Hydraulic groundwater modeling

- Week 12

- Find the error! – Critical analysis of simulations

Critically evaluating simulation results

- Important step independent of model source
- Evaluation includes:
  - Applicability check (conceptual model)
  - Quality check (see lecture week 11)
  - Correct choice of geometry & boundary conditions
  - Parameter check

- Trivial errors are the most common ones (but hard to identify)

How this lecture works

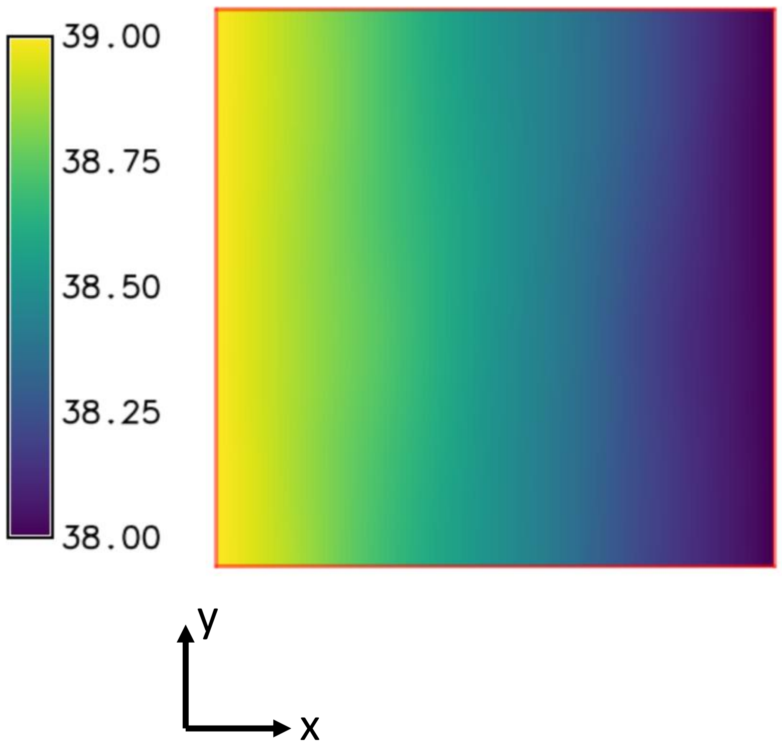
- The following slides contain different scenarios
  - Slide 1: Scenario description
  - Slide 2: Erroneous simulation results
  - Slide 3: Identification of the error
- Your task:
  - Read slides 1 & 2 of each scenario carefully and try to identify the error
    - Take all the time you need (pause the video)
  - Then read slide 3 for verification (or help)

Scenario 1: Heterogeneous aquifer

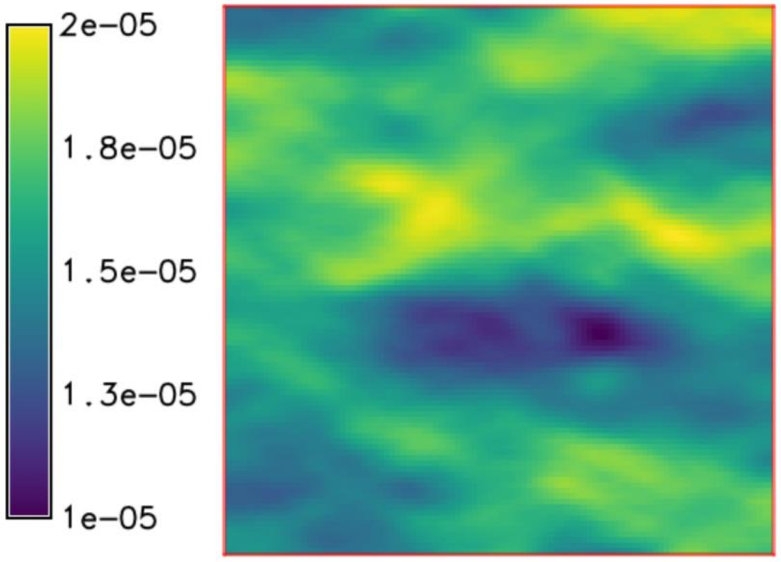
- Simulate the steady state groundwater flow in a slightly heterogeneous aquifer with a mean hydraulic conductivity of 0.0001 m/s (20% variation) and a porosity of 25%. The hydraulic gradient in the unconfined aquifer is 1% from west to east with an water level height of around 39 meters. It is around 6 meters depth to the water level from the surface. The modeling domain is 100 x 100 m.

