Appendix J

Natural Attenuation Analysis

WOC Natural Attenuation Analysis

Chlorinated hydrocarbons can degrade under a variety of environmental conditions. However, the most important process for the natural biodegradation of the highly chlorinated solvents, such as PCE and TCE, is reductive dechlorination. During this process, the chlorinated hydrocarbon is used as an electron acceptor, not as a source of carbon, and a chlorine atom is removed and replaced with a hydrogen atom. The following process illustrates the transformation of chlorinated ethenes via reductive dechlorination:

PCE → TCE → DCE → VC → Ethene → Ethane
or
PCE → TCE → DCE → VC → Carbon Dioxide

In general, reductive dechlorination occurs by sequential dechlorination from PCE to TCE to DCE to vinyl chloride (VC) to ethene. Depending upon environmental conditions, this sequence may be interrupted, with other processes then acting upon the products. During reductive dechlorination, all three isomers of DCE can theoretically be produced. However, Bouwer (1994) reports that under the influence of biodegradation, *cis*-1,2-DCE is a more common intermediate than *trans*-1,2-DCE, and that 1,1-DCE is the least prevalent of the three DCE isomers when they are present as daughter products. Reductive dechlorination of chlorinated solvent compounds is associated with the accumulation of daughter products and an increase in the concentration of chloride ions. Reductive dechlorination affects each of the chlorinated ethenes differently. Of these compounds, PCE is the most susceptible to reductive dechlorination, because it is the most oxidized. Conversely, VC is the least susceptible to reductive dechlorination, because it is the least oxidized of these compounds. As a result, the rate of reductive dechlorination decreases as the degree of chlorination decreases.

For the WOC site, to determine the occurrence of natural attenuation under the site-specific conditions, a total of four rounds of natural attenuation groundwater sampling were conducted on selected wells in November 1996, June 2001, June 2003, and January 2004. The groundwater samples were analyzed for the presence of the primary contaminants, as well as their daughter products, such as DCE and VC. The samples were also analyzed for other geochemical parameters, such as dissolved oxygen (DO), ferrous iron, nitrate, nitrite, sulfate, sulfide, methane, chloride, total organic carbon (TOC), pH, oxidation/reduction potential (ORP), temperature, and alkalinity. The analytical results are summarized in Table J-1. The results from June 2003 and January 2004 are also presented on Figures J-1 and J-2, respectively. The laboratory reports are contained in Appendix H.

To determine if biodegradation is occurring under the site-specific conditions, a systematic evaluation is conducted of the chemical and geochemical data collected during the natural attenuation sampling. The values of all chemical and geochemical parameters are compared to a

critical value, and a score value is awarded based on the likelihood that biodegradation is occurring. This evaluation method is based on the fact that biodegradation will cause predictable changes in groundwater chemistry. For example, if the DO concentration in the area is less than 0.5 mg/L, which indicates that reductive dechlorination is likely, three points are awarded; if the DO concentration is greater than 5 mg/L, which prohibits the anaerobic reductive dechlorination, negative (-) 3 points are awarded. The score awarded to a well is a sum of the points awarded for each chemical or geochemical parameter. The likelihood that the biodegradation is occurring is interpreted based on the scoring system as follows:

Biodegradation Evaluation Criteria

SCORE	INTERPRETATION
0 to 5	Inadequate evidence for anaerobic reductive dechlorination of chlorinated compounds.
6 to 14	Limited evidence for anaerobic reductive dechlorination of chlorinated compounds.
15 to 20	Adequate evidence for anaerobic reductive dechlorination of chlorinated compounds.
>20	Strong evidence for anaerobic reductive dechlorination of chlorinated compounds.

An evaluation of January 2004 sampling results is shown in Table J-2.

As shown in Table J-2, the scores from all the LSGS wells are less than 1, indicating inadequate evidence in support of anaerobic biodegradation of chlorinated compounds. Evaluation of the parameters from shallow well MW-201S resulted in a score of 5, indicating a possibility for slight biological activities in the shallow aquifer. This is believed to possibly be occurring due to the presence of the petroleum impacted site(s) to the east.

