Passive Multi-Level Sampling for the Characterization of VOCs Groundwater Plumes and Mass Discharge from NAPL Sources. Designing a new Sampling Device: from Modelling to Field Measurements

S. Kaskassian

Direction Recherche et Développement
19, rue de la Villette
69425 Lyon Cedex 3
Tél. : 04 37 91 20 50 – Fax : 04 37 91 20 69

Framework of the project

- 4-years R&D project, partially supported by ADEME, led by BURGEAP with following partners
  - IMFT: Prof. Marcoux
  - LHYGES: Prof. Schaefer, Dr. Razakarisoa
  - MGF Grimaldi: M. Vanneau
  - SOLVAY Electrolyse France: Dr. Cazaux

- Project objectives
  - Develop a new multi-level groundwater sampling device
  - Compare the developed sampler to existing tools

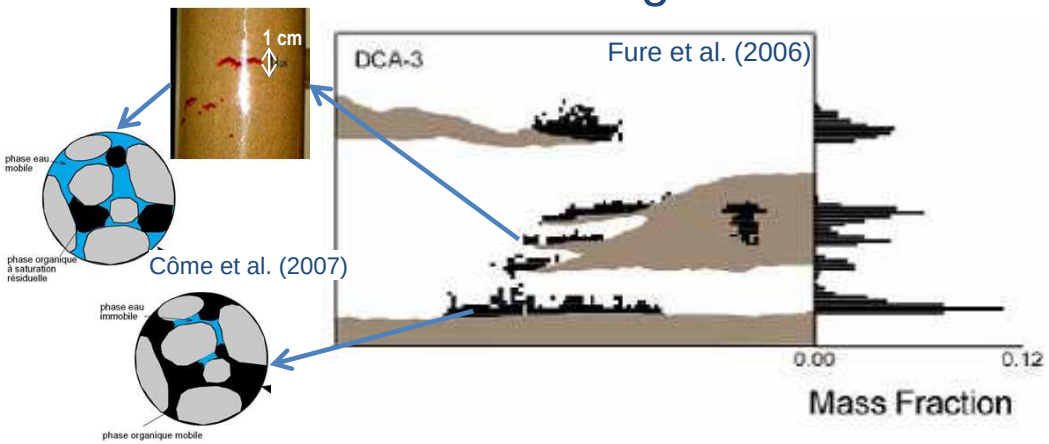
➡ **Measure the "true" groundwater concentrations profile in wells and the mass discharge from NAPL source to the plume**

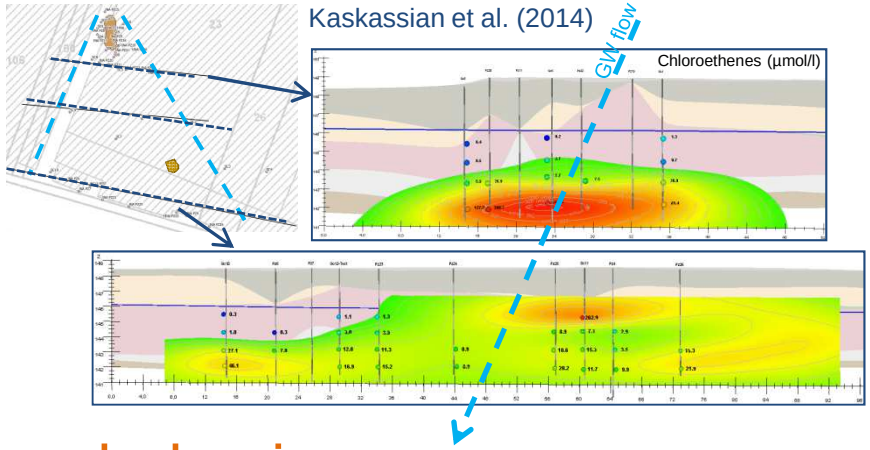
Accurate mean for source delineation and mass flux measurements

Insights for site conceptual model, long term source attenuation and remediation actions

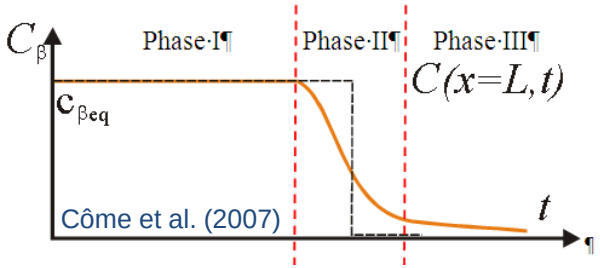
Mass discharge from NAPL sources

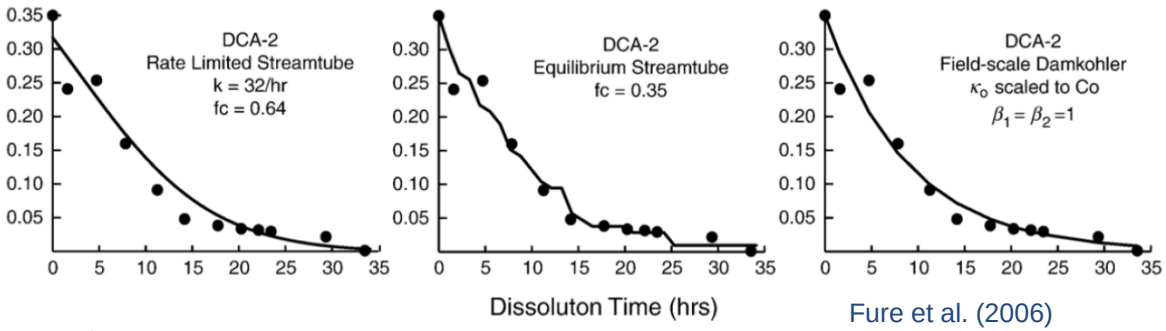
- NAPL sources exhibit non homogeneous distribution in aquifers
  - Discrete distribution of NAPL as lenses and small size ganglia
  - Heterogeneous GW concentrations in plume
  - Preferential discharge at locations with high concentrations & velocities





