A highly parameterised groundwater modelling study: Insights into recharge estimability in the face of non-uniqueness and the impacts of climate versus pumping

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Summary

Groundwater models are used routinely for water resources management and environmental decision-making support. The recent advances in computing power and technology have led to the development of state-of-the-art modelling methodologies that are capable of supporting the application of complex and highly parameterised models to real-world field-scale settings. Despite this, the use of highly parameterised models to address practical hydrology questions is largely lacking. The objectives of this thesis are to: (1) demonstrate the application of a highly parameterised modelling approach for disentangling climate and human impacts for a regional setting, (2) evaluate the estimability of recharge and its spatial variability through calibration of field-scale steady-state groundwater models, and (3) assess the extent to which time-varying recharge can be informed through field-scale transient model calibration.

First, this thesis presents the application of a highly parameterised modelling strategy to quantify climate and pumping contributions to aquifer depletion for a regional setting (Uley South Basin, USB; southern Australia). The strategy involves calibration-constrained model predictions of natural and pumped conditions. Results show that, while both climate and pumping impacts are highly variable in both space and time, the impact of pumping is, in general terms, greater than that of climate (by 2.7 times on the basis of time-averaged impacts). The results serve as a response to a recent Parliamentary Enquiry into the cause of USB groundwater-level decline.

Second, this thesis investigates the extent to which recharge and its spatial variability can be informed via the calibration of field-scale steady-state groundwater models. Recharge estimation by these means is known to be hampered by the non-uniqueness between recharge and aquifer parameter (e.g., hydraulic conductivity; *K*) values. Here, a systematic analysis of calibration-based recharge estimates is undertaken subject to varying degrees of hydraulic parameter information. Results show that, for a synthetic reality based on a highly parameterised model of USB, a surprisingly large amount of *K* information (>100 *K* preferred values) is required to obtain reasonable recharge estimates (<10% average error). The use of pumping data reduces error in both average and spatially variable recharge estimates, whereas submarine groundwater discharge (as a calibration target) reduces average recharge error only. This study suggests that the estimation of recharge through calibration may be impractical for real-world settings.

Third, this thesis evaluates time-varying recharge estimability via calibration of transient groundwater models. Transient model calibration requires the additional consideration of aquifer storage parameters (e.g., specific yield; S_y). The analysis undertaken here is similar to that of the second study, i.e., recharge estimates, subject to varying degrees of aquifer parameter information and water-level data, are investigated. Results show that reasonable estimates of monthly recharge (<30% recharge root-mean-squared error) require a large amount of transient water-level data, and that the spatial distribution of *K* is known (i.e., through joint recharge-and-S_y estimation). Joint estimation of recharge, S_y and *K*, however, does not yield reasonable recharge values. This study indicates that the estimation of recharge through calibration for real-world settings may require an impractical amount of water-level and hydraulic parameter data.