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Groundwater Modeling

Feb. 24, 2022.

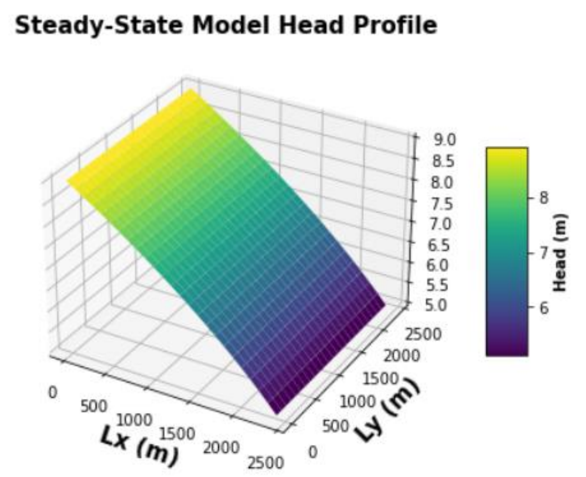
Homework 5 Discussion

Challenge 1: Describe how the two head profiles differ, and explain why this is the case

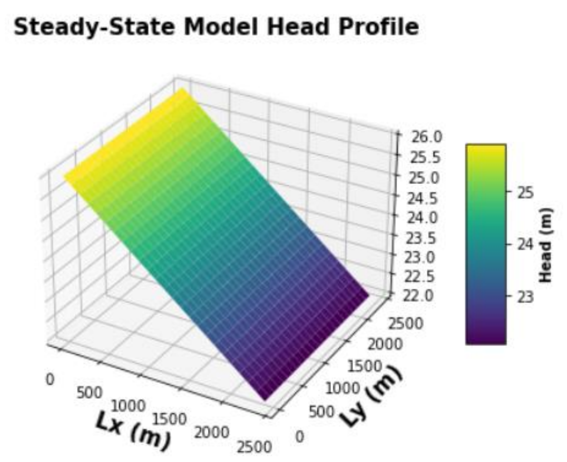
- Q = -KA dh/dl

The area is a function of aquifer thickness for a <u>Confined</u> system. However, in an <u>Unconfined</u> aquifer the area is a function of head, making the equation non-linear.

Though the overall head gradient from left to right is the same for a <u>confined</u> system, it is not for an <u>unconfined</u> case, that is why the plot for "Head differences" show changes in the head for an Unconfined case, but for the Confined case there will be no difference in head.

