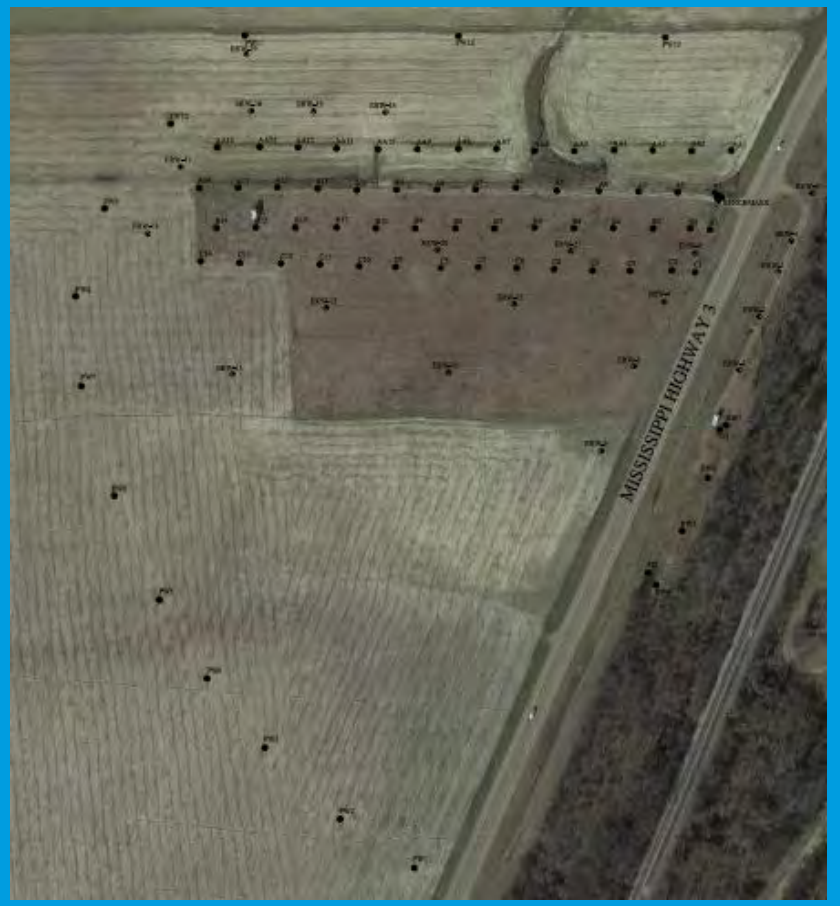
TWO CASES FOR MOBILE DUAL PHASE EXTRACTION TECHNOLOGY

Bruce Tease, PhD
Ramboll Environ



ERAC CONFERENCE
MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY
SEPTEMBER 23 AND 24, 2015

RAMBOLL ENVIRON

PROJECT TEAM

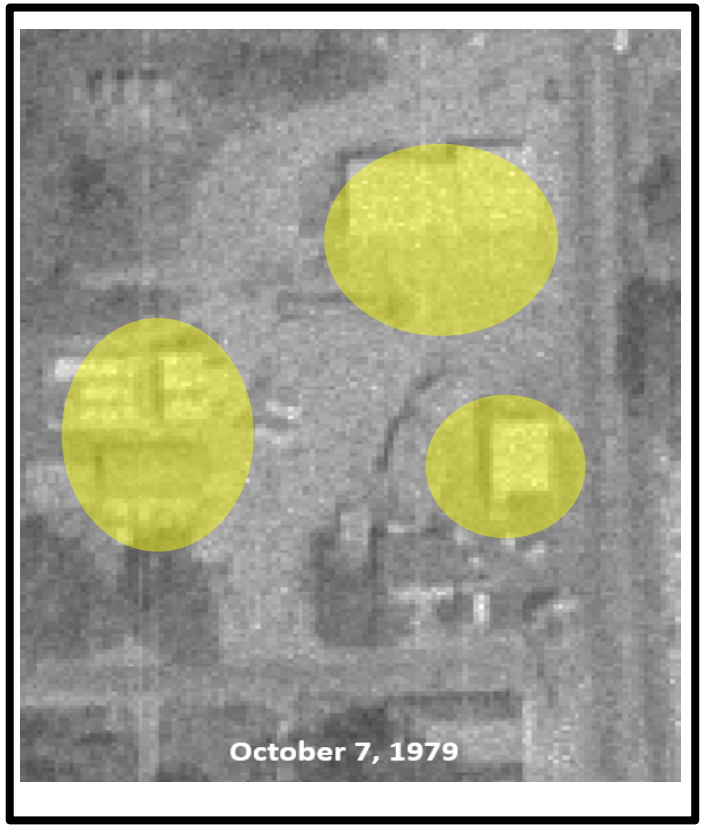
Baton Rouge Office Principal:	**Johnny Hebert**
Atlanta Office Engineers:	**Keith Cole and Juliet Rose**
Monroe Office Field Staff:	**Sarah Rogers and Lucy Cross**
MS RPG:	**Shiar Rahaim & Co, Summit**
Project Manager / Data Analysis Amherst, MA	**Bruce Tease and Hilary Adam**
DPE and Air Sparge Services:	**Fruits & Associates, Atlanta**
Orin Technologies:	**Verona, WI**
Specialty Laboratory Sevices	**Alpha Analytical Labs, Westborough, MA**

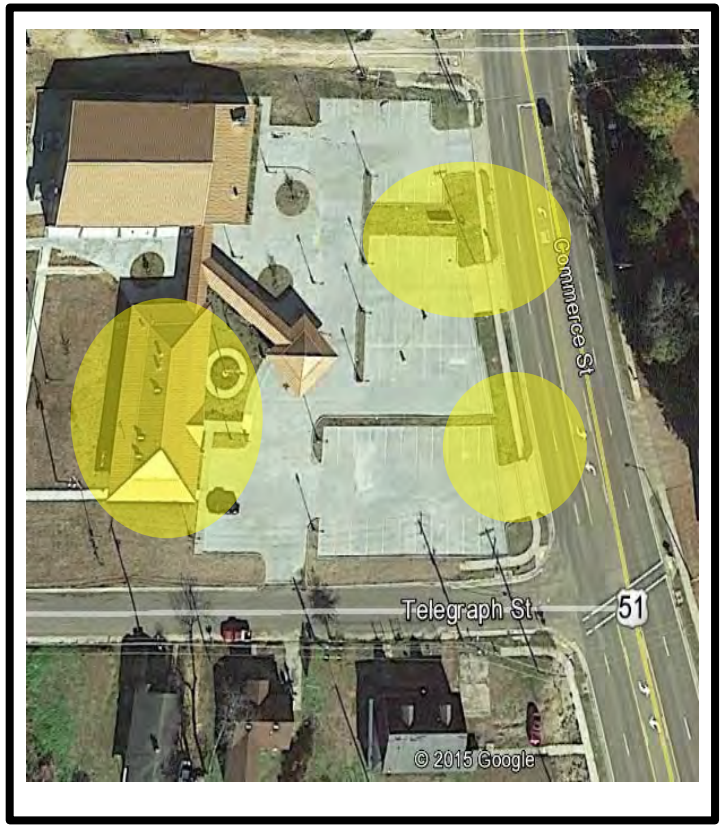
Key Requirements for Successful Remediation Projects

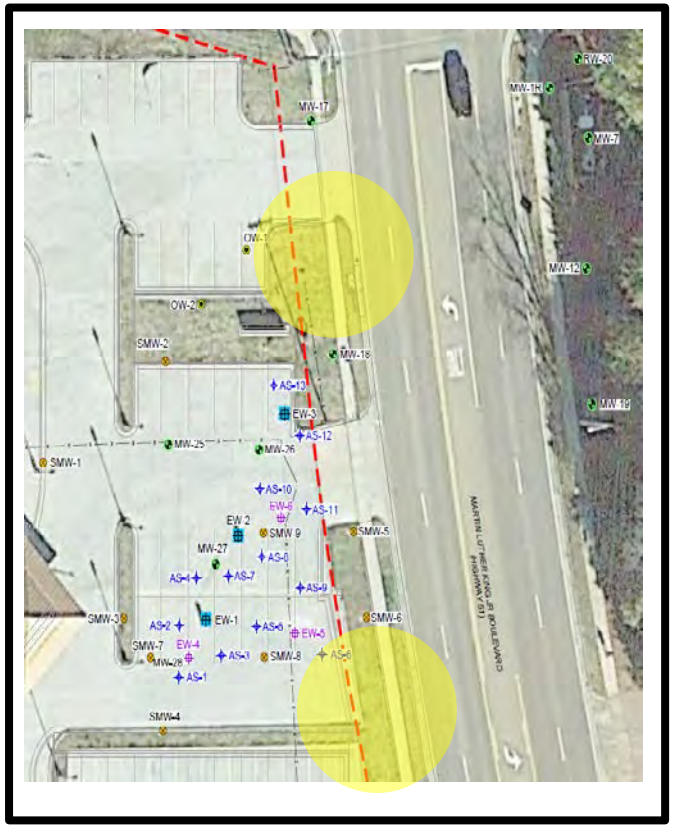
Knowledge of:

- COCs & Sources
- Site Characterization & Pilot Test Findings
    - Partitioning of COCs – Preferential Migration Pathways
    - Horizontal and Vertical Groundwater Flow Trends – seasonal and historical
    - Dissolved Phase Concentrations at Free Product Wells
    - Extent of Impacted Soil (by Default GW) Below Groundwater Table – SOURCE ZONE
- Plan B for Anticipated Equipment Downtime
- Mechanism to Demonstrate Effectiveness of Achieving Cleanup Goals

SMALL SITE - GASOLINE RELEASE INVOLVING THREE SOURCES



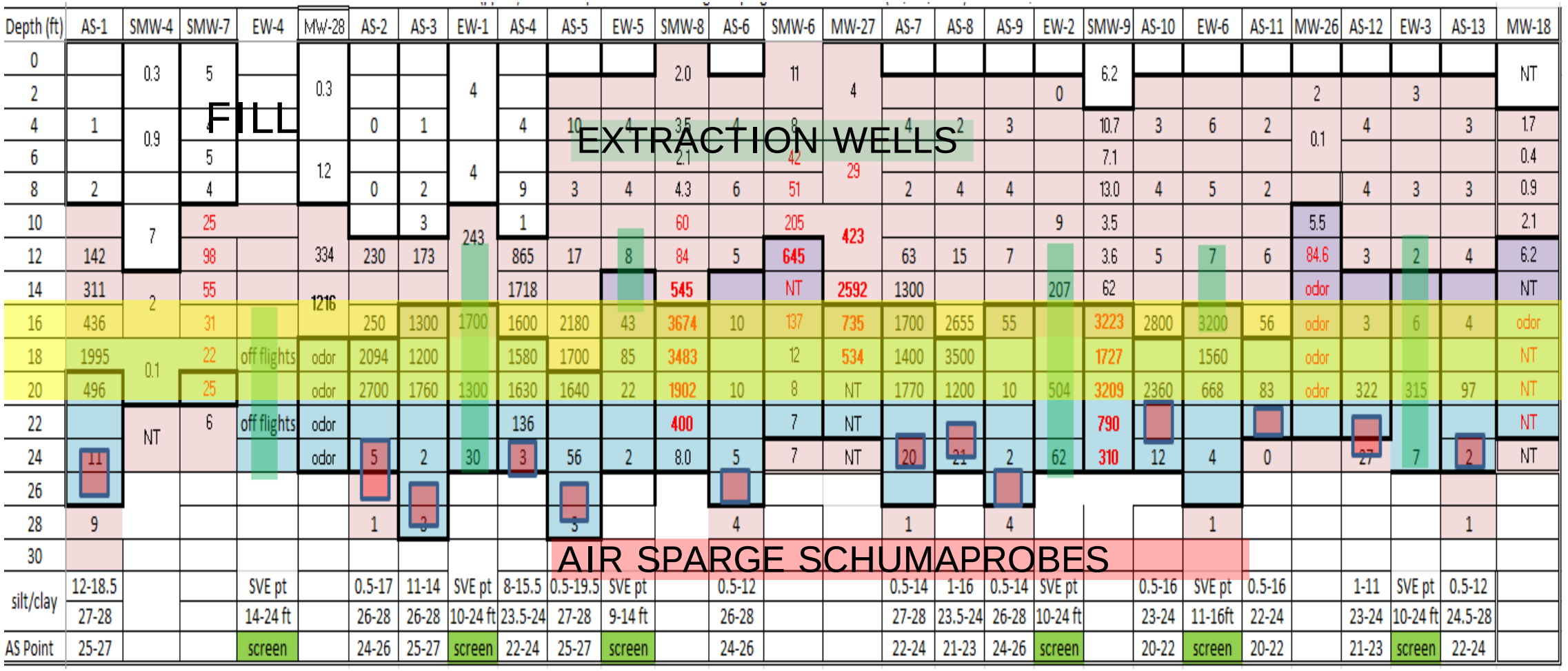




Take Home Messages for Small Site Case Study

- Comprehensive File Review = Basis for the Initial Conceptual Site Model
- Mobile DPE Equipment Proved to be an Invaluable Tool During Pilot Test
    - Identified Zones of Max/Min Air Flow Rates and TOV Levels (Spatially and Vertically)
    - Supported the Reality that ROI is Seldom a Circle - Area of Influence was a Channel
    - Identified High Groundwater Yield with Limited Cone of Influence
    - Greatest Area of Impact Found in a 10-foot sand zone 14-24 feet Below/Above Silt/Clay
    - Recovery of Vapor Phase PHCs >>> Groundwater Phase PHCs (>200:1)
- DPE Enhanced with Air Sparging was the Remedial Approach of Choice – 10x More TOVs with AS
- Mobile DPE Minimized Disturbance of Senior Center Activities
- Off Site Disposal of Recovered Groundwater was Preferred due to Absence of Sanitary Sewer
- Free Product and Dissolved Phase BTEX UST Program Targets Achieved Within 6 Months

Vertical Profile of PHCs (TOVs in ppmv) in Soil Monitoring, Extraction, and Air Sparge Points

