



High Resolution Characterization of VOCs & Petroleum Hydrocarbons



Bruce Tunncliffe
Vertex Environmental Inc.

SMART Remediation
Vancouver, BC
January 27, 2015

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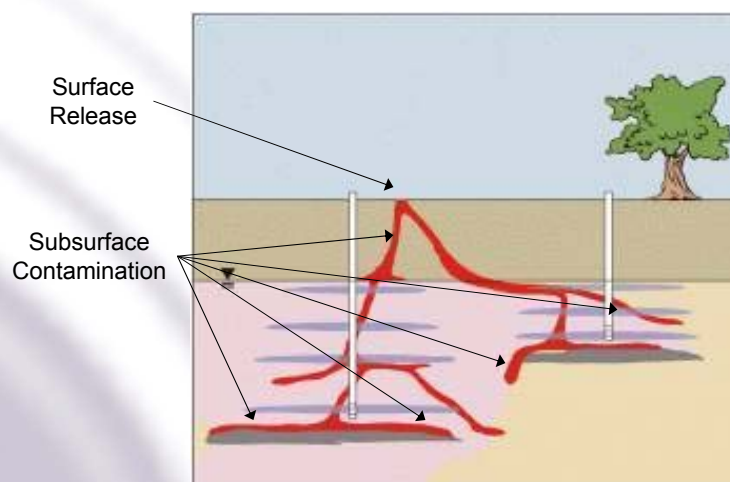
Vertex Environmental Inc.



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SMART – Vancouver
January 27, 2015
Bruce Tunnicliffe

Subsurface Impacts

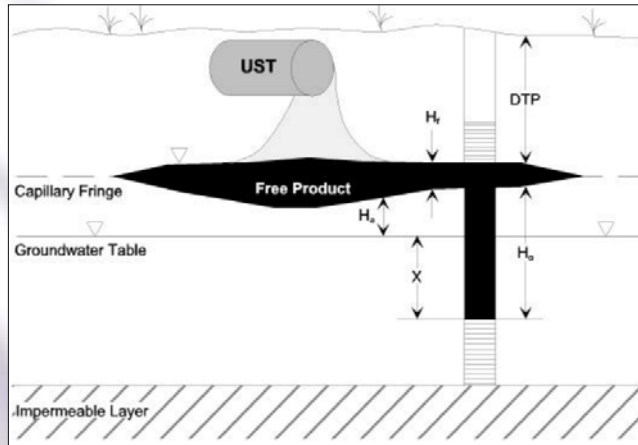


Source: EPA, 2010



Subsurface Impacts

Contaminant Distribution vs Site Measurements



Source: EPA (1996)



Accuracy vs Precision



Very Accurate
Very Precise



Very Accurate
Not Precise

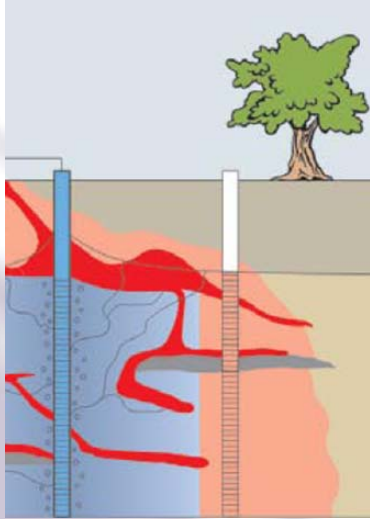


Somewhat Accurate
and Precise

"It is better to be roughly right than precisely wrong"



Overview



- Background
- High Res Characterization
 - Laser Induced Fluorescence (LIF)
 - Membrane Interface Probe (MIP)
 - Hydraulic Profiling Tool (HPT)
- Case Studies
 - LIF
 - MIP
- Questions

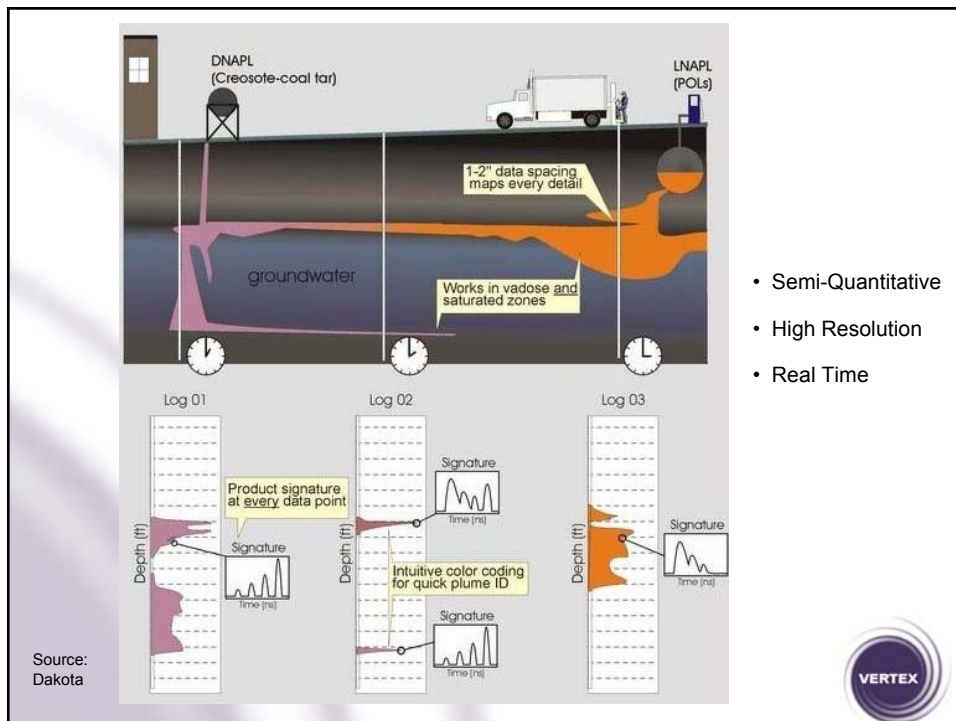


Vertex Background

- Bruce Tunnicliffe
 - Masters of Engineering – University of Waterloo
 - In-Situ Remediation (permanganate & bedrock)
- Vertex Environmental
 - Environmental Contracting
 - High Resolution Characterization
 - Remediation and Injection Services
 - Remedial Design
 - Implementation (bench, pilot, full-scale)



High Resolution Characterization



Laser Induced Fluorescence

for Pure Phase Contamination, LNAPL



Laser Induced Fluorescence

- Developed by US Army ('90s)
- UVOST: Ultra-Violet Optical Screening Tool
- Equipment
 - Direct push (Geoprobe)
 - Probe
 - Fibre optic cable





- Semi-Quantitative
- High Resolution
- Real Time

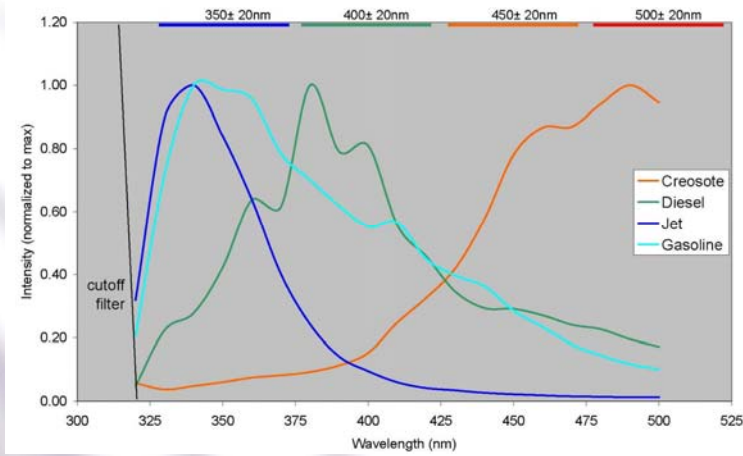


Laser Induced Fluorescence

kerosene gasoline diesel oil



Laser Induced Fluorescence



naphthalene



phenanthrene

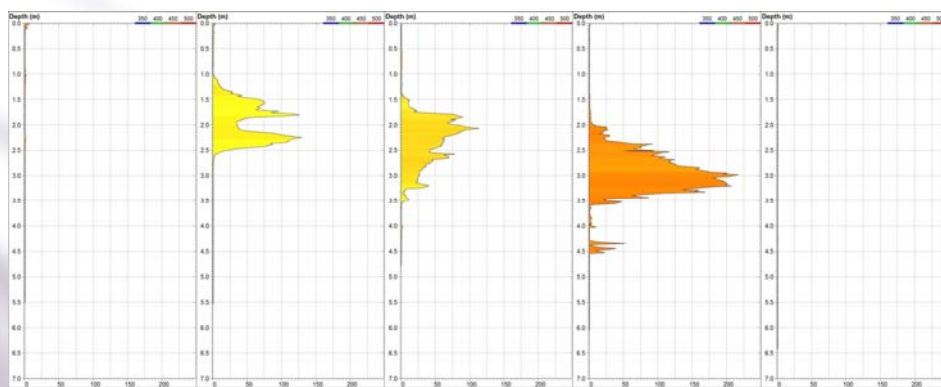


pyrene



benzo[e]pyrene

LIF Output



Cross Section of LIF Points

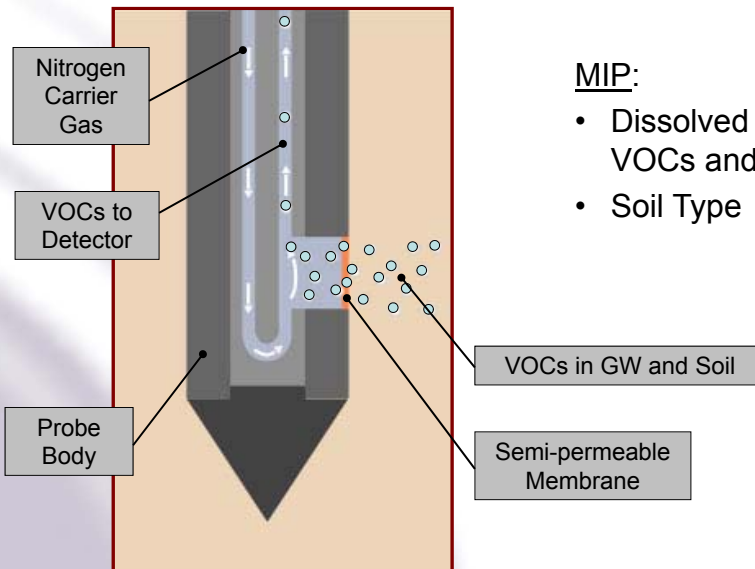


Membrane Interface Probe

for Dissolved Phase Contamination



Membrane Interface Probe

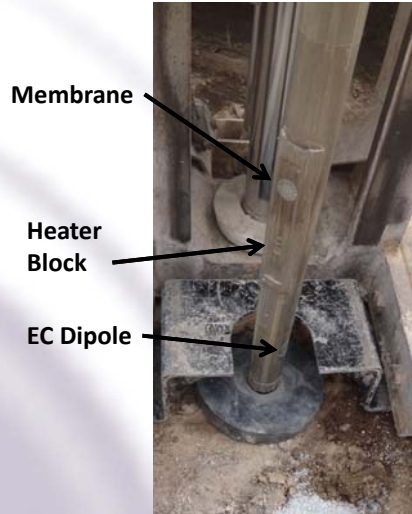


MIP:

