Simulation of Pumping Induced Groundwater Flow in Unconfined Aquifer Using Arbitrary Lagrangian-Eulerian Method

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Introduction:

The conventional approach (following the Dupuit assumption) for characterizing groundwater flow in unconfined aquifer is restricted when complex physics is applied. A new simulation method is introduced and tested by comparing the model results with the analytical solution. Model development is accompanied by conducted field tests .

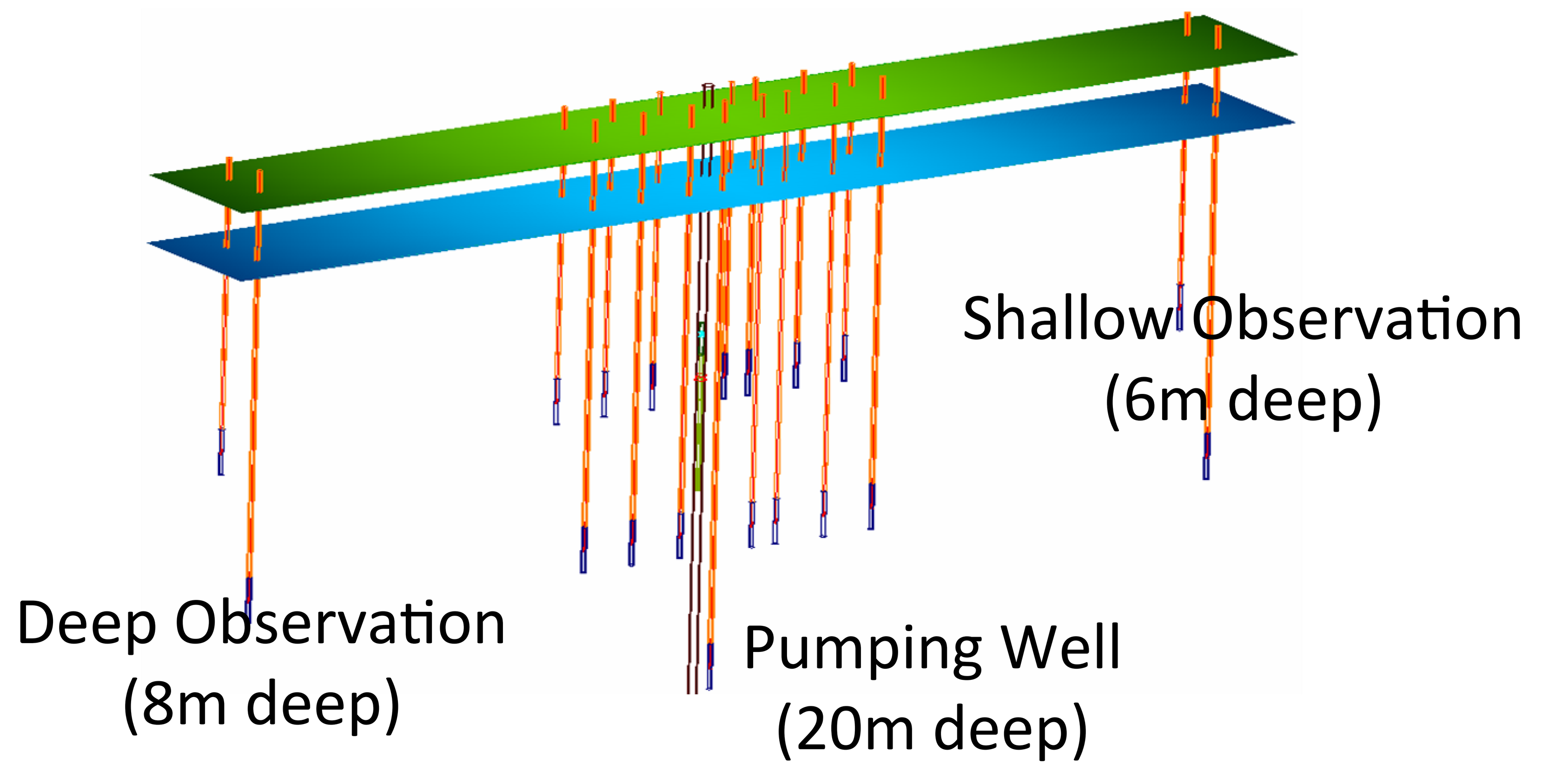

Figure 1. Borehole and observation set-up at Plötzin test site

Computational Methods:

- Steady State

• Darcy's Law: $\nabla(\rho \cdot \mathbf{u}) = 0 \qquad \mathbf{u} = -\frac{k}{\mu}\nabla p$

