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***Monitored Natural Attenuation
2003 Performance and Compliance Monitoring
Annual Report for Test Area North
Operable Unit 1-07B***



Idaho National Engineering and Environmental Laboratory

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**Monitored Natural Attenuation 2003 Performance
and Compliance Monitoring Annual Report for
Test Area North Operable Unit 1-07B**

June 2004

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ABSTRACT

This report presents a compilation and analyses of volatile organic compound and radiological data collected in support of the monitored natural attenuation remedy at Test Area North, Operable Unit 1-07B during Fiscal Year 2003. Groundwater monitoring followed the performance/compliance strategy as described in the *Monitored Natural Attenuation Remedial Action Work Plan for Test Area North Final Groundwater Remediation, Operable Unit 1-07B*. This document describes 2003 groundwater sampling activities, analytical results, well maintenance, and groundwater level measurements. The groundwater monitoring data suggest that the monitored natural attenuation remedy continues to trend toward meeting remedial action objectives.

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ACRONYMS

bls	below land surface
COC	contaminant of concern
DCE	dichloroethene
DO	dissolved oxygen
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FLUTE™	Flexible Liner Underground Technology
FY	fiscal year
INEEL	Idaho National Engineering and Environmental Laboratory
MCL	maximum contaminant level
MMO	methane monooxygenase
MNA	monitored natural attenuation
MS	matrix spike
MSD	matrix spike duplicate
ORP	oxidation/reduction potential
OU	operable unit
PCE	tetrachloroethene
QA/QC	quality assurance/quality control
RAO	remedial action objective
RPD	relative percent difference
sMMO	soluble methane monooxygenase
SRPA	Snake River Plain Aquifer
TAN	Test Area North
TCE	trichloroethene
TSF	Technical Support Facility
VC	vinyl chloride
VOC	volatile organic compounds

Monitored Natural Attenuation 2003 Performance and Compliance Monitoring Annual Report for Test Area North Operable Unit 1-07B

1. INTRODUCTION

This document presents a compilation and analysis of data collected as part of monitored natural attenuation (MNA) activities conducted at Test Area North (TAN) Operable Unit (OU) 1-07B during Fiscal Year (FY)2003. This MNA annual report is intended to document the progress of the MNA component of remediation at TAN OU 1-07B, which is located at the Idaho National Engineering and Environmental Laboratory (INEEL). The MNA performance is being tracked by periodic measurements of contaminant of concern (COC) concentrations throughout the groundwater plume. This report presents concentration data of sufficient quality and quantity to ensure that observed trends in the data support the predicted rates of attenuation for COCs. Groundwater monitoring activities and maintenance and/or repair activities associated with monitoring wells are reported in Section 2. Section 3 presents groundwater monitoring data for COCs. Interpretations and trend analyses are presented in Section 4. Section 5 presents a summary of the data and interpretations.

1.1 Background

Injection Well TSF-05 was used for wastewater disposal at TAN until 1972. Wastewater containing organic, inorganic, and radioactive contaminants was injected directly into the Snake River Plain Aquifer (SRPA) for approximately 20 years. These disposals resulted in a 2-mile-long plume of groundwater contamination, which included significant concentrations of trichloroethene (TCE). Because of the size and distribution of TCE concentrations within the plume, a multi-component remedy involving in situ bioremediation, pump and treat methods, and MNA was designed to achieve effective clean up, as delineated in the *Record of Decision Amendment—Technical Support Facility Injection Well (TSF-05) and Surrounding Groundwater Contamination (TSF-23) and Miscellaneous No Action Sites, Final Remedial Action* (DOE-ID 2001). The MNA component was selected for remediation of the distal portion of the plume containing TCE concentrations between 5 and 1,000 µg/L.

1.2 Governing Documents for Monitored Natural Attenuation Groundwater Monitoring

The Monitored Natural Attenuation Final Inspection Report for Test Area North, Operable Unit 1-07B (ICP 2004) documented the approval of the Monitored Natural Attenuation Remedial Action Work Plan for Test Area North Final Groundwater Remediation, Operable Unit 1-07B (DOE-ID 2003a) and the Monitored Natural Attenuation Operations, Monitoring, and Maintenance Plan for Test Area North, Operable Unit 1-07B (DOE-ID 2003b). The MNA Remedial Action Work Plan now governs MNA operations at TAN, and sampling is now governed by the MNA Operations, Monitoring, and Maintenance Plan. This annual report is written to meet the objectives of the MNA Remedial Action Work Plan and to reflect the monitoring strategy outlined in these two governing documents.

1.3 Project Objectives

Specific objectives for groundwater monitoring are established in the MNA Remedial Action Work Plan (DOE-ID 2003a). The remedial objectives defined in the MNA Remedial Action Work Plan are described below.

Performance Objectives:

- Monitor whether the natural attenuation process continues to trend toward the remedial action objectives (RAOs) for the distal zone of the plume
- Monitor plume expansion.

Compliance Objectives:

- Conduct groundwater monitoring at all MNA performance-monitoring wells at a frequency and duration sufficient to demonstrate that the remedy is operational, functional, and effective
- Demonstrate at the end of the remedial action period that RAOs for groundwater have been attained.

This annual report presents groundwater monitoring data and data interpretation that demonstrate the progress that was made during FY-03 toward meeting the performance and compliance objectives.

2. FISCAL YEAR 2003 MONITORED NATURAL ATTENUATION GROUNDWATER MONITORING ACTIVITIES

This section provides an overview of activities performed during FY-03 in support of the MNA remedy and summarizes the monitoring well network. Groundwater sampling was conducted in wells located in Zones 1, 2, and 3 to gather sufficient data to support conclusions that the concentrations continue to trend toward meeting the RAOs. Vertical profile groundwater sampling was performed in some wells to elucidate contaminant concentration profiles with depth. Water levels were measured in wells located throughout the contaminant plume and surrounding areas to monitor the groundwater gradient and flow direction. A summary of monitoring well maintenance activities is also included.

2.1 Groundwater Sampling

To monitor the performance of MNA at TAN, samples were collected and analyzed for COCs from a monitoring well network of 17 wells (see Table 2-1 and Figure 2-1) (DOE-ID 2003b). The monitoring network strategy is intended to monitor whether the natural attenuation process continues to trend toward the RAOs in Zones 1 and 2 and to monitor plume expansion in Zone 3. Wells in Zones 1 and 2 are sampled and analyzed annually during performance operations. Wells in Zone 3 are sampled and analyzed every 3 years during performance operations starting in FY-03. Tritium and volatile organic compounds (VOCs) were monitored in wells from all three zones. Strontium-90, cesium-137, and uranium 234 were monitored in selected Zone 1 wells.

Table 2-1. Monitoring well network.

Zone	Well	Sampling Frequency	FY-03 Sampling ^a		
			VOCs ^b	Tritium	Rad ^c
1	TAN-16	Annual	X	X	NA ^e
	TAN-51 ^d	Annual	X	X	NA ^e
	TAN-54 ^d	Annual	X	X	NA ^e
	TAN-55 ^d	Annual	X	X	NA ^e
	TAN-25	Annual	NA ^e	X	X
	TAN-28	Annual	NA ^e	X	X
	TAN-29	Annual	NA ^e	X	X
	TAN-30A	Annual	NA ^e	X	X
	TAN-37	Annual	NA ^e	X	X
	TSF-05	Annual	NA ^e	X	X
2	TAN-52 ^d	Annual	X	X	NA ^e
	TAN-21	Annual	X	X	NA ^e
	ANP-8	Annual	X	X	NA ^e

Table 2-1. (continued).

Zone	Well	Sampling Frequency	FY-03 Sampling ^a		
			VOCs ^b	Tritium	Rad ^c
3	GIN-4	Every 3 years	X	X	NA ^e
	TAN-56 ^d	Every 3 years	X	X	NA ^e
	TAN-57 ^d	Every 3 years	X	X	NA ^e
	TAN-58	Every 3 years	X	X	NA ^e

a. Shading indicates well was sampled for analyte.

b. TCE, PCE, *cis*-DCE, *trans*-DCE, and VC.

c. Strontium-90, cesium-137, and uranium-234.

d. Well was sampled at multiple depths during Fiscal Year 2003.

e. Analyses were not required.

DCE = dichloroethene

PCE = tetrachloroethene

TCE = trichloroethene

VC = vinyl chloride

Presentation of the COC data is given in Section 3. In accordance with the MNA Operations, Monitoring, and Maintenance Plan (DOE-ID 2003b), Sampling and Analysis Plan tables are included in Appendix A of this report for the performance operations sampling and analyses performed during FY-03.

As part of the MNA remedy, a number of wells have been equipped with Flexible Liner Underground Technology (FLUTETM) systems, allowing for sample collection at discrete depths. These wells include TAN-51, TAN-52, TAN-54, TAN-55, and TAN-56. Well TAN-57 also was sampled at vertical intervals using a low-flow submersible pump. An objective of vertical profile sampling was to demonstrate that the suspected trends in COC concentrations were not an artifact of the three-dimensional contaminant distribution.

2.2 Field Parameter Monitoring

Field parameters include water levels, pH, oxidation/reduction potential (ORP), temperature, specific conductivity, and dissolved oxygen (DO). With the exception of water levels, all field parameters were measured during well purging before sample collection using a multi-parameter water quality instrument. Water levels were measured in 79 TAN wells on October 30, 2003. These data are presented in Appendix B (Tables B-1 and B-2 and Figures B-1 and B-2). The data are used to evaluate groundwater flow and mechanisms of TCE degradation described in Section 4.4.

2.3 Well Maintenance

Well maintenance of the monitoring well network during FY-03 proceeded according to the *Well Maintenance Work-off Schedule for Fiscal Years 2003, 2004, and 2005* (INEEL 2003a). This document establishes minimum maintenance requirements and procedures for recording and tracking maintenance. The purpose of this well maintenance program is to implement and document routine maintenance and standardization efforts to improve performance and cost of field sampling activities. By the end of FY-05, all wells currently monitored will have been inspected and maintained.

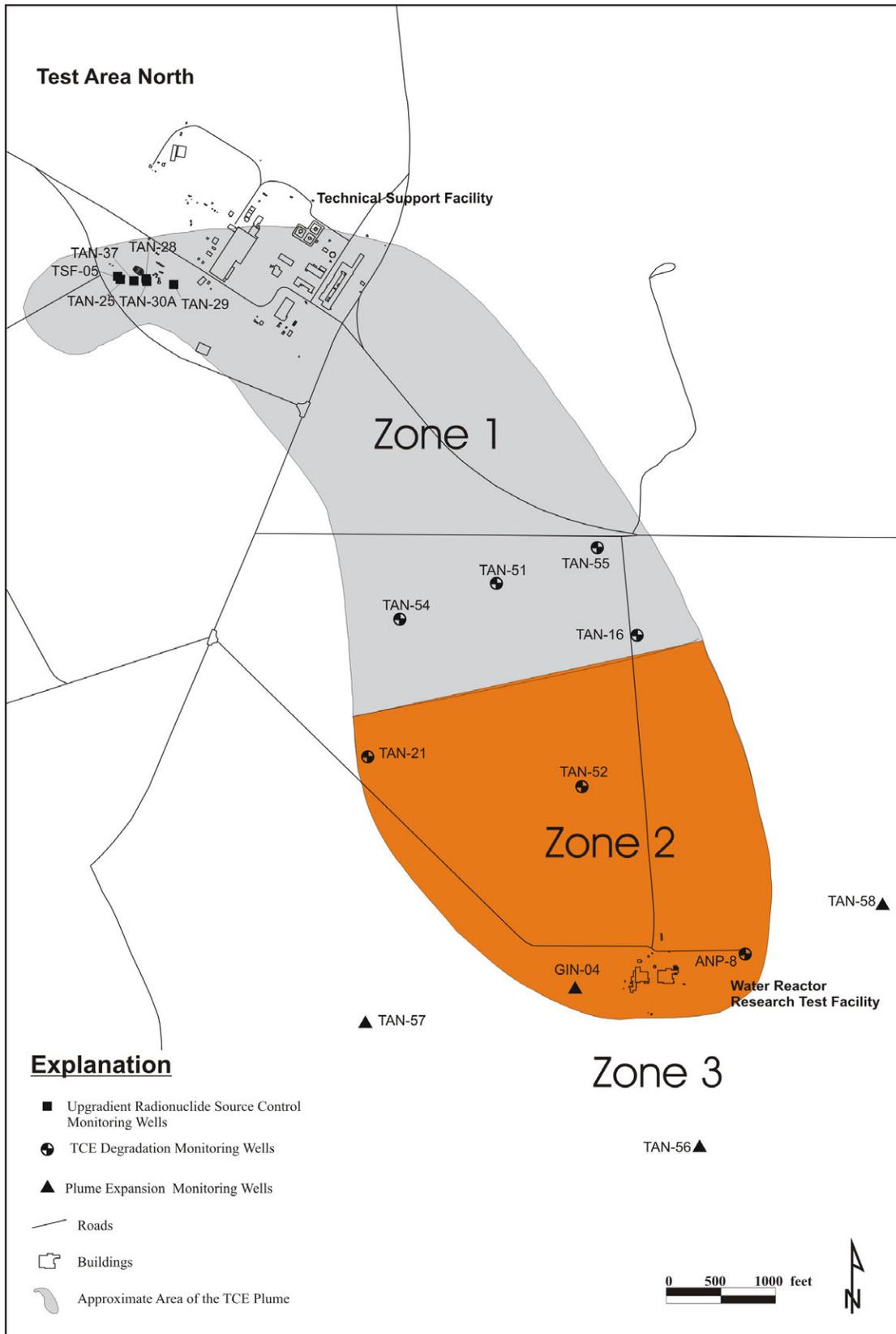


Figure 2-1. Map of the monitored natural attenuation contaminant of concern monitoring-well network.

Additional well maintenance activities included installation and maintenance of FLUTE™ liners. Well TAN 56 has been identified as one of the Zone 3 MNA wells to be used in the assessment of the vertical water chemistry profile and to monitor plume expansion. A FLUTE™ system was installed by FLUTE™ representatives in Well TAN-56 on May 5, 2003. The system was tested on May 6, 2003. During 2002 MNA sampling activities, samplers observed that the FLUTE™ tubing bundles in Wells TAN-52 and TAN-55 had slipped down into the well casings, making sampling difficult. On May 6, 2003, following completion of installation and testing in TAN-56, FLUTE™ representatives pulled the tubing bundles up to their original positions in these two wells.

3. ANALYTICAL RESULTS

This section presents concentration data for TCE, tetrachloroethene (PCE), *cis*-dichloroethene (*cis*-DCE), *trans*-dichloroethene (*trans*-DCE), vinyl chloride (VC), tritium, strontium-90 (Sr-90), cesium-137 (Cs-137), and uranium-234 (U-234) from groundwater monitoring in MNA Zones 1, 2, and 3 during FY-03. These results are interpreted in Section 4. Other data collected during FY-03 MNA sampling to support documentation of attenuation mechanisms are presented and discussed in Section 4.

3.1 Volatile Organic Compound Data

As required by the MNA Operations, Monitoring, and Maintenance Plan (DOE-ID 2003b), all MNA samples were analyzed for the following VOCs: PCE, TCE, *cis*-DCE, *trans*-DCE, and VC. These data are presented in Table 3-1. The maximum contaminant levels (MCLs) for PCE, TCE, *cis*-DCE, and *trans*-DCE are 5, 5, 70, and 100 µg/L, respectively. Only TCE and PCE were detected at concentrations greater than their respective MCLs. The TCE concentrations in all samples taken from wells within Zones 1 and 2 exceeded the MCL; PCE concentrations in most samples from these zones also exceeded the MCL. Contaminants TCE and PCE were detected in water from the Zone-3 Wells TAN-57 and GIN-4. Of these, only TCE in GIN-4 is above the MCL. No VOCs were detected in water from TAN-56 or TAN-58.

Table 3-1. Volatile organic compound results from Fiscal Year 2003 monitored natural attenuation groundwater monitoring.

Zone	Well Name	Well ID	Date	Sample Depth (ft bls)	PCE (µg/L)	TCE (µg/L)	<i>cis</i> -DCE (µg/L)	<i>trans</i> -DCE (µg/L)	VC (µg/L)
1	TAN-54	1340	8/19/03	234	9.9	106 D	2.3	0.8 J	1 U
			8/19/03	318	9.8	96.9 D	2.5	0.95 J	1 U
			8/19/03	330.5	13.6	112 D	2.7	0.84 J	1 U
			8/20/03	347	13.6	123 D	2.5	0.85 J	1 U
			8/20/03	373	14.2	134 D	2.6	0.87 J	1 U
			8/20/03	394	19.5	143 D	3	0.94 J	1 U
			8/20/03	420	16.9	131 D	3	0.93 J	1 U
	8/20/03	460	17.3	174 D	3.2	1.1	1 U		
	TAN-55	1341	8/27/03	221	7.1	55.9	2	0.58 J	1 U
			8/27/03	251	8.9	63.2	1.8	0.56 J	1 U
			8/27/03	265	10.4	83.8	2.7	0.87 J	1 U
			8/27/03	317	16.1	173 D	6.1	1.9	1 U
			9/2/03	332	13.8	144 D	4.6	1.4	1 U
			9/2/03	373.5	10.4	126 D	3.4	1.3	1 U
9/3/03			439	10	85.9	2.5	0.85 J	1 U	
9/3/03	449	9.3	78.2	2.4	0.59 J	1 U			
9/3/03	461	8.5	71.1	2.2	0.69 J	1 U			

Table 3-1. (continued).

