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Tools and Methods to Reduce and Control Uncertainties Associated with the Use of In Situ Remediation Techniques (Chemical Oxidation) for Organic Contaminants in Soil and Groundwater

Remtech 2010
Banff, Alberta

Prepared by Jean Paré, P. Eng.
Chemco Inc.

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The Chemistry works but the geology screw it up …

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Presentation Agenda

- Chemical Oxidation – Technology Review and Limitations
- Field application challenges and contact issue
- Tools, testing and tricks
  - Before you get to the field
  - When you're in the field
  - Follow up After injection events
- Case Study Presentation

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Chemical Oxidation – Technology Review

- Oxidants are introduced or mixed into the soil and groundwater to attack the organic contaminants
- Chemical oxidation treatments are commonly used in potable and wastewater applications
- Oxidants are non-specific and will react with the targeted contaminants AND with the soil organic content (SOD).
- Chemical oxidation reactions involve the transfer of electrons and the breaking of chemical bonds
- Water is the carrier for the oxidants used in chemical oxidation (except for ozone)
- If you have enough oxidant present and sufficient time you will push reaction to FULL mineralization (CO_2, H_2O, Cl^-) of the contaminant of concern

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Common Chemical Oxidants

- Potassium or sodium permanganate
- Hydrogen Peroxide alone
- Catalyzed Hydrogen Peroxide
  - Hydrogen Peroxide with iron (regular Fenton reagent reaction)
  - Need to establish acidic conditions (ideal pH between 4 and 6)
  - Modified Fenton Reagent with chelated species (neutral pH)
- Ozone
  - Ozone is a gas and must be produced on site
  - The gas must be injected into the soil
- Persulfate
  - Requires activation to generate free sulphate radicals.
  - Heat, chelated metal, high pH or hydrogen peroxide can be used to activate the persulphate. Activation method can be adapted to site conditions.
- Percarbonate
  - Requires activation to generate free radicals

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Chemical Oxidation – Limitations

- All chemical oxidation reactions occur in the WATER or moisture phase (except for ozone)
- Kinetics of the chemical oxidation reaction is thus influence by the contaminant of concern solubility and availability in the groundwater or moisture phase
- Sorbed phase contamination might be challenging to remediate (less available)
- In NAPL containing sites, contamination can persist because of the highly hydrophobic properties of the chemicals that make up the NAPLs
- Injection technique must induce proper contact between the contaminant and the oxidant for a proper duration for the required reaction to occurs (kinetics)

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Field application challenges and contact issue

- Good treatment require good contact
- Application challenges
  - Geology (Silts and Clays, Sands, gravel and other)
  - Heterogeneity
  - Low GW Velocity
  - < Fracture Pressures
  - High Volumes to inject
  - Reagent Kinetics
  - Depth
    - Shallow environment
    - Deep environment

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Field application challenges and contact issue

14 Subsurface Compartments Potentially Containing Chlorinated Solvents

	Source		Plume	
	Transmissive	Low Permeability	Transmissive	Low Permeability
DNAPL	Low Pressure Injection	Mixing or Heating	Absent	Absent
Aqueous	Low Pressure Injection	Fracturing	Low Pressure Injection	High Pressure Injection
Sorbed	Low Pressure Injection	Fracturing	Low Pressure Injection	High Pressure Injection
Vapor	x	x	x	x

Source – Management of Chlorinated Solvents in Soils and Groundwater, August 2009 -ESTCP

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Before you get to the field

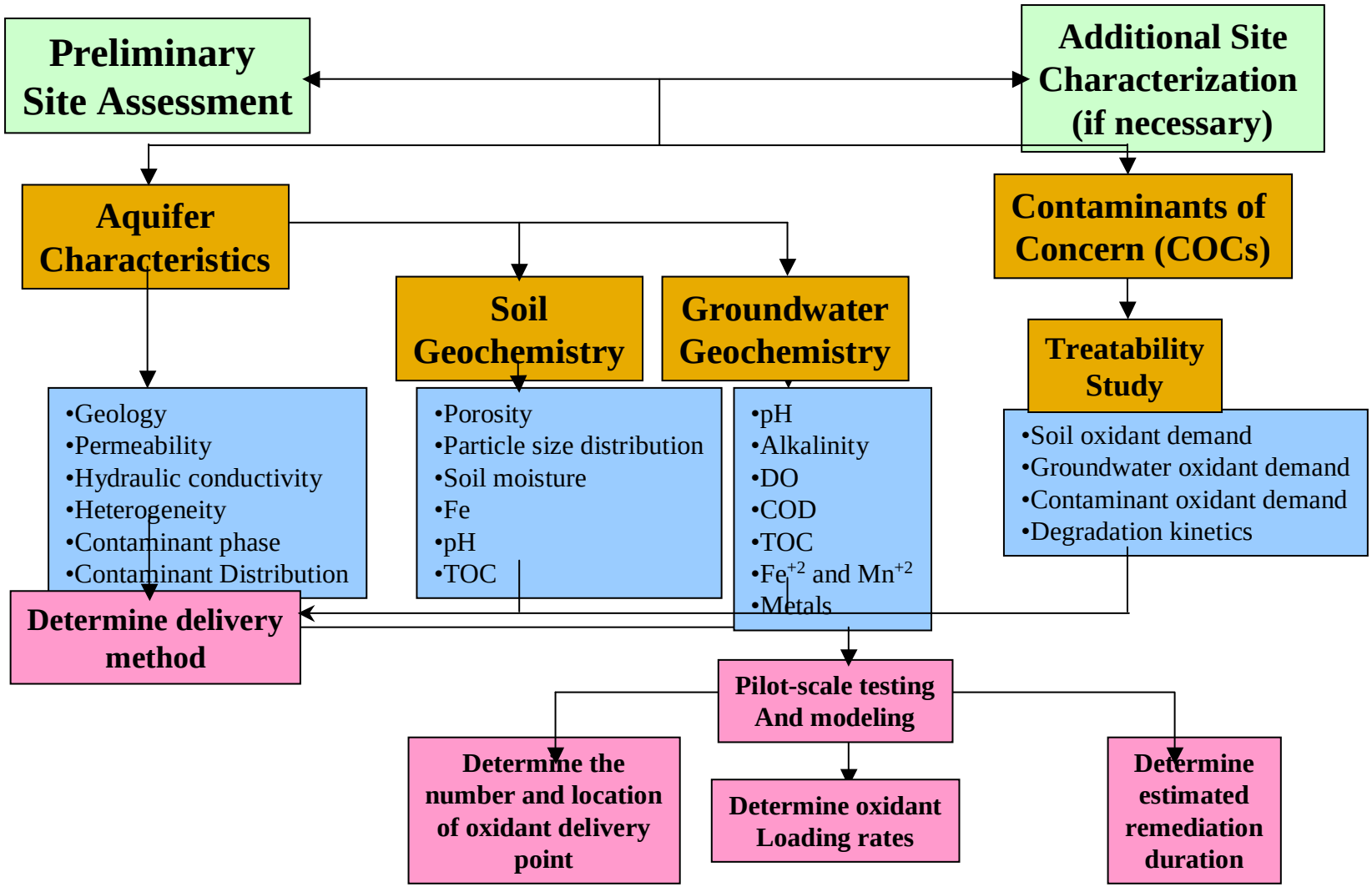
- Validating the qualification and quantification of the selected oxidant or amendment with bench scale lab study

  Soil and Groundwater Oxidant Demand validation and treatability study are ALWAYS recommended

  (If it doesn't work in the lab in ideal contact condition it WON'T work in the field)

- Make sure you have all the necessary data and you injection plan is set properly

Carus Haz Rem Assessment Process



(Adapted from R. L. Siegrist et al., "Principles and Practices of In Situ Chemical Oxidation Using Permanganate", p. 202.)

