Nanoremediation – a Site Owner‘s Perspective

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NanoRem Final Conference

Nanoremediation for Soil and Groundwater Clean-up - Possibilities and Future Trends

Solvay Site, Contamination

- Primary Source: Manufacturing of PCE, TCE, HCA (solid but soluble in PCE) from 1945–1976
- Alluvial aquifer highly permeable
- From 2002: hydraulic barrier
  - 28 m3/h, PCE max. 500 µg/l,
  - <150 kg/year removed (decreasing but slowly)
- From 2008: primary source containment
  - Decrease increases but not enough
- Test field (PCE 5000 µg/l) downstream primary source containment
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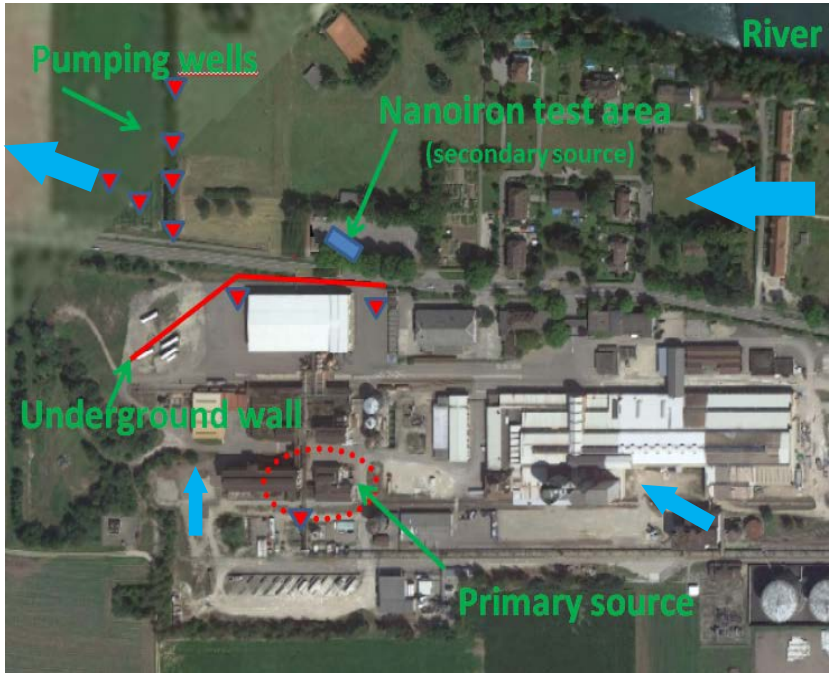
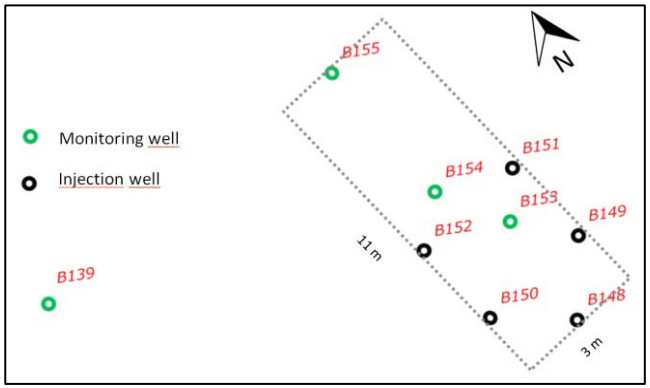
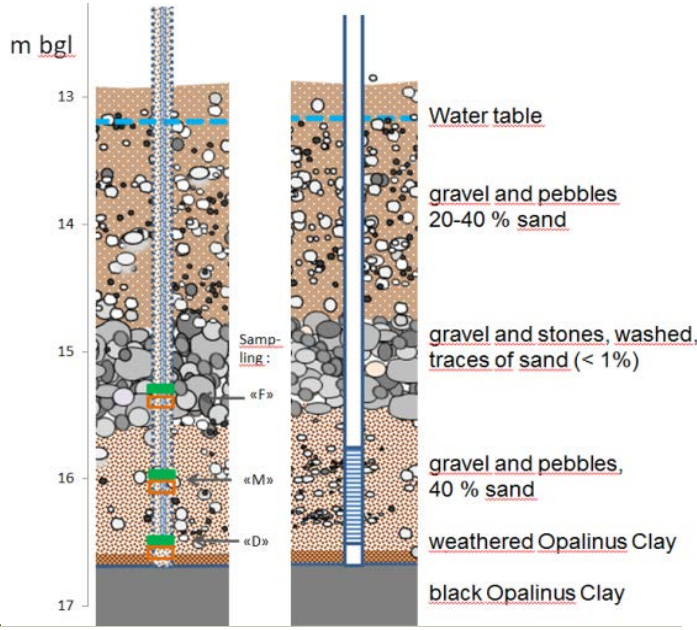


