

Addressing “cis-Stall” at a Former Dry Cleaning Facility

Presented By:

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Technology Overview

- Chlorinated ethenes include:
 - Two carbons with a double bond
 - Perchloroethene -PCE- (4 chlorines)
 - Trichloroethene -TCE- (3 chlorines)
 - *Cis-* and *trans-*dichloroethene -DCE- (2 chlorines)
 - Vinyl chloride -VC- (1 chlorine)
- Ideal degradation pathways for each compound are different

Common current and former uses:

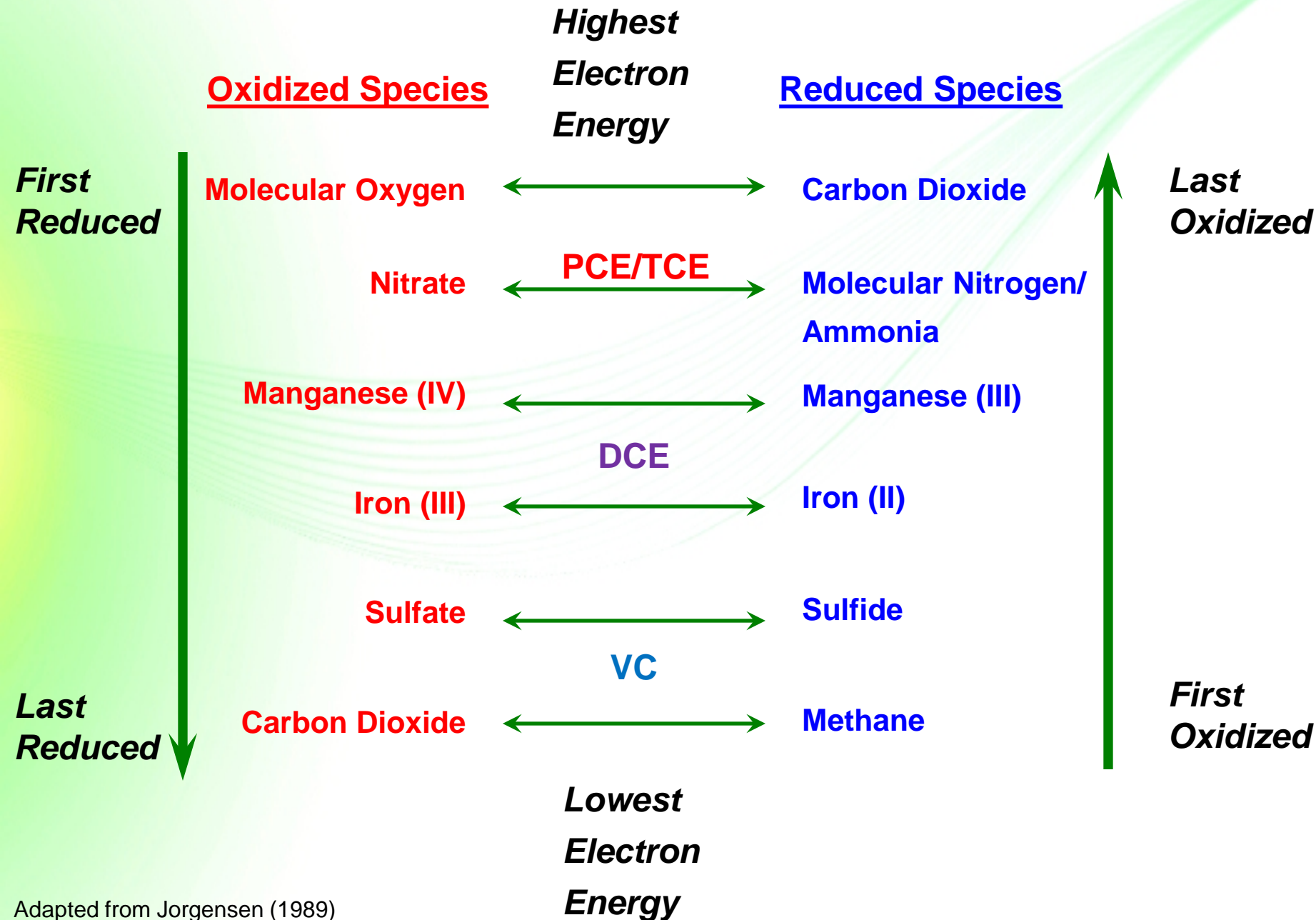
PCE – dry cleaning solvent, stain removers

TCE – industrial degreaser

Technology Overview

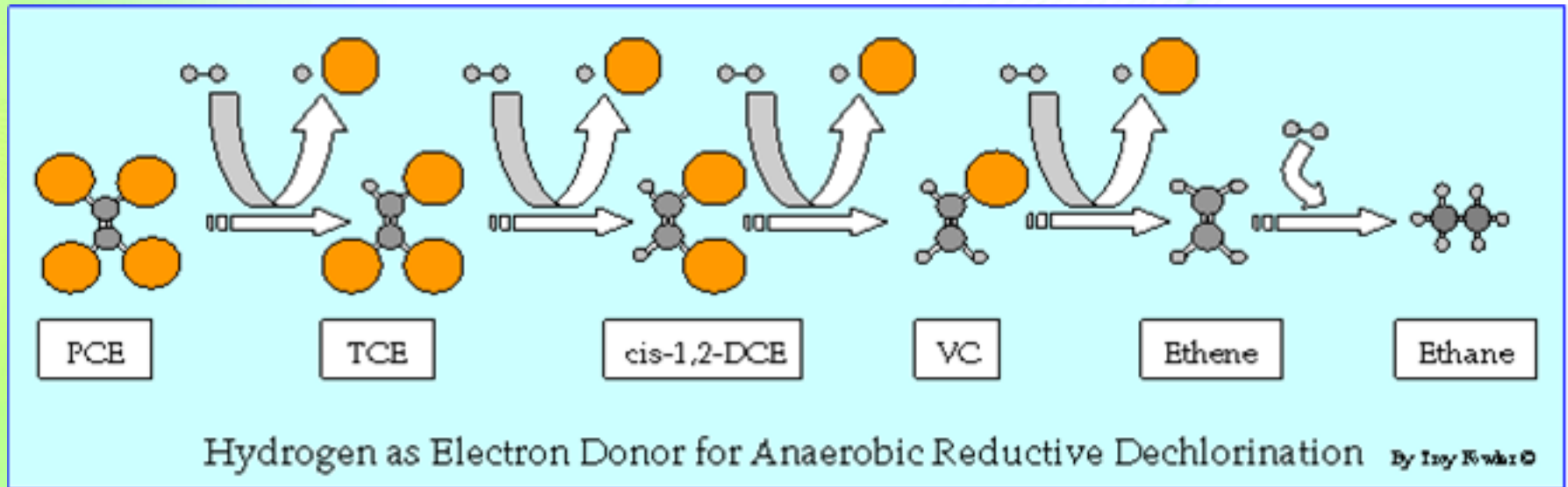
- Potential chlorinated ethenes degradation pathways
 - Biological
 - Reductive dechlorination
 - Aerobic oxidation
 - Anaerobic oxidation
 - Co-metabolism
 - Abiotic
 - Beta-elimination
 - Hydrogenation
 - Fe-S electron shuttle reactions
 - Humic/fulvic electron shuttle reactions

Electron Tower Theory



Technology Overview

– Anaerobic reductive dechlorination



Electron donors:

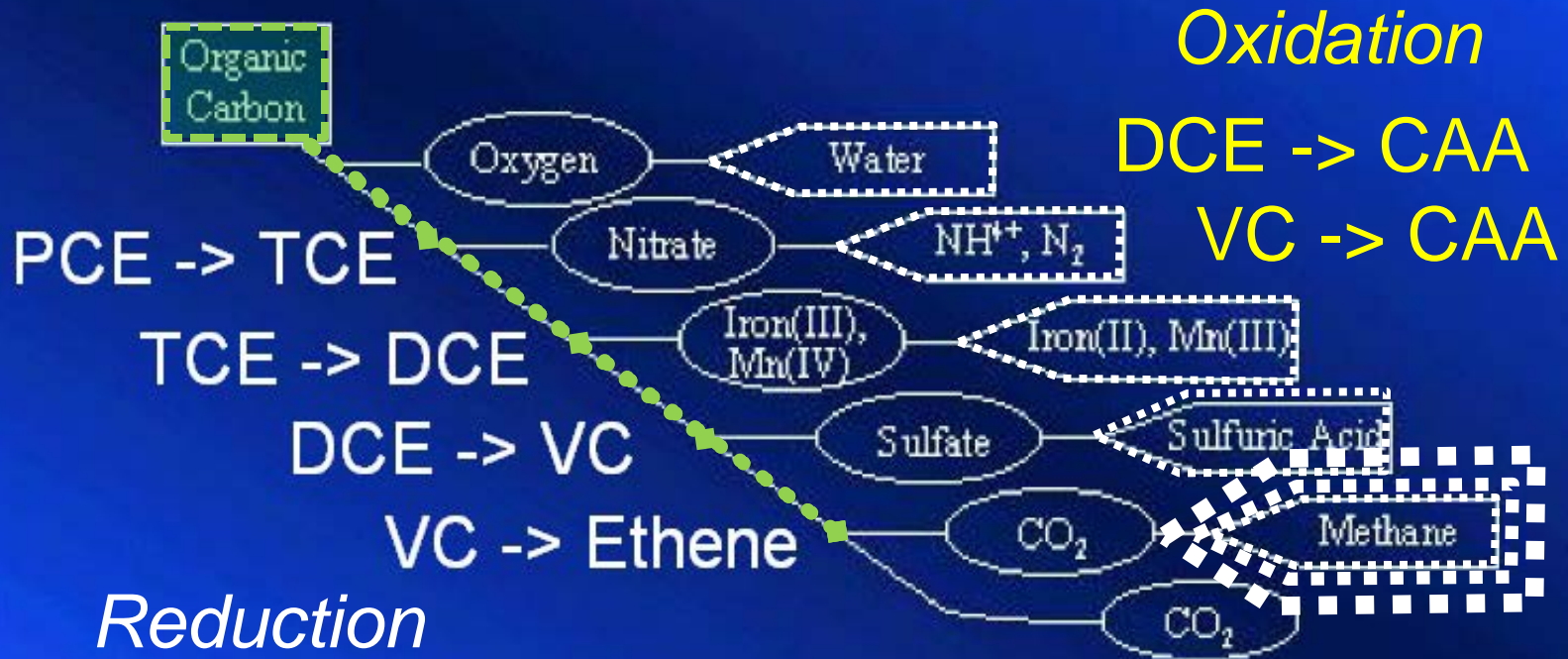
EOS® oil fermentation

EHC cellulose fermentation (80%)

Zero-valent iron corrosion creates hydrogen gas (H_2)

Technology Overview

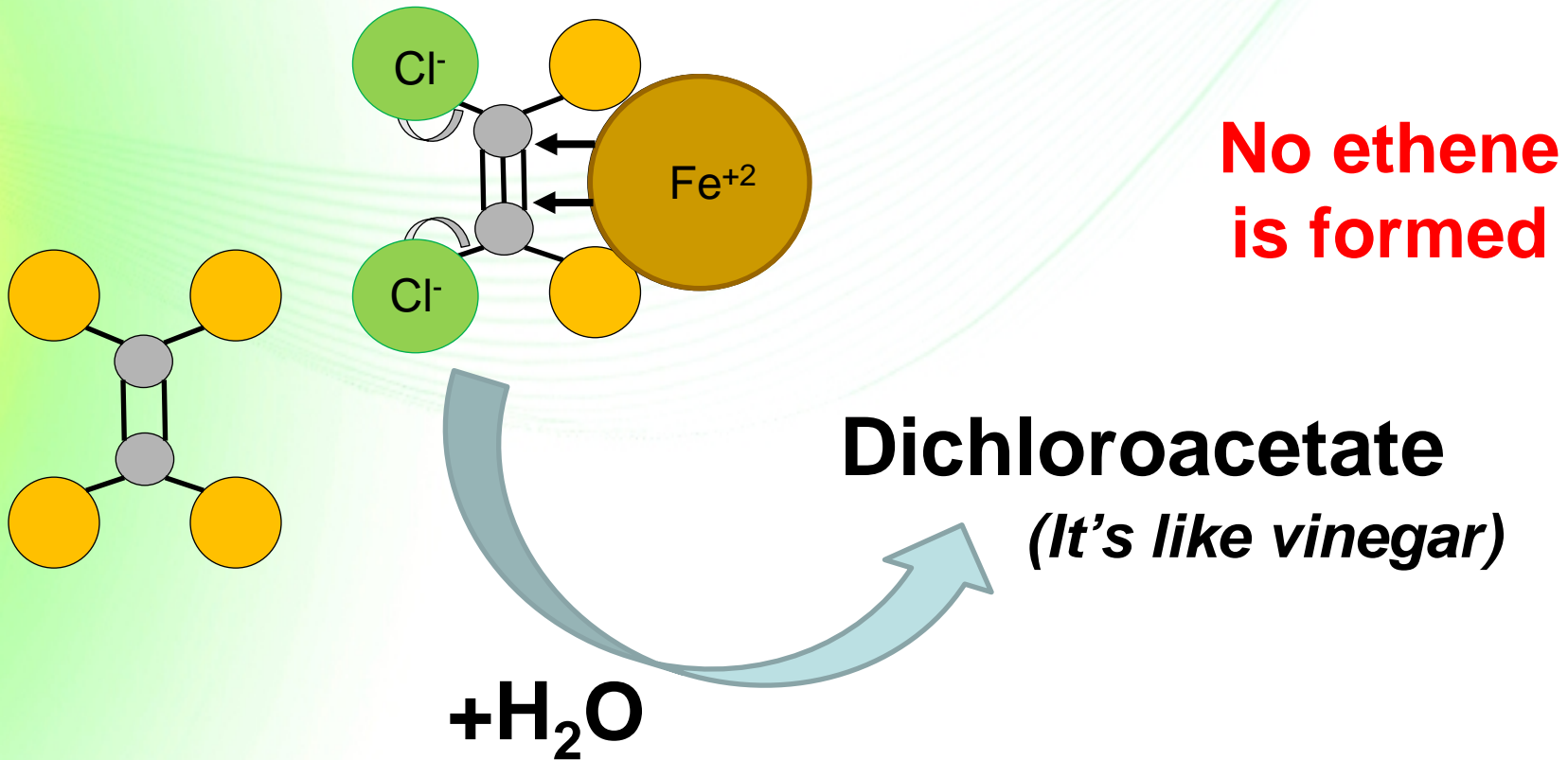
Electron Tower Theory



Adapted from Jørgensen (1989).

Technology Overview

– Beta elimination



Beta elimination:
EHC zero valent iron (20%)

Technology Overview

– BounTA[®]

