Solution to Exercise 5

WATR 404/604
First Semester 2018

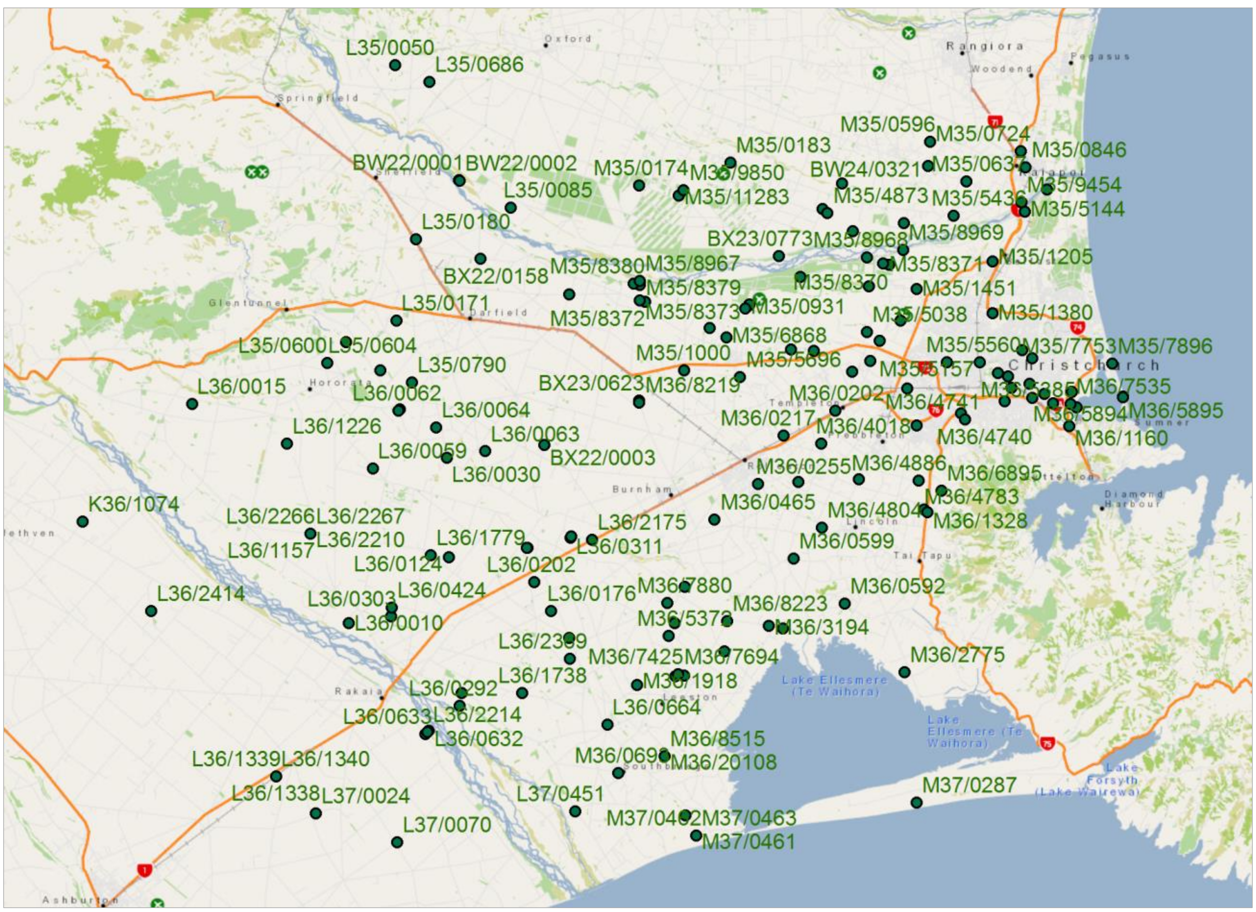
Prepared by David R. Maidment

Question 1

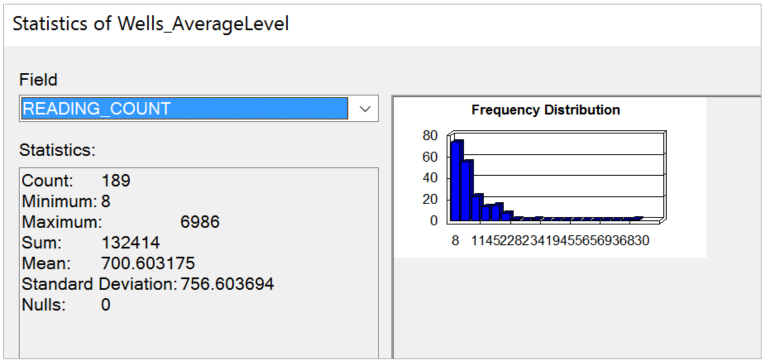
To be turned in: Make a map of the observation wells over the Selwyn aquifer. How many wells are there? How many observations have been made at these wells (Hint: Use the Reading_Count attribute). What is the average number of observations per well in the region?

