Evaluating the Performance of Short-Term Heat Storage in Alluvial Aquifer with 4D Electrical Resistivity Tomography and Hydrological Monitoring

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1. Introduction

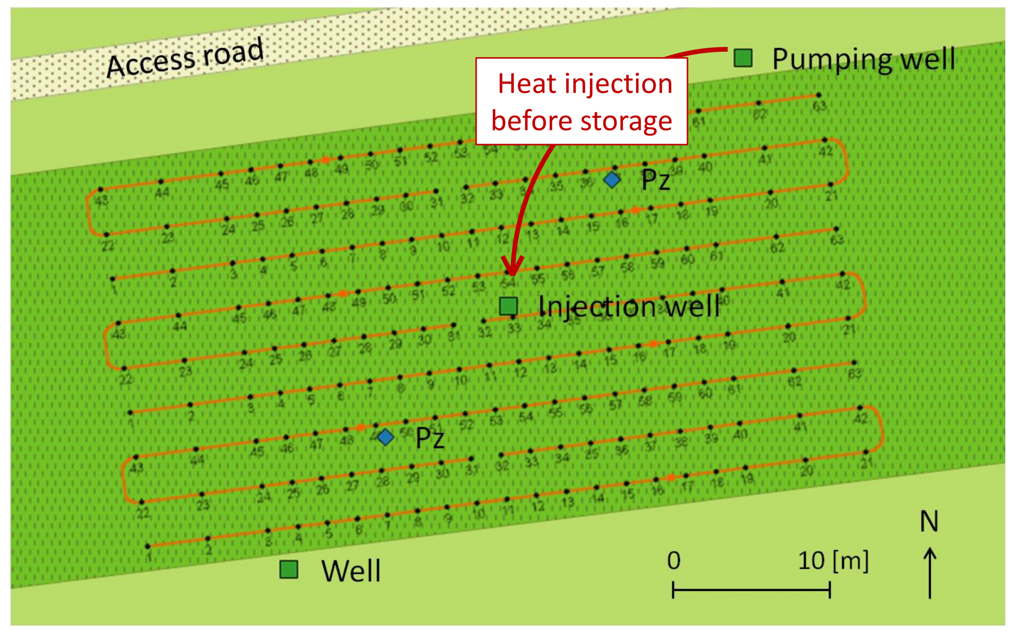

Fig 1. Site plan

The study site is located in an old alluvial plain. It is a captive aquifer composed of sands and gravels covered by a clayey loam layer. It shows an historical chloride contamination. The site is equipped with wells and piezometers to monitor it. Pumping tests have shown the high permeability of the aquifer (K ≈ 10-3 m/s).

A heat storage and recovery experiment is then carried out and monitored with 3D ERT images [1,2,3] and hydrological monitoring. The 3D ERT grid is formed by 9 parallel profiles of 21 electrodes. Dipole-dipole and gradient measurements are taken along each line. Cross-lines dipole-dipole measurements are taken between the external lines of each group of 3 lines.

