Table 6
Quarterly PCE Groundwater Sampling Results - May 2003 through February 2008
Jones Road Groundwater Plume Federal Superfund Site (SUP075)
Harris County, Texas
Shaw Project Number 137226

Updated: April 28, 2008

Location ID	May '03	Aug. '03	Nov. '03	Feb. '04	May '04	Aug. '04	Nov. '04	Feb. '05	May '05	Aug. '05	Nov. '05	Feb. '06	May/ Jul. '06	Aug. '06	Nov. '06	Feb. '07	May '07	Aug. '07	Nov. '07	Feb. '08	Additional Comments
AD11502	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	ND	NS	ND	NS	NS	NS	ND	NS	ND	NS	
AD11511	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	ND	NS	ND	
AD11603	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	ND	NS	NS	ND	ND	NS	NS	NS	NS	
AD11619	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	
AD11702	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	ND	ND	NS	NS	
AD11714	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	ND	NS	NS	
BH11603	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	ND	NS	NS	ND	ND	NS	NS	ND	NS	
BH11614	NS	NS	NS	NS	NS	ND	NS	ND	NS	NS	ND	NS	ND	ND	NS	NS	ND	ND	NS	ND	
BH11710	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	May '06-no access
BL10810	NS	NS	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
BL10818A	ND	ND	ND	ND	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
BL10819	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.069 LJ	ND	ND	0.071 LJ	ND	
BL10825	ND	ND	ND	ND	0.5 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
CP11510	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	
CP11610	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	ND	NS	NS	NS	
CP11650	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
CP11710	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	NS	NS	ND	ND	NS	NS	ND	NS	
CP11711	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	ND	NS	NS	ND	ND	NS	ND	NS	ND	
CP11718	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	NS	ND	NS	NS	NS	NS	NS	NS	
DK11503	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	
DK11603	NS	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	NS	
DK11611	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	ND	NS	NS	ND	NS	NS	NS	ND	NS	ND	
DK11702	NS	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	ND	NS	NS	NS	ND	NS	NS	NS	
DK11703	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	ND	NS	NS	NS	ND	NS	NS	NS	ND	
DK11707	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	
DK11710	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	
DK11718	NS	NS	NS	NS	ND	NS	ND	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	ND	NS	NS	
DK11719	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
DM11502	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	
DM11506	NS	NS	NS	NS	NS	ND	NS	ND	NS	NS	ND	NS	ND	NS	NS	NS	ND	ND	NS	NS	
DM11507	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	ND	NS	NS	ND	ND	NS	ND	NS	ND	
DM11509	NS	NS	NS	NS	NS	NS	NS	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
DM11513	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	ND	NS	
DM11515	NS	NS	NS	NS	NS	NS	ND	NS	ND	NS	NS	NS	ND	NS	NS	NS	ND	ND	NS	ND	
DM11715	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	No access, unable to contact owner.
ES11610	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	
ES11627	1.9	1.6	2.2	3.4	3.1 J	2.4	3	6.1	4.2	2.7	1.1	3.1	3.3	2.4	4.2	7.1	6	4	2.9	2.8	Filtration System added Feb. '05.
ES11630	NS	0.3 J	ND	ND	ND	1	ND	ND	0.99	0.17 J	1.6	1.4	1.9	1	1.1	0.63	1.1	0.97	0.95	0.75	
ES11643	0.3 J	ND	ND	.35 J	ND	ND	0.36 J	ND	0.57	0.84	0.86	0.55	0.76	0.56	0.5	0.41 LJ	0.59	0.95	1.3	0.58	
ES11703	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS	NS	ND	NS	Jul. '06, Aug. '06, Nov. '06, Feb '07, May '07, Aug '07, and Feb '08 - no power to well; house under construction.
ES11713	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
ES11718	NS	NS	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	Nov. '06 no access gate locked.
ES11730	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
FB11502	NS	NS	NS	NS	NS	ND	NS	NS	ND	ND	NS	NS	NS	NS	NS	NS	NS	ND	NS	ND	
FB11607	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	Nov. '06 & Feb '07 - sampling refused by owner.
FB11610	NS	NS	NS	NS	ND	NS	ND	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	May '06-no access
FB11614	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	ND	NS	NS	ND	NS	NS	NS	NS	ND	NS	
FV11014	204	178	240	590	240	210	240	200	210	200	270	470	230	230	281	207	206	11.6	115	103	Filtration System
FV11022	36.2	53.2	48	42	36	57 J	40	37	38	57	45	44	47	52	62.2	64.8	42.3	43.4	64	57	Filtration System
FV11023	183	153	190	240	190	210	170	140	120	130	150	90	130	130	145	142	130	104	93.1	89.2	Filtration System
FV11025	NS	NS	NS	NS	5.5	7.3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Filtration System Refused by Owner. Sampling refused by owner as of Nov. '04

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FV11102	NS	6.3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	No access from owner, filtration system refused.
FV11110	0.6	0.9	0.68	0.81	ND	0.98	0.20 J	0.36 J	0.51	0.57	0.46 J	0.33 LJ	0.47 LJ	ND	0.32 LJ	0.35 LJ	ND	0.39 LJ	0.23 LJ	ND	
FV11118	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.076 J	ND	ND	ND	ND	ND	0.069 LJ	ND	ND	0.10 LJ	ND	Owner installed filtration system as of Feb. '06.
FV11123	ND	ND	0.23J	ND	ND	0.29 J	0.15 J	0.25 J	ND	0.16 J	0.15 J	ND	0.19 LJ	ND	0.10 LJ	0.13 LJ	ND	ND	0.12 LJ	ND	
FV11127	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
FV11130	11.3	5.3	8.1	10	7.6	4	3.2	6.9	4.8	5	7.9	3.7	9.9	11	14.6	17.5	31.6	36.6	40.4	45	Filtration System
FV11135	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
FV11202	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Re-sampled July '06.
FV11203	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
FV11210	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Owner installed filtration system as of Feb. '06. Sample taken from faucet May 07'
FV11215	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	0.16 LJ	ND	ND	ND	ND	ND	ND	ND	Owner installed filtration system as of Feb. '06.
FV11226	ND	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
FV11231	ND	NS	NS	NS	2.6 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS	ND	ND	ND	NS	Feb '07 and Feb '08 - No power to the well.
FV11302	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
FV11306	ND	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Shares well with FV11314
FV11315	NS	NS	NS	NS	ND	NS	ND	ND	ND	ND	ND	ND	0.26 LJ	ND	ND	ND	ND	ND	ND	ND	
FV11319	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Re-sampled July '06.
FV11322	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS	ND	No Access-Gate Locked Nov '07
FV11326	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
GL11302	NS	NS	NS	NS	NS	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
GL11310	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	
GL11402	NS	NS	NS	NS	NS	ND	ND	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	
GL11422	NS	NS	NS	NS	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	No access. Gate locked.
GL11502	NS	NS	NS	NS	ND	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
GL11503	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
GL11506	NS	NS	NS	NS	NS	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
GL11514	NS	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
GL11606	NS	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
GL11614	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
GL11622	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
GL11702	NS	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	May '06-not sampled per owner's request.
JR11010	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.14 J	ND	0.18 LJ	ND	ND	0.13 LJ	ND	ND	ND	0.28 LJ	0.21LJ	
JR11043	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.083 LJ	ND	ND	0.14	ND	Shares w/PWS well JR11035. Too far south, not on the map.
JR11414	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
JR11427	9	9	12	19	14	20	20	21	24	24	24	21	29	31	43.2	47.4	43.9	50.4	41.2	37.4	Filtration System
JR11503	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
JR11515	0.7	1	0.75	0.62	ND	1	0.58	0.82	0.57	1.2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Oct.'05-not sampled per owner's request.
JR11526	NS	1.2	1.8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Shares well with JR11528.
JR11527	NS	NS	NS	180	94	79	120	93	190	68	89	100	94	100	124	127	141	137	122	110	Could not sample prior to Nov. '03. Filtration System.
JR11528	1.3	1.5	1.3	2.6	1.5	3	2.2	3.1	1.7	2.9	3.6 J	6	3.4 J	3.1	4.3	4.5	3.9	6.6	9.6	6.6	Filtration system installed June '06.
JR11535	121	101	71	ND	69	45	84	64	140	64	57	67	50	71	67.4	84.7	75.1	85.5	83.9	74.7	Filtration System. Feb. '04 result is correct. Shares well with FV11011.
JR11600	0.8	1.1	1.4	2.7	2.4	1.8 J	1.9 JV	1.8	2.2	2.2 JV	2	3.3 J	2.1	3.4	3.4 J	5.3	4.4	4.2	7.1	6.2	
JR11614	8.8	10.2	14	15	15	21	16	18	19	22	36	31	28	33	42.5	23.4	30.8	33.8	33.8	28.2	Filtration System
JR11620	ND	ND	0.15J	.43J	ND	.39 J	0.29 J	0.44 J	0.15 J	0.36 J	0.40 J	0.43 LJ	0.46 LJ	ND	0.58	0.7	0.63	ND	1.1	0.72	
JR11642	0.6	1.2	0.86	2.2	0.77	1.7	1.4	1.6	0.64	1.6	1.6	2.3	2.1	1.6	1.7	1.6	3.8	11.3	24	28	Filtration System
JR11646	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	

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JR11650	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
JR11655	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.14 LJ	ND	ND	ND	ND	ND	ND	0.092 LJ	ND	
JR11663	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
JR11702	ND	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
JR11707	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
JR11718	ND	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	No access. Gate locked May '07.
JR11729	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
JR117291/2	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
JRW11050A	ND	NS	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
JRW11107	ND	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
JRW11203	ND	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
JRW11206	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
JRW11215	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
JRW11222	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
JRW11234	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
JRW11351	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
JRW11352	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
JRW11354	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
JRW11358	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
MI11502	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
MI11507	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	NS	ND	NS	ND	
MI11510	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	ND	NS	NS	ND	ND	NS	ND	
MI11515	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	NS	
MI11603	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
MI11611	NS	NS	NS	NS	ND	NS	NS	ND	NS	NS	ND	NS	NS	ND	NS	NS	ND	NS	ND	NS	
OV11503	NS	NS	NS	NS	ND	ND	ND	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	
OV11507	NS	NS	NS	NS	NS	ND	ND	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	NS	No power to well in Nov. '05 and Feb. '06.
OV11519	NS	NS	NS	NS	ND	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
OV11523	NS	NS	NS	NS	NS	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
OV11527	NS	NS	NS	NS	NS	ND	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
OV11534	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
OV11547	NS	NS	NS	NS	.38 J	ND	ND	ND	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
OV11602	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
OV11603	NS	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
OV11610	NS	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
OV11618	NS	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
OV11623	NS	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
OV11626	NS	NS	NS	NS	ND	ND	ND	ND	NS	ND	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	Pump broken Nov. '05; shares well with OV11618
OV11634	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Re-sampled July '06.
OV11635	NS	NS	NS	0.91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Feb '04 duplicate samples: ND & 0.91
OV11642	ND	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
OV11651	NS	NS	NS	NS	ND	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
OV11738	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
PH11602	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Re-sampled July '06.
PH11603	ND	NS	NS	NS	ND	ND	ND	ND	2.8	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	No water to well Nov. '05; gets water from PH11610
PH11610	ND	NS	NS	NS	ND	ND	ND	ND	3.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Re-sampled July '06.
PH11611	ND	NS	NS	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Re-sampled July '06.
PH11618	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
PH11619	ND	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Re-sampled July '06.
PH11626	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS	ND	ND	No power to well Aug '07
PH11627	NS	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
PH11643	NS	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
PH11650	ND	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.051 LJ	ND	

Table 6
Quarterly PCE Groundwater Sampling Results - May 2003 through February 2008
Jones Road Groundwater Plume Federal Superfund Site (SUP075)
Harris County, Texas
Shaw Project Number 137226

Updated: April 28, 2008

Location ID	May '03	Aug. '03	Nov. '03	Feb. '04	May '04	Aug. '04	Nov. '04	Feb. '05	May '05	Aug. '05	Nov. '05	Feb. '06	May/ Jul. '06	Aug. '06	Nov. '06	Feb. '07	May '07	Aug. '07	Nov. '07	Feb. '08	Additional Comments
PH11651	NS	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS	Feb. '07 not sampled per owner's request
PH11702	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	
PH11710	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	May '06-not sampled per owner's request.
PH11713	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	
PH11722	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
PH11738	NS	NS	NS	ND	ND	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	
PH11739	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	NS	NS	NS	NS	NS	NS	Nov. '06 - no access gate locked; Feb '07 - not sampled per owner's request.
TC11018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.27 LJ	ND	ND	
TC11019	1.5	2.9	1.4	2.5	.5 J	5.1	2.4	3.8	5.3	3.8	5.4	ND	ND	8.8	7.4	13.2	23	20.6	17.4	22.8	Filtration System
TC11022	4.7	5.3	6.8	6.1	7.4	6.2	7.5	9.5	8	12	15	15	16	17	19.4	15	12.3	11.2	8.6	9.2	Filtration System. Re-sampled July '06.
TC11027	NS	NS	NS	NS	10	6.6	13	12	8.7	10	23	17	18	11	NS	NS	16	21.9	21.1	22.4	Filtration System. No power to the well through Feb '04. Re-sampled July '06. Nov. '06 and Feb '07 - no power to well.
TC11034	ND	0.5	ND	ND	ND	ND	ND	ND	ND	0.37 J	0.28 J	0.28 LJ	0.31 LJ	0.73	0.37 LJ	0.57	ND	0.23 LJ	0.58	ND	
TC11035	1.6	ND	0.26J	1.4	.4 J	0.31 J	0.99	0.33 J	ND	0.57	2.1	1.1	1.1	0.82	1.9	2.5	ND	2.3	4.9	2.5	
TC11103	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.14 J	ND	0.090 LJ	ND	ND	ND	ND	ND	ND	ND	Filtration System
TC11104	58.4	50.2	96	140	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Currently sharing water with the well located at TC11034.
TC11106	1.4	1.9	1.4	2.2	2.3 J	2.9	2.7	2.3	ND	4.4	4	4	3	3.1	2.9	3.5	2.4	2.6	3.3	2.4	2 wells- 1st drilled
TC11107	13.4	11	15	14	17	16	18	21	18	21	19 J	17	20	21	32.8	35.7	NS	29.1	31.1	39.4	Filtration System. Unable to sample because pump head disconnected Aug '07.
TC11108	ND	0.5	ND	.18J	ND	.2 J	ND	0.16 J	ND	3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Shares well with TC11106.
TC11110	1.2	1	1.2	1.5	ND	1.9	1.8	1.3	2.6	1.8	2.3	3.1	3.1	3.4	3.1	2.2	2.2	1.7	2	1.8	
TC11115	NS	12.3	16	12	21	21	19	20	30	23	13 J	24	32 J	15	41.5	38	33.1	29.1	44	32.3	Filtration System
TC11118	2	1.7	2.6	4.4	3 J	6.1	3.3	3.7	3.1	3.5	4.4	5.7 J^	ND	5.6	5.8	4.8	4.5	5.5	5.6	6.6	Filtration System
TC11126	2.7	3.2	3.1	5.1	6.6	10	5.7	7.7	7.1	7.1	6.7	7.2 J^	7	5.1	10.1	8.6	7.1	8	7.4	NS	Filtration System. No power to well Feb 'o8.
TC11130	1.9	1.9	1.4	3.7	3.8 J	4.4	1.9	1.4	1.8	3.4	3.2	2.3	4.4	7.3	10.8	6.4	6.3	5.2	5.3	4.2	Filtration System installed Oct. '06.
TC11132	ND	ND	ND	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	NS	ND	ND	ND	ND	NS	Nov. '06 no access gate locked. No power to well Feb '08.
TC11135	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TC11140	ND	NS	ND	.19J	.42 J	ND	ND	ND	0.32 J	0.30 J	0.38 J	0.29 LJ	0.38 LJ	0.40 LJ	0.47 LJ	0.44 LJ	ND	0.53	0.61	0.40LJ	Feb '07 - sample taken from kitchen faucet per owner's request.
TC11203	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TC11206	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TC11214	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS	NS	ND	ND	ND	ND	Nov. '06 and Feb '07 no access gate locked.
TC11215	ND	NS	NS	NS	NS	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	The pump had problems, the sampler could not complete the purge in Feb. '05.
TC11219	ND	NS	NS	ND	ND	ND	ND	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TC11227	ND	NS	NS	NS	NS	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
TC11303	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
TC11315	NS	NS	NS	NS	ND	ND	ND	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TC11318	ND	NS	NS	NS	NS	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
TC11330	NS	NS	NS	NS	NS	ND	ND	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TC11331	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	NS	ND	ND	No power to the well Nov. '04 to Feb. '06 No power to well Aug '07.
TH11602	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	

