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Enabling Delta Life

SOILMATCH

Optimizing In-situ Chemical Oxidation of Residual DNAPL: Geochemical Controls and Sediment Oxidant Demand

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Towards effective source zone remediation

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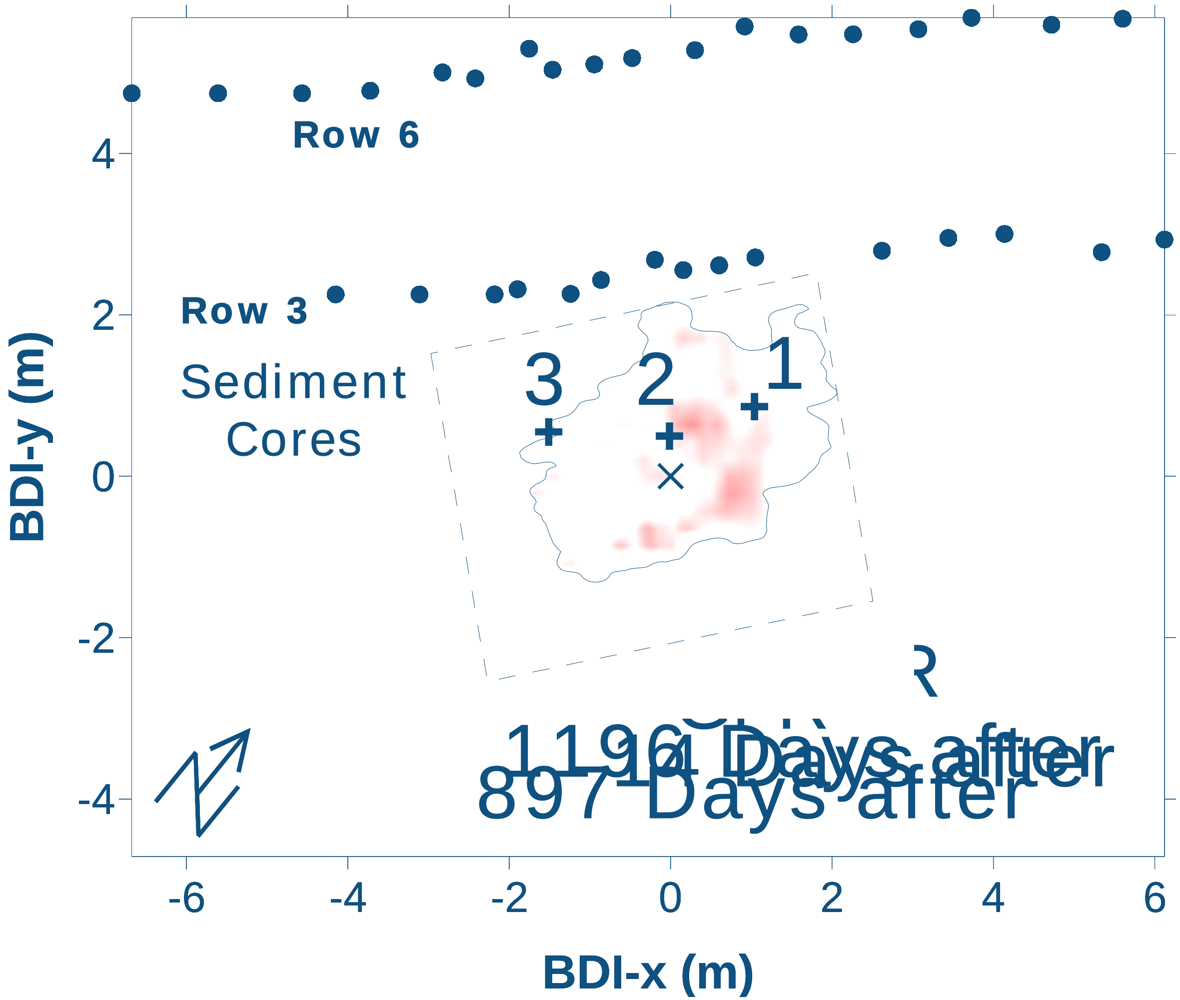
Borden DNAPL Infiltration (BDI) Site

3D “Homogeneous” Aquifer

Figure 17: Photograph of the completed excavation showing the southeast, south, and west walls. A meter stick is resting vertically on the aquitard for scale. A 3.5" diameter outer steel core barrel is shown slightly left of the center of the photo.

Thomson (MSc Thesis, 2004)