In summary, although chlorinated hydrocarbon concentrations are generally decreasing, preliminary natural attenuation screening for this site suggests that anaerobic biodegradation through reductive dechlorination is not the primary cause. The decrease in contaminant concentrations observed within the LSGS unit, and the current plume definition, is the result of attenuation mechanisms such as sorption, dilution, evaporation, dispersion, or abiotic degradation.

Table J-1
Analytical Results for Natural Attenuation Parameters

Well ID	Date Sampled	Natural Attenuation Parameters									
		D.O. (mg/L)	Nitrate (mg/L)	Fe^{2+} (mg/L)	Sulfate (mg/L)	Sulfide (mg/L)	Alkalinity (mg/L)	Chloride (mg/L)	TOC (mg/L)	pH	ORP mv
MW-1S	11/18/96	NT	NT	NT	57	NT	170	160	4.6	7.40	NT
MW-2S	11/19/96	NT	NT	NT	72	NT	190	170	4.5	7.60	NT
MW-3S	11/19/96	NT	NA	NT	94	NA	150	230	3.8	7.40	NT
	06/12/01	NT	0.81	NA	210	0.5	555	520	NT	NA	NA
MW-4S	11/18/96	NT	NT	NT	69	NT	200	150	5.0	7.40	NT
	06/06/01	NT	0.77	NA	58	0.5	152	140	NT	NA	NA
MW-5S	11/18/96	NT	NT	NT	67	NT	220	140	3.9	7.30	NT
	06/08/01	NT	0.29	NA	16	< 0.50	218	160	NT	NA	NA
MW-6S	11/20/96	NT	NT	NT	76	NT	230	120	3.7	7.40	NT
MW-7S	11/19/96	NT	NT	NT	110	NT	94	150	5.6	7.80	NT
MW-100S	06/18/03	6.14	1.5	NT	84	NT	190	180	<10	7.70	85
	09/19/03	5.10	1.4	0.0	83	0.0	210	180	1.53	7.01	208
MW-102S	06/11/01	NA	2.0	NA	91	NA	238	95	NT	NA	NA
	06/17/03	5.90	4.2	0.4	90	ND	390	28	<20	7.77	160
MW-103S	06/07/01	NA	2.1	NA	87	< 0.5	242	220	NT	NA	NA
MW-104S	06/11/01	NA	0.48	NA	93	NA	211	140	NT	NA	NA
	06/17/03	6.43	1.2	NT	100	NT	290	140	<20	7.53	183
	09/19/03	5.96	1.3	0	97	0.0	410	160	< 1.0	6.97	414
MW-201S	06/18/03	5.04	7.1	0.1	130	ND	340	340	<5.0	7.32	148
	09/18/03	5.20	7	0.2	130	0.0	370	130	1.25	6.81	320
	01/12/04	4.52	3	<0.1	130	<0.1	300	260	<5.0	7.32	180
ARCO MW-2	06/18/03	1.60	<0.2	<0.1	100	ND	580	460	1.1	6.67	164
	09/19/03	2.42	< 0.20	0.1	100	0.0	560	87	< 1.00	6.35	190
MW-2M	12/05/96	NT	NT	NT	98	NT	180	240	3.2	7.90	NT
	06/14/01	NA	NT	NA	130	NA	360	260	NT	NA	NA
	06/13/03	5.28	8.6	3.0	120	ND	160	290	<1.0	7.78	33
	01/12/04	5.92	7.7	<0.1	120	<0.1	180	300	<1.0	7.85	121
MW-3M	12/03/96	NT	NT	NT	97	NT	180	240	NT	7.40	NT
	06/16/03	5.12	NT	NT	NT	NT	NT	NT	NT	7.53	85
MW-4M	12/02/96	NT	NT	NT	72	NT	160	200	3.4	7.70	NT
	06/14/01	NA	NT	NA	100	NA	198	280	NT	NA	NA
	06/16/03	5.85	NT	NT	NT	NT	NT	NT	NT	7.60	58
MW-6M	12/06/96	NT	NT	NT	130	NT	260	270	4.6	6.80	NT
	06/14/01	NA	NT	NA	100	NA	279	320	NT	NA	NA
	06/13/03	7.45	NT	NT	NT	NT	NT	NT	NT	7.55	55