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Harris County, Texas
Shaw Project Number 137226

Updated: April 28, 2008

Location ID	May '03	Aug. '03	Nov. '03	Feb. '04	May '04	Aug. '04	Nov. '04	Feb. '05	May '05	Aug. '05	Nov. '05	Feb. '06	May/ Jul. '06	Aug. '06	Nov. '06	Feb. '07	May '07	Aug. '07	Nov. '07	Feb. '08	Additional Comments
TH11603	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.64	ND	ND	ND	ND	ND	ND	ND	Multiple spigots needed to be used to get the pump running continuously.
TH11610	10.6	3.1	11	6	6.4	11	4.1	9.8	15	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Filtration system removed prior to Aug. '05 at owner's request.
TH11611	ND	ND	ND	ND	.27 J	ND	0.21 J	ND	ND	0.32 J	0.36 J	0.66	ND	0.57	1.1	0.85	0.85	0.91	0.84	0.34LJ	
TH11618	7.9	ND	ND	4.8	7.6	5.6	ND	2.3	22	ND	ND	ND	0.64	ND	ND	26.2	136	89.9	93.5	98.5	Filtration System
TH11619	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Per owner request, not sampled Aug.'05.
TH11620	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.19 J	0.15 J	0.21 LJ	0.11 LJ	ND	ND	0.056 LJ	ND	ND	0.071 LJ	ND	
TH11627	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Currently sharing water with the well located at TH11635.
TH11635	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TH11642	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.19 J	0.18 J	ND	0.20 LJ	0.24 LJ	0.19 LJ	0.27 LJ	0.21 LJ	0.22 LJ	0.32 LJ	ND	
TH11643	ND	NS	NS	NS	ND	ND	ND	ND	ND	0.11 J	ND	ND	ND	ND	ND	ND	ND	ND	0.059 LJ	ND	
TH11651	NS	NS	NS	NS	ND	NS	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
TH11703	ND	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TH11713	NS	NS	NS	NS	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TH11722	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TH11723	NS	NS	NS	NS	NS	ND	NS	NS	NS	ND	ND	7.8 J	ND	ND	ND	ND	ND	ND	ND	ND	Feb. '06-Owner independently sampled well and declined filtration system.
TH11733	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.11 LJ	ND	ND	ND	ND	NS	ND	ND	
TH11737	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	
TO10615	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Too far east, not on map.
TO10619	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Shares Well with TO10627
TO10624	ND	NS	NS	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
TO10627	ND	NS	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TO10635	ND	NS	ND	ND	ND	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TO10700	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TO10700LPT	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	Well discovered Nov. 2006
TO10727	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.051 LJ	ND	
TO10827	0.5	NS	0.97	1.5	1.3	2	1.7	2	2.6	3.4	2.0 J	2.6	3	3.5	3.4	4	6	5.6	5	5.1	Filtration system installed July 2007.
TO10830	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TO10835	2	2.8	3.8	6.6	8.8	7.8	6.2	13	10	9.7	5.9	ND	NS	10	14.8	18.1	15.5	NS	24	29.6	Filtration System. No access Aug '07.
TO10902	7.1	13.8	16	12	10	16	17	19	16	21	28 J	41	41	41	37.9	48.2	20.4	35.1	24.6	26.8	Filtration System. Re-sampled July '06.
TO10903	18.2	16.8	7.9	37	20	22	25	28	42	33	41	51 J^	54	56	66.5	67.4	65.2	74.2	99	75.3	Filtration System. Re-sampled July '06.
TO11011	ND	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	May '06-no power to well.
TO11023	NS	NS	NS	NS	0.51	0.64 J	0.38 J	0.63	1.6	0.76	0.55	0.35 LJ	0.6	ND	0.56	1.5	1.4	1.7	2.1	1.2	Difficult to access
TO11024	24.5	19.9	30	37	15	18	22	25	18	32	33	42	25	NS	NS	NS	NS	NS	NS	NS	Filtration System. No power to well Aug. '06, Nov. '06, Feb. '07, May 07, Aug '07', Nov '07, and Feb '08.
TO11033	0.5	0.8	NS	1.1	1.2	1.4	1.4	1.4	1	NS	1.9	2.1	2.7	3.9	3.7	4.2	4.2	4	2.8	1.8	No power to well Aug. '05.
TO11051	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Shares Well with TO11033
TO11102	0.3 J	0.8	0.64	0.92	NS	1.1	0.99	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Sampling crew was unable to contact owner. Difficult to access.
TO11115B	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TO11116	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Shares Well with TC11131
TO11116MO	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TO11202	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	
TO11205	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TO11230	ND	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	NS	ND	No power Nov. '04 to Feb. '06 and Nov '07.
TO11305	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	

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Location ID	May '03	Aug. '03	Nov. '03	Feb. '04	May '04	Aug. '04	Nov. '04	Feb. '05	May '05	Aug. '05	Nov. '05	Feb. '06	May/ Jul. '06	Aug. '06	Nov. '06	Feb. '07	May '07	Aug. '07	Nov. '07	Feb. '08	Additional Comments
TO11309	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	
TO11310	NS	NS	NS	NS	NS	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
TO11314	NS	NS	NS	NS	NS	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
TO11335	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	No Access , Gate locked. Aug '07-not sampled per property manager's request.
TO11338	ND	NS	NS	NS	ND	ND	ND	0.25 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TT11011	13.2	10.8	6.2	18	16 J	31 J	21	26	31	29	32	37	39	32	42.1	57.1	48.1	52.7	69	67.4	Filtration System
TT11014	27.3	25.7	24	38	28	20	16	25	20	32	27	59	44	26	31.6	99.6	106	95.2	140	80.6	Filtration System. Re-sampled July '06.
TT11015	*ND	*ND	*ND	*ND	*ND	*ND	*ND	*ND	*ND	30	30	38	42	28	32.6	36.8	27.3	23.1	28	28.6	* Filtration System inside the Garage. Difficult access, unable to contact owner.
TT11031	NS	5.3	7.1	12	9.1	11	7.4	12	14	9.2	15	14	13	7.6	11.9	10.5	13	9.3	NS	8.1	Filtration System -No Access-Gates Lock Nov '07
TT11039	ND	0.8	NS	0.2J	.23 J	ND	0.88	0.45 J	0.63	2.7	3.6	1.9	NS	NS	NS	NS	NS	NS	NS	NS	May '06-no access
TT11102	0.4 J	1.1	ND	0.55	0.54	0.84	0.82	0.93	0.86	1.3	1.5	1.3	ND	0.76	0.64	0.26 LJ	0.28 LJ	ND	0.22 LJ	ND	
TT11103	ND	ND	ND	0.12J	ND	ND	ND	ND	ND	0.15 J	0.21 J	0.16 LJ	ND	ND	ND	0.073 LJ	ND	ND	ND	ND	
TT11106	22.4	7.4	6	9.9	12	19	7.9	7.9	6.7	4.8	6.5	6.4	4.8	33	66.3	62.9	62.4	45.5	31	16.3	Filtration System. Pump replaced Mar. '06.
TT11107	4.2	3.7	5.3	7.5	5.2	9.7	9.4	16	19	35	44	38 J	57	98	120	142	129	158	230	183	Filtration System
TT11112	ND	ND	ND	ND	ND	ND	0.093 J	0.24 J	0.27 J	0.23 J	0.28 J	ND	ND	ND	ND	0.085 LJ	ND	ND	0.17 LJ	0.17LJ	
TT11114	ND	ND	ND	ND	ND	ND	ND	0.17 J	0.16 J	0.26 J	0.23 J	ND	0.11 LJ	ND	0.15 LJ	0.15 LJ	ND	ND	0.16 LJ	ND	
TT11115	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	New residence Feb. '07.
TT11118	1.4	1.6	1.5	1.3	1.2	1.7	1.2	1.5	1.3	1.7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	No power as of Nov. '05.
TT11123	4.5	NS	2.7	2.7	NS	8.9	5.8	8.8	NS	8.1	6.8	6	NS	4.1	3.7	NS	NS	NS	11	NS	Filtration System. Difficult to access. Feb. '07, May 07', and Aug '07, and Feb '08.
TT11124	ND	0.6	ND	0.54	.4 J	ND	0.34 J	0.28 J	0.26 J	0.33 J	0.42 J	0.47 LJ	0.37 LJ	ND	0.35 LJ	0.32 LJ	ND	0.38 LJ	ND	0.43LJ	
TT11127	4.7	3.1	3.9	14	21	23	13	20	15	15	4.6	2.8	ND	3.5	2	12.4	14.6	16.4	23	23.3	Filtration System
TT11131	3.6	3	3.4	6	5.8	5.8	4.7	4.9	3.4	6.6	4	4.8	6.3	4	4.5	8.3	10.8	13.1	23	25.4	Filtration System
TT11139	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TT11202	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Re-sampled July '06.
TT11203	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.16 J	0.17 J	ND	ND	ND	0.17 LJ	0.18 LJ	NS	NS	NS	NS	Owner requests no further sampling as of Feb. '07
TT11215	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Re-sampled July '06.
TT11219	ND	NS	NS	NS	NS	ND	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
TT11222	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TT11227	ND	NS	NS	NS	NS	ND	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
TT11230	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
TT11303	ND	NS	NS	NS	NS	ND	ND	ND	ND	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	Re-sampled July '06.
TT11306	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	Planned to re-sample July '06 - no power to well.
TT11322	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Re-sampled July '06.
TT11323	NS	NS	NS	NS	NS	ND	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
WE10514	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Too far east, not on map.
WE10710	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	
WE10711	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	Re-sampled July '06.
WE10715	ND	NS	ND	ND	ND	ND	ND	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	
WE10719	ND	NS	ND	ND	ND	ND	ND	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	
WE10727	ND	NS	ND	ND	ND	ND	ND	ND	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	
WE10814	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.23 LJ	ND	ND	ND	ND	ND	ND	ND	ND	No power May and Aug. '05.
WE10815	ND	NS	ND	ND	ND	ND	ND	ND	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Re-sampled July '06.
WE10831	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
WE10931	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
WE11322	ND	NS	NS	NS	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

Table 6
Quarterly PCE Groundwater Sampling Results - May 2003 through February 2008
Jones Road Groundwater Plume Federal Superfund Site (SUP075)
Harris County, Texas
Shaw Project Number 137226

Updated: April 28, 2008

Location ID	May '03	Aug. '03	Nov. '03	Feb. '04	May '04	Aug. '04	Nov. '04	Feb. '05	May '05	Aug. '05	Nov. '05	Feb. '06	May/ Jul. '06	Aug. '06	Nov. '06	Feb. '07	May '07	Aug. '07	Nov. '07	Feb. '08	Additional Comments
Sampling Results Summary	**May '03**	**Aug. '03**	**Nov. '03**	**Feb. '04**	**May '04**	**Aug. '04**	**Nov. '04**	**Feb. '05**	**May '05**	**Aug.' 05**	**Nov. '05**	**Feb. '06**	**May/Jul. '06**	**Aug. '06**	**Nov. '06**	**Feb '07**	**May '07**	**Aug. '07**	**Nov. '07**	**Feb. '08**	**EXPLANATION OF COLORS**
# of green sampling results	104	45	67	69	158	153	157	151	107	118	126	138	140	143	133	136	141	142	138	138	**PCE < 0.5 ppb (Quantitation Limit)**
# of yellow sampling results	22	26	20	21	16	19	19	16	22	20	16	15	16	17	18	13	12	11	13	10	**PCE >=0.5 to <= 5.0**
# of red sampling results	17	19	20	24	27	29	23	26	25	25	27	27	22	25	24	28	28	30	30	31	**PCE > 5.0 ppb (MCL)**
# of Yellow plus Red	**39**	**45**	**40**	**45**	**43**	**48**	**42**	**42**	**47**	**45**	**43**	**42**	**38**	**42**	**42**	**41**	**40**	**41**	**43**	**41**	
Total Addresses Sampled	143	90	107	114	201	201	199	193	154	163	169	180	178	185	175	176	181	183	181	179	
Total # of Filtration Systems	24	24	24	27	29	32	32	33	33	31	31	31	32	32	33	33	34	34	35	35	

Notes:
All results are prior to filtration system, unless otherwise indicated in comments.
* Filtration System inside the Garage. No access. Sampling at nearest outside faucet prior to August 2005.

Appendix A

Final Treatability Study Report

Shaw Environmental, Inc.

2790 Mosside Boulevard
Monroeville, PA 15146
412.372.7701
Fax: 412.372.7135

Shaw® Shaw Environmental, Inc.

October 16, 2007

Ms. Marilyn Czimer Long, P.G.
Texas Commission on Environmental Quality
MC-136
State Lead Section
12100 Park 35 Circle
Austin, TX 78753

Subject: **Final Treatability Study Report for**
Jones Road Groundwater Plume Federal Superfund Site
Houston, Harris County, Texas
Shaw Project Number 128885

Dear Ms. Long:

Enclosed are three copies of the above referenced report. Shaw Environmental, Inc. (Shaw) incorporated TCEQ and EPA comments into this final version of the report. A hard copy of this report was also sent to Mr. Gary Baumgarten of EPA Region 6. An electronic version of this report, minus the CD with the raw analytical data reports, was e-mailed to the distribution on this letter.

If you have any questions or comments, please feel free to call me at (412) 858-3309.

Very truly yours,

Richard B. Wice, P.G., CHMM
Senior Project Hydrogeologist

RBW/bam

cc: Gary Baumgarten, EPA Region 6
Subash Pal, TCEQ
Russell Perry, Shaw
Project File 128885

FINAL
TREATABILITY STUDY REPORT
for
JONES ROAD GROUNDWATER PLUME FEDERAL SUPERFUND SITE
HOUSTON, HARRIS COUNTY, TEXAS

Shaw's Project No. 128885

Prepared for:

State Lead Section
Remediation Division
Texas Commission on Environmental Quality

Prepared by:

Shaw Environmental, Inc.
3010 Briarpark Drive, Suite 400
Houston, Texas 77042

October 2007

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EXECUTIVE SUMMARY

Soil and groundwater samples from the Jones Road Groundwater Plume Federal Superfund Site (Jones Road), Houston, Texas were used to perform remedial technology treatability studies. Samples were collected from the site during the summer of 2006 and the laboratory treatability study tests were conducted during the Fall of 2006. Tetrachloroethene (PCE) and its daughter products are present in site soils and groundwater in shallow (water table) and deeper aquifer zones. Insitu chemical oxidation (ISCO) treatability studies were performed using potassium permanganate and activated persulfate oxidation at the Shaw Technology Development Laboratory (TDL) in Knoxville, Tennessee. Biostimulation, bioaugmentation, and Zero Valent Iron (ZVI) treatability studies were performed at the Shaw Technology Laboratory in Lawrenceville, New Jersey.

Treatability tests for potassium permanganate and bioaugmentation with lactate were most effective in treating PCE and its daughter products. To a lesser extent, activated persulfate oxidation also reduced PCE and its daughter products. Implementation of insitu technologies at the Jones Road site will be complicated due to the clays, the presence of discontinuous clayey sand, and sand lenses beneath the site. Initial pilot testing should be performed using potassium permanganate to treat source zone contamination in the shallow 28-50 foot depth saturated zone. Deeper contamination, greater than 50 feet, may be part of a follow-up pilot test using bioaugmentation and lactate to develop treatment zones as contaminant migration barriers. Prior to the final design of a pilot study, a detailed conceptual site model (CSM) showing the subsurface, and a hydraulic analysis of the site (in and around the former Bell Dry Cleaners), is needed. The CSM will help determine where to install pilot test injection/extraction wells and monitoring points, as well as provide inputs for dosage control and flow rates.

