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Field Trial of Residual LNAPL Recovery Using CO_2-Supersaturated Water Injection

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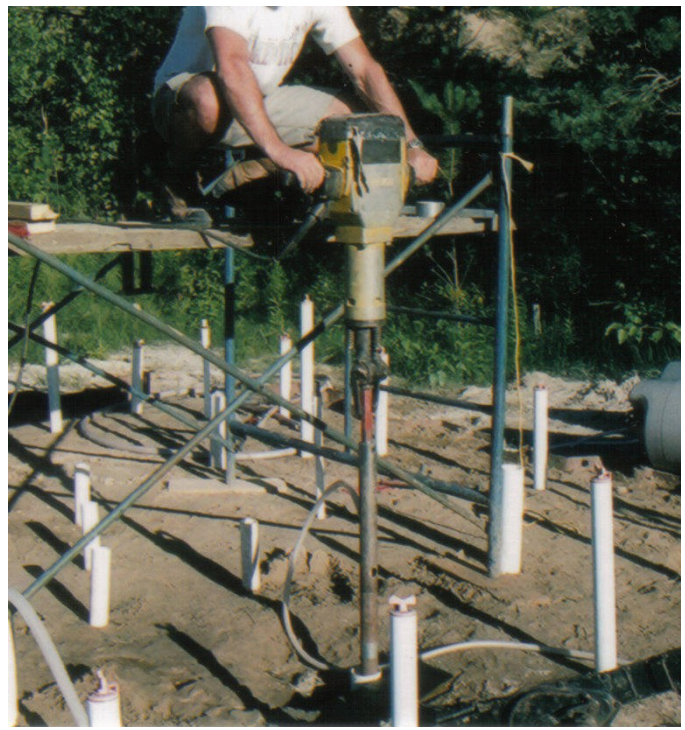
31-Oct-07

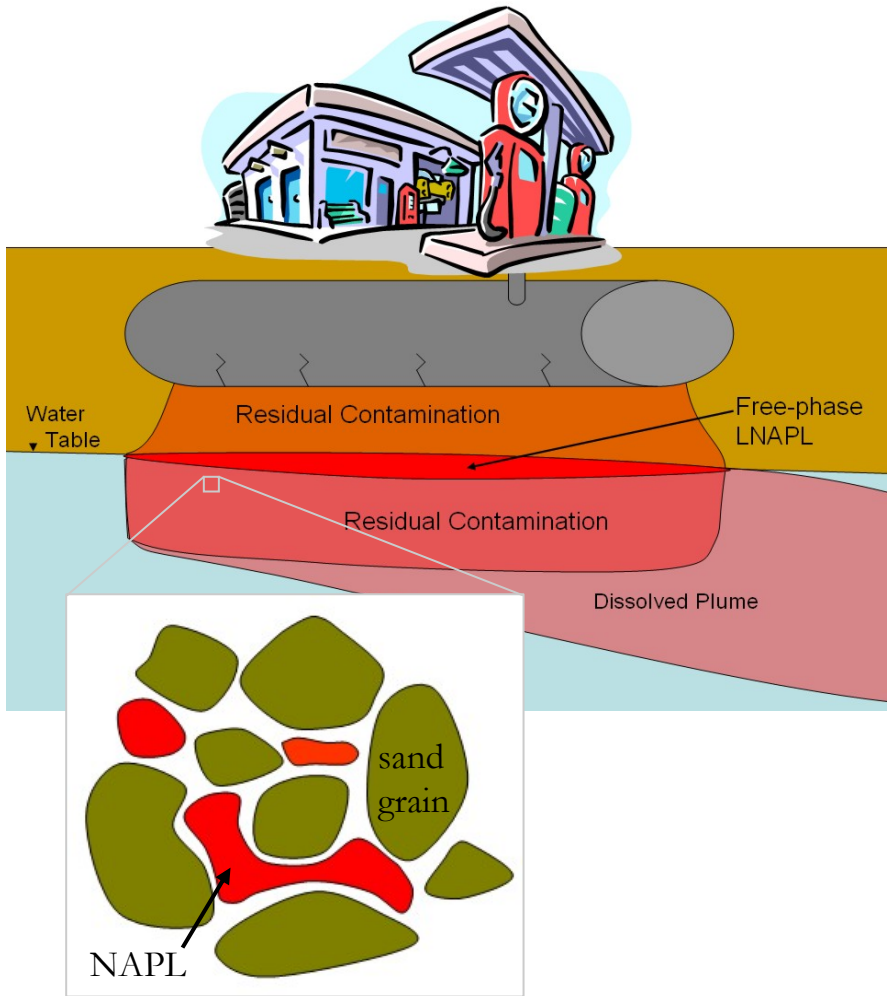
Overview

- Introduction
- Principles of Supersaturated Water Injection (SWI)
- Results and Interpretation
- Comparisons
- Applicability
- Summary