Ground water flow direction

Our experience with Nanoremediation: Pilot test area

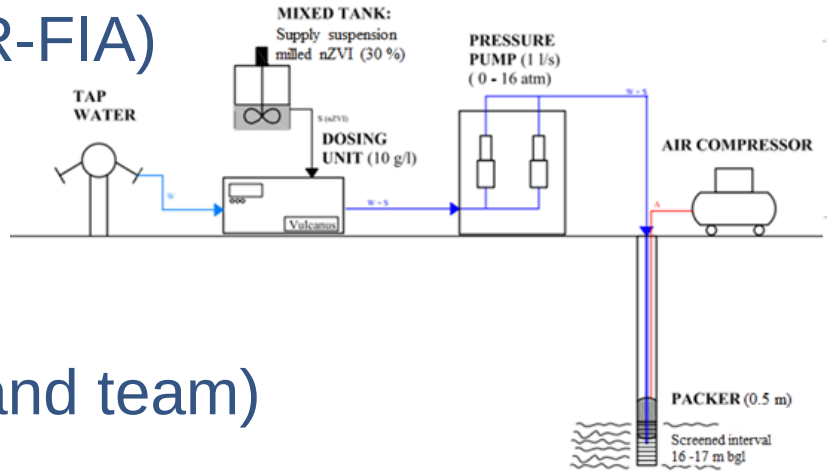
- "Direct push" not possible => drilling of wells
  - 5 injection wells (reactive zone) screened at bottom
  - 3 new monitoring locations with 3 sampling levels (F, M, D) by micro-pump (collapsed soil)
- Special observations:
  - Gravel layer with little sand (high speed groundwater until 20m/day)
  - Soil contamination increases with the depth until reaching "free phase" (trapped after bedrock sampling)



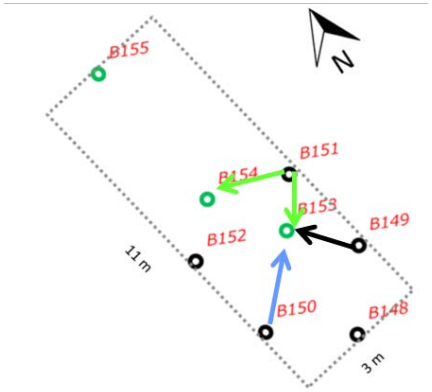


Our experience with Nanoremediation: Nano iron injection

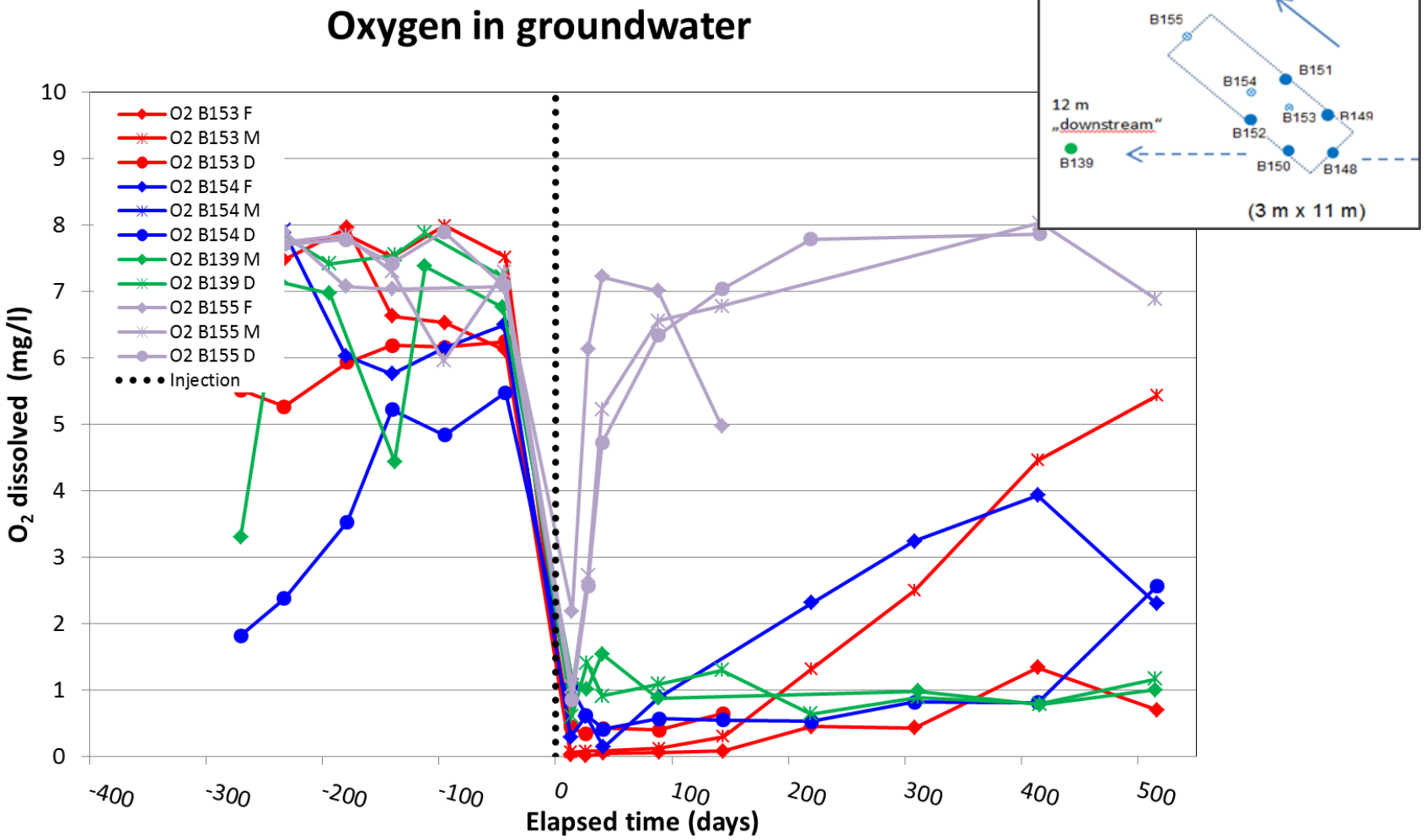
- 500 kg of milled nano iron (UVR-FIA)
  - freshly produced
  - 30 % iron in ethylene glycol



