	20.3983	$311,227
Periodic	5	$10,616	$10,616	0.8753	$9,292
Periodic	10	$10,616	$10,616	0.7661	$8,133
Periodic	15	$10,616	$10,616	0.6706	$7,119
Periodic	20	$10,616	$10,616	0.5869	$6,231
Periodic	25	$10,616	$10,616	0.5137	$5,453
Capital	26	$72,316	$72,316	0.5002	$36,173
		$570,798			$432,334

TABLE E-6A
Alternative 4 – Site SS016 Cost Estimate for OSA Bioreactor
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

CAPITAL COSTS

	Unit	Unit Cost	Quantity	Line Item Cost	Total Cost	Comments
Remedial Design	EA	$39,928	1	$39,928	**$39,928**	Includes planning, engineering, permitting, costing and other cost
Excavation						
Pre-Mobilization	LUMP SUM	$5,722.00	1	$5,722		Bid from ERRG
Mobilization	LUMP SUM	$3,900.00	1	$3,900		Bid from ERRG
Site Preparation	LUMP SUM	$3,350.00	1	$3,350		Bid from ERRG
Infrastructure Removal	LUMP SUM	$19,975.00	1	$19,975		Bid from ERRG
Excavation of Bioreactor and Backfill with Biomulch	LUMP SUM	$41,560.00	1	$41,560		Bid from ERRG
Relocate surface water drain	LUMP SUM	$6,240.00	1	$6,240		Bid from ERRG
Install bollards and chain fence	LUMP SUM	$11,390.00	1	$11,390		Bid from ERRG
Install monitoring well	LUMP SUM	$1,450.00	1	$1,450		Bid from ERRG
Demobilization/Site Clean up	LUMP SUM	$3,460.00	1	$3,460		Bid from ERRG
					$97,047.00	
Materials						
Biomulch	Cu Yd	$61.20	340	$20,808.00		Bid from ERRG
Clay Soil	Cu Yd	$73.50	60	$4,410.00		Bid from ERRG
					$25,218.00	
Labor						
ERRG - Level B	HR	$198.00	8	$1,584.00		Bid from ERRG
ERRG - Level C	HR	$104.00	4	$416.00		Bid from ERRG
CH2M HILL - Construction	HR	$55.00	195	$10,725.00		Assumes 15 days to complete bioreactor w/ one person on site
CH2M HILL - Preparation	HR	$55.00	40	$2,200.00		Actual Prep Time
Auto Mileage - Construction	DAY	$45.00	15	$675.00		Assumes 15 days to complete bioreactor w/ one person on site
Auto Mileage - Preparation	DAY	$45.00	4	$180.00		Actual Prep Time
					$15,780.00	

TABLE E-6A
Alternative 4 – Site SS016 Cost Estimate for OSA Bioreactor
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

CAPITAL COSTS

	Unit	Unit Cost	Quantity	Line Item Cost	Total Cost	Comments
Waste Disposal						Assumes 750 total tons of excavated soil
Disposal at Off Base Class I Landfill (RCRA Haz)	TONS	$209.07	250	$52,267.50		
Disposal at Off Base Class I Landfill (State Haz)	TONS	$139.80	250	$34,950.00		
Disposal at Off Base Class II Landfill	TONS	$31.00	250	$7,750.00		
					$94,967.50	
Manifold						
Materials	LUMP SUM	$300.00	1	$300.00		Estimate of PVC, Fittings, Bag Filters, Valves
					$300.00	
EW03x16 Solar Modification						
Mount	EA	$325.00	1	$325.00		Actual cost from Sierra Solar Systems
85 Watt Modules	EA	$305.00	3	$915.00		Actual cost from Sierra Solar Systems
Solar Pump	EA	$2,122.00	1	$2,122.00		Actual cost from Sierra Solar Systems
Control Box	EA	$81.00	1	$81.00		Actual cost from Sierra Solar Systems
					$3,443.00	
Other:						
Utility Locating-Trench	HRS	$157.50	3			Estimate based on verbal quote
					$472.50	
Subtotal					**$306,116.00**	

O&M COSTS	1 Field Tech Hr/Mo	Estimate for time required for basic regular maintenance
	$56.72	
	Cost/yr	
	$680.64	

TABLE E-6B

Alternative 4 – Site SS016 Cost Estimate for GET System O&M

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Extraction Wells	Average Flow	Average Energy/Mo	Cost/kwh	Estimated Cost/Mo	Estimated Cost/Yr
EW605x16	10.7	16	$0.07	$1.12	$13.44
EW610x16	3.6	16	$0.07	$1.12	$13.44
EW01x16	22.6	16	$0.07	$1.12	$13.44
EW02x16	5.8	16	$0.07	$1.12	$13.44
	42.7				**$54**

Carbon Changeout

Total Flow from EWs w/Alternative	Adjusted Frequency of changeout	Cost per changeout	Carbon Cost/Yr
43	516 days	$47,828	**$33,832**

Labor

Field Tech Hr/Mo	Cost per Field Tech Hr	Labor Cost/Mo	Labor Cost/Yr
2	$57	$113	**$1,361**

Total GET System Cost/Yr	**$35,247**

Periodic Costs

Item	Interval	Equipment Cost	Labor Cost	Total
Pump Replacement	5 years	$1,700	$454	**$2,154**
Motor Control Center Repairs	5 years	$2,000	$0	**$2,000**

TABLE E-6C

Alternative 4 – Site SS016 Present Value Analysis

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$306,116	$306,116	1	$306,116
Annual O&M	1-30	$1,077,831	$35,928	20.3982	$732,860
Periodic	4	$17,000	$17,000	0.8989	$15,281
Periodic	5	$16,616	$16,616	0.8753	$14,544
Periodic	8	$17,000	$17,000	0.808	$13,736
Periodic	10	$16,616	$16,616	0.7661	$12,730
Periodic	15	$16,616	$16,616	0.6706	$11,143
Periodic	20	$16,616	$16,616	0.5869	$9,752
Periodic	25	$16,616	$16,616	0.5137	$8,536
Periodic	30	$16,616	$16,616	0.4497	$7,472
		$1,484,411			**$1,116,162**

TABLE E-6D

Site SS016 Cost Estimate for Interim GET System O&M

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Extraction Wells	Average Flow	Average Energy/mo (kwh)	Cost/kwh	Estimated Cost/mo	Estimated Cost/yr
EW605x16	13.4	16	$0.07	$1.12	$13.44
EW610x16	2.7	16	$0.07	$1.12	$13.44
EW01x16	23.3	16	$0.07	$1.12	$13.44
EW02x16	6.8	16	$0.07	$1.12	$13.44
EW03x16	1	16	$0.07	$1.12	$13.44
TPE-W	0.05	16	$0.07	$1.12	$13.44
	47.25				**$81**

Carbon Changeout

Total Flow from EWs at SS016	Adjusted Frequency of changeout	Cost per changeout	Carbon Cost/yr	EW Cost/yr	Total GET System Cost/yr
47.25	469	$47,828	$34,436	$80.64	**$34,517**

EW Cost/Yr	**$81**

Periodic Costs

Item	Interval	Equipment Cost	Labor Cost	Total
Pump Replacement	5 years	$1,700	$454	**$2,154**
Motor Control Center Repairs	5 years	$2,000	$0	**$2,000**

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$759,366	$34,517	20.3982	$704,077
Periodic	5	$14,924	$14,924	0.8753	$13,063
Periodic	10	$14,924	$14,924	0.7661	$11,433
Periodic	15	$14,924	$14,924	0.6706	$10,008
Periodic	20	$14,924	$14,924	0.5869	$8,759
Periodic	25	$14,924	$14,924	0.5137	$7,666
Periodic	30	$14,924	$14,924	0.4497	$6,711
		$819,062			$761,718

TABLE E-7A

Alternative 5 – Site SD037 Cost Estimate for EVO Injections

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

CAPITAL COSTS - Technology Demonstration						
	Unit	**Unit Cost**	**Quantity**	**Line Item Cost**	**Total Cost**	**Comments**
Injection Well Installation						
IDW costs	EA	$1,500.00	6	$9,000.00		Bin rental and IDW disposal
Additional Cost	DAY	$200.00	4	$800.00		Consumables, H&S, equipment rental (4 days spent installing Iws)
Labor	DAY	$529.10	4	$2,116.40		One (1) person on site for 13 hours per day at a $40.7 bill rate
Well Installation	FT	$114.00	265	$30,210.00		Seven (7) wells total 265 feet – includes installation and completion
Auto Mileage	DAY	$45.00	4	$180.00		Mileage to and from Travis AFB – approximately 90 miles
Development	HR	$150.00	33	$4,950.00		Development costs per hour
					$47,256.40	
Performance Monitoring Well Installation						
IDW costs	EA	$1,500.00	3	$4,500.00		Bin rental and IDW disposal
Additional Cost	DAY	$200.00	5	$1,000.00		Consumables, H&S, equipment rental (5 days spend installing MWs)
Labor	DAY	$529.10	5	$2,645.50		One (1) person on site for 13 hours per day at a $40.7 average bill rate
Well Installation	FT	$48.00	333.5	$16,008.00		Seven (7) wells total 333.5 feet – includes installation and completion
Auto Mileage	DAY	$45.00	5	$225.00		Mileage to and from Travis AFB – approximately 90 miles
Development	HR	$150.00	33	$4,950.00		Development costs per hour
					$29,328.50	
Mobilization/Demobilization	EA	$1,000.00	0.5		$500.00	One (1) mob/demob split between SD037 and DP039
Injection Costs						
Labor	HR	$40.70	480	$19,536.00		One (1) person at $40.7 average per hour for 24 hours a day
Vehicle Rental	DAY	$45.00	20	$900.00		Mileage to and from Travis AFB – approximately 90 miles
Additional Cost	DAY	$200.00	14	$2,800.00		Includes consumables, H&S, and equipment rental
					$23,236.00	
Emulsified Vegetable Oil	LB	$1.31	61,695		$80,820.45	Depends on stock price of vegetable oil – cost based on price in Oct 2009
Fixed Costs	EVENT	$16,160.00	1		$16,160.00	Includes planning, engineering, permitting, and building manifold
Utility Clearance	HRS	$157.50	3		$472.50	Cost is 105% of hourly cost for utility clearance during characterizatoin
Surveying Wells	WELL	$118.18	14		$1,654.52	Price from Phillippe Engineering
Total Event Costs					**$199,428.37**	
CAPITAL COSTS - Post-Demonstration Optimization						
	Unit	**Unit Cost**	**Quantity**	**Line Item Cost**	**Total Cost**	**Comments**
Injection Well Installation						
IDW costs	EA	$1,560.00	6	$9,360.00		Bin rental and IDW disposal
Additional Cost	DAY	$208.00	4	$832.00		Consumables, H&S, equipment rental (4 days spent installing Iws)
Labor	DAY	$550.26	4	$2,201.06		One (1) person on site for 13 hours per day at a $40.7 bill rate
Well Installation	FT	$118.56	265	$31,418.40		Seven (7) wells total 265 feet – includes installation and completion
Auto Mileage	DAY	$46.80	4	$187.20		Mileage to and from Travis AFB – approximately 90 miles
Development	HR	$156.00	33	$5,148.00		Development costs per hour
					$49,146.66	
Performance Monitoring Well Installation						
IDW costs	EA	$1,560.00	3	$4,680.00		Bin rental and IDW disposal
Additional Cost	DAY	$208.00	5	$1,040.00		Consumables, H&S, equipment rental (5 days spend installing MWs)
Labor	DAY	$550.26	5	$2,751.32		One (1) person on site for 13 hours per day at a $40.7 average bill rate
Well Installation	FT	$49.92	333.5	$16,648.32		Seven (7) wells total 333.5 feet – includes installation and completion
Auto Mileage	DAY	$46.80	5	$234.00		Mileage to and from Travis AFB – approximately 90 miles
Development	HR	$156.00	33	$5,148.00		Development costs per hour
					$30,501.64	

TABLE E-7A

Alternative 5 – Site SD037 Cost Estimate for EVO Injections

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Mobilization/Demobilization	EA	$1,040.00	0.5		$520.00	One (1) mob/demob split between SD037 and DP039
Injection Costs						
Labor	HR	$42.33	480	$20,317.44		One (1) person at $40.7 average per hour for 24 hours a day
Vehicle Rental	DAY	$46.80	20	$936.00		Mileage to and from Travis AFB – approximately 90 miles
Additional Cost	DAY	$208.00	14	$2,912.00		Includes consumables, H&S, and equipment rental
					$24,165.44	
Emulsified Vegetable Oil	LB	$1.36	61,695		$84,053.27	Depends on stock price of vegetable oil – cost based on price in Oct 2009
Remedial Design	EVENT	$16,806.40	1		$16,160.00	Includes planning, engineering, permitting, costing and other costs associated with design of injection
Utility Clearance	HRS	$163.80	3		$491.40	Cost is 105% of hourly cost for utility clearance during characterizatoin
Surveying Wells	WELL	$122.91	14		$1,720.70	Price from Phillippe Engineering
Total Event Costs					**$206,759.10**	
OPERATION AND MAINTENANCE						
Total Sampling and Analysis Costs						
Labor and Equipment	WELL	$197.40	24	$4,737.60		Six (6) wells sampled 2 x in year 1 for initial sample and baseline and six (6) wells 2 x following expansion
Analysis	WELL	$228.00	24	$5,472.00		Unit Cost based on analytes listed in work plan
					$10,209.60	

SD037 - EA

O&M

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	Total Cost/Yr
6	2	$188	63	**$1,635**

TABLE E-7B
Alternative 5 – Site SD037 Cost Estimate
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

GET

Extraction Well	Average Flow	Average Energy/mo	Cost/kwh	Estimated Cost/mo	Estimated Cost/yr
EW510x37	4.16	206	$0.07	$14.42	$173.04
EW511x37	1.72	206	$0.07	$14.42	$173.04
EW599x37	5.1	206	$0.07	$14.42	$173.04
EW700x37	4.54	206	$0.07	$14.42	$173.04
EW701x37	1.3	206	$0.07	$14.42	$173.04
EW702x37	2.44	206	$0.07	$14.42	$173.04
EW703x37	1.49	206	$0.07	$14.42	$173.04
EW704x37	0.74	206	$0.07	$14.42	$173.04
EW705x37	2	206	$0.07	$14.42	$173.04
EW706x37	0.52	206	$0.07	$14.42	$173.04
EW707x37	0.69	206	$0.07	$14.42	$173.04
	24.69				**$1,557.36**

Carbon Changeout

Total Flow from EW's at SD037	25
% of Total Flow	16%
Adjusted Frequency of changeout	300
Cost per changeout	$30,000
Carbon Cost/yr	$36,500
Carbon Cost/yr due to SD037	$5,840
EW Cost/yr	$1,557.36
Total GET System Cost/yr	**$7,397.36**

MNA

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	Total Cost/Yr
6	2	$188	63	**$1,635**

Total Cost/yr Interim **$9,032.00**

TABLE E-7B

Alternative 5 – Site SD037 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Periodic Costs

	Interval	Equipment Cost	Labor Cost	Total
Pump Replacement	5 years	$1,700	$454	$2,154

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$270,960	$9,032	20.3983	$184,237
Periodic	5	$23,694	$23,694	0.8753	$20,739
Periodic	10	$23,694	$23,694	0.7661	$18,152
Periodic	15	$23,694	$23,694	0.6706	$15,889
Periodic	20	$23,694	$23,694	0.5869	$13,906
Periodic	25	$23,694	$23,694	0.5137	$12,172
Periodic	30	$23,694	$23,694	0.4497	$10,655
		$413,124			$275,751

TABLE E-7C

Alternative 5 – Site SD036 Cost Estimate for EVO Injection

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

CAPITAL COSTS - Technology Demonstration	Unit	Unit Cost	Quantity	Line Item Cost	Total Cost	Comments
Injection Well Installation-18,500 µg/L						
IDW costs	EA	$1,500.00	2	$3,000.00		Bin rental and IDW disposal
Additional Cost	DAY	$200.00	4	$800.00		Consumables, H&S, equipment rental
Labor	DAY	$533.00	4	$2,132.00		One (1) person on site for 13 hours per day at a $41 bill rate
Well Installation	FT	$114.00	200	$22,800.00		Four (4) wells 50 feet deep per well – includes installation and completion
Auto Mileage	DAY	$45.00	1	$45.00		Auto mileage to and from Travis AFB – approximately 90 miles
Development	HR	$150.00	20	$3,000.00		development costs per well for mob/demob and 8 hours of development
					$31,777.00	
Injection Well Installation-3,760 µg/L						
IDW costs	EA	$1,500.00	2	$3,000.00		Bin rental and IDW disposal
Additional Cost	DAY	$200.00	4	$800.00		Consumables, H&S, equipment rental
Labor	DAY	$533.00	4	$2,132.00		One (1) person on site for 13 hours per day at a $41 bill rate
Well Installation	FT	$114.00	140	$15,960.00		Six (6) wells 35 feet deep per well-includes installation and completion
Auto Mileage	DAY	$45.00	4	$180.00		Auto mileage to and from Travis AFB – approximately 90 miles
Development	HR	$150.00	20	$3,000.00		Development costs per well for mob/demob and 8 hours of development
					$25,072.00	
Mobilization/Demobi	EA	$1,000.00	1		$1,000.00	There will likely be one (1) mob/demob for all field work
Injection Costs						
Labor	HR	$41.00	240	$9,840.00		One (1) person at $41 per hour for 24 hours a day
Auto Mileage	DAY	$45.00	10	$450.00		Auto mileage to and from Travis AFB – approximately 90 miles
Additional Cost	DAY	$200.00	10	$2,000.00		Includes consumables, H&S, and equipment rental
					$12,290.00	
Emulsified Vegetable Oil						Depends on stock price of vegetable oil – cost based on price in Oct 2009
18,500 µg/L	LB	$1.51	6,009	$9,073.59		
3,760 µg/L	LB	$1.51	12,085	$18,248.35		
					$27,321.94	
Fixed Costs						Includes planning, engineering, permitting, and building manifold
18,500 µg/L	EVENT	$13,320.00	1			
3,760 µg/L	EVENT	$13,320.00	1			
					$26,640.00	
Utility Clearance	HRS	$157.50	8		$1,260.00	Cost is 105% of hourly cost for utility clearance during characterizatoin
Surveying Wells	WELL	$118.18	8		$945.44	Price from Phillippe Engineering
Total Event Costs					**$126,306.38**	

CAPITAL COSTS - Post-Demonstration Optimization	Unit	Unit Cost	Quantity	Line Item Cost	Total Cost	Comments
Injection Well Installation-18,500 µg/L						
IDW costs	EA	$1,560.00	2	$3,120.00		Bin rental and IDW disposal
Additional Cost	DAY	$208.00	4	$832.00		Consumables, H&S, equipment rental
Labor	DAY	$554.32	4	$2,217.28		One (1) person on site for 13 hours per day at a $41 bill rate
Well Installation	FT	$118.56	200	$23,712.00		Four (4) wells 50 feet deep per well – includes installation and completion
Auto Mileage	DAY	$46.80	1	$46.80		Auto mileage to and from Travis AFB – approximately 90 miles
Development	HR	$156.00	20	$3,120.00		development costs per well for mob/demob and 8 hours of development
					$33,048.08	
Injection Well Installation-3,760 µg/L						

TABLE E-7C
Alternative 5 – Site SD036 Cost Estimate for EVO Injection
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

IDW costs	EA	$1,560.00	2	$3,120.00		Bin rental and IDW disposal
Additional Cost	DAY	$208.00	4	$832.00		Consumables, H&S, equipment rental
Labor	DAY	$554.32	4	$2,217.28		One (1) person on site for 13 hours per day at a $41 bill rate
Well Installation	FT	$118.56	140	$16,598.40		Six (6) wells 35 feet deep per well-includes installation and completion
Auto Mileage	DAY	$46.80	4	$187.20		Auto mileage to and from Travis AFB – approximately 90 miles
Development	HR	$156.00	20	$3,120.00		Development costs per well for mob/demob and 8 hours of development
					$26,074.88	
Mobilization/Demobi	EA	$1,040.00	1		$1,040.00	There will likely be one (1) mob/demob for all field work
Injection Costs						
Labor	HR	$42.64	240	$10,233.60		One (1) person at $41 per hour for 24 hours a day
Auto Mileage	DAY	$46.80	10	$468.00		Auto mileage to and from Travis AFB – approximately 90 miles
Additional Cost	DAY	$208.00	10	$2,080.00		Includes consumables, H&S, and equipment rental
					$12,781.60	
Emulsified Vegetable Oil						Depends on stock price of vegetable oil – cost based on price in Oct 2009
18,500 µg/L	LB	$1.57	6,009	$9,436.53		
3,760 µg/L	LB	$1.57	12,085	$18,978.28		
					$28,414.82	
Remedial Design						Includes planning, engineering, permitting, costing and other costs associated with design of injection
18,500 µg/L	EVENT	$13,852.80	1			
3,760 µg/L	EVENT	$13,852.80	1			
					$27,705.60	
Utility Clearance	HRS	$163.80	8		$1,310.40	Cost is 105% of hourly cost for utility clearance during characterizatoin
Surveying Wells	WELL	$122.91	8		$983.26	Price from Phillippe Engineering
Total Event Costs					**$131,358.64**	

TABLE E-7C
Alternative 5 – Site SD036 Cost Estimate for EVO Injection
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

OPERATION AND MAINTENANCE						
Total Costs Sampling and Analysis						
Labor and Equipment	WELL	$197.40	60	$11,844.00		Fifteen (15) wells 2 x in year 1 for initial and baseline and Fifteen (15) wells 2 x following expansion
Analysis	WELL	$274.00	60	$16,440.00		Unit Cost based on analytes listed in work plan
					$28,284.00	

SD036 - MNA
O&M

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	Total Cost/Yr
6	2	$188	63	**$1,635**

TABLE E-7D

Alternative 5 – Site SD037 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

GET

Extraction Well	Average Flow	Average Energy/mo	Cost/kwh	Estimated Cost/mo	Estimated Cost/yr
EW593x36	2.5	206	$0.07	$14.42	$173.04
EW594x36	0.98	206	$0.07	$14.42	$173.04
EW595x36	3.71	206	$0.07	$14.42	$173.04
					$519.12

Carbon Changeout

Total Flow from EW's at SD037	7.19
% of Total Flow	5%
Adjusted Frequency of changeout	300
Cost per changeout	$30,000
Carbon Cost/yr	$36,500
Carbon Cost/yr due to SD037	$1,825
EW Cost/yr	$519.12
Total GET System Cost/yr	**$2,344.12**

Periodic Costs

	Interval	Equipment Cost	Labor Cost	Total
Pump Replacement	5 years	$1,700	$454	$2,154

MNA

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	Total Cost/Yr
6	2	$188	63	**$1,635**

Total Cost/yr Interim	**$3,978.76**

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$119,370	$3,979	20.3983	$81,165
Periodic	5	$4,904	$4,904	0.8753	$4,292
Periodic	10	$4,904	$4,904	0.7661	$3,757
Periodic	15	$4,904	$4,904	0.6706	$3,289
Periodic	20	$4,904	$4,904	0.5869	$2,878
Periodic	25	$4,904	$4,904	0.5137	$2,519
Periodic	30	$4,904	$4,904	0.4497	$2,205
		$148,794			$100,106

TABLE E-7E

Alternative 5 – Present Value Analyses

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

SD037 Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$199,428	$199,428	1	$199,428
Capital	1	$206,759	$206,759	0.9737	$201,321
Annual O&M	1-30	$49,039	$1,635	20.3982	$33,344
Periodic	1	$10,210	$10,210	0.9737	$9,941
Periodic	6	$269,140	$269,140	0.8523	$229,388
Periodic	12	$269,140	$269,140	0.7264	$195,503
Periodic	18	$269,140	$269,140	0.6191	$166,625
Periodic	24	$269,140	$269,140	0.5276	$141,998
Periodic	30	$269,140	$269,140	0.4497	$121,032
		$1,811,136			$1,298,581

SD036 Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$126,306	$126,306	1	$126,306
Capital	1	$131,359	$131,359	0.9737	$127,904
Annual O&M	1-30	$49,039	$1,635	20.3982	$33,344
Periodic	1	$28,284	$28,284	0.9737	$27,540
Periodic	6	$140,084	$140,084	0.8523	$119,394
Periodic	12	$140,084	$140,084	0.7264	$101,757
Periodic	18	$140,084	$140,084	0.6191	$86,726
Periodic	24	$140,084	$140,084	0.5276	$73,908
Periodic	30	$140,084	$140,084	0.4497	$62,996
		$1,035,408			$759,875

SD033 Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$61,890	$2,063	20.3983	$42,082
		$61,890			$42,082

SD043 Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$38,640	$1,288	20.3983	$26,273
		$38,640			$26,273

Total WIOU Present Value
$2,126,810

TABLE E-7F

Alternative 5 – Site SS015 Cost Estimate for EVO Injections

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

CAPITAL COSTS - Technology Demonstration

	Unit	Unit Cost	Quantity	Line Item Cost	Total Cost	Comments
Injection Well Installation						
IDW costs	EA	$1,500.00	1	$1,500.00		Bin rental and IDW disposal
Additional Cost	DAY	$200.00	5	$1,000.00		Consumables, H&S, equipment rental
Labor	DAY	$533.00	5	$2,665.00		One (1) person on site for 13 hours per day at a $41 bill rate
Well Installation	FT	$114.00	250	$28,500.00		Five (5) wells 25 feet deep per well – includes installation and completion
Auto Mileage	DAY	$45.00	5	$225.00		Mileage to and from Travis AFB approximately 90 miles
Development	HR	$150.00	40	$6,000.00		Development costs per well for mob/demob and 8 hours of development
					$39,890.00	
Performance Monitoring Well Installation						
IDW costs	EA	$1,500.00	1	$1,500.00		Bin rental and IDW disposal
Additional Cost	DAY	$200.00	1	$200.00		Consumables, H&S, equipment rental
Labor	DAY	$533.00	1	$533.00		One (1) person on site for 13 hours per day at a $41 bill rate
Well Installation	FT	$48.00	60	$2,880.00		Two (2) wells 30 feet deep per well – includes installation and completion
Auto Mileage	DAY	$45.00	1	$45.00		Mileage to and from Travis AFB approximately 90 miles
Development	HR	$150.00	10	$1,500.00		Development costs per well for mob/demob and 8 hours of development
					$6,658.00	
Mobilization/Demobilization	EA	$1,000.00	1		**$1,000.00**	There will likely be one (1) mob/demob for all field work
Injection Costs						
Labor	HR	$55.00	24	$1,320.00		One (1) person at $55 per hour for 24 hours a day
Vehicle Rental	DAY	$75.00	1	$75.00		One (1) truck rental per day
Additional Cost	DAY	$200.00	1	$200.00		includes consumables, H&S, and equipment rental
					$1,595.00	
Emulsified Vegetable Oil	LB	$1.51	1,066		**$1,609.66**	Depends on stock price of vegetable oil – cost based on price in Oct 2009, weight based on design tool
Fixed Costs	EVENT	$16,160.00	1		**$16,160.00**	Includes planning, engineering, permitting, and building manifold
Utility Clearance	HRS	$157.50	2		**$315.00**	Cost is 105% of hourly cost for utility clearance during characterizatoin
Surveying Wells	WELL	$118.18	7		**$827.26**	Price from Phillippe Engineering
Total Event Costs					**$68,054.92**	

CAPITAL COSTS - Post-Demonstration Optimization

	Unit	Unit Cost	Quantity	Line Item Cost	Total Cost	Comments
Injection Well Installation						
IDW costs	EA	$1,560.00	1	$1,560.00		Bin rental and IDW disposal
Additional Cost	DAY	$208.00	5	$1,040.00		Consumables, H&S, equipment rental
Labor	DAY	$554.32	5	$2,771.60		One (1) person on site for 13 hours per day at a $41 bill rate
Well Installation	FT	$118.56	250	$29,640.00		Five (5) wells 25 feet deep per well – includes installation and completion
Auto Mileage	DAY	$46.80	5	$234.00		Mileage to and from Travis AFB approximately 90 miles
Development	HR	$156.00	40	$6,240.00		Development costs per well for mob/demob and 8 hours of development
					$41,485.60	
Performance Monitoring Well Installation						
IDW costs	EA	$1,560.00	1	$1,560.00		Bin rental and IDW disposal
Additional Cost	DAY	$208.00	1	$208.00		Consumables, H&S, equipment rental
Labor	DAY	$554.32	1	$554.32		One (1) person on site for 13 hours per day at a $41 bill rate
Well Installation	FT	$49.92	60	$2,995.20		Two (2) wells 30 feet deep per well – includes installation and completion
Auto Mileage	DAY	$46.80	1	$46.80		Mileage to and from Travis AFB approximately 90 miles
Development	HR	$156.00	10	$1,560.00		Development costs per well for mob/demob and 8 hours of development
					$6,924.32	

TABLE E-7F
Alternative 5 – Site SS015 Cost Estimate for EVO Injections
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Mobilization/Demobilization	EA	$1,040.00	1		**$1,040.00**	There will likely be one (1) mob/demob for all field work
Injection Costs						
Labor	HR	$57.20	24	$1,372.80		One (1) person at $55 per hour for 24 hours a day
Vehicle Rental	DAY	$78.00	1	$78.00		One (1) truck rental per day
Additional Cost	DAY	$208.00	1	$208.00		includes consumables, H&S, and equipment rental
					$1,658.80	
Emulsified Vegetable Oil	LB	$1.57	1,066		**$1,674.05**	Depends on stock price of vegetable oil – cost based on price in Oct 2009, weight based on design tool
Remedial Design	EVENT	$16,806.40	1		**$16,806.40**	Includes planning, engineering, permitting, costing and other costs associated with design of injection
Utility Clearance	HRS	$163.80	2		**$327.60**	Cost is 105% of hourly cost for utility clearance during characterizatoin
Surveying Wells	WELL	$122.91	7		**$860.35**	Price from Phillippe Engineering
Total Event Costs					**$70,777.12**	
OPERATION AND MAINTENANCE						
Total Sampling and Analysis Costs						
Labor and Equipment	WELL	$197.40	20	$3,948.00		Five (5) wells 2 x the first year for initial and baseline, and Five (5) wells 2 x following expansion
Analysis	WELL	$228.00	20	$4,560.00		Unit Cost based on analytes listed in work plan
					$8,508.00	

MNA

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	Total Cost/Yr
6	2	$188	63	**$1,635**

TABLE E-7F

Alternative 5 – Site SS015 Cost Estimate for EVO Injections

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$68,055	$68,055	1	$68,055
Capital	1	$70,777	$70,777	0.9737	$68,916
Annual O&M	1-30	$49,039	$1,635	20.3982	$33,344
Periodic	1	$8,508	$8,508	0.9737	$8,284
Periodic	6	$56,652	$56,652	0.8523	$48,284
Periodic	12	$56,652	$56,652	0.7264	$41,152
Periodic	18	$56,652	$56,652	0.6191	$35,073
Periodic	24	$56,652	$56,652	0.5276	$29,890
Periodic	30	$56,652	$56,652	0.4497	$25,476
		$479,639			$358,474