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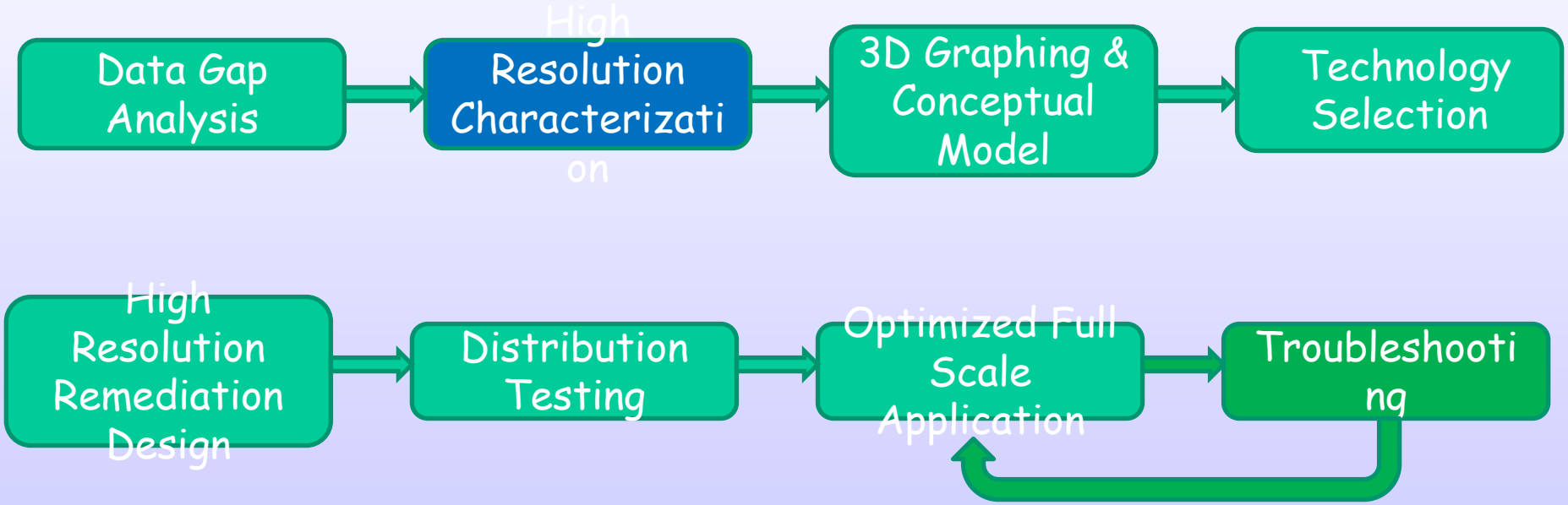
Tools, testing and tricks

Search and Destroy™ Methodology Targeted Distribution



Source - Vironex

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Tools, testing and tricks

When you're in the field

- Making sure you are injecting in the adequate zone
  CHARACTERIZE, CHARACTERIZE, CHARATERIZE
- Validating the distribution and dilution of the oxidant or amendment in the subsurface aquifer through the use of an INERT tracer PRIOR moving with you're expensive oxidant or amendment.
- Evaluate the pro and cons of the various equipments and techniques to induce proper contact

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Tools, testing and tricks

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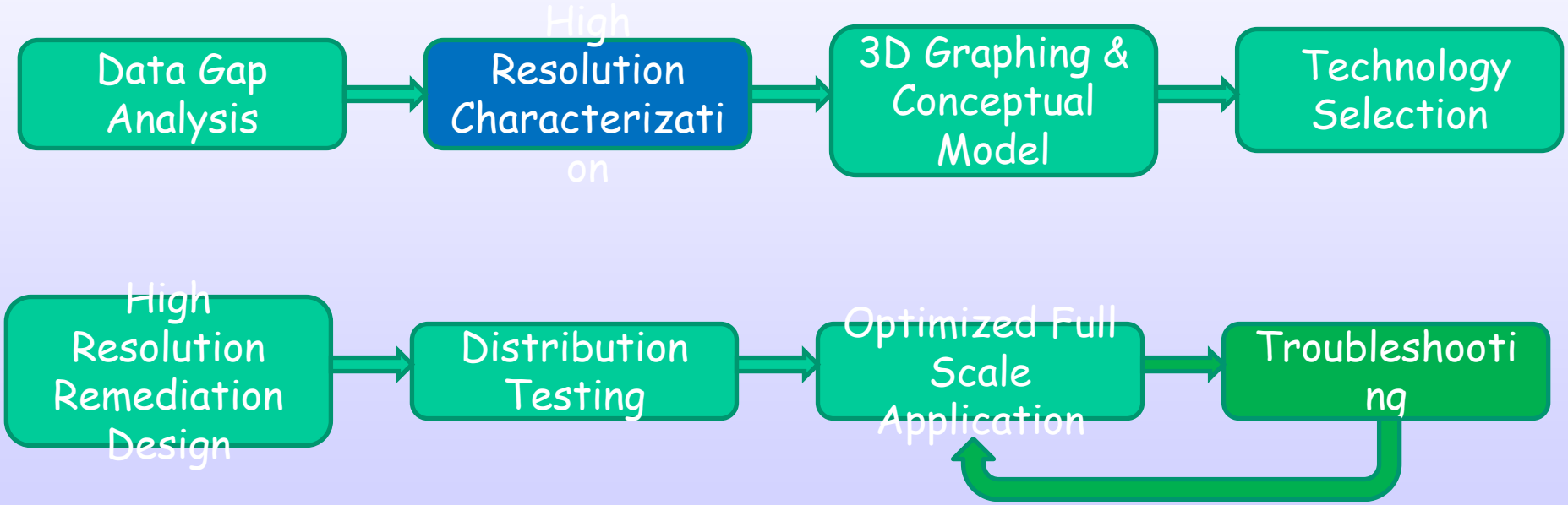
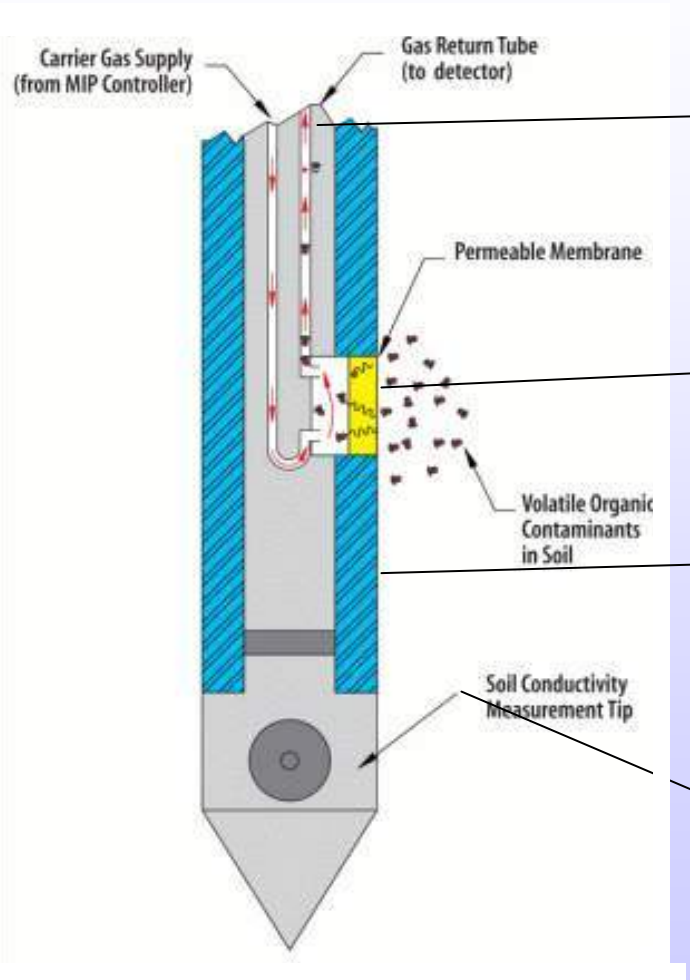


