Surgical In-Situ Chemical Oxidation Remediation Utilizing a High Resolution Site Characterization-Driven Approach to Optimize Reagent Delivery and Remediation Strategy

Mike Mazzarese (Vironex, Inc., Bowie, MD, USA), Eliot Cooper (Vironex, Inc., Golden, CO, USA), Scott Wisher (Vironex, Inc., Golden, CO, USA), Brendan Gerber (Vironex, Inc., Bowie, MD, USA)

Some Reasons In-Situ Remediation Can Fail

- Lack of detailed characterization data (especially in source zones), relying on monitoring well data for site characterization and design
- Lack of information regarding mass vs. lithology and hydraulic conductivity of target intervals
- Inadequate subsurface reagent distribution
- High expectations not taking into consideration rebound from back diffusion

High Resolution Profiling

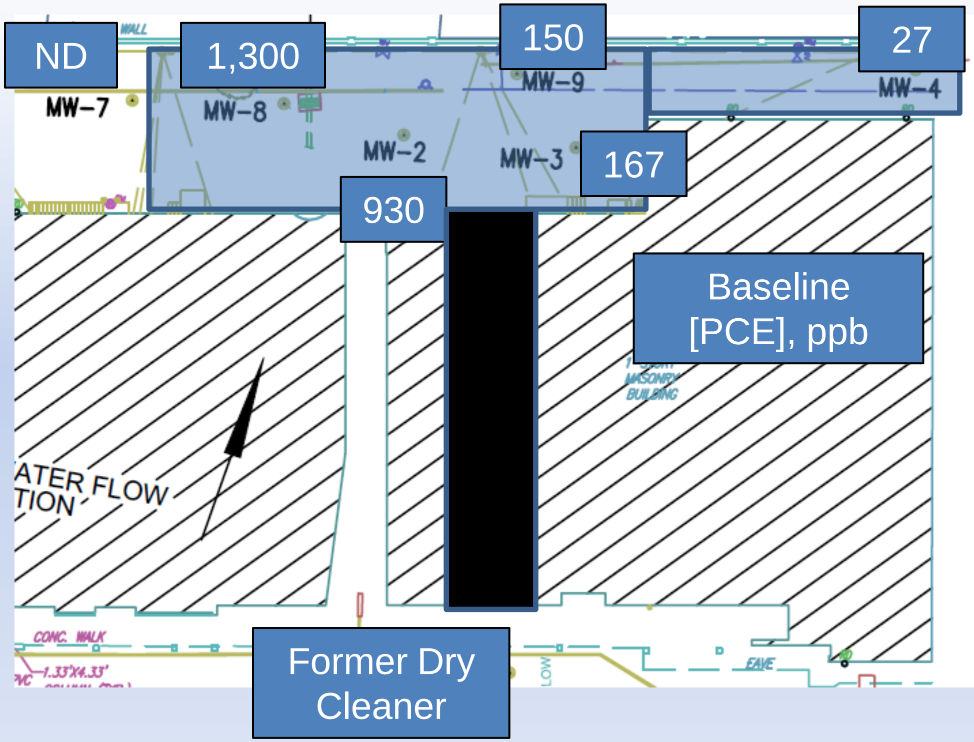
- Tools: Membrane Interface Probe (MIP), Hydraulic Profiling Tool (HPT), Electrical Conductivity (EC), Laser Induced Fluoresce (LIF)
  - Lack of vertical characterization data => MIP
  - Lack of information regarding mass vs. lithology/hydraulic conductivity => MIP/HPT
  - Lack of understanding regarding subsurface reagent distribution => EC
  - Poor expectations regarding rebound from back diffusion => MIP/HPT

Project Summaries

- Site 1: VA Dry Cleaner
  - Direct Sensing Technologies: Membrane Interface Probe (MIP), Electrical Conductivity (EC) radius of influence verification
  - Remediation Strategy: In Situ Chemical Oxidation (ISCO) injection with potassium permanganate (KPmag)
- Site 2: NC Former Retail Gas Station
  - Direct Sensing Technologies: MIP, EC radius of influence verification
  - Remediation Strategy: ISCO injection with high pH activated Klozur (sodium persulfate)
- Site 3: ON Manufacturing Site
  - Direct Sensing Technologies: MIP, EC radius of influence verification
  - Remediation Strategy: ISCO injection and in situ mixing with High pH activated Klozur (sodium persulfate)

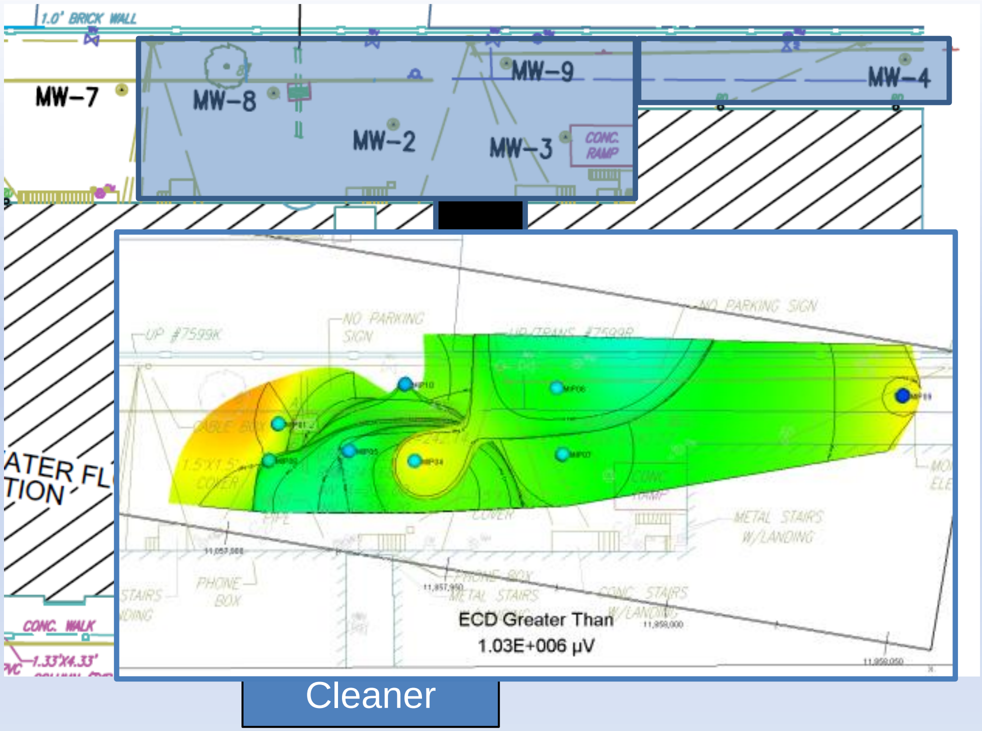
Site #1 – Base Design

- VA (DC Metro) Dry Cleaner
  - Risk based goal of 100 ppb PCE at property boundary
- Preliminary design based on well data
  - Wells screened 3-6 m bgs, GWT @ 2.4 m bgs => Injection zone = 2.4-6 m bgs
  - Injection Footprint = 600 m^2
  - 1,920 kg Potassium Permanganate specified based on COCs and estimated PNOD, @ 1% solution = 190,000 Liters