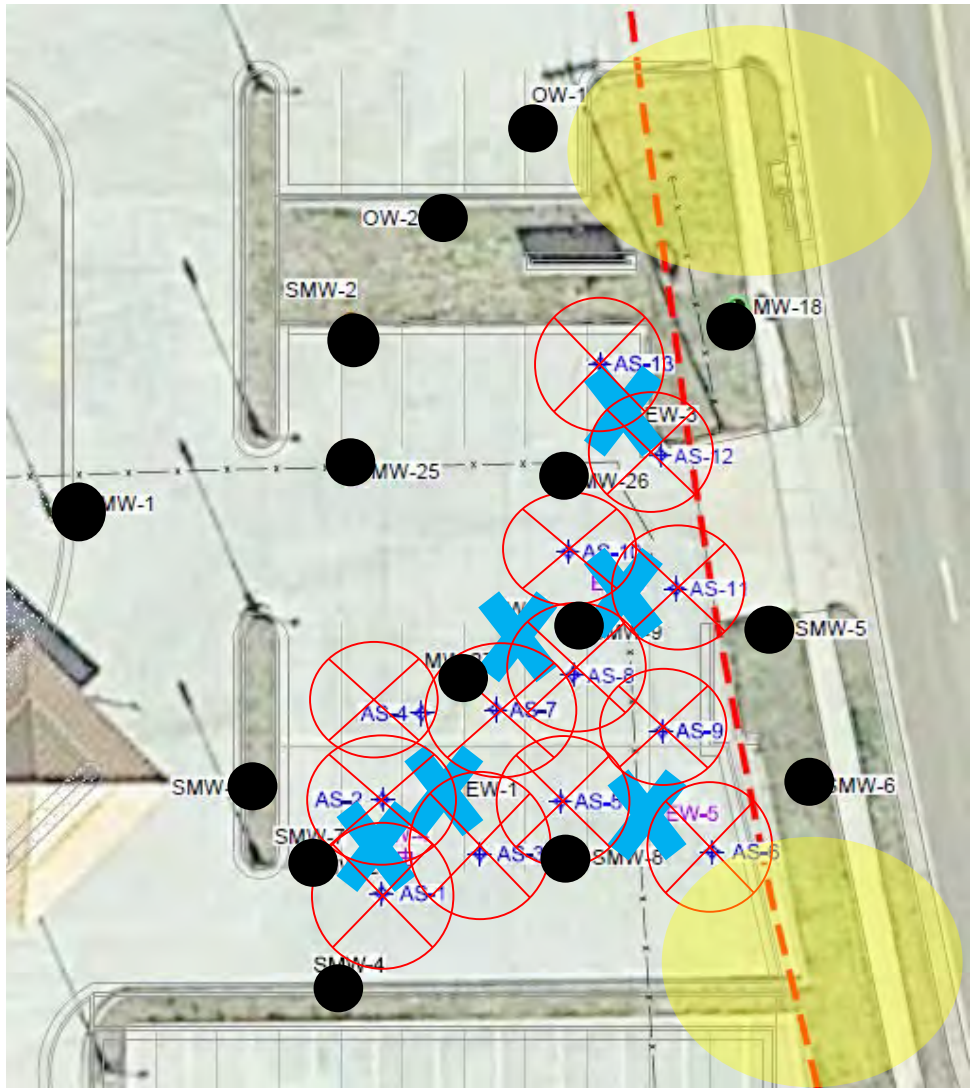


Depth (ft)	AS-1	SMW-4	SMW-7	EW-4	MW-28	AS-2	AS-3	EW-1	AS-4	AS-5	EW-5	SMW-8	AS-6	SMW-6	MW-27	AS-7	AS-8	AS-9	EW-2	SMW-9	AS-10	EW-6	AS-11	MW-26	AS-12	EW-3	AS-13	MW-18
0		0.3	5		0.3			4				2.0		11	4					6.2							NT
2																			0					2		3		
4	1	0.9				0	1		4	10	4	3.5	4	8		4	2	3		10.7	3	6	2	0.1	4		3	1.7
6			5		1.2			4				2.1		42	29					7.1								0.4
8	2		4			0	2		9	3	4	4.3	6	51		2	4	4		13.0	4	5	2		4	3	3	0.9
10		7	25				3	243	1			60		205	423				9	3.5				5.5				2.1
12	142		98		334	230	173		865	17	8	84	5	645		63	15	7		3.6	5	7	6	84.6	3	2	4	6.2
14	311	2	55		1216				1718			545		NT	2592	1300			207	62				odor				NT
16	436		31			250	1300	1700	1600	2180	43	3674	10	137	735	1700	2655	55		3223	2800	3200	56	odor	3	6	4	odor
18	1995	0.1	22	off flights	odor	2094	1200		1580	1700	85	3483		12	534	1400	3500			1727		1560		odor				NT
20	496		25		odor	2700	1760	1300	1630	1640	22	1902	10	8	NT	1770	1200	10	504	3209	2360	668	83	odor	322	315	97	NT
22		NT	6	off flights	odor				136			400		7	NT					790								NT
24	11				odor	5	2	30	3	56	2	8.0	5	7	NT	20	21	2	62	310	12	4	0		27	7	2	NT
26																												
28	9					1	3			3			4			1		4				1					1	
30																												
silt/clay	12-18.5			SVE pt		0.5-17	11-14	SVE pt	8-15.5	0.5-19.5	SVE pt		0.5-12			0.5-14	1-16	0.5-14	SVE pt		0.5-16	SVE pt	0.5-16		1-11	SVE pt	0.5-12	
	27-28			14-24 ft		26-28	26-28	10-24 ft	23.5-24	27-28	9-14 ft		26-28			27-28	23.5-24	26-28	10-24 ft		23-24	11-16ft	22-24		23-24	10-24 ft	24.5-28	
AS Point	25-27			screen		24-26	25-27	screen	22-24	25-27	screen		24-26			22-24	21-23	24-26	screen		20-22	screen	20-22		21-23	screen	22-24	

Sily/Clay

Fine Sand/Saturated Soils

Site Plan Showing DPE Wells, Monitoring Wells, and Air Sparge Schumaprobe Points



Monitoring Well

Sparge Well ROI

DPE Well

30 Feet

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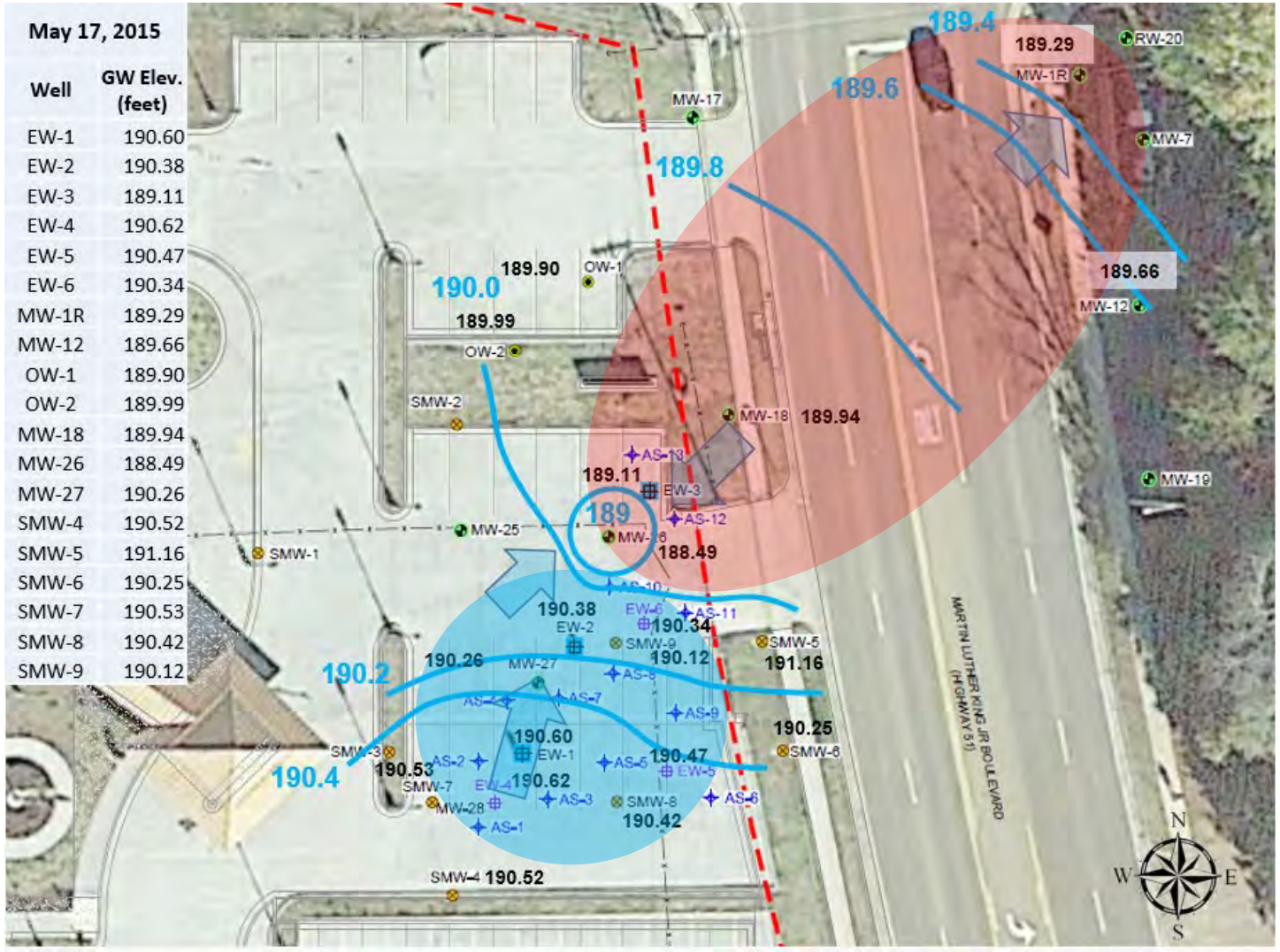
Groundwater Flow Pattern (May 2015)

May 17, 2015	
Well	GW Elev. (feet)
EW-1	190.60
EW-2	190.38
EW-3	189.11
EW-4	190.62
EW-5	190.47
EW-6	190.34
MW-1R	189.29
MW-12	189.66
OW-1	189.90
OW-2	189.99
MW-18	189.94
MW-26	188.49
MW-27	190.26
SMW-4	190.52
SMW-5	191.16
SMW-6	190.25
SMW-7	190.53
SMW-8	190.42
SMW-9	190.12



Relatively Flat GW Table (<1%)

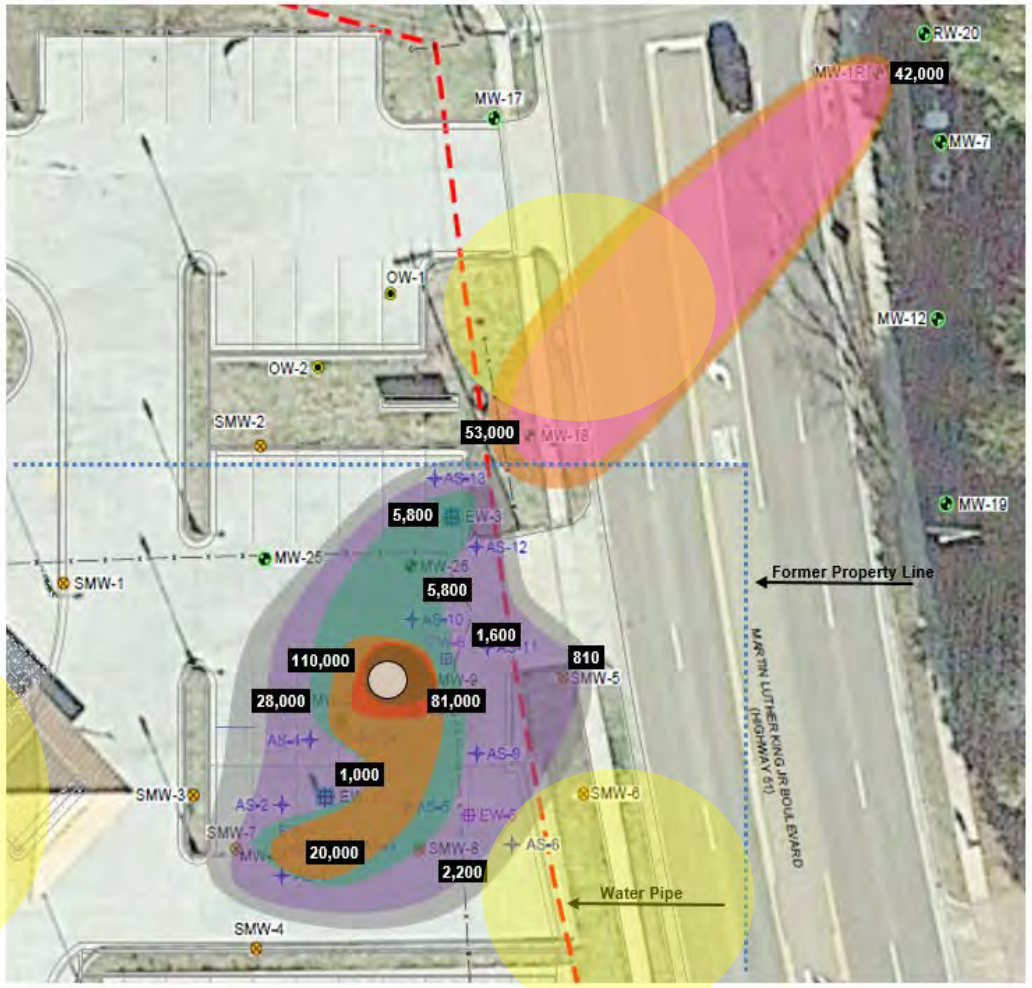
Upward Vertical Gradient

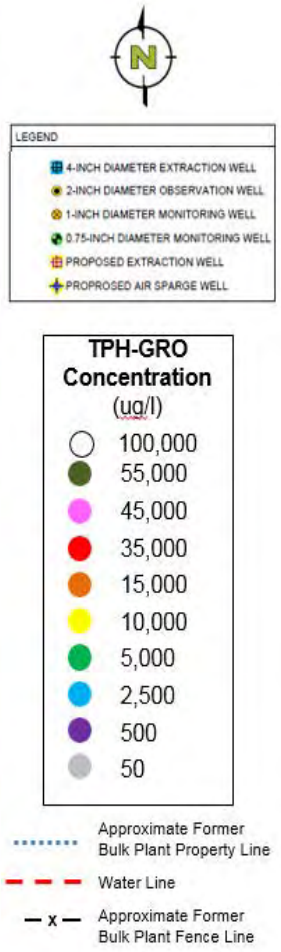
Downward Vertical Gradient

GW Depression

Groundwater Contamination Pre-Remediation (ug/l)