- Injection (Aquatest equipment and team)
  - 10 g/l Fe (10 m^3/well)
  - LiCl added to suspension (20mg/l)
  - 5-7 atm injection pressure (50 l/min)
  - On top of the bedrock



Our experience with Nanoremediation
Monitoring results (nZVI reactivity)



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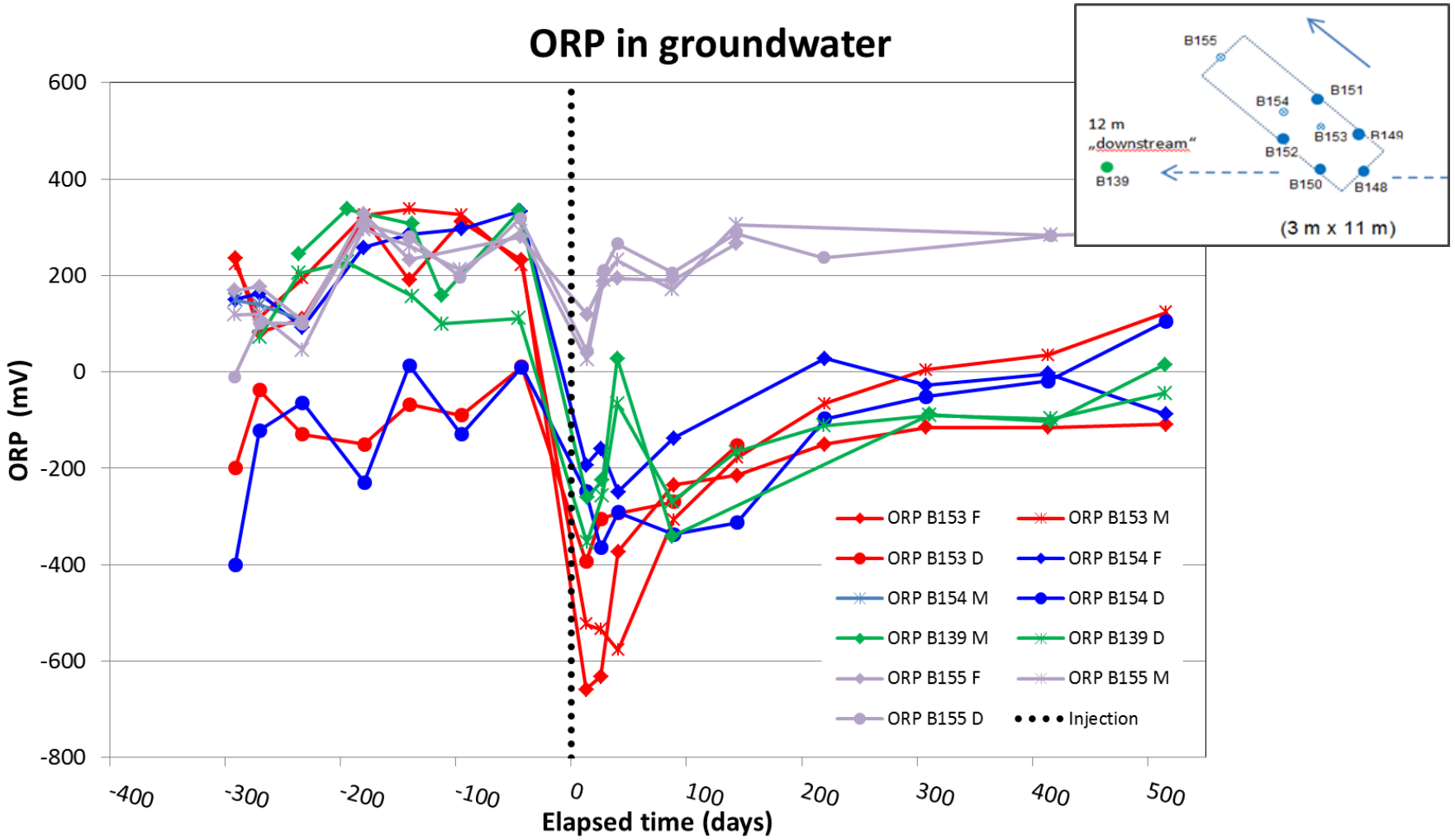

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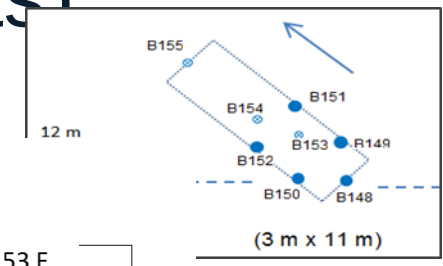

