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HWRS 482

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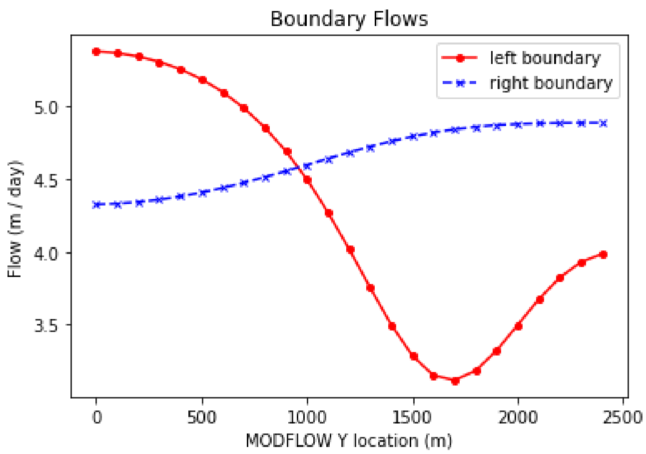
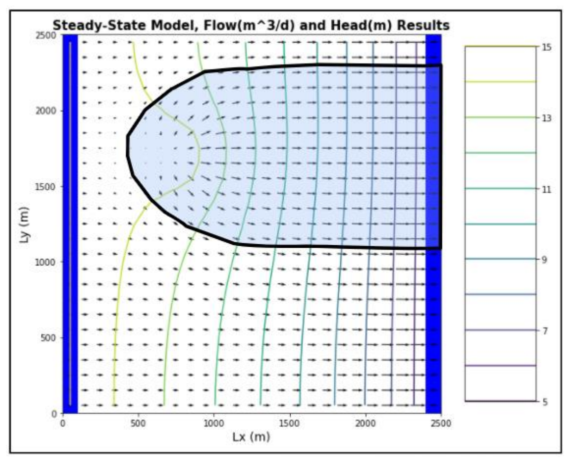
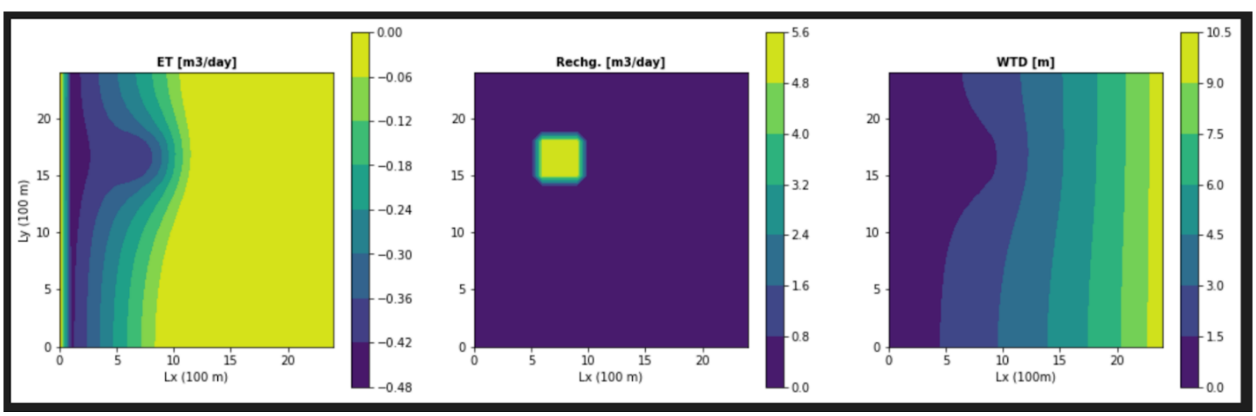
Challenge

1.For the initial boundary head values and recharge and ET rates: plot the flow across the left and right boundaries. Explain what you see and why it makes sense. Plot the equipotentials and flow vectors in plan view and outline (hand draw) the area that would be affected by recharge (i.e. if it were contaminated). Explain what you are seeing and why. Plot ET, Recharge and Water Table depth and explain why we see the patterns we do.







For the first graph (boundary flows) we see this pattern due to the recharge in the y=1500 area. there is less flow in the left probably due to a no flow boundary. In the contour diagram we see them distorting on account of recharge. We can see the same distortion when we plot ET and water table depth. The overall pattern here is due to recharge in this area. It looks as thought there is the least amount of et away from the recharge area.

2.Calculate the water balance for the model. Report all of the inflows and outflows with units and show that mass is being balanced. Explain what controls each term in your water balance.