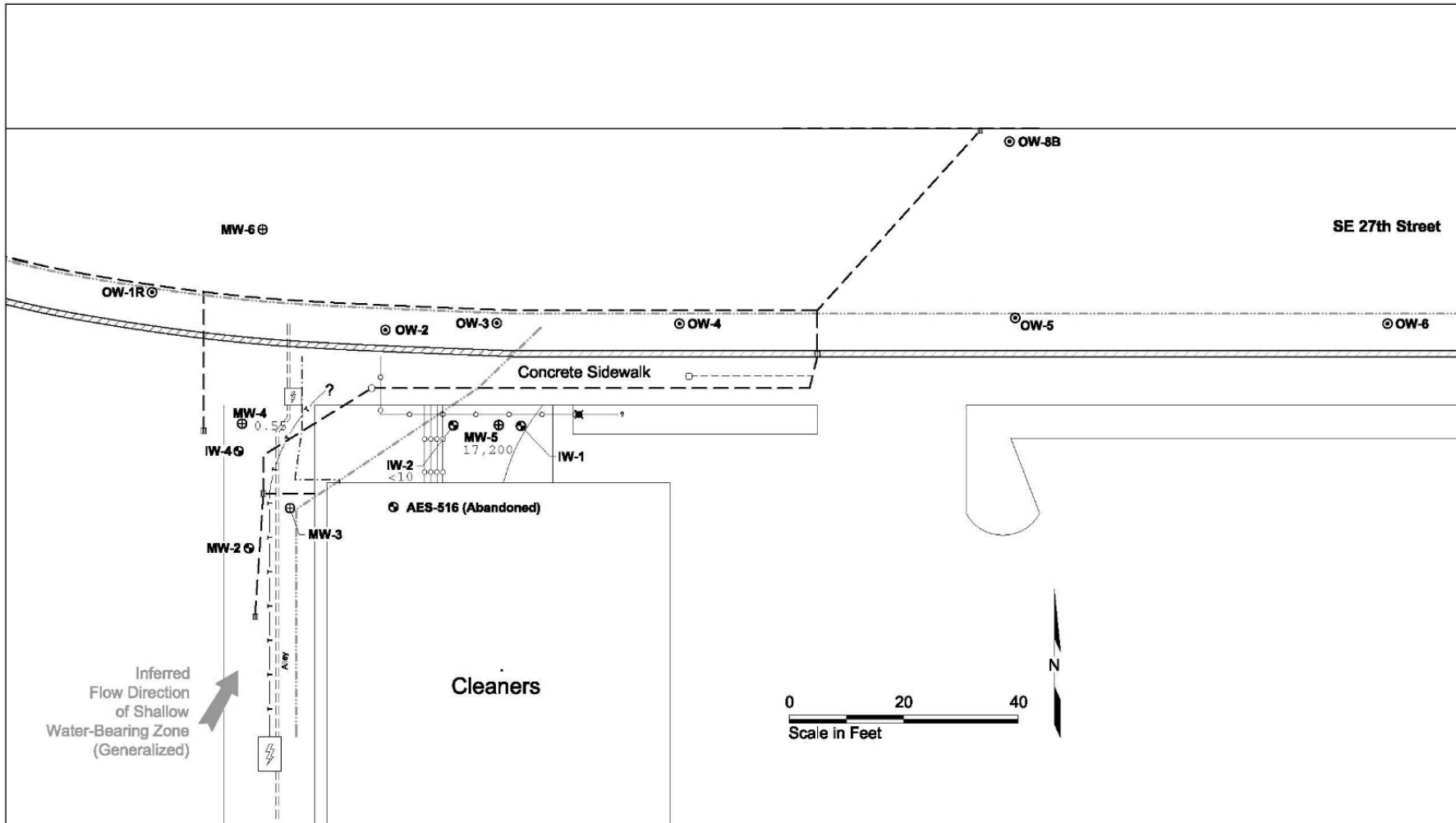
- Macro- and micro-nutrient blend
- Fully water soluble
- Develops microbial populations for current conditions
- Can be mixed with most amendments
- Supports oxidative or reductive processes

Site Summary

- Former dry cleaner facility
- Downtown commercial area
- Spent solvents historically “stored” in alley
- Dense glacial till of sandy silt with clay