- Long term NAPL dissolution & plume behavior
  - 3 step dissolution : equilibrium / sharp non-equilibrium / long term tailing
  - Source decay model ?





Existing multi-level GW sampling designs

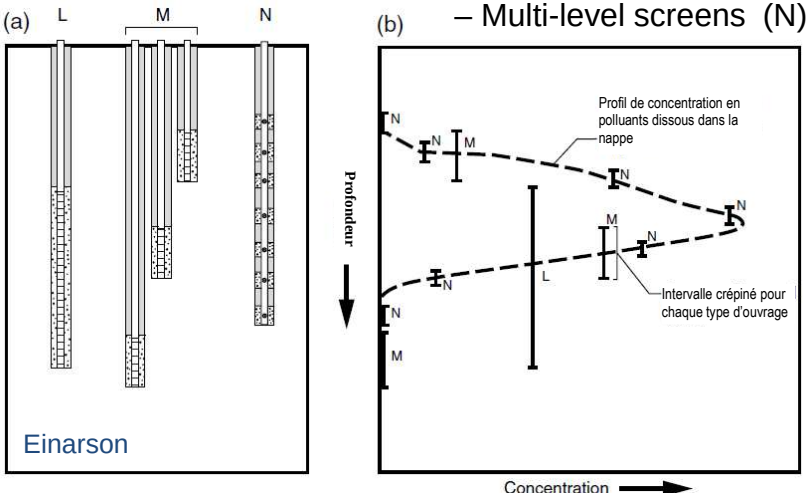
1. Pore water sampling (direct push)
   - Direct push tools
   - 1 location = 1 depth !
2. Different well designs
   - Simple / multiple pumps with or without packers
   - Effect of sand filter & screen length !
3. Equipped borehole
   - Permanent equipment
   - Localized sampling ports

1

Waterloo Profiler / Geoprobe Profiler

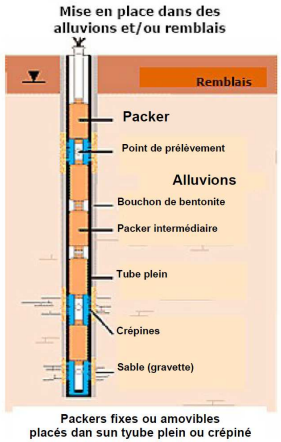
2

Long screen well (L) – Cluster wells (M) – Multi-level screens (N)



3

Waterloo Multi-level System

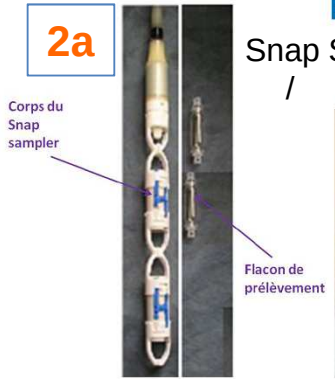


Tools for Multi-Level sampling in wells

1. Active methods
   a) Pumping between baffles or packers
   b) Direct push tools (not in a well)

1a

2a

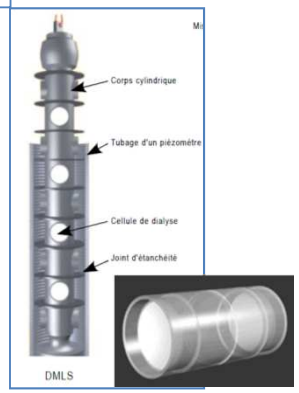


Snap Sampler / PREMUNIX

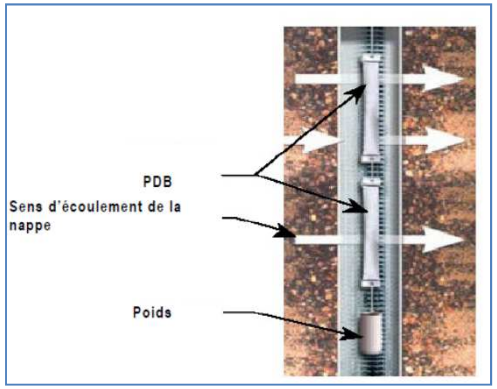
2. Passive methods
   a) Instantaneous concentration measurement = grab (thief) sampler
   b) Equilibrium concentration measurement = equilibrium diffusive sampler (contaminant-selective membranes)
   c) Time-average concentration measurement = accumulative diffusive sampler or permeation sampler