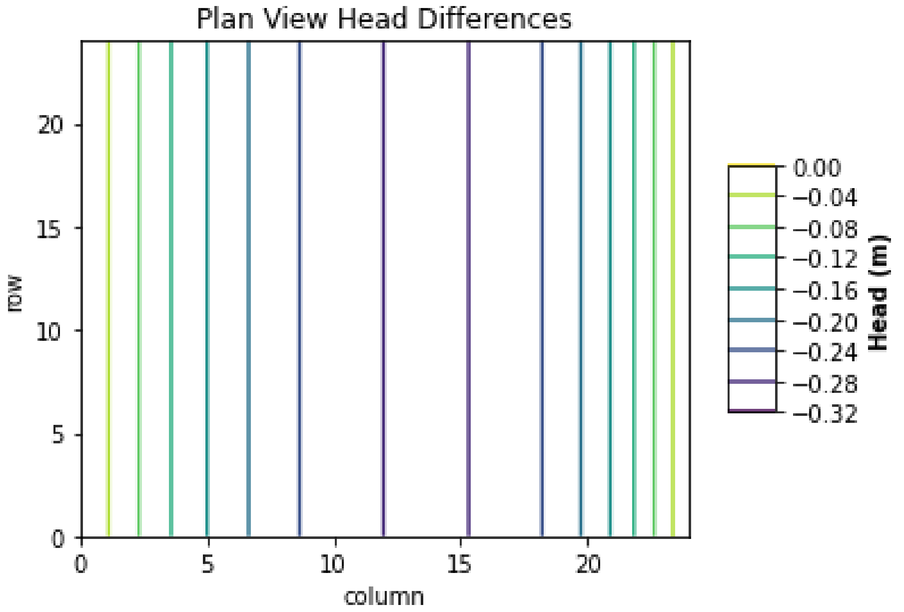


Unconfined
H_left = 9 m; H_right = 5 m

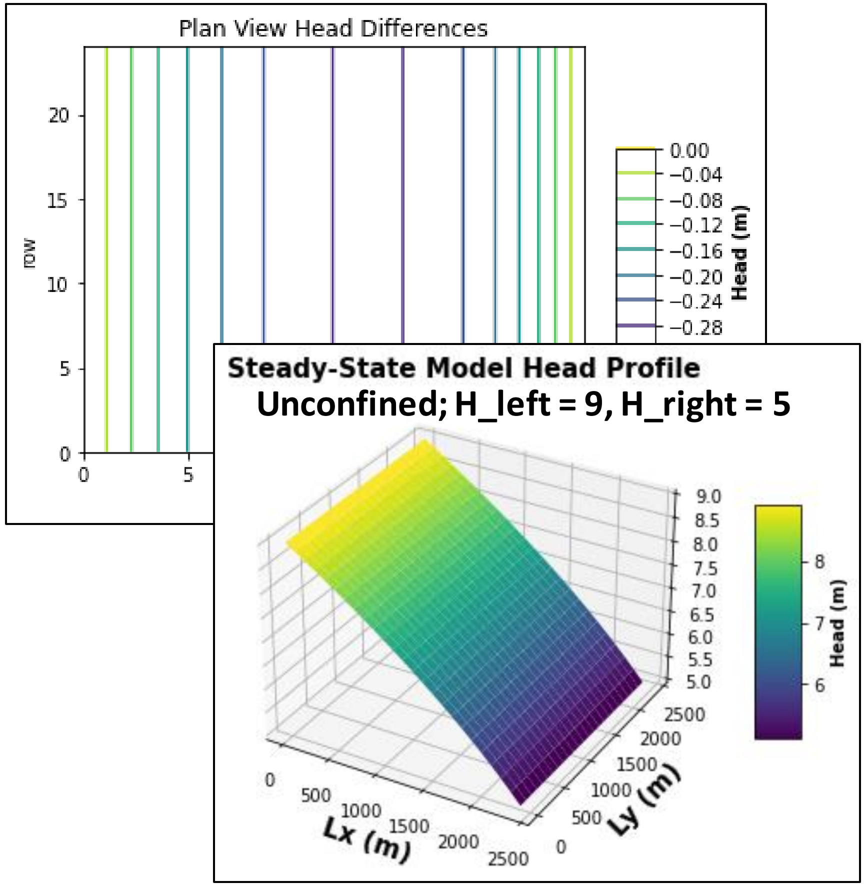


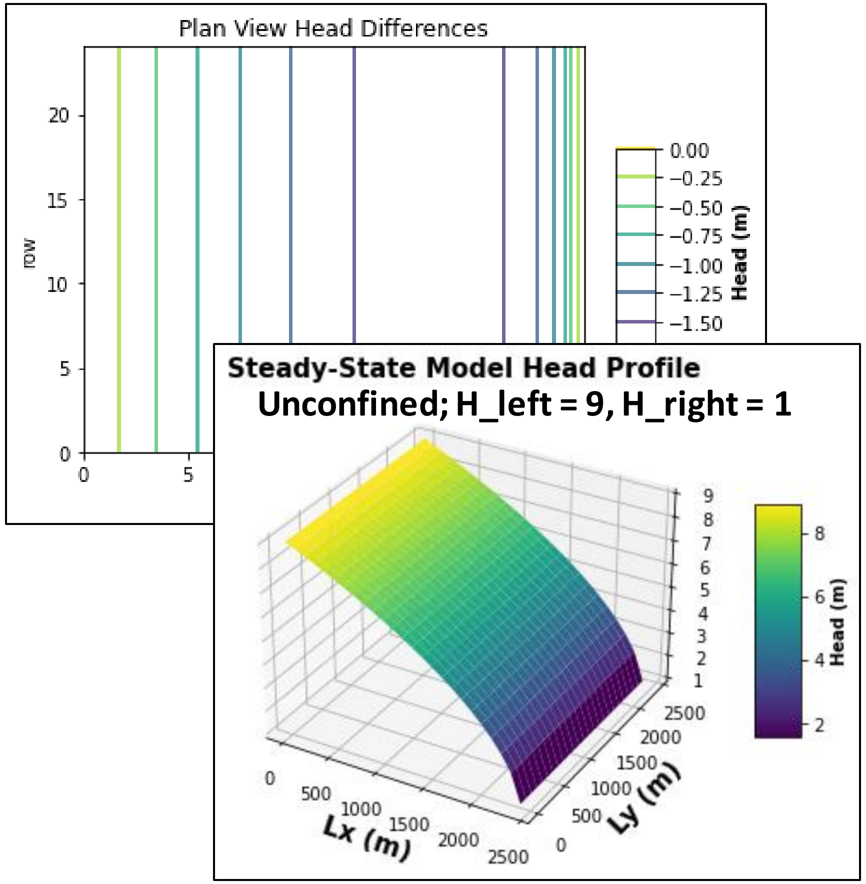
Confined
H_left = 26 m; H_right = 22 m

Unconfined



Challenge 1: Increasing the overall head gradient exaggerates the curve of the <u>unconfined</u> head profile because there is a greater variation of aquifer thickness as the system is trying to conserve the steady-state condition. On the other hand, there is no effect on the <u>confined</u> head profile because the thickness is maintained constant so the gradient will always be linear.

