



Source Zone Treatment Using Injection
of ZVI into a Fractured Rock Aquifer



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Overview - FeroxSM Process (ZVI Injection)

FeroxSM Process

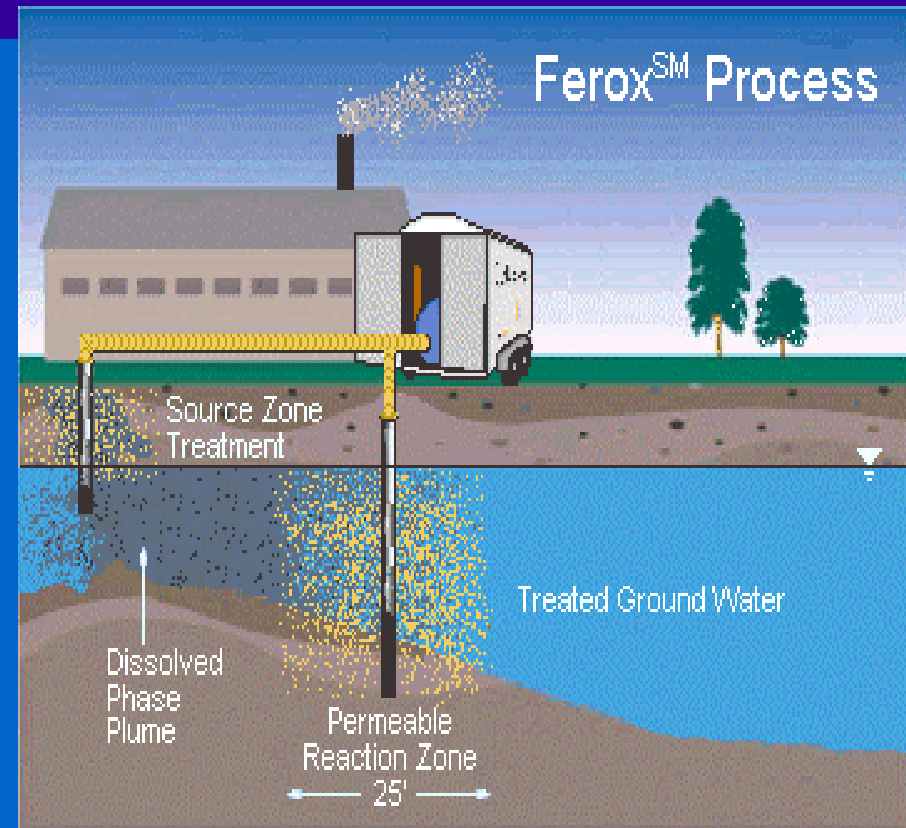
U.S. Patent # 5975798 November 1999:

Applied to address source contamination

Injections possible underneath existing structures/utilities

Not limited by depth of application

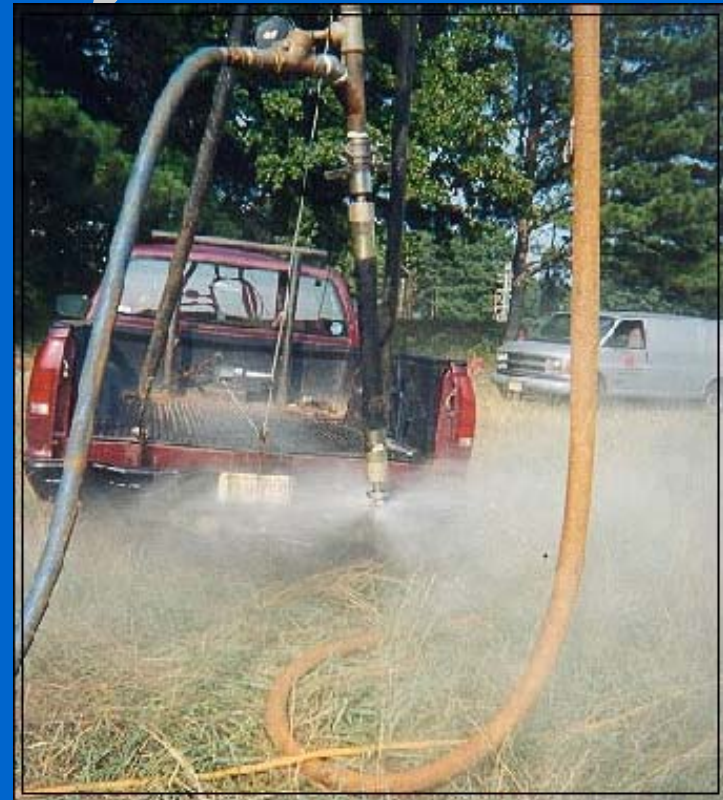
Iron powder injected to Mirror Contamination Heterogeneity