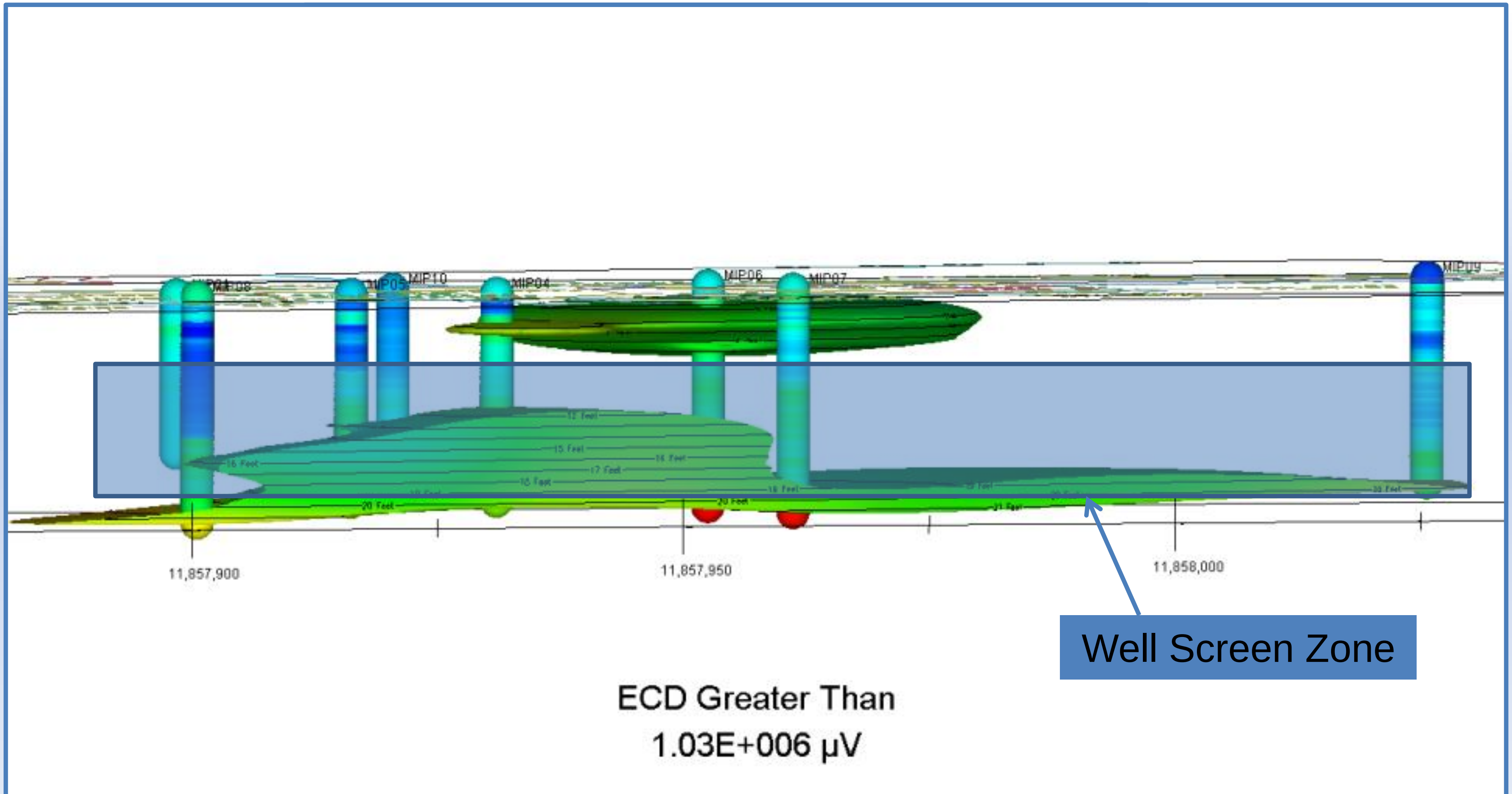


Site #1 – Optimized Design

- Optimized Approach
  - Pilot Phase (4 days)
    - MIP (1.5 days)
    - 3D imaging
    - Confirmation Sampling/PNOD Sample Collection (0.5 days)
    - Injection Testing (2 days)
      - Determine flow rate and pressure vs. depth
      - Determine ROI (EC + visual)
  - Full Scale Injection (9 days)



