Grant Hawkins
3 December 2010

GIS Semester Project – Working With Water Well Data in Irion County, Texas

Question for the Project

Upon picking a random point in Irion county, Texas, to what depth would I have to drill a water well to encounter fresh water? How does water depth vary across the county through time?

The steps that I needed to take to solve this problem in the most generalized sense were as follows:
1. Download the cultural and water level data from the internet

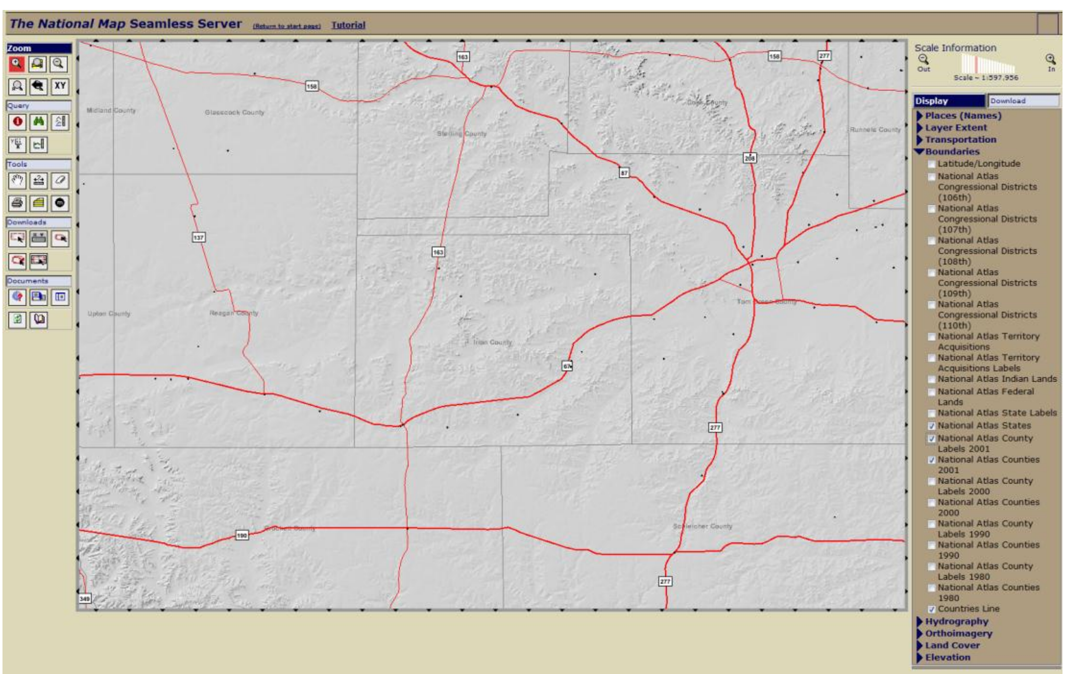
2. Process the data so that I could work with it and get meaningful results

3. Generate raster surfaces based on this data, and conduct raster calculations to see what kind of information can be revealed through the powers of GIS.

These three steps are laid out chronologically in a much more detailed fashion throughout the rest of this paper.

Data Collection

For cultural data collection including roads, cities, railroads, airport, county lines, and a basic DEM, I used the USGS Seamless Viewer online to zoom in on an area including all of Irion County, and pieces of the surrounding counties including Reagan, Glasscock, Sterling, Coke, Tomgreen, Schleicher, and Crockett [Figure 1]. Extracting the data was made simple with the click-and-drag download box tool.



[Figure 1 – USGS Seamless Viewer]

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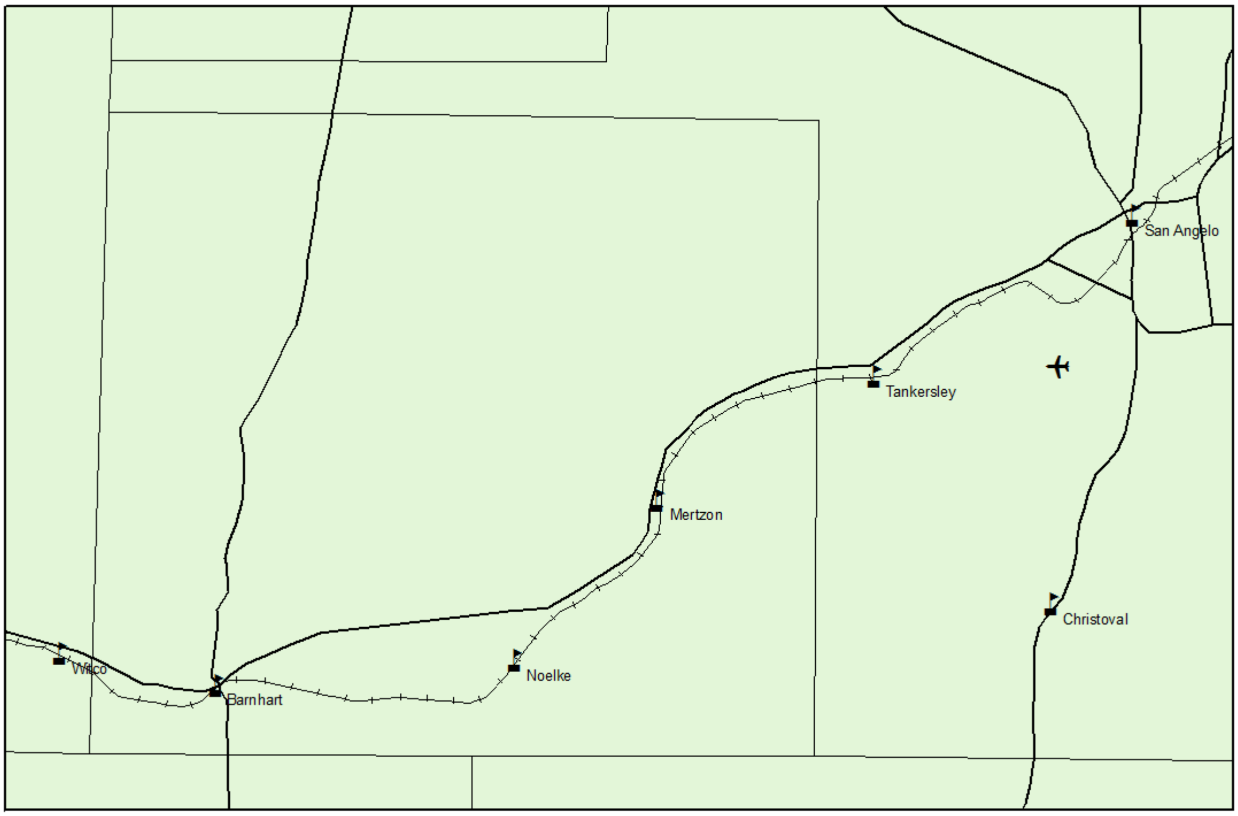
The data from the USGS Seamless viewer was downloaded in the Geographic NAD 83 Coordinate System. Thus, when I imported the culture into ArcMap, the Coordinate System for the project was initially set to NAD 83 as well. The initial culture in ArcMap can be seen in Figure 2 below.