Hydraulic vs. Liquid Atomized Injection



Hydraulic Pumping



Liquid Atomization

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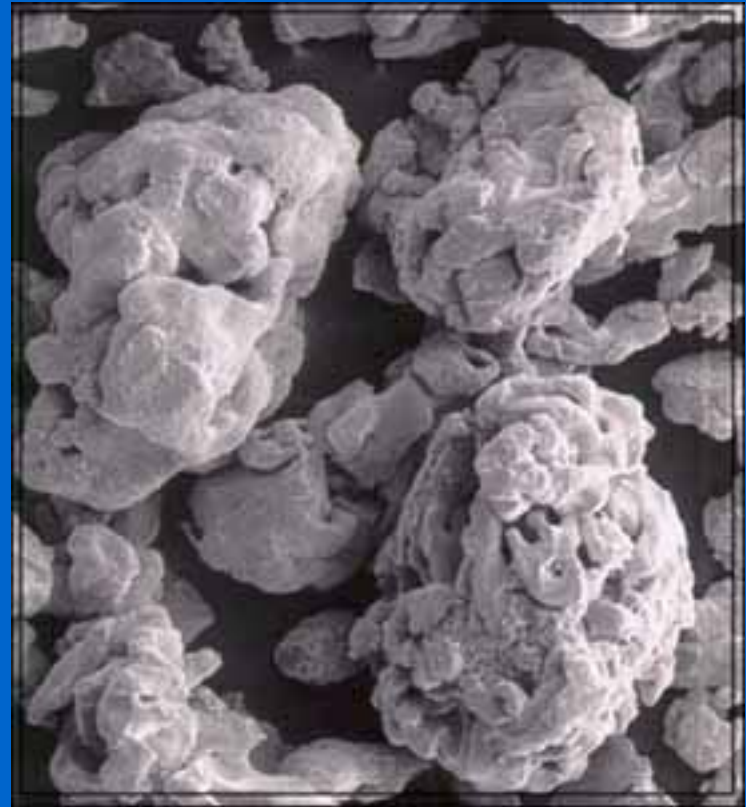




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Reactive Sponge Iron Powder

- High Surface Area
- **FDA Certified 95+% Pure**
- Trace Carbon Elements Enhance Reactivity
- 40-70 μm size particles



