



Molasses Injection to Enhance Reductive Dechlorination - A large Scale Pilot Test -

November 9, 2004

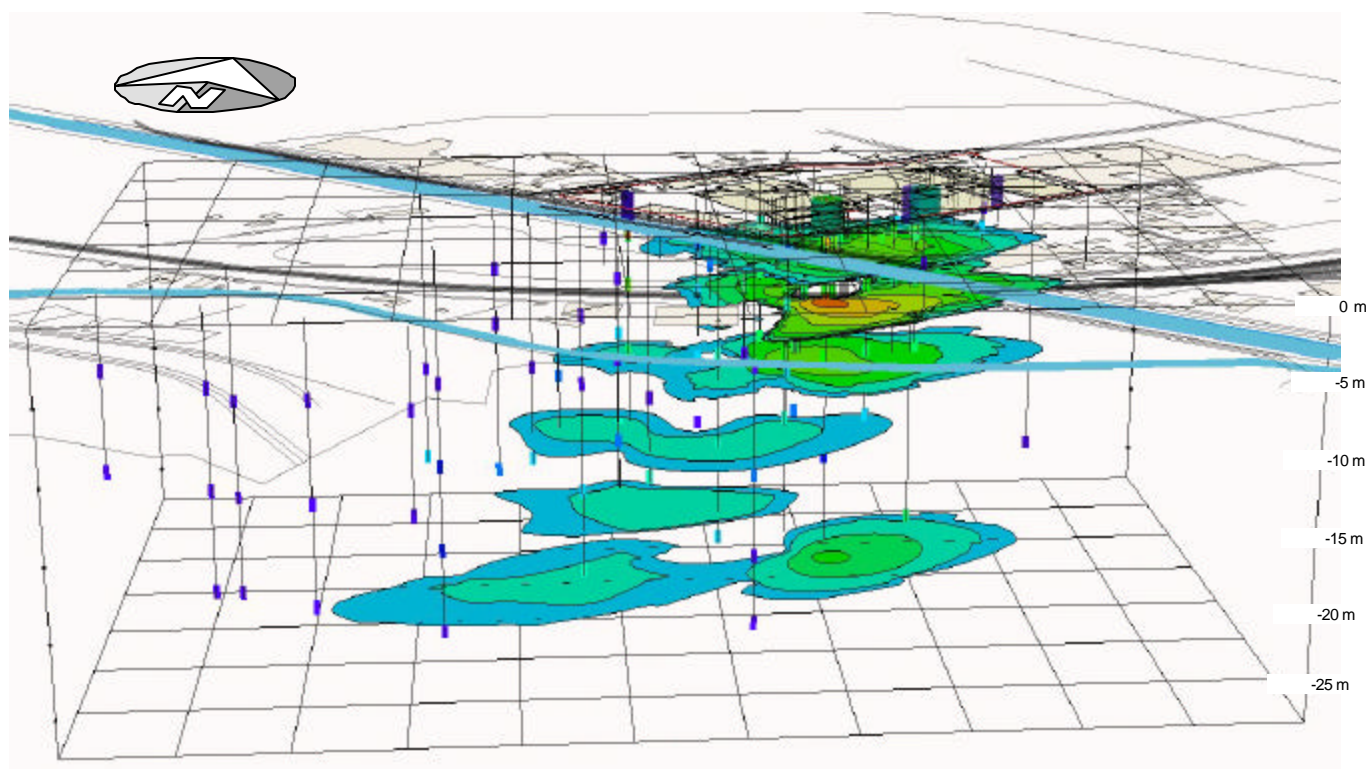


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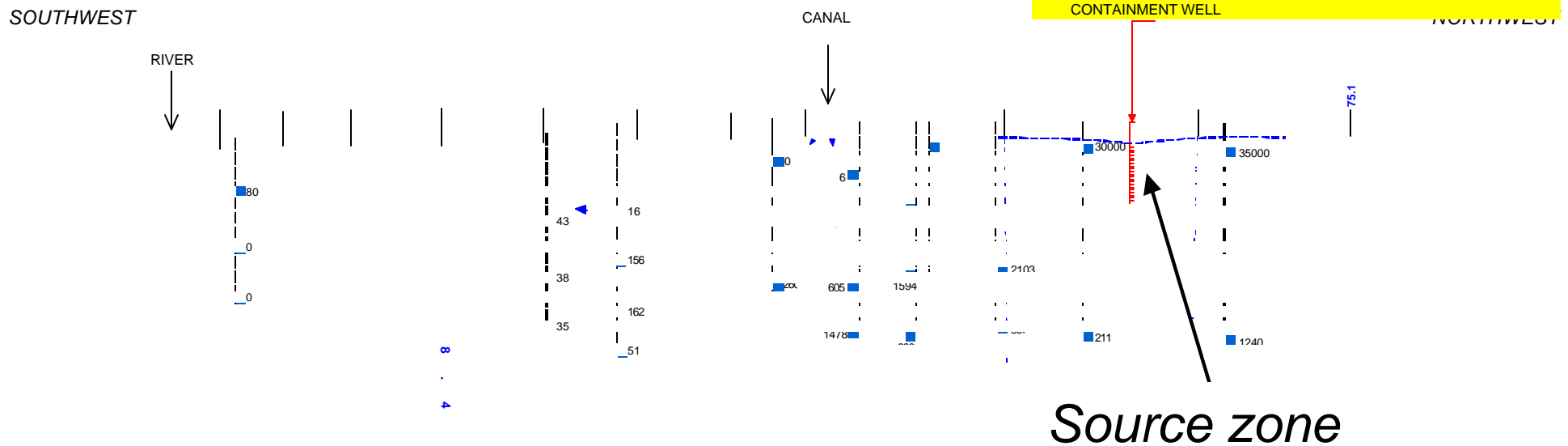
Site Setting

- Site in Reims, Champagne region, 130 km NE of Paris
- Hydrogeology: Chalk Aquifer
 - High transmissivity, Dual porosity, high Sorption
- Extensive Groundwater Contamination with TCE





Plume Characterization



Remediation Approach:

- Containment pumping
- Treat source zones only (plume too deep to create a risk)



Source Zone (Detail)

15,000

1

2

Source area with clear zoning:

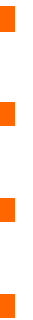
1. Almost no breakdown occurring
2. >50% breakdown products

⇒ Reductive Dechlorination can be used to lower TCE concentrations.

⇒ Advantageous in the dual-porosity Chalk (difficult to treat with hydraulic techniques)

Remediation Approach/Objectives

- Investigate the reason for the different behaviour in the two zones (proved to be sewage leakage)
 - Verify whether enhanced reductive dechlorination can be a solution suitable in both zones
 - Find a technically suitable, cost effective application that allows to establish a mass balance
- ⇒ Perform a Pilot Test to enhance Reductive Dechlorination and compare the results for the two zones



Methodology

- Use Containment Pumping to draw the electron donator through the two zones.
 - Avoids « uncontrolled » migration of the Electron donator
- Use infiltration Wells for Electron Donator introduction

Advantages:

- Attains the whole aquifer over the screened depth
- Low cost as no injection array needed
- Can be easily repeated, if needed

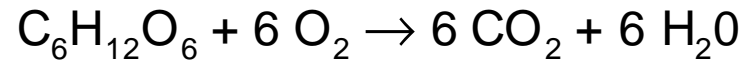
But:

- Need to know the dispersion within the aquifer to establish Mass Balance

⇒ Tracer test, Transport Model to predict the electron donator concentration in the aquifer