Source - Vironex

Search - **How The MIP Works**

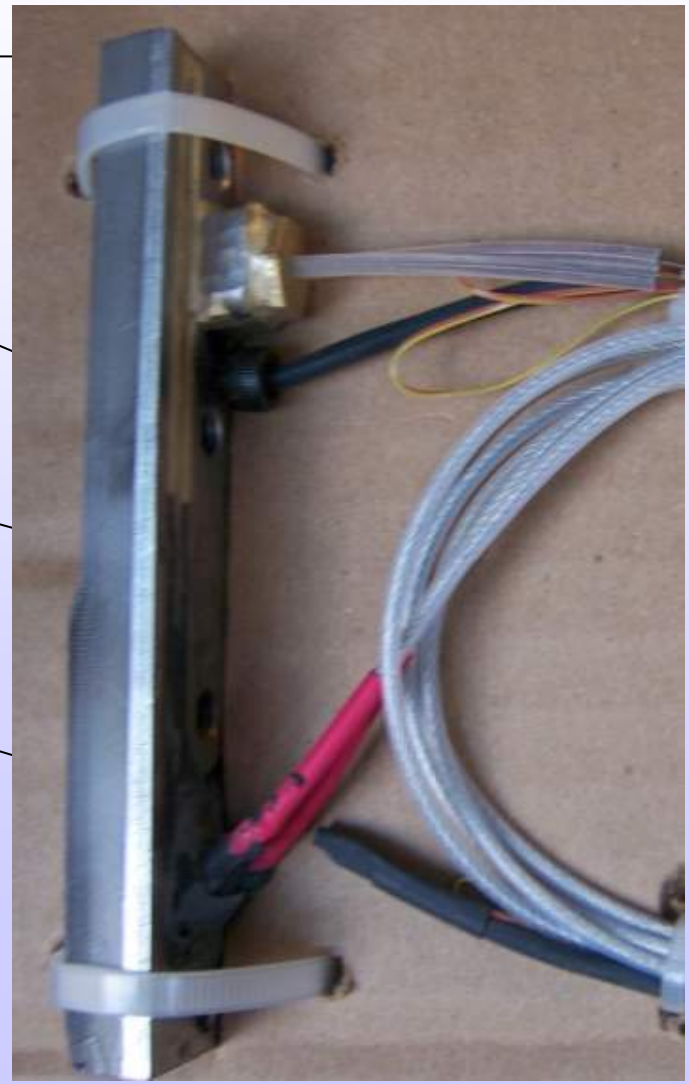


Nitrogen Carrier Gas

Permeable Membrane

Heater Block 120^0C

Soil Conductivity



Source - Vironex

Vironex
1225 East McFadden Ave
Santa Ana, CA 92705
P:(714) 647-8290
F:(714) 647-8291
www.vironex.com

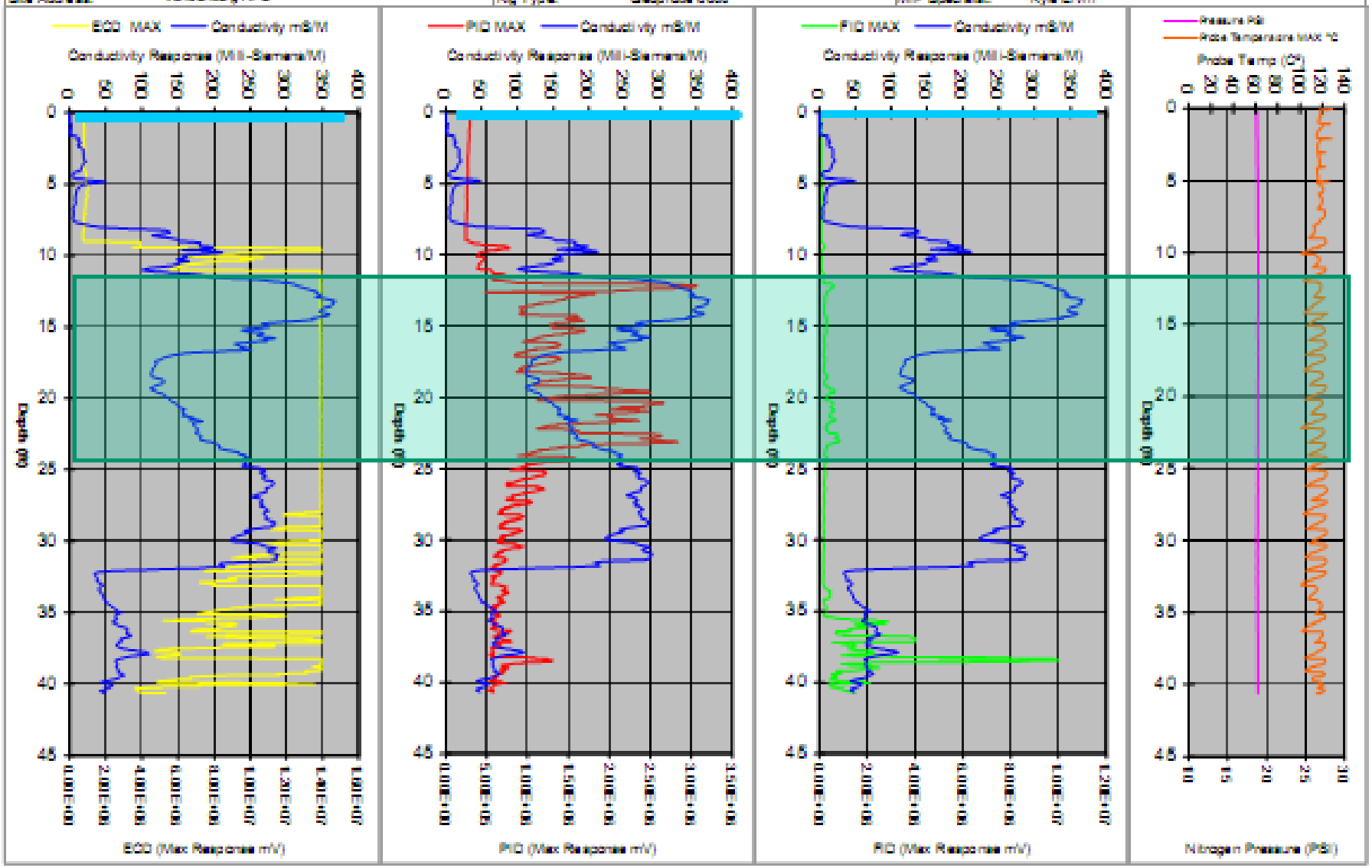
Boring Name: 3-MIP-10 **Total Depth (ft):** 40.65