TABLE E-7G

Alternative 5 – Site SS015 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

MNA

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	Total Cost ($)/Yr
10	3	$188	$63	**$2,703**

Total Cost/yr Interim	**$2,703**

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$2,703	$2,703	20.3983	$55,137
		$2,703			$55,137

TABLE E-8A

Alternative 6 – Site DP039 Cost Estimate for EVO PRB

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

CAPITAL COSTS	Unit	Unit Cost	Quantity	Line Item Cost	Total Cost	Comments
Injection Well Installation						
IDW costs	EA	$1,500.00	6	$9,000.00		Bin rental and IDW disposal
Additional Cost	DAY	$200.00	14	$2,800.00		Consumables, H&S, equipment rental
Labor	DAY	$500.40	14	$7,005.60		One (1) person on site for 12 hours per day at a $44.7 average bill rate
Well Installation	FT	$114.00	787	$89,718.00		Thirteen (13) wells total depth – includes installation and completion
Auto Mileage	DAY	$45.00	14	$630.00		Drive to and from Travis AFB – approximately 90 miles
Development	HR	$150.00	21	$3,150.00		Development costs per well for mob/demob and 8 hours of development
					$112,303.60	
Performance Monitoring Well Installation						
IDW costs	EA	$1,500.00	1	$1,500.00		Bin rental and IDW disposal
Additional Cost	DAY	$200.00	3	$600.00		Consumables, H&S, equipment rental
Labor	DAY	$500.40	3	$1,501.20		One (1) person on site for 12 hours per day at a $41.7 average bill rate (according to total imp. Cost/hrs on the impl PN)
Well Installation	FT	$48.00	159	$7,632.00		three wells 73', 50', and 36' deep, includes completion
Auto Mileage	DAY	$45.00	3	$135.00		Drive to and from Travis AFB – approximately 90 miles
Development	HR	$150.00	20.5	$3,075.00		Development costs per well for mob/demob and 8 hours of development
					$14,443.20	
Mobilization/Demobilization	EA	$1,000.00	0.5		$500.00	One (1) mob/demob for field work
Injection Costs						
Labor	HR	$41.70	325	$13,552.50		25 days at 13 hours per
Auto Mileage	DAY	$45.00	25	$1,125.00		Drive to and from Travis AFB – approximately 90 miles
Additional Cost	DAY	$200.00	13	$2,600.00		Includes consumables, H&S, and equipment rental
					$17,277.50	
Emulsified Vegetable Oil	LB	$1.31	31,911		$41,803.41	Depends on stock price of vegetable oil – cost based on price in Oct 2009
Remedial Design	EVENT	$16,160.00	1		$16,160.00	Includes planning, engineering, permitting, costing and other costs associated with injection design
Utility Clearance	HRS	$157.50	3		$472.50	Cost is 105% of hourly cost for utility clearance during characterizatoin
Surveying Wells	WELL	$118.18	16		$1,890.88	Price from Phillippe Engineering 13 IWs and 3 MWs
Total Event Costs					**$204,851.09**	
OPERATION AND MAINTENANCE						
Total Costs Sampling and Analysis						
Labor and Equipment	WELL	$197.40	10	$1,974.00		Five (5) wells 2 x the first year
Analysis	WELL	$274.00	10	$2,740.00		Unit Cost based on analytes listed in work plan
					$4,714.00	

DP039 - EA

O&M

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	Total Cost/Yr
7	3	$188	63	**$1,949**

TABLE E-8A

Alternative 6 – Site DP039 Cost Estimate for EVO PRB

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$204,851	$204,851	1	$204,851
Annual O&M	1-30	$58,470	$1,949	20.3982	$39,756
Periodic	1	$4,714	$4,714	0.9737	$4,590
Periodic	6	$238,486	$238,486	0.8523	$203,262
Periodic	12	$238,486	$238,486	0.7264	$173,236
Periodic	18	$238,486	$238,486	0.6191	$147,647
Periodic	24	$238,486	$238,486	0.5276	$125,825
Periodic	30	$238,486	$238,486	0.4497	$107,247
		$1,460,465			$1,006,414

TABLE E-8B

Alternative 6 – Site DP039 Cost Estimate for Bioreactor

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

CAPITAL COSTS

	Unit	Unit Cost	Quantity	Total Cost	Comments
Dillard-Bin Delivery	bin	$1,040.00	1	$1,040	Bin with liner delivered to Travis AFB
Dillard-Waste Disposal	bin	$3,315.00	1	$3,315	Disposal of IDW to Cleanharbors landfill
Geotech-Solar Pump	pump system	$5,314.30	1	$5,314	Includes all materials (panels, pump, mount, misc materials)
Dolver Costs					
Mobilization/Demobilization/Clean-up	per mob	$2,930.00	1	$2,930	Movement to and from Travis AFB and decon
Excavation	crew	$1,904.00	1	$1,904	Performed with crew in Level C
Excavation of 20'x20'x20'	8,000 cu ft	$14,294.00	1	$14,294	Only includes actual excavation
Construction and Backfill Bioreactor	bioreactor	$23,224.00	1	$23,224	Purchased gravel, mulch was on site
Install blank casing in Extraction Well	well	$561.00	1	$561	EW563x39
Abandon Extraction Well	well	$2,038.00	1	$2,038	EW563x39 – includes $1,080 for delivery of iron pyrite
Install Solar Panel	system	$1,275.00	1	$1,275	Includes trenching and installation
Saratoni-2000 lbs Soybean Oil	tote	$1,460.30	2	$2,921	Includes delivery, taxes, fuel surcharge
Curtis and Tompkins	sampling	$1,482.75	1	$1,483	Includes all sampling during and right after install
WDC	event	$15,096.00	1	$15,096	Includes mob, coring, well installation, development and decon
CAL INC	event	$1,940.00	1	$1,940	Lead monitoring
Precision Locating	location	$139.00	3	$417	Utility locator
CH2M HILL staff on site	hr	$55.00	165	$9,075	Includes CH2M HILL employee onsite 11 hours per day for 3 weeks
Total Capital to Install Bioreactor				**$86,827**	

O&M COSTS

1 Field Tech Hr/Mo

$56.72

Cost/yr

$680.64

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$86,827	$86,827	1	$86,827
Annual O&M	1-30	$20,400	$680	20.3982	$13,871
Periodic	4	$17,000	$17,000	0.8989	$15,281
Periodic	8	$17,000	$17,000	0.808	$13,736
Periodic	12	$17,000	$17,000	0.7264	$12,349
Periodic	16	$17,000	$17,000	0.6529	$11,099
Periodic	20	$17,000	$17,000	0.5869	$9,977
Periodic	28	$17,000	$17,000	0.4743	$8,063
		$209,227			$171,204

TABLE E-8C

Alternative 6 – Site DP039 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

GET

Extraction Well	Average Flow	Average Energy/mo	Cost/kwh	Estimated Cost/mo	Estimated Cost/yr
EW563x39	1.07	206	$0.07	$14.42	$173.04
EW782x39	1.53	206	$0.07	$14.42	$173.04
	2.6				**$346.08**

Carbon Changeout

Total Flow from EW's at DP039	% of Total Flow	Adjusted Frequency of changeout	Cost per changeout	Carbon Cost/yr	Carbon Cost/yr due to DP039	EW Cost/yr	Total GET System Cost/yr
2.6	3%	300	$30,000	$36,500	$986	$346.08	**$1,331.58**

MNA

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	Total Cost/Yr
3	2	$188	63	**$880**

Total Cost/yr Interim	**$2,211.90**

Periodic Costs

Item	Interval	Cost	Labor Cost	Total
Pump Replacement	5 years	$1,700	$454	**$2,154**
Motor Control Center Repairs	5 years	$2,000	$0	**$2,000**

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$61,170	$2,039	20.3983	$41,592
Periodic	5	$8,308	$8,308	0.8753	$7,272
Periodic	10	$8,308	$8,308	0.7661	$6,365
Periodic	15	$8,308	$8,308	0.6706	$5,571
Periodic	20	$8,308	$8,308	0.5869	$4,876
Periodic	25	$8,308	$8,308	0.5137	$4,268
Periodic	30	$8,308	$8,308	0.4497	$3,736
		$111,018			$73,680

TABLE E-9
Alternative 7 – Site SD034 Cost Estimate
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Interim Action **Passive Skimming/GET**

Passive Skimming

# of Wells w/ Skimmers	Field Tech Hrs/mo	Technician Cost	Data Management Hrs/mo	Data Management Cost	Cost/yr
5	2	$113	1	$57	**$2,042**

GET

Extraction Well	Average Flow	Average Energy/mo (kwh)	Cost/kwh	Estimated Cost/mo	Estimated Cost/yr
EW01x34	0.36	206	$0.07	$14.42	$173.04
EW03x34	0.7	206	$0.07	$14.42	$173.04
	1.06				**$346.08**

Carbon Changeout

Total Flow from EW's at DP039	% of Total Flow	Adjusted Frequency of changeout	Cost per changeout	Carbon Cost/yr	Carbon Cost/yr due to SD034	EW Cost/yr	Total GET System Cost/yr
1.1	1%	300	$30,000	$36,500	$365	$346.08	**$711.08**

Labor

Field Tech Hr/Mo	Cost per Field Tech Hr	Labor Cost/Mo	Labor Cost/Yr
2	$57	$113	**$1,361**

Total O&M Cost/Yr **$4,114**

Periodic Costs

Item	Interval	Cost	Labor Cost	Total
Pump Replacement	5 years	$1,700	$454	**$2,154**
Motor Control Center Repairs	5 years	$2,000	$0	**$2,000**

Present Value Analysis - Time to Cleanup: 62 yrs

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$123,428	$4,114	20.3983	$83,924
Periodic	5	$6,308	$6,308	0.8753	$5,521
Periodic	10	$6,308	$6,308	0.7661	$4,833
Periodic	15	$6,308	$6,308	0.6706	$4,230
Periodic	20	$6,308	$6,308	0.5869	$3,702
Periodic	25	$6,308	$6,308	0.5137	$3,240
Periodic	30	$6,308	$6,308	0.4497	$2,837
		$161,276			$108,288

TABLE E-9

Alternative 7 – Site SD034 Cost Estimate

Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Selected Alternative - 7

EA

# of Wells in Network	# of QA/QC Samples	$ to Sample/Well	VOC Analysis	TPH-G Analysis	TPH-D Analysis	Cost/Yr
4	1	$188	$63	$63	$73	**$1,613**

Passive Skimming

# of Wells w/ Skimmers	Field Tech Hrs/mo	Technician Cost	Data Management Hrs/mo	Data Management Cost	Cost/yr
5	2	$113	1	$57	**$2,042**

Present Value Analysis

Cost Type	Year	Total Cost	Total Cost/Yr	Discount Factor (2.7%)	Present Value
Capital	0	$0	$0		$0
Annual O&M	1-30	$94,605	$3,655	22.0646	$80,639
		$94,605			$80,639

Appendix F
Sustainability Evaluations

APPENDIX F

Sustainability Evaluations

In the mid-1990s, when the Air Force was following the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process to select interim remedies for its contaminated groundwater sites, little consideration was given to the materials used to build remedy infrastructure or the energy demands of the resulting treatment systems. During the period of interim remediation, there has been a growing recognition that most remedies use energy, water, and other resources and thus have an environmental "footprint." Efforts to conserve natural resources, minimize waste generation, and reduce energy use can improve environmental performance while protecting human health and the environment.

To this end, the Air Force conducted sustainability evaluations of the Travis Air Force Base (AFB) interim groundwater remedies and the remedial alternatives developed in this Focused Feasibility Study (FFS). This appendix provides the results of these evaluations.

The term "sustainability" is often used in the context of broad social, economic, and environmental health issues. For example, the U.S. Environmental Protection Agency (EPA) describes sustainable development as that which meets the needs of the present without compromising the needs of future generations, while minimizing overall burdens to society. For the purposes of this FFS, the sustainability evaluations are concerned only with groundwater remedy selection. Section 4.2.4 (Sustainability) of the FFS describes sustainability in remedial action systems and "green" remedial actions in more detail.

Sustainable design in remediation projects is a systematic, balanced planning and management of risk concept. Sustainability includes many aspects of environmental, social, economic, and health developments. This sustainability evaluation quantifies environmental footprints for the remedial alternatives developed in the FFS. Although this is not considered a full life-cycle analysis, it does consider energy and materials consumed on the site during the life of the project. The tool selected to perform the analysis quantifies select sustainability metrics for comparing the environmental footprints of remediation alternatives.

This appendix provides the results of sustainability evaluations conducted for the current site-specific groundwater interim remedial actions (IRAs) and the remedial alternatives developed in this FFS. The purpose of these evaluations is to identify and compare environmental footprints for each IRA and proposed remedial alternatives at each site. The results of the footprint analysis are not part of the formal criteria for remedy selection, but rather information to be considered within the appropriate elements of the nine (9) criteria. A short discussion of green and sustainability factors have been included under the short-term effectiveness criterion provided in Section 9 of the FFS.

The scope of the evaluations in this appendix includes estimates of key components of energy use and resulting air emissions related to the remediation of groundwater at Sites FT004, FT005, LF006, LF007C, LF008, SS016, ST027B, SS030, SD031, SD033, SD034, SD036, SD037, DP039, and SD043.

The Air Force will continue to apply the principles of green and sustainable remediation as part of Remedial Process Optimization after the final remedies are implemented.

F.1 Sustainable Remediation Tool

The sustainability evaluations provided in this appendix were conducted using the Air Force Center for Engineering and the Environment (AFCEE) Sustainable Remediation Tool (SRT) (AFCEE, 2009). The SRT is an easy to use Excel-based computer tool that provides key calculations, databases, conversion factors, user interfaces, and output reports. The SRT is released as a public domain computational tool available at: http://www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/sustainableremediation/srt/index.asp.

The SRT allows users to estimate sustainability metrics for specific technologies. The current technologies in the SRT are (1) Excavation, (2) Soil Vapor Extraction, (3) Pump and Treat, (4) Enhanced Bioremediation, (5) In Situ Chemical Oxidation, (6) Permeable Reactive Barrier (PRB), (7) Monitored Natural Attenuation (MNA)/Long-term Monitoring (LTM), and (8) Thermal Soil Treatment.

There are seven (7) alternatives containing nine (9) separate technology components developed for the FFS. The components are as follows: (1) No Action, (2) MNA, (3) Groundwater Extraction and Treatment (GET), (4) Bioreactors, (5) Emulsified Vegetable Oil (EVO) injections, (6) Phytoremediation, (7) Enhanced Attenuation (EA), (8) EVO Permeable Reactive Barrier (PRB), and (9) Passive Skimming.

Five (5) different SRT modules were used to evaluate the components that make up the alternatives in the FFS. The Pump and Treat module was used for all sites with the GET component (Sites FT004, FT005, LF008, SS016, SS029, SS030, SD031, SD033, SD034, SD036, SD037, DP039 and SD043). All sites containing MNA (or EA) as a component were evaluated with the MNA/LTM module. This list of sites includes Sites FT004, FT005, LF006, LF008, SS015, SD034, SD036, SD037 and DP039. A phytoremediation test area has been established at Site DP039. To calculate the environmental footprints associated with conducting future operations and maintenance (O&M), the worker transportation sub-module within the SRT was used. Bioreactors were also part of the components for Sites SS016 and DP039. The Excavation and PRB modules were used to capture the sustainability metrics associated with installation and O&M activities for the bioreactors. EVO injections were part of the alternative at four (4) sites (Sites SS015, SD036, SD037 and DP039). The Enhanced Bioremediation module was used to calculate their sustainability metrics.

The only component of the seven (7) alternatives that did not “fit” into the SRT modules was passive skimming. Therefore, the environmental footprint of passive skimming was not included in the analysis for Alternative 7 (Site SD034); however, the EA portion was evaluated. Even though a quantitative evaluation for passive skimming could not be made for Site SD034, it is likely that a passive skimmer system has significant energy and air emission benefits when compared with existing pump-and-treat activities at the site.

The results of the evaluations using the SRT do not have the same standing as the nine (9) CERCLA remedy selection criteria specified in the FS guidance (EPA, 1988). Rather, they are simply considerations in the FFS evaluations. The SRT results are specifically used to support evaluation of the Short-term Effectiveness criterion within Section 9 of the FFS. This criterion includes the factor of protection of workers during remedial action. The SRT results provide a comparison of potential lost labor hours and injury risks between the IRA and FFS alternative for each site.

F.2 Basis of Sustainability Evaluations

The primary bases for the SRT evaluations include the following two (2) scenarios:

- Maintain the existing groundwater IRA specified in the applicable Interim Record of Decision (IROD) for each site (refer to Section 2).
- Implement the applicable alternative developed in this FFS for each site (refer to Sections 7, 8, and 9). For some sites, the existing IRA and the FFS alternative are the same. For other sites, IRA optimization actions have already been incorporated into the interim remedy and are carried forward into the FFS alternative.

The O&M durations used in the SRT evaluations are based on the time-to-cleanup estimates provided in Appendix D.

F.2.1 Interim Remedial Actions and Alternatives

Summary descriptions of the bases for the SRT evaluations at each site are provided in the following list:

- **Site FT004**
  - **Maintain IRA –** Continue groundwater extraction and treatment (GET) system operation using eight (8) existing extraction wells. Operate the GET system for at least 35 years to achieve cleanup objectives. Conduct semiannual sampling of ten (10) wells for at least 35 years.
  - **Implement FFS Alternative 2 –** Discontinue operation of the current GET system. Initiate a program of MNA. Conduct semiannual sampling of ten (10) wells for at least 35 years.
- **Site FT005**
  - **Maintain IRA –** Continue GET system operation using six (6) off-base extraction wells. Operate the GET system for at least 10 years to achieve cleanup objectives. Conduct semiannual sampling of 30 wells for at least 10 years.
  - **Implement FFS Alternative 2 –** Discontinue operation of the current GET system. Initiate a program of MNA. Conduct semiannual sampling of 30 wells for at least 43 years.
- **Site LF006**
  - **Maintain IRA –** Continue program of MNA for at least 5 years to achieve cleanup objectives. Conduct semiannual sampling of 13 wells for at least 5 years.
  - **Implement FFS Alternative 2 –** Same as the existing MNA IRA.

- **Site LF007C**
  - **Maintain IRA –** Continue solar-powered GET system operation using two (2) on-base extraction wells. Operate the GET system for at least 26 years to achieve cleanup objectives. Conduct semiannual sampling of eight (8) wells for at least 26 years.
  - **Implement FFS Alternative 3 –** Same as the existing GET system IRA.
- **Site LF008**
  - **Maintain IRA –** Continue GET operations using three (3) existing extraction wells. Operate the GET system for 100 years to achieve cleanup objectives. Conduct semiannual sampling of eight (8) wells for at least 100 years.
  - **Implement FFS Alternative 2 –** Discontinue operation of the current GET system. Initiate a program of MNA. Conduct semiannual sampling of eight (8) wells for at least 100 years.
- **Site SS015**
  - **Maintain IRA –** Not feasible to continue the current program of MNA. Contaminant concentrations are increasing and entirely natural attenuation processes do not appear sufficient to remediate the plume. With an increasing trend, the time-to-cleanup is indeterminate.
  - **Implement FFS Alternative 5 –** Conduct in situ treatment of the contaminant source zone using EVO injection. Implement a program of monitored EA within the distal portions of plume. Maintain and operate the remediation system for at least 25 years. Conduct semiannual sampling of 19 wells for at least 70 years.
- **Site SS016**
  - **Maintain IRA –** Continue GET operations using six (6) existing extraction wells. Operate the GET system for 100 years. Conduct semiannual sampling of 15 wells for at least 100 years.
  - **Implement FFS Alternative 4 –** Continue GET operations using four (4) existing extraction wells. Excavate contaminant source area and install an in situ bioreactor. Operate GET system and bioreactor for at least 62 years. Conduct semiannual sampling of 33 wells for at least 62 years.
- **Site ST027B**
  - **Maintain IRA –** Continue program of MNA. Conduct semiannual sampling of eight (8) wells for at least 50 years.
  - **Implement FFS Alternative 2 –** Same as the existing program of MNA.

- **Site SS029**
  - **Maintain IRA –** Continue GET system operation using seven (7) existing extraction wells. Operate the GET system for at least 100 years. Conduct semiannual sampling of 18 wells for at least 100 years.
  - **Implement FFS Alternative 3 –** Same as the existing GET system IRA.
- **Site SS030**
  - **Maintain IRA –** Continue GET operations using six (6) existing extraction wells. Operate the GET system for at least 22 years. Conduct semiannual sampling of eleven (11) wells for at least 22 years.
  - **Implement FFS Alternative 3 –** Same as the existing GET system IRA.
- **Site SD031**
  - **Maintain IRA –** Continue GET system operation using three (3) existing extraction wells. Operate the GET system for at least 15 years. Conduct semiannual sampling of six (6) wells for at least 15 years.
  - **Implement FFS Alternative 2 –** Discontinue operation of the current GET system. Initiate a program of MNA. Conduct semiannual sampling of six (6) wells for at least 15 years.
- **Site SD033**
  - **Maintain IRA –** Continue GET system operation using two (2) existing extraction wells. Operate the GET system for 91 years. Conduct semiannual sampling of five (5) wells for at least 91 years.
  - **Implement FFS Alternative 2 –** Discontinue operation of the current GET system. Initiate a program of MNA. Conduct semiannual sampling of five (5) wells for at least 60 years.
- **Site SD034**
  - **Maintain IRA –** Continue GET system operation using two (2) existing extraction wells. Operate the GET system for 91 years. Conduct semiannual sampling of five (5) wells for at least 91 years.
  - **Implement FFS Alternative 7 –** Discontinue operation of the current GET system. Continue intermittent free product removal, as required. Initiate a program of MNA. Conduct semiannual sampling of five (5) wells for at least 60 years.
- **Site SD036**
  - **Maintain IRA –** Continue GET system operation using three (3) existing extraction wells. Operate the GET system for at least 91 years. Conduct semiannual sampling of nine (9) wells for at least 91 years.
  - **Implement FFS Alternative 5 –** Discontinue operation of the current GET system. Conduct in situ treatment of the contaminant source zone using EVO injection.

Implement a program of monitored EA within the distal portions of plume. Maintain and operate the remediation system for at least 60 years. Conduct semiannual sampling of nine (9) wells for at least 60 years.

- **Site SD037**
  - **Maintain IRA –** Continue GET system operation using eleven (11) existing extraction wells. Operate the GET system for at least 91 years to achieve cleanup objectives. Conduct semiannual sampling of 34 wells for at least 91 years.
  - **Implement FFS Alternative 5 –** Discontinue operation of the current GET system. Conduct in situ treatment of the contaminant source zone using EVO injection. Implement a program of monitored EA within the distal portions of plume. Maintain and operate the remediation system for least 60 years. Conduct semiannual sampling of 34 wells for at least 60 years.
- **Site DP039**
  - **Maintain IRA –** Continue GET system operations using two (2) existing extraction wells. Operate the GET system for at least 70 years. Conduct semiannual sampling of 15 wells for at least 70 years.
  - **Implement FFS Alternative 6 –** Discontinue GET system operations. Install an in situ bioreactor in the contaminant source zone. Maintain an existing area of phytoremediation. Install an EVO PRB. Implement a program of monitored EA within the distal portions of plume. Operate and maintain the remediation system for at least 30 years. Conduct semiannual sampling of 15 wells for at least 58 years.
- **Site SD043**
  - **Maintain IRA –** Continue GET system operation using one (1) existing extraction well. Operate the GET system for at least 91 years. Conduct semiannual sampling of three (3) wells for at least 91 years.
  - **Implement FFS Alternative 2 –** Discontinue operation of the current GET system. Initiate a program of MNA. Conduct semiannual sampling of three (3) wells for at least 60 years.

F.2.2 Air Emissions

For the air emissions analysis, metrics associated with the production of carbon dioxide (CO_2), sulfur oxides (SO_x), nitrogen oxides (NO_x), and particulate matter (PM_{10}) were considered. The following primary components were evaluated for their air emission impacts:

- **Vehicle Use for GET O&M Activities –** Sustainability metrics for vehicle use for GET O&M were calculated assuming 30 miles per round trip, for an estimated 1,560 miles annually. O&M visits for the GET are assumed to take place one (1) time per week for the duration of operations. It was assumed that O&M activities will remain constant for the entire duration of remediation. Air emissions were calculated by multiplying the specific vehicle emission factors times the total number of vehicle miles driven.

- **Vehicle Use for Bioreactor and EVO O&M Activities –** Sustainability metrics for vehicle use for bioreactor and EVO O&M activities were calculated assuming 30 miles per round trip and four (4) trips per year, for an estimated 120 miles annually. Bioreactor O&M activities are assumed to continue for 25, 30, and 62 years for Sites SS015, DP039, and SS016, respectively. The SRT calculates the O&M activities to rejuvenate the bioreactor every 5 years with vegetable oil. The EVO activities will continue for 25 years for Site SS015, 30 years for Site DP039, and 60 years for Sites SD036 and SD037. Air emissions were calculated by multiplying the specific vehicle emission factors times the total number of vehicle miles driven.

- **Vehicle Use for Phytoremediation O&M Activities –** Sustainability metrics for vehicle use for phytoremediation O&M activities were calculated assuming 30 miles per round trip and four (4) trips per year, for an estimated 120 miles annually. One additional trip every 2 years was assumed for bringing fertilizer to the site. It was assumed that phytoremediation O&M will continue for 30 years. The heavy equipment portion of the SRT Excavation module was used to estimate the sustainability impacts of vehicle use for phytoremediation support.

- **Vehicle Use for Semiannual Sampling Activities –** Sustainability metrics for vehicle use for semiannual sampling were calculated assuming 30 miles per round trip, for an estimated 60 miles annually. It was assumed that semiannual sampling activities would remain constant for the duration of remediation activities for all alternatives. Laboratory analysis was not included in the evaluation because it is not part of the SRT. However, because laboratory analysis is a part of every potential remedial alternative, except No Action, the environmental impacts from laboratory analysis should not yield different results during the Comparative Analysis of Alternatives.

- **Substrate Injection Activities –** Sustainability metrics associated with EVO injections were calculated based on the total weight of EVO substrate estimated in the conceptual designs for each alternative. Air emissions (CO_2) were calculated by multiplying the substrate emission factor by the total weight of substrate.

- **GET System Energy Usage –** Sustainability metrics for GET system energy usage were derived from the estimated power consumption required to operate the existing pump-and-treat systems. The extracted groundwater is treated with air strippers or granular activated carbon (GAC) prior to proper discharge. Greenhouse gas emissions were calculated by multiplying appropriate emissions factors times the estimated total power consumption.

  The SRT evaluation includes transport and disposal of GAC. The SRT also uses a conversion factor to calculate pounds of CO_2 generated based on quantity of GAC and EVO used during the project. Treated water is discharged into the stormwater drainage system or used for irrigation on a seasonal basis.

  There are variations in the source of grid electricity across regional and local scales. In cases where a large percentage of the electricity is derived from wind and hydro power, evaluation findings may be altered. The standard SRT assumptions were used to calculate electricity metrics for the FFS (U.S. Average from Energy Information Administration, 2002; Updated State level Greenhouse Gas Emission Coefficients for

Electricity Generation 1998-2000, http://tonto.eia.doe.gov/ftproot/environment/e-supdoc-u.pdf).

- **Beneficial Reuse of Treated Groundwater –** Conveyance systems for seasonal beneficial reuse of treated groundwater have already been constructed for Sites LF007C, FT004, and SD031. An underground pipeline is used to convey treated water from the NGWTP to the on-base recreational Duck Pond. Current restrictions on the use of environmental restoration funds limit other possible beneficial reuse of treated groundwater at other sites.

F.2.3 Energy Usage

For the energy usage analysis, metrics associated with power consumption include the following:

- **GET System Operations –** Sustainability metrics for GET system energy usage were derived from the estimated power consumption required to operate the existing pump-and-treat systems. The amount of electricity was calculated by multiplying the GET power requirement times the estimated operating time of the system.
- **Vehicle Use for GET O&M Activities –** Sustainability metrics for the energy value of vehicle use for GET O&M were calculated based on the gallons of diesel and gasoline consumed during the remediation time frame. The energy values are calculated by multiplying the specific vehicle emission factors times quantity of fuel consumed.
- **Vehicle Use for Bioreactor and EVO O&M Activities –** Sustainability metrics for the energy value of vehicle use for EVO O&M were calculated based on the gallons of diesel and gasoline consumed during the remediation time frame. The energy values are calculated by multiplying the specific vehicle emission factors times quantity of fuel consumed.
- **Vehicle Use for Phytoremediation O&M Activities –** Sustainability metrics for the energy value of vehicle use for phytoremediation O&M were calculated based on the gallons of diesel and gasoline consumed during the remediation time frame. The energy values are calculated by multiplying the specific vehicle emission factors times quantity of fuel consumed.
- **Vehicle Use for Semiannual Sampling Activities –** Sustainability metrics for the energy value of vehicle use for semiannual sampling activities were calculated based on the gallons of diesel and gasoline consumed during the remediation time frame. The energy values are calculated by multiplying the specific vehicle emission factors times quantity of fuel consumed.

Conveyance systems for seasonal beneficial reuse of treated groundwater have already been constructed for Sites LF007C, FT004, and SD031. An underground pipeline is used to convey treated water from the NGWTP to the Base recreational Duck Pond. Current restrictions on the use of environmental restoration funds limit other possible beneficial reuse of treated groundwater at other sites.

F.2.4 Non-renewable Resource Use

The different remediation alternatives being evaluated will result in the use of different amounts of non-renewable resources such as fuel and/or electricity. Possible renewable resources were used in the alternatives for Sites LF007C and DP039. Two (2) solar powered extraction wells are part of Alternative 3 at Site LF007C. Alternative 6 at Site DP039 includes the use of a small solar-powered pump to recirculate the source area groundwater for in situ bioremediation via the existing bioreactor.

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.

F.3 Results of SRT Analysis

F.3.1 Primary Analysis

The results of SRT analysis are summarized in Table F-1. The footprints for certain greenhouse gases and energy use for each alternative have been presented because these sustainability metrics represent key components associated with typical remediation systems used by the Air Force.

CO_2 emissions were higher for the optimized IRA GET systems compared with Alternative 2 (Sites FT004, FT005, LF008, SD031, SD033, and SD043), Alternative 5 (Site SD037), and Alternative 7 (Site SD034). The largest difference in CO_2 emissions typically occurred when comparing IRA GET systems and Alternative 2 (MNA). In most cases, the GET systems emitted 30-plus times the amount of CO_2 compared with MNA. The CO_2 emissions for Alternative 4 (Site SS016) and Alternative 6 (Site DP039) were higher than the optimized IRA GET systems. The CO_2 emissions for Alternative 5 were either approximately the same (Site SD037) or 47 percent higher (Site SD036) than the IRA GET systems. The higher CO_2 emissions associated with the alternatives is mainly due to the production and transportation of the substrate. The remaining greenhouse gas emissions (SO_x, NO_x, and PM_{10}) are all higher for GET systems compared with each of the alternatives.