⇒ Use a reference well outside the Molasses Plume for comparison

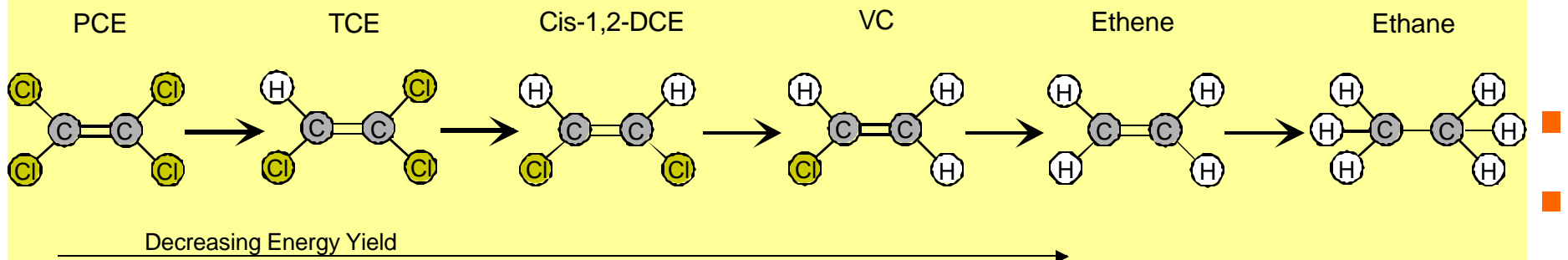
Reductive Dechlorination: how it works (1/2)



Electron Donator (Nutrient) + Electron Acceptor (Respiration)

- Naturally Electron Acceptors:
 - O_2 , NO_3^- , Fe_3^+ , SO_4^{2-}
- Anthropogenic Electron Acceptors:
 - Chlorinated solvents (PCE, TCE,)

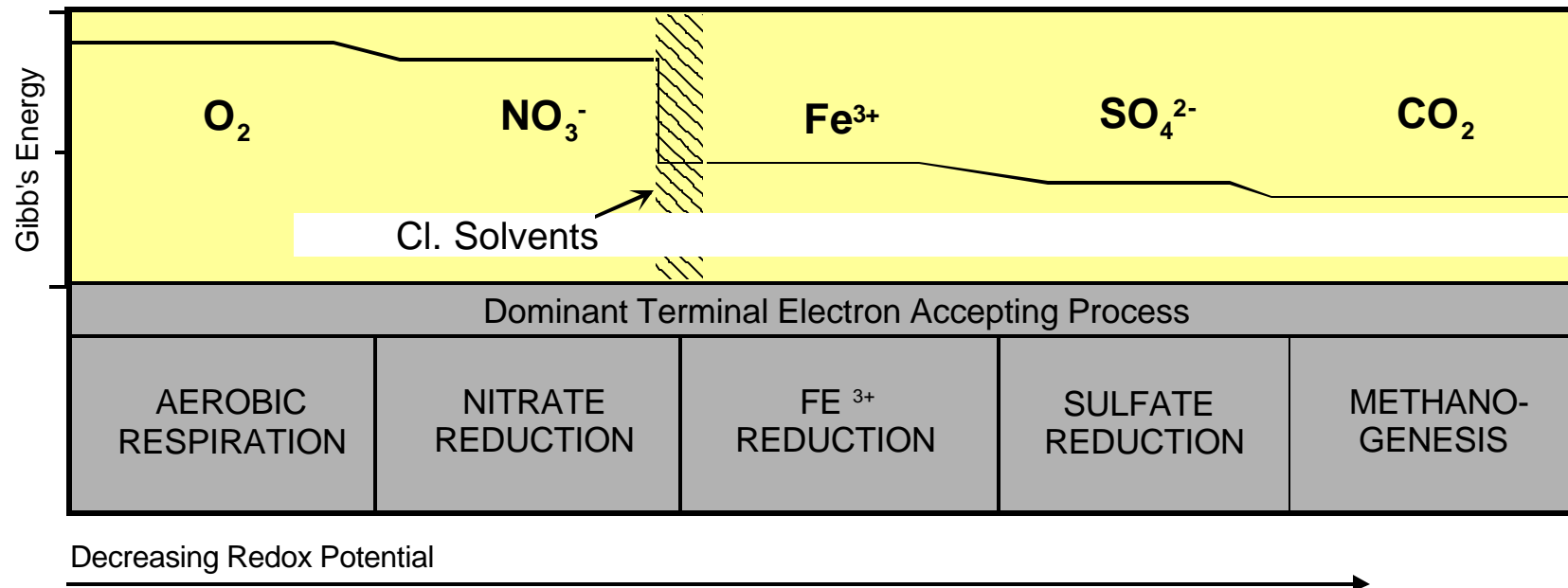
Sequential Reductive Dechlorination



Reductive Dechlorination: how it works (2/2)

Competing Electron Acceptors:

O_2 , NO_3^- , Solvents, Fe^{3+} , SO_4^{2-}



⇒ Measure the Concentrations of the Electron Acceptors present !