Remaining Mass in Source Zone



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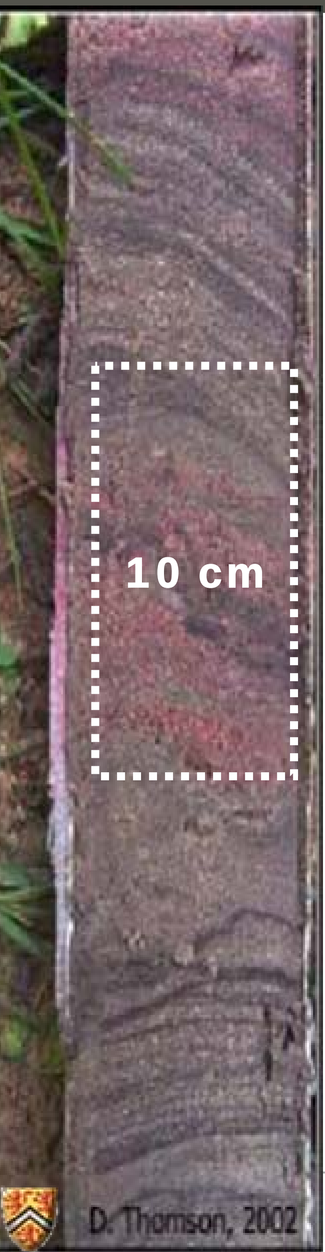
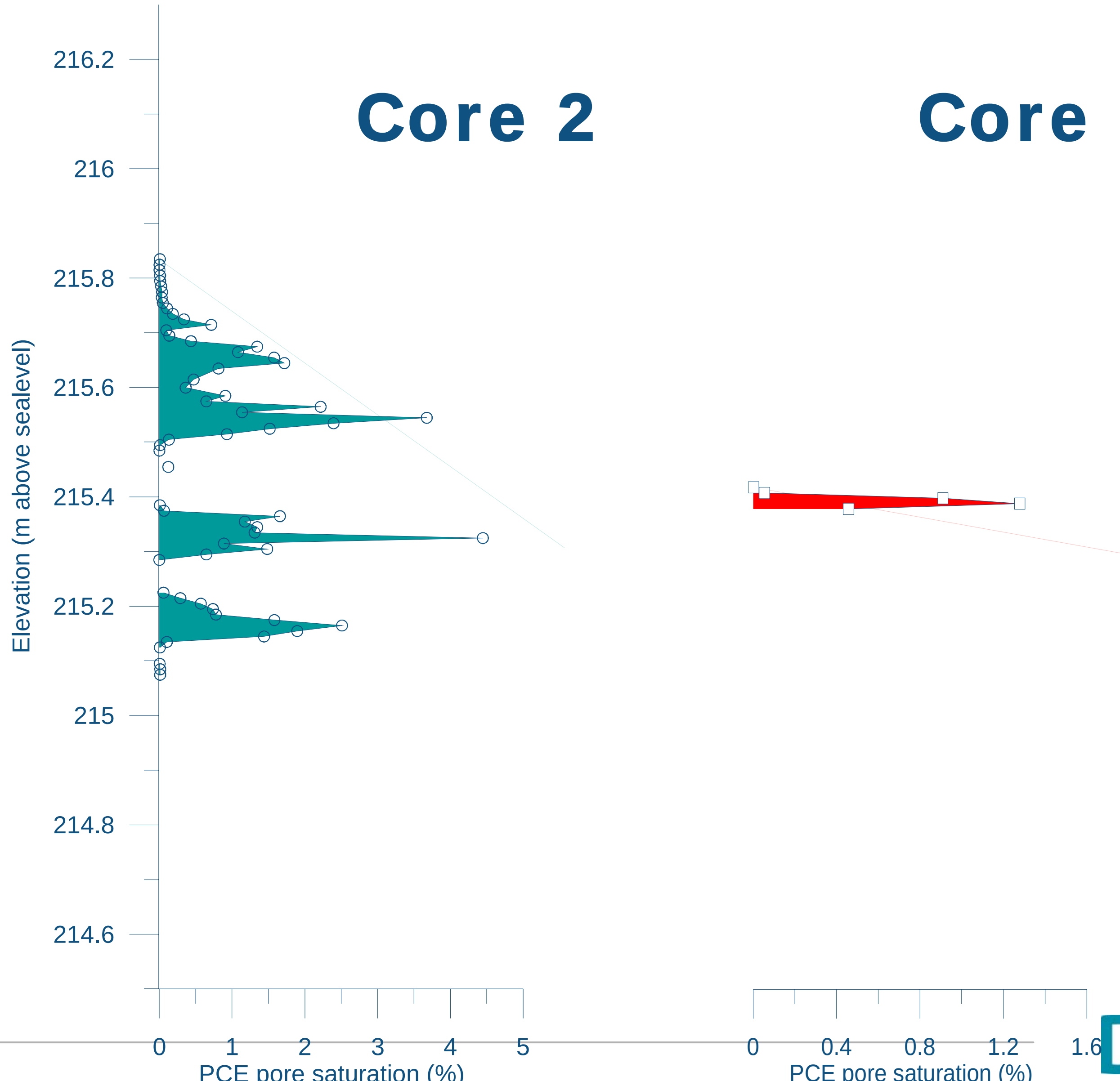
DNAPL pore saturation variability





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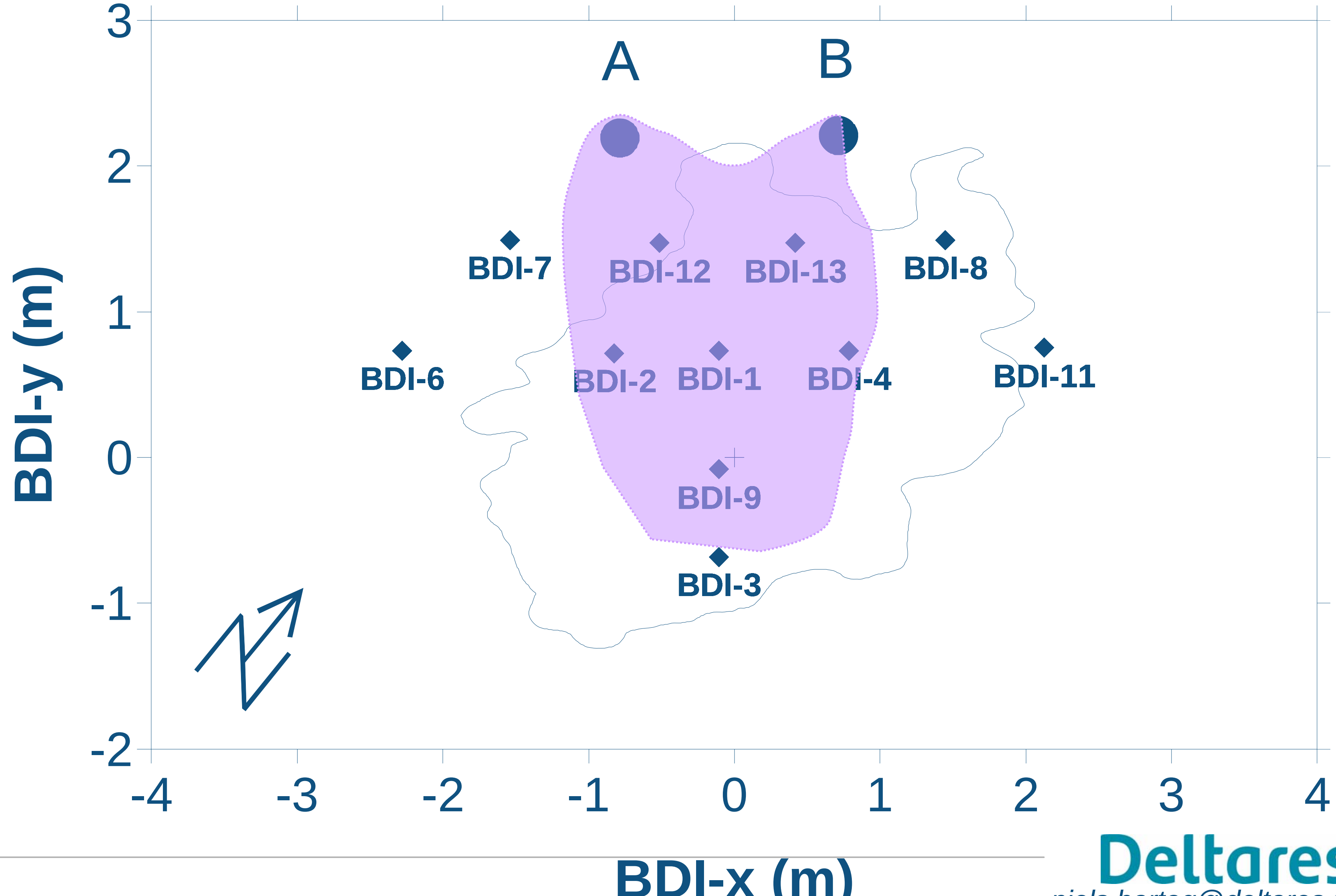
Permanganate Injection Overview



