Editor's Message: Stand on the shoulders of giants, don't hide behind them

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Groundwater models are great. They are seen as an objective way to integrate all available data and knowledge on a system and to make predictions. Unfortunately, this objectivity is hard to achieve in practice and is often lacking, so groundwater models should de facto be considered subjective. Throughout the development of a groundwater model, from the design of the conceptual model, to the parameterisation of the numerical model, and to the definition of the objective function, there are a multitude of decisions that need to be made, with often very limited data to support site-specific choices. When confronted with a lack of data, the scientific reflex is to delve into the available academic and grey literature to find values of parameters for similar systems or justify assumptions based on applications in other areas.

The quote often attributed to Isaac Newton, “Standing on the shoulders of giants”, encapsulates that process; advancing science by building upon the work of your predecessors rather than reinventing the wheel. Alas, rather than advancing science and encouraging innovation, citing previous works in papers and reports often becomes a rigid framework in which each deviation from the well-trodden path is greeted with a high level of suspicion by reviewers. Legitimacy of groundwater models is most often sought by adhering to well-established guidelines or referring to often-cited textbooks, rather than arguing and making decisions based on local system knowledge and the modeller's experience. The prime example of this in groundwater modelling are referrals to Table 2.2 on page 29 of Freeze and Cherry (1979): “Range and Values of Hydraulic Conductivity and Permeability” when choosing ranges for hydraulic conductivities. Hydrogeologists and modellers should not need to feel the urge to hide behind this table when estimating such ranges, but acknowledge their own experience and local knowledge in estimating parameter

ranges. The flipside of estimating model parameters from the modeller's experience is that it requires intellectual bravery to accept responsibility for these values.

Being critical of and not blindly following best modelling practice requires an additional, active and often considerable intellectual effort. This becomes very clear when defining the objective function required to minimise measurement to model misfit. Rather than actively filtering or weighting the available data as a function of the potential of an observation to constrain the parameters of the model relevant to the model prediction, more often than not, all available observations are included, with equal weight, in the objective function. To give an extreme example; including a head observation in the same grid cell as an active pumping well will contribute little to constraining parameters. On the contrary, including such an observation can be counterproductive, as it may result in parameter estimates that are not representative at a larger scale.

There are a number of very good modelling textbooks and modelling guidelines available that strive to advise on good modelling practice, but ironically often have the opposite effect. A classic example are the Murray Darling Basin groundwater modelling guidelines (Middlemis et al. 2000). These guidelines were the de facto industry standard in groundwater modelling in Australia for over a decade. The guidelines have a very elaborate section on model calibration that is an excellent summary of the then state of the art in calibration and uncertainty analysis. Almost fleetingly, the author included a statement that a normalised root mean squared error of less than 10 % can be considered adequate for a regional-scale groundwater model. Not surprisingly, a great many of groundwater model reports in Australia cited this number to claim that a model was well calibrated, showing a lack of a critical appraisal of their available data and a lack of intellectual bravery by hiding behind this rule of thumb.

The goal of this editorial by no means is to point the finger at groundwater modellers and shout ‘J'accuse’. This requirement of adhering to best practice guidelines is more often than not required by clients and stakeholders. Admittedly, it is a daunting task for a layman with limited technical understanding of groundwater modelling practice, to judge if a groundwater model is fit for purpose and has been a good investment of resources. We, as a

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scientific community, do ourselves a disservice by avoiding to take responsibility of model choices and hiding behind citations. It actually complicates an honest peer review of groundwater models.

Hydrogeologists are encouraged to embrace the subjectivity in their model choices and foster a culture of intellectual openness and honesty. To achieve this goal, it is essential to establish a well-defined model prediction and, even more important, explicitly list all model assumptions. A well-defined prediction enables the modeller to shift the focus from trying to incorporate and match all data and observations, to critically evaluating data in relation to their contribution in constraining the prediction. An explicit listing of all assumptions in the groundwater model report allows one to justify a particular choice and discuss or test its effect on the model prediction. As long as it is technically feasible within the available resources, groundwater modellers should strive to numerically evaluate the effect of model choices on a prediction through, for instance, formal sensitivity analysis. This is the only way to objectively quantify the effect of assumptions on model predictions. When this is not possible, the justification of a choice

from the modellers or hydrogeologists local knowledge or experience will be a valuable starting point for discussion with peers during model review.

With this rant, this author does not want to provide a free pass to ignore available literature, textbooks and guidelines, nor should it give an excuse for complete subjectivity in groundwater modelling. Quite the opposite. Modellers are encouraged to spend more time and energy on finding the optimal way of making their predictions in an environment that encourages debate on crucial model choices, rather than desperately trying to copy what is considered best practice out of an angst not to tick all the boxes of a generic reviewers' checklist.

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