Scenario 1: Simulation results

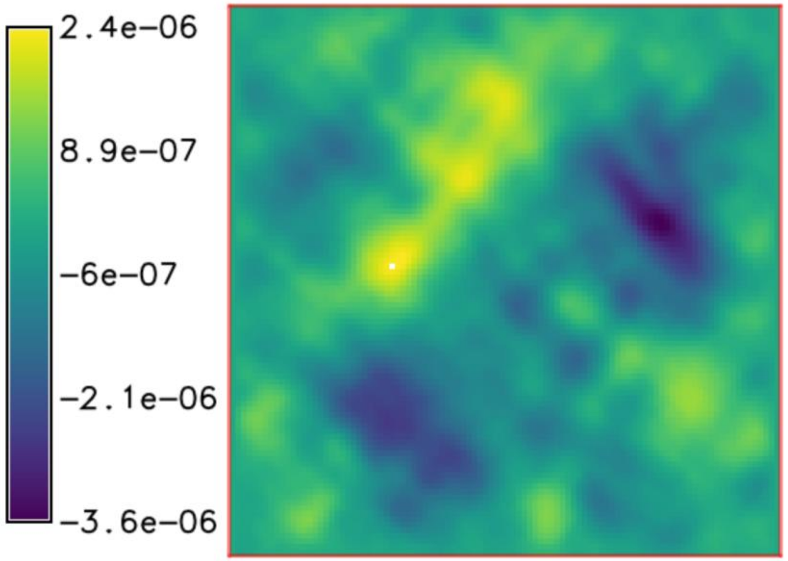
Hydraulic head (m)



Velocity in x (m/s)



Velocity in y (m/s)



Scenario 1: Solution

- For a hydraulic head of 1% = 1m/100m and a hydraulic conductivity of 0.0001 m/s we would expect a flow velocity of

$$v = K\,I = 0.0001\frac{m}{s} \cdot 0.01 = 0.000001\frac{m}{s} = 10^{-6}\frac{m}{s}$$

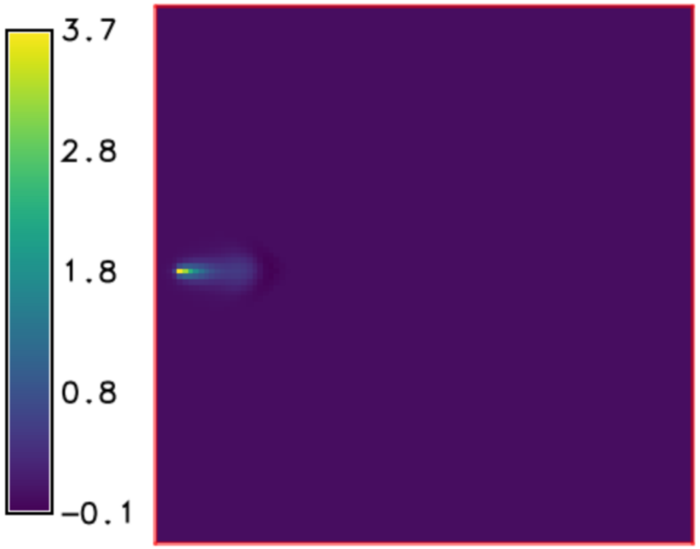
The calculated velocity is too high. As the hydraulic gradient is given correct, probably the used hydraulic conductivity is wrong.

Scenario 2: Tracer test

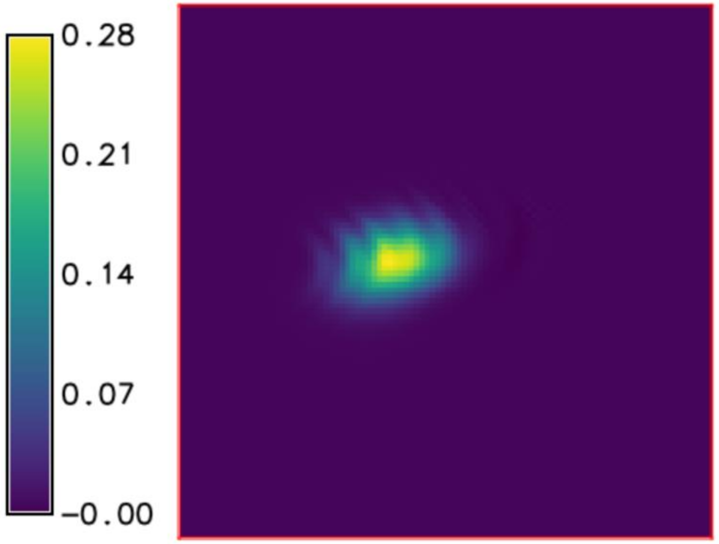
- Building upon scenario 1 (with the wrong velocity), a tracer test is simulated. 50 kg of material are injected 5m to the east from the western boundary of the modeling domain in the middle. The diffusivity is set to 0.00001 m^2/s and the dispersive length to 0.1 m. There is no retardation.