• Thiem Equation: $h(r)^2 - h_0^2 = \frac{Q}{\pi K}\ln(\frac{r}{r_0})$

- Unsteady State

• Darcy's Law: $\rho S(\frac{\partial p}{\partial t}) + \nabla(\rho \cdot \mathbf{u}) = Q_m$

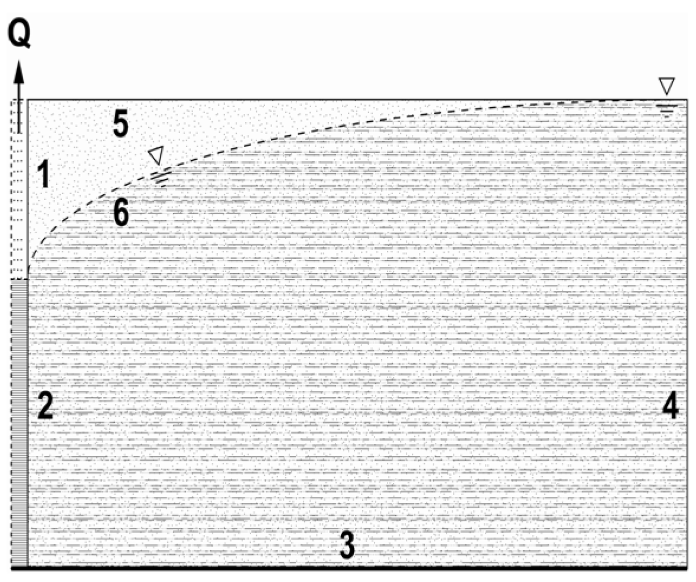

Figure 2. Concept and boundary set-up

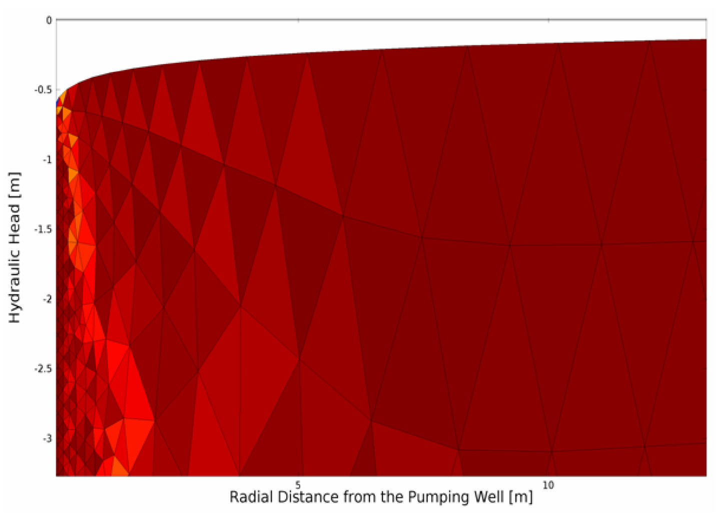

Figure 3. Groundwater table tracked via moved mesh

Boundary Conditions:

- Top: groundwater table moves when the borehole is pumped constantly.
- Bottom: impermeable aquifer bottom, no flow condition applied.
- Left: groundwater abstraction.
- Right: pressure constrain.

Results:

- Simulation results coincide well with analytical solution.
- The position of groundwater table can be tracked with moving mesh method.
- The observed vertical variance of hydraulic heads in the vicinity of pumping well can be simulated with the method.