Hunters Point Brownfield Site

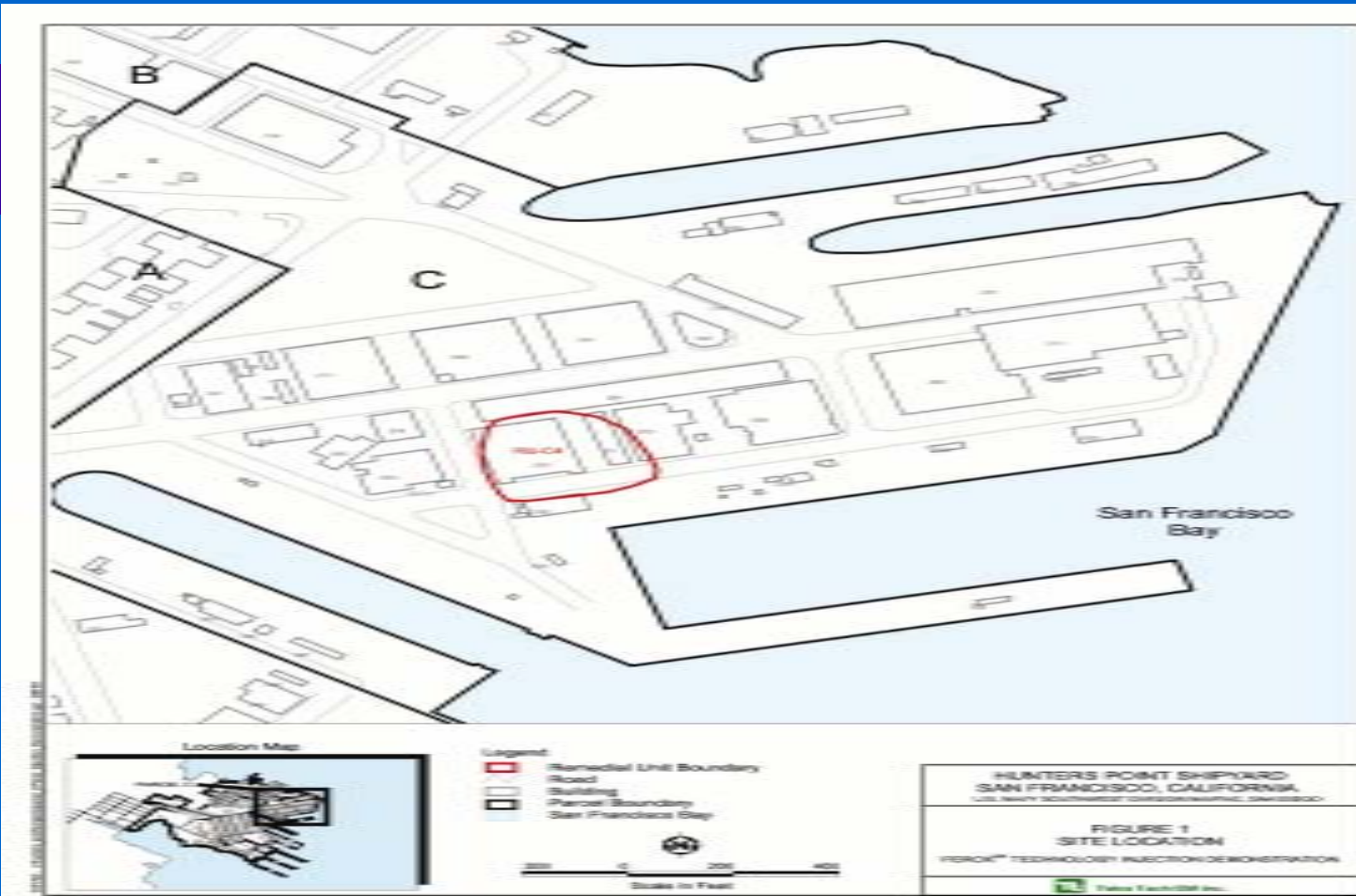
- Established in 1869 as the first dry dock on the Pacific Coast
- Navy operated facility from 1940 until 1976. Site activities included ship building, maintenance and submarine servicing and testing.
- In 1991, DOD listed the Shipyard for Closure.
- Navy investigations have identified 6 parcels A through F for treatment



Hunters Point Brownfield Site

- The Site has spectacular views of downtown San Francisco and is well situated between the airport, 3-com park and mission bay
- A 25-year development Plan estimated at \$5 billion dollars is favored by the city of San Francisco to revitalize the blighted southeastern section of the city
- Once each parcel is remediated, it is estimated that developers will create a 500-acre planned waterfront community made up of residential, commercial, mixed-use, retail and light industrial uses.





**Naval Facilities Engineering Service Center
 Naval Facilities Engineering Command – Southwest Division**

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Project Objectives

- **Determine capability and cost-effectiveness for ZVI powder injection to reduce TCE/PCE source contamination**
- **Evaluate plume/DNAPL displacement concerns as a result of injection**
- **Assess treatment Radius of Influence at the project site**

ZVI Powder Distribution

Injection Point	Interval (ft bgs)	Mass of Iron (lbs)
F1	27 - 30	530
	24 - 27	530
	19 - 22	795
	16 - 19	795
	13 - 16	530
	9 - 12	805
		3985

Injection Point	Interval (ft bgs)	Mass of Iron (lbs)
F2	27 - 30	635
	24 - 27	635
	21 - 24	635
	18 - 21	635
	15 - 18	910
	12 - 15	805
	9 - 12	795
		5050