[Figure 2 – Irion County Culture in ArcMap]

For the water data itself, I used the Texas Water Development Board website (Figure 3). By selecting “groundwater and well water” on their “Data” page, the user is sent to a page which lists data by county name

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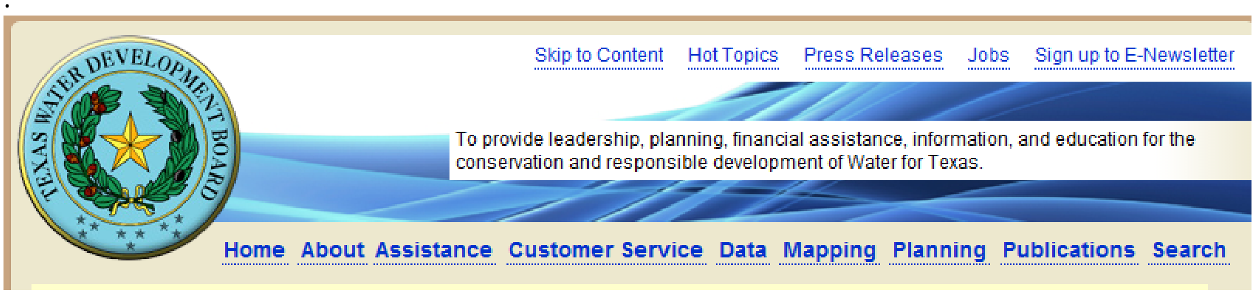

[Figure 3 – TWDB Website Main Selection Menu]

Irion County

- Infrequent Constituent Report Grouped by Well Number **(pdf)**
- Cooperator Infrequent Constituent Report Grouped by Well Number **(pdf)**
- Record of Wells Report **(pdf)**
- Water Level Report **(pdf)**
- Water Quality Report **(pdf)**
- Casing Table **(txt)**
- Infrequent Constituent Water Quality Table **(txt)**
- Cooperator Infrequent Constituent Water Quality Table **(txt)**
- Well Site Remarks Table **(txt)**
- Well Data Table **(txt)**
- Five Day Water Level Table **(txt)**
- Water Level Table **(txt)**
- Water Quality Table **(txt)**

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Jack County

- Infrequent Constituent Report Grouped by Well Number **(pdf)**
- Cooperator Infrequent Constituent Report Grouped by Well Number **(pdf)**
- Record of Wells Report **(pdf)**

[Figure 4 – Water Data Listed By Counties on TWDB Website]

Unfortunately, the information that I needed was located in two separate text files. These were the Well Data Table (weldta) and the Water Level Table [Figure 4]. The Well Data Table contained the critical information of actual locations of the water wells in decimal degrees. The Water Level Table contained the critical information of water depth readings for the wells. Luckily, both tables had state well ID #'s listed as well, so I knew that I would be able to join the tables when the time came.

After being unable to determine what geographic coordinate system the water well data was given in on the TWDB website, I resorted to sending an email (unanswered) and then making a phone call to the TWDB. Debra at TWDB assured me that the water well data was presented in NAD 83, and not NAD 27. So, when I imported the data into ArcMap, I used the Nad 83 Geographic coordinate system. This happened to be the same coordinate system as the USGS Seamless Viewer data that I downloaded. So, this made all the data I was using easier to work with. After importing the culture, background, and water well data, I made sure to double check that the decimal degree readings in the bottom left-hand corner were correct for the city locations and for the water wells.

At the end of the Data Collection process, I had an ArcMap file with culture shape files and two separate point shape files for the water wells. It is also worth mentioning that I now defined the coordinate system for the project as a UTM Zone 14N Projection, since I ultimately wanted to be working with calculations in meters, rather than decimal degrees. Because of the on-the-fly projection capabilities of ArcMap, the well locations and culture were shown as having locations defined by meters now at this point, even though they were still defined in terms of decimal degrees (I would have to fix this later).

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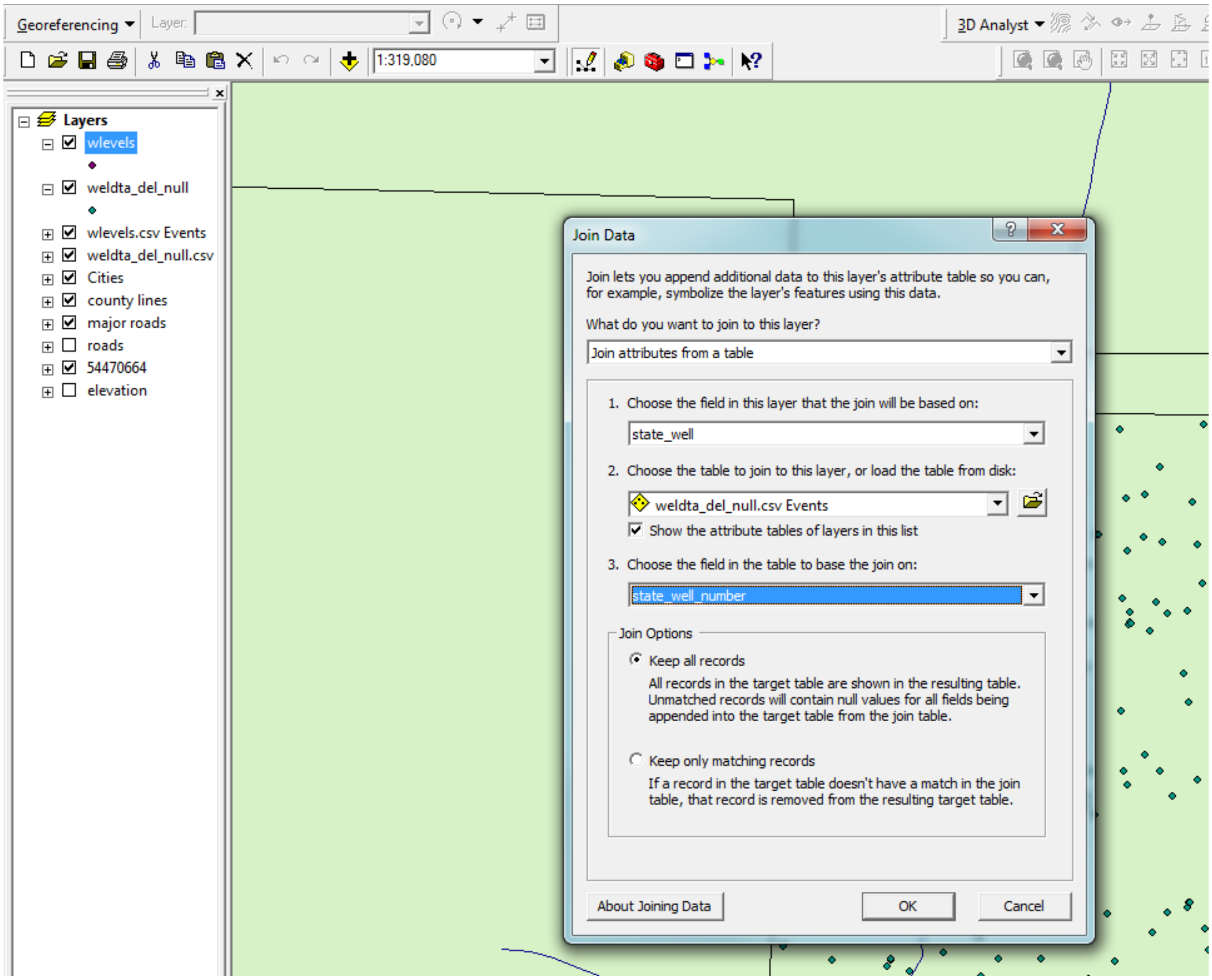
Data Preprocessing

As mentioned in the previous section, at this point in the process, the Well Data file contains latitude and longitude measurements in decimal degrees, for each water well, while the Water Levels file contains water level readings for the wells, with some wells having multiple readings spaced out across time and others having only one. In order to more easily work with the data in ArcMap, I chose to do a many-to-one join of the two shape files, using the "Join" option under "Joins and Relates" for the specific layer of interest (Figure 5).