Scenario 2: Simulation results

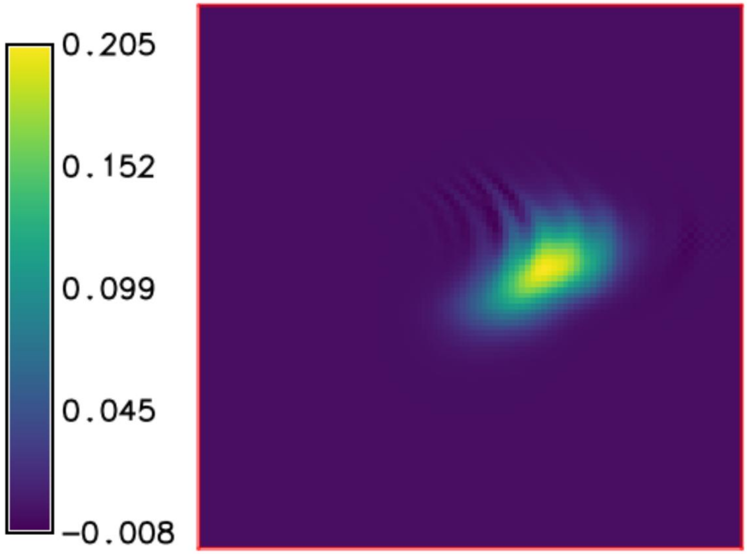
Concentration day 1 (kg/m³)



Concentration day 10 (kg/m³)