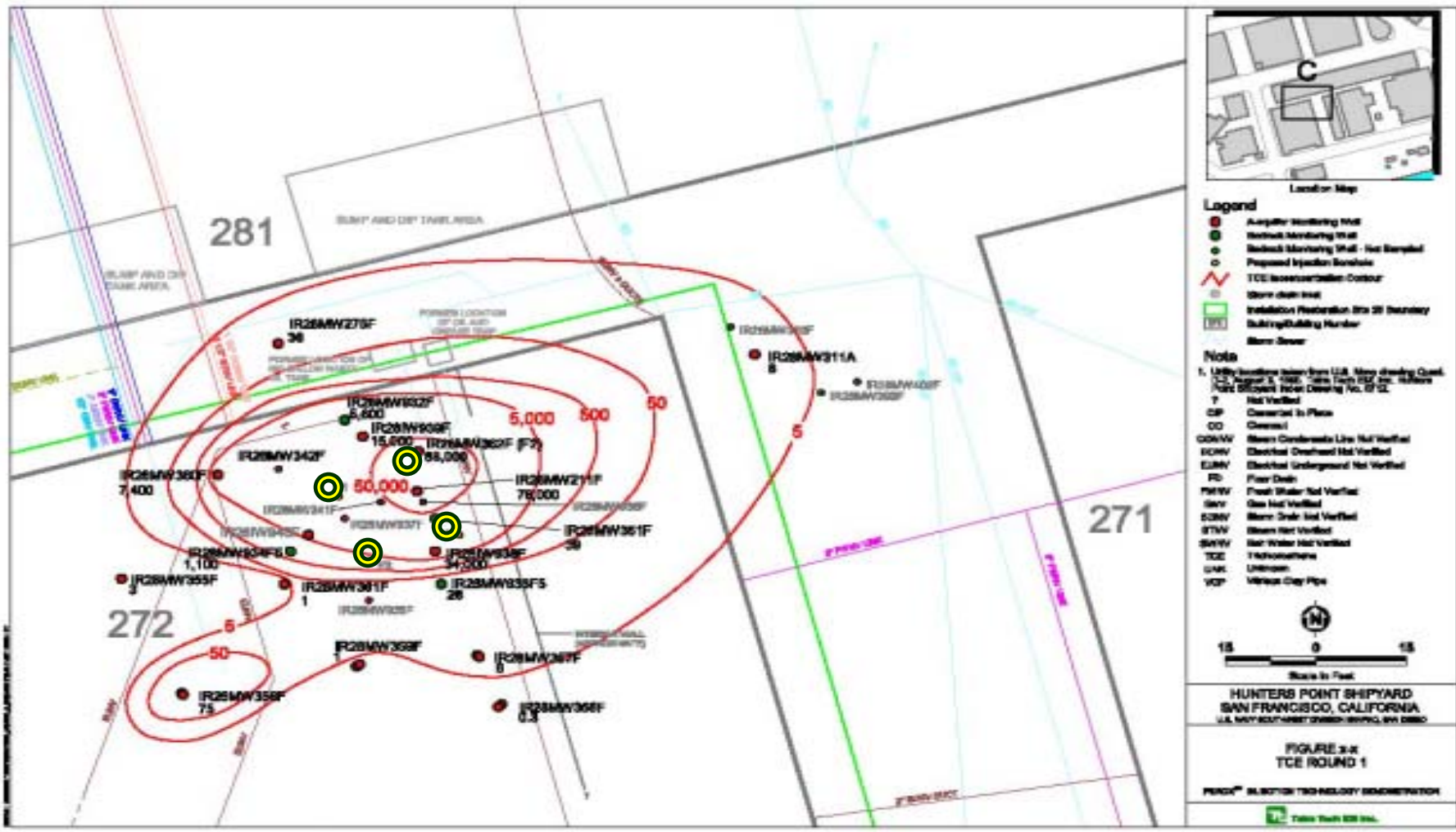
Injection Point	Interval (ft bgs)	Mass of Iron (lbs)
F3	27 - 30	530
	24 - 27	530
	18 - 21	780
	16 - 19	805
	13 - 16	530
	10 - 13	740
		3915

Injection Point	Interval (ft bgs)	Mass of Iron (lbs)
F4	27 - 30	530
	24 - 27	424
	21 - 24	530
	11 - 14	1060
	8 - 11	795
		3339

TOTAL = 16,289 lbs



Pre-Injection TCE Contours



TCE Concentrations

TCE					
Location	Distance from Nearest Injection Point (ft)	Baseline	Post-Injection		
		12/1/02	1/6/03	2/3/03	3/17/03
IR28MW362F (F2) - 0	0.0	88000	11	78	4
IR28IW938F - 5 ft	4.9	34000	13	28	23
IR28MW211F - 6 ft	6.0	76000	420	730	850
IR28MW341F - 8 ft	7.8	41000	100	160	160
IR28MW933F5 - 9 ft	8.7	26	38	26	25
IR28IW939F - 9 ft	9.0	15000	460	520	820
IR28MW342F - 10 ft	9.8	5100	47	79	180
IR28MW934F5 - 13 ft	13.1	1100	400	490	480
IR28MW932F - 13 ft	13.3	5300	120	110	84
IR28MW361F - 15 ft	15.0	1	130	100	83
IR28MW359F - 19 ft	18.6	0.5	55	47	47
IR28MW360F - 20 ft	19.5	7400	690	610	630
IR28MW357F - 22 ft	22.1	6	35	53	76
IR28MW275F - 29 ft	29.5	36	68	70	85
IR28MW358F - 32 ft	31.7	0.3	4	1	0.9
IR28MW355F - 39 ft	38.7	3	17	17	20