[Figure 5 – Joining Two Attribute Tables]

Upon joining the shape files, I ended up with one layer containing all the relevant information that I needed (and much more, unfortunately). Figure 6 shows the joined attribute table, now having both location and water depth values assigned to one point. At this point in the process, there are 1258 individual records, for 371 individual wells. Some wells have many different water level depths, and some have only one. The water levels readings are spaced out over time sporadically as well.

Attributes of wlevels

FID	Shape *	state_well	pn_well_vi	depth_from	mm_date	dd_date	yy_date	FID	state_well *	latitude	lat_dec	longitude	long_dec	aquifer_co	aquifer_id
1234	Point	4447904	P	-183.68	8	26	2009	304	4447904	311706	31.284999	1010946	-101.162777	218EDRDA	13
1235	Point	4447904	P	-182.81	10	0	2009	304	4447904	311706	31.284999	1010946	-101.162777	218EDRDA	13
1236	Point	4326901	P	-106.11	1	0	2010	9	4326901	313124	31.523332	1004649	-100.780277	218EDDT	13
1237	Point	4326901	P	-104.56	6	0	2010	9	4326901	313124	31.523332	1004649	-100.780277	218EDDT	13
1238	Point	4326901	P	-103.98	7	0	2010	9	4326901	313124	31.523332	1004649	-100.780277	218EDDT	13
1239	Point	4333601	P	-23.88	1	0	2010	23	4333601	312648	31.446666	1005408	-100.902222	110AVAN	13
1240	Point	4333601	P	-23.33	6	0	2010	23	4333601	312648	31.446666	1005408	-100.902222	110AVAN	13
1241	Point	4333601	P	-27.92	7	0	2010	23	4333601	312648	31.446666	1005408	-100.902222	110AVAN	13
1242	Point	4335401	P	-40.38	1	0	2010	74	4335401	312637	31.44361	1004444	-100.745555	110AVPS	22
1243	Point	4335401	P	-39.38	6	0	2010	74	4335401	312637	31.44361	1004444	-100.745555	110AVPS	22
1244	Point	4335401	P	-40.24	7	0	2010	74	4335401	312637	31.44361	1004444	-100.745555	110AVPS	22
1245	Point	4342604	P	-30.79	1	0	2010	111	4342604	311840	31.311111	1004728	-100.79111	110AVAN	13
1246	Point	4342604	P	-30.57	6	0	2010	111	4342604	311840	31.311111	1004728	-100.79111	110AVAN	13
1247	Point	4342604	P	-34.04	8	24	2010	111	4342604	311840	31.311111	1004728	-100.79111	110AVAN	13
1248	Point	4349501	P	-194.8	1	0	2010	163	4349501	311213	31.203611	1005626	-100.940555	218EDDT	13
1249	Point	4349501	P	-193.16	6	0	2010	163	4349501	311213	31.203611	1005626	-100.940555	218EDDT	13
1250	Point	4349501	P	-195.67	7	0	2010	163	4349501	311213	31.203611	1005626	-100.940555	218EDDT	13
1251	Point	4351401	P	-40.67	1	0	2010	206	4351401	311108	31.185555	1004411	-100.736388	218ALRS	13
1252	Point	4351401	P	-41.25	8	24	2010	206	4351401	311108	31.185555	1004411	-100.736388	218ALRS	13
1253	Point	4357103	P	-183.48	6	0	2010	215	4357103	310633	31.109166	1005912	-100.986666	218EDRDA	13
1254	Point	4357103	P	-182.93	8	24	2010	215	4357103	310633	31.109166	1005912	-100.986666	218EDRDA	13
1255	Point	4447904	P	-183.61	1	0	2010	304	4447904	311706	31.284999	1010946	-101.162777	218EDRDA	13
1256	Point	4447904	P	-185.09	6	0	2010	304	4447904	311706	31.284999	1010946	-101.162777	218EDRDA	13
1257	Point	4447904	P	-184.82	7	0	2010	304	4447904	311706	31.284999	1010946	-101.162777	218EDRDA	13

Record: 0 Show: All Selected Records (1258 out of 1258 Selected) Options

[Figure 6 – The Joined Attribute Table]

Once I joined the two tables, the combined water well shape file did not display on my map at all. The reason for this is that I joined the Water Well Data table with the spatial coordinates **to** the Water Level table without spatial coordinates. When I initially imported the Water Level shape file without the spatial coordinates, I chose arbitrary data fields for the X's and Y's to be determined from, since there were no meaningful values given. Thus, I now had the combined file that I wanted, but now needed to reclassify x and y coordinates to the latitude and longitude decimal degree fields.

After unsuccessfully searching for an "X/Y Reclassification" function in ArcMap and ArcToolbox, I resorted to exporting the new combined shape file's attribute table to Microsoft Excel, and then added it right back in to ArcMap again, this time defining the X and Y as the latitude and longitude fields.

This step of exporting and then importing once again, also helped solve another problem I had, which was that I knew that I would eventually have to do calculations, and interpolations in order to create a water level surface. But, the x and y coordinates that the data were in, were decimal degrees of latitude and longitude, while the depth readings were in feet. I needed to get the data's coordinate system to be defined as UTM 14N, so that the x and y coordinates would not just be projected on the fly into UTM coordinates (system of the data frame), but would actually be defined in terms of UTM units (meters). So, when I exported my combined well data event file to a shape file to fix the X/Y coordinate problem of not being defined at all (see above paragraph), I also exported it in the coordinate system of the data frame, which was UTM (Figure 7).

[Figure 7 – Exporting Attribute Table In Data Frame Coordinate System]

The next step in data preprocessing was to make sure that all of my wells were drawing from the same aquifer across the state. I decided to do this because there was a dominant aquifer comprising over 90% of the measurements taken, and it would allow me to avoid having seemingly anomalous water depth values later on. So, I removed all data points that were not taken from the Edwards-Trinity Plateau aquifer, which had an ID code of 13 in the attribute table. I was able to select these data points by using the "select by" feature under the "options" tab in the attribute table for the water well layer. Once the desired data points were selected, I exported them to a new, more pared-down shape file. This type of process would end up being repeated a few times over to simplify the dataset I was working with.

For a significant number of the data points I was now working with, the "water depth from surface" held a value of zero (Figure 8). But, a zero value could mean either that the fresh water was at the surface of the well and possibly spilling over, or that the water depth was deeper than the depth of the water well. Since a zero value could mean either of the above, and would be difficult to deal with if it meant the water was deeper than the depth of the well, I decided to throw out all of the data points with null values for water depth for this project. I did this using the "select by" option in the options menu of the attribute table for the water wells.