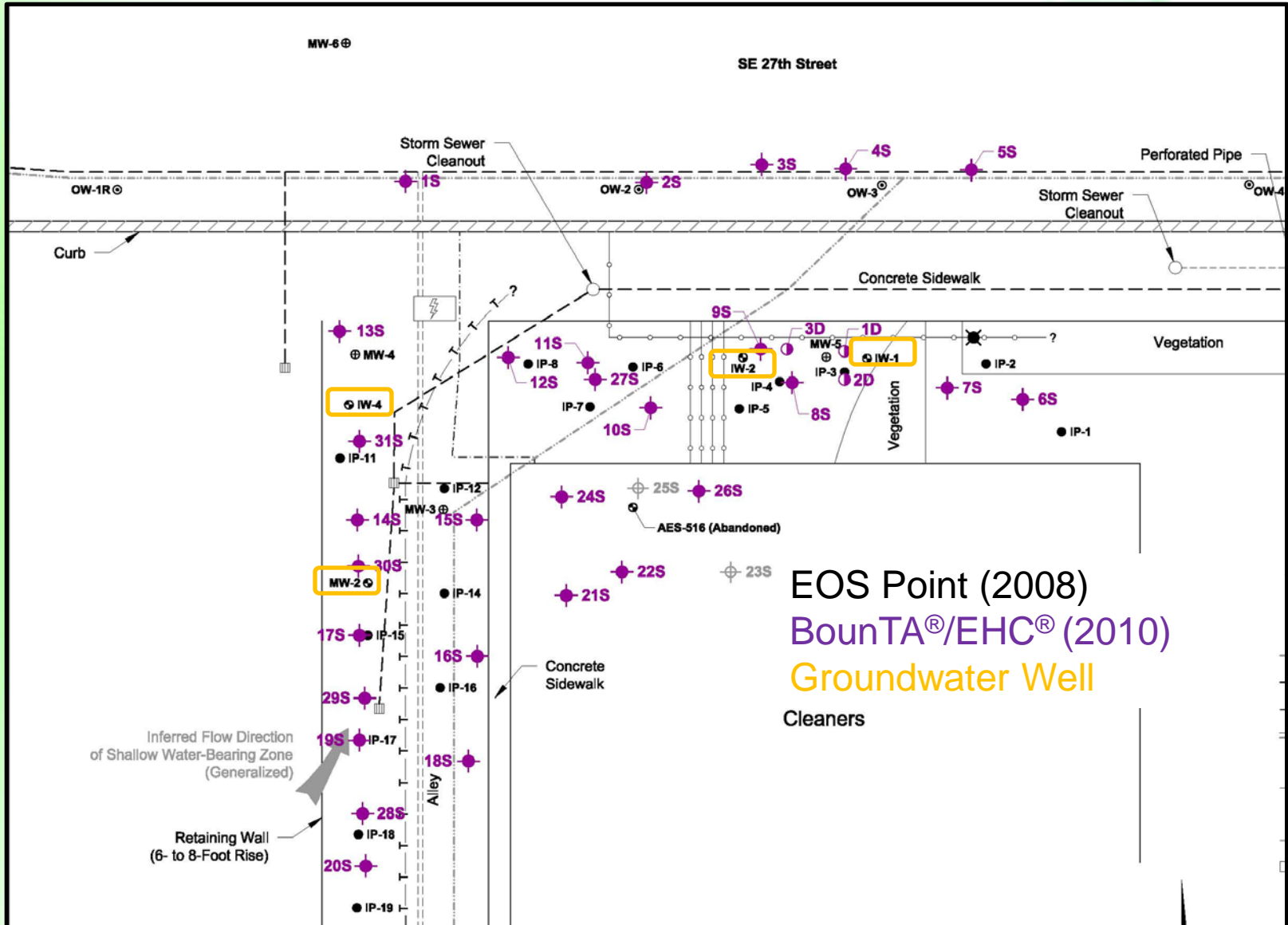
Site Map



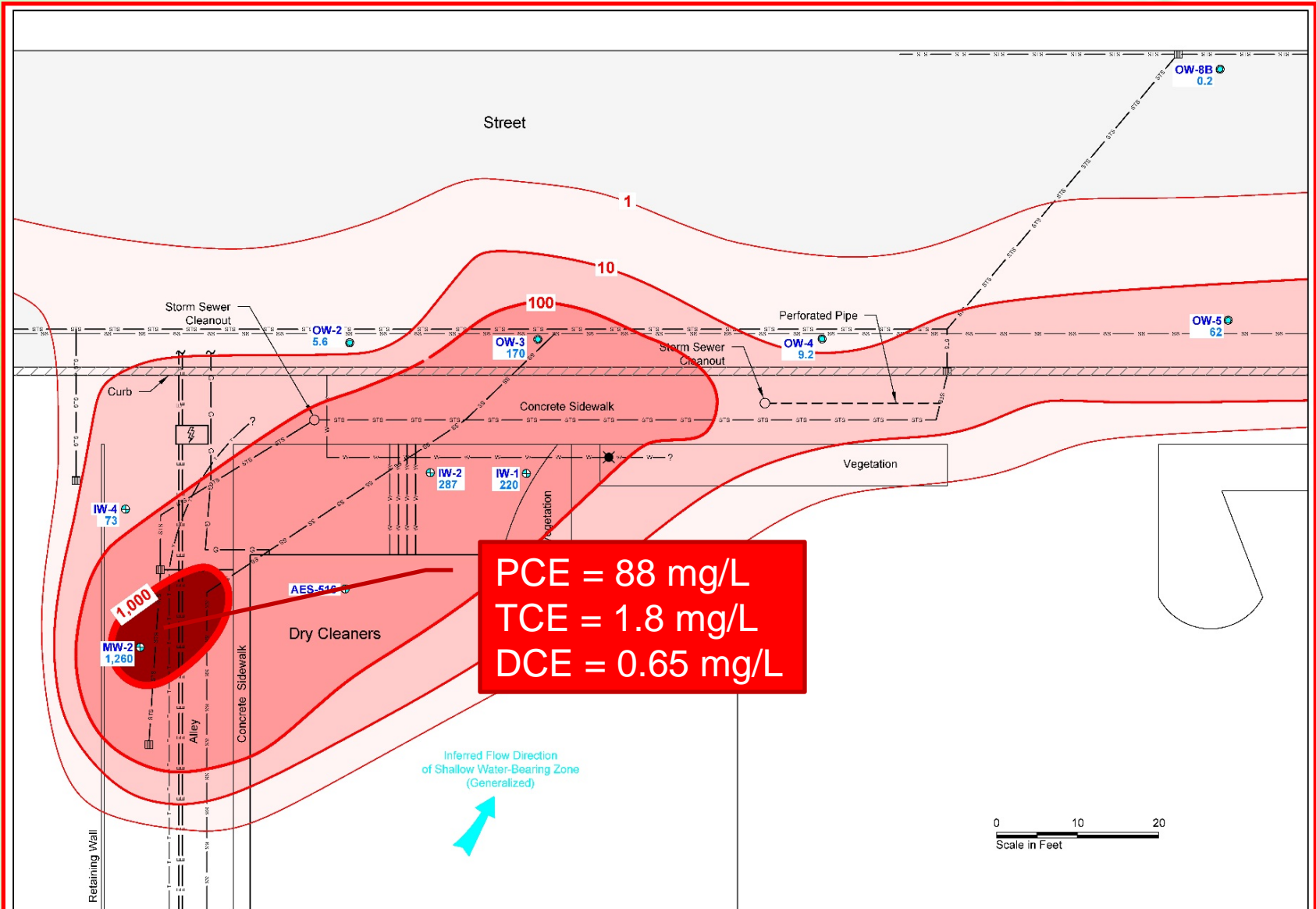
Remediation Summary

- 1999 – DNAPL source control
 - Source area excavation
 - 22,000 pounds of Fenton's slug injected into wells
- 2008 – Reductive bioremediation
 - 3 rounds of EOS[®] emulsified oil injection
 - 2,000 gallons of electron donor injected
 - Serious short-circuiting issues
- 2010 – “*cis*-stall” correction
 - 2,525 pounds of EHC[®] electron donor amendment
 - 485 pounds of BounTA[®] nutrient amendment