The total energy consumption for IRA activities (primarily GET) is higher than all the proposed alternatives, except for Site FT005. The IRA for Site FT005 is an MNA evaluation conducted for 5 years; therefore, it has a relatively small environmental footprint compared with the alternative. The total energy reduction for Alternative 2 ranged from 95 to 97 percent. The reduction observed for Alternatives 4 and 5 is 42 and 90 to 95 percent, respectively. The total energy reduction for Alternative 6, which contains the most "green" technologies, is 74 percent.

As expected, the SRT estimates much higher total energy consumption for the existing GET systems when compared with MNA or other lower energy technologies such as bioreactors, EVO injections, and phytoremediation. In fact, even if MNA timeframes were over 100 years, the energy use and air emission impact of MNA would still be considerably less than that for GET systems. Partial reliance on solar energy could improve the sustainability of the remaining GET systems. It is interesting to note that the need for frequent vegetable oil injections in bioreactors or frequent EVO in situ injections will increase the environmental footprints for air emissions because transportation of EVO to the site and injection equipment consume petroleum resources.

Because the frequency of future vegetable oil injections for each applicable site has yet to be determined and will be based on performance monitoring through the period of interim groundwater remedial action and possibly into the implementation and operation of the final remedies, the actual footprint values from these remedial alternatives may vary from the SRT estimates. Also, specific assumptions that were used in the SRT analysis, such as the sources of electricity generation that support Travis AFB and the vendors of materials that are used by the selected remedies, could change while a remedy is in action. By focusing on the parameters that contribute to the footprint of the remedial alternatives, it will be possible to respond to changing conditions and reduce as much as practicable the actual footprints during remedy implementation and operation.

F.3.2 Sensitivity Analysis

Some estimated footprints are anticipated to be more sensitive to input parameters than others. The sensitivity of the outputs to various input information can be determined by conducting a sensitivity analysis, which involves varying the input parameters and tracking the change of the output. For this analysis, the largest contributors to the footprints for Alternative 6 were evaluated. The following items were evaluated during the sensitivity analysis:

- Reduce the amount of visits for O&M and sampling events by 50 percent.
- Double the amount of vegetable oil injected per event for EVO injections.
- Double the amount of substrate used in the bioreactor.
- Double the miles for transportation and disposal of materials for construction of bioreactor.

All components of Alternative 6 include O&M operations. The number of site visits for bioreactor O&M, EVO O&M and sampling was reduced by 50 percent. This 50 percent reduction in O&M and sampling created a proportional decrease in footprints for both CO_2 emissions and energy use (47 to 50 percent decrease).

The amount of vegetable oil used for the EVO injections and bioreactor are based on standard biobarrier designs and actual substrate use in the bioreactor. The effect of doubling the amount of EVO for both the biobarrier injection activities and bioreactor remedies was as follows:

- A 50 percent increase in remedy CO_2 emissions was observed.
- Increased total energy use for the biobarrier injections and the bioreactor was 35 and 40 percent, respectively.
- Little to no change in NO_x, SO_x, and PM_{10} values was observed when EVO was doubled for injection activities. However, an increase of approximately 40 percent was observed for these footprints for the bioreactor component.

Assumptions based on local suppliers in the area were used for the travel distances to deliver materials and dispose of materials from the site. The effect of doubling the mileage was as follows:

- A 3 percent increase in CO_2 emissions for the bioreactor activities was observed.
- The increase for NO_x, SO_x, and PM_{10} ranged from 5 to 20 percent, with SO_x being the least affected.

TABLE F-1
Sustainability Evaluation Results
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

	Air Emissions							Non-renewable Resource Use					
	CO_2		NO_x	SO_x	PM_{10}	Passenger Car Greenhouse Gas Emission Equivalents[b]	Household Greenhouse Gas Emission Equivalents[c]	Total Energy Consumption[d]			Equivalent to Average Annual Power Consumption for U.S. Households[e]		
Site	(tons)[a]	(tons/yr)	(tons)	(tons)	(tons)			(megajoules)	(kWh)	(kWh/yr)	(households)	Interim Remedial Action	FFS Remedial Alternative
FT004													
Existing IRA – GET	48	1.4	0.091	0.11	0.024	8	4	740,000	205,600	5,874	19	Continue GET – O&M only (eight [8] extraction wells and GAC; 35 years); includes groundwater sampling (ten [10] wells) during GET operation	–
Alternative 2 – MNA	1.3	0.04	0.001	0	0.0001	0	0	20,000	5,600	160	0.5	–	MNA – Ten [10] wells (O&M only – 35 years)
FT005													
Existing IRA – GET	22	2.2	0.0643	0.099	.0191	4	2	336,000	93,200	9,320	9	Continue GET – O&M only (six [6] extraction wells and GAC; 10 years); includes groundwater sampling (thirty [30] wells) during GET operation	–
Alternative 2 – MNA	1.7	0.04	0.0013	0	0.0001	0	0	26,000	7,200	167	0.68	–	MNA – 30 wells (O&M only – 43 years)
LF006													
Existing IRA and Alternative 2 – MNA	0.12	0.02	0.0001	0	0	0	0	1,800	500	100	0	Continue MNA, includes groundwater sampling (thirteen [13] wells) for 5 years	MNA – 13 wells (O&M only – 5 years)
LF007C													
Existing IRA and Alternative 3 – GET	30	1.2	0.031	0.013	0.0044	5	3	445,000	124,200	4,777	12	–	Continue GET – O&M only (two [2] solar-powered extraction wells and GAC; 26 years; includes groundwater sampling (eight [8] wells) during GET operation
LF008													
Existing IRA – GET	124	1.2	0.253	0.32	0.067	21	11	2,159,000	596,000	5,960	56	Continue GET – O&M Only (three [3] extraction wells and GAC; 100 years); includes groundwater sampling (eight [8] wells) during GET operation	–
Alternative 2 – MNA	3.9	0.04	0.003	0	0.0003	1	0	59,000	16,000	160	1.5	–	MNA – eight (8) wells (O&M only – 100 years)
SS015													
Existing IRA – MNA	0.16	0.03	0.0001	0	0	0	0	2,400	670	134	0.1	Continue MNA, includes groundwater sampling (16 wells) for 5 years	–
Alternative 5 – EVO (Year 1)	29	29	0.0027	0.0007	0.0001	5	3	7,400	2,070	2,070	0.2	–	EVO (Capital and O&M for first year)
Alternative 5 – EVO (reinject years)	58	29	0.0054	0.0014	0.0002	10	5	14,800	14,140	2,070	0.2	–	EVO (Capital and O&M; years 6 and 11)
Alternative 5 – EVO (O&M years)	1	0.04	0.0007	0	0.0001	0	0	13,000	3,600	164	0.3	–	EVO (O&M all years without injections)
Alternative 5 – EVO (Total)	88	3.5	0.0088	0.0021	0.0004	15	8	35,200	9,810	392	0.9	–	EVO TOTAL – 25 years
Alternative 5 – EA	2.7	0.04	0.002	0	0.0002	0	0	41,000	11,000	157	1.0	–	EA – 19 wells (O&M only – 70 years)
Alternative 5 – Total	**91**	**1.3**	**0.0108**	**0.0021**	**0.0006**	**15**	**8**	**76,200**	**20,810**	**297**	**2.0**	**–**	**–**
SS016													
Existing IRA – GET	284	2.8	1.10	1.9	0.36	47	25	4,459,000	1,216,000	12,160	114	Continue GET – O&M only (six [6] extraction wells and GAC; 100 years); includes groundwater sampling (15 wells) during GET operation	–
Alternative 4 – Collection Trench component	10	10	0.077	0.0001	0.0037	2	1	130,000	36,000	36,000	3	–	Provisional alternative component – Excavation (capital and O&M only)
Alternative 4 – Excavation and Bioreactor components	190	3.1	0.12	0.004	0.0059	31	17	270,000	75,000	1,210	7	–	Bioreactor (capital and O&M only) – 62 years
Alternative 4 – GET component	133	2.1	0.452	0.8	0.1502	22	12	2,138,000	591,000	9,532	55	–	Continue GET – O&M only (four [4] extraction wells and GAC; 62 years); includes groundwater sampling (33 wells) during GET operation
Alternative 4 – Total	**332**	**5.4**	**0.6**	**0.8**	**0.160**	**55**	**30**	**2,538,000**	**702,000**	**11,323**	**66**	**–**	**–**

TABLE F-1
Sustainability Evaluation Results
Basewide Groundwater Focused Feasibility Study, Travis Air Force Base, California

Site	Air Emissions							Non-renewable Resource Use					
	CO_2		NO_x	SO_x	PM_{10}	Passenger Car Greenhouse Gas Emission Equivalents[b]	Household Greenhouse Gas Emission Equivalents[c]	Total Energy Consumption[d]			Equivalent to Average Annual Power Consumption for U.S. Households[e]	Interim Remedial Action	FFS Remedial Alternative
	(tons)[a]	(tons/yr)	(tons)	(tons)	(tons)			(megajoules)	(kWh)	(kWh/yr)	(households)		
ST027B													
Alternative 2 – MNA	2	0.04	0.001	0	0.0001	0	0	29,000	8,100	162	1	–	MNA – eight (8) wells (O&M only – 50 years)
SS029													
Existing IRA and Alternative 3 – GET	310	3.1	1.303	2.3	0.4303	51	27	4,959,000	1,416,000	14,160	133	Continue GET – O&M only (seven [7] extraction wells and GAC; 100 years); includes groundwater sampling (18 wells) during GET operation	–
SS030													
Existing IRA and Alternative 3 – GET	79	3.6	0.351	0.620	0.1201	13	7	1,213,000	333,600	15,164	31	Continue GET – O&M only (six [6] extraction wells and GAC; 22 years); includes groundwater sampling (eleven [11] wells) during GET operation	–
SD031													
Existing IRA – GET	18	1.2	0.027	0.024	0.0056	3	2	278,400	77,300	5,153	7	Continue GET – O&M only (three [3] extraction wells and GAC; 15 years); includes groundwater sampling (six [6] wells) during GET operation	–
Alternative 2 – MNA	0.6	0.04	0.0004	0	0	0	0	8,400	2,300	153	0.2	–	MNA – six (6) wells (O&M only – 15 years)
SD033													
Existing IRA – GET	76	0.8	0.1007	0.092	0.021	13	7	1,154,000	325,000	3,571	30	Continue GET – O&M only (two [2] extraction wells and GAC; 91 years); includes groundwater sampling (five [5] wells) during GET operation	–
Alternative 2 – MNA	2.3	0.04	0.0017	0	0.0002	0	0	35,000	9,700	162	0.9	–	MNA – five (5) wells (O&M only – 60 years)
SD034													
Existing IRA – GET/Passive Skimming	70	0.8	0.0677	0.03	0.010	12	6	1,044,000	295,000	3,242	28	Continue GET – O&M only (two [2] extraction wells and GAC; 91 years); includes groundwater sampling (five [5] wells) during GET operation	–
Alternative 7 – MNA/Passive Skimming	2.3	0.04	0.0017	0	0.0002	0	0	35,000	9,700	162	1	–	MNA – five (5) wells (O&M only – 60 years)
SD036													
Existing IRA – GET	73	0.8	0.096	0.084	0.02	12	6	1,135,000	319,700	3,513	30	Continue GET – O&M only (three [3] extraction wells and GAC; 91 years); includes groundwater sampling (nine [9] wells) during GET operation	–
Alternative 5 – EVO (Year 1)	44	44	0.009	0.003	0.0004	7	4	16,600	4,570	4,570	0.4	–	EVO (Capital and O&M for first year)
Alternative 5 – EVO (reinject years)	88	44	0.0172	0.005	0.0008	15	8	33,200	9,140	4,570	1	–	EVO (Capital and O&M; years 6 and 11)
Alternative 5 – EVO (O&M years)	2.3	0.04	0.0017	0	0.0002	0	0	35,000	9,700	170	1	–	EVO (O&M all years without injections)
Alternative 5 – EVO (Total)	134	2.2	0.028	0	0.0014	22	12	84,800	23,410	390	2.2	–	EVO TOTAL – 60 years
Alternative 5 – EA	2.3	0.04	0.0017	0	0.0002	0	0	35,000	9,700	162	1	–	MNA – nine (9) wells (O&M only – 60 years)
Alternative 5 – Total	**137**	**2.3**	**0.0292**	**0.008**	**0.0016**	**22**	**12**	**119,800**	**33,110**	**552**	**3**	**–**	**–**
SD037													
Existing IRA – GET	144	1.6	0.427	0.84	0.16	24	13	2,225,400	625,000	6,868	59	Continue GET – O&M only (eleven [11] extraction wells and GAC; 91 years); includes groundwater sampling (34 wells) during GET operation	–
Alternative 5 – EVO (Year 1)	43	43	0.006	0.002	0.0003	7	4	12,000	3,300	3,300	0.3	–	EVO (Capital and O&M for first year)
Alternative 5 – EVO (reinject years)	86	43	0.012	0.004	0.0006	14	8	24,000	6,600	3,300	0.6	–	EVO (Capital and O&M; years 6 and 11)
Alternative 5 – EVO (O&M years)	2.3	0.04	0.0017	0	0.0002	0	0	35,000	9,700	170	1	–	EVO (O&M all years without injections)
Alternative 5 – EVO (Total)	131	2.2	0.02	0.01	0.001	21	12	71,000	19,600	327	1.8	–	EVO TOTAL – 60 years
Alternative 5 – EA	2.3	0.04	0.002	0	0.0002	0	0	35,000	9,700	162	1	–	MNA – 34 wells (O&M only – 60 years)
Alternative 5 – TOTAL	**134**	**2.2**	**0.022**	**0.006**	**0.001**	**21**	**12**	**106,000**	**29,300**	**488**	**3**	**–**	**–**

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Site	Air Emissions							Non-renewable Resource Use					
	CO_2		NO_x	SO_x	PM_{10}	Passenger Car Greenhouse Gas Emission Equivalents	Household Greenhouse Gas Emission Equivalents	Total Energy Consumption[d]			Equivalent to Average Annual Power Consumption for U.S. Households[e]	Interim Remedial Action	FFS Remedial Alternative
	(tons)[a]	(tons/yr)	(tons)	(tons)	(tons)	Equivalents[b]	Equivalents[c]	(megajoules)	(kWh)	(kWh/yr)	(households)		
DP039													
Existing IRA – GET	86	1.2	0.11	0.099	0.023	14	7	1,241,000	341,000	4,871	32	Continue GET – O&M only (two [2] extraction wells and GAC; 70 years) includes groundwater sampling (15 wells) during GET operation	–
Alternative 6 – Bioreactor component	140	4.7	0.065	0.0001	0.0033	23	12	180,000	50,000	1,667	4.7	–	Bioreactor (O&M Only – 30 years) – PRB Module
Alternative 6 – EVO component (Year 1)	37	37	0.019	0.006	0.0009	6	3	31,000	8,600	8,600	0.8	–	EVO (Capital and O&M for first year)
Alternative 6 – EVO (reinject years)	74	37	0.0038	0.01	0.002	12	6	62,000	17,200	8,600	1.6	–	EVO (Capital and O&M; years 6, 11, 16, 21, and 26)
Alternative 6 – EVO (O&M years)	2	0.1	0.0014	0	0.0001	0	0	29,000	8,100	300	0.8	–	EVO (O&M all years without injections)
Alternative 6 – EVO (Total)	113	3.8	0.584	0.02	0.003	18	9	122,000	33,900	1,130	3.2	–	EVO TOTAL – 30 years
Alternative 6 – Phytoremediation component	1.3	0.04	0.002	0	0.0002	1	0	17,000	4,700	157	0.4	–	Phytoremediation (O&M only – used excavation module to capture labor hours for phytoremediation)
Alternative 6 – MNA component	2.3	0.04	0.0017	0	0.0002	0	0	35,000	9,700	167	1	–	MNA – 15 wells (O&M only – 58 years)
Alternative 6 – TOTAL	**257**	**4.4**	**0.127**	**0.018**	**0.007**	**41**	**21**	**354,000**	**98,300**	**1,695**	**9.2**	–	–
SD043													
Existing IRA – GET	68	0.7	0.058	0.012	0.007	11	6	1,014,000	285,000	3,132	27	Continue GET – O&M only (one [1] extraction well and GAC; 91 years); includes groundwater sampling (three [3] wells) during GET operation	–
Alternative 2 – MNA	2.3	0.04	0.0017	0	0.0002	0	0	35,000	9,700	162	1	–	MNA – three (3) wells (O&M only – 60 years)

[a] The use of tons indicates American or short tons (1 American or short ton = 2,000 pounds).
[b] 12,080 pounds (6.04 tons) of CO_2 for the average passenger vehicle, assuming 12,000 miles per year at 20.3 miles per gallon; Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle (http://www.epa.gov/otaq/climate/420f05004.htm#step4).
[c] Annual household total energy emissions of 22,880 pounds of CO_2 per year (11.44 tons/yr). EPA's Unit Conversions, Emissions Factors, and Other Reference Data Report (Nov 2004), EIA/DOE 2002.
[d] Energy consumption for each technology evaluated with SRT takes into consideration all the sources of energy consumed during the lifecycle of the technology. Energy sources include gasoline, diesel, electricity, and natural gas.
[e] Residential Energy Consumption of 10,656 kWh/single-family home-year reported by the U.S. Department of Energy in 2006.

Notes:
kWh = kilowatt-hour
kWh/yr = kilowatt-hour per year
tons/yr = tons per year

Appendix G
Response to Comments

Responses to Comments on the
Draft Basewide Groundwater Focused Feasibility Study
Travis Air Force Base, California

EPA Region IX

No.	Comments	Responses
REVIEW COMMENTS – Nadia Hollan Burke, EPA Region IX dated March 30, 2011		
GENERAL COMMENTS		
1.	The definition and identification of Remedial Action Objectives (RAOs) in the Focused Feasibility Study (FFS) is incomplete, and thereby the basis for establishing and evaluating the remedial action alternatives is not sufficient. RAOs should specify the contaminant(s) of concern, exposure route(s) and receptor(s), and an acceptable contaminant level or range of levels for each exposure route. In addition, RAOs should consist of medium-specific operable unit-specific goals for protecting human health and the environment and that these objectives should be as specific as possible but not so specific that the range of alternatives that can be developed is unduly limited. Please revise the RAOs and relevant analysis based on meeting the RAOs.	
1a.	**EPA and AF Discussion During the April 21, 2011 Meeting:** The AF agreed that the RAO's could be improved, and suggested that the Draft Final WABOU FS, dated January 28, 1998, could be used as a starting point for revisions. EPA committed to review the WABOU RAOs and provide the AF feedback regarding this idea. **EPA Response:** EPA reviewed Section 4.0 Remedial Action Objectives (RAOs) and the language associated with the groundwater portion of the WABOU FS. We generally agree that the WABOU FS RAOs is more in line with our expectations, and modeling them would be appropriate for the basewide groundwater FFS. We have the following suggestions for modifying them to be more relevant for the current FFS: • **Section 4.1 General RAOs, Page 4-2, first bullet:** Add "and the environment" after "protect human health." • **Section 4.1.2 RAOs for Groundwater, Page 4-2:** The focus of the WABOU FS was on plume containment, minimizing exposure, and "cost-effectively" reducing concentrations. We assume that RAOs for the basewide groundwater will be associated with achieving aquifer standards throughout all of the groundwater plumes, including the source areas, in addition to those associated with containment and preventing exposure. We also wanted to ensure that cost-effectiveness would not be	We revised the Section 5.1 text as follows: "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 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. • Preliminary cleanup goals – Preliminary Cleanup Goals (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 applicable.

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	included as part of an RAO for final groundwater cleanup, as this is a criteria already being used to evaluate the remedial options and whether the RAOs could be met.	• 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 applicable. • 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."
2.	Many of the treatability and rebound studies at individual sites have not been completed, therefore it is unclear how final remedial actions (RAs) can be evaluated consistently in the (FFS). While results to indicate success of the treatability studies to date are promising, more information in the Conceptual Site Models (CSM) to support the analysis of implementability and long-term effectiveness would be beneficial. For example, enhanced reductive dechlorination (ERD) via emulsified vegetable oil (EVO) injection within contaminant source areas is currently being evaluated for technical implementability, so it is unclear how this criteria can be appropriately applied. Please revise the FFS to include more complete evaluations of the treatability and rebound studies at individual sites, and/or provide applicable case studies to show likely success to further support the evaluations of this alternative in the FFS.	
2a.	**EPA and AF Discussion During the April 21, 2011 Meeting:** The AF was concerned that the "completion" of the studies may not occur for several years, and pointed to the RI/FS Guidance Section 3.3.2.4 regarding evaluating innovative technologies in the FFS and the "reasonable belief" standard to allow the screening of innovative technologies to move forward through the process. The AF also agreed to add more information about the treatibility study information. EPA and AF discussed that the long term implementability depends on the success of the O&M and monitoring program. **EPA Response**: The intent of the comment was not to imply that the	We agree that there is sufficient data on the performance of Enhanced Reductive Dechlorination (ERD) to carry this technology through the FS screening process. We also agree that additional data is required to present this treatment approach as a proposed remedy to the public and to select it as a final groundwater remedy in a ROD. We have scheduled quarterly monitoring events through the Proposed Plan and ROD stages to collect this data and support the remedy selection process. It is important to recognize that the generation of vinyl chloride (VC) by ERD is an undesirable outcome when the in situ treatment fails to complete the dechlorination process to ethene or ethane. The presence of VC represents the

No.	Comments	Responses
	demonstration treatment technologies [such as EVO injection for enhanced reductive dechlorination (ERD) and the bioreactors] need to be completed to the point of cleanup; but that the demonstration period be concluded so that there is sufficient monitoring data to evaluate the likelihood of a treatment technology to be successful. A previous pilot study for ERD at Travis AFB, using vegetable oil at SS015, caused increased concentration of vinyl chloride. This undesirable outcome causes concern related to the "reason to believe" that the technology will work. Until the results of the more recent EVO injection study at SSO15 indicate that vinyl chloride concentrations will be reduced, it is difficult to assess whether the pilot study was successful. Nevertheless, it is understood that there is enough "reason to believe" this innovative technology could be successful in order to allow it to go forward through the screening process. However, if the AF wishes to select this technology at the proposed plan stage, more evidence should be provided up to and including additional quarterly performance monitoring data and literature search for successful implementation of these technologies at similar sites, or a combination of this technology with another technology to ensure achievement of RAOs would be necessary.	completion of the second dechlorination step in the treatment of trichloroethene (TCE, the original contaminant), so we expect to see the concentration of VC rise as the concentrations of TCE and DCE (the product of the first dechlorination step) fall. The observed breakdown of VC to ethene or other harmless daughter products will ultimately determine the success or failure of this in situ treatment.
3.	The status of each site has not been consistently discussed in the FFS. As a result, it is unclear if all of the current interim remedial actions (IRAs) are effective or if optimizations are required for those not undergoing additional studies. Please revise the FFS to provide consistent evaluations of each site including an assessment of the current IRAs and optimization efforts.	
3a.	**EPA and AF Discussion During the April 21, 2011 Meeting:** The AF needed EPA to provide more specific examples, and suggested if sections need to be removed to prevent inconsistency they would be open to that. **EPA Response:** EPA's primary concern is a clarity issue between what the IROD remedy was, what alternatives are being evaluated, and what optimization or treatability study has been conducted site by site. Tables ES-5, 2-2, 2-5, 3.2-1, 3.3-1, 3.4-1 and 3.5-1 in the FFS provides some of this information, however there are terminology issues between the IROD, the current alternatives and optimization efforts, and it is unclear how the alternatives from the IROD were or weren't carried forward for further analysis. We will provide the AF more specific suggestions on how to improve clarity and completeness regarding the events that have occurred since the IRODs. See also General Comment 5.	We added new tables to Section 7 and the Executive Summary that are similar in design to the sample tables that EPA provided. These new tables present site-by-site listing of the IRAs, the IRA technology processes, IRA optimization actions, and the status of any optimization evaluations.

No.	Comments	Responses
4.	Land use controls (LUCs) and vapor intrusion (VI) issues have not been appropriately addressed in the FFS. The FFS indicates that the existing LUCs both on- and off-base will be re-examined and re-addressed as necessary in the Basewide Groundwater Record of Decision (ROD), however no further information is presented in the FFS. Similarly, VI issues have not been addressed in the FFS despite being directly related to groundwater contamination. Addition of a remedy component to a ROD without consideration of the nine evaluation criteria would be a deviation from the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (RI/FS Guidance) (EPA, 1988). Please re-evaluate how these issues are addressed in the FFS so that appropriate RAOs, remedial alternatives development, etc. for all components of the groundwater operable unit can be established and evaluated prior to the ROD.	
4a.	**EPA and AF Discussion During the April 21, 2011 Meeting**: The AF indicated that Land Use Controls (LUCs) were already evaluated and selected previously in the Interim RODs, and are a component of all the remedies. Further, the FFS describes the LUCs in detail, and the AF was unclear regarding what additional information EPA needed. The AF stated that the vapor instrusion (VI) pathway was already evaluated and determined not to be a significant exposure pathway. AF will add additional references to FFS to explain the status of both these issues. EPA committed to re-read the LUCs section to see if properly described per the guidance regarding the LUCs analysis needed for the FS, and re-review the supporting Vapor Intrusion Assessment report completed in early 2010. **<u>Insitutional Actions/LUCs/ICs:</u>** EPA re-reviewed The Draft FFS Sections 3.1.4.3 Land Use Controls on Groundwater Use, 6.3.2 Institutional Actions, and Table 6-1 Screening of Groundwater Remedial Technologies and Process Options/General Response Actions/Institutional Actions. • In order to provide better clarification and consistent analysis regarding LUCs and the subset of LUCs referred to as Institutional Controls (ICs), EPA suggests using the process for identification and terminology to describe and categorize the ICs from EPA's November 2010 Interim Final Guidance regarding Institutional Controls (ICs), *Figure 1. Examples of IC Categories and Enforcement Processes*. EPA's September 2000 Fact Sheet regarding ICs is also a useful reference, and includes examples and guidance regarding Federal Facilities including active military bases. For example, the sections referring to "Institutional Actions" that are intended to include both ICs and engineered controls should be changed to refer to LUCs, and sections referring to LUCs that are actually discussing ICs, should be modified to "Institutional Controls" to eliminate	**Land Use Controls** Section 3.1.4.3 describes the LUCs and how they are enforced at Travis AFB. We added subheadings to Section 3.1.4.3 to clarify the layered components of the LUCs that are already being actively implemented. New subheadings are provided for the following: "Travis AFB General Plan, Base Civil Engineering Work Requests, Excavation Permits, and Off-base Plume Management." Concerning the naming convention used in the FFS, we are using the term "Land Use Controls" as a General Response Action as well as three remedial technology terms (Administrative Mechanisms, Engineering Controls, Access Restrictions, and Monitoring). As described in the response to Specific Comment 6, we added additional text to Section 3.1.4.3 to improve the description of LUCs and deleted the last paragraph in this section that referred to the re-examining and re-addressing of LUCs. We added the following new second paragraph to Section 3.1.4.3 to further clarify the ongoing enforcement of LUCs at Travis AFB: "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)." We added LUC process options to new Table 6-6. All LUC process options were either applicable or potentially applicable, except for "fences" and "signs." The screening comments for these two process options are "Screened out because process option would interfere with base activities." The responses to Specific Comments #6 and 50 as well as Section 5 (Legal) Comment #8 contain more descriptive LUC text.

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	confusion. • EPA had significant concerns with intention and meaning of the following statements on Page 3.1-5: "The existing LUCs both on- and off-base will be ***re-examined and re-addressed*** as necessary in the final Basewide Groundwater ROD," and "The existing LUCs will also be Augmented…" This seems to imply that the process for "re-examining" the LUCs will be completed in the ROD as opposed to the FS. If the original LUCs evaluated and selected in the IRODs requires any re-examination or adjustment, this process should be initiated in the FS stage. Various EPA Guidance regarding Institutional controls (ICs), as sub-set of LUCs, states: ○ "institutional controls…should be evaluated and implemented with the same degree of care as is given to other elements of the remedy (EPA OSWER Directive No. 9355.7-04, Land Use in CERCLA Remedy Selection Process, May 1995, Page 9) ○ "evaluated in the same level of detail as other remedy components….and are subject to the nine evaluation criteria…" (EPA OSWER 9355.0-74FS-P, Institutional Controls: A Site Manager's Guide to Identifying, Evaluating, and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups, September 2000, Page 5) ○ "evaluation and selection of ICs should generally follow a process similar to other remedy components." (EPA OSWER 9355.0-89, Institutional Controls: A Guide to Planning, Implementing, Maintaining, and Enforcing Institutional Controls at Contaminated Sites, Interim Final, November 2010, Page 6) • Information regarding the past evaluation and selection of the LUCs contained in 3.1.4.3 should be summarized and added to Section 6.3.2, including the references to previous IRODs. • LUCs in Section 6.3.2 and Table 6-1 should also be described with more specificity, and include the information from 3.1.4.3 regarding the LUC mechanisms. Additionally, as indicated in the EPA comments issued regarding Section 5, it should be clear where on- and off- site LUCs may differ. **Vapor Intrusion:** EPA re-reviewed Section 3.1.4.3 Land Use Controls on Groundwater Use, 3.1.14 Vapor Intrusion, Appendix G Site ST027-Area B Human Health Risk Assessment, and the Final Vapor Intrusion (VI) Assessment Report (March 24, 2010). • EPA had concerns with the implication of the following statement in Section 3.1.4.3: "The existing LUCs will also be augmented to identify the	**Vapor Intrusion** We deleted the last paragraph in Section 3.1.4.3 which included the reference to the augmentation of LUCs. We have revised Section 3.1.15 as follows: "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, 2010h). 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 VI 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 VI 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 VI risk at Travis AFB. Although no current significant risk from VI was identified during the VI assessment, the assumptions used in the VI 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 final Vapor Intrusion Assessment Report to pose a potential for future significant VI risk. By itself, this future action would not constitute the establishment of a new complete VI pathway. However, to proactively address the VI 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 VI risk in the Final 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 VI 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."