Solution

Here is a map of the observation wells in the Selwyn Aquifer



The statistics of the Reading_Count attribute of the Wells feature class are shown below. There are **189** wells and a total of **132,414** observations, or an average of **700** observations per well.

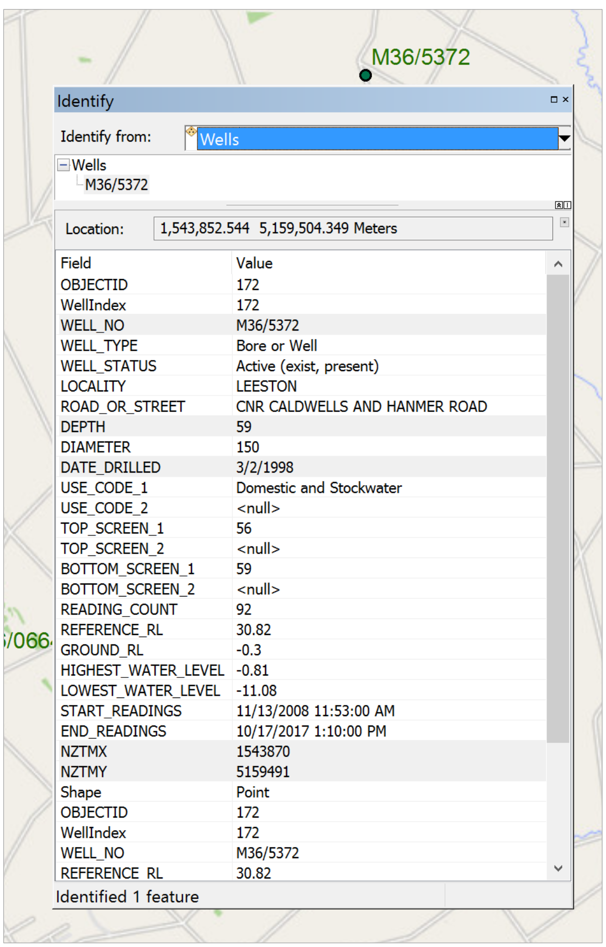


Question 2

To be turned in: Choose another observation well from the dataset and prepare a similar description of it like the one you've seen above for L36/2175. How does your well compare with L36/2175? [Hint make sure this well is upstream of Te Waihora/Lake Ellesmere because this is important for Question 4].

Solution

Well M36/5372 was drilled on 3/2/1998 and has 92 measurements from 11/13/2008 to 10/17/2017. It is located at NZTMX = 1543870, NZTMY = 5159491. It is 59 meters deep and has a reference level (top of well) of 30.82m. Its diameter is 150 mm.



The well is screened from 56 to 59m below the reference level. The ground elevation is 0.3 m below the top of the well, and the highest and lowest water levels are 0.81m and 11.08 meters below the top of the well, respectively. This means that the water table is very near the ground surface in this location.

USE_CODE_2	<null>
TOP_SCREEN_1	56
TOP_SCREEN_2	<null>
BOTTOM_SCREEN_1	59
BOTTOM_SCREEN_2	<null>
READING_COUNT	92
REFERENCE_RL	30.82
GROUND_RL	-0.3
HIGHEST_WATER_LEVEL	-0.81
LOWEST_WATER_LEVEL	-11.08

The water level is consistently in the gravels at the top of the well zone, shown by the arrows below.

Borelog for well M36/5372

Grid Reference (NZTM): 1543871 mE, 5159492 mN
Location Accuracy: 1 - 2m
Ground Level Altitude: 30.5 m +MSD Accuracy: < 0.1 m
Driller: Smiths Welldrilling
Drill Method: Rotary Rig
Borelog Depth: 59.0 m Drill Date: 02-Mar-1998

