Successful Use of In-Situ Chemical Oxidation Technologies for the Removal of Chlorinated Solvents in Soils and Multiple Aquifers at a Southeastern Louisiana Industrial Facility

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Battelle Abstract

Trichloroethane (TCA) and methylene chloride (MeCl) were released at two locations at a facility in Southeastern Louisiana over two decades ago. The compounds seeped into shallow groundwater (9 to 12 feet) then through a 12 foot thick leaky aquitard and into two confined aquifers at 24 to 45 foot and 50 to 60 foot depth. The plumes in all three water bearing zones extended over a 2 acre area.

Immediately after the releases were discovered, a pump and treat system using an air stripper was operated to reduce concentrations and contain the contaminated groundwater on-site. Concentrations of TCA and MeCl decreased significantly during the operation of the pump and treat system; however, degradation products of TCA including 1,1 dichloroethylene (DCE) ranging up to 2 mg/L and vinyl chloride (VC) ranging up to 0.180 mg/L continued to be detected in groundwater. These concentrations exceeded standards developed for the site in accordance with the State of Louisiana Risk Evaluation and Corrective Action Program (RECAP).

The operating facility was densely occupied and removal of contaminated vadose zone soils at the source areas was not possible. Corrective action alternatives for soils included thermal treatment with vapor extraction and in-situ chemical oxidation (ISCO). Alternatives for groundwater included air sparge enhanced with ozone and ISCO. ISCO was chosen as the preferred alternative for both soil and groundwater.

Geology and geochemistry were evaluated and an injection program was designed and implemented including: high pressure injection of Fenton's Reagent into vadose zone soils on four foot centers at each source location; and injection of pH activated sodium persulfate into a 100 injection points completed within each of the three separate water-bearing zones.

Data show reduction of soil contaminants to below the RECAP industrial standards. Contaminant concentrations in the three separate water-bearing zones were reduced, residual treatment is ongoing and appropriate RECAP standards appear achievable.

The Groundwater Remediation included eight activities completed in the order listed below.

1) Additional Geologic Assessment Using Geoprobe Soil Conductivity Methods and Installation of Additional Monitor Wells

2) Baseline Groundwater Monitoring and Re-Assessment of Treatment Areas

3) Round 1 ISCO Injections included 136,500 pounds of sodium persulfate activated with a sodium hydroxide solution into 100 injection points completed into the shallow, intermediate and deep zones within each treatment area as identified during the baseline assessment. (December 2007 through April 2008).

4) Round 1 Post-Injection Groundwater Monitoring included collection of groundwater samples from 35 monitor wells during May 2008 approximately one month after the Round 1 injections were completed. Analytical results showed reductions of COCs; however, COCs remained elevated in some areas.

5) Round 2 ISCO Injections included an additional 61,000 pounds of sodium persulfate activated with a sodium hydroxide solution into select areas based on Round 1 post-injection monitoring results. (August through October 9, 2008).