Site #1 – MIP Imaging

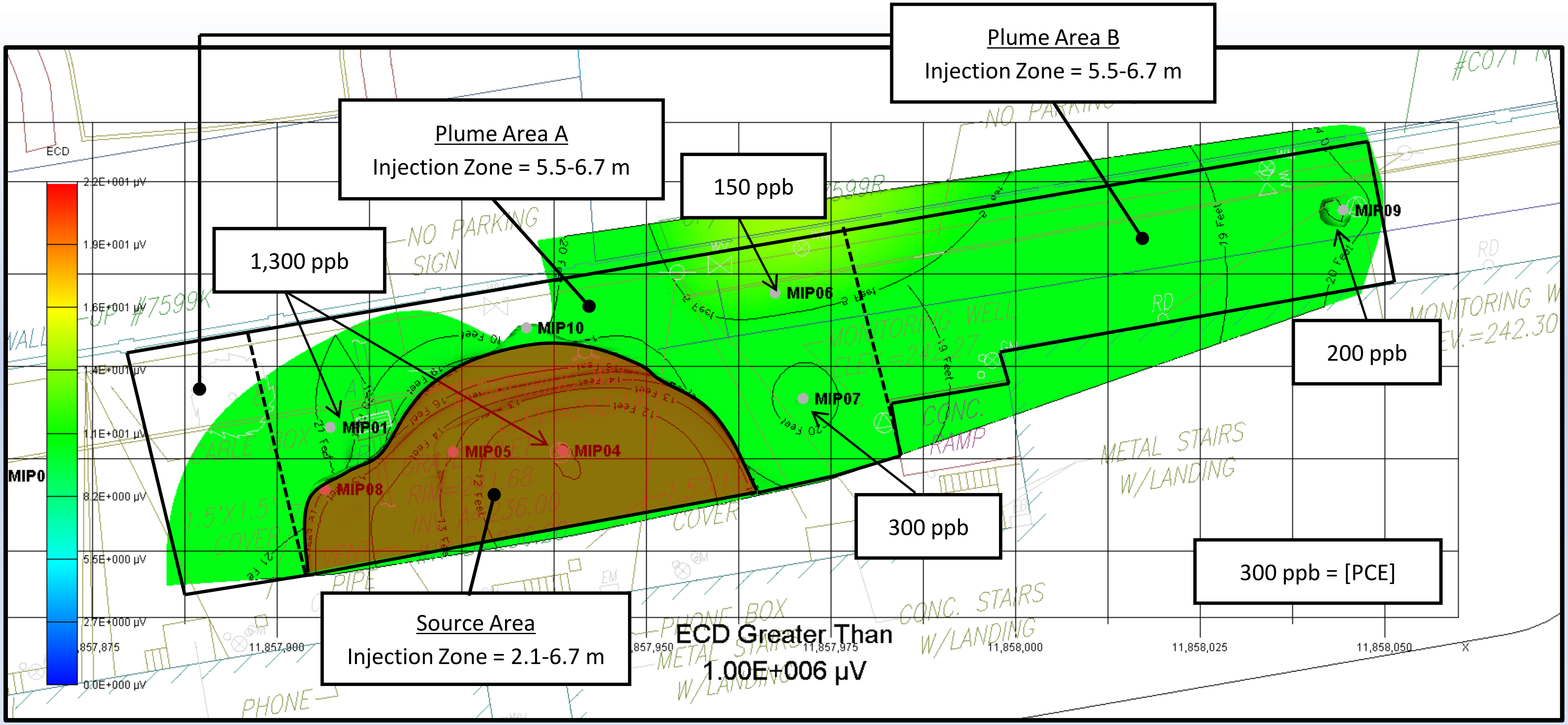


ECD Greater Than
1.03E+006 µV

Site #1 – Optimized Design

- Revised Design
  - Design based on MIP data, discrete groundwater sampling, lab determined PNOD, and ROI from pilot test
  - Injection zone varied per MIP cross section
  - Permanganate concentration varied based on discrete sampling data
  - Injection Footprint = 460 m^2 **(-140 m^2)**
  - 2,169 kg **(+13%)** KPmag specified based on new COC concentrations and PNOD, @ 1-2% solution = 119,000 L **(-38%)**

Site #1 – Optimized Design

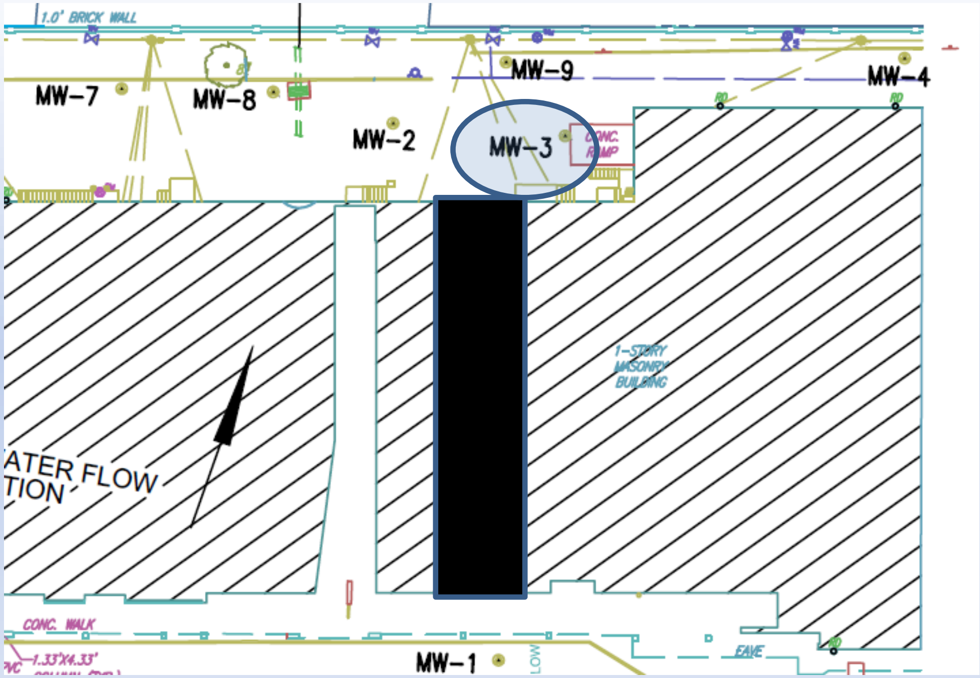


Site #1 – Data Summary

		PCE	TCE	DCE	VC	Total	Notes
MW-2	Jan. - 09	1,500	12	43	ND	1,555	
	Apr. - 11	300	2.5	5.9	ND	308	
	Feb. - 12	N/S	N/S	N/S	N/S		N/S because well water still colored
	Sep. - 12	20	ND	ND	ND	20	
					% Change	-98%	Assuming average of Jan and April 2011 values as baseline
MW-3	Jan. - 09	140	3.4	11	ND	154	
	Apr. - 11	8.2	1.5	2.7	ND	12	
	Feb. - 12	69	2.9	11	ND	83	
	Sep. - 12	230	2.9	11	ND	244	
					% Change	192%	Assuming average of Jan and April 2011 values as baseline
MW-5	Jan. - 09	950	6.3	13	1.6	970.9	
	Apr. - 11	720	8.4	16	ND	744.4	
	Feb. - 12	N/S	N/S	N/S	N/S		N/S because well water still colored
	Sep. - 12	ND	ND	ND	ND	0	
					% Change	-100%	Assuming average of Jan and April 2011 values as baseline
MW-8	Apr. - 11	1,300	ND	8	ND	1,308	
	Feb. - 12	ND	ND	ND	ND	0	
	Sep. - 12	ND	ND	ND	ND	0	
					% Change	-100%	Assuming April 2011 value as baseline
MW-9	Apr. - 11	150	2.6	ND	ND	152.6	
	Feb. - 12	22	ND	ND	ND	22	
	Sep. - 12	ND	ND	ND	ND	0	
					% Change	-100%	Assuming April 2011 value as baseline