Notes:

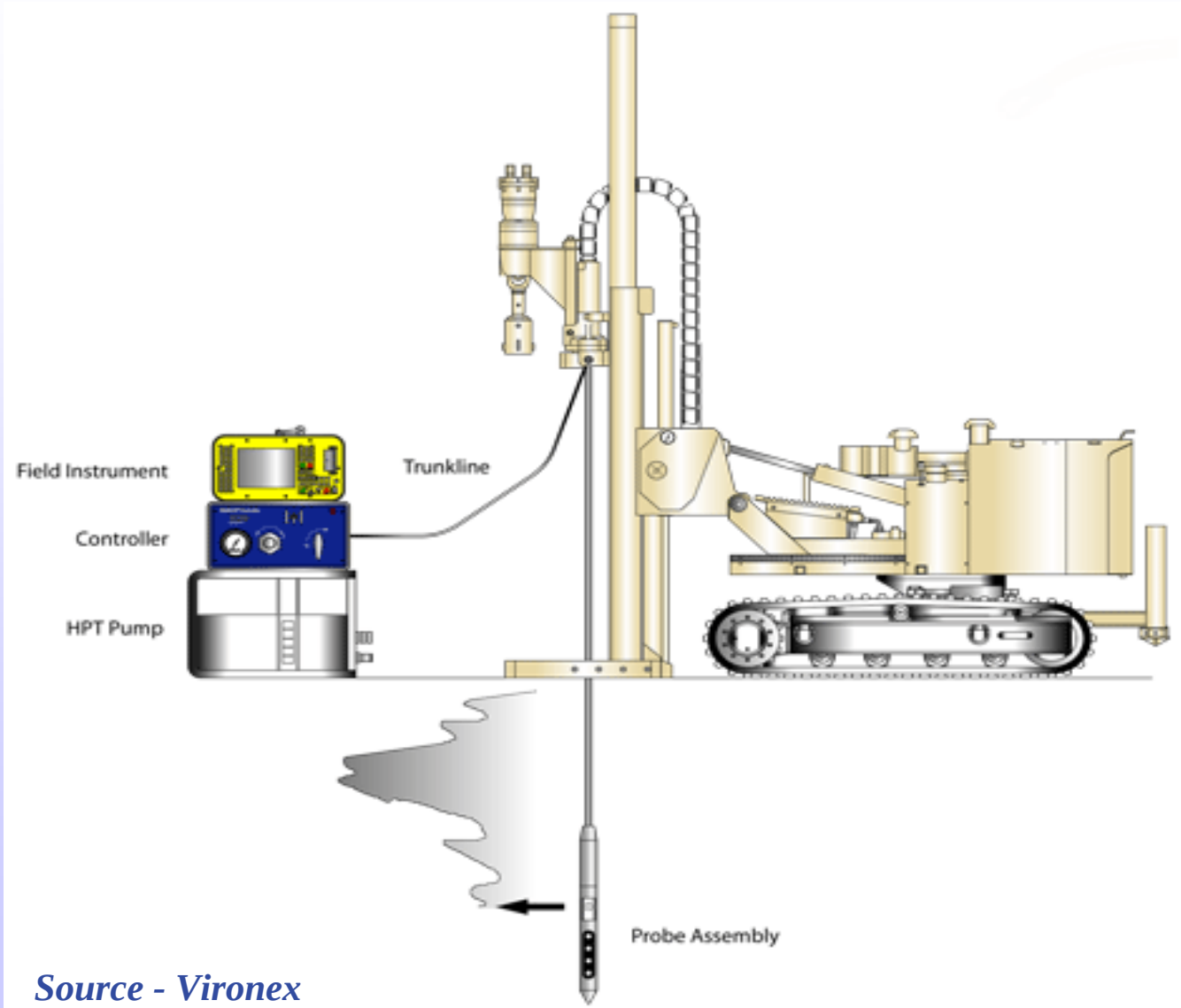
GW Depth (ft):

Depth to GW Provided by Client

Job Information		MIP Sampling Information			
Client Company:	Tetra Tech	Trunkline Length:	150'	Start Boring Time:	Fri Apr 25 2008 13:17
Project Name:	Vandenberg AFB MIP	Probe Type:	6510	End Boring Time:	Fri Apr 25 2008 14:02
Site Address:	Vandenberg AFB	Rig Type:	Geoprobe 6600	MIP Specialist:	Kyle Ervin



Search - **How The HPT Works**



Source - Vironex

Search - **Why MIP/HPT before injecting ?**

- Locate contaminant mass through high vertical resolution
- Define injection flows and pressures
- Don’t get fooled by tight sands or clays with low conductivity