Modeling Permanganate Oxidation Reactions (PHREEQC)

Oxidation Reactions with MnO4

PCE

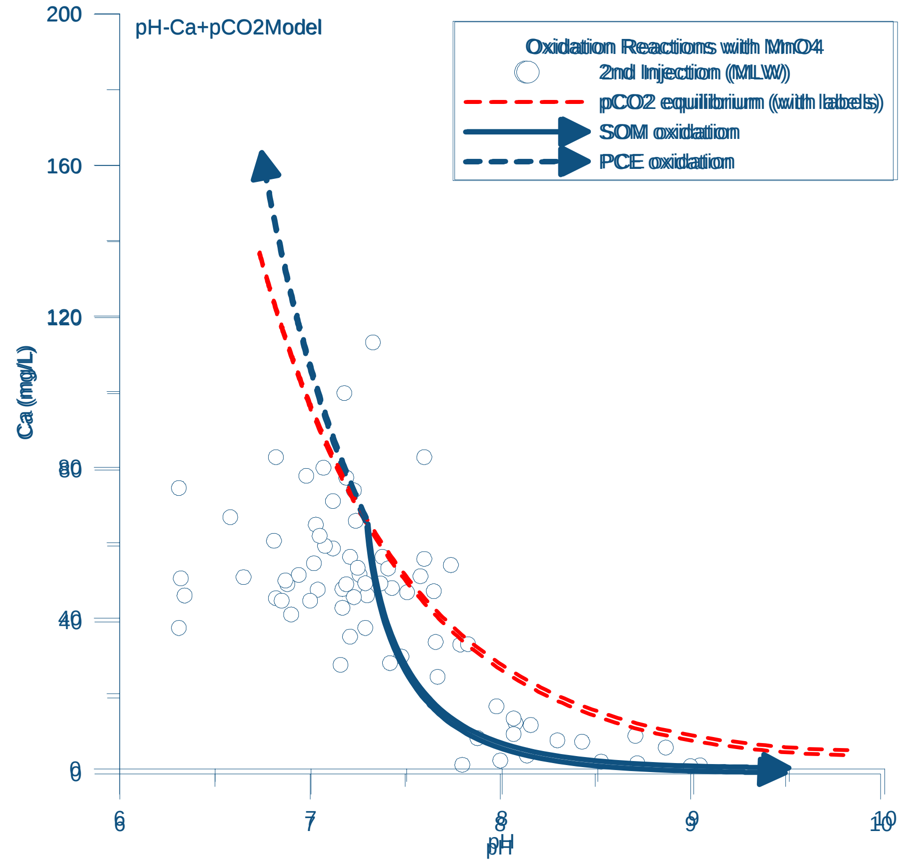
$4\ H_2O + 4\ MnO_4^- + 3\ \mathbf{C_2Cl_4} \rightarrow$

$8\ H^+ + 4\ MnO_2 + 6\ CO_2 + 12\ Cl^-$

SOM

$12\ H^+ + \mathbf{C_9H_{10}O_5} + 12\ MnO4^- \rightarrow$

$11\ H_2O + 9\ CO_2 + 12\ MnO_2$



> 95% MnO4 consumed by sediment!

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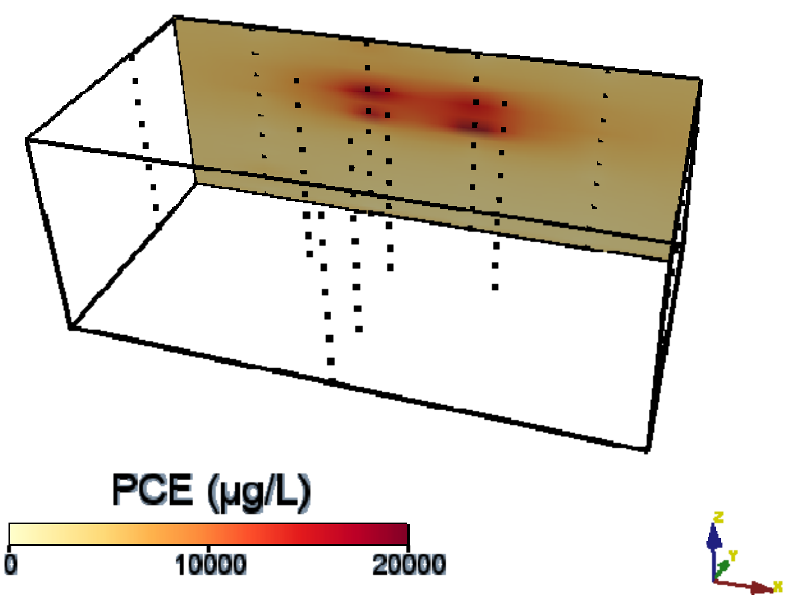
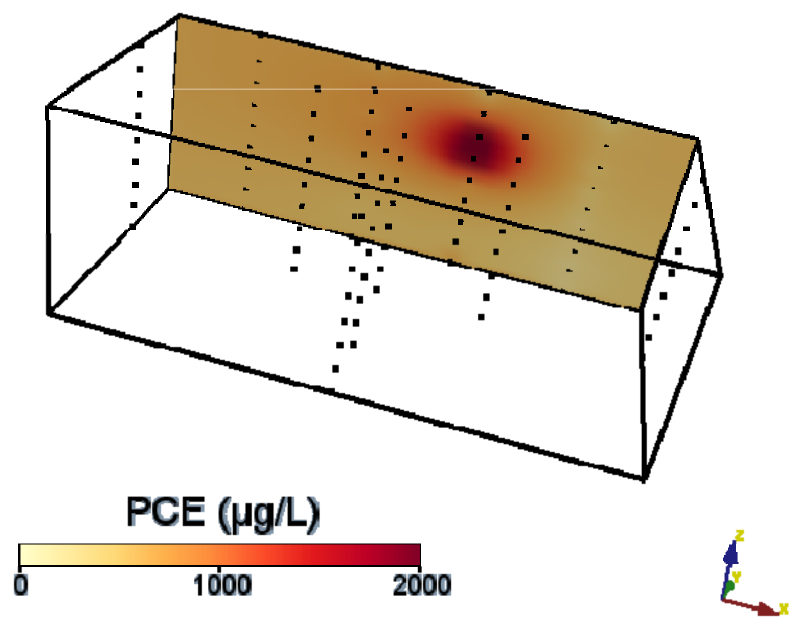
PCE Concentrations in MLWs

