STUDYING OF NANOIRON PARTICLES MIGRATION IN HOMOGENEOUS ARTIFICAL CREATED AQUIFER IN 3-D ORDERING

VEGAS (Research facility for subsurface remediation)
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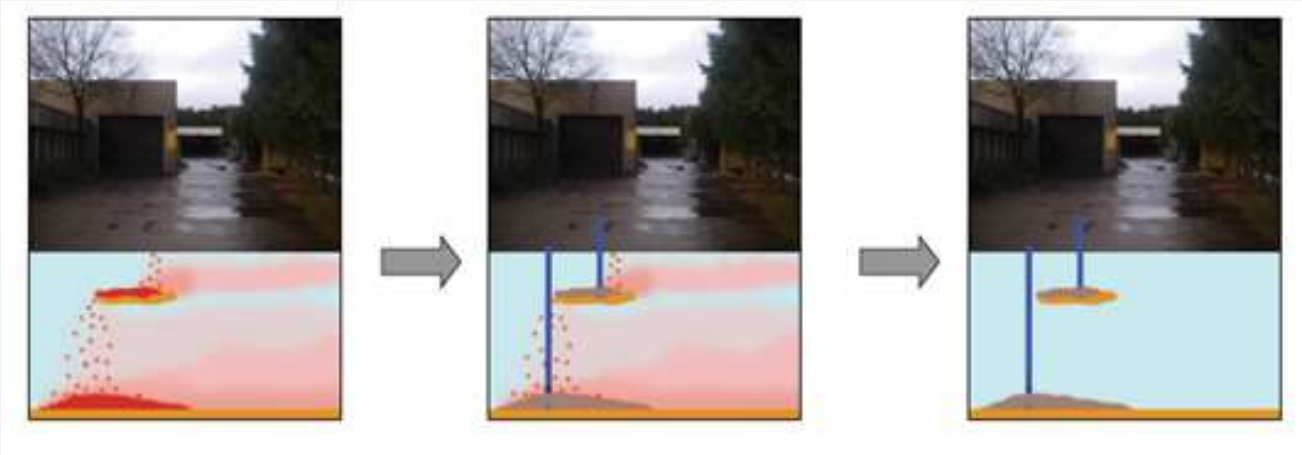
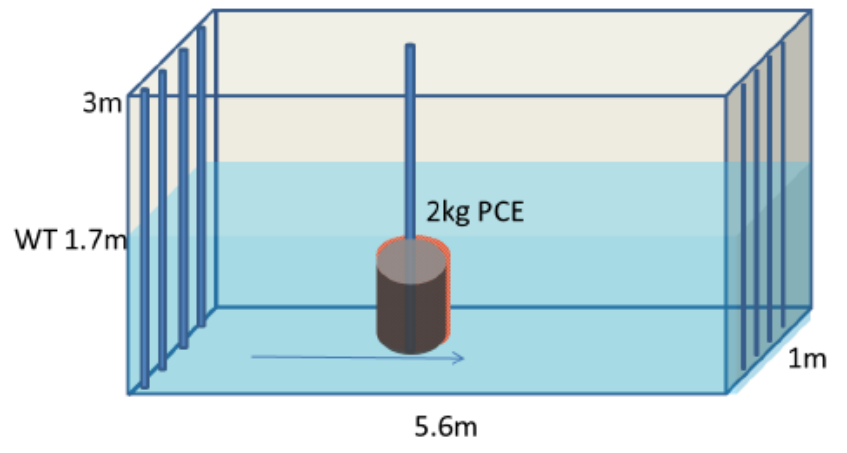
Large Scale Flume (LSF) Experiment - Motivation

- Nano-scaled particles have potential advantages
  - Reactivity of nZVI much higher than iron filings (specific surface)
  - Economical application also in greater depth and underneath buildings
  - Applicable to large range of contaminants (organic substances, heavy metals, pesticides etc.)