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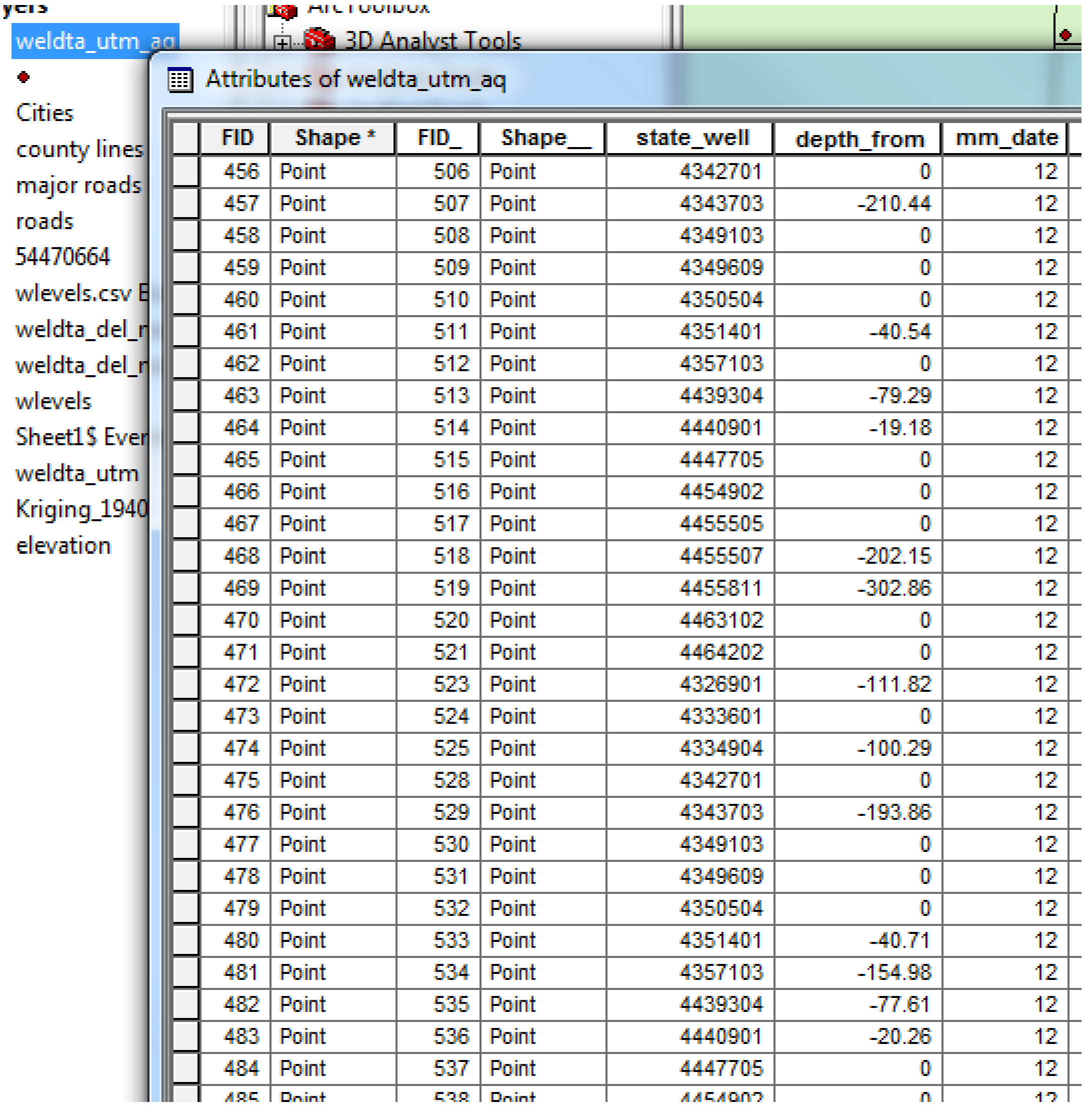

FID	Shape *	FID_	Shape__	state_well	depth_from	mm_date
456	Point	506	Point	4342701	0	12
457	Point	507	Point	4343703	-210.44	12
458	Point	508	Point	4349103	0	12
459	Point	509	Point	4349609	0	12
460	Point	510	Point	4350504	0	12
461	Point	511	Point	4351401	-40.54	12
462	Point	512	Point	4357103	0	12
463	Point	513	Point	4439304	-79.29	12
464	Point	514	Point	4440901	-19.18	12
465	Point	515	Point	4447705	0	12
466	Point	516	Point	4454902	0	12
467	Point	517	Point	4455505	0	12
468	Point	518	Point	4455507	-202.15	12
469	Point	519	Point	4455811	-302.86	12
470	Point	520	Point	4463102	0	12
471	Point	521	Point	4464202	0	12
472	Point	523	Point	4326901	-111.82	12
473	Point	524	Point	4333601	0	12
474	Point	525	Point	4334904	-100.29	12
475	Point	528	Point	4342701	0	12
476	Point	529	Point	4343703	-193.86	12
477	Point	530	Point	4349103	0	12
478	Point	531	Point	4349609	0	12
479	Point	532	Point	4350504	0	12
480	Point	533	Point	4351401	-40.71	12
481	Point	534	Point	4357103	-154.98	12
482	Point	535	Point	4439304	-77.61	12
483	Point	536	Point	4440901	-20.26	12
484	Point	537	Point	4447705	0	12
485	Point	538	Point	4454902	0	12

[Figure 8 – "0" Values for Water Depth]

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ArcGIS Processing

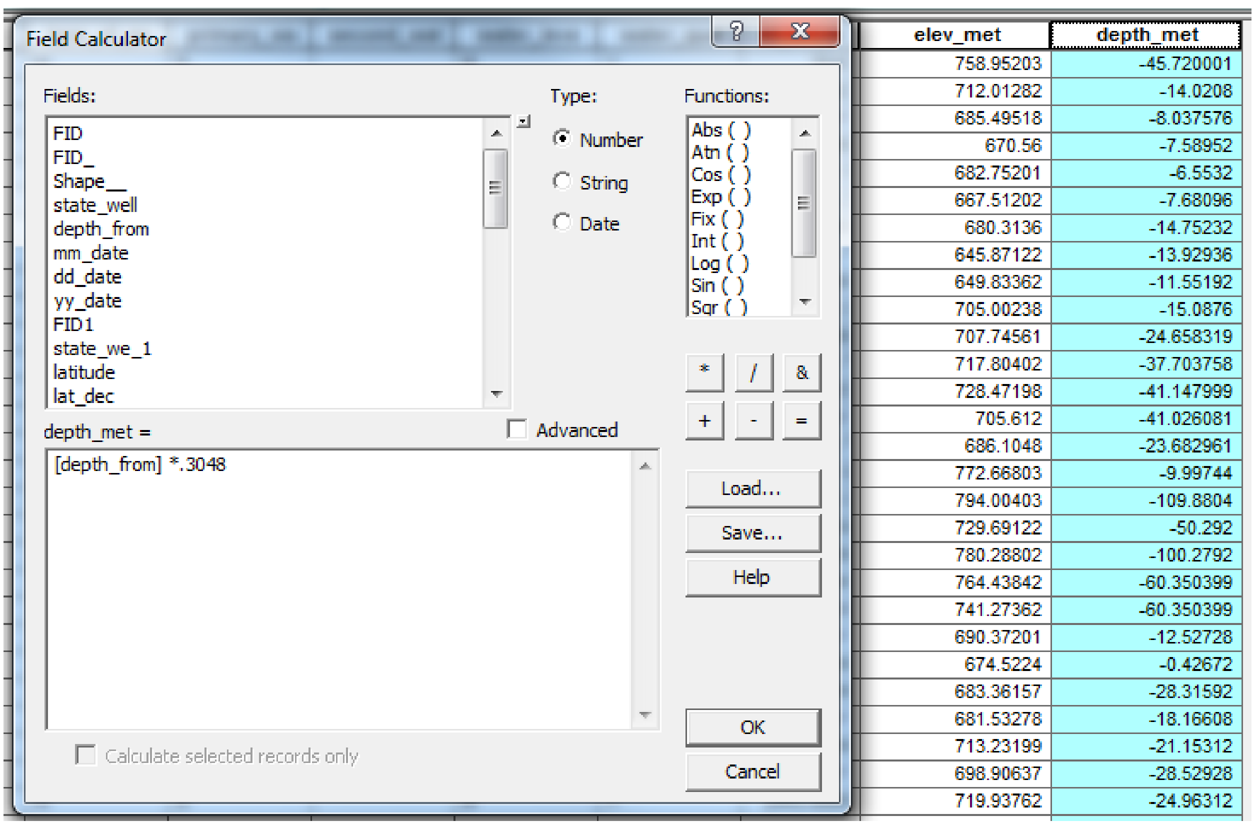
Objective 1: Try to Get a Handle of the Relation Between Surface Elevation and Water Level Depth

I initially downloaded a DEM raster from the USGS Seamless viewer. My plan was to generate water depth surfaces using the kriging interpolation function, and then subtract this raster from the DEM to get a "thickness below surface raster." This would have required generating a new DEM raster in feet above sea level with the raster calculator, since the initially downloaded DEM was in meters.