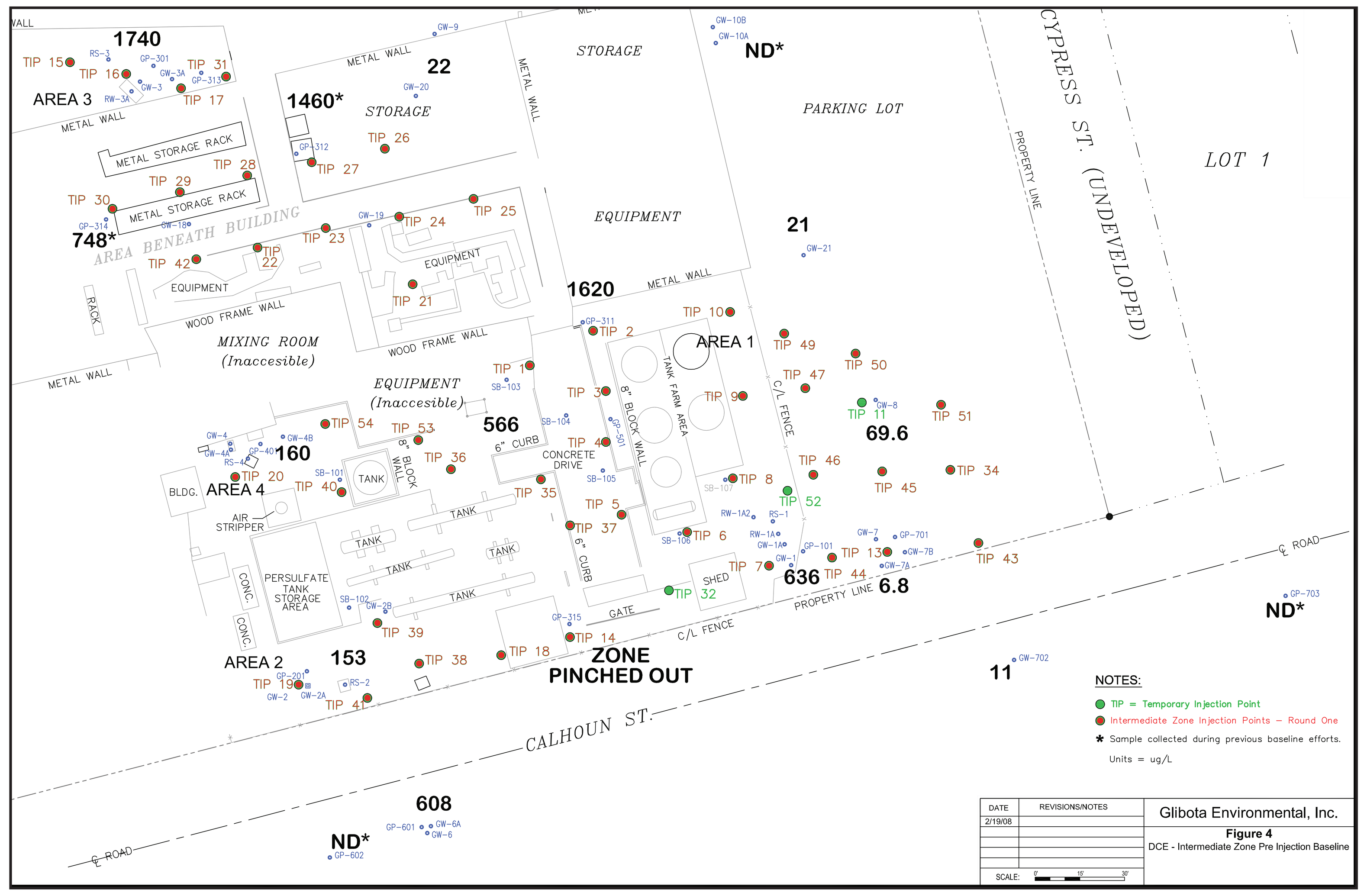
6) Round 2 Post-Injection Groundwater Monitoring included collection of groundwater samples from 35 monitor wells in October 2008 twenty days after the Round 2 injections were completed; April 2009 six months after the Round 2 injections; and January 2010 fifteen months after the Round 2 injections.

7) Round 3 ISCO Injections included an additional 60,000 pounds of sodium persulfate activated with a sodium hydroxide solution into 25 injection points in areas with residual DCE including the intermediate zones of Areas 1 and 3 and the area beneath the building and into the intermediate zone at six off-site locations near monitor wells GW-702 and GW-6A.