LSF Experiment - Goals

- Remediation of PCE source (2kg) utilizing ZVI nanoparticles (Nanofer 25s) and Carbo-Iron particles
- Design, set-up and test of injection system
- Transport and targeted deposition of NP in the subsurface, and of necessary flow velocities
- Quantification of remediation (degradation) rates and longevity of NP (reinjection intervals)



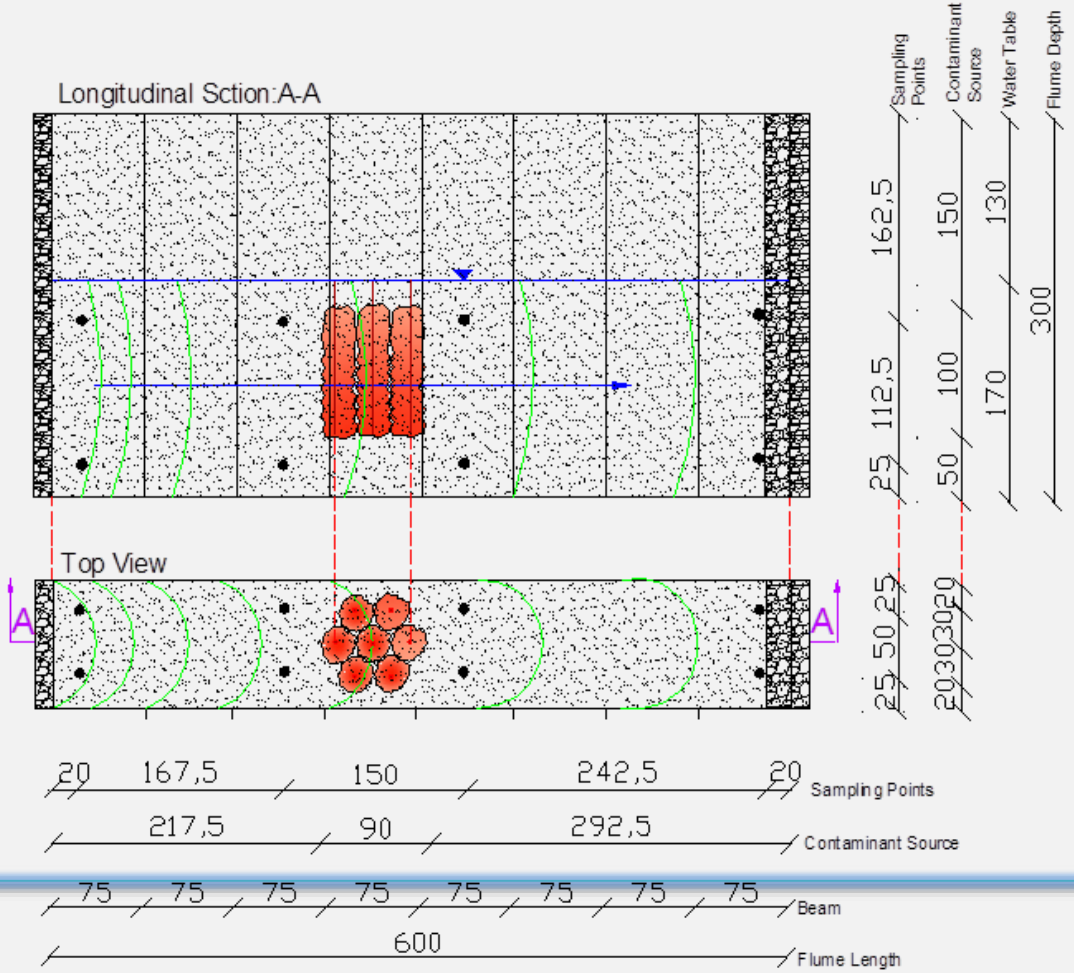
LSF Experiment - Set-up

- Stainless steel walls and glass front
- 16m x 1m x 3m (L x W x H), subdivided into two compartments, each 8m long
  - **LSF1 (Remediation of PCE source using nZVI particles)**
  - LSF2 (Remediation of PCE source using Carbo-Iron particles)
- 36 sampling and measurement ports in each compartment
- Unconfined aquifer, Homogeneous soil structure (medium sand)
- Inflow BC: Constant flux, Outflow BC: Constant head
- Flow rate: Q = 0.1 m^3/d
- Darcy flux: q ~ 0.07 m/d
- Seepage velocity: v ~ 0.2 m/d
- Inflow DO concentration: < 1mg/L

