HWRS 582 – Groundwater modeling

HM5 – Recharge me

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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.

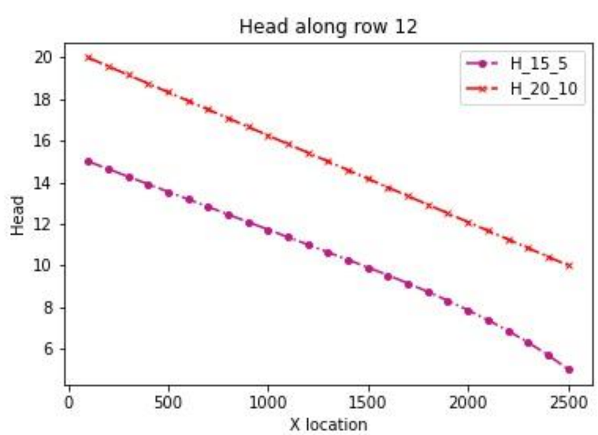

Figure 1. Transect through row 12 (fully saturated and partially saturated).

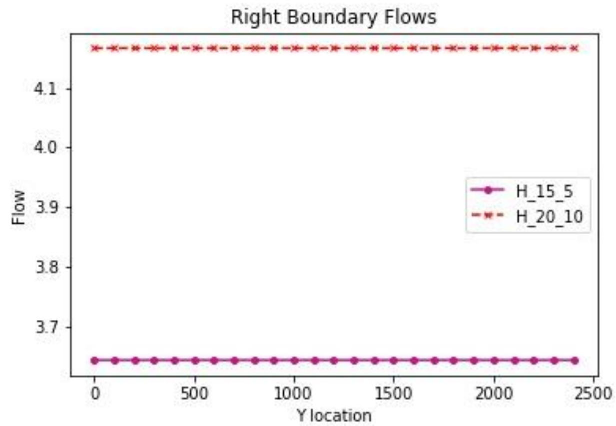

Figure 2. Flow through the right boundary condition (fully saturated and partially saturated).

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 given for water that is entering the system. More water is cumulated in the middle of the domain than in the boundaries, therefore more water is pushing to go out of the domain.

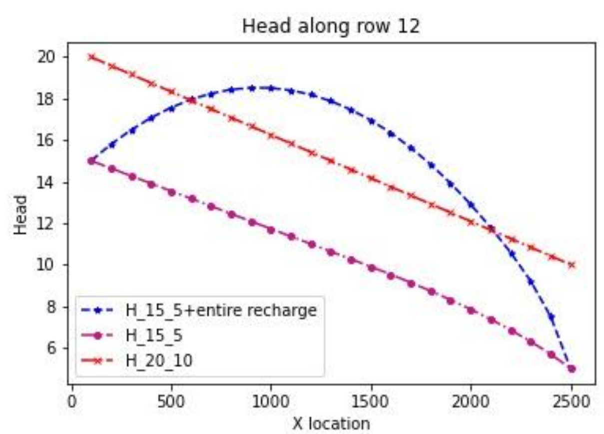

Figure 3. Transect in the boundary conditions and close to the well.

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.

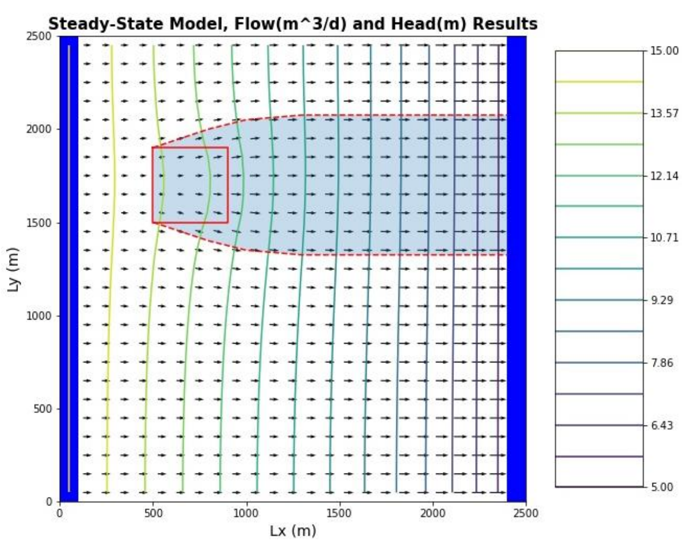

Figure 4. Contamination zone by the farm.

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.

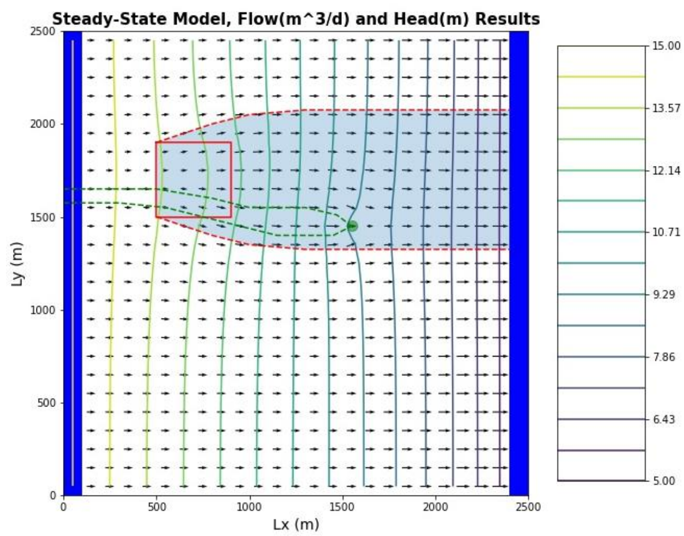

Figure 5. Interaction between the well and the farm.