INTERACTING VADOSE ZONE – GROUNDWATER FLOW AT THE SPYDIA SITE, LAKE TAUPO

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Introduction

Non-point sources from farmed catchments are one of the main causes for groundwater and surface water pollution in New Zealand. Little is understood about the pathways and the transformation processes of contaminants on their way from the land surface through the subsurface to rivers and lakes. In the past, research focussed mainly on the saturated domain. Less attention was given to the zone between the surface and the groundwater table (i.e. the vadose zone). A holistic approach to modelling processes in the surface–subsurface continuum, with consideration of parameter and model uncertainties, is a precursor for reliably predicting the effects of land use change, farming practices, and climate change scenarios on freshwater quality.

Spydia Field Experimental Site

The *Spydia* site is located in the Tutaeuaua sub-catchment (E 175.79977, S 38.61423) north of Lake Taupo, on a sheep and beef farm under pastoral land use. The monitoring site was established in the headwaters of the catchment, on a gentle hillslope (0.08 m/m) leading from the upper (topographical) catchment boundary through a wetland and into the upper reach of the Tutaeuaua stream. The vadose zone materials in the area encompass a young volcanic soil developed on the underlying unwelded Taupo Ignimbrite (1.8 ka BP Taupo eruption) followed by an older soil (Palaeosol), and Oruanui Ignimbrite (OI) material below (26.5 ka BP). The occurrence and thickness of the materials is variable in the area.
Vertical water fluxes through the vadose zone at the *Spydia* site are measured using Automated Equilibrium Tension Plate Lysimeters (AETLs) installed at 0.4, 1.0, 2.6, 4.2, and 5.1 m below the ground surface with three plates per depth. In addition, tensiometers, TDR, and temperature probes were installed at the same locations. Altogether 42 groundwater observation wells have been installed around the *Spydia* site to monitor groundwater water levels and chemistry.

Modelling

A HYDRUS-1D model was set up to describe the variably saturated flow in the unsaturated zone at the *Spydia* (0-4.2 m depth). Observed pressure head data at three different depths (0.4, 1.0, 2.6 m) was used to estimate effective hydraulic properties by inverse modelling (Wöhling et al. 2008). Further, we used model ensembles in a Bayesian Model Averaging (BMA) framework to forecast tensiometric pressure head and conducted a predictive analysis and uncertainty estimation (Wöhling and Vrugt 2008). The pressure head simulations at the observation locations matched very well the measured values. It can be shown that the mean BMA forecast exhibits similar predictive capabilities as the best individual performing ensemble member. The BMA uncertainty bounds generally encapsulated the observed data

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and uncertainty ranges increased with increasing depth and dryness in the vadose zone profile (Figure 1).

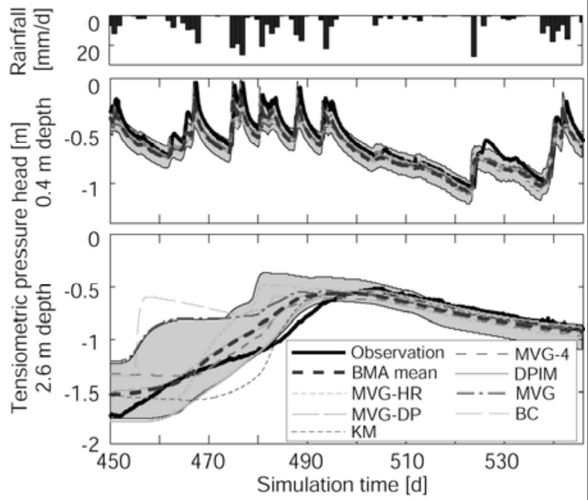

Figure 1: Pressure head forecasts of the BMA ensemble members at the 0.4 and 2.6 m depths.

The analytical TEXAS2D and numerical FEMWATER models were set up for the unsaturated zone flow around the *Spydia* site to estimate effective hydraulic conductivity, aquifer thickness, and groundwater flow direction under assumed steady-state conditions. The models were calibrated using observed groundwater levels.

The effective hydraulic conductivity and aquifer thickness resulting from the TEXAS2D model were K_s = 3.54 E-6 ms^{-1} and d = 33.7 m, respectively. The saturated zone in the upslope area of the site is located in OI materials. Laboratory analysis of OI samples resulted in a median hydraulic conductivity of $K_{s,median}$ = 0.83 E-6 ms^{-1}. Further results from the unsaturated (vertical) flow modelling suggest that the assumed percolation rate in the TEXAS2D model was probably too high. Further analysis with TEXAS2D is required.

The calibration of the FEMWATER model, starting from slightly different assumptions, resulted in a hydraulic conductivity estimate of K_s = 1.67 E-6 ms^{-1} for the OI materials. Both measured groundwater levels and modeling results show that groundwater flow follows mainly the slope with a tendency for diverging flow in the lower region of the *Spydia* site.

Outlook

With our current work, we have started to understand the dynamics of the interacting vadose zone – groundwater flow at the *Spydia* experimental site. One of the remaining challenges is the upscaling of the 1D vadose zone model into the scale of the groundwater model considering the spatial heterogeneity of the stratigraphy and the related hydraulic properties. Another challenge is the coupling of the flow models to an integrated vadose zone – groundwater modelling framework.

References

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