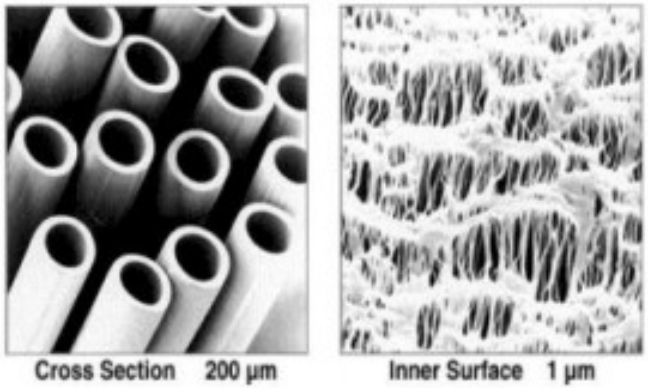


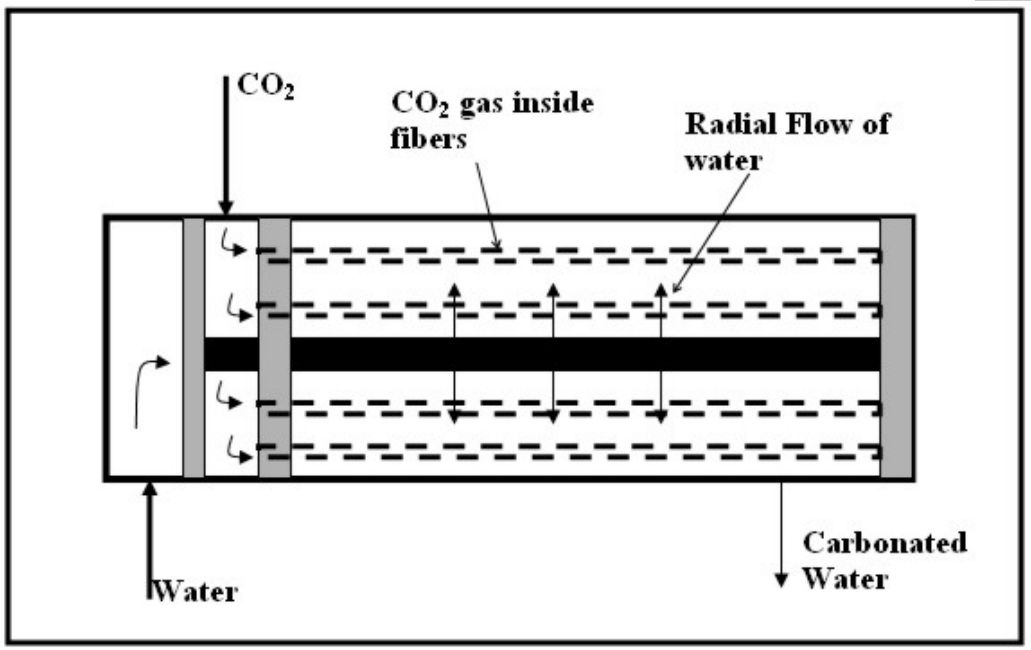
Introduction

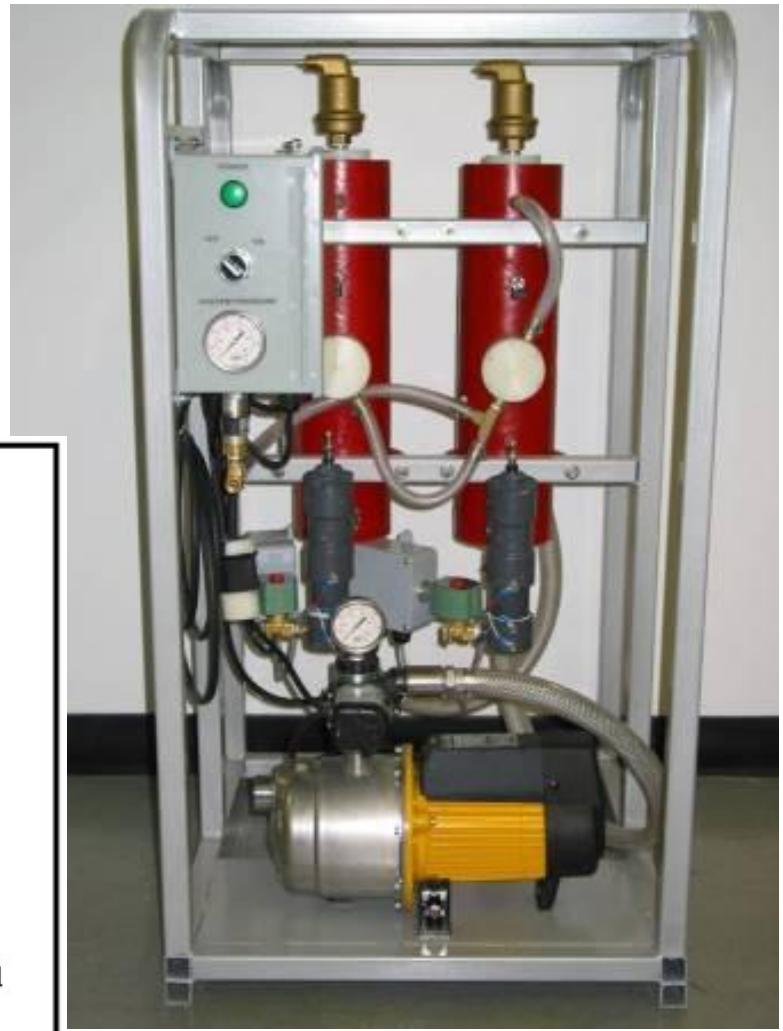
- Residual contamination usually consists of small “blobs” of NAPL held between grains that are difficult to remove and are a continuing source of groundwater contamination
- Often a result of fluctuating water table elevation (i.e. seasonal variation)



