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Influence of confining layers' heterogeneity on the barometric response functions in semi-confined aquifers

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It has been shown that Barometric Response Functions (BRFs) can provide a useful tool for detecting the occurrence of highly conducive bodies which span across aquifer confining layers and can potentially give rise to pathways for pollutant migration (Hussein et al 2013, Odling et al 2015).

Analytical models employed to estimate BRFs from geological system properties assume homogeneity within the aquifer and its confining layer. These assumptions are rarely satisfied in practice. Our study focusses on the impact on predicted BRFs of heterogeneous distribution of high conductivity geomaterials within the confining layer. The work is grounded on a suite of three-dimensional, transient numerical computations of groundwater flow in a confining layer-aquifer system for i) a perfectly homogeneous two-layer setting where a single highly conducive block is fully penetrating the confining layer and ii) a heterogeneous two-layer system where hydraulic conductivity in the confining layer is modelled as a stochastic process. Our numerical results are interpreted through a comparison against those associated with an analytical model which assumes system homogeneity.

Monitoring points located in the middle of the modelled aquifer domain, mimicking screened boreholes in field conditions, are used to extract water level records. The output is used to obtain the corresponding BRFs (in terms of gain and phase components) and compared vis-a-vis the selected analytical solution. The results show a wide variety of BRF responses, especially in the gain component, which vary from almost confined to unconfined scenarios.

Our simulations show that the BRFs are a viable tool to improve understanding of the degree of spatial continuity within low permeability heterogeneous geological materials such as glacial till which is frequently found overlying water bearing units across the UK and other localities worldwide. As such, it has the potential to improve groundwater vulnerability assessment protocols.

The results are promising and support the merit of additional developments through, e.g., numerical Monte Carlo simulations which can be performed to extract meaningful statistical information on the nature of BRFs as a function of randomly heterogeneous confining layers.

Keywords: groundwater vulnerability, numerical modeling, barometric response functions, semi-confined aquifers

References

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