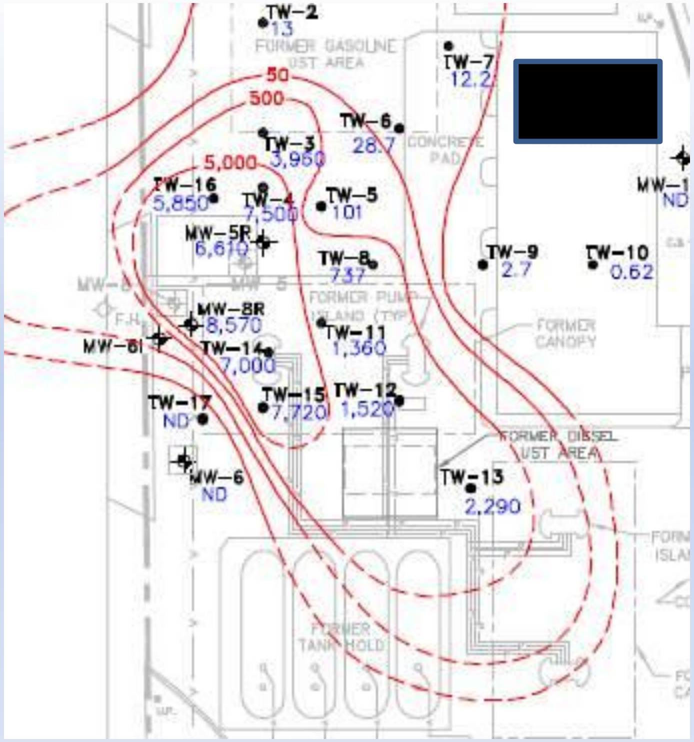
Site #1 – Next Steps

- Path Forward
  - Additional MIP investigation in area of MW-3
  - Directional injection or angle borings to overcome access issues



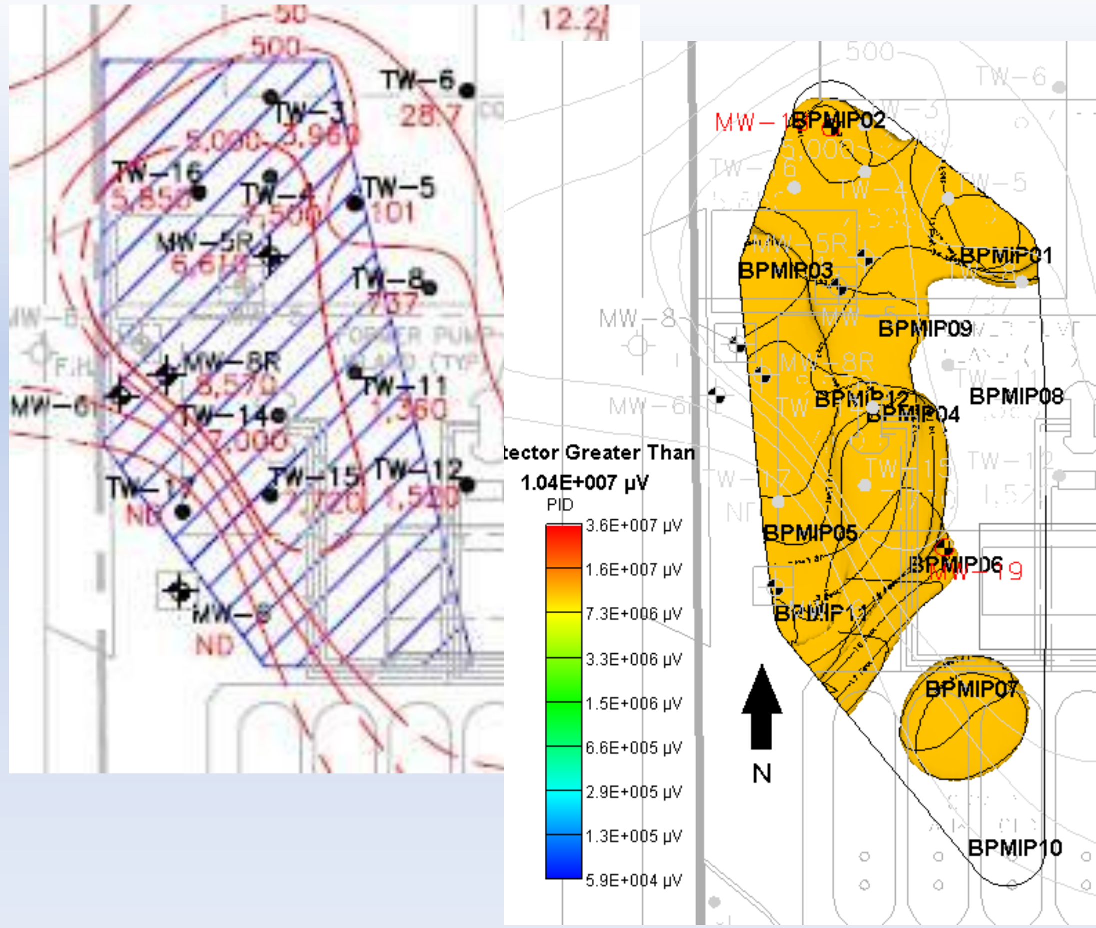
Site #2 - Base Design

- NC, Confidential Location
  - Risk based goal of 5,000 ppb Benzene
  - Original design based on monitoring well data and TPH-GRO soil data
  - Wells screened 3-6 m bgs, GWT @ 3 m bgs => Injection zone = 3-6 m bgs
  - Injection Footprint = 230 m^2
  - 8,900 kg sodium persulfate (SP) specified based on COCs and estimated SOD, @ 12% solution = 70,000 L (100% mobile porosity injected)