No.	Comments	Responses
	potential for vapor intrusion issues at groundwater sites and to prevent the inadvertent exposure of Base personnel and contractors to contaminated vapors, taking into account the site-specific nature and implementation of the selected remedies." Further, this is the first time vapor intrusion (VI) issues are raised in the FFS (other than the executive summary), leading the reader to the conclusion that there are existing VI pathway concerns. Perhaps an additional sentence to explain that an assessment had been conducted and although there are no current pathways, in order to ensure protectiveness in the future, in the event site conditions change, LUCs will be augmented. • The first paragraph of Section 3.1.14 seems to imply that vapor intrusion (VI) is a potential pathway of concern however the pathway isn't addressed in the remedial alternatives. The FFS states that VI will be "addressed in the pending Basewide Groundwater ROD." First, the AF should clarify whether vapor intrusion is or isn't a current and/or future pathway of concern for each site, and provide a brief summary of the results from the referenced March 2010 *Vapor Intrusion Assessment Report (VI Report)*. Further, even if VI is not a current pathway, but still considered a potential future pathway, actions should be proposed to ensure future exposures do not occur. Protection of human health from the VI pathway should be included as a remedial action objective, and included as a component of the remedial alternatives evaluation in the FFS for the sites where this applies. For example, according to the VI Report conclusions, Section 5.2 there is a potentially significant future VI Risk for Sites SD034 and SS016. • Section G.1-1 states that "*Based on current and likely future site use*, the vapor intrusion pathway is considered incomplete due to the lack of buildings or structures at or near the site and is not evaluated in this HHRA." This seems to imply that the pathway is incomplete due to site use status, and not also other factors affecting the potential for vapor intrusion (depth of groundwater, etc.). If site use was different, and the pathway could exist due to other factors, then land use controls will be needed to ensure site use remains consistent with the assumptions for the pathway to remain incomplete. The AF should either include an evaluation of LUCs to control land use for this site, or show why the pathway would be incomplete regardless of land use.	We evaluated the vapor intrusion pathway in the draft final *Site ST027 – Area B Human Health Risk Assessment*. As all parties agreed at the 15 June 2011 Response to Comments meeting, we are pulling Appendix G – Site ST027B Risk Assessments from the FFS and treating it as separate ST027B human health and ecological risk assessment reports. Because it has already received regulatory review, these reports will be published in a draft final format after all responses to agency comments on Appendix G are considered to be acceptable. The FFS will refer to these reports as appropriate.
5.	The FFS appears to provide a biased screening of technologies and assembly and screening of alternatives, deviating from the intent of the NCP and RI/FS Guidance. The screening of technologies based on technical implementability, effectiveness, and relative cost is presented in a Table, however the narrative does not provide the rationale to support the Table. After the initial screening of technologies, not all the technologies that could	

No.	Comments	Responses
	be applicable to the various sites were assembled to be evaluated for each site; instead only a select grouping of technologies was selected for evaluation, and the rationale behind how the particular technologies were chosen for each site is unclear. While EPA understands the intent for the FFS to be focused on the new technologies not yet evaluated in the previous FSs supporting the IRODs, the alternatives that are not being screened out still need to undergo a detailed and comparative alternatives analysis. Please revise the FFS so that there is clear rationale behind the screening of the alternatives for the various sites, and a detailed and comparative analysis of all the alternatives not screened for each site is conducted.	
5a.	**EPA and AF Discussion During the April 21, 2011 Meeting:** The AF needed more specific information regarding the Table referenced and the issues with the screening analysis. During the technical meeting on March 16th, EPA conceptually discussed this concern with the AF, and the AF indicated they might be able provide a Table clarifying the technologies screening process. **EPA Response:** This issue is somewhat related to General Comment No. 3. Table 6-1 in the FFS provides some information regarding the screening process, however it is still unclear to EPA what alternatives were screened for which sites and why some are not included in this screening, or were not carried forward for detailed analysis. We will provide the AF an example of a Table that might better present the screening process and the rationale for the technologies that were brought forward for detailed analysis. Additionally, the text should focus on the supporting rationale for the decisions represented in the table.	We added new tables to Section 9 that are similar in design to the sample tables that EPA provided. They present site-by-site listings of the alternatives developed in the two original feasibility studies (FSs) and Focused Feasibility Study (FFS), the remedial alternatives developed in the two original FSs and the FFS, and the remedial alternatives that were selected in the two IRODs and considered the Air Force preferred remedy in the FFS. We also added new tables to Section 9 to clarify the comparative analysis of alternatives. We rewrote Section 6 to accommodate a number of EPA comments, including this General Comment. We also revised Section 7 to further clarify the relationships between the existing interim remedial actions and the alternatives in the FFS.
6.	The NCP requirement for treatment in the reduction of toxicity, mobility, or volume through treatment criterion was not considered when alternatives were evaluated in the FFS. According to the RI/FS Guidance, the reduction of toxicity, mobility, or volume through treatment evaluation criterion is satisfied when treatment is used to reduce the principal threats at a site through destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media. Excavation and off-site disposal do not reduce the toxicity and volume of the contaminants by treatment, instead, contaminants are moved to another location. Please revise the FFS to evaluate whether alternatives reduce toxicity, mobility or volume of contaminants through treatment. In addition, please ensure that the FFS discusses how destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction in contaminant mobility, or reduction of total volume of contaminated media are achieved by the groundwater RAs.	

No.	Comments	Responses
6a.	**EPA and AF Discussion During the April 21, 2011 Meeting:** The AF requested additional information regarding this aspect of the guidance and wanted confirmation regarding whether excavation and off-site disposal were the only remedial actions affected. **EPA Response:** As discussed, there is a preference for treatment and or destruction that will permanently make changes to the constituent of concern to make it less toxic, mobile and or reduces volume. This preference is discussed in the RI/FS Guidance on Page 1-4, Section 1.3.1 Cleanup Standards, and Pages 6-8 through 6-10, Section 6.2.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment. EPA expects the AF to apply this evaluation to all the alternatives.	We removed Excavation from the FFS, because it is associated with soil actions and could cause confusion when discussing groundwater remediation. We acknowledge that EPA considers groundwater extraction and treatment to be a treatment technology and evaluated Alternative 3 under this criterion accordingly. We also clarified Section 8 – Detailed Analysis of Alternatives, Subsections 8.2.2.4, 8.3.2.4, 8.4.2.4, 8.5.2.4, 8.6.6, and 8.7.2.4 that specifically address the reduction toxicity, mobility, or volume through treatment criterion. Also, in Section 9 – Comparative Analysis of Alternatives, we clarified the text where the criterion is addressed in Subsection 9.2.4. The parts of the comment pertaining to Appendix G – Site ST027B Risk Assessments are addressed in the draft final *Site ST027 – Area B Human Health Risk Assessment and*/or the draft final *Site ST027 – Area B Ecological Risk Assessment*.
7.	The results of the human health and ecological risk assessments provided as Appendices G1 and G2, respectively, and not integrated into the FFS. Summary of the risks that triggered the need for remedial action at these sites has not been provided except for one site, ST027-Area B in Appendix G. The risk assessments are also not referenced in the main text; the only mention of Appendix G is in Appendix C Lines of Evidence for MNA, Section C.1.4.6, ST027, Page C-15. To promote clarity, please include a brief summary of or cite any previous Human Health Risk Assessments (HHRAs) and Ecological Risk Assessments (ERAs) that were conducted at the other 17 sites and explain how results of the risk assessments are used in the development of Contaminants of Concern (COCs), RAOs, Preliminary Cleanup Goals (PCGs), and evaluation of remedial alternatives. In addition, several risks and non-cancer HIs could not be verified due to discrepancies noted in tables of the document. Several specific comments have been prepared to address this issue.	
7a.	**EPA and AF Discussion During the April 21, 2011 Meeting:** The AF agreed that a summary of the previous human health and ecological risk assessments could be added to the FFS. **EPA Response:** The WABOU FS Section 2 is a good example of how the risk assessment results can be summarized and provided in the FS.	As all parties agreed at the 15 June 2011 Response to Comments meeting, we are pulling Appendix G from the FFS and treating it as separate ST027B human health and ecological risk assessment reports. Because it has already received regulatory review, these reports will be published in a draft final format after all responses to agency comments on Appendix G are considered to be acceptable. The FFS will refer to these reports as appropriate. We added the following text as the Introduction to the former Appendix G (now provided in the draft final *Site ST027-Area B Human Health Risk Assessment* and draft final *Site ST027-Area B Ecological Risk Assessment)* and as the last three (3) paragraphs to new Section 3.1.14 (Risk Assessments) to provide

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		additional clarification and context for the risk assessments conducted at Site ST027B: “The risk assessments provided are specific to Site ST027B. This site is unique, because ST027B was historically managed under the Petroleum-only Contaminated (POCO) Sites Program and not under CERCLA. Under the POCO program, HHRAs and ERAs were not required and were therefore not conducted. As a result, Site ST027 was not evaluated in any of the four (4) operable unit-specific Remedial Investigations (RI) (WIOU RI, NOU RI, EIOU RI, and WABOU RI); was not included in either of the two (2) operable unit-specific Feasibility Studies (FS) (NEWIOU FS and WABOU FS); and not included in either of the two (2) Groundwater Interim Records of Decision (IROD) (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.” We also added the following new paragraphs, including a reference to the ST027B risk assessment, to Section 3.6 – Site ST027B Conceptual Site Model, Subsection 3.6.5, last paragraphs: “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, 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 HHRA and ERA are now needed for Site ST027B. These risk assessments are provided in two (2) separate reports, including the Site ST027 – Area B Human Health Risk Assessment and the Site ST027 – Area B Ecological Risk Assessment.” Chemicals of concern for all Travis AFB groundwater sites were established during four (4) RI’s. They are listed in new Table 3-1, new Table 3-2 and

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		Table 5-4. They are also listed in Section 3.4 and Table 3-1 of the *Groundwater IROD for the NEWIOU* and Section 3.3 and Table 3-1 in the *Groundwater IROD for the WABOU*. The selection of remedial action objectives and PCGs is described in Section 5. We added a new Section 3.1.14 (Risk Assessments) and renumbered the Vapor Intrusion section as 3.1.15. The text of the new Section 3.1.14 follows: "As part of the CERCLA process, remedial investigations were conducted at all Travis groundwater sites, and the results of those investigations were reported in the remedial investigation reports that are listed in Section 3.1.8.3. The remedial investigations 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 Hazard Index 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

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		where COCs are no longer detectable, final remedial actions are warranted at all of the groundwater sites mentioned in this FS report to achieve the Preliminary Cleanup Goals that are described in Section 5. Since groundwater is located beneath the depth at which ecological receptors are expected to be present, there are no chemicals of ecological concern for all sites.”
8.	The FFS does not discuss all of the contaminants detected at each site, and does not indicate PCGs for all Contaminants of Concern (COCs). For example, Section 3.2.4.1 states that, at Site FT004, TCE is the primary contaminant. The figures in the conceptual site model (CSM) show the lateral extent of TCE (Figure 3.2-4) and 1,1-dichloroethene (DCE) (Figure 3.2-5) at Site FT004. However, Table 1-1 in the Groundwater Sampling and Analysis Program 2009-2010 Annual Report (the GSAP) lists ten contaminants of concern (COCs) for Site FT004, including seven which have historically exceeded the interim remediation goals (IRGs). In addition to TCE and 1,1-DCE, these include cis-1,2-DCE, 1,2-dichloroethane (DCA), vinyl chloride, bis(2-Ethylhexyl)phthalate, and nickel. Section 5.4 Preliminary Cleanup Goals (PCGs), and Table 5-4 only identify one chemical per site. Different COCs may require different types of remedial action. Please include a comprehensive list of the COCs at each site, indicate their distribution, establish PCGs, and explain how the various types of contamination can be addressed.	
8a.	**EPA and AF Discussion During the April 21, 2011 Meeting:** The AF indicated that the primary COC was used as the indicator compound during the FFS analysis. The EPA and AF discussed adding a Table to provide additional information regarding the other COCs and PCGs. **EPA Response:** While EPA was ok with the use of one COC for purposes of the FFS analysis, the FFS should still identify all of the PCGs for each of the COCs. The WABOU FS Tables 2-2 and 4-2 are good examples of the information EPA requested.	We revised Table 5-4 to provide a summary of all the current and historical COCs detected at each site. Additional summaries of contaminants that historically exceeded the IRG/PCG are provided in Tables 3.1-1 and 3.1-2. Concurrent with the revisions to Section 5.4, we also added two (2) new tables to Section 3.1 – Travis AFB Conceptual Site Model: • Table 3.1-1 – Summary Statistics of ERP Sites and Chemicals of Concern • Table 3.1-2 – Summary of ERP Groundwater Sites, Chemicals of Concern, and Historical Analyses We added two (2) new sentences following the bullet list in Section 3.1.8 to reference these new tables as follows: “A summary of ERP groundwater sites, chemicals of concern and some statistical data is provided in Table 3.1-1. A summary of sites, chemical of concern, and historical analyses is provided in Table 3.1-2.”

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SPECIFIC COMMENTS		
1.	**Section 2.1.2.1, NEWIOU Groundwater Sites, Page 2-2:** The description of Site LF007 is incomplete. Section 3.2.1.4 (Site LF007) states that a portion of the eastern part of the landfill at Site LF007 was used by the Defense Reutilization and Marketing Office to store excess waste materials including oils, hydraulic fluid, and solvents for resale and disposal. Section 3.2.1.4 also indicates that a skeet range was located at Site LF007. However, this information is not included in Section 2.1.2.1. Please revise Section 2.1.2.1 to include available information regarding the historical uses at the contaminated groundwater sites. In addition, please revise Section 3.2.1.4 to discuss whether any evidence of a skeet range has been found (e.g., skeet fragments, lead shot). If evidence of a skeet range is present, please revise the FFS to address the ecological risk to graveling birds.	**EPA and AF Discussion During the May 26, 2011 Meeting:** The AF explained that Section 2.1.2.1 presents a summary description of LF007 that only pertained to groundwater issues. The Defense Reutilization and Marketing Office (DRMO) was located in LF007 Area E, which contained soil contaminants only, and those contaminants were remediated to residential levels in 2007. The skeet range at LF007 was active prior to the establishment of the municipal landfill, so any evidence of the skeet range was erased either during the operation of the landfill or during the closing and capping of the landfill in 2003. Since the DRMO and the skeet range do not contribute to the development and evaluation of groundwater alternatives, no changes were made to the text.
2.	**Section 2.1.2.1, NEWIOU Groundwater Sites, Page 2-3:** While Site SS029 (MW-329 Area) indicates that the historical uses which resulted in groundwater contamination are unknown, the text describing Site SS030 does not. Please revise Section 2.1.2.1 to clarify the historical practices that resulted in groundwater contamination at Site SS030 are unknown.	We revised the second sentence in the ninth bullet in Section 2.1.2.1 as follows: "Historical practices associated with Building 1125 are believed to have resulted in groundwater contamination with chlorinated VOCs."
3.	**Table 2-2, Summary of NEWIOU and WABOU Groundwater Sites and Groundwater Interim Remedial Actions:** This Table includes SS041 which is identified as part of WABOU but it is not discussed in text up to this point or included in previous tables. Please provide additional information about SS041, and clarify it is status as a component of this FFS. Even if the no action alternative has been identified as the only appropriate alternative for this site, it should still be evaluated in the FFS along with the other sites so that this alternative can be appropriately selected in the Proposed Plan.	We deleted the second paragraph of Section 1.2.1. We added Site SS041 as a new bullet to Section 2.1.2.2 – WABOU Groundwater Sites as follows: • "**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." We added a new Site SS041 bullet to Section 3.4.1.1 – WIOU Conceptual Site Models: "**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 West Treatment and Transfer Plant. The interim groundwater action achieved a cleanup of the pesticide contaminant (heptachlor epoxide) to below its interim cleanup goal (0.01 µg/L) and its practical quantitation limit (0.01 µg/L). A

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		surface soil remedial action in 2003 achieved residential cleanup levels. Since all media of concern were addressed by these two actions, SS041 was placed in a No Further Remedial Action Planned 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." We added a new SS041 row to Table 3.4-1 that documents its current status. We added a new paragraph to Section 7.4.1 (formerly Section 7.2.1) as follows: "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 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, SS041 was placed into a No Further Remedial Action Planned (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." We added "Site SS041" to the Alternative 1 – No Action row under the Applicable Site column in Table 8-1.
4.	**Section 3, Conceptual Site Models:** The CSMs in Section 3 are missing a brief discussion of the effectiveness of MNA or the current operating remedy, needed optimization, and other relevant interim remedy performance issues. Please revise the CSMs to include a summary of any issues for each plume.	We added a new Table 6-1 (Summary of Site IRA Technologies and Status) to Section 6 to clarify the status and performance of the existing IRAs and optimization measures. Section 2.6.3 – MNA Assessments, Table 2-4 – Summary of MNA Assessments, and Table 2-5 – Summary of Groundwater Interim Remedial Action Performance provide a summary of MNA effectiveness.
5.	**Section 3.1.4.2, Groundwater Use, Page 3.1-3:** The text indicates that groundwater wells in the vicinity of Travis AFB are limited to domestic, stock-watering, and irrigation wells and that the domestic wells, several of which are downgradient of Travis AFB, are used typically for households and gardens. This information is based on the Final East Industrial Operable Unit Remedial Investigation Report, dated October 1995 (1995 EIOU RI Report). As such, it is unclear if this information remains accurate, and if a well inventory of the area has been completed more recently. In addition, it should be stated what the status of the aquifer is according to the Water Quality Control Plan for the San Francisco Bay Basin Please revise the FFS to update the information regarding groundwater use since the 1995 EIOU RI	We revised Section 3.1.4.2, Groundwater Use with the following text: "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 (California RWQCB, 2010). Approximately 3,562 acre-feet per year of groundwater is pumped for agricultural use from the Suisun-Fairfield Valley groundwater basin (USGS, 2003). Although there are fifteen (15) public water supply wells within the Suisun-Fairfield Valley groundwater basin, they do not serve a municipal

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	Report was completed.	population (USGS, 2003). The nearest city to Travis AFB is Fairfield, CA, which uses surface water rather than groundwater for the municipal water supply. Fairfield is located west and cross-gradient 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. This well is sampled semiannually for VOCs through the GSAP and, through the 2Q10 GSAP event, no Site SS030 chemicals of concern (COCs) have been detected in this well.”
6.	**Section 3.1.4.3, Land Use Controls on Groundwater Use, Page 3.1-5:** The text states that the existing Land Use Controls (LUCs) both on-and off-base will be re-examined and re-addressed as necessary in the final Basewide Groundwater ROD. The LUCs are part of the remedial action alternatives, and as such should be specifically identified and evaluated as part of the alternatives analysis and must be addressed in the FFS in more detail than has been provided. Please integrate LUCs throughout the FFS.	We replaced the second paragraph with the following text: “Land Use Controls 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 remedial action objective (RAO) of Land Use Controls is to prevent the exposure of human or ecological receptors to unacceptable risks from soil, groundwater and surface water. To meet this RAO, Travis shall 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 environmental impact analysis process (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' 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

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		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 insure the landowners do not engage in water development or soil disturbing activities that would interfere with the government's rights under the easements." We also deleted the last paragraph in Section 3.1.4.3.
7.	**Section 3.1.5, Habitats and Wildlife, Page 3.1-6:** This section describes terrestrial and aquatic/wetland habitats but does not discuss the significance of this information to the FFS. Also, there is no figure that shows the habitat locations with respect to the 18 groundwater sites. Please include a discussion of the significance of the Habitat and Wildlife section to the Ecological Risk Assessment, presented in Appendix G 2, and include a figure that shows the habitats on the Base.	We added a new Figure 3.1-1 to show the locations of the groundwater ERP sites, as well as sensitive habitats such as wetlands and endangered species occurrences. We added the following sentence to Section 3.1.5: "There are no ecological receptors to groundwater contamination at Travis AFB." The part of the comment pertaining to Appendix G2 is addressed in the draft final *Site ST027 – Area B Ecological Risk Assessment,* now provided as a separate document.
8.	**Section 3.1.5.3, Wildlife, Page 3.1-8; and Appendix G2 (Section G2-2.1, Ecological Setting, Page G2-2-1; and Figure G2-2, Site ST027-Area B Sample Locations and Exposure Area)**: Section 3.1.5.3 states that amphibian species including the California tiger salamander (*Ambystoma californiense tigrinum*), a California Species of Special Concern, have been observed in herbaceous wetlands and vernal pools at Travis AFB. Figure G2-2 shows the Site ST027-Area B exposure area, which includes surface water bodies within 300 feet of the site, suggesting that the aquatic habitat may be used by species inhabiting Site ST027-B. For example, the California tiger salamander is known to inhabit abandoned burrows of other fossorial species and Section G2-2.1 mentions the presence of a ground squirrel burrow at the northern edge of the site. During the winter, adult California tiger salamanders have been reported to emerge from their burrows and roam, often more than a mile, to lay their eggs in vernal pools (ECC HCPA, 2006). Please discuss the possible presence of amphibians and reptiles within Site ST027-B and include these classes as potential ecological receptors in the Conceptual Site Model presented on Figure G2-3 or provide justification to support not evaluating these potential ecological receptors.	We added the following paragraph to the end of Section 3.6.1: "Ecological habitat quality at 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 flight line maintenance. In addition, all of 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." As all parties agreed at the 15 June 2011 Response to Comments meeting, we are pulling Appendix G – Site ST027B Risk Assessments from the FFS and treating it as separate ST027B human health and ecological risk assessment reports. The part of the comment pertaining to Appendix G2 is addressed in the draft final *Site ST027-Area B Ecological Risk Assessment*, now provided as a separate document.
9.	**Section 3.1.6.3, Bedrock, Page 3.1-10:** The text states that unweathered bedrock is likely to have much lower permeability than the alluvium, but this has not been confirmed with field testing. Throughout the CSM, it appears that the assumption is that contamination has not permeated through the bedrock, however this assumption has not been verified, and the available	We disagree that bedrock characterization is a data gap, because contamination in shallow bedrock is only observed at a few onbase sites. Predominantly, the contamination at Travis AFB is dissolved and has been bounded vertically in the alluvium. When contamination has been observed in the bedrock, it is located in the upper bedrock that is locally weathered and fractured. With depth the

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	data suggested that bedrock has indeed been contaminated in locations where wells have been installed. The lack of bedrock characterization at the majority of the source areas constitutes a potentially significant data gap affecting the FFS analysis. Please provide additional lines of evidence that have been gathered to support the assumption for the assumed extent of bedrock contamination, what remaining data gaps there are, and clarify to what extent these data gaps has been considered in evaluation of implementability, cost, and volume criteria.	bedrock becomes less weathered and more competent and retards the flow of groundwater. Also, because refusal of an auger rig is often used to demark the boundary between alluvium and bedrock, significant bedrock characterization cannot be conducted without the use of specialized drilling equipment. We revised the text under the subheading of Bedrock in Section 3.1.6.3 as follows to clarify the issue of contamination in shallow bedrock: "Almost all of the contaminant mass at Travis 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) and therefore generally has 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 to 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. Due to 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 to 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."

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10.	**Section 3.1.4.4, Surface Water, Page 3.1-6**: The issue of potential surface water contamination is raised but not addressed completely in the FFS. This section states that the West Branch of Union is a gaining stream, and that TCE has been detected in surface water samples. This section also indicates that the portion of the Main Branch of Union Creek near piezometers PZ01Sx29 and PZ01Dx29 maybe a gaining stream. As shown in Figure 3.5-3, this section of the stream crosses the Site SS029 TCE plume, including the area of the plume where TCE concentrations exceed 100 ug/L. Please revise the text and describe if the contamination of surface water at Travis Air Force Base is a concern, and explain the rationale supporting this assessment. If it is a concern, please describe the actions that might be taken to address it in the appropriate sections of the FFS. Additionally, the locations of some of the surface water features described in Section 3.1.4.4 are not clear. Please include a figure that shows labeled surface water bodies, stream sections that are thought to be gaining streams, and the locations of surface water samples.	We added the following text as the new last paragraph of Section 3.1.4.5: "This FFS report addresses the groundwater medium. The final *NEWIOU Soil, Sediment, and Surface Water ROD* (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."
11.	**Section 3.1.13, Receptors, Page 3.1-19:** A discussion of the potential ecological receptors should be included in this section.	We revised the first sentence of Section 3.1.13 as follows: "There are no current human or ecological receptors of contaminated groundwater at Travis AFB."
12.	**Section 3.2.4.4, Groundwater Contamination at Site LF007, Page 3.2-4 and Figure 3.2-12:** The last paragraph of Section 3.2.4.4 (LF007D) states that 1,4-dichlorobenzene and benzene were detected at concentrations exceeding IRG at LF007D and references Figure 3.2-12 to indicate the location of the contamination; however, only TCE results are shown on this figure. Please either include results for the detected contaminants on the figure or eliminate the figure reference.	TCE is not a site LF007D COC. Therefore, we revised Figure 3.2-7 to show the concentrations of 1,4-dichlorobenzene and benzene that were detected at LF007D during 2010, rather than TCE concentrations.
13.	**Figure 3.2-2, Site Map, North IRA – Sites LF007B/LF007C/LF007D, NEWIOU:** Table 3.2-1 indicates that monitoring wells at Site LF007B are being used in an ongoing MNA assessment, but these wells are not identified. On Figure 3.2-2, it appears that there is only one monitoring well within the western portion of the Landfill 2 boundary, marked LF007B. Please include text stating which wells are being sampled as part of the MNA assessment.	We revised the Status and Comments column in Table 3.2-1 as follows: FT004/SD031 "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 "Groundwater monitoring for MNA is ongoing. The MNA sampling network for Site LF006 includes monitoring wells MW208x06, MW208Dx06, MW259x07, MW1729x31, MW1730x31, and MW1731x31."

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		LF007B “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.” LF007D “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.”
14.	**Figure 3.2-3, Groundwater Isocontours at Sites FT004/SD031/LF006/ LF007:** The figure does not include sufficiently detailed equipotential lines to support the depicted capture zone. Please either use contour lines at 1-foot or 0.5-foot intervals, or explain in the text how the capture zone was estimated.	We revised Figure 3.2-3 to remove the line depicting the approximate extent of hydraulic capture. The FT004 groundwater extraction system has been shut down for a rebound study, so there is currently no hydraulic capture.
15.	**Figures 3.2-4 through 3.6-3:** There are several figures on which plume boundaries do not appear to be well-defined. These include some areas in which there are no monitoring wells immediately downgradient of the plume to ensure that the extent of the plume remaining constant. Please show how these plumes are being monitored for lateral migration of contaminants: a. Figure 3.2-4: There do not appear to be any monitoring wells located downgradient of the Site FT004 TCE plume. b. Figure 3.3-7: There are no monitoring wells downgradient of the Site SS016 cis-1,2-DCE plume. Additionally, no cis-1,2-DCE sampling result is shown for MW109x16, which is the well that defines the concave shape of the eastern edge of the plume. c. Figure 3.4-7: Only a few monitoring wells define the boundaries of the two smaller TCE plumes in the northern portion of Site SD037 and the smaller plume in the central part of the site. d. Figure 3.5-3: A 1,2-DCA concentration of 4.7 micrograms/liter (ug/L) was detected at well MW119x05, but analytical results are not provided for any of the surrounding wells. e. Figure 3.6-3: At Site ST027B there do not appear to be monitoring wells located downgradient of the TCE plume.	Response by item: a. The extent of the TCE plume at Site FT004 has declined over time. As the plume has receded, the network of routinely monitored wells has also retracted, with stakeholder consent. The current distal monitoring network for site FT004 was established in the NAAR (CH2M HILL, 2010a) and is assessed annually. If TCE concentrations in downgradient wells MW757x04 or MW131x04 begin to increase, indicating potential plume migration, the downgradient monitoring wells will be considered for sampling. They include MW752x04, MW753x04, MW754x04, MW755x04, MW756x04, and MW1000x04. As shown in Figure 3.2-3, there is a groundwater trough running through FT004, and groundwater flow converges to the monitoring wells south of the site. Wells downgradient of MW757x04 and MW131x04 were not sampled during the 2009-2010 GSAP because of ND results over several previous sampling events. b. There are no monitoring wells downgradient of the SS016 cis-1,2-DCE plume, because the downgradient area is in the middle of the flight line, which consists of active aircraft runways, taxiways and parking ramps. Due to the presence of the flight line, which significantly restricts construction and field activities, the nearest downgradient monitoring well to MW1022x16 is located at downgradient Site SS029. However, a data point for well MW792x27, which was non-detect for cis-1,2-DCE, was missing from Figure 3.3-7. We revised this figure to include the missing data point, and the plume shape has also been revised. Well MW109x16 was not sampled in 2010, because the shape of the TCE plume would not change significantly without this data point. However, since TCE and DCE concentrations in this well were both close to their MCLs, we will add this

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		well to the next GSAP round. We also revised the definition of the pink area to “DCE ≥ 100.” c. The groundwater contamination in the WIOU is considered a single co-mingled groundwater plume. Groundwater monitoring network for the WIOU is focused on monitoring the groundwater plume as a whole. Over time, the WIOU plume has receded, leaving some areas of the historical WIOU plume below the MCL, and resulting in a few small and isolated areas of TCE contamination. However, these areas are still considered part of the WIOU groundwater plume. The monitoring network is adequate to monitor the WIOU groundwater plume and evaluate potential plume migration. The monitoring wells in the portion of the WIOU plume that are associated with the SD037 source area are adequate to monitor source area remediation and will continue to be evaluated throughout the groundwater operation and maintenance period. d. We revised Figure 3.5-3 to show the 1,2-DCA concentrations detected at all of the Site FT005 monitoring and extraction wells sampled in 2010. e. The TCE plume at Site ST027B was defined with HydroPunch® data as well as monitoring well data. The downgradient extent of TCE contamination at the site is defined by HydroPunch® samples collected from soil borings SB2046x27, SB2047x27, and samples collected from monitoring well MW2048x27. We revised Figure 3.6-3 to include HydroPunch® groundwater data collected from soil borings SB2046x27 and SB2047x27. Due to construction restrictions on the flightline, additional downgradient monitoring wells were not installed.
16.	**Figure 3.2-7, North IRA – TCE Distribution at Site LF007C, NEWIOU:** It is not clear whether the in-situ groundwater samples marked on the figure have already been collected or whether these show future sampling locations. The locations of four in-situ groundwater samples and six potential step-out samples are shown on Figure 3.2-7, but they are not referenced in the main text, nor are the results of the sampling included on the figure. Please clarify whether or not this sampling has already occurred, and if so, provide the results.	We have revised the third paragraph of Section 3.2.5.3 as follows: “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 the U.S. Fish and Wildlife Service is complete.”
17.	**Section 3.3.6, Contaminant Source, Page 3.3-5:** The last sentence of the section states, “TCE reemerged from the bedrock into the alluvium downgradient of the OSA source area,” which implies that pure solvent is being discharged into the alluvium. Please revise the sentence to clarify whether pure TCE or groundwater containing dissolved TCE is being discharged into the alluvium.	We have revised the last sentence of Section 3.3.6 as follows: “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.”