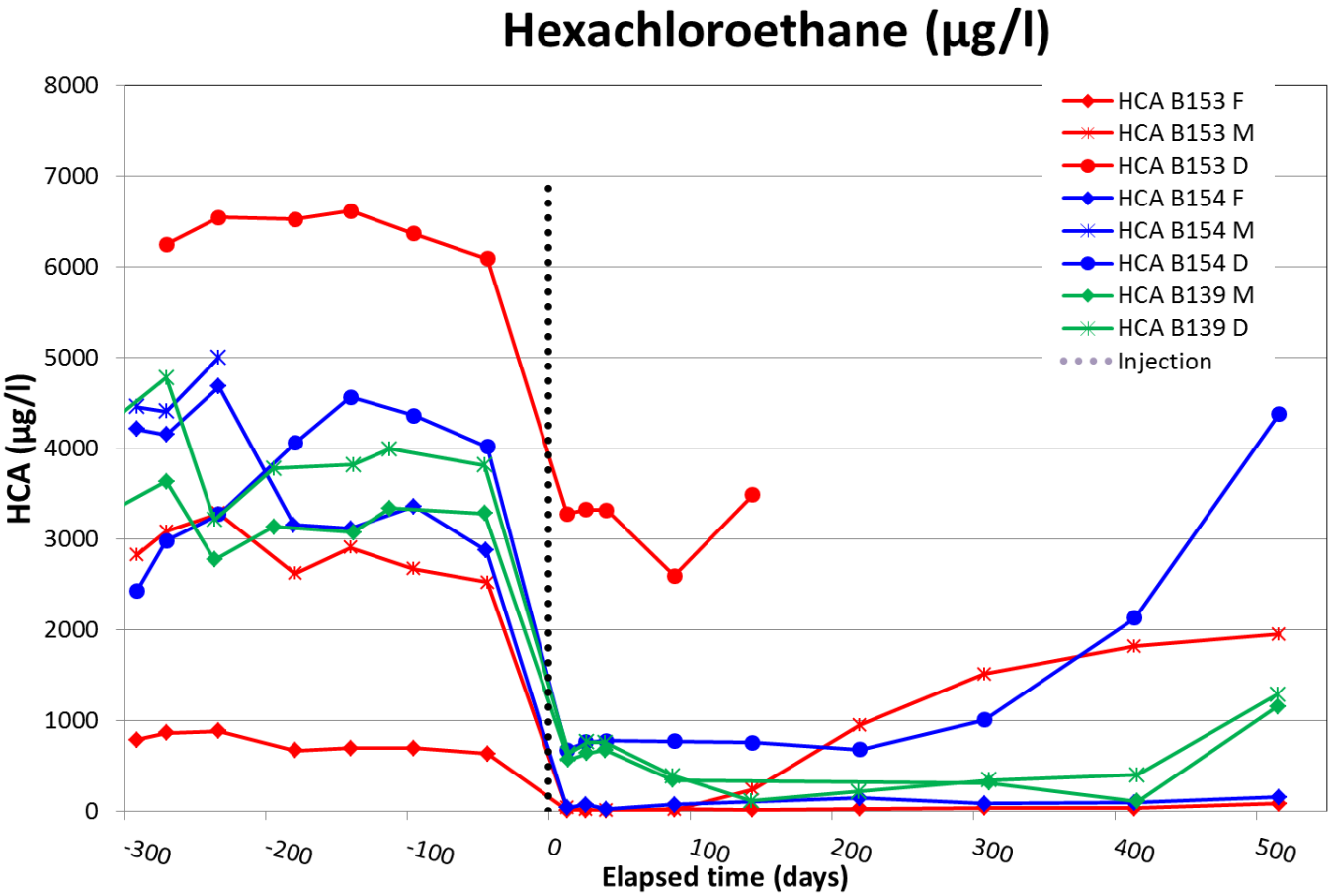

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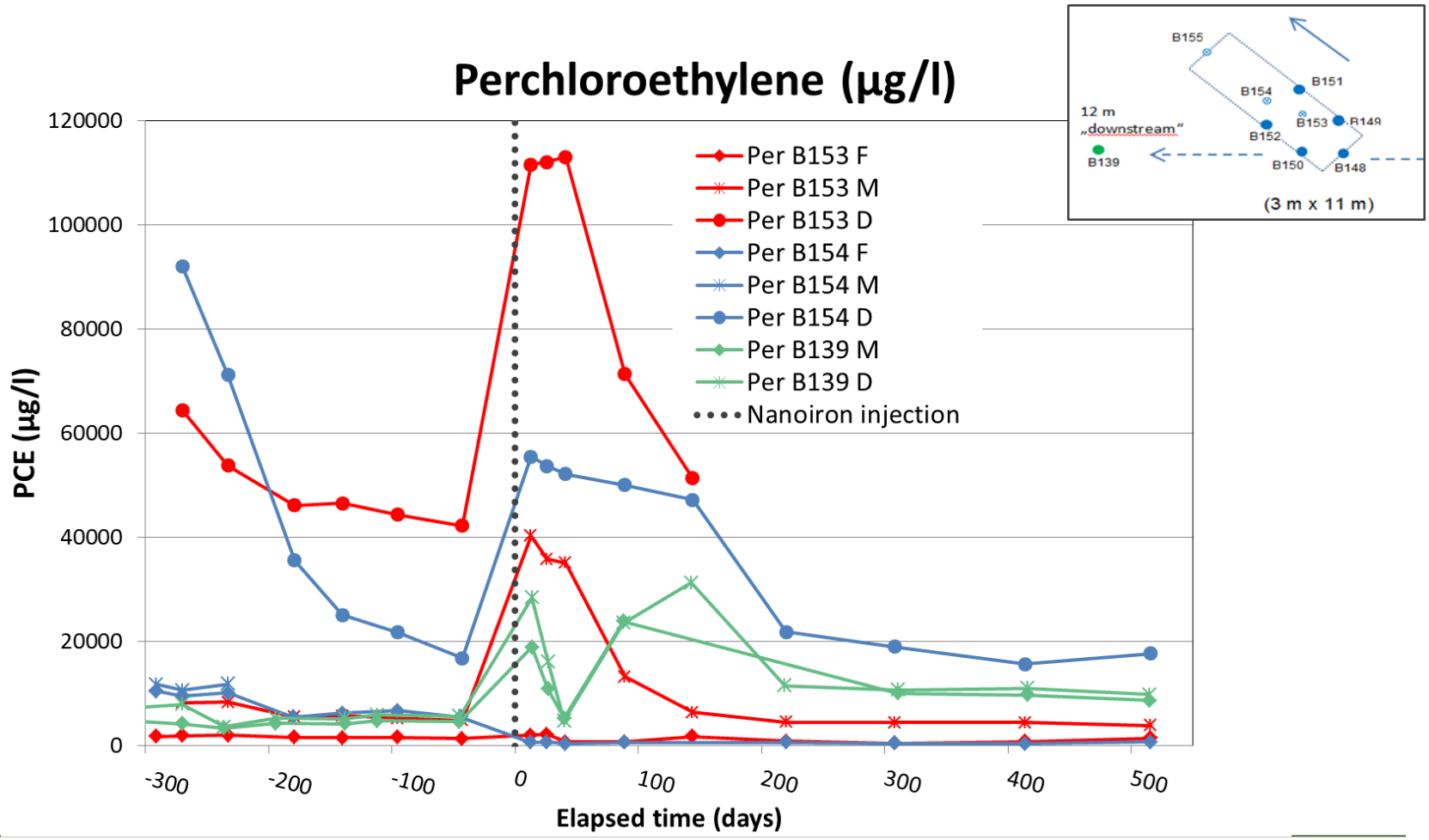