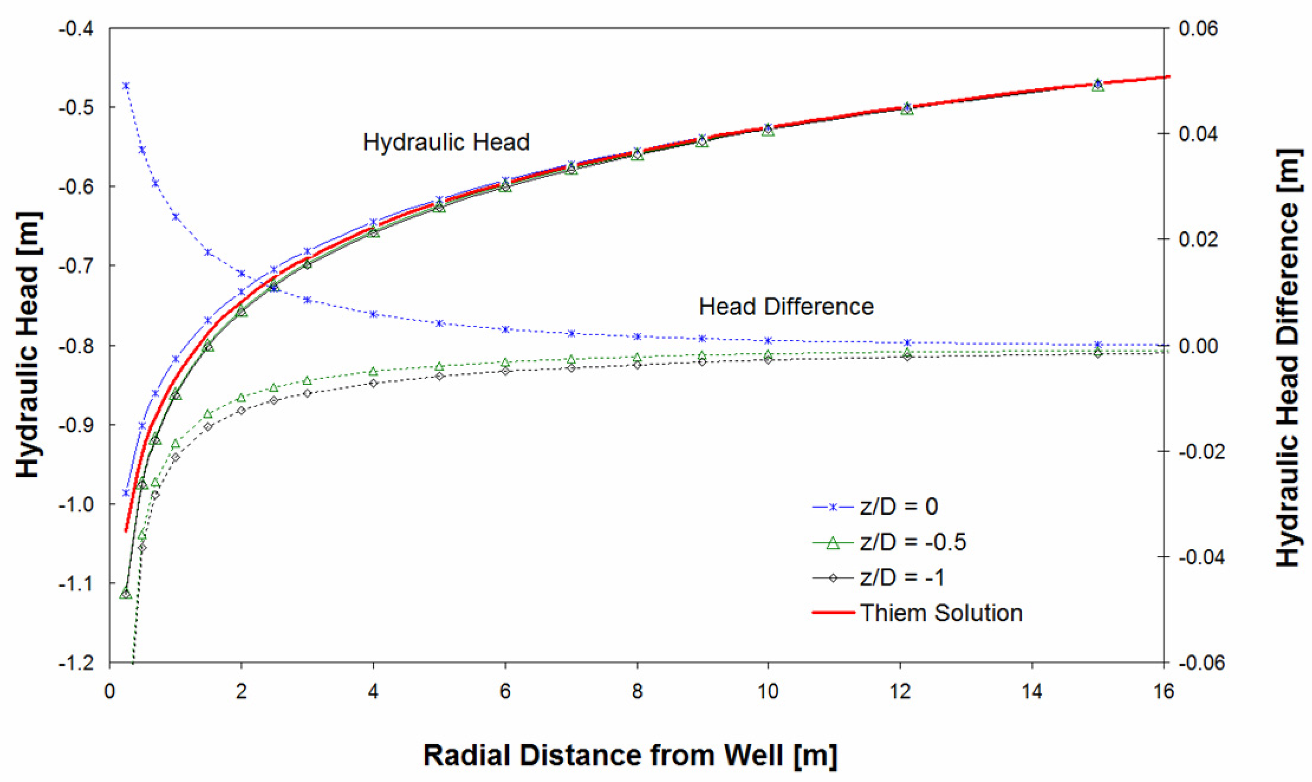

Figure 4. Numerical simulation vs. analytical solution

Variable	*Value*	*Units*
Hydraulic Conductivity	$1.7 \cdot 10^{-3}$	m/s
Pumping Rate	60	m^3/h
Storage Coefficient	$0.8 \cdot 10^{-8}$	1/Pa

Table 1. Input parameters (Field test calibration result)

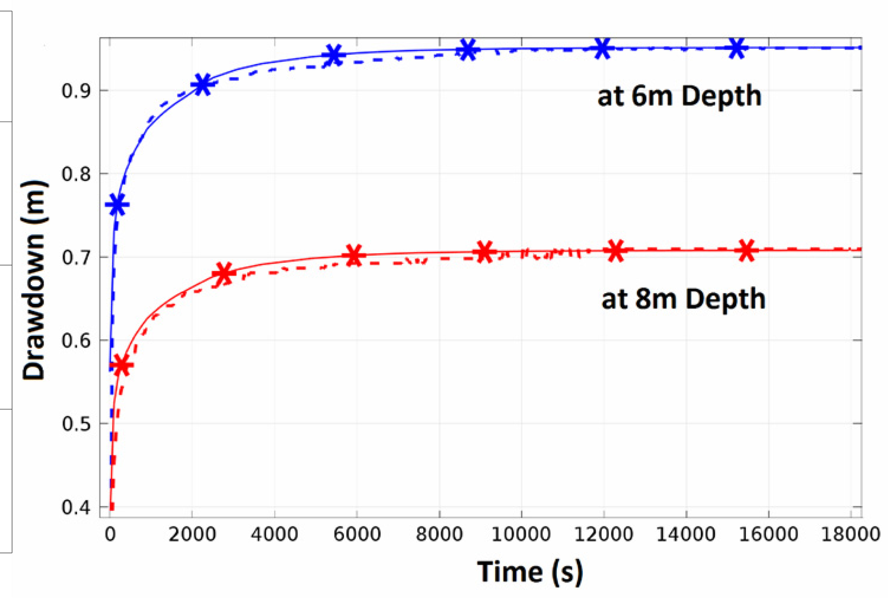

Figure 5. Vertical variation of hydraulic heads (r=1m)

Conclusions :

- The good verification test result gives indications for the model reliability.
- A promising further application future is expected due to the model flexibility, in terms of coupling with other physical processes and application of complex boundary conditions.
- The limitation and difficulty of the model is the choice of model region in order to avoid the outer boundary influence.

Links:

1. Geoscience Center Georg-August University: http://www.uni-goettingen.de/de/8483.html
2. Hölscher Wasserbau GmbH, Germany: http://www.hoelscher-wasserbau.de/seiten/index.html

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