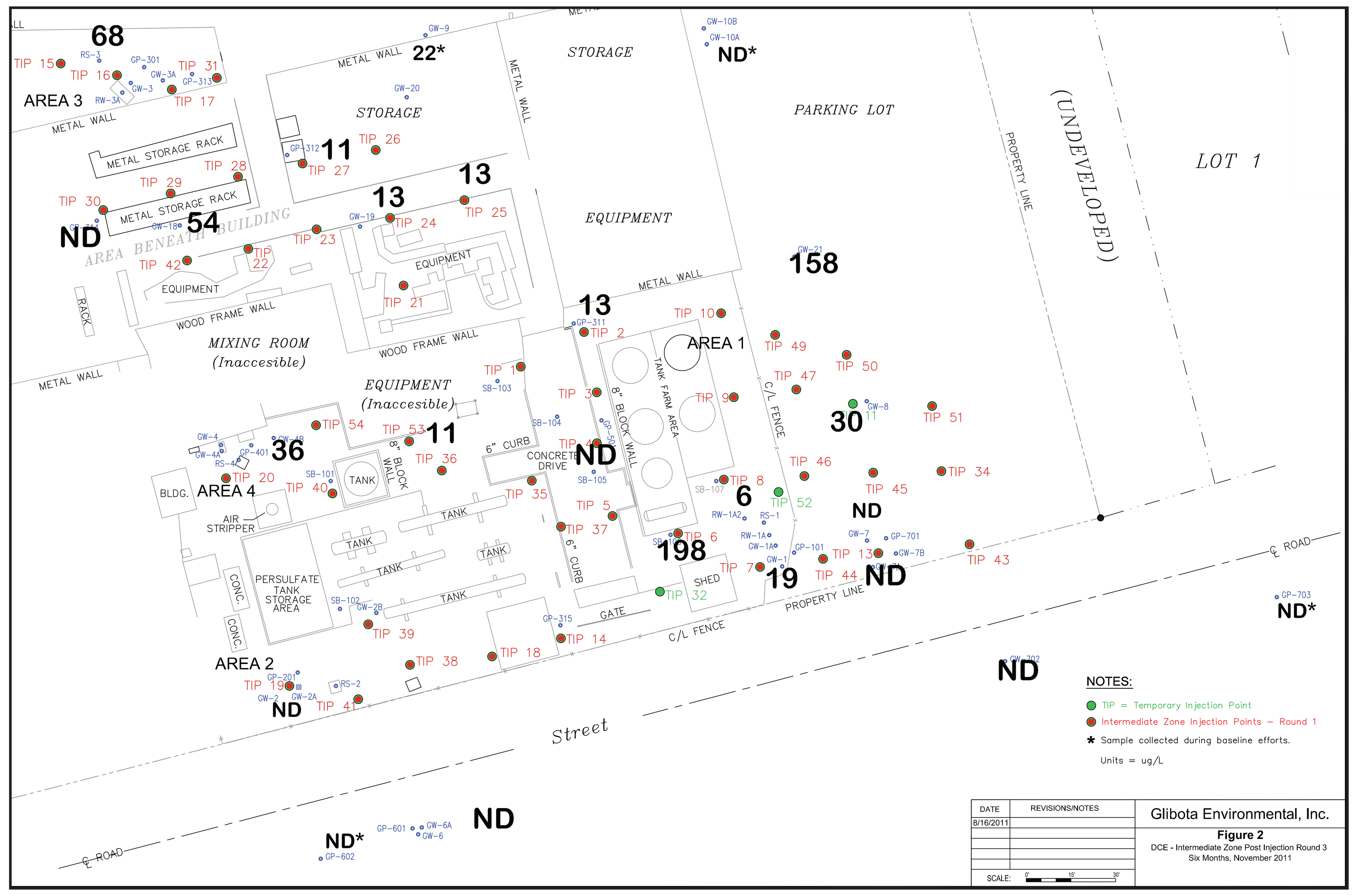
8) Round 3 Post-Injection Groundwater Monitoring included collection of groundwater samples from 35 monitor wells during May 2011 six months after the Round 3 injections and November 2011 twelve months after the Round 3 injections.