Table J-1
Analytical Results for Natural Attenuation Parameters

Well ID	Date Sampled	Natural Attenuation Parameters									
		D.O. (mg/L)	Nitrate (mg/L)	Fe^{2+} (mg/L)	Sulfate (mg/L)	Sulfide (mg/L)	Alkalinity (mg/L)	Chloride (mg/L)	TOC (mg/L)	pH	ORP mv
MW-7M	12/05/96	NT	NT	NT	71	NT	170	170	3.6	7.50	NT
	06/17/03	3.90	NT	NT	NT	NT	NT	NT	NT	7.64	86
MW-105M	06/04/01	NA	NT	NA	103	NA	175	250	NT	NA	NA
	06/12/03	4.92	6.5	<0.1	96	ND	180	270	<1.0	7.36	122
	01/12/04	5.75	7.8	<0.1	110	<0.1	180	280	<1.0	7.78	104
MW-107M	06/04/01	NA	NT	NA	120	NA	182	320	NT	NA	NA
	06/13/03	5.95	6.5	1.5	110	ND	190	290	1.2	7.27	139
	09/19/03	4.89	5.9	0.0	100	0.0	200	110	< 1.00	6.75	222
	01/12/04	6.73	6.5	<0.1	110	<0.1	190	290	1.2	7.29	158
MW-108M	06/16/03	9.46	6.0	1.0	120	ND	100	280	<1.0	7.05	187
	09/22/03	8.06	4.7	0.0	97	0.0	250	270	<1.0	6.76	259
	01/12/04	7.84	4.6	<0.1	110	<0.1	250	270	<1.0	7.57	216
MW-109M	06/16/03	5.04	9.2	1.0	110	ND	260	410	<1.0	7.28	174
	09/22/03	4.70	7.6	0.0	84	0.0	160	420	<1.0	6.74	354
	01/12/04	5.47	9.4	<0.1	97	<0.1	170	470	<1.0	7.25	166
MW-110M	06/17/03	3.01	1.6	<0.1	91	ND	180	170	3.5	7.69	114
	09/22/03	3.29	1.4	0.1	80	0.0	170	170	<1.0	7.10	293
	01/12/04	3.40	1.6	<0.1	97	<0.1	180	190	3.5	7.57	145

* Notes:

$CaCO_3$ = Calcium Carbonate

mg/L = milligrams per liter

D.O. = Dissolved Oxygen

ORP = Oxidation-Reduction Potential

TOC = Total Organic Carbon

DOC = Dissolved Organic Carbon

For the June 2003 sampling event, field test kits were used to determine Ferrous Iron (Fe^{2+}) and Sulfide concentrations.

