Understanding Parameter estimation & uncertainty

NATIONAL CENTRE FOR GROUNDWATER RESEARCH AND TRAINING

This resource introduces parameter estimation and uncertainty — crucial concepts not only for environmental modellers, but also for groundwater managers and decision makers. It is designed for a general audience.

WHAT IS NUMERICAL MODELLING?

Numerical modellers use physics and maths to build computer-based representations — or 'models' — of environmental systems. Although these models only approximate the enormous detail of reality, they can be very useful for predicting what might happen in certain conditions. For example, meteorologists use numerical models to help predict the weather.

Hydrogeologists use modelling extensively, to help work out things like:

- where rainfall eventually ends up
- how much water can be taken from a well without affecting a nearby stream
- how much water will be available to allocate to irrigators during the next dry season
- if contamination occurs in an aquifer, how quickly it will spread and where it will go.

PARAMETER ESTIMATION

To develop a model, we have to have some 'parameters', (or context) to build on. For weather prediction, relevant parameters might be the temperature range or the evaporation rate.

For groundwater, we primarily model the underground landscape, and so parameters are things like the types of soil or geologic material in a catchment (and how well they conduct water), or how full an aquifer is. We get these parameters by conducting fieldwork, for example, by doing pumping tests at bores, by measuring rainfall, or by recognising various physical principles, such as that water runs downhill.

Models encapsulate what we know, but often the available data is insufficient, so we need to 'join the dots' to complete the parameters. This can be achieved by calibrating the model or 'history matching' — that is, by running the model in a historical scenario and adjusting the model's parameters until outputs match what really happened.

HOW RELIABLE ARE NUMERICAL MODELS?

Numerical models are only approximate representations of possible scenarios — they're not scale models like matchbox cars — but they are nonetheless useful tools for understanding what does and what could happen. In general, the more comprehensive and accurate the input data is, the more accurate the model will be.

Meteorologists, for example, can see weather in real time and space via satellites, and then use highly developed models to predict future weather. These days, the nightly news is usually fairly reliable, but often not exactly right. If the weather report says it will be sunny and 30°C, the actual weather might be a few degrees off, but you can be fairly confident that you won't need a thick jacket. Knowing the margin for error is important, because it can help you decide whether to bring an umbrella.

Likewise with other types of environmental modelling, there will always be some amount of uncertainty (unfortunately there's no such thing as a perfect model because we cannot know everything) so quantifying the range of uncertainty can be vital. This is especially true for groundwater, as data quality is far poorer than that available to weather forecasters.

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UNCERTAINTY IS IMPORTANT!

Of course, the main objective is to improve the accuracy of predictions; we can do this by improving our models, or by taking more measurements out in the real world.

A good model is not a crystal ball — it should encapsulate what we know and quantify what we don't. Calculating uncertainty is crucial as it allows us to manage the range of possible and likely scenarios, to make more informed decisions, and to minimise risk.

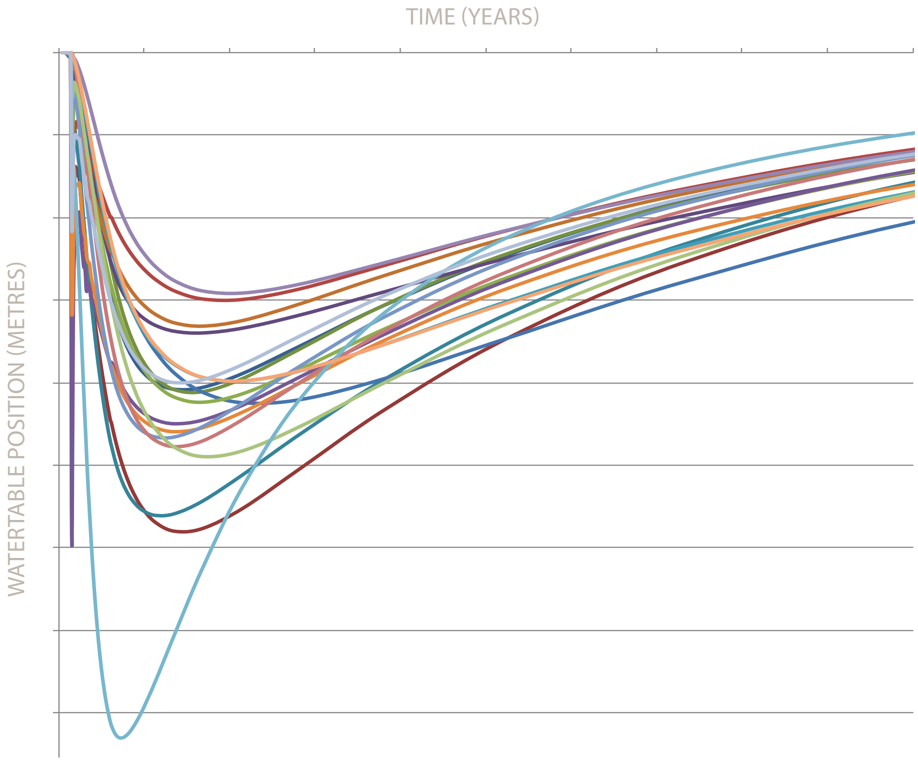
The image to the right shows a number of different modelled scenarios for drawdown — that is, the dropping of the watertable as a result of nearby pumping, say from a bore — and the time taken for the water table to recover its position.

You can see in this graph a range of scenarios, all of which are the results of models which have been calibrated in slightly different ways. The variety shows the range of uncertainty. If, for example, you were managing a nearby wetland, knowing this uncertainty range would allow you to manage pumping to avoid lowering the water table below the reach of the wetland's vegetation.

Capturing uncertainty is particularly important in groundwater modelling, because underground data is typically limited — we can't see it and normally we only have 'snapshots' of underground conditions gathered from bores large distances apart.

Additionally, underground geology is usually extremely varied; therefore, there is a large range of properties that govern the flow of water through the earth. Joining the dots between these 'snapshots' can be a challenge!

Not only is effectively quantifying uncertainty crucial in helping us manage the environment, it can also help us to work out where it will be most beneficial or cost effective to gather extra data, improve the model or focus research.



Predicted change in water table position over time, as a result of heavy pumping from a nearby bore ('drawdown').

INTRODUCING PEST

Professor John Doherty has spent many years working in environmental modelling, and has developed PEST, a cutting-edge software package which works as an 'add on' to groundwater models, to improve parameter estimation and also to quantify the uncertainty associated with environmental modelling.

John emphasises the importance of capturing uncertainty: 'Environmental decision-making must acknowledge uncertainty; if its existence is not only acknowledged but quantified, decision-making can then focus on balancing risk against benefits as different management strategies are considered'.

PEST itself and other support software are freely available at www.pesthomepage.org.

The NCGRT regularly runs training on the use of PEST — check www.groundwater.com.au for future sessions.

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