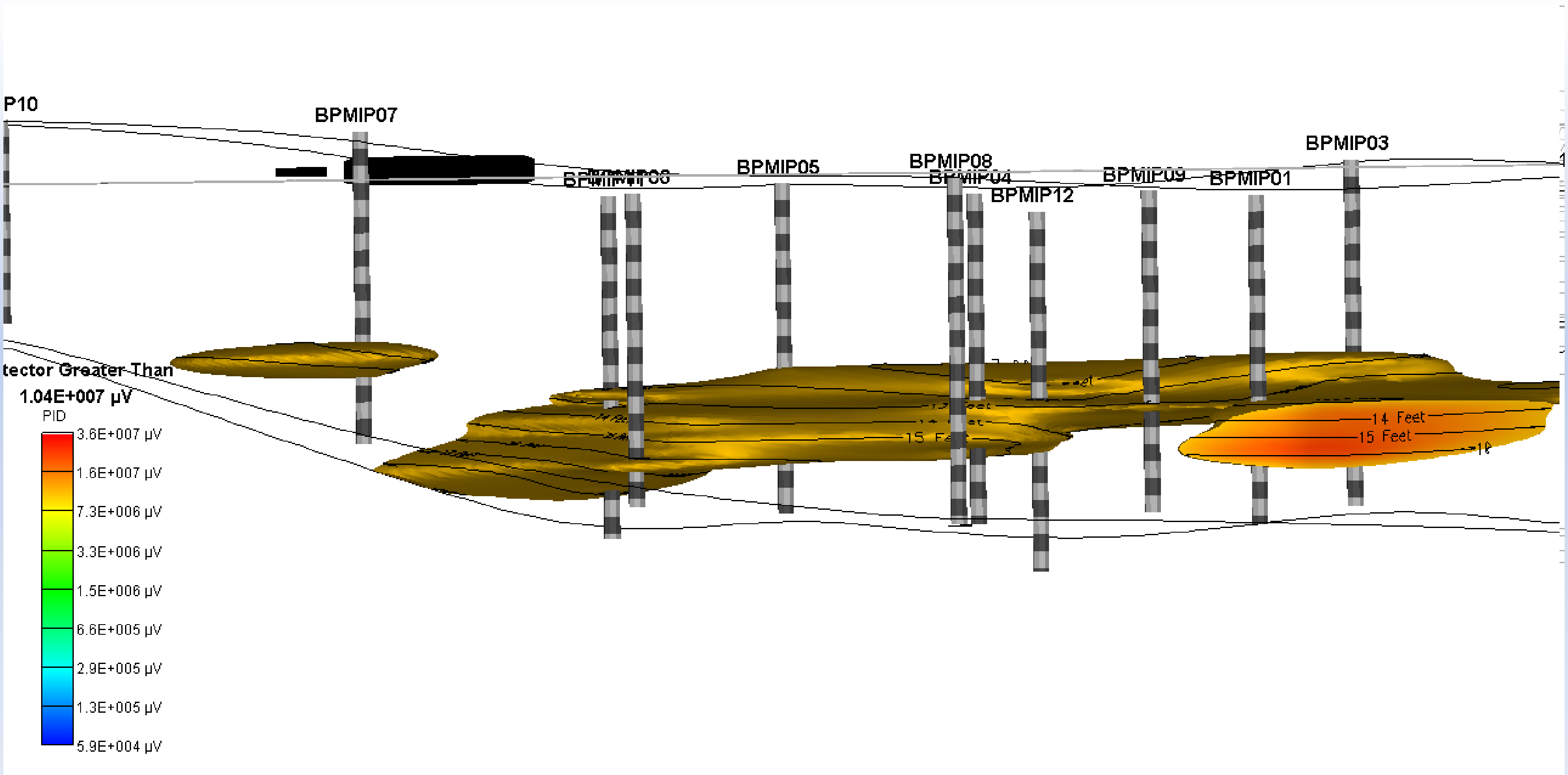


Site #2 – Optimized Design

- Optimized Approach
  - Pilot Phase (4 days)
    - MIP (2 days)
    - 3D imaging
    - Confirmation Sampling/SOD/pH buffering Sample Collection (0.5 days)
    - Injection Testing (1.5 days)
      - Determine flow rate and pressure vs. depth
      - Determine ROI (EC)
  - Full Scale Injection (6 days)

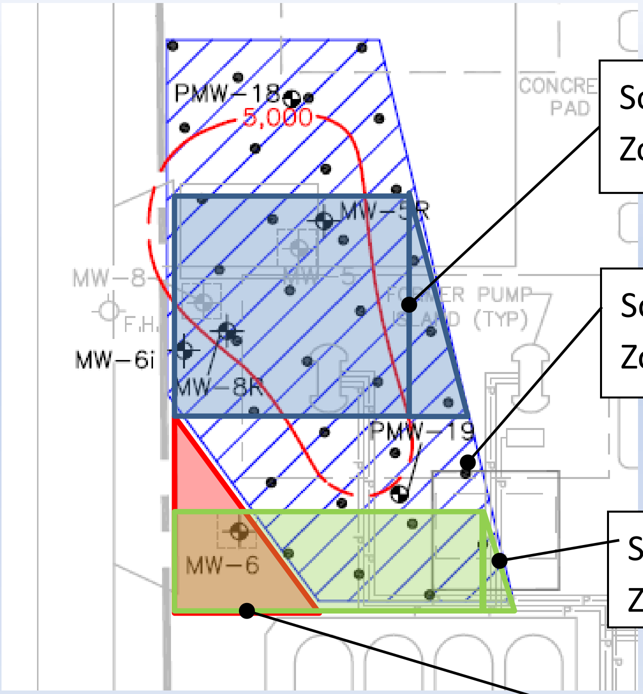


Site #2 – MIP Imaging



Site #2 – Optimized Design

- Revised Design
  - Revised design based on MIP data and discrete soil samples
  - Injection zone = 3.7-5.2 ft bgs or 3.7-6.1 m bgs
  - Injection Footprint = 280 m^2 (increase from 230 m^2 to include additional mass identified with the MIP)
  - 4,700 kg (-47%) SP based on COCs and known SOD, @ 12% solution = 43,000 L (-39%)



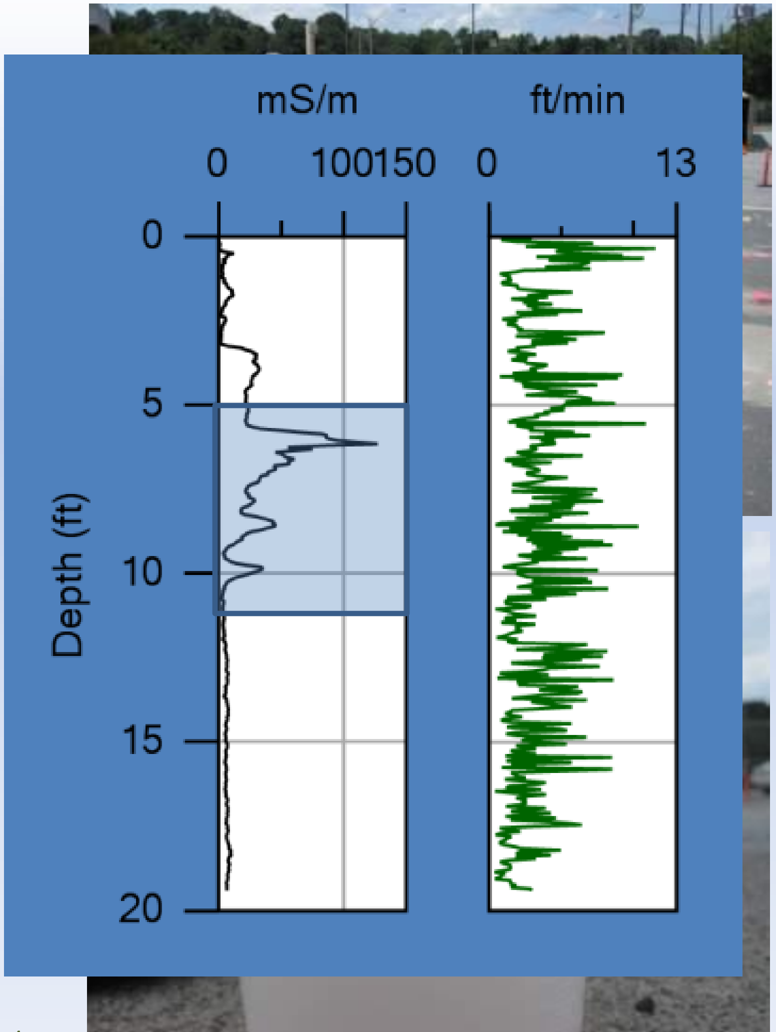
Source-Core = Injection Zone = 3.7-5.2 m bgs