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Tools, testing and tricks

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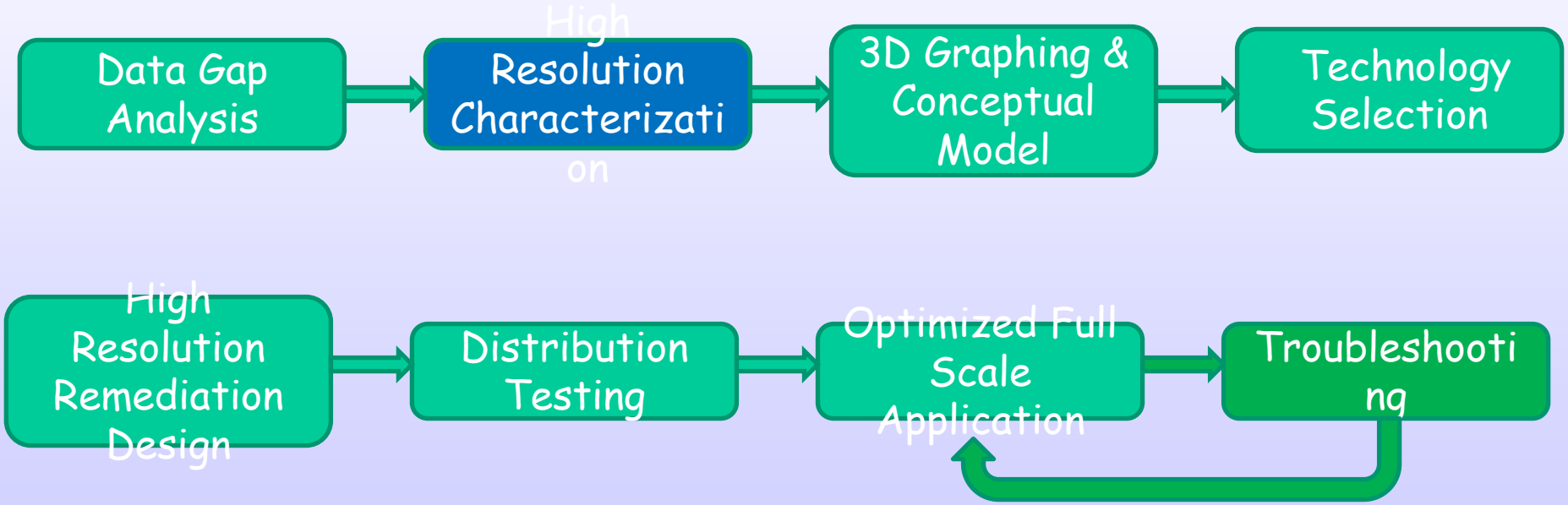
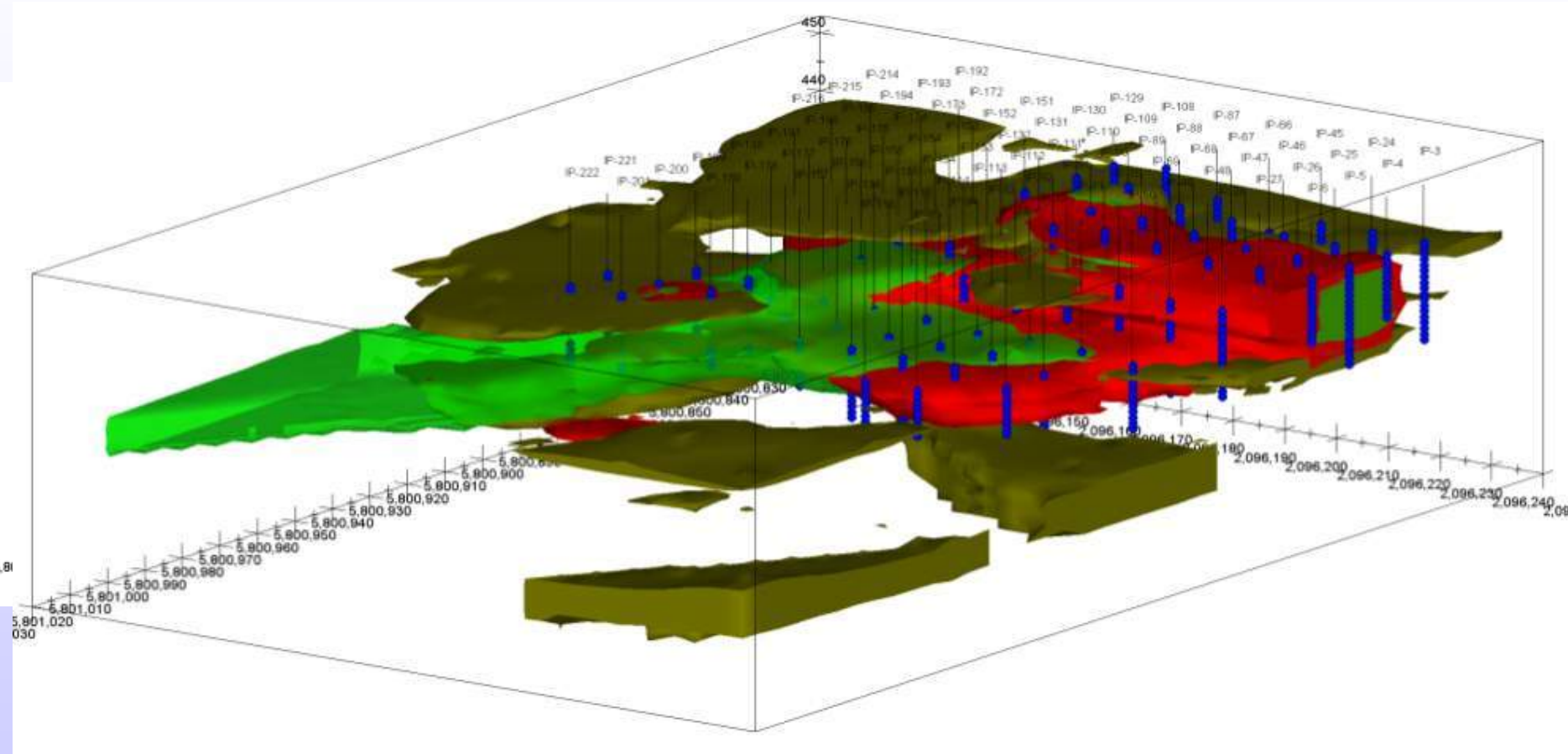
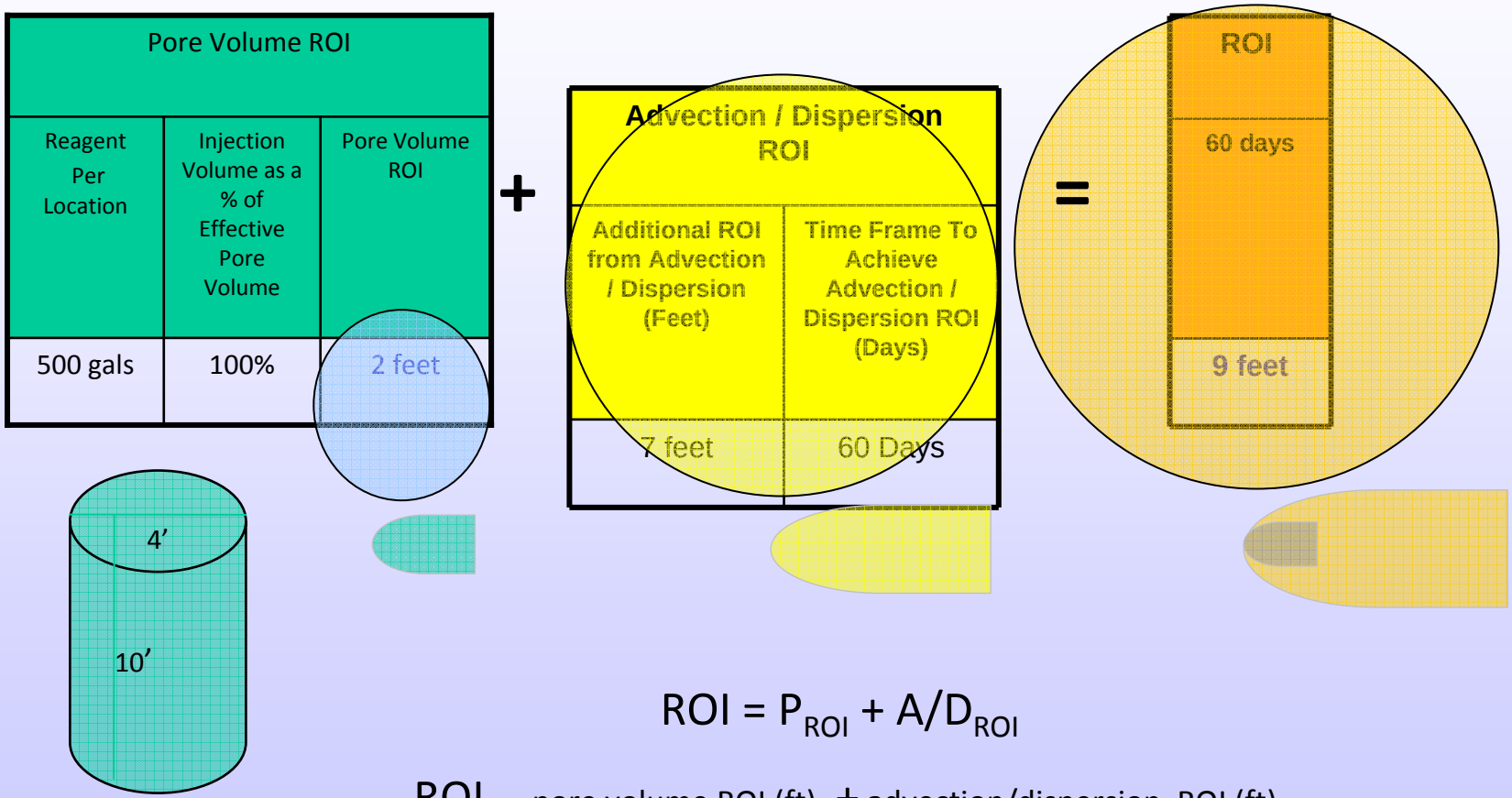