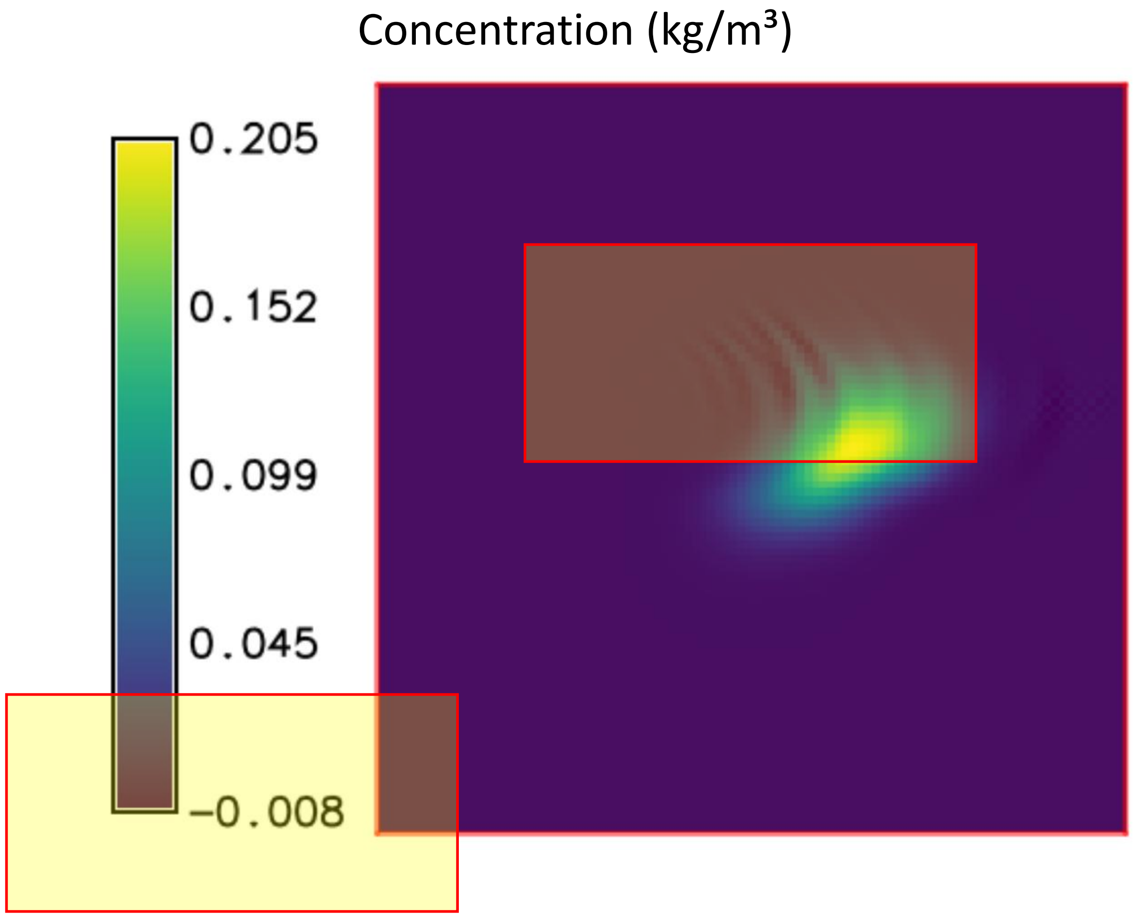


Concentration day 20 (kg/m³)



Scenario 2: Solution

- The simulation is unstable



Scenario 3: Pumping station

- Based on scenario 1 (wrong hydraulic conductivity), a pumping test is conducted with a pumping rate of 1.5 m^3/s in the middle of the domain-

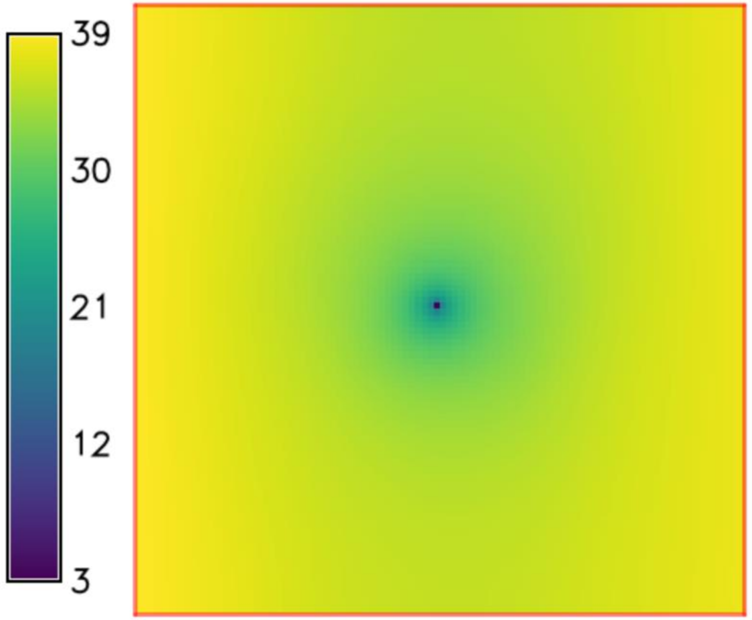
Scenario 3: Simulation results

- The simulation does not converges. Why (or what do you do to constrain your mistake)?

Scenario 3: Solution

- The given pumping rate of 1.5 m³/s is too large.
- Once hydraulic head becomes negative the system does not converge

Hydraulic head (m) with q=1.25 m³/s

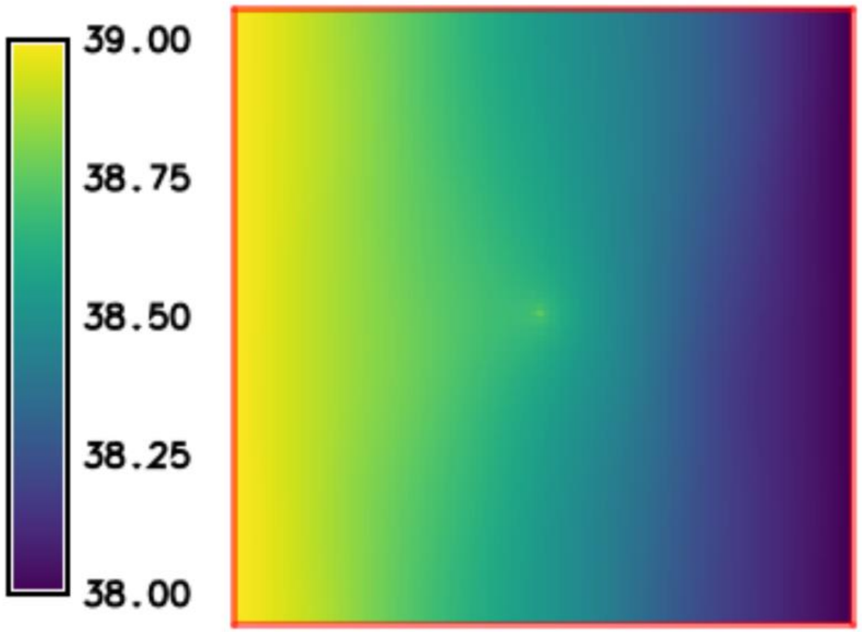


Scenario 4: Pumping station revised

- By fixing mistake from scenario 3 by correcting the pumping rate to 0.015 m^3/s, you know receive the following result