1.0 INTRODUCTION

Shaw Environmental, Inc. (Shaw) is pleased to present to the Texas Commission on Environmental Quality (TCEQ) this Treatability Study Report for soils and groundwater contamination at the Jones Road Groundwater Plume Federal Superfund site (Jones Road), located in Houston, Texas. The work items performed as part of this treatability study were presented to the TCEQ in the Treatability Study Work Plan (Shaw, October 12, 2006). The following technologies were included in the Work Plan for consideration at the Jones Road site:

- Activated Persulfate Insitu Chemical Oxidation (ISCO)
- Potassium Permanganate ISCO
- Biostimulation
- Bioaugmentation
- Abiotic Treatment Using Zero Valent Iron (ZVI)

The ISCO technology treatability studies were performed at Shaw's technology development laboratory (TDL) located in Knoxville, Tennessee. The biostimulation, bioaugmentation, and ZVI treatability studies were performed at Shaw's Technology Laboratory in Lawrenceville, New Jersey. Standard Operating Procedures (SOPs) and standard industry practices, procedures, and professional judgment were used by the Shaw labs during these studies. Samples for the treatability studies were collected during the summer of 2006 as part of the Geoprobe® and deep well rotosonic drilling field activities. Raw laboratory analytical data reports are included as a CD in this report.

This report is organized as follows: the remainder of Section 1.0 provides a brief site description, the test objectives, and the field activities associated with the treatability study sample collection. Section 2.0 provides a description of the treatability study technologies. ISCO technology treatability study procedures and test results are presented in Section 3.0. Biostimulation., bioaugmentation and ZVI treatability study procedures and test results are presented in Section 4.0. Section 5.0 presents a discussion on the implementation of the appropriate technology at the site as part of a pilot test, including a discussion of site factors that may affect full-scale implementation.

1.1 Site Description

The Jones Road site is located approximately one-half mile north of the intersection of Jones Road and FM 1960, outside the city limits of northwest Houston, Harris County, Texas. The Vadose Zone shallow and deeper groundwater in this area has been impacted by chlorinated

solvents volatile organic compounds (VOCs), mainly tetrachloroethene (PCE), trichloroethene (TCE), dichloroethene (DCE) and vinyl chloride (VC), believed to be from operations conducted at the former Bell Dry Cleaners site located in the Cypress Center Shopping Center at 11600 Jones Road.

A comprehensive description of the Jones Road site background and site conditions may be found in the Remedial Investigation Report (Shaw, 2006). Details of the Geoprobe® field investigation may be found in the July 2006 Geoprobe® Investigation Report (Shaw, 2007).

1.2 Study Objectives

The Jones Road site treatability study objective is to evaluate potential insitu remedial technologies that will effectively remediate the chlorinated solvents in the saturated zone soils and groundwater at the site. Treatability studies determine if the technology is effective and provide information on the application concentrations and time required for the target VOCs to be treated.

Specific objectives of the ISCO treatability studies include:

- Evaluate treatment effectiveness of permanganate and FeEDTA-activated persulfate for destruction of VOCs in soil/groundwater slurries;
- Provide an estimate of the oxidant dosing requirements by measuring the soil oxidant demand (SOD);
- Measure the acid buffering capacity of the soil to determine the effect of persulfate oxidation on soil pH;
- Evaluate the effect of pH and ORP change on metals.

Specific objectives of the bioaugmentation, biostimulation, and ZVI treatability studies include:

- Determine which technology would provide the most rapid and complete biodegradation of PCE under site-specific conditions;
- Determine the dosage of bacteria, electron donor, or ZVI required for treatment.

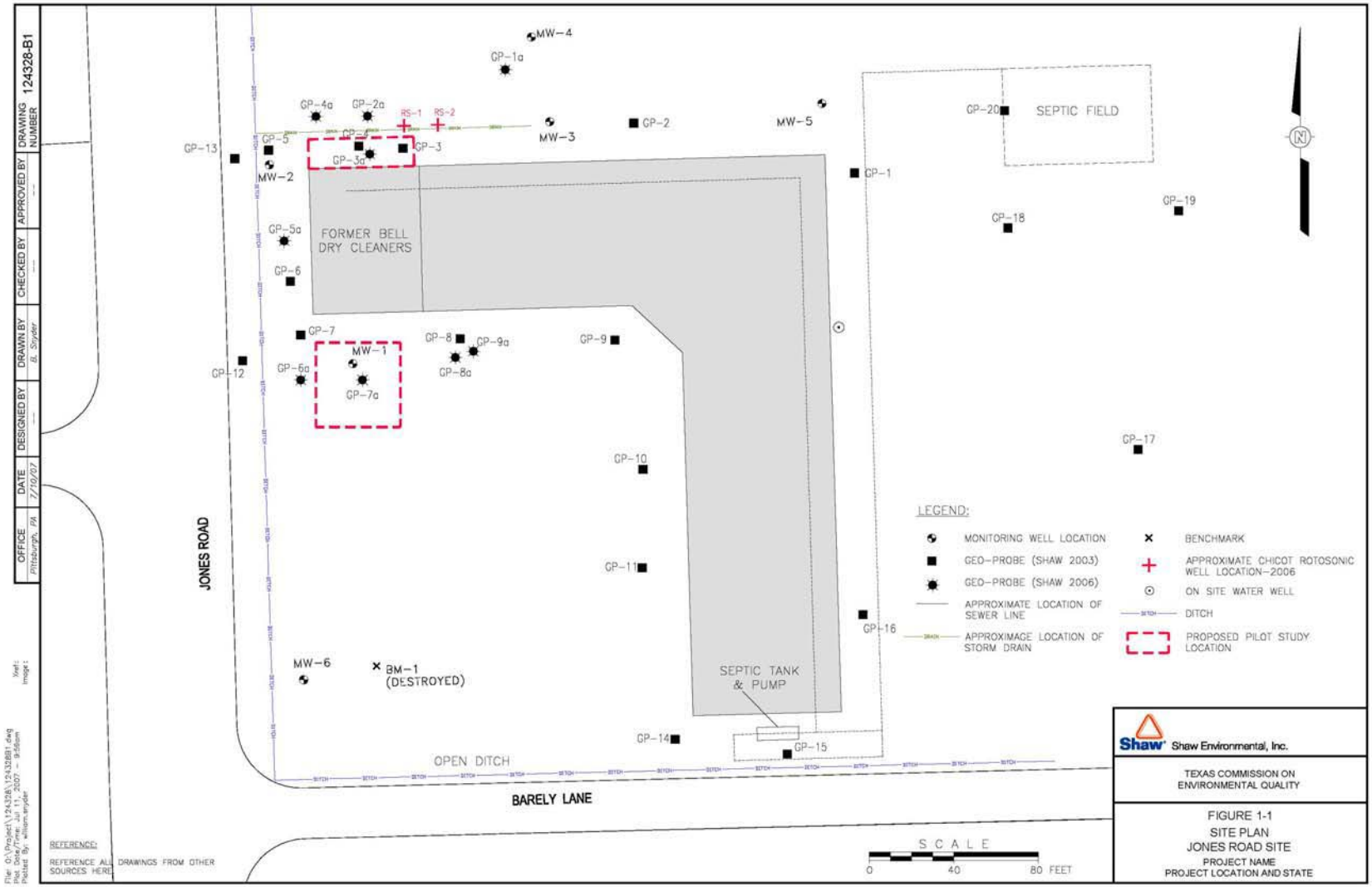
1.3 Treatability Study Sample Collection

Soil and groundwater samples for this treatability study were collected during the July 2006 Jones Road Geoprobe® Study and the July 2006 rotosonic well drilling field activities. The soil and groundwater samples for the Lawrenceville Technology Laboratory studies were collected from Geoprobe® boring GP-3A (see **Figure 1-1**). Soil and groundwater samples were collected in accordance with the Jones Road Site Treatability Study Work Plan and other project-specific planning documents (Health and Safety, QA).

Soil samples from GP-3A for the bioremediation treatability studies were collected from four depth intervals (20-21 feet below ground surface [bgs], 27-29 feet bgs, 37-38 feet bgs, and 49-50 feet bgs) representing silts, clays, and clay sand at this location. Samples were field prepared in sealed paraffin wax coated tubes to preserve insitu conditions. Groundwater for the treatability studies was collected in five 1-liter bottles from the temporary well installed at GP-3A. The well screen in temporary well GP-3A was from 30 to 50 feet bgs.

Composite soil samples for the Knoxville TDL Treatability Studies were collected from rotosonic drilling location RS-1 (see **Figure 1-1**). RS-1 is located approximately 24 feet northeast of GP-3A. Both locations are on the north side of the building, an area with very high PCE concentrations in groundwater.

During the July 2006 Geoprobe® investigation, the groundwater PCE concentration for temporary well GP-3A was 190,000 micrograms per liter (µg/L). Water samples were not obtained from rotosonic location RS-1. Soils underlying the site in the shallow aquifer zone are generally low permeability clays, silty clays, and clayey sands. A geotechnical sample profile at location GP-9A from 6 to 32 feet bgs had low levels of organic carbon (good for ISCO applications), and permeabilities range from 10^{-6} cm/s to 10^{-8} cm/s. Soil boring data from the July 2006 Geoprobe® work also indicates subsurface soils are generally low permeability; sands or clayey sands, if present, are discontinuous layers or lenses. Section 5.0, dealing with recommendations for pilot tests, discusses technology implementation issues.


MW-4
GP-1a
GP-4a
GP-2a
RS-1
RS-2
GP-5
GP-3a
GP-3
MW-3
GP-2
MW-5
GP-20
SEPTIC FIELD
GP-13
MW-2
GP-1
GP-19
GP-18
GP-5a
FORMER BELL DRY CLEANERS
GP-6
GP-7
GP-8
GP-9a
GP-9
MW-1
GP-12
GP-6a
GP-8a
GP-7a
GP-17
GP-10
JONES ROAD
GP-11
GP-16
MW-6
BM-1 (DESTROYED)
SEPTIC TANK & PUMP
GP-14
GP-15
OPEN DITCH
BARELY LANE
LEGEND:
MONITORING WELL LOCATION
GEO-PROBE (SHAW 2003)
GEO-PROBE (SHAW 2006)
APPROXIMATE LOCATION OF SEWER LINE
APPROXIMAGE LOCATION OF STORM DRAIN
BENCHMARK
APPROXIMATE CHICOT ROTOSONIC WELL LOCATION-2006
ON SITE WATER WELL
DITCH
PROPOSED PILOT STUDY LOCATION
SCALE
0 40 80 FEET
Shaw Environmental, Inc.
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
FIGURE 1-1
SITE PLAN
JONES ROAD SITE
PROJECT NAME
PROJECT LOCATION AND STATE
REFERENCE:
REFERENCE ALL DRAWINGS FROM OTHER SOURCES HERE
DRAWING NUMBER 124328-B1
APPROVED BY
CHECKED BY
DRAWN BY B. Snyder
DESIGNED BY
DATE 7/10/07
OFFICE Pittsburgh, PA

2.0 TREATMENT TECHNOLOGY DESCRIPTION

The following sections describe the treatment technologies that were evaluated as part of this study.

2.1 Permanganate Oxidation

Chemical oxidation using potassium or sodium permanganate is widely used in drinking water applications. ISCO using sodium or potassium permanganate is also used to remediate hazardous waste sites with soil and groundwater contaminated with chlorinated VOCs. ISCO technology has been applied to a wide range of site soils, from clays to sands. The greater the clay content, the more closely spaced injection points and multiple applications of oxidant may be needed. Ideally, any insitu technology application is best suited at sites with moderate permeabilities and lower fine (silt/clayey) content. PCE and TCE are well-suited for oxidation by permanganate. Permanganate reacts rapidly with nonconjugated (i.e., nonaromatic) double bonds in chlorinated ethenes, and oxidizes the chlorinated ethenes to carbon dioxide and chloride ions. The reaction between PCE and permanganate is shown below.

$$3C_2Cl_4 + 4MnO_4^- + 4H_2O \rightarrow 6CO_2 + 4MnO_2 + 12Cl^- + 8H^+$$

Insitu permanganate oxidation involves the injection (by gravity or under pressure) of sodium or potassium permanganate solution into the subsurface. Oxidant is delivered to the subsurface using injection probes, treatment walls, soil mixing, hydraulic fracturing, or vertical or horizontal wells.

The effectiveness of ISCO with permanganate depends on three factors: 1) the kinetics of the reaction between the permanganate and the contaminants; 2) the contact between the oxidant and the contaminants, and 3) competitive reaction of permanganate with other reduced/oxidizable species. If the contaminants targeted are reactive (e.g., chlorinated ethenes), and if sufficient oxidant is added (to overcome the demand from other reduced species, as well as naturally occurring organic matter), the limiting factor to the successful application is the transport of the oxidant to the contaminated area, but not the reaction itself. Clayey silts at Jones Road will somewhat complicate oxidant transport and distribution in the subsurface. The oxidation of contaminants by permanganate is essentially an instantaneous reaction. If the permanganate contacts the contaminant, a reaction will occur. Significant oxidation is observed in as little as a few hours after addition.

2.2 Activated Persulfate Oxidation

Persulfate ion ($S_2O_8^{-2}$) is a strong oxidant capable of oxidizing most organic compounds to carbon dioxide and other mineral products. The standard reduction potential for the half reaction shown below is +2.01 volts (V).

$$S_2O_8^{-2} + 2e^- \rightarrow 2SO_4^{-2} \qquad E° = +2.01\ V$$

It is on the same order as that for ozone and higher than that for permanganate and hydrogen peroxide, but less than that for the hydroxyl radical (Fenton's reagent intermediate). As shown in the half reaction above, the product of persulfate reduction is sulfate ion (SO_4^{-2}), which is a relatively benign species. Sulfate ion has a secondary federal drinking water standard maximum contaminant level (MCL), which is a recommended, but unenforceable limit of 250 mg/L.

It is believed that persulfate reacts with organic compounds primarily by the sulfate radical ($SO_4•^-$), which can be generated in solution by several mechanisms. The sulfate radical shown, in the reaction below, is a powerful oxidizing species with a standard electrode reduction potential of +2.6 V, which is similar to that for the hydroxyl radical (OH•) species (+2.8 V).

$$SO_4•^- + e^- \rightarrow SO_4^{-2} \qquad E° = +2.6\ V$$

The hydroxyl radical is a powerful oxidizing species that is generated with catalyzed hydrogen peroxide (CHP) systems. The persulfate anion radical in contrast to the hydroxyl radical has a longer lifetime in solution and is more selective in its reactions (P. Neta, 1987). Generation of the sulfate radical may be accomplished by homolytic scission of the persulfate ion, which can be activated by heat or ultraviolet (UV) radiation (G. E. Hoag, 2000; P. Neta, 1987 and C. Liang, 2001):

$$S_2O_8^{-2} \text{ or } {}^-O_4S\text{-}SO_4^- \rightarrow 2\ SO_4•^-$$

Heat activation for persulfate activation can be accomplished at temperatures in the range of 20°C to 60°C, which can be accomplished insitu without extreme heat generation processes. Steam heating has been used as a practical means to provide persulfate activation for insitu treatment. However, at the Jones Road site, due to cost, steam heat would not be a viable alternative.

Sulfate radicals may also be generated by one-electron oxidation reactions, such as with metals (C. Liang, 2001; FMC, 2001 and G. E. Hoag, 2000):

$$S_2O_8^{-2} \text{ or } {}^-O_4S\text{-}SO_4^- + M^{+n} \rightarrow SO_4•^- + SO_4^{-2} + M^{+(n+1)}$$

Recently, new methods of persulfate reaction activation have been developed using: chelated metals, such as iron (II) ethylenediamine tetraacetic acid (FeEDTA), hydrogen peroxide addition,

or an alkaline pH (P. Block, 2004). These new methods most likely also involve the generation of the sulfate radical, and possibly the hydroxyl radical and related species for reaction with organic compounds.

Metal complex activation of persulfate has been effective in treating aromatics and chlorinated ethenes, but chlorinated ethanes and chlorinated methanes have proven to be somewhat resistant to persulfate with this form of activation (P. Block, 2004).

Alkaline activation of persulfate has been shown to be most effective for the treatment of chlorinated ethane and chlorinated methane compounds. Alkaline activation uses a base such as sodium hydroxide to adjust initial pH in the range of 11 to 12.5. The alkaline conditions are typically neutralized during treatment by the generation of hydrogen sulfate anion (HSO_4^-), which is an acid. This occurs during natural decomposition of the persulfate reagent that is catalyzed by high pH and species present in the soil. The equation for the decomposition reaction is shown below.

$$S_2O_8^{-2} + H_2O \rightarrow 2HSO_4^- + \frac{1}{2} O_2$$

Study results show that persulfate can be effective on recalcitrant organics. Specifically, persulfate has been shown to degrade BTEX, chlorinated ethenes, chlorinated ethanes, and chlorinated methane compounds (C. Liang, 2001 and P. Block, 2004).