Remediation Summary

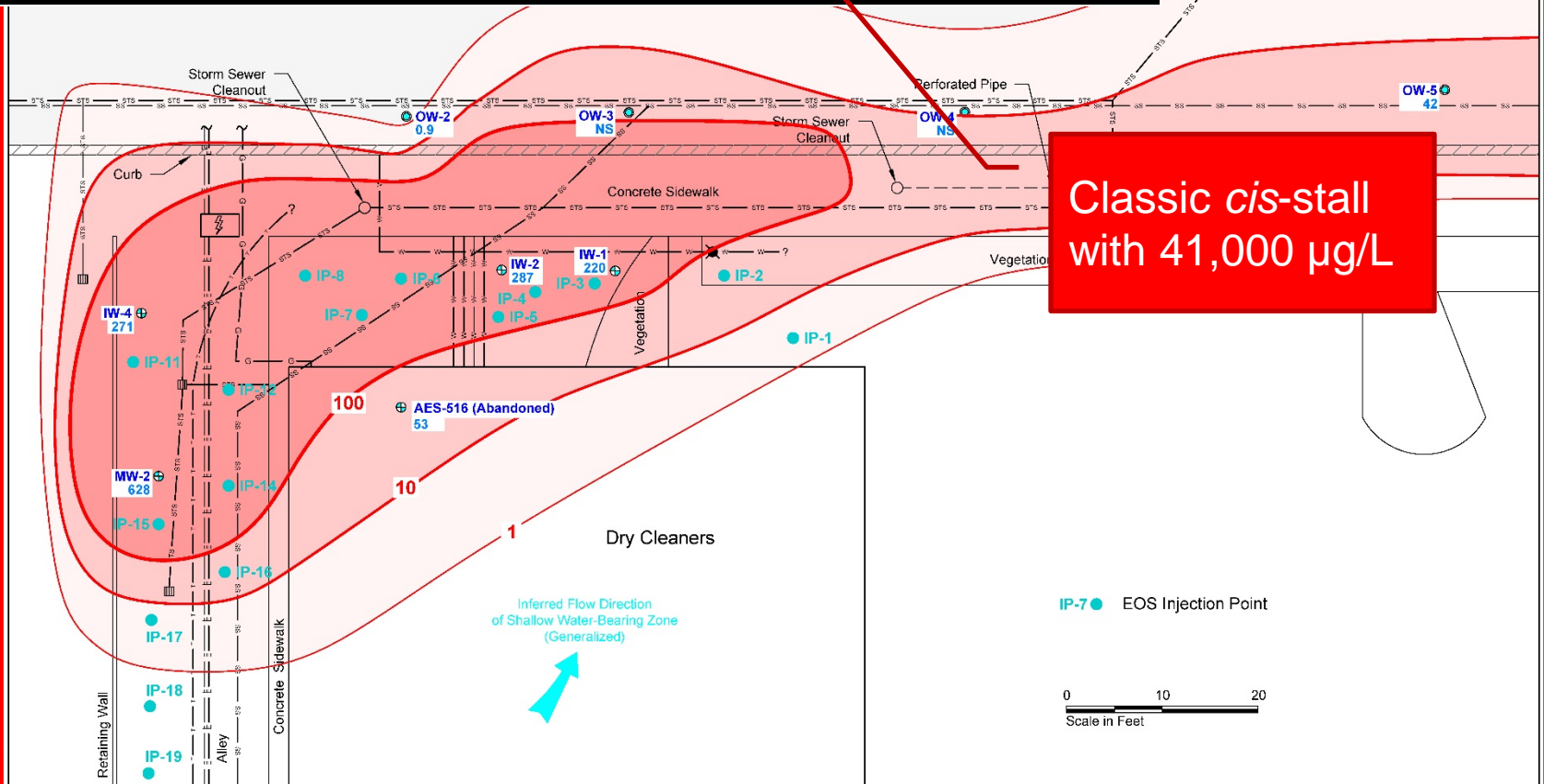


2007 Pre-EOS[®] Bulk Molar Concentrations



15 Months Post-EOS[®] cVOC Bulk Molar Concentrations

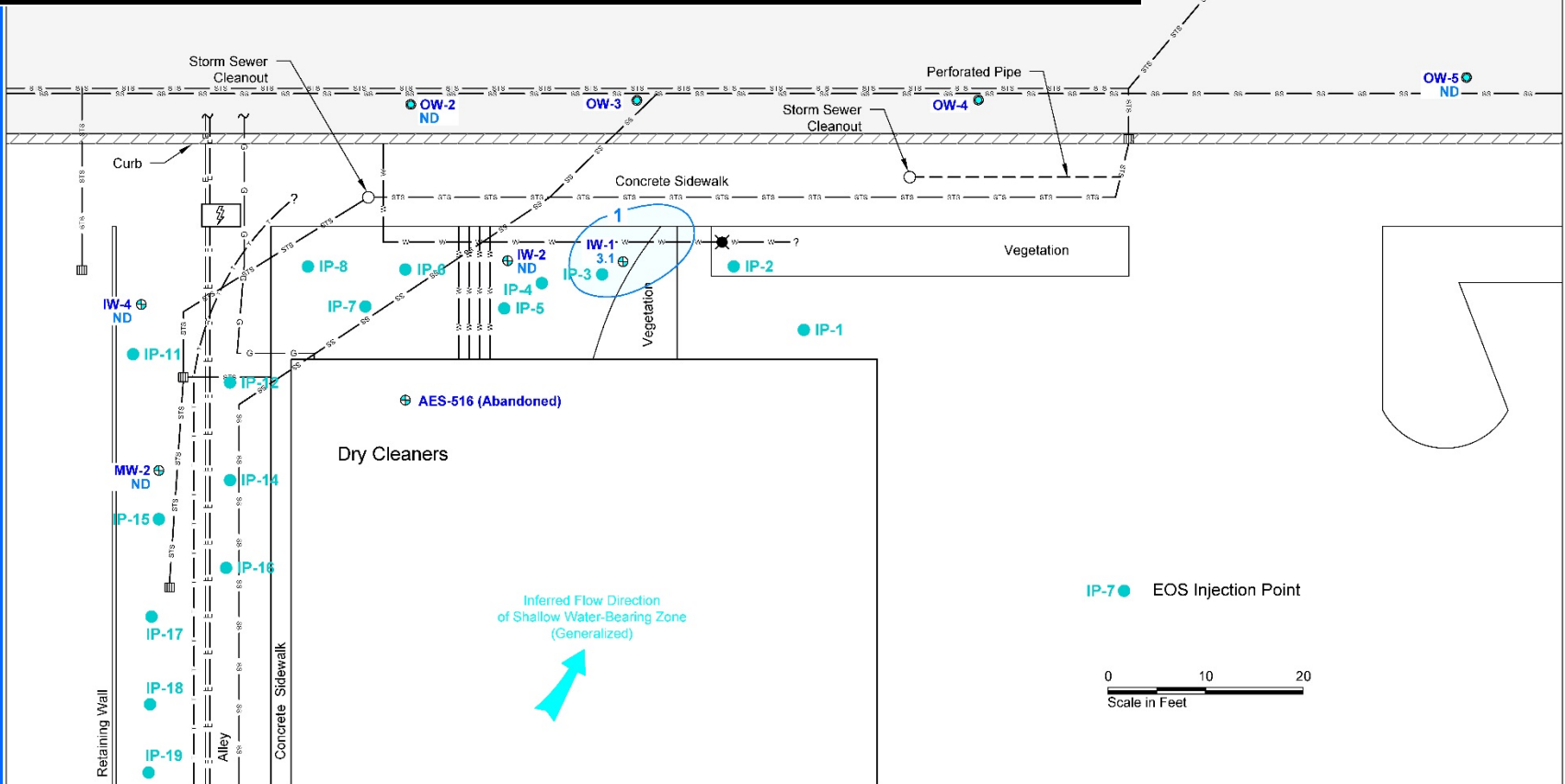
Monitoring Well	Sampling Date	pH	ORP (mV)	[milligrams per liter (mg/L)]							
				TOC	PCE	TCE	cDCE	VC	Ethene	Ethane	Methane
MW-2	7/28/2009	6.15	-129	130	0.17	0.22	41	6.9	0.50 U	0.50 U	3.0 U
IW-1	7/28/2009	6.23	-188	2.0	2.5	0.42	8.7	1.5	0.10	0.10 U	1.1 U
IW-2	7/28/2009	6.11	-190	83	0.10 U	0.02 U	11	5.9	1.0 U	1.0 U	8.0 U
IW-4	7/28/2009	6.23	-195	21	0.03	0.04	18	2.9	0.10 U	0.10 U	1.1 U



15 Months Post-EOS[®]

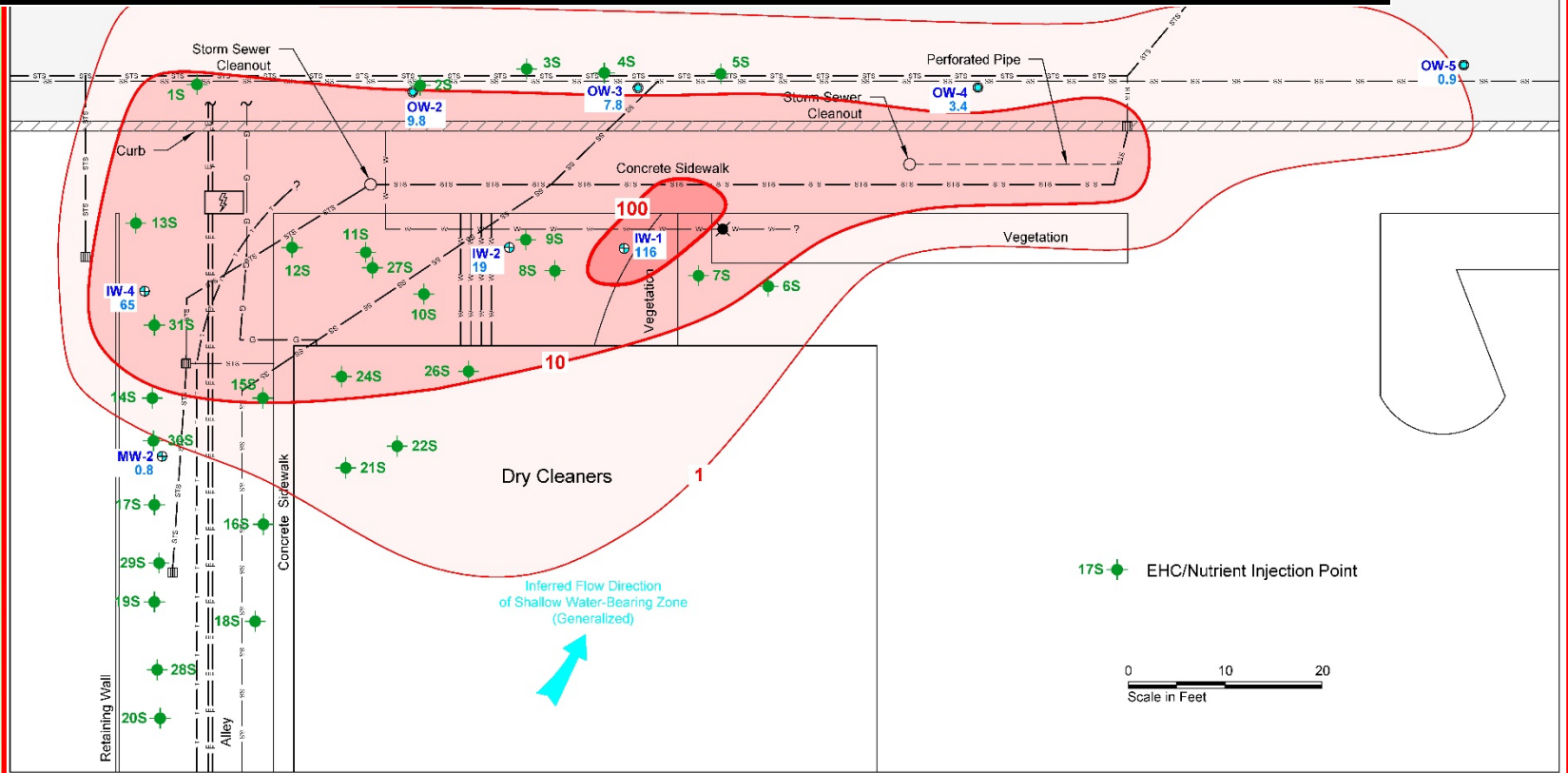
Ethene Bulk Molar Concentrations

Monitoring Well	Sampling Date	pH	ORP (mV)	[milligrams per liter (mg/L)]							
				TOC	PCE	TCE	cDCE	VC	Ethene	Ethane	Methane
MW-2	7/28/2009	6.15	-129	130	0.17	0.22	41	6.9	0.50 U	0.50 U	3.0 U
IW-1	7/28/2009	6.23	-188	2.0	2.5	0.42	8.7	1.5	0.10	0.10 U	1.1 U
IW-2	7/28/2009	6.11	-190	83	0.10 U	0.02 U	11	5.9	1.0 U	1.0 U	8.0 U
IW-4	7/28/2009	6.23	-195	21	0.03	0.04	18	2.9	0.10 U	0.10 U	1.1 U