LSF Experiment - Set-up

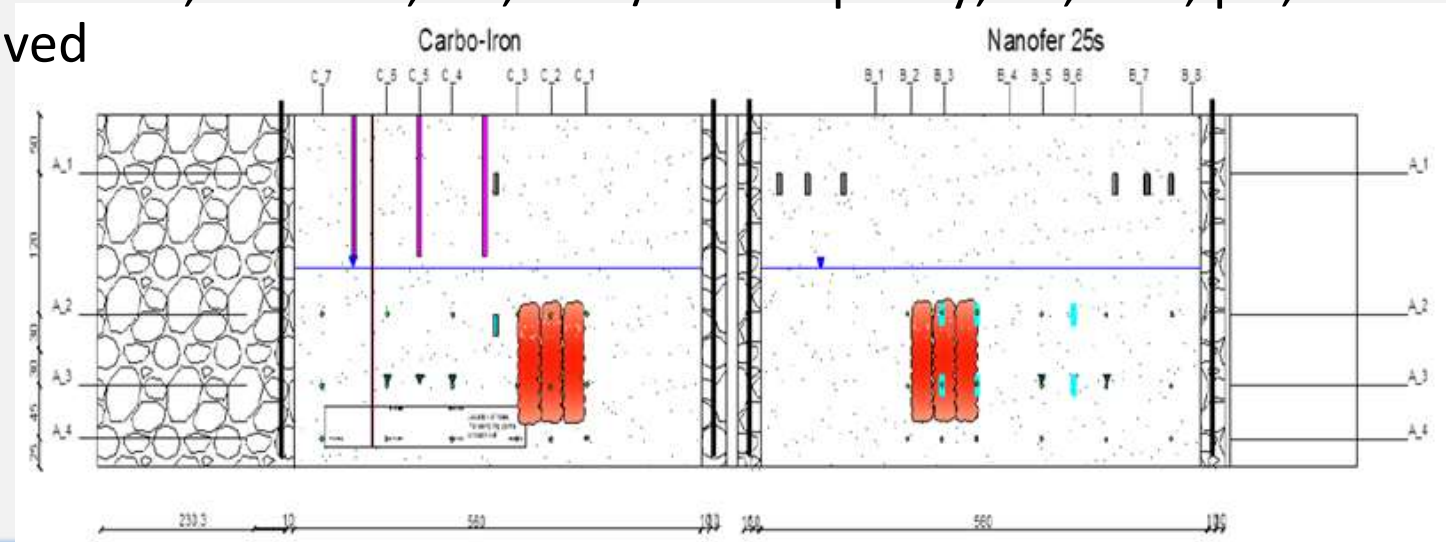
LSF1 Experiment – Tracer test

- Goal
  - to validate the permeability of whole flume
  - to establish the initial conditions in the experiment