Inflows (input)	Outflows (output)
• Flux in (Q_in) • Recharge (R)	• Flux out (Q_out) • Evapotranspiration (ET)

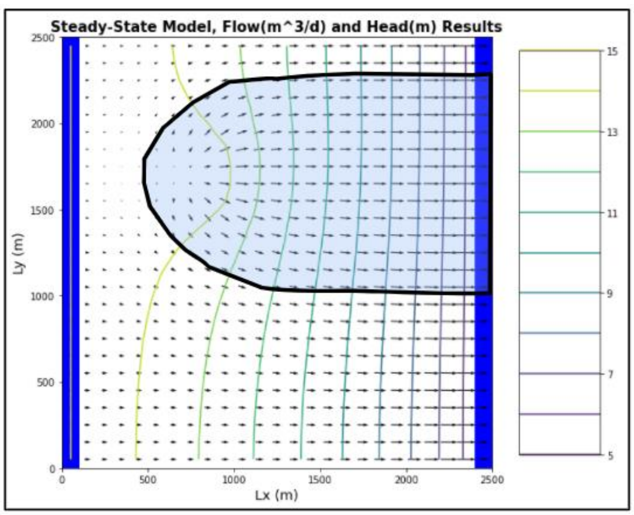
- dS/dt = input - output
- 0 = Q_in + R - Q_out - ET
-
- Q_out + ET = Q_in + R
- $116\ m^3/d + 70\ m^3/d = 106\ m^3/d + 80\ m^3/d$
- $186\ m^3/d = 186\ m^3/d$

```
Total ET [m3/day]: -70.35179571458139
Total Recharge [m3/day]: 80.0
Left Flux = 106.4442   Right_flux= 116.0927
```

Figure 2. Water Balance of Baseline Model

Q_out is controlled by the amount of water leaving our domain, Q_in is controlled by the amount of water entering our domain. ET is controlled by the amount of evapotranspiration we tell the model to output, it depends on the value we give it and this is the same for recharge. We get a value for ET and Recharge after totaling the values for each cell in our domain.

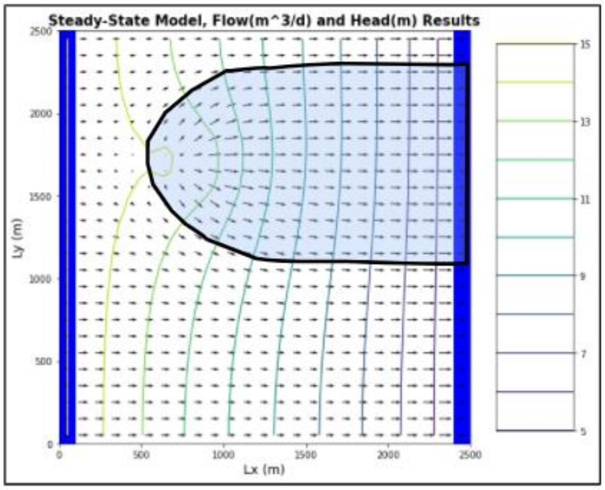
3. Change the extinction depth in your model. Report the new water balance numbers. Provide a plot of the new head contours and fluxes. Explain what changed and why.



- dS/dt = input - output
- 0 = Q_in + R - Q_out - ET
- Q_out + ET = Q_in + R
- $125\ m^3/d + 34\ m^3/d = 79\ m^3/d + 80\ m^3/d$
- $159\ m^3/d = 159\ m^3/d$

```
Total ET [m^3/day]: -34.226034936495125
Total Recharge [m^3/day]: 80.0
Left Flux = 78.9073  Right_flux= 124.681
```

Figure 3b. Water Balance using Extinction Depth of 1



- dS/dt = input - output
- 0 = Q_in + R - Q_out - ET

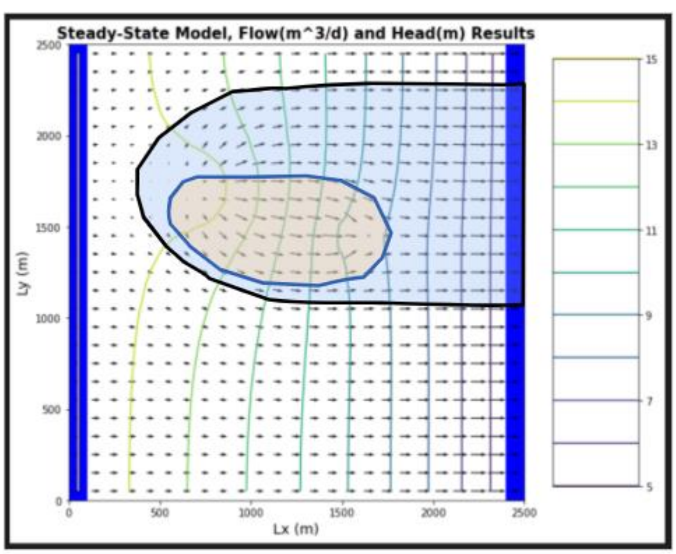
- Q_out + ET = Q_in + R
- 88 m^3/d + 132 m^3/d = 140 m^3/d + 80 m^3/d
- 220 m^3/d = 220 m^3/d