Before 1st Injection



After 1st Injection

•Plume size reduction



•10-fold reduction [PCE]

•100-fold reduction PCE flux

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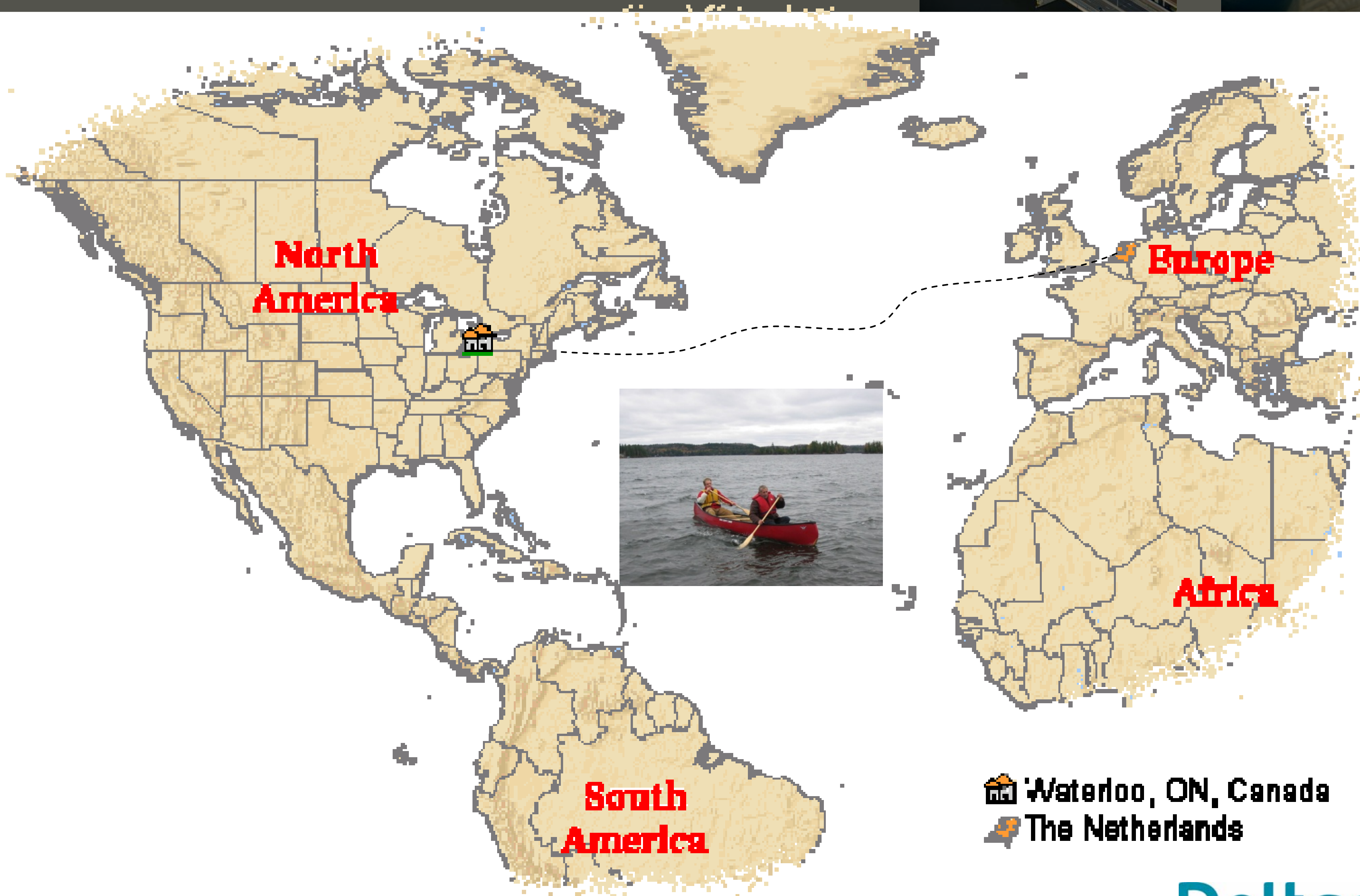
Canada ←→ The Netherlands



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Overview contaminated Sites in The Netherlands

Site Characteristics 15,000 most urgent sites		*Occurrence (% of total)*
Contaminant type (C)	C.1 Chlorinated Hydrocarbons	45
	C.2 Aromatics/Oil/MTBE/Cyanide	45
	C.3 Other	10
Geo-hydrology (G)	G.1 Permeable (sandy)	45
	G.2 Layered, permeable and impermeable layers	45
	G.3 Other	10
Built Environment (B)	B.1 Urban	70
	B.2 Industrial	25
	B.3 Other	5

Holland In-Situ Proeftuin
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Optimizing the ISCO remediation of Chlorinated Solvents

