HWRS 582 – Groundwater modeling

HM2 - Challenge

Luis De la Fuente

Submitted on 01/22/2021

1) Show, based on the flux with horizontal distance from a constant head boundary, that the model is steady-state. Repeat this for a homogeneous and for a heterogeneous column for which zones of different K are placed in series with the direction of flow. Note that the best way to do this is to take the values from the .list file into Excel, combine them with the K values from the .bcf file, and calculate the flux at each point. Keep in mind that heads are calculated at the center of a cell (a node) and the K values are defined over each cell.

Answer: Following the definition of steady-state, we have that the total flux entering and going out of each cell must be the same. In our case, I calculated the flow in the horizontal and vertical direction, finding that they are almost the same (Fig. 1 and 2) which proves that the model did the right calculations. However, probably in the horizontal direction, the model required more iterations to have the same value. Figure 3 shows the gradient as surface and contour, which is linear in the same way as the spreadsheet we used the last week.

	Flux ->																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
2		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
3		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
4		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
5		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
6		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
7		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
8		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
9		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
10		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
11		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
12		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
13		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
14		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
15		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
16		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
17		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
18		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
19		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
20		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
21		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
22		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
23		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
24		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1
25		-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.0	-2.1	-2.1

Figure 1. Horizontal flux in each cell. 1 layer (Amplificated 10000 times)

Flux î																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1																									
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 2. Vertical flux in each cell. 1 layer (Amplificated 10000 times)

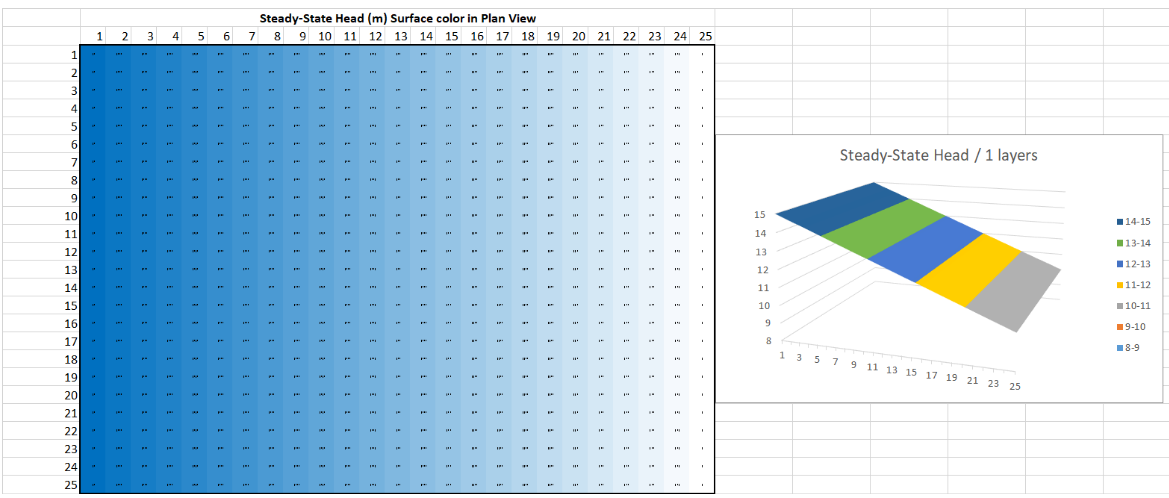

Figure 3. Surface Water head and 3D representation. 1 layer.

In the case of the heterogeneous (2 layers), I calculated the same figures, finding that the horizontal flux (Fig. 4) has similar values but do not the same. Another problem for that differences could be the decimal values used to solve the water head. Apparently, 2 decimals are not enough when you work with high hydraulic conductivities. In the vertical flux (Fig. 5), I had newly a constant value of zero.

Flux ->

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
2		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
3		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
4		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
5		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
6		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
7		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
8		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
9		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
10		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
11		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
12		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
13		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
14		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
15		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
16		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
17		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
18		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
19		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
20		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
21		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
22		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
23		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
24		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5
25		-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-4	-4	-4	-8	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5

Figure 4. Horizontal flux in each cell. 2 layers (Amplificated 10000 times)

Flux î

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1																									
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 5. Vertical flux in each cell. 2 layers (Amplificated 10000 times)