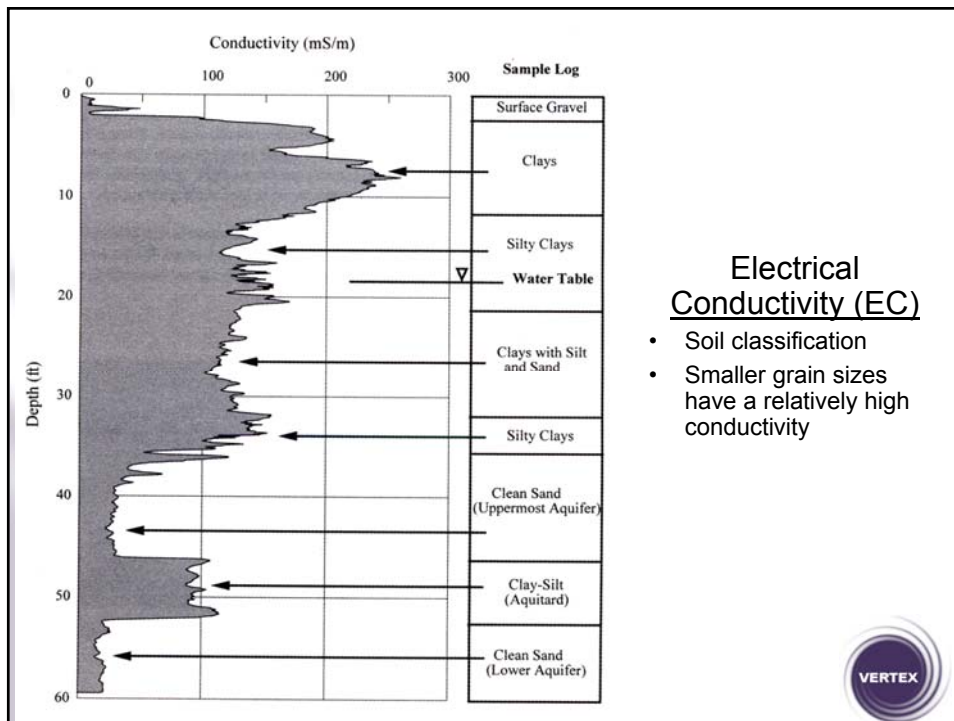
- Dissolved Phase VOCs and PHCs
- Soil Type



Membrane Interface Probe



- Three detectors:
 - Photoionization Detector (PID)
 - Flame Ionization Detector (FID)
 - Halogen Specific Detector (XSD)
- Electrical Conductivity
 - Used to determine soil classification

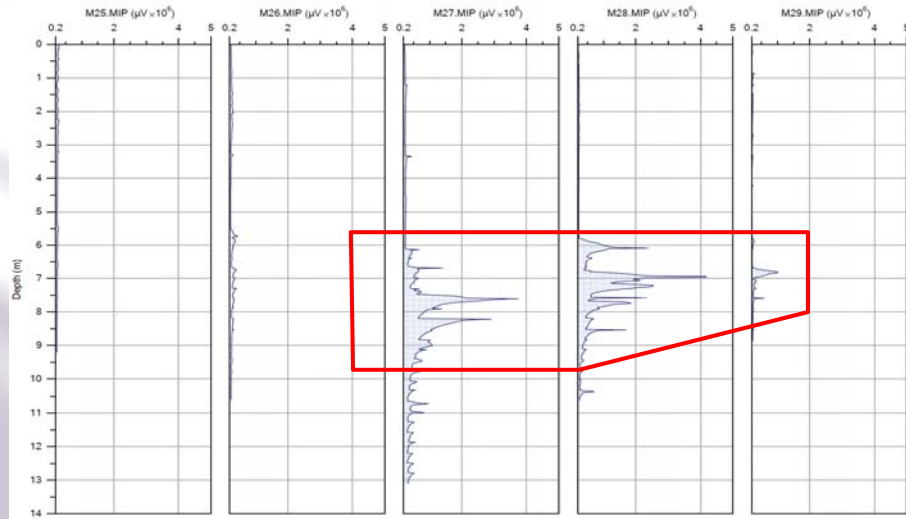


Electrical Conductivity (EC)

- Soil classification
- Smaller grain sizes have a relatively high conductivity



MIP Output

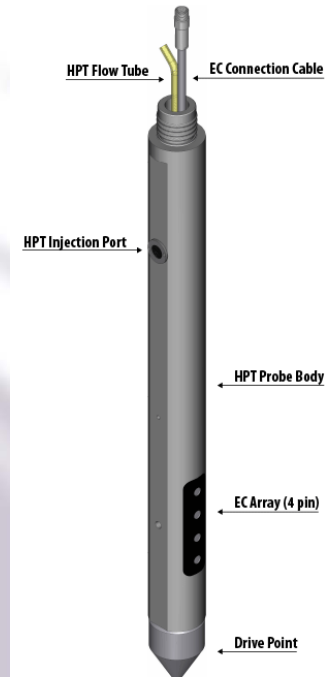


Cross Section of MIP Points

Hydraulic Profiling Tool

for estimating Formation Permeability






Hydraulic Profiling Tool

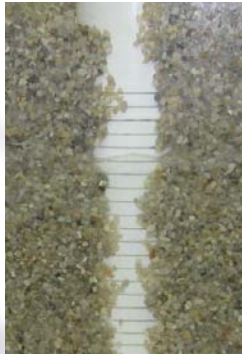
- Direct Push
- Assess Groundwater Permeability
- Water Injected into the Ground
 - Flow and Back-pressure measured
- EC: Estimate Soil Type
- Result: Hydraulic Conductivity
 - on a cm scale

High Resolution

How High is High Resolution?



Traditional Methods



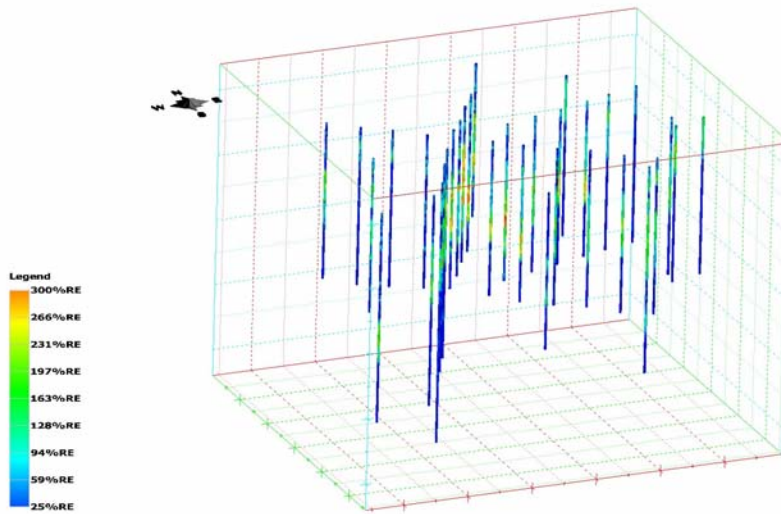
High Resolution



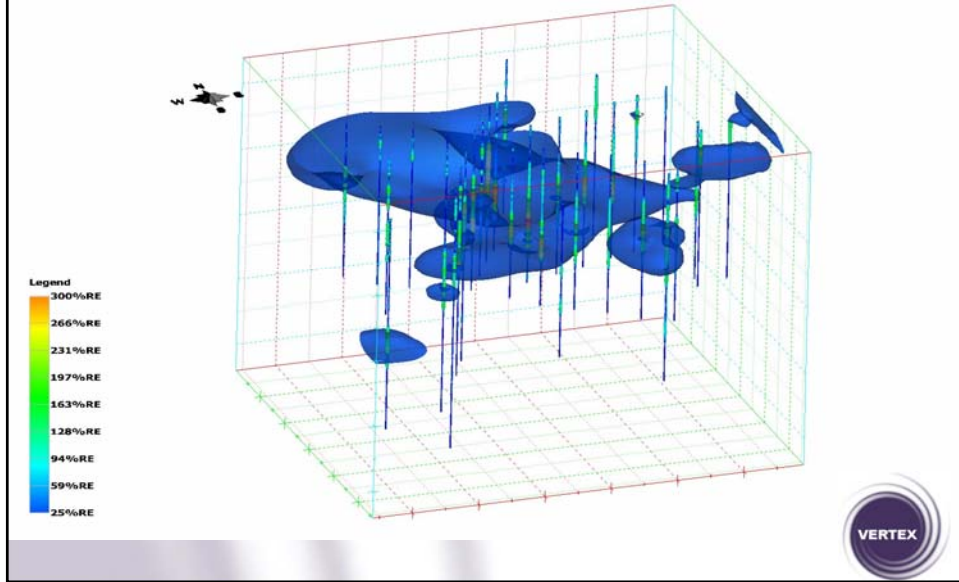
VS

Characterization	Resolution	Daily Data Points
Monitoring Well	1 screen	4
MIP	60 m/day x 30 cm	200
LIF	90 m/day x 1 cm	9,000
HPT	60 m/day x 1 cm	6,000