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18.	**Section 3.3.7.1, Status of the OSA Component of the Site SS016 IRA, Page 3.3-6:** The last sentence of the first paragraph on the page states that vapor treatment is no longer required, but does not provide data supporting this conclusion. Please revise the section to explain why vapor treatment is no longer required.	Since the requirement for vapor treatment is a conclusion and not really appropriate for the FFS, we deleted this sentence.
19.	**Section 3.4.2.6, Groundwater Contamination, Page 3.4.2-4:** The potential for vapor intrusion at Building 554 is not discussed in the FFS. A high concentration of vinyl chloride (3,220 ug/L) is reported for MW216x15, which is located within 50 feet of the building (see Figure 3.4-16).Please address this issue and provide evidence that demonstrates whether or not vapor intrusion is a concern at Building 554.	We added the following paragraph before the last paragraph in Section 3.4.2.6: "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, 2010h). 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 VI exposure pathway and protecting office personnel."
20.	**Figure 3.5-3, South IRA – TCE Distribution at Sites SS029/SS030 and 1,2-DCA Distribution at Site FT005, NEWIOU:** The individual 1,2-DCA results do not match the plume outlines. Concentrations of 1,2-DCA, presented in red text, indicate that this compound was only detected at wells EW733x05 and MW119x05. Yet several areas are shown in blue, indicating 1,2-DCA concentrations greater than 0.5 ug/L. The wells within these areas are either labeled ND or do not have an associated concentration value, suggesting that they were not sampled. Please resolve this discrepancy. Additionally, Section 3.5.5.1 (Page 3.5-4) states that rebound of 1,2-DCA concentrations occurred at EW02x05, EW734-05, and EW735-05, but these wells are also shown as ND. Please revise the figure to include the concentrations that resulted in restarting these extraction wells.	We revised Figure 3.5-3 to show the 1,2-DCA concentrations detected at all of the Site FT005 monitoring and extraction wells sampled in 2010.
21.	**Section 3.6.1, Site Description, Page 3.6-1:** The number of aboveground storage tanks (ASTs) constructed to replace the 14 removed underground storage tanks (USTs) has not been provided. The text states that, "Numerous new aboveground storage tanks have been constructed to replace the USTs." Please revise the FFS to clarify the number of ASTs installed at Site ST027B.	We revised the text of Section 3.6.1 to clarify the number of AST's at Site ST027B as follows: "Four (4) new above ground storage tanks have been constructed at Site ST027 to replace the USTs. However none of the above ground storage tanks are located within ST027B."
22.	**Section 4.2.4 Sustainability:** EPA supports Travis AFB proactive identification and implementation of sustainable remedial actions at the site. EPA's Superfund Green Remediation Strategy (EPA, 2010) may be useful for Travis AFB to consider in developing their green remediation strategy.	We added the following reference to the bullet list of documents in Section 4.2.4 – Sustainability and to Appendix B – References Environmental Protection Agency (EPA). 2010. *Superfund Green Remediation Strategy*. Office of Solid Waste and Emergency Response and Office of Superfund Remediation and Technology Innovation. September. http://www.epa.gov/superfund/greenremediation/

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23.	**Section 4.5.4, Criterion 4 – Reduction of Toxicity, Mobility, or Volume through Treatment, Page 4-9:** Section 4.5.4 does not include the requirement for treatment in the criterion, reduction of toxicity, mobility, or volume through treatment. Therefore, the excavation and off-site disposal components of Alternatives 4 (Excavation, Bioreactor, and GET), 5 (EVO and EA) and 6 (Excavation, Bioreactor, Phytoremediation, EVO PRB, and EA) will not reduce the toxicity and volume of the contaminants by treatment. Similarly, removal of free-phase Stoddard solvent by passive skimming, as proposed in Alternative 7 (Passive Skimming and EA), does not reduce the toxicity and volume of contaminants by treatment, instead, contaminants are moved to another location. Please revise Section 4.5.4 to clearly indicate that treatment is required to satisfy the reduction of toxicity, mobility, or volume through treatment criterion and updated the affected sections of the FFS.	Since Excavation is a component of the Bioreactor construction, and because its discussion could be confusing in the context of groundwater remediation, we have removed the reference to Excavation from the description of Alternatives 4 and 6. We revised Section 4.5.4 as follows: "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." Table 4-1 is a new Table that is modeled after Table 6-2 in the FS guidance. We added additional narrative and tables to Section 6 to clarify the treatment process options that are evaluated as best satisfying the effectiveness, implementability, and relative cost evaluation criteria. Refer to the response to General Comment 5. We also clarified Section 8 – Detailed Analysis of Alternatives, and the subsections pertaining to the Reduction of Toxicity, Mobility, and Volume through Treatment (8.2.2.4, 8.3.2.4, 8.4.2.4, 8.5.2.4, 8.6.6, and 8.7.2.4). A new Table has been provided for each of these subsections following the new Table 4-1 (and FS guidance Table 6-2) format. Also, in Section 9 – Comparative Analysis of Alternatives, we clarified the text where the criterion is addressed in Subsection 9.2.4. In summary: Alternative 1 – No Action does not satisfy the Reduction of Toxicity, Mobility, and Volume through Treatment criterion because no treatment action is taken, no monitoring is conducted, and no evaluations are performed. Alternative 2 – MNA satisfies the criterion using intrinsic treatment of contaminants via natural physical, chemical, and biological processes. Contaminants are degraded by these processes into a smaller volume of less toxic compounds. Alternative 3 – GET relies on physical removal of contaminants and adsorption of the contaminants on activated carbon. An ex situ treatment process then destroys the contaminants when the spent carbon is regenerated at an off-site facility.

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		Alternative 4 –Bioreactor, and GET. The Bioreactor component of Alternative 4 satisfies the criterion by reducing contaminant toxicity and volume via in situ enhanced reductive dechlorination processes within the plume source area. Alternative 5 – EVO and EA. The comment is unclear in assigning excavation and off-site disposal technologies to Alternative 5 – EVO and EA. Under this alternative, excavation and off-site disposal are not conducted. The criterion of Reduction of Toxicity, Mobility, and Volume through treatment is satisfied under Alternative 5 through in situ enhanced reductive dechlorination within the plume source area. In the distal (i.e., non-source portions of the plume) the criterion is further satisfied by intrinsic bioremediation using natural physical, chemical, and biological processes (EA). Under Alternative 6 –Bioreactor, Phytoremediation, EVO PRB, and EA the criterion is satisfied by several technology components of the alternative. The Bioreactor component of Alternative 4 satisfies the criterion by reducing contaminant toxicity and volume via in situ enhanced reductive dechlorination treatment of the plume source area. The Phytoremediation part of the alternative also contributes to meeting the criterion through another type of biological treatment in the mid-portion of the plume. The EVO PRB component of Alternative 6 also satisfies the criterion by reducing contaminant toxicity and volume via in situ enhanced reductive dechlorination processes. Also, in situ treatment of the distal portion of the plume satisfies the criterion via intrinsic bioremediation using natural physical, chemical, and biological processes (EA). Alternative 7 – Passive Skimming and EA. We agree that the Passive Skimming component of Alternative 7 does not satisfy the criterion of Reduction of Toxicity, Mobility, and Volume through treatment. However, the EA component of Alternative 7 does satisfy the criterion by reducing contaminant toxicity and volume via intrinsic physical, chemical, and biological processes.
24.	**Section 4.5.5, Criterion 5 – Short-term Effectiveness, Page 4-9:** Section 4.5.5 does not include the protection of the community during RAs, protection of workers during RAs, environmental impacts or the time until remedial response objectives are achieved as factors which should be addressed under Criterion 5 (Short-term Effectiveness). Based on Section 6.2.3.5 (Short-term Effectiveness) of the RI/FS Guidance, these factors should be addressed under this criterion. Please revise the FFS to address the protection of the community during RAs, protection of workers during RAs, environmental impacts or the time until remedial response objectives are achieved as factors which should be addressed under Criterion 5 (Short-term Effectiveness).	We revised the criterion description provided in Section 4.5.5 as follows: "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 remedial action objectives. 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."

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25.	**Section 4.5.6, Criterion 6 – Implementability, Page 4-9:** Section 4.5.6 does not discuss the construction and operation, reliability of technology, ease of undertaking additional RA, and monitoring considerations as components of the technical feasibility of implementing each alternative under Criterion 6 (Implementability). According to Section 6.2.3.6 (Implementability) of the RI/FS Guidance, these factors should be addressed under this criterion. Please revise the FFS to discuss the construction and operation, reliability of technology, ease of undertaking additional RA, and monitoring considerations as components of the technical feasibility of implementing each alternative under Criterion 6.	We revised the criterion description provided in Section 4.5.6. as follows: "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."
26.	**Section 5, Preliminary Cleanup Goals and Tables:** Legal review of this section is still pending. Additional comments will be provided when the legal review is completed.	Additional comments and responses related to Section 5 are provided in the Legal section of this table.
27.	**Table 5-4, Summary of Groundwater Contaminants Exceeding the Preliminary Cleanup Goal:** The source of the PCGs was not provided on Table 5-4, and only one PCG is identified per site. As a result, it is unclear how the PCGs were established. Please revise Table 5-4 to include a reference to the source of the PCGs, and include all the applicable COCs.	We added the following footnote to Table 5-4: "* 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." We also revised Table 5-4 to include all COCs and their PCGs for each site.
28.	**Section 6.1.1, General Response Actions for Groundwater, Page 6-1:** The definition of removal provided in Section 6.1.1 is peculiar as soil is not typically removed from an aquifer; rather, soil may be removed from a source area. Similarly, removal may include technologies such as soil vapor extraction, skimming, etc. As such, the definition of the removal general response action for groundwater is unclear. Please revise the definition of removal provided in Section 6.1.1. In addition, please consider whether removal includes other technologies for addressing source areas.	We revised the definition of the Removal GRA as follows: "Actions taken to physically remove contaminated groundwater or pure contaminant from an aquifer." In the reformatted Table 6-7 (Screening of Groundwater Remedial Technologies and Process Options), the Removal GRA includes Technologies for Groundwater Extraction and Free Product Removal. The corresponding technology process options include Extraction Wells and Passive Skimming, which have been used in IRAs to address source areas at the appropriate Travis AFB sites.
29.	**Sections 6.3, Technology and Process Options Descriptions, 6.4, Summary of Technology and Process Option Screening, and Table 6.5,Summary of General Response Actions, Technologies, and Process Options:** The screening process utilized in Sections 6.3, 6.4 and Table 6.5 does not meet the requirements established in the RI/FS Guidance. As discussed in Sections 4.2.4 (Identify and Screen Remedial Technologies and Process Options) and 4.2.5 (Evaluate Process Options) of the RI/FS	We revised Section 6.2.1 (Technical Implementability Screening) to describe the first step in the evaluation process; we added Section 6.4.1 (Current Technical Implementability Screening) to describe how this step was carried out in the FFS. We revised Section 6.2.2 (Evaluation of Process Options) to describe the evaluations of process options on the basis of effectiveness, implementability, and cost; we added Section 6.4.2 (Current Evaluation of Process Options) to carry out these evaluations.

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	Guidance, process options and entire technology types should be eliminated from further consideration on the basis of technical implementability and then process options should be evaluated on the basis of effectiveness, implementability and cost. Please revise Sections 6.3 and 6.4 and Table 6.5 to evaluate technologies and process options on the basis of effectiveness, implementability and cost.	We also added new tables to supplement and clarify the effectiveness, implementability, and relative cost screening already provided in reformatted Table 6-7 – Screening of Groundwater Remedial Technologies and Process Options. The new tables are “measles charts” intended to graphically depict how the representative process options perform against the criteria of effectiveness, implementability, and relative cost. The tables also depict the technologies 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. The tables are supported by the additional rationale provided in Section 6.4.
29a	EPA appreciates the effort to rewrite Section 6 to address EPA’s concerns, and this section is greatly improved. However, there are some remaining concerns related to the evaluation of cost, effectiveness, and implementability as they are presented in the revised Section 6. These include but are not limited to the comments below: a. It is unclear if the response adequately addresses the comment, as it relates to cost. For example the text in Section 6.2.2 indicates that; “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.” It is unclear if that was the result of the screening process or indicative of the way in which technologies were screened. b. Additionally in it is unclear if the cost have been appropriately applied; Section 6.4.2.3 states, “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. It should be noted however, that these capital costs will be relevant to the total costs that are provided during the close-out documentation process once remedial actions have successfully achieved clean-up. c. Additional detail should be presented as to why process options are screened out in Table 6-6. Many of the Ex-Situ ans Disposal processes the text states, “Screened out as not feasible. Groundwater treatment using LGAC adsorption is used at the CGWTP, NGWTP, and SBBGWTP as part of the ongoing IRAs.” However no details are provided in Table 6-6 as to why these options are not technical implementable. More detail should be provided for these process options or they should be considered potentially implementable.	a. The quoted text was taken directly from Section 4.2.5.3 (Cost Evaluation) of EPA’s "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA." EPA has withdrawn the comment. b. We added the following sentence after the third sentence in Section 6.4.2.3: "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." c. We revised the screening comments in Table 6-6 for the following process options: “Membrane Osmosis – 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 and High Energy Electron Irradiation – 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, Distillation, Solvent Extraction, Precipitation, and Ion Exchange – 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.

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	d. There are some inconsistencies in the discussion of effectiveness on Page 6-10. Monitored Natural Attenuation (MNA) is deemed ineffective at Site SS015, but Enhanced Attenuation (EA) was deemed effective. The MNA discussion indicates that the increased concentrations of daughter products is due to incomplete degradation as a result of injecting of vegetable oil for a treatability. But vegetable oil injections is an EA treatment, not MNA. Please resolve this discrepancy. Additionally please explain why EA is considered effective if there are increased daughter products. e. The implementability discussion as related to Chemical Oxidation on Page 6-17 is limiting as there are some non-exothermic ISCO processes, including modified Fenton's Reagent and permanganate. ISCO may be implementable in some areas with modified Fenton's Reagent or permanganate and therefore should be retained as potentially implementable. Additionally this discussion should be deferred pending revision of the ISCO/ERD technical memorandum. f. There are some inconsistencies in how treatment technologies are described in the text for example slurry walls and interceptor trenches are described as having "limited effectiveness," but phytoremediation is first described as effective and then later in the same section indicates that "effectiveness is limited. Also, the bioreactor is described as effective but since this is not a proven technology, this treatment technology should be considered as potentially effective.	Reductive Dechlorination – 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 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. Ozone/hydrogen peroxide oxidation – 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. Fixed Bed Reactor, Fluidized Bed Reactor, and Reductive Dechlorination – 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. Aquifer Reinjection – 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. Discharge to Treatment Works – 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 additional volume of water and 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. Deep Well Injection – 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." d. We revised the MNA/SS015 sub-bullet as follows: "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

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		contaminant mass in the 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." e. We revised the first complete sentence of the Chemical Oxidation paragraph as follows: "There are potential adverse impacts to human health and subsurface infrastructure from exothermic chemical processes associated with several but not all chemical oxidants." According to Table 6-6, chemical oxidation is potentially applicable. According to Table 6-7, chemical oxidation is retained as a potential process option. As we agreed in our teleconference, most of the pertinent information from the ISCO/ERD tech memo is already in the FFS. Therefore, all references to the ISCO/ERD technical memorandum in the FFS will be removed, and the tech memo will not be finalized. f. We added the following sentences to the soil-bentonite slurry wall effectiveness evaluation on page 6-11: "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." We changed the description of the interceptor trench effectiveness evaluation on page 6-11 from "limited effectiveness" to "Potentially Effective." We revised the first complete sentence in the interceptor trench effectiveness evaluation on page 6-11 as follows: "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." We changed the description of the phytoremediation effectiveness evaluation on page 6-13 from "Effective" to "Potentially Effective." We revised the second complete sentence in the phytoremediation effectiveness evaluation on page 6-13 as follows: "This process option is effective when the contamination is confined to the upper portion of a shallow aquifer." We changed the description of the bioreactor technology to "Potentially Effective," based on EPA's observation that the bioreactor is not a proven technology. Please note that the Final Bioreactor Progress Report (CH2M HILL HILL, 2011) that was sent to all parties in May 2011 does show that this technology works under Travis-specific conditions. The groundwater contaminants in the DP039 source area are undergoing complete reductive dechlorination with no vinyl chloride production.

No.	Comments	Responses
30.	**Section 6.3.2, Institutional Actions:** More detail should be provided regarding the proposed institutional actions (also known as Institutional Controls). Specific media of concern, remedial action objectives, the specific enforceable controls, etc. should be identified so they can be included in the alternatives analysis as a component of the remedial actions, such as the Land Use Controls (LUC) program and associated Base General Plan requirements.	Because of the amount of new text that has been added to Section 6, Section 6.3.2 is now Section 6.5.2. We replaced the first paragraph in the renamed Section 6.5.2 with the following text: "Land Use Controls 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 remedial action objective (RAO) of Land Use Controls is to prevent the exposure of human or ecological receptors to unacceptable risks from soil, groundwater and soil gas. To meet this RAO, Travis shall 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 environmental impact analysis process (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' 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 insure the landowners do not engage in water development or soil disturbing activities that would interfere with the government's rights under the easements."

No.	Comments	Responses
31.	**Section 6.3.3.2, Enhanced Attenuation, Page 6-4:** The definition of Enhanced Attenuation (EA) provided in Section 6.3.3.2 does not correspond with the industry standard. EA is the result of applying (e.g., injecting) an enhancement (e.g., microbes) that manipulates a natural attenuation process [i.e., monitored natural attenuation (MNA)] leading to an increased reduction in mass flux of contaminants (ITRC, 2007). However, the FFS implies that application of EA is distinct from the natural attenuation process and in some cases, states that EA is the injection of a substrate. Please revise the FFS to utilize the industry standard definition for EA. In addition, please revise Alternatives 5, 6, and 7 to replace EA with MNA unless an enhancement is specifically being applied to manipulate the natural attenuation process.	The term "bioaugmentation" is usually used in industry to describe the use of microbes, either a concentrated batch of microbes that are naturally-occurring at the site or a batch of "designer" microbes that promote reductive dechlorination, to initiate or accelerate biological remediation. We revised the first paragraphs of Section 6.5.5.1 (formerly Section 6.3.3.2) as follows: "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 implement 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 the plume will stabilize and shrink in a suitable time frame (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, etc.), source area destruction (e.g., chemical or biological oxidation or reduction, etc.), 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." In Section I and Figure 1 of the cited ITRC guidance, source and/or primary plume treatment can include Removal (e.g., excavation, thermal, vapor extraction, etc.), Destruction (e.g., chemical or biological oxidation or reduction, etc.), and Containment. The ITRC reference does not constrain the approach to source area remediation to a biological, chemical, or physical technology. Any technology that reduces the mass flux from the source area into the hydraulically downgradient portion of the plume is viable under EA. Alternatives 5, 6, and 7 all combine attenuation processes with a source zone treatment. Therefore, the EA terminology used in these FFS alternatives is consistent with the definition used in the cited ITRC reference as being the industry standard. Further, if the comment's parenthetical statements are edited out, the wording is consistent with that provided by the SRNL reference: "…any type of intervention that we might implement in a source plume that increases the magnitude of attenuation by natural processes beyond that which occurs without our intervention.

No.	Comments	Responses
32.	**Section 6.3.3.2, Enhanced Attenuation, Page 6-4:** The groundwater IRAs already in operation at Travis AFB demonstrate containment and MNA and do not demonstrate the viability of EA. Please revise Section 6.3.3.2 to evaluate EA on the basis of effectiveness, implementability and cost to demonstrate the viability of EA.	We evaluate EA on the basis of effectiveness, implementability, and cost in the reformatted Section 6.4.2 – Current Evaluation of Process Options.
33.	**Section 6.3.4.1, Physical Barriers, Page 6-4:** Information to support the limits of the effective installation of containment systems to a depth of approximately 60 feet below ground surface (bgs) have not been provided in Section 6.3.4.1. The text states that, "These containment systems can be effectively installed to a depth of approximately 60 feet bgs depending on the nature of the subsurface materials." Please revise Section 6.3.4.1 to support the depth limitation for the containment systems.	We revised the reference depth to "approximately 100 feet below ground surface" to be consistent with the reference cited in the U.S. EPA Contaminated Site Cleanup Information (CLU-IN) website and added the reference to FFS Appendix B (References). National Research Council (NRC), 1999. *Groundwater and Soil Cleanup: Improving Management of Persistent Contaminants*. National Academy Press, ISBN: 0-309-06549-6.
34.	**Section 6.3.5.1, Groundwater Extraction, Page 6-6:** The presence of dense nonaqueous phase liquid (DNAPL) is primarily related to the type of release that occurred. However, the DNAPL subsection of Section 6.3.5.1 only discusses the presence of DNAPL in terms of the solubility of the contaminant. Please revise Sections 2 (Background) and 3 (Conceptual Site Models) to include discussions related to presence of DNAPL. In addition, revise Section 6.3.5.1 to discuss the impact of DNAPL on groundwater extraction systems.	We revised the DNAPL subsection in the reformatted Section 6.5.4.1 as follows: "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 increases 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)." In Section 2 – Background, Section 2.4.1.1 Source Control Objectives provides the background information on the IRAs implemented to address source zones with likely DNAPL contamination. In Section 3.1 – Travis AFB Conceptual Site Model, the issue of Primary Contaminant Sources is discussed in Section 3.1.9. Specific discussions regarding DNAPL are provided in Section 3.1.9.2 – Dense Nonaqueous Phase

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		Liquids, Section 3.1.10.1 – DNAPL Release Mechanisms, Section 3.1.10.2 – Dissolution of DNAPL Source Zones, and Section 3.1.10.3 – Groundwater Plume Formation. These discussions are supported by Figure 3.1-7 – Conceptual DNAPL Movement Through Clayey Soils, Figure 3.1-8 – Conceptual DNAPL Source Zone, Figure 3.1-9 – Conceptual DNAPL Source Zone Dissolving Over Time, Figure 3.1-10 – Conceptual Plume Formation at a DNAPL Site, and Figure 3.1-11 – Advancing Solvent Plume in Layered Alluvium.
35.	**Section 6.3.5.2, Source Removal, Page 6-7:** Excavation and disposal is the only source removal technology discussed in Section 6.3.5.2. If other source removal technologies [e.g., six-phase heating (SPH), electrical resistive heating (ERH), steam enhanced extraction (SEE)] have not been evaluated due to their previous elimination in the FSs supporting the IRODS, then this should be explained. Otherwise, they should be included in the screening evaluation. Further, it is unclear why free product removal is not discussed as a source removal technology. Please revise Section 6.3.5.2 to evaluate other source removal technologies, if needed, and to include free product removal as a source removal technology. Further, please reorganize Section 6 (Identification and Screening of Technologies) such that source removal is associated with in-situ treatment.	Since Excavation is a component of the Bioreactor construction, and because its discussion could be confusing in the context of groundwater remediation, we removed the reference to Excavation from the description of Alternatives 4 and 6. We deleted the In situ Thermal Treatment technology from the In situ Treatment GRA. We renamed it In situ Thermal Removal and placed the technology under the Removal GRA. We then added a new Section 6.5.4.2 – In situ Thermal Removal. The following list clarifies the reorganization of the original Section 6.3.5 – Removal: Section 6.5.4 – Removal (GRA) Section 6.5.4.1 – Groundwater Extraction Section 6.5.4.2 – In situ Thermal Removal Section 6.5.4.3 – Free Product Removal The last sentence in the comment is incompatible with Specific Comment 23, which states that excavation and free product removal are not “treatment,” because the contaminants are only moved to another location. Free product removal and in situ thermal removal are similar in this regard. Therefore, they are appropriately placed under the GRA of Removal, not the GRA of In situ Treatment.
36.	**Section 6.3.6.1, In situ Bioremediation, Page 6-8:** In situ bioremediation (ISB) may not always be effective for recalcitrant compounds. As such, it is unclear why the first sentence of Section 6.3.6.1 states that, “Bioremediation is an established remediation methodology for chlorinated solvents and other recalcitrant compounds.” Please revise this sentence or clarify how in situ bioremediation is effective for recalcitrant compounds.	We revised the first sentence of Section 6.5.5.2 (formerly Section 6.3.6.1) as follows: “Bioremediation is an established remediation methodology for chlorinated solvents such as those found at the Travis AFB groundwater sites.”
37.	**Section 6.3.6.1, In situ Bioremediation, Page 6-8:** The text incorrectly defines ISB and Enhanced Bioremediation. The text does not clearly indicate that ISB involves injection of a substrate and Enhanced Bioremediation requires the addition of microbes that may be missing or not present in sufficient numbers for ISB to be effective. As a result, Section 6.3.6.1 appears misleading. Please revise Section 6.3.6.1 to indicate that ISB involves	We revised the first paragraph of the reformatted Section 6.5.5.2 (formerly Section 6.3.6.1) as follows: “In situ biological treatment, or bioremediation, is an established remediation methodology for chlorinated solvents such as those found at Travis AFB groundwater sites.” We added the following paragraph to the end of reformatted Section 6.5.5.2 before the start of the subsections:

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	injection of a substrate and Enhanced Bioremediation requires the addition of microbes that may be missing or not present in sufficient numbers for ISB to be effective. Further, please revise the Enhanced Bioremediation subsection to include the discussion of Carbon Substrate Injection (i.e., enhanced ISB) on Page 6-12.	"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, or enhanced reductive dechlorination (ERD), or biostimulation (Parsons, 2004). Bioaugmentation involves the injection of a microbial amendment comprised of non-native organisms known to carry dechlorination of the target chlorinated compounds to completion (Parsons, 2004)." The reference cited in this paragraph is the final *Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents* (Parsons, 2004). This document was prepared by Parsons Corporation in collaboration with the Environmental Security Technology Certification Program (ESTCP), the U.S. Army Corps of Engineers (USACOE), and the Naval Facilities Engineering Service Center (NFESC). Section 1, page 1-1 of the cited reference provides the following definition: "Enhanced in situ anaerobic bioremediation involves the delivery of an organic substrate into the subsurface for the purpose of stimulating microbial growth and development, creating an anaerobic groundwater treatment zone, and generating hydrogen through fermentation reactions. This creates conditions conducive to anaerobic biodegradation of chlorinated solvents dissolved in groundwater. In some cases, organisms may need to be added, but only if the natural microbial population is incapable of performing the required transformations." This definition is not entirely consistent with the statement in the comment that Enhanced Bioremediation "requires the addition of microbes." The addition of a substrate alone can constitute Enhanced Bioremediation if the natural microbial population proves capable of performing the required transformations. In the FFS, the potential addition of microbes is addressed by the technology process option of Bioaugmentation because it may, or may not, be required under the conditions at Travis AFB. The first paragraph of Section 2.2.6 in the cited reference states the following: "Bioaugmentation involves the injection of a microbial amendment comprised of non-native organisms known to carry dechlorination of the target chlorinated compounds to completion." In summary, the terms used in the FFS are as follows: • Intrinsic bioremediation is without addition of substrate or microbes. • Enhanced bioremediation includes addition of a substrate, but does not necessarily involve the addition of microbes. • Bioaugmentation includes addition of microbes if the natural microbial

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		population is incapable of performing the required transformations regardless of the nutrients provided by a substrate. We added a subsection on Carbon Substrate Injection after the text of reformatted Section 6.5.5.2.
38.	**Section 6.3.6.1, In situ Bioremediation, Page 6-12:** The EPA Hazardous Waste Clean-up Information (CLU-IN) website states "A permeable reactive barrier (PRB) is defined as an in situ method for remediating contaminated ground water that combines a passive chemical or biological treatment zone with subsurface fluid flow management. Treatment media may include zero-valent iron, chelators, sorbents, and microbes to address a wide variety of ground-water 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." Based on this definition, the Permeable Reactive Barrier subsection is incomplete. Please revise the Permeable Reactive Barrier subsection to utilize the CLU-IN (or another industry standard) definition for PRBs.	We revised the Permeable Reactive Barrier subsection of reformatted Section 6.5.5.2 (In situ Biological Treatment) as follows: "**Permeable Reactive Barrier**. A permeable reactive barrier (PRB) is defined as an in situ method for remediating contaminated ground water that combines a passive chemical or biological treatment zone with subsurface fluid flow management. Treatment media may include zero-valent iron, chelators, sorbents, and microbes to address a wide variety of ground-water 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."
39.	**Section 6.3.6.2, In situ Chemical Treatment, Page 6-15:** Zero-valent iron (ZVI) has not been included as an in situ chemical oxidation process option (ISCO). ZVI should be included as an in situ technology and not just a PRB, as discussed on Page 6-22. Please revise Section 6.3.6.2 to include ZVI under the ISCO category.	We added a new bullet to the oxidants subsection in the reformatted Section 6.5.5.3 (In situ Chemical Treatment) as follows: • **Zero Valent Iron.** 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, etc.), 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. We also added ZVI Slurry Injection as an In situ Chemical Treatment option to new Table 6-6 (Technical Implementability Screening of Groundwater Technologies). We added the following Zero Valent Iron Slurry Injection subsection to reformatted Section 6.5.5.5 (In situ Chemical Treatment):

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		"**Zero Valent Iron Slurry Injection.** Injection of a zero valent iron (ZVI) slurry mixture can be used to reduce concentrations of chlorinated compounds via abiotic reductive dechlorination. Commercially available processes include the Ferox^{TM} process and Z-Loy^{TM}. Either process can be implemented using an area treatment configuration or as a PRB to intercept a migrating plume. Ferox^{TM} 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^{TM} 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^{TM} is another ZVI substrate engineered for injection, much like Ferox^{TM}. Using Z-Loy^{TM}, 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^{TM} is the same as that of Ferox^{TM} described above. Similar to the Ferox^{TM} process, in situ treatment costs with Z-Loy^{TM} are relatively high."
40.	**Section 6.3.6.2, In situ Chemical Treatment, Page 6-21:** The comparison of ERD and ISCO Technology Process Options subsection appears to be premature As discussed in Sections 4.2.4 (Identify and Screen Remedial Technologies and Process Options) and 4.2.5 (Evaluate Process Options) of the RI/FS Guidance, process options and entire technology types should be eliminated from further consideration on the basis of technical implementability and then process options should be evaluated on the basis of effectiveness, implementability and cost. Further, it is unclear why the comparison of ERD and ISCO Technology Process Options subsection does not evaluate the use of ZVI instead of ISCO reagents, as ZVI would persist long enough to address contaminants that may later diffuse from soil, provided the ZVI was installed appropriately. Please revise Section 6.3.6.2 and the Comparison of ERD and ISCO Technology Process Options subsection to evaluate process options and entire technology types on the basis of technical implementability and then process options should be evaluated on the basis of effectiveness, implementability and cost. Further, please revise the Comparison of ERD and ISCO Technology Process Options subsection to evaluate the use of ZVI instead of ISCO reagents.	We revised Section 6.2.1 (Technical Implementability Screening) to describe the first step in the evaluation process; we added Section 6.4.1 (Current Technical Implementability Screening) to describe how this step was carried out in the FFS. We revised Section 6.2.2 (Evaluation of Process Options) to describe the evaluations of process options (including ERD, ISCO, and ZVI) on the basis of effectiveness, implementability, and cost; we added Section 6.4.2 (Current Evaluation of Process Options) to carry out these evaluations. The new tables ("measles charts") that are described in the response to Specific Comment #29 also support these evaluations. The Comparison of ERD and ISCO Technology Process Options subsection in reformatted Section 6.5.5.5 (In situ Chemical Treatment) now supports the screening against the criteria of effectiveness, implementability, and relative cost. We did not use ZVI in the ERD/ISCO comparison, because there is no rationale to choose a long-lasting solid active substance over a short-lived liquid. As the comment pointed out, ZVI would only be effective after a solvent diffused out of a tight soil layer into a layer where ZVI was present. This diffusion limitation would significantly increase the projected cleanup times over a liquid that could penetrate the tight soil and break down contaminants at their source. Also, as the comment pointed out, the ZVI would have to be "installed appropriately." We learned during our 1999-2002 installation and evaluation of

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		a permeable reactive treatment wall at Site DP039 that ZVI injection in a slurry mixture is extremely challenging in tight clays and cannot be relied upon to achieve the distribution of iron and groundwater flow pattern needed to achieve PCGs. We added a discussion of this treatability study in Section 6.
41.	**Section 6.3.6.3, In situ Thermal Treatment, Page 6-24:** The necessity for a treatability study for in situ thermal treatment has not been discussed in Section 6.3.6.3. In addition, information and/or reference to substantiate the second paragraph of Section 6.3.6.3 has not been provided. Please revise Section 6.3.6.3 to discuss the necessity for a treatability study for in situ thermal treatment. In addition, please verify other statements in this section about thermal treatment.	We changed the title of this section to "In situ Thermal Removal" and reformatted it to Section 6.5.4.2. We added the following sentence after the second paragraph of reformatted Section 6.5.4.2: "A treatability study is typically required to demonstrate the effectiveness of in situ thermal treatment." We listed the following reference that supports the statements made in this section and added this reference to FFS Appendix B (References): Environmental Protection Agency (EPA), 2011. Thermal Treatment: In situ. U.S. EPA Contaminated Site Cleanup Information (CLU-IN). http://www.clu-in.org/techfocus/default.focus/sec/Thermal_Treatment%3A_In_Situ/cat/Overview/
42.	**Section 6.3.6.4, Ex Situ Treatment, Page 6-25:** Section 6.3.6.4 does not present a discussion of ex situ treatment technologies and process options. As a result, ex situ treatment technologies and process options cannot be evaluated. Please revise Section 6.3.6.4 to present a discussion of ex situ treatment technologies and process options so that an evaluation can be conducted.	We added the following bullets to the reformatted Section 6.5.5.4 (Ex Situ Treatment) to provide descriptions of air stripping, liquid-phase granulated activated carbon, ultraviolet oxidation, and thermal oxidation: • 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 • Liquid-phase granulated activated carbon – Contaminants are adsorbed onto activated carbon by passing contaminated groundwater through a carbon column. • Ultraviolet oxidation – 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. • 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. We also revised the new tables previously mentioned to include these ex situ treatment technologies in the evaluations of effectiveness, implementability, and cost.