TPH-GRO (ug/l) in Groundwater (December 2013)





Well	TPH-GRO	BTEX	RATIO
EW-2	110,000	46,800	2.4
SMW-9	81,000	28,280	2.9
MW-28	20,000	16,470	1.2
MW-27	28,000	12,700	2.2
EW-3	5,800	2,980	1.9
MW-26	5,800	4,110	1.4
EW-1	1, 000	415	2.4
	Average TPH:BTEX = 2.1		
MW-18	53,000	21,790	2.4
MW-1R	42,000	ND	NA

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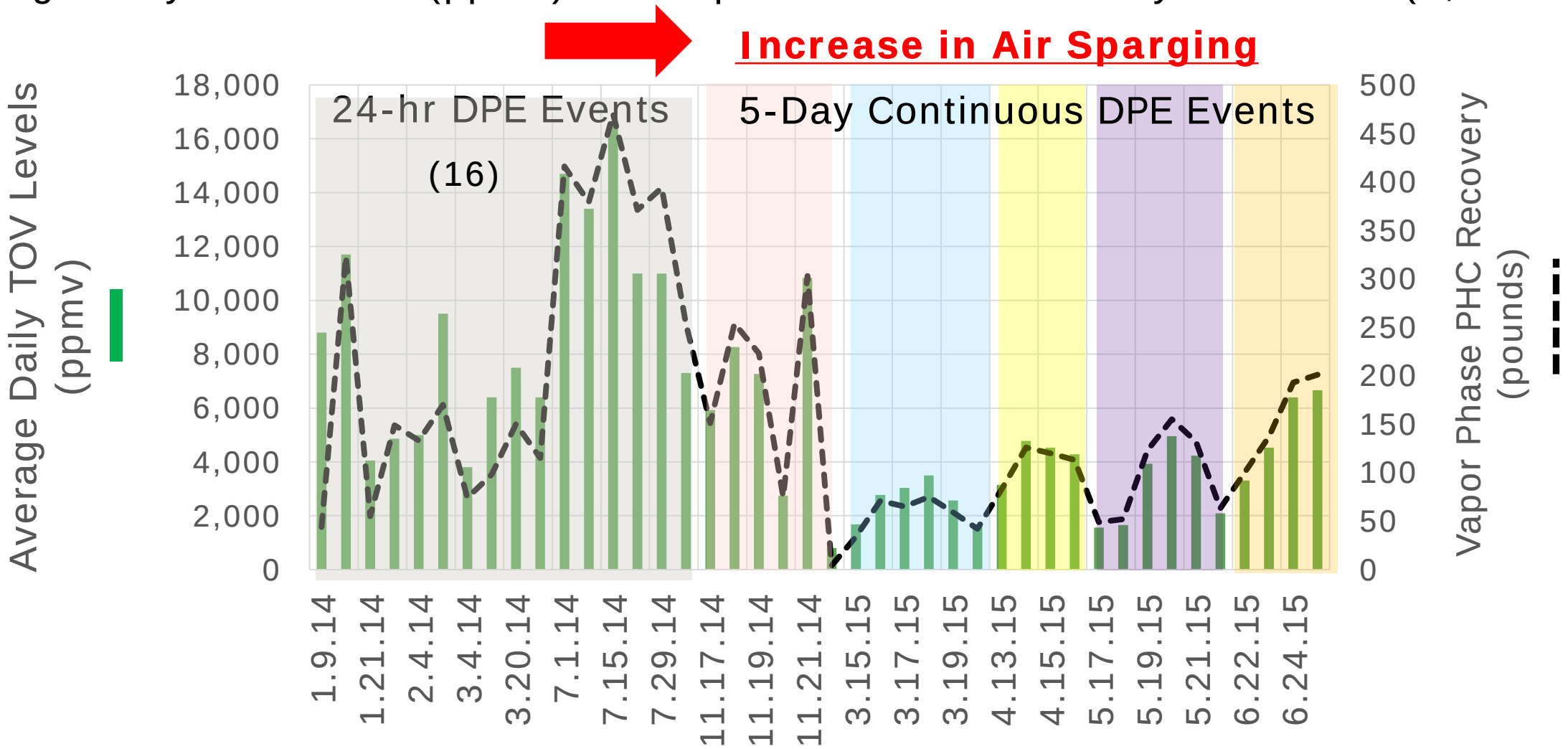
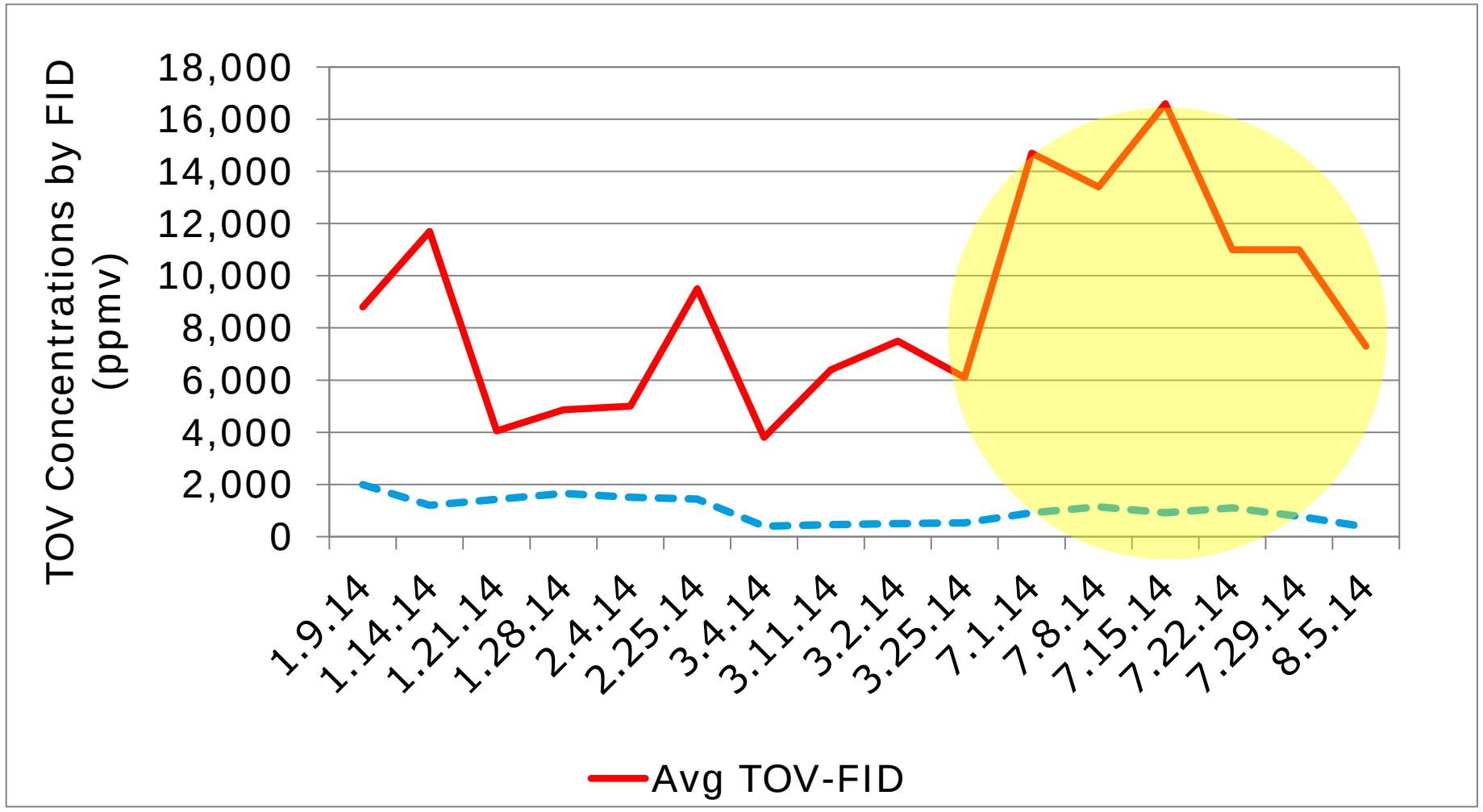
Average Daily TOV Levels (ppmv) and Vapor Phase Petroleum Hydrocarbons (6,598 lbs)



Trends in FID and PID TOV Levels (ppmv) During DPE Events



Air Sparging More Effective on Recovery of Aliphatic PHCs Than Aromatic PHCs

Preferred Vapor Phase PHC Mass Recovery Calculation Method

Method	TOVs (ppmv)	Pounds/hr
FID – CF (ppmv/0.6)	4,220	**0.86**
FID – Gas Law Equation	4,220	2.32
PID – CF (ppmv/0.6)	300	0.06
PID – Gas Law Equation	300	0.16
TO-15 Method	3,529 mg/m3	**0.43**
APH Method (MADEP)	13,161 mg/m3	**1.6**

Based on an air flow rate of 33 acfm at EW-2 over 1-hour period

Gas Law Equation where,

1 ppmv TOV = Av. Mwt of gasoline (g/mole)/Gas Law Constant of 24.05 mg/m^3

Vapor Phase VOC Concentrations from Virgin Petroleum Products Analyzed by the MADEP APH Method and EPA Method TO-15

	MINERAL SPIRITS	#2 FUEL OIL	GASOLINE	KEROSENE
TO-15 SUM OF HITS, ug/m^3	1,488,000	974,900	638,000	261,900
APH SUM OF HITS, ug/m^3	21,983,000	6,469,000	4,300,000	4,082,000
APH/TO-15 Ratio	14.8	6.6	6.7	15.6

Presentation by Andy Rezendes, Alpha Analytical, Inc. (August 15, 2011)

Take Home Message: Vapor Phase VOC Concentrations Will Be Site Specific

Recommend Testing Air Samples Periodically via Both TO-15 and APH Methods

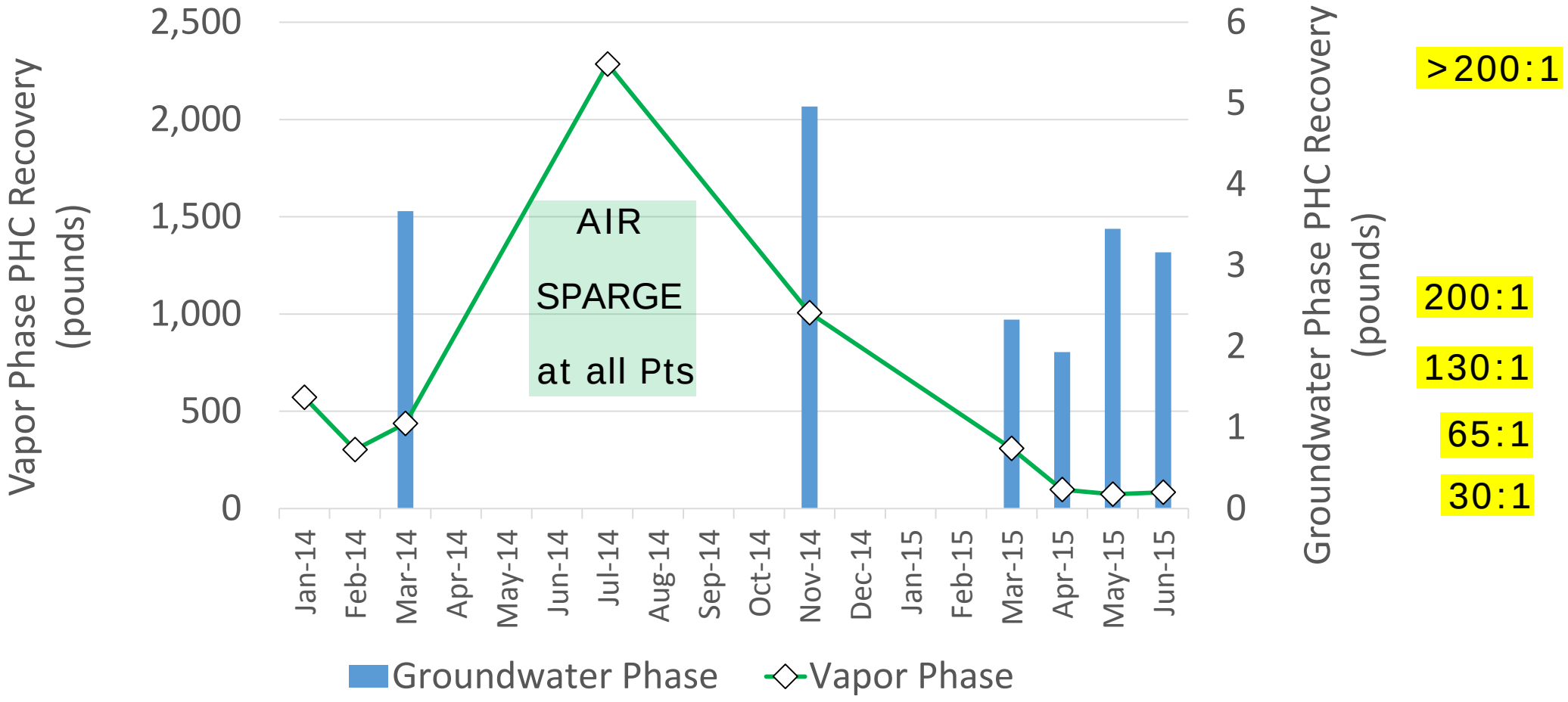
Mass Recovery of Vapor Phase PHCs (May 2015)

Date	Average TOV by FID (ppmv)	Air Flow Rate (cfm)	Total Time (hrs)	Total PHC (mg/m3)	Total PHCs (pounds)
5.17.15	1,559	159	24	2,598	37
5.18.15	1,653	157	24	2,755	39
5.19.15	3,932	147	24	6,553	87
5.20.15	4,956	139	24	8,260	104
5.21.15	4,230	151	24	7,050	96
5-Day Event Totals	3,266	151	120	27,216	**363**