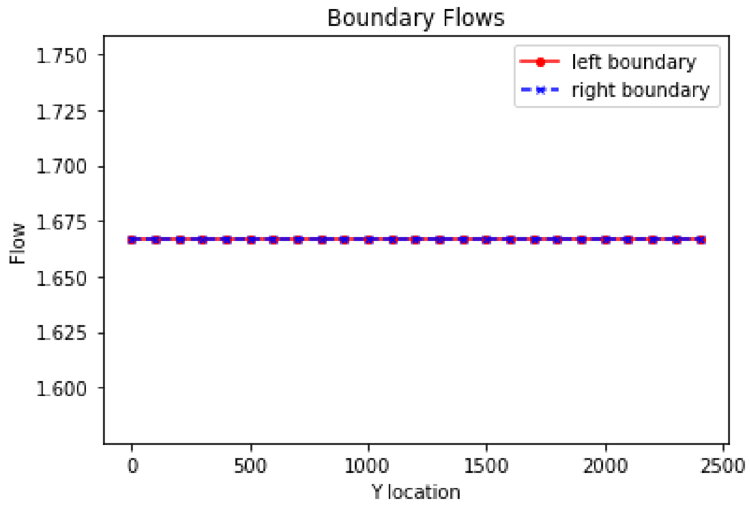




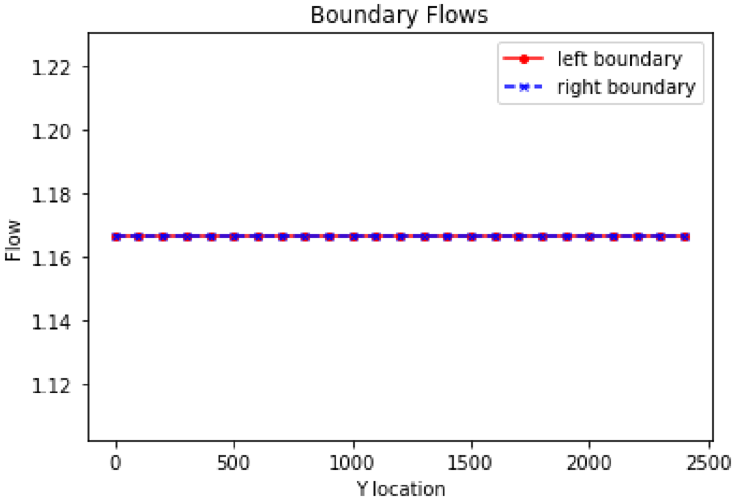
Challenge 2: Calculate the fluxes for unconfined and confined and explain the behavior. Is the flow the same for both boundary conditions? Why or why not?

Both cases are under steady-state conditions; dictating zero change in storage. Boundary fluxes are the same in the 2 situations.

CASE 1: Confined System
H_left = 26 m; H_right = 22 m
Flow in = flow out = 41.6675 m3/d



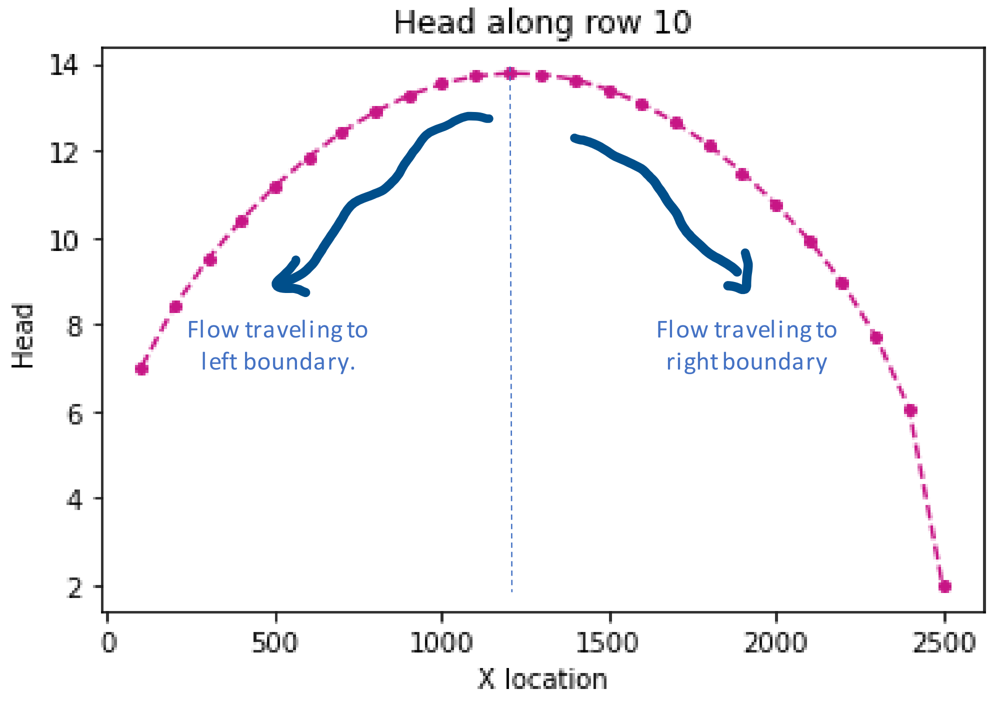
CASE 2: Unconfined System
H_left = 9 m; H_right = 5 m
Flow in = flow out = 29.1625 m3/d



The total Flow is higher in the Confined case because it is a linear gradient so the area through the flow goes is higher than in Unconfined. However, in Unconfined system the total Flow is lower because the gradient is changing on each cell to conserve the steady-state condition, and in this case the area through the flow travels is decreasing along, reducing the Total Flow.

Challenge 3: Head transect and boundary flows, unconfined system, recharge across entire system

- Due to the recharge happening in the entire domain, the flow direction is partitioned in two halves of the domain now. From 0 to location 1250 it is traveling backwards (going to the left boundary), and from location 1250 to 2500 is traveling towards the left boundary. We can see this on the Flux plot, where the left boundary has a negative flux and the right boundary has a positive flux.
- Flux in the left boundary **+** recharge have to equal the right flow to maintain steady state conditions. (-268.46 + 575 = 306.54), that is why the right flow has a higher magnitude than the left flow.
- Also, the right flux boundary has a higher magnitude than the left flux because this one is moving with the overall aquifer gradient, instead of backwards as the left boundary flow.