No.	Comments	Responses
43.	**Table 6-1, Screening of Groundwater Remedial Technologies and Process Options:** Several technologies discussed in Section 6.3 (Technology and Process Options Descriptions) are not included in Table 6-1. For example, Ex-Situ Treatment does not include ultraviolent oxidation (UV/Ox), as mentioned in Section 6.3.6.4 (Ex Situ Treatment). In addition, In-Situ Thermal Treatment does not include ERH, hot air injection, hot water injection, steam injection, radio frequency heating, thermal conduction or vitrification. Please revise Table 6-1 to include all the technologies discussed in Section 6.3, or explain why these technologies were eliminated from further consideration.	We added UV/Ox and thermal oxidation to the Ex Situ Treatment GRA portion of reformatted Table 6-7 (Screening of Groundwater Remedial Technologies and Process Options). The new Table 6-6 (Technical Implementability Screening of Groundwater Technologies) and the reformatted Table 6-7 evaluates the thermal process options that are mentioned in reformatted Section 6.5.4.2 (In situ Thermal Removal). We revised the Description cell of the In situ Thermal Removal row of new Table 6-6 as follows: "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."
44.	**Section 6.4, Summary of Technology and Process Option Screening, Page 6-26:** Representative physical and hydraulic barrier technologies under the containment general response action and a representative in situ chemical treatment technology from the in situ treatment general response action have not been included in Section 6.4 (summary of Technology and Process Option Screening) and carried forward in the FFS despite several of the process options being retained in Table 6-5 (Summary of General Response Actions, Technologies, and Process Options). Please revise Section 6.4 to include representative physical and hydraulic barrier and in situ chemical treatment technologies. Alternatively, please revise the FFS to clarify why these technologies have not been selected for further evaluation.	Representative process options are those process options that best satisfy the criteria of effectiveness, implementability, and relative cost under site-specific conditions. These representative process options are then used to develop potential alternatives that undergo a detailed analysis. None of the physical or hydraulic barrier process options under the Containment General Response Action scored high enough in the initial screening of alternatives to be representative process options. For example, both hydraulic barriers and groundwater extraction rely upon installed extraction wells. They score the same when it comes to implementability. However, because a hydraulic barrier will extract contaminants at lower concentrations, it will not be as effective as a groundwater extraction network in a source area. This will also impact the relative cost, since a hydraulic barrier will have a longer O&M period and therefore a greater total cost. Although in situ chemical treatment did not score high enough to be representative process options, in situ treatment is still carried into the detailed analysis of alternatives. Many process options (including all of the Containment process options and several in situ chemical treatment process options) are not designated as being representative but are still considered to be potentially applicable, because they moderately satisfy the criteria of effectiveness, implementability, and relative cost and may have some usefulness under specific future conditions. We added additional narrative to Section 6 and new Tables 6-8, 6-9, and 6-10 to clarify the effectiveness, implementability, and relative cost screening. These new tables are "measles charts" intended to graphically depict how all process options performed against the criteria of effectiveness, implementability, and relative cost.

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45.	**Section 7.2.2, Assembly of Groundwater Remedial Alternatives, Page 7-2, and Appendix E, Cost Estimates:** Appendix E includes assumptions regarding the number of new groundwater monitoring wells, injection wells, and extraction wells that will be needed for individual alternatives. However, Section 7.2 (Assembly of Groundwater Remedial Alternatives) does not include a discussion of the current groundwater monitoring systems. As a result, it is unclear if the proposed number of new groundwater monitoring wells, injection wells, and extraction wells is appropriate. For example, Section E.2.2 (Basis of Estimate) assumed that Alternative 2 (MNA) includes no additional capital costs for new monitoring wells. While this assumption can be made, Section 7.2.2 (Alternative 2 – Monitored Natural Attenuation) should discuss the current monitoring network and provide justification that the current monitoring network is sufficiently adequate to monitor MNA and that no replacement wells will be required over the timeframe necessary to achieve preliminary cleanup goals (PCGs). Please revise Section 7.2 to include a discussion regarding the current groundwater monitoring systems at each site and provide justification for the number of new groundwater monitoring wells, injection wells, and extraction wells proposed in Appendix E.	We added a new Table 7-9 – Adequacy of Monitoring Networks to Support Remedial Alternatives to Section 7.4 (formerly Section 7.2). This Table presents the type and number of wells currently at the site and how many additional wells, if any, it was assumed would be needed to implement the remedial alternative. The Table also provides the reason additional wells may or may not be needed. We also added the following text to the end of Section 7.4 (formerly Section 7.2): "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."
46.	**Section 7.2.4, Alternative 4 – Excavation, Bioreactor, and GET, Page 7-9**: This section indicates that the continuing source of trichloroethene (TCE) contamination into the hydraulically downgradient portions of the Site SS016 plume "will be greatly reduced" by the 2010 bioreactor installation at Site SS016. However, Page 6-14 states that performance data from the bioreactor is not yet available. As a result, it is unclear if the continuing source of TCE contamination into the hydraulically downgradient portions of the Site SS016 plume will be greatly reduced by the 2010 bioreactor installation at Site SS016. Similarly, several of the proposed RAs include the complete and/or partial discontinuation of groundwater extraction and treatment (GET) systems which were operational during the IRA. MNA has been proposed for the RAs at these sites while the GET systems undergo rebound studies. However, the results from these rebound studies are still outstanding. As a result, it is unclear if the proposed RAs are sufficient to meet the RAOs. Please revise to the FFS to clarify that performance data from the bioreactor and results from the rebound studies remain outstanding and may alter the proposed RAs.	We agree that the selection of final remedies at the sites will largely depend on the performance of the bioreactors, EVO injections, and rebound studies during the period of interim remediation. Final remedies will be selected in the pending Basewide Groundwater ROD utilizing this information. We added the following text to the first paragraph following the bullet list in Section 7.4.4 (formerly Section 7.2.4): "Performance data for the bioreactor will continue to be evaluated for the remainder of the period of interim remediation." We also added the following text to the first paragraph following the bullet list in Section 7.4.5 (formerly Section 7.2.5): "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." We added the following text to the second paragraph following the bullet list in Section 7.4.5 (formerly Section 7.2.5): "Rebound study data will continue to be evaluated for the remainder of the period of interim remediation." We added the following text to the third paragraph following the bullet list in Section 7.4.5 (formerly Section 7.2.5):

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		"Performance data for attenuation process in the distal portions of the plumes will continue to be evaluated for the remainder of the period of interim remediation." And, we added the following text as the second paragraph following the bullet list in Section 7.4.6 (formerly Section 7.2.6): "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."
47.	**Table 8-2, Estimated Time to Achieve Preliminary Cleanup Goals for Alternative 2 – MNA:** This Table indicates that MNA will take over 100 years to achieve PCGs at LF007D and LF008. As such, it is unclear why other groundwater RAs have not been proposed for these sites to expedite achievement of PCGs. Further, it is unclear why modeling to estimate the cleanup timeframe for these sites has not been included in the FFS. Please revise the FFS to clarify why other groundwater RAs have not been proposed for these sites to expedite achievement of PCGs. In addition, please provide modeling to support the cleanup timeframes for the sites.	Estimates of the time required to achieve PCGs and descriptions of the modeling are provided in Appendix D – Remediation Timeframe Calculations. This Appendix is referenced as a footnote in Table 8-3 (formerly Table 8-2) and in Tables 8-6 and 8-11 (formerly Tables 8-4 and 8-7). Technology screenings for Sites LF007D and LF008 are provided in the revisions to Section 6 (see response to General Comment 5). We added the following rationale for the appropriate remedial technology for each site: "At Site LF007D low concentrations of benzene (3 µg/L vs. PCG of 1 µg/L) and 1,4-dichlorobenze (12.6 µg/L vs. PCG of 5 µg/L) were detected in the 2010 GSAP. Concentrations of 1,4-dichlorobenze have been decreasing over time. Concentrations of benzene have remained stable. The plume size is small and limited to the vicinity of monitoring MW261x07 (refer to Figure 3.2-12). The plume lies beneath a closed and capped landfill and downgradient of an active 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 LF007C cleanup. The technology that best satisfies the evaluation criteria at Site LF007D is MNA." "At Site LF008, low concentrations of alpha chlordane (0.34J 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, 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."

No.	Comments	Responses
48.	**Section 7, Assembly and Screening of Alternatives, Page 7-1 to 7-13:** Section 7 does not include a Table listing which groundwater RAs are applicable to each site. As a result, it is unclear if contingency alternatives exist for individual sites. Further, proposed Alternative 2 (MNA) sites should have an active alternative considered in addition to MNA. This allows another alternative to be considered without undergoing the nine evaluation criteria assessment should a remedy failure under MNA occur. Please revise Section 7 to include a Table listing which groundwater remedial alternatives are applicable for each site. In addition, please ensure proposed Alternative 2 (MNA) sites have an active alternative considered in addition to MNA should a remedy failure under MNA occur.	We added new Table 7-7 – Summary of Alternative Assembly from Representative Process Options and new Table 7-8 – Assembly of Remedial Alternatives. Following the evaluations conducted in Section 6, new Table 7-7 provides listings of the process options that best satisfy the evaluation criteria of Effectiveness, Implementability, and Relative Cost at each site using a measles chart format. New Table 7-8 depicts the assembly of the representative process options into Alternatives 1 through 7 and the applicable sites. To clarify the transition from the interim alternatives previously selected in the NEWIOU and WABOU IRODs and the FFS alternatives, we added new Section 7.1 – Summary of Previous Alternative Development and new Section 7.2 – Summary of Previously Selected Interim Remedial Alternatives. Within these new text sections, we added new Table 7-1 – Summary of Selected Interim Remedial Alternatives for NEWIOU ERP Sites and new Table 7-2 -- Summary of Selected Interim Remedial Alternatives for WABOU ERP Sites. We also added a new Table 7-3 – Summary of Historical NEWIOU Groundwater Remedial Alternatives and new Table 7-4 – Summary of Historical WABOU Groundwater Remedial Alternatives. These new tables are similar in design to the sample tables that EPA provided in response to General Comment #5. They list the alternatives developed in the Initial Screening of Alternatives and present a site-by-site listing of the remedial alternatives that were evaluated in the Detailed Analysis of Alternatives and subsequently selected in the NEWIOU and WABOU Groundwater IRODs. We also added new Table 7-5 – Summary of Interim Remedial Action Performance and Status to clarify for each site the alternative(s) implemented as the IRA, the IRA objectives, the IRA performance and status, and optimization actions. Further, we added new Table 7-6 – Comparison of Previous and Current Remedial Alternatives Terminologies. This Table reconciles the differences in alternative naming conventions used in the NEWOU FS, WABOU FS, and the current FFS. We verified that all sites that are candidates for Alternative 2 (MNA) also have an active alternative considered in order to allow a contingency remedy to be selected in the case where the MNA alternative fails. This discussion is provided in Section 7.4.3, Alternative 3 – GET.

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49.	**Section 7.2 Assembly of Groundwater Remedial Alternatives, Page 7-2:** The terminology for the representative process options in 7.2 is different from the terminology used in Section 6 and 7.1. Please consider keeping the same terminology regarding the representative process options throughout Section 6 and 7 so that the information in the text and tables can be easily compared to each other.	We added the following text and bullets to Section 7.4 (following Table 7-8) to clarify the naming of alternatives using the GET acronym, carbon substrate injection, LUCs, and groundwater monitoring: "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.

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		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.”
50.	**Section 7.2 Assembly of Groundwater Remedial Alternatives, Page 7-2:** While the text says LUCs are a component of all the alternatives except 1, they should be retained in the alternatives analysis for comparison.	As we described during the 15 June 2011 Response to Comments meeting, the LUCs that are in place at Travis AFB apply equally to all groundwater sites. There are no meaningful comparisons that can be made in the alternatives analysis. We made no text changes based on this comment.
51.	**Section 7.2.2, Alternative 2 – Monitored Natural Attenuation, Page 7-4:** The Implementation of Alternative 2 at Site FT004 subsection states that, “To fully implement MNA at this site, the monitoring requirements for both monitoring and extraction wells would be revised as appropriate.” However,	We added the following text to Section 7.4.2.1 (formerly Section 7.2.2): “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 cost estimate, it was assumed that the same number of

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	details regarding how the monitoring requirements would be revised have not been provided. As a result, it is unclear if the costs provided in Appendix E (Cost Estimates) are appropriate. Please revise the FFS to provide details regarding how the monitoring requirements would be revised.	wells [(ten (10)] currently sampled at the site would continue to be sampled under Remedial Alternative 2." We added a similar text addition to Section 7.4.2.1 (formerly Section 7.2.2) under the Site SD031 discussion: "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 cost estimate, it was assumed that the same number of wells [(six (6)] currently sampled at the site would continue to be sampled under Remedial Alternative 2."
52.	**Section 7.2.3.3, Implementation of Alternative 3 at Site SS030, Page 7-8:** The criterion that would trigger a data gap investigation at Site SS030 to be conducted has not been specified. The text states that, "If required, a data gap investigation will be conducted to verify the boundaries of the off-base portion of the plume." Please revise the FFS to clarify what criterion will trigger a data gap investigation.	We revised the second paragraph of Section 7.4.3.3 (formerly Section 7.2.3.3) as follows: "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 FT005 extraction well system drew the 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 SS030 extraction wells does not work and the eastern boundary of the SS030 plume remains unclear, then the Base will investigate the east 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." We are no longer calling this field work a data gap investigation, because it will not have a material impact on the remedy selection process.
53.	**Section 7.2.2.4, Implementation of Alternative 2 at Site ST-27B, Page 7-7:** The text states that, "A data gaps investigation conducted in 2009 found that TCE concentrations in the Site ST027B plume are relatively low and localized. Chlorinated VOC contamination is not widespread, and MNA is an appropriate remedy (CH2M HILL, 2010n)." However, Section 3.6.4 (Groundwater Contamination) states that TCE and other volatile organic compound (VOCs) were detected at concentrations above IRGs during the fourth quarter sampling in 2009. Specifically, Section 3.6.4 states that TCE was detected at a maximum concentration of 474 ug/L. It is unclear how this	We revised the first paragraph of Section 7.4.2.4 (formerly Section 7.2.2.4) as follows: "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 inexpensively collect a large amount of data. The installation of ST027B

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	concentration is considered relatively low. Please revise the FFS to clarify how MNA is an appropriate groundwater RA at a site with TCE and other VOC detections above IRGs.	monitoring wells was based on this soil gas data, and it was determined that the Gore-sorber soil gas data correlated well with the solvent detections in the groundwater. Since the plume has been there since the mid-1980's after the use of TCE was banned by EPA, and the site is surrounded by either very low soil gas detections or a lack of detections, 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, 2010n). 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 that has considerable security and safety restrictions. Based on these considerations, MNA is a viable remedy for ST027B."
54.	**Section 8.2.2.5, Short-term Effectiveness, Page 8-6:** The discussion of short-term effectiveness presented in Section 8.2.2.5 does not estimate the time to achieve cleanup goals for each site. The time to achieve cleanup goals has only been provided for Alternative 2 (MNA) in Table 8-2 (Estimated Time to Achieve Preliminary Cleanup Goals for Alternative 2 – MNA). Please revise Section 8.2.2.5 to provide the time to achieve cleanup goals for each site.	Section 8.2.2.5 addresses short-term effectiveness for MNA only. However, Section 6.2.3.5 of EPA's Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA states that time-to-cleanup estimates are discussed under Short-Term Effectiveness. So, we moved all time-to-cleanup text and references to time-to-cleanup tables from the Compliance with ARARs subsections to the Short-Term Effectiveness subsections in Section 8 – Detailed Analysis of Alternatives.
55.	**Section 8.3, Alternative 3 – GET, Pages 8-8 to 8-13 and Section 8.4, Alternative 4 – Excavation, Bioreactor, and GET, Pages 8-13 to 8-18:** Sections 8.3 and 8.4 do not discuss GET system shutdown. In addition, costs associated with GET system shutdowns have not been discussed in Appendix E (Cost Estimates). As such, it is unclear if the groundwater RAs were appropriately scoped and costed so as to reflect a – 30%/ +50% margin as allowed for during the FFS process. Please revise the FFS to discuss GET system shutdowns and the associated costs.	We revised the cost estimates provided in Appendix E and summarized in Section 8 to include system shutdown costs as follows: For Table E-5C, we made revisions to address demolition/removal/well abandonment costs in year 26. We also revised Section 8, Table 8-7 (formerly Table 8-5) with the new capital and present value costs. We revised the basis of estimate in Appendix E Section E.3.2 to include the following new bullet items: • Complete demolition and removal of all groundwater treatment plant components at the NGWTP • Abandon four (4) extraction wells upon achieving PCGs. For Sites SS029/SS030, the cost estimate did not change when considering demolition/removal/well abandonment costs, because the estimated time to achieve PCGs is 62 years (i.e., 32 years beyond the PV analysis period of 30 years). We revised Appendix E, Section E.3.3 to include the following new bullet: • No demolition, removal, or abandonment costs were estimated because of the extended period required to treat contamination at Site SS029 (62 years). The SBBGWTP is expected to stay in operation until the PCGs

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		are achieved and the present value cost estimates are based on a maximum 30 year period. Present value costs will not be sensitive to potential costs incurred beyond that time. Similarly, for Site SS016, the cost estimate did not change when considering demolition/removal/well abandonment costs because the estimated time to achieve PCGs is 62 years (i.e., 32 years beyond the PV analysis period). We revised Appendix E, Section E.4.3 to include the following bullet: • No demolition, removal, or abandonment costs were calculated due to the extended period required to treat contamination at Site SS016 (62 years). Because the CGWTP is expected to stay in operation until PCGs are achieved, the present value cost estimates that are based on a 30 year period will not be sensitive to potential costs incurred in the future.
56.	**Section 8.4.1, Components of the Alternative, Page 8-13:** It is unclear why excavation has been included as a component of Alternative 4 (Excavation, Bioreactor, and GET) since the excavation has already occurred. Similarly, it is unclear why Section E.4 (Alternative 4 – Excavation, Bioreactor, and GET) include estimates and costs associated with the excavation. Please revise Sections 8.4.1 and E.4 to exclude discussion and costs associated with the excavation as it has already been conducted.	Since Excavation is a component of the Bioreactor construction, and because its discussion could be confusing in the context of groundwater remediation, we have removed the reference to Excavation from the description of Alternatives 4 and 6. For the cost estimates, we excluded the already expended capital costs from the cost estimates. Therefore, we revised the presentation of the cost data to move the capital costs incurred in 2010 out of the body of the tables to an informational footnote. For each Table we revised the footnotes as follows: Table 8-9 (formerly Table 8-6: "[c] Actual capital cost incurred in 2010 was $306,116." Table 8-12 (formerly Table 8-8): "[c] Actual capital cost incurred in 2010 was $138,832." "[d] Actual capital cost incurred in 2010 was $257,665." "[e] Actual capital cost incurred in 2010 was $406,187." Table 8-14 (formerly Table 8-9): "[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." We revised the introductory sentence of Section E.4.2 to state the following: "The basis for the bioreactor capital costs at Site SS016 are the actual costs incurred during the 2010 IRA optimization. The following cost items are included:" We revised the second paragraph of Section E.5.2 to state the following: "The basis for Alternative 5 capital costs at Site SS015 are the actual costs incurred during the 2010 IRA optimization. The following cost items are included:" We revised the second paragraph of Section E.5.3 to state the following: "The

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		basis for Alternative 5 capital costs at Site SD036 are the actual costs incurred during the 2010 IRA optimization. The following cost items are included:" We revised the second paragraph of Section E.5.4 to state the following: "The basis for Alternative 5 capital costs at Site SD037 are the actual costs incurred during the 2010 IRA optimization. The following cost items are included:"
57.	**Section 8.4.2.8, Contingency Actions, Page 8-17:** Costs associated with the contingency actions discussed in Section 8.4.2.8 have not been included in Appendix E, Cost Estimates. As such, it is unclear if the groundwater RAs were appropriately scoped and costed so as to reflect a -30%/ +50% margins as allowed for during the FFS process. Please revise the FFS to include the costs associated with the contingency actions discussed in Section 8.4.2.8.	Because of the meaning that some personnel have assigned to the term "contingency action," which implies that the selected remedy has failed to perform as designed and an Explanation of Significant Differences is needed to carry out a subsequent remedial action, we are replacing this term with "performance enhancement measures" throughout the text. The performance enhancement measures listed in Section 8.4.2.8 comprise a range of increasingly aggressive measures, and the selection and execution of the appropriate measures would have a significant impact on the cost. For example, an increase in the amount or frequency of vegetable oil injections into the bioreactor would result in a relatively minor cost increase, since this is an O&M activity that would be performed on a regular basis. The installation of additional monitoring wells could have a greater impact, depending on the number of wells needed, their locations, and their depths. However, since we assume that the -30%/+50% margin is based on the original capital cost, it is highly unlikely that any combination of measures will result in a cost increase above 50 percent of the bioreactor installation and startup costs.
58.	**Section 8.5.2.7, Cost, Page 8-21:** Based on Section E.5 (Alternative 5 – EVO and EA) only two injection wells have been proposed. It is unclear how two injection wells will sufficiently address contamination at Sites SS015, SD036, and SD037. Please revise the FFS to clarify how two injection wells are appropriate to scope and cost Sites SS015, SD036, and SD037 to reflect a -30%/ +50% margin as allowed for during the FFS process.	For Site SS015, we revised Section E.5.2, third bullet as follows: • Install five (5) 4-inch-diameter injection wells (up to 25 feet bgs). We revised Table E-7, Alternative 5 to reflect technology demonstration and post-demonstration optimization costs. Section E.5.2 now includes the following bullets: • Assumed similar scope and cost for injection system expansion (i.e., post-demonstration optimization) as the work conducted during the 2010 technology demonstration. The expansion will serve to address additional contamination beyond the demonstration treatment zone. • Expansion costs were escalated by 4 percent for inflation. For Sites SD036 and SD037, we revised Table E-7, Alternative 5 to reflect technology demonstration and post-demonstration optimization costs. We revised Sections E.5.3 and E.5.4 to include the following bullets: • Assumed similar scope and cost for injection system expansion (i.e., post-demonstration optimization) as the work conducted during the 2010 technology demonstration. The expansion will serve to address additional contamination beyond the demonstration treatment zone.

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		• Expansion costs were escalated by four (4) percent for inflation. We also revised the costs summarized in Table 8-8 in Section 8.5.2.7.
59.	**Section 8.6.5, Long-term Effectiveness and Permanence, Pages 8-24 to 8-25:** The discussion provided in Section 8.6.5 is for individual components of the alternative rather than the whole alternative. Please revise Section 8.6.5 to discuss the long-term effectiveness and permanence of Alternative 6 (Excavation, Bioreactor, Phytoremediation, EVO PRB, and EA) as a whole.	We revised Section 8.6.5 to include the following new second paragraph: "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." We deleted the original Subsection 8.6.5.1.
60.	**Section 8.6.6, Reduction of Toxicity, Mobility, or Volume through Treatment, Page 8-25:** The text states that the entire mass and volume of contaminants will eventually be treated to PCGs within about 65 years, and the treatment will be irreversible. However, Section 8.6.7 (Short-term Effectiveness) indicates that 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. Please revise the FFS to address this discrepancy.	Since time-to-cleanup is addressed under the Short Term Effectiveness criterion, we deleted the last sentence of the second paragraph of Section 8.6.6. The correct cleanup time is 58 years, which is found in the second paragraph of Section 8.6.7.
61.	**Section 8.6.5.3, Phytoremediation Long-term Effectiveness and Permanence, Page 8-24:** Section 8.6.5.3 includes installation of irrigation as an optimization action. It is unclear how extraction of contaminated groundwater and distribution of it onto trees as irrigation water would meet the RAO of protecting human health by reducing the risk of potential exposure to groundwater contaminants. Please revise the FFS to clarify how extraction of contaminated groundwater and distribution of it onto trees as irrigation water would meet the RAO of protecting human health by reducing the risk of potential exposure to groundwater contaminants, as it could potentially lead to additional exposure pathways.	We revised the text in the last bullet in Section 8.6.5.3 as follows: "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." The irrigation system described in the comment is only a conceptual optimization measure. No design has been developed, and there are no current plans to install such a system. If Travis AFB installed this type of system, it would likely be a part of a post-ROD implementation of the final remedial action. Travis AFB would work with the regulatory agencies to develop an appropriate design that would be protective of human health and the environment.
62.	**Table 9-2, Comparison of Implemented Interim Remedial Actions and Focused Feasibility Study Remedial Alternatives, Page 9-6:** Table 9-2	We replaced the original Table 9-2 with a new Table 9-2 -- Comparison of Historical and Current NEWIOU Sites Alternative Development and a new

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	does not provide an unbiased range of alternatives. Instead Table 9-2 compares the originally selected IRAs for each site to a single groundwater RA without utilizing the nine evaluation criteria established by the RI/FS Guidance and NCP. Please revise Table 9-2 to provide a comparison of currently operating IRAs for each site to groundwater RAs utilizing the nine evaluation criteria as a method of comparing alternatives.	Table 9-3 -- Comparison of Historical and Current WABOU Sites Alternative Development. These new tables are similar in design to the sample tables that EPA provided in response to General Comment #5. They list the alternatives developed in the Initial Screening of Alternatives and present a site-by-site listing of the remedial alternatives that were evaluated in the Detailed Analysis of Alternatives, the alternatives selected in the NEWIOU and WABOU Groundwater IRODs, and the alternatives developed and evaluated in the FFS. Both new Tables 9-2 and 9-3 list the IRA and several FFS alternatives for each site. Typically, the FFS alternatives include no action, MNA, and GET. We also deleted the Comments column provided in the original Table 9-2, since most of that information can be found in the text. We also added a new Section 9.3 – Summary of Comparative Analysis. Within this new section, we added measles charts for each evaluation criterion. These charts depict the comparative performance of each alternative at each site for each evaluation criterion (e.g., Overall Protection of Human Health and the Environment, Compliance with ARARs, etc.).
63–77.	Specific Comments related to Appendix G – Site ST027B Risk Assessments	Responses to Specific Comments 63 through 77 are provided in the draft final *Site ST027-Area B Human Health Risk Assessment* and/or draft final *Site ST027-Area B Ecological Risk Assessment*. As all parties agreed at the 15 June 2011 Response to Comments meeting, we are pulling Appendix G – Site ST027B Risk Assessments from the FFS and treating it as separate ST027B human health and ecological risk assessment reports.
EDITORIAL COMMENTS		
1.	**Executive Summary:** Table ES-5 is useful to show the interim alternative compared to the new alternative, and would be helpful to also add the interim remedial alternatives on Tables ES-3 and ES-4 as well.	We added new Tables ES-6, ES-7, ES-8, ES-12, and ES13 to clarify the relationships between the historical alternatives and the current alternatives developed in the FFS.
2.	**General:** There are several places in which non-detect (ND) values are reported, but the detection limits are not specified. For example, in Section 3.2, detection limits are missing from Figures 3.2-4, 3.2-5, 3.2-6, 3.2-7, 3.2-8, 3.2-11, and 3.2-12. Please provide detection limits for all reported results in which the contaminant was not detected.	We revised figures 3.2-4, 3.2-5, 3.2-6, 3.2-7, 3.2-8, 3.2-11, 3.2-12, 3.3-5, 3.3-6, 3.3-7, 3.4-10, 3.4-19, 3.4-20, 3.4-21, 3.4-27, 3.4-28, 3.4-33, 3.4-34, 3.5-3, 3.5-4, 3.5-5, 3.5-6, 3.5-7, 3.6-3, 3.6-4, and 3.6-5 to include the detection limit of the chemical(s) posted.
3.	**Section 1.2.2, Petroleum-only Contaminated Sites, Page 1-2:** Petroleum-only Contaminated (POCO) program Sites SS014, ST018, ST027 Area A (ST027A), and ST028 have not been included on Figure 1-3 (Groundwater Sites and Contaminant Plumes, SEWIOU and WABOU). However, POCO program Site ST032 has been included on Figure 1-3.	We removed ST032 from Figures ES-1, 1-2, 1-3, and 2-1.