➡ PFM actually & directly measures the contaminants mass flux

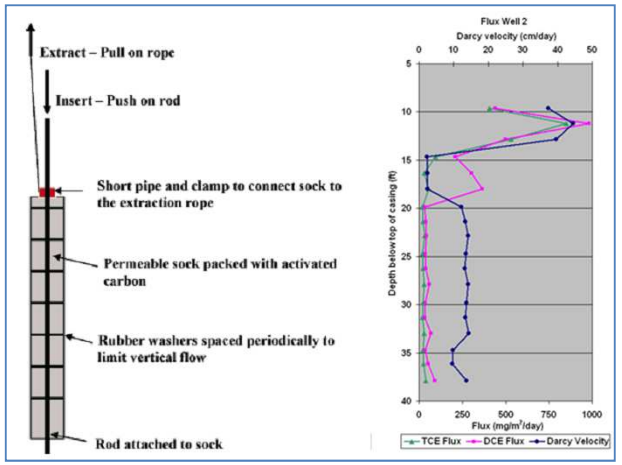
2b DMLS



PDB



2c PFM



Design of a new sampler – MGF Grimaldi

- For detailed GW concentration profile measurement
  - Passive multi-level sampler (no pumping)
  - Installed in wells (Int. Diam. ≥ 50mm ~ 2 inches)
  - Sample all fluids (groundwater, NAPL if present) at any given depth
  - Fluid permeation through screen (large slots)
  - Composed of 33cm (1 foot) long modules = sampling chamber
  - Modular system to fit any sampling depth / interval design
  - Each module is separated from the others (below & above) by small size (5cm long) air-packers
  - Low-pressured air controlled sampler (open / close chambers & inflate / deflate packers)
  - Resistant materials to organic contaminants & extreme pH / salinity

⇨ **Design verification & optimization ?**

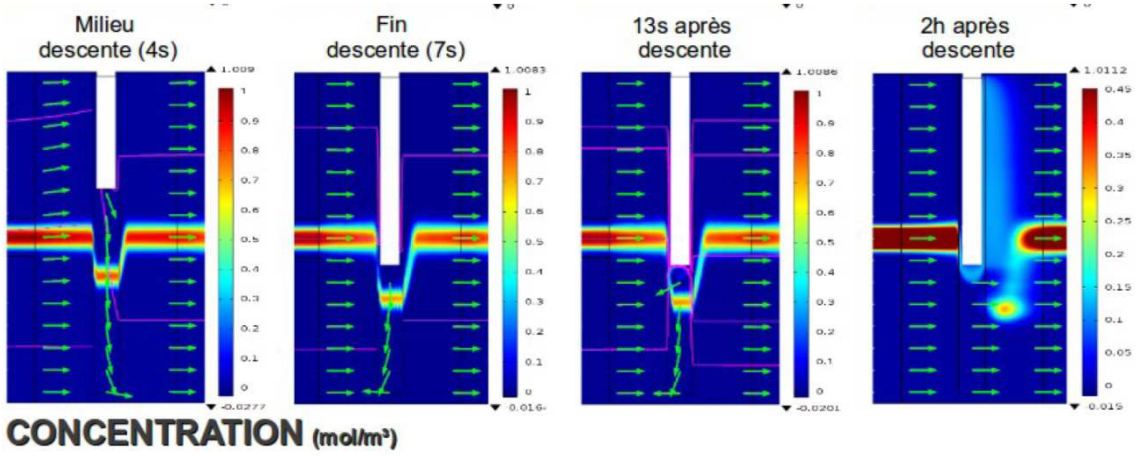
Evaluation of potential limitations and user guidance ?

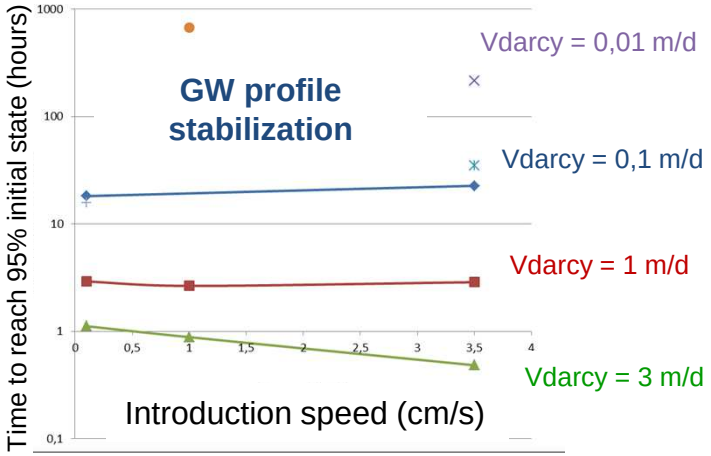
Numerical models & small-scale lab. experiments