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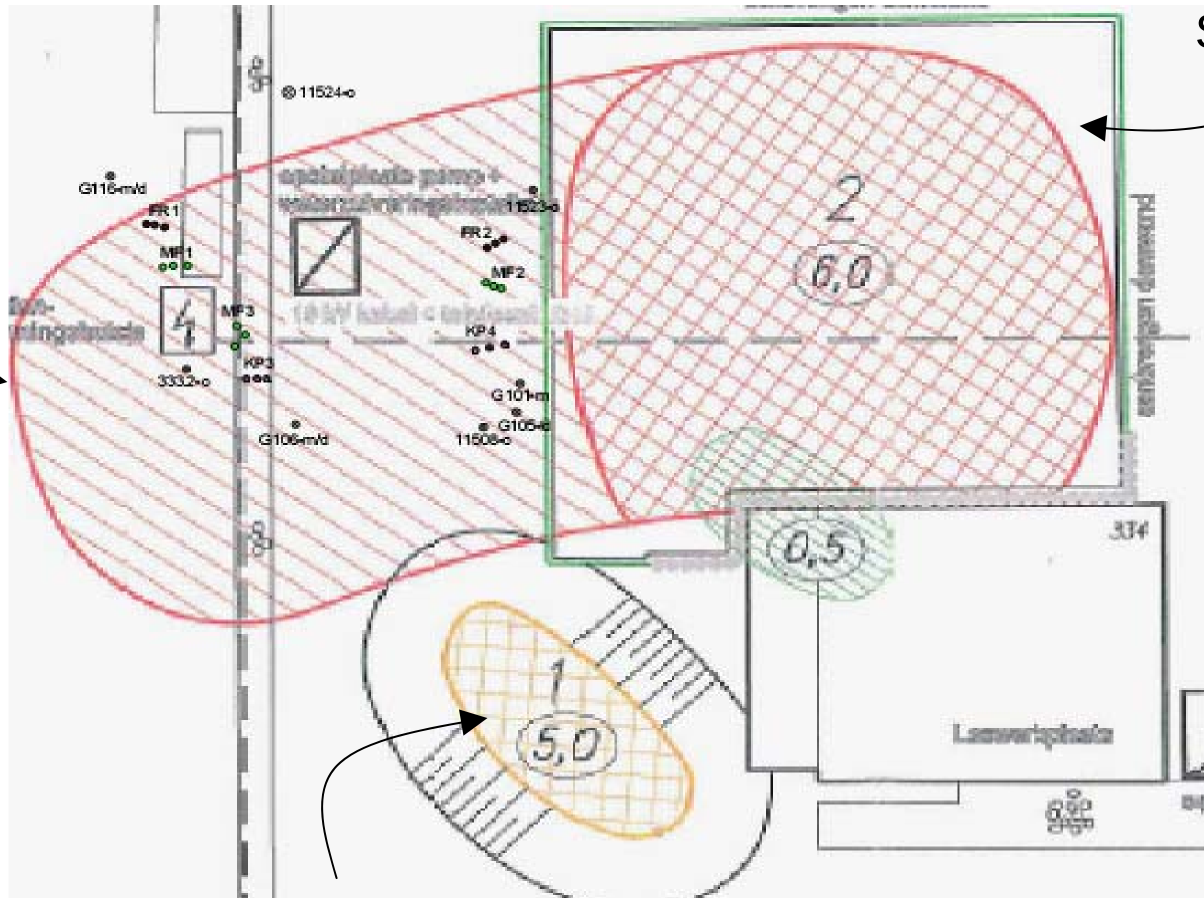
Overview Contaminated Site



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50% : 50%

Fenton’s Reagens

Permanganate

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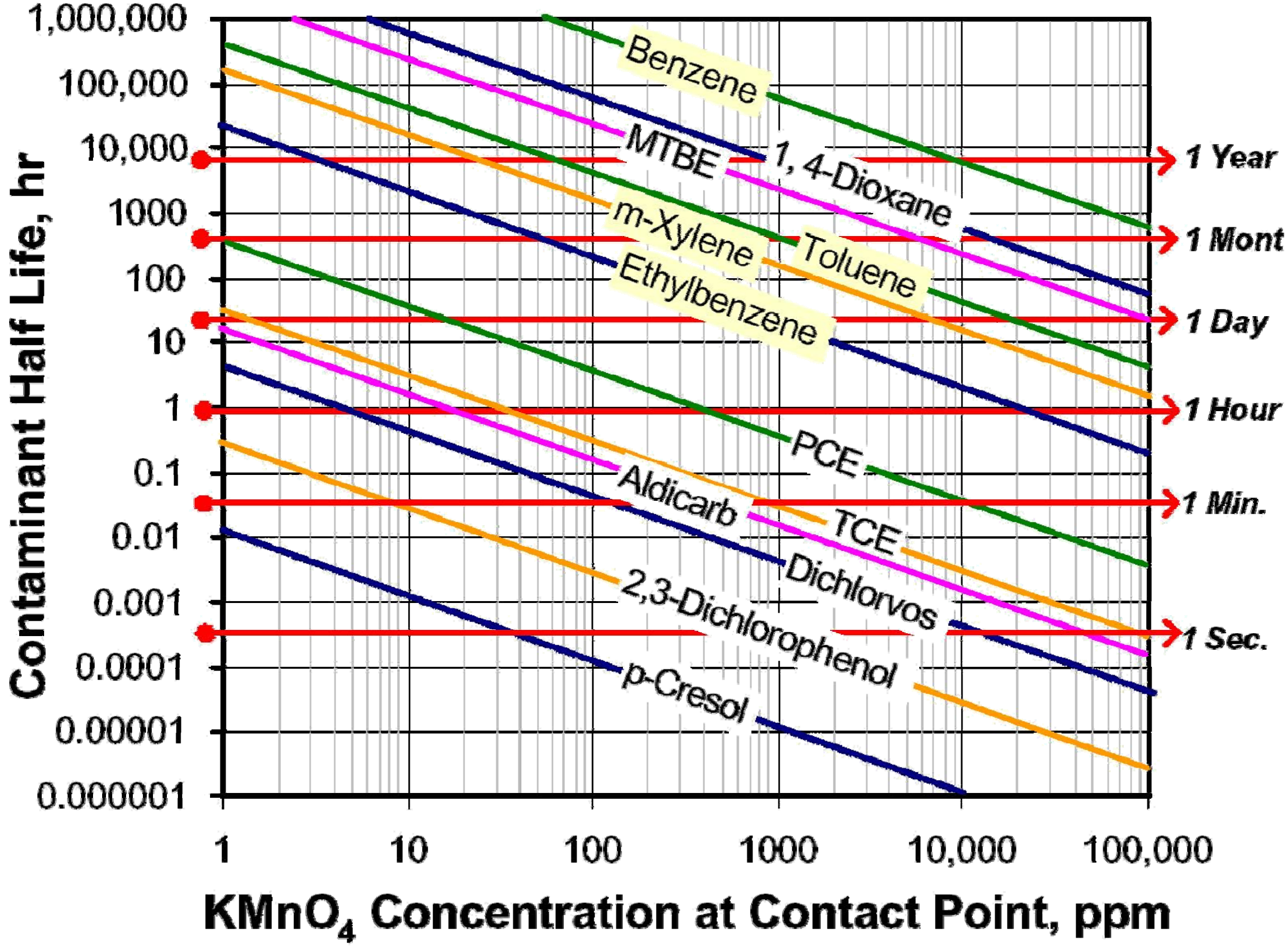
Rates of contaminant oxidation with MnO4