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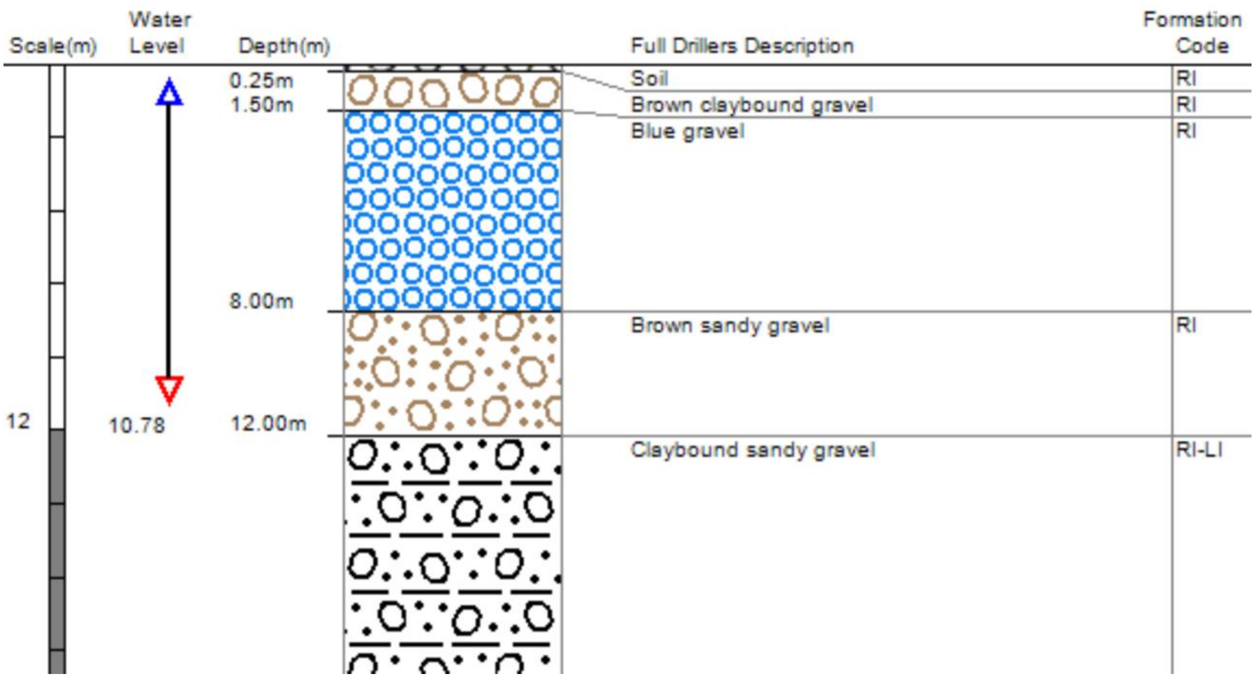