Large-scale lab. experiment & field tests

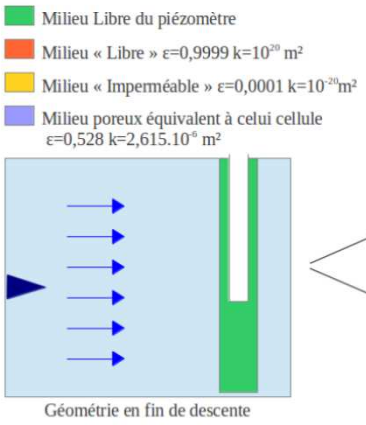
COMSOL numerical models (2D) – IMFT

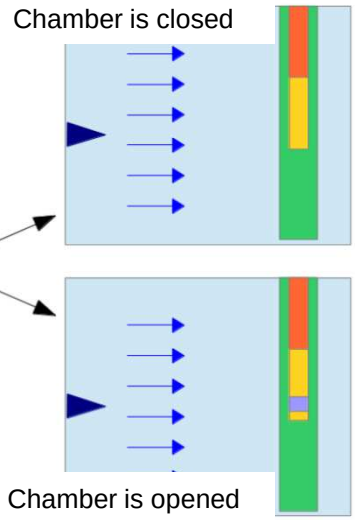
- Profile perturbation due to sampler introduction in wells

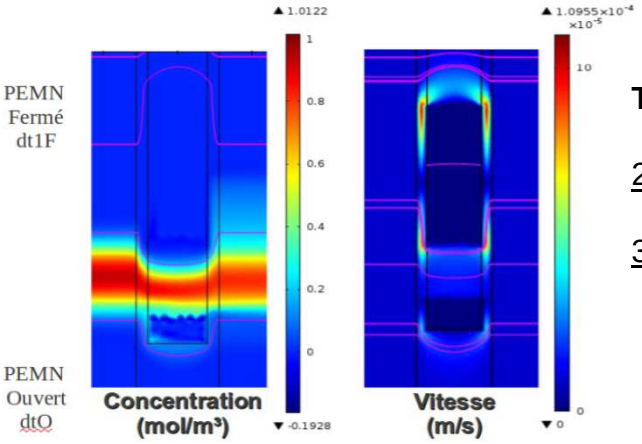




- Effect of closing / opening the sampling chambers







Time to reach 95% of initial state

2D-Model # 4h35 (open/closed)

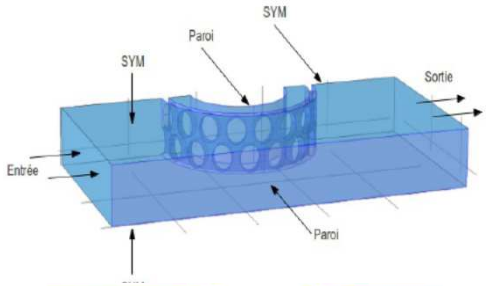
3D-Small scale lab exp.

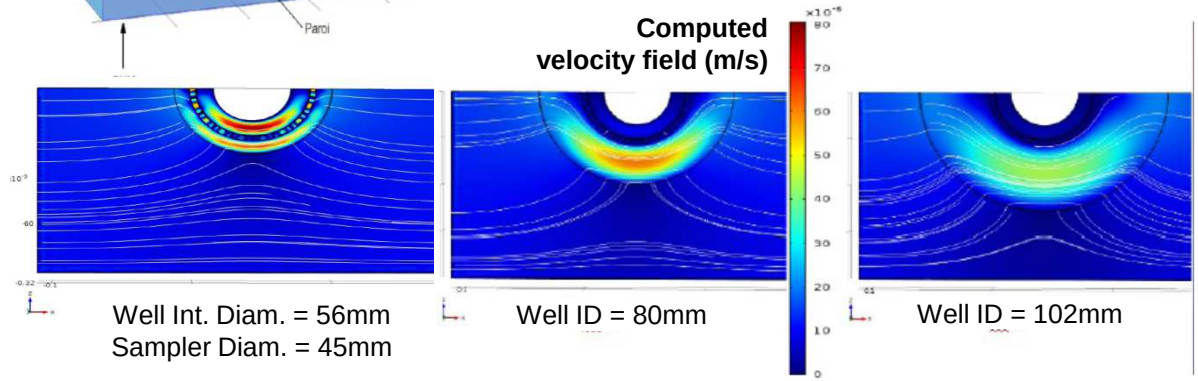
dtO_{EXP}	3h35 ± 0h31
$dt1F_{EXP}$	4h32 ± 1h20