Ref: Waldemer, R., Determination of the Rate of Contaminant Oxidations by Permanganate: Implications for In Situ Chemical Oxidation (ISCO), M.S. Thesis, Oregon

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Natural and Contaminant Oxidant Demand

Factors:

Contaminant Oxidant Demand

- Mass, Volume, Distribution

Sediment Oxidant Demand (SOD, NOD)

- Geochemistry, Heterogeneity

Groundwater Oxidant Demand

- Groundwater composition, Redox status, Groundwater flow

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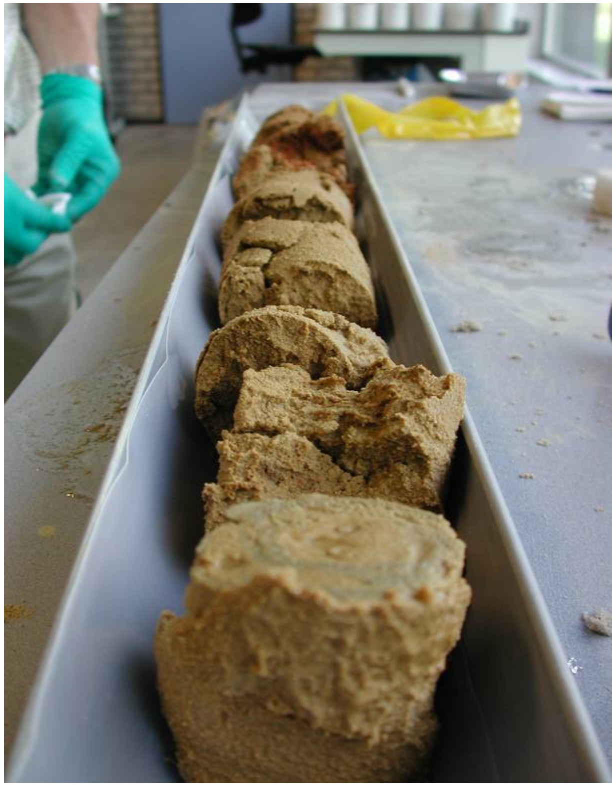
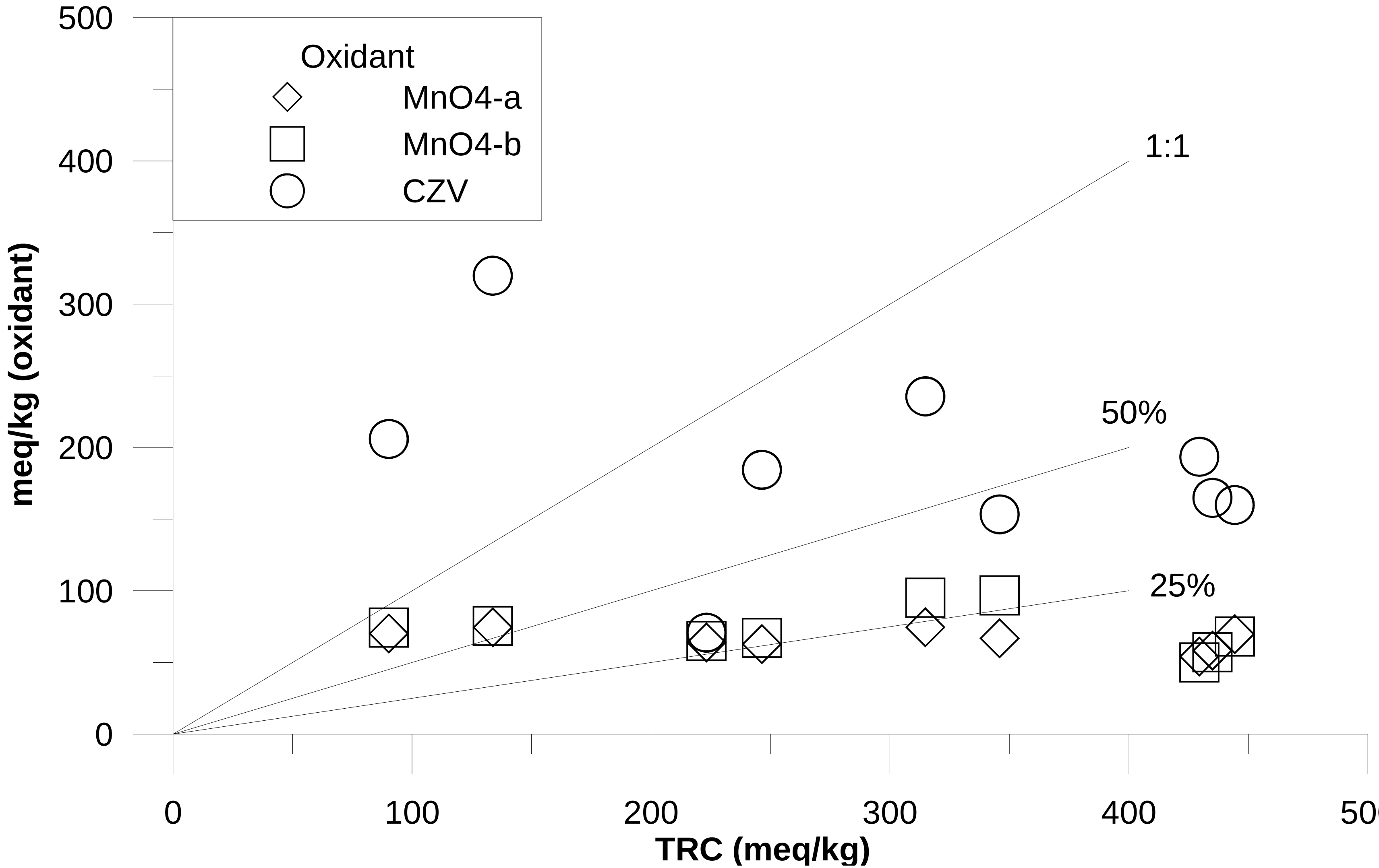
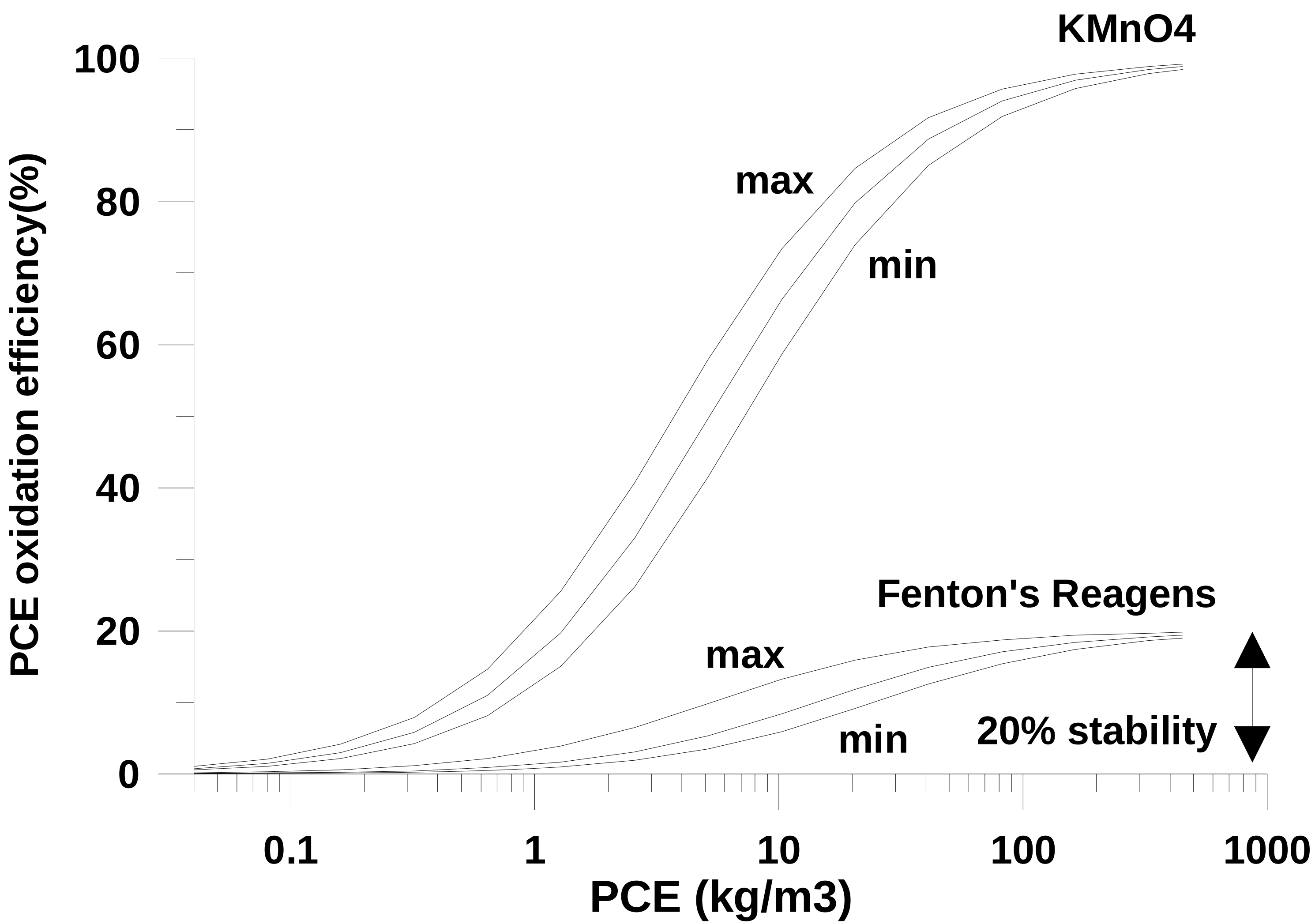
Soil Samples for Geochemistry and Reactivity