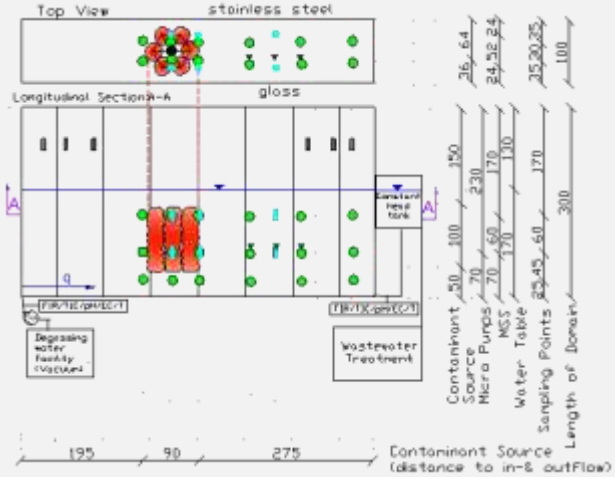
LSF1 Experiment - Monitoring

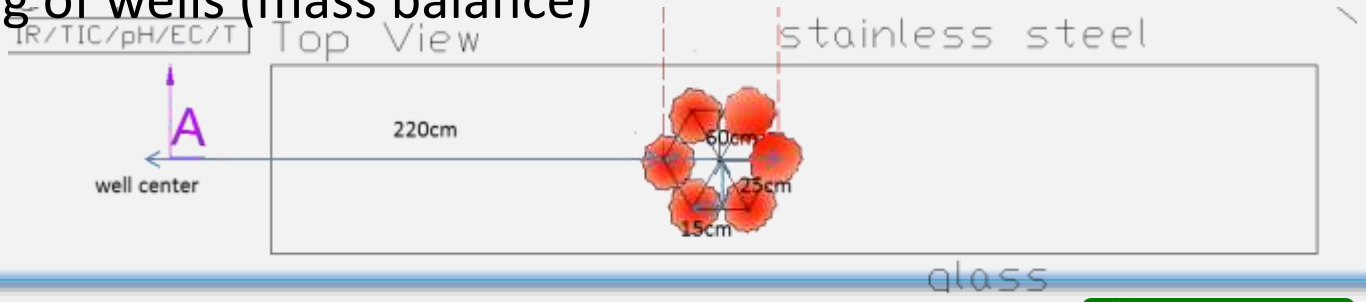
- Inflow/Outflow
  - online sensor for milieu parameter
  - Measuring parameters → Q, pH, ORP, DO, EC, head
- Flow Domain
  - 12 magnetic susceptibility sensor, 3 micro pump, 36 sampling points for liquid samples, 12 piezometer/pressure transducer
  - Measuring parameters → NP concentration (in bulk); PCE, TCE, DCE, VC, ethene, chloride; H2; Acid/base capacity; EC, ORP, pH; Fe dissolved



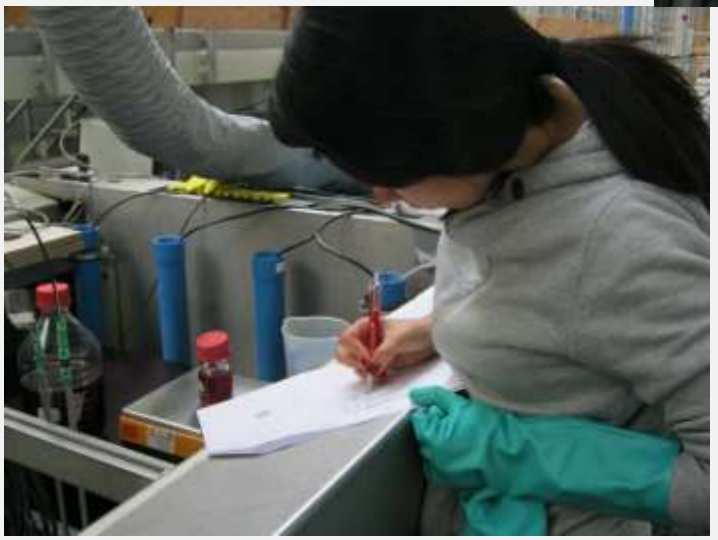
LSF1 Experiment – Source Emplacement

- Contaminant
  - PCE (free phase)
- Total amount
  - 2kg = 1234 mL
- Requirement
  - liquid PCE in source is not to migrate after emplacement
- Approach
  - inject in 6 location in 10 depth (each location 200mL, each depth 20 mL), at the corner of hexagon, keep center clean for drilling of wells (mass balance)