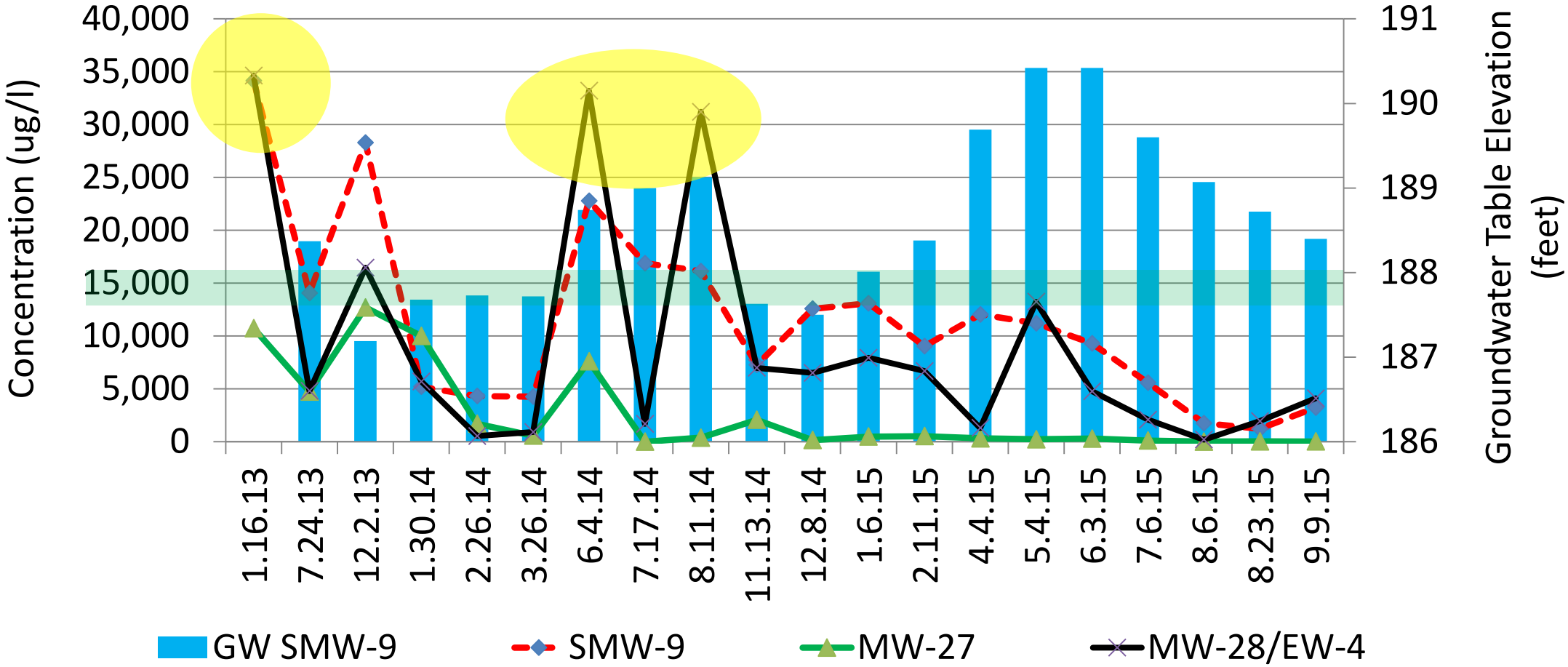
Mass Recovery of Groundwater Phase PHCs (May 2015)

Parameter	Concentration (ug/l) Sample Date (May 2015)						Average	
	17-May	18-May	19-May	20-May	21-May	22-May	May-15	Apr-15
Benzene	280	450	390	500	480	510	435	264
Toluene	1,000	2,100	1,900	2,400	1,900	2,700	2,000	1,303
Ethylbenzene	100	150	140	170	28	180	128	186
Total Xylenes	890	1,400	1,500	1,400	1,600	1,600	1,398	2,156
Total BTEX	2,270	4,100	3,930	4,470	4,008	4,990	3,961	2,609
MTBE	540	610	620	450	480	410	518	371
1,2,4 TMB	190	108	240	180	190	190	183	166
1,3,5 TMB	68	<100	<100	<100	<100	<120	68	58
Naphthalene	55	<20	<20	<20	<20	<25	55	44
n-Propylbenzene	12	<20	<20	<20	<20	<25	12	73
TPH-GRO	5,300	7,200	8,500	7,000	6,400	6,800	**6,867**	**3,907**
GW Volume (gal)	2,100	11,325	11,725	12,950	9,375	12,625	**60,100**	**58,970**
Mass Recovery of PHCs (pounds)	0.09	0.68	0.83	0.76	0.50	0.72	**3.50**	**1.90**

Comparison of TOV_{FID} Derived Vapor and TPH-GRO Derived Groundwater Phase PHC Recovery Estimates

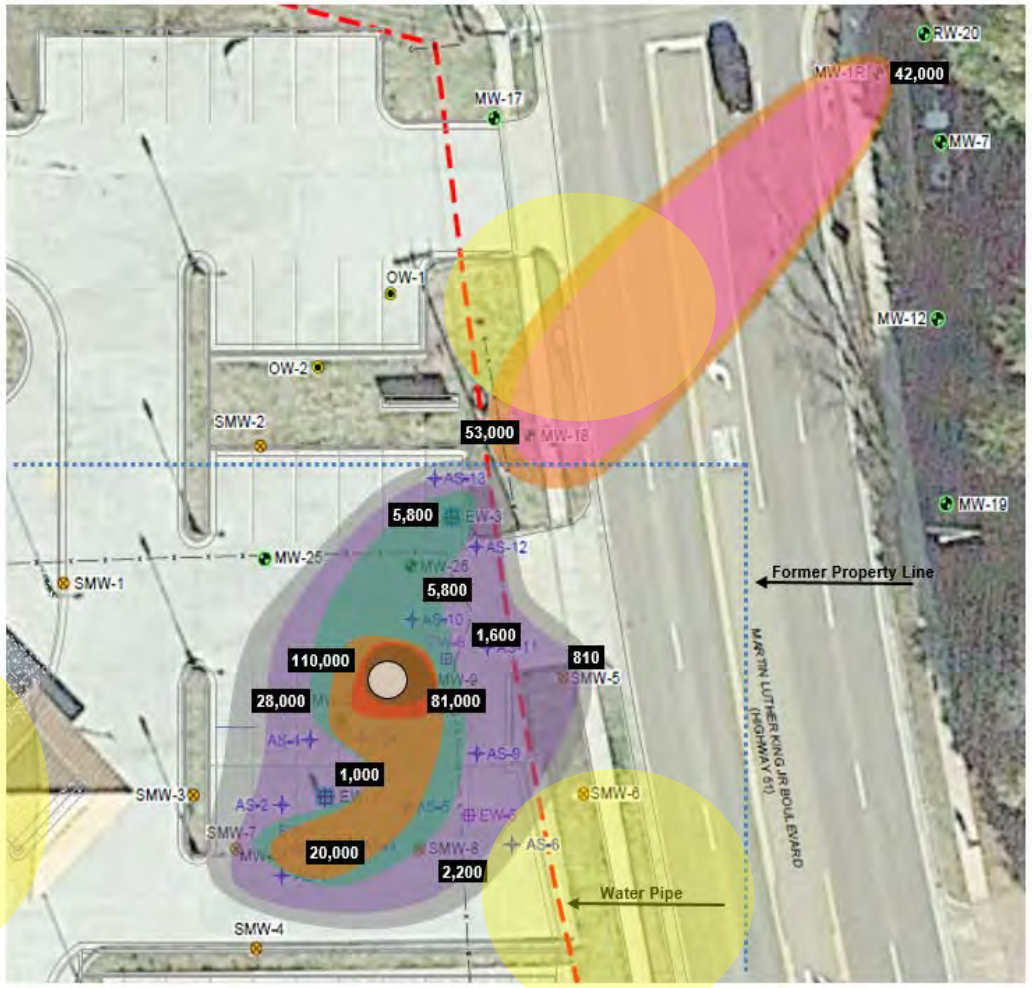


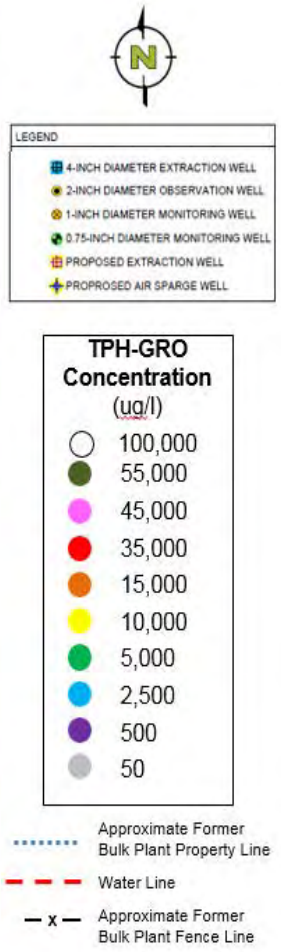
BTEX Concentration (ug/l) and Groundwater Table Elevation Trends at Free Product Wells



Groundwater Contamination Pre-Remediation (ug/l)

TPH-GRO (ug/l) in Groundwater (December 2013)





Well	TPH-GRO	BTEX	RATIO
EW-2	110,000	46,800	2.4
SMW-9	81,000	28,280	2.9
MW-28	20,000	16,470	1.2
MW-27	28,000	12,700	2.2
EW-3	5,800	2,980	1.9
MW-26	5,800	4,110	1.4
EW-1	1, 000	415	2.4
	Average TPH:BTEX = 2.1		
MW-18	53,000	21,790	2.4
MW-1R	42,000	ND	NA

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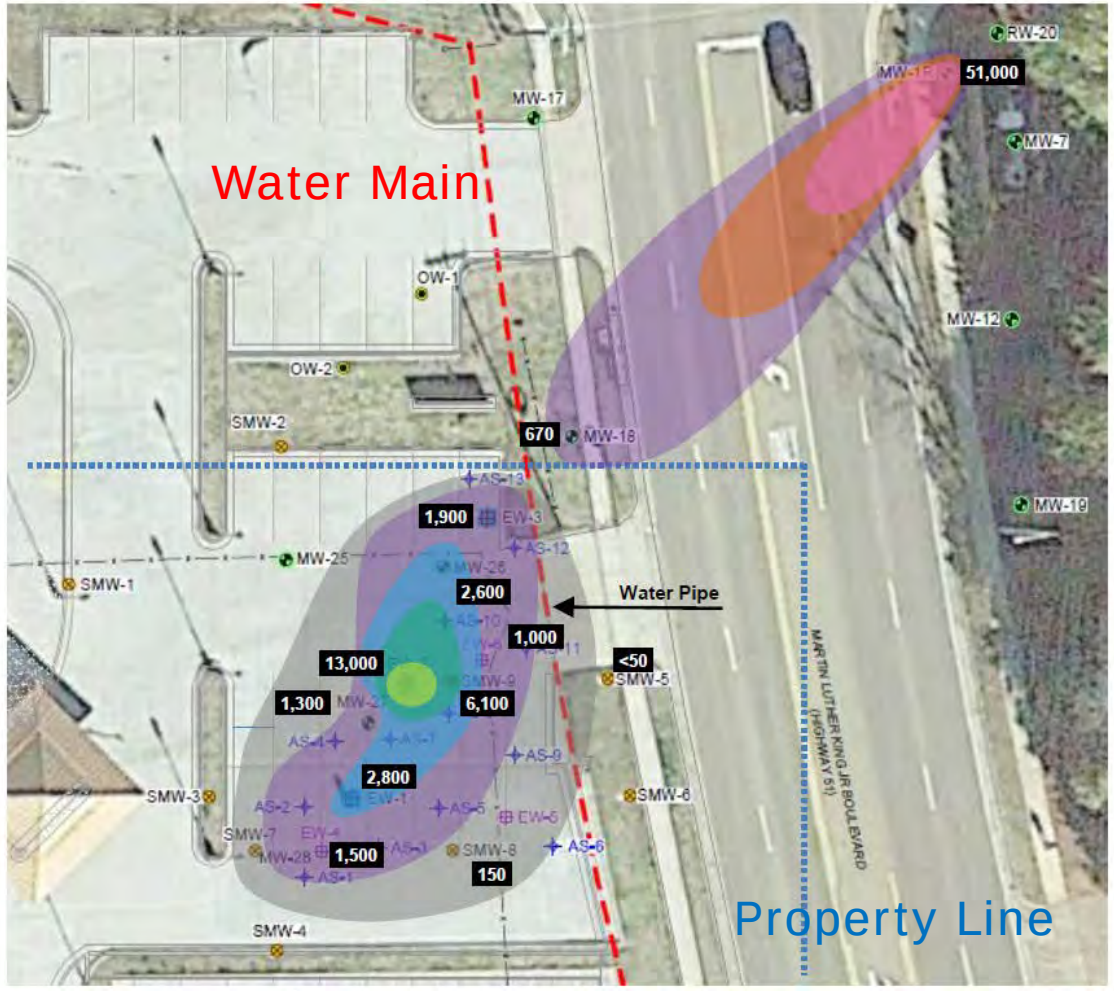
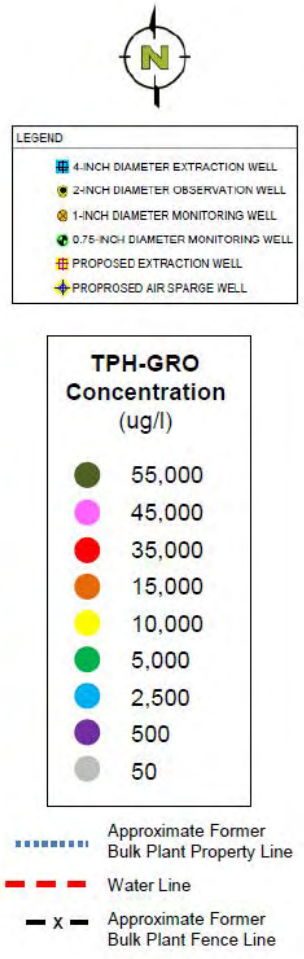
Groundwater Contamination after 6 x 24-hr DPE Events (ug/l)