NA = Data collected by thers, but not available to GeoTrans

NT = Not tested or analyzed

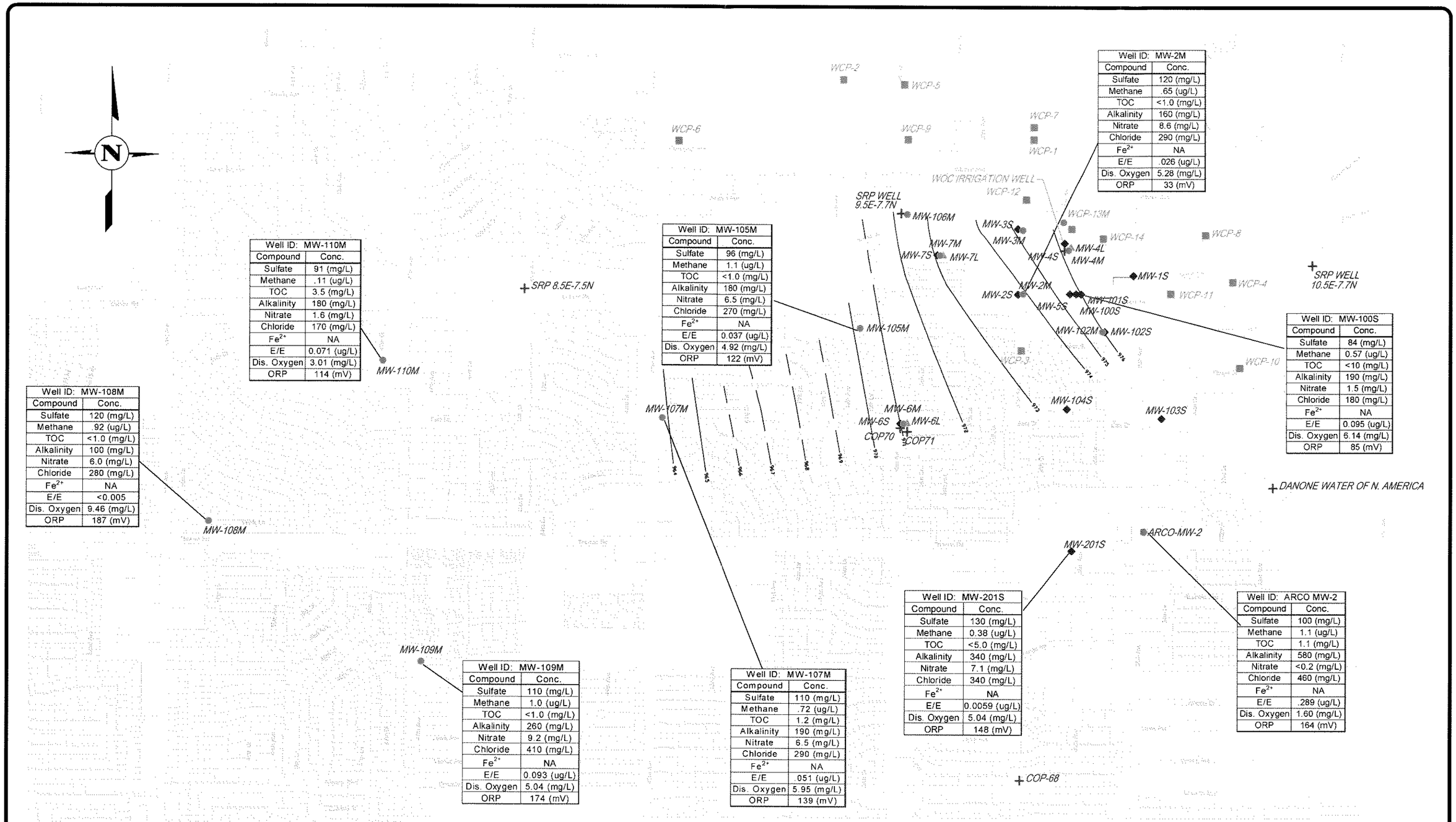
ND = Not detected at or above method reporting limit

Table J-2
Analytical Parameters and Weighting for Preliminary Screening for Anerobic Biodegradation Process
For the Sampling Event of January 2004