PCE Concentrations

Location	Distance from Nearest Injection Point (ft)	Baseline	Post-Injection		
		12/1/02	1/6/03	2/3/03	3/17/03
IR28MW362F (F2) - 0	0.0	125	0.5	0.5	0.5
IR28IW938F - 5 ft	4.9	250	0.5	0.5	0.5
IR28MW211F - 6 ft	6.0	500	2	0.3	0.5
IR28MW341F - 8 ft	7.8	100	0.5	0.5	0.5
IR28MW933F5 - 9 ft	8.7	0.5	0.5	0.5	0.5
IR28IW939F - 9 ft	9.0	130	1	1	3
IR28MW342F - 10 ft	9.8	85	1	1	2
IR28MW934F5 - 13 ft	13.1	2.5	0.3	0.5	0.5
IR28MW932F - 13 ft	13.3	89	2	1	0.5
IR28MW361F - 15 ft	15.0	0.5	0.4	0.5	0.5
IR28MW359F - 19 ft	18.6	0.5	0.4	0.5	0.5
IR28MW360F - 20 ft	19.5	140	12	7	10
IR28MW357F - 22 ft	22.1	0.5	0.5	0.5	0.5
IR28MW275F - 29 ft	29.5	14	30	23	30
IR28MW358F - 32 ft	31.7	0.5	0.5	0.5	0.5
IR28MW355F - 39 ft	38.7	0.5	0.5	0.5	0.5
IR28MW356F - 39 ft	39.4	0.5	0.5	0.5	0.5
IR28MW311A - 58 ft	58.0	0.5	0.5	0.5	0.5

cis-1,2-DCE Concentrations

Location	Distance from Nearest Injection Point (ft)	Baseline	Post-Injection		
		12/1/02	1/6/03	2/3/03	3/17/03
IR28MW362F (F2) - 0 ft	0.0	160	0.5	5	0.3
IR28IW938F - 5 ft	4.9	250	0.5	1	0.9
IR28MW211F - 6 ft	6.0	500	2	8	15
IR28MW341F - 8 ft	7.8	100	0.4	2	4
IR28MW933F5 - 9 ft	8.7	2	1	0.6	0.6
IR28IW939F - 9 ft	9.0	420	9	10	21
IR28MW342F - 10 ft	9.8	17	1	3	8
IR28MW934F5 - 13 ft	13.1	37	54	44	41
IR28MW932F - 13 ft	13.3	410	22	28	43
IR28MW361F - 15 ft	15.0	0.6	3	2	2
IR28MW359F - 19 ft	18.6	0.5	0.2	0.5	0.5
IR28MW360F - 20 ft	19.5	320	18	12	11
IR28MW357F - 22 ft	22.1	0.5	0.2	0.5	0.5
IR28MW275F - 29 ft	29.5	2	5	3	3
IR28MW358F - 32 ft	31.7	0.5	0.5	0.5	0.5
IR28MW355F - 39 ft	38.7	0.5	0.5	0.5	0.5
IR28MW356F - 39 ft	39.4	11	13	6	6
IR28MW311A - 58 ft	58.0	2	3	2	2

Vinyl Chloride Concentrations

Location	Distance from Nearest Injection Point (ft)	Baseline	Post-Injection		
		12/1/02	1/6/03	2/3/03	3/17/03
IR28MW362F (F2) - 0 ft	0.0	125	0.5	0.4	0.5
IR28IW938F - 5 ft	4.9	250	0.5	0.5	0.5
IR28MW211F - 6 ft	6.0	500	2	0.7	0.8
IR28MW341F - 8 ft	7.8	100	0.5	0.5	0.5
IR28MW933F5 - 9 ft	8.7	0.5	0.5	0.5	0.5
IR28IW939F - 9 ft	9.0	50	0.7	1	2
IR28MW342F - 10 ft	9.8	25	0.5	0.5	0.7
IR28MW934F5 - 13 ft	13.1	2.5	0.5	0.5	0.5
IR28MW932F - 13 ft	13.3	25	0.8	1	4
IR28MW361F - 15 ft	15.0	0.5	0.5	0.5	0.5
IR28MW359F - 19 ft	18.6	0.5	0.5	0.5	0.5
IR28MW360F - 20 ft	19.5	12.5	0.8	0.5	0.5
IR28MW357F - 22 ft	22.1	0.5	0.5	0.5	0.5
IR28MW275F - 29 ft	29.5	0.5	0.5	0.5	0.5
IR28MW358F - 32 ft	31.7	0.5	0.5	0.5	0.5
IR28MW355F - 39 ft	38.7	0.5	0.5	0.5	0.5
IR28MW356F - 39 ft	39.4	0.5	0.5	0.5	0.5
IR28MW311A - 58 ft	58.0	0.5	0.5	0.5	0.5