Electron Donator: Molasses

- Mixture of uncrystallized sugars ($C_6H_{12}O_6$) in aqueous phase
- \approx 45% of solid sugar by mass
- Molecular Weight: 180 grams
- Carbon Fraction: 72 grams/mol (40%)

- ⇒ 180 grams of C per kg of Molasses
- Dilution 10:1 \Rightarrow C-Concentration: \approx 20 g/l at the injection
- Designed Molasses concentration to reduce competing electron acceptors and TCE: **£** 500 mg/l

- Cost (Europe): 250 €/ton

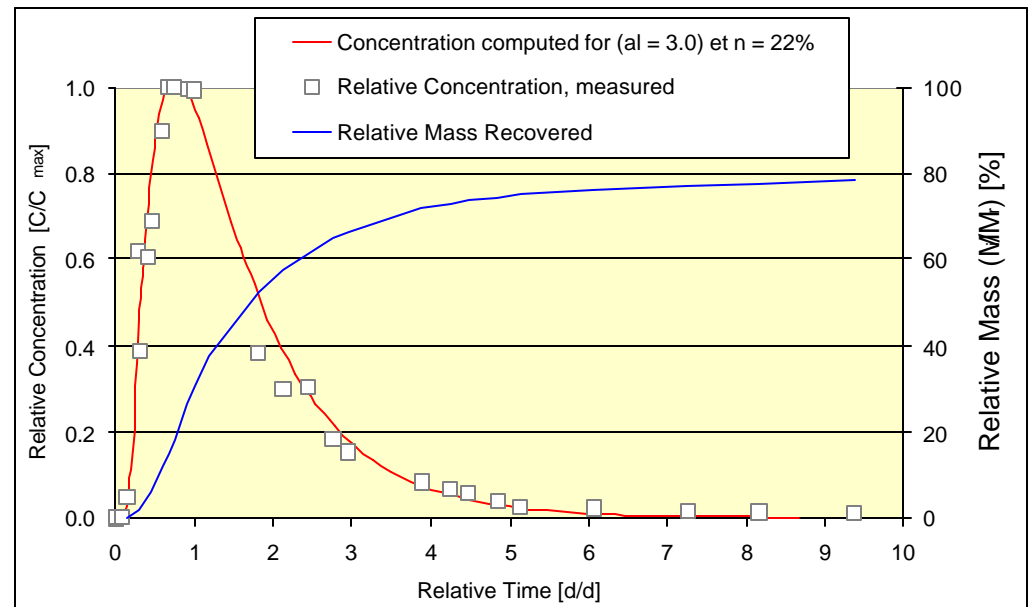
Chalk: double Porosity Phenomenon

Conduct a tracer test to compute:

- Porosity
- Dispersivity (longitudinal and horizontal), need two wells

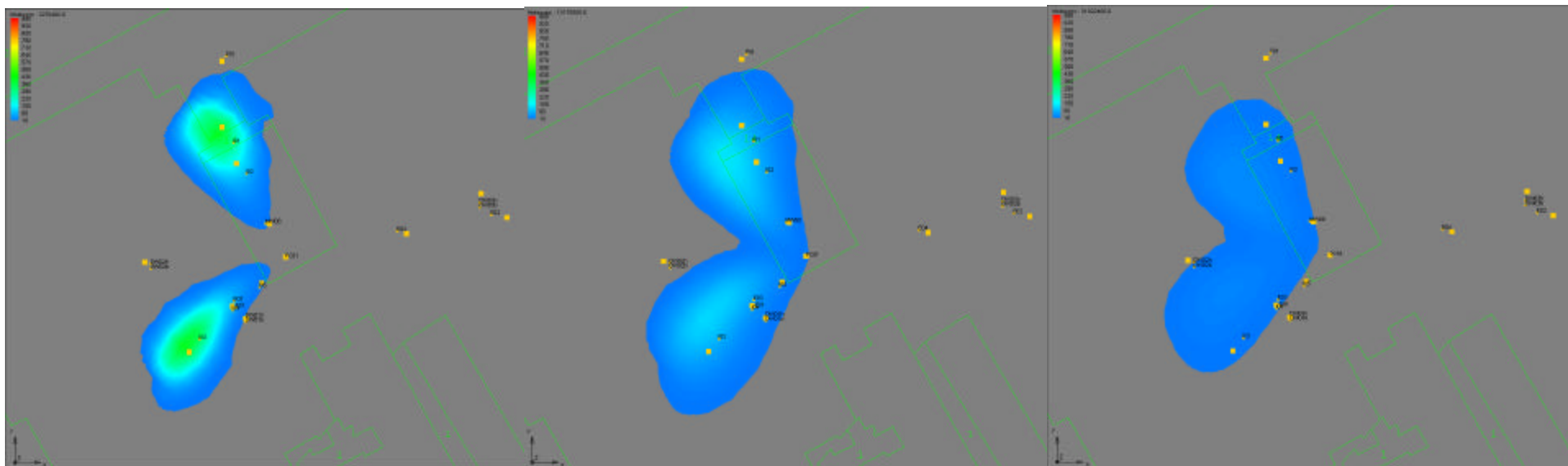
Information to be put in a 3D Groundwater F&T model to