		Criterium #1		Criterium #2		Wells at center of the plume								Wells at down gradient of the plume					
						MW-2M		MW-201S		MW-105M		MW-107M		MW-108M		MW-109M		MW-110M	
Parameters	Unit	Conc.	Score	Conc.	Score	Conc.	Score	Conc.	Score	Conc.	Score	Conc.	Score	Conc.	Score	Conc.	Score	Conc.	Score
Dissolved Oxygen[1]	mg/L	<0.5	3	>5	-3	5.92	-3	4.52	0	5.75	-3	6.73	-3	7.84	-3	5.47	-3	3.40	0
Nitrate	mg/L	<1	2	>1	0	7.7	0	3	0	7.8	0	6.5	0	4.6	0	9.4	0	1.6	0
Ferrous Iron	mg/L	<1	0	>1	3	<0.1	0	<0.1	0	<0.1	0	<0.1	0	<0.1	0	<0.1	0	<0.1	0
Sulfate	mg/L	<20	2	>20	0	120	0	130	0	110	0	110	0	110	0	97	0	97	0
Sulfide	mg/L	<1	0	>1	3	<0.1	0	<0.1	0	<0.1	0	<0.1	0	<0.1	0	<0.1	0	<0.1	0
Methane	mg/L	<0.5	0	>0.5	3	--	--	0.00067	0	0.0012	0	0.029	0	0.0008	0	0.015	0	0.0064	0
ORP[2]	mv	<-100	2	<50	1	121	0	180	0	104	0	158	0	216	0	166	0	145	0
pH	--	5<pH<9	0	<5, or >9	-2	8.00	0	7.79	0	7.78	0	7.29	0	7.51	0	7.25	0	7.57	0
TOC	mg/L	<20	0	>20	2	<1.0	0	<5.0	0	<1.0	0	1.2	0	<1.0	0	<1.0	0	<1.0	0
Temperature	F	<20	0	>20	1	22.84	1	22.01	1	24.51	1	25.81	1	24.38	1	25.72	1	23.57	1
CO2	mg/L	<2x bg.	0	> 2x bg.	1	--		--	--	--	--	--	--	--	--	--	--	--	--
Alkalinity	mg/L	<2x bg.	0	> 2x bg.	1	180	0	300	0	180	0	190	0	250	0	170	0	180	0
Chloride	mg/L	<2x bg.	0	> 2x bg.	1	300	0	260	0	280	0	290	0	270	0	470	0	190	0
hydrogen	ng/L	<1	0	>1	3	--		--	--	--	--	--	--	--	--	--	--	--	--
BTEX	mg/L	<0.1	0	>0.1	2	<0.001	0	<0.001	0	<0.001	0	<0.001	0	<0.001	0	<0.001	0	<1.0	0
DCE[3]	ug/L	<ND	0	>ND	2	<1.0	0	1.5	2	1.5	2	1.5	2	<1.0	0	<1.0	0	<1.0	0
VC[3]	ug/L	<ND	0	>ND	2	<1.0	0	<1.0	0	<1.0	0	<1.0	0	<1.0	0	<1.0	0	<1.0	0
DCA[3]	ug/L	<ND	0	>ND	2	<1.0	0	<1.0	0	<1.0	0	<1.0	0	<1.0	0	<1.0	0	<1.0	0
Chloroethane[3]	ug/L	<ND	0	>ND	2	<1.0	0	<1.0	0	<1.0	0	<1.0	0	<1.0	0	<1.0	0	<1.0	0
Ethene+Ethane	ug/L	>10	2	>100	3		0	0.021	0	0.034	0	0.9	0	0.049	0	<0.005	0	0.036	0
Chloroform	ug/L	<ND	0	>ND	2	<1.0	0	10	2	<1.0	0	<1.0	0	<1.0	0	<1.0	0	<1.0	0
Total Score							**-2**		**5**		**0**		**0**		**-2**		**-2**		**1**

Note:
1: If oxygen concentration is between 0.5 to 5 mg/L, score is 0
2: If ORP is greater than 50, score is 0
3: Points awarded only when the compound is a doughter product, not material released
-- Not measured or not available

Source: EPA, *Technical Protocal for Evaluating Natural Attenuation of Chlorinated Solvent in Groundwater*. EPA/600/R-98/128



Well ID:	MW-2M
Compound	Conc.
Sulfate	120 (mg/L)
Methane	.65 (ug/L)
TOC	<1.0 (mg/L)
Alkalinity	160 (mg/L)
Nitrate	8.6 (mg/L)
Chloride	290 (mg/L)
Fe^{2+}	NA
E/E	.026 (ug/L)
Dis. Oxygen	5.28 (mg/L)
ORP	33 (mV)