pH

Location	Distance from Nearest Injection Point (ft)	Baseline	Post-Injection		
		12/1/02	1/6/03	2/3/03	3/17/03
IR28MW362F (F2) - 0 ft	0.0	7.32	8.24	8.27	8.39
IR28IW938F - 5 ft	4.9	6.63	8.38	8.85	8.97
IR28MW211F - 6 ft	6.0	6.9	8.52	7.91	8.11
IR28MW341F - 8 ft	7.8	6.92	7.87	8.51	8.38
IR28MW933F5 - 9 ft	8.7	6.74	7.01	7.03	7.11
IR28IW939F - 9 ft	9.0	7.11	8.17	8.52	8.55
IR28MW342F - 10 ft	9.8	6.77	8.18	8.61	8.49
IR28MW934F5 - 13 ft	13.1	6.81	6.72	6.81	6.83
IR28MW932F - 13 ft	13.3	7.06	8.23	8.33	8.1
IR28MW361F - 15 ft	15.0	6.8	7.54	7.99	7.97
IR28MW359F - 19 ft	18.6	6.87	6.98	7.27	7.31
IR28MW360F - 20 ft	19.5	6.91	7.08	7.17	7.2
IR28MW357F - 22 ft	22.1	6.75	7.25	7.21	7.26
IR28MW275F - 29 ft	29.5	6.87	6.96	7.03	6.92
IR28MW358F - 32 ft	31.7	7.3	7.22	7.41	7.33
IR28MW355F - 39 ft	38.7	7.15	7.6	7.82	7.86
IR28MW356F - 39 ft	39.4	6.57	7.25	7.34	7.52
IR28MW311A - 58 ft	58.0	6.71	6.83	6.88	6.81

Oxidation Reduction Potential (mv)

Location	Distance from Nearest Injection Point (ft)	Baseline	Post-Injection		
		12/1/02	1/6/03	2/3/03	3/17/03
IR28MW362F (F2) - 0 ft	0.0	88.5	-555.2	-436	-529.6
IR28IW938F - 5 ft	4.9	58.9	-578.1	-689.7	-621.7
IR28MW211F - 6 ft	6.0	166.3	-555.7	-447.2	-509.1
IR28MW341F - 8 ft	7.8	170.7	-351.1	-471.3	-565.9
IR28MW933F5 - 9 ft	8.7	101.2	-318.1	-261.7	-231.4
IR28IW939F - 9 ft	9.0	38.8	-392.1	-427.1	-196.1
IR28MW342F - 10 ft	9.8	159.7	-323.9	-569	-426.5
IR28MW934F5 - 13 ft	13.1	79.4	-2	138.1	138.7
IR28MW932F - 13 ft	13.3	-87.6	-428	-313.4	-179.3
IR28MW361F - 15 ft	15.0	97.6	-378.3	-448.3	-230.9
IR28MW359F - 19 ft	18.6	102.1	48.7	242.9	249.4
IR28MW360F - 20 ft	19.5	90.6	12.3	253.3	235.2
IR28MW357F - 22 ft	22.1	97.3	164.1	308.2	288.3
IR28MW275F - 29 ft	29.5	59.2	242.1	196.8	-41.5
IR28MW358F - 32 ft	31.7	85.5	210.4	231.2	86.1
IR28MW355F - 39 ft	38.7	98.1	45.5	154.4	249.3
IR28MW356F - 39 ft	39.4	115.8	182.2	149.7	282.1
IR28MW311A - 58 ft	58.0	124.8	61.3	137	149.6

Conclusion Summary

- Technology is effective in significant source reduction
- Little or no evidence of contaminant displacement deeper or outside pilot test area
- Technology safely applied within and adjacent to structures. (Shallow Injections may require pulse injection)