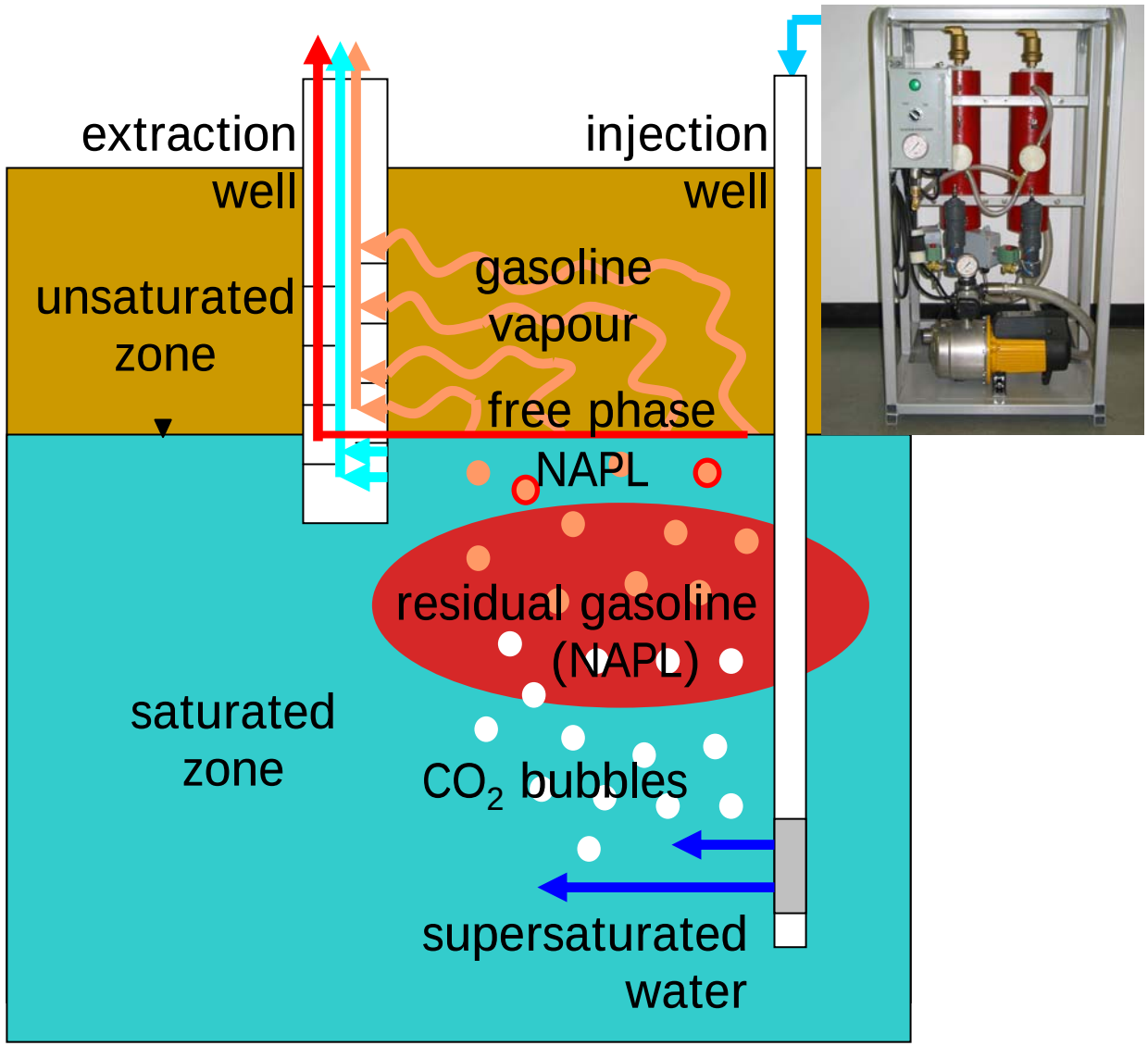
Gas InFusion™ Generator



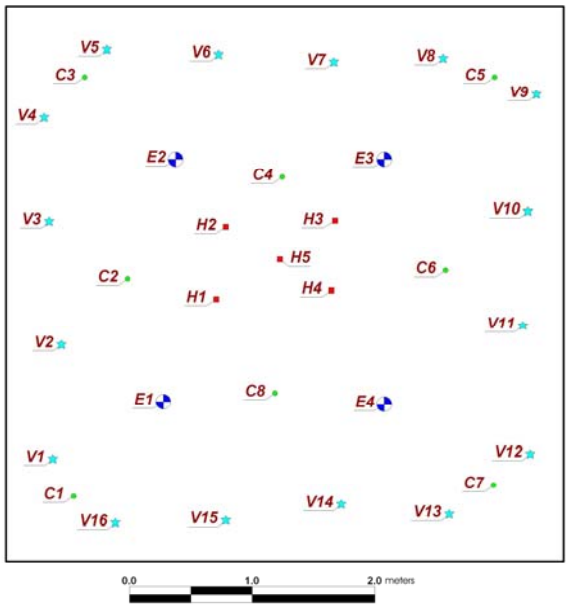




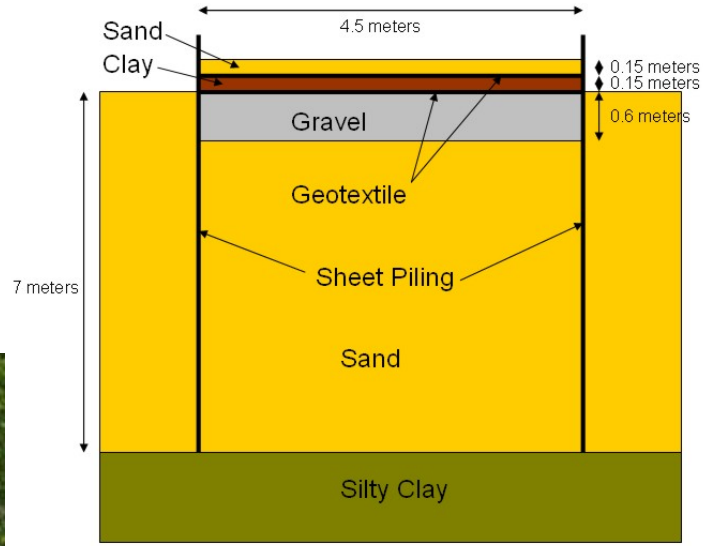
Conceptual Model



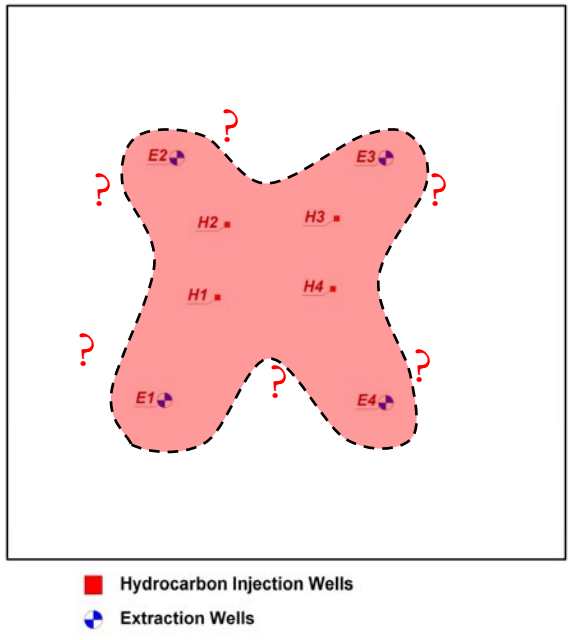
The Cell

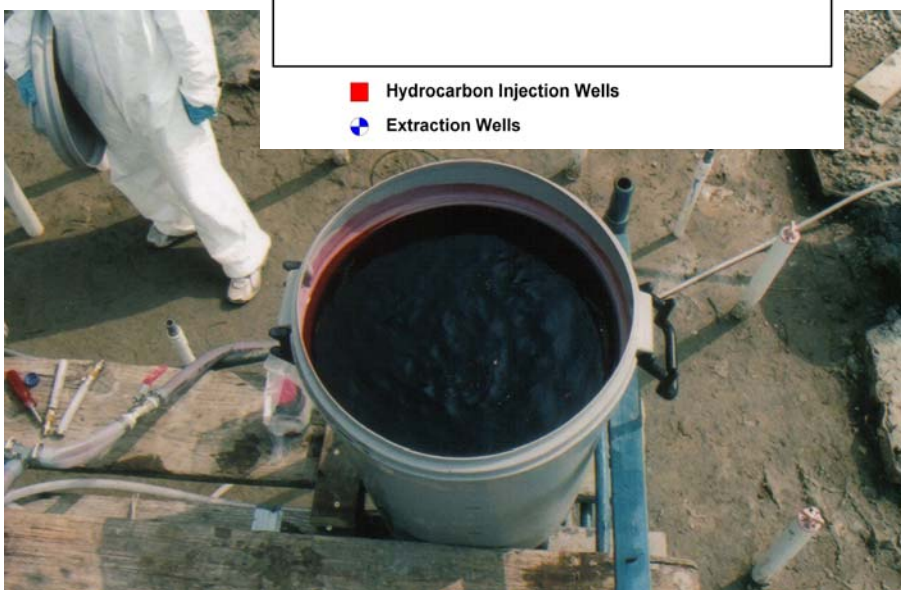


- Vent Wells
- Hydrocarbon Injection Wells
- Extraction Wells
- CO_2 Injection Wells