The persulfate reagent is very soluble in water to concentrations of 30 to 40 percent and the solutions are relatively stable especially at lower concentrations (1 to 10 percent). These properties allow for optimum delivery and distribution to the subsurface matrix without the solubility limitations encountered with potassium permanganate. The reagent is similar to permanganate with respect to safety issues (e.g., handling and reactivity). All ISCO materials are handled in accordance with manufacturers' instructions, and only properly trained field personnel are used to handle, mix, and inject ISCO materials.

2.3 Technology Description of Bioaugmentation, Biostimulation, and Abiotic Treatment Using ZVI

Both bioaugmentation and biostimulation are insitu remedial biotechnologies that have been shown to be cost-effective treatments for the removal of chlorinated ethenes. ZVI treatment of chlorinated ethenes is an abiotic reaction that occurs at the surface of the metal particle. The purpose for performing laboratory testing of these technologies is to verify that the complete biodegradation of PCE will occur at a reasonable rate under site-specific conditions. As is the case with ISCO, the ability to deliver and distribute the bioremediation amendments may be complicated by site conditions (clayey soil).

PCE can be degraded under anaerobic conditions by specific bacteria through reductive dehalogenation, where PCE is sequentially reduced to TCE, cis-1,2- DCE, VC, then ethene. In each case, the reactions are mediated by bacteria that thrive under low oxidation-reduction potential, and are driven by the presence of an electron donor (carbon source or hydrogen). In order for complete biodegradation/dechlorination of PCE to occur, specific bacteria capable of this process must also be present. *Dehalococcoides* sp. (DHC), some of which are capable of degrading chlorinated ethenes to ethene, are the only microbial species known to completely dechlorinate PCE, so their abundance and distribution in a contaminated aquifer is critical for effective biodegradation of TCE.

Biostimulation

Insitu anaerobic biostimulation involves stimulating the degradation of indigenous microbial populations by introducing electron donor (substrate) and/or nutrients into the subsurface. These materials can be delivered to the subsurface using injection probes, treatment walls, soil mixing, pneumatic fracturing, or vertical or horizontal wells. The assumption with this approach is that the indigenous microbial population contains DHC, but the native DHC are unable to maintain high levels of degradation due to unfavorable oxidation-reduction potential, insufficient nutrient (e.g., nitrogen, phosphorous) levels, insufficient microbial levels, and/or lack of electron donor. As such, the success of a biostimulation approach is dependent upon the ability to distribute amendments in the subsurface, create favorable oxidation-reduction potential insitu, enhance the growth of DHC, and ultimately stimulate microbially-enhanced reductive dehalogenation of PCE and its daughter products.

Biostimulation requires that DHC are present within the contaminated aquifer. The presence of reduced gases, such as ethene or ethane, are often evidence that the complete reduction of PCE is occurring biologically, and that DHC are present and active. In addition, polymerase chain reaction (PCR) analysis is a recently developed molecular biological tool that is capable of determining the presence of DHC in aquifers.

Bioaugmentation

Bioaugmentation is similar to biostimulation, except that it involves the delivery of microorganisms (in addition to substrate and nutrients) to the subsurface to stimulate biological degradation. These organisms can be cultured directly from site material, or can be obtained from an outside source. Evidence of biological degradation found at a site, such as the presence of daughter products of the degradation of the target contaminants and suitable geochemical conditions, may be indicative of an active microbial population. Alternately, PCR analysis can be used to determine whether a particular species of bacteria is present in site soil and groundwater, indicating whether complete dechlorination of native bacteria is likely. Site soil

collected from the area of the site where degradation appears to be occurring, or where these organisms appear to be present, can often be enriched in the laboratory to select the population responsible for degradation. The bacterial culture can then be grown in the laboratory to produce large batches of active microorganisms that are then added to the subsurface, along with appropriate substrate and nutrient.

Alternate sources of active microbial cultures of DHC have been obtained from sites where DHC are naturally occurring. There are several cultures available to Shaw, most notably our SDC-9™ culture, which has been shown to completely and rapidly degrade PCE to ethene using lactate as an electron donor.

Abiotic Treatment Using ZVI

ZVI treatment of chlorinated ethenes is an abiotic reaction that occurs at the surface of the metal particle. The degradation reaction occurs via electron transfer between the dissolved contaminant and the iron, as corrosion of the iron facilitates the reductive dehalogenation reactions needed to sequentially dechlorinate the PCE to ethene and ethane. Several types of ZVI have been used, including iron filings (1 mm diameter), microscale ZVI (micron-sized particles), and bimetallic nanoscale ZVI (100 nm diameter, doped with palladium catalyst). Addition of metal catalysts to the surface of the ZVI particles typically increases the rate of the dehalogenation and hydrogenation surface reactions, thereby increasing the overall rate of contaminant removal. Field applications have included the use of permeable reactive barrier, dispersed injection into source areas, and *ex situ* reactors. Selection of the most appropriate ZVI type and field application is dependent upon several factors. These factors include site geochemical conditions, contaminant type and concentration, site hydrogeologic conditions, and cost.

3.0 ISCO TREATMENT STUDY

Treatability studies were conducted to evaluate permanganate and activated persulfate oxidation for the treatment of PCE and PCE degradation products in Jones Road soil and groundwater slurries. These studies were conducted during the Fall of 2006. The batch experiments investigated both oxidant dosing and treatment time requirements. Persulfate was activated using a ferrous iron (Fe^{+2}) EDTA complex (FeEDTA).

The experimental approach described below entailed site soil preparation, characterization of test soils and groundwater, soil oxidant demand tests, acid/base titration of site soil, and reagent treatment effectiveness tests on soil and groundwater mixtures.

3.1 Sample Preparation and Chemicals

Soil and groundwater samples were received at the TDL on July 25 and July 26, 2006. The samples were shipped on ice and stored at 4°C until used in treatment study testing. Samples were identified as follows:

Type	Amount	TDL Lab #
SOIL	5-GAL BUCKET	10506
GW	5 X 1-LITER	10507

The samples of soil received for batch slurry testing were mixed manually in the 5-gallon bucket to apparent homogeneity at 4°C in a manner to minimize VOC loss. The 5 liters of site groundwater collected were homogenized in a sterile chilled glass container. Samples were stored with zero headspace at 4°C prior to testing. The homogenized site groundwater and site soil were sampled for analysis of volatile organic compounds (VOCs) of concern using a modified EPA SW-846 Method 8015, which uses purge-and-trap gas chromatography with flame ionization detection methodology (GC/FID).

Potassium permanganate was obtained from Carus (Carox USP grade), and sodium persulfate was obtained from FMC (Klozur™ Environmental grade).

The soil sample was also analyzed for acid buffering capacity using laboratory standard operating procedures (SOP). These measurements were used to determine the soil's ability to adjust the pH in response to protons released from persulfate decomposition.

3.2 Soil Oxidant Demand Testing

Soil Oxidant Demand (SOD) tests were performed to measure the amount of oxidant consumed in the course of treatment required to destroy the target VOCs. The amount and rate of oxidant

consumption is used to determine oxidant dosing and reaction condition requirements for treatment. The soil composite was used to measure the SOD with various oxidant systems. Tests were performed on soil/groundwater slurries containing 200 grams (g) of soil and 200 milliliters (mL) of groundwater in 500-mL polyethylene sample bottles. The soil sample was also analyzed for percent solids. Permanganate SOD was tested using an initial potassium permanganate concentration of 10 g/L. FeEDTA activated persulfate SOD was tested with a starting concentration of 20 g/L sodium persulfate and 150 mg/L Fe^{2+} as FeEDTA. The test bottles were capped, placed onto a temperature controlled oscillating shaker table at 15ºC and mixed periodically for the duration of the test.

In each test the amount of oxidant consumed was determined by measuring the loss of oxidant as a function of time to define the consumption characteristics for each oxidant system. Because of the impact of pH on persulfate and the potential for pH decrease during treatment due to persulfate degradation, the pH was also monitored. Tests were monitored for a six week time period using sample points of 2, 7, 14, 21, 28, 35, 42 and 49 days.

3.3 Oxidation Effectiveness Tests

Slurry tests using permanganate and FeEDTA activated persulfate were performed on site soil and groundwater mixtures. The bench scale testing designed to evaluate the two oxidation methods is described in detail below.

The test samples were prepared by mixing 100 g site soil and 150 mL groundwater in 210 mL test bottles. A small volume of headspace was left in each bottle to allow for slurry mixing. Initial characterization of site soil and groundwater indicated the PCE concentration levels were 532 µg/L PCE in groundwater and non detectable in soil (10 µg/kg detection limit), which were probably too low to determine the treatment effect. Therefore, PCE was spiked by adding 1.5 mL of 144 mg/L aqueous PCE solution into each test bottle to produce an aqueous test concentration in the range of 1-2 mg/L. Then all test bottles were allowed to equilibrate overnight before adding any reagent. All bottles were hand mixed periodically at 24 to 72 hour intervals by gently turning each bottle end over end. Test bottles were temperature controlled at 15ºC for the test duration.

Permanganate Oxidation

Permanganate was tested at three dosages (3, 5, and 10 g/L) and three treatment times (1, 4, and 14 days). A total of 11 bottles (three permanganate dosages at three sampling times and two control bottles at sampling times of 0 and 14 days) were prepared for permanganate oxidation. Each test bottle was amended with the appropriate amount of potassium permanganate to produce the desired initial concentration as detailed in **Table 3-1**. Control slurry tests (no amendment) were established identical to the oxidant slurry test to measure any VOC loss due to

procedures or bacterial degradation. The control bottles were sampled at T-0 hours and T-14 days (water and soil). **Table 3-1** below describes the slurry batch tests and sampling schedule.

Table 3-1
Permanganate Oxidation Batch Test Experimental Details

Test	Potassium Permanganate Conc. (g/L)	Sample Points (Days)				Soil (g)	Water (ml)	Potassium Permanganate (g)	Manganese Sulfate[1] (g)
		T-0	T-1	T-4	T-14				
C1	0	X			X	100	150	0	0
M1	3		X	X	X	100	150	0.3	0.8
M2	5		X	X	X	100	150	0.75	1.5
M3	10		X	X	X	100	150	1.5	2.9

Note:

[1] Manganese sulfate ($MnSO_4 \cdot H_2O$) was added to the samples at the end of the treatment to quench the remaining permanganate.

At three sampling points, T-1, T-4, and T-14 days, a bottle from each permanganate treatment concentration was sacrificed for analysis. A portion of the water phase was transferred to 50 mL plastic vials for analysis for remaining permanganate. The rest of the soil/groundwater slurry was quenched by the addition of manganese sulfate ($MnSO_4 \cdot H_2O$). Both soil and groundwater phases were sampled at all three time points for VOC analysis. The soil phase was also analyzed for moisture content.

FeEDTA Activated Persulfate Oxidation

Persulfate was tested at three dosages (2, 5, and 10 g/L) and three treatment times (4, 8, and 21 days). A total of 11 bottles (three persulfate dosages at 3 sampling times and two control bottles at sampling times of 0 and 21 days) were prepared for persulfate oxidation. Each test bottle was amended with appropriate amount of sodium persulfate and FeEDTA to produce the desired initial concentration as detailed in **Table 3-2**. The low persulfate dose resulted in a nominal aqueous concentration of 2 g/L sodium persulfate activated with 100 mg/L chelated iron (Fe as FeEDTA). The medium level dose was 2.5 times (2.5X) the low dose amount, which produced a nominal aqueous concentration of 5 g/L activated with 150 mg/L chelated iron. The high level dose was 2 times (2 X) the medium dose, producing a nominal aqueous concentration of 10 g/L activated with 200 mg/L FeEDTA.

At three sampling points, T-7, T14 and T-21 days, a bottle from each persulfate treatment concentration was sacrificed for analysis. The reaction was quenched by placing the test bottle

in the refrigerator at ~4°C. The low temperature also helps to minimize the volatilization loss of VOC of concern. A portion of the water phase was transferred to 50 mL plastic vials for analysis of the remaining persulfate and pH. Both soil and groundwater phases were sampled at all three time points for VOC analysis. Soil phase was also analyzed for moisture content. The control bottles were sampled at T-0 hours and T-21 days (water and soil). **Table 3-2** below describes the slurry batch tests and sampling schedule.

Table 3-2
FeEDTA Activated Persulfate Oxidation Batch Test Experimental Details

Test	Sodium Persulfate Conc. (g/L)	FeEDTA Conc. (mg Fe/L)	Sample Points (Days)				Soil (g)	Water (ml)	Sodium Persulfate (g)	FeEDTA Solution, 20 g/L (mL)
			T-0	T-4	T-8	T-21				
C2	0	0	X			X	100	150	0	0
S1	2	100		X	X	X	100	150	0.3	0.75
S2	5	150		X	X	X	100	150	0.75	1.13
S3	10	200		X	X	X	100	150	1.5	1.5

3.4 Sample Characterization Results

Results from the VOC analyses of site soil and groundwater sample composites, as well as soil buffering capacity or alkalinity, are summarized in **Table 3-3** for PCE and PCE degradation products. Measurement data for the soil buffering capacity are included in **Appendix A.**

Table 3-3
Jones Road Site Material Composite Characterization

Sample Type	Units	PCE	TCE	cis-1,2 DCE	trans-1,2 DCE	Vinyl chloride	Alkalinity to pH 4.50
Jones Road Soil Comp.	µg/Kg	5U	5U	5U	5U	5U	1700 mg $CaCO_3$/kg
Jones Road GW Comp.	µg/L	532	91.3	82.2	12.5U	12.5U	NA

U = Analyte was not detected at the stated detection limit. Detection limits elevated due to laboratory dilution requirements.
J = Analyte was detected at a level below the method quantification limit; stated values is an estimate

3.5 Soil Oxidant Demand Results

Results from the SOD tests are tabulated below in **Table 3-4**. The data collected included plots of oxidant consumption as a function of time, as presented in **Appendix B**. The value given is the total grams of oxidant consumed per kilogram of wet soil in 49 days treatment time.

Table 3-4
Summary of Persulfate Consumption Rates in SOD Tests

Test	Description[a]	Oxidant Consumption g oxidant / kg wet soil
Persulfate SOD	20 g/L Persulfate +150 mg F^{+2}/L as FeEDTA	0.9[b]
Permanganate SOD	10g/L Permanganate	2.4[b]

[a] Both tests in 200 g soil composite: 200 mL GW
[b] Based on measurement on day 49.

Table 3-4 shows the total grams of oxidant consumed per kilogram of wet soil in 49 days treatment time. Both the FeEDTA activated persulfate SOD and the permanganate SOD at 0.9 and 2.4 g/kg, respectively, were in the very low range for oxidant consumption showing very little change in concentration with the majority of the oxidant remaining after 49 days treatment time. The plots show variability in test results as a function of time, and this was primarily due to the low consumption observed compared to the test dose value. Small errors in oxidant concentration measurement at test points produced relatively large swings in the resulting consumption value.

The pH behavior from the persulfate tests is typically characterized by a shift to low pH over time. This is caused by the acid product from persulfate decomposition and the low site soil buffering capacity. The persulfate tests ended in the pH range of 7.0, which is consistent with very little persulfate decomposition. Minimal pH effect, as shown here, indicates efficient use of persulfate in destroying VOCs and not in reacting with matrix interferences.

3.6 Batch Slurry Test Results

Samples were analyzed using a modified EPA SW-846 Method 8015 (purge-and-trap GC/FID methodology). A summary of VOC analytical data is included in **Appendix C**. Initial sample characterization indicated that the percent solids in the site soil composite was 84.2 percent, and that there was 532 µg/L PCE in the groundwater composite, and non-detectable VOC in the soil composite. To better test the treatment effectiveness, all samples were spiked with PCE solution, which resulted in final PCE concentrations of 1.2~1.5 mg/L.

Permanganate Oxidation

The permanganate treated sample had no detectable VOCs (detection limit 2.5 µg/L) after one (1) day treatment, indicating that permanganate oxidation is very effective in treating PCE and daughter products. Consistent with SOD results, permanganate consumption was fairly low with

more than 80 percent of the originally dosed permanganate remaining in the sample after 14 days of treatment. Permanganate concentrations at three dosage levels didn't change significantly from one (1) day treatment samples to 14 day treatment samples, indicating most of the oxidation reaction occurred in the first 24 hours. This is expected based on the relatively fast reaction kinetics between permanganate and the target VOCs.