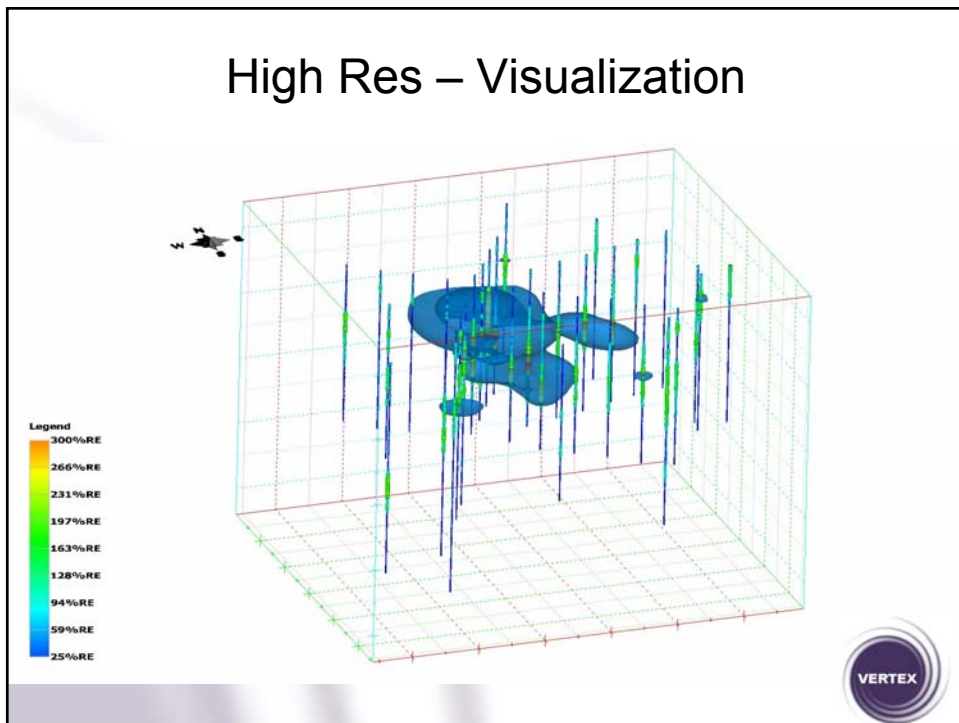
High Res – Visualization



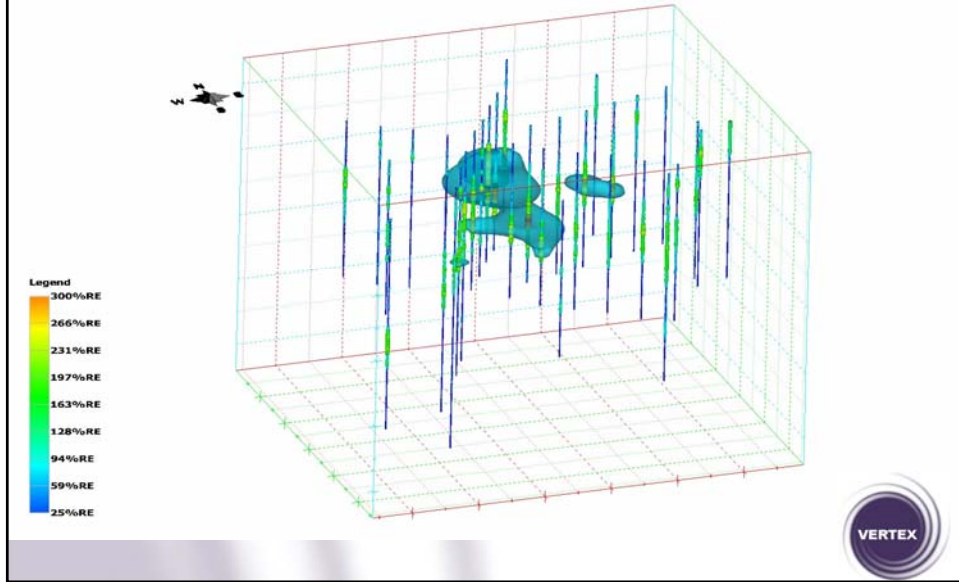
High Res – Visualization



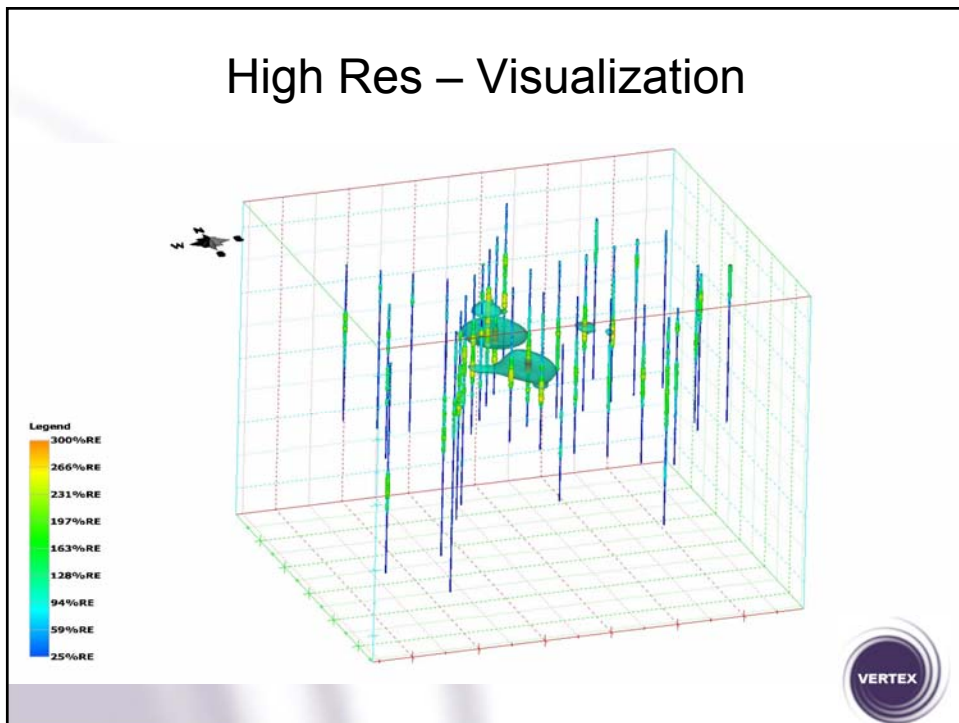
High Res – Visualization



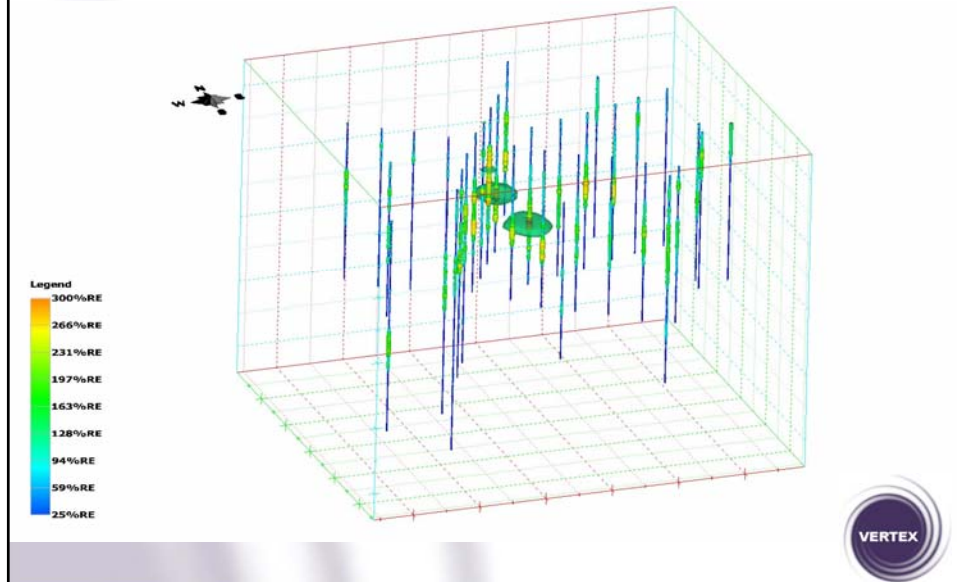
High Res – Visualization



High Res – Visualization



High Res – Visualization



Case Study #1

Using High Res
to Define Contamination



Case Study #1

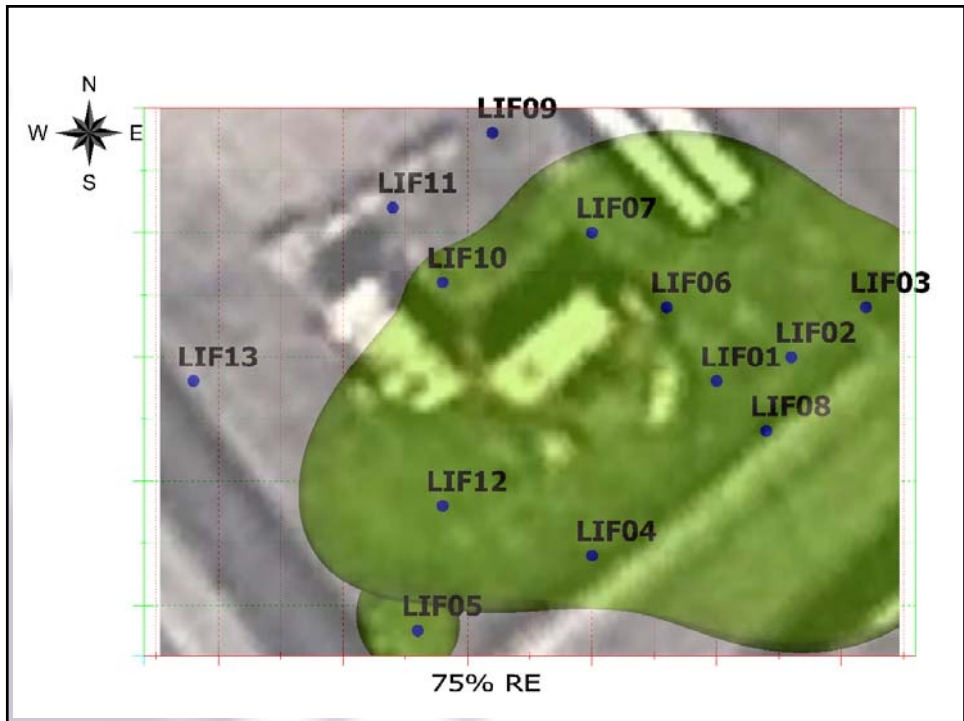
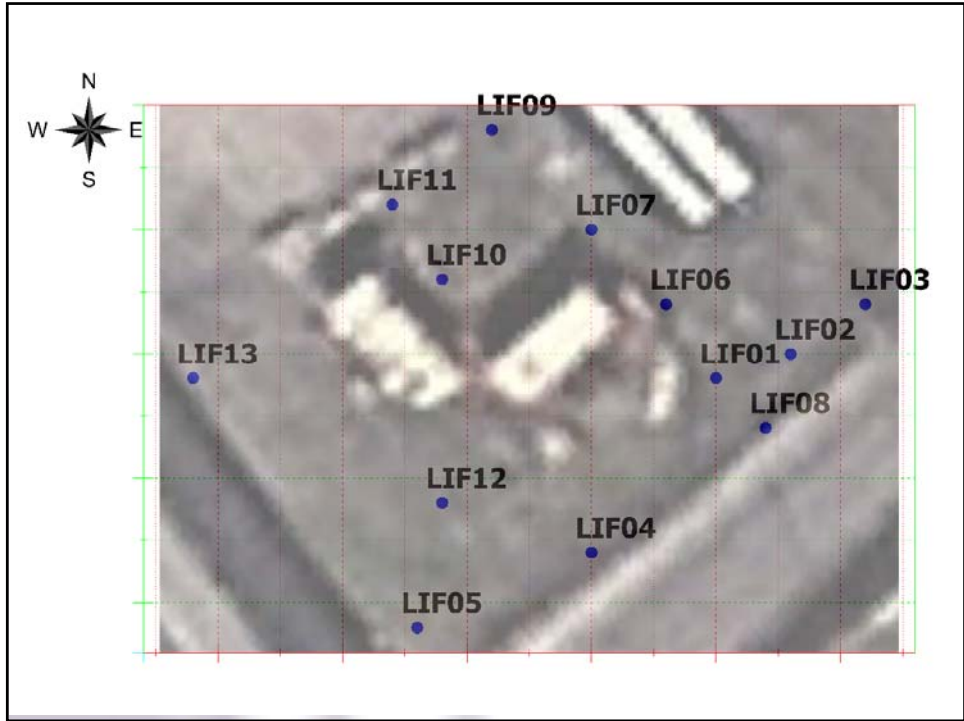
Site details / background:

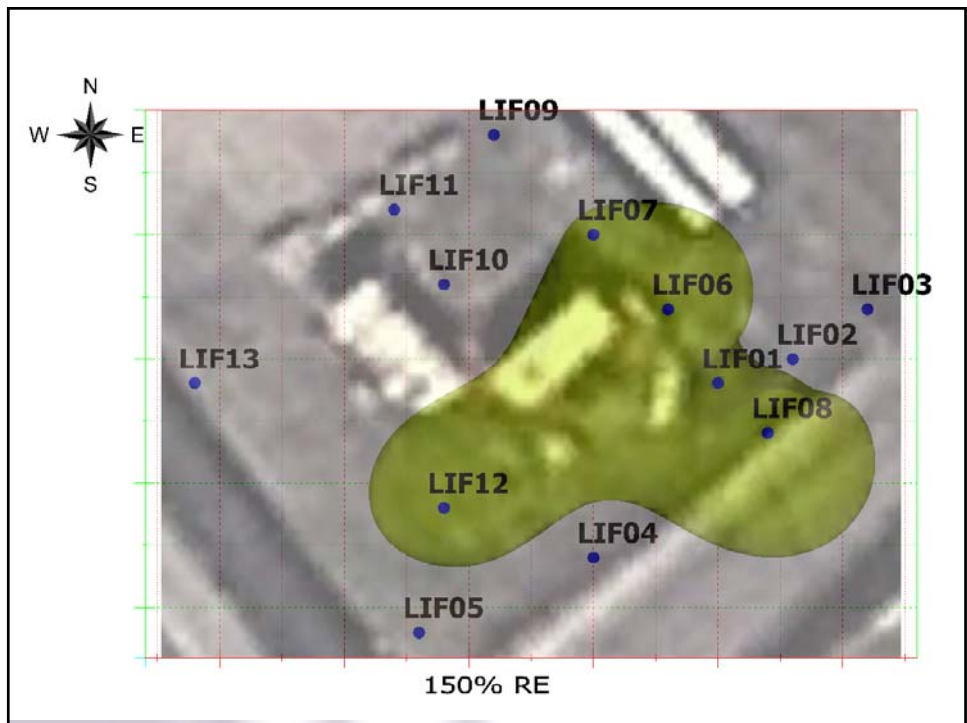
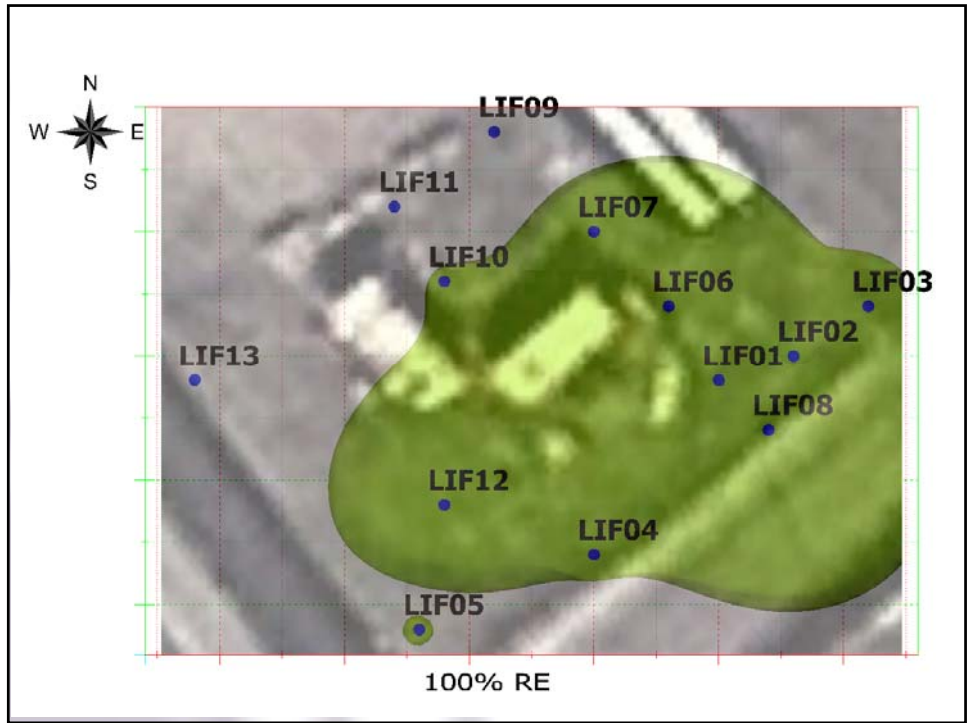
- Quebec
- By active rail yard
- Roads and rail all around Site
- Fuel leak: PHC impacts
- Small area but deep (10 m) PHC & LNAPL
- MPE system installed on-site
- High resolution to assist with vertical and horizontal definition of PHCs

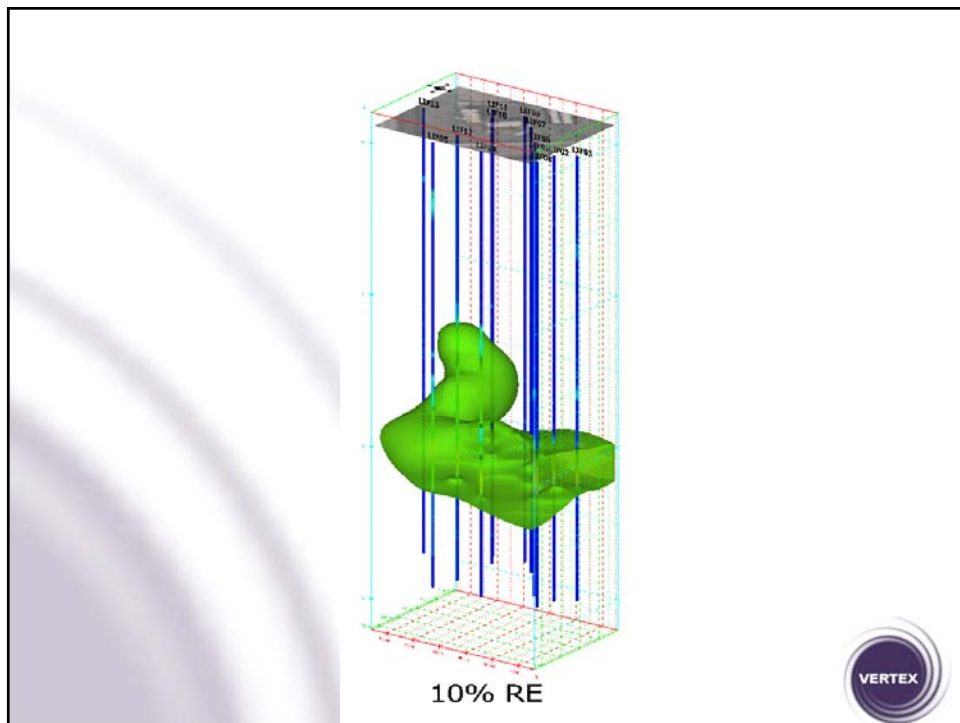
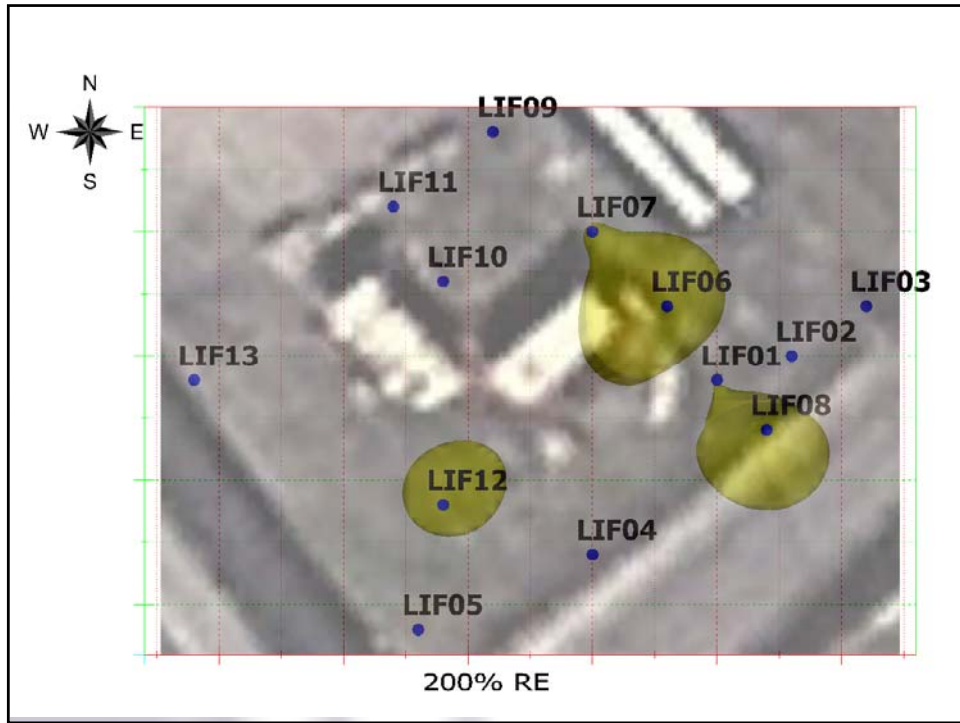