Scenario 4: Simulation results

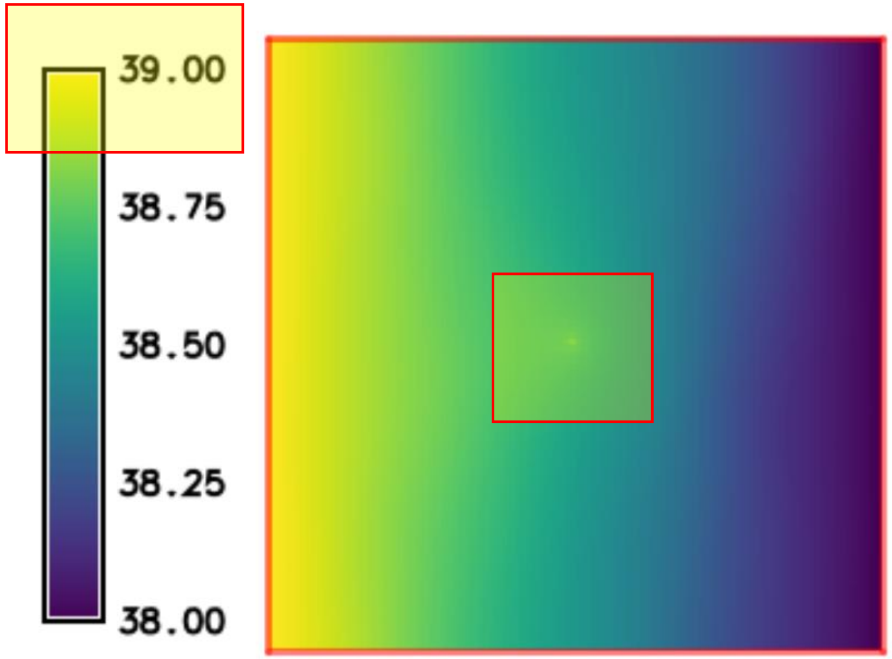
Hydraulic head (m)

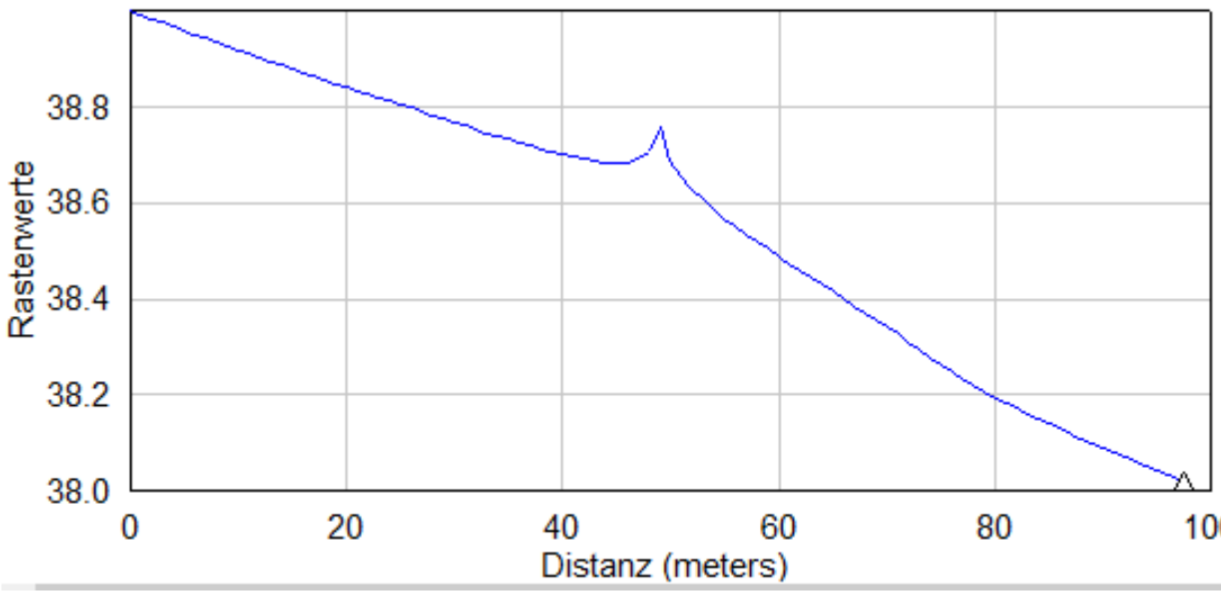


Scenario 4: Solution

- An injection instead of a withdrawl was simulated

Hydraulic head (m)