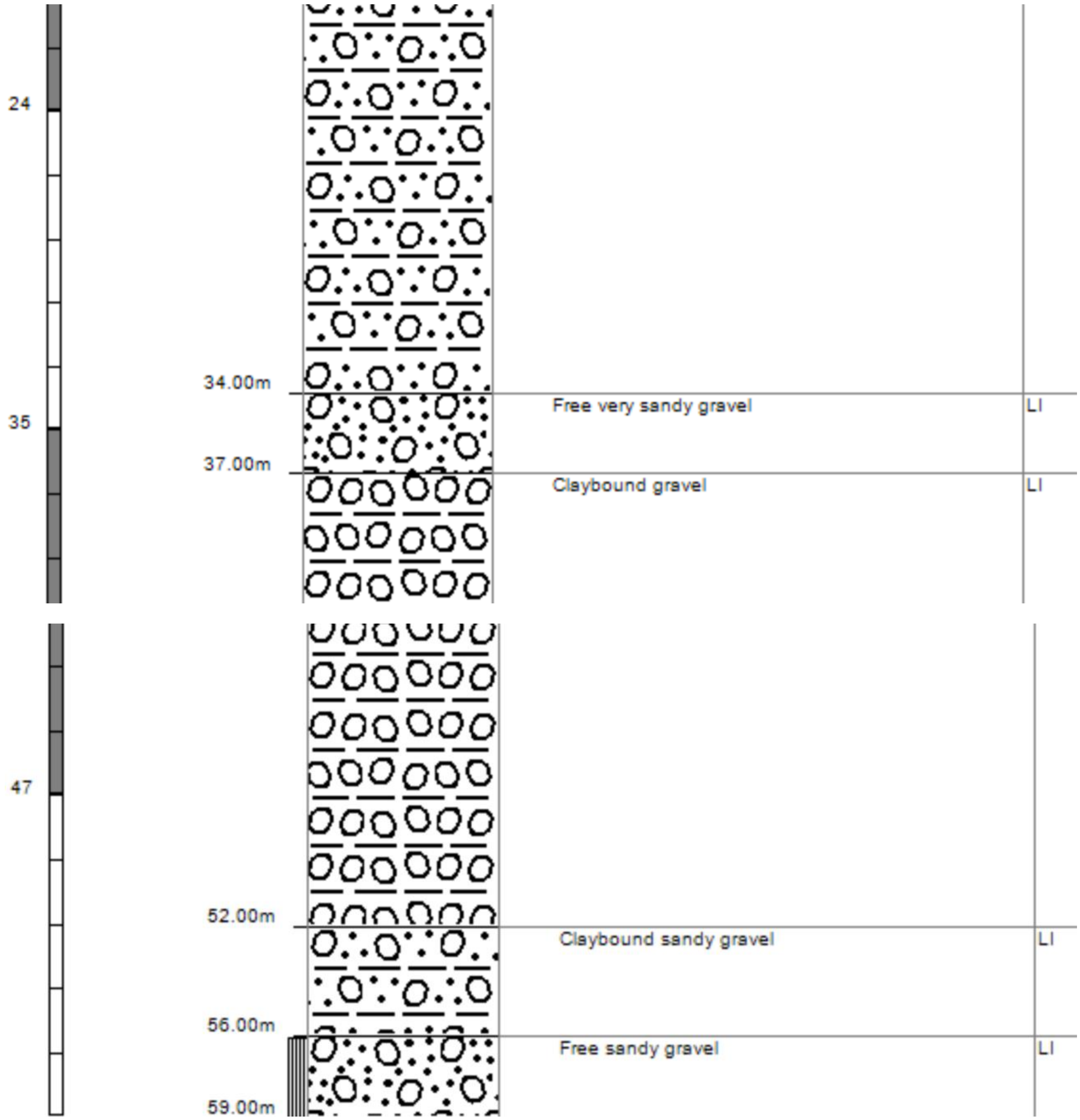
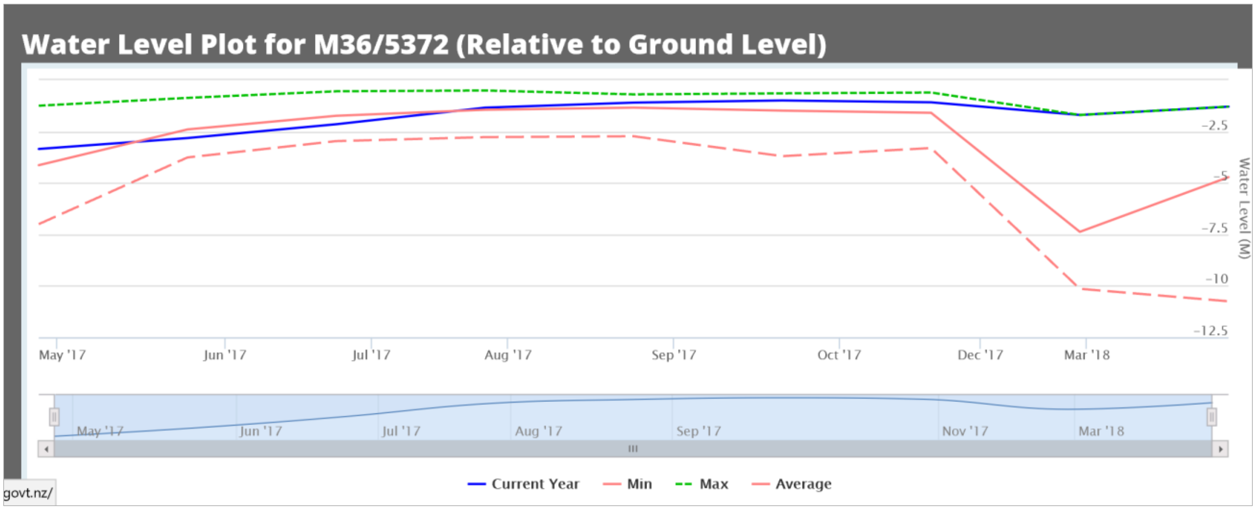
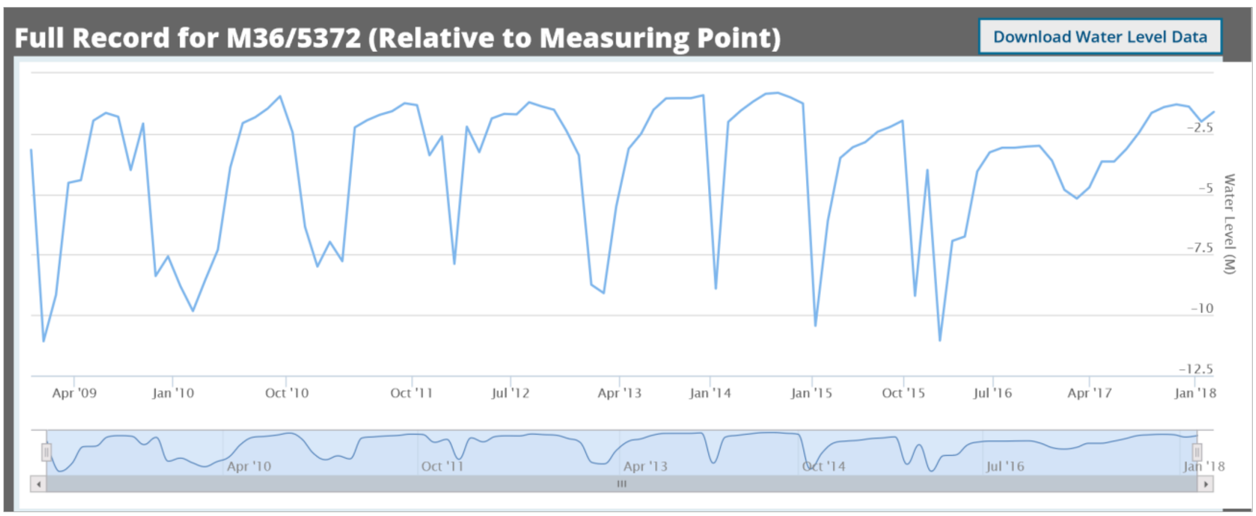



