Sensitivity analysis and hydraulic parameter estimation in an unconfined aquifer using oscillatory pumping tests

A. Poulain, University of Mons
P. Goderniaux, University of Mons
N. Lavenant, University of Rennes 1
C. Petton, University of Rennes 1
O. Bour, University of Rennes 1
L. Longuevergne, University of Rennes 1

Keywords: sinusoidal pumping test, parameter estimation, sensitivity analysis

Oscillatory pumping tests provide several advantages compared to conventional pumping tests. There is no extraction or injection of significant quantities of water. Monitoring the aquifer response is easier because the frequency characteristics of the stress and induced signals are known, and the data post processing can be performed by using standard tools. Recently, several publications have shown that sinusoidal pumping tests may provide an estimation of the aquifers hydraulic properties and help characterizing their scale-dependent variability. Most of these periodic pumping tests have however been conducted in confined aquifers. In this work, we investigate the possibility to use sinusoidal pumping tests in unconfined aquifers to quantify the hydraulic properties and estimate the uncertainty inherent to the method. In this study, the relation between three variables (amplitude of the groundwater level fluctuations in the stressed and a nearby monitoring well, and the phase shift between the two signals) and two parameters (specific yield and hydraulic conductivity) are particularly examined (*Figure 1*).

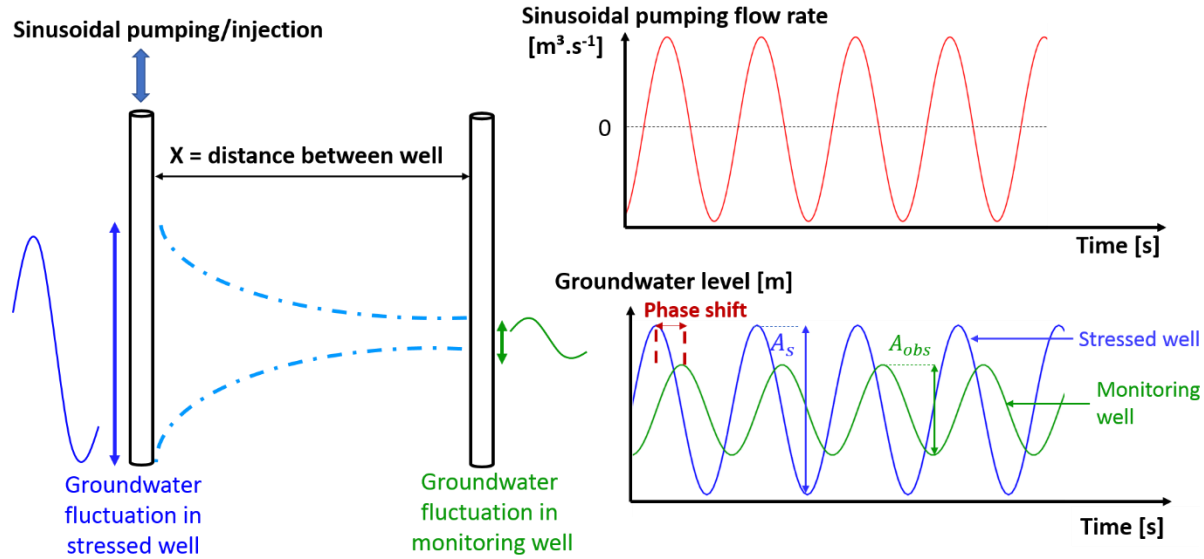

Figure 1: Conceptual model and experimental setup of a sinusoidal pumping test.

To understand the behavior of groundwater levels in the context of sinusoidal pumping tests, a sensitivity analysis of the variables as a function of the hydraulic parameters is first performed. The uncertainty related to the inversion of the hydraulic parameters, using sinusoidal pumping test measured data is then examined. This study was performed with 3D modeling tools such as MODFLOW [1] coupled with UCODE [2], at the scale of an experimental site.
Real sinusoidal pumping field tests were performed in an experimental site located in a porous and fractured chalk aquifer. Different sinusoidal pumping tests have been conducted using two 50 m deep wells. Strictly sinusoidal signals, corresponding to successive equivalent injection and pumping stages, were induced using a slug, externally and automatically controlled. Several sequences characterized by different frequency values were applied at the level of

the stressed well. The aquifer response was monitored in both stressed and monitoring wells. The amplitude and phase shift values were used to inverse the data and quantify the hydraulic properties inherent to the experimental site chalk aquifer. Inverted parameters values were compared to results obtained with conventional pumping tests.

The sensitivity analysis, uncertainty analysis and the experimental field pumping tests allowed understanding the hydraulic behavior of the chalk aquifer in the context of sinusoidal pumping operations. The amplitude and phase shift show high sensitivity to hydraulic conductivity and porosity, although not in the same direction, and with a frequency dependence. The uncertainty study highlights the possibility to estimate the hydraulic parameters in unconfined aquifer. Hydraulic conductivity estimated values tend to increase in correlation with the signal frequency decrease, but values generally agree with conventional pumping results. Regarding porosity, the estimated value is systematically underestimated.

References

[1] Harbaugh, A. W. (2005), MODFLOW-2005, The U.S. Geological Survey modular ground-water model - The Ground-Water Flow Process., U.S. Geological Survey Techniques and Methods 6-A16, U.S. Geological Survey.

[2] Hill, M.C. and Tiedeman, C.R., 2007. Effective groundwater model calibration. With Analysis of data, sensitivities, predictions and uncertainty. John Wiley & Sons, New Jersey, 455 pp.