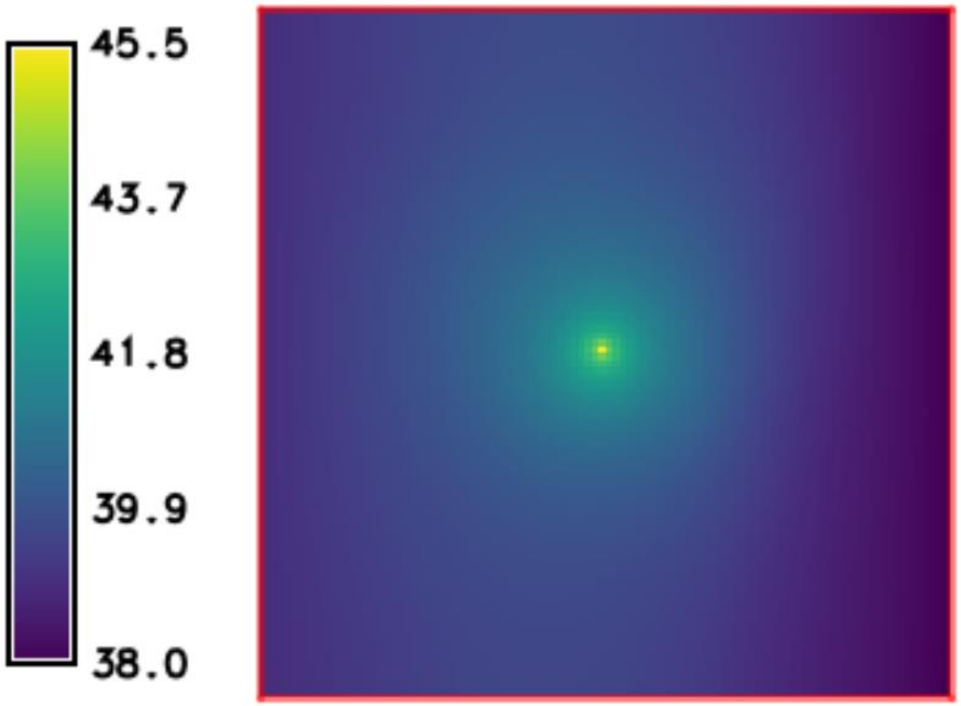


Scenario 5: Injection simulation

- Based on scenario 1, the installation of an injection borehole of a geothermal system with an extraction borehole at an deeper aquifer is considered. The company is excited by the high pumping rates it can use to inject the water into the upper unconfined and highly conductive aquifer. What are they doing wrong?

Scenario 5: Simulation results

Hydraulic head (m)



Scenario 5: Solution

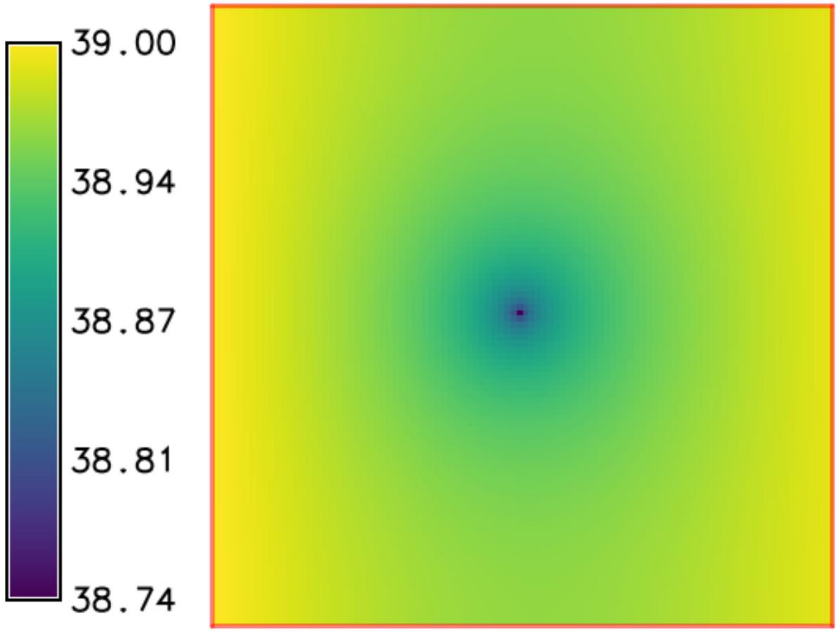
- The hydraulic head is above the surface.