Zone	Well Name	Well ID	Date	Sample Depth (ft bls)	PCE (µg/L)	TCE (µg/L)	<i>cis</i> -DCE (µg/L)	<i>trans</i> -DCE (µg/L)	VC (µg/L)
1	TAN-51	1316	8/18/03	240	13.6	176 D	2	1 U	1 U
			8/18/03	263	14.9	88.9	1.3	1 U	1 U
			8/18/03	283.5	7.4	61.7	0.89 J	1 U	1 U
			8/19/03	322	8	45.2	0.52 J	1 U	1 U
			8/19/03	342A*	4.7	41.5	0.5 J	1 U	1 U
			8/19/03	342B*	5.8	53.5	0.96 J	1 U	1 U
			8/19/03	342B*	5	43.6	0.66 J	1 U	1 U
			8/18/03	367	15.8	186 D	4.8	1.6	1 U
			8/18/03	413	14	131 D	3.9	1.3	1 U
			8/18/03	460	4.4	42.7	0.57 J	1 U	1 U
TAN-16	752	8/27/03	307	5.7	41.8	1.4	1 U	1 U	
2	TAN-52	1317	8/25/03	220	6.1	37.6	0.84 J	1 U	1 U
			8/25/03	242	7.8	48.8	1.2	1 U	1 U
			8/25/03	266	7.5	48.9	1.2	1 U	1 U
			8/25/03	303	5.7	45.2	1.4	1 U	1 U
			8/25/03	303	7.9	54	1.4	0.4 J	1 U
			8/25/03	361	6.9	47.6	1.2	1 U	1 U
			8/25/03	373	7.3	51.4	1.4	1 U	1 U
			8/27/03	395	6.7	46.9	1.4	1 U	1 U
			8/27/03	438	6.3	37	0.84 J	1 U	1 U
			8/27/03	456	7.9	43	0.94 J	1 U	1 U
TAN-21	793	8/26/03	432	3.2	5.6	1 U	1 U	1 U	
ANP-8	76	8/27/03	268	3.6	15.5	1 U	1 U	1 U	
3	TAN-57	1343	9/8/03	230	0.97 J	2.2	1 U	1 U	1 U
			9/9/03	285	1.4	2.6	1 U	1 U	1 U
			9/16/03	353	1.8	3.3	1 U	1 U	1 U
			9/19/03	400	1.8	4.2	1 U	1 U	1 U
			9/22/03	438	1.8	3.8	1 U	1 U	1 U
	TAN-58	1344	9/4/03	295	1 U	0.9 J	1 U	1 U	1 U
	GIN-4	162	8/26/03	292	2.4	7.4	1 U	1 U	1 U
	TAN-56	1342	9/9/03	223	1 U	1 U	1 U	1 U	1 U
			9/9/03	242	1 U	1 U	1 U	1 U	1 U
			9/10/03	275	1 U	1 U	1 U	1 U	1 U

Table 3-1. (continued).

Zone	Well Name	Well ID	Date	Sample Depth (ft bls)	PCE (µg/L)	TCE (µg/L)	<i>cis</i> -DCE (µg/L)	<i>trans</i> -DCE (µg/L)	VC (µg/L)
			9/10/03	334	1 U	1 U	1 U	1 U	1 U
			9/10/03	334	1 U	1 U	1 U	1 U	1 U
			9/10/03	387	1 U	1 U	1 U	1 U	1 U
			9/10/03	403	1 U	1 U	1 U	1 U	1 U
			9/10/03	454	1 U	1 U	1 U	1 U	1 U

* In TAN-51 there are two sampling ports at 342-ft depth, "A" and "B."

bls = below land surface

D = result was reported from a diluted run.

DCE = dichloroethene

J = estimated value; results are below the practical quantitation limit.

PCE = tetrachloroethene

TCE = trichloroethene

U = below the detection limit

VC = vinyl chloride

3.2 Radionuclide Data

Radionuclide data were collected for performance and compliance monitoring. During past evaluations, tritium has been used as a conservative tracer to monitor plume migration. Therefore, tritium data were collected from all of the MNA monitoring wells. These data are included in Table 3-2. All of the tritium concentrations observed during FY-03 groundwater monitoring were below the drinking water standard of 20,000 pCi/L. As shown in Table 3-2, tritium was not detected in TAN-52, TAN-56, TAN-57, TAN-16, TAN-21, ANP-8, TAN-58 and GIN-4.

Table 3-2. Tritium results from Fiscal Year 2003 monitored natural attenuation groundwater monitoring.

Zone	Well Name	Well ID	Date	Sample Depth (ft bls)	Tritium (pCi/L)	Detection Limit (pCi/L)	Counting Error (pCi/L)
1	TAN-54	1340	08/19/03	234	625	326	120
			08/19/03	318	562	308	113
			08/19/03	330.5	767	336	129
			08/20/03	347	668	305	116
			08/20/03	373	918	314	129
			08/20/03	394	626	298	112
			08/20/03	420	901	299	123
			08/20/03	460	997	293	126
	TAN-55	1341	08/27/03	221	519	394	133
			08/27/03	251	185 U	397	121
			08/27/03	265	299 UJ	386	122
			08/27/03	317	932	388	147
			09/02/03	332	1,080	375	127

Table 3-2. (continued).

Zone	Well Name	Well ID	Date	Sample Depth (ft bls)	Tritium (pCi/L)	Detection Limit (pCi/L)	Counting Error (pCi/L)		
1	TAN-51	1316	09/02/03	373.5	788	366	120		
			09/02/03	404	498	323	103		
			09/03/03	439	243 UJ	377	116		
			09/03/03	449	605	379	122		
			09/03/03	461	594	371	119		
			08/18/03	240	1,080	329	139		
			08/18/03	263	617	307	115		
			08/18/03	283.5	608	307	115		
			08/19/03	322	188 UJ	294	91.9		
			08/19/03	342B*	324	286	96.1		
			08/19/03	342B*	235 UJ	322	102		
			08/19/03	342A*	117 U	320	95.5		
			08/18/03	367	1530	299	145		
			08/18/03	413	1440	321	149		
			08/18/03	460	142 U	311	94.2		
			TAN-16	752	08/27/03	307	30.1 U	389	111
			TAN-28	1008	08/18/03	242	4,400	286	217
			TAN-29	1010	08/18/03	253	2,960	309	189
			TAN 30A	1012	08/18/03	313	2,860	291	182
TAN-25	1117	08/19/03	218	2,750	310	186			
TAN-37A	1163	08/18/03	240	2,130	290	162			
TAN-37B	1163	08/18/03	272	2,310	324	177			
TSF-05A	71	08/19/03	235	2,520	287	172			
		08/19/03	235	2,690	330	190			
TSF-05B	71	08/20/03	270	3,140	334	203			
		08/20/03	270	3,030	328	198			
		08/25/03	220	152 U	394	118			
		08/25/03	242	149 U	384	115			
2	TAN-52	1317	08/25/03	266	306 UJ	395	125		
			08/25/03	303	304 UJ	393	124		
			08/25/03	303	242 U	391	121		
			08/25/03	361	151 U	391	117		
			08/25/03	373	273 UJ	392	123		
			08/27/03	395	246 UJ	353	111		
			08/27/03	438	30.1 U	388	111		
			08/27/03	456	0 U	385	109		

Table 3-2. (continued).

Zone	Well Name	Well ID	Date	Sample Depth (ft bls)	Tritium (pCi/L)	Detection Limit (pCi/L)	Counting Error (pCi/L)
	TAN-21	793	08/26/03	432	-92.8U	399	109
	ANP-8	76	08/27/03	268	-90.6 U	390	106
			09/08/03	230	-153 U	341	98.5
			09/09/03	285	129 U	350	106
	TAN-57	1343	09/16/03	353	52.4 U	360	108
			09/17/03	400	-29.1 U	274	80.9
			09/22/03	438	-174 U	271	77.6
	TAN-58	1344	09/04/03	292	-198 U	365	105
	GIN-04	162	08/26/03	292	-123 U	398	107
3			09/09/03	223	-46.3 U	345	102
			09/09/03	242	-294 U	346	97.9
			09/10/03	275	-211 U	352	101
	TAN-56	1342	09/10/03	334	30.1 U	336	100
			09/10/03	334	-207 U	337	96.5
			09/10/03	387	121 U	328	99.2
			09/10/03	403	-16.5 U	328	96.9
			09/10/03	454	-82.4 U	351	103

* In TAN-51 there are two sampling ports at 342 ft depth, "A" and "B."

bls = below land surface.

J = estimated value; results are below the practical quantitation limit.

U = below the detection limit or minimum detection activity.

Radionuclides also were monitored near the residual source area in Zone 1. Data for the radionuclides cesium-137 (^{137}Cs), strontium-90 (^{90}Sr), and uranium-234 (^{234}U) are included in Table 3-3. The MCLs for cesium-137, strontium-90, and uranium-234 are 119, 8, and 27 pCi/L, respectively (DOE-ID 1995). Cesium-137 was detected in TSF-05 and TAN-25 at concentrations above drinking water standards. Strontium-90 was detected at concentrations above drinking water standards in all of the wells monitored for strontium-90. Uranium-234 was detected in all wells at levels below drinking water standards. Strontium-90, cesium-137, and uranium-234 data are flagged as estimated values (J) because the samples were improperly preserved.

3.3 Quality Assurance/Quality Control

The required data presented in this section were acquired in accordance with quality assurance/quality control (QA/QC) procedures delineated in the *Phase C Groundwater Monitoring Plan, Test Area North Operable Unit 1-07B* (INEEL 2002). Data validation activities identified no significant quality issues affecting the credibility of the data presented. Appendix C presents the discussion and presentation of the data from which QA/QC interpretations were made.

Table 3-3. Strontium-90, cesium-137, and uranium-234 results from Fiscal Year 2003 monitored natural attenuation groundwater monitoring.

Well Name	Well ID	Date Collected	Sample Depth (ft bls)	Gamma Spec (Cesium-137) (pCi/L)	Strontium-90 (pCi/L)	Uranium-233/234 (pCi/L)
TAN-25	1117	8/19/03	218	705 J	534 J	3.67 J
TAN-28	1008	8/18/03	242	-0.457 U	257 J	6.35 J
TAN-29	1010	8/18/03	253	-0.796 U	47 J	6.96 J
TAN-30A	1012	8/18/03	313	-0.762 U	0.185 UJ	5.88 J
TAN-37A	1163	8/18/03	240	3.34 UJ	457 J	6.11 J
TAN-37B	1163	8/18/03	272	9.93 UJ	470 J	3.02 J
TSF-05A	71	8/19/03	235	345 J	1,320 J	3.64 J
				348 J	1,420 J	3.5 J
TSF-05B	71	8/20/03	270	380 J	1,260 J	1.15 J
				412 J	1,370 J	1.76 J

bls = below land surface.
U = below the detection limit or minimum detected activity.
J = estimated value; results below practical quantitation limit.

4. DATA EVALUATION

Ultimately, the performance of MNA is determined by assessing whether the RAOs will be achieved at the end of long-term operations. Data presented in this annual report are evaluated to assess the interim performance of MNA at achieving this ultimate goal. Evaluation of the FY-03 data presented in Section 3 follows the strategy outlined in the MNA Remedial Action Work Plan (DOE-ID 2003a). This strategy involves evaluation of TCE concentration data for peak breakthrough (Section 4.1), evaluation of plume dimensional changes (Section 4.2), and evaluation of radionuclide concentration data (Section 4.3).

Presentation of additional data and interpretation is included in Section 4.4. The purpose of Section 4.4 is to provide information from FY-03 groundwater monitoring and activities that support the conceptual model and data interpretation guidelines in the MNA Remedial Action Work Plan. This includes response to the MNA Remedial Action Work Plan guidance to verify mechanisms of TCE degradation and to evaluate the conceptual model of TCE transport (DOE-ID 2003a).

4.1 Breakthrough Analyses

The period of time in which peak breakthrough will occur has been predicted in each well included in the MNA monitoring program using the numerical model. Three predictions were made for each well: one using the actual estimated half-life of 13.2 years and two conservative estimates using 14.7- and 20-year half-lives (DOE-ID 2003a; INEEL 2003b). In most wells, the peak breakthrough predictions for this range of TCE degradation half-lives spanned a period of several years. The breakthrough analyses presented in Figures 4-1 through 4-4 show concentration data over time for each screened well and the predicted period of peak breakthrough. Statistical analyses to confirm peak breakthrough will not be presented in this report because, for all wells, either there is insufficient groundwater monitoring data to confirm trends or the peak breakthrough has not occurred.

Peak breakthrough in Zone 1 wells has already occurred or will be confirmed within the next 10 years. Peak breakthrough is expected to occur in TAN-16 at some time between 2004 and 2006. The current data appear to demonstrate a concentration peak followed by a decline (Figure 4-1). However, confirmation of peak breakthrough will be demonstrated with continued groundwater monitoring. According to model predictions, peak breakthrough in the FLUTE™ wells in Zone 1 (TAN-51, TAN-54, and TAN-55) occurred before 2001. Data are insufficient to evaluate peak breakthrough in these Zone 1 wells because groundwater monitoring in these wells began after the peak breakthrough period; monitoring began in 2001 for TAN-51 and 2002 for the other wells. Future groundwater monitoring of Zone 1 wells will be used to confirm a declining trend in TCE concentration that would be expected after the occurrence of peak breakthrough.

Peak breakthrough in Zone 2 wells (TAN-21, TAN-52, ANP-8, and GIN 4) will occur in the future, as demonstrated in Figures 4-2 through 4-4. Analysis of breakthrough will occur for these wells in the future, using statistical analyses of TCE concentrations to confirm a declining trend.

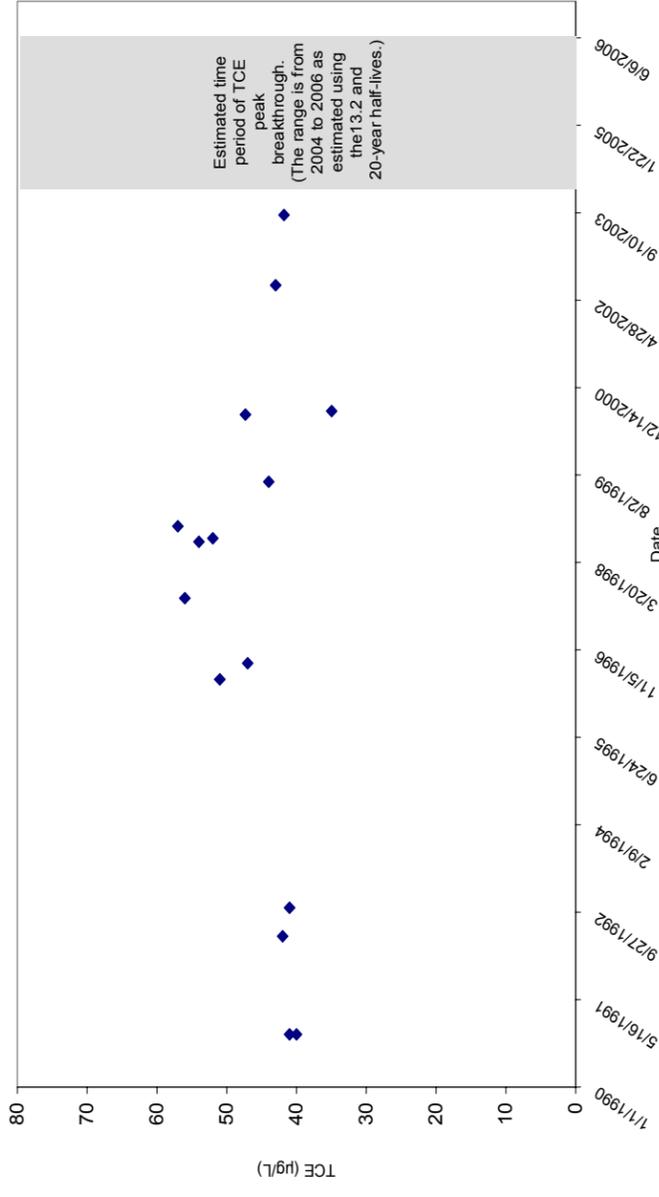


Figure 4-1. Trichloroethene peak breakthrough analysis in Well TAN-16.

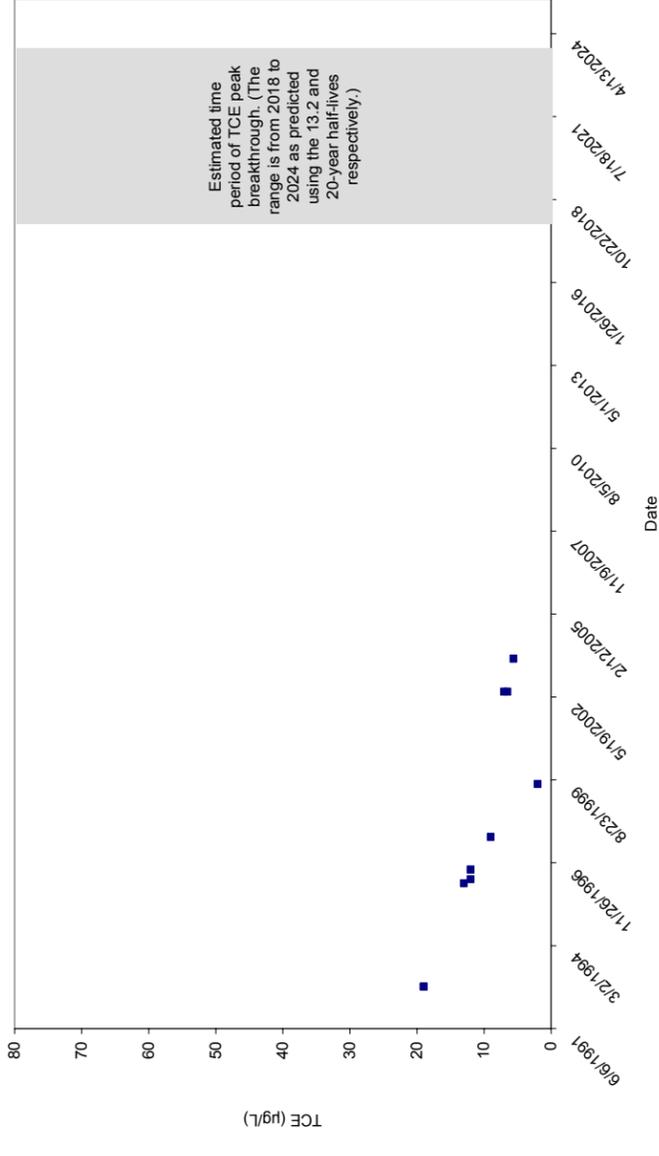


Figure 4-2. Trichloroethene peak breakthrough analysis in Well TAN-21.

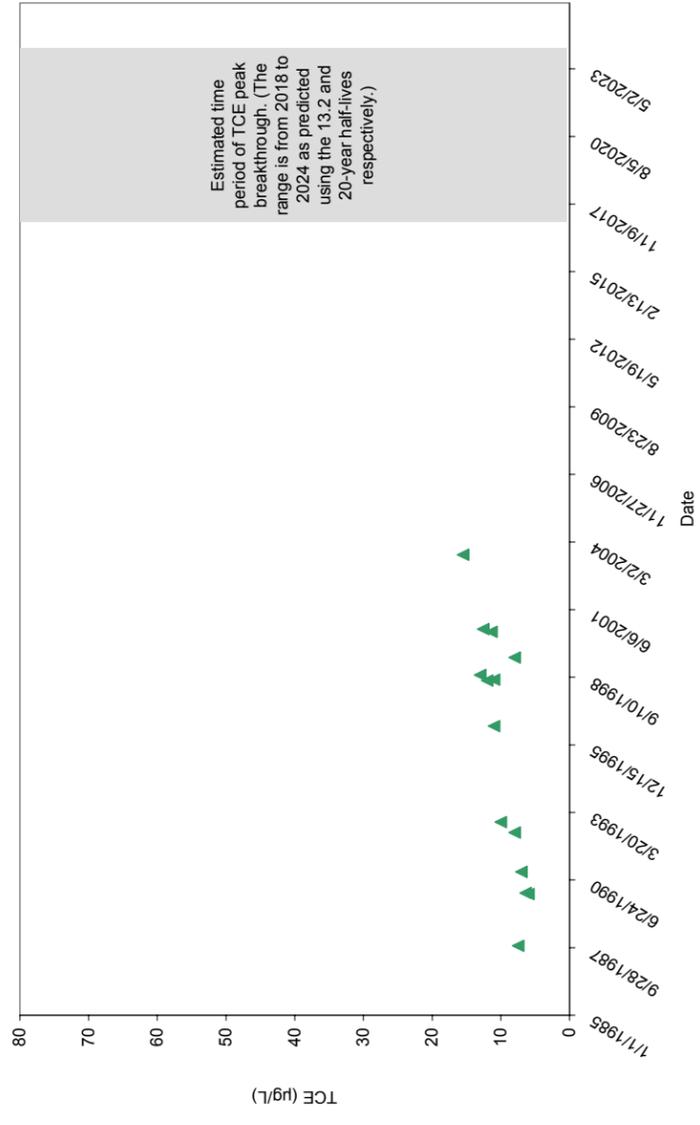


Figure 4-3. Trichloroethene peak breakthrough analysis in Well ANP-8.