Well ID:	MW-110M
Compound	Conc.
Sulfate	91 (mg/L)
Methane	.11 (ug/L)
TOC	3.5 (mg/L)
Alkalinity	180 (mg/L)
Nitrate	1.6 (mg/L)
Chloride	170 (mg/L)
Fe^{2+}	NA
E/E	0.071 (ug/L)
Dis. Oxygen	3.01 (mg/L)
ORP	114 (mV)

Well ID:	MW-105M
Compound	Conc.
Sulfate	96 (mg/L)
Methane	1.1 (ug/L)
TOC	<1.0 (mg/L)
Alkalinity	180 (mg/L)
Nitrate	6.5 (mg/L)
Chloride	270 (mg/L)
Fe^{2+}	NA
E/E	0.037 (ug/L)
Dis. Oxygen	4.92 (mg/L)
ORP	122 (mV)

Well ID:	MW-100S
Compound	Conc.
Sulfate	84 (mg/L)
Methane	0.57 (ug/L)
TOC	<10 (mg/L)
Alkalinity	190 (mg/L)
Nitrate	1.5 (mg/L)
Chloride	180 (mg/L)
Fe^{2+}	NA
E/E	0.095 (ug/L)
Dis. Oxygen	6.14 (mg/L)
ORP	85 (mV)

Well ID:	MW-108M
Compound	Conc.
Sulfate	120 (mg/L)
Methane	.92 (ug/L)
TOC	<1.0 (mg/L)
Alkalinity	100 (mg/L)
Nitrate	6.0 (mg/L)
Chloride	280 (mg/L)
Fe^{2+}	NA
E/E	<0.005
Dis. Oxygen	9.46 (mg/L)
ORP	187 (mV)

Well ID:	MW-201S
Compound	Conc.
Sulfate	130 (mg/L)
Methane	0.38 (ug/L)
TOC	<5.0 (mg/L)
Alkalinity	340 (mg/L)
Nitrate	7.1 (mg/L)
Chloride	340 (mg/L)
Fe^{2+}	NA
E/E	0.0059 (ug/L)
Dis. Oxygen	5.04 (mg/L)
ORP	148 (mV)

Well ID:	ARCO MW-2
Compound	Conc.
Sulfate	100 (mg/L)
Methane	1.1 (ug/L)
TOC	1.1 (mg/L)
Alkalinity	580 (mg/L)
Nitrate	<0.2 (mg/L)
Chloride	460 (mg/L)
Fe^{2+}	NA
E/E	.289 (ug/L)
Dis. Oxygen	1.60 (mg/L)
ORP	164 (mV)

Well ID:	MW-109M
Compound	Conc.
Sulfate	110 (mg/L)
Methane	1.0 (ug/L)
TOC	<1.0 (mg/L)
Alkalinity	260 (mg/L)
Nitrate	9.2 (mg/L)
Chloride	410 (mg/L)
Fe^{2+}	NA
E/E	0.093 (ug/L)
Dis. Oxygen	5.04 (mg/L)
ORP	174 (mV)

Well ID:	MW-107M
Compound	Conc.
Sulfate	110 (mg/L)
Methane	.72 (ug/L)
TOC	1.2 (mg/L)
Alkalinity	190 (mg/L)
Nitrate	6.5 (mg/L)
Chloride	290 (mg/L)
Fe^{2+}	NA
E/E	.051 (ug/L)
Dis. Oxygen	5.95 (mg/L)
ORP	139 (mV)

Explanation

- Deep Groundwater Monitoring Wells
- Intermediate Groundwater Monitoring Wells
- Shallow Groundwater Monitoring Wells
- WCP Wells
- ARCO Well
- Production Well