2. Background

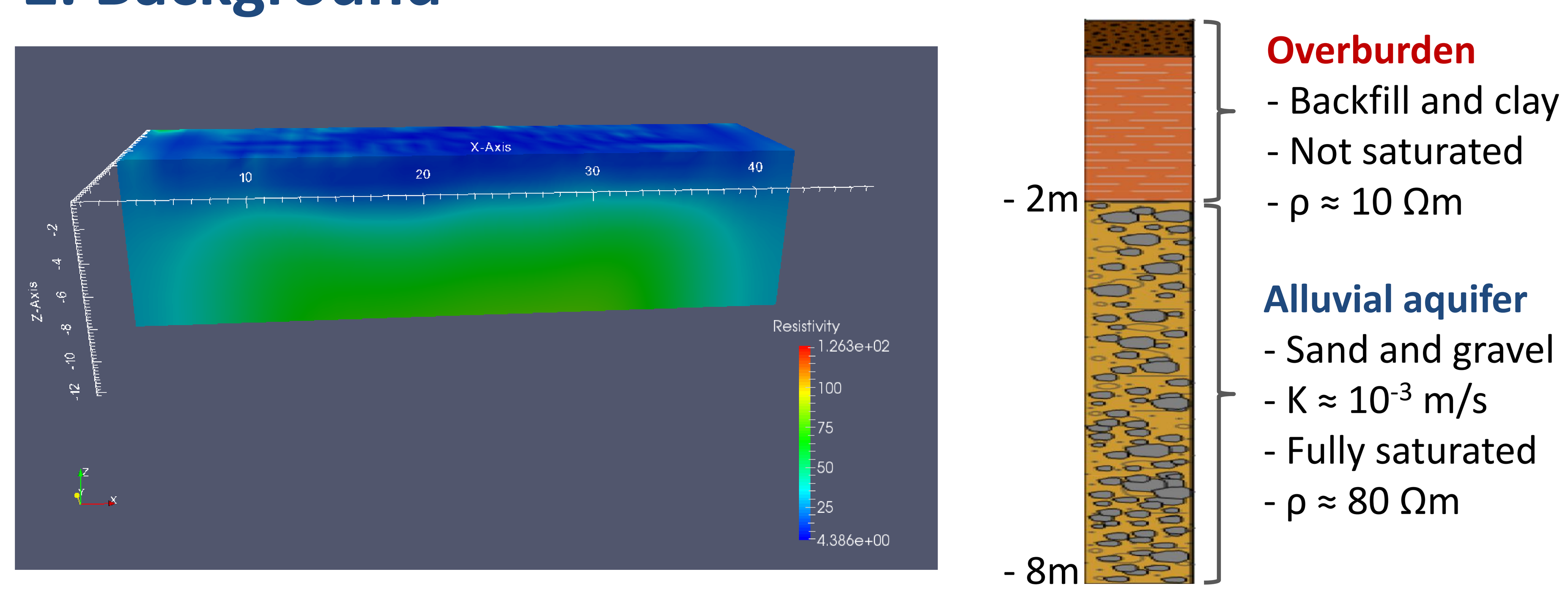

Fig 2. Electrical and geological backgrounds

A 3D ERT background image is taken before the heat injection. It will be used as a reference.

The background resistivity distribution is in accordance with the geological log of the central well. The depth of investigation is sufficient to cover the zone where resistivity changes are expected.

3. Geophysical monitoring

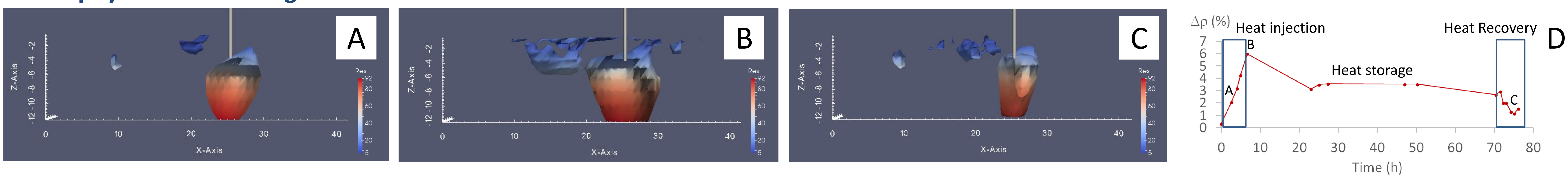

Fig 3. Change in resistivity after 2 hours (during heat injection) (A) ; after 7 hours (beginning of heat storage) (B) ; after 75 hours (after heat pumping) (C) ; Breakthrough curve for the cell [X=23 m, Y=11 m, Z=-7 m] (D)