Then, I was going to generate a slope map with the 3D Analyst Toolbar, and look at the areas over which depth from the surface to the water table was relatively constant, and that where changed relatively rapidly.

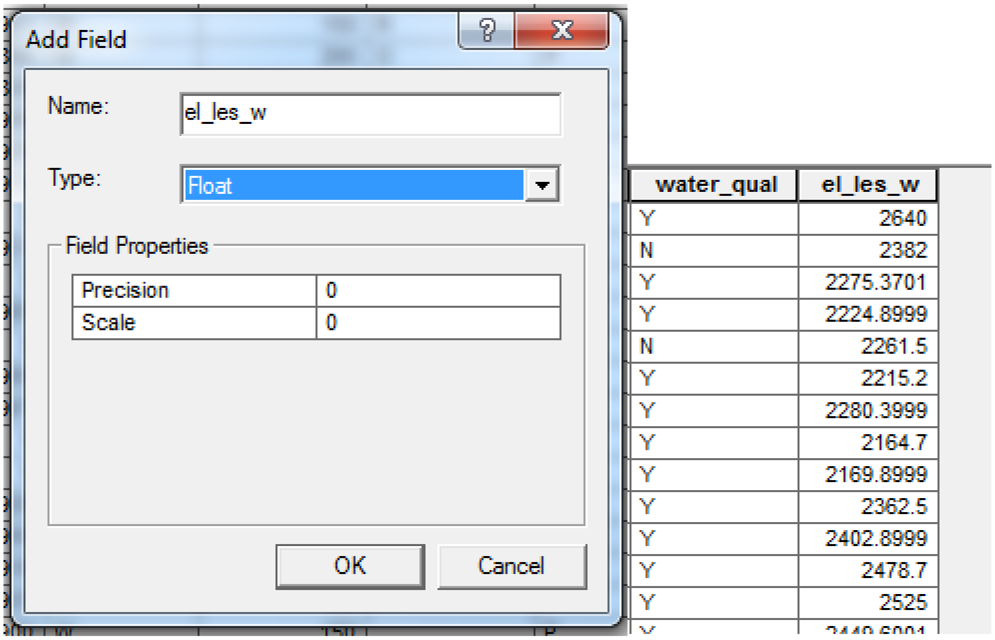
However….in the midst of calculating a new DEM based off the USGS DEM, I noticed that there was a "land surface elevation field" in the same attribute table that contained the water depth measurements (the only water well layer file I am working with)! I had not noticed this before since the attribute table contained so many fields and I was just focusing on a few of them. Thus, I learned the valuable lesson of needing to "clean up" the attribute table at the beginning of a project and take stock of what you actually have and don't have.

So, now I was able to create a new field in the attribute table of the water well shape file devoted to holding the value of the elevation (feet) minus the depth to water (feet) from the Edwards Trinity Plateau Aquifer.
Since my coordinate system was in meters (UTM), I created two new fields in the attribute table and used the "Field Calculator" function to calculate the surface elevation above mean sea level and the drill depth in meters, by multiplying the measurements in feet by .3048 (Figure 9).



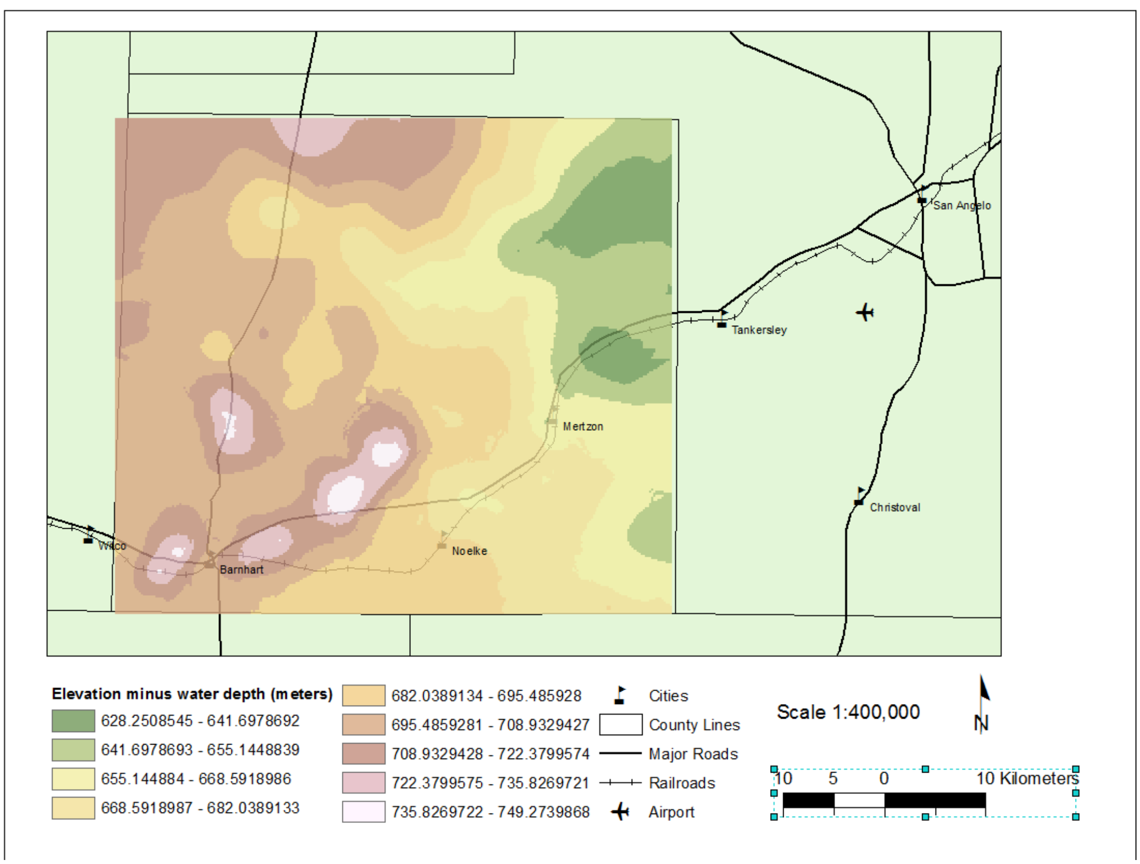
elev_met	depth_met
758.95203	-45.720001
712.01282	-14.0208
685.49518	-8.037576
670.56	-7.58952
682.75201	-6.5532
667.51202	-7.68096
680.3136	-14.75232
645.87122	-13.92936
649.83362	-11.55192
705.00238	-15.0876
707.74561	-24.658319
717.80402	-37.703758
728.47198	-41.147999
705.612	-41.026081
686.1048	-23.682961
772.66803	-9.99744
794.00403	-109.8804
729.69122	-50.292
780.28802	-100.2792
764.43842	-60.350399
741.27362	-60.350399
690.37201	-12.52728
674.5224	-0.42672
683.36157	-28.31592
681.53278	-18.16608
713.23199	-21.15312
698.90637	-28.52928
719.93762	-24.96312

[Figure 9 – Field Calculator]



[Figure 10 – Add Field Function & New Field in Attribute Table]

The next step I took was to use the “Add Field” and “Field Calculator” functions once again to add a field containing the value in meters of the elevation added to the water well depth (since the water well depth was a negative value). In order to generate the raster surface representing this thickness across the county, I was able to use the “Kriging” function found in ArcToolbox under “Interpolation Features.” Figure 11 shows the results of this interpolation.