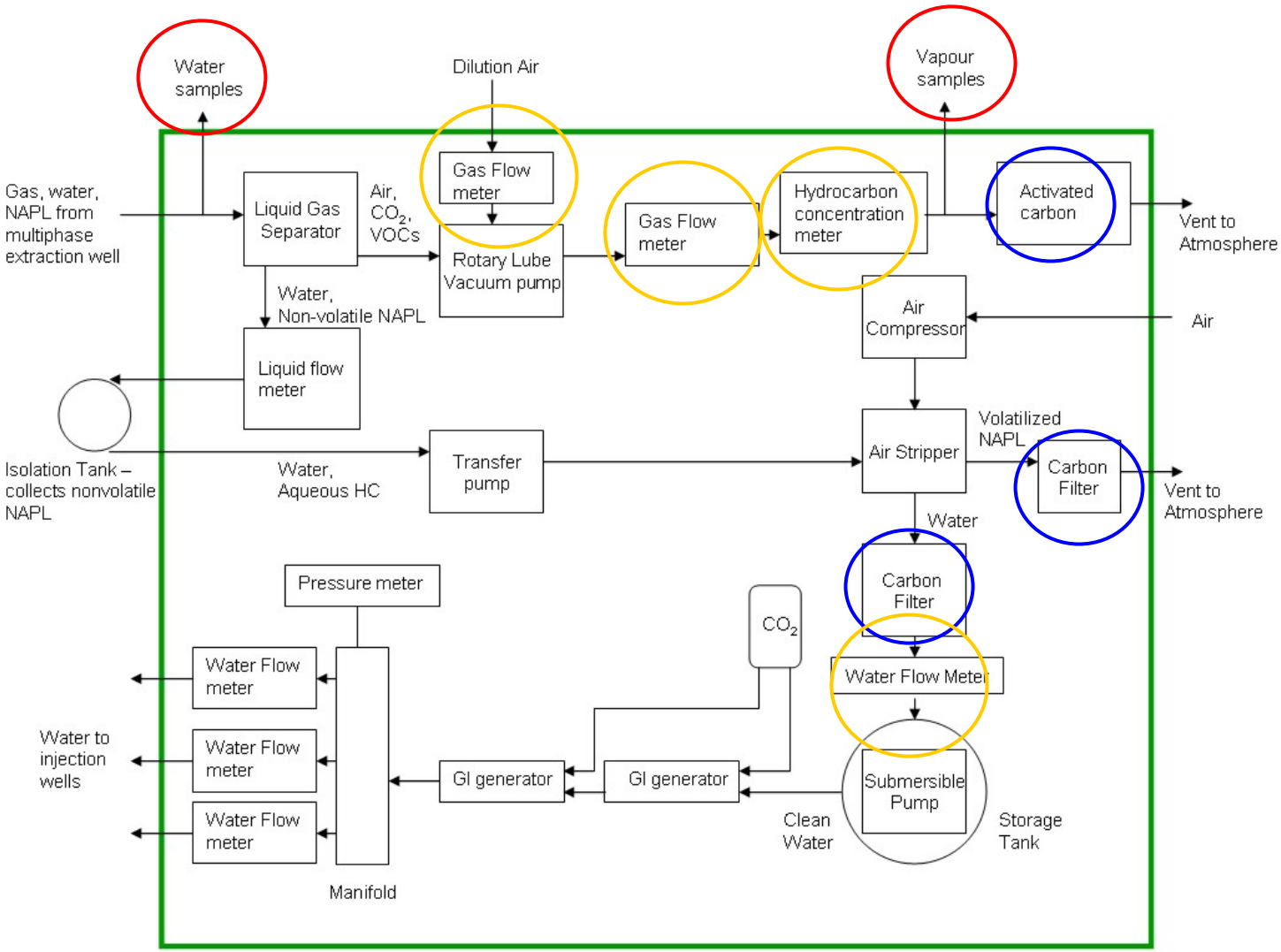
Contaminant Injection



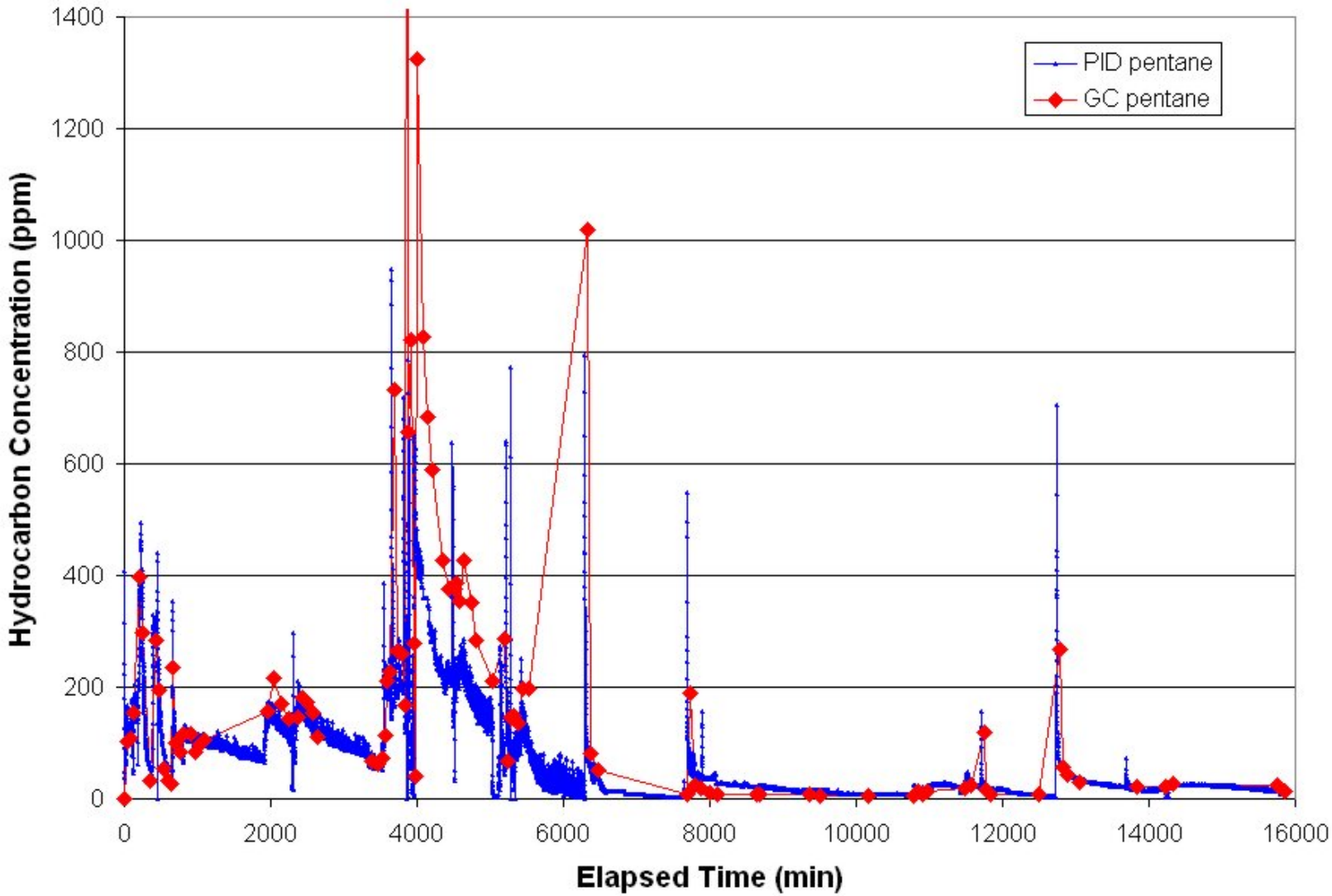


Contaminant	Volume (L)	Vapour P (kPa)
Pentane	80	68
Hexane	80	20
Soltrol 130	40	0.052

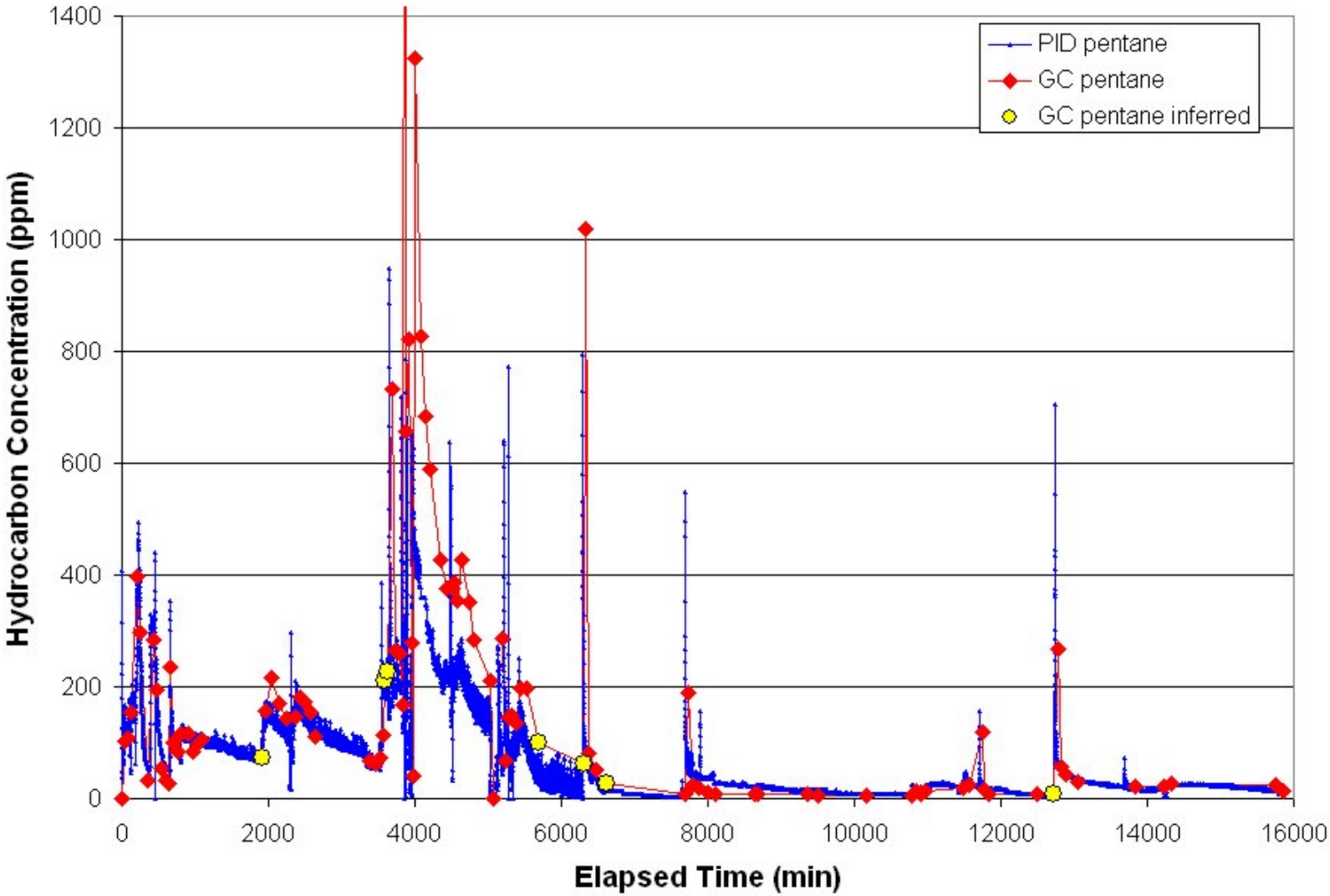
Multi-Phase Extraction System



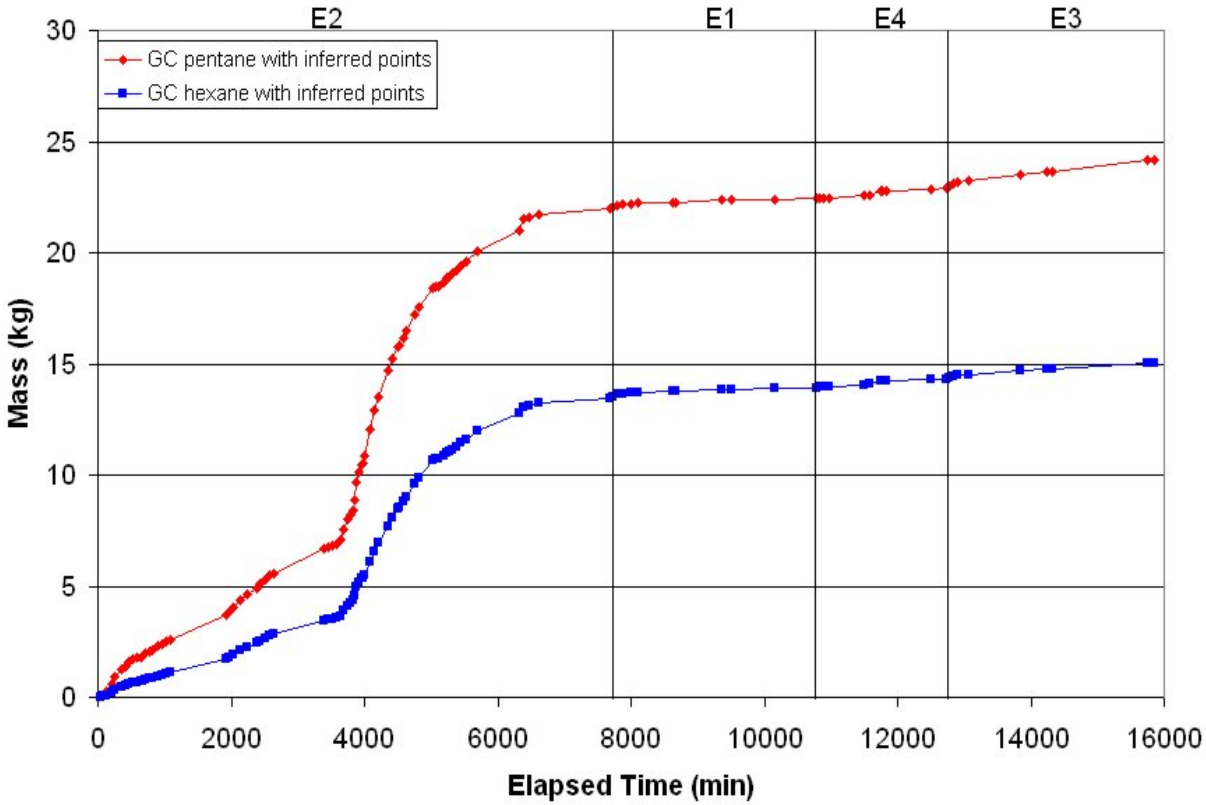
Results


PID pentane
GC pentane
Hydrocarbon Concentration (ppm)
0
200
400
600
800
1000
1200
1400
0
2000
4000
6000
8000
10000
12000
14000
16000
Elapsed Time (min)