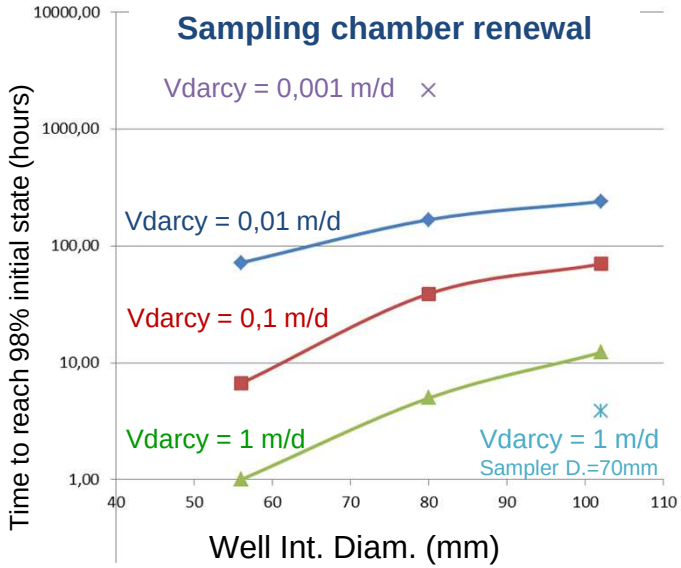
COMSOL numerical models (2D/3D) – IMFT

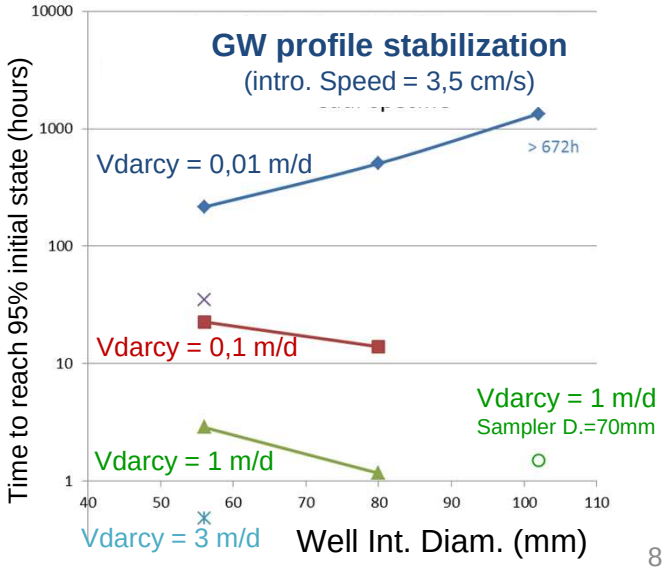
- Duration for the renewal of the sampling chamber volume due to water flow through slots

Sensitivity analysis









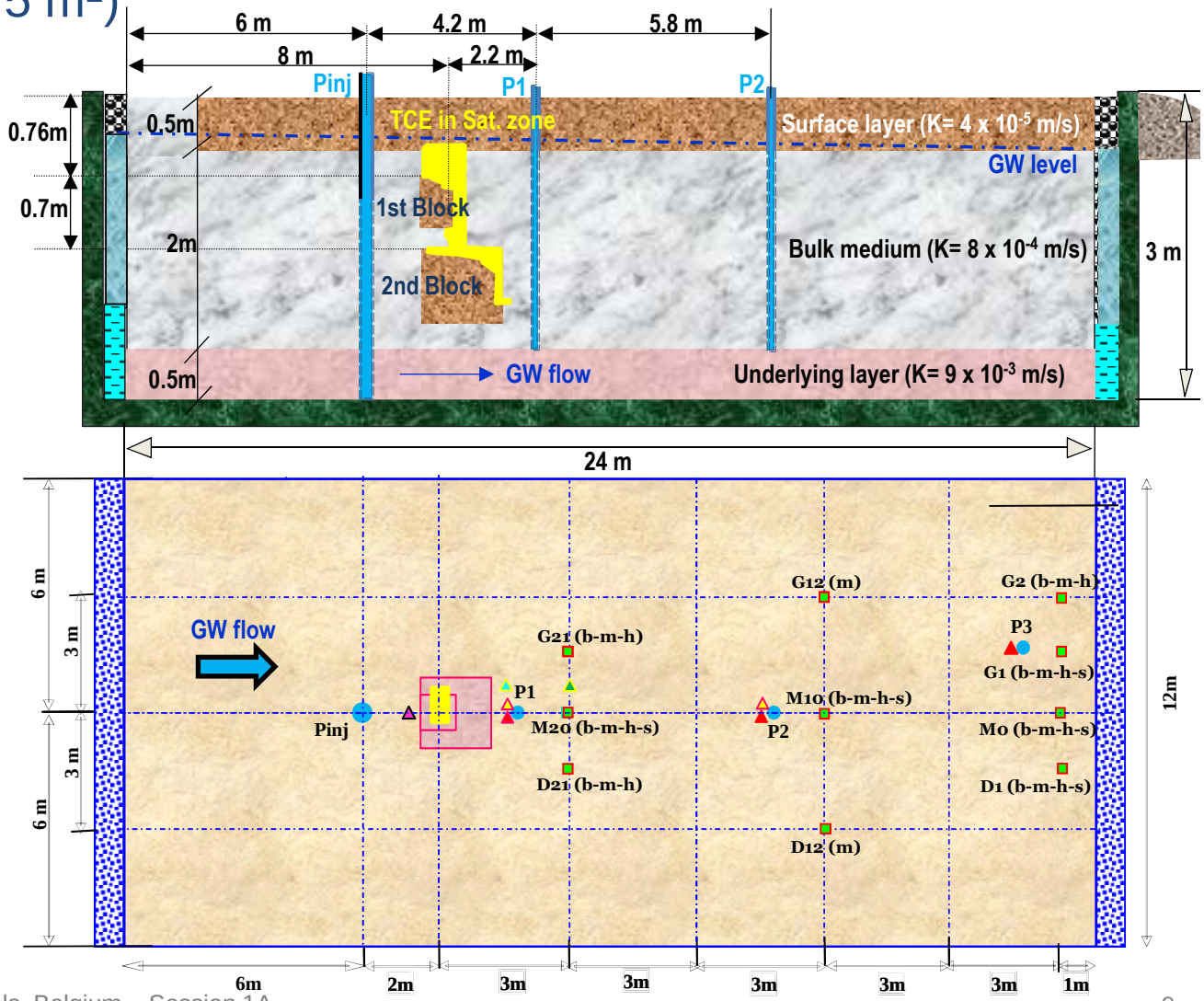
How long to wait after the sampler introduction in the well ?