24
35
34.00m
Free very sandy gravel
LI
37.00m
Claybound gravel
LI
47
52.00m
Claybound sandy gravel
LI
56.00m
Free sandy gravel
LI
59.00m





The average water level is 3.81 below the reference level.

WELL_NO	M36/5372
REFERENCE_RL	30.82
AVERAGE_WATER_LEVEL	-3.813462
StandardDeviation	2.842713
Maximum	-0.81
Minimum	-11.08
Count_	93
[illegible]	[illegible]

Compared to the well in the exercise text, L36/5372, the new well, M26/5372 is much deeper (59m vs 18.3 meters. It is located nearer to the coast at a lower elevation (30.82m vs 67.25m). Its water level measurements are consistently closer to the land surface (average depth -3.81m vs -6.11m). Both wells are of diameter 150 mm. The well screen in the new well is 3m long (56m to 59m) compared to 1.5m in the well in the project text (16.8m to 18.3m). The new well has a lot fewer measurements (93) compared to the 407 in the well in the exercise text, and both are less than the 700 measurements that are the average for the region.

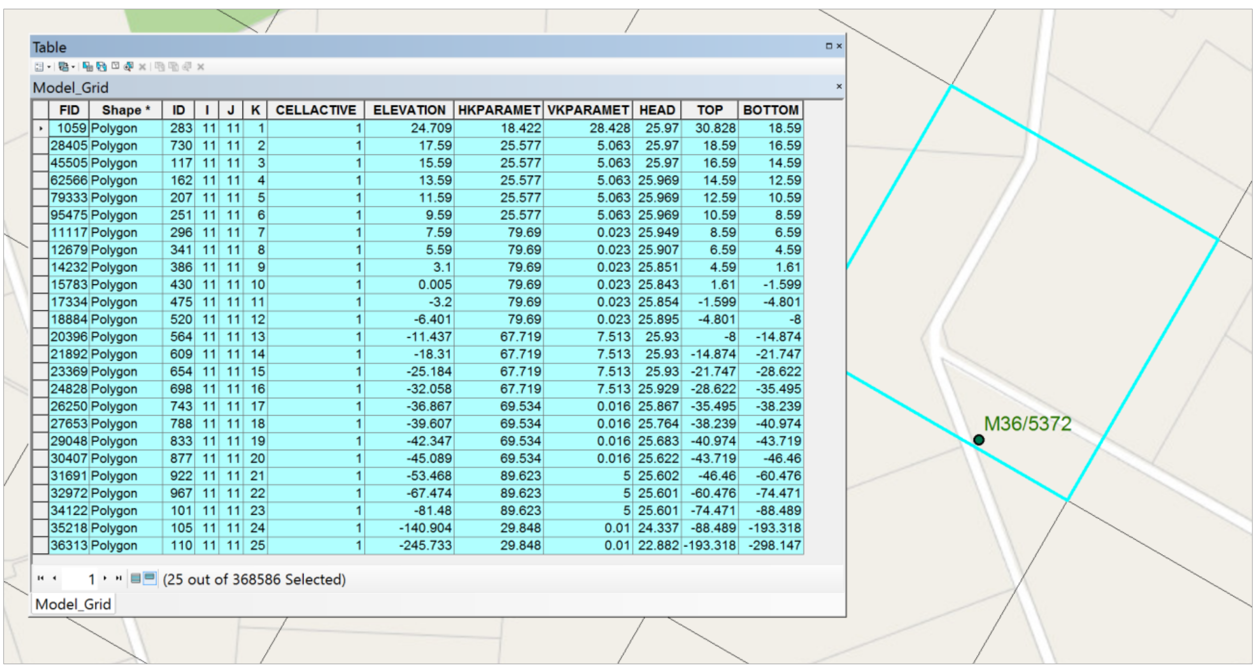
	Well L36/2175	**Well M36/5372**
Reference Level	67.25 m	30.82 m
Date Drilled	4/23/2007	3/2/1998
Depth of Well	18.3	59 m
Diameter of Well	150 mm	150 mm
Top of Screen	-16.8 m	-56 m
Bottom of Screen	-18.3 m	-59 m
Number of Measurements	407	93
First Measurement	5/17/2007	11/13/2008
Last Measurement	1/31/2018	10/17/2017
Highest Level	-1.39	-0.81
Lowest Level	-13.356	-11.08
Average Level	-6.11	-3.81