Results


PID pentane
GC pentane
GC pentane inferred
Hydrocarbon Concentration (ppm)
0
200
400
600
800
1000
1200
1400
0
2000
4000
6000
8000
10000
12000
14000
16000
Elapsed Time (min)

Mass Removed



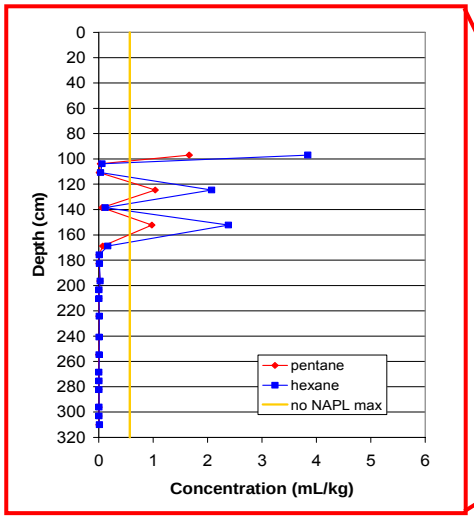
Contaminant	Mass (kg)	%
Pentane	24	57
Hexane	15	32
Total	39	**44**

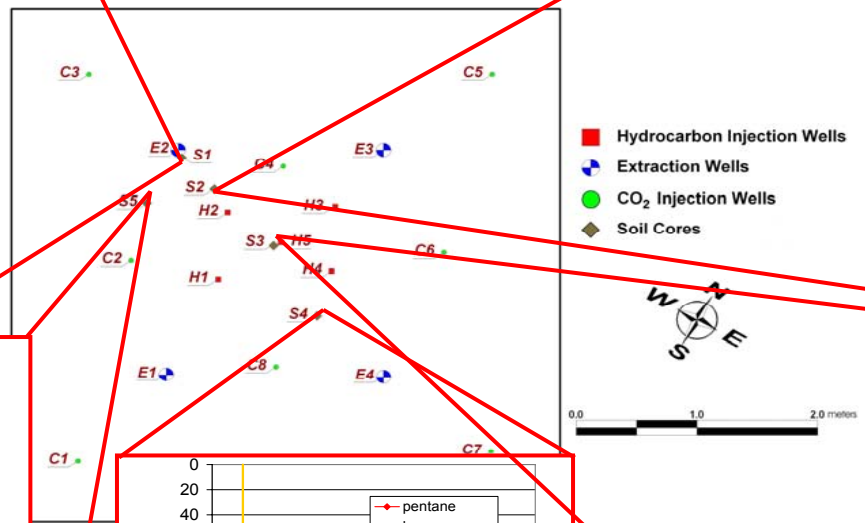
Vapour

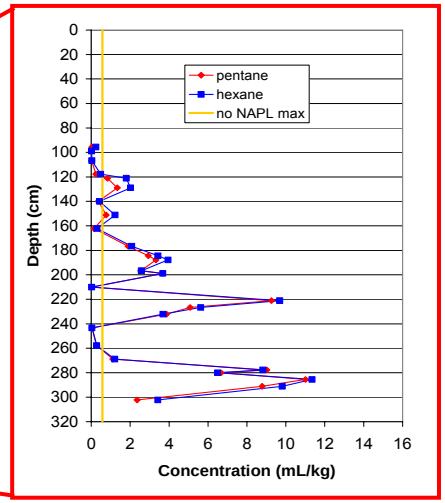
Contaminant	Mass (g)	%
Pentane	57	0.13
Hexane	40	0.08
Soltrol 130	3	0.003