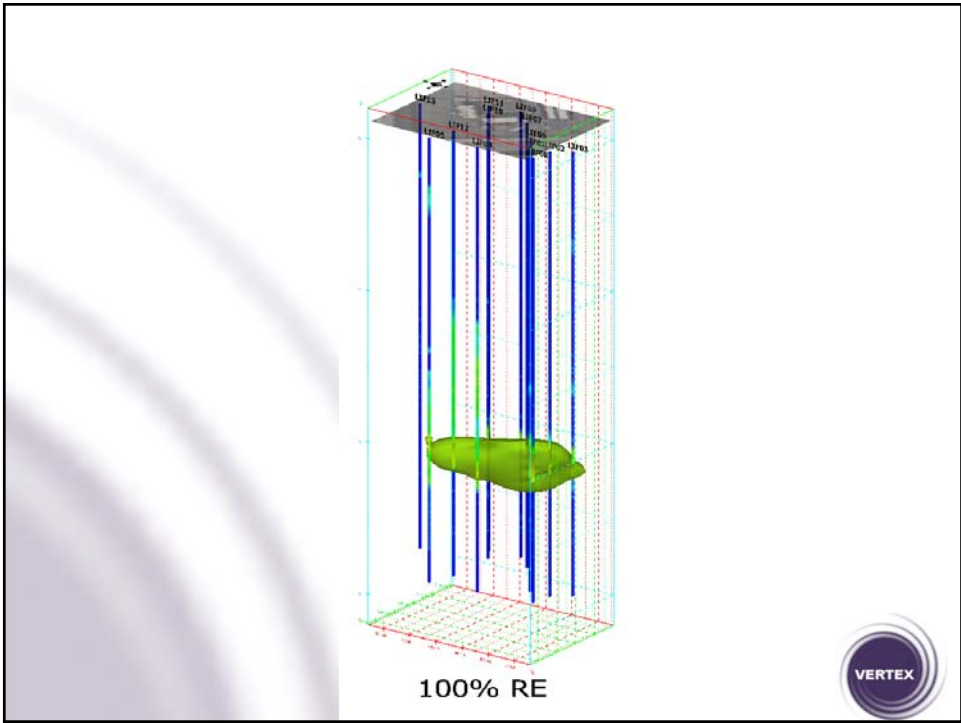
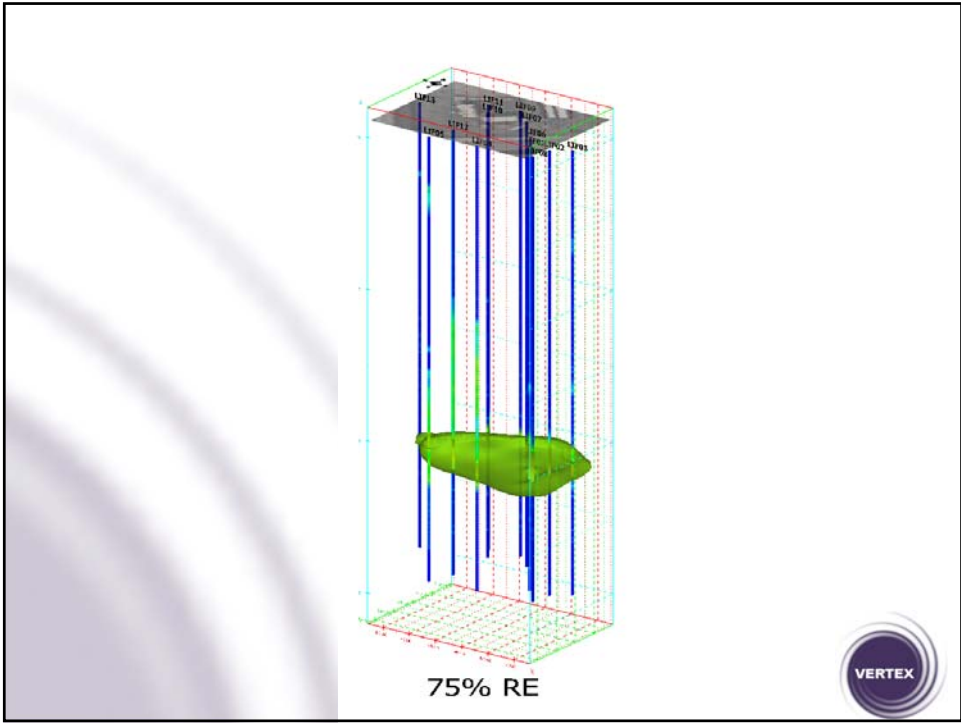
Case Study #1

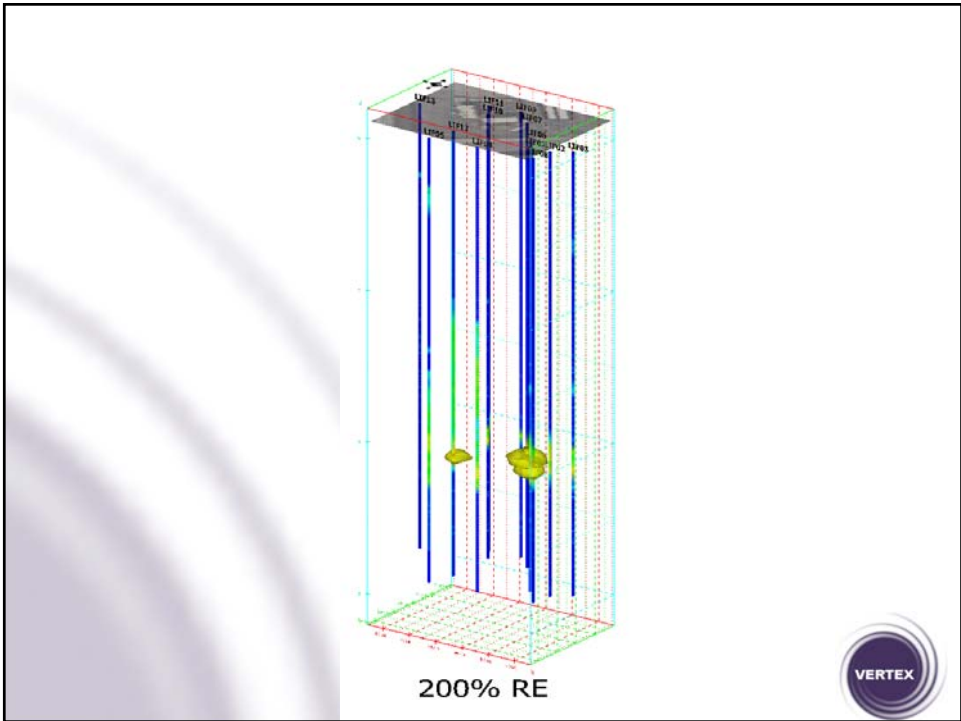
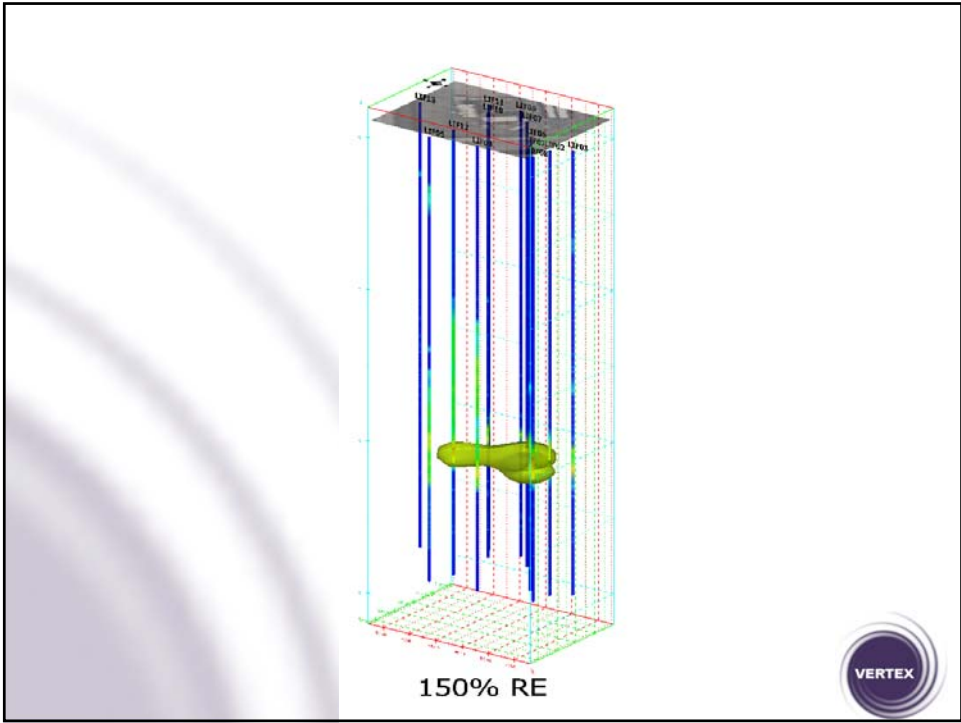


