1. *Explain why the values are not constant along the boundary (relate to the definition of a Type I boundary). Explain the shapes of the flow distributions and why they are not the same for the left (inflow) and right (outflow) boundaries.*

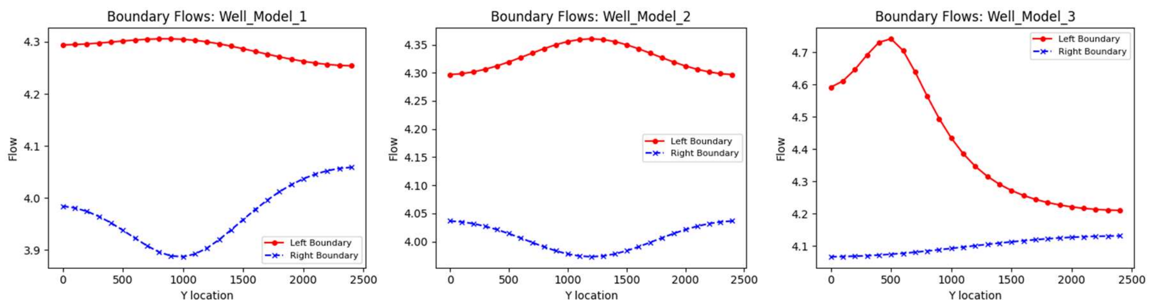


Figure 1: From left to right; Well_Model_1, well position [0,10,15]; Well_Model_2, well position [0,12,12]; Well_Model_3, well position [0,5,5] (positions in MODFLOW coordinates).

The values are not constant along the boundaries of each model for flow due to the capture by the well cell (a negative flux, Type 2 boundary condition.) I visualize this as a mass balance equation for the model (amount of water into the system is the amount of water out of the system (with reduced systems like our current model, we do not account storage within the system.) The MODFLOW {model}.list file shows this with a perfectly balanced flow in = flow out, with the well seen as a contribution to flow out (negative flux out).

The Type 1 boundary conditions along all borders of the model are the h_{left} = 20 m, h_{right} = 10 m, with the top and bottom boundaries having no flow (I guess these could be Type 2 boundaries, with the flux in/out equal to 0).

2. *How do you interpret the flow along this transect? Hint, also look at the flow along a transect just upgradient from the well [:{row-1}].*

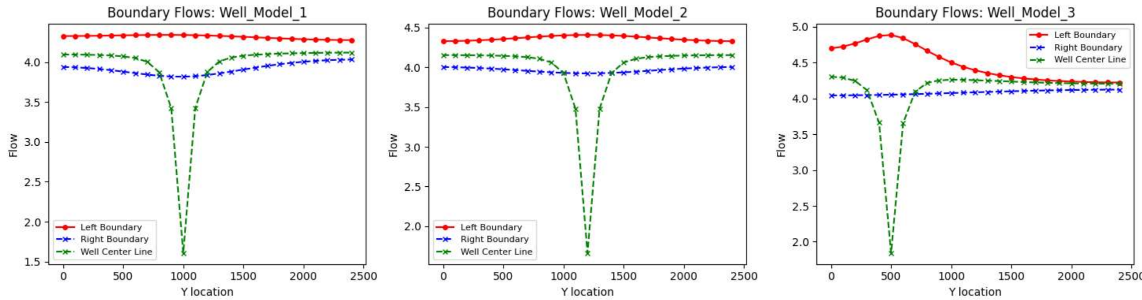
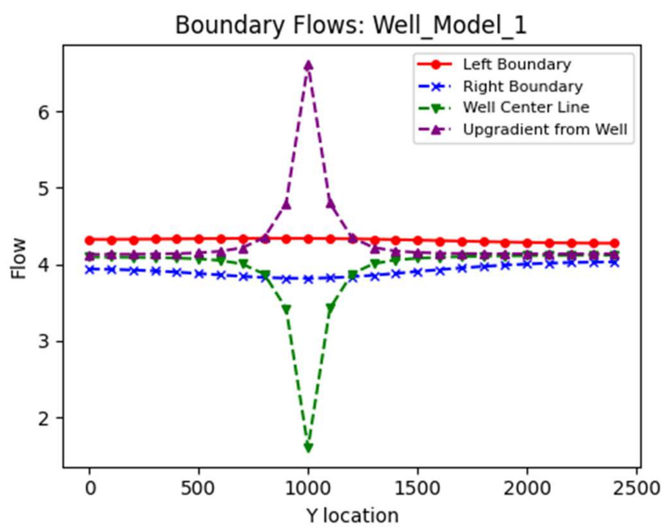


Figure 2: Center line flow transects overlain on the prior flow graphs for all three models; each "Well Center Line" goes straight through the column on which the well is situated within the flopy/MODFLOW model.

I interpret the flow along these transects as showing the sink/capture that the well brings to the model; at these points, overall flow is reduced due to a negative flux within the model at the well coordinates.