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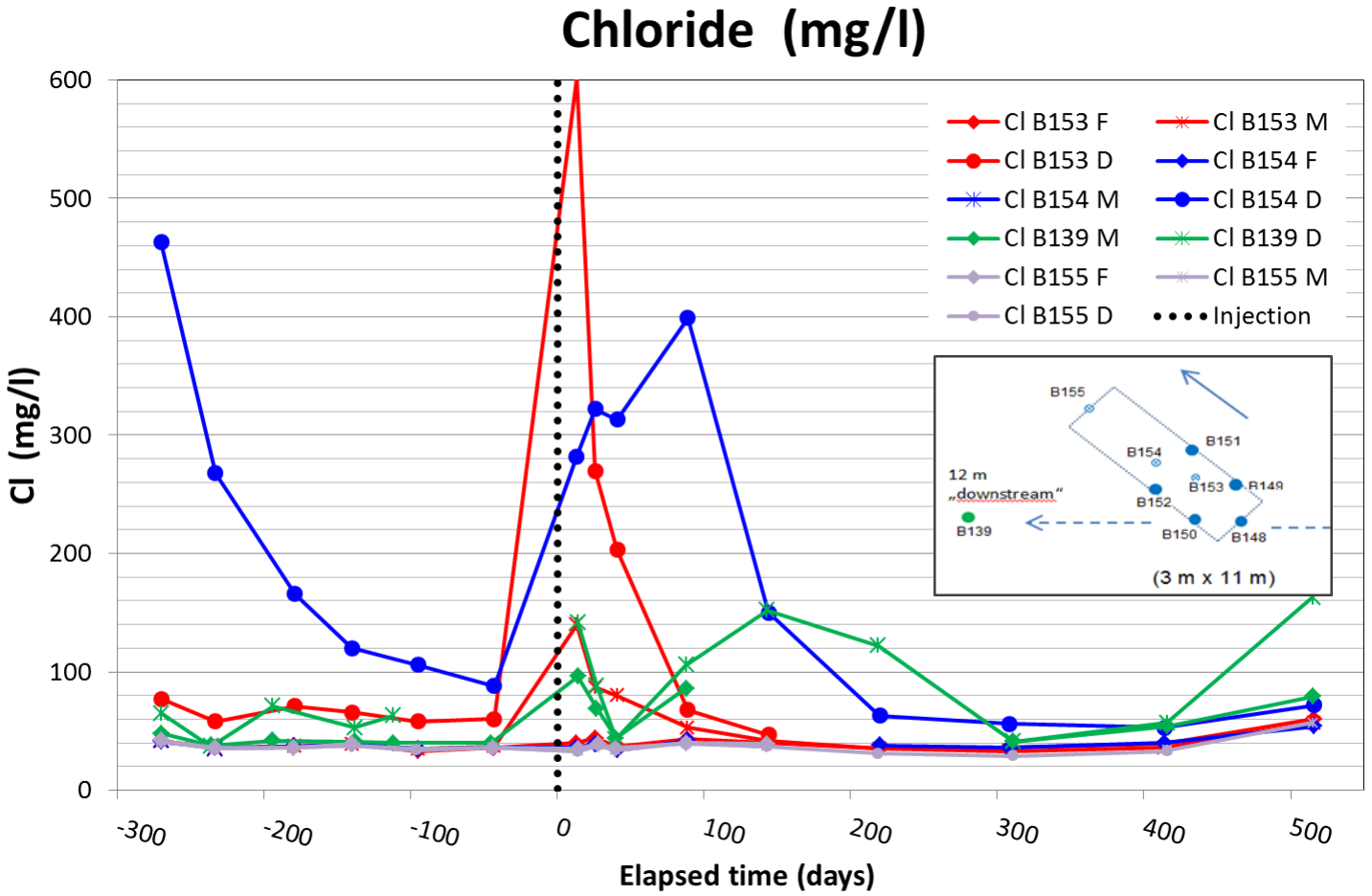
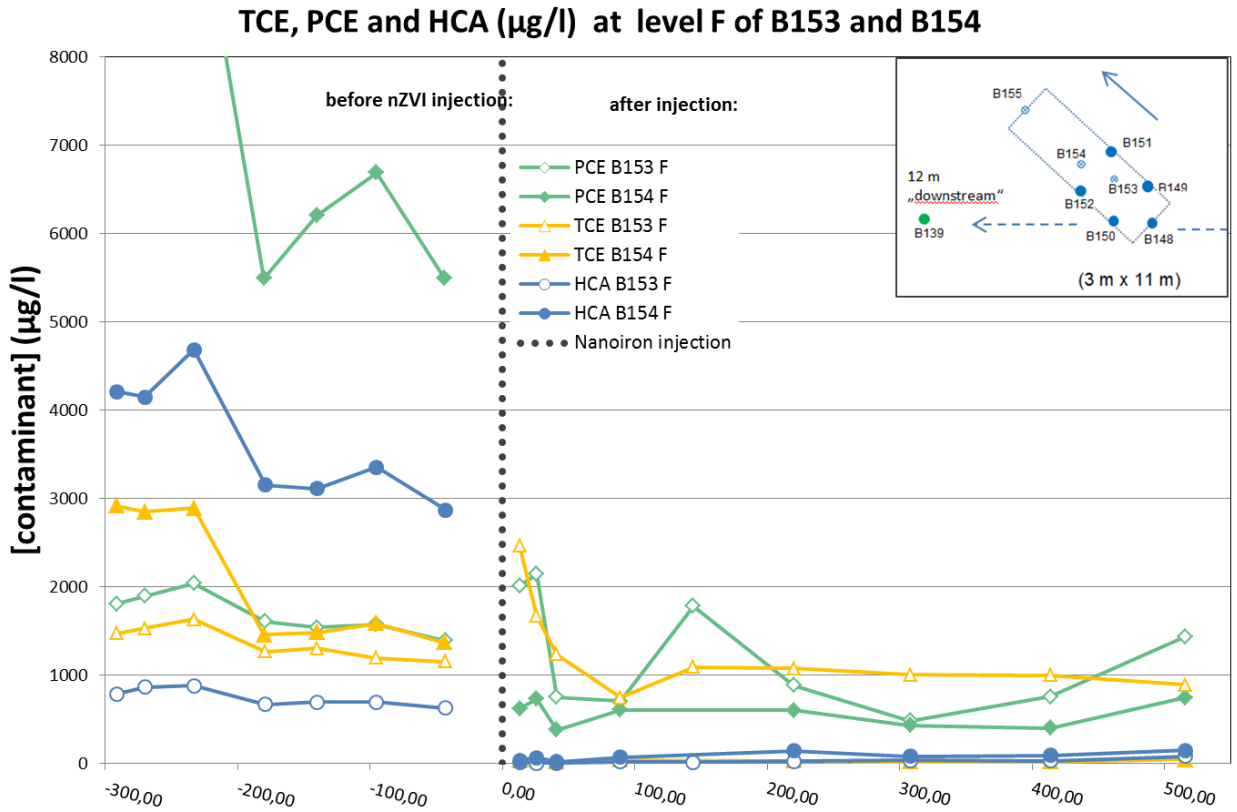


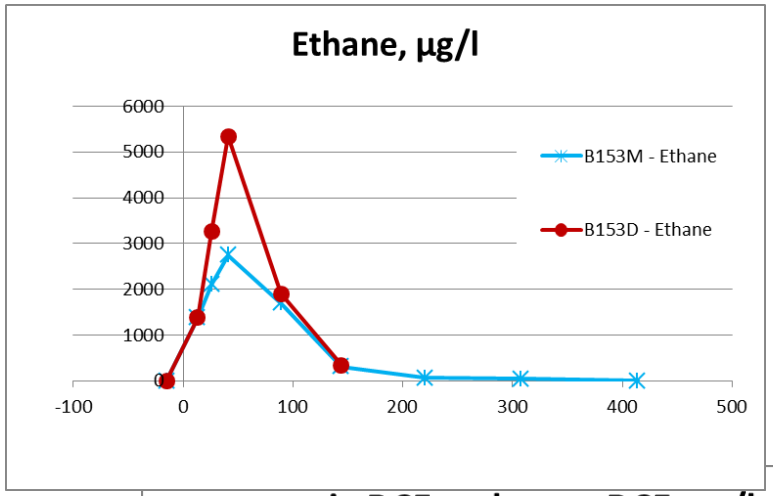
Our experience with Nanoremediation
Monitoring results (contaminants)