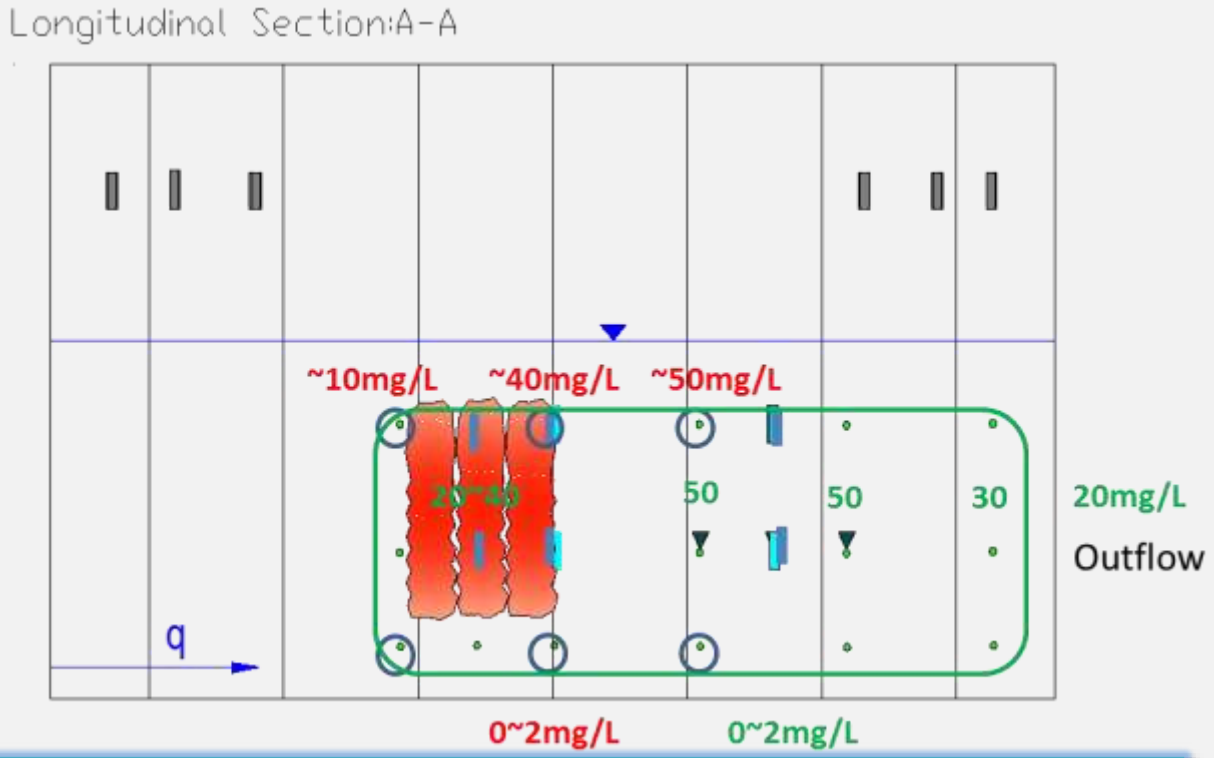


LSF1 Experiment – Source Emplacement



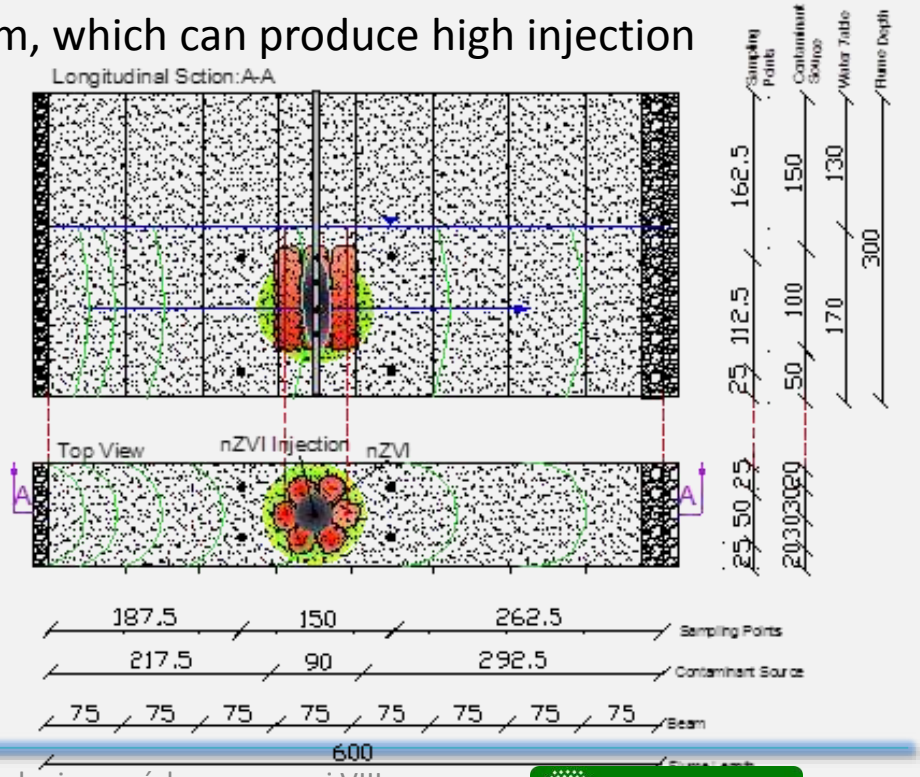
LSF1 Experiment – Monitoring of PCE distribution

- After 2 days: first concentration was observed (a, c, d)
- After 2 weeks: concentration stable
- After 8 weeks (just before injection): PCE concentration for whole flume measured