Source Area B = Injection Zone = 3.7-5.2 ft bgs

Source Area A = Injection Zone = 3.7-6.1 m bgs

Area added due to MIP survey results

Site #2 – Equipment Photos



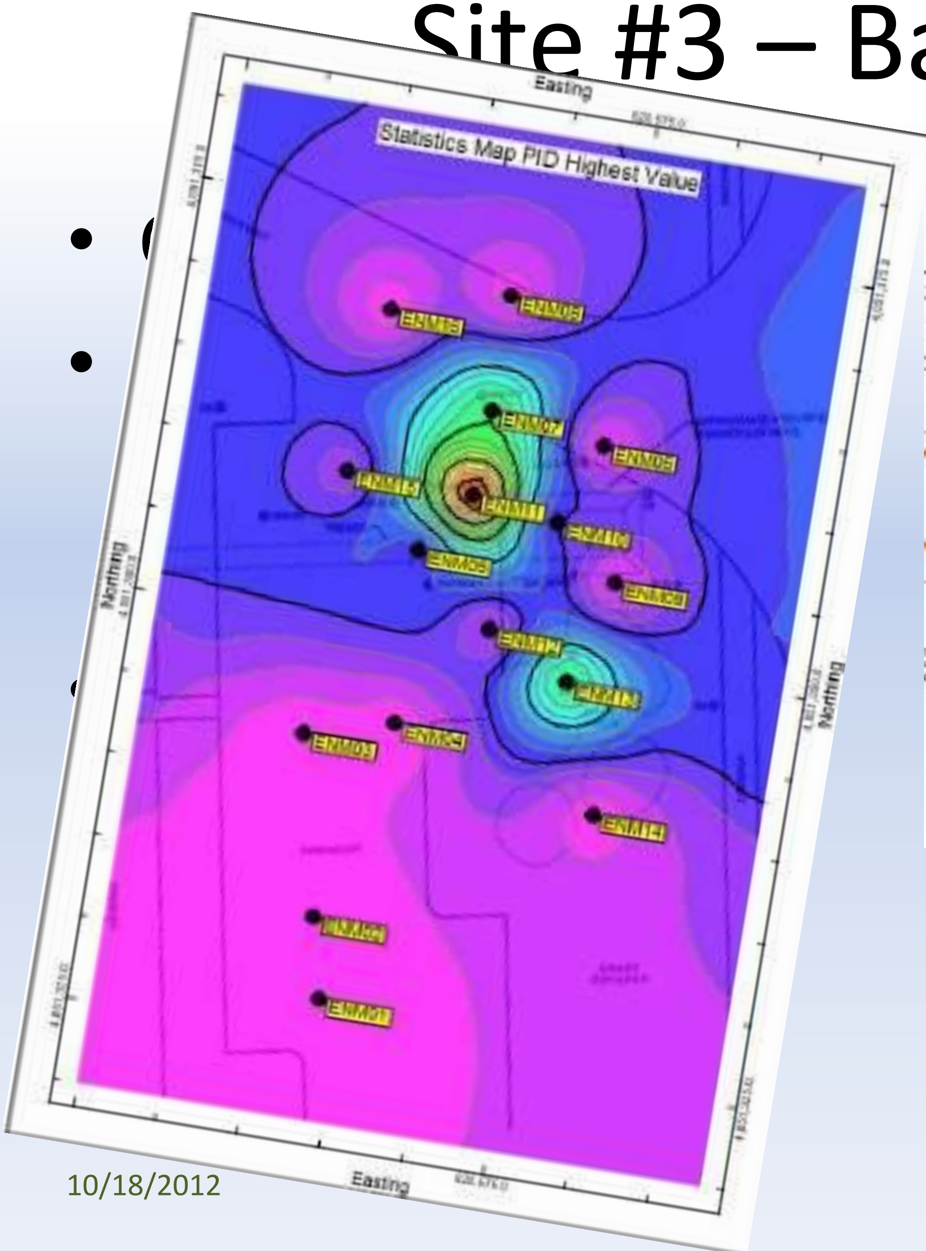
ROI Verification Using EC

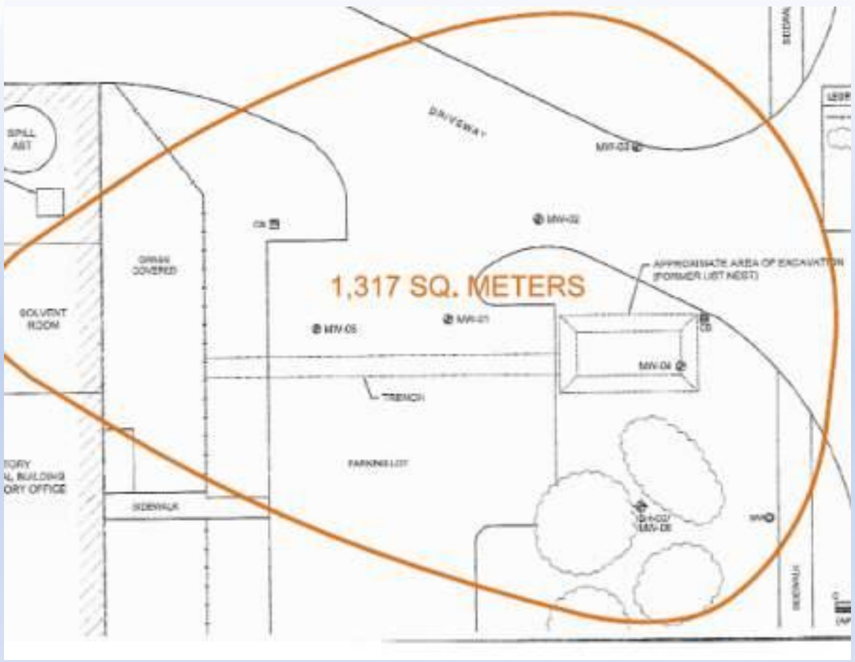
- EC can be used to track reagent distribution provided that the reagent or tracer provides a response over the baseline geological response
- Examples of reagents that can be tracked:
  - Sodium Persulfate, Sodium Percarbonate, Sodium and Potassium Pmag, Sodium Bicarbonate, Sodium Lactate