Source - Vironex

MIP 3D Imaging / Injection Locations



Radius of Influence (ROI)



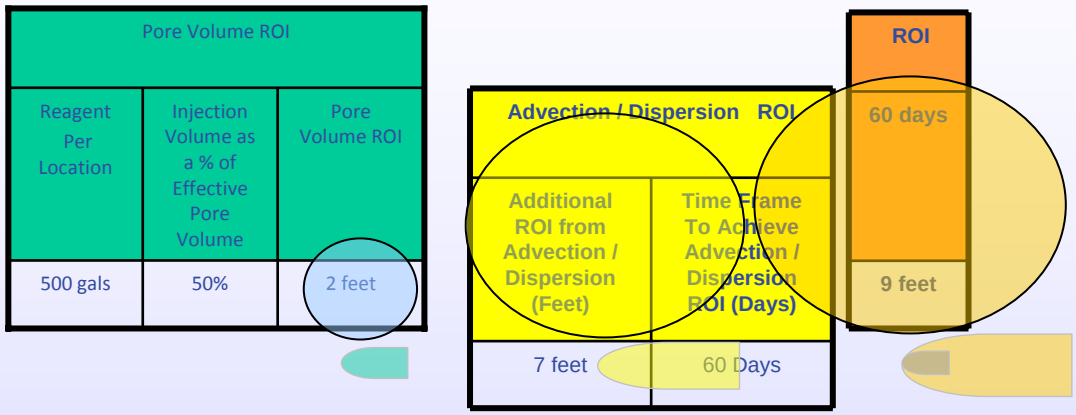
$$ROI = P_{ROI} + A/D_{ROI}$$

ROI = pore volume ROI (ft) + advection/dispersion ROI (ft)

9 feet = 2 feet + 7 feet @ 60 days

Kinetics > ROI_T

ROI Realities



Tight Soils

- Low Injection Pore Volumes
- Tighter Spacing
- Higher Reagent Concentrations

- Reagent Persistence
- Exceed Fracture Pressure

Permeable Soils / Flat Gradient

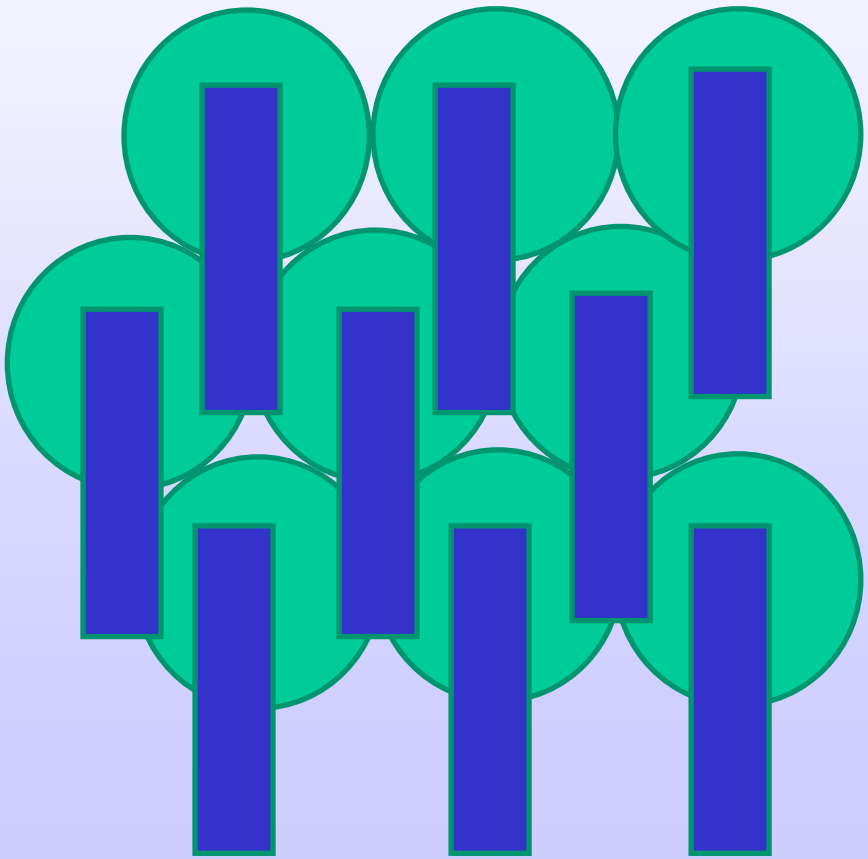
- Requires High Injection Pore Volume
- Stay Below Fracture Pressure

Permeable Soils / Steep Gradient

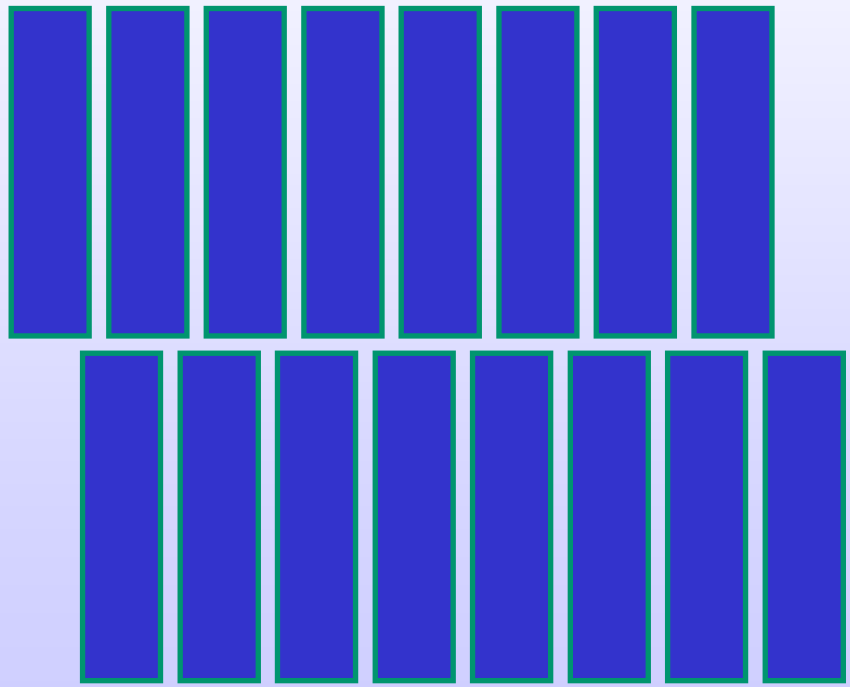
- Lower Residence Time

Distribution Primarily Advection Driven
10’ ROI @ 30% pore Volume

- Advection & Dispersion



Advection Only



Injection < Fracture Pressure

$$P_{Imax} < [(d_{dry}\, g\, h_{dry} + d_{sat}\, g\, h_{sat}) - d_{water}\, g\, h_{sat}]\ psi$$

P_{Imax} = Maximum injection pressure to prevent structural failure (fracturing)