Depends on Vdarcy, Vintroduction, Well & Sampler Diam.

Sampler Diam. / Well ID > 70% for shorter waiting time

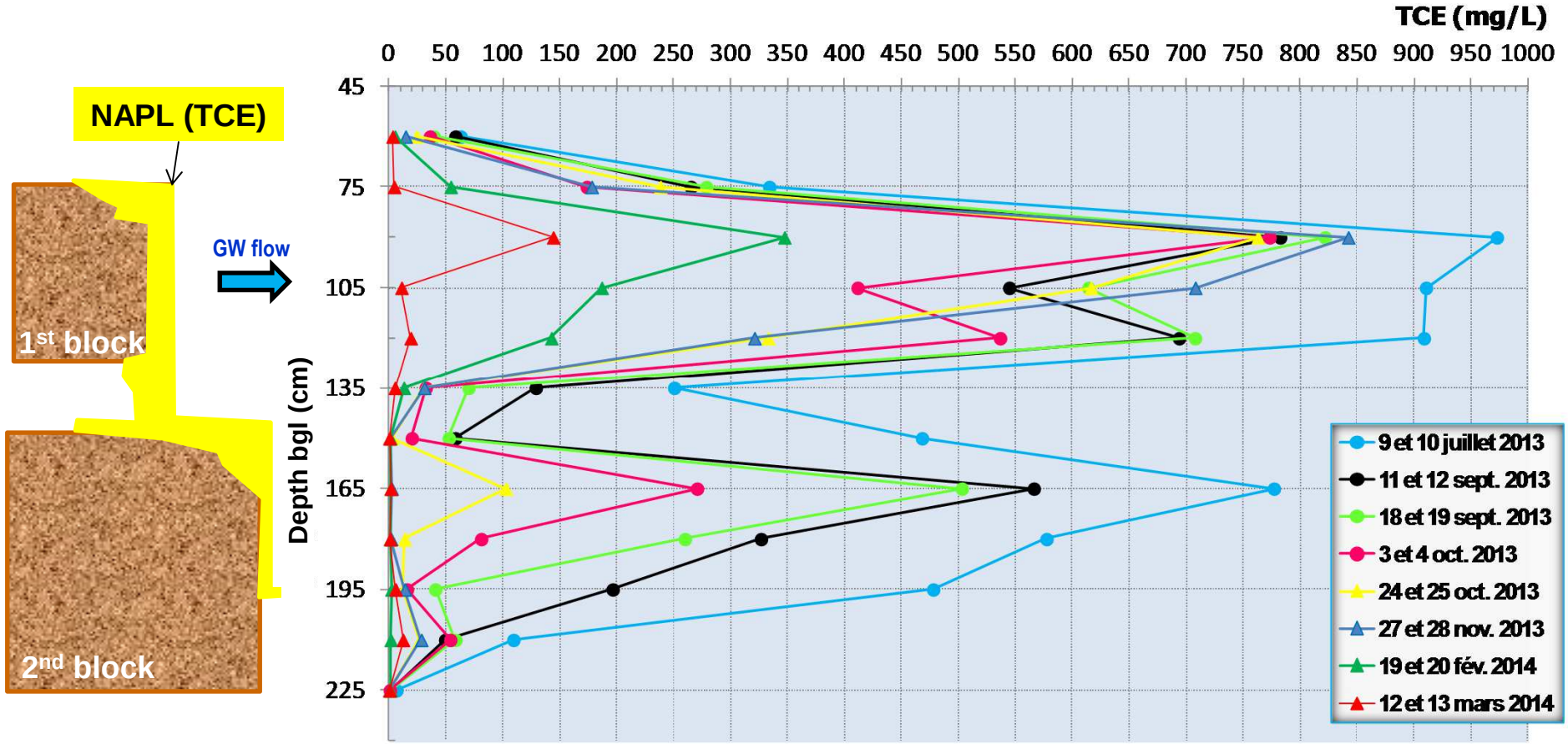
Large scale lab. Experiment – LHYGES (1)

- SCERES experimental 3D basin
  - Source = 12 L of NAPL (TCE) injected 10cm below the GW level (top of 1st block, 0,5 m^2)
  - 3 wells
  - 17 locations for pore water sampling
    - ▲ near each well (6 depths)
    - ■ At 3, 9 and 15m from the source (3 to 4 depths)
- Experiments
  - Tracer tests
  - GW profile measurements
    - New sampler
    - Pore water ports
    - DMLS and others