TPH-GRO (ug/l) in Groundwater (March 2014)





Well	TPH-GRO	BTEX	RATIO
EW-2	13,000	6,320	2.0
SMW-9	6,100	4,260	1.4
MW28/EW4	1,500	916	1.6
MW-27	1,300	569	2.3
EW-3	1,900	1,015	1.9
MW-26	2,600	1,940	1.3
EW-1	1,500	1,218	1.2

Average TPH:BTEX = 1.4

MW-18	670	238	2.8
MW-1R	51,000	ND	NA

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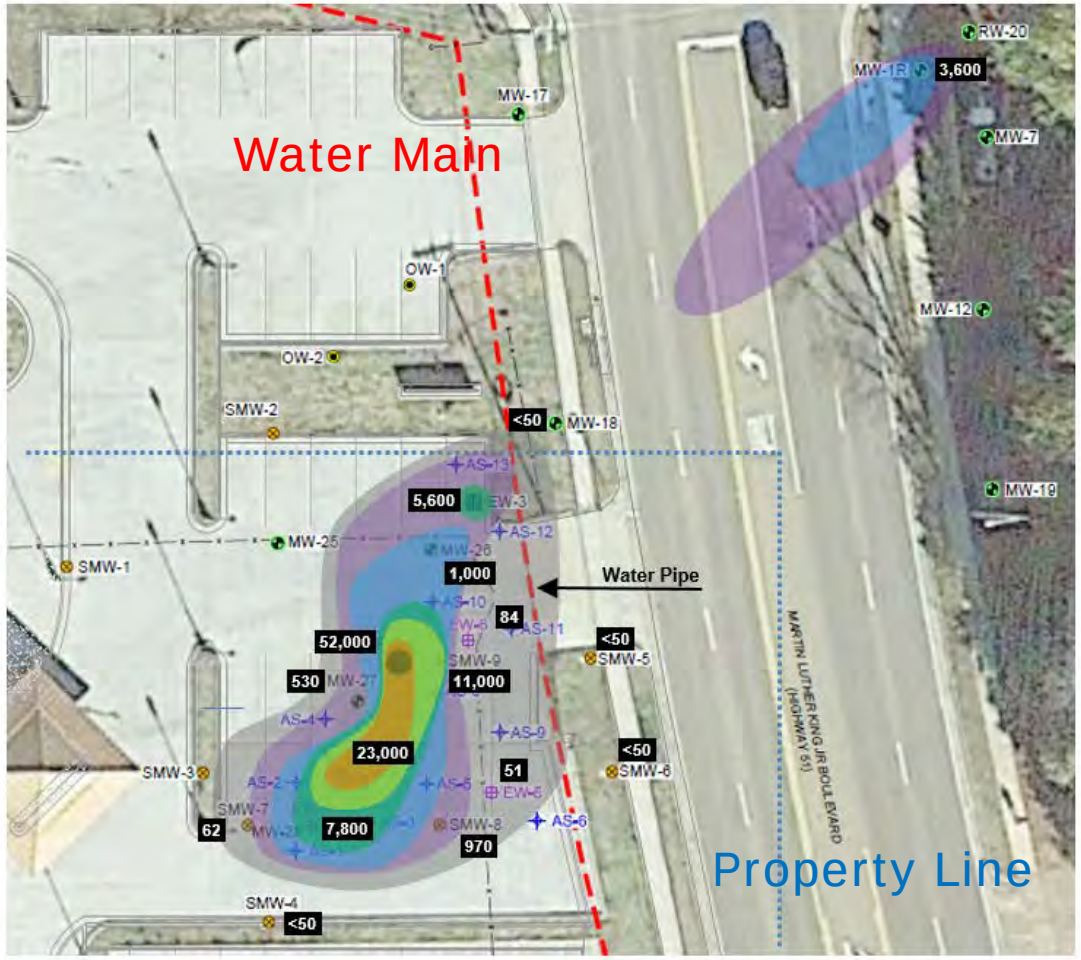
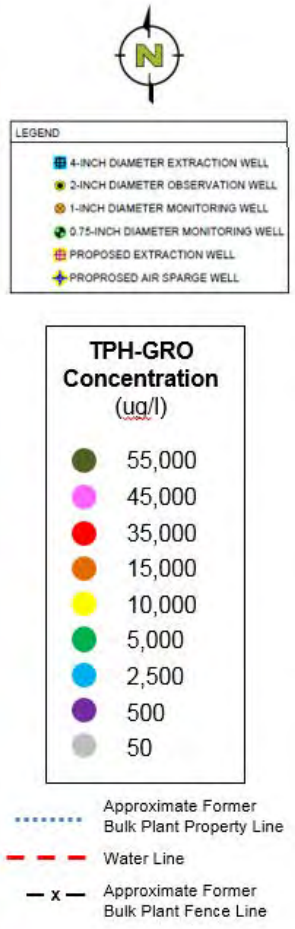
Groundwater Contamination after 16 x 24-hr and 5 x 5-Day DPE/AS Events

TPH-GRO (ug/l) in Groundwater (June 2015)





Well	TPH-GRO	BTEX	RATIO
EW-2	52,000	37,700	1.4
SMW-9	11,000	9,300	1.2
MW28/EW4	7,800	4,770	1.6
MW-27	530	294	1.8
EW-3	5,600	4,550	1.2
MW-26	1,000	1,002	1.0
EW-1	23,000	18,530	1.2
	Average TPH:BTEX = 1.3		
MW-18	<50	<50	NA
MW-1R	3,600	771	4.7

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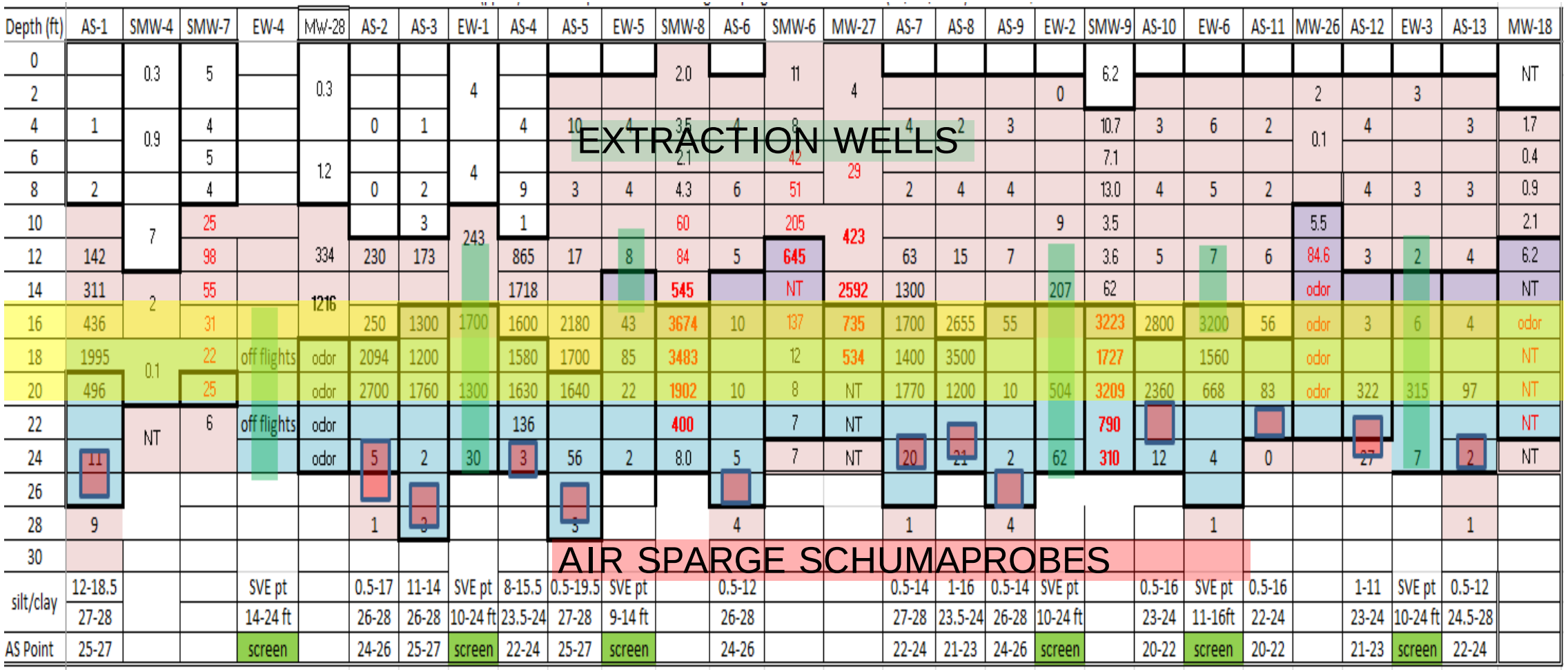
Rebound in Dissolved Phase Concentrations at Extraction Wells Attributed to High Groundwater Table Elevation

- Air Sparge Vapors are Recovered by Extraction Wells in Vadose Zone at Interface Between Sand and Silt/Clay Formations - Provided Sufficient Well Screen is Exposed within Sand Zone

- During High Groundwater Table Elevations, the Amount of Exposed Well Screen Decreases and Air Sparge Vapors Redistribute into Groundwater

- Ratio of TPH-GRO:BTEX Concentrations Decreases with Successive DPE Events Suggesting Aliphatic PHCs are More Readily Recovered than BTEX Compounds

Vertical Profile of PHCs (TOVs in ppmv) in Soil, Soil Conditions and Extraction Wells, Air Sparge Points



Depth (ft)	AS-1	SMW-4	SMW-7	EW-4	MW-28	AS-2	AS-3	EW-1	AS-4	AS-5	EW-5	SMW-8	AS-6	SMW-6	MW-27	AS-7	AS-8	AS-9	EW-2	SMW-9	AS-10	EW-6	AS-11	MW-26	AS-12	EW-3	AS-13	MW-18
0		0.3	5		0.3			4				2.0		11	4					6.2							NT
2																			0					2		3		
4	1	0.9	4			0	1		4	10	4	3.5	4	8		4	2	3		10.7	3	6	2	0.1	4		3	1.7
6			5		1.2			4				2.1		42	29					7.1								0.4
8	2		4			0	2		9	3	4	4.3	6	51		2	4	4		13.0	4	5	2		4	3	3	0.9
10		7	25				3	243	1			60		205	423				9	3.5				5.5				2.1
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20	496		25		odor	2700	1760	1300	1630	1640	22	1902	10	8	NT	1770	1200	10	504	3209	2360	668	83	odor	322	315	97	NT
22		NT	6	off flights	odor				136			400		7	NT					790								NT
24	11				odor	5	2	30	3	56	2	8.0	5	7	NT	20	21	2	62	310	12	4	0		27	7	2	NT
26																												
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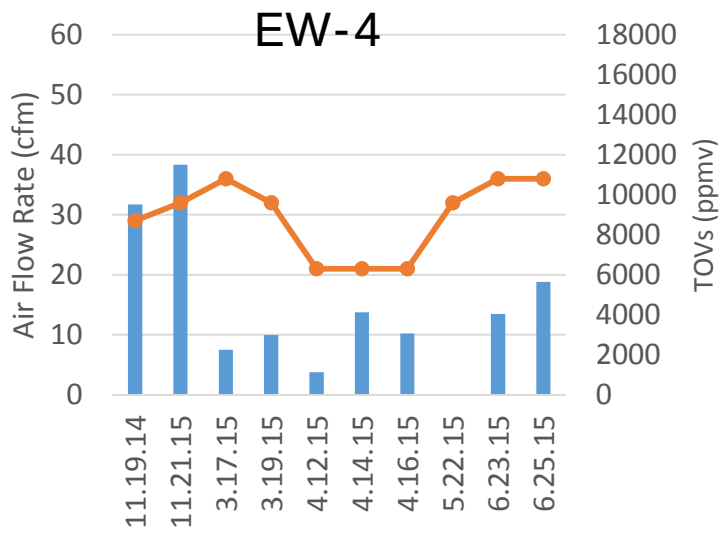
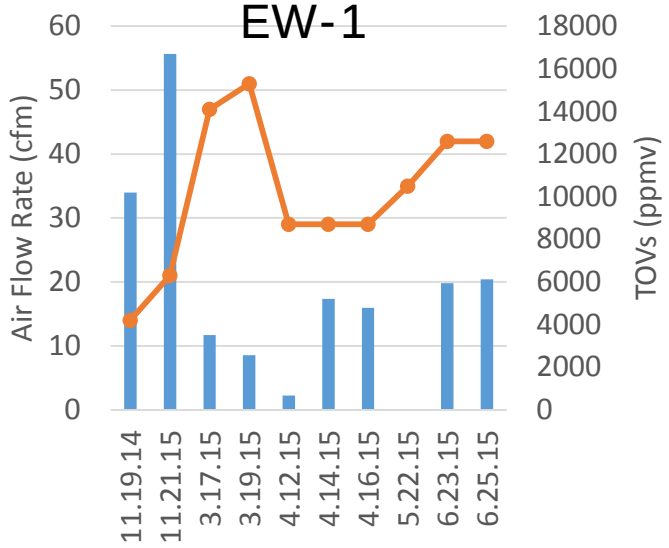
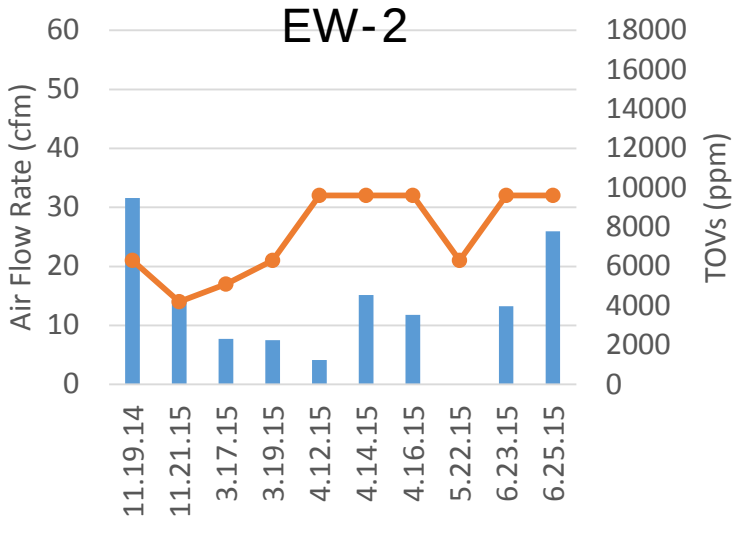
silt/clay	12-18.5			SVE pt		0.5-17	11-14	SVE pt	8-15.5	0.5-19.5	SVE pt		0.5-12			0.5-14	1-16	0.5-14	SVE pt		0.5-16	SVE pt	0.5-16		1-11	SVE pt	0.5-12	
	27-28			14-24 ft		26-28	26-28	10-24 ft	23.5-24	27-28	9-14 ft		26-28			27-28	23.5-24	26-28	10-24 ft		23-24	11-16ft	22-24		23-24	10-24 ft	24.5-28	
AS Point	25-27			screen		24-26	25-27	screen	22-24	25-27	screen		24-26			22-24	21-23	24-26	screen		20-22	screen	20-22		21-23	screen	22-24	