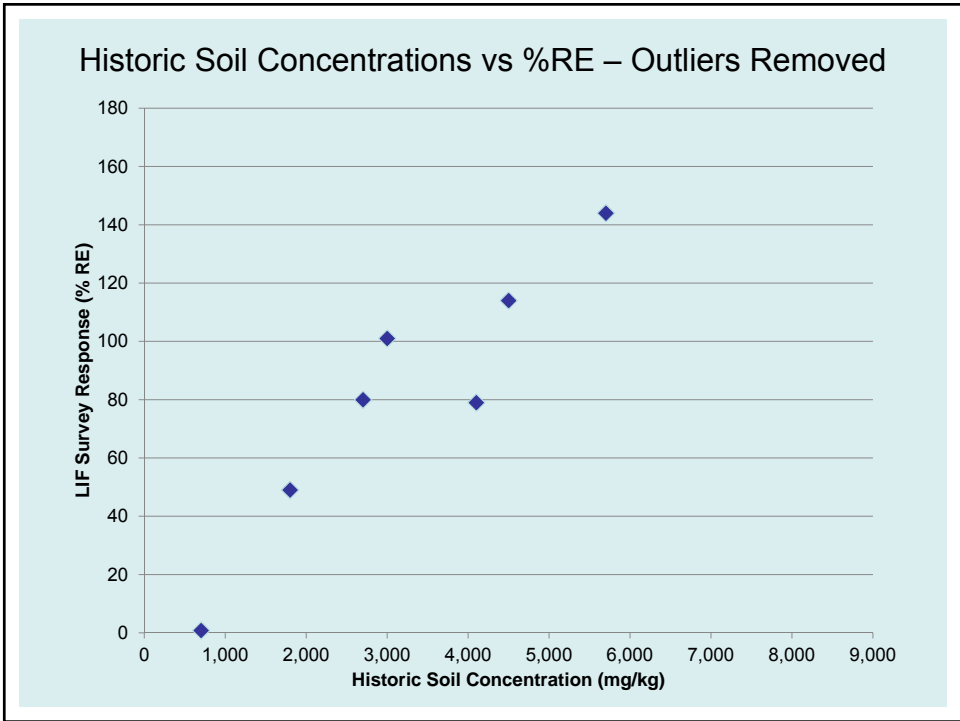
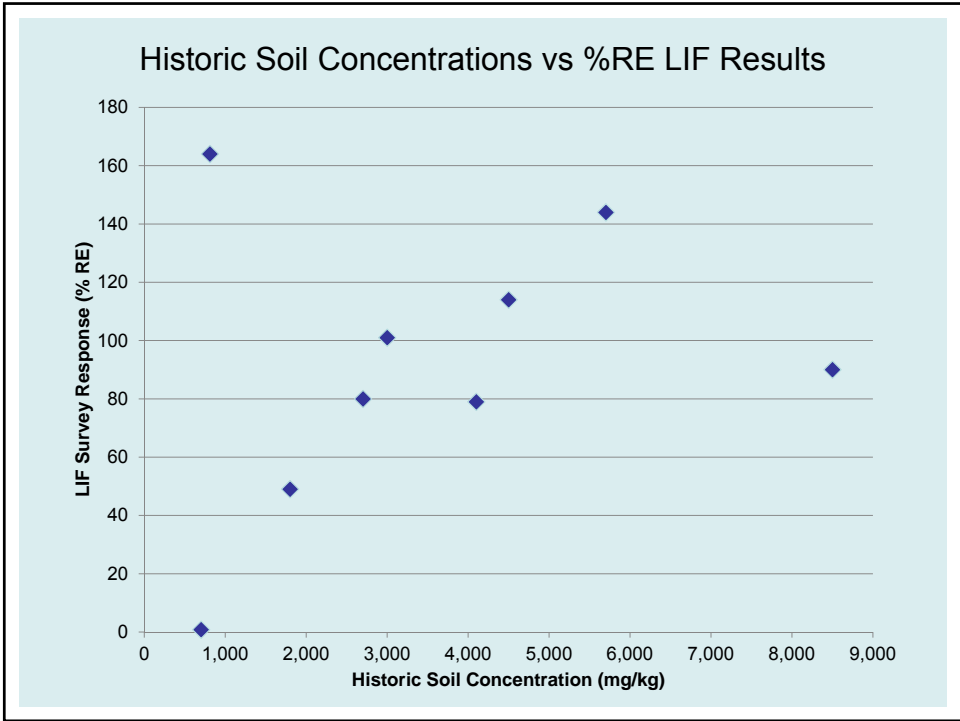


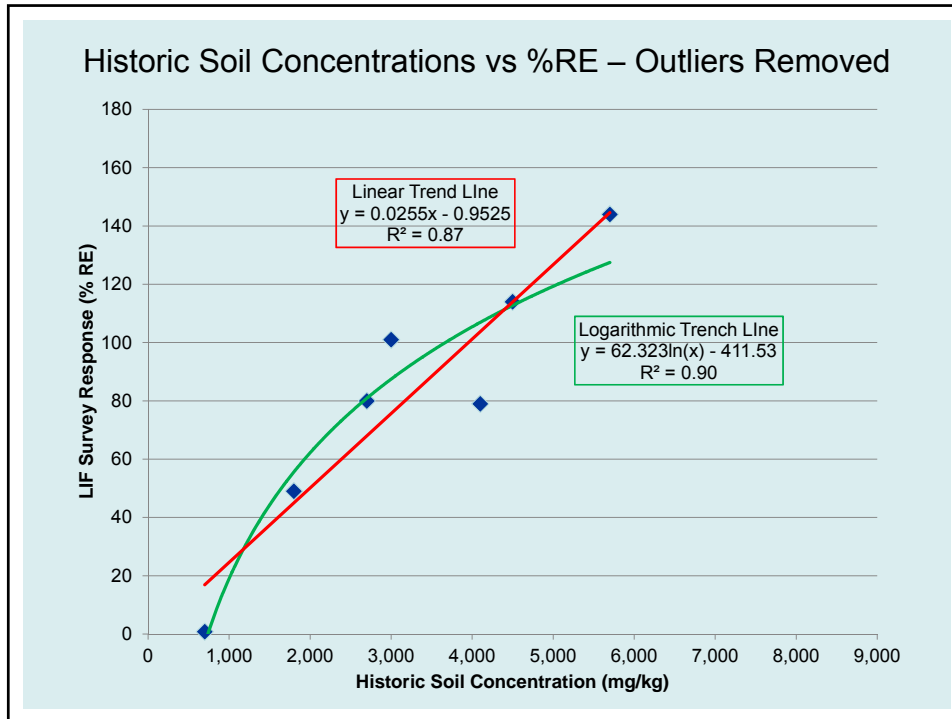












Case Study #1

- Clean-up Criteria = 3,500 mg/kg PHCs
 - Linear correlation: 3,500 mg/kg = ~88 %RE
 - Logarithmic correlation: 3,500 mg/kg = ~97 %RE
- Take Away – Based upon LIF we can:
 - Effectively plan remediation and/or RA
 - Look for PHC seams
 - Plan MPE and/or excavation with confidence