4. Results and discussion

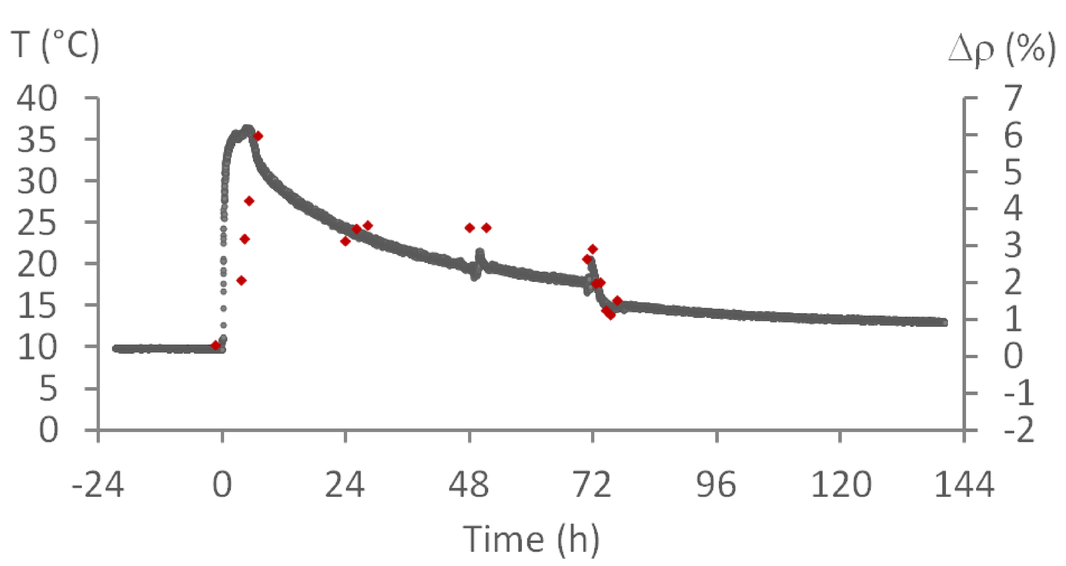

Fig 4. Temperature monitored in the injection well. The resistivity variation (in red) corresponds to the data showed in figure 3d.

Figures 3a, b and c show the volume of the heated plume for main steps of the experiment (2% change isoline). Figure 4 shows the temperature in the injection well correlated with resistivity variations.

During heat injection, ground water is heated by 30 K and injected during 320 minutes.
→ From time = 0 to time = 5,33 h
We sampled groundwater after 48 h.
After 3 days of storage, we recovered heat starting at time = 71 h and during 5 h.
→ From time = 71 h to time = 76 h

Resistivity variations correspond to temperature variations. Due to the chloride contamination, it was only possible to complete a semi-quantitative comparison between those two parameters.

5. Conclusions and perspectives

We carried out a push/pull test. 70% of the injected energy was retrieved after almost 5 h of pumping. The volume of water pumped is 2.5 times bigger.
This experiment of 4D ERT allowed us to obtain semi-quantitative results and to estimate the size of the thermal affected zone (TAZ) in 3D at different time steps (Figure 3).
The use of a coupled / joint inversion to take into account salt concentration differences could lead to quantitative results.

Time	Volume re-pumped	Energy recovered	Temperature
71 h	0 %	0 %	21°C
73 h	100 %	35 %	17°C
76 h	250 %	70 %	14°C

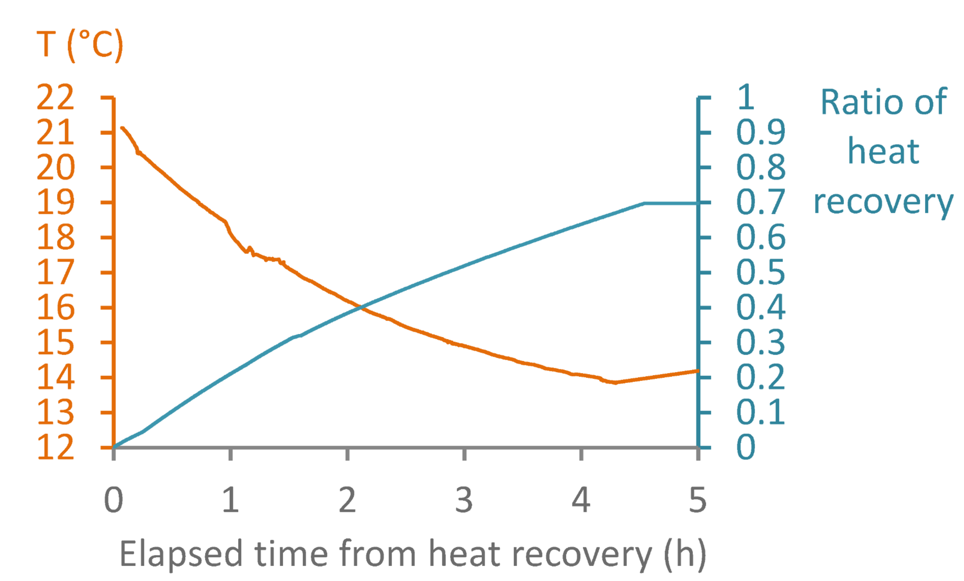

Fig 5. Efficiency of heat storage and temperature of pumped groundwater

References [1] Hermans T., A. Vandenbohede, L. Lebbe, and F. Nguyen. 2012. A shallow geothermal experiment in a sandy aquifer monitored using electric resistivity tomography. *Geophysics*, **77**, 1, B11-B21.
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