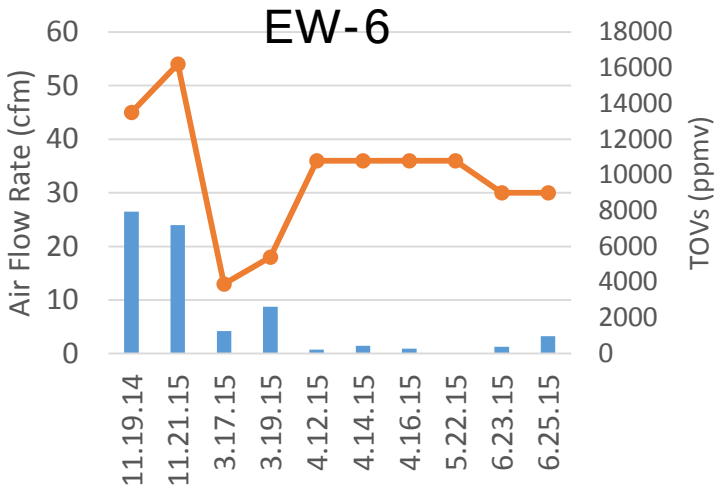
Sily/Clay Fine Sand Saturated Soils

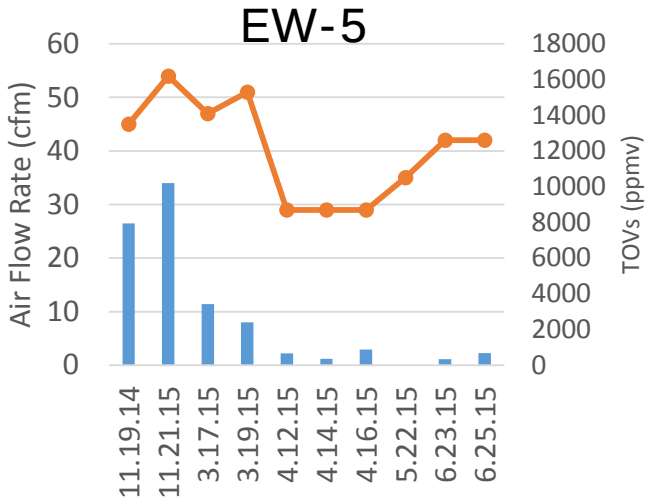
TOV (ppmv) and Air Flow Rate (acfm) Trends per Extraction Well

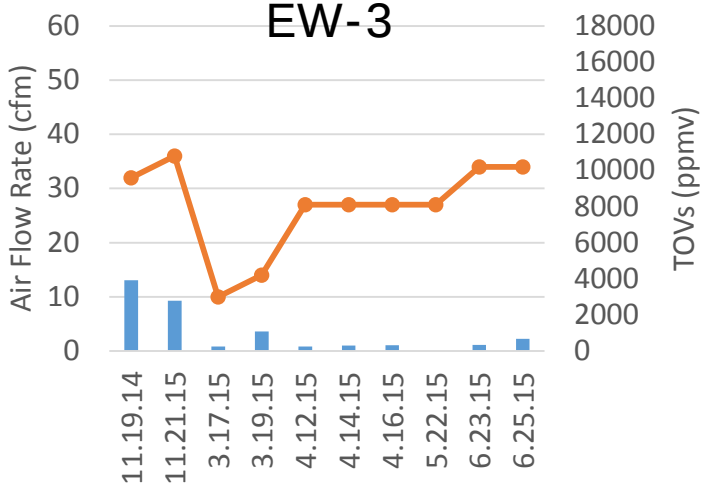












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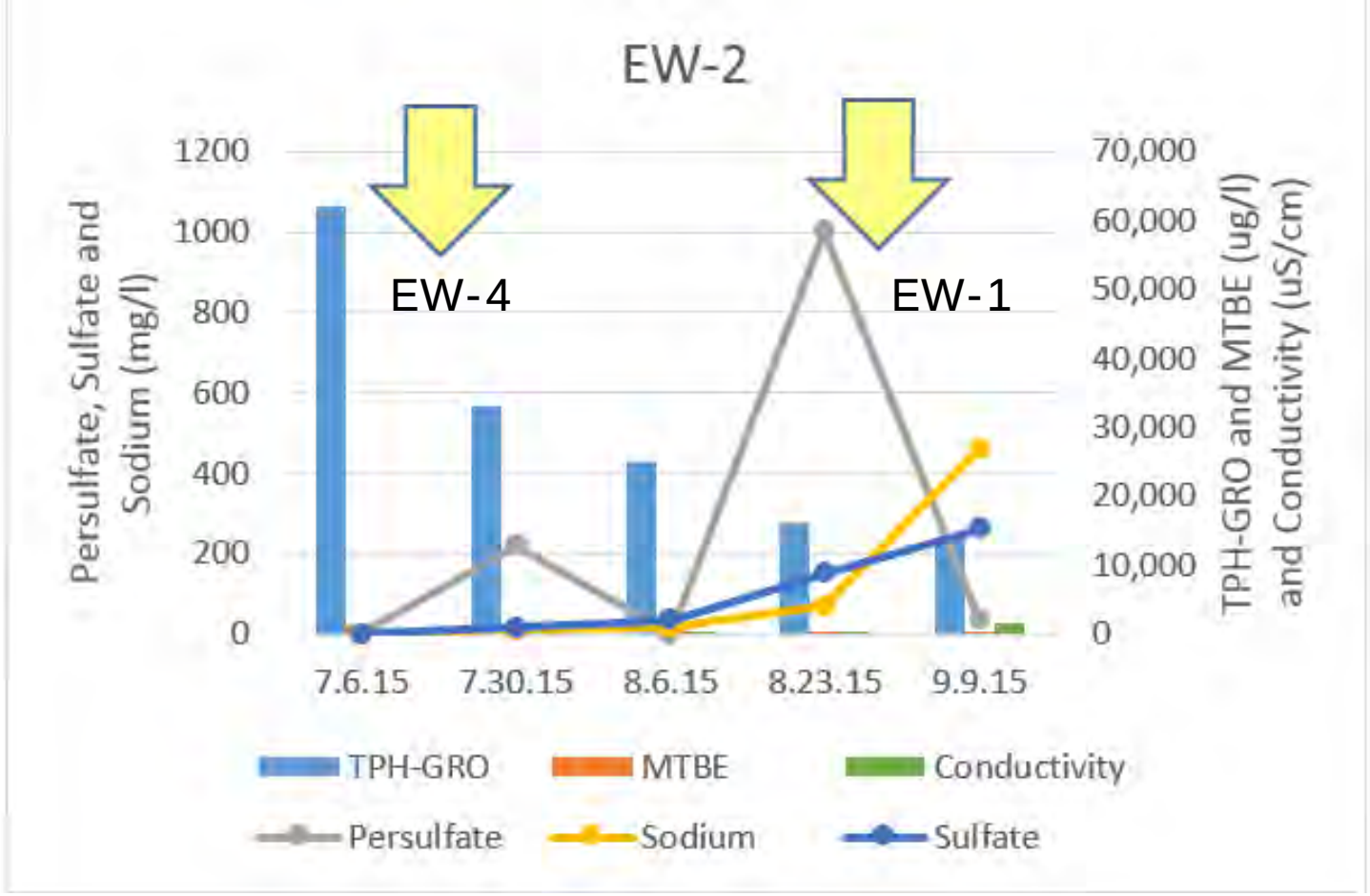
TOVs

Air Flow

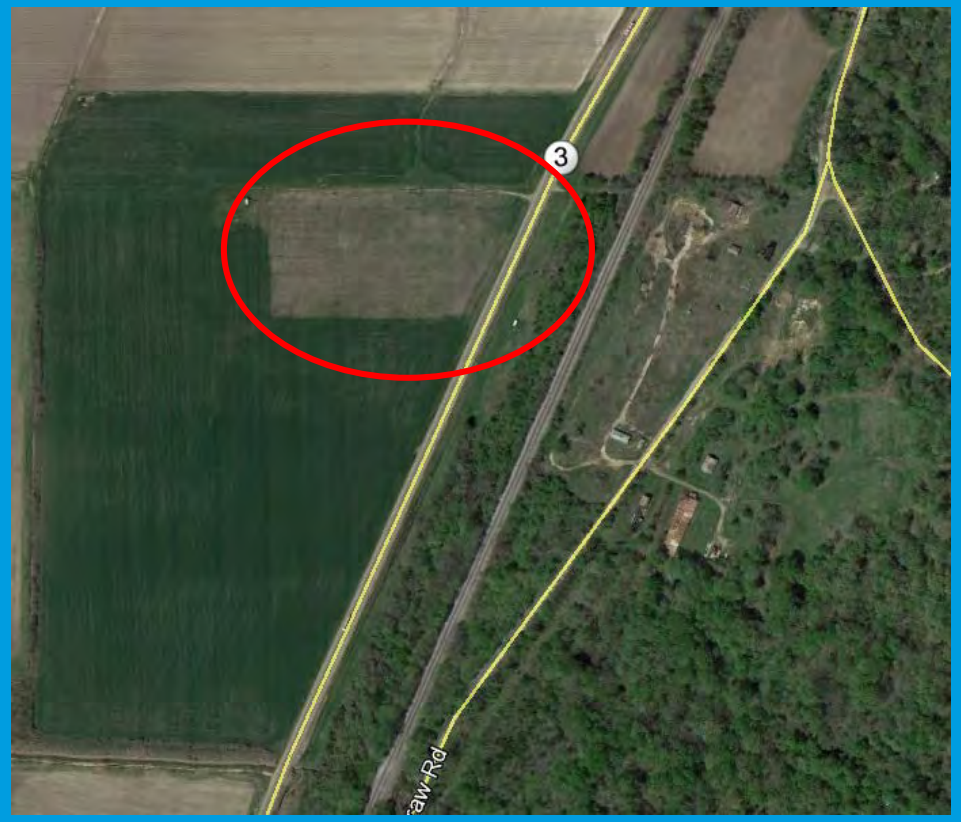
Preliminary Results of 2 ISCO Injections (ORIN) Employing Sodium Persulfate At Most Impacted EW-2 to Achieve/Sustain TRGs at Property Line



Task	Equipment	Consulting Labor	Analytical Services
WELL INSTALLATION			
4” dia Extraction Wells (6)	$25,000	$5,000	$2,240 (14 soil spls)
Air Sparge Points (13)	$11,000	$10,000	$4,480 (28 soil spls)
DPE and AIR SPARGING EVENT			
5-Day Pilot Test	$30,000	$17,000	$10,000 (air & groundwater samples)
24-Hour	$12,000	$1,250	$160/scrub tank sample/event $2,400 (13 wells/6 events)
5-Day	$60,000	$6,000	$800/5 scrub tank samples/event $2,400 (13 wells/event)
GROUNDWATER DISPOSAL			
Petroleum Contact Water $0.15/gal for 10,000 gal/day $1500/5500 gal tankers/day	$1,800 disp. $3,000 trans. Per 24hr event		
REPORTING			
CAP		$40,000	
Summary Report		$20,000	

Based on 6 x 24-Hr DPE/AS Events = $290,000 (12% wells; 35% DPE; 35% Labor; 8% lab 10 % GW Disposal

LARGE SITE (30 ACRES)– RELEASE OF STRAIGHT RUN GASOLINE AND CRUDE OIL FROM FORMER ASPHALT REFINERY



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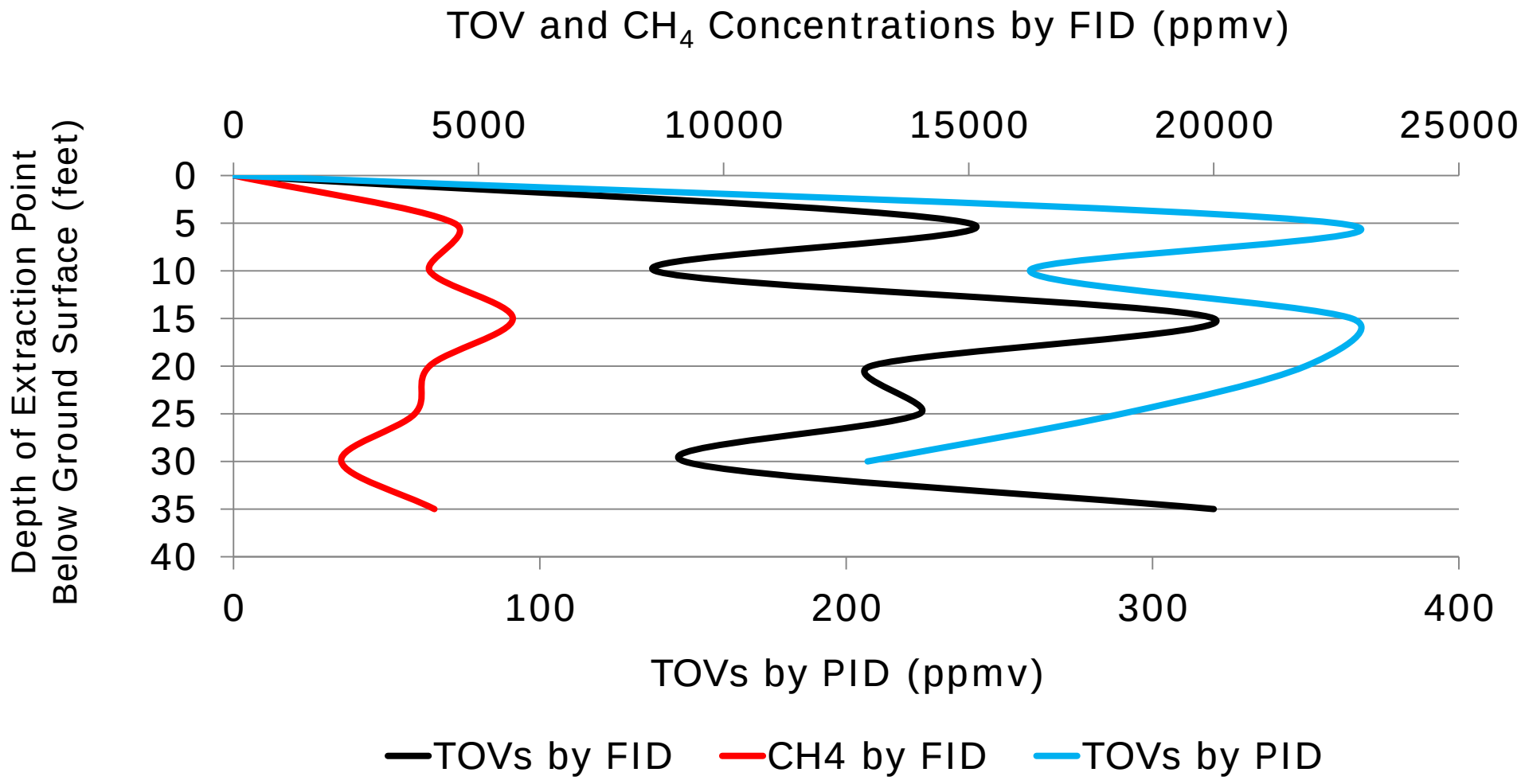
ERAC CONFERENCE
MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY
SEPTEMBER 23 AND 24, 2015