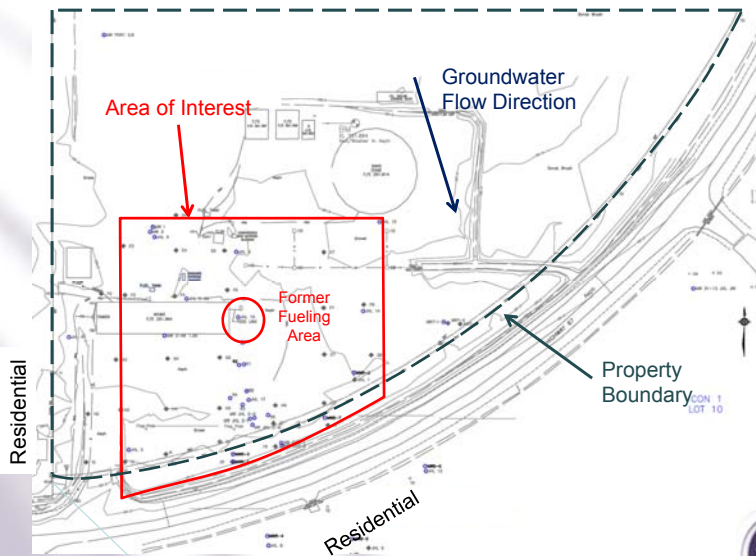


Case Study #2

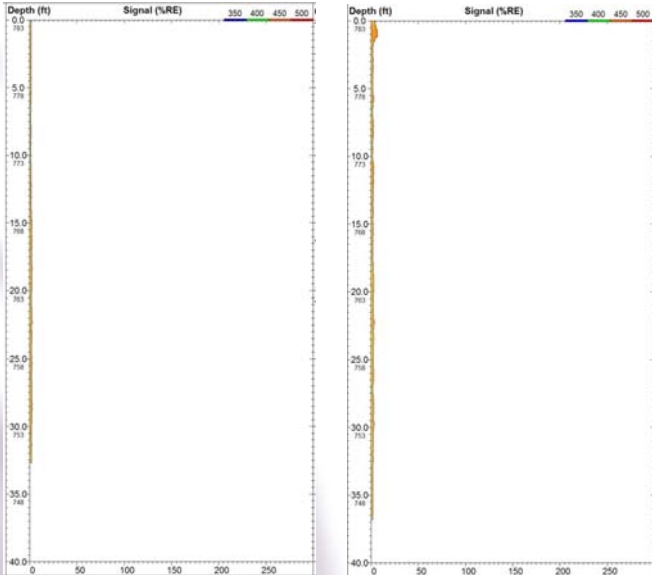
Using High Res to Define ISCO



Case Study #2



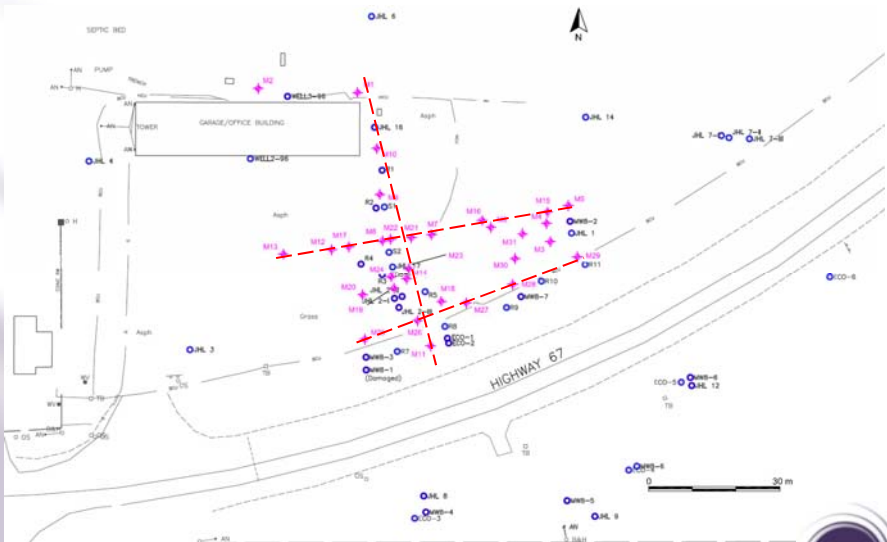
LIF Results



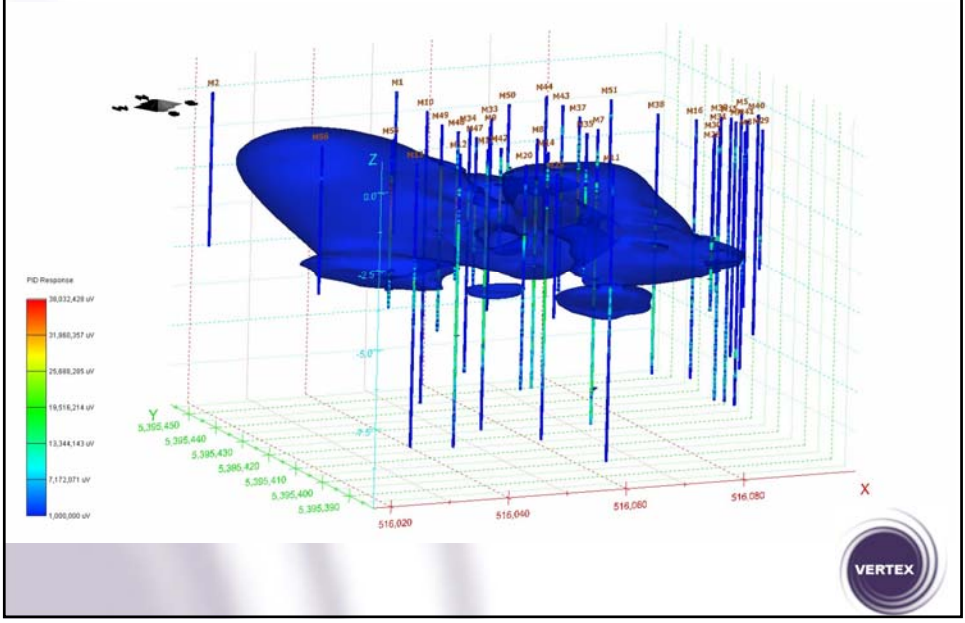
No NAPL detected



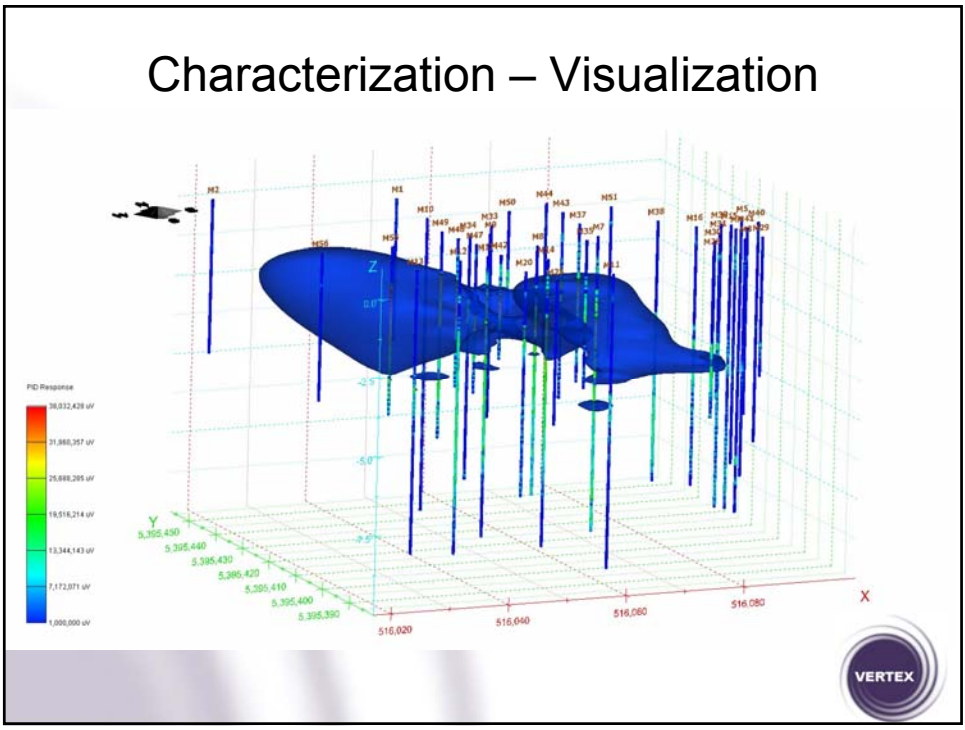
MIP Investigations



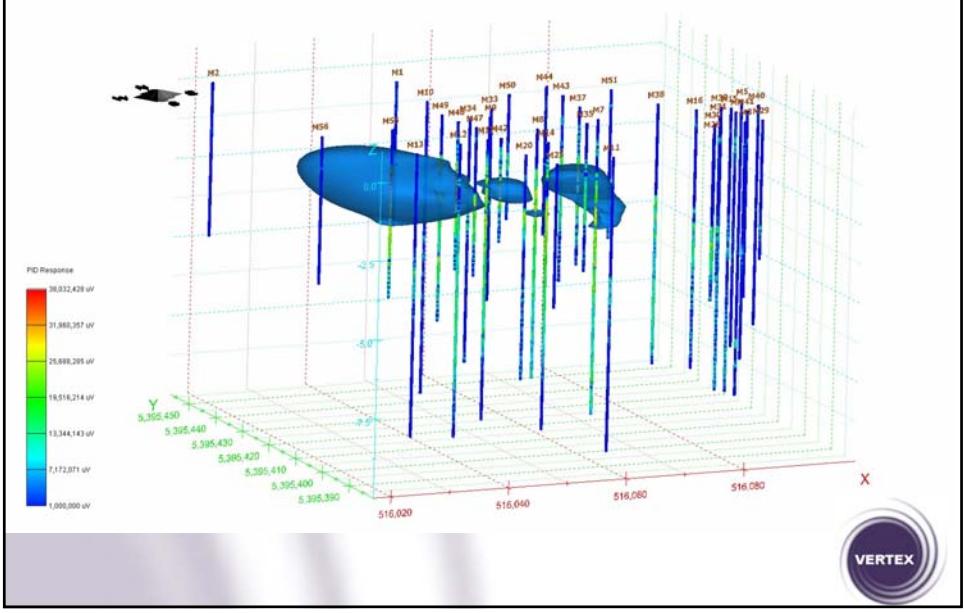
Characterization – Visualization



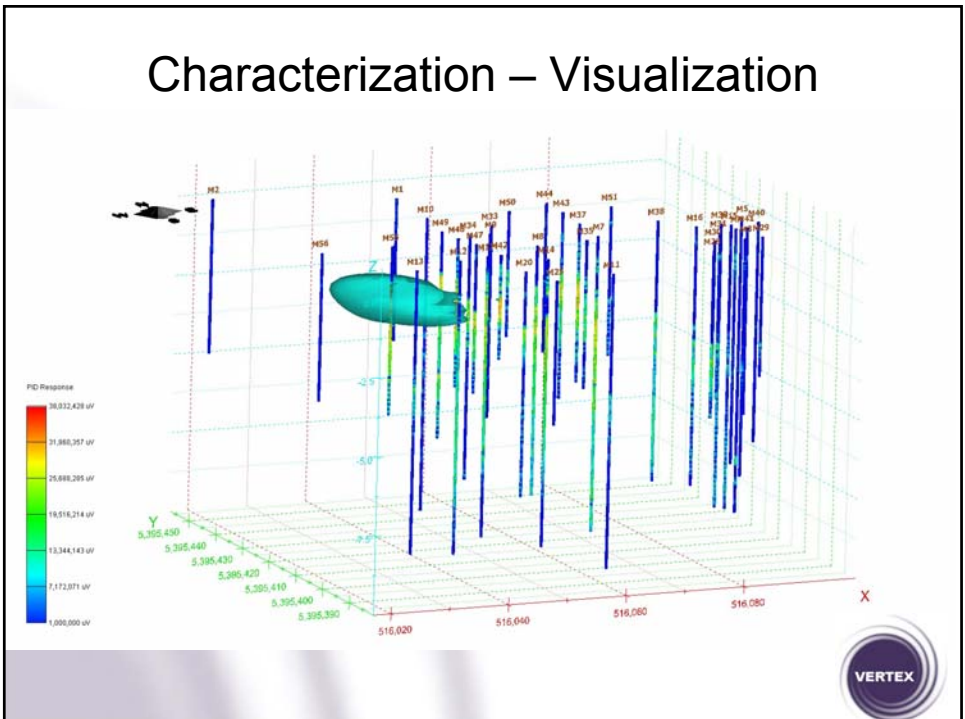
Characterization – Visualization



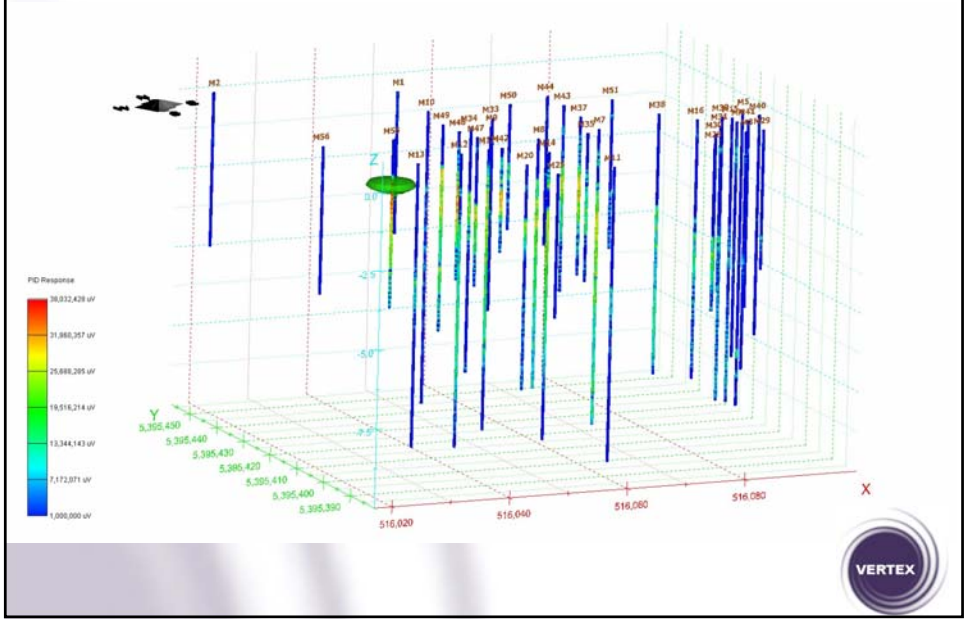
Characterization – Visualization



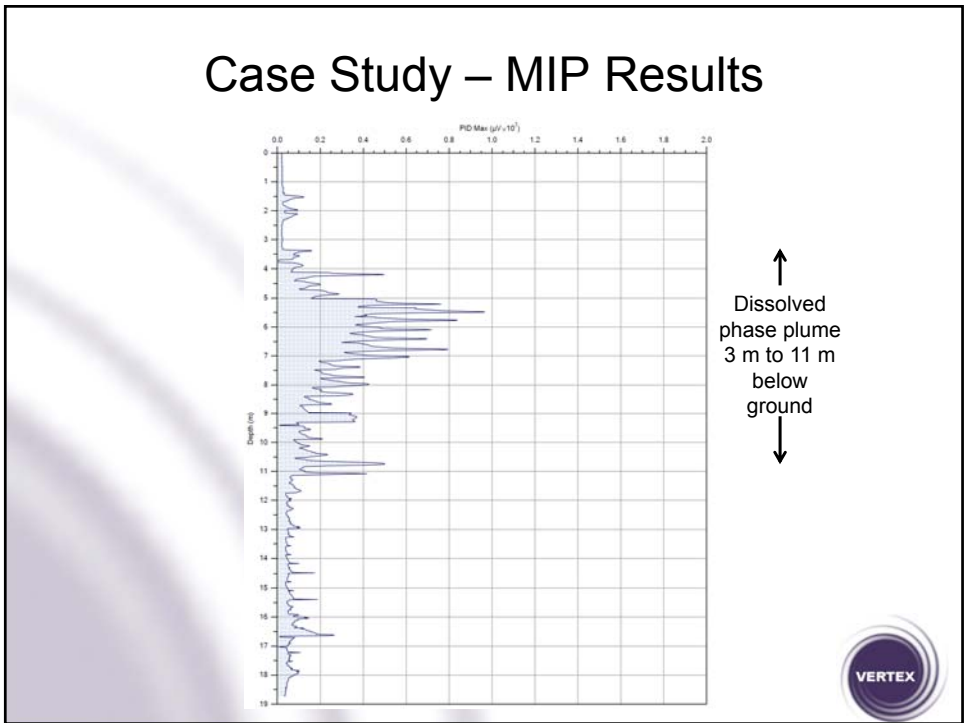
Characterization – Visualization



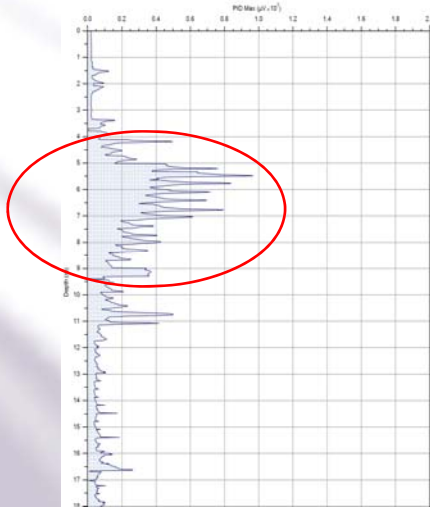
Characterization – Visualization



Case Study – MIP Results



Case Study - Oxidant Loading Rates



Original Design: Inject 29.6 kg/m
from 3 m to 23 m bgs

Original Design (kg/m)	Re-Design (kg/m)	Depth (m)
0.0	0.0	0 m
29.6	38.0	3 m
	44.3	
	31.7	
	25.3	
	19.0	23 m

MIP Results

MIP PID Results

Interim MIP sampling

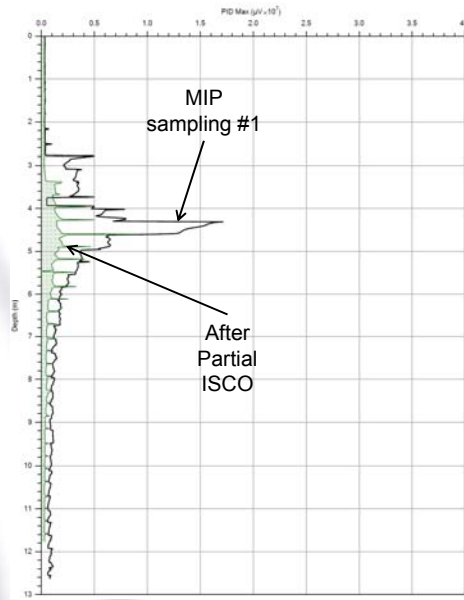
Fall 2011
Black Line

After Partial ISCO

Summer 2012
Green Line

Location

Core of Injection



MIP Results

MIP PID Results