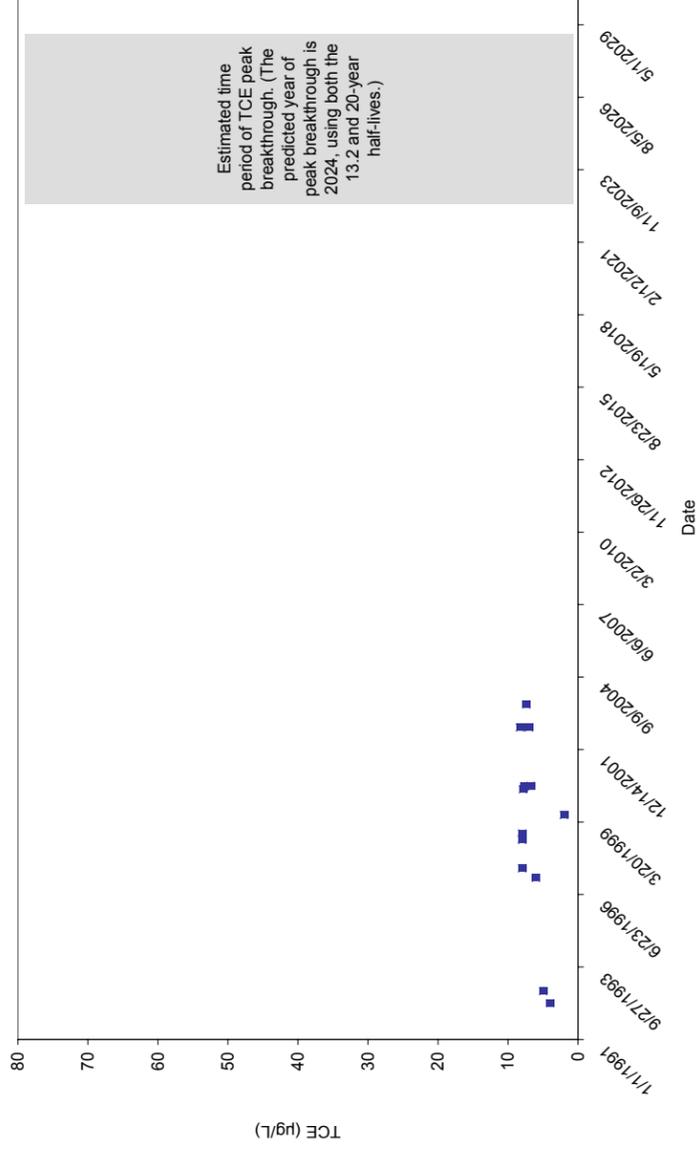


Figure 4-4. Trichloroethene peak breakthrough analysis in Well GIN-4.

4.2 Plume Expansion

Groundwater monitoring of Zone-3 wells suggests that there has been no significant plume expansion since FY-02. In addition, VOCs were not detected in TAN-56. According to Section 4.5 of the MNA Remedial Action Work Plan (DOE-ID 2003a), VOC detection in this well would represent a 15% plume expansion. There also has been no VOC detection in TAN-58. The extent of the TCE groundwater plume in the vicinity of TAN-57 has not been previously known. The COC concentration data presented here from TAN-57 represent the first sampling event at this location. Trichloroethene (TCE) was detected in TAN-57 at concentrations below the MCL. Groundwater monitoring will be conducted in TAN-57 during FY-04 to evaluate the extent of the plume and to determine if TCE concentrations are reproducible and/or increasing. The Wells GIN-4 and ANP-8 are located near the leading edge of the plume. Evaluation of concentration increase in these wells will provide early indication of plume expansion.

4.3 Radionuclide Analyses

Natural attenuation mechanisms, as discussed in the MNA Remedial Action Work Plan (DOE-ID 2003a), are expected to decrease concentrations of radionuclides. Observations from FY-03 groundwater monitoring support the conclusions of the MNA Remedial Action Work Plan regarding radionuclide attenuation and migration from the residual source area. A reduction in strontium-90 concentrations coincident with increasing distance from the source area has been documented in the MNA Remedial Action Work Plan. A comparison of the FY-03 groundwater monitoring data to the data presented in the MNA Remedial Action Work Plan revealed that the FY-03 concentrations are within the same range. This comparison demonstrates that strontium-90 has not migrated further downgradient. Cesium-137 was detected in TSF-05 and TAN-25 only, which are wells within the residual source area.

4.4 Discussion of Conceptual Model

Groundwater monitoring from FY-03 confirms the conceptual model of the plume and guidelines for data interpretation in the MNA Remedial Action Work Plan (DOE-ID 2003a). This section presents analyses and results of additional data gathering activities performed during FY-03 that confirm assumptions used in forming the conceptual model for the distal zone of the plume. These include an interpretation of vertical profile sampling used to confirm the degradation mechanism (Section 4.4.1), a discussion confirming the MNA Remedial Action Work Plan guidance on using the numerical model for data interpretation (Section 4.4.2), a discussion on the FY-03 water level data (Section 4.4.3), and a presentation of evidence of the TCE degradation mechanism (Section 4.4.4).

4.4.1 Vertical Profiles

Tritium and PCE have been used as tracers to evaluate degradation of TCE independent of geohydrologic processes using the tracer corrected method, as discussed in the MNA Remedial Action Work Plan (DOE-ID 2003a) and Engineering Design File (EDF) -3739, "Degradation Rate Coefficient for Aerobic Trichloroethene Attenuation (Draft)."^a This analysis compared the concentration ratio of TCE to a conservative tracer (either tritium or PCE) with distance from the source to demonstrate TCE reduction relative to the tracer. An objective of vertically discrete sampling and the data interpretation presented here is to provide evidence that this observed concentration reduction is a result of degradation, not vertical contaminant distribution.

a. EDF-3739, 2004, "Degradation Rate Coefficient for Aerobic Trichloroethene Attenuation (Draft)," Idaho National Engineering and Environmental Laboratory, June 2004.

The vertical profiles of VOCs and tritium are plotted in Appendix D, Figures D-1 through D-7. In general, tritium data show a similar vertical concentration distribution as TCE, suggesting that the TCE vertical concentration trends are due to permeability and physical aquifer parameters, not to degradation kinetics and chemical processes. The capability to use tritium as a tracer is diminishing because tritium concentrations in the distal portion of the plume are being reduced to below detection limits.

Concentrations of PCE also tended to be higher at depths correlating to high TCE concentrations (Appendix D). Vertically discrete samples were used to calculate TCE:PCE ratios for each depth within each vertically sampled well, and the ratios were then averaged (Appendix D, Table D-1). A comparison of these averages from FY-03 to historical data used in the tracer corrected method (DOE-ID 2003a), demonstrates that these averages are consistent with the data used to calculate the TCE degradation half-life. Therefore, the conclusion of TCE degradation with increasing distance from the source drawn from the historical data set also can be drawn from the FY-03 data. The data indicate that variation of the TCE:PCE ratio within a single well is small. While the TCE:PCE ratio tends to decrease with increasing distance from the source, there is no such trend with depth.

This analysis of vertical profiles confirms that the monitoring well network defined in the MNA Operations, Monitoring, and Maintenance Plan is sufficient to monitor performance of MNA (DOE-ID 2003b). The data indicate that the conclusion of TCE degradation with distance from the source using the tracer corrected method is not a product of vertical contaminant distribution. Therefore, the current network of monitoring wells that are screened at specific intervals and that can be sampled at discrete depths is sufficient. Monitoring of wells that are sampled using vertically discrete sampling techniques will continue to occur during performance monitoring, as directed by the MNA Operations, Monitoring, and Maintenance Plan (DOE-ID 2003b), to evaluate TCE peak breakthrough at these locations.

4.4.2 Comparison of Model Predictions to Observations

The numerical model used to formulate the conceptual design of contaminant transport and degradation is intended to predict time of peak concentration of TCE in water from a specific well. According to the MNA Remedial Action Work Plan, the model should not be used to predict concentrations because significant uncertainty is inherent in the model regarding prediction of TCE concentrations (DOE-ID 2003a).

Model-predicted TCE concentrations, summarized in the following discussion, are derived from the 2003 MNA numerical model update (INEEL 2003b). The 2003 model-predicted TCE concentrations for specific wells are included in vertical profiles of TCE concentrations, and are shown in the figures included in Appendix D as solid (13.2-year TCE degradation half-life) and dashed (20-year TCE degradation half-life) vertical lines. The TCE concentration data from the other wells in Zones 1 and 2 also were compared to the modeled predictions. This comparison showed the following:

- TCE concentrations in water from TAN-16 and GIN-04 were higher than the 13.2-year half-life predicted concentration but lower than the 20-year half-life predicted concentration
- The TCE concentration in water from TAN-21 was significantly lower than the predicted concentrations for both half-lives
- TCE concentrations in water from TAN-51, TAN-54, and TAN-52 at all depths were lower than the predicted concentrations for both half-lives

- TCE concentrations in ANP-8, which is located east of the assumed plume axis, was higher than the predicted TCE concentrations for both half-lives
- TCE concentrations in TAN-55, which is located east of the assumed plume axis, for all depths were higher than the predicted TCE concentrations for the 13.2-year half-life, and for most depths, the concentrations were higher than the predicted concentrations using the 20-year half-life.

Tritium concentrations in water from TAN MNA wells were also compared to the model predicted concentrations (Appendix D). This comparison was not possible for samples collected from TAN-16, TAN-21, TAN-52, ANP-8, and GIN-04 because tritium concentrations in water samples from those wells were below detection limits. The comparison showed the following:

- Tritium concentrations in water from TAN-51 and TAN-54 at all depths were less than the predicted concentrations
- Tritium concentrations in water from TAN-55, located east of the assumed plume axis, were higher for most depths than the predicted concentration.

The comparison demonstrated that the predicted TCE and tritium concentrations were greater than observed concentrations for most wells. Those wells with predicted concentrations less than measured concentrations were east of the assumed plume axis, while those wells with predicted concentrations greater than measured concentrations generally were west of the assumed axis. These comparisons suggest that the actual plume axis is east of the assumed axis, as derived from the numerical model. However, sensitivity analysis has demonstrated that the method used to calculate the degradation rate of TCE is accurate, despite deviations in well locations relative to the assumed plume axis (DOE-ID 2000). As stated in the MNA Remedial Action Work Plan (DOE-ID 2003a), these uncertainties are recognized and the model should only be used to predict the timing of peak TCE concentration breakthrough for MNA wells.

4.4.3 Analyses of Groundwater Flow

Water levels were measured in 79 wells at and near TAN on October 30, 2003. These data are provided in Appendix B, Table B-1. Water-level elevations in these wells ranged from 4,552.88 (OWSLEY-2) to 4,572.19 ft above mean sea level (ANP-9).

A local potentiometric surface map, constructed from 2003 water-level data from 32 of the measured wells, is presented in Figure 4-5. The water-level contours, although not extended past MNA monitoring wells, indicate that the direction of groundwater flow generally is to the south within the TCE plume area and is consistent with flow directions from previous years. The average horizontal hydraulic gradient is about 2.8 ft/mile. South of the TCE plume, water-level contours indicate that the hydraulic gradient steepens and that the groundwater-flow direction changes to the southwest. The downgradient change in flow direction is supported by the TCE detected at concentrations less than the MCL in TAN-57 during the first sampling event in this well (FY-03). Well TAN-57 is located southwest of the extent of the 5- μ g/L TCE plume.

Comparison of water levels in 70 wells that were measured both in 2002 and 2003 showed that water levels were declining in TAN monitoring wells. Measurements for both years were made at the end of the irrigation pumping season and probably represent the annual low water level. The average decline in TAN wells from September 2002 to October 2003 was 2.80 ft; declines ranged from 1.15 ft in TAN-24A to 4.07 ft in TAN-52. These declines are attributed to regional drought conditions and seasonal variations.

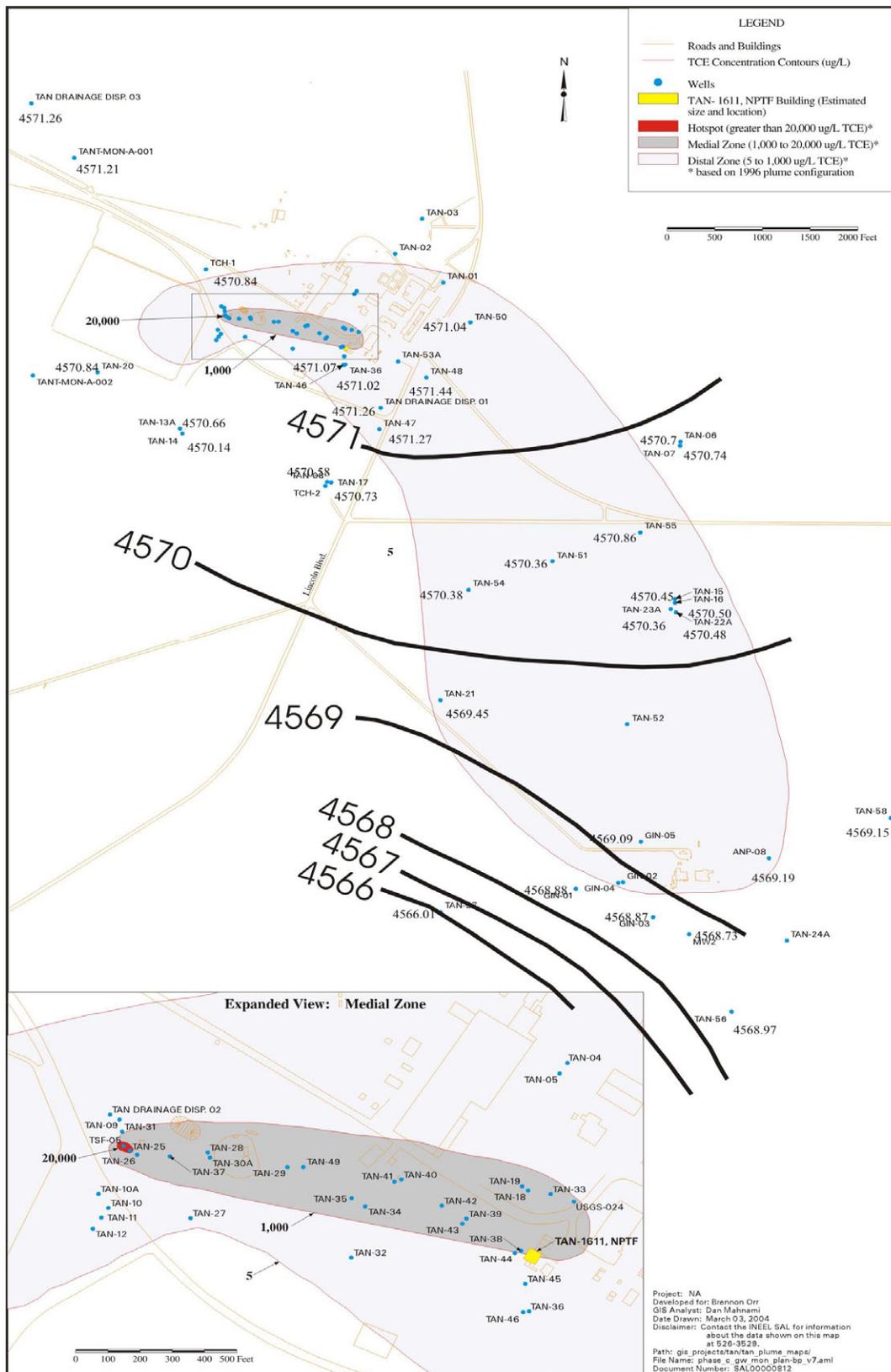


Figure 4-5. Potentiometric surface map.

Water-level data from 66 wells were compared to evaluate water-level fluctuations from 2000 to 2003. Of these 66 water-level comparisons, water-level declines ranged from 4.23 to 8.01 ft. Declines in 62 wells ranged between 4.5 and 6.5 ft and the average water-level decline was 5.91 ft. The small range of declines indicates that the general direction, gradient, and velocity of groundwater flow has remained consistent at TAN and that these declines have not affected natural attenuation of TCE within the plume.

4.4.4 Evidence of Trichloroethene Degradation Mechanism

In conjunction with the in situ bioremediation field evaluation, MNA was evaluated as a remedy for the distal portion of the plume. The results indicated that TCE was being degraded aerobically relative to two internal “tracers,” PCE and tritium, and that the degradation half-life of TCE was from 9 to 21 years (Sorenson et al. 2000). An updated estimate of the TCE half-life using an expanded data set (including more recent groundwater monitoring data) is 13.2 years (DOE-ID 2003a; EDF-3739 [see footnote a]). Based on field and laboratory data, the degradation mechanism was identified as aerobic cometabolism by indigenous methanotrophs, propanotrophs, or phenol-oxidizers.

Cometabolism is defined as the transformation of an organic compound by a microorganism that is unable to use the substrate as a source of energy or as one of its constituent elements (Alexander 1967). Cometabolism, as the name implies, occurs in conjunction with the metabolism of another substrate, which the microorganism uses for carbon and/or energy. Thus, aerobic cometabolism requires the presence of the primary substrate (i.e., oxygen) and the cometabolic substrate. The VOCs TCE, *cis*-DCE, *trans*-DCE, and VC have all been shown to be susceptible to cometabolic oxidation under aerobic conditions (e.g., Wilson and Wilson 1985; Semprini et al. 1990). PCE has been shown to be resistant to both direct and cometabolic oxidation (McCarty 1996). The enzyme soluble methane monooxygenase (sMMO), which is present in methanotrophs, is known to cometabolize TCE. For a review of cometabolic enzymes and cometabolic mechanisms, refer to the *Final Quick Win Vertical Profile Sampling Report* (Wymore, Harris, and Sorenson 2003).