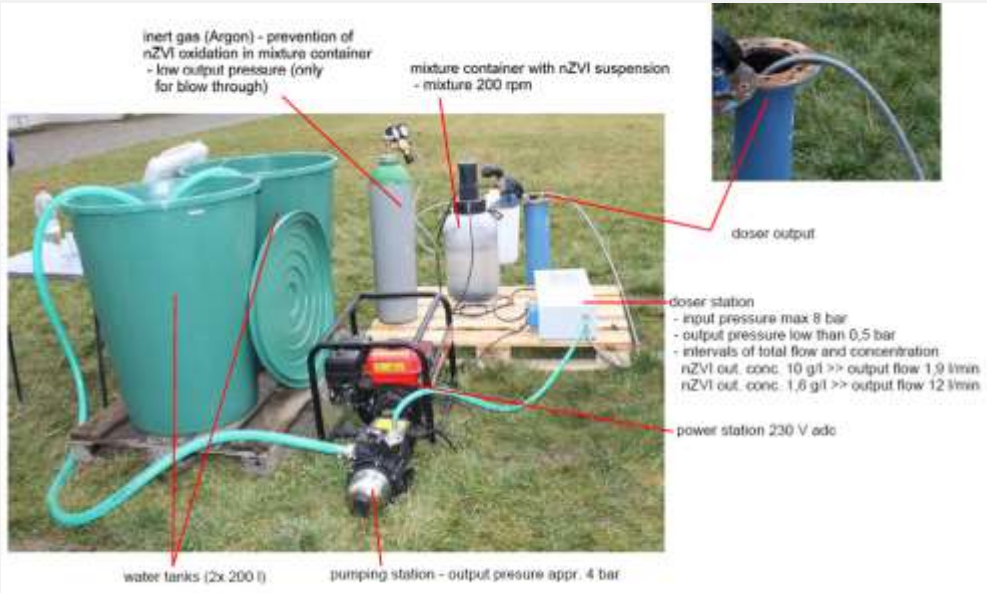
LSF1 Experiment – Nanoparticle injection

- Goal → sufficient ZVI concentration throughout source zone
- Injection system → direct push, continuous injection
- Carrier fluid → DI water
- Particle concentration in suspension → 10 g/L
- Total ZVI mass injection → 10 kg
- Injection suspension vol. → 1 m³
- Size of rod:
  1” ID with 4 small openings at the bottom, which can produce high injection velocity around the openings