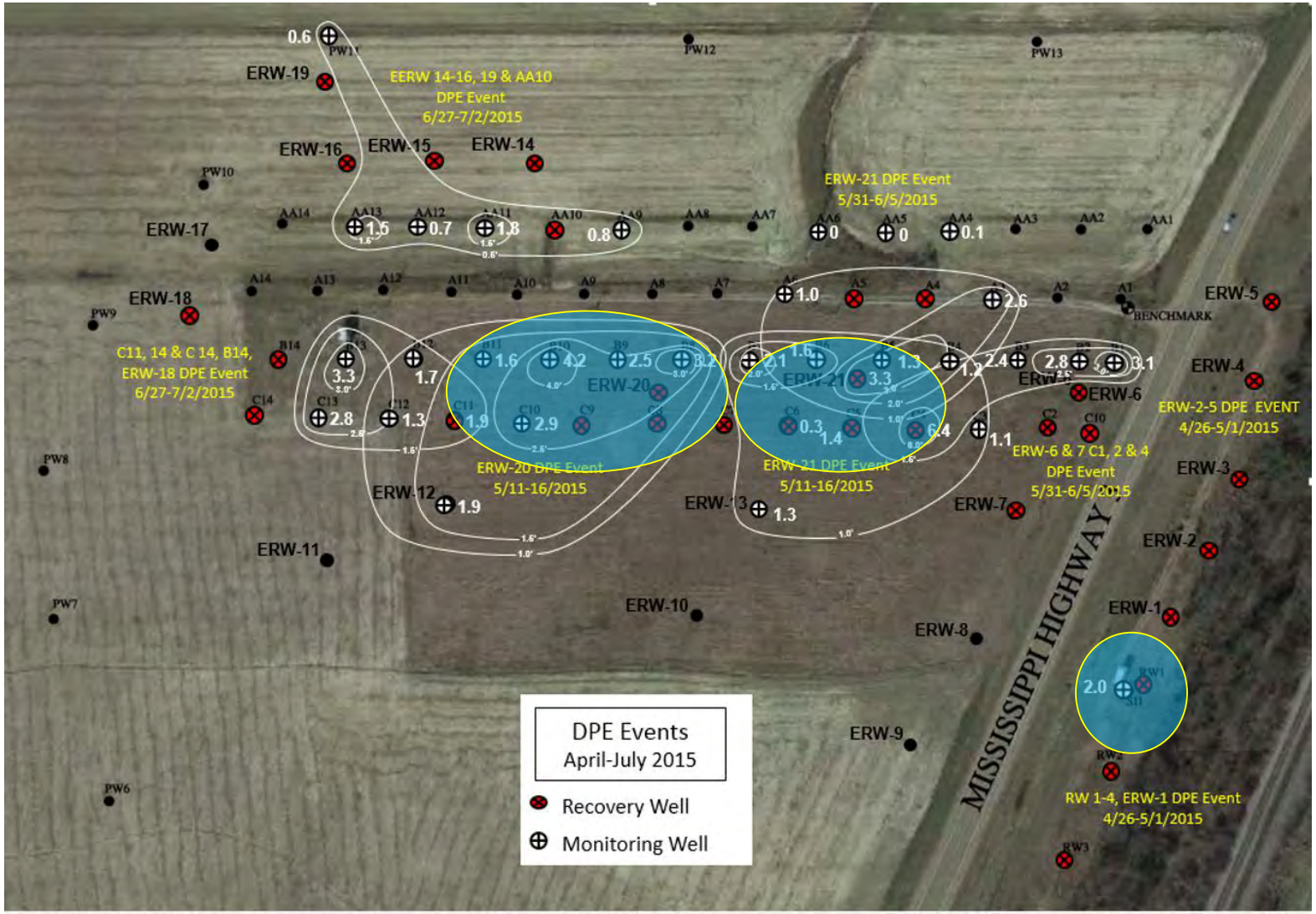
Take Home Messages for Large Site Case Study

- Mobile DPE Technology Eliminated Long Transfer Pipe Runs, Line Fouling, and Downtime
- Altering Stinger Depths Identified Preferential Pathways and Aided in Free Product Recovery
- Impact Zone Well Below Groundwater Table – Limited to Sand Layers vs Dense silt/clay
- On-Site Treatment via LGAC and Activated Alumina Vessels & Discharge via NPDES Permit
- High Methane Levels Detected by FID Analyzer – Indicator of Substantial Bioremediation
- Of a Total of 61 Extraction Wells, < 20 Exhibit Free Product
- Of a Total of 61 Extraction Wells < 20 Exhibit Ample Groundwater Recovery
- Vapor Phase PHC Recovery >>> Groundwater Phase Recovery

Cumulative TOV and Methane Levels by FID and TOVs by PID During DPE Pilot Study



Cumulative Groundwater Table Elevation Depression During DPE Events



EWs Where GW Table Drop at Nearby Wells was Greatest Coincided with Most Sand Layers and Greatest Free Product Presence

TOV Levels in Soil, and Sand Layers and Free Product Observations

Boring Depth (feet)	Westernmost Borings within Soy Field					Central Portion of Agricultural Field (grass area)							Abutting US Highway 3 (to the West)				Abutting US Highway 3 (to the East)				
	ERW 18	ERW 17	ERW 19	ERW 16	ERW 11	ERW 12	ERW 15	ERW 14	ERW 20	ERW 10	ERW 13	ERW 21	ERW 9	ERW 8	ERW 7	ERW 6	ERW 1	ERW 2	ERW 3	ERW 4	ERW 5
0-2																0	278				
2-4																					
4-6	0	0		7						4	36	0	26	48	0	0	305	60		610	0
6-8		0	0		0	0	0	0	0	0	8	0	777	515	26	0	202	1173		810	
8-10				0							0	0	738	421	17			1062		1012	18
10-12				0			5							1118		60		302		209	221
12-14	0											128		330	614			1024		711	220
14-16				0		23	5	1	0	3	0	237	67	421	1047	435	62		699	1084	370
16-18		0	0		0	599	74	3		0	21	303	303	25	652	599	174		25	1274	
18-20				0		751		204	0	63	110	442	4	2	358	734				980	970
20-22					0		740	1143				973	478	3	85	476			23	78	384
22-24		2	0	1241	3	248	765				157		163	8	76	90	5	8		38	27
24-26	0	0	203	38	73	1281	670	660	300	771	1197	398	15			30		6	2		19
26-28			233	28	16	1255	427		850	444	906	948	3	1	6			9		17	3
28-30			0	12	32	1288		83	1124	74	1268	466			8		37			18	7
30-32	0	0		16	10	215		88	981	218	140	391			3	38				1	67
32-34		0	0			129	16		1177	15	70		0	0			20	8	0		
34-36	0	0	0	10	16	49		24	1172		85	73			1	3				0	10
36-38		0	0	4		19	0		301	3	20										8
38-40	0		0	0		4		4	604		2	56	0								5
40-42									143			51					0				
42-44									145												
44-46												3									
46-48									105												
48-50																	0				
50-52																					
52-54																	0				
54-56																					
56-58																					
58-60																					

A	Clayey silt	D	Yazoo clay	
B	Fine sand lens		Free product	Depth to Groundwater
C	Silty clay		Black silty clay	