Research at other sites suggests the possibility of lithoautotrophic ecosystems that are driven by the production of hydrogen from interactions with basalt in deep anaerobic portions of an aquifer (Stevens, McKinley, and Fredrickson 1993; Stevens and McKinley 1995; DOE-ID 2000). It is possible that hydrogen is produced deep in the anaerobic portion of the aquifer at the TAN site. This hydrogen provides the energy source to drive methanogenesis. This methane migrates upwards to the upper portion of the aquifer due to buoyancy, where it is utilized by methanotrophic bacteria. These methanotrophs produce sMMO, which cometabolizes TCE. Although the presence of a deep hydrogen-driven biosphere has not been confirmed at TAN, the conditions in the SRPA beneath TAN are similar to the conditions in the studies referenced above. The hypothesis that a similar system is present in the aquifer at TAN can be tested by verifying the presence or absence of sMMO.

4.4.4.1 Enzyme Probes. Direct evidence that the mechanisms for aerobic cometabolic degradation are active consists of the enzyme probe data, which demonstrate that the enzymes necessary are present and active in the aquifer. Activity-dependent enzyme probes are research tools used during FY-03 to provide direct evidence that the mechanism for aerobic cometabolic oxidation of chlorinated ethenes is present and active in the aquifer. The probes work by reacting with enzymes that are known to degrade TCE. If an appropriate enzyme is present and active within a given sample, then application of the probes will result in a fluorescent product that can easily be seen under a microscope. If the appropriate enzyme is not present, or is present but not active in a given sample, then the probes will not be transformed into a fluorescent product. Two activity dependent probes were applied: the coumarin assay was used as a probe for sMMO; and 3-ethynyl-benzoate, 3 hydroxy-phenylacetylene, *trans*-cinnamionitrile, and phenylacetylene were used as toluene mono-, and dioxygenase probes. Several control studies were also

applied in the enzyme probing to confirm the detection of the cometabolic enzymes. An explanation of the enzyme probes and control studies is found in the Final Quick Win Sampling Report (Wymore, Harris, and Sorenson 2003).

The results of enzyme probe sample analysis are presented in Appendix E, Table E-1 (i.e., excepting the results of the controls). The “Toluene Probes” column lists a plus sign for each of the four different toluene oxygenase enzyme probes that yielded a positive response for a given sample. For example, in TAN-58, all four toluene probes produced a positive response. The “Methane Probes” column presents the response to the methane probe, and the “Coumarin Intensity” column presents the intensity of the fluorescent response to the sMMO probe. As shown in Table E-1, sMMO was detected in all samples, and toluene oxygenases were detected in 10 of the 12 samples. Table E-2 presents the results of control studies, which in all cases confirmed the detection of toluene oxygenases and sMMO.

Data presented in Appendix E demonstrate that toluene oxygenases and sMMO are present and active both within the contaminant plume and outside the contaminant plume, based on application of activity-dependent enzyme probes to groundwater samples. These results are consistent with conclusions from previous application of enzyme probes at TAN (Wymore, Harris, and Sorenson 2003).

4.4.4.2 Dissolved Gas Monitoring. Indirect evidence of aerobic cometabolic degradation of TCE includes detection of the primary substrate (i.e., methane), degradation byproducts, and energy sources. Gas concentrations of methane, hydrogen, carbon monoxide, and ethane were monitored in the same wells for which VOCs were analyzed. Vertical concentration profiles are presented in Appendix F. The gases were collected as dissolved gas samples and were analyzed by reduction gas analysis following the bubble strip method (Chapelle et al. 1997). The presence of dissolved oxygen (DO) is necessary to support oxidation of the primary substrate. The DO data are presented with the field parameters in Appendix B.

The presence of these gases suggests that conditions within the aquifer are conducive to aerobic cometabolism (North Wind 2002; Wymore, Harris, and Sorenson 2003). The DO data indicate that the aquifer was consistently aerobic. The detection of hydrogen above equilibrium in TAN-51, TAN-54, TAN-52, TAN-55, and TAN-56 is consistent with the hypothesis of hydrogen produced in the deep aquifer (DOE-ID 2003a). The detection of high concentrations of hydrogen in the other wells is likely a byproduct of the submersible electric pumps that were used to collect samples in the non-FLUTE™ wells. Methane was detected in all wells and above the equilibrium value in TAN-51, TAN-54, TAN-56, TAN-57, TAN-58, TAN-16, and TAN-21. The presence of methane at varying concentrations suggests that methanotrophic activity could be occurring in the aquifer. Carbon monoxide was observed in water from all of the wells at concentrations above the calculated equilibrium concentration of 0.13 $\eta\text{m/L}$. The observed concentrations range from 0.2 to 4.6 $\eta\text{m/L}$. Production of carbon monoxide in laboratory studies has been observed during aerobic cometabolism of TCE by MMO when the pH is in the range of what is observed at TAN (Vogel, Criddle, and McCarty 1987; Fogel, Taddeo, and S. Fogel 1986; Lontoh et al. 2000). Therefore, if this mechanism of aerobic cometabolism of TCE were occurring in the aquifer, then production of carbon monoxide would be expected. The presence of methane, hydrogen, oxygen, and carbon monoxide is one line of indirect evidence that TCE is being cometabolized.

5. SUMMARY

This section provides a summary of the results presented in Section 3 and evaluated in Section 4. The data indicate that, as predicted, MNA is progressing toward achieving the RAOs. Section 5.1 is a summary of results of monitoring for TCE (VOCs), and Section 5.2 summarizes radionuclide-monitoring results. Section 5.3 summarizes the conclusions of Section 4.4.

5.1 Evaluation of Trichloroethene Concentrations and Trends

The TCE concentration data and other data related to TCE degradation indicate that MNA continues to trend toward meeting RAOs. The current data indicate that future groundwater monitoring will provide confirmation of peak breakthrough in TAN-51, TAN-55, and TAN-54 and that future groundwater monitoring will demonstrate peak breakthrough in TAN-16 and Zone 2 wells. The data also indicate that the plume has not significantly expanded.

5.2 Evaluation of Radionuclide Data

Groundwater monitoring of radionuclides during FY-03 indicates that the natural attenuation mechanisms, as defined in the MNA Remedial Action Work Plan for the radionuclides tritium, cesium-137, strontium-90, and uranium-234 continue to be functional within the contaminant plume (DOE-ID 2003a). No migration of strontium-90 or cesium-137 from the source area was observed. Tritium and uranium-234 were not detected above MCLs.

5.3 Verification of the Conceptual Model

Section 4.4 presents data interpretation from FY-03 groundwater monitoring that supports the conceptual model for MNA at TAN, as presented in the MNA Remedial Action Work Plan (DOE-ID 2003a). The MNA Remedial Action Work Plan called for a technical assessment to verify the biological mechanism for TCE degradation and to update the numerical transport model (DOE-ID 2003a). Conclusions drawn from data collected during FY-03 (as described in Section 4.4) include the following:

- Vertical profile sampling has been used to demonstrate that TCE degradation observations are not due to vertical contaminant distribution, and that wells screened at intervals and those that can be sampled at discrete depths are useful for evaluating peak breakthrough (Section 4.4.1).
- The numerical model has been updated using the most recent TCE half-life estimate (INEEL 2003b). A comparison of observed concentrations to numerical model predicted concentrations (Section 4.4.2) has demonstrated, as noted in the MNA Remedial Action Work Plan, that the numerical model should only be used for predicting the time period during which peak breakthrough will occur.
- Potentiometric surface calculated from FY-03 data confirmed the regional groundwater flow and continued water level decline.
- Groundwater monitoring for dissolved gases and enzyme probing of select samples has provided direct and indirect evidence of the presence of the TCE degradation mechanism at TAN (Section 4.4.4). No further enzyme probe and dissolved gas sampling is required to document the degradation mechanism.

6. REFERENCES

- Alexander, M., 1967, "Agriculture and the Quality of Our Environment," N. C. Brady ed., *American Association for the Advancement of Science*, Washington D.C., pp. 331–342.
- Chapelle, F. H., D. A. Vroblesky, J. C. Woodward, and D. R. Lovley, 1997, "Practical Considerations for Measuring Hydrogen Concentrations in Groundwater," *Environmental Science and Technology*, Vol. 31, No. 10, pp. 2873–2877.
- DOE-ID, 1995, *Record of Decision for the Technical Support Facility Injection Well (TSF-05) and Surrounding Groundwater Contamination (TSF-23) and Miscellaneous No Action Sites, Final Remedial Action*, DOE/ID-10139, U.S. Department of Energy Idaho Operations Office, U.S. Environmental Protection Agency, Idaho Department of Environmental Quality, August 1995.
- DOE-ID, 2000, *Field Demonstration Report, Test Area North Final Groundwater Remediation, Operable Unit 1-07B*, DOE/ID-10718, Revision 0, U.S. Department of Energy Idaho Operations Office, March 2000.
- DOE-ID, 2001, *Record of Decision Amendment—Technical Support Facility Injection Well (TSF-05) and Surrounding Groundwater Contamination (TSF-23) and Miscellaneous No Action Sites, Final Remedial Action*, DOE/ID-10139 Amendment, Revision 0, U.S. Department of Energy Idaho Operations Office, U.S. Environmental Protection Agency, Idaho Department of Environmental Quality, September 2001.
- DOE-ID, 2003a, *Monitored Natural Attenuation Remedial Action Work Plan for Test Area North Final Groundwater Remediation, Operable Unit 1-07B*, DOE/ID-11055, Revision 0, U.S. Department of Energy Idaho Operations Office, June 2003.
- DOE-ID, 2003b, *Monitored Natural Attenuation Operations, Monitoring, and Maintenance Plan for Test Area North, Operable Unit 1-07B*, DOE/ID-11066, Revision 0, Idaho National Engineering and Environmental Laboratory, June 2003.
- DOE-ID, 2004, *Quality Assurance Project Plan for Waste Area Groups 1, 2, 3, 4, 5, 6, 8, 10, and Deactivation, Decontamination, and Decommissioning*, DOE/ID-10587, Revision 8, U.S. Department of Energy Idaho Operations Office, March 2004.
- EPA Method 8260B, 1996, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, SW-846, 3d ed., "Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)," Revision 2, U.S. Environmental Protection Agency. (Accessed online at <http://www.epa.gov/epaoswer/hazwaste/test/pdfs/8260b.pdf>; Web page visited June 4, 2004.)
- Fogel, M. M., A. R., Taddeo, and S. Fogel, 1986, "Biodegradation of Chlorinated Ethenes by a Methane-Utilizing Mixed Culture," *Applied and Environmental Microbiology*, Vol. 51, No. 4, pp.720–724.
- ICP, 2004, *Monitored Natural Attenuation Final Inspection Report for Test Area North, Operable Unit 1-07B*, ICP/EXT-03-00089, Revision 0, Idaho Completion Project, Idaho National Engineering and Environmental Laboratory, January 2004.
- INEEL, 2002, *Phase C Groundwater Monitoring Plan, Test Area North Operable Unit 1-07B*, INEEL/EXT-99-00021, Revision 1, Idaho National Engineering and Environmental Laboratory, April 2002.

- INEEL, 2003a, *Well Maintenance Work-off Schedule for Fiscal Years 2003, 2004, and 2005*, INEEL/EXT-02-01462, Revision 0, Idaho National Engineering and Environmental Laboratory, January 2003.
- INEEL, 2003b, *2003 Update to the Test Area North Large-Scale Groundwater Flow and Transport Model for the Assessment of Monitored Natural Attenuation*, INEEL/INT-03-00709, Revision 0, Idaho National Engineering and Environmental Laboratory, December 2003.
- Lontoh, S., J. A. Zahn, A. A. DiSpirito, and J. D. Semrau, 2000, "Identification of Intermediates of In Vivo Trichloroethylene Oxidation by the Membrane-Associated Methane Monooxygenase," *FEMS Microbiology Letters*, Vol. 186, pp. 109–113.
- Manahan, S. E., 1994, *Environmental Chemistry*, Sixth Edition, Lewis Publishers, Boca Raton, Florida.
- McCarty, P. L., 1996, "Biotic and Abiotic Transformations of Chlorinated Solvents in Ground Water," *Symposium on Natural Attenuation of Chlorinated Organics in Ground Water*, Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C., EPA/540/R-97/504, pp. 7–11.
- North Wind, 2002, *Final Accelerated Site Technology Deployment Vertical Profile Sampling Report*, NEW-ID-2002-055, Revision 0, North Wind, Inc., Idaho Falls, Idaho.
- Sander, R., 2004, *Compilation of Henry's Law Constants for Inorganic and Organic Species of Potential Importance in Environmental Chemistry*, Air Chemistry Department, Max-Planck Institute of Chemistry, Mainz, Germany, <http://www.mpch-mainz.mpg.de/~sander/res/henry.html>, Web page updated March 27, 2004, Web page visited June 4, 2004.
- Semprini, L., P. V. Roberts, G. D. Hopkins, and P. L. McCarty, 1990, "A Field Evaluation of In-Situ Biodegradation of Chlorinated Ethenes: Part 2, Results of Biostimulation and Biotransformation Experiments," *Ground Water*, Vol. 28, No. 5, pp. 715–727.
- Sorenson, K. S., L. N. Peterson, R. L. Ely, and R. E. Hinchee, 2000, "An Evaluation of Aerobic Trichloroethene Attenuation Using First-Order Rate Estimation," *Bioremediation Journal*, Vol. 4, No. 4, pp. 337–358.
- Stevens, T. O and J. P. McKinley, 1995, "Lithoautotrophic Microbial Ecosystems in Deep Basalt Aquifers." *Science*, Vol. 270, pp. 450-454.
- Stevens, T. O., J. P. McKinley, and J. K. Fredrickson, 1993, "Bacteria Associated with Deep, Alkaline, Anaerobic Groundwaters in Southeast Washington," *Microbial Ecology*, Vol. 25, pp. 5-30.
- Vogel, T. M., C. S. Criddle, and P. L. McCarty, 1987, "Transformations of Halogenated Aliphatic Compounds," *Environmental Science and Technology*, Vol. 21, No. 8, pp. 722-736.
- Wilson, J. T. and B. H. Wilson, 1985, "Biotransformation of Trichloroethylene in Soil," *Applied and Environmental Microbiology*, Vol. 49, pp. 242-243.
- Wymore, R. A., K. L. Harris, and K. S. Sorenson, 2003, *Final Quick Win Vertical Profile Sampling Report*, NWE-ID-2003, Revision 0, North Wind, Inc. Idaho Falls, Idaho.

Appendix A
Sampling and Analysis Plan Tables

Plan Table Number: MNA-PERFORMANCE

SAP Number: DOE/D-11068

Date: 08/13/2003

Project: MNA PERFORMANCE OPERATIONS (ANNUAL)

Project Manager: SUANKU D. E.

SMO Contact: KIRCHNER, D. B.

Sampling Activity	Sample Description			Planned Date	Sample Location			Enter Analysis Types (AT) and Quantity Requested																					
	Sample Type	Sample Matrix	Cell Type		Sampling Method	Area	Type of Location	Location	Depth (ft)	AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
MNA190	REG	GROUND WATER	GRAB		8/18/2003	TAN	MONITORING WELL	TAN-55 (1342)	223							1													
MNA191	REG	GROUND WATER	GRAB		8/18/2003	TAN	MONITORING WELL	TAN-56 (1342)	242							1													
MNA192	REG	GROUND WATER	GRAB		8/18/2003	TAN	MONITORING WELL	TAN-55 (1342)	275							1													
MNA193	REG/OC	GROUND WATER	DUP		8/18/2003	TAN	MONITORING WELL	TAN-55 (1342)	334							2													
MNA194	REG	GROUND WATER	GRAB		8/18/2003	TAN	MONITORING WELL	TAN-55 (1342)	387							1													
MNA195	REG	GROUND WATER	GRAB		8/18/2003	TAN	MONITORING WELL	TAN-55 (1342)	403							1													
MNA196	REG	GROUND WATER	GRAB		8/18/2003	TAN	MONITORING WELL	TAN-55 (1342)	454							1													
MNA197	REG	GROUND WATER	GRAB		8/18/2003	TAN	MONITORING WELL	TAN-57 (1343)	230							1													
MNA203	REG	GROUND WATER	GRAB		8/18/2003	TAN	MONITORING WELL	TAN-57 (1343)	285							1													
MNA204	REG	GROUND WATER	GRAB		8/18/2003	TAN	MONITORING WELL	TAN-57 (1343)	353							1													
MNA205	REG	GROUND WATER	GRAB		8/18/2003	TAN	MONITORING WELL	TAN-57 (1343)	400							1													
MNA206	REG	GROUND WATER	GRAB		8/18/2003	TAN	MONITORING WELL	TAN-57 (1343)	438							1													
MNA207	REG	GROUND WATER	GRAB		8/18/2003	TAN	MONITORING WELL	TAN-38 (1344)	285							1													
MNA208	OC	WATER	FBLK		3/18/2003	TAN	FIELD BLANK	GC	NA							1													
MNA209	OC	WATER	FBLK		3/18/2003	TAN	FIELD BLANK	GC	NA							1													
MNA210	OC	WATER	FBLK		3/18/2003	TAN	FIELD BLANK	GC	NA							1													

The sampling activity displayed on this table represents the first six characters of the sample identification number. The complete sample identification number (10 characters) will appear on field guidance forms and sample labels.

AT1: Dissolved Gases
 AT2: Gamma Spec
 AT3: Microbiological Analysis
 AT4: Sr-90
 AT5: Tritium
 AT6: U-234
 AT7: VOCs (TAL)
 AT8: VOCs (TAL) - MS/MSD
 AT9:
 AT10:
 Analysis Suites:

Comments:
 VOCs TAL = Vinyl Chloride, Trichloroethene, Tetrachloroethene, cis-1,2-Dichloroethene, trans-1,2-Dichloroethene
 Gamma Spec = analysis of concern is Cs-137
 Microbiological Analysis = Enzyme Probe
 Dissolved Gases = Methane, Ethane, Hydrogen, and Carbon Monoxide

Contingencies:

Appendix B

Field Parameters for Fiscal Year 2003

Appendix B

Field Parameters for Fiscal Year 2003

Field parameters for Fiscal Year 2003 include water levels, pH, oxidation/reduction potential (ORP), temperature, specific conductivity, and dissolved oxygen (DO). These data are presented below in Tables B-1 and B-2 and Figures B-1 and B-2.

Table B-1. Water level data from 2003 measurements.