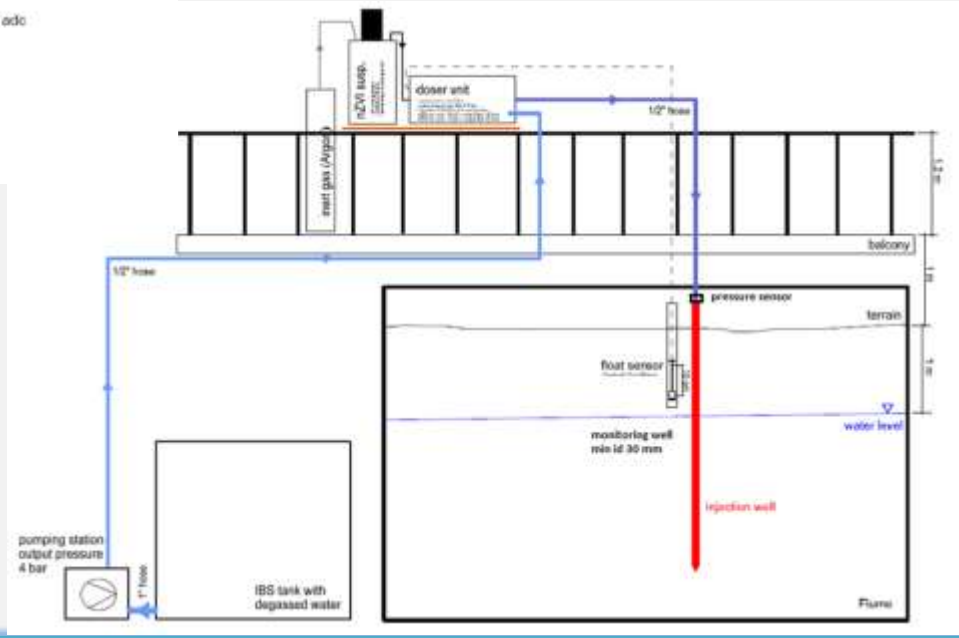


LSF1 Experiment – Nanoparticle injection

- dosing and injection system



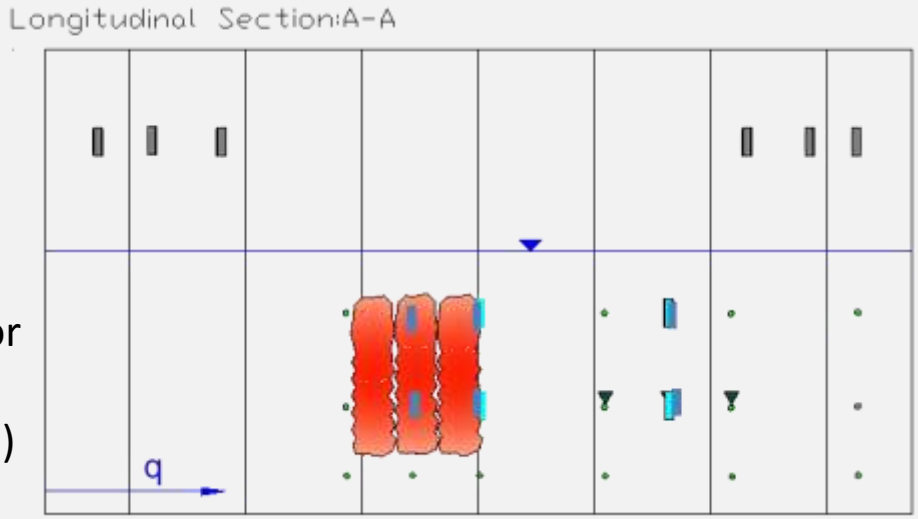
Boundary conditions (Contaminant zone = 0.64 m³)	
Inflow/ Outflow	Constant head
Water Table	1.7 m
Base flow discharge (Q)	0.005 m³/h
Darcy Flux (Seepage Velocity)	0.07 m/d (0.22 m/d)
NP suspension concentration	10 g/L (mixied online)
Concentrate concentration	240 g/L
Dillution	with degassed water (1:25)
Total volume of suspnsion	1m³ (10 kg Fe0)
Injection depth	10 depths (from 140cm to 50 cm)
volume of suspnsion at each depth	0.1 m³
NP injection rate (Q_{inj})	0.1 m³/h (10 h)



LSF1 Experiment – Nanoparticle injection

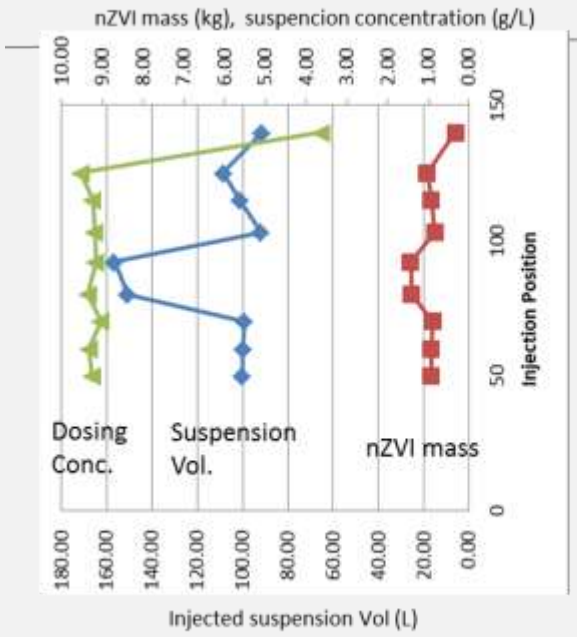
LSF1 Experiment – Monitoring of NP injection

- Inflow: constant flux BC
  - Q , pH, ORP, T, DO
- Outflow: constant head BC
  - Q, pH, ORP, T
- Heads (continuously)
  - 12 pressure transducers at top sampling plane
  - 12 piezometers at bottom sampling plane
- Dosing system
  - Parameter: Q, P
- Porous media (Soil samples)
  - Not during injection
- Susceptibility detector (NP mobility)
  - 12 points (continuous)
- Liquid Sampling points/Micro Pump
  - Location: close to susceptibility detector
  - Frequency: once during injection
  - Parameter: suspension solid phase (NP)



LSF1 Experiment – Preliminary injection results

- Injection: 9 elevations
- Total: 1m³ suspension with 8.75kg nZVI
- Injected V each 100L except
  2 elevations (at 92 & 80 cm)
- Injected mass: each 1kg except 3 elevations (at 140, 92, 80cm)
- Concentration: each > 9 g/L except 1 elevation (at 140cm)