[Figure 11 – Thickness Ground Before Reaching Water in the Aquifer]

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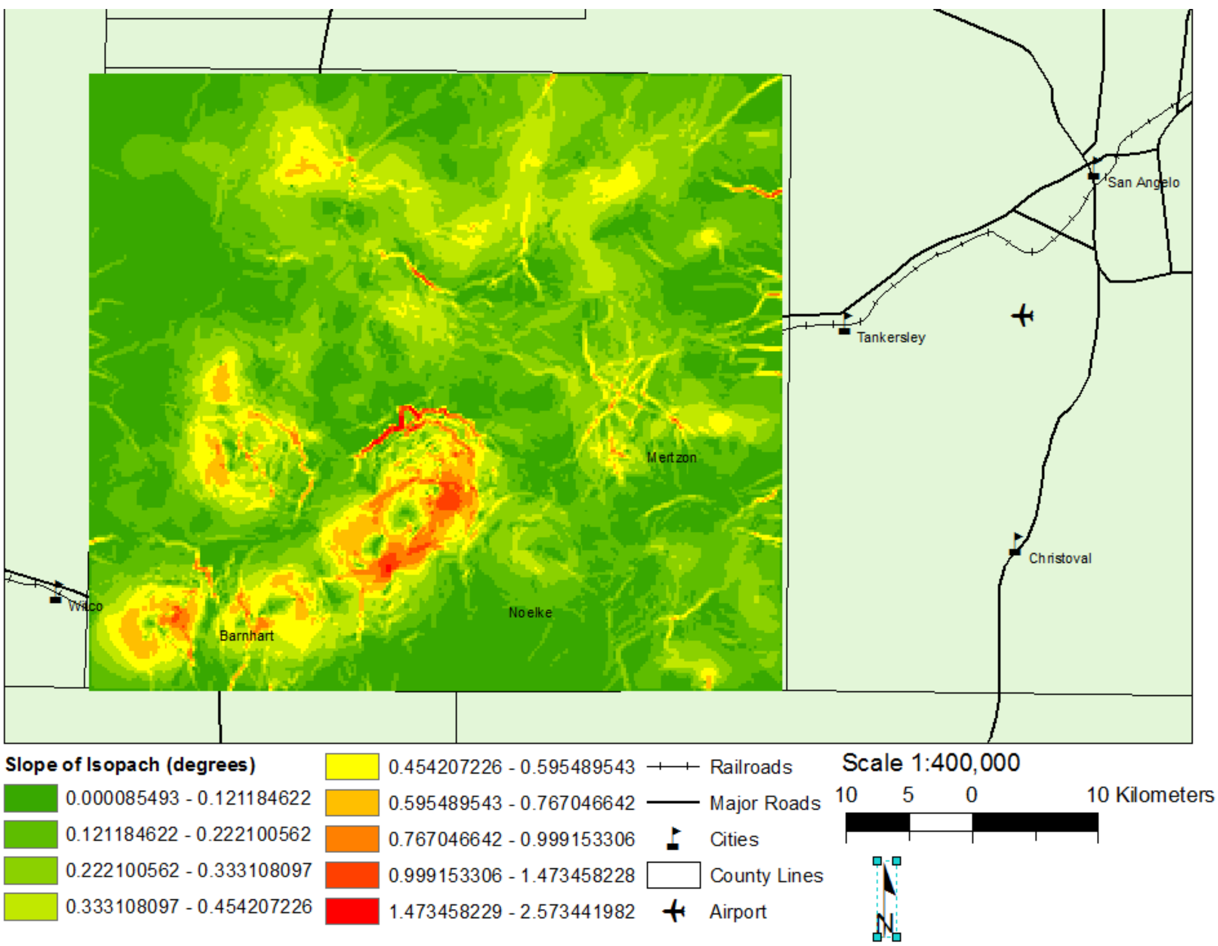
Figure 11 shows the average thickness represented from the layer of earth from the surface down to the water level in the aquifer, on average since 1940, across the entire county. This layer of earth shows to be on average quite a bit thicker in the Southwest portion of the county and thins as one moves Northeast. So, we can tell from this map that the water level does not mimic topography exactly, meaning the drill depth to fresh water is not constant across the state, and varies on the order of a hundred meters. An Irion County resident can expect to drill a much deeper hole to reach the aquifer if he lives in Barnhardt rather than Mertzon.

Note: the legend in this map and subsequent maps show unattractive values for the value bins, with uneven boundary numbers and many numbers after the decimal place. I kept receiving an error message related to ArcMap being unable to generate a unique histogram due to my having too many values in the layer. This prevented me from being able to re-classify the bins to more even and attractive numbers.

The next step in this objective was to calculate a slope raster based of the above isopach. To do this, I used the "slope" function in the 3D analyst toolbar, and designated the previous isopach as the input layer. The result is presented in Figure 12.



[Figure 12 – Slope of the Figure 11 Isopach Map]

Figure 12 shows the average slope of the isopach map presented in Figure 11. The dull green areas are areas that have relatively little change in depth to water level as you move about laterally. The bright red splotches are areas or more rapid change. A resident of Irion County who lives in one of these areas could expect to experience a greater change in the water level of his water well over the years, as these high flux points are likely to be the most variable over time.

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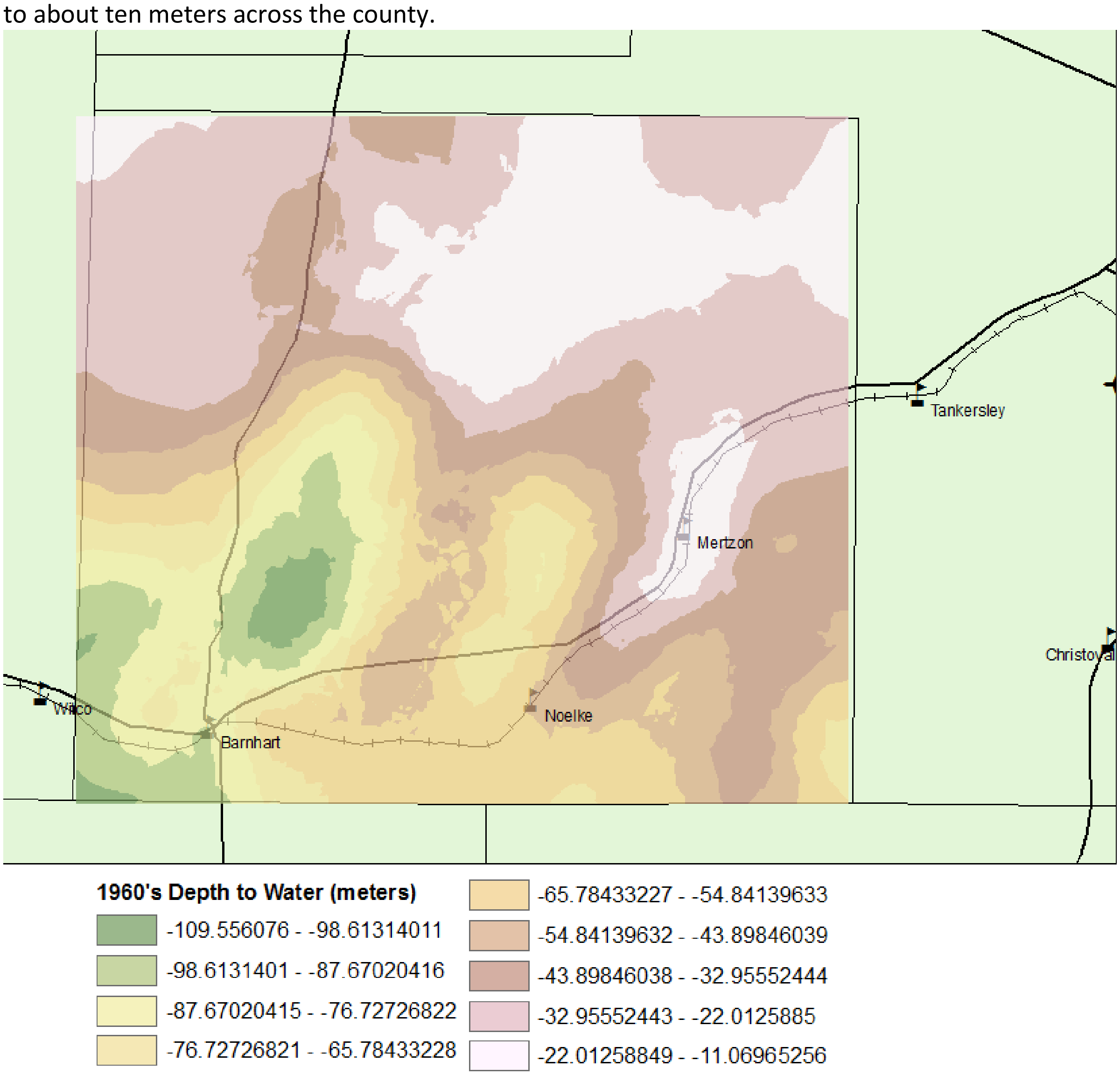
ArcGIS Processing