- Determine the concentration range of Molasses at the various locations in the flow field
- Allow a mass balance for the VOC treated in the aquifer zone reached





3D-Groundwater F&T Model



1 month after injection

4 month

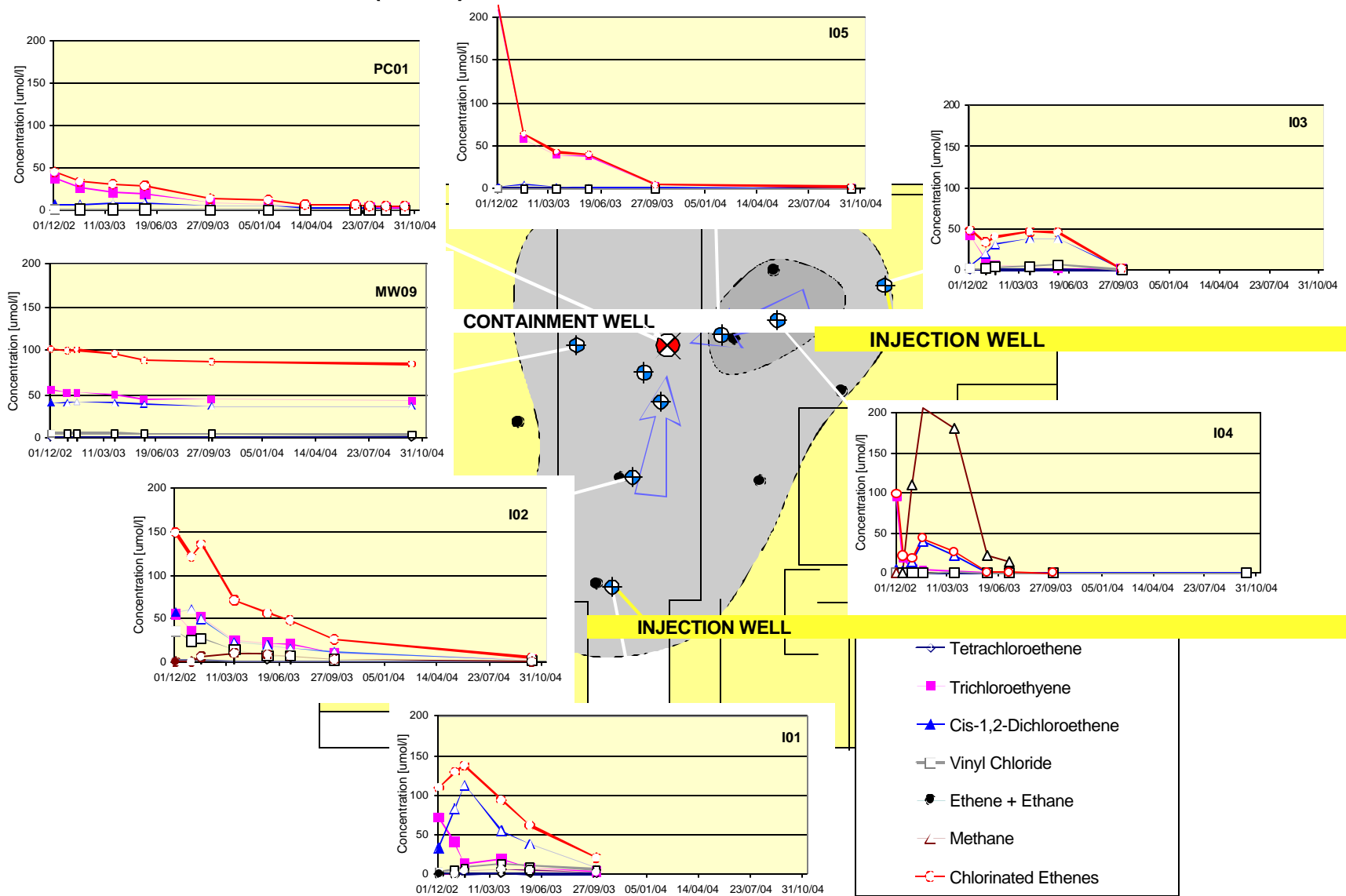
12 month

⇒ Need to inject about 150 kg of Molasses per Location

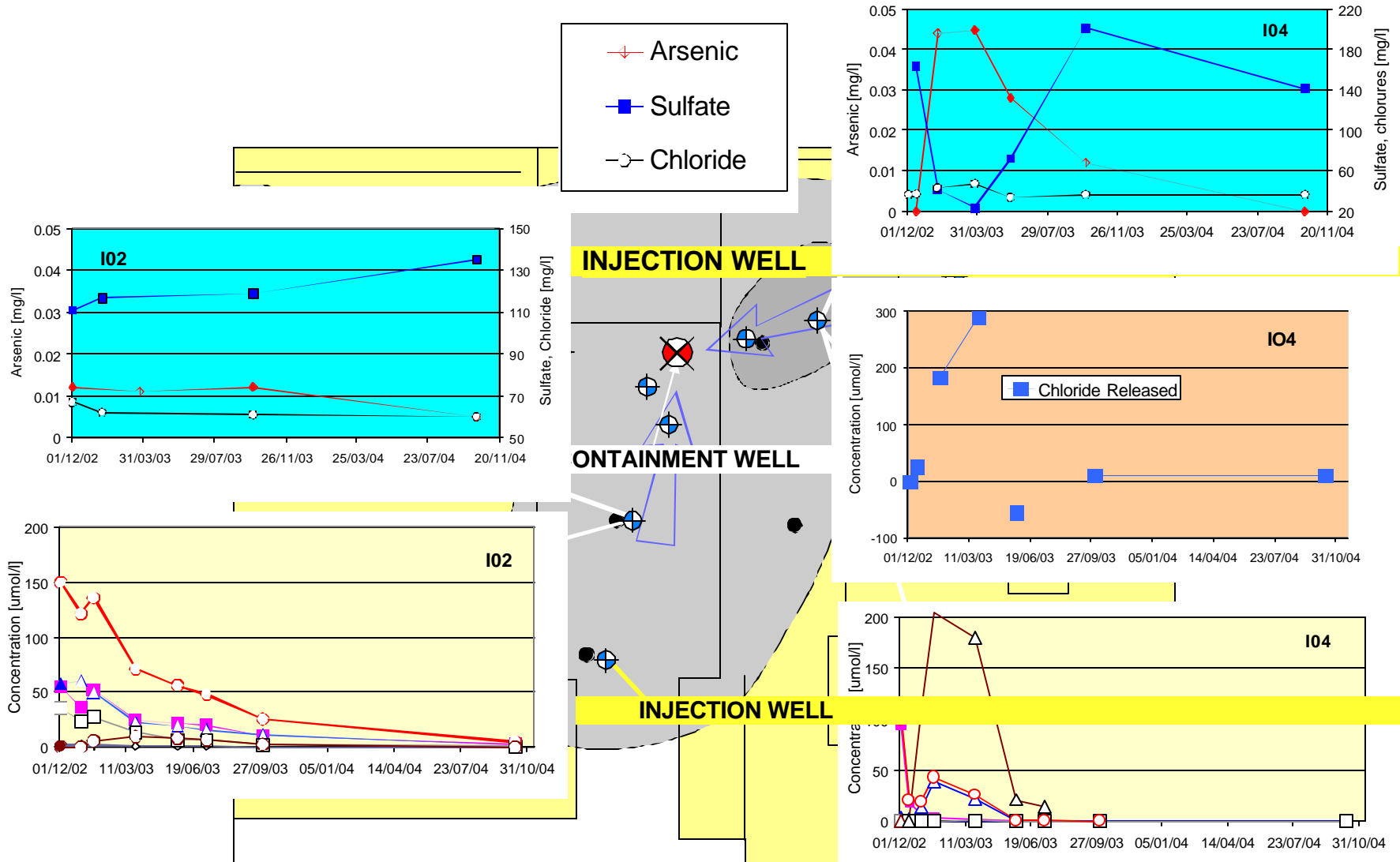
⇒ Monitoring Time: £ 1 year



Results (1/3)

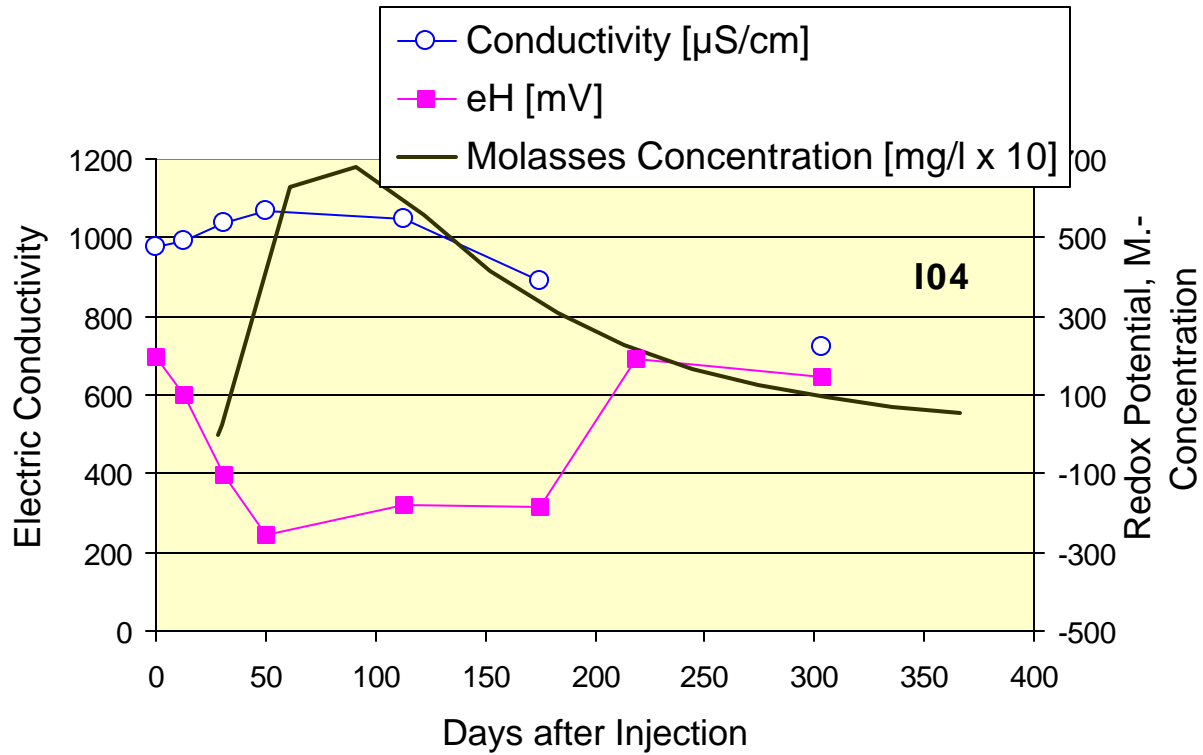


Results (2/3)





Results (3/3)





Mass Balance

10 m

Treated Aquifer Thickness:	6 m
Porosity:	20 %
Aquifer Volume:	1000 m ³
Mobile/Sorbed Phase	0.3
Concentration Decrease	15 mg/l
Mass Removed per zone	10 kg
Total	20 kg