Persulfate reacts through a free radical pathway generating free radicals, which are almost as strong an oxidant as hydroxyl radicals. The standard oxidation potential of the sulfate radical () is 2.6 V. Sodium persulfate is activated by increasing pH to 10.5 using sodium hydroxide. Activated persulfate can break molecules with high activation energy like DCE and VC into water and CO2 and salt (NaCl). The persulfate anion, alone, is a strong oxidant (2.1 V) and is relatively stable and can persist in the subsurface for weeks to months before decomposing.

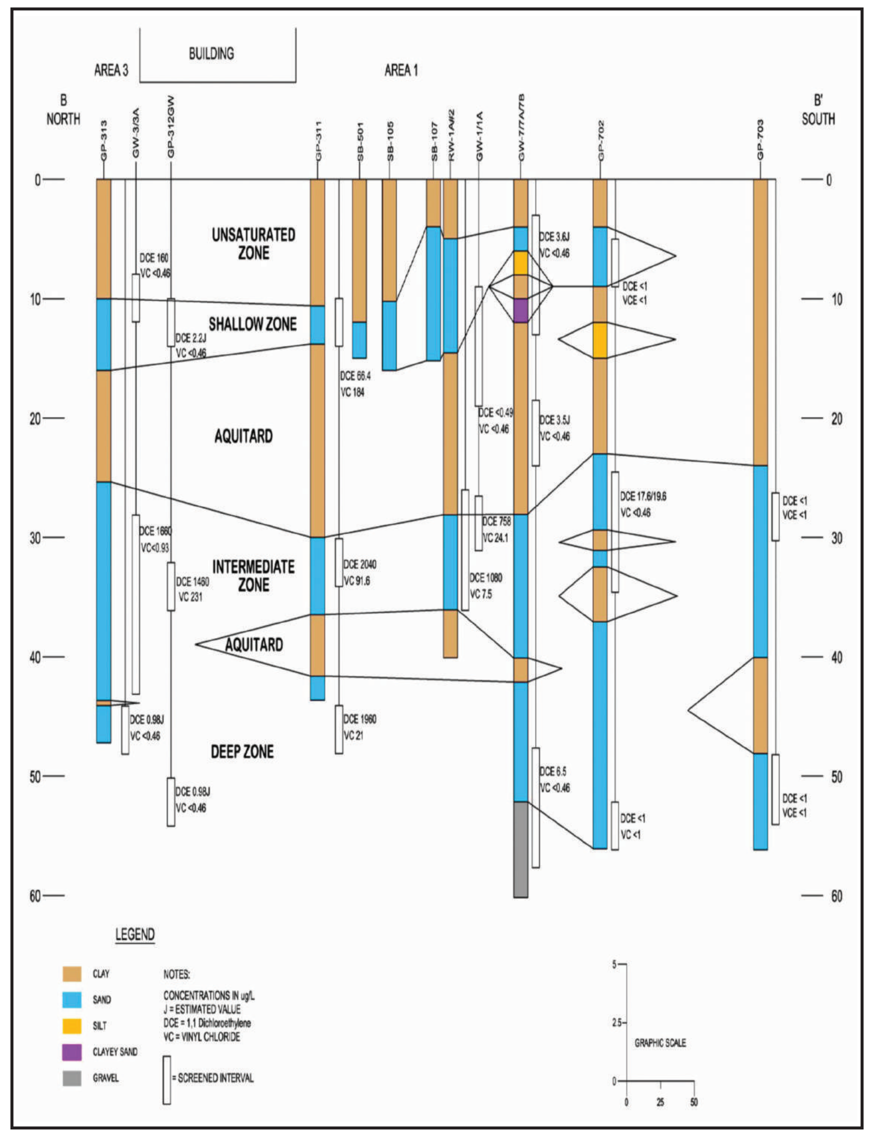
The solution was delivered to the injection points with low pressure double diaphragm pumps powered with compressed air. Surfacing of persulfate solution was observed at some locations during Round 3. When surfacing was observed, injection rates were reduced and/or multiple injection rounds were performed. At some locations injection rates were minimal and 275 gallon totes were used to gravity feed the targeted volume of solution over a period of days.