The 14 day control sample had a PCE concentration of 1,575 µg/L comparing to the 0 day control concentrations of 1,244 µg/L and 1,252 µg/L. The increase in PCE concentration in control is probably due to the equilibrium between soil and aqueous phases. It also indicates that there was no significant loss during the test due to volatilization or biodegradation, etc.

The completed data set from metal analysis is presented in **Appendix D**. Highlighted values in **Table 3-5** show metals that exceeded EPA drinking water MCLs in some treated samples and, therefore, are of particular concern. Permanganate treated samples liberated metals that exceeded MCL concentrations for silver, barium, chromium, lead, selenium, and thallium. There are two sources for the elevated metal concentration: the trace metal content in permanganate and mobilization from the soil. Based on the product specification from the permanganate supplier (Carus), the possible contribution from metal content in permanganate was calculated and it accounts for no more than 15 percent of the metal concentrations measured in the permanganate treated samples. Therefore, the elevated metal concentrations are mostly from mobilization from the soil. However, based on experience, the metal concentrations will attenuate to baseline levels after the permanganate is consumed and the natural site redox condition is reestablished to static conditions. Pilot study and full-scale design applications are developed with thought to mobilized metals attenuation. These results provide guidance for metals monitoring during pilot-scale testing.

FeEDTA Activated Persulfate Oxidation

After 21 days of treatment, there were significant concentrations of VOCs detected in the FeEDTA activated persulfate samples. Unexpectedly, the low persulfate dose (2 g/L persulfate activated with 100 mg/L chelated iron) achieved the highest treatment efficiency with 96.9 percent PCE reduction in 21 days, and the medium persulfate dose (5 g/L persulfate activated with 150 mg/L chelated iron) resulted in the lowest treatment efficiency with 63.25 percent PCE reduction in 21 days. Other VOCs, including VC, DCE, and TCE, also showed different extent of reduction. **Figure 3-1** plotted the PCE concentrations at different treatment durations and different persulfate doses.

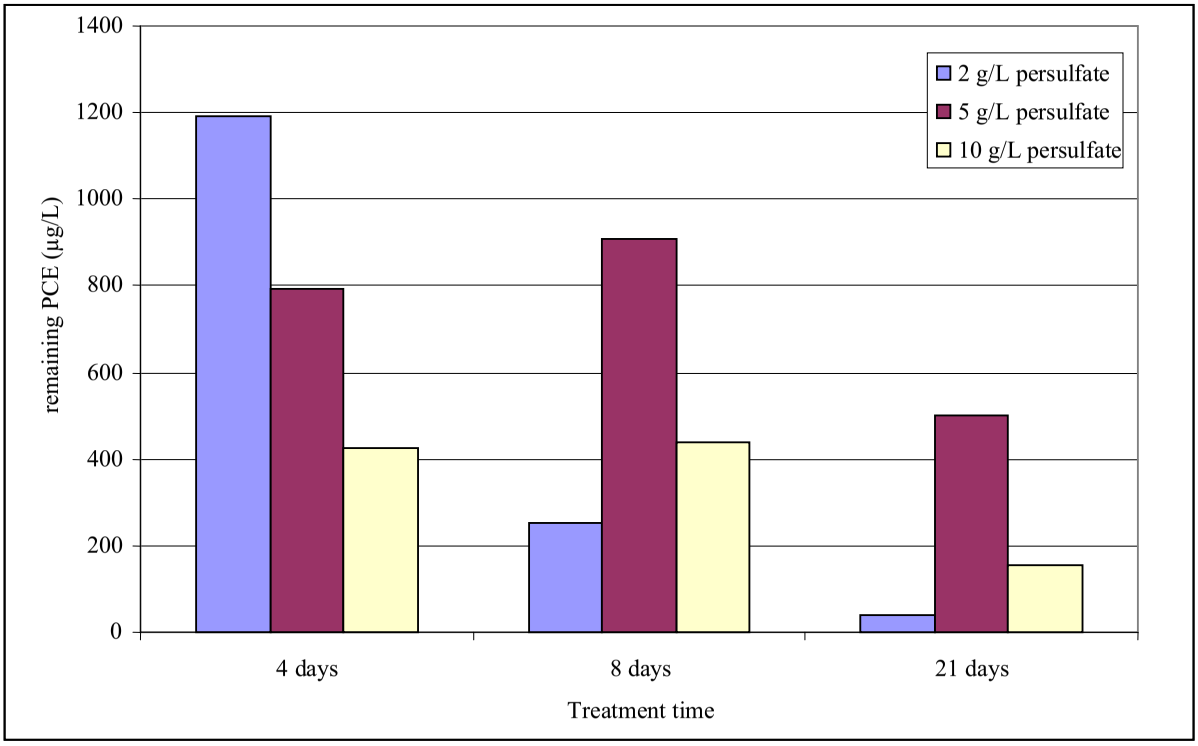
Table 3-5
Concentrations of Selected Metals in Initial and Final Time Point Samples

Sample ID	Treatment	Ag (mg/L)	Ba (mg/L)	Cr (mg/L)	Pb (mg/L)	Se (mg/L)	Ti (mg/L)
EPA Drinking Water MCL	*NA*	*0.1*	*2*	*0.1*	*0.015*	*0.05*	*0.002*
C1-0	Baseline control	0.012U	0.171	0.026U	0.012U	0.012U	0.012U
C2-0	Baseline control	0.012U	0.162	0.026U	0.012U	0.012U	0.012U
C1-21	21 day control	0.012U	0.162	0.026U	0.012U	0.012U	0.012U
C2-14	14 day control	0.012U	0.213	0.026U	0.012U	0.012U	0.012U
M1-14	3 g/L permanganate for 14 days	0.076	1.61	**0.232**	**0.015**	**0.153J**	**0.243**
M2-14	5 g/L permanganate for 14 days	**0.114**	**2.19**	**0.288**	**0.033**	**0.299J**	**0.496**
M3-14	10 g/L permanganate for 14 days	**0.242**	**4.5**	**0.472**	**0.107**	**0.747J**	**1.3**
S1-21	2 g/L persulfate for 21 days	0.017	0.438	0.026U	**0.357**	0.012U	0.012U
S2-21	5 g/L persulfate for 21 days	0.034	0.164	0.026U	**0.35**	0.012U	0.012U
S3-21	10 g/L persulfate for 21 days	0.044	0.106	0.026U	**0.298**	0.012U	0.012U

U – Laboratory reporting limits;
J – Estimated value may be biased slightly low. Continuing standard outside 80-120 percent criteria at 79 percent;
Bold numbers indicate the values exceed EPA drinking water MCL.

Figure 3-1

PCE Concentration Change Over Time In FeEDTA Activated Persulfate Oxidation



The analysis results for the 21 day control sample at 96 µg/L PCE revealed a loss of more than 90 percent PCE concentration from the day 0 control concentration of 1,243 and 1,252 µg/L. This is probably due to the breakage of the bottle mouth of this sample, which resulted in loss of VOCs due to volatilization. However, the analysis results of the 14 day control used in permanganate treatment can be used here to verify that the loss due to volatilization or biodegradation is negligible given the normal test condition.

The batch test pH measurement results were consistent with persulfate concentration. The pH of control samples and low dose persulfate treated samples remained consistent from day 4 to day 21. The medium dose persulfate treated samples had a trend of decreasing pH slowly from 7.64 on day 4 to 7.21 on day 21. The high dose persulfate treated sample resulted in a pH decrease from 7.69 on day 4 to 6.94 on day 21, but was still in the neutral range.

The batch test persulfate consumption was consistent with the SOD test results. Less than 20 percent of the dosed persulfate was consumed over the 21 days of treatment.

As shown in **Table 3-5**, Fe-EDTA activated persulfate didn't elevate the metal concentrations in the water phase except for lead. The lead concentrations in persulfate treated samples ranged from 0.298 mg/L to 0.357 mg/L, much higher than the EPA drinking water action level (0.015 mg/L). Based on FMC product specification, the lead from persulfate contributes less than 1 percent to the actual measured concentrations. So the elevated lead concentration is likely due to leaching from the soil. Similar to the permanganate treatment, the lead concentration is expected to decrease to baseline level over time after the oxidant is consumed. Lead should be monitored during the pilot-study and any full-scale application.

3.7 Conclusions and Recommendations

Results of the Knoxville TDL Study indicate that permanganate oxidation is an effective method to treat the PCE and daughter products found at the Jones Road site, with 100 percent reduction in one day. A permanganate dose of 3 g $KMnO_4$ per kg of soil is recommended for field implementation. However, permanganate treatment caused leaching of metals, including silver, barium, chromium, lead, selenium, and thallium from the soil to water phase.

FeEDTA activated persulfate oxidation was effective to a certain extent in treating the PCE at the site, with up to 96.9 percent of reduction in 21 days. This treatment method was not able to reduce PCE concentration below USEPA drinking water MCLs (5 µg/L) within the time frame of this study (21 days) due to the slow reaction kinetics, but it's possible that it can reach the standard given sufficiently long reaction time. A dose of 2 g of persulfate per kg of soil is appropriate for this site. Persulfate oxidation did not significantly alter the metal concentrations in the water phase, except for lead which was increased to concentrations above the MCL.

Given that the SOD of the site soil is fairly low and the reaction between permanganate and VOCs is fast compared to persulfate, 3 g permanganate per kg soil is recommended to be applied at the Jones Road site. Metal concentrations, particularly silver, barium, chromium, lead, selenium, and thallium, should be monitored to document metal concentrations over time. Elevated concentrations of these metals should be expected in the short term, but they should attenuate to baseline levels over time, based on the experience of both Shaw and others.

4.0 BIOSTIMULATION, BIOAUGMENTATION, AND ZVI TREATMENT STUDY

Treatability studies were conducted to evaluate biostimulation, bioaugmentation, and ZVI for the treatment of PCE and PCE degradation products in Jones Road soil and groundwater slurries. These studies were conducted during the Fall of 2006. The experimental approach described below entailed site soil and groundwater preparation, application of various biostimulation amendments, application of Shaw's SDC-9™ culture to amended samples, and tests of ZVI using various amendments.

4.1 Materials and Methods

Biostimulation/Bioaugmentation Microcosms

Microcosms were prepared in glass serum bottles (approximate volume, 160 mL). All microcosm preparation and sampling was performed in a Coy anaerobic chamber. Thirty grams of homogenized site soil and 143-mL of site groundwater was added to each bottle. For the treatment tests that had lactate or emulsified oil substrate (EOS) added as an electron donor, the concentration of the admendment was 1,000 milligrams per liter (mg/L). This concentration was based on the extensive knowledge and experience of the personnel conducting the test. Lactate and EOS were not added to the killed and live control treatments. A total of 24 bottles was prepared. The bottles were sealed with Teflon®-lined butyl rubber stoppers and crimp caps.

Six sets of microcosm treatments were prepared in triplicate as follows:

Treatment 1: KILLED CONTROL: These treatments were amended with a formaldehyde solution (final concentration in groundwater approximately one (1) percent by volume) to inactivate microbial activity, and were used to evaluate abiotic loss of VOCs.

Treatment 2: LIVE CONTROL: This treatment did not receive any amendments except for deionized water (to simulate addition of amendments performed for the other treatments). This treatment served as a control to monitor VOC loss in the absence of any amendments.

Treatment 3: BIOSTIMULATION 1 (LACTATE): Bottles were amended with lactate to serve as the electron donor. Lactate was added such that a concentration of approximately 1,000 mg/L was attained. Nutrient solution and yeast extract was also added to ensure that the bacteria were not limited in nitrogen, phosphorus, or other trace nutrients. This treatment was used to evaluate the effects of anaerobic biostimulation on contaminant biodegradation.

Treatment 4: BIOSTIMULATION 2 (EOS): Bottles were also amended with an emulsified EOS to serve as the electron donor. EOS was added such that a concentration of approximately 1,000 mg/L was attained. Nutrient solution and yeast extract were also added to ensure that the bacteria were not limited in nitrogen, phosphorus, or other trace nutrients. This treatment was used to evaluate the effects of anaerobic biostimulation on contaminant biodegradation.

Treatment 5: BIOAUGMENTATION 1: Shaw's SDC-9™ culture was used as the bacterial inocculum. SDC-9™ was added in a one-time event concentration of 10^5 cells per milliliter (ml). Nutrient solution and yeast extract were also added to ensure that the bacteria were not limited in nitrogen, phosphorus, or other trace nutrients. Bottles were amended with lactate to serve as the electron donor. Lactate was added such that a concentration of 1,000 mg/L was attained.

Treatment 6: BIOAUGMENTATION 2: Shaw's SDC-9™ culture was used as the bacterial inocculum. SDC-9™ was added in a one-time event concentration of 10^5 cells per milliliter (ml). Nutrient solution was also added to ensure that the bacteria were not limited in nitrogen, phosphorus, or other trace nutrients. Bottles were be amended with an EOS to serve as the electron donor. EOS was added such that a concentration of 1,000 mg/L was attained.

A parallel set of bottles was prepared for each treatment (six [6] bottles total) and sampled at each time point to measure anions, pH and ORP throughout the study.

Sampling and Analysis. Bottles were incubated with gentle shaking at 15°C at all times except during the actual sampling procedure. Bottles were allowed to shake for 24 hours after initial setup to allow complete mixing of amendments into the soil and groundwater matrix, after which the aqueous phase was sampled and analyzed for VOCs via EPA Method 8260. This sampling was designated as time zero (t_o).

Sampling events were performed at 1, 5, 7, 9, and 13 weeks of incubation. At each sampling event, microcosm bottles were removed from the shaker and placed in the anaerobic chamber. Sufficient time was allowed for the solids to settle (usually 30 to 60 minutes), so that the supernatant groundwater could be sampled. At each sampling event, approximately 2-3 ml of groundwater was removed from the serum bottle and analyzed for VOCs and reduced gases. In addition, at least one bottle from the live control, biostimulation, and bioaugmentation treatments was analyzed for volatile fatty acids, anions, pH, and ORP at each sampling event (equal sample volume was collected from all bottles and treatments to maintain equal groundwater volumes in all the treatments). Glass beads were added to the bottles after sampling to maintain zero headspace.

ZVI Microcosms

Microcosms were prepared in glass serum bottles (approximate volume, 60 mL). All microcosm preparation and sampling was performed in an anaerobic chamber. Approximately 10 g of homogenized site soil and 50-mL of site groundwater were added to each of the bottles. A total of nine bottles were prepared. The bottles were sealed with Teflon®-lined butyl rubber stoppers and crimp caps.

Three sets of microcosm treatments were prepared in triplicate as follows.

Treatment 1: LIVE CONTROL: This treatment did not receive any amendments except for deionized water (to simulate addition of amendments performed for the other treatments). This treatment served as a control to monitor VOC loss in the absence of any amendments.

Treatment 2: ZVI 1: Bottles were amended with a nanoscale ZVI (nZVI) at a dosage of 0.2 g/L.

Treatment 3: ZVI 2: Bottles were amended with a microscale ZVI (mZVI) at a dosage of 0.5 g/L.

Microcosm bottles were incubated with gentle shaking at 15°C. At each sampling event, microcosm bottles were removed from the shaker, and sufficient time was allowed for the soils to settle so that the supernatant groundwater could be sampled. Approximately 2-3 ml of groundwater sample was drawn directly from the bottles, and immediately analyzed for VOCs at t= 0, 1 week, 3 weeks, 4 weeks, and 5 weeks. At 6 weeks, samples were analyzed for reduced gases (i.e., methane/ethane/ethene) in order to verify the contaminant mass balance.

4.2 Results and Discussion

Biostimulation/Bioaugmentation Microcosms

Results of the biostimulation and bioaugmentation study are summarized in **Tables 4-1** through **4-8** and **Figure 4-1**. Both bioaugmentation treatments, as well as biostimulation with lactate, were successful in treating chlorinated ethenes from the microcosms. Biostimulation with EOS was unsuccessful for completely treating the chlorinated PCE, as dechlorination stalled at DCE.

When bioaugmentation with Shaw's dechlorinating culture SDC-9™ was employed, PCE and TCE were reduced to non-detectable concentrations (i.e. below the PQL of 50 ppb (0.4 mM)) within one week in all samples (**Tables 4-1** and **4-2** and **Figure 4-1**).

