Predicting the effects of civil engineering projects on the groundwater environment: choosing the right tool for the job

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One Size Fits All?
Outline

- Planning
  - Conceptual model
  - Data
  - Selecting the right approach
- A tiered approach
- Solving other problems
The big question

How do we get from HERE? To HERE?

Figure 3.1 b): Isotherms 10 years after tunnel activation
Uncertainty

“The trouble with the world is that the stupid are cocksure while the intelligent are full of doubt”

Bertrand Russell
• Unique to each problem
• Appropriate to:
  • Scale of interest
  • Question being asked
Scale of interest
A word about data

- Civil engineering projects are often not short of data
- But is it the right kind of data?
  - Often very detailed and localised
  - Focussed on operational aspects
- May not help with:
  - Regional context
  - Longer term trends
Regional Context
Temporal Variations

- Environment Agency and National Groundwater Level Archive

![Graph showing water level variations over time](image)
Approach to modelling

• **How much:**
  • Data?
  • Time?
  • Money?
  • Much certainty do we need?

• **A tiered approach is needed**
Tools available

- Analytical solutions
- Analytical models
- Simple numerical models
- Complex, 3D solute and density modelling

Increasing
- Complexity (data requirements)
- Time needed
- Cost
Tiered approach - Analytical Solutions

- Nothing new to report
- But we still have this problem

\[
\begin{align*}
\frac{\partial \theta_t}{\partial t} + v \frac{\partial \theta_t}{\partial x} &= - \frac{K_m}{\rho_w c_w} \frac{\partial \theta_t}{\partial z} \quad \text{at } z = b \\
\frac{\partial \theta_m}{\partial t} &= \kappa_m \frac{\partial^2 \theta_m}{\partial z^2} \quad 0 \leq z \leq b \\
\theta_t(x,0) &= \theta_m(x,z,0) = 0 \\
\theta_t(x,t) &= \theta_m(x,b,t) \\
\theta_t(0,t) &= \begin{cases} 
\theta_0 & 0 \leq t \leq t_0 \\
0 & t > t_0
\end{cases}
\end{align*}
\]

Solution:
\[
\theta_{out}(t) = \theta_0 F(t,t_0,t_B,t_{cb},\sigma)
\]
\[
\sigma = \frac{2b \rho_m c_m}{\alpha \rho_w c_w}
\]
\[
t_{cb} = \frac{b^2}{\kappa_m}
\]
\[
t_a = \frac{x}{v}
\]
and \(t_B\) is the breakthrough time.
If we add:
New Analytical Solution Tools

- Easy to set up and use
- Only moderate amounts of spatial complexity
- Useful for scoping calculations
Tiered approach – lumped water balance
Stonehenge Tunnel – lumped water balance

- Saturated Chalk in places
- Return water via soakaways
- Regulators still concerned about potential impact on River Avon SAC
• Chalk very heterogeneous
• Insufficient data to characterise/model with confidence
• Selected a lumped water balance approach
• Regulators were happy
Tiered approach - simple analytical models

- **Pluses:**
  - Quick (and therefore cheap)
  - Easy to keep track of assumptions

- **Minuses:**
  - No spatial heterogeneity
  - Not as flexible as MODFLOW
WINFLOW analytical model
Tiered approach - MODFLOW

- **Pluses:**
  - Well established and widely used
  - Environment Agency standard
  - Wide range of GUIs (pre/post-processing)
  - Many add-ons

- **Minuses:**
  - Limited geometry
Tiered approach – MODFLOW plus add-ins

- 6km long Victorian adit
- Excavated in PT Sandstone
- Now runs under SSSI
Simulating a long adit in a regional model
Simulating a long adit in a regional model

- **USGS MODBRNCH code (adapted by Sheffield Uni)**
- **Issues**
  - Time stepping
  - Boundary conditions (stage and flow)
  - Model stability
  - Non-steady state
- **Successfully calibrated**
- **Simulated observed flows**

![Graph showing simulated flows and net tunnel gain](image)

- **Sandfields abstraction**
- **Seedy Mill injection**
- **Net gain along tunnel**
- **Overflow to Bourne Brook**
Tiered approach – Finite element modelling e.g. FEFLOW

- Improved geometry
- More effective simulation of thermal and density problems
Other Issues

- Largely driven by Environment Agency plus water company concerns
- Contamination:
  - Suspended solids
  - Grout
- Thermal influences
London Models
Potential Contamination - Grout
Potential Contamination - Thermal

Figure 3.1 b): Isotherms 10 years after tunnel activation
Potential Contamination - Thermal
Conclusions

• One size doesn’t fit all

• Planning:
  • What question are we trying to answer?
  • What data do we need?
  • What is our conceptual model?
  • How much money/time have we got?

• Then select the right approach