Question 3

To be turned in: Prepare an aquifer layer table like the one above for the Model_Grid cell that contains the observation well that you chose for Question 2. Does your cell have a greater or lesser transmissivity than the one I selected?

Solution

The model cell containing well M36/5372 is cell I = 11, J = 11. It has 25 layers in the Modflow model.



Table

Model_Grid

FID	Shape *	ID	I	J	K	CELLACTIVE	ELEVATION	HKPARAMET	VKPARAMET	HEAD	TOP	BOTTOM
1059	Polygon	283	11	11	1	1	24.709	18.422	28.428	25.97	30.828	18.59
28405	Polygon	730	11	11	2	1	17.59	25.577	5.063	25.97	18.59	16.59
45505	Polygon	117	11	11	3	1	15.59	25.577	5.063	25.97	16.59	14.59
62566	Polygon	162	11	11	4	1	13.59	25.577	5.063	25.969	14.59	12.59
79333	Polygon	207	11	11	5	1	11.59	25.577	5.063	25.969	12.59	10.59
95475	Polygon	251	11	11	6	1	9.59	25.577	5.063	25.969	10.59	8.59
11117	Polygon	296	11	11	7	1	7.59	79.69	0.023	25.949	8.59	6.59
12679	Polygon	341	11	11	8	1	5.59	79.69	0.023	25.907	6.59	4.59
14232	Polygon	386	11	11	9	1	3.1	79.69	0.023	25.851	4.59	1.61
15783	Polygon	430	11	11	10	1	0.005	79.69	0.023	25.843	1.61	-1.599
17334	Polygon	475	11	11	11	1	-3.2	79.69	0.023	25.854	-1.599	-4.801
18884	Polygon	520	11	11	12	1	-6.401	79.69	0.023	25.895	-4.801	-8
20396	Polygon	564	11	11	13	1	-11.437	67.719	7.513	25.93	-8	-14.874
21892	Polygon	609	11	11	14	1	-18.31	67.719	7.513	25.93	-14.874	-21.747
23369	Polygon	654	11	11	15	1	-25.184	67.719	7.513	25.93	-21.747	-28.622
24828	Polygon	698	11	11	16	1	-32.058	67.719	7.513	25.929	-28.622	-35.495
26250	Polygon	743	11	11	17	1	-36.867	69.534	0.016	25.867	-35.495	-38.239
27653	Polygon	788	11	11	18	1	-39.607	69.534	0.016	25.764	-38.239	-40.974
29048	Polygon	833	11	11	19	1	-42.347	69.534	0.016	25.683	-40.974	-43.719
30407	Polygon	877	11	11	20	1	-45.089	69.534	0.016	25.622	-43.719	-46.46
31691	Polygon	922	11	11	21	1	-53.468	89.623	5	25.602	-46.46	-60.476
32972	Polygon	967	11	11	22	1	-67.474	89.623	5	25.601	-60.476	-74.471
34122	Polygon	101	11	11	23	1	-81.48	89.623	5	25.601	-74.471	-88.489
35218	Polygon	105	11	11	24	1	-140.904	29.848	0.01	24.337	-88.489	-193.318
36313	Polygon	110	11	11	25	1	-245.733	29.848	0.01	22.882	-193.318	-298.147

1 (25 out of 368586 Selected)

Model_Grid

Importing this table into Excel and coloring it in reveals that there are 7 hydrogeological layers with distinct properties.