Site #2 – Data Summary

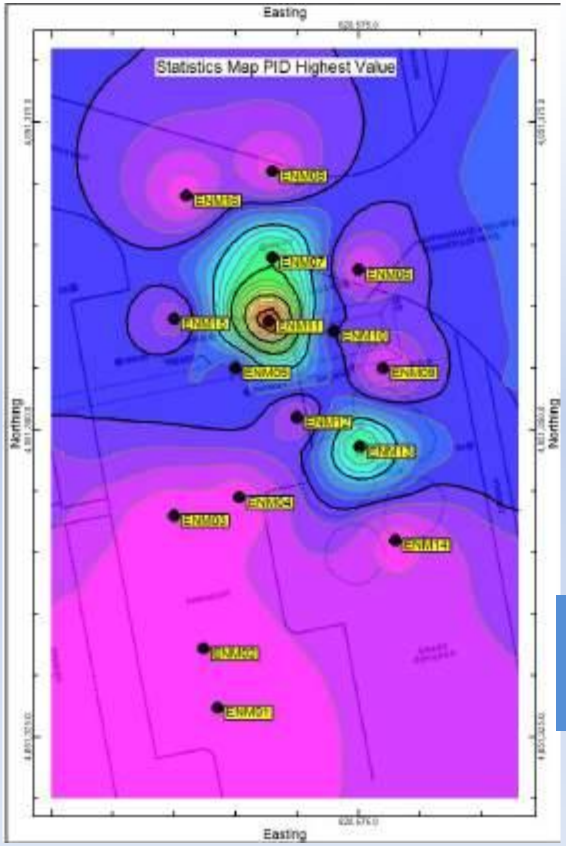
MW-5R								
Event Description	Date	Benzene	Toluene	Ethylbenzene	Xylene (total)	Methyl Tert Butyl Ether	Total	% Change
		ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	
6-months prior	10/31/2011	7960	28000	2660	13800	3830	56250	
2-weeks prior	5/22/2012	7980	32200	3470	19200	3820	66670	
1-week after	6/14/2012	244	1190	227	1120	36.9	2818	95%
1-month after	7/9/2012	336	2010	481	2400	48.4	5275	91%
2-month after	8/14/2012	201	1050	283	1300	48.5	2883	95%
MW-8R								
Event Description	Date	Benzene	Toluene	Ethylbenzene	Xylene (total)	Methyl Tert Butyl Ether	Total	% Change
		ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	
6-months prior	10/31/2011	8000	32100	3180	17200	3170	63650	
2-weeks prior	5/22/2012	8270	36400	3360	17800	3920	69750	
1-week after	6/14/2012	726	760	47	242	96.3	1871	97%
1-month after	7/9/2012	4540	17100	1870	10800	1530	35840	46%
2-month after	8/14/2012	4370	19300	1610	8780	2000	36060	46%