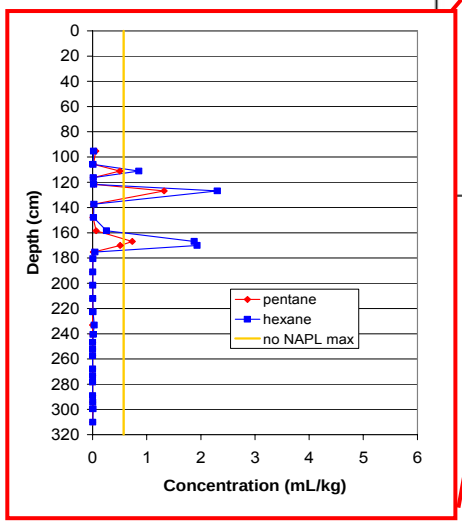
Water

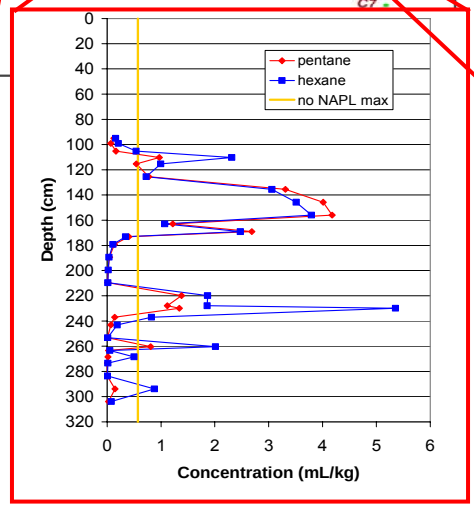
Soil Sampling

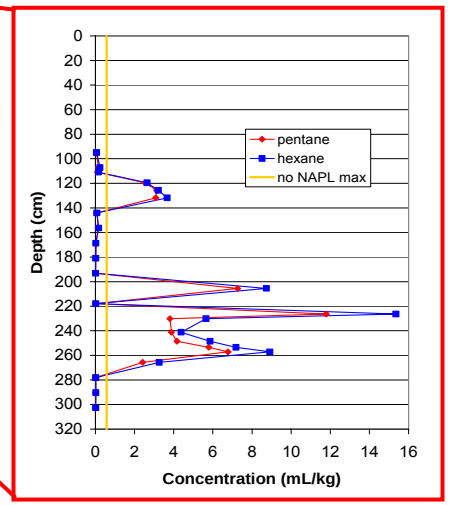


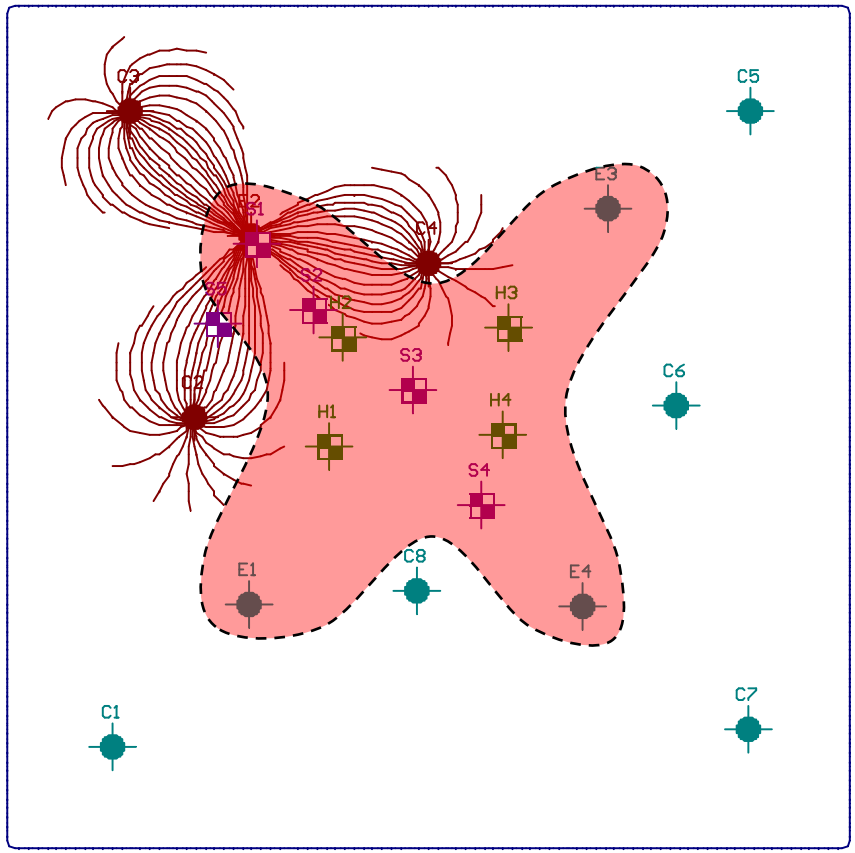


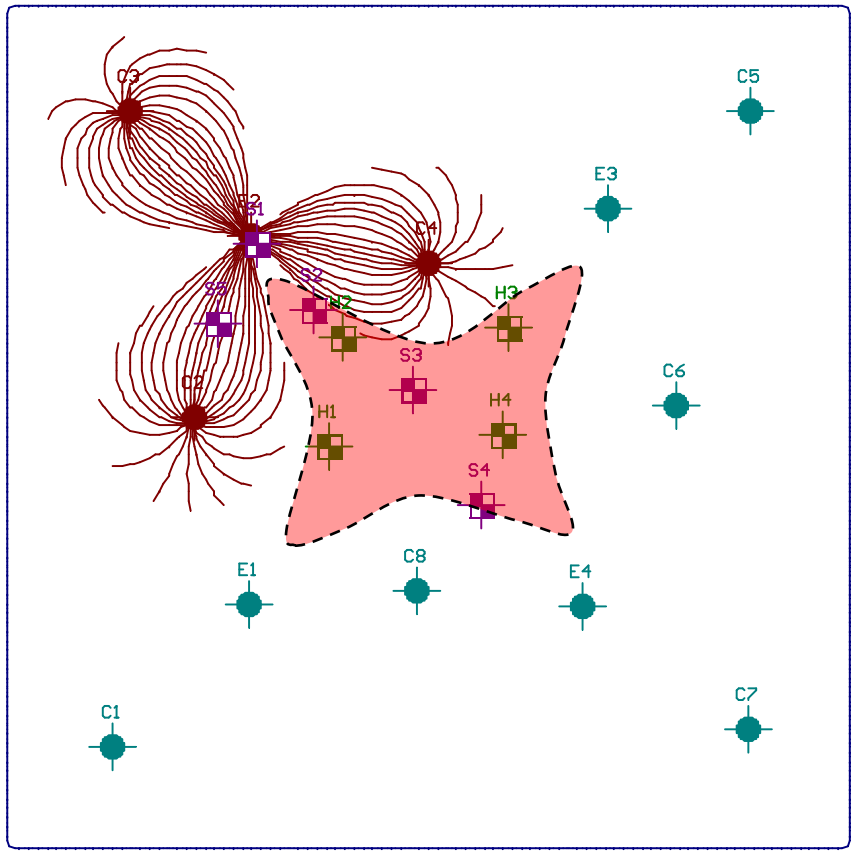




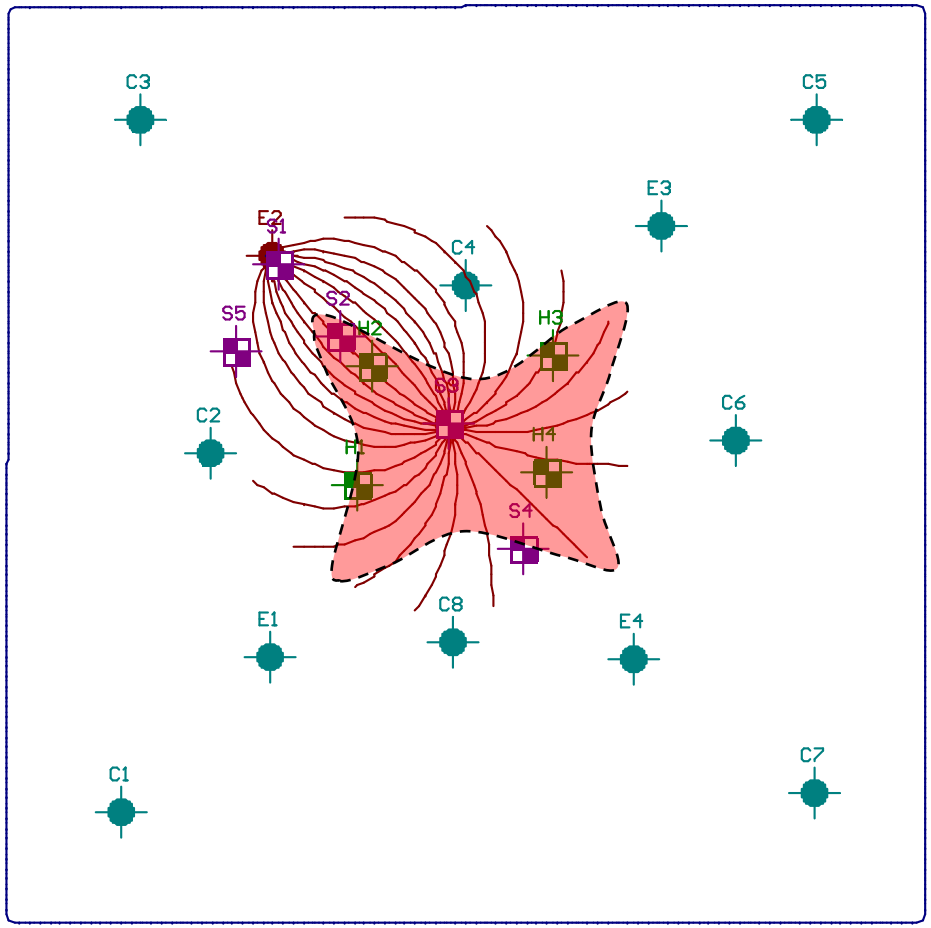




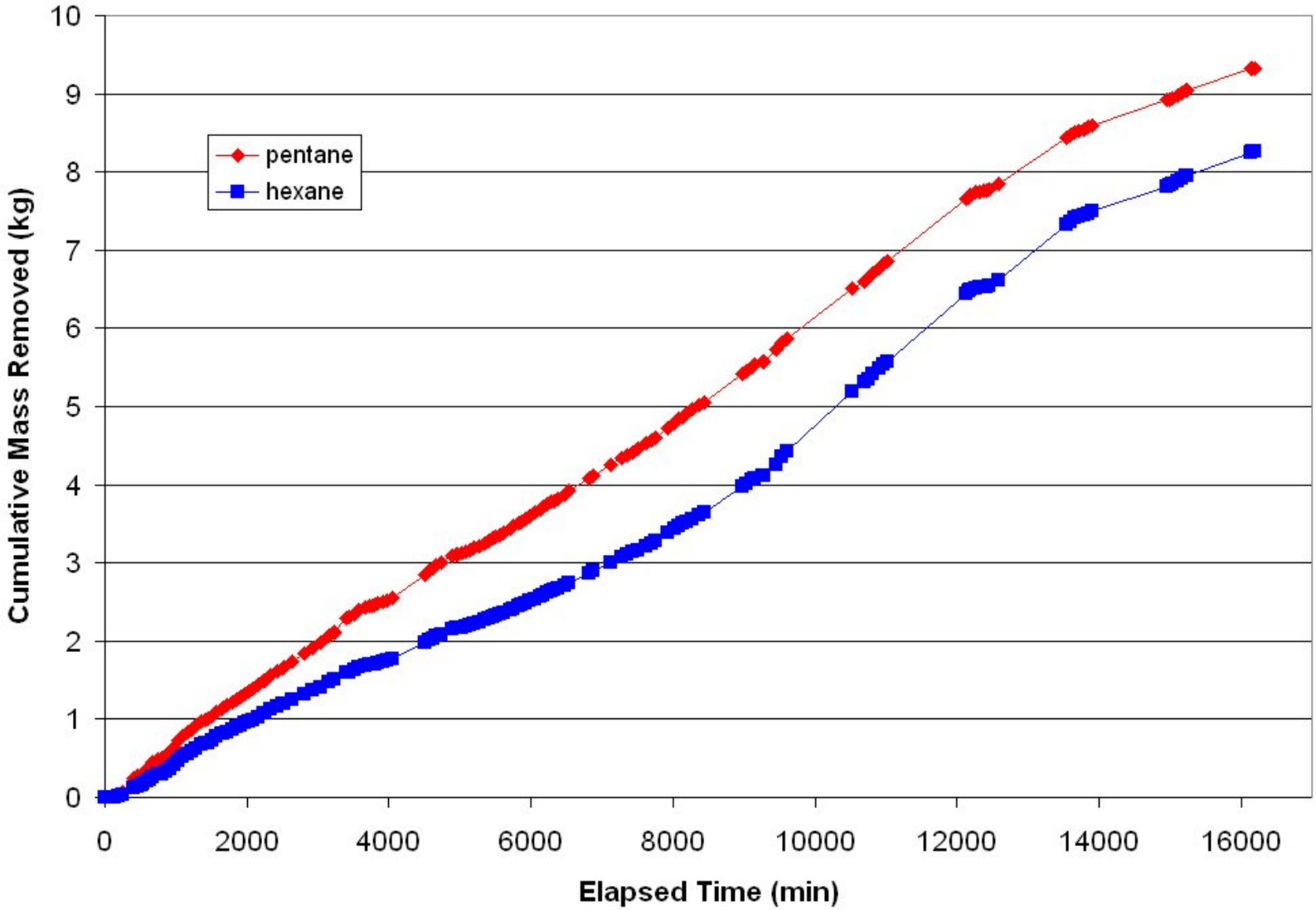

C3
C5
E3
S1
C4
S2
H2
H3
S3
C6
C2
H1
H4
S4
E1
C8
E4
C1
C7


C3
C5
E3
S1
S2
C4
S5
H2
H3
S3
C6
C2
H1
H4
S4
E1
C8
E4
C7
C1

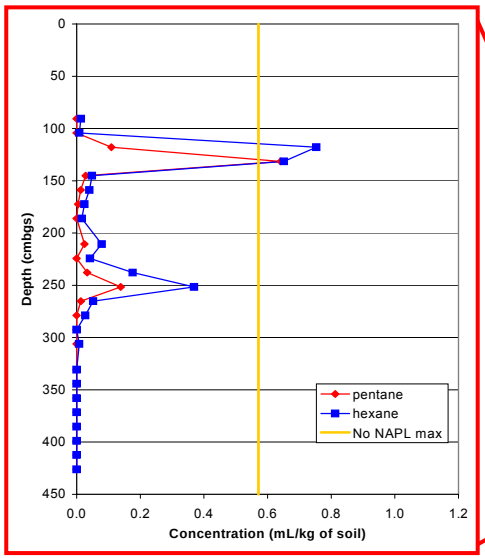
Predictive Modeling

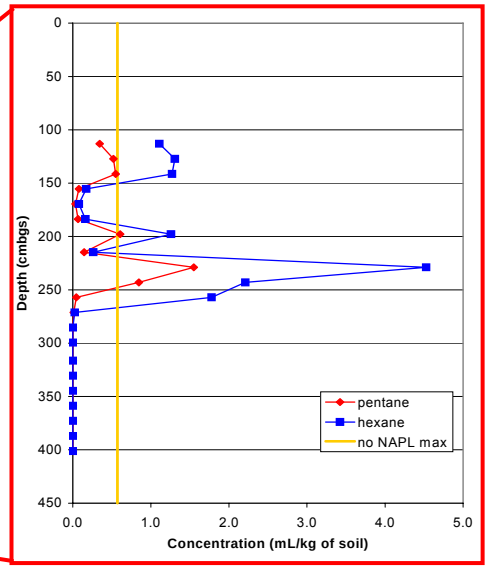


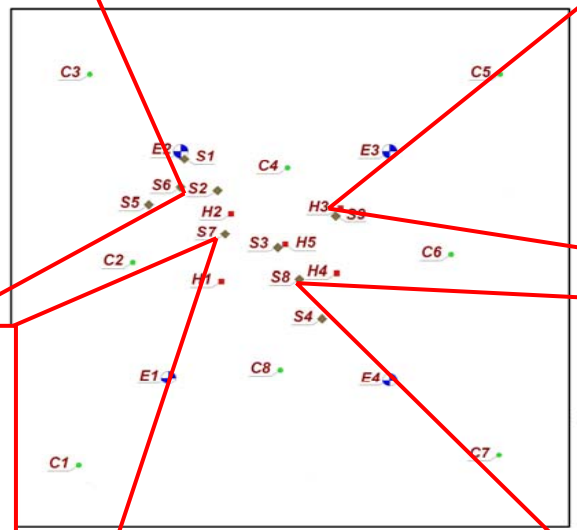
Phase II Results

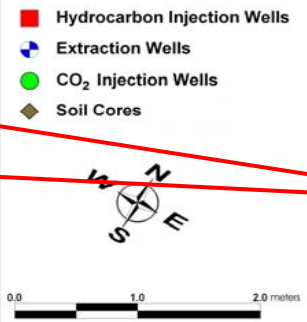


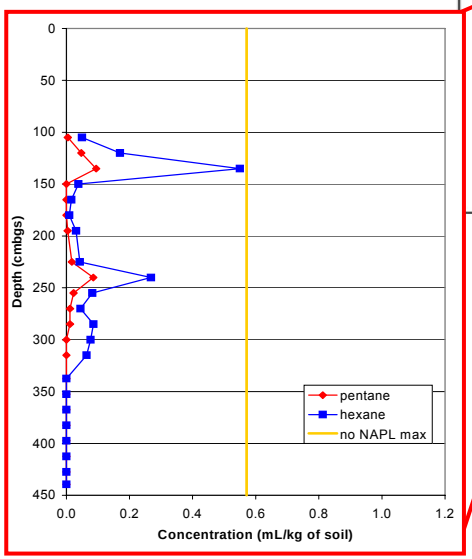
Soil Sampling II

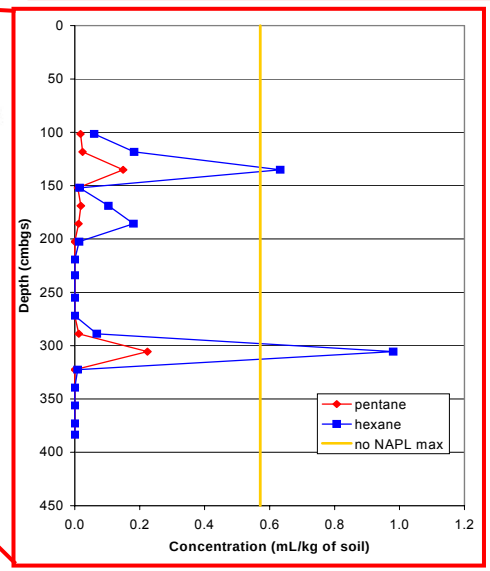




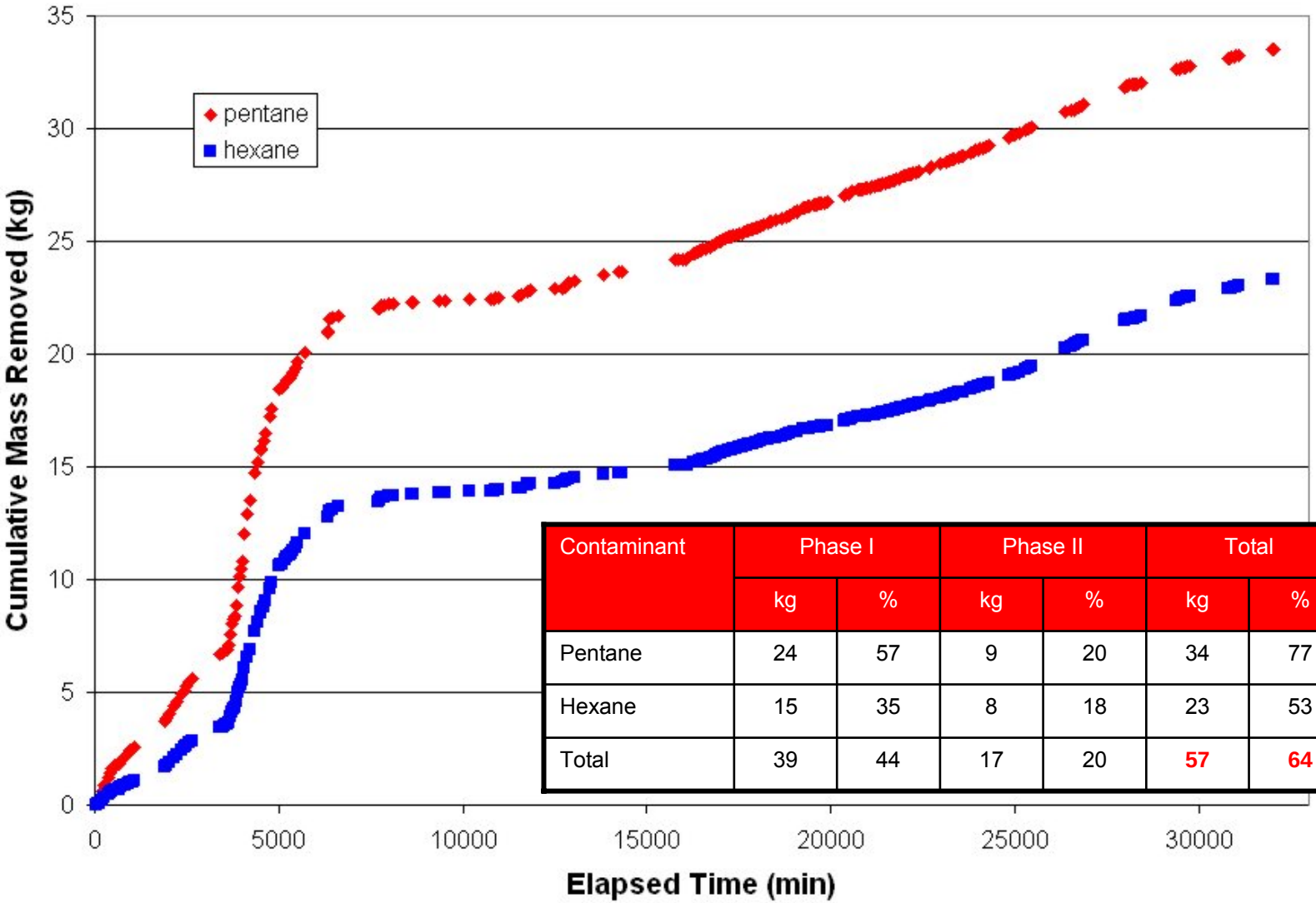








Total Mass Removed



Contaminant	Phase I		Phase II		Total	
	kg	%	kg	%	kg	%
Pentane	24	57	9	20	34	77
Hexane	15	35	8	18	23	53
Total	39	44	17	20	**57**	**64**

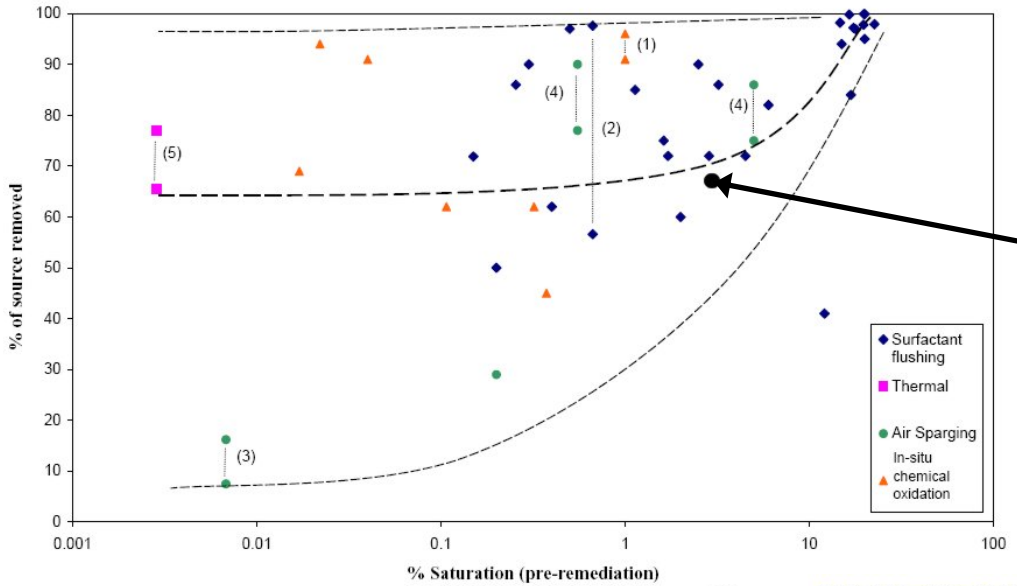
Comparison with air sparging