0 1000 2000

APPROXIMATE SCALE IN FEET

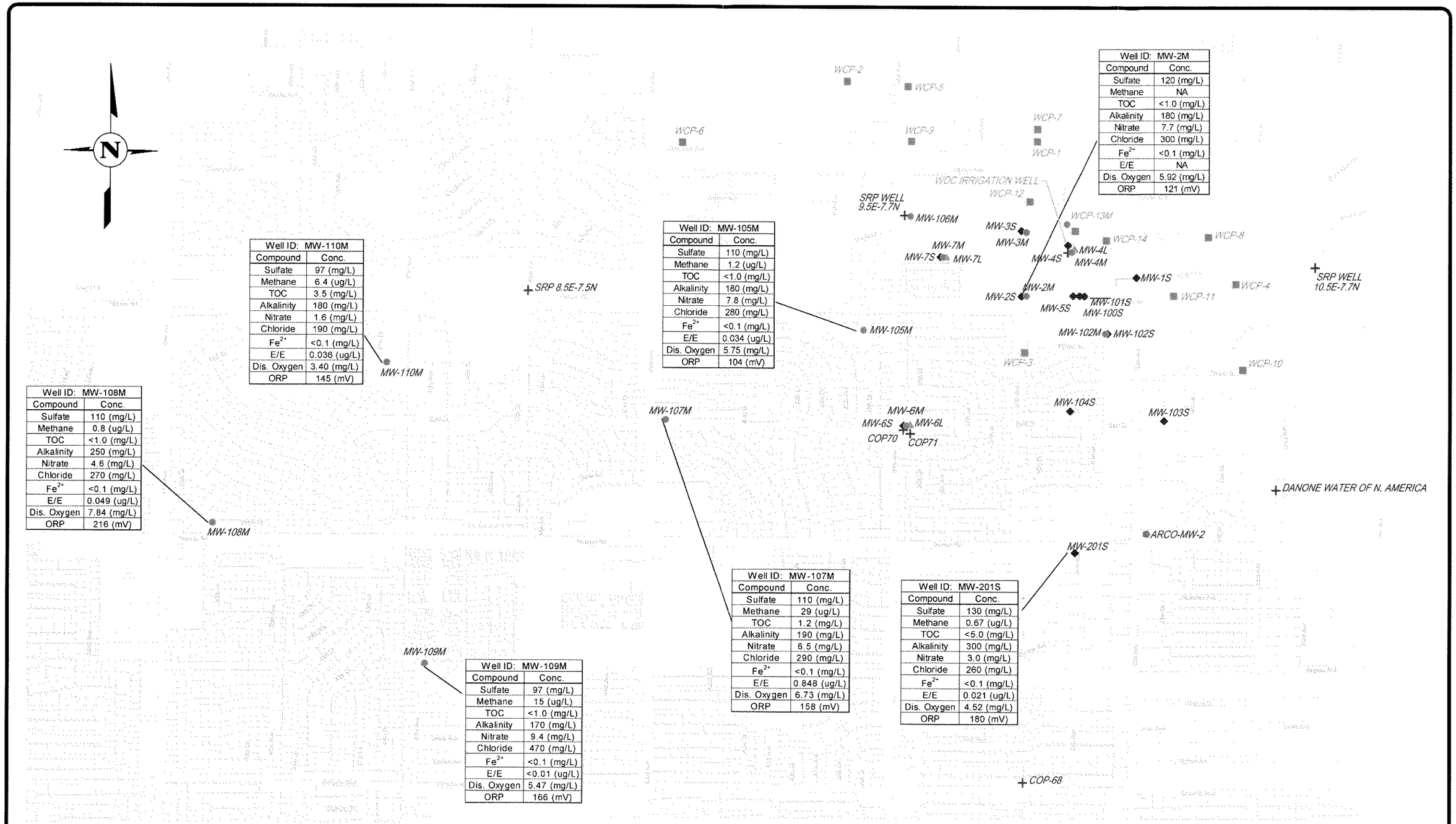
TITLE: UIC GROUNDWATER MONITORING NATURAL ATTENUATION PARAMETERS JUNE 2003

LOCATION: UNITED INDUSTRIAL CORPORATION

GeoTrans, Inc. A TETRA TECH COMPANY

CHECKED	SB
DRAFTED	JLB
PROJECT	2209.002
DATE	02/11/04

FIGURE J-1



Well ID:	MW-2M
Compound	Conc.
Sulfate	120 (mg/L)
Methane	NA
TOC	<1.0 (mg/L)
Alkalinity	180 (mg/L)
Nitrate	7.7 (mg/L)
Chloride	300 (mg/L)
Fe^{2+}	<0.1 (mg/L)
E/E	NA
Dis. Oxygen	5.92 (mg/L)
ORP	121 (mV)

Well ID:	MW-110M
Compound	Conc.
Sulfate	97 (mg/L)
Methane	6.4 (ug/L)
TOC	3.5 (mg/L)
Alkalinity	180 (mg/L)
Nitrate	1.6 (mg/L)
Chloride	190 (mg/L)
Fe^{2+}	<0.1 (mg/L)
E/E	0.036 (ug/L)
Dis. Oxygen	3.40 (mg/L)
ORP	145 (mV)

Well ID:	MW-105M
Compound	Conc.
Sulfate	110 (mg/L)
Methane	1.2 (ug/L)
TOC	<1.0 (mg/L)
Alkalinity	180 (mg/L)
Nitrate	7.8 (mg/L)
Chloride	280 (mg/L)
Fe^{2+}	<0.1 (mg/L)
E/E	0.034 (ug/L)
Dis. Oxygen	5.75 (mg/L)
ORP	104 (mV)

Well ID:	MW-108M
Compound	Conc.
Sulfate	110 (mg/L)
Methane	0.8 (ug/L)
TOC	<1.0 (mg/L)
Alkalinity	250 (mg/L)
Nitrate	4.6 (mg/L)
Chloride	270 (mg/L)
Fe^{2+}	<0.1 (mg/L)