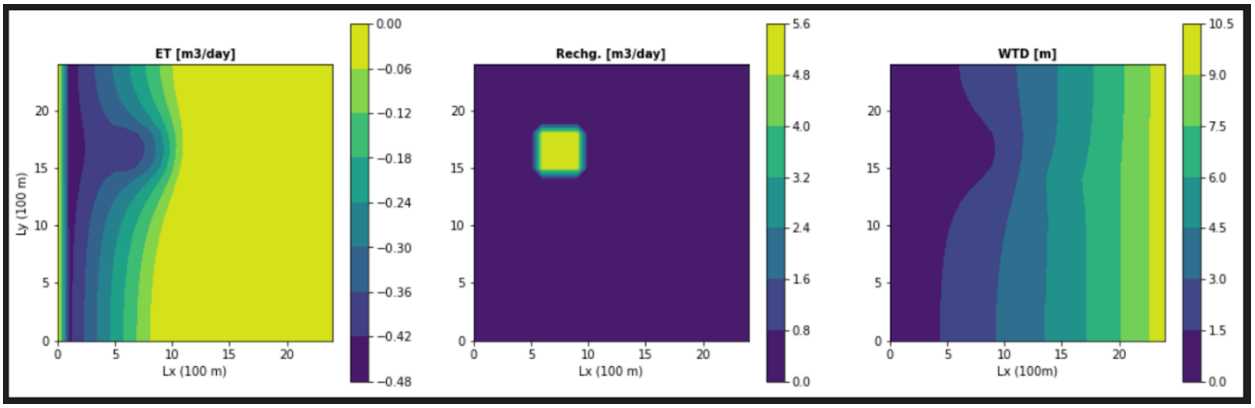
```
Total ET [m^3/day]: -131.8804266648367
Total Recharge [m^3/day]: 80.0
Left Flux = 140.0117  Right_flux= 88.1317
```

Figure 3d. Water Balance using Extinction Depth of 8

The ET, left flux, and right flux changed. The deeper you go the lower the right flux out and the higher the ET. This is because you are accounting for more ET in a higher extinction depth. When we tried it for an extinction depth of 1 the ET was -34 and when we did it for 8, the ET was -131.

4. Now start the well pumping, extracting 20 m3/day. Plot the equipotentials and flow vectors in plan view and outline (hand draw) the area that would be affected by recharge (i.e. if it were contaminated). Plot ET,Recharge and Water Table depth and explain why we see the patterns we do. How does the well change the zone that is affected by the recharge area? How does it affect the ET map?





We continue to see a pattern that relates to the recharge area. The WTD plot also shows another slight distortion due to the well. We see a higher ET near the recharge area but the well doesn't seem to affect the ET map. The well captures some of the water in the contamination zone but not all of it. There is still a large area of the domain that is still affected by the recharge.

5. Write a mass balance for the well. How much water is coming from a boundary? How much is originating as recharge? How do you account for the impact of ET on this mass balance? At steady state, what are the effects of 'capture' by the well?

```python
# Getting flux from the well
flux_vals2 = np.squeeze(fff)
left_well = np.round(flux_vals[10,14], 4)
right_well = np.round(flux_vals[10,15], 4)
top_well = np.round(flux_vals2[9,15], 4)
bottom_well = np.round(flux_vals2[10,15], 4)

print('left of the well flux =', left_well)
print('right of the well flux =', right_well)
print('top of the well flux =', top_well)
print('bottom of the well flux =', bottom_well)
print('Well flux in =', left_well + abs(right_well) + top_well + abs(bottom_well))
```

✓ 0.8s

```
Total ET [m3/day]: -66.26632084313314
Total Recharge [m3/day]: 80.0
left of the well flux = 10.0257
right of the well flux = -0.0756
top of the well flux = 5.4132
bottom of the well flux = -4.4855
Well flux in = 20.0
```

Recharge is accounted for by the value we input. We account for ET in the mass balance by subtracting it. At steady state the well will capture the amount of water we specified as the rate of pumping. In our case it should take up 20.

Glossary questions:

Define Evapotranspiration. Explain in the real world (1) the components of evapotranspiration (2) where this water is pulled from and (3) the physical drivers and controls that determine evapotranspiration rates.

Evapotranspiration is the water lost to the atmosphere. It happens when water is evaporated from the soil and or plants. You need the evaporation from plants, transpiration, and evaporation from soil. The water is pulled from the subsurface or the atmosphere (rain, snow). What controls and drives evapotranspiration rates are the age of plants, temperature, soil cover, the amount of energy coming from the sun, among others.

Describe how the evt package in MODFLOW models evapotranspiration. List the assumptions and simplifications that this package is making.

According to USGS the EVT package simulates ET by a head-dependent flux which is distributed over the top of the model. The fluxes are then multiplied by the horizontal area their corresponding cells to get the volumetric flux rates. Assumptions that MODFLOW makes are: only including ET from the saturated zone, and recharge is sometimes calculated by precipitation and losses between the land and water table

What is a land surface model? What are the differences between groundwater models like MODFLOW and land surface models that also simulate the shallow subsurface? When is each preferred over the other?

A land surface model is a simulation of the water exchange between land and the atmosphere. It is a diagram of the water balance. MODFLOW has more detail on the process of getting the subsurface water numbers where the surface model also provides fluxes in the atmosphere. MODFLOW doesn’t do that. If you want to be concise and want a diagram for people who don’t want to hear all of the other details, then you can use a land surface model to portray the fluxes. You would want to use MODFLOW to get some of the numbers you want to put on your land surface model.