Objective 2: Presentation of Water Level in the Aquifer Through Time

For this objective, I once again used the Kriging function in found in ArcToolbox to generate rasters representing an average water surface for three separate decades: The 1940's the 1960's and the 2000's. Since the kriging function averaged out any data points that had multiple values within any one of the given decades, the resulting surfaces were a sort of average of the water surface for the decade. But, even this was a stretch, since water levels vary dramatically from year to year, and the kriging function was tasked with interpolating a surface of based off of points.

The purpose of this was to see whether this type of analysis could be used to see if time comparisons could be made with this level of detail and coherency within a data set, over long spans of time. Was the water level in the 1940's higher than it is now, on average? What about the 1960's?

To type of result that I got for each decade can be seen in Figure 13 below. Depths range from about a hundred meters to about ten meters across the county.



[Figure 13 – 1960's Interpolated Surface for Depth to Water]

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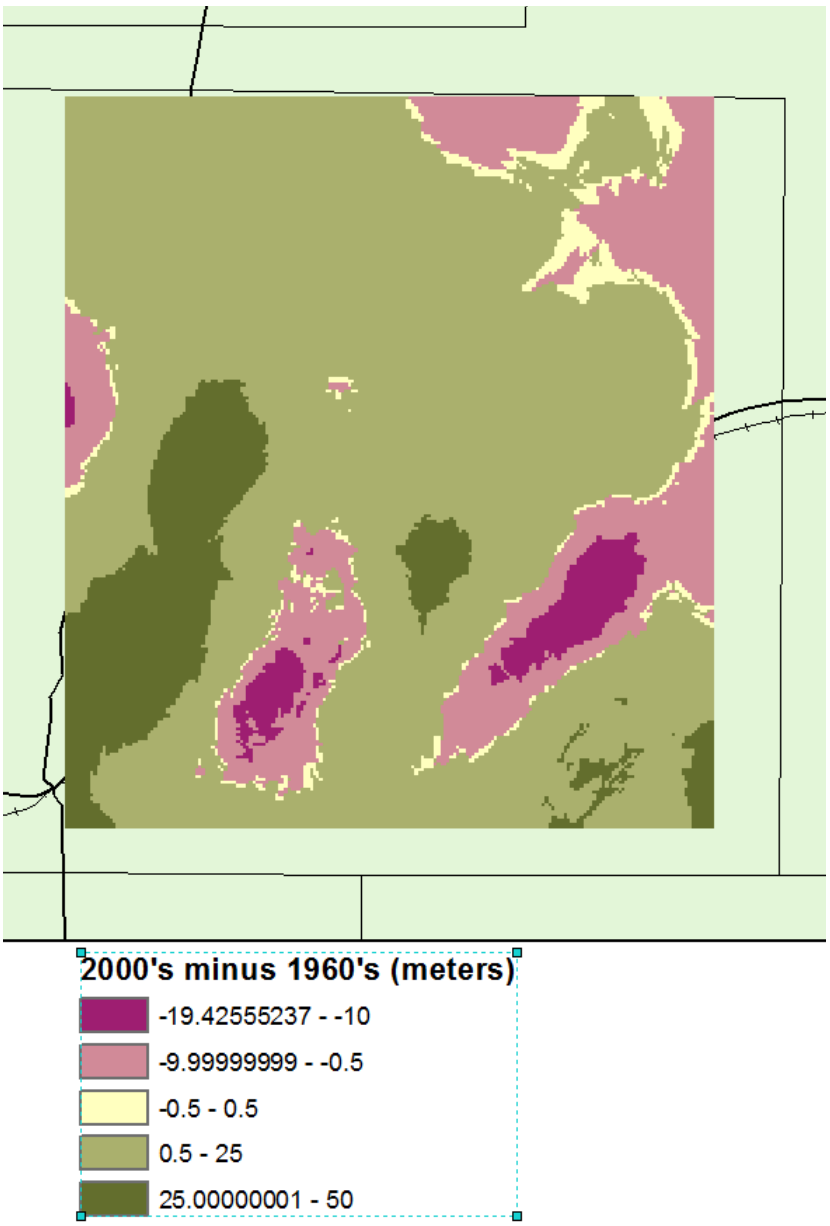
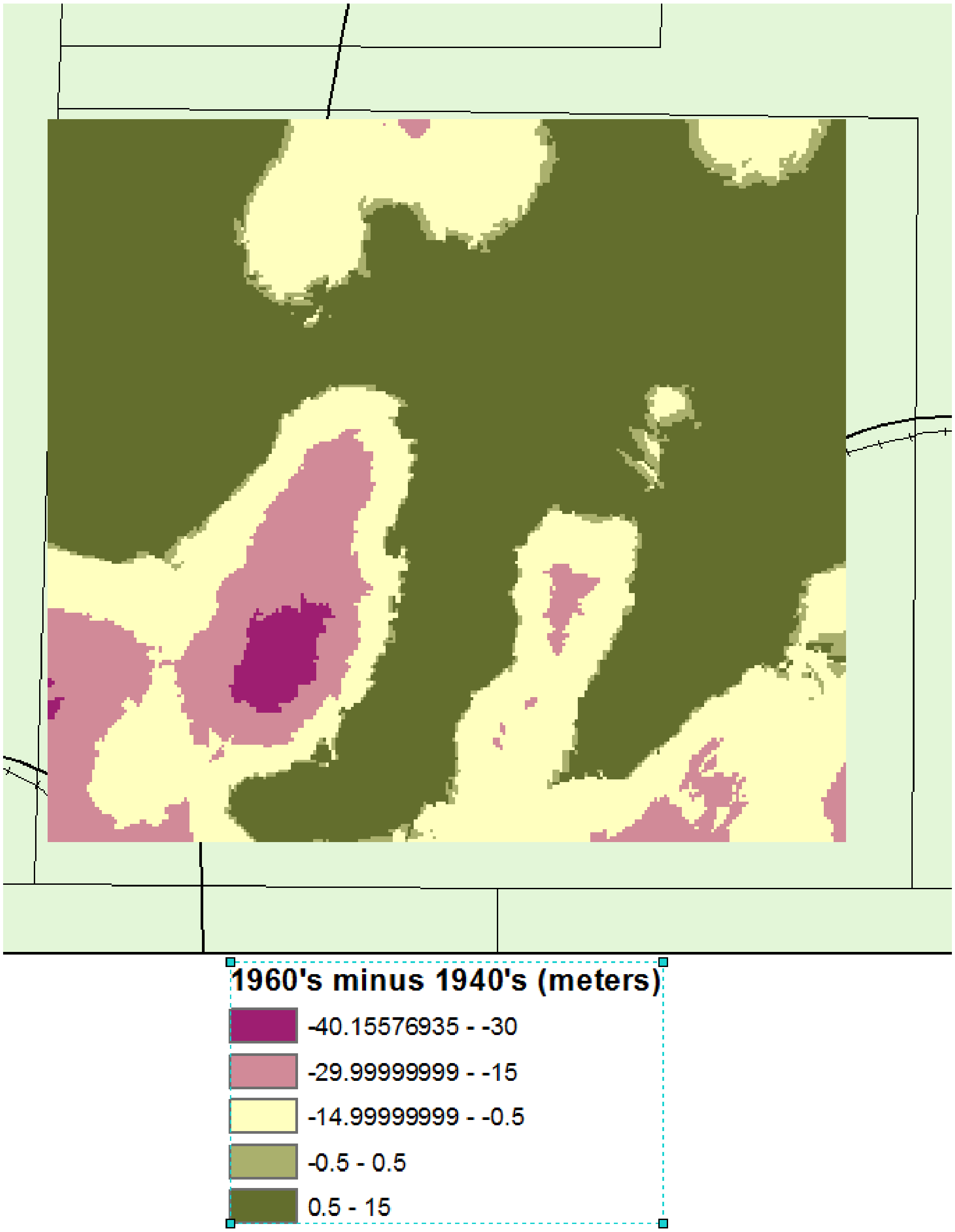
The next step for this objective was to use the raster calculator to subtract the different decade water level rasters from each other, so that I could compare them. The results of this are presented in Figures 14-16.