Well Name	Measuring Point Elev. (ft)	Depth to Water, Top of Casing (ft)	2003 Water Elevation (ft)	Water Level Change, (from 2002 to 2003) (ft)	Water Level Change, (from 2000 to 2003) (ft)
ANP-5	4874.65	303.38	4571.27	-2.83	-6.11
ANP-6	4797.05	225.71	4571.34	-2.86	-5.72
ANP-7	4936.68	364.49	4572.19	-2.79	-8.01
ANP-8	4790.67	221.48	4569.19		
ANP-9	4788.24	232.47	4555.77	-3.01	-6.11
ANP-10	4787.64	230.8	4556.84	-3.21	-6.39
FET-DISPOSAL	4785.85	214.51	4571.34	-2.73	-6.25
GIN-1	4788.11	219.23	4568.88	-2.41	-5.11
GIN-3	4788.43	219.56	4568.87	-2.81	-5.66
GIN-5	4788.31	219.22	4569.09	-2.86	-5.73
MW-2	4789.43	220.7	4568.73	-3.02	-5.81
NONAME	4786	216.71	4569.29	-3.05	-5.64
OWSLEY-2	4785.95	233.07	4552.88	-2.99	-6.07
P&W-1	4897.22	325.87	4571.35	-2.88	-6.38
P&W-2	4892.91	321.52	4571.39	-2.85	-6.09
P&W-3	4887.43	315.68	4571.75	-2.79	-6.77
PSTF	4788.23	218.48	4569.75	-3.15	-5.58
TANT-MON-A-001	4782.08	210.87	4571.21		-6.27
TAN-04	4803.61	232.53	4571.08	-3.75	-6.04
TAN-04	4803.61	234.51	4569.1		
TAN-05	4804.03	233.13	4570.9		-6.07
TAN-05	4804.03	233.1	4570.93		
TAN-06	4788.73	218.03	4570.7	-2.82	-5.99
TAN-07	4788.65	217.91	4570.74	-2.84	-5.98
TAN-08	4791.58	221	4570.58	-3.04	-4.75
TAN-09	4782.62	211.37	4571.25	-2.77	-6.24
TAN-10	4782.73	211.49	4571.24	-3.03	
TAN-10A	4782.63	211.43	4571.2	-2.74	-5.92
TAN-11	4782.83	211.47	4571.36	-2.74	-5.92
TAN-12	4782.78	211.43	4571.35	-2.69	-5.92

Table B-1. (continued).

Well Name	Measuring Point Elev. (ft)	Depth to Water, Top of Casing (ft)	2003 Water Elevation (ft)	Water Level Change, (from 2002 to 2003) (ft)	Water Level Change, (from 2000 to 2003) (ft)
TAN-13A	4782.41	211.75	4570.66	-3.08	-4.53
TAN-14	4782.69	212.55	4570.14	-2.94	-5.11
TAN-15	4788.88	218.43	4570.45	-2.83	-5.8
TAN-16	4788.81	218.31	4570.5	-2.82	-5.8
TAN-17	4792.653	221.92	4570.733		
TAN-18	4804.37	233.46	4570.91	-2.36	-6.27
TAN-19	4805.67	234.6	4571.07	-2.72	-6.12
TAN-20	4782.88	212.04	4570.84	-3.05	-5.25
TAN-21	4789.2	219.75	4569.45	-2.91	-5.41
TAN-22A	4788.76	218.28	4570.48	-2.73	-6.1
TAN-23A	4788.6	218.24	4570.36	-2.82	-5.82
TAN-24A	4790.93	220.32	4570.61	-1.15	-4.23
TAN-27	4782.41	211.2	4571.21	-2.73	-6
TAN-28	4784.02	212.93	4571.09	-2.71	-6.08
TAN-29	4784.065	212.88	4571.185	-2.275	
TAN-30A	4784.03	212.84	4571.19	-3.06	-6.09
TAN-32	4787.42	216.32	4571.1	-2.73	-6.02
TAN-33	4800.41	229.36	4571.05	-2.7	-6.11
TAN-34	4785.188	214.33	4570.858	-2.9	
TAN-35	4784.541	213.41	4571.131	-2.7	
TAN-36	4796.35	225.33	4571.02	-2.74	-6.01
TAN-37	4784.35	213.09	4571.26	-2.79	-6.14
TAN-41	4785.94	214.85	4571.09	-2.73	-6.1
TAN-42	4802.58	231.55	4571.03	-2.7	-6.15
TAN-43	4801.78	231.04	4570.74	-2.71	-6.45
TAN-44	4800.75	230.6	4570.15	-2.47	-7.01
TAN-45	4797.71	226.66	4571.05	-2.71	-6.06
TAN-46	4796.36	225.29	4571.07	-2.7	-6.01
TAN-47	4790.51	219.24	4571.27	-3.04	-4.93
TAN-48	4790.2	218.76	4571.44	-2.91	-5.59
TAN-49	4783.654	212.44	4571.214		
TAN-50	4790.84	219.8	4571.04	-2.7	-5.97
TAN-50	4790.84	219.44	4571.4		
TAN-51	4788.59	218.23	4570.36	-3.44	-5.58
TAN-52	4788	219.48	4568.52	-4.07	-6.48
TAN-54	4789.36	218.98	4570.38	-3.15	-5.24
TAN-55	4789.64	218.78	4570.86	-2.97	-5.5
TAN-56	4790.05	221.08	4568.97	-2.38	-5.35

Table B-1. (continued).

Well Name	Measuring Point Elev. (ft)	Depth to Water, Top of Casing (ft)	2003 Water Elevation (ft)	Water Level Change, (from 2002 to 2003) (ft)	Water Level Change, (from 2000 to 2003) (ft)
TAN-57	4790.3	224.29	4566.01	-2.92	-5.69
TAN-58	4791.7	222.55	4569.15	-2.86	-5.93
TAN-1859	4785.23	214.07	4571.16		
TAN-1860	4784.99	213.74	4571.25		
TAN-1861	4785.528	214.29	4571.238		
TAN-CH2 mon. 1	4791.94	214.64	4577.3	-0.35	
TAN-CH2 mon. 2	4791.94	222.81	4569.13	-2.65	
TAN-D1	4789.21	217.95	4571.26	-2.82	-5.93
TAN-D3	4780	208.74	4571.26	-2.89	-6.31
TSF-05	4783.34	211.75	4571.59		
USGS-07	4790.81	222	4568.81	-2.82	-5.96
USGS-24	4796.99	225.9	4571.09	-2.71	-6.08
USGS-25	4850.87	279.65	4571.22	-2.84	-6.14
USGS-26	4790.65	219.54	4571.11	-2.73	-6.22

Table B-2. Purge data from monitored natural attenuation monitoring wells.

Zone	Well Name	Date	Sample Depth (ft bls)	Temp. °C	Press. in. Hg	ORP (mV)	DO (mg/L)	pH	Specific Cond. (µS/cm)
1	TAN-54	8/19/03	234	14.74	25.172	193	6.35	7.85	415
		8/19/03	318	13.53	25.139	198	2.2	7.52	421.63
		8/19/03	330.5	12.88	25.138	205	5.65	7.7	421.8
		8/20/03	347	13.09	25.232	223	7.43	7.9	414.32
		8/20/03	373	12.6	25.213	228	7.69	7.86	418.47
		8/20/03	394	13.96	25.215	227	7.01	7.94	410.63
		8/20/03	420	13.35	25.216	231	7.41	8.04	420.34
		8/20/03	460	13.52	25.187	228	6.17	7.99	413.68
	TAN-55	8/27/03	221	13.28	25.172	176	7.89	7.96	454.77
		9/3/03	251	13.41	25.362	160	9.35	8.16	449.71
		8/27/03	265	14.44	25.144	185	5.52	7.84	455.29
		9/3/03	317	12.8	25.322	174	7.11	7.99	496.75
		9/2/03	332	11.98	25.342	164	6.7	7.85	497.54
		9/2/03	373.5	12.76	25.331	169	7.32	7.99	490.1
		9/2/03	404a	12.86	25.336	181	7.57	7.95	479.96
		9/3/03	404b	12.8	25.314	186	7.13	8.09	472.21
		9/3/03	439	13.4	25.379	187	7.62	7.88	449.16
		9/3/03	449	12.17	25.378	192	7.58	7.9	458.47

Table B-2. (continued).

Zone	Well Name	Date	Sample Depth (ft bls)	Temp. °C	Press. in. Hg	ORP (mV)	DO (mg/L)	pH	Specific Cond. (µS/cm)
1	TAN-51	9/3/03	461	12.79	25.382	195	7.1	7.89	466.17
		8/18/03	240	12.23	25.194	173	11.71	8.2	456.08
		8/18/03	263	12.79	25.206	186	14.04	8.14	389.63
		8/18/03	283.5	12.2	25.234	185	11.8	7.97	382.32
		8/19/03	322	11.51	25.249	244	10.16	7.96	340.77
		8/19/03	342A	12.53	25.24	226	5.81	7.81	329.97
		8/19/03	342B	11.96	25.243	230	6.87	7.82	325.61
		8/18/03	367	12.85	25.241	172	7.47	8.02	485.26
		8/18/03	413	12.5	25.247	173	6.27	7.87	470.64
	8/18/03	460	13.21	25.274	170	9.48	7.92	324.07	
	TAN-16	8/27/03	307	12.01	No data	207	5.26	7.36	422
	TAN-28	8/18/03	242	14.17	25.285	-114	6.74	0.64	933.17
	TAN-29	8/18/03	253	14.87	25.238	-166	6.87	0.08	813.81
	TAN 30A	8/18/03	313	15.15	25.279	26	5.79	9.04	662.08
	TAN-25	8/19/03	218	16.04	25.23	-153	7.51	0.61	7891.22
TAN-37A	8/18/03	240	16.25	25.216	-206	6.62	1.21	1160.38	
TAN-37B	8/18/03	272	16.38	25.195	-215	6.64	1.63	1158.87	
2	TAN-52	8/25/03	220	13.05	25.368	-174	-0.09	7.85	2719.64
		8/25/03	242	13.45	25.348	-180	9.63	8.4	2827.28
		8/25/03	266	12.46	25.334	-180	7.6	8.2	2735.3
		8/25/03	303	14.19	25.323	1382	6.2	15.34	2986.44
		8/25/03	361	11.92	25.302	1321	7.56	12.94	2863.33
		8/25/03	373	12.62	25.293	1344	8.79	13.28	2901.01
		8/27/03	395	12.42	25.176	194	7.82	8.1	423.91
		8/27/03	438	12.13	25.174	193	7.84	7.88	405.66
		8/27/03	456	12.96	25.183	196	7.82	6.71	397.91
		TAN-21	8/26/03	432	12.42	No data	-47	0.6	9.22
ANP-8	8/27/03	268	13.31	No data	263	7.22	7.39	387	
3	TAN-57	9/8/03	230	12.76	No data	188	9.71	7.84	328
		9/9/03	285	11.81	No data	178	10.1	7.84	330
		9/16/03	353	11.91	No data	229	9.59	7.88	341
		9/17/03	400	13.2	No data	221	8.87	7.94	352
		9/22/03	438	12.2	No data	234	7.62	7.8	364
	TAN-58	9/4/03	292	16.05	No data	255	7.63	7.61	337

Table B-2. (continued).

Zone	Well Name	Date	Sample Depth (ft bls)	Temp. °C	Press. in. Hg	ORP (mV)	DO (mg/L)	pH	Specific Cond. (µS/cm)
	GIN-04	8/26/03	292	13.42	No data	19	5.23	7.42	434
		9/9/03	223	14.85	24.958	172	2.88	7.72	387.68
		9/9/03	242	14.75	24.926	169	7.47	7.93	372.29
		9/10/03	275	14.27	25.156	154	6.28	7.86	352.34
3	TAN-56	9/10/03	334	14.43	25.153	199	7.91	7.95	358.01
		9/10/03	387	14.45	25.161	190	7.61	7.94	354.2
		9/10/03	403	14.07	25.198	170	7.71	8.16	352.33
		9/10/03	454	13.99	25.198	175	8.07	8.11	352.49

bls = below land surface
 DO = dissolved oxygen
 ORP = oxidation/reduction potential

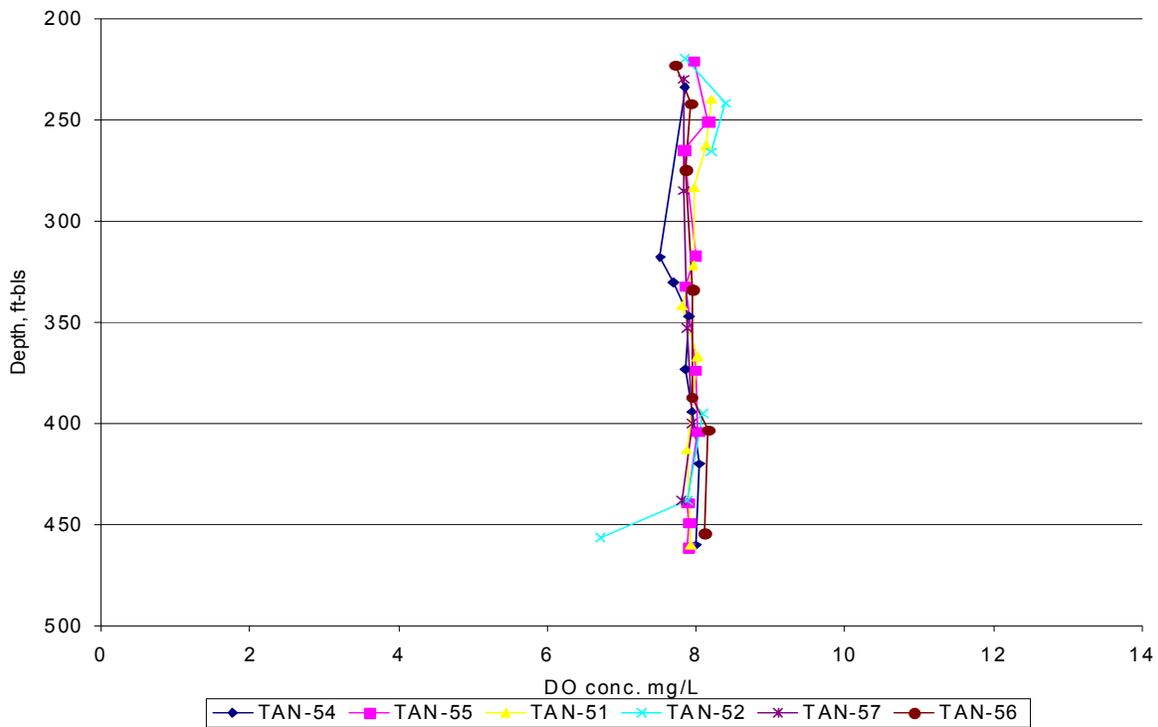


Figure B-1. Vertical profiles of pH.

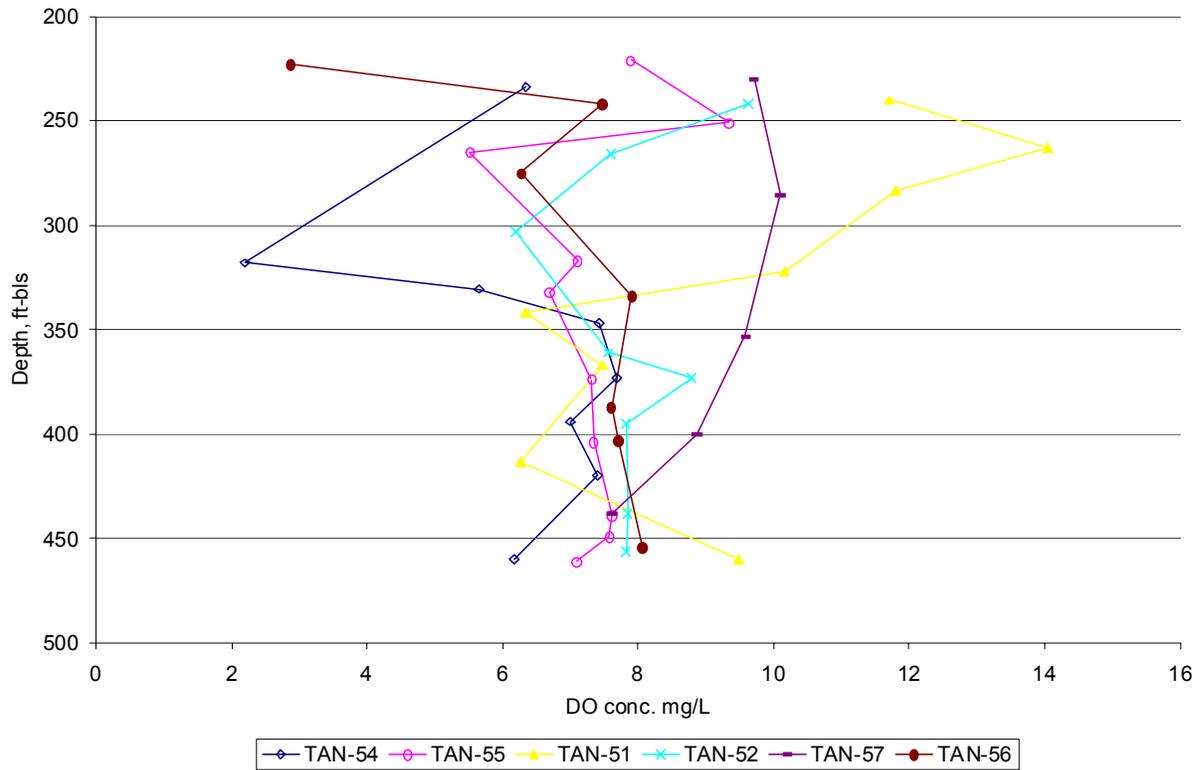


Figure B-2. Vertical profiles of dissolved oxygen concentration.

Appendix C
Quality Assurance/Quality Control

Appendix C

Quality Assurance/Quality Control

This section describes quality assurance/quality control (QA/QC) components of MNA data during Fiscal Year (FY) 2003. These components consist of completeness, validation, precision and accuracy, and comparability of 2003 MNA data. The FY-03 data were collected under the requirements of the *Monitored Natural Attenuation Operations, Monitoring, and Maintenance Plan for Test Area North, Operable Unit 1-07B* (DOE-ID 2003b).

C-1. DATA COMPLETENESS

Under the MNA Operations, Monitoring, and Maintenance Plan (DOE-ID 2003b), 10 wells required sampling for VOCs and tritium, and six wells required sampling for radionuclides, including tritium. Appropriate duplicates, field blanks, trip blanks, and matrix spikes were required for QA/QC purposes. Table C-1 is a summary of the required and completed sampling and analyses for radionuclides and volatile organic compounds (VOCs). As shown, sampling for all contaminants of concern (COCs) from the monitoring well network was 100% complete. All duplicate samples were completed as planned. The results of these duplicate samples are included with the presentation of results in Section 3. No analytes were detected in any of the field or trip blanks collected and analyzed. Three field blanks were required for the VOC and tritium data. One of the three field blanks was not analyzed. Trip blanks also were required for each sample cooler with samples to be analyzed for VOCs. This was completed as required.

Table C-1. Field and laboratory data completeness summary.

