Justin Headley

10 Feb 2022

HWRS 582 – HW3 Discussion

**The Challenge**

1. For the initial values of background and inclusion K, plot the flow into the left and out of the right boundary. (The code, as provided, makes this plot for you.)
   * Explain why the values are not constant along the boundary (relate to the definition of a Type I boundary).
     1. In a Type I boundary, head is constant. But this does not mean that flux is constant. Head is a constant 20m at the left boundary and 10m at the right boundary. The chart shows flow as a function of the y-coordinate. The low-K inclusion is in the middle of the grid, so because of Darcy’s law, q=K\*(dH/dL), if K is lower in the middle, and dH/dL is constant \*from the far-left boundary to the far-right one\*, then q must be lower.
   * Explain why the flow distributions are the same for the left and right boundaries.
     1. The flow distributions are the same for the left and right boundaries (for each boundary, the x-coord is constant, and the y-coord changes, because they’re columns) because this is a steady-state system, and in a steady-state system, Qin (left boundary) must equal Qout (right boundary) for no change in storage, and mass is conserved.
2. Add a plot of the left-to-right flow along a line that passes through the center of the inclusion. What can you learn from comparing this distribution to that seen on the boundaries?
   * ![Chart, line chart

     Description automatically generated]()
   * My understanding of what the question is asking is that the left and right boundaries are for fixed columns with changing y-coordinates, and then the line that passes through the center is also for a column in the middle of the grid. In that case, the flow going straight through the middle of the inclusion would be lower, and the flow immediately surrounding the inclusion would be higher, since water has to now find a way to move around the traffic jam.
3. Calculate the total flow into (and out of) the domain. Use this to calculate the Keq of the heterogeneous system with the K values as given in the starter code.
   * Starter code K values are 1 m/day for high K and 0.1 m/day for low K. Total flow for this is 96.65 m^3/day. The Keq in this case is 0.97 m/day. This is found with Darcy’s law, since we know Q, we know the cross-sectional area of the whole model, and we have constant head at the boundaries.
4. Repeat this calculation for the following K values for the inclusion (keeping the background K as it is given): 0.01, 0.1, 1, 10, 100.
   * 
5. Compare the Keq calculated based on the total flow into and out of the domain to the harmonic and arithmetic mean K values calculated based on the area occupied by each medium (rather than the length for a 1D system). Can you draw any general conclusions about the impact of high or low K heterogeneities on the equivalent K for the flow system examined?
   * First, arithmetic means in heterogeneous situations are right out. Second, even a harmonic mean would only give a correct Keq if the flow were entirely 1-dimensional. Which in this case, it is not. A lot of vector math goes into calculating flow across gradients that aren’t normal to cells, and that’s why we have computers do it for us.
   * The general conclusion seems to be that for this relatively small (5x5 cells) inclusion, the Keq doesn’t change much, regardless of the K inside it. Keq was only raised 19% when K in the inclusion was increased by 5 orders of magnitude. The inclusion only made up 4% of the total area of the model, though.

**Discussion questions**

1. Does the equipotential distribution depend on the absolute or relative K values for the background and the inclusion? How would you use the model to test your answer?
   1. They change for the absolute K. You can test this by running the model repeatedly and adjusting K values with each run. For example, you can see when the inclusion K is 100 m/day, the equipotential lines “bulge out” around the inclusion (and flow goes INTO the inclusion), and if K is 0.1 m/day, the lines curve in like an hourglass (and the flow goes AROUND the inclusion).
2. Discuss what it means to say that, for steady state flow, there are equivalent Type I and Type II boundary conditions. How might this be useful in practice?
   * 1. It is possible to have effectively identical boundary conditions, regardless of whether it’s type I or type II. E.g., a type II constant flux boundary condition could also have a constant head, as well.
3. What would you find if you altered your model to consider unconfined conditions??
   1. If conditions were unconfined, then the saturated vertical thickness would not be constant. So far, we’ve really only been working with pressure head. But if elevation head were also lowered, then the cross-sectional area of the aquifer would start decreasing. This means that for a steady-state model, while Qout still needs to equal Qin, the specific flux, q, would have to increase as the elevation head decreased, due to the reduced area.

**Glossary questions:**

1. What is FloPy? How is it different from MODFLOW and how does it interact with MODFLOW? What are some advantages (easy) and disadvantages (harder) of using FloPy rather than building MODFLOW models manually?
   1. FloPy is a Python package that allows one to run MODFLOW in a slightly easier way. I don’t believe it actually interacts with MODFLOW directly, but it just changes the text in MODFLOW’s input files, and then gives a command to run MODFLOW. Advantages are that it allows you to adjust the input files much faster than trying to do it manually. For example, having to set the K for 625 individual grid cells in a text document is very time-consuming, but with FloPy, it can be done with just one line of code. The disadvantage is that it requires knowledge of Python, so there is a steep learning curve.
2. Given that the distribution of K is always heterogeneous at the small scale, what does it mean to provide one K value per grid cell? What are the implications for the K values we use in models in general? How does this change if we are modeling with different spatial resolutions (i.e. grid cell sizes)?
   1. One K value per grid cell is the “average K” of that cell. We always have to approximate the average conditions of a grid cell. Because we don’t have an infinite amount of computing power, we have to make a tradeoff between model resolution and model accuracy. Larger grid cell sizes might not account for real world heterogeneity as well, but computations can run faster, and the heterogeneity might not even be different enough to make running a finer-resolution model worth it.
3. What does it mean for a groundwater model to be confined? How does this simplify calculations of groundwater flux? How do we specify this with cell types in MODFLOW?
   1. A confined aquifer’s saturated thickness is not dependent on head. This makes the equations of flow linear equations, which are much easier to solve. I’m not sure how we specify this in mudflow, but my two thoughts are it is either by defining the vertical thickness to be constant throughout the entire grid, or by setting the boundaries as constant heads with section 4.1 of the code. Because I do not believe an unconfined aquifer would have constant head at both boundaries.