Cost

Molasses Injection, Cost in Euro

Pilot Test

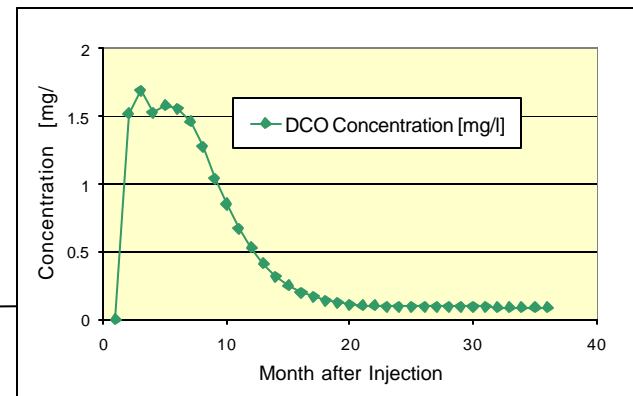
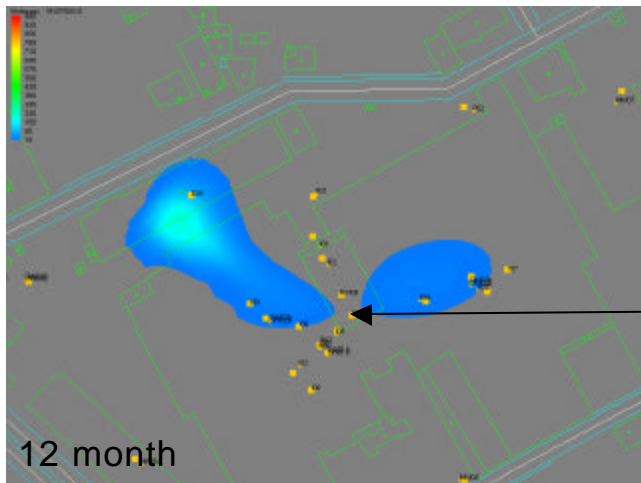
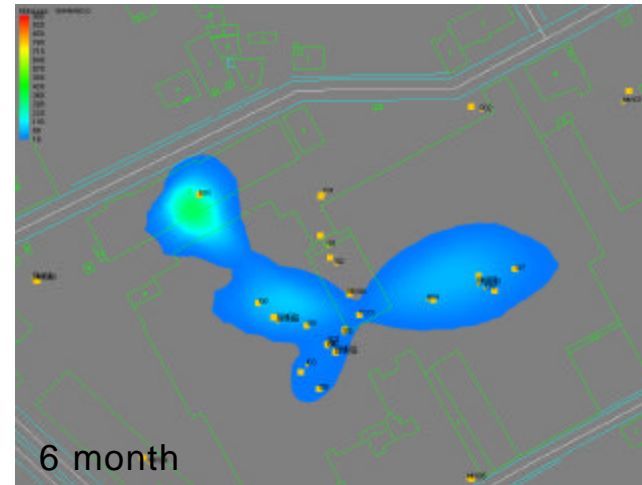
Consulting	10,000.-
Injection, Molasses	2,500.-
Monitoring, 9 month, 5 campaigns	7,000.-
Analyses: VOC, Geochemical Indicators	6,500.-
Total	26,000.-
<i>Cost per kg of TCE removed (20 kg)</i>	<i>1,300.-</i>

Full Scale Application (expected: 200 kg removed)

Consulting	15,000.-
Injection Wells (6)	10,000.-
Monitoring Network (4)	7,000.-
Injection	5,000.-
Monitoring, 2 years, 4 campaigns	6,000.-
Analyses, VOC	2,000.-
Total	45,000.-
<i>Cost per kg of TCE removed (200 kg)</i>	<i>225.-</i>



Forecast....



Conclusions

- Enhanced Reductive Dechlorination is a viable Technique
- Reaction Mechanism and Metabolites may vary even on one site (Methane/Ethene) at similar DCO concentrations
- Evidence for entire dechlorination sequence
- Molasses concentration of 200 mg/l sufficient for degradation
- Attacks also the sorbed Phase/"immobile" porosity: no Concentration Rebound observed

⇒ **Dare it! It does not cost much and does no harm**