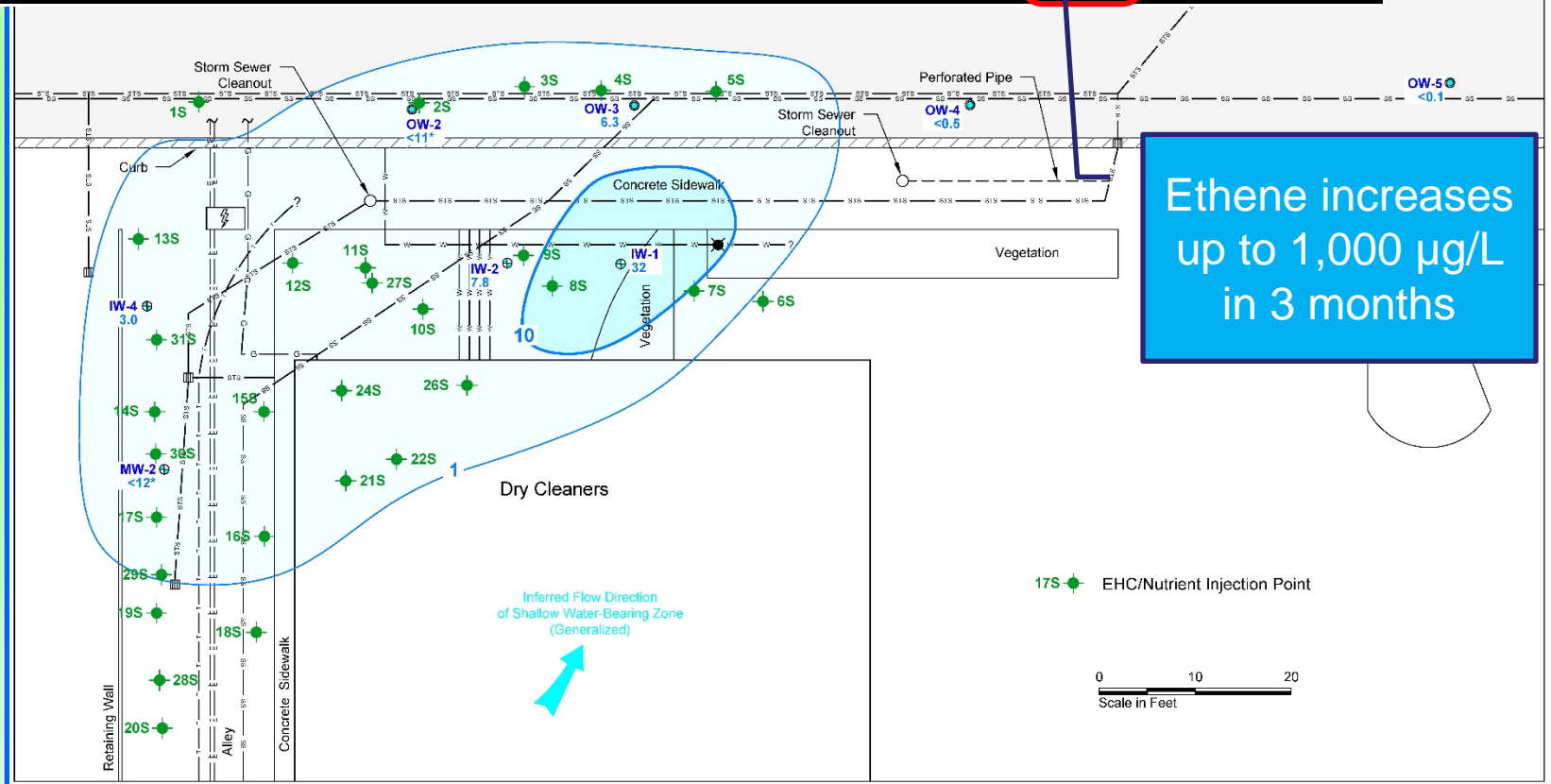
3 Months Post-BounTA[®]/EHC[®] cVOC Bulk Molar Concentrations

Monitoring Well	Sampling Date	pH	ORP (mV)	TOC	PCE	TCE	[milligrams per liter (mg/L)]				
							cDCE	VC	Ethene	Ethane	Methane
MW-2	5/26/2010	6.67	-187	330	0.01 U	0.01 U	0.010 U	0.017	0.065	360 U	8.3 U
IW-1	5/25/2010	6.39	-94	360	0.05 U	0.05 U	6.6	1.9	1.0	0.5 U	7.6 U
IW-2	5/25/2010	6.74	-112	4800	0.05 U	0.05 U	0.77	0.46	0.25	0.20 U	4.7 U
IW-4	5/25/2010	6.15	-112	6.2	0.041	0.02 U	2.5	1.9	0.096	0.04 U	1.0 U



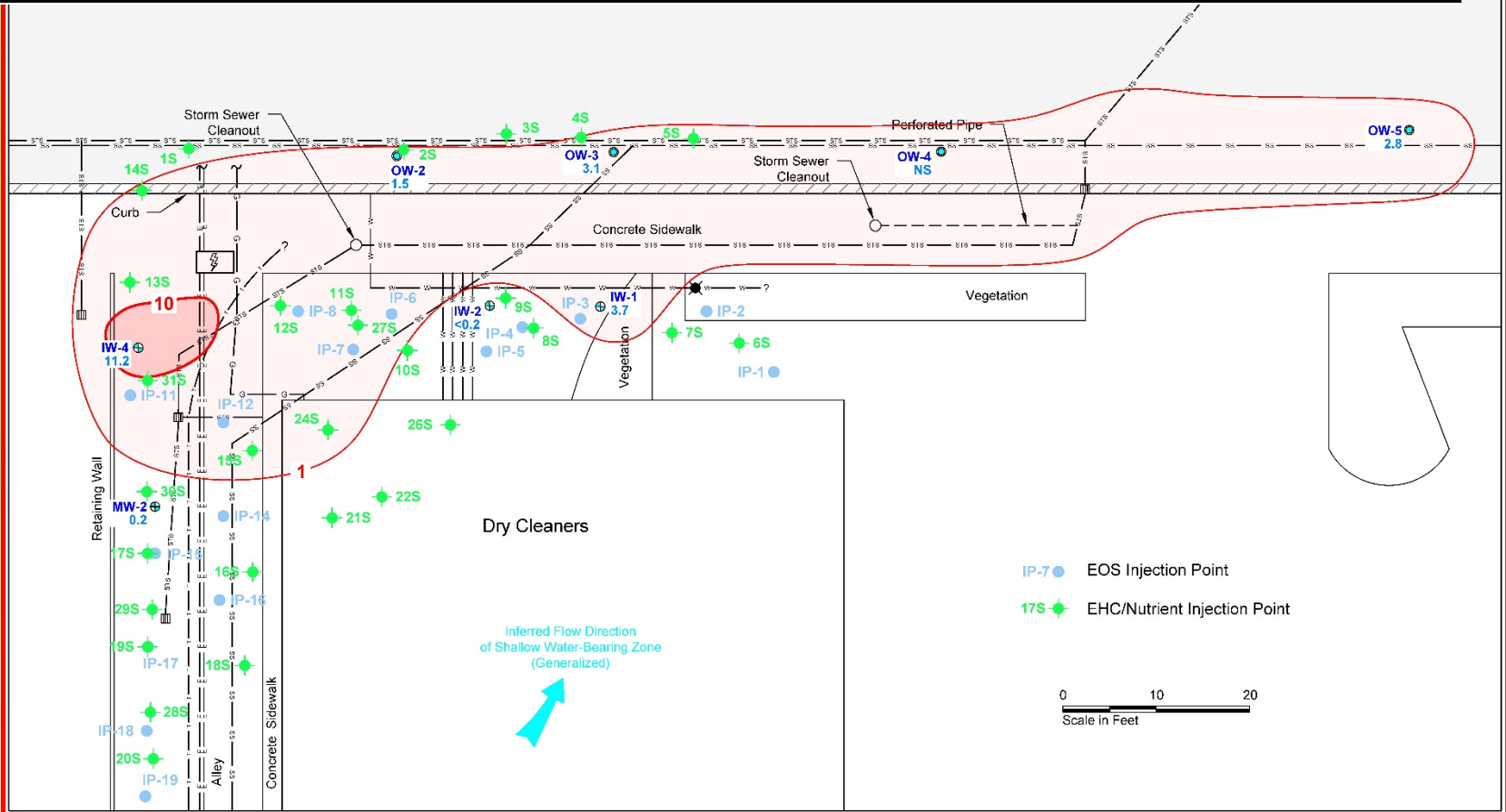
3 Months Post-BounTA[®]/EHC[®] cVOC Bulk Molar Concentrations