Analyses	Sample Type	Number Required or Planned	Number Collected
TCE, PCE, cis-DCE, trans-DCE, and VC	Primary samples	53	53
	Duplicates	1 per 20 samples = 3	3
	Field Blanks	1 per 20 samples = 3	N/A
	Trip Blanks	1 per cooler = 5	N/A
Tritium	Primary samples	61	61
	Duplicates	1 per 20 samples = 3	5
	Field Blanks	1 per 20 samples = 3	N/A
Gamma spec (Cs-137), Strontium-90, and Uranium-234	Primary samples	8	8
	Duplicates	1 per 20 samples = 1	2
<u>Primary sampling completion</u>			100%
DCE = dichloroethene			
PCE = tetrachloroethene			
TCE = trichloroethene			
VC = vinyl chloride			

C-2. DATA VALIDATION

Data collected for use in Monitored Natural Attenuation (MNA) performance and compliance monitoring are definitive level data requiring a Level B validation during performance operations. This data validation level is required for all analyses specified in the *Monitored Natural Attenuation Remedial Action Work Plan for Test Area North Final Groundwater Remediation, Operable Unit 1-07B* (DOE-ID 2003a). In general, definitive level data are generated using approved analytical methods. The VOC data were generated using the Environmental Protection Agency (EPA) approved method, SW-846 8260B, "Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry." Tritium was analyzed using liquid scintillation counting methods. Cesium-137 was analyzed using gamma spectrometry methods. Strontium-90 and uranium 234 data were produced using gas flow proportional and gross alpha methods. Data validation requirements were followed according to the requirements summarized in the MNA Operations, Monitoring, and Maintenance Plan (DOE-ID 2003b). Data validation activities identified no significant quality issues affecting the credibility of these data.

C-2.1 Precision

Precision is a measure of reproducibility of measurements under a given set of conditions. Overall precision consists of two components: (1) field precision, which is affected by sample collection methods and natural heterogeneity in the groundwater matrix, and (2) laboratory precision, which is affected by analytical methods. Overall precision can be assessed through the collection of duplicate samples, which for purposes of this project were defined as samples collected for the same analytes from the same location during the same mobilization. Precision in this report is evaluated by calculating the relative percent difference (RPD) of the duplicate samples. The RPD is calculated for field duplicates to represent overall precision, and it is calculated for matrix spike duplicates (MSDs) to represent laboratory precision (EPA 1996). The laboratory precision requirement for trichloroethene (TCE) measurements is less than 14% RPD (DOE-ID 2003b).

Relative percent difference values for field duplicates of VOC, tritium, and radionuclide samples are presented in Tables C-2 and C-3. For many of the duplicate samples, RPD was not calculated because the contaminants were not detected in the samples above the method detection limits (MDLs). For all samples that were non-detect, the duplicate sample also was non-detect. Field duplicate TCE samples for which an RPD was calculated were 20.4 and 17.4%, demonstrating overall precision for TCE sampling and analysis. The RPD values of duplicate samples for radionuclides were generally small with the exception of uranium-234 in TSF-05B. The uranium-234 results for this TSF-05B sample were 1.15 and 1.76 pCi/L, while the detection limits for these values were 0.49 and 0.43 pCi/L. The presented values are also below the practical quantitation limit (the laboratory flagged the data with "J"). Therefore, it is not surprising that the RPD value is high (41.29%) considering the limits of the analyses methods, and the RPD may be insignificant, considering the low concentrations.

Table C-2. Volatile organic compound precision, as estimated by field duplicates.

Well Name	Sample Depth (m)	PCE RPD (%)	TCE RPD (%)	Cis-DCE RPD	Trans-DCE RPD	VC RPD
TAN-51	342	14.81	20.39	NA*	NA*	NA*
TAN-52	303	32.35	17.74	NA*	NA*	NA*
TAN-56	334	NA*	NA*	NA*	NA*	NA*

DCE = dichloroethene
PCE = tetrachloroethene
RPD = relative percent difference
TCE = trichloroethene
VC = vinyl chloride
* Values were below detection limits.

Table C-3. Tritium precision, as estimated by field duplicates.

Well Name	Sample Depth (m)	Tritium RPD (%)	Sr-90 RPD (%)	U-233/234 RPD (%)	Gamma Spec (Cesium-137) RPD (%)
TAN-51	342B	N/A*	No sample	No sample	No sample
TAN-52	303	N/A*	No sample	No sample	No sample
TSF-05A	235	7	7.30	3.92	0.87
TSF-05B	270	4	8.37	41.92	8.08
TAN-56	334	N/A*	No sample	No sample	No sample

RPD = relative percent difference
* Values were below detection limits

Laboratory precision is represented by the RPD of the MSD samples. As demonstrated in Table C-4, the calculated RPD between the matrix spike (MS) and MSD samples are all less than 7%, which demonstrates compliance with the requirement of less than 14% RPD for laboratory precision on TCE analyses (DOE-ID 2003b).

C-2.2 Accuracy

Field QC and laboratory QA samples and analyses from the FY-03 MNA groundwater monitoring activities indicate that the data are accurate within the specified limitations. Accuracy is a measure of bias in the sampling and analysis procedures. Sampling activities that can affect accuracy include preservation, handling, and the sample matrix. All analyses of field and trip blanks collected during FY-03 sampling showed that analytes were not detected, indicating that there was no contamination of samples, which would make the analyses inaccurate. The MNA Operations, Monitoring, and Maintenance Plan requires MS recoveries to be within 71 to 120% (DOE-ID 2003b). The MS samples were complete and all recoveries were within the required limitations (see Table C-4).

Table C-4. Matrix spike and matrix spike duplicate results.

Well Name	Depth (ft)	MS Percent Recovery (%)	MSD Percent Recovery (%)	MS/MSD RPD (%)
TAN 51	322	108	101	7
TAN-54	420	90	92	2
TAN-57	230	90	86	4

MS = matrix spike
MSD = matrix spike duplicate
RPD = relative percent difference

C-3. COMPARABILITY OF DATA

Data comparability was ensured by following standard sample collection techniques, in adherence with the Quality Assurance Project Plan for Waste Area Groups 1,2,3,4,5,6,7,10, and Deactivation, Decontamination, and Decommissioning, (DOE-ID 2004)

Appendix D
Vertical Profiles

Appendix D

Vertical Profiles

The vertical profiles of volatile organic compounds (VOCs) and tritium are plotted in Figures D-1 through D-7. Vertically discrete samples were used to calculate trichloroethene:tetrachloroethene (TCE:PCE) ratios for each depth within each vertically sampled well. These averaged ratios are shown in Table D-1 following the figures.

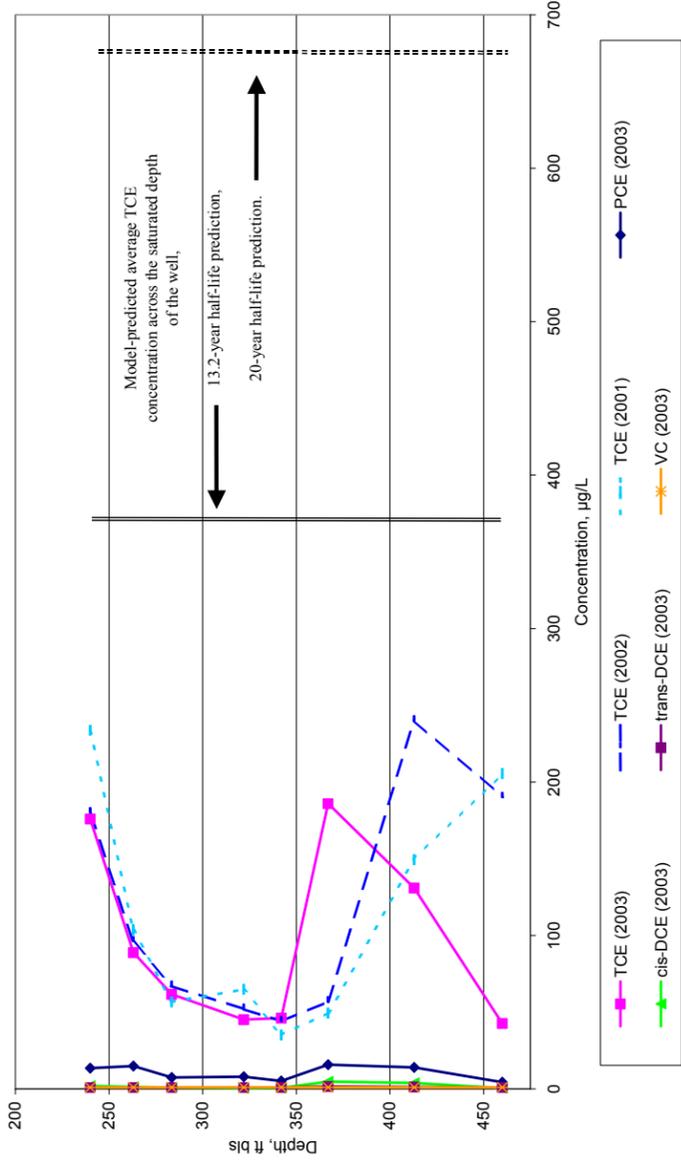


Figure D-1. Well TAN-51 volatile organic compound concentration vertical profile compared with model predictions.

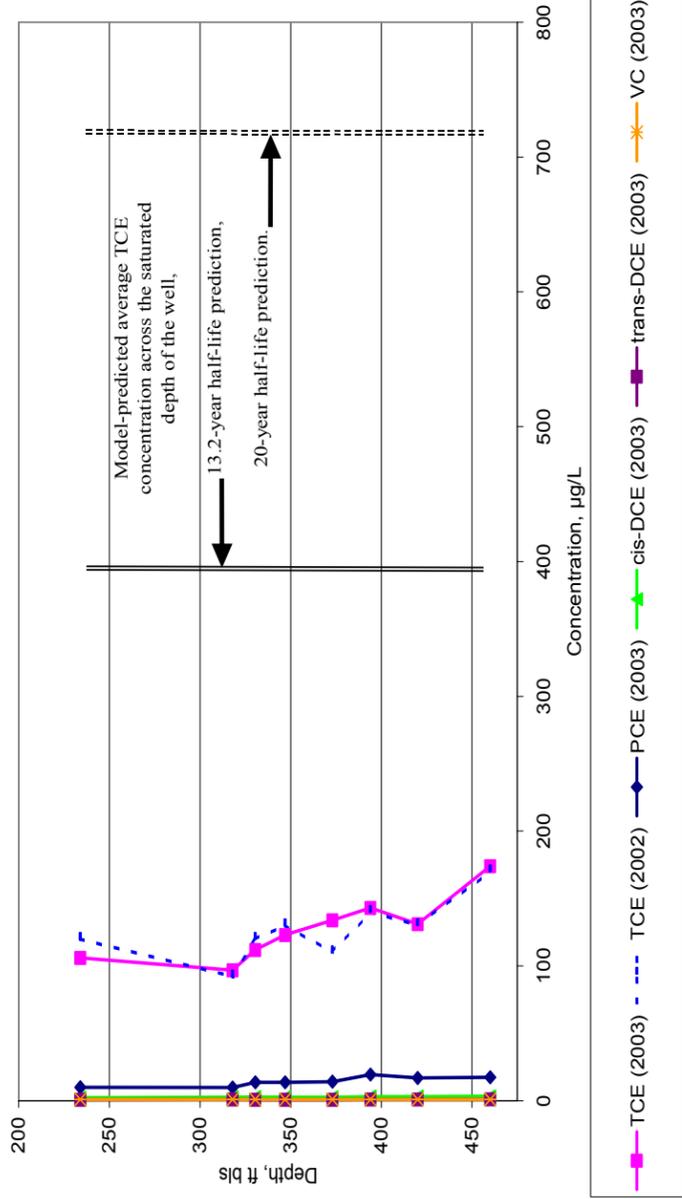


Figure D-3. Well TAN-54 volatile organic compound concentration vertical profile compared with model predictions.

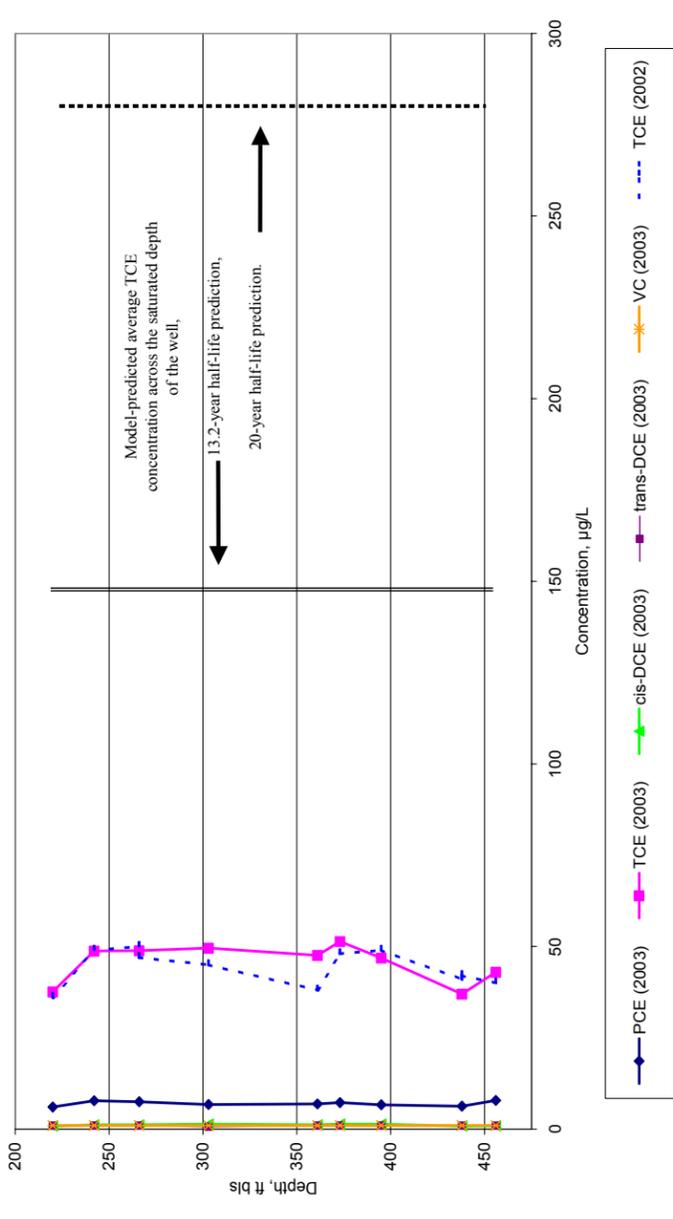


Figure D-2. Well TAN-52 volatile organic compound concentration vertical profile plot compared with model predictions.

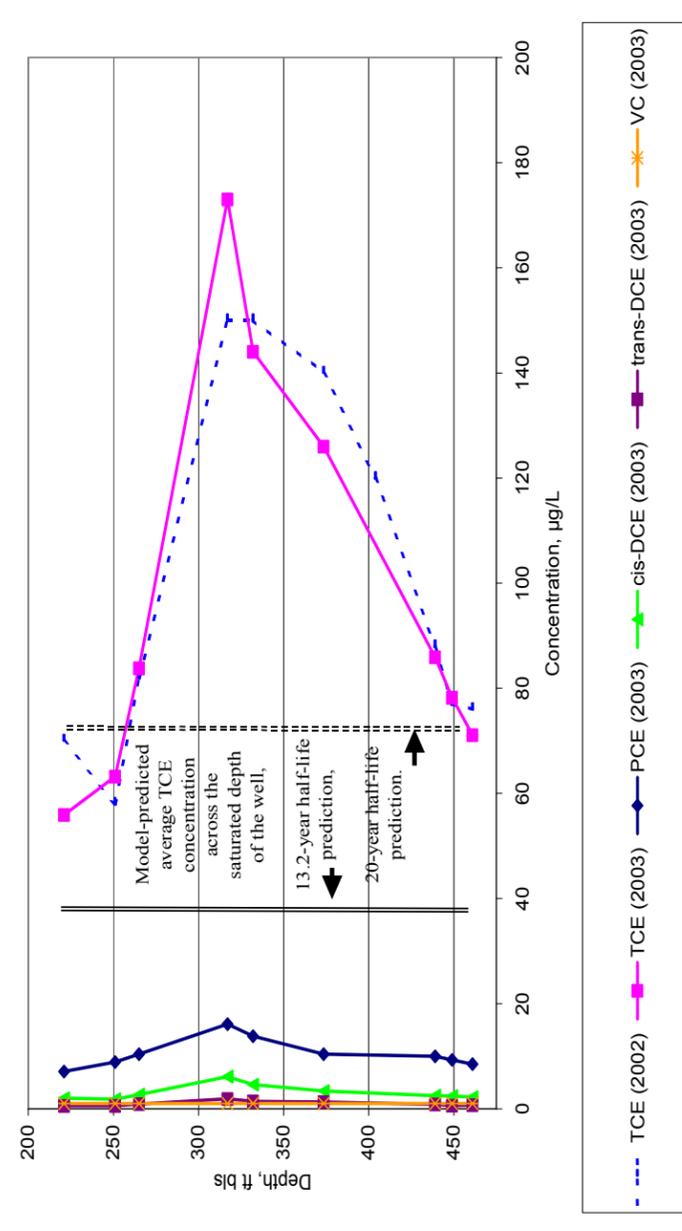


Figure D-4. Well TAN-55 volatile organic compound concentration vertical profile plot compared with model predictions.

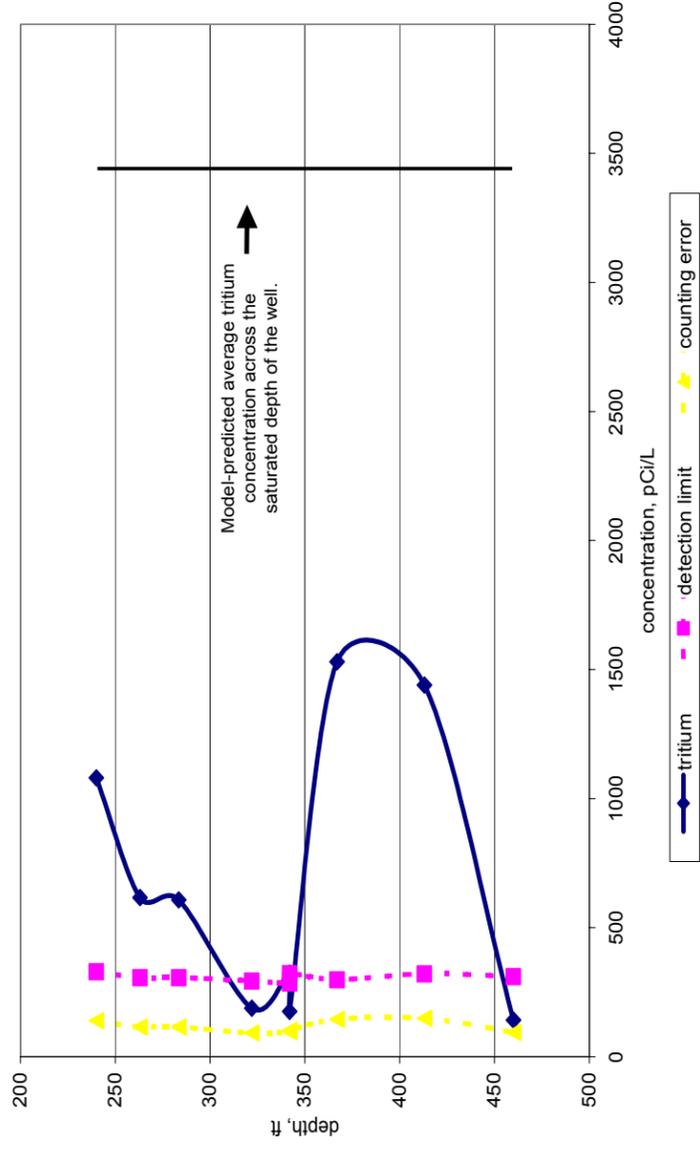


Figure D-5. Tritium concentration profiles with depth in water from Well TAN-51 including model predictions.