Total Reduction Capacity vs. Oxidant Demand



Remediation Efficiency



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Assessment of critical parameters: simplified

$$Oxidant_{req} = \left(\frac{Oxidant_{cont} + Oxidant_{NOD}}{Oxidant_{stab}} \right)$$

$$Oxidant_{eff} = \frac{Oxidant_{cont}}{\left(\frac{Oxidant_{cont} + Oxidant_{NOD}}{Oxidant_{stab}} \right)}$$

Main Assumptions:

•Direct injection in NAPL zone, no travel

•Oxidant reacts with NOD first, no competetion (worst case)

•Constant degree of decomposition

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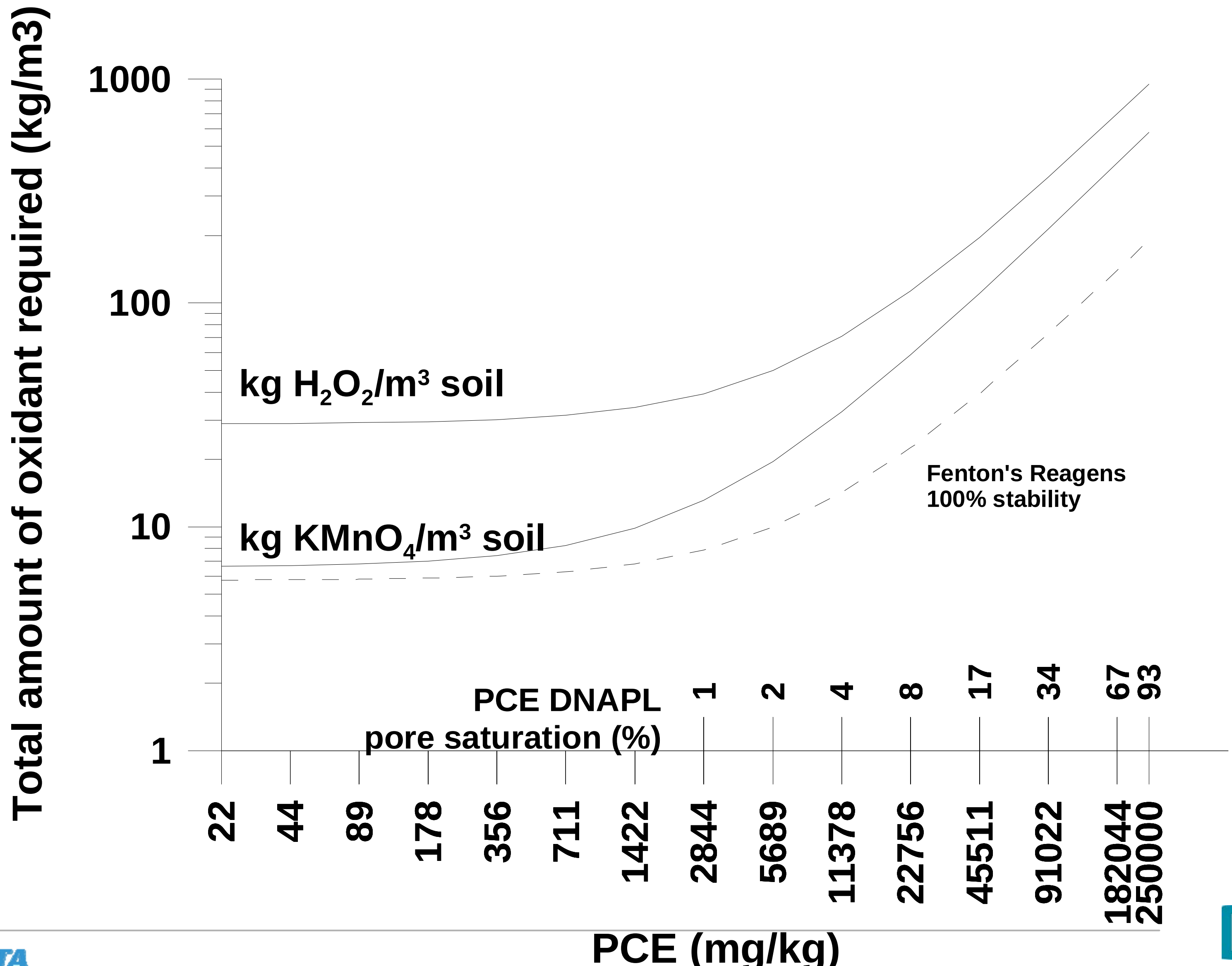
Cost-effectiveness (kg/m³ × €/kg)



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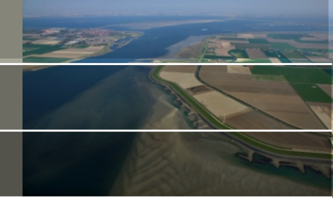
Conclusions



- Oxidant specific NOD tests should be performed, due to different reaction mechanisms for different oxidants used in ISCO.
- The influence of NOD on oxidation efficiency is especially important for lower contamination degrees.
- At higher contamination degrees, oxidant stability becomes the dominating factor for ISCO efficiency.
- Remedial ISCO strategies only be based on site-specific cost-effectiveness determinations.

- Source zone characterization crucial for cost-effective optimization of remediation strategy

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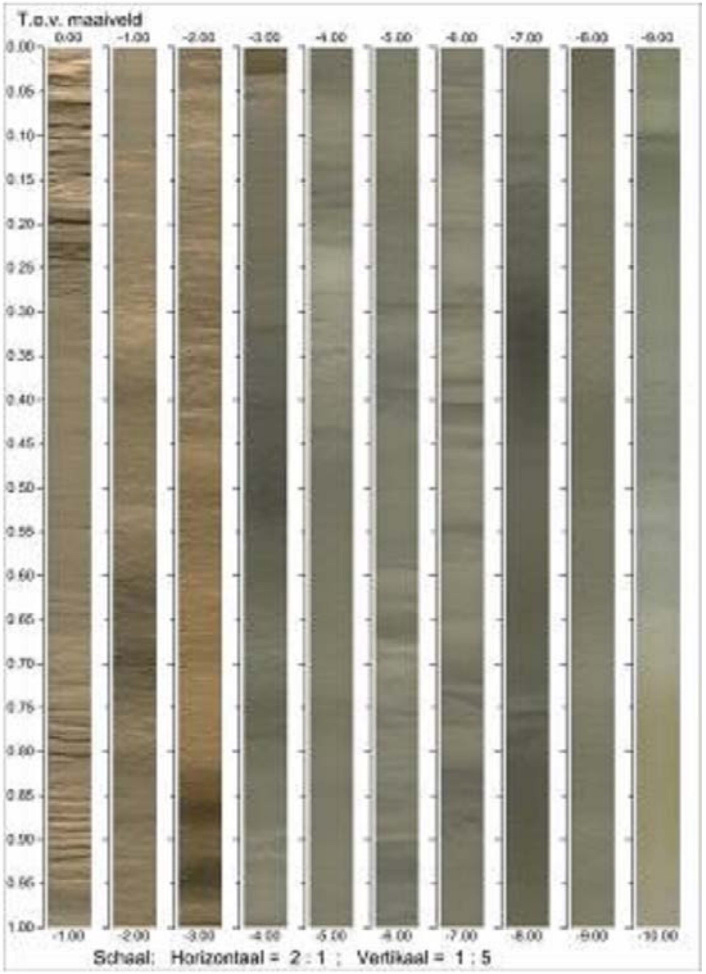
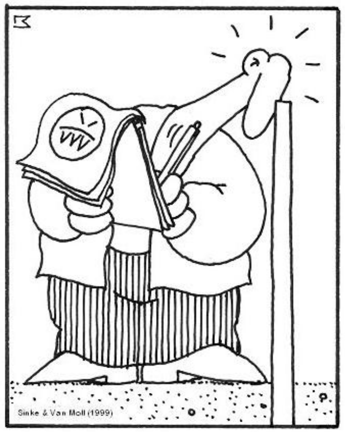
Videocone: Take a peak in the black box





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