Monitoring Well	Sampling Date	pH	ORP (mV)	TOC	PCE	TCE	cDCE	VC	Ethene	Ethane	Methane	[milligrams per liter (mg/L)]											
MW-2	5/26/2010	6.67	-187	330	0.01 U	0.01 U	0.010 U	0.017	0.065	360 U	8.3 U												
IW-1	5/25/2010	6.39	-94	360	0.05 U	0.05 U	6.6	1.9	1.0	0.5 U	7.6 U												
IW-2	5/25/2010	6.74	-112	4800	0.05 U	0.05 U	0.77	0.46	0.25	0.20 U	4.7 U												
IW-4	5/25/2010	6.15	-112	6.2	0.041	0.02 U	2.5	1.9	0.096	0.04 U	1.0 U												



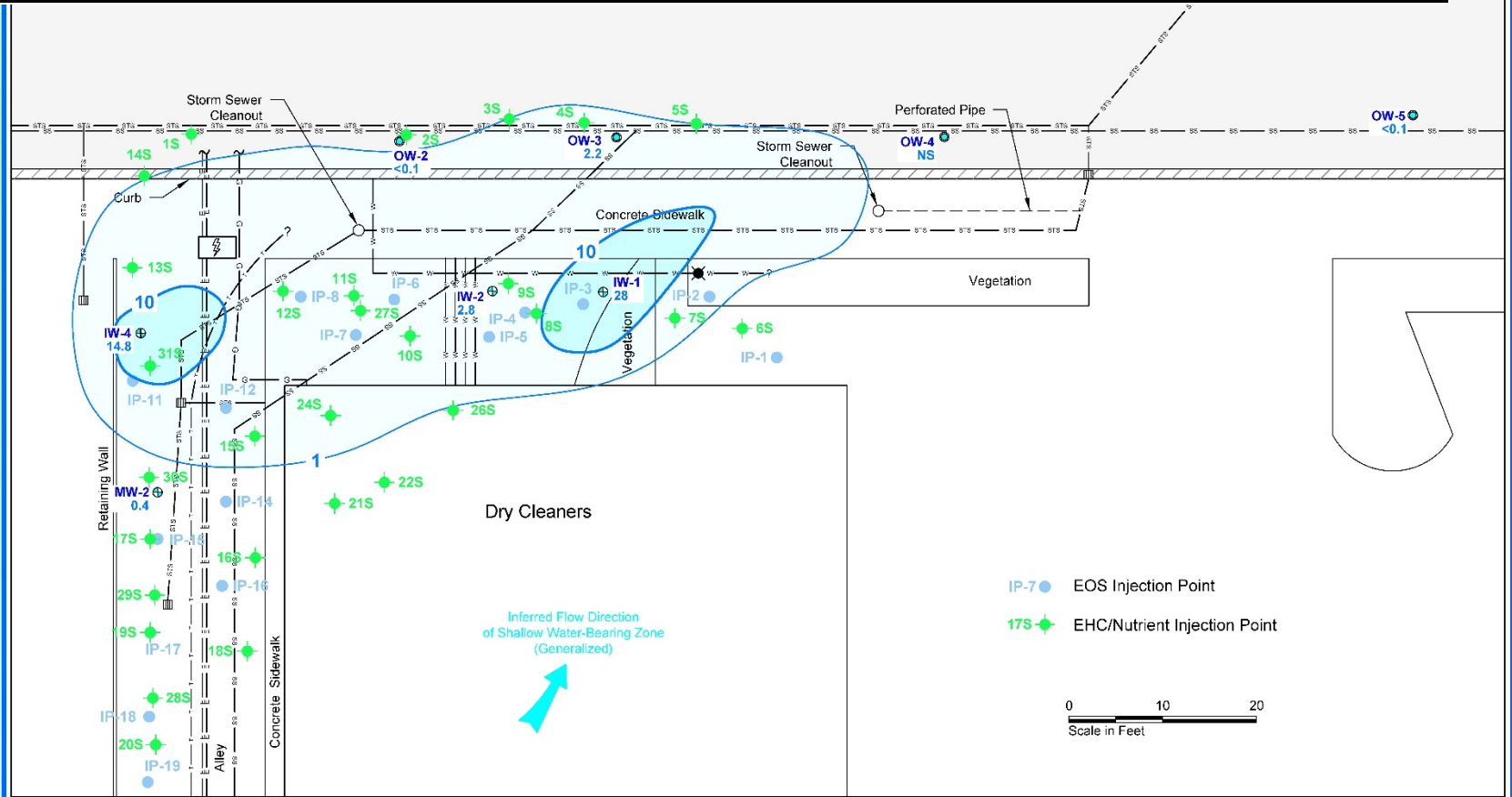
21 Months Post-BounTA[®]/EHC[®] cVOC Bulk Molar Concentrations

Monitoring Well	Sampling Date	pH	ORP (mV)	TOC	[micrograms per liter (µg/L)]						
					PCE	TCE	cis-DCE	VC	Ethene	Ethane	Methane
MW-2	11/15/2011	6.74	-97	11	0.0072	0.0023	0.0039	0.0034	0.0059	0.0065	4.9
IW-1	11/14/2011	7.06	-221	76	0.0010 U	0.0010 U	0.060	0.17	0.73	0.17	21
IW-2	11/14/2011	7.06	-198	59 J	0.010 U	0.002 U	0.002 U	0.002 U	0.00038	0.093	17
IW-4	11/15/2011	6.53	-167	8.7	0.010 U	0.0055	0.31	0.41	0.39	0.087	8.6