Table 4-1
PCE Levels (µM) in the Bioaugmentation and Biostimulation Microcosms

Time (Weeks)	PCE					
	SDC-9™ + Lactate	SDC-9™ + EOS	Lactate	EOS	Live Control	Killed Control
0	1.7±0.5	0.8±0.1	2.3±0.8	1.1±0.1	2.4±0.3	2.7±0.3
1	<0.3	<0.3	ND[a]	ND	3.2±0.3	3.1±0.3
5	<0.7	<0.7	<0.7	<0.7	2.9±0.5	3.3±0.3
9	ND	ND	<0.6	<0.6	2.6±0.3	3.1±0.1
13	ND	ND	<0.2	<0.6	2.5±0.4	2.9±0.3

[a] ND; No data point taken.

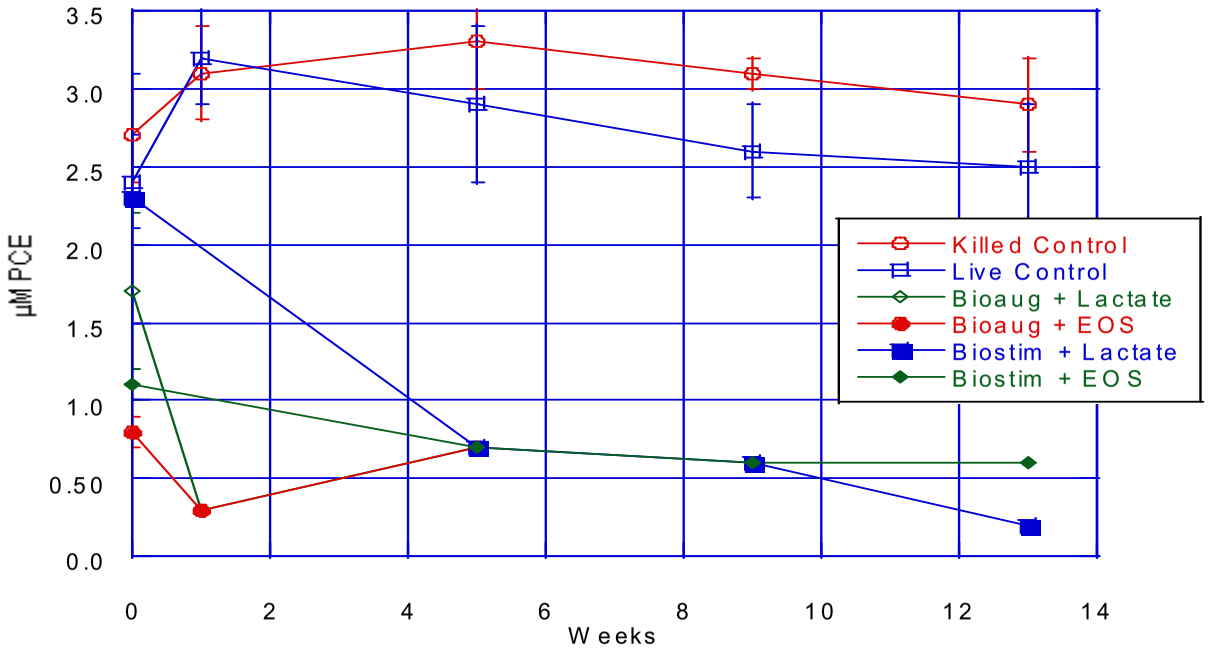
Table 4-2
TCE Levels (µM) in the Bioaugmentation and Biostimulation Microcosms

Time (Weeks)	TCE					
	SDC-9™ + Lactate	SDC-9™ + EOS	Lactate	EOS	Live Control	Killed Control
0	0.8±0.2	0.4±0.1	0.5±0.2	0.5±0.0	0.6±0.1	0.6±0.1
1	<0.4	<0.4	ND[a]	ND	0.7±0.0	0.7±0.0
5	<0.9	<0.9	<0.9	<0.9	0.6±0.1	0.8±0.1
9	ND	ND	<0.8	<0.8	0.6±0.1	0.7±0.0
13	ND	ND	<0.2	<0.8	0.6±0.1	0.7±0.1

[a] ND; No data point taken.

Figure 4-1

PCE Levels in Biostimulation and Bioaugmentation Microcosms



The PCE and TCE breakdown products DCE and VC were reduced below detection (PQL of 120 ppb (1.9 mM)) within five weeks (**Tables 4-3** and **4-4**).

Table 4-3
DCE Levels (µM) in the Bioaugmentation and Biostimulation Microcosms

Time (Weeks)	DCE					
	SDC-9™ + Lactate	SDC-9™ + EOS	Lactate	EOS	Live Control	Killed Control
0	0.7±0.2	0.5±0.1	0.6±0.2	0.7±0.0	0.6±0.0	0.7±0.0
1	0.6±0.8[b]	2.9±0.3	ND[a]	ND	0.7±0.1	0.7±0.0
5	<1.2	<1.2	5.2±0.6	4.9±0.3	0.6±0.1	0.7±0.0
9	ND	ND	1.8±2.4[b]	4.1±0.1	0.5±0.0	0.9±0.4[b]
13	ND	ND	<0.3	5.2±0.1	0.6±0.1	0.7±0.1

[a] ND; No data point taken. Concentration less than detected limit.
[b] One-half of the detection limit was used for non-detect replicates.

Table 4-4
VC Levels (µM) in the Bioaugmentation and Biostimulation Microcosms

Time (Weeks)	VC					
	SDC-9™ + Lactate	SDC-9™ + EOS	Lactate	EOS	Live Control	Killed Control
0	0.4±0.1	<0.8	<0.8	<0.8	<0.8	<1.1
1	1.3±1.3	0.7±0.2	ND[a]	ND	<0.8	<1.3
5	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9
9	ND	ND	2.1±2.6	<1.6	<1.6	<3.2
13	ND	ND	0.3±0.2[b]	<1.6	<1.6	<1.6

[a] ND; No data point taken. Concentration less than detected limit.
[b] One-half of the detection limit was used for non-detect replicates.

Measurable concentrations of ethene, the likely degradation end product of biostimulation/ bioaugmentation, were present in both bioaugmentation treatments (**Table 4-5**), thus indicating that complete dechlorination was occurring.

Table 4-5
Ethene Levels (µM) in the Bioaugmentation and Biostimulation Microcosms

Time (Weeks)	Ethene					
	SDC-9™ + Lactate	SDC-9™ + EOS	Lactate	EOS	Live Control	Killed Control
0	<0.29	<0.29	<0.07	<0.07	<0.07	<0.07
1	2.0±1.5	0.05±0.01[c]	ND[a]	ND	<0.07	<0.07
5	6.4±5.1	47±5.3[b]	1.7±1.9[c]	<0.07	<0.07	<0.07
7	20.3±14.2[b]	81.2±23.7[b]	<71.4[b]	<3.57	<0.07	<0.07
9	ND	ND	<7.14[b]	<7.14[b]	<0.07	<0.07
13	ND	ND	6.5±0.8	<0.36	<0.07	<0.07
16	ND	ND	6.3±2.3	<23.9	<0.07	<0.07

[a] ND; No data point taken. See Note b.
[b] High methane levels in sample masked ethene.
[c] One-half of the detection limit was used for non-detect replicates.

As expected, dechlorination of VOCs via biostimulation took considerably longer than when bioaugmentation was employed. In the biostimulation microcosms, PCE and TCE levels were reduced below the PQL of 120 ppb (1.9 mM) at five weeks, with 500 ppb (5 mM) DCE present at that time. Complete dechlorination to ethene occurred in the lactate treatment, but dechlorination appeared to stall at DCE in the EOS treatment. Ethene was detected in only the lactate treatment.

There was no measurable loss of PCE in both the killed and live controls over the course of the study. Initial PCE concentration in the EOS-amended treatments was substantially less than in the controls and lactate-amended treatments; this is likely the result of PCE partitioning into the oil. For the lactate bioaugmentation treatment, the reduced initial time zero PCE concentration (relative to the controls) may reflect partial biodegradation of the PCE within the 24-hour equilibration period. Evaluation of overall contaminant molar balances was inhibited by elevated methane concentrations, which interfered with the ethene analysis (**Table 4-5**). Ethene analyses for the lactate-amended treatments (biostimulation and bioaugmentation) that were not impacted by methane showed that final ethene levels of approximately 6.4 mM were obtained, which is approximately 1.6-times the stoichiometric ethene concentration that would be expected based on the initial chlorinated ethene concentrations. This discrepancy is likely due to sorbed PCE mass that was initially on the soil.

No ethane was detected in any of the biological treatments (**Table 4-6**).

Table 4-6
Ethane Levels (µM) in the Bioaugmentation and Biostimulation Microcosms

Time (Weeks)	Ethane					
	SDC-9™ + Lactate	SDC-9™ + EOS	Lactate	EOS	Live Control	Killed Control
0	<0.27	<0.27	<0.07	<0.07	<0.07	<0.07
1	<0.24	<0.07	ND[a]	ND	<0.07	<0.07
5	<0.91	<0.91	<0.91	<0.07	<0.07	<0.07
7	<1.33	<1.33	<66.7	<3.33	<0.07	<0.07
9	ND	ND	<6.67	<6.67	<0.07	<0.07
13	ND	ND	<0.33	<0.33	<0.07	<0.07
16	ND	ND	<0.33	<22.3	<0.07	<0.07

[a] ND; No data point taken. Concentration less than detected limit.

The pH data obtained during the course of this study are presented in **Table 4-7**. There were no significant changes in pH over the course of the study, with pH ranging between 6.7 and 8.0 in all treatments.

Table 4-7
pH (Standard Units) in the Bioaugmentation and Biostimulation Microcosms

Time (Weeks)	pH					
	SDC-9™ + Lactate	SDC-9™ + EOS	Lactate	EOS	Live Control	Killed Control
0	7.17	7.35	7.08	7.42	7.75	7.52
1	7.12	7.30	ND[a]	7.40	7.72	7.48
5	6.71	6.49	6.68	6.85	7.59	6.99
9	ND[a]	ND[a]	6.78	7.04	7.99	7.14
13	ND[a]	ND[a]	6.77	6.88	7.11	7.26

[a] ND; No data point taken.

The ORP data obtained during the course of this study are presented in **Table 4-8**. Negative ORP values were observed in the three successful biological treatments (both bioaugmentation treatments and biostimulation with lactate), which is consistent with the success of these treatments. Positive ORP values were observed in the controls, which is consistent with the lack of dechlorination in these treatments.

Table 4-8
ORP (Millivolts) in the Bioaugmentation and Biostimulation Microcosms

Time (Weeks)	ORP					
	SDC-9™ + Lactate	SDC-9™ + EOS	Lactate	EOS	Live Control	Killed Control
0	62	5	100	120	120	200
1	-120	-156	ND[a]	ND[a]	50	220
5	-120	-105	-86	18	2	11
9	ND[a]	ND[a]	78	112	126	163
13	ND[a]	ND[a]	31	138	124	177

[a] ND; No data point taken.

ZVI Microcosms

Data from the ZVI testing are presented in **Tables 4-9** and **4-10**. Both ZVI treatments, NZVI and MZVI, were effective at treating the chlorinated ethenes. Contaminant degradation rates in each of the ZVI treatments were comparable. Both ethane and ethene were detected in each ZVI treatment at the final sampling event (t=5 weeks).

The rate of PCE degradation in the ZVI treatments was less than the rate of PCE degradation observed in the bioaugmentation and lactate biostimulation studies. However, no transient accumulation of DCE or VC was observed in the ZVI treatments.

Table 4-9
Contaminant Levels (µM) in Jones Road ZVI Microcosms.

Time (Weeks)	PCE			TCE		
	NZVI	MZVI	Live Control	NZVI	MZVI	Live Control
0	2.5±0.6	2.0±0.4	2.3±0.5	0.5±0.1	0.4±0.1	0.5±0.1
1	1.5±0.3	1.1±0.4	2.2±0.4	<0.4	<0.4	0.5±0.1
3	0.6±0.2	0.3±0.1	1.7±0.4	<0.2	<0.2	0.4±0.1
4	0.4±0.2	0.1±0.0[a]	1.3±0.2	<0.2	<0.2	0.4±0.1
5	0.4±0.2	<0.1	1.2±0.3	<0.2	<0.2	0.4±0.1

Time (Weeks)	DCE			VC		
	NZVI	MZVI	Live Control	NZVI	MZVI	Live Control
0	0.5±0.1	<0.5	0.5±0.1	<0.8	<0.8	<0.8
1	0.4±0.0	<0.4	0.5±0.1	<0.8	<0.8	<0.8
3	0.3±0.0	<0.2	0.5±0.1	<0.4	<0.4	<0.4
4	0.2±0.0	<0.2	0.4±0.1	<0.4	<0.4	<0.4
5	0.2±0.0	<0.2	0.5±0.1	<0.4	<0.4	<0.4

[a] One-half of the detection limit was used for non-detect replicates.

Table 4-10
Final Ethane and Ethene Values (µM) for ZVI Microcosms.

	NZVI	MZVI	Live Control
Ethene	1.9±0.3	2.4±0.2	<0.1
Ethane	0.6±0.1	0.8±0.1	<0.1

PCE concentrations in the Live Control decreased by approximately 50 percent during the 5-week study. The reason for this decrease is unclear. Contaminant molar balances in the two ZVI treatments showed greater than an 83 percent molar conversion to ethene (based on initial aqueous phase chlorinated ethene concentrations). No ethene or ethane was detected in the control.

4.3 Conclusions

Results of the Lawrenceville Technology Laboratory study indicate the following:

- Bioaugmentation with lactate or EOS, and biostimulation with lactate, resulted in the complete dechlorination of PCE;
- Bioaugmentation with SDC-9™ increased the treatment kinetics relative to biostimulation;
- Treatment using both NZVI and MZVI resulted in complete dechlorination of PCE, with no transient accumulation of DCE or VC.

Overall, results of this study show that bioaugmentation, biostimulation with lactate, and NZVI/MZVI are potential treatment options for PCE at the site.

5.0 CONCLUSION AND RECOMMENDATION

Treatability studies using both microcosm testing of soils and groundwater from the Jones Road site have identified several insitu technologies that successfully degraded PCE and its daughter products. Treatability testing determined that permanganate oxidation was the most effective ISCO technology. Bioremediation treatability testing determined that both bioaugmentation and biostimulation effectively treated PCE and its daughter products in Jones Road soils and groundwater. Biostimulation with lactate had the best reaction kinetics. ZVI also effectively treated the PCE and its daughter products.

As discussed in Section 1.0 of this report, subsurface soils at the Jones Road site are clays, clayey sands, and sandy clays with intermittent sand lenses. Sand layers are discontinuous and at variable depths in the shallow saturated zone (depths of approximately 28-50 feet bgs) at the site. PCE and its daughter products are also present in the vadose zone soils at the site, and at deeper depths in the saturated zone. Due to the presence of low permeability zones, site conditions pose a challenge to implementing an insitu remedial technology at the site. Another challenge, not addressed by this report, are logistics for a pilot study or full-scale implementation, since the facility is occupied and the lot on the south side of the former dry cleaner is an open public area, and the area with the highest shallow groundwater contamination (GP-3A) is a narrow alley with underground utilities. These conditions do not eliminate the possibility of performing a pilot study and full-scale technology application at the Jones Road site. Insitu treatment in the shallow source area is critical for mass VOC destruction and mitigation of the source area. **Figure 1-1**, the Site Plan, shows the potential locations for pilot studies.

Site conditions at Jones Road, including abundant clays, deep contamination migration, and an existing source area, may require the application of remedial technologies in combination. The technology that addresses the shallow source area may not be what is needed at deeper depths. For example, ISCO technologies may be more appropriate in shallower source zones and biotechnologies may be more appropriate at depth or in extended plume areas. An immediate need is to implement a technology that would, in a short amount of time, significantly reduce the mass and mobility of PCE source material. July 2006 Geoprobe® studies detected significant concentrations of PCE (i.e., GP-3A = 190,000 µg/L, GP-7A = 43,000 µg/L) near the former Bell Dry Cleaners. An ISCO pilot study, using potassium permanganate, should be performed in this area. Prior to selecting one of the proposed test sites shown on **Figure 1-1**, a conceptual site model (CSM) needs to be developed that includes, as detailed as possible, geologic cross sections and hydraulic information. The CSM will allow for the placement of both injection and monitoring wells and selection of well screen intervals. The CSM will help evaluate where to install pilot study monitoring points to evaluate how the ISCO acts within the various clay and

sand layers. PCE and daughter products have migrated laterally and downward through the subsurface at the site. Applying an insitu technology like ISCO, or a biotechnology, has a good chance of destroying VOCs along preferential flow pathways.