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Left Head = 7 m.  Right Head = 2 m.
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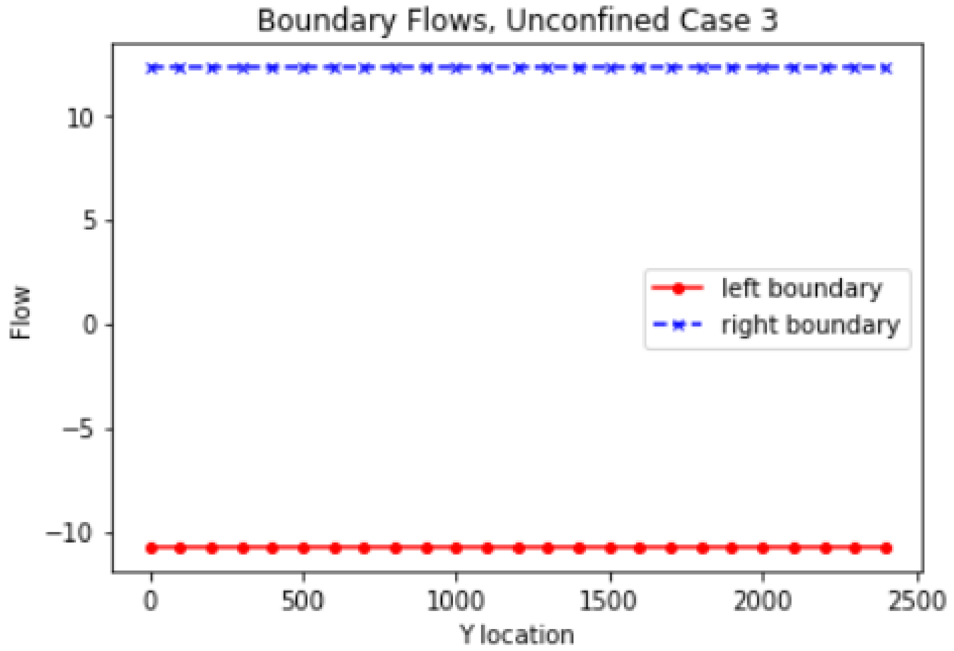


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Left Flow=-268.46 m3/d.    Right Flow=306.54 m3/d
Difference=575.0 m3/d
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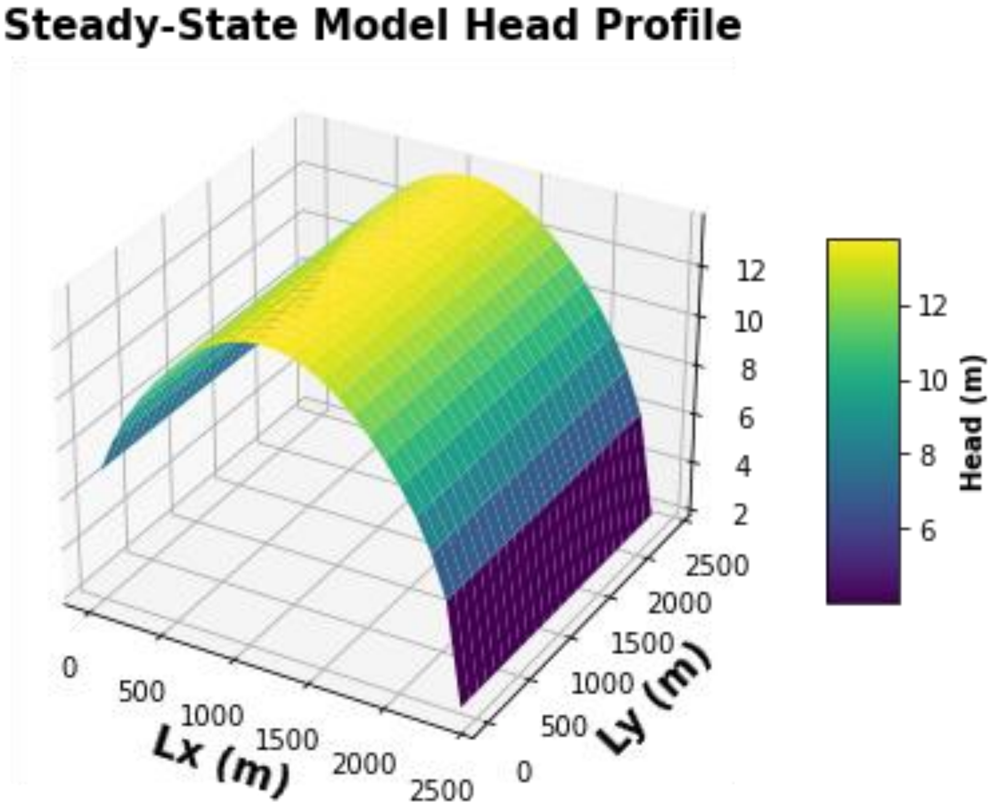
Challenge 3: Head profile, unconfined, recharge across entire system

- Flow in this system remains 2D because it is a single layer which allows flux across only two boundaries in a single direction.
- Recharge is introduced as an instantaneous value across the cell area. The misconception that it flows upward into the cell (as in a physical system) can mislead into thinking it is a 3D system.



Challenge 4: Calculating Excess Irrigation

Unconfined, with recharge limited to beneath farm

Irrigation Efficiencies and Lint Yields of Upland Cotton Grown at the Maricopa Agricultural Center, 1995

Mike Sheedy and Jack Watson

Irrigation rate and timing effects on Arizona cotton yield, water productivity, and fiber quality

K.R. Thorp*, A.L. Thompson, K.F. Bronson

USDA-ARS, U.S. Arid Land Agricultural Research Center, 21881 N Cardon Ln, Maricopa, AZ 85138, United States