Immediately upgradient of the well cells, this green line is inverted, showing a distinct increase in flow near the well location:



This change immediately upgradient also implies the capture action of the well, showing how it pulls in more water immediately upgradient of the well, while retarding the flow downgradient from the well (well-screens are omnidirectional, with water being pulled into the well approximately orthogonal to the surface of the casing, under "perfect" conditions). I would imagine if I set $h_{left} = h_{right}$, the flow around the well would be like the actual well position flow.

3. *Describe how water flows through the domain. To aid in your description, draw a line through all of the flow vectors that terminate in the well. This approximates the capture zone of the well. Use this to refine your description of the flow system, being as specific as possible about where water that ends up being extracted by the well originates on the inflow boundary.*

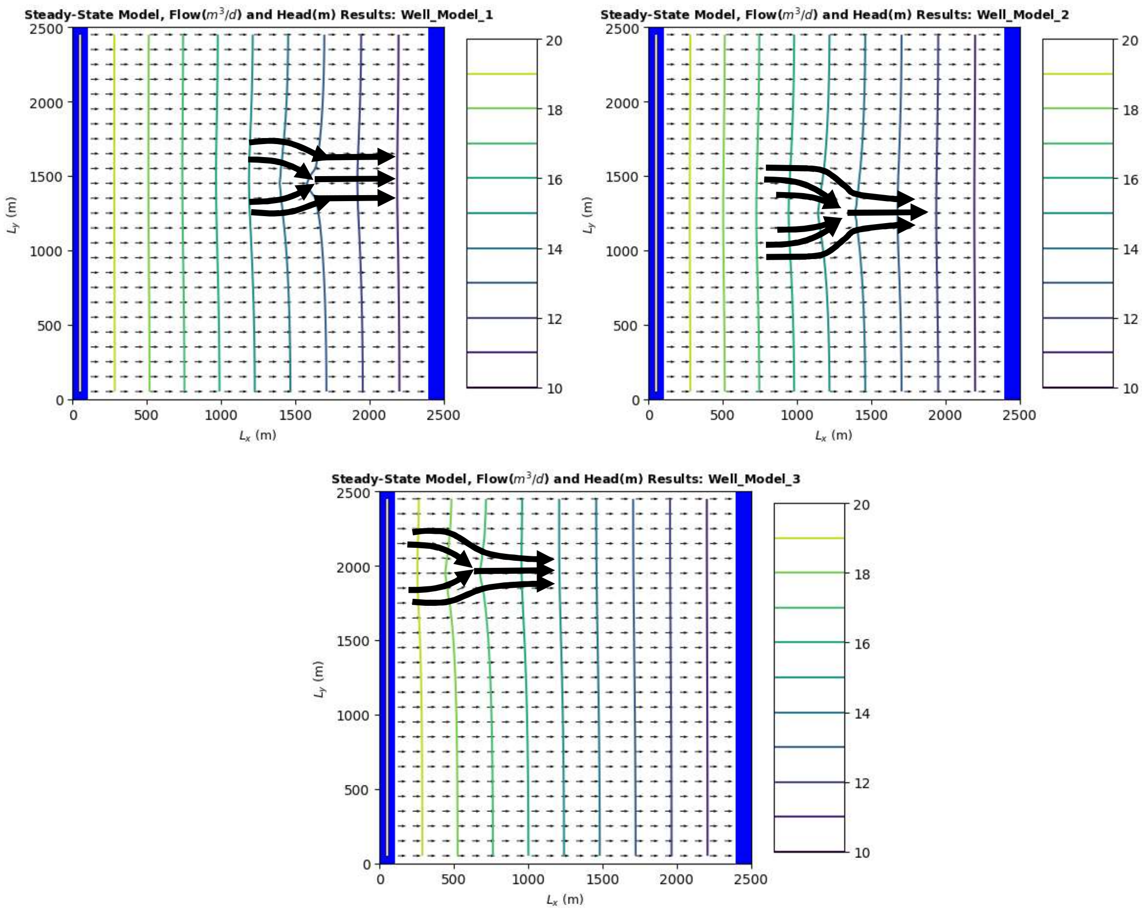


Figure 3: Flownets with equipotential lines overlain for all 3 well locations; Initial, Centered, and Off-centered models. Black arrows indicate relative flow path of a particle released on the left boundary around the well (inferred from flow vectors). Uses initial - 8 m/d flux at the well location.

Flow through the system is relatively linear, almost 1-dimensional in nature, at the initial conditions for well draw (q_{well} = -8 m/d) for the majority of the model domain; however, in the cells immediately surrounding the well (in a 2-3 cell radius around well) are "drawn" towards the negative flux, Type 2 boundary set by the well draw. Flow vectors upgradient in the same row as the well tend to have a larger magnitude upgradient, and lower magnitude down gradient, indicating there is capture by the well.