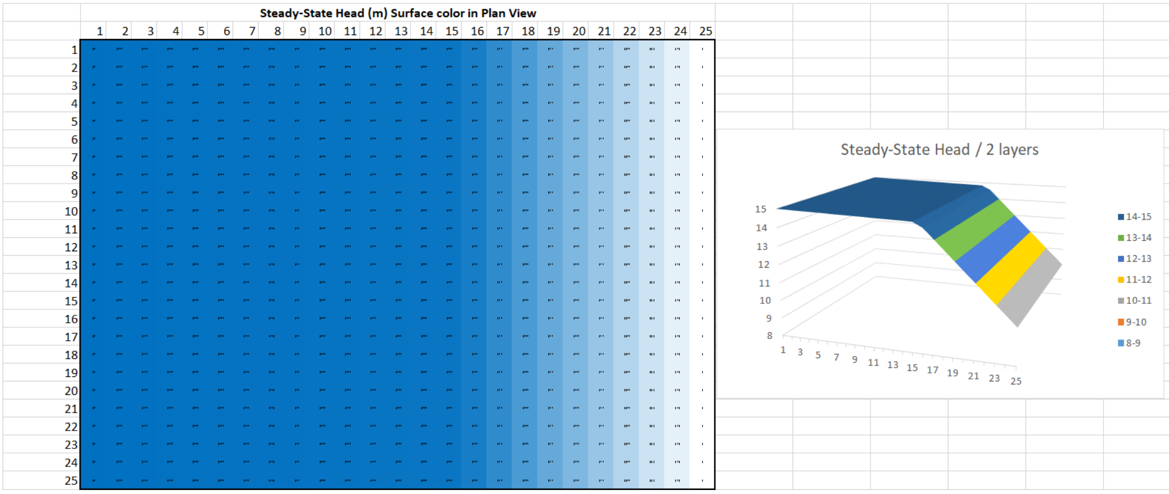

Figure 6. Surface Water head and 3D representation. 2 layers.

2) Show the steady-state head contour in plan view for the heterogeneous (zones in series) condition. Use this plot to defend a contention that flow is 1D. Then, drawing on your Excel assignment, use the results to explain WHY the equivalent hydraulic conductivity, Keq, is closer to the lower of the two K values.

Answers: Figure 7 shows that all the color sections are completely vertical. That means that the flux must be horizontal given that flow lines are always perpendicular to the equipotential lines. Additional, figures 2 and 5 presents zero flux in the vertical direction which confirms that the dimensionality of the problem is 1D.

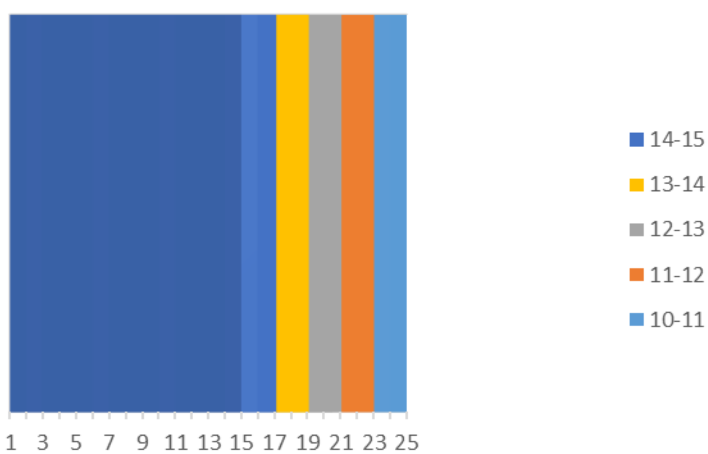

Figure 7. Steady-state head with 2 layers.

The last figure shows too that the higher energy loss in the right section, which has the lower hydraulic conductivity (0.1 m/day). In fact, the first layer only required 0.18 m of energy. The other 4.82m is lost in the layer with lower conductivity. Given that Keq can be understood as the more representative conductivity, Keq will be controlled by the lower conductivity. Another, example of the same situation happens when you try to characterize the average speed in a race. If a person did waking and biking in the same race, the average speed will be controlled by the mode in which more distance was done by the person.

3) Build a model based on a homogeneous domain with a square region of lower K in the middle of the domain. What can you learn based on your explanation of what controls the effective K for a 1D flow system now that you are applying it to a 2D system? What do you think the Keq of this entire system would be compared to the high and low K values? Explain why it is much more difficult to develop a direct solution for this 2D system than it was for a 1D system (including the zones placed in series).

Answers: In this situation, we must apply another concept to understand the water behavior. I call the concept of laziness; water always takes the easiest path flow between 2 points. In other words, water always moves to minimize the total energy used, therefore if the water has the chance to take an easy path it will always take it. In our exercise, water has the chance to move in both directions (in homework 1, we imposed one direction), therefore the water that faces the region with low conductivity will prefer to change the direction and move through a region with high conductivity because that requires less energy. In conclusion, the Keq will be like the conductivity where more water is moving through.

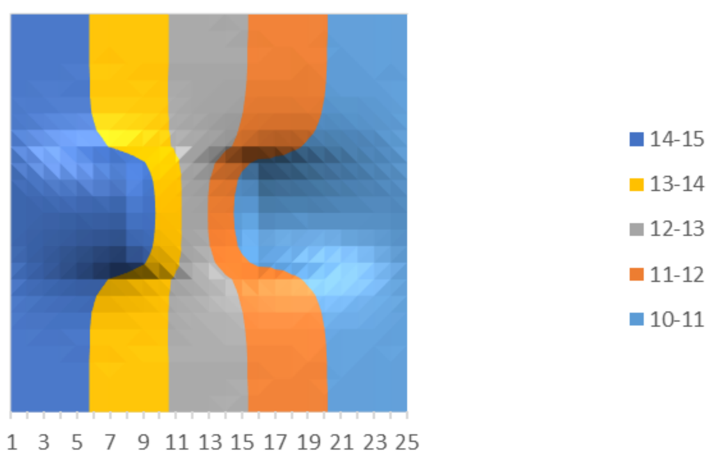

Figure 8. Steady-state head with a square region of low conductivity.