Annual excess irrigation = recharge rate *days

= 0.0365 m/year

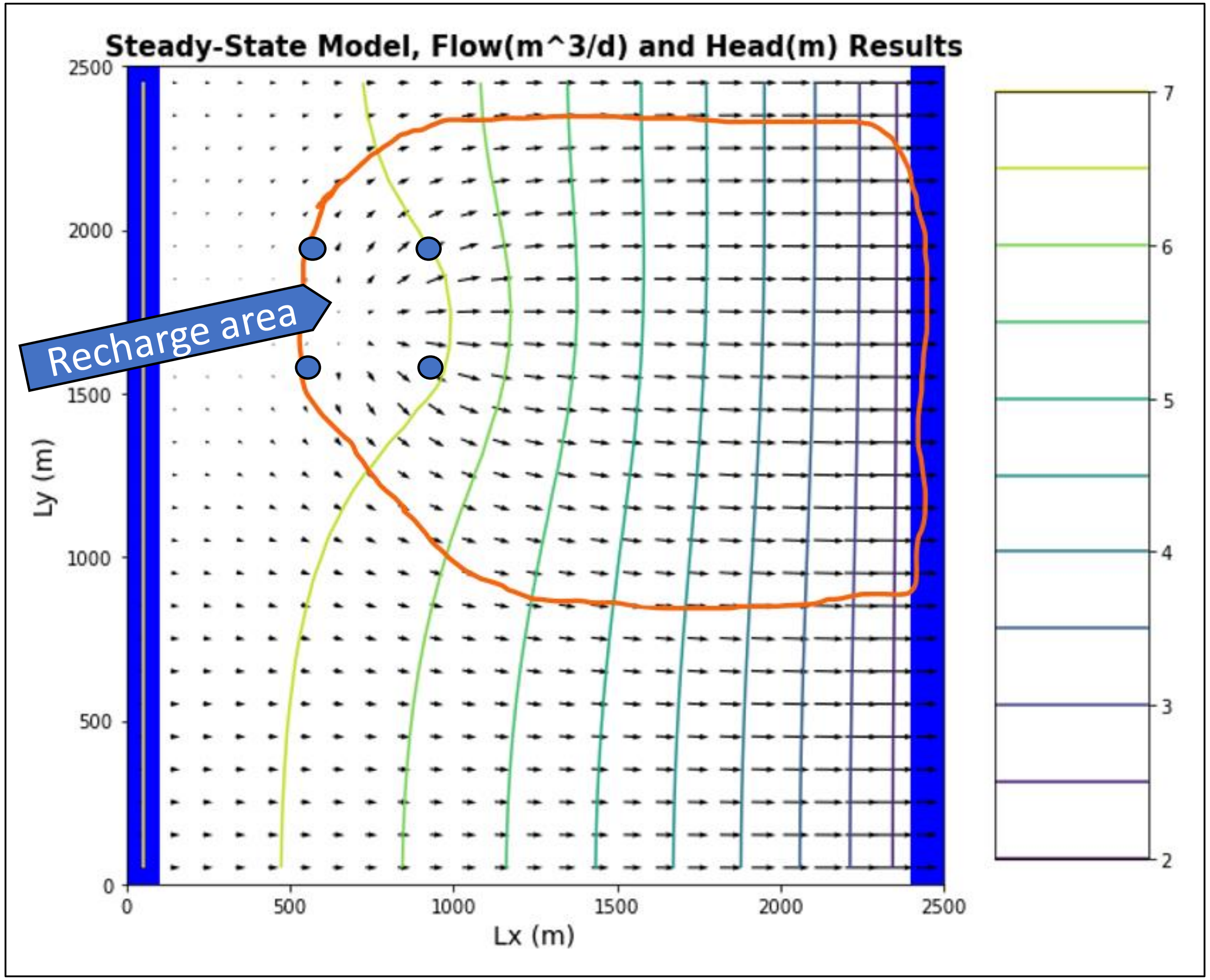
Efficiency for cotton in southern AZ = 80%

Annual total irrigation = excess/(1-efficiency)

= 0.1825 m/year

Challenge 4

Introducing recharge decreases the head gradient around the source, reducing flux in the established lateral direction of flow. This allows flow to radiate outward. Flow vectors originating in the recharge area indicate the potential contamination zone for pollutants introduced at this source. Notice how large the contamination zone is (defined by orange circle) in comparison to the area receiving irrigation.