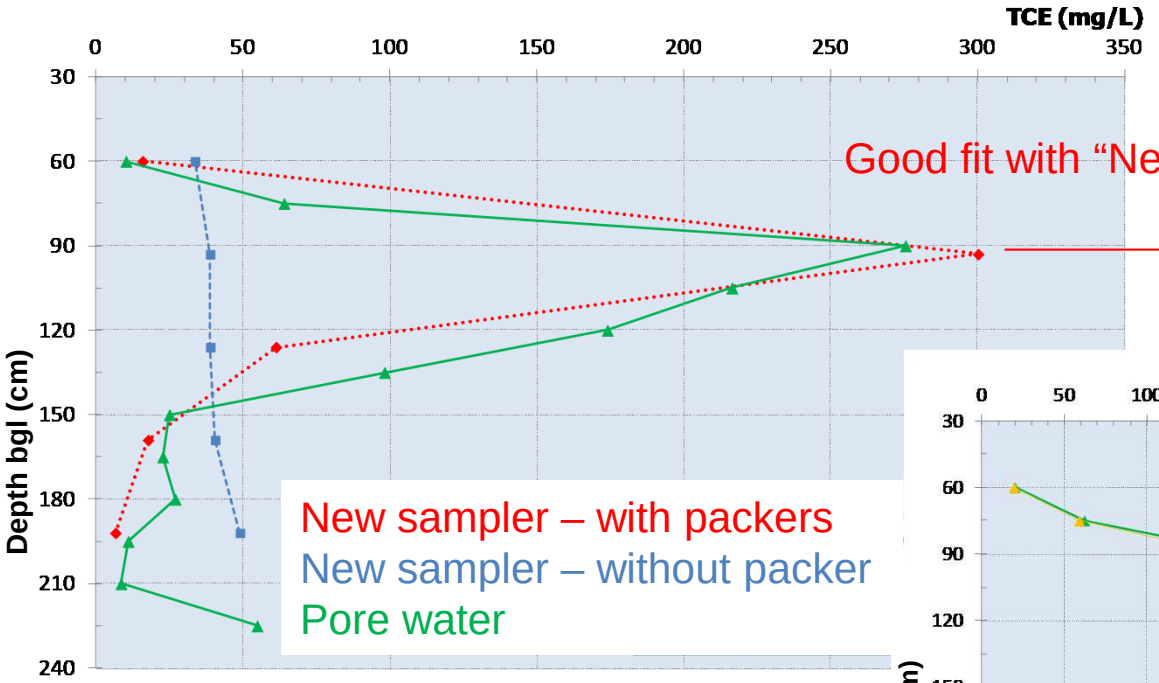
Large scale lab. Experiment – LHYGES (2)

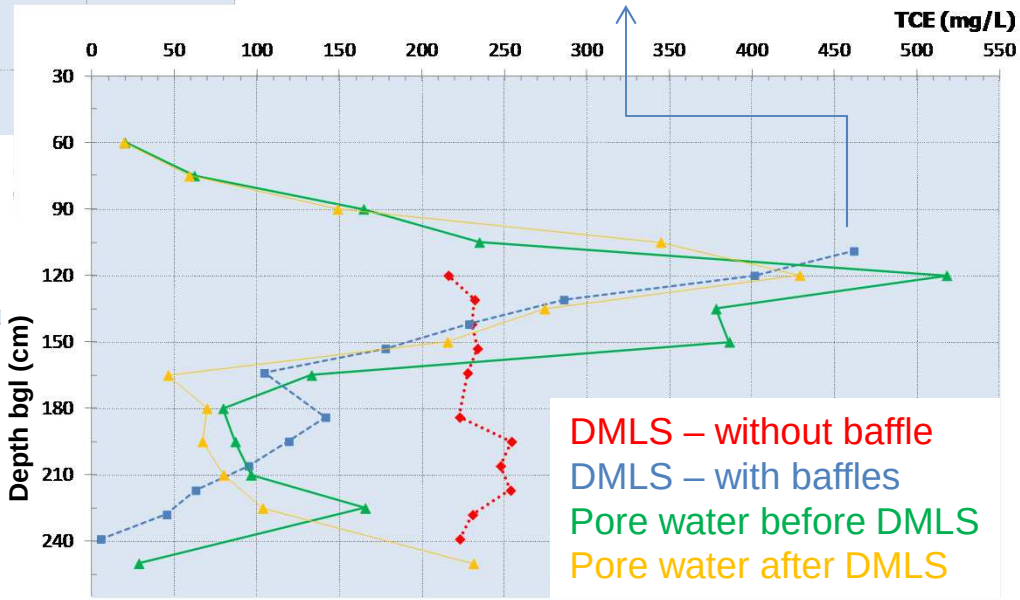
- Monitoring of GW concentration profiles with time
  - Profiles with **pore water** sampling near Well P1 (near source)
  - Peak concentrations at low-K blocks (NAPL accumulation)
  - NAPL attenuation with time (8 months)



Large scale lab. Experiment – LHYGES (3)

- GW profiles comparison in well P2 : different sampling methods
  - Profiles obtained with **New sampler** (ML grab sampler with permeation) & **DMLS** (diffusion sampler) **consistent with pore water sampling**