Scenario 6: Detailed pumping test

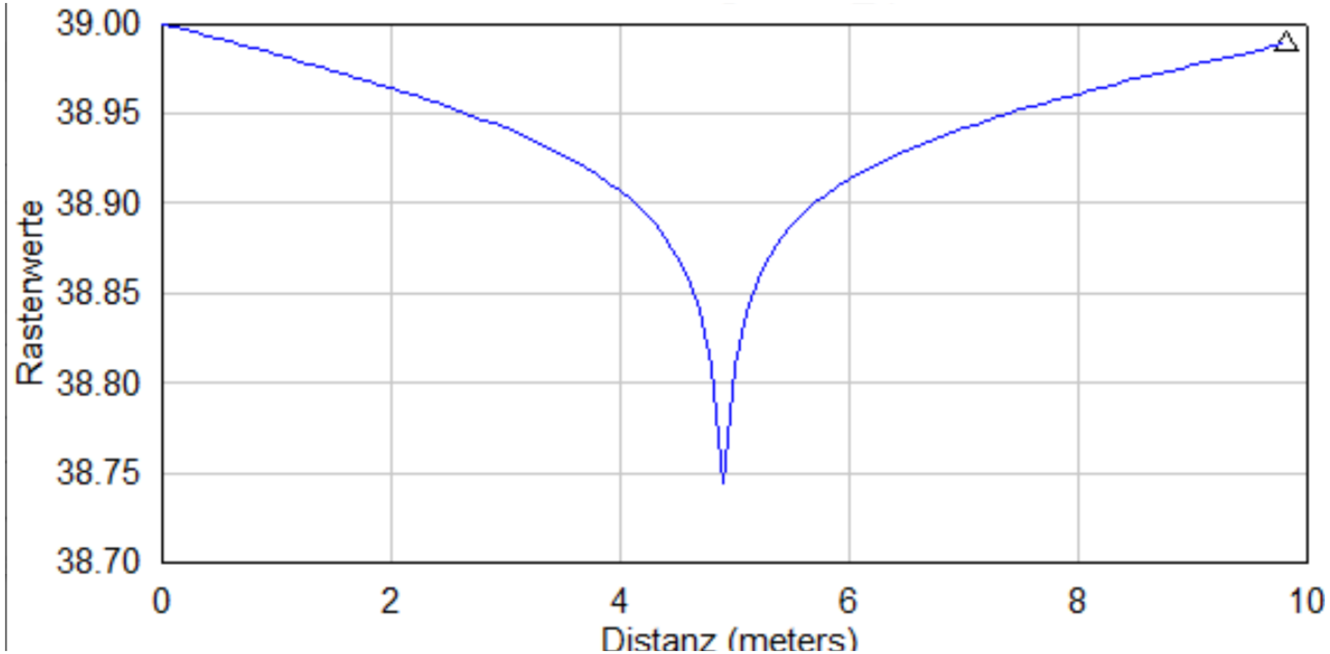
- In a confined aquifer of 25m thickness with a hydraulic head of 35m and a hydraulic gradient of 0.1% a pumping test is conducted. To observe the pumping test a high spatial discretization of 0.1m is set. To keep the computational load manageable, the simulation domain is croped to 10 x 10m. The storativity is 0.0001 and the hydraulic conductivity is 0.0015 m/s. The pumping rate is 0.01 m^3/s.

Scenario 6: Simulation results

Hydraulic head (m)