Challenge 5

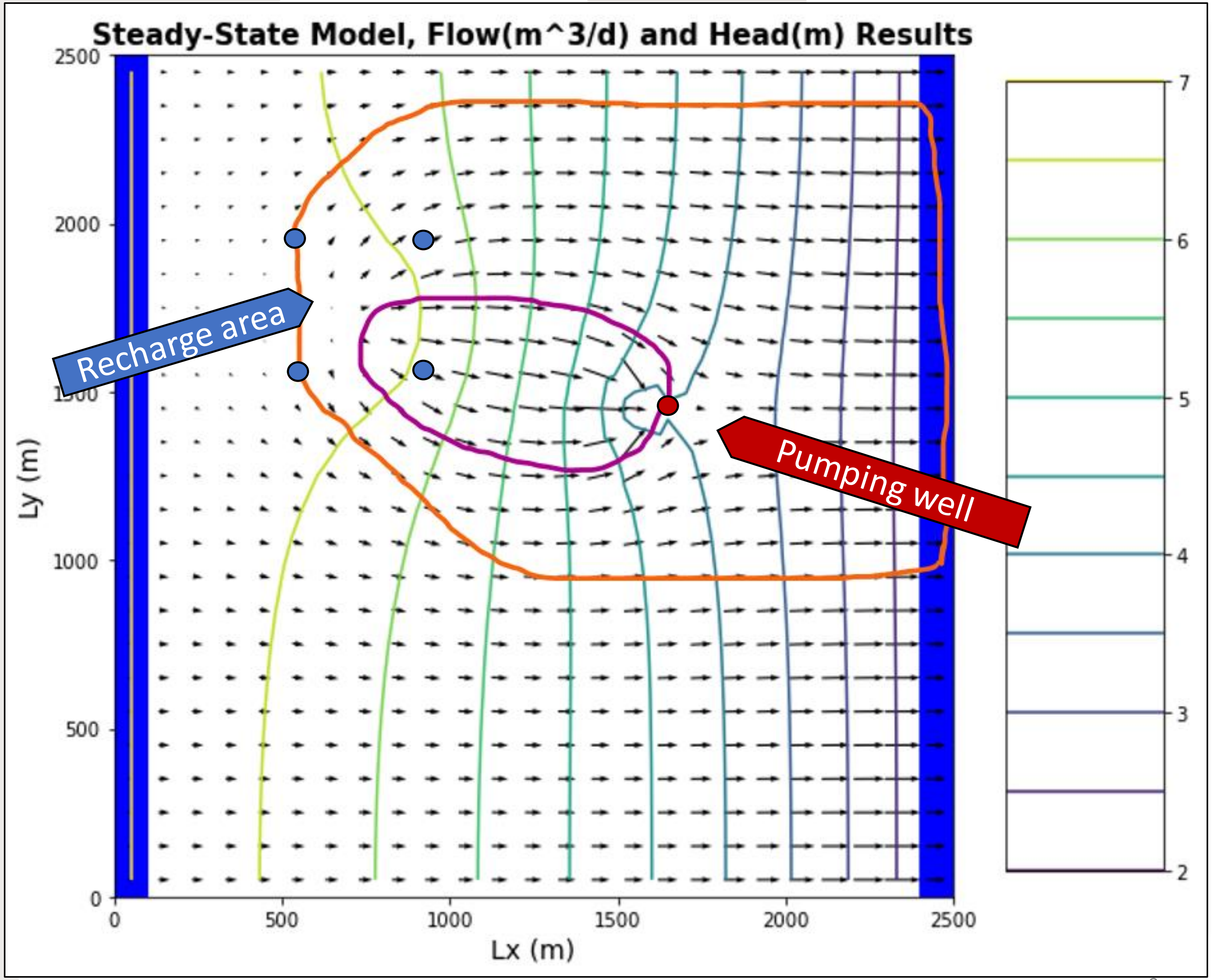
- Recharge flux = 1e-4 m/d located in [6:10,6:10].

Recharge flow = flux*Area
Recharge flow = 1e-4 * (100m * 100m) = 1 m^3/d

- Pumping well 8 m^3/d located at [0,10,15]

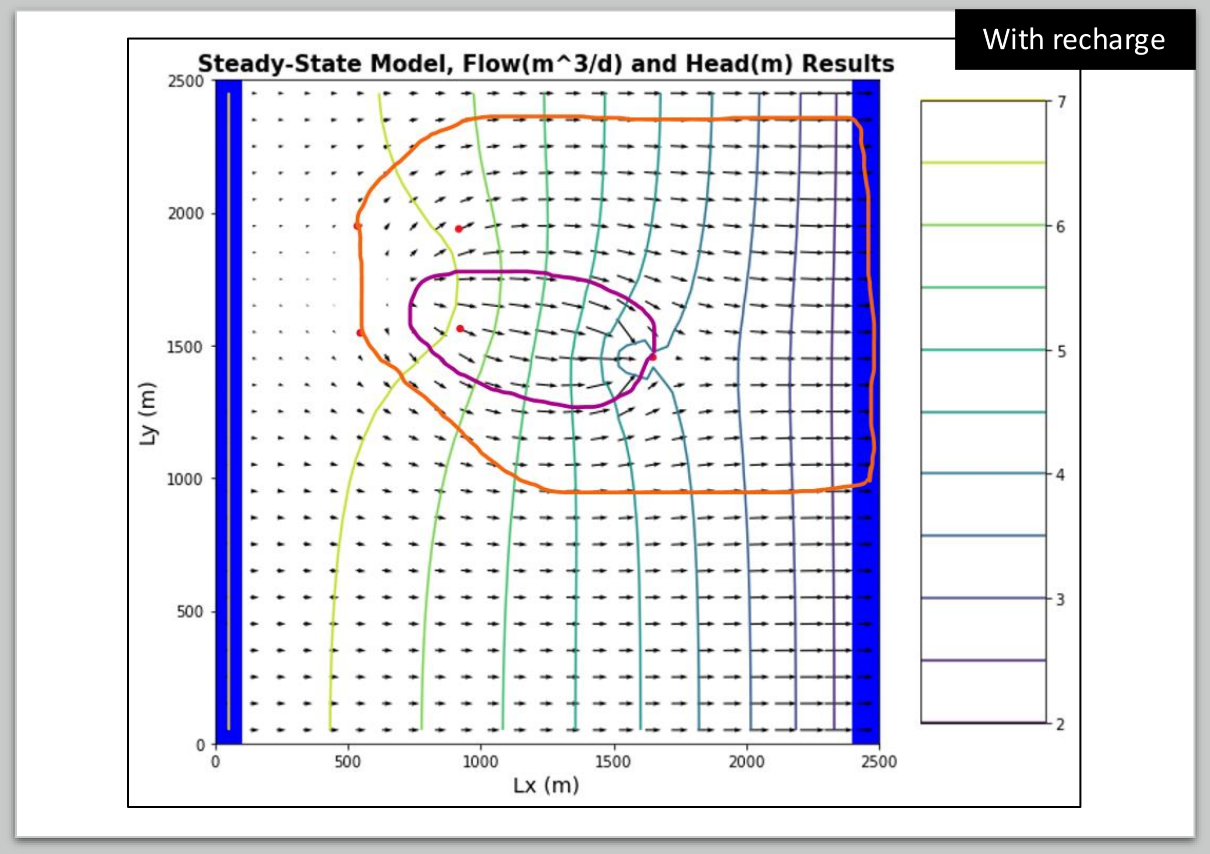
Even though the recharge flow is way lower than the pumping rate, it has a huge impact zone, which is not the case for the pumping well.