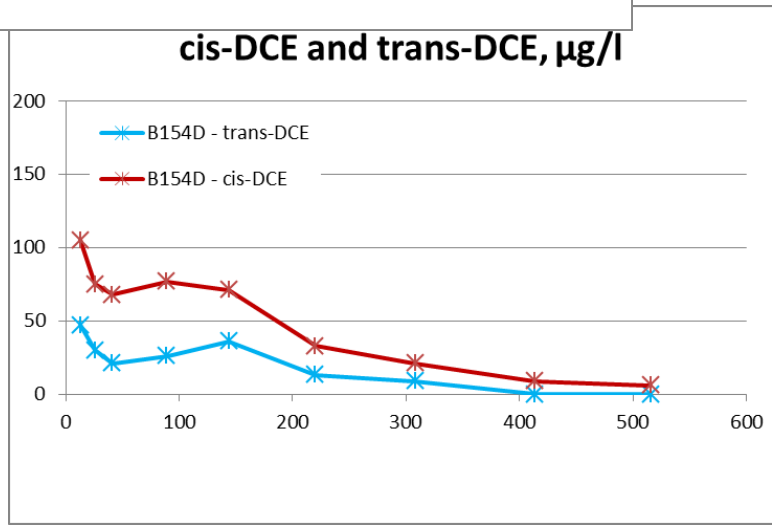
- Best results at level F (all contaminants) – no rebound



Monitoring results (metabolites)

- Ethene only detected during injection
- Hydrogen, Ethane still present 6 months after
- cis- and trans-DCE only detected at deepest of B153 and B154 but rapid decrease