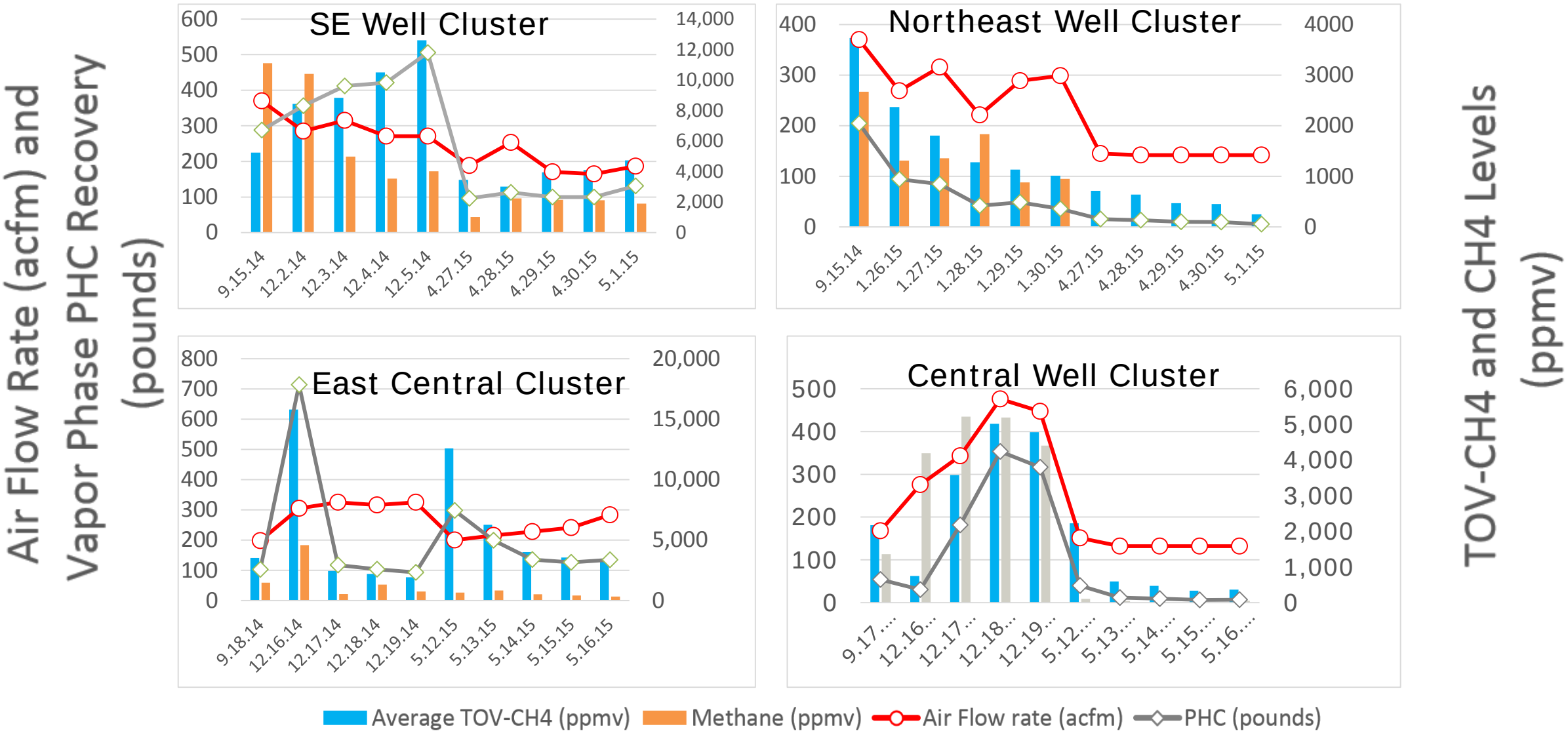
GW Table

Smear Zone

Downward

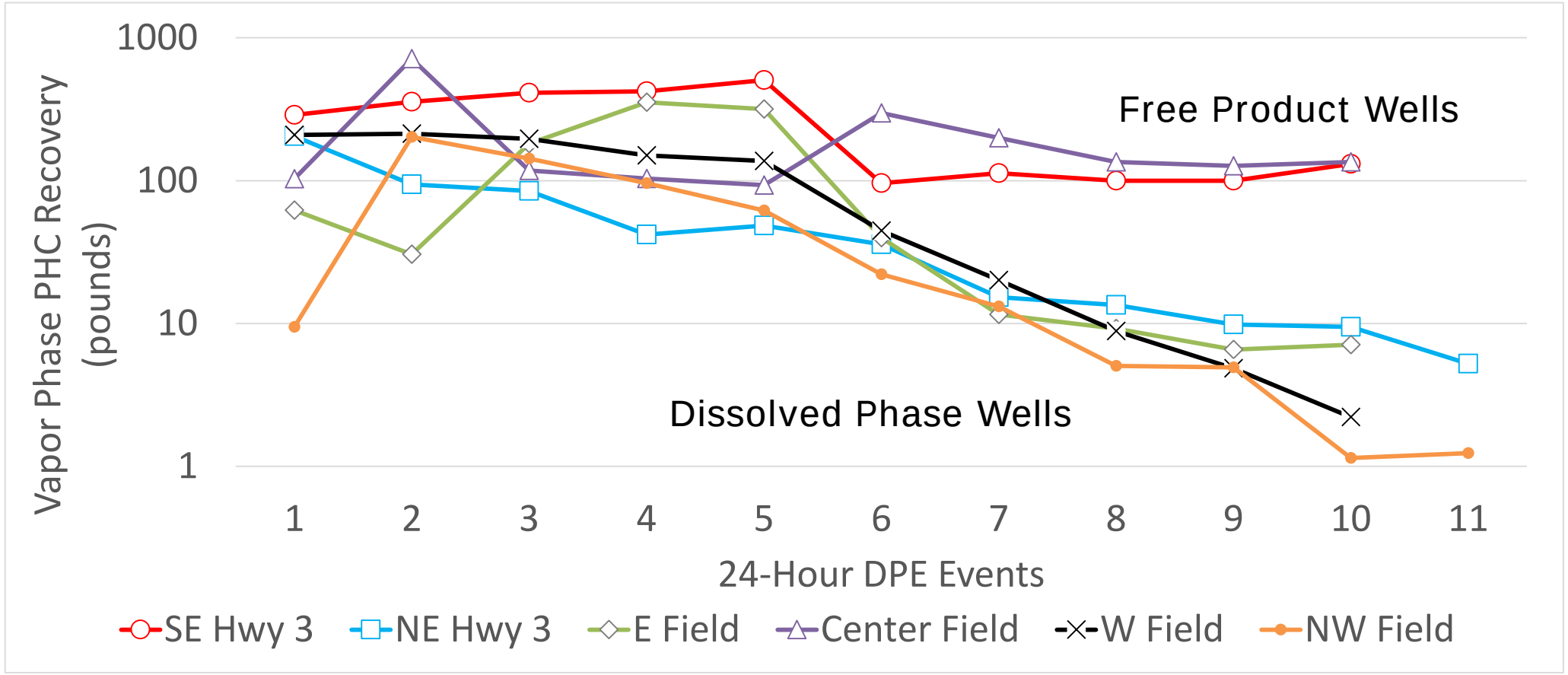
Vertical Trend

Recovery of Vapor Phase PHCs and TOV & Methane Levels

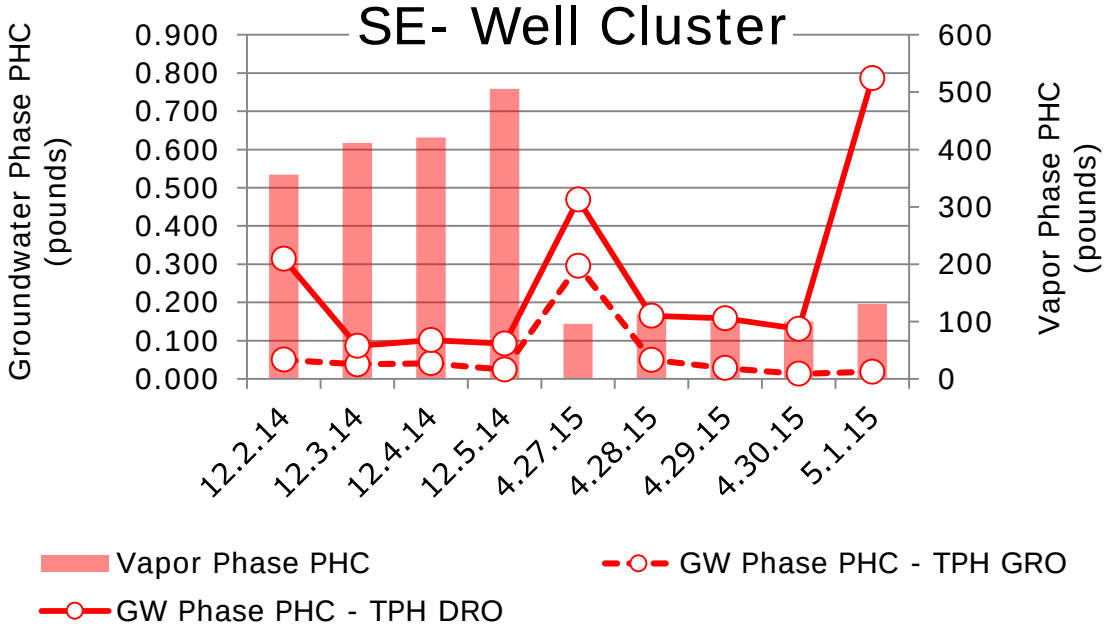


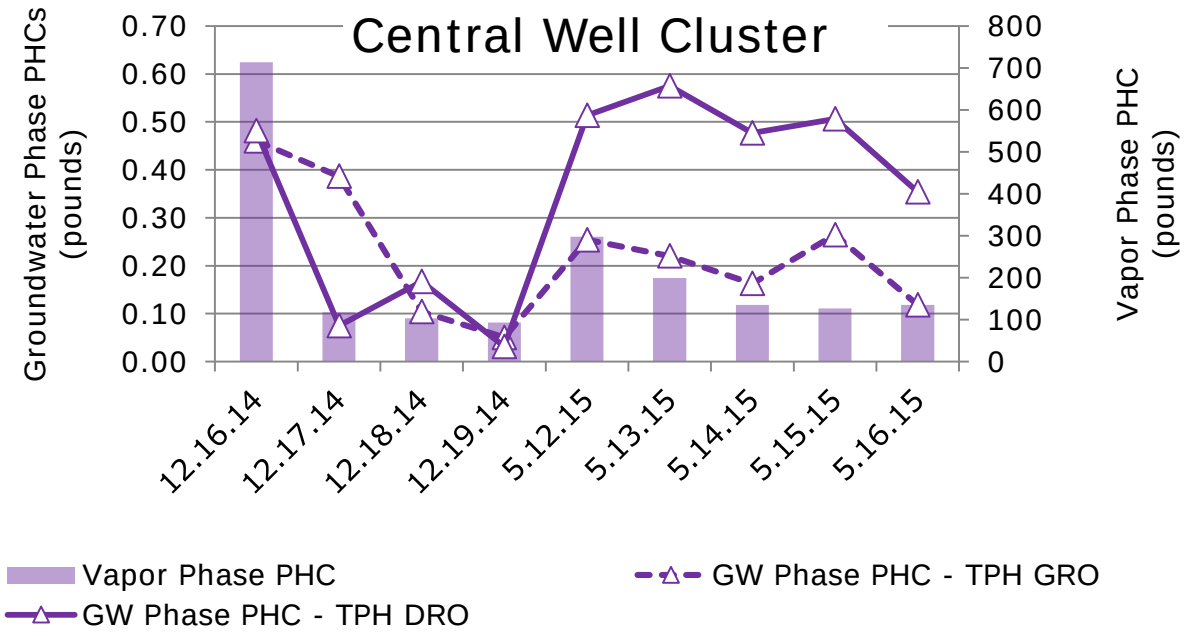
Change bar color graph 4 and reduce font on side legends

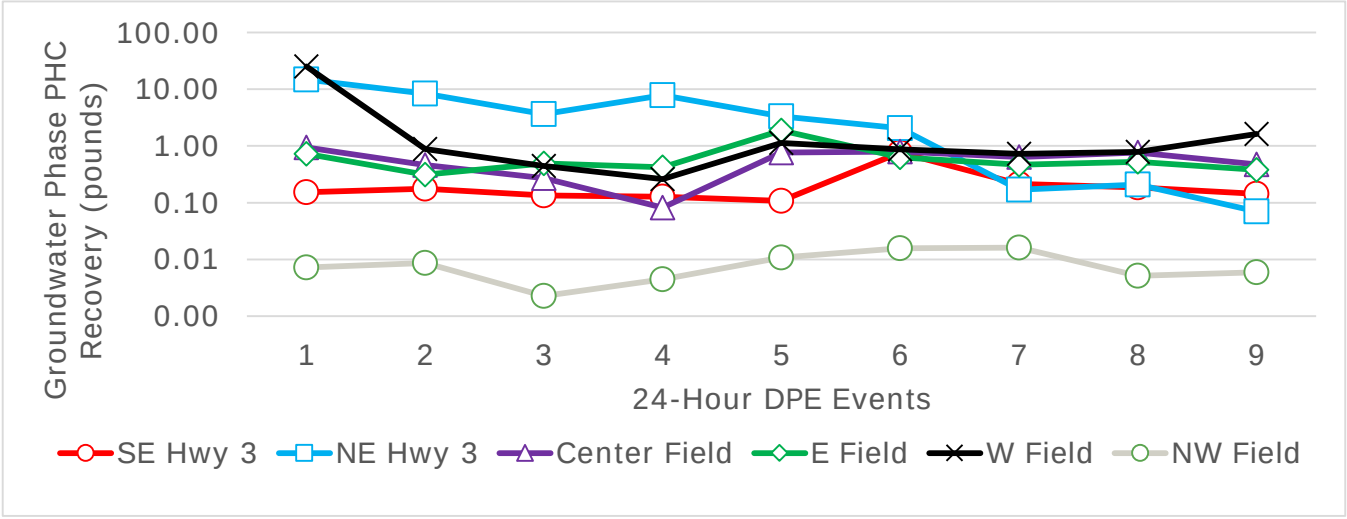
Vapor Phase PHC Recovered from 6 Well Clusters During 11 x 24-Hour DPE Events



Recovery of Groundwater Phase PHCs (TPH-GRO vs -DRO)





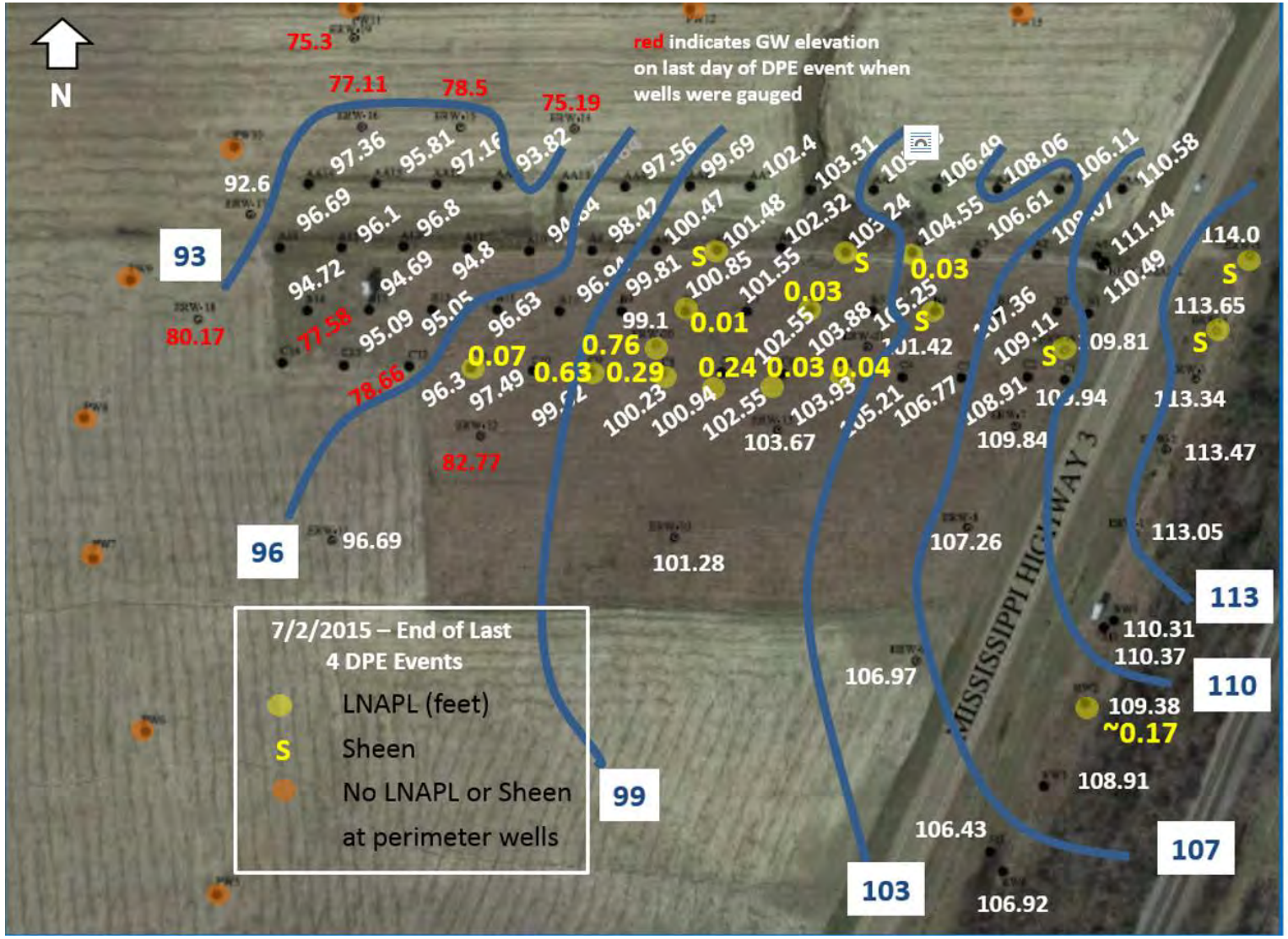


Task	Equipment	Consulting Labor	Analytical Services
WELL INSTALLATION			
4” dia Extraction Wells (21)	$60,000	$35,000	$21,000 (70 soil samples)
DPE Events			
5-Day Pilot Test	$30,000	$27,000	$30,000 (Groundwater Forensics & 61 well samples)
5-Day	$60,000	$16,000	$800/5 scrub tank samples/event $10,000 (40 wells/event)
GROUNDWATER DISPOSAL	$1,000/5-day	$750/5-day	$2,000/5-day event
Carbonair LGAC (2 x 2,000 lbs) Activated Alumina	$6,000 $600/month		
REPORTING			
CAP		$50,000	
Summary Report		$35,000	

Based on 11 x 24 hr Events to date = $540,000

15% Wells; 28% DPE, 40% Labor, 15% Lab and 2% GW Treatment

Groundwater Flow Contours and Free Product Thickness Following DPE Events (July 2015)



- Hydraulic Gradient to the East is Twice that in the West
- Free Product Ranges from a Sheen to 0.8 feet