HWRS 582 – Groundwater modeling

HM5 – Recharge me

Luis De la Fuente

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1. **For the initial boundary head values and pumping and recharge rates, compare the head versus x distance - along a transect from the middle of one constant head boundary to the other - to the results for the BoxModel. Now reduce the boundary heads to 15 and 5. Compare this result and explain any observed differences. The overall gradient is the same, as is the K of the medium ... is the flow the same for both boundary conditions? Why or why not?.**

In the original situation, the gradient is constant given that the medium is fully saturated, and it is in steady-state. When we change the water head at the boundaries, the right side is not fully saturated. That means that the water has a lower cross-section to flow (the unsaturated zone is not considered in the model). However, the fully saturated area is still pushing more water than the partially saturated. Therefore, to equally the flow the saturated region must store more energy (Water head) to push the water through a lower cross-section available. Moreover, the cross-section depends on the water head and vice versa, so the unsaturated region has a nonlinear solution. (Figure 1).

As mentioned, the flow is the same in both boundary conditions given the steady state condition. However, the total flow leaving the system is different between both scenarios. Figure 2 shows that the situation with unsaturated allows less flow in the system due to the higher loss of energy.

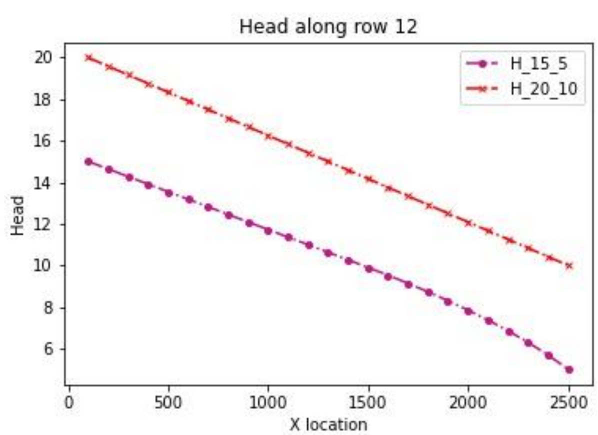

Figure 1. Transect through row 12 (fully saturated and partially saturated).

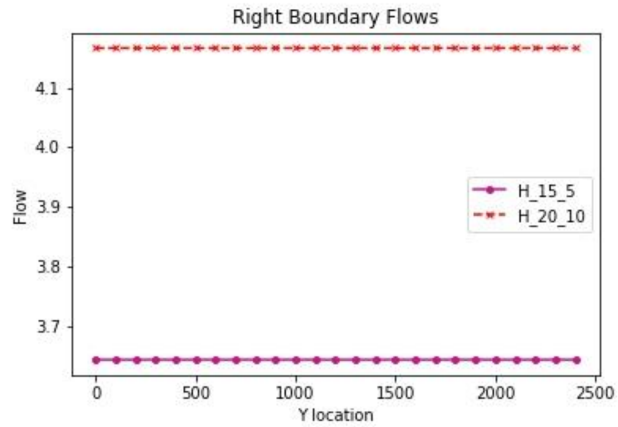

Figure 2. Flow through the right boundary condition (fully saturated and partially saturated).

2. **Now add recharge at a constant rate of 1e-4 m/day over the entire top boundary. Explain the head transect and boundary flows. Is flow in this system 2D or 3D? Is it represented as 2D or 3D? Explain what you mean by your answers.**

Similar to the previous question, the amount of water that is entering vertically in the system is more than the saturated flow in the baseline condition. That means that to keep the water head in the boundary condition with a higher flow, the energy must be stored inside of the system. This way the extra energy inside will push the extra flow. The parabolic shape of the water head is the result of the big amount of water that is entering the system. That water is changing the direction of the flow from only left-right toward both directions (left and right boundary condition). For that reason, a lot of water is cumulated in the middle of the domain than in the boundaries.

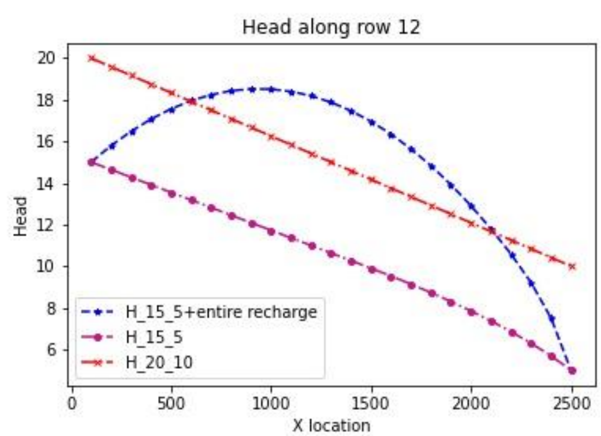

Figure 3. Transect in the boundary conditions and close to the well.

The rechange is creating a preferential vertical flow however the boundary conditions have a horizontal flow. Therefore, the flownet is necessarily 2D, however, we are using only one column cell to represent the movement. That means that the model should model only horizontal flow. However, modflow is using the simplification that flow is mainly horizontal in each cell to solve the problem.

3. Now model a system with zero recharge except for a farm located in [6:10, 6:10] - in python terms. Recharge beneath the farm is 1e-4 m/day due to excess irrigation. First, calculate the annual excess irrigation, in meters, that has been applied to the farm. Second, assuming that the crop is cotton, it is located in southern Arizona, and cotton is grown all year (for simplicity), calculate the total irrigation rate on the farm that would be associated with this amount of excess irrigation. Finally, identify the area within the domain that might be subject to contamination if the recharge water was somehow tainted.