FID	ID	I	J	K	CELLACTIVE	ELEVATION	HKPARAMET	VKPARAMET	HEAD	TOP	BOTTOM
10599	28306	117	118	1	1	24.709	18.422	28.428	25.97	30.828	18.59
28405	73018	117	118	2	1	17.59	25.577	5.063	25.97	18.59	16.59
45505	117730	117	118	3	1	15.59	25.577	5.063	25.97	16.59	14.59
62566	162442	117	118	4	1	13.59	25.577	5.063	25.969	14.59	12.59
79333	207154	117	118	5	1	11.59	25.577	5.063	25.969	12.59	10.59
95475	251866	117	118	6	1	9.59	25.577	5.063	25.969	10.59	8.59
111174	296578	117	118	7	1	7.59	79.69	0.023	25.949	8.59	6.59
126794	341290	117	118	8	1	5.59	79.69	0.023	25.907	6.59	4.59
142325	386002	117	118	9	1	3.1	79.69	0.023	25.851	4.59	1.61
157838	430714	117	118	10	1	0.005	79.69	0.023	25.843	1.61	-1.599
173343	475426	117	118	11	1	-3.2	79.69	0.023	25.854	-1.599	-4.801
188848	520138	117	118	12	1	-6.401	79.69	0.023	25.895	-4.801	-8
203969	564850	117	118	13	1	-11.437	67.719	7.513	25.93	-8	-14.874
218923	609562	117	118	14	1	-18.31	67.719	7.513	25.93	-14.874	-21.747
233690	654274	117	118	15	1	-25.184	67.719	7.513	25.93	-21.747	-28.622
248280	698986	117	118	16	1	-32.058	67.719	7.513	25.929	-28.622	-35.495
262500	743698	117	118	17	1	-36.867	69.534	0.016	25.867	-35.495	-38.239
276535	788410	117	118	18	1	-39.607	69.534	0.016	25.764	-38.239	-40.974
290485	833122	117	118	19	1	-42.347	69.534	0.016	25.683	-40.974	-43.719
304079	877834	117	118	20	1	-45.089	69.534	0.016	25.622	-43.719	-46.46
316915	922546	117	118	21	1	-53.468	89.623	5	25.602	-46.46	-60.476
329727	967258	117	118	22	1	-67.474	89.623	5	25.601	-60.476	-74.471
341227	1011970	117	118	23	1	-81.48	89.623	5	25.601	-74.471	-88.489
352184	1056682	117	118	24	1	-140.904	29.848	0.01	24.337	-88.489	-193.318
363139	1101394	117	118	25	1	-245.733	29.848	0.01	22.882	-193.318	-298.147

Extracting the data from this table, and summarizing them produces the Aquifer Layer table for this cell, as shown below.

Layer	Top	Bottom	Conductivity (m/day)	Thickness (m)	Transmissivity (m^2/day)	% of Transmissivity
A	30.83	18.59	28.43	12.24	348.0	2.4
B	18.59	8.59	25.577	10	255.8	1.8
C	8.59	-8	76.69	16.59	1272.3	8.8
D	-8	-28.622	67.72	20.622	1396.5	9.6
E	-28.622	-46.46	69.534	17.838	1240.3	8.5
F	-46.46	-88.489	89.623	42.029	3766.8	25.9
G	-88.489	-298.147	29.848	209.658	6257.9	43.0
Total				329	14538	100.0

Aquifer Layer Table for Model_Grid Cell (I,J) = (11,11)