CSM and pilot study results will also allow for an evaluation and planning of a full-scale technology application. CSM information is also critical for developing an appropriate implementation of an ISCO or biotechnology to deeper zones. Although in some areas ISCO should be conducted first, another pilot study to evaluate application and sustainability of a bioaugmentation technology in deeper zones should be considered. In deeper zones, greater than 50 feet and possibly 100 feet, PCE contamination may be addressed by developing zones within sand units where a sustained active bioremediation zone acts as a migration barrier. Such an approach utilizes ISCO in shallower source type areas and biotechnology in deeper migration pathway zones. Because of complex site conditions and the deep nature of the contamination, TCEQ will need to consider a multiple technology approach to the Jones Road site.

More specific details (design) on how to address site-specific conditions would be included in a pilot study work plan. Actions often associated with pilot studies may include short-term aquifer tests (open well and packer studies) to evaluate site hydraulics. Bromide tracer studies are often used with insitu applications to evaluate delivery and distribution pathways. Potassium permanganate with its unique purple color acts as its own tracer.

A pilot test would include a test well network, including injection and extraction wells, and monitoring wells. Insitu technology amendments (ISCO or biotechnology) are placed in the test treatment zone through the injection wells. The pilot test may include single or multiple injections. One or several injection/extraction well pairs may be used during the test. Several monitoring well points may be installed between the injection and extraction wells. Whenever possible, existing monitoring wells are used as monitoring points. The treatment dosage is based on treatability study results and the hydraulic data collected during short-term aquifer tests. Groundwater is recovered from the extraction wells and analyzed on a pre-determined frequency to evaluate PCE and daughter product concentrations. Along with VOCs, natural attenuation parameters and metals are often part of the pilot test analytical program. Extraction well flow rates are based on short-term aquifer test data and tracer test results. Injection, extraction, and monitoring well placement and screen intervals would be based on the CSM and aquifer characteristics.

A report of pilot test results, including a description of the test design and procedures, expected results, and actual results, would be prepared after the test. The report would also include recommendations and a conceptual design for a full-scale (selected area or site-wide) application.

Once a CSM is developed and pilot tests are conducted, a more complete technology assessment and application strategy can be developed which addresses cost, site conditions, and life-cycle engineering for a full-scale remedial technology implementation.

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Appendix A

Soil Acid Buffering Capacity Measurement Data

Project/No.: Jones Road/121615.05 Date: 8/30/2006

Sample TDL 10506 Reagent/G.W. TDL 10507

Sample Wt. (g): 50 Water Volume (mL) 100

Base Reagent/Conc.: H_2SO_4 0.1 N Initials XZ

Reading No.	Time	Acid Add'n (mL)	Total Vol Acid (mL)	pH	Acid meq. per kg Soil		Comments
1		0	0	7.4	0.00		
2		1	1	7.05	2.00		
3		1	2	6.83	4.00		
4		1	3	6.69	6.00		
5		1	4	6.43	8.00		
6		1	5	6.3	10.00		
7		1	6	6.24	12.00		
8		2	8	5.96	16.00		
9		2	10	5.58	20.00		
10		2	12	5.33	24.00		
11		2	14	5.09	28.00		
12		2	16	4.67	32.00		Alkalinity (mg $CaCO_3$/kg)
13		1	17	4.31	34.00		1700
14		1.0	18	4.12	36.00		
15		0.5	18.5	4.09	37.00		
16		0.5	19	4.09	38.00		
17		1.0	20	3.86	40.00		
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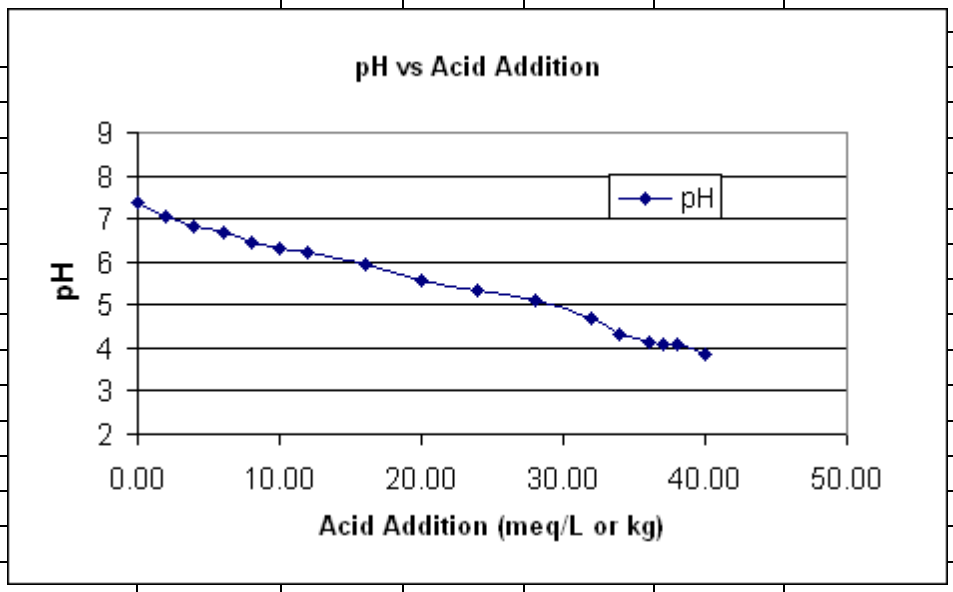


Notes:

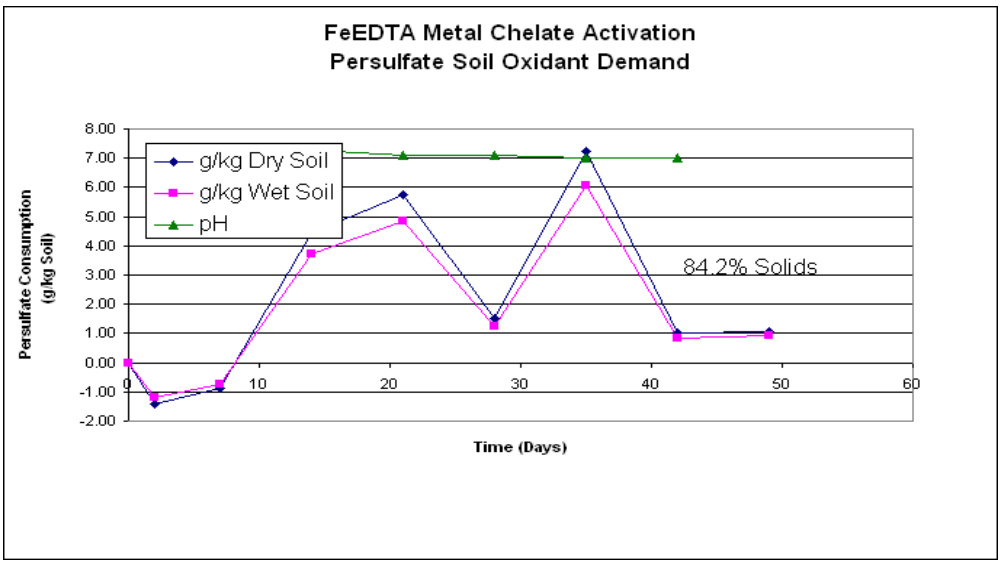
Appendix B

Soil Oxidant Demand Test Data

Project Name:	Jones Road	Date Started:	8/30/2006
Project Number:	121615.05	Analyst Initials:	XZ
Client Sample No. (Soil):	NA	Client Sample No. (Water):	NA
Description:	Clayey soil	Description:	Groundwater
TAL Sample No.:	10506	TAL Sample No.:	10507
Solids (%):	84.20%	Volume Used (mL):	200
Fraction -4 mm particle size :	NA		
Weight Used (g):	200	Initial Weight $Na_2S_2O_8$ (g):	4.00
Test Temp (°C)	15	Initial Conc. $Na_2S_2O_8$ (mg/L):	20,000

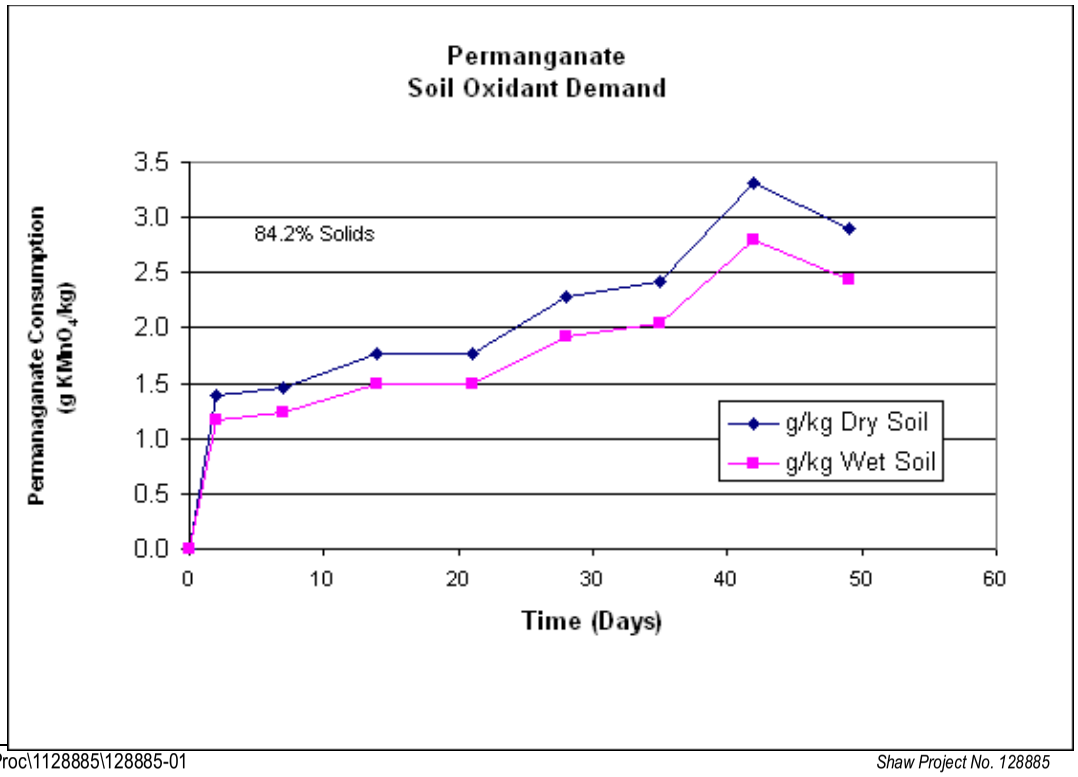
FeEDTA at 150 mg/L Fe

Time (Days)	Persulfate Conc. (mg/L)	Persulfate Addition (g)	Total $Na_2S_2O_8$ Added (g)	pH (SI)	Persulfate Consumed (g/kg Dry Soil)	Persulfate Consumed (g/kg Wet Soil)
0	17,271	0.0	4.00		0.00	0.00
2	18,300	0.0	4.00	7.15	-1.41	-1.19
7	17,900	0.0	4.00	6.99	-0.86	-0.73
14	14,042	0.0	4.00	7.3	4.44	3.74
21	13,090	0.0	4.00	7.1	5.75	4.84
28	16,184	0.0	4.00	7.09	1.50	1.26
35	12,019	0.0	4.00	7.02	7.22	6.08
42	16,541	0.0	4.00	7.02	1.00	0.85
49	16,482	0.0	4.00	7.02	1.09	0.91



Project Name:	Jones Road	Date Started:	8/30/2006
Project Number:	121615.050000	Analyst Initials:	XZ
Client Sample No. (Soil):	NA	Client Sample No. (Water):	NA
Description:	Clayey soil	Description:	Groundwater
TAL Sample No.:	10506	TAL Sample No.:	10507
Solids (%):	84.20%	Volume Used (mL):	200
Fraction -4 mm particle size :	NA		
Weight Used (g):	200	Initial Weight $KMnO_4$ (g):	2.000
Test Temp (°C)	15	Initial Conc. KMnO4 (mg/L):	10,000

Time (Days)	$KMnO_4$ Conc. (mg/L)	$KMnO_4$ Addition (g)	Total $KMnO_4$ Added (g)	Time (Days)	$KMnO_4$ Consumed (g/kg Dry Soil)	$KMnO_4$ Consumed (g/kg Wet Soil)
0	8636	0.0	2.00	0	0.00	0.00
2	7625	0.0	2.00	2	1.39	1.17
7	7575	0.0	2.00	7	1.46	1.23
14	7350	0.0	2.00	14	1.77	1.5
21	7350	0.0	2.00	21	1.77	1.5
28	6975	0.0	2.00	28	2.28	1.9
35	6875	0.0	2.00	35	2.42	2.0
42	6225	0.0	2.00	42	3.32	2.8
49	6525	0.0	2.00	49	2.90	2.4



Appendix C

Treatment Effectiveness Test VOC Analysis Data

VOC Analytical Data
Laboratory Chemical Oxidation Treatment Study
Jones Road Superfund Site
November 2006

Treatment	Dosage (g/L)	Sample ID	Water							Soil						
			VC (µg/L)	trans-DCE (µg/L)	Cis-DCE (µg/L)	TCE (µg/L)	PCE (µg/L)	Oxidant (mg/L)	pH	VC (µg/kg)	trans-DCE (µg/kg)	Cis-DCE (µg/kg)	TCE (µg/kg)	PCE (µg/kg wet soil)	Solids content	PCE (µg/kg dry soil)
0 day Control	NA	C1-0	25 U	25 U	34.412	16.687	1243.918	0	7.49	3.43 U	3.43 U	3.43 U	3.43 U	42.583	77.42%	0
	NA	C2-0	25 U	25 U	14.823	8.382	1252.424	0	7.57	4.83 U	4.83 U	4.83 U	4.83 U	39.909	75.51%	0
14 day control	NA	C2-14	25 U	25 U	63.504	57.295	1575.233	0	7.12	5.55 U	5.55 U	5.55 U	5.55 U	91.464	75.46%	0
21 day control	NA	C1-21	2.5 U	2.5 U	2.5 U	2.5 U	95.547	0	7.9	5.67 U	5.67 U	5.67 U	5.67 U	15.009	70.16%	0
1 day, permanganate	3	M1-1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2540		4.63 U	4.63 U	4.63 U	4.63 U	4.63 U	64.90%	0
	5	M2-1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	4280		5.2 U	5.2 U	5.2 U	5.2 U	5.2 U	67.55%	0
	10	M3-1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	8800		4.43 U	4.43 U	4.43 U	4.43 U	12.481	67.55%	18.48
4 days, permanganate	3	M1-4	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2590		4.75 U	4.75 U	4.75 U	4.75 U	4.75 U	68.40%	0
	5	M2-4	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	5480		4.98 U	4.98 U	4.98 U	4.98 U	4.98 U	67.36%	0
	10	M3-4	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	8800		5.13 U	5.13 U	5.13 U	5.13 U	5.13 U	70.44%	0
14 days, permanganate	3	M1-14	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2630		5.38 U	5.38 U	5.38 U	5.38 U	5.38 U	72.20%	0
	5	M2-14	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	4240		5.26 U	5.26 U	5.26 U	5.26 U	5.26 U	69.02%	0
	10	M3-14	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	8360		5.24 U	5.24 U	5.24 U	5.24 U	5.24 U	67.77%	0
4 days, persulfate	2	S1-4	2.5 U	2.5 U	57.938	55.494	1191.344	1785	7.56	9.45 U	9.45 U	9.45 U	9.45 U	118.825	75.50%	0
	5	S2-4	2.5 U	2.5 U	28.352	16.379	795.244	4760	7.64	8.9 U	8.9 U	8.9 U	8.9 U	60.864	69.14%	0
	10	S3-4	2.5 U	2.5 U	18.523	7.973	424.266	9401	7.69	7.0 U	7.0 U	7.0 U	7.0 U	34.79	71.64%	0
8 days, persulfate	2	S1-8	2.5 U	2.5 U	15.388	5.759	251.393	1963.5	7.74	3.9 U	3.9 U	3.9 U	3.9 U	45.111	68.34%	0
	5	S2-8	2.5 U	2.5 U	28.223	15.094	909.551	4760	7.44	4.55 U	4.55 U	4.55 U	4.55 U	52.275	75.35%	0
	10	S3-8	2.5 U	2.5 U	24.851	14.057	438.149	9282	7.4	3.78 U	3.78 U	3.78 U	3.78 U	37.022	72.55%	0
21 days, persulfate	2	S1-21	2.5 U	2.5 U	2.5 U	2.5 U	42.011	1696	7.65	4.83 U	4.83 U	4.83 U	4.83 U	9.069	73.08%	0
	5	S2-21	2.5 U	2.5 U	20.934	11.016	498.767	4641	7.21	4.90 U	4.90 U	4.90 U	4.90 U	27.065	71.44%	0
	10	S3-21	2.5 U	2.5 U	10.819	4.465	154.452	9044	6.94	4.24 U	4.24 U	4.24 U	4.24 U	9.007	74.79%	0