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	Please revise Figure 1-3 to include and identify POCO program sites or clarify why POCO program Site ST032 was included on Figure 1-3.	
4.	**Section 2.6.2, IRA Optimization, Page 2-11:** Seven sites are described in this section but references to figures showing historical and current extent of contamination are not provided for each individual site. Please revise each bullet point in Section 2.6.2 to cite the relevant figure showing historical and current extent of contamination.	We added the following sentence to the end of the bullet in Section 2.6.2 with the subheading Site LF007C: "Figure 2-3 shows the historical and current extent of contamination in the North IRA, which includes Site LF007C." We added the following sentence to the end of the bullet in Section 2.6.2 with the subheading Site SS015: "Figure 2-8 shows the historical and current extent of contamination at Site SS015." We added the following sentence to the end of the bullet in Section 2.6.2 with the subheading Site SS016: "Figure 2-5 shows the historical and current extent of contamination at Site SS016." We added the following sentence to the end of the bullet in Section 2.6.2 with the subheading Site SS030: "Figure 2-10 shows the historical and current extent of contamination in the South IRA, which includes Site SS030." We added the following sentence to end of the bullet in Section 2.6.2 with the subheading Site SD036: "Figure 2-6 shows the historical and current extent of contamination in the WIOU, which includes Site SD036." We added the following sentence to the end of the bullet in Section 2.6.2 with the subheading Site SD037: "Figure 2-6 shows the historical and current extent of contamination in the WIOU, which includes Site SD037." We also added the boundaries of SD036 and SD037 to Figure 2-6. We added the following sentence to the end of the bullet in Section 2.6.2 with the subheading Site DP039: "Figure 2-7 shows the historical and current extent of contamination at Site DP039."
5.	**Section 2.6.2 IRA Optimization, Page 2-12, Site SD036**: The reference provided in the last sentence cites SS036 and it should be SD036.	We revised the last sentence for Section 2.6.2 in the bullet with the subheading Site SD036 as follows: "More complete descriptions of the optimization measures are provided in the *Sites SD036/SD037 Remedial Process Optimization Work Plan (*CH2M HILL, 2010e)."
6.	**Section 3.1.4.1, Land Use, Page 3.1-2:** The population for Solano County is based on 2006 U.S. Census Bureau data; however, 2009 U.S. Census Bureau data is available. Please update Section 3.1.4.1 to list the population for Solano County based on the 2009 U.S. Census Bureau.	We revised the second sentence of Section 3.1.4.1 as follows: "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)." We revised the reference in Appendix B as follows: " U.S. Census Bureau. 2009a. July 1, 2009 Population Estimate for Solano County, California. www.census.gov/popest/counties/CO-EST2009-01.html. Accessed on April 20, 2011."

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		We added the following reference to Appendix B: "U.S. Census Bureau. 2009b. July 1, 2009 Population Estimate for Fairfield and Vacaville, California. http://www.census.gov/popest/cities/SUB-EST2009-04.html. Accessed on April 20, 2011."
7.	**Section 3.1.7, Groundwater, Page 3.1-11:** The first full paragraph states that "A third mound is in the western corner of the Base in the WABOU," but this mound is not located in a corner (see Figure 3.1-1). Please revise the sentence to state that the mound is in the western part of the Base.	We revised the first sentence of paragraph six of Section 3.1.7 as follows: "A third mound is in the western part of the Base in the WABOU."
8.	**Figure 3.1-11, Advancing Solvent Plume in Layered Alluvium:** The figure contains a diagram showing three curves, labeled t_4, t_5, and t_6 but there is no indication as to what these curves mean or why they were included on the figure. Please provide an explanation for this diagram.	We deleted the erroneous inset diagram with the t_4, t_5, and t_6 curves in Figure 3.1-12.
9.	**Section 3.1.9.1 LNAPL, Page 3.1-14:** Please distinguish ST027 as ST027A and ERP Site ST027B, similar to how ERP Site SD034 is distinguished.	We revised the fourth sentence of Section 3.1.9.1 as follows: "Travis AFB sites with LNAPL releases include POCO Sites SS014, ST018, ST027A, ST028, ST032, and ERP Site SD034." To add clarity, we added "ST027B" to the list of sites in the second sentence of the second paragraph in Section 3.1.9.2 (Dense Nonaqueous Phase Liquids).
10.	**Section 3.2.1, North IRA Site Descriptions, Page 3.2-2, Figure 3.2-1, Site Map – North IRA, Sites FT004/SD031/LF006/LF007, NEWIOU and Figure 3.2-3, Groundwater Isocontours at Sites FT004/SD031/LF006/LF007:** The location of the groundwater interceptor trench discussed in second-to-last paragraph of Section 3.2.1 is not provided. Please include the trench on both of these figures.	We added the groundwater interceptor trench to Figures 3.2-1, 3.2-2, and 3.2-3.
11.	**Figures 3.2-4 and 3.2-6 through 3.2-12:** Each of the cross-sections in these figures is labeled A-A', potentially creating confusion between the cross-sections for different sites. Please use a unique identifier for each cross-section (B-B', C-C', etc.)	We corrected the cross section labels to show unique identifiers for each cross section.
12.	**Figure 3.2-5, North IRA – 1,1-DCE Distribution at Sites FT004/SD031, NEWIOU and Figure 3.2-8, Site SD031 Cross Section A-A':** Figure 3.2-8 shows a maximum 1,1-DCE concentration of 78.8 ug/L at well EW566X31, but Figure 3.2-5 shows a value of 1.6 ug/L for the same well. Please resolve this discrepancy.	We corrected Figure 3.2-5 so that the 1,1-DCE data is consistent with the data shown in Figure 3.2-8. The correct concentration for 1,1-DCE at Well EW566x31 is 78.8 µg/L.
13.	**Section 3.3.1.1, Oil Spill Area, Page 3.3-1:** The last sentence of the first paragraph under the Building 18 subheading describes a removal action that occurred in 1997, but cites a report published in 1995. Please resolve this discrepancy.	We revised the last sentence of the first paragraph under the Building 18 subheading as follows: "The OWS was removed in 1997, and the UST was removed from the building and disposed of in January 1998 (SSPORTS, 1998)".

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		We also added the SSPORTS, 1998 reference below to Appendix B – References : "Supervisor of Shipbuilding, Conversion and Repair (SSPORTS) Environmental Detachment. 1998. *Removal Summary Report for Underground Storage Tank Site P-18. Travis Air Force Base, California.* April."
14.	**Figures 3.3-5, 3.3-6, 3.3-7:** There is inconsistent labeling of numbers in thousands (comma vs. no comma). Please correct this to improve readability.	We corrected Figures 3.3-5, 3.3-6, and 3.3-7 so that the concentration values with four or more digits contain commas.
15.	**Figure 3.3-5 and 3.5-3**: These figures show different TCE data results for the same wells. Either correct the discrepancy or identify the sources of data, if different.	We corrected the TCE concentrations on Figure 3.5.3 so they are consistent with Figure 3.3-5.
16.	**Sections 3.4.1.5, 3.5.5 Status of Groundwater Interim Remedial Actions:** Please identify the start date for the GET systems similar to other sections.	We added the following sentence under the subheading WIOU GET System in Section 3.4.1.5: "The WIOU GET System was started up in February 2000." We added the following sentence to the third paragraph of Section 3.5.5: "The South IRA GET System was started up on 6 July 1998."
17.	**Figures 3.4-7, 3.4-8, and 3.4-9**: These figures show TCE plume boundaries and the locations of groundwater monitoring wells, but analytical results for individual wells are not posted. Please include TCE concentrations on these figures, as was done on the other figures showing contaminant distribution (e.g. Figure 3.2-4). Similarly, Figure 3.5-3 includes individual results for 1,2-DCA (Site FT005), but not for TCE (Sites SS029 and SS030). Please include individual TCE results on this figure.	We revised Figures 3.4-8 and 3.4-9 to include the TCE concentrations. However, the scale on Figure 3.4-7 is too condensed to allow for adding the Well IDs and TCE concentrations for each boring without excessive clutter. We revised Section 3.5.4 as follows: "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."
18.	**Section 3.4.1.4, Groundwater Contamination, Pages 3.4.1-6 and 3.4.1-7; and Figures 3.4-8 and 3.4-9:** The text states that the sources of chlorinated VOC contamination at sites SD036 and SD037 were likely damaged and leaking sanitary sewer lines, but these sanitary sewer lines are not shown on the site figures. Please include the sanitary sewer lines on Figures 3.4-8 and 3.4-9.	We revised Figures 3.4-8 and 3.4-9 to show the locations of the sanitary sewer lines.

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19.	**Figures 3.4-26 through 3.4-28:** The location of the phytoremediation study is shown separately from groundwater elevation and TCE concentration data. Please revise Figures 3.4-26, 3.4-27, and 3.4-28 to include the outline of the phytoremediation area.	We revised Figures 3.4-26 through 3.4-28 to show the outline of the phytoremediation area.
20.	**Figure 3.4-27** shows TCE concentrations of 664 ug/L for MW2056Ax39 and 442 ug/L for MW2056Bx39. Figure 3.4-30 includes a location labeled MW2056x29A/B with a TCE concentration of 442 ug/L, but the 662 ug/L value is not included.	We added the 664 µg/L TCE concentration to MW2056x39A/B of Figure 3.4-30.
21.	**Figure 3.5-3 and Figure 3.5-4:** a. The concentration of TCE at MW269x30 is shown as 10.1 ug/L on Figure 3.5-3 but is shown as 23.6 ug/L on Figure 3.5-4. b. The concentration of TCE at EW01x30 is shown as 3.5 ug/L on Figure 3.5-3 but is shown as 6.2 ug/L on Figure 3.5-4. c. The concentration of TCE at MW03x30 is shown as 58.5 ug/L on Figure 3.5-3 but is shown as 44.2 ug/L on Figure 3.5-4. d. The concentration of TCE at MW001Ax30 is shown as 9.9 ug/L on Figure 3.5-3 but is shown as 14.7 ug/L on Figure 3.5-4. e. The concentration of TCE at MW001Bx30 is shown as 14.7 ug/L on Figure 3.5-3 but is shown as 15.1 ug/L on Figure 3.5-4.	We revised Figure 3.5-3 to show TCE concentrations for MW269x30 as 23.6 µg/L, for EW01x30 as 6.2 µg/L, for MW03x30 as 44.2 µg/L, for MW2001Ax30 as 14.1 µg/L, and for MW2001Bx30 as 15.1 µg/L.
22.	**Figure 3.5-3 and Figure 3.5-6:** The concentration of TCE at EW04x29 is shown as 121 ug/L on Figure 3.5-3 but is shown as 210 ug/L on Figure 3.5-6.	We revised Figure 3.5-3 to show that EW04x29 has a TCE concentration of 210 µg/L.
23.	**Appendix E, Cost Estimates:** Costs associated with the preparation, submittal, and revision of remedial design (RD) documents have not been included in the cost estimates in Appendix E. As a result, it is unclear if the cost estimates to reflect a -30%/ +50% margin as allowed for during the FFS process. Please revise Appendix E to provide the costs associated with the RD documents.	We revised Appendix E as follows: "Remedial Design (RD) costs were developed in one (1) of two (2) ways. For sites in which the remedial alternative includes EVO injections (Alternatives 5 and 6), the Emulsified Oil Design Tool (ESTCP, 2007) software was used to develop the costs. For sites in which the alternative did not include EVO injections, the RD costs were developed using the percentages on Exhibit 5-8 of *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (EPA, 2000). The remedial design costs for the following sites are expected to be negligible: Sites FT004, LF006, LF007B, LF007D, LF008, ST027B, SD031, SD033, and SD043 under Alternative 2 – MNA; Site SS029 under Alternative 3 – GET; and Site SD034 under Alternative 7 – Passive Skimming and EA." The remedial design costs are included in Tables E-4 through E-9 and costs have been updated in Section 8.

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SUSTAINABILITY EVALUATION (APPENDIX F)		
INTRODUCTION		
1.	EPA appreciates Travis AFB applying concepts of sustainability to the proposed remedial actions at the Base. We suggested in the March 30, 2011 Specific Comment 22. Section 4.2.4 Sustainability that EPA's Superfund Green Remediation Strategy (EPA, 2010) may be useful for Travis AFB to consider in developing their green remediation strategy. In order to provide further guidance regarding sustainability and green remediation concepts, we have the following suggestions for the AF to consider regarding Appendix F, Sustainability Evaluations.	We have read the 2010 EPA Strategy and agree it contains many good ideas for creating greener, more sustainable projects. Because the Air Force SRT was developed in 2008 and 2009, it has slightly different goals and objectives. Regardless, we believe these two approaches are fundamentally compatible and the focus should be on the common ground and not the differences.
GENERAL COMMENTS		
1.	Sustainability is a broad concept most usually applied to communities or nations, and usually includes many aspects of the social, economic, and environmental health of the community or nation. Appendix F should acknowledge this larger context, and note that the Sustainability Evaluation treats only a small subsection of sustainability. EPA is generally using "Green Remediation" to describe the strategy for reducing the environmental footprint of Superfund Cleanups, and would prefer Travis AFB use this terminology and strategy in the context of the FFS. See also General Comment 4 and Specific Comments 1a. 1b., and 3.	We replaced the first paragraph of Appendix F with the following text: "When the Air Force was following the CERCLA process in the mid-1990's to select interim remedies for its contaminated groundwater sites, very little consideration was given to the materials used to build remedy infrastructure or the energy demands of the resulting treatment systems. During the period of interim remediation, there has been a growing recognition that most remedies use energy, water and other resources (and thus have an environmental 'footprint.'. So, efforts to conserve natural resources, minimize waste generation, and reduce energy use can improve environmental performance while protecting human health and the environment. To assist in this endeavor, the Air Force conducted sustainability evaluations of the Travis AFB interim groundwater remedies and the remedial alternatives developed in this Basewide Groundwater Focused Feasibility Study (FFS). This Appendix provides the results of these evaluations. The term "sustainability" is often used in the context of broad social, economic, and environmental health issues. For example, EPA describes sustainable development as that which meets the needs of the present without compromising the needs of future generations, while minimizing overall burdens to society. For the purposes of this FFS, the sustainability evaluations are concerned only with groundwater remedy selection. Section 4.2.4 (Sustainability) of the FFS describes sustainability in remedial action systems and "green" remedial actions in more detail."
2.	Appendix F and the associated Draft FFS sections should more directly describe how the results of the Sustainability Evaluation may or may not be included in remedy selection. For example, are the results background information only, or are they being used to inform the various criteria, such as	We added the following new paragraph at the end of Section F.1: "The results of the evaluations using the SRT do not have the same standing as the nine (9) CERCLA remedy selection criteria specified in the FS guidance (EPA, 1988). Rather, they are simply considerations in the FFS evaluations.

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	how the short-term and long-term effectiveness may be affected? It should be clear in the Draft FFS and the Appendix that the results are not being used as criteria itself in remedy selection but rather information to be considered within the appropriate elements of the nine criteria. See also Specific Comments 1c, 3 and 6.	The SRT results are specifically used to support evaluation of the Short-term Effectiveness criterion within Section 9 – Comparative Analysis of Alternatives. This criterion includes the factor of protection of workers during remedial action. The SRT results provide a comparison of potential lost labor hours and injury risks between the IRA and FFS alternative for each site." We also added a new Section 6.4.2.4 – Consideration of Green and Sustainable Process Options. This new section follows the required evaluation of the Effectiveness, Implementability, and Relative Cost criteria. We revised the last sentence in Section 4.2.4 as follows: "The results of the sustainability evaluations described in Appendix F were used in the development of the groundwater remedial alternatives described in the subsequent sections of this FFS."
3.	The results are presented assuming a certain estimated timeframe for cleanup. It would be more useful to see the results presented in numbers that allow remedial alternatives to be compared regardless of the estimated duration of cleanup (for example, per year as opposed to per life-cycle). Also, for EPA to better understand how the analysis was conducted and independently interpret the results, the input and output files from the SRT should be made available (perhaps electronically) to the reviewers. See also Specific Comments 2, 4, and 8.	We revised Table F-1 to include tabulations of CO_2 generation and Total Energy Consumption for the duration of cleanup and per year. The tons of other air emissions (NO_x, SO_x, and PM_{10}) are so small on a per year basis that they are provided only for the duration of cleanup. We downloaded the SRT runs, input and output files, SRT-Version 2.1 and the SRT user manual onto a CD and placed the CD in a plastic pocket at the back of Appendix F.
4.	Regardless of the results from the Sustainability Evaluation for the competing alternatives, and regardless of which alternative is selected for each site, the Sustainability Evaluation should identify opportunities (if any) for reducing the greenhouse gas emissions from the selected remedies. We understand that the Sustainable Remediation Tool (SRT) is designed to evaluate a few key emissions, and it can be a useful tool for this purpose. We note that there are other items of importance to the environmental footprint of a remedy, such as emissions of air toxics, use of natural resources including water, generation of waste, and effects on ecosystems, that the SRT does not appear to quantify or evaluate. The AF should still consider these various "green remediation" options to improve the sustainability of the selected remedy. For example, purchasing renewable energy credits, optimizing the operation of a remedial action in order to increase efficiency and methods to reduce use of resources and materials, reduce waste generation, reduce travel, etc. can be evaluated. Appendix F should note this, to help put the Sustainability Evaluation in the larger context of environmental footprint analyses. See also Specific Comment 5 and 7.	One of the benefits of the SRT (or any similar tool) is that it can determine the parts of a remedy that "drive" GSR impacts. We addressed this in the portion of Section 9 – Comparative Analysis of Alternatives that covers the short-term effectiveness criterion. We revised the fourth paragraph of Section 9.2.5.2 as follows: "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 CO_2 emissions were higher for the IRA activities compared to Alternative 2. In most cases, the IRA GET operations emitted 30-plus times the amount of CO_2 compared to MNA. The total energy reduction for Alternative 2 sites ranged from 95 to 97 percent compared to IRA GET systems. The footprints for carbon dioxide generation and energy consumption are summarized in Table 9-10. More detailed information is provided in Appendix F." We revised the last paragraph in Section 9.2.5.4 as follows: "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

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		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 to Alternative 4. The total energy reduction for Alternative 4 was 42 percent. The footprints for carbon dioxide generation and energy consumption are summarized in Table 9-10. More detailed information is provided in Appendix F." We also revised the last paragraph in Section 9.2.5.5 as follows: "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." We revised the last paragraph in Section 9.2.5.6 as follows: "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 to Alternative 6. The higher CO_2 emissions associated the Alternatives 6 are mainly due to the production of the substrate. The total energy reduction for Alternative 6 was 74 percent. The footprints for carbon dioxide generation and energy consumption are summarized in Table 9-10. More detailed information is provided in Appendix F." And, we revised the last paragraph in Section 9.2.5.7 as follows: "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 to Alternative 7. The

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		total energy reduction for Alternative 7 was also percent. The footprints for carbon dioxide generation and energy consumption are summarized in Table 9-10. More detailed information is provided in Appendix F." The Air Force's SRT is an advanced GSR screening tool which does not perform a full life-cycle analysis, but does consider the life-cycle of on-site energy and material use. We believe this level of analysis is suitable for most FS work. We realize that other factors can be included in a green and sustainability evaluation such as the ones listed. We selected the SRT for our analysis and believe it is adequate for pointing out the "big picture" GSR impacts for this FS. We added the following paragraph as the last introductory paragraph in Appendix F: "The Air Force will continue to apply the principles of green and sustainable remediation as part of Remedial Process Optimization (RPO) after the final remedies are implemented."
SPECIFIC COMMENTS		
1.	**Introduction, page F-1:** The text states that "This Appendix provides the results of sustainability evaluations conducted for the current site-specific groundwater interim remedial actions (IRAs) and the remedial alternatives developed in this Basewide Groundwater Focused Feasibility Study (FFS). The purpose of these evaluations is to identify primary **sustainability impacts**, evaluate **life-cycle impacts**, and **assess how these impacts can be incorporated into the final remedy selection process**." The following are specific comments associated with the **bolded** text: a. **"sustainability impacts" and "life-cycle impacts":** The term "impact" has a specific meaning in the context of a life-cycle assessment, which is not necessarily observed in the Sustainability Evaluation. For example, while global warming potential (in CO2 equivalents) may be considered an impact, NOx, SOx, and PM10 emissions are not considered impacts, but instead are parameters used to compare emissions from the alternative remedies. It can still be valuable to quantify these parameters, without referring to them as "impacts". b. **"life-cycle impacts":** The Sustainability Evaluation does not really evaluate the life-cycle of the remedies, because the Evaluation does not extend to the full life-cycle of the remedy. That is, it includes only some of the off-site activities (personnel transportation and off-site electricity generation), while leaving out others (such as manufacturing of materials and use of off-site services). Although few life-cycle assessments truly include all life-cycle components, most will include key off-site services and	a. We changed "impacts" to "parameters" in the Introduction. b. The Air Force's SRT is an advanced GSR screening tool which does not perform a full life-cycle analysis, but does consider the life-cycle of on-site energy and material use. We believe this level of analysis is suitable for most FS work. c. We added text to Appendix F stating that this analysis is to supplement the evaluation of alternatives and we will discuss in the short-term effectiveness paragraph for each alternative. We inserted the following new fourth, fifth, and sixth paragraphs to Appendix F as follows: "Sustainable design in remediation projects is a systematic, balanced planning and management of risk concept. Sustainability includes many aspects of environmental, social, economic, and health developments. This sustainability evaluation quantifies environmental footprints for the remedial alternatives developed in the Basewide Groundwater Focused Feasibility Study (FFS). Although this is not considered a full life-cycle analysis; it does consider energy and materials consumed on the site during the life of the project. The tool selected to perform the analysis quantifies select sustainability metrics for comparing the environmental footprints of remediation alternatives. This Appendix provides the results of sustainability evaluations conducted for the current site-specific groundwater interim remedial actions (IRAs) and the remedial alternatives developed in this FFS. The purpose of these evaluations is to identify and compare environmental footprints for each

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	manufacturing which are required to support the activity being evaluated. Although Appendix F notes the activities included in the Sustainability Evaluation clearly in Section F.2.2, it should acknowledge it the introduction the broader scope of a true life-cycle assessment, and mention typical life-cycle activities that the Sustainability Evaluation does not include. c. **"assess how these impacts can be incorporated into the final remedy selection process":** Appendix F does not include an assessment of how the impacts can be "incorporated into the final remedy selection process". Instead, Appendix F provides only the results of the Sustainability Evaluation. Section 4.2.4 Sustainability in the Draft FFS indicates that sustainability was considered as a factor in developing remedial components, and as such certain remedial alternative components were identified as "green remedial alternatives". Since a complete assessment of whether a particular remedial alternative is "sustainable" was not completed, rather sustainable or "green" components were evaluated, it does not seem possible to conclude that any particular remedial alternative is "sustainable." EPA suggests rather than try to characterize the alternatives as "sustainable" as a whole, use the results to inform the nine criteria analysis of all the remedial alternatives being evaluated.	IRA and proposed remedial alternatives at each site. The results of the footprint analysis are not part of the formal criteria for remedy selection, but rather information to be considered within the appropriate elements of the nine criteria. A short discussion of green and sustainability factors have been included under the short-term effectiveness criterion provided in Section 9 – Comparative Analysis of Alternatives. The scope of the evaluations in this Appendix includes estimates of key components of energy use and resulting air emissions related to the remediation of groundwater at Sites FT004, FT005, LF006, LF007C, LF008, SS016, ST027B, SS030, SD031, SD033, SD034, SD036, SD037, DP039, and SD043." We revised Section 9.2.5.2, fourth paragraph as follows: "The CO_2 emissions were higher for the IRA activities compared to Alternative 2. In most cases, the IRA GET operations emitted 30-plus times the amount of CO_2 compared to MNA. The total energy reduction for Alternative 2 sites ranged from 95 to 97 percent compared to IRA GET systems." We revised Section 9.2.5.4, fourth paragraph as follows: "CO_2 emissions were 15 percent higher for the optimized IRA GET system compared to Alternative 4. The total energy reduction for Alternative 4 was 42 percent." We revised Section 9.2.5.5, sixth paragraph as follows: "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 95-97 percent for sites SD037 and SD036, respectively." We revised Section 9.2.5.6, fifth paragraph as follows: "The CO_2 emissions were 75 percent higher for the GET system compared to Alternative 6. The higher CO_2 emissions associated the Alternatives 6 are mainly due to the production of the substrate. The total energy reduction for Alternative 6 was 74 percent." We revised Section 9.2.5.7, fourth paragraph as follows: "The CO_2 emissions were 97 percent higher for the IRA GET system compared to Alternative 7. The total energy reduction for Alternative 7 was also 97 percent."

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2.	**Section F.1, page F-1:** This section should include a website link to Air Force Center for Engineering and the Environment (AFCEE) Sustainable Remediation Tool (SRT) (AFCEE, 2009), since it is available on-line. Also, in addition to the SRT tool, the input and output files from the SRT should be made available (perhaps electronically) to the reviewers so that the specifics of the analysis can be reviewed.	We added the website link to Appendix F, Section F.1. The SRT runs, input and output files, SRT-Version 2.1 and the SRT user manual have been saved onto a CD and placed in a plastic pocket at the back of Appendix F.
3.	**Section F.1, page F-1:** The text states that "The SRT allows users to estimate sustainability metrics for specific technologies. The current technologies in the SRT are (1) Excavation, (2) Soil Vapor Extraction, (3) Pump and Treat, (4) Enhanced Bioremediation, (5) In situ Chemical Oxidation, (6) Permeable Reactive Biobarrier (PRB), (7) Monitored Natural Attenuation (MNA)/Long-term Monitoring, and (8) Thermal Soil Treatment." A few of the remedy alternatives in the FS do not seem to fit any of the 8 categories noted above in the SRT. For example, the in-situ bioreactors (Sites SS016 and DP039), the in situ treatment of the contaminant source zone using emulsified vegetable oil injection (Sites SS015, SD036, and SD037), and phytoremediation (Site DP039), may not be exact fits to the technologies offered in the SRT. The Sustainability Evaluation should note where adjustments may have been made to help "fit" these remedy alternatives into the SRT model, and whether this may have led to substantial inaccuracies in the results.	We added the following text to Section F.1 to describe the extent that the SRT modules were used for the sustainability evaluation: "There are seven alternatives containing nine (9) separate technology components developed for the FFS. The components are: (1) No Action, (2) MNA, (3) Groundwater Extraction and Treatment (GET), (4) Bioreactors, (5) Emulsified Vegetable Oil (EVO) injections, (6) Phytoremediation, (7) Enhanced Attenuation (EA), (8) EVO Permeable Reactive Barrier (PRB), and (9) Passive Skimming. Five (5) different SRT modules were used to evaluate the components which make up the alternatives in the FFS. The Pump and Treat module was used for all sites with the GET component (FT004, FT005, LF008, SS016, SS029, SS030, SD031, SD033, SD034, SD036, SD037, DP039 and SD043). All sites containing MNA (or EA) as a component were evaluated with the MNA/LTM module. This list of sites includes FT004, FT005, LF006, LF008, SS015, SD034, SD036, SD037 and DP039. A phytoremediation test area has been established at DP039. To calculate the environmental footprints associated with conducting future operations and maintenance (O&M), the worker transportation sub-module within the SRT was utilized. Bioreactors were also part of the components for sites SS016 and DP039. The Excavation and PRB modules were used to capture the sustainability metrics associated with installation and O&M activities for the bioreactors. EVO injections were part of the alternative at four sites (SS015, SD036, SD037 and SD039). The Enhanced Bioremediation module was used to calculate their sustainability metrics. The only component of the seven alternatives that did not "fit" into the SRT modules was passive skimming. Therefore, the environmental footprint of passive skimming was not included in the analysis for Alternative 7 (SD034); however the EA portion was evaluated. Even though a quantitative evaluation for passive skimming could not be made for site SD034, it is likely that a passive skimmer system has significant energy and air emission benefits when compared to existing P&T activities at the site."

No.	Comments	Responses
4.	**Section F.2, page F-1:** The text states "The operations and maintenance (O&M) durations used in the SRT evaluations are based on the time-to-cleanup estimates provided in Appendix D." EPA previously commented in the March 30, 2011 review (Specific Comments 24, 47, and 54) that time to achieve cleanup goals for each proposed remedial alternative for each site need to be added to the FFS analysis, and requested additional information to support the estimates developed. The need for accurate remedial action and O&M duration is also critical to the Sustainability Analysis. For example, in some cases (e.g., Sites FT004, LF008, SD031, SD033, and SD043) the AF used the same duration for the MNA option as the groundwater extraction and treatment option. We would typically assume that MNA would have a longer duration, and more years of sampling, number of personnel visits per year, etc. would add to the environmental footprint of an MNA remedy. See also Specific Comment 8.	As described in the responses to Specific Comments 24, 47, and 54, the time-to-cleanup goals were already a part of the FFS analysis, but the results of the time-to-cleanup analyses were presented in a different part of the report. As a part of the responses, we moved the time-to-cleanup discussions from the ARARs section to the Short Term Effectiveness section of the report. The SRT evaluations are based on the time-to-cleanup estimates provided in Appendix D. The idea that MNA would typically have a longer duration than a groundwater extraction approach is conceptually correct. However, the GET footprint should be greater than the MNA footprint, since MNA only requires monitoring at a pre-established interval. GET requires the expenditure of energy, more infrastructure material, and a greater number of site visits to ensure that the system is functioning properly and that repairs are carried out promptly. We revised several cleanup times based on site-specific conditions as described below. Information regarding the duration required to achieve cleanup goals at the referenced sites is also provided in Appendix D and in the comments column of Table D-1. Site FT004 – After approximately a decade of interim remediation, a small portion of the residual TCE plume remains at a concentration exceeding 100 µg/L, which suggests that the interim system had reached asymptotic conditions. Continued operation of the GET system will not decrease the remediation time of this limited area. However, remediation of the residual contaminants could be addressed by MNA processes. The time required to achieve cleanup goals for the entirety of the Site FT004 plume is governed by the time to achieve cleanup under MNA (i.e., 35 years). Site LF008 – The IRA GET system operated for approximately a decade but concentrations of organochlorine pesticides, primarily alpha chlordane, remained consistent and very low. The time to achieve cleanup is assumed to be the same under the GET IRA as under MNA (>100 years), although it is possible for MNA to achieve cleanup goals in a slightly quicker timeframe once conditions more suitable for reductive dechlorination are naturally achieved. Site SD031 – After approximately a decade of interim remediation, a small portion of the residual 1,1-DCE plume exceeding the PCG (max. 1,1-DCE = 7.3 µg/L) is not hydraulically captured by the current IRA GET system. The entire GET system is currently shut down for a rebound study. Because a portion of the residual plume is not addressed by the IRA GET system, the time to achieve cleanup for the entirety of the plume is considered the same under the GET IRA as under a program of MNA (15 years). Sites SD033 and SD043 – Groundwater contamination within these sites is incorporated into the overall WIOU plume. The WIOU plume includes the following component sites: SD033, SD034, SS035, SD036, SD037, and SD043.