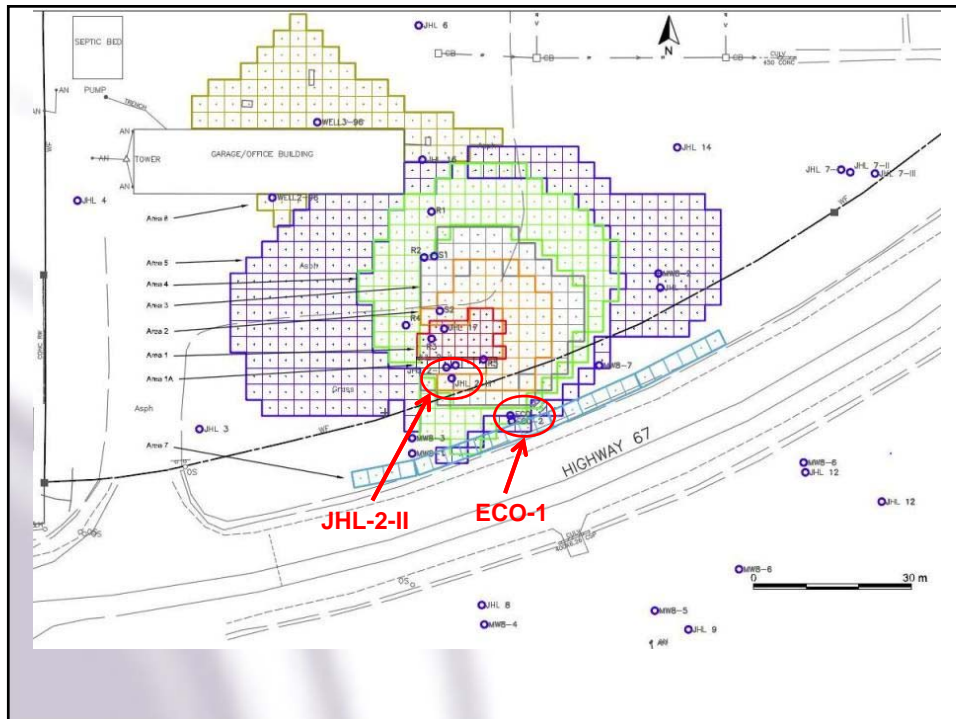
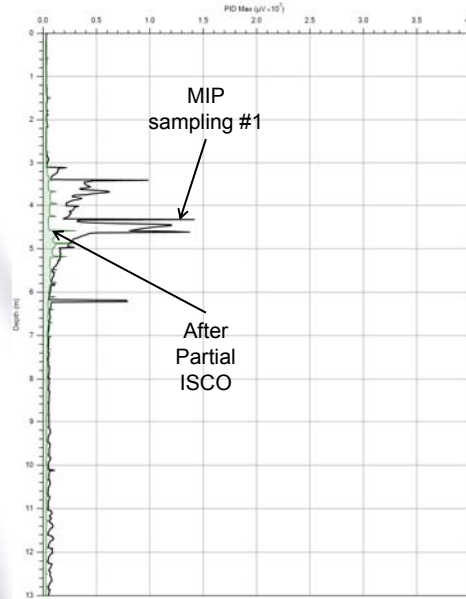
Interim MIP sampling

Fall 2011
Black Line

After Partial ISCO

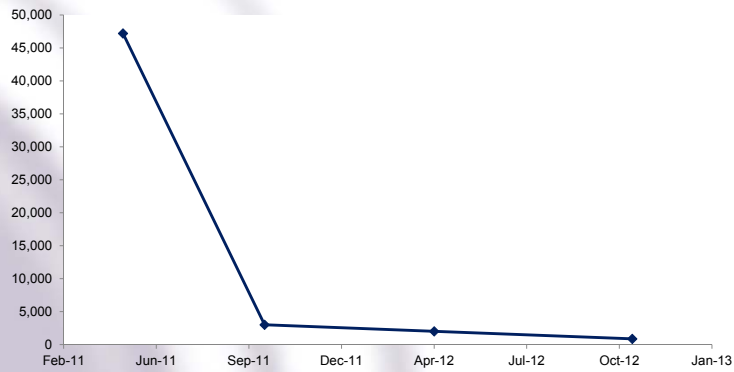
Summer 2012
Green Line

Location
East Edge of the Core of Injection



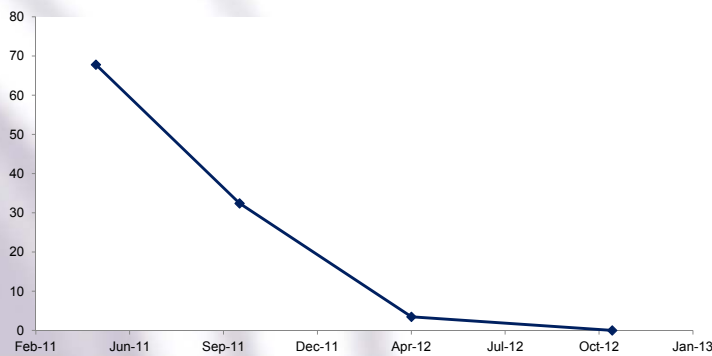
Case Study – Analytical Results

Parameter	Units	Groundwater Standards	JHL2-II (11 m, 35 ft)				% Reduction
			May-11	Oct-11	Apr-12	Nov-12	
Total BTEX & PHCs	ug/L	-	47,190	3,026	2,017	894	98
PHC(F1-C6 to C10)	ug/L	750	25,000	<130	850	530	98



Case Study – Analytical Results

Parameter	Units	Groundwater Standards	ECO-1				% Reduction
			May-11	Oct-11	Apr-12	Nov-12	
Total BTEX & PHCs	ug/L	-	68	32	4.0	<0.40	
Benzene	ug/L	5.0	51	12	4	<0.2	100
PHC(F1-C6 to C10)	ug/L	750	<100	<25	<25	<25	-



Conclusions / Summary

“It is better to be roughly right
than precisely wrong”

- High Resolution Characterization:
 - LIF: free phase = 1 cm resolution
 - MIP: dissolved phase = 30 cm resolution
 - HPT: groundwater permeability = 1 cm resolution
 - High res data – produce 3D visualization



Questions?

Thank You for
Your Time

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