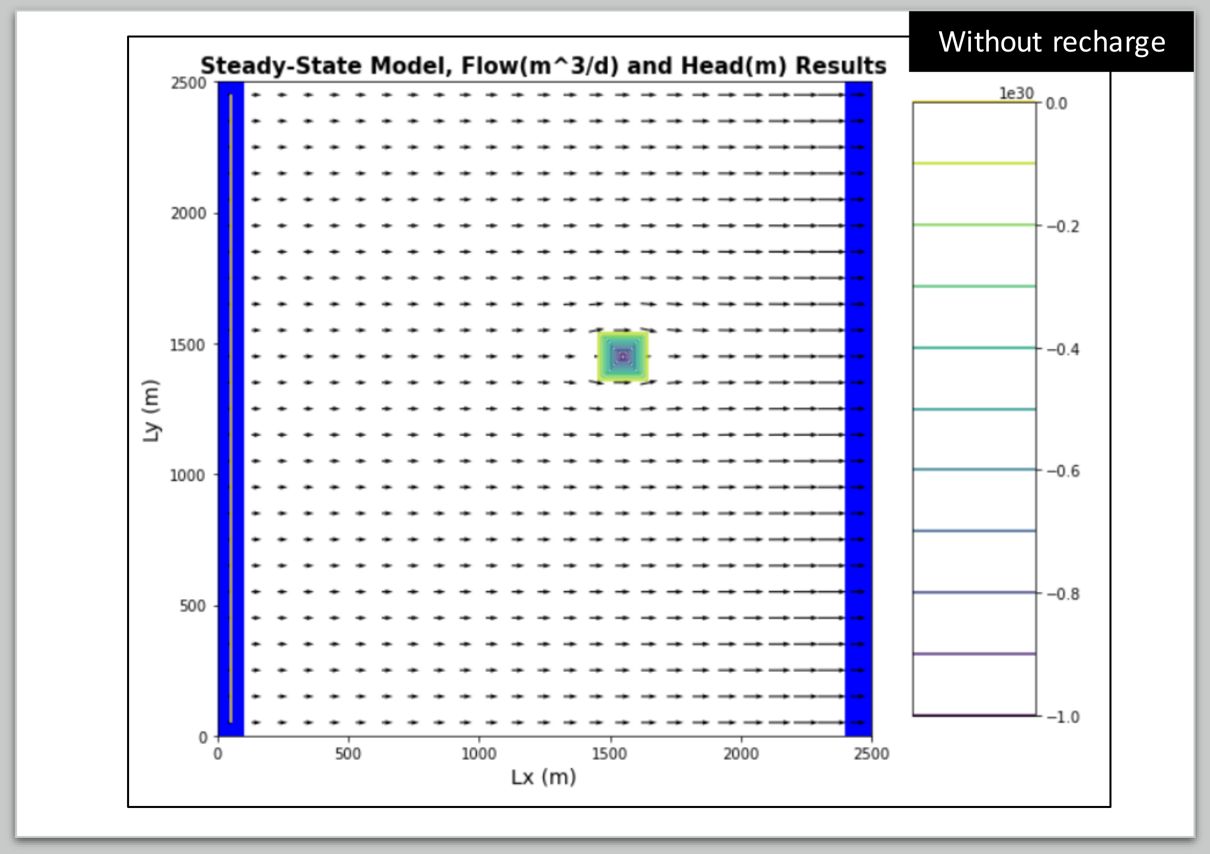
A single pumping well only reduces the area of contamination by less than one half. This is remarkable considering the orders of magnitude difference between recharge and pumping rates. Full remediation would require a series of wells perpendicular to the direction of flow.



