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Borehole water level response to barometric pressure fluctuations as an indicator of semi confined aquifer vulnerability: application to the East Yorkshire Chalk aquifer, UK

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Borehole water levels fluctuate in response to deformation of the surrounding aquifer caused by surface loading due to changes in barometric pressure or strain variations caused by Earth and ocean tides. This response reflects the effectiveness of the aquifer confining unit as a protective layer against aquifer contamination and therefore groundwater vulnerability. In this study, time series of borehole water levels and barometric pressure are being investigated using time series analysis techniques with the aim of developing a methodology for assessing groundwater vulnerability in the confined/semi-confined part of the Chalk aquifer in East Yorkshire, UK.

The chalk aquifer in East Yorkshire is an important source for industrial and domestic water supply. The aquifer water quality is threatened by surface pollution particularly by nitrates from agricultural fertilizers. The confined/semi-confined part of this aquifer is covered by various types of superficial deposits resulting in a wide range of the aquifer's degree of confinement. Eight boreholes across the aquifer have been selected for monitoring to cover the various types of confining units. Automatic pressure transducers have been installed to record total head pressure and barometric pressure measurements at each borehole at 15 minutes recording intervals.

A Matlab code has been created to analyze and separate the different stresses contributing to the borehole water level signal using time series analysis and frequency signal processing techniques. It is shown that there are four main factors other than barometric pressure that contribute to borehole water level signal fluctuations. These are rainfall recharge, Earth tides, sea tides, and anthropogenic effects (e.g. pumping) close to the borehole location. In order to estimate the barometric response function water levels fluctuations due to stresses other than barometric pressure should be removed as otherwise they will mask the response relation of interest. Due to the highly variable nature of the UK weather, rainfall recharge forms a complicated signal over a wide range of frequencies 0.001-0.1 cycles/day. Methods for characterizing and removing this recharge signal are discussed. Earth tides and sea tide induced periodic water level changes are removed using the Fourier series trigonometric form solved by the least squares regression technique. Boreholes are found to respond differently to Earth tides and the amplitude of the reconstructed tidal signal in the time domain ranges from 0.4 to 4.0 cmH2O.

Short and long term static barometric efficiency is estimated for each borehole using linear regression techniques. Boreholes results suggest that short and long term static barometric efficiencies range from 0.4 to 0.95 and 0.2 to 0.6 respectively. These results are discussed in terms of the confined/ semi-confined nature of the aquifer. The cross spectral deconvolution averaging technique has been applied to barometrically induced water level and corresponding barometric pressure time series to estimate the barometric response function. Limitations of applying this technique to borehole water level time series data are discussed. Estimated barometric response functions show a wide range of semi-confined responses indicating a range of vertical hydraulic diffusivities of the confining layer. These barometric response functions have been fitted to theoretical response models in order to estimate the hydraulic properties of the aquifer and confining units. The results show good correspondence with the geology of the confining units and allow hydraulic properties of the confining units to be quantified for vulnerability assessment.