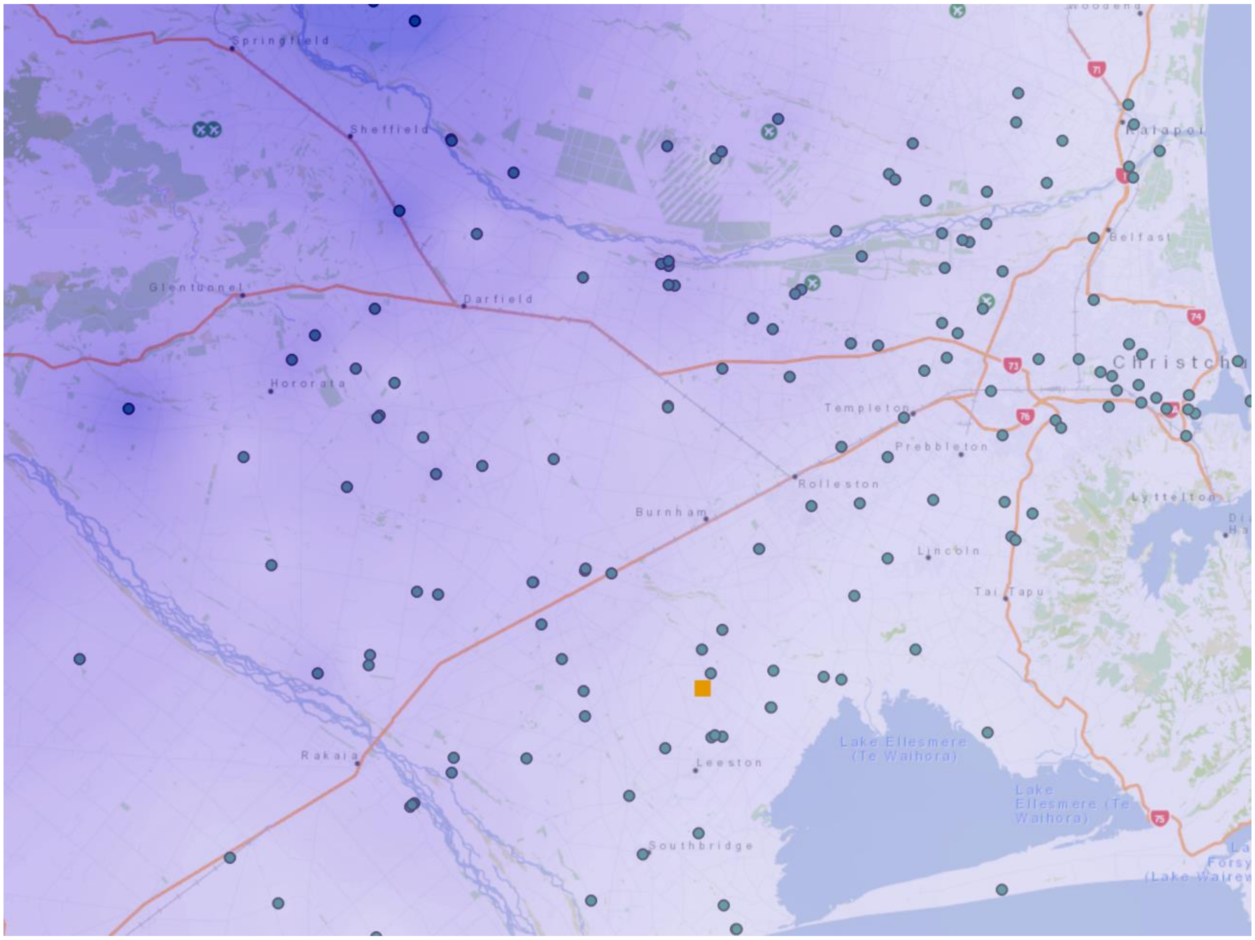
This layer has a total thickness of 329 m compared to 293 m in the cell used in the exercise text. Its transmissivity is 14,538 m^2/day compared to 24,020 m^2/day., so although the aquifer is thicker here its transmissivity is smaller. The average hydraulic conductivity of this cell is K = 14538/329 = 44.2 m/day.

Question 4

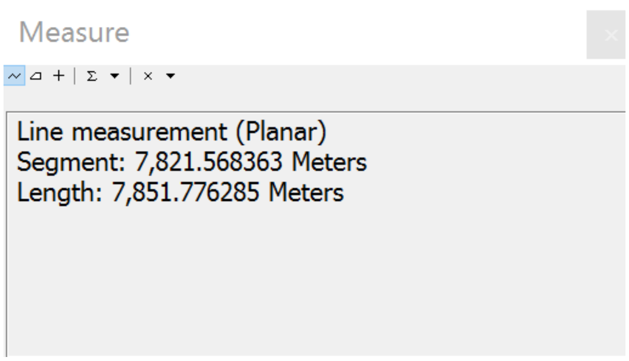
To be turned in: Make a WaterLevelMap of the Selwyn aquifer and estimate the travel time to Te Waihora/Lake Ellesmere from the well you chose in Question 2.

Solution

The water level map is shown below along with the location of the selected well as the orange square.



The measure distance to Te Waihora is 7851 m



The piezometric head at the selected well is 26.98m and at Te Waihora on this flow path is 15.91m.

We can compute the slope of the WaterLevelMap along this line as

$$\frac{dh}{dL} = \frac{26.98 - 15.91}{7851} = 0.00141\, m/m$$

This means that the fall of the water level (dh) is about 1.4 meters per km of flow distance (dL). If we take this gradient and multiply it by an estimate of the average conductivity that we worked out earlier (44.2 meters/day), you get a measure of the Darcy Velocity

$$q = K_{avg}\frac{dh}{dL} = 44.2 * 0.00141 = 0.0623\, m/day$$

and if we divide the Darcy Velocity by the average porosity, n, of about 0.1, we get an estimate of the actual seepage velocity V_s of water in this aquifer

$$V_s = \frac{q}{n} = \frac{0.0623}{0.1} = 0.623\, m/day$$

This means that water seeping through the aquifer from the area of Well M36/5372, would reach Te Waihora/Lake Ellesmere:

$$Travel\ Time = \frac{L}{V_s} = \frac{7851}{0.623} = 12{,}597\ days = 34.5\ years$$

This is much longer than the 18.1 years that was computed in the exercise script for a well that is much further away from the lake than this one is. This shows that what really governs the flow time to the lake is the composite of the hydrogeological properties along all the portions of the flow path and that this cannot be reliably estimated by looking at just one model cell as we have done in the simplified computation performed here. This is what proper groundwater simulation models are needed to describe the flow behavior of aquifers like this one.