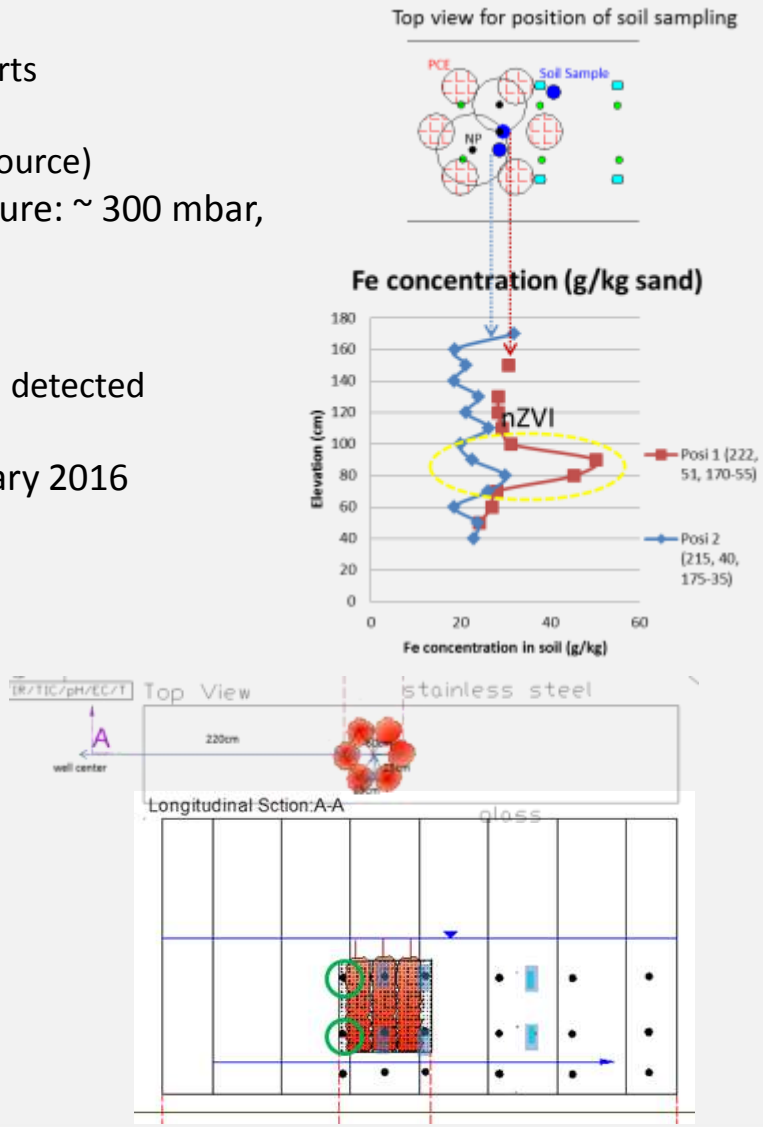


Elevation (cm)	Position (A-C)	Time (min)	dosing Vol (L)	Injected vol. of ZVI concentrate (L)	Injected mass of ZVI (kg)	Injetion concentration (g/L)
140	A	160	91.45	1.37	0.33	3.63
125	A-B	168	108.57	4.27	1.03	9.52
115	B	65	101.26	3.86	0.94	9.24
103	B	76	92.08	3.49	0.85	9.18
92	B	98	156.61	5.92	1.43	9.16
80	B	106	150.69	5.82	1.41	9.35
70	C	68	99.27	3.70	0.90	9.04
60	C	68	99.96	3.85	0.93	9.33
50	C	68	100.08	3.82	0.93	9.25

LSF1 Experiment – Preliminary injection results

- 5 days after injection
  - PCE free phase was observed in all sampling ports
- 1 week after injection
  - Free phase still observed in a1B, a3B (close to source)
- Water Table Increase: max. 50 cm; Injection Pressure: ~ 300 mbar, Pmax 800 mbar
- NP Transport:
  - MSS (r= 26cm) no detection
  - Soil samples (r=15cm) only at z=90 - 70cm, nZVI detected

  → NP transported max. 15cm
- Additional research necessary; Reinjection February 2016



Děkuji za pozornost!