4. *Look at the plan view drawdown plot. Why aren't the drawdown contours circles? Either explain why this is correct, or fix the plot.*

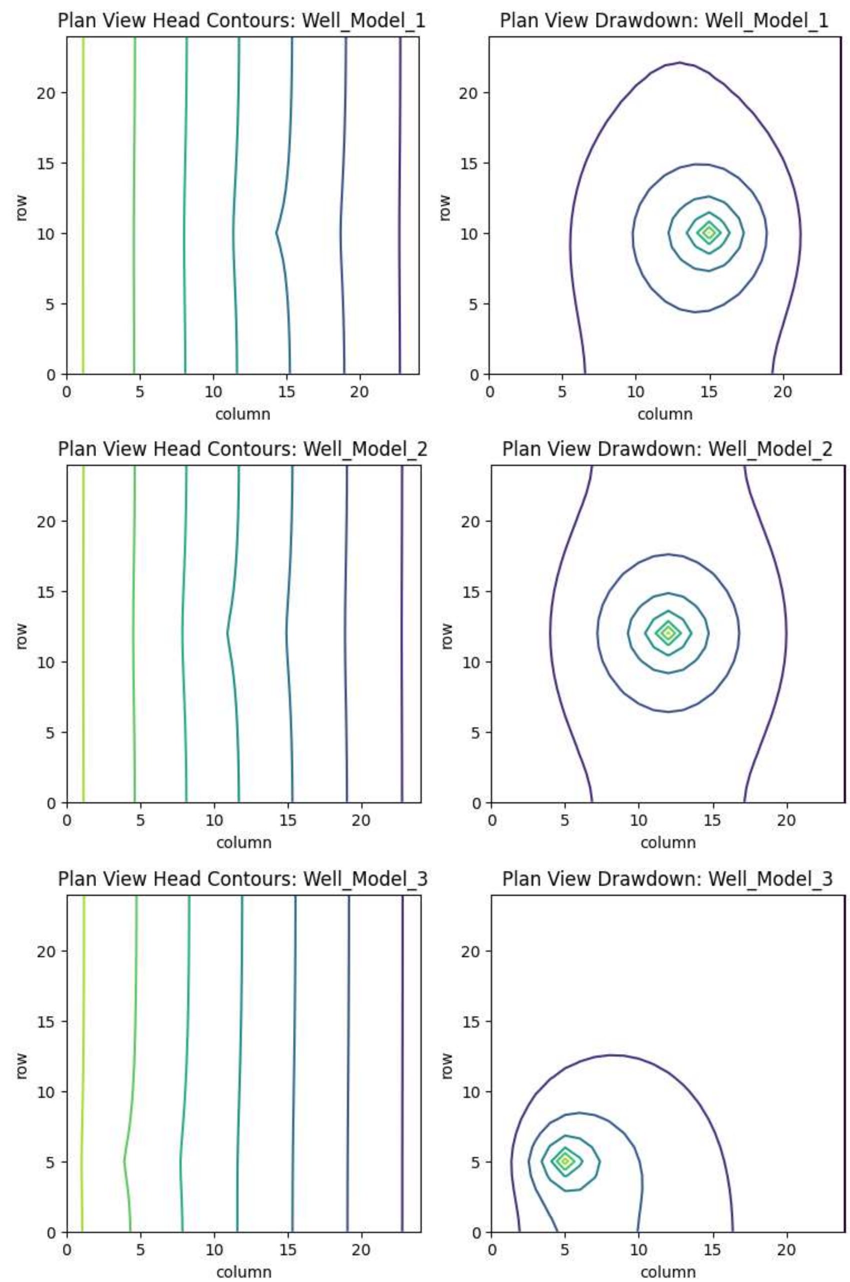


Figure 4: Head contours and the plan view drawdown of all 3 model conditions.

The well drawdown contours aren't perfect circles due to the No-flow boundary conditions along the top/bottom of the model domain; the equipotential lines must be perpendicular to the no-flow boundary where they intersect the boundary. Another reason is possibly due to the steady-state head gradient already in place (h_{left} = 20 m, h_{right} = 10 m; the centered model shows symmetry, similar to the last homework, but the initial and off-centered models show a noticeable skew in contours (both these models skew in the direction opposite of what I'd expect).

5. ***Be sure to include the drawdown plot in your discussion - compare this plot to the equipotentials and flow vectors. Something is not right about how the well location is shown. Fix it and explain what was wrong!!***

The above graphs (from 4 and 5) show that plotting via a combo of matplotlib/numpy modules result in graph positions flipped from the flopy modules graphing method. This is due to the way Python and MODFLOW count rows; Python counts row from the bottom up in this case, whereas MODFLOW starts from the top down (e.g.: The row at 2500 meters on the y-axis would be row 1 in MODFLOW, but would be row 24 within Python.)