Parameter	Supersaturated Water Injection	Air Sparging (Tomlinson et al, 2003)
Length of Time (days)	5.2	7
Gas	CO_2	Air
Total Volume of Gas (m^3)	122	1400
Total Volume of Water (L)	57,247	n/a
Gas Saturation (%)	2-16	15-60
Approximate Gas Saturation Distance from Injection/Sparge Point (m)	≥ 5.3	≥ 2.5

Comparison with Dover trials

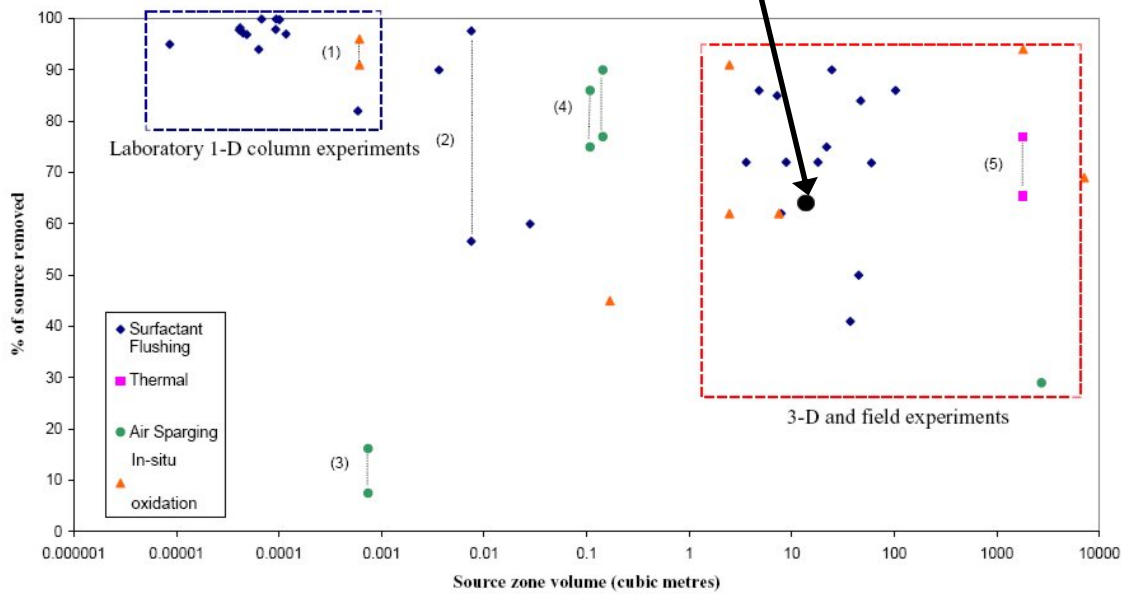
- Trials conducted in cells at Dover Air Force Base
  - Subsurface consists of layers of sand and silty sand
- Cosolvent flushing with ethanol (Brooks et al, 2004)
  - removed 64% of the 91.7 liters emplaced PCE in 40 days
- Surfactant flooding (Childs et al, 2004)
  - removed 68% of the 77.9 liters of emplaces PCE

Comparison with other methods



Supersaturated Water Injection

Soga et al, 2004



Applicability to contaminants of concern

Compound	Vapour Pressure (kPa)
Pentane	**68**
MTBE	33
Hexane	**20**
Benzene	13
Ethanol	7.9
PCE	2.4
Soltrol 130	**0.052**
Ethylene Glycol	0.012
Napthalene	0.011

Summary

- 64% of the emplaced volatile compounds were removed
- A negligible amount of the non-volatile compound was removed
  - but there is evidence to indicate mobilization of hexane so Soltrol may have been mobilized as well
- Results are promising for the continued development of the technology

Acknowledgements

- Dr. Jim Barker
- Dr. Neil Thomson & Dr. Mario Ioannidis
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- Cindy Doughty, Claudia Naas, Marianne van der Griendt, Shirley Chatten, Bob Ingelton, Bob Ingelton, Paul Johnson, Scott Piggott, Dr. John Chatzis, Alex Oiffer, Nick La Posta, Michelle Fraser, Juliana Freitas, Jiri Beranek, Jacqueline Kreller, Dinah Augustine
- Minh Le from C3 Environmental
- Don Kierstad & Mike Campbell from SCG Industries
- inVentures Technologies, C3 Environmental, API, CFI & NSERC

References

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- Tomlinson, D.W., N.R. Thomson, R.L. Johnson, and J.D. Redman. 2003. Air Distribution in the Borden Aquifer during In Situ Air Sparging. *Journal of Contaminant Hydrology. 67*: 113-132.

Questions?