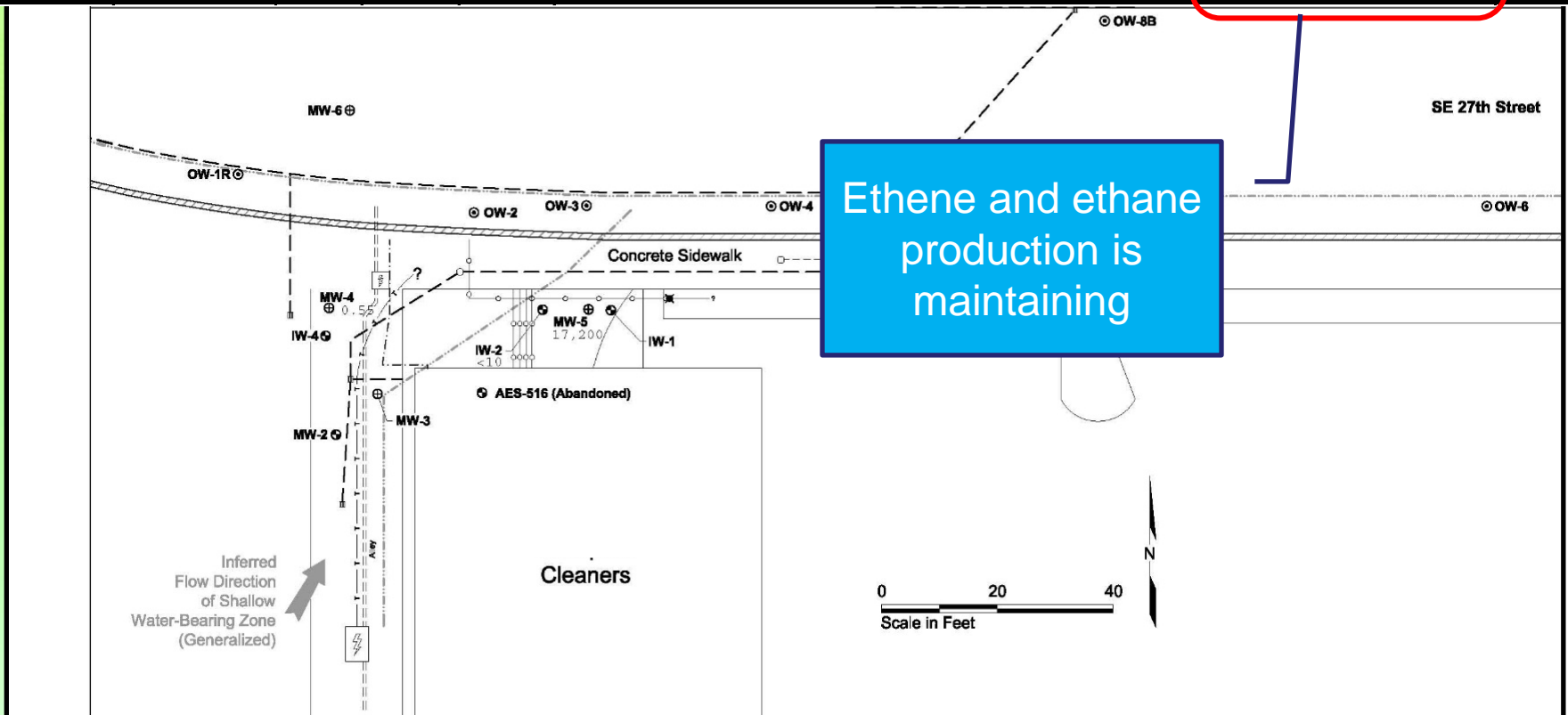
21 Months Post-BounTA[®]/EHC[®] cVOC Bulk Molar Concentrations

Monitoring Well	Sampling Date	pH	ORP (mV)	TOC	PCE	TCE	cis-DCE	VC	Ethene	Ethane	Methane
					[micrograms per liter (µg/L)]						
MW-2	11/15/2011	6.74	-97	11	0.0072	0.0023	0.0039	0.0034	0.0059	0.0065	4.9
IW-1	11/14/2011	7.06	-221	76	0.0010 U	0.0010 U	0.060	0.17	0.73	0.17	21
IW-2	11/14/2011	7.06	-198	59	0.010 U	0.002 U	0.002 U	0.002 U	0.00038	0.093	17
IW-4	11/15/2011	6.53	-167	8.7	0.010 U	0.0055	0.31	0.41	0.39	0.087	8.6



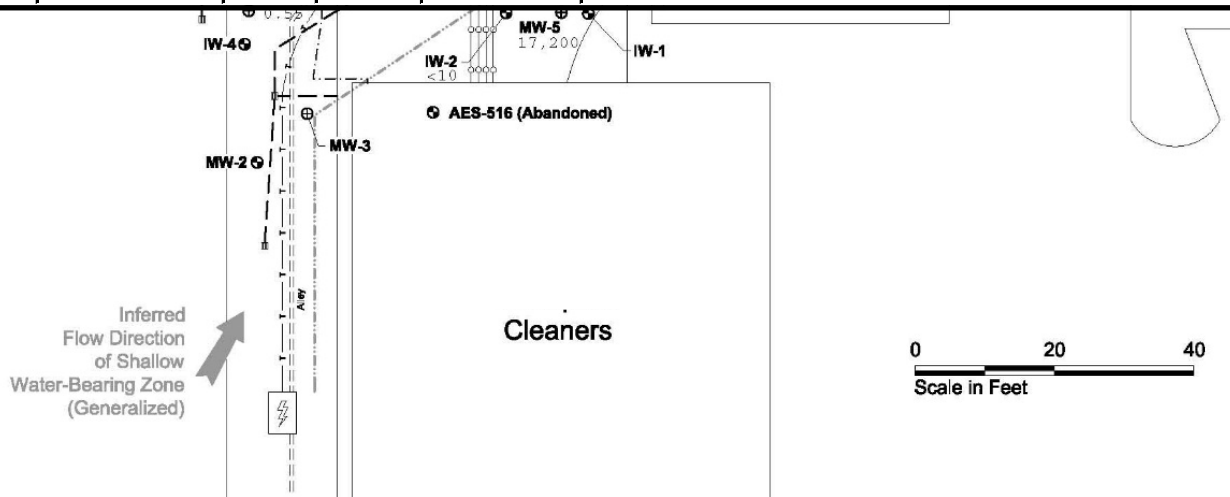
47 Months Post-BounTA[®]/EHC[®] Groundwater Concentrations

Monitoring Well	Sampling Date	pH	ORP (mV)	TOC	PCE	TCE	cis-DCE	VC	Ethene	Ethane	Methane
					[micrograms per liter (µg/L)]						
MW-2	1/29/2014	7.18	-46	2.5	0.0026	0.0012	0.0014 U	0.00032	0.00011	0.00074	1.0
IW-1	1/29/2014	7.1	-140	3.8	0.00057	0.0023	0.069	0.081	0.39	0.36	18
IW-2	1/29/2014	7.05	-111	5.7	0.0002 U	0.00031	0.00044	0.00028	0.0013	0.41	17
IW-4	1/29/2014	6.66	-85	2.2	0.0022	0.0061	0.039	0.055	0.35	0.039	2.6



21 Months Post-BounTA[®]/EHC[®] cVOC Bulk Molar Concentrations

Monitoring Well	Sampling Date	pH	ORP (mV)	TOC (mg/L)	PCE	TCE	cis-DCE	VC	Ethene	Ethane	Methane
					[micrograms per liter (µg/L)]						
MW-5	7/28/2009	7.53	18.9	1.2	12000	570	20 U	20 U	2.5 U	2.5 U	30 U
MW-5	5/26/2010	7.98	18.3	1.6	18000	1200	300	100 U	2.6	5.0 U	97 U
MW-5	11/17/2010	7.21	0.8	4.8	9900	2100	11000	590	6.8	0.30	600
MW-5	5/25/2011	7.92	-229	1.3	8400	2200	5600	1000	14	0.15	690
MW-5	11/15/2011	7.69	-274	5.6	8600	2600	3900	680	19	0.16	860
MW-5	2/16/2012	5.64	-283	19000	1200	990	13000	530	5.4	5.3	230
MW-5	7/24/2012	5.57	-193	23000	440	300	4500	4500	1600	3.5	5800
MW-5	10/10/2012	5.69	-257	19000	400	300	4400	2900	810	1.3	2400
MW-5	1/30/2013	6.67	-198	14000	400	300	3200	1900	350	0.66	1200
MW-5	6/6/2013	5.66	-327	6800	510	210	1600	1100	1600	3.70	1600
MW-5	8/27/2013	5.78	-83	11000	400	250	1100	220	370	5.3	7900
MW-5	1/28/2014	5.65	-107	6200	360	140	670	190	980	16	15000
MW-5	8/20/2014			6500	330	91	370	72	820	33	16000



Conclusions

- EHC[®] product application
 - Maintained electron donor loading
 - Homogenized treatment
- BounTA[®] product amendment
 - Substantially increased microbial activity
 - Developed complete dechlorinating microbes
 - Corrected *cis*-stall
 - No bio-augmentation required

**BounTA[®] cost 2.4% of the
EHC amendment cost**

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Further reading about this site available at:

Fowler, T., Reinauer, K. *Enhancing Reductive Dechlorination with Nutrient Addition*, Remediation Journal. Winter 2013.

Fowler, T., Thompson, B., Mueller, J. *Acetone and 2-Butanone Creation Associated with Biological and Chemical Remediation of Environmental Contamination*, Remediation Journal. Winter 2011.



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