The annual excess would be 0.0365 m (1e-4 m/day x 365 days). The irrigation can be calculated assuming that the cotton crop has evapotranspiration equal to the potential evapotranspiration in Tucson (2100mm/year).

$$Excess = Irrigation - Demand$$

$$0.0365 \frac{m}{year} = Irrigation - 2.1 \frac{m}{year}$$

$$Irrigation = 2.14 \frac{m}{year}$$

The contamination zone is shown in a blue region in figure 4.

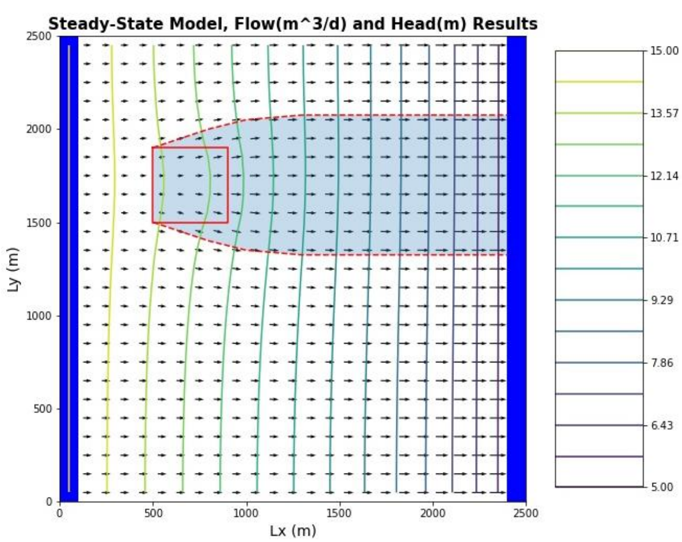

Figure 4. Contamination zone by the farm.

4. Lastly, start the well pumping at a rate of 8 m3/day. Using one color, identify the capture zone of the well. Using a second color, show the area that might be contaminated by the irrigated farm fields. Comment on the impact of the well on the pattern of potential contamination.

Figure 5 shows in the green dash line the capture zone of the well and in the blue region the contamination from the farm. Given that both regions are overlapping we can assume that the well will be contaminated. However, it is not clear how much water tainted will be capture for the well. That depends on the well if it is fully penetrated and if the pollutant presents only advection, or advection and diffusion. For example, if the well is capturing water only from the bottom of the aquifer and the pollutant is moving only through advection, then the well could be not contaminated. On the other hand, if we assume no diffusion or dispersion, and a complete mix at the well. The concentration will be the weighted sum of the flow coming from the farm (intersection between green dash line and red square) and the flow that enters the capture zone from the left boundary condition (intersection between the blue line and green dash line).

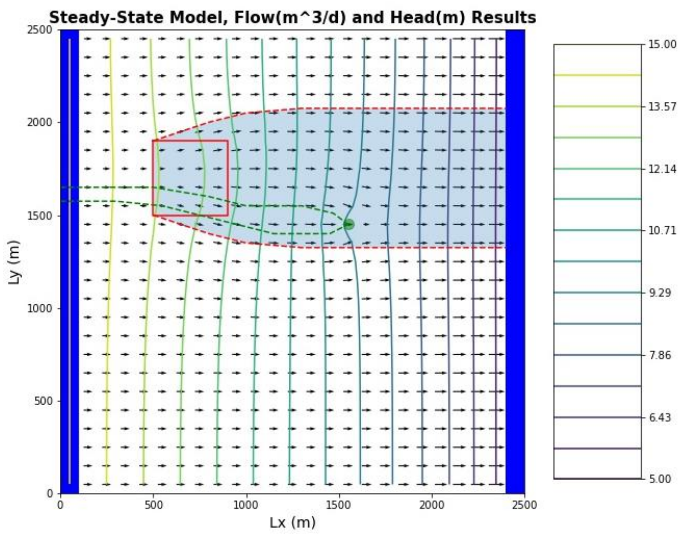

Figure 5. Interaction between the well and the farm.

Discussion Points

5. How can MODFLOW, which does not model unsaturated flow, represent an unconfined aquifer?

Two elements help mudflow to deal with that. The first one is that all the region that is above the water head if not modeled. That means that the available cross-section in the cell is less than the dimensions of the cell. The second element is that the transmissibility of the cell is not represented as T=K*b (K: conductivity, b=aquifer thickness). In that case, the transmissibility depends on the water head T=K*H (H: Water head). That creates an implicit solution that must be solved iteratively.

6. What do you think would happen (in MODFLOW) if you pumped an unconfined aquifer so hard that the water level dropped below the bottom of the aquifer? Explain this from the point of view of what is happening in the model ... then think about what would happen in real life!

I think the model would not converge because it does not deal with negative pressure. In real life, you will have air inside of the pump. When that happens, traditionally the pump stops, or it does not pump water. Therefore, you must wait to recover the static level in the aquifer to fill the water at the pump and restart the pumping. It has happened to me so many times…

7. How will the steady state capture zone of a model with recharge differ from that in the same model without recharge?

Figure 5 shows that the capture zone of the well with the recharge is not horizontal. It moved hundreds of meters toward the recharge. Therefore, the recharge area changed completely where the water is capture by the well.

8. What is recharge? What does it mean to define recharge for a MODFLOW model? How is it related to defining ET and precipitation? Where, exactly, is the top boundary of the model?

Recharge, ET, and precipitation are kind of magic concepts in Modflow. These positive or negative flows are added instantly in the cell without any delay for traveling from the ground surface to the center of the cell. In some way, they are just a creation or destruction of flow inside of the cell. Magic…The top boundary is in the water table in an unconfined aquifer and at the top of the confined aquifer in that case.