Challenge 5

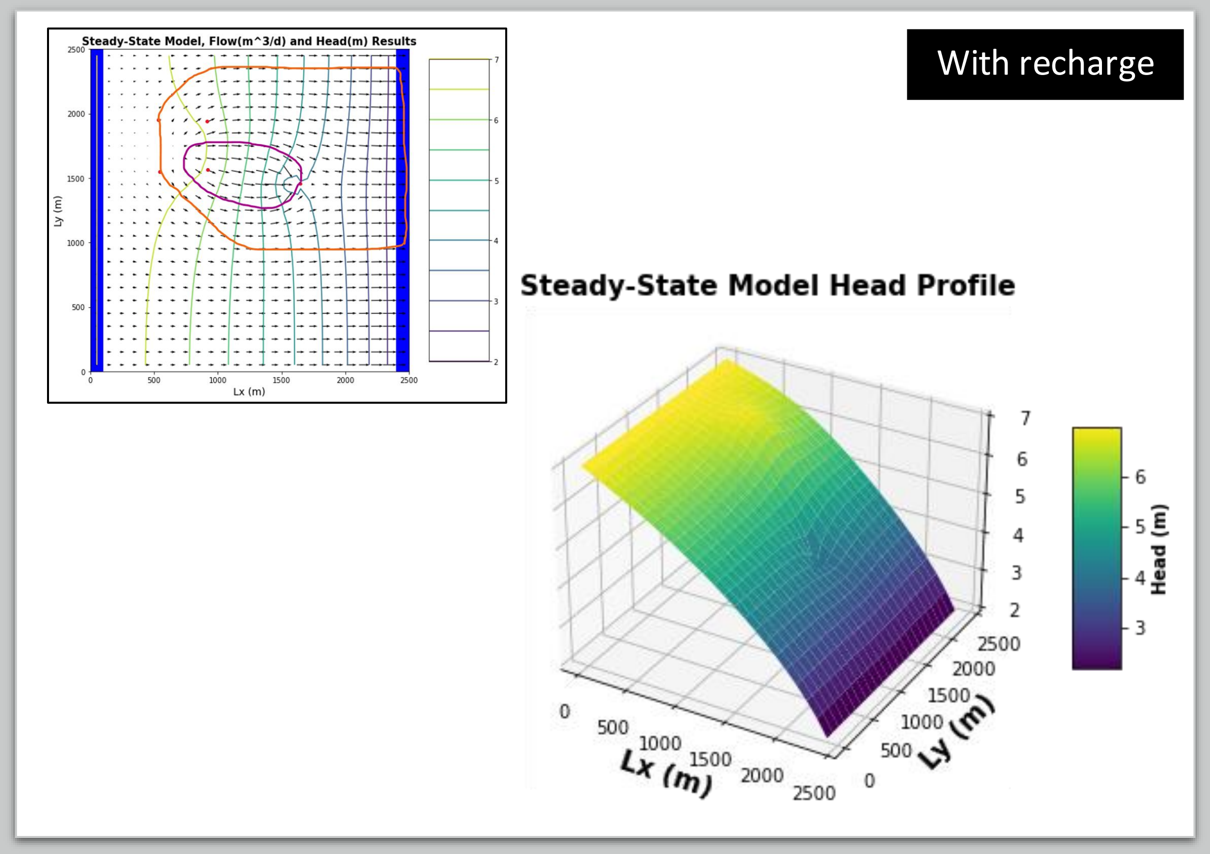
The model is not specified to be unconfined, so it continues calculating cells that have a head area of zero. This results in negative head values that break the model. It is the hydrologists' responsibility to understand the mechanisms of the model and interpret results such as this that do not represent the physical system.

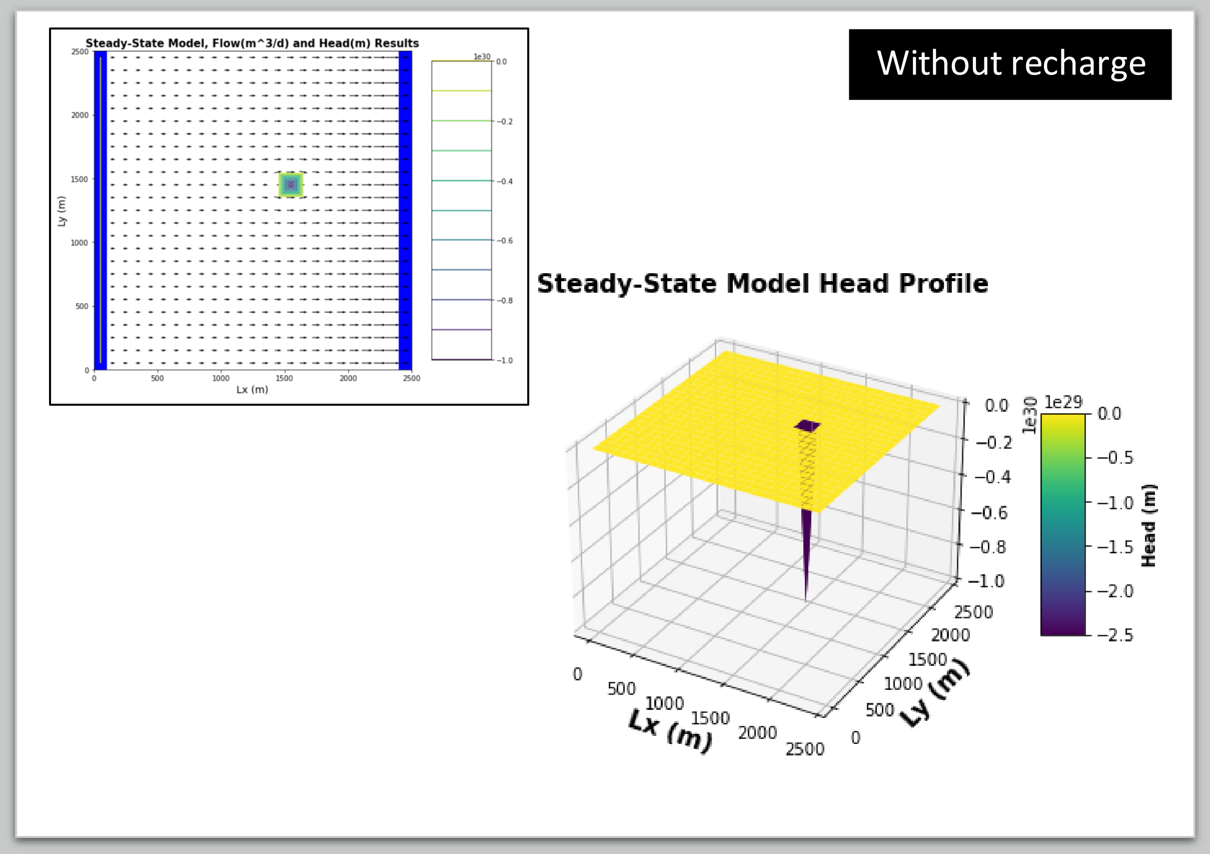




Challenge 5

Pumping with a high rate, and without a recharge in the system, produces a situation where the cross-sectional area through which the flow travels is zero at some point, so if there is no area to flow, the model produces an error in the calculations, shown by the negative localized head at the well cell.





Thank You