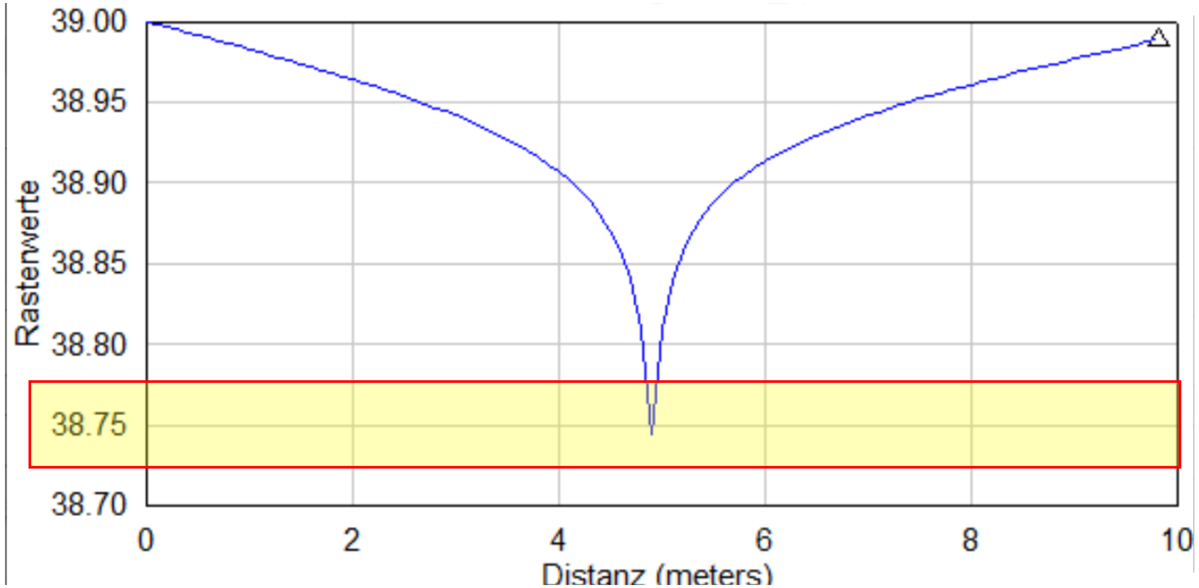
Hydraulic head (m) – WE profile



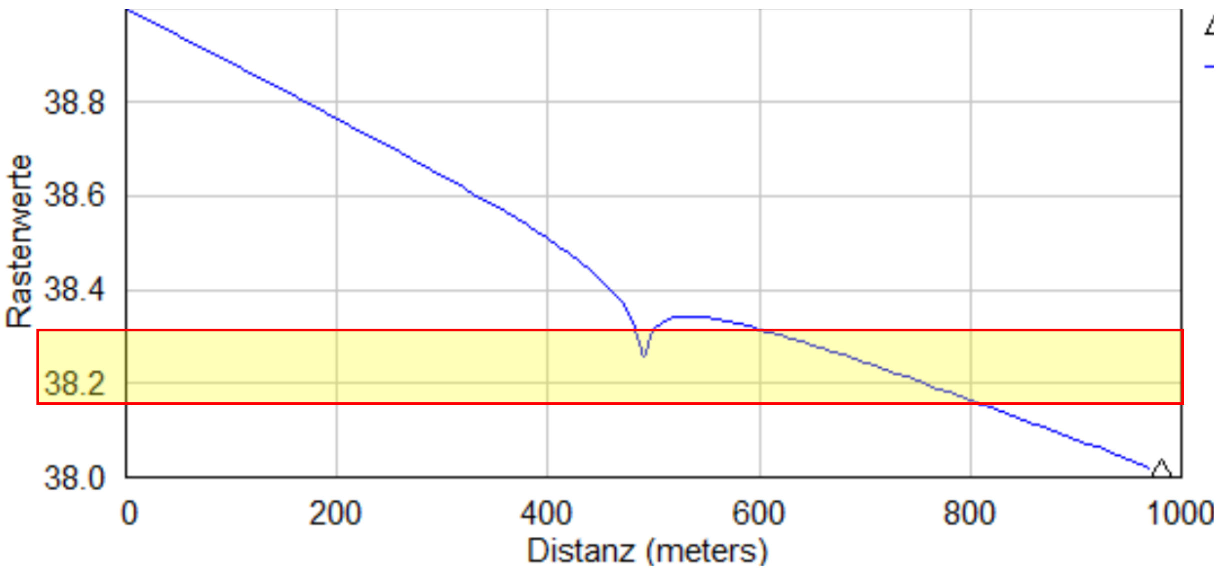
Scenario 6: Solution

- The domain is too small.
- The drawdown cone is influenced by the Dirichlet BC.

Hydraulic head (m) – WE profile



Hydraulic head (m) – WE profile @1000m domain



Lessons learned

- A lot of things can go wrong when simulating
- Mistakes will always happen
- Some errors are easy to find – some not
- The computer is only crunching numbers -> YOU have to think!
- To critically question any simulation result is crucial!
- Groundwater modeling is about combining modeling experience with hydrogeological knowledge