-----Rule Of Thumb-----

$P_{Imax} = DPT_p + (DTI * 0.5PSI)$ **(includes safety factor)**

DTI = Depth To Target Interval
DPT_p = Direct Push Compaction Factor

Source: Remediation Hydraulics – Payne, Quinnan, Potter - CRC Press

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Tools, testing and tricks

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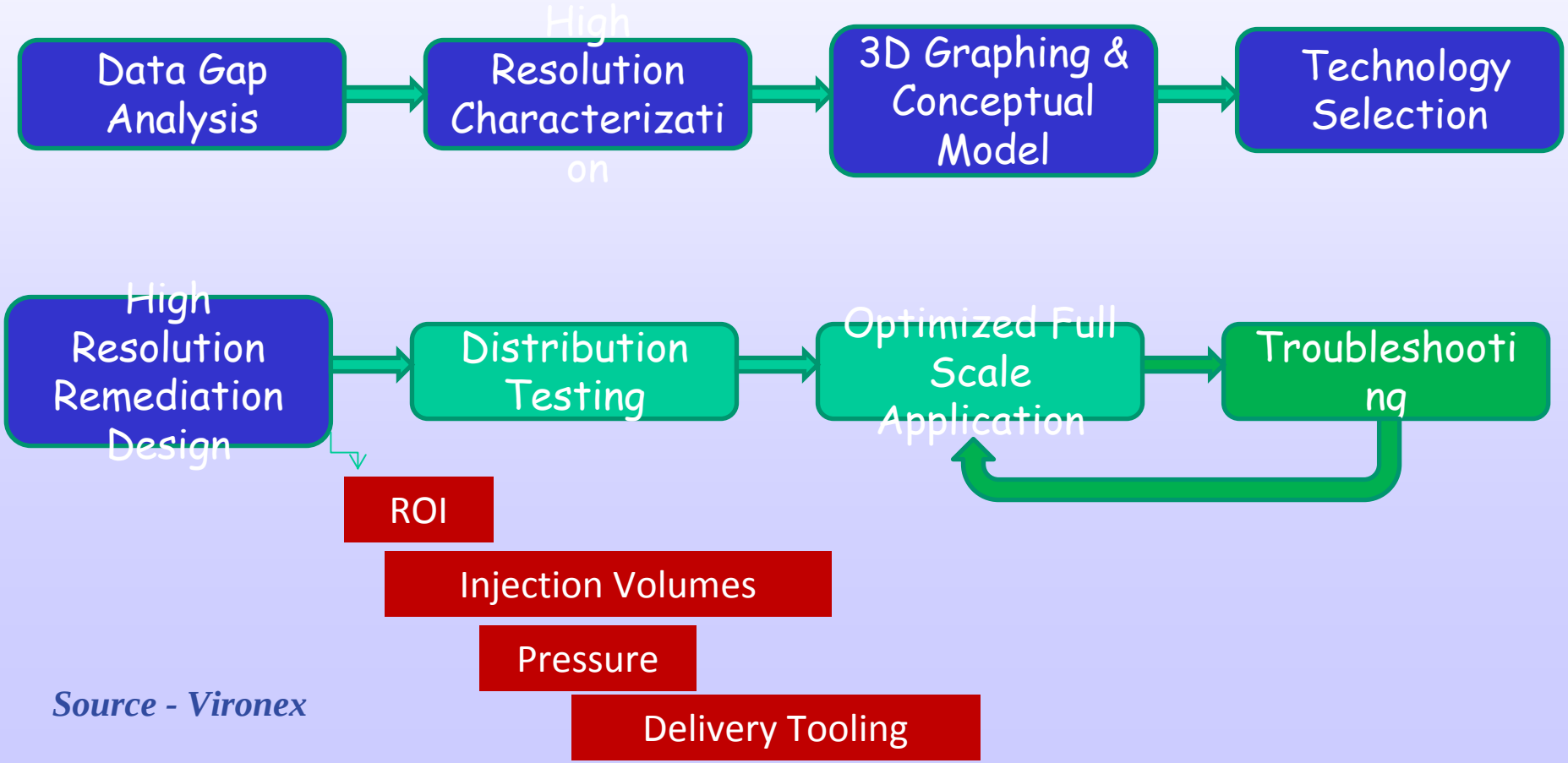

Source - Vironex

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Delivery Systems


Source - Vironex

	Injection Pressure
Direct Push	
❑ Bottom-Up or Top-Down tools (screens 1 to 5 feet) targeting of discrete lithologies	➢ Low to Moderate
Injection Wells	
❑ Injection wells	➢ Low
❑ Packer isolation of open bore holes	➢ Low to High
Fracturing	
❑ DPT fracturing of tight formations	➢ Moderate to High
❑ Pneumatic and Hydraulic	
Extraction / Injection	➢ Low
Electrokinetic	

Destroy - **Why Distribution Testing**

Avoid Major Design Changes During Full-Scale

- Confirm Injection Pressure and Flow Assumptions
- Confirm Formation Acceptance of Design Volume
- Confirm Vertical and Horizontal Distribution of Reagents Over Time

Source - Vironex

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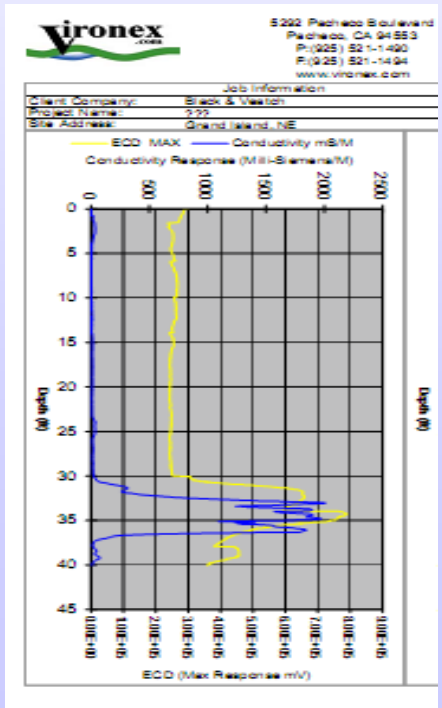
Tools, testing and tricks

Follow up After injection events

- Validate oxidant/amendment distribution (may integrate inert tracer to evaluate dilution factor) with :
- Core samples
- Hydropunch sampling
- Electrical Conductivity
- Groundwater sampling through monitoring well