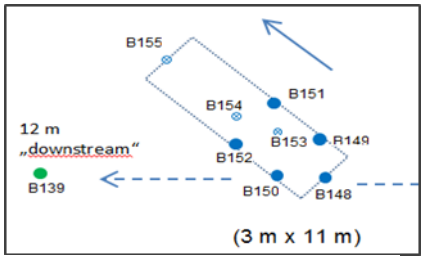


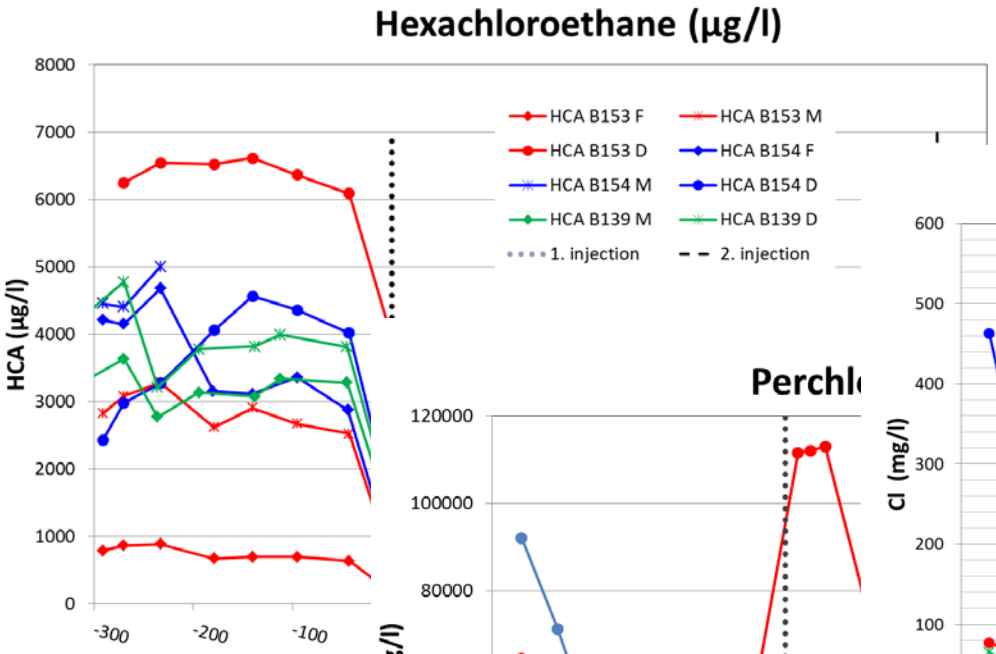


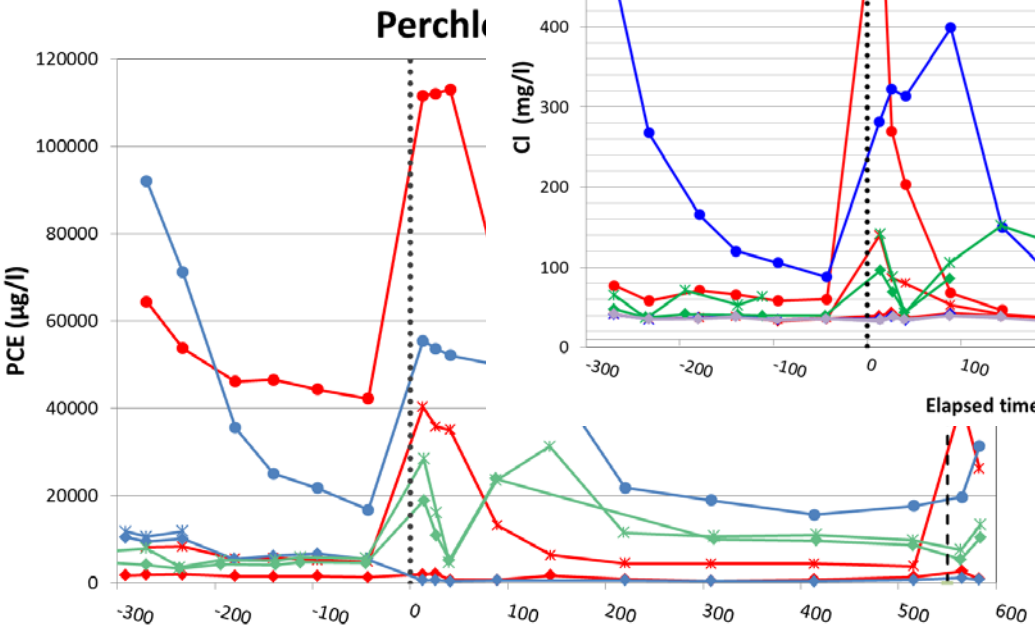
Our experience with Nanoremediation
Conclusions of the pilot test

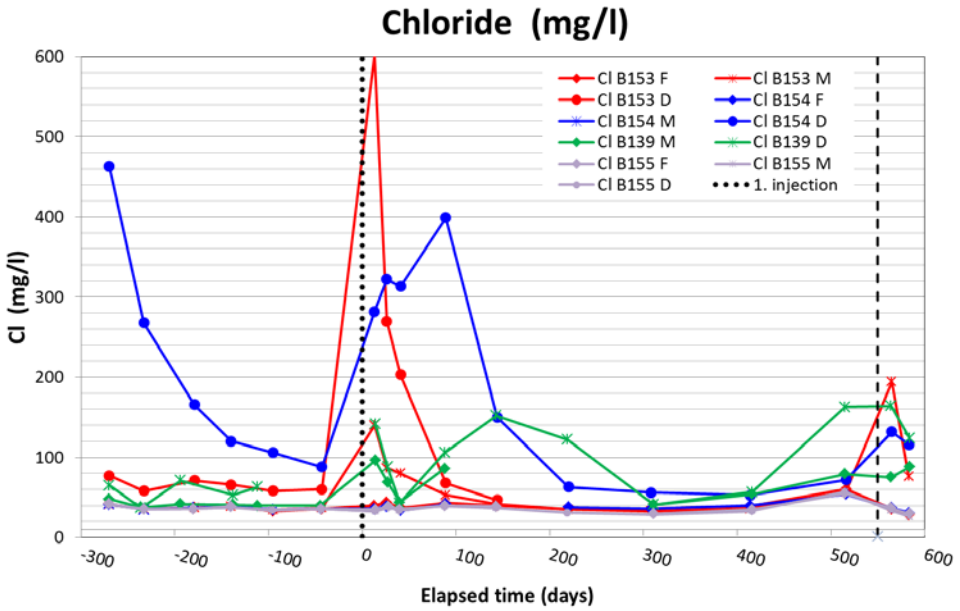
- Injection through screened wells possible
- ≥ 2 m travel distance for nZVI confirmed
- Fast reduction of O_2, hexachloroethane, NO_3^{--} ...
- 6-9 months reactivity of nZVI indicated (H_2, ethane) but permeability decrease expected
- Solubilisation or flushing of free phase at aquifer bottom and the reduction of HCA mask the reduction of PCE and TCE
- Good and long lasting results for upper layer
- Encourage us to do an new injection (mix nano and micro iron) made 18 months after first one

Our experience with Nanoremediation
The new injection – Oct. 16









Conclusions as a site owner for nanoremediation

- Interesting technology to have a quick impact on contamination but need some conditions to obtain best results (direct push, soil permeability, water flow, oxygen, contaminant concentration)
- Low risk of nZVI in soil (low distance, high reactivity, rust as by-product) -> but still some reluctance from authorities (“nano”).
- Still degradation product and some mobilization so useful to have hydraulic barrier downstream

Conclusion as a site owner for nanoremediation – some cost evaluation

(to launch the debate)

- **Pump and treat**: from 50 to 500 € to treat 1 kg of chlorinated compounds – expected time: decades
- **nZVI** :
  - Cost of nZVI: 100 €/kg
  - Stoichiometry 1,3 Kg iron to treat 1 kg of chlorinated compound.
  - Efficiency – selectivity in groundwater: 50% (???)
  - Operating cost (direct push – additives -injection): 40 €/Kg CVOC (???)
  - So total cost: 300 € to treat 1kg of chlorinated compounds
  - Expected time: years

Conclusion as a site owner for nanoremediation – potential improvements

- Increase cost-effectiveness of the technology
  - Decrease non useful nZVI consumption (oxygen, nitrate depletion,…) -> increase selectivity with other compounds, electric fields, …
  - Decrease number of drillings (increase mobility: surfactants, …)
  - Decrease cost of iron (mix with micro, production process improvements…)

- Improve the follow-up of the reaction zone (direct adjustment during injection process)
  - Specific geophysical techniques?

- Combine nano and bioremediation to avoid rebound

Thank you for your attention

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