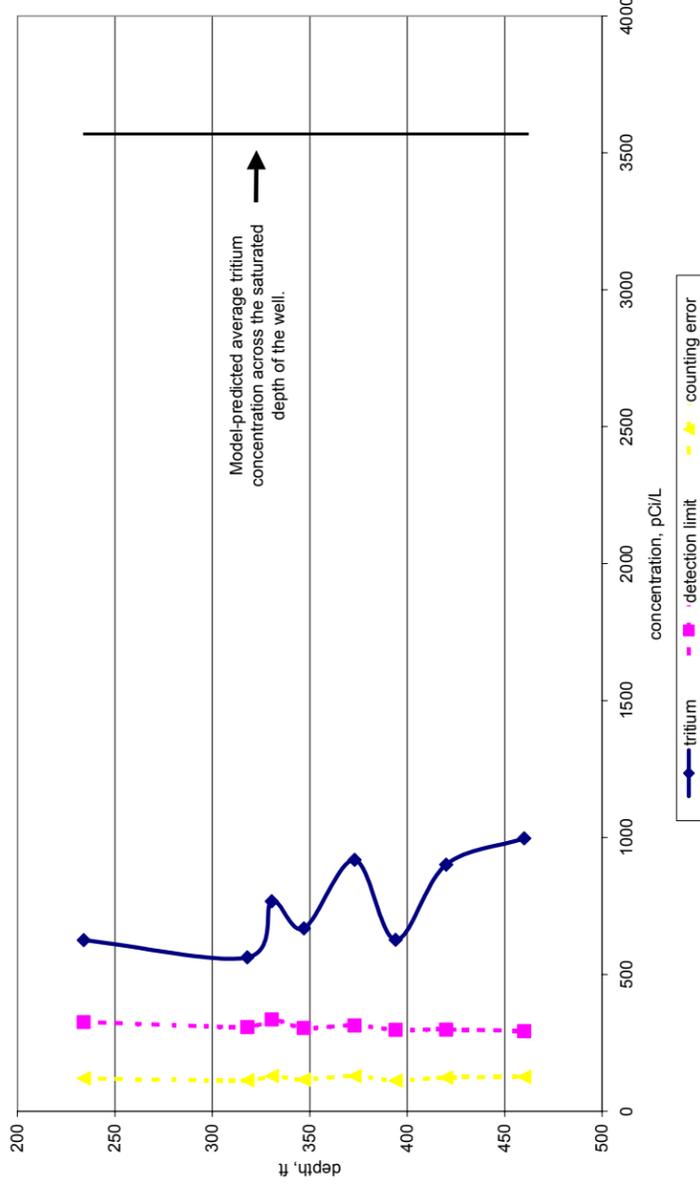


Figure D-6. Tritium concentration profiles with depth in water from Well TAN-54 including model predictions.

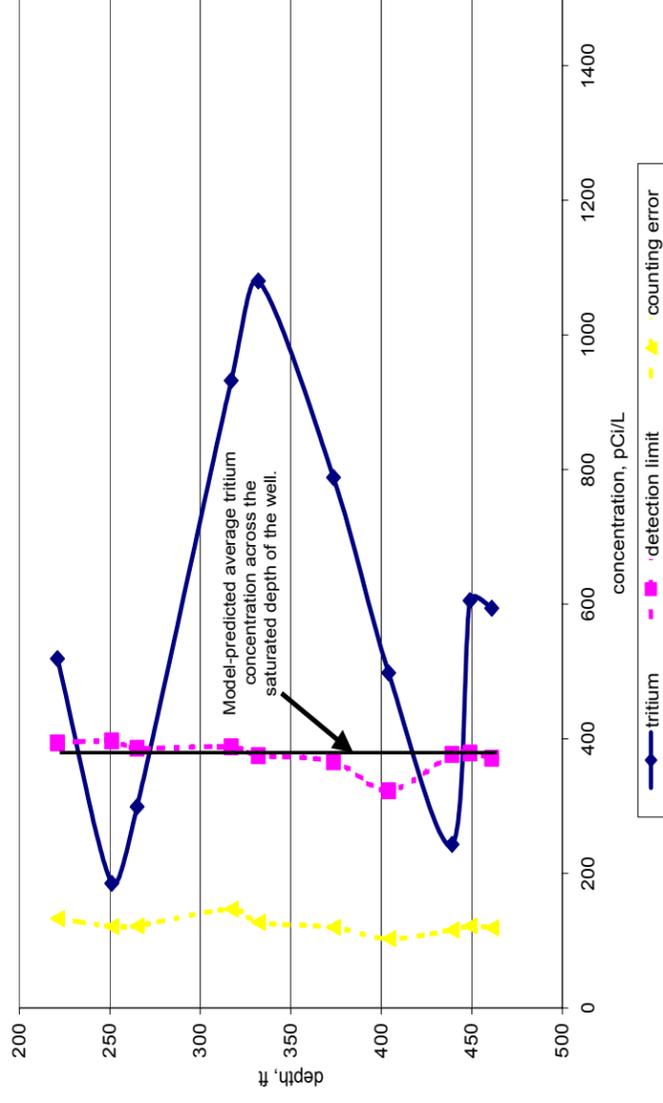


Figure D-7. Tritium concentration profiles with depth in water from Well TAN-55 including model predictions.

Table D-1. Average trichloroethene:tetrachloroethene ratios at different depths in each well, including standard deviation.

Well Name	Distance from TAN-39 (ft)	Average Natural Log of TCE:PCE with Depth	Standard Deviation
TAN-51	3,615	2.41	0.26
TAN-52	5,619	2.11	0.11
TAN-57	8,520*	0.96	0.11

PCE = tetrachloroethene
TCE = trichloroethene
* This distance is approximated.

Appendix E
Enzyme Probe Results

Appendix E

Enzyme Probe Results

E-1. ENZYME PROBE RESULTS

The results of enzyme probe sample analysis are presented in Table E-1, which includes all results except those of the controls. The “Toluene Oxygenase” column lists a plus sign for each of the four different toluene oxygenase enzyme probes that yielded a positive response for a given sample. The “Methane sMMO Probe” column presents the response to the methane probe, and the coumarin intensity column presents the intensity of the fluorescent response to the soluble methane monooxygenase (sMMO) probe.

Table E-1. Results of the applications of toluene oxygenase and soluble methane monooxygenase probes to Test Area North samples.

Well Name	Depth (ft bls)	Toluene Oxygenase (Number of Positive Probes)	Methane sMMO Probe	Coumarin, (Intensity/min)
58	295	++++	+	+10
16	307	++	+	+23
	230	+	+	+12
57	285	+	+	+7
	438	+	+	+10
56	242		+	+21
	438	++	+	+8
52	242	+++	+	+6
	361	+++	+	+9
	413		+	+9
51	322	+	+	+4
	240	++	+	+8

bls = below land surface

sMMO = soluble methane monooxygenase

E-2. CONTROL STUDIES

Table E-2 demonstrates the results of control studies performed for the sMMO enzyme probe studies. One control study was the naphthalene assay, where after addition of naphthalene, the product naphthol was monitored using a compound that forms a purple conjugate. If the purple color change is observed, then this is evidence that the sMMO enzyme is present in a given sample. From Table E-2, it can be seen that the color change was observed for all samples.

A second control study was the addition of a reductant, formate. Because cells gain no direct benefit from cometabolic trichloroethene (TCE) degradation, these systems are often reductant limited. The fluorescent response to application of coumarin to environmental samples was measured both in the absence and presence of formate. Table E-2 indicates that in all cases, the addition of formate resulted in a statistically significant increase in the fluorescent response.

A third control study was the application of an irreversible inhibitor, phenylacetylene, to the samples. Phenylacetylene is known to deactivate the sMMO enzyme. Thus, application of phenylacetylene to samples known to contain sMMO, as evidenced by a positive response to the application of coumarin, should result in the loss of the fluorescent response. Table E-2 indicates that inhibition of the fluorescent signal was observed in all samples to which phenylacetylene was applied.

Table E-2. Study results for soluble methane monooxygenase probe controls.

Well Name	Depth (ft bls)	Napthalene ^a	Formate ^b	Phenylacetylene ^c	Methane ^c
58	295	+	+	I	I
16	307	+	+	I	I
57	230	+	+	I	I
	285	+	+	I	I
56	242	+	+	I	I
52	438	+	+	I	I
	242	+	+	I	I
	361	+	+	I	I
51	413	+	+	I	I
	322	+	+	I	I
	240	+	+	I	I
57	438	+	+	I	I

a. “+” indicates a purple color change in response to the naphthalene assay.

b. “+” indicates a statistically significant increase in fluorescent response upon formate addition.

c. “I” indicates inhibition of the fluorescent signal.

bls = below land surface

The final and perhaps most convincing control study involved the use of methane as a competitive inhibitor. Methane is the primary substrate for the sMMO enzyme. Since the cometabolic transformation of TCE and other chlorinated ethenes is performed by the same active site on the sMMO enzyme, TCE and methane compete for this active site. The presence of high levels of methane can inhibit TCE degradation because the enzyme “prefers” methane over any other substrate. This is also true for the sMMO enzyme probe, coumarin. The samples were exposed to methane and then exposed to the atmosphere. In all cases, inhibition of the fluorescent signal was observed under methane-saturated conditions, and restoration of the fluorescent signal occurred when the samples were re-exposed to the atmosphere.

Appendix F
Dissolved Gas Profiles

Appendix F

Dissolved Gas Profiles

For dissolved gases, concentration profiles are presented in Table F-1 and in Figures F-1 through F-12.

Table F-1. Dissolved gases concentrations.

Zone	Well Name	Depth (ft bls)	H2		CO		CH4		C2H6	
			Average, nM	Error	Average, nM	Error	Average, nM	Error	Average, nM	Error
1	TAN 54	234	1.553	1.463	1.115	0.119	1.507	0.023	0.057	0.114
		318	1.776	0.736	0.913	0.223	2.998	0.057	0.313	0.184
		330.5	1.627	1.633	1.210	0.315	1.386	0.148	0.000	0.000
		347	1.994	0.139	0.423	0.009	1.146	0.009	0.000	0.000
		373	2.458	1.050	0.579	0.089	1.196	0.053	0.000	0.000
		394	2.279	0.911	0.528	0.051	1.272	0.110	0.000	0.000
		420	2.176	0.057	0.813	0.583	1.307	0.352	0.060	0.000
		460	2.552	0.343	1.279	0.129	1.880	0.067	0.000	0.000
	TAN 55	221	4.284	1.405	0.259	0.011	0.941	0.059	0.000	0.000
		251	3.381	1.283	0.479	0.326	0.902	0.031	0.000	0.000
		265	3.177	0.713	0.428	0.239	1.194	0.036	0.161	0.000
		317	3.193	0.239	0.469	0.125	2.105	0.002	0.186	0.000
		332	1.759	1.068	0.504	0.207	1.506	0.964	0.048	0.000
		373.5	3.236	1.433	0.264	0.011	1.367	0.280	0.000	0.000
		404	1.489	0.210	0.433	0.164	1.148	0.074	0.111	0.000
		439	1.580	0.111	0.507	0.212	1.509	0.958	0.000	0.000
	TAN 51	449	1.933	0.031	0.234	0.019	1.246	0.222	0.028	0.000
		461	1.426	0.500	0.420	0.139	1.124	0.028	0.000	0.000
		240	2.424	1.167	1.563	0.145	1.715	0.540	0.000	0.000
		263	0.752	0.129	0.922	0.317	2.240	0.156	0.240	0.000
		283.5	0.580	0.059	0.680	0.180	2.630	0.145	0.404	0.000
		322	2.103	0.126	0.448	0.070	1.049	0.077	0.000	0.000
		342	2.232	0.842	0.606	0.139	2.409	0.329	0.052	0.024
		342	1.007	0.418	0.622	0.078	2.371	0.237	0.175	0.074
	TAN 16	367	1.740	0.125	1.483	0.478	2.352	0.253	0.158	0.195
		413	0.741	0.176	0.875	0.209	2.226	0.199	0.115	0.026
	TAN 16	307	245.259	54.169	4.555	0.832	92.728	18.816	1.220	0.000

Table F-1. (continued).

Zone	Well Name	Depth (ft bls)	H2		CO		CH4		C2H6	
			Average, nM	Error	Average, nM	Error	Average, nM	Error	Average, nM	Error
2	TAN 52	220	2.225	0.251	0.628	0.017	1.181	0.174	0.000	0.000
		242	1.330	0.510	0.561	0.144	0.862	0.103	0.000	0.000
		266	2.223	0.952	1.139	0.267	1.027	0.144	0.000	0.000
		303	2.654	0.556	1.398	0.032	1.244	0.517	0.000	0.000
		361	2.464	1.067	0.890	0.316	1.893	0.341	0.000	0.000
		373	2.335	0.033	1.018	0.192	1.327	0.081	0.000	0.000
		395	3.120	0.947	0.737	0.104	1.314	0.133	0.000	0.000
		438	2.728	0.318	0.411	0.012	0.855	0.161	0.000	0.000
		456	3.073	0.001	0.342	0.042	1.064	0.179	0.036	0.000
		ANP 8	268	65.938	6.204	0.507	0.381	2.684	0.399	0.210
TAN 21	432	19.761	12.815	0.729	0.120	4.462	0.211	0.919	0.208	
3	TAN 57	230	324.909	75.557	0.654	0.042	57.949	18.416	0.196	0.064
		285	204.235	7.636	1.556	0.238	34.068	2.582	0.053	0.105
		353	188.494	16.842	2.053	0.352	43.709	17.102	0.000	0.000
		400	70.288	8.085	1.693	0.241	8.813	0.125	0.000	0.000
		438	73.230	20.728	0.520	0.064	2.670	0.066	0.000	0.000
	TAN 56	223	5.445	0.255	0.510	0.010	2.782	0.326	0.000	0.000
		242	4.624	2.533	0.797	0.162	0.529	0.114	0.000	0.000
		275	3.132	0.297	0.321	0.001	0.385	0.014	0.000	0.000
		334	4.026	0.247	0.853	0.938	0.721	0.075	0.000	0.000
		387	3.049	1.536	0.509	0.060	0.485	0.191	0.120	0.021
GIN 4	403	2.679	0.607	0.367	0.025	0.661	0.107	0.000	0.000	
	454	2.218	0.503	0.419	0.133	0.543	0.004	0.000	0.000	
	TAN 58	292	46.089	6.255	0.943	0.115	1.834	0.869	0.224	0.000
	TAN 58	295	20.145	5.241	0.385	0.075	96.929	18.792	0.000	0.000

bls = below land surface
C2H6 = ethane
CO = carbon monoxide
H2 = hydrogen
H4 = methane
nM = nano molar