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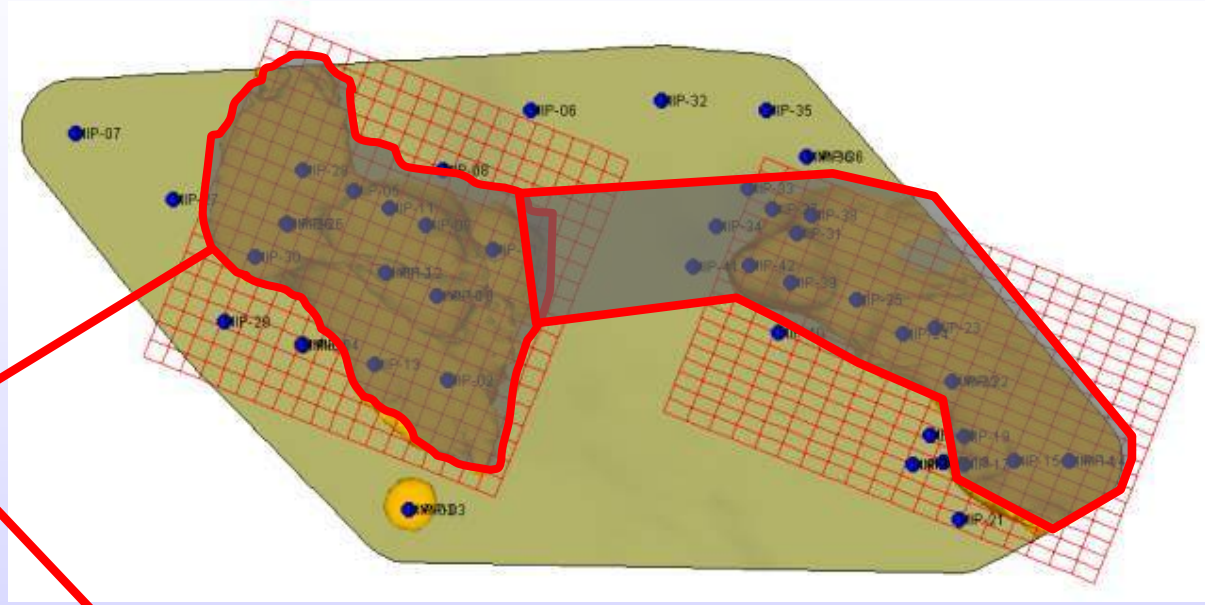
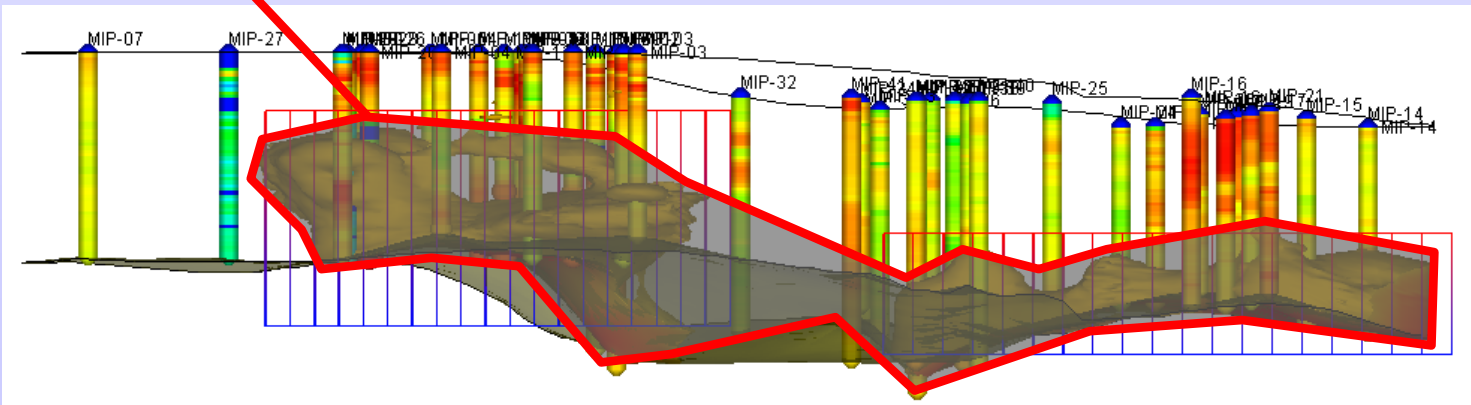
Outputs Visual Data
Dry Cleaner Case Study

Injection

Strategic Injection Strategy





Source: Vironex

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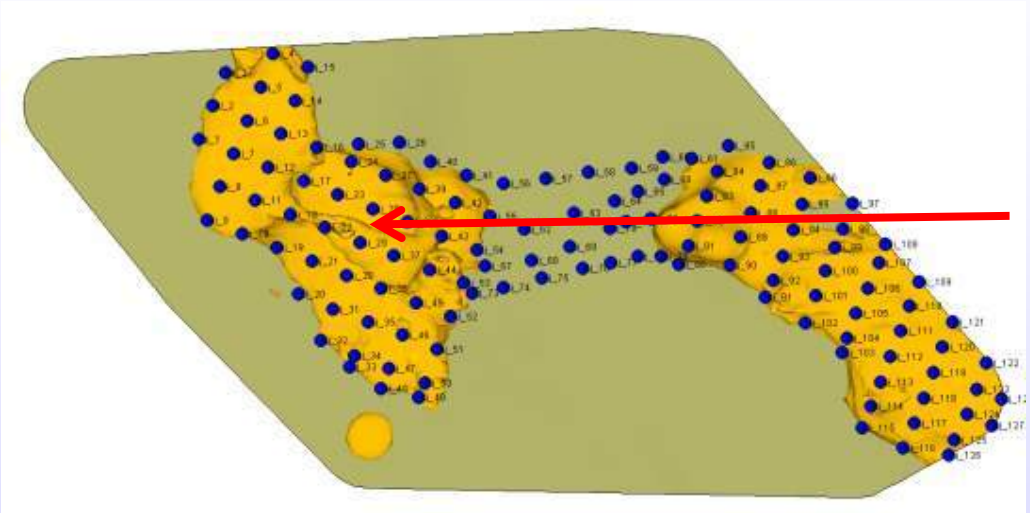
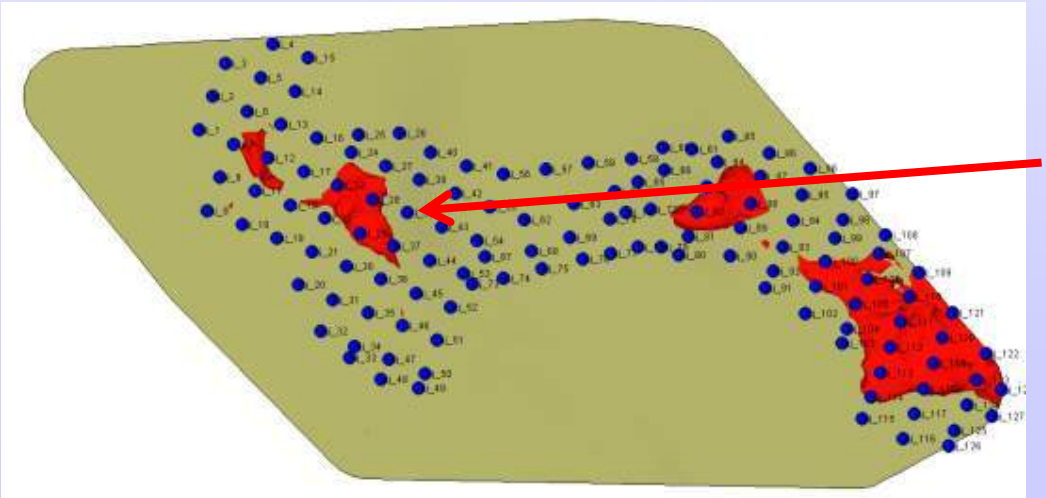
Outputs Visual Data
MIP Post Injection

Injection

Strategic Injection Strategy



Pre-Injection MIP



Post-Injection MIP

Source: Vironex

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Who we are

- Canadian Company founded in 1988
- Production and warehouse facilities in Quebec, Ontario and in Western Canada with Quadra Chemicals
- **Sectors of activity**
  - Industrial and Municipal Waste Water
    - Contaminated Soil and Groundwater
    - Air, Odours and Atmospheric Emissions
  - Process Water
- **Products**: coagulants, flocculants, nutrients, bacterial preparations strains, oxidants, catalysts, oxygen and hydrogen release compounds, odour control agents
- **Services**: technical support, product selection, product supply and sourcing, logistics, laboratories (SOD and treatability testing), design and staff training.

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Acknowledgements

- Carus Chemical
- FMC Corporation
- Progressive Engineering & Construction
- Vironex

Thank you for your attention !
Have a good day !!!

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