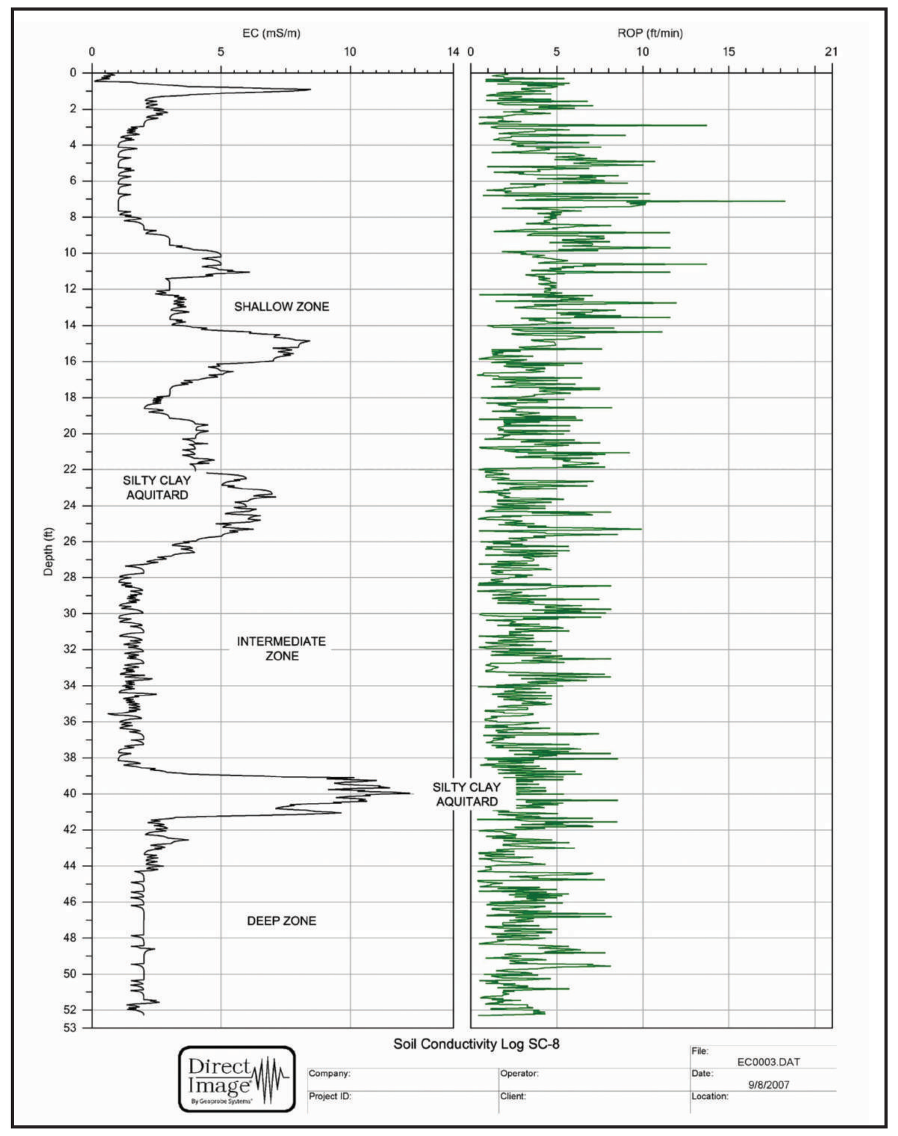


DCE Intermediate Zone Pre-Injection Baseline



DCE Intermediate Zone Post-Injection Round 3





Analytical Data Summary For DCE in Groundwater

Well	Sep-06	Baseline Pre-Injection Sept/Oct 07	Post - Injection Round 1 May-08	Post-Injection Round 2 October-08	Post-Injection Round 2 6 Months April-09	Post-Injection Round 2 15 Months January-10	Post-Injection Round 2 24 Months October-10	Post-Injection Round 3 6 months May-11	Post-Injection Round 3 12 months Nov-11
Shallow Zone									
GW-1	ND	21	ND	ND	ND	ND	ND		
GW-2	ND	5	ND	ND	ND	ND	ND		
GW-3	160	67	64.2	94.4	90	12	6	886	560
GW-4	ND	ND	ND	ND	ND	ND	ND		
GW-7	ND	44	ND	ND	ND	ND	ND		
GW-8	248	175	ND	ND	ND	ND	ND		
GW-9	ND	NS	NS	NS	NS	NS	NS		
GW-311s	66.4	6.9	ND	ND	7.3	ND	ND	2J	ND
GW-312s	ND	NS	NS	NS	NS	NS	NS		
GW-315s	24	7.9	9.3	ND	29	77	ND	21	ND
TIP 4s			678	12.4	53	40	159	249	160
Intermediate Zone									
GW-1A	758	636	29	8.4	36	11	ND	4J	19
RW-1A#2	1080	697	400	451	384	200	76	15	6
GW-2A	61.8	153	ND	ND	ND	ND	ND		
GW-3A	1660	1740	46.8	464	620	228	161	105	68
GW-4A/TIP 19	NS	NS	ND	8.5	109	ND	16	45	36
GW-7A	ND	9	9.8	28.5	33.9	13	ND	2J	ND
GW-7A#2		6.8	ND	ND	ND	ND	ND		