E/E	0.049 (ug/L)
Dis. Oxygen	7.84 (mg/L)
ORP	216 (mV)

Well ID:	MW-107M
Compound	Conc.
Sulfate	110 (mg/L)
Methane	29 (ug/L)
TOC	1.2 (mg/L)
Alkalinity	190 (mg/L)
Nitrate	6.5 (mg/L)
Chloride	290 (mg/L)
Fe^{2+}	<0.1 (mg/L)
E/E	0.848 (ug/L)
Dis. Oxygen	6.73 (mg/L)
ORP	158 (mV)

Well ID:	MW-201S
Compound	Conc.
Sulfate	130 (mg/L)
Methane	0.67 (ug/L)
TOC	<5.0 (mg/L)
Alkalinity	300 (mg/L)
Nitrate	3.0 (mg/L)
Chloride	260 (mg/L)
Fe^{2+}	<0.1 (mg/L)
E/E	0.021 (ug/L)
Dis. Oxygen	4.52 (mg/L)
ORP	180 (mV)

Well ID:	MW-109M
Compound	Conc.
Sulfate	97 (mg/L)
Methane	15 (ug/L)
TOC	<1.0 (mg/L)
Alkalinity	170 (mg/L)
Nitrate	9.4 (mg/L)
Chloride	470 (mg/L)
Fe^{2+}	<0.1 (mg/L)
E/E	<0.01 (ug/L)
Dis. Oxygen	5.47 (mg/L)
ORP	166 (mV)

Explanation

- Deep Groundwater Monitoring Wells
- Intermediate Groundwater Monitoring Wells
- Shallow Groundwater Monitoring Wells
- WCP Wells
- ARCO Well
- Production Well

0 1000 2000
APPROXIMATE SCALE IN FEET

TITLE: UIC GROUNDWATER MONITORING NATURAL ATTENUATION PARAMETERS JAN, 2004

LOCATION: UNITED INDUSTRIAL CORPORATION

GeoTrans, Inc.

CHECKED	SB
DRAFTED	JLB
PROJECT	2209.002
DATE	02/11/04

FIGURE J-2