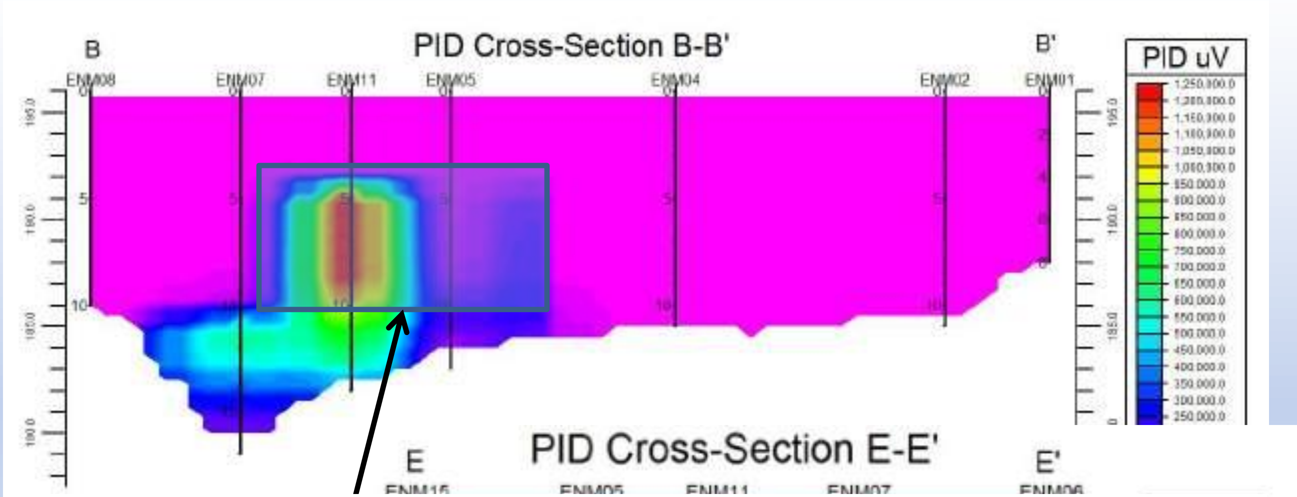
Site #3 – Base Design

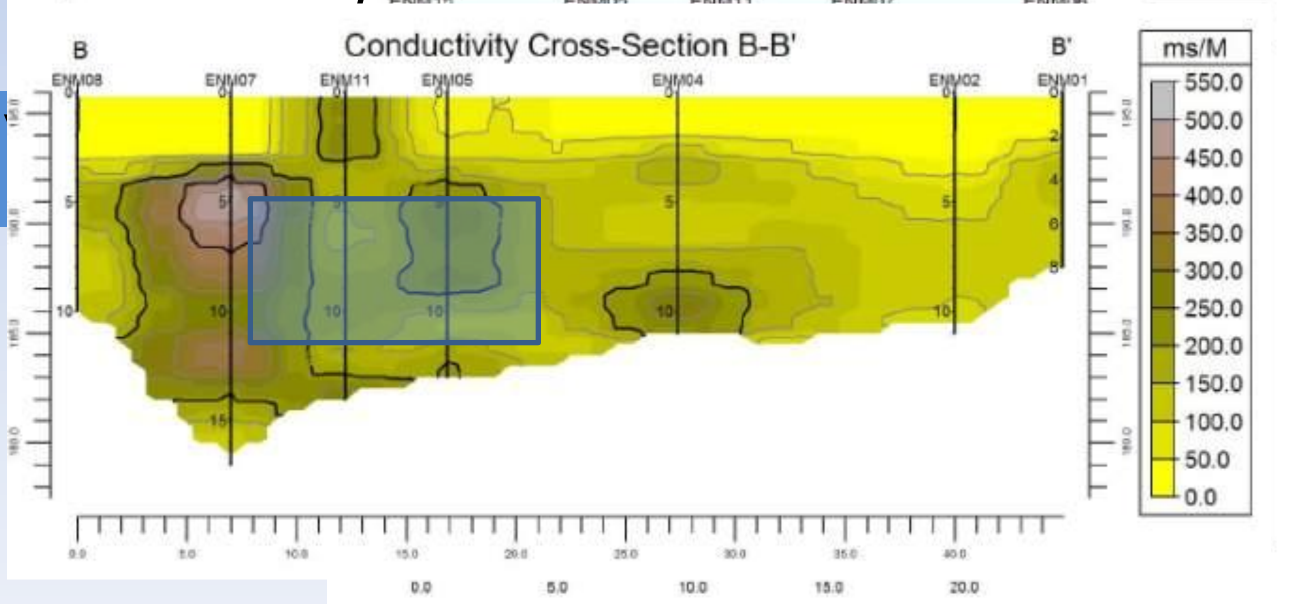




Site #3 – MIP Imaging



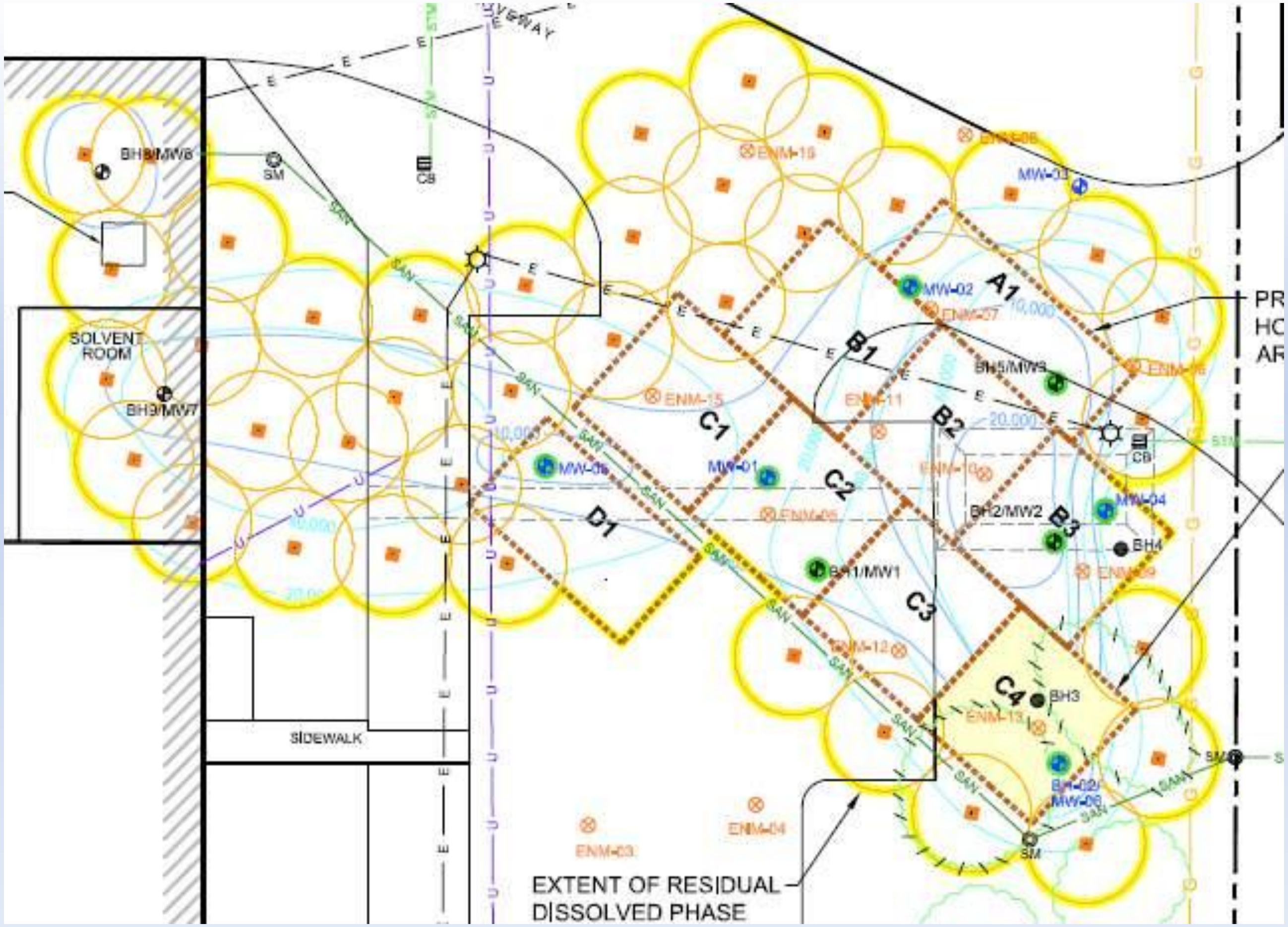




Site #3 – Optimized Design

- Groundwater (Plume): Caustic Activated SP Injection
- Groundwater (Source): Caustic Activated SP In Situ Mixing
- Vadose Soil (Source): Excavation/Offsite Disposal

Site #3 – Optimized Design



Site #3 – Project Photographs




Conclusions

- High Resolution tools, when applicable, are critical to developing accurate and dynamic Conceptual Site Models and effective remedial designs
- The tools allow you to understand how the geology/hydrogeology impacts contaminant distribution and the potential for rebound/back diffusion to set realistic expectations for remediation
- ISCO application iterations are more precise and targeted
- Lower life cycle cost savings over traditional sampling and design methods

Questions?

Thank you!

mmazzarese@vironex.com