No.	Comments	Responses
		The time to achieve cleanup goals is based on the entirety of the plume, not the time to achieve PCGs within the individual administrative site boundaries. The time to achieve cleanup under the IRAs is estimated at 91 years. Under Alternative 6, the remediation time is estimated to be 60 years.
5.	**Section F.2.2, pages F-5 and F-6:** There are some key activities that do not seem to be mentioned in Section F.2.1 that may be substantial contributors to the emissions. In general, the Sustainability Evaluation should acknowledge any material used in significant amounts and should note whether omission of manufacturing of the materials may have led to substantial underestimates in the results of the Sustainability Evaluation. Materials such as vegetable oil may be important to include in the Sustainability Evaluation due to the large amounts used in the remedies, or in terms of energy intensity per unit of the material. Notes on other key activities that should be mentioned in the Sustainability Evaluation are provided below. **a. Vehicle Use for Semiannual Sampling Activities:** Is the footprint from laboratory analysis also included in the Sustainability Evaluation? If not, this should be stated here, and notes should be made regarding the likely underestimation in the results. **b. Sustainability metrics for GET system energy usage:** The Sustainability Evaluation should describe the assumptions made regarding the power mix used for grid electricity. Local vs. regional variations in grid mix may result in widely differing results for air emissions. **c. The <u>extracted groundwater</u> is treated with air strippers or <u>granular activated carbon prior to proper discharge</u>:** Does the Sustainability Evaluation include the emissions from transportation and regeneration of the granular activated carbon? Also, the Sustainability Evaluation should describe the fate of the extracted groundwater after treatment. Is it re-injected on-site? Is it treated again in one of the base's wastewater treatment plants? The re-injection or the additional processing of the groundwater in a wastewater treatment plant will require additional energy, which may be important in the footprint estimates.	We agree there are additional life-cycle impacts that could be considered for every technology that the FFS evaluated. We selected the SRT because it accounts for many of the key contributions to energy use and air emissions. The SRT is not a full life-cycle analysis tool, but it provide a level of detail that adequately supports an FS evaluation, particularly when the entire report is based on technology screening and estimates of capital and 30-year operating costs. a. We added the following sentences to the Vehicle Use of Semiannual Sampling Activities bullet: "Laboratory analysis was not included in evaluation because it is not part of SRT. However, because laboratory analysis is a part of every potential remedial alternative, except No Action, the environmental impacts from laboratory analysis should not yield different results during the Comparative Analysis of Alternatives." b. We added the following sentences to the Sustainability metrics for GET system energy usage bullet: "There are variations in the source of grid electricity across regional and local scales. In cases where a large percentage of the electricity is derived from wind and hydro power, this can alter the evaluation finding. The standard SRT assumptions were used to calculate electricity metrics for the FFS. (US Average from Energy Information Administration, 2002; Updated State level Greenhouse Gas Emission Coefficients for Electricity Generation 1998-2000 http://tonto.eia.doe.gov/ftproot/environment/e-supdoc-u.pdf)" c. We added the following sentences to the GET System Energy Usage bullet: "The SRT evaluation includes transport and disposal of GAC. The SRT also uses a conversion factor to calculate pounds of CO_2 generated based on quantity of GAC and EVO used during the project. Treated water is discharged into the stormwater drainage system or seasonally used for irrigation." We added a new last bullet for Beneficial Reuse of Treated Groundwater bullet to Section F.2.3 as follows: "Conveyance systems for seasonal beneficial reuse of treated groundwater have already been constructed for Sites LF007C, FT004, and

No.	Comments	Responses
		SD031. An underground pipeline is used to convey treated water from the NGWTP to the base recreational Duck Pond. Current restrictions on the use of environmental restoration funds limit other possible beneficial reuse of treated groundwater at other sites." Wastewater treatment is not conducted at Travis AFB. A local municipal wastewater treatment plant is used for this purpose, but it does not receive treated groundwater. Also, re-injection of treated groundwater is not conducted at Travis AFB because of the presence of tight clays in the subsurface.
6.	**Section F.2.3, page F-6:** Worker safety should not be a part of the "environmental footprint" analysis of the remedies at Travis, as it is already considered as a component to evaluate short term effectiveness. Please remove this discussion from Appendix F and confirm that any worker safety issues were included in the into the FFS evaluation consistent with Table 6-3 of the RI/FS Guidance.	We deleted the SRT analysis on worker safety from the FFS.
7.	**Section F.3, page F-6:** As noted in Specific Comment 5. above, the Sustainability Evaluation should note the possible sources of underestimation or inaccuracies in the analyses. Section F.3 would be an appropriate place to include that discussion.	We added the following paragraph to Section F.3 on page F-6: "Because the frequency of future vegetable oil injections for each applicable site has yet to be determined and will be based on performance monitoring through the period of interim groundwater remedial action and possibly into the implementation and operation of the final remedies, the actual footprint values from these remedial alternatives may vary from the SRT estimates. Also, specific assumptions that were used in the SRT analysis, such as the sources of electricity generation that support Travis AFB and the vendors of materials that are used by the selected remedies, could change while a remedy is in action. By focusing on the parameters that contribute to the footprint of the remedial alternatives, it will be possible to respond to changing conditions and reduce as much as practicable the actual footprints during remedy implementation and operation."
8.	**Section F.2.1 and Table F-1:** Please confirm that the estimated cleanup times presented in Appendix D for each technology are consistent with the estimated times provided in F.2.1. and used for the results presented in Table F-1. Please also confirm that the timeframe used for "lifecycle" of the technology cited in Table F-1 is synonymous with the estimated cleanup times. In order to reduce confusion and allow the results to be more useful, we suggest that the results also be presented per year of operation so that the results could be compared for the remedial alternatives regardless of how long estimate is for cleanup times, as it would be easier to see how the results would be affected by changes to the cleanup time estimates.	We revised the SRT evaluations to be consistent with the remediation timeframes provided in Appendix D. The following revisions were made: FT005 IRA GET changed from 21 to 10 years LF006 IRA MNA changed from 4 to 5 years SD033 IRA GET changed from 60 to 91 years SD034 IRA GET changed from 60 to 91 years SD036 IRA GET changed from 60 to 91 years SD037 IRA GET changed from 60 to 91 years DP039 IRA GET changed from 71 to 70 years DP039 ALT 6 changed from 30 to 58 years SD043 IRA GET changed from 60 to 91 years

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		Results were presented on an annual basis for CO_2 and Total Energy Consumption in Table F-1. The terms “life-cycle,” “remediation time frame (RTF),” and “time to cleanup” are synonymous. Each is defined by the duration required to achieve the PCGs listed in Section 5.
LEGAL COMMENTS – Nadia Hollan Burke, Supplemental Comments, Section 5, 25 May 2011		
1.	5.1.1. General Remedial Action Objectives. Please clarify that utilizing “sustainable technologies” is the same as “green practices” as referenced at page ES-3.	To avoid confusion, we revised the Sustainable Remediation subsection on page ES-3 as follows: “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.”
2.	5.2.1.1 – 5.2.1.2 Applicable Requirements and Relevant and Appropriate Requirements. Please note at the end of two paragraphs defining “Applicable” and “Relevant & Appropriate” that: “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.”	We added the following paragraph to the end of Section 5.2.1.2: “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.”
3.	5.2.1.3 To Be Considered (TBC). Clarification is needed in this section regarding the role of the TBC—they are not “targets” per se, but are potential standards, and if selected in the ROD, it is no longer a TBC but an enforceable standard. Please consider revising the second sentence as follows: “…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*.” Please also add the following at the end of the paragraph: “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.”	We revised the second sentence of Section 5.2.1.3 as follows: “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.” We added the following sentence to the end of Section 5.2.1.3: “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.”

No.	Comments	Responses
4.	5.2.1.5 Administrative Requirements. Please add to the following sentence: "This permit exemption applies to all administrative requirements, as well as to permits and associated fees.	We revised the fourth sentence of the second paragraph in Section 5.2.1.5 as follows: "This permit exemption applies to all administrative requirements, as well as to permits and associated fees."
5.	5.3.1 Chemical Specific ARARs, last paragraph and 5.3.1.1 Air Force's Position. The AF states that SWRCB Res 92-49 provision requiring cleanup to background or best water quality reasonable if background "is not an ARAR for the purpose of remedy selection," but in Table 5-1 lists it as "Relevant & Appropriate." EPA believes that Section IIIG. of Resolution 92-49 is potentially "Relevant and Appropriate" for the Travis AFB groundwater remedy. Because this is a narrative standard, the AF, as the lead Agency, needs to exercise its discretion to choose the cleanup level, giving deference to the State's interpretation of its own requirements. EPA does not believe that the Technical and Economic Feasibility Analysis (TEFA) is itself an ARAR, but rather a subjective process that the lead Agency should apply, giving deference to State guidance on conducting TEFAs, in order to ultimately establish a numerical value when setting a limit above background. If background is not attainable, EPA believes the AF should conduct a TEFA (giving deference to state TEFA guidance which itself is not an ARAR) in order to convert the narrative value of Section III.G into a numerical value above background but not to exceed federal or state MCLs. Because the portion of Resolution 92-49 that is a potential ARAR is a narrative standard, the implementation of the ARAR will be left to the discretion of the Air Force. Further, the discussion in Section 5.3.1.1 Air Force's Position is confusing and at times conflicts with the Air Force ARARs Table 5-1, and the issues expressed above. These sections should be clarified to ensure consistency.	The discussion in 5.3.1 and 5.3.1.1 reflects the Air Force's position on the non-applicability of California nondegradation provisions in SWRCB Resolutions 92-49, 68-16 and elsewhere. To the extent that the ARAR determinations of "relevant and appropriate" or "applicable" are confusing or appear to conflict with the discussion in 5.3.1.1, we replaced the determinations in Table 5-1 with "TBC." Additionally, we are in the process of preparing a TEFA, and thus revised the last sentence in Section 5.3.1 as follows: "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]."" We also deleted the last sentence of Section 5.3.1.1. Concerning Table 5-1, Item 2, we replaced "Relevant and Appropriate" in the "ARAR Determination" section with "TBC." Under the Comments section, we replaced the Comments text with "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." Concerning Table 5-1, Item 5, we replaced "Relevant and appropriate" in the "ARAR Determination" section with "TBC." We replaced the Comments text with the following: "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."
6.	Table 5-1, Chemical-specific ARARs, Item No. 4. The AF provides comments with respect to the Water Quality Control Plan, San Francisco Bay Basin (Basin Plan) "that the 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." EPA is unsure what the AF means by "accepting" "cleanup levels" but not recognizing the beneficial use designations provisions of the Basin Plan as	To the extent that the ARARs determinations are confusing, we replaced "Relevant and Appropriate" in the "ARAR Determination" section with "TBC" and replaced "are potentially relevant and appropriate" in the "Description" section with "potentially apply."

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	potential ARARs. This seems at odds with the AF's inclusion of Chp 2 (beneficial uses) and Chp 3 (water quality objectives) of the Basin Plan as potentially "relevant and appropriate" in Table 5-1. EPA believes these sections of the San Francisco Bay Basin Plan (Basin Plan) are potentially "Applicable" to groundwater treatment systems and treatment system effluents discharged to surface water, specifically, the designated beneficial uses and water quality criteria (i.e., water quality objectives based upon such beneficial use). This includes both the numerical and narrative toxicity standards. EPA does not view the remainder of the Basin Plan as an ARAR.	
7.	Table 5-2, Location Specific ARARs, Items No. 5-8. For the state requirements: California Endangered Species Act; Wildlife Species/habitat; Mammals, fish, and reptiles provisions; and Rare native plants, the AF references Air Force Instruction 32-7064, 17 September 2004 ("AF Instruction"), and notes that "state species will be protected when practicable and the appropriate state authority will be contacted if conflict arises. The State may provide procedures for minimization of impacts and harm to species." The AF, however, has not provided any citations to the specific chapters and pages within the AF Instruction (which is 84 pages) that correlates to each listed state natural resource law with a potential conflict. Further, EPA disagrees generally with the AF's citation to AF Instruction 32-7064, because it is not an ARAR and appears to be at direct odds with the statutory purpose of ARARs, which in this instance is to faithfully apply the more stringent state laws protecting species and habit in California, and not just comply "when practicable" as the AF contends. Under Section 120(a) of CERCLA, with a few exceptions, the federal government is required to comply with CERCLA at federal facilities in the same manner as a non-federal party must, including implementation of more stringent state standards, e.g., ARARs. See 42 U.S.C. § 9620(a). EPA is not aware of any "military mission" justification under CERLCA authorizing the AF to waive more stringent state environmental laws pursuant to Section 121(d) of CERCLA and 40 CFR 300.430(f)(1)(ii)(C) at federal facilities listed on the NPL, such as the Travis AFB. Accordingly, EPA believes all such references to the AF Instruction should be deleted from the Focused Feasibility Study.	While the Air Force disagrees with the EPA's expansive view of the CERCLA waiver of sovereign immunity, and would instead assert that the state statutes and regulations at issue only qualify as relevant and appropriate ARARs because of Air Force policy, as expressed in Air Force Instruction (AFI) 32-7064, para. 7.1.2., discussions with the base's natural resources manager indicate there are no California listed endangered species, or California "fully protected species", animal or plant, on Travis AFB, let alone on any sites potentially impacted by groundwater remediation activities. Therefore, the Air Force deleted items 5-8 of Table 5.2 and deleted the text "as well as relevant and appropriate provisions of the California Fish and Game Code and California Code of Regulations pertaining to state listed plant and animal species" from the narrative in Section 5.3.2.
8.	Table 5-3, Action-specific ARARs, Item No. 5. Institutional Controls. The AF needs to distinguish how the state's LUC provisions would apply on federally owned land versus privately owned land. The AF should also elaborate on the existing ICs on federal land pursuant to the Base Master Plan.	The California regulation set forth in Item 5 contains the distinction EPA seeks. When a federal agency transfers land to a private entity, California requires that a land use covenant be placed on the land during the transfer process. *22 CCR Section 67391.1(e)(1)*. When a federal agency is keeping the land, or is transferring it to another federal agency, California requires the federal agency to use "other mechanisms to ensure that future land use will be compatible with the levels of hazardous materials" that remain on the property. *22 CCR Section 67391.1(e)(2)*.

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		Travis AFB, of course, is not transferring the land that is subject to the basewide groundwater FFS. We inserted a narrative into the FFS (see below) that will further describe the land use controls it will use to ensure future land use will be compatible with the risks that remain on the property. The proposed plan and record of decision will include more details on the LUCs, including language that is standard in most of the Air Force's California RODs regarding potential future transfers of the land to private or federal entities, along with the notice the Air Force would give EPA and the state of such transfers. Concerning the comment that "the AF should also elaborate on the existing ICs on federal land pursuant to the Base Master Plan," we believe information on specific ICs belongs in the text of the FFS, proposed plan and ROD, rather than in the ARARs table. The proposed plan and ROD will contain more details on those LUCs. The Comments text for Item 5 already states that "the ROD will clearly define and include limitations on land use and other institutional control mechanisms…" To address EPA's comment, we added the following sentence to the end of the Comments text for Item 5 when the ARARs Table appears in the ROD: "This ROD sets forth such land use controls in Section ______." FFS narrative (for inclusion, as appropriate in Sections 3.1.4.3 and 6.5.2): "Land Use Controls 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 remedial action objective (RAO) of Land Use Controls is to prevent the exposure of human or ecological receptors to unacceptable risks from soil, groundwater and soil gas. To meet this RAO, Travis shall 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 environmental impact analysis process (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' groundwater sites subject to LUCs, to record a land use

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		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 insure the landowners do not engage in water development or soil disturbing activities that would interfere with the government's rights under the easements."
9.	Table 5-3, Items No. 8-9. Groundwater treatment and Groundwater monitoring state requirements appear redundant and not more stringent than the CERCLA groundwater RA alternatives (other than no action) and operation and maintenance (O&M) procedures. Accordingly EPA would not list these as Relevant and Appropriate unless the AF can specify how they are different or more stringent than any selected CERCLA remedy, O&M and corresponding EPA implementing guidance.	We deleted Items #8 and 9 from Table 5-3. We also deleted Items #11 and 12 from Table 5-3, which, upon re-examination, set forth procedural rather than substantive requirements.
10.	Table 5-3, Item No. 13. CERCLA already requires that activities on a Superfund Site are conducted in compliance with HAZWOPER and a site specific Health and Safety Plan, so reference to State Hazardous Waste Contingency Plan and Emergency Procedures seems redundant and not more stringent. This is already part of CERCLA process.	We deleted Item #13 in Table 5-3.
11.	Table 5-3, Items No. 19-21. For the Air Emission Standards, the requirements should be listed as "State" not local, as the Air Boards are state-based boards. Likewise, the word "Local" should be deleted from the heading "Federal, State, or Local Requirement," on all of the ARARs Tables 5-1 through 5-3, because by definition ARARs are only federal and state requirements.	For the Air Emission Standards, we listed the requirements as "State" instead of local. We revised the fifth heading on all ARARs Tables 5-1 through 5-3 to "Federal or State Requirement." Additionally, we will re-evaluate these ARARs for relevance in the ROD should the remedial alternatives selected for groundwater sites not include elements that are addressed by the listed regulations.

Responses to Comments on the Draft Basewide Groundwater Focused Feasibility Study Travis Air Force Base, California

Regional Water Quality Control Board

No.	Comments	Responses
REVIEW COMMENTS – Alan D. Friedman, P.E., Regional Water Quality Control Board dated March 30, 2011		
GENERAL COMMENTS		
1.	Water Board staff have reviewed the subject document, dated January 26, 2011, that describes the development and evaluation of potential remedial alternatives that can be applied to 18 groundwater sites at Travis AFB. This report is intended to support the upcoming selection of final remedial actions in the Groundwater Record of Decision (ROD) next year. All groundwater sites are currently undergoing interim remedial actions per two interim groundwater RODs, the final Interim ROD for the NEWIOU (1998) and the final Groundwater Interim ROD for the WABOU (1999). The current document is 'focused' in that it evaluates remedial technologies that take into account the cleanup progress already made at the groundwater sites. We have the following comments: We concur with the operation of interim remedies, and the optimization or alteration of them if they are not successful. We also concur with the concept of 'focusing' remedial alternatives based on the operational experience gained over the past decade at Travis, but despite this experience, the groundwater at many sites remains above the preliminary cleanup goals and Travis is now choosing remedial alternatives on the basis of recently initiated rebound studies that are not completed (for Sites FT004, FT005, LF008, SD031, SD033, SD034, SD043), or on the operation of other cleanup technologies such as bioreactors and/or EVO injections that have just started (for Sites SS015, SS016, DP039, SD036, SD037). There are also sites with offsite plumes, namely Sites LF007C and SS030, whose dimensions are not fully defined and for which remedial alternatives are not fully established.	We agree that the EVO injections at multiple sites and the SS016 bioreactor are still undergoing performance evaluations, and there is insufficient data to demonstrate with certainty that these biology-based technologies will be able to reach Preliminary Cleanup Goals. However, the initial results from all of these optimizations have been very promising, and we will be collecting and reporting analytical data on a quarterly basis throughout the remedy selection period. As long as the performance monitoring continues to show the viability of these optimizations, we will continue to treat these technologies as the Air Force preferred remedies. Rebound studies are a little different in that we do not expect to complete a rebound study until the final remedial action has been selected, it has reached the established cleanup levels, and no contaminant has exceeded the cleanup levels for an established period of time. Similar to the optimizations, we will continue to report the results of these rebound studies throughout the remedy selection period. We acknowledge that characterization of Site LF007C is not yet complete. We will conduct data gaps investigations and potential GET system optimizations after the U.S. Fish and Wildlife Service allows access to the site and the soil is dry enough to allow heavy equipment activities. In the context of the FFS, Alternative 3 – GET will still likely be the preferred alternative. The system design may require one (1) or more additional extraction wells, but the technical approach to groundwater remediation will likely stay the same. For Site SS030, the effectiveness of GET system operational changes continues to be assessed. We expect the results of this assessment to be available by August 2011. Similar to the situation at Site LF007C, the results of this assessment may result in an expansion of the existing GET system, but the technical approach to groundwater remediation at Site SS030 will likely remain the same (i.e., FFS Alternative 3 – GET).

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2.	Ideally, a 'focused' feasibility study would recommend cleanup alternatives based on completed, successful operational experience, whose success would be gauged by comparison with proposed cleanup goals from a completed Technical and Feasibility Analysis (TEFA, discussed below), if necessary. Instead, we are being asked to review the FFS, then the proposed plan with the TEFA arriving last, just a few months before the groundwater ROD. Given that we do not know when all of the data needed to evaluate the chosen remedial alternatives will be available, we request that Travis reconsider the timing and order in which these documents are prepared, as we are not certain if we can give a full evaluation of these documents absent all supporting information.	We also agree that cleanup alternatives should ideally be based on successful operational experience. For sites with components of Groundwater Extraction and Treatment (GET), free product removal, Monitored Natural Attenuation (MNA), and/or Enhanced Attenuation (EA), we believe that a sufficient volume of evidence is available to support remedy selection. This evidence is mainly provided in the two (2) five-year reviews of the IRAs and in the more recent Natural Attenuation Assessment Report (NAAR). For Sites SS015, SS016, SD036, SD037, and DP039; we agree that in situ biological treatment using enhanced reductive dechlorination (ERD) via bioreactors and emulsified vegetable oil injection are still undergoing performance evaluations. These technologies are innovative in nature, and EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (Section 4.3.2.4) allows innovative technologies to be carried through the remedy screening phase if they offer significant advantages over existing remedies. We will continue to collect performance data on these optimizations and report it to the regulatory agencies during monthly Remedial Program Manager's meetings and in annual Remedial Process Optimization (RPO) reports. We began the ERD technology demonstrations as quickly as possible after a contractor was procured and work plans were developed. We agree that starting these demonstrations earlier and collecting performance data over a longer period would have been preferable. We agree that the sequence of events leading up to the ROD is not ideal. However, the formal requirement for conducting a TEFA was not clearly established until early 2011. At that time, the draft FFS had already been submitted for regulatory agency review. We anticipate that the TEFA will be complete or almost complete by the time that the draft ROD is ready for agency review.
3.	We do not concur with the rejection of SWRCB Order No. 92-49 as an ARAR for the groundwater remedial actions. Order 92-49 requires dischargers 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." Instead Travis has proposed MCLs for groundwater cleanup. Order 92-49 continues to say that in setting alternative cleanup levels less stringent than background, that the Water Board, pursuant to Chapter 15, must find that "it is technologically or economically infeasible to achieve the background value…" and that there will not be "a substantial present or potential hazard to human health or the environment as long as the concentration limit greater than background is not exceeded."	The discussion in Sections 5.3.1 and 5.3.1.1 reflects the Air Force's position on the non-applicability of California nondegradation provisions in SWRCB Resolutions 92-49, 68-16 and elsewhere. To the extent that the ARAR determinations of "relevant and appropriate" or "applicable" are confusing or appear to conflict with the discussion in 5.3.1.1, we replaced the determinations in Table 5-1 with "TBC." Additionally, we are in the process of preparing a TEFA, and thus revised the last sentence in Section 5.3.1 as follows: "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

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		direction: "...in applying any alternative cleanup levels less stringent than background, apply Section 2550.4 of Chapter 15 [of 23 CCR]."" We also deleted the last sentence of Section 5.3.1.1. Concerning Table 5-1, Item 2, we replaced "Relevant and Appropriate" in the "ARAR Determination" section with "TBC." Under the Comments section, we replaced the Comments text with "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."
4.	Water Board staff are open to the argument that groundwater cleanup beyond the MCL may not be needed, if groundwater is not used for drinking water and if appropriate land use controls are applied. We also are open to the argument that cleanup beyond the MCL may also be infeasible, given that the interim remedial actions applied for a decade have not achieved MCLS nor will they for several more decades. Travis, subsequent to the submission of the draft FFS, has indicated that they will prepare a TEFA. We concur with this decision and expect that this document will fully defend the cleanup to MCLs and that the final FFS will fully defend the chosen remedial alternatives.	We will prepare a TEFA to support the Air Force's position on the cleanup of groundwater to MCLs.
5.	MNA was stated to be an effective remedy at all or at least portions of Sites FT004, LF006, LF007B, LF007D, SS015, SD031, SD033, SD037, and DP039 (though MNA is apparently not achieving plume stability at SS015 and DP039). For most sites, no conclusive evidence of biological degradation was found, and it was assumed that physical processes were responsible for the observed attenuation. While we have agreed that MNA is occurring at many sites and have supported all of the requests to initiate rebound studies to evaluate whether MNA would be successful, we also believe that Travis should continue to better understand why attenuation is occurring at each site, so as to more firmly conclude that attenuation will continue. We also will consider MNA as an effective remedy at a given site only if it can also be shown that all sources are being remediated to the extent feasible, and that agreed upon cleanup standards can be met in a reasonable timeframe.	We are currently developing a work plan for conducting an evaluation of the biological component of natural attenuation processes at Travis AFB. The effectiveness of MNA as a remedy at these sites has been evaluated over an 8 to 10 year period, as documented in the NAAR (CH2M HILL, 2010). The NAAR concluded that natural attenuation was occurring at Travis AFB, resulting in stable or shrinking plumes at several of the sites. In fact, at Site LF006, which has an IRA of MNA, none of the site COCs were detected at concentrations exceeding MCLs during 2010. MNA has been shown to be an effective remedy at this site. Because aquifer conditions are naturally aerobic at Travis AFB and therefore not conducive to anaerobic biodegradation, the NAAR also concluded that the primary mechanisms for MNA at Travis AFB are physical. However, research into aerobic biodegradation has recently shown that compounds such as TCE can be broken down by aerobic microbes through cometabolism. A work plan to investigate the potential contribution of cometabolism to natural attenuation at Travis AFB is being developed and is expected to be available for comment in July. Under this work plan, samples will be collected and analyzed for the presence of cometabolic enzymes known to degrade TCE as well as the presence of genes capable of producing the cometabolic enzymes. If cometabolic enzymes as well as genes that produce those enzymes are present at Travis AFB, it will be concluded that there is a biological as well as a physical component to natural attenuation at Travis AFB.

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6.	Contingency actions are listed in the detailed discussion of the groundwater remedial alternatives, but the discussion lacks sufficient detail to evaluate these actions. In those cases where resumption of the historic groundwater extraction systems is proposed, there is no discussion of how this could be modified or optimized to improve upon its historic performance. This is also true of proposing increased EVO injection. Several actions are proposed that have had no operational history at Travis such as the injection of chemical oxidants, or the use of bioaugmentation or zero valent iron barrier walls. Thus it is uncertain whether these should be considered viable remedial alternatives. In a few cases, it was stated that Travis would simply implement "another remedial technology," without stating how such a technology would be chosen.	Based on discussions with several EPA representatives, we will be using the term "contingency action" to describe a second remedial action that is initiated when the initial selected remedy is not performing as designed, and all efforts to optimize the initial remedy or return it to a functional state have failed. We changed the titles of the subsections referenced in this comment from "Contingency Actions" to "Performance Enhancing Measures." We removed the bullet "Implementation of another remedial technology" from the appropriate sections, since it is not a performance enhancing measure for an initial selected remedy. The decision to resume groundwater extraction at a site with an existing IRA GET system will be based on the performance data obtained for the applicable site. If statistically increasing contaminant concentrations are observed within plumes, or portions of plumes, undergoing rebound studies, then the resumption of GET and potential optimization of the GET system will be evaluated. The nature of the optimization will depend entirely on the site-specific system performance, and in some cases it may be logical to modify system operation (e.g., pulsed pumping, changing pumping speeds, etc.) to find the optimum performance level when taking contaminant concentration and plume configuration into account. Potential future modification or optimization of a GET system does not preclude the FFS from identifying GET as the preferred remedial alternative. The GET system design or operation may change, but not necessarily the overall technological approach. We are collecting performance data on the EVO injections and bioreactor demonstrations for three reasons: to demonstrate the viability of ERD processes used by the EVO injections and bioreactors to successfully achieve contaminant-specific cleanup goals, to identify the conditions for which process optimization is needed, and to establish the Operation and Maintenance requirements for each system. Ultimately, the empirical data will support remedy selection in the ROD after the period of interim remediation is concluded. If the ERD performance data demonstrates that a performance enhancing measure, such as bioaugmentation of native microbial populations with proprietary non-native populations, is needed to sustain biological remediation, then the Air Force will coordinate this action with the regulatory agencies. As with the GET systems discussed above, potential future modification or optimization of a remedial alternative does not preclude the FFS from identifying it as the preferred remedial alternative. The detailed implementation of the alternative may change, but not necessarily the technology. The FFS did consider several innovative technologies, including chemical

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		oxidation and zero valent iron barrier walls. These technology processes were evaluated within the context of a feasibility study and CERCLA guidance against the criteria of effectiveness, implementability, and relative cost. However, they were not selected as being representative process options, and were not assembled into remedial alternatives for more detailed evaluation.
7.	LUCs are mentioned as a representative process option of all remedial alternatives, and are stated to have been successfully implemented and protective of human health through application of restrictions to minimize unauthorized exposure to contaminants. Given the importance of LUCs, particularly since the groundwater under Travis is technically a drinking water source that remains above drinking water standards, further detail on how and where LUCs are applied with respect to groundwater use should be detailed.	Section 3.1.4.3 describes the LUCs and how they are enforced at Travis AFB. We added subheadings to Section 3.1.4.3 to clarify the layered components of the LUCs that are already being actively implemented. New subheadings are provided for the following: "Travis AFB General Plan, Base Civil Engineering Work Requests, Excavation Permits, and Off-base Plume Management". We replaced the first sentence of the first paragraph of Section 3.1.4.3 with the following text: "Land Use Controls 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 remedial action objective (RAO) of Land Use Controls is to prevent the exposure of human or ecological receptors to unacceptable risks from soil, groundwater and surface water. To meet this RAO, Travis shall 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 environmental impact analysis process (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' 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

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		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 insure the landowners do not engage in water development or soil disturbing activities that would interfere with the government's rights under the easements." We also deleted the last paragraph in Section 3.1.4.3 that referred to the re-examining and re-addressing of LUCs. We added the following new second paragraph to Section 3.1.4.3 to further clarify the ongoing enforcement of LUCs at Travis AFB: "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 report is the final *Annual Report on the Status of Land Use Controls on Restoration Sites in 2010* (Travis AFB, 2011)."

Responses to Comments on the Draft Basewide Groundwater Focused Feasibility Study Travis Air Force Base, California

Department of Toxic Substances Control

No.	Comments	Responses
REVIEW COMMENTS – Jose Salcedo, P.E., Department of Toxic Substances Control		
GENERAL COMMENTS		
1.	DTSC reviewed this document and had no comments.	No response necessary.