GW-8 i		69	ND	ND	ND	11	ND	39	30
GW-10 i	ND	NS	NS	NS	NS	NS	NS		
GW-21 i		21.6	1220	221	186	106	231	306	158
GW-311 i	2040	1620	120	ND	40	ND	7	15	13
GW-311 i Dup			138	NS	NS	NS	NS		
TIP 4 i		NS	12.2	ND	2	ND	ND	ND	ND
TIP 6 i		NS	137	8.1	283	170	312	416	198
TIP 36 i		566	ND	ND	ND	21	30	ND	11
Intermediate Zone Beneath Building									
GW-18 i		NS	131	139	105	125	60	75	54
GW-19 i		NS	121	12.3	29	12	5	19	13
GW-20 i		22	NS	NS	NS	NS	NS		
TIP 25 i		NS	10.6	16.6	377	90	18	43	13
TIP 27 i/GP-312	1460	NS	862	60.1	92	ND	7	11	11
TIP 30 i/ GP314	738	NS	ND	5.2	56	99	59	7	ND
Deep Zone									
GW-2 D		ND	NS	NS	NS	NS	NS		
GW- 4 D		ND	NS	NS	NS	NS	NS		
TIP 4 D			7.8	ND	ND	ND	ND	2J	ND
TIP 6 D		61.6	25.2	ND	33.8	20	16	101	47
GW-7B	ND	ND	ND	ND	ND	ND	ND		
GW-8 D		45	ND	ND	ND	ND	ND		
GW-10 D	ND	NS	NS	NS	NS	NS	NS		
GW-21 D		ND	NS	NS	NS	NS	NS		
GW-311 D	1960	620	25.4	ND	ND	ND	ND	ND	ND
GW-315 D	26	71	37	ND	558	227	129	4630	2290
Off-Site		6664.8					1292		
GW-6A	876	608	313	1170	1020	693	615	4J	ND
GW-702	17.7	11	84.7	121	133	141	94	1J	ND
GW-702 DUP	19.6	12	96	112	105	154	95		
Trip Blank		ND	ND	ND	ND	ND	ND	ND	ND

Bold Red indicates the DCE RECAP Standard of 10 ug/L is exceeded
Concentrations are in ug/l