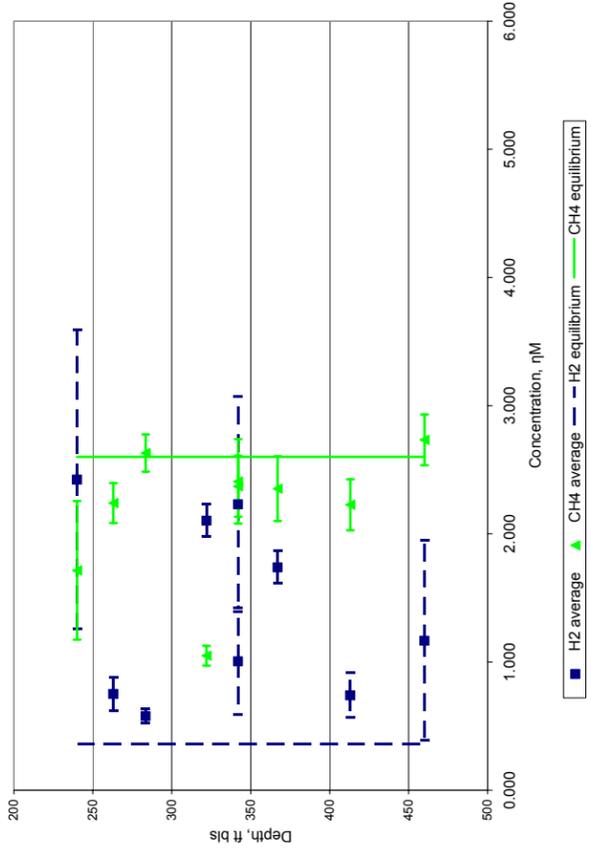


Figure F-1. Well TAN-51 methane and hydrogen concentrations.^a

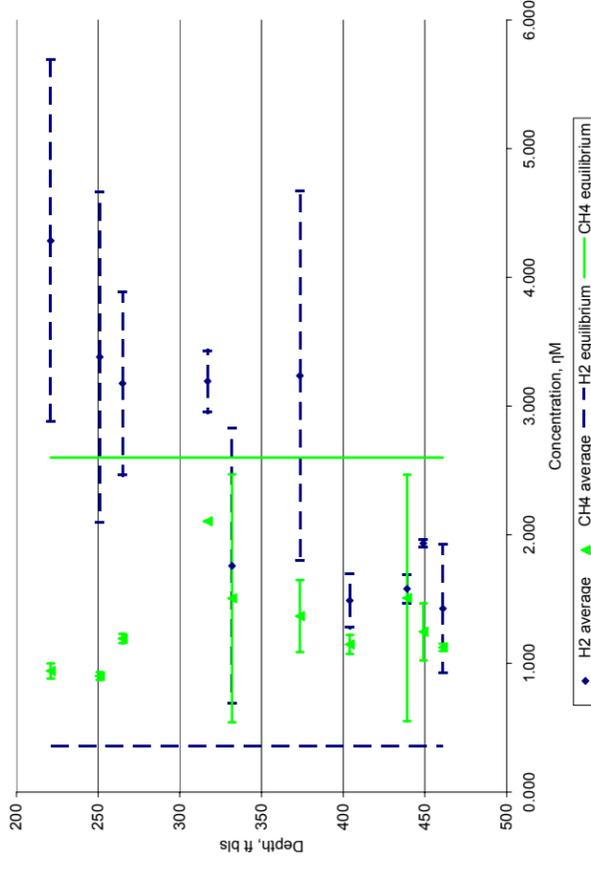


Figure F-2. Well TAN-55 methane and hydrogen concentrations.^a

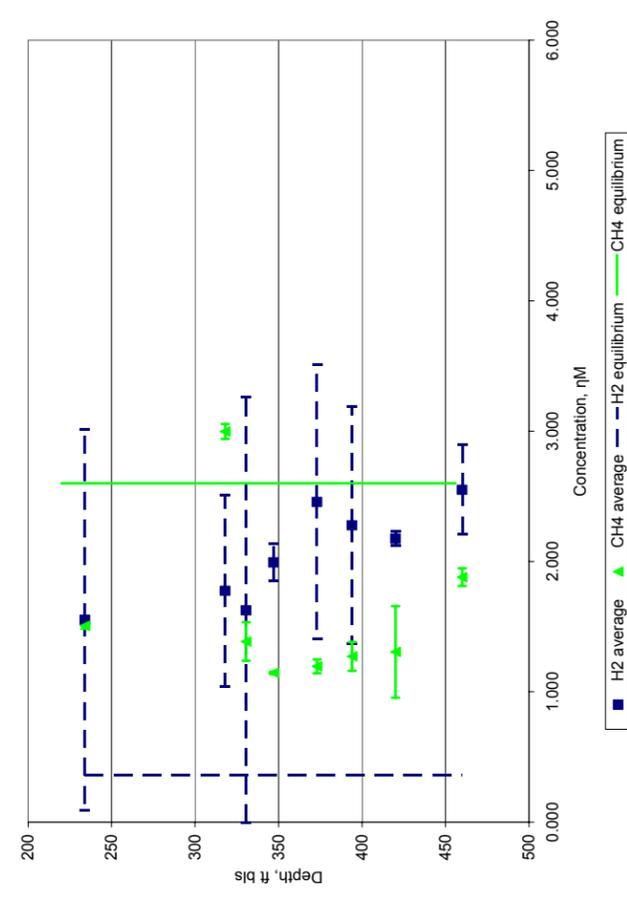


Figure F-3. Well TAN-54 methane and hydrogen concentrations.^a

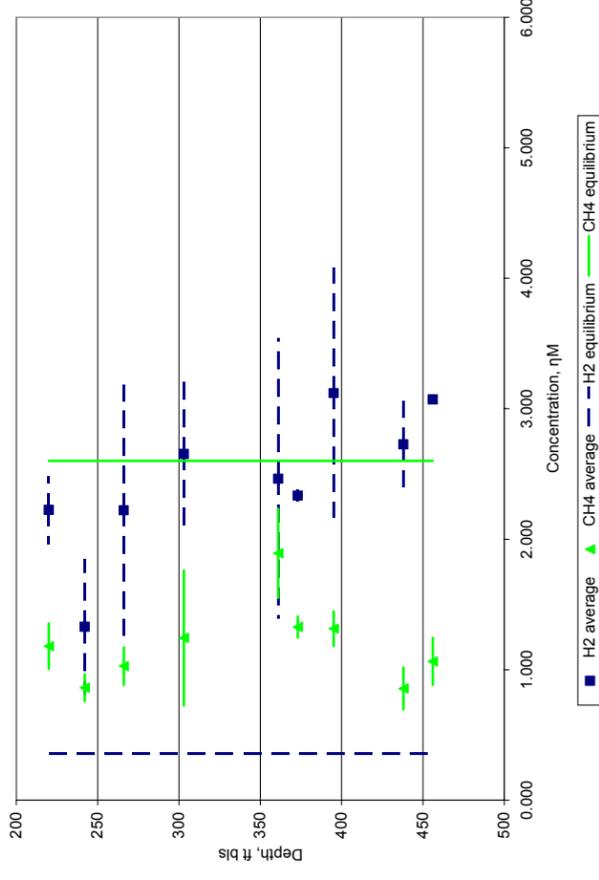


Figure F-4. Well TAN-52 methane and hydrogen concentrations.^a

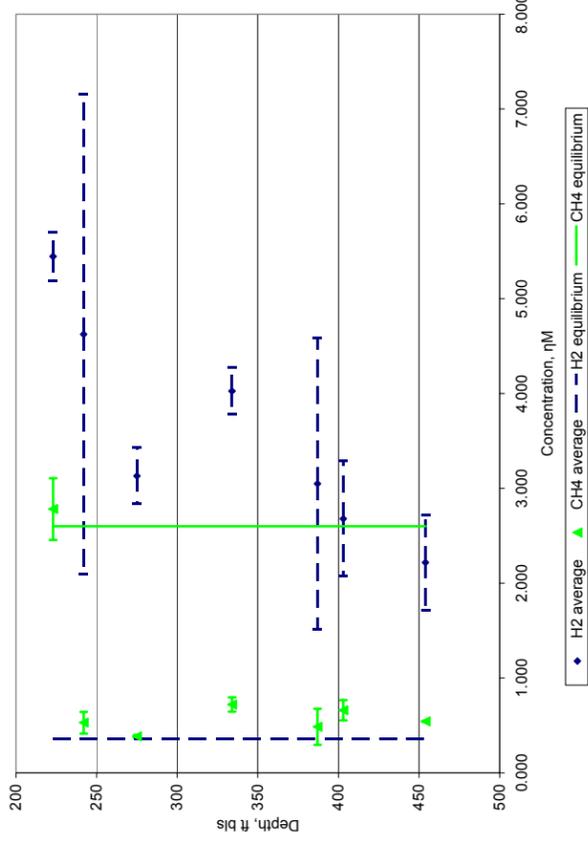


Figure F-5. Well TAN-56 methane and hydrogen concentrations.^a

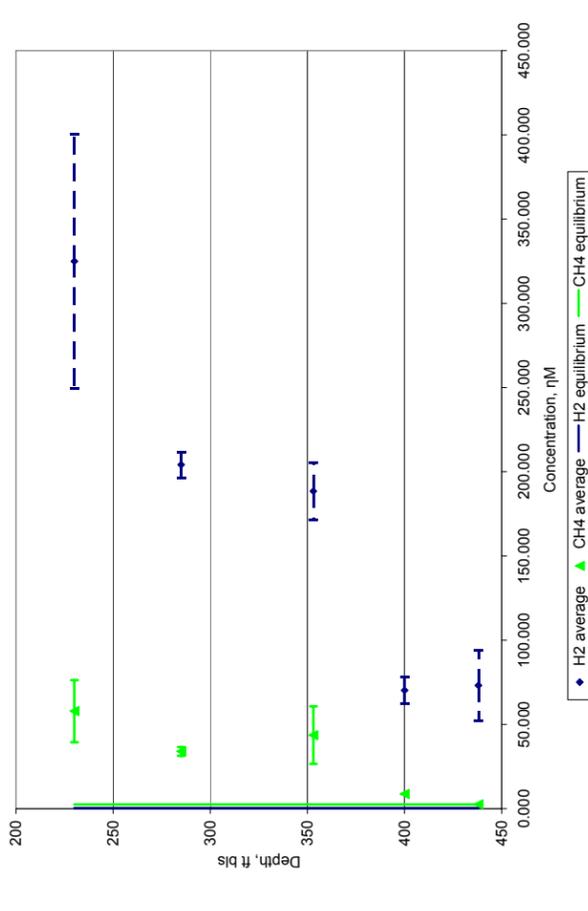


Figure F-6. Well TAN-57 methane and hydrogen concentrations.^a

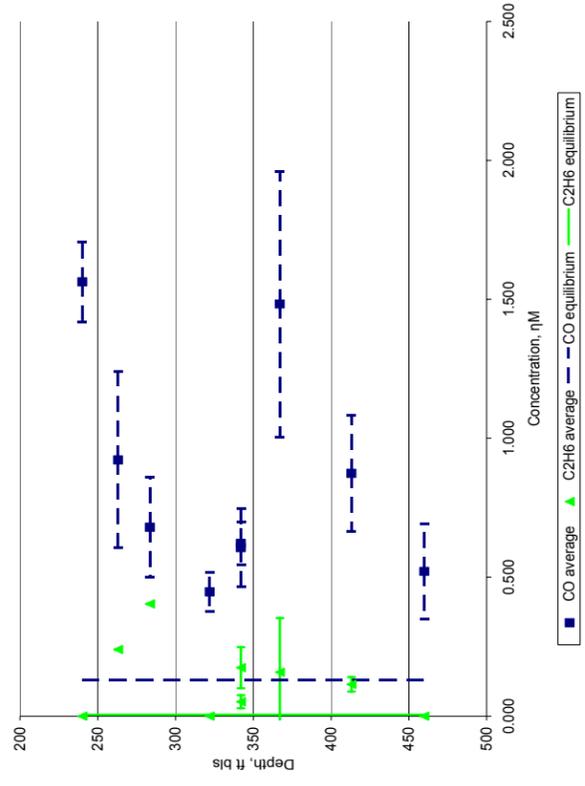


Figure F-7. Well TAN-51 ethane and carbon monoxide concentrations.^a

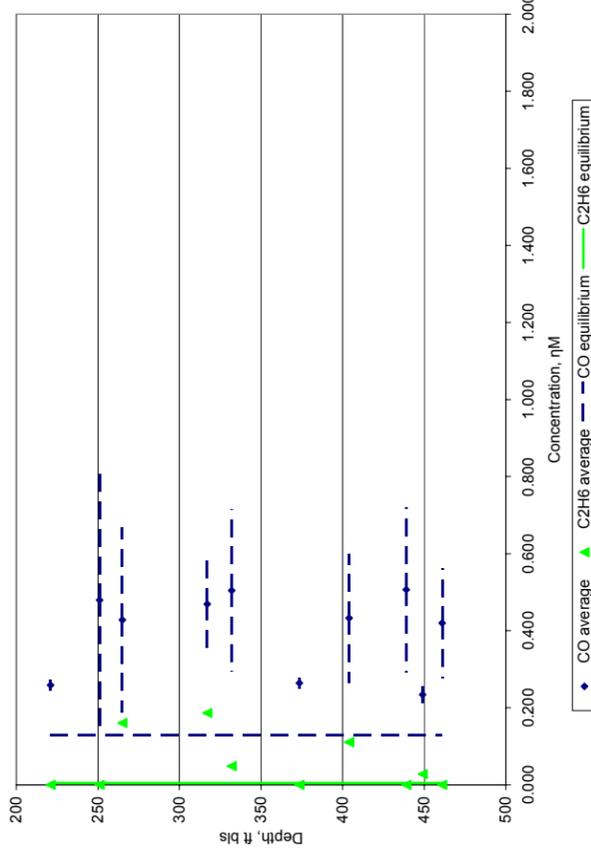


Figure F-8. Well TAN-55 ethane and carbon monoxide concentrations.^a

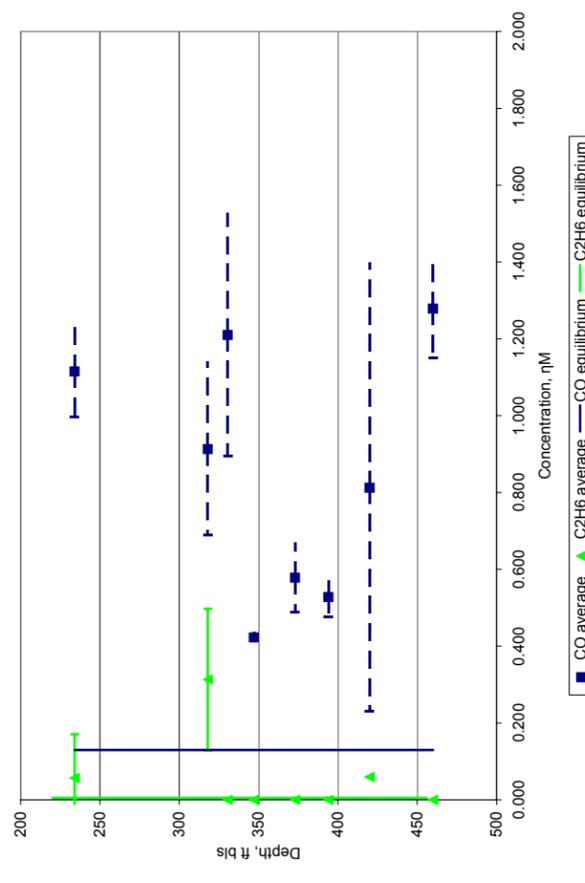


Figure F-9. Well TAN-54 ethane and carbon monoxide concentrations.^a

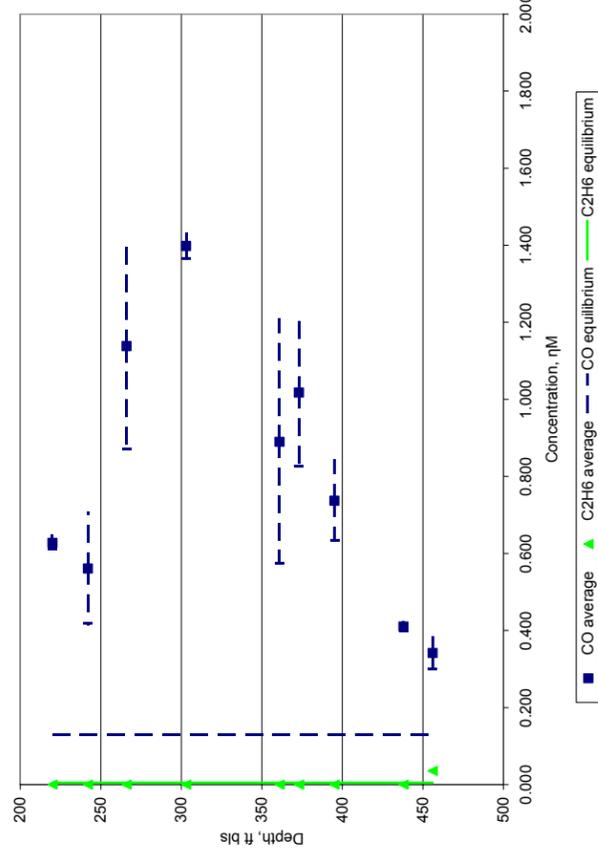


Figure F-10. Well TAN-52 ethane and carbon monoxide concentrations.^a

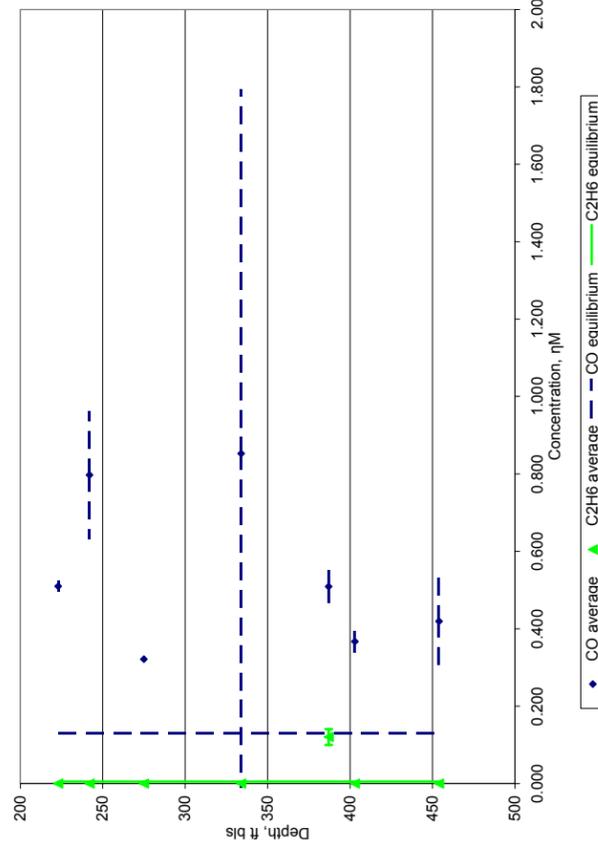


Figure F-11. Well TAN-56 ethane and carbon monoxide concentrations.^a

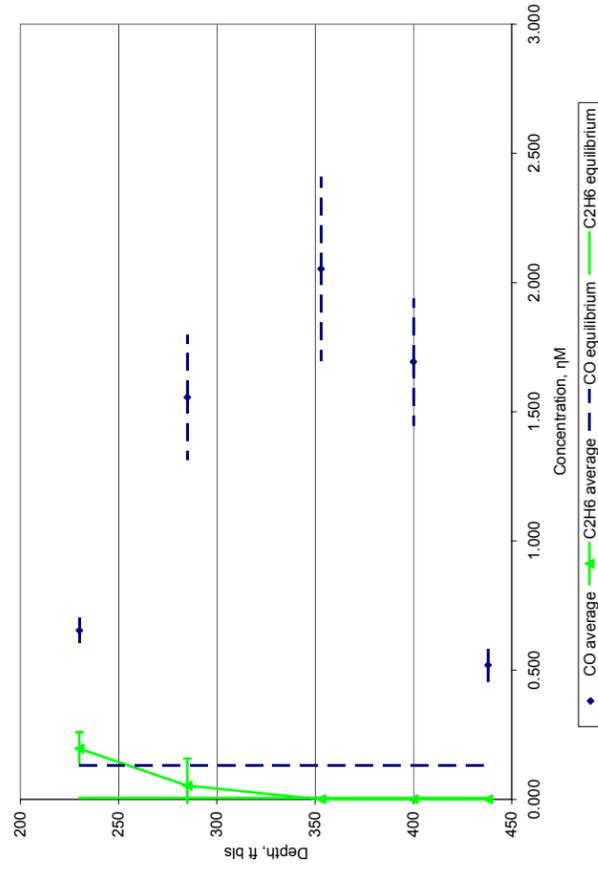


Figure F-12. Well TAN-57 ethane and carbon monoxide concentrations.^a

^a Although atmospheric contamination was unlikely because of (1) the closed-loop system used to collect the dissolved gas samples and (2) the short period of time between sample collection and analysis, if the reported concentrations are near or below the equilibrium atmospheric concentrations, then the possibility that the presence of the gas in the sample was solely due to contamination could not be excluded. However, if the reported concentrations are significantly higher than the equilibrium concentration, then the possibility that atmospheric contamination is solely responsible for the presence of the gas in the sample can be excluded. Comparison of the measured concentrations to those concentrations that would be expected if the sample were in equilibrium with the atmosphere permitted assessment of the potential for atmospheric contamination. The extent to which each gas partitions into the aqueous phase was determined using Henry's Law. To make this calculation, two things must be known. First, the atmospheric concentrations of each gas needed to be known. Second, the partitioning coefficients, in this case the Henry's Law constants, needed to be known. The required data were obtained from Manahan (1994) and Sander (2004) and the equilibrium concentrations were calculated including corrections for elevation and temperature. The values are represented in Figures F-1 through F-12 as vertical lines.