Understanding Tracers & groundwater modelling

Background

NATIONAL CENTRE FOR GROUNDWATER RESEARCH AND TRAINING

This resource introduces tracers, which can be used in groundwater modelling to improve the reliability of modelling predictions. It follows on from an earlier resource which discusses numerical modelling more generally as well as parameter estimation and uncertainty. It is designed for a general audience.

DATA AND MODELLING

Typically, the confidence that we can have in the predictions made by groundwater models increases as the availability of quality data increases.

It is often said that we are model rich and data poor, meaning that we often don't have enough data to correctly calibrate models. Or is it that we are not data poor, but neglecting other data sources?

Water level data over time is a common data source that is used to calibrate models. Field estimates of the properties of the aquifer (i.e. the most difficult parameter in groundwater: hydraulic conductivity) are also observations that are widely used. The issue with these data types is that they tell us exactly what is happening at the point of measurement, but they may tell us very little about what may be happening only metres away.

It is widely understood that using water level data alone can lead to what is known as 'non-uniqueness', where a wide range of parameter values may be able to reproduce field data, but you can't be confident in the predictions of these models. That is, you could have 100 different models that fit the data, but which one is the 'right' one? They may fit field data for the wrong reasons.This is where tracer data can be useful.

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WHAT ARE TRACERS?

In a tracer test, one possibility is for a 'tracer' (coloured dye, a chemical or water with a different temperature) to be injected into one location (say, a well) and the time taken for the tracer to get to another location (a stream, for example) is measured. This can tell us about what is happening between our water level measurements.

Other possible tracers, known as 'environmental' tracers, are naturally-occurring chemicals or temperature differences. Environmental tracers can tell us about where groundwater may have come from, and when it fell as rain and recharged an aquifer.

Temperature is a widely used environmental tracer; temperature data is commonly used to measure the exchange of water between groundwater and streams and wetlands. Groundwater temperature typically remains stable, whereas surface-water temperature changes throughout the day with the heat of the sun. Changes in groundwater temperature beneath streams can therefore be used to determine how much water is being exchanged between the surface water and groundwater. Determining the difference between surface water and groundwater can be important information to help ensure that we're not counting water twice in water management, which could lead to over-allocation.

HEAT TRACERS AND MODELLING

Sometimes, water level data alone is insufficient to calibrate a groundwater model. When observations of temperature are included, the model parameters may be able to be 'constrained' and a 'unique' set of parameters may be identified. This means we can have more faith in the model's predictions.

Hydraulic conductivity (that is – how easily water can move through a given

Want to know more?

The NCGRT is conducting a wide variety of research on tracers. In November 2012, the NCGRT organised a well-attended and successful workshop at its UNSW node. The workshop focused on theoretical and technical issues around the use of heat as a tracer of water flow in groundwater and at interfaces between groundwater and surface-water bodies.

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material, such as clay or sandstone) has the biggest range of any physical parameter. By contrast, thermal conductivity (that is, the ability of a given material to conduct heat) has a very small range of parameters. This makes temperature a very useful tracer; if you know the soil or rock type, you can make a very good educated guess at its thermal conductivity.

Heat is also a good tracer because it's 'free', unlike other tracers such as dye, and exists naturally in the environment. Natural variations in temperature can then be used to estimate groundwater flow rates.

Even where there are not natural variances in groundwater temperature, it is possible to injected heated water and use this to measure the movement of groundwater.

WAYS TO USE TRACERS

The use of tracers is an established technique in groundwater; however, their use in modelling is new.

Tracers are often used:

- to gain a better understanding of parameters between observation wells
- to locate fractures in fractured rock aquifers
- to obtain understanding of large scale 'hydraulic conductivity' or groundwater flow rates
- in deep bores (hundreds of metres), the 'shape' of a temperature against depth graph can tell us whether water is moving upwards or downwards (for example, downward flow may be groundwater recharge from rain – see Fig. 1)
- to determine the exchange between groundwater and streams.

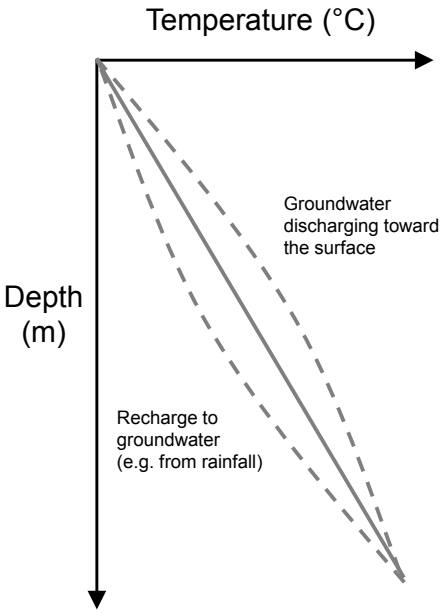

Fig. 1 Example of temperature in a bore hole to infer recharge of rainfall or groundwater discharging towards the surface. The solid line represents the expected temperature in a bore where no vertical flow is present.

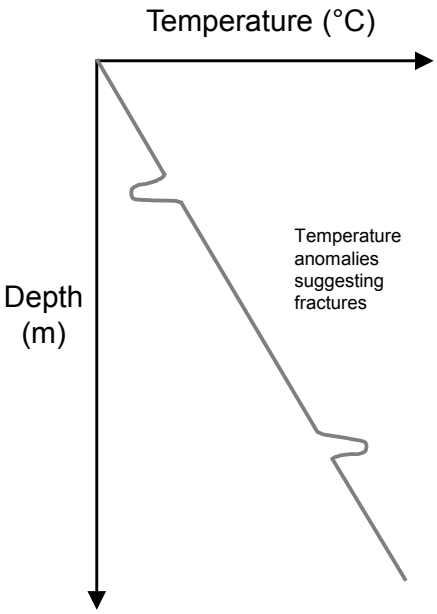

Fig. 2 Temperature anomalies in a bore may suggest fractures. In certain types of aquifers, fractures may carry much of the groundwater flow.

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