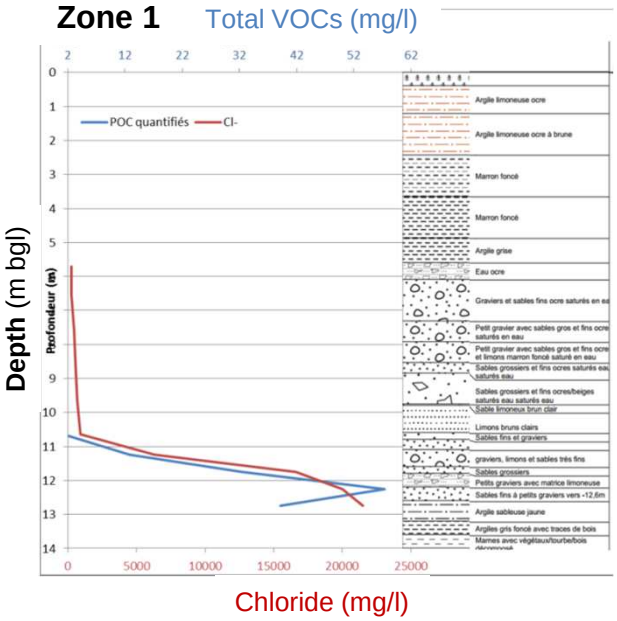


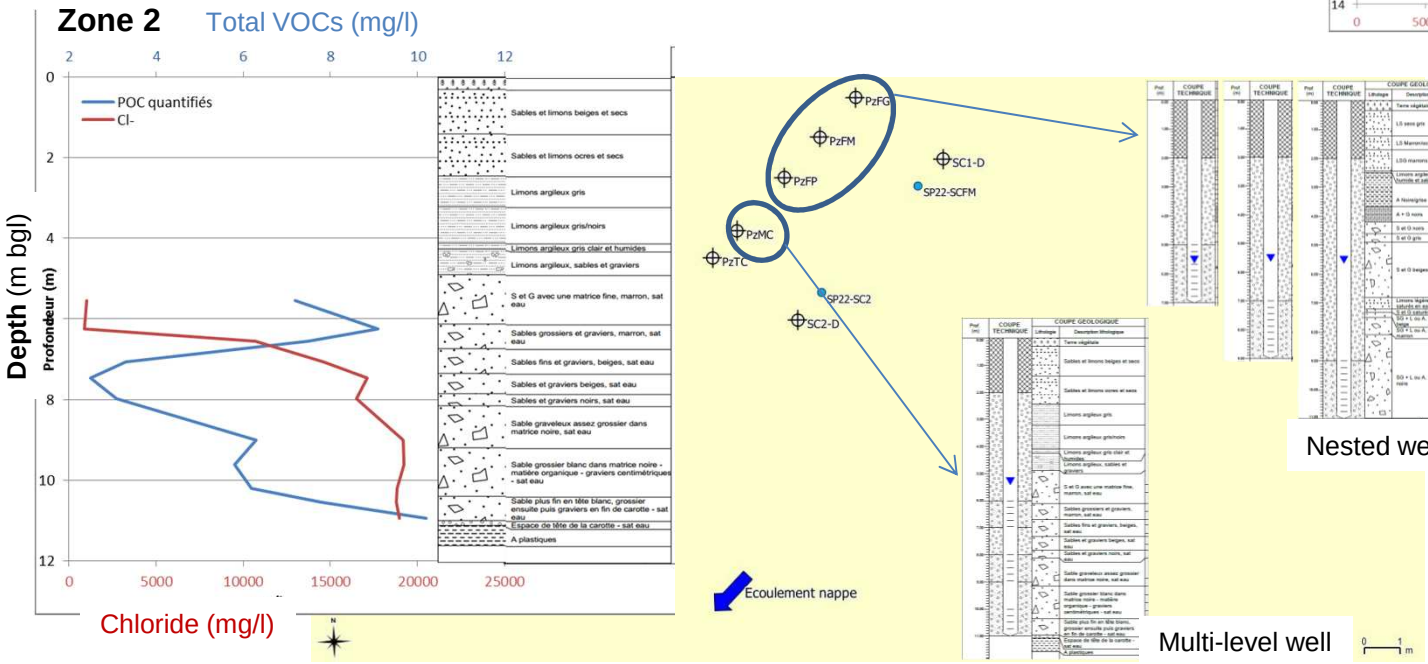
➡ **Packers / baffles are needed even for passive sampling in long screened wells.**

Installed to isolate sampling chambers for both new sampler and DMLS

Field work – SOLVAY

- GW profiles comparison in wells (2 zones)
  - Profiles obtained with Geoprobe SP22
  - Comparisons with - due next month
    - new sampler / PDB / DMLS / PFM
    - Pumping between packers in long screened wells
    - Pumping in multi-level screened and nested wells
  - Contaminants : Cl-, Cl-propene, 1,2-DCA, VC, cis-DCE, TCE, PCE





Following work

- Lab. Test for sampler materials
  - Material behavior in contact solutions of various concentrations
  - Sorption / desorption tests with polymer materials
- Large scale lab. Experiments in SCERES basin
  - New source injection for sampler comparison (flux measurement): new sampler developed + pumping & K-profile / PFM
  - Local tracer test to check for flow through and around the sampler installed in wells
  - Computed model: flow velocity, concentration & flux profile
- Field tests
  - Velocity profile measurements
  - Comparison for GW concentration & mass flux measurements
  - modelling

⇨ **Technical guidelines for multi-level sampling (concentrations & fluxes)**

New sampler release (patent pending) with user's guide

Thank you for your attention

Any questions ?

Many thanks to all partners / colleagues

- ADEME: Dr. Duclos
- BURGEAP: M. Gleize, Dr. Côme
- IMFT: Prof. Marcoux
- LHYGES: Prof. Schaefer, Dr. Razakarisoa
- MGF Grimaldi: M. Vanneau
- SOLVAY Electrolyse France: Dr. Cazaux