U – Laboratory reporting limits

Appendix D

Treatment Effectiveness Test Metal Analysis Data

Metal Analysis Data
Laboratory Chemical Oxidation Treatment Study
Jones Road Superfund Site
November 2006

Sample ID	Ag (mg/L)	Al (mg/L)	As (mg/L)	Ba (mg/L)	Be (mg/L)	Ca (mg/L)	Cd (mg/L)	Co (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	K (mg/L)	Mg mg/L)
MDL	*0.012*	*0.086*	*0.012*	*0.005*	*0.005*	*0.150*	*0.012*	*0.026*	*0.026*	*0.026*	*0.150*	*0.75*	*0.015*
C1-0	<0.012	1.54	<0.012	0.171	<0.005	34.1	<0.012	<0.026	<0.026	<0.026	0.486	<0.75	6.39
C2-0	<0.012	1.35	<0.012	0.162	<0.005	32	<0.012	<0.026	<0.026	<0.026	0.479	<0.75	6.50
C1-21	<0.012	8.59	<0.012	0.162	<0.005	27.2	<0.012	<0.026	<0.026	<0.026	4.7	<0.75	5.86
C2-14	<0.012	1.41	<0.012	0.213	<0.005	40.5	<0.012	<0.026	<0.026	<0.026	0.566	<0.75	8.01
M1-14	0.076	0.519	<0.012	1.61	<0.005	203	<0.012	<0.026	0.232	<0.026	< 0.150	116	35.8
M2-14	0.114	0.863	<0.012	2.19	<0.005	220	<0.012	<0.026	0.288	<0.026	< 0.150	284	44.1
M3-14	0.242	0.788	<0.012	4.5	<0.005	472	<0.012	<0.026	0.472	<0.026	< 0.150	920	68.9
S1-21	0.017	0.936	<0.012	0.438	<0.005	133	<0.012	<0.026	<0.026	<0.026	44.5	<0.75	20.6
S2-21	0.034	0.974	<0.012	0.164	<0.005	220	<0.012	<0.026	<0.026	<0.026	86.4	<0.75	35.1
S3-21	0.044	0.309	<0.012	0.106	<0.005	322	<0.012	0.070	<0.026	<0.026	115	<0.75	48.7

Sample ID	Mn (mg/L)	Mo (mg/L)	Na (mg/L)	Ni (mg/L)	P (mg/L)	Pb (mg/L)	S (mg/L)	Sb (mg/L)	Se (mg/L)	Sn (mg/L)	Ti (mg/L)	V (mg/L)	Zn mg/L)
MDL	*0.026*	*0.026*	*0.055*	*0.012*	*0.026*	*0.012*	*0.026*	*0.012*	*0.012*	*0.026*	*0.012*	*0.026*	*0.012*
C1-0	<0.026	<0.026	133	<0.012	0.242	<0.012	6.45	<0.012	<0.012J	<0.026	<0.012	<0.026	<0.012
C2-0	<0.026	<0.026	125	<0.012	0.303	<0.012	6.62	<0.012	<0.012J	<0.026	<0.012	<0.026	<0.012
C1-21	<0.026	<0.026	120	<0.012	0.161	<0.012	6.45	<0.012	<0.012J	<0.026	<0.012	<0.026	<0.012
C2-14	<0.026	<0.026	132	<0.012	0.211	<0.012	6.49	<0.012	<0.012J	<0.026	<0.012	<0.026	<0.012
M1-14	574	<0.026	186	<0.012	<0.026	0.015	9.24	<0.012	0.153J	<0.026	0.243	<0.026	<0.012
M2-14	839	<0.026	205	<0.012	<0.026	0.033	10.1	<0.012	0.299J	<0.026	0.496	<0.026	<0.012
M3-14	1163	<0.026	233	<0.012	<0.026	0.107	19.0	<0.012	0.747J	0.031	1.30	<0.026	<0.012
S1-21	0.376	<0.026	403	0.065	0.151	0.357	361	<0.012	<0.012J	<0.026	<0.012	<0.026	0.066
S2-21	0.358	<0.026	736	0.050	0.120	0.350	528	<0.012	<0.012J	<0.026	<0.012	<0.026	0.034
S3-21	1.10	<0.026	1137	0.062	0.102	0.298	552	<0.012	<0.012J	<0.026	<0.012	<0.026	0.047

J Qualifier = Estimated values maybe biased slightly low. Continuing standard outside 80-120% criteria at 79%.

Appendix B

Simple Capture Zone Modeling Report

SIMPLE CAPTURE ZONE MODELING
Jones Road Groundwater Plume Superfund Site
Houston, Texas

Final—July 2009

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Table 1 Summary of Capture Zone Model Results, Jones Road Site

Acronyms and Abbreviations

DCE	dichloroethylene
EPA	U.S. Environmental Protection Agency
FS	feasibility study
ft/ft	feet per foot
MCL	maximum contaminant level
PCE	tetrachloroethylene
PWS	public water supply
RI	remedial investigation
TCEQ	Texas Commission on Environmental Quality
USGS	U.S. Geological Survey

Executive Summary

The Texas Commission on Environmental Quality, through a Cooperative Agreement with the U.S. Environmental Protection Agency, is undertaking a remedial investigation and feasibility study in the residential and commercial area surrounding the former location of the Bell Dry Cleaners site (Bell facility). The Bell facility is located at 11600 Jones Road, Houston, Texas. The Jones Road Groundwater Plume Site (Jones Road site) is located approximately one-half mile north of the intersection of Jones Road and FM 1960, outside the Houston city limits in northwest Harris County. The groundwater is contaminated with tetrachloroethylene (PCE), trichloroethene, *cis*-1,2-dichloroethylene (DCE), *trans*-1,2-DCE, and vinyl chloride. The extent of the plume has been documented from the southern end of Echo Spring Lane to Tower Oaks Boulevard and from Timber Hollow Drive to the eastern side of Jones Road.

A two-dimensional model was designed to perform a simple capture zone analysis of the Chicot Aquifer underlying the Jones Road site. The primary goal of the model is to assist in quantifying the number of wells and the respective pumping rates required in order to show hydraulic capture of the existing PCE plume. The model is intended to be simple, conservative, and is not to be used for purposes beyond preliminary capture zone analysis.

In this model, the Chicot Aquifer is simulated as an unconfined, homogeneous, and isotropic aquifer under steady-state conditions. The width of the model domain along the north-south axis is 4650 feet. The east-west axis of the model domain has a total length of 4600 feet. The grid was set to uniform thicknesses in the vertical, or z, direction of 100 and 200 feet. The saturated thickness of the Chicot Aquifer is more on the order of 300 feet in thickness at the site (Shaw 2008); however, the 100-foot thickness is conservative and most representative of the portion of the Chicot Aquifer impacted by the dissolved phase PCE. Initially, six hydraulic extraction wells were simulated in the model. The number of extraction wells was increased in specific scenarios in order to obtain complete hydraulic capture of the contamination plume. The wells are screened 50 feet into the aquifer and pumped at a constant rate. All boundaries of the model are treated as constant-head boundaries that simulate the observed hydraulic gradient of 0.003 feet/foot at the site.

A variety of pumping rates were modeled, with the goal of obtaining the lowest possible pumping rate that (1) does not dry up model cells and (2) still captures flowpaths within the contaminated zones. To account for the fact that hydraulic conductivity at the site has not been measured, the effects of pumping under a range of hydraulic conductivities were considered.

A scenario using a hydraulic conductivity of 50 feet per day results in little drawdown beyond the area immediately adjacent to a well for both the 100- and 200-foot aquifer thicknesses. The

capture zone for each well is relatively narrow, and gaps through which PCE might migrate are clearly present in the overall capture zone. Additional pumping wells would be required in this scenario to produce hydraulic capture of the plume. Conversely, a conductivity of 5 feet per day in a 100-foot-thick aquifer results in a significant amount of drawdown and a capture zone that encompasses the current plume and adjacent areas. For a 200-foot-thick aquifer, the cone of depression is shallower for a conductivity of 5 feet per day and therefore results in narrower capture zones for each well; gaps are present in the overall capture zone for the scenario using a hydraulic conductivity of 5 feet per day and a 200-foot-thick aquifer. For a hydraulic conductivity of 20 feet per day and an aquifer thickness of 100 feet, capture can be achieved with five wells pumping continuously at 20 gallons per minute and a sixth well pumping at 25 gallons per minute. The 200-foot-thick aquifer results in less drawdown at each well for a conductivity of 20 feet per day, and the plume is not hydraulically captured.

Two additional pumping wells were added to the scenario where the hydraulic conductivity is 20 feet per day and the aquifer thickness is 200 feet. In order to obtain complete hydraulic capture of the PCE plume, four of the eight wells have a pumping rate of 20 gallons per minute and four wells are pumping at a rate of 25 gallons per minute. This is the most reasonable scenario and the one recommended when determining the cost of a potential treatment system.

The model results presented in this report are basic and derived from a noncalibrated model. Site-specific aquifer and pump tests would be required prior to completing the design of a remediation system.

1.0 Introduction

The Texas Commission on Environmental Quality (TCEQ), through a Cooperative Agreement with the U.S. Environmental Protection Agency (EPA), is undertaking a remedial investigation (RI) and feasibility study (FS) in the residential and commercial area surrounding the former location of the Bell Dry Cleaners site (Bell facility). The Bell facility was located at 11600 Jones Road, Houston, Texas. The Jones Road Groundwater Plume Site (Jones Road site) is located approximately one-half mile north of the intersection of Jones Road and FM 1960, outside the Houston city limits in northwest Harris County. The groundwater is contaminated with tetrachloroethylene (PCE), trichloroethene, *cis*-1,2-dichloroethylene (DCE), *trans*-1,2-DCE, and vinyl chloride. The extent of the plume has been documented from the southern end of Echo Spring Lane to Tower Oaks Boulevard and from Timber Hollow Drive to the eastern side of Jones Road.

Approximately 231 public water supply (PWS) and private wells have been identified within a one-half-mile radius of the former Bell facility. Filtration systems have been installed on residential wells where PCE has been detected at levels exceeding the maximum contaminant level (MCL); an additional filtration system was installed on a well where PCE concentrations are below the MCL, at the request of the owner. Between 100 and 150 residential wells were monitored on a quarterly basis between May 2003 and May 2008.

The EPA and TCEQ funded the construction of a waterline connecting the City of Houston water supply to the Jones Road community. Community members can participate in the EPA and TCEQ-funded waterline project on a voluntary basis. As of this report, approximately 50 percent of the property owners and well owners have connected to the waterline and relinquished their water wells. Figure 1 shows the current Jones Road waterline service area (TCEQ, 2007). In addition, the entire Jones Road area falls within the boundary of the North Harris County Regional Water Authority (NHCRWA, July 2002) (Figure 2). The effects of groundwater withdrawals from within the greater water authority perimeter, as well as more local-scale pumping near Jones Road, are multidimensional and complex and by necessity could not be included in this simple model. However, it is important to note that the local hydraulic gradient in the Jones Road area has changed as a result of homeowners turning off their own wells and connecting to the waterline. Whereas the local gradient was previously northward (from the Bell facility towards the neighborhood north of Jones Road), it is now more southwesterly. This change is very likely due to the reduced hydraulic effect of several hundred homeowner wells being shut down.

2.0 Purpose of the Model

The purpose of this model is to perform a simple capture zone analysis of the Chicot Aquifer underlying the Jones Road site. More specifically, the goal is to develop a model to assist in quantifying the number of wells and the respective pumping rates required in order to show hydraulic capture of the existing PCE plume. These data would then be available to staff who are evaluating various remediation alternatives as part of the Jones Road FS. The model is intended to be simple, conservative, and is not to be used for purposes beyond preliminary capture zone analysis. Due to the lack of hydraulic data from the residential wells, changing conditions as those wells stopped pumping and homeowners connected to the waterline, and the short time frame required to complete the model, the model is not calibrated to local flow conditions. The aquifer is simulated as an unconfined, homogeneous, and isotropic aquifer under steady-state conditions.

3.0 Conceptual Site Model

Two primary hydrostratigraphic units have been defined for the Jones Road site: the Chicot Aquifer and the Evangeline Aquifer (Figure 3). The Chicot Aquifer is composed of the youngest water-bearing unit in the Coastal Plain of Texas. The unit is laterally discontinuous and includes fluvial-deltaic deposits of gravel, sand, silt, and clay. The presence of the Chicot Aquifer in the subsurface can be delineated by a higher sand-clay ratio relative to the underlying Evangeline Aquifer (Baker, 1979). A thick sequence of laterally discontinuous, interbedded sand and clay layers separates the shallow sediments of the Chicot Aquifer from the deeper layers (Kasmarek and Strom, 2002). This sequence of interbedded sand and clay layers results in a weak hydraulic connection between the Chicot Aquifer and the land surface. The Chicot Aquifer is commonly differentiated from the Evangeline Aquifer on the basis of its contrasting, relatively lower transmissivity. A weak hydraulic connection exists between the Chicot and Evangeline Aquifers, allowing for water to move vertically between the two hydrostratigraphic units. This model examines groundwater flow in the Chicot Aquifer only. Figure 4 was adapted from the RI report (Shaw, 2009) and represents a type section for the site. Figure 4 is quite detailed and was used as the starting point for the simplified block diagram presented in Figure 3.

The regional groundwater flow direction in Harris County is generally south-southeast (Kasmarek and Strom, 2002). This is consistent with the regional flow direction and hydraulic gradient (approximately 0.003 feet per foot [ft/ft]) developed by the U.S. Geological Survey (USGS) and shown in Figure 5. Recent water level measurements from monitoring wells at the site support a southeasterly flow direction under a gradient of 0.003 ft/ft (Shaw, 2007). The large number of private and PWS wells within Harris County and, more specifically, the Jones Road site, may affect the local groundwater flow directions. Data logger information obtained

from five wells within the Jones Road site indicates that the local groundwater flow direction varies from south, southeast, and southwest in the Chicot Aquifer. However, the fact that private wells are contaminated with PCE is clear evidence that on a local scale the hydraulic gradient was, at some time, due west of the Bell facility. In fact, these wells were likely to have exerted some hydraulic control on the plume and may continue to do so. To further complicate the picture, approximately 50 percent of the private wells in the Jones Road community are now turned off as some homeowners chose to connect to the PWS pipeline. This has resulted in a change in the site-scale hydraulic gradient, and groundwater at the site now flows to the southeast (Shaw, 2007). While the effect of these changes on PCE migration is beyond the scope of this report, connecting homeowners to the waterline may have resulted in the unintended consequence of reducing the hydraulic containment previously exerted by homeowner wells.

4.0 Statement of the Problem

An RI was completed for the site (Shaw, 2009) and an FS is in progress. The FS will evaluate a number of remedial alternatives, including a groundwater pump and treat system. This model provides decision-making personnel with a conservative estimate of the number of wells and the respective pumping rates required in order to capture the existing Jones Road PCE plume. These data will be used in FS cost estimates of the pump and treat alternative.

5.0 Model Software Selected

The model was developed using a recent version of MODFLOW to characterize the movement of groundwater through the system. MODFLOW is a three-dimensional, finite-difference, groundwater flow code originally developed by the USGS (McDonald and Harbaugh, 1988). MODFLOW was selected for use in this project because the code is nonproprietary, well documented, and has been verified for a wide range of field problems (Anderson, 1993). Groundwater Vistas was used as a graphical interface to the code.

6.0 Model Parameters

6.1 Model Grid

Figures 6 and 7 illustrate the approximate model domain with respect to residential wells, the Bell facility, and the approximate distribution of PCE in November 2007 for both aquifer thicknesses simulated. The model domain is defined by a 93-row by 92-column, finite-difference grid. Cells are uniformly 50 feet in both the x and y directions. The east-west axis of the model grid has a total length of 4600 feet. The width of the grid along the north-south axis is 4650 feet. The vertical, or z, direction of the grid was set to uniform thicknesses of 100 and 200 feet. The saturated thickness of the Chicot Aquifer is more on the order of 300 feet thick at