The 2000's and 1960's comparison shows that the 2000's on average had a higher water level in some spots than the 1960's and a lower water level in others.



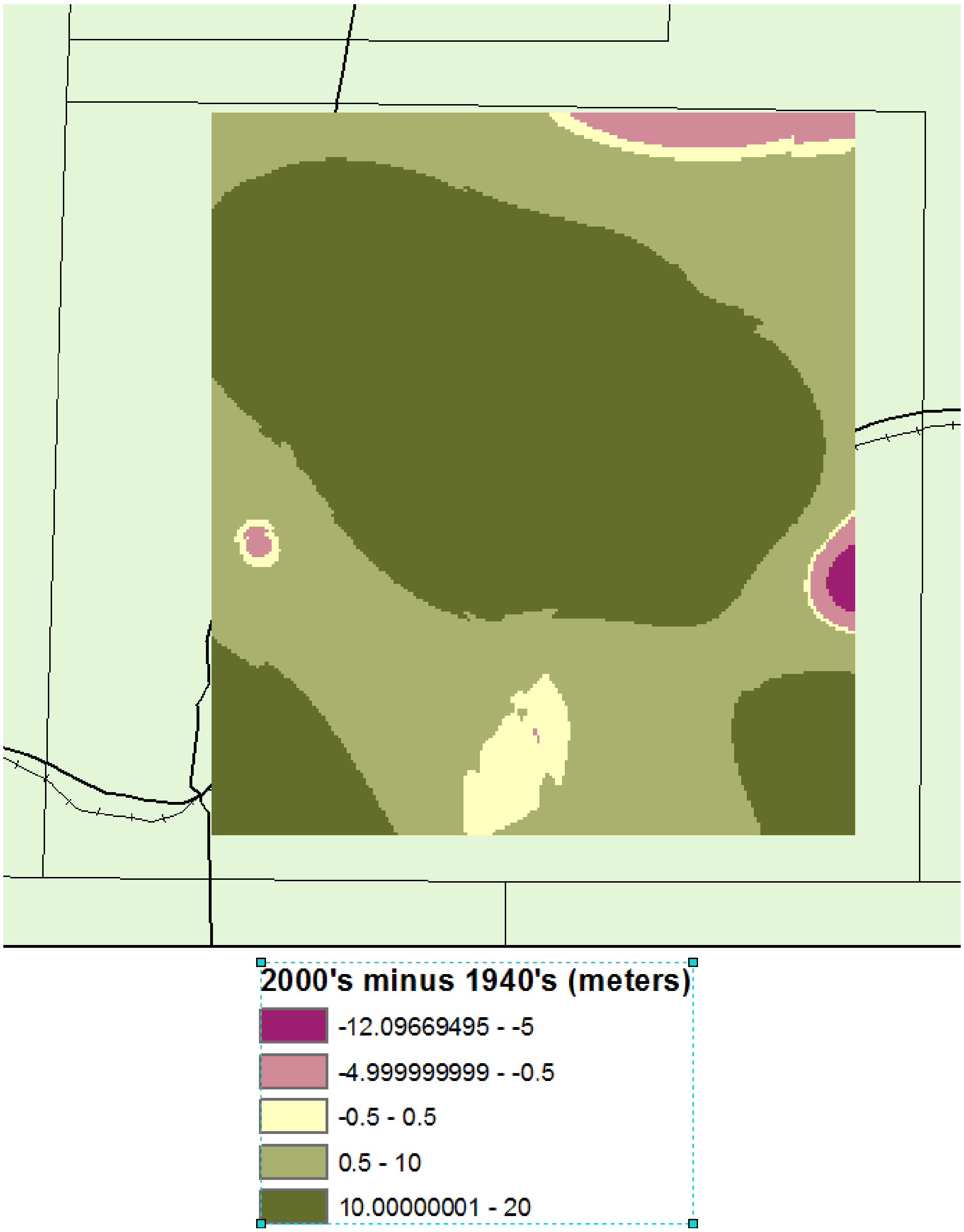
[Figure 14 – Average Water Level of 2000's Minus Average Water Level of the 1960's]

The 1960's seemed to overall have a higher water level in the aquifer than the 1940's.



[Figure 15 – Average Water Level of 1960's Minus Average Water Level of the 1940's]

The 2000's looked to have a higher water level in the aquifer than the 1940's, on average.



[Figure 16 – Average Water Level of 1960's Minus Average Water Level of the 1940's]

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Conclusion

Over the course of the past few weeks, my project has evolved to something a bit different than what was originally planned. This was the case largely because the sporadic nature of the water well reporting across Irion county presented me with more problems than I initially assumed. The analysis conducted to show relative depths to the water level in the aquifer across the county seemed to be more meaningful than the average decades comparisons. Neither of the two types of analysis are of the sort that I would be willing to base heavy investment upon them.

To answer my initial questions, (Upon picking a random point in Irion county, Texas, to what depth would I have to drill a water well to encounter fresh water? How does fresh water depth vary across the county through time?), I would have to say that the person asking the questions would be best off querying the Water Well Data and Water Level Tables on the TWDB website for the nearest well with the most recent measurement taken. As far as a variance through time goes, again I might be most confident answering this question using a rainfall history over Irion County.

With all of this said, I still think the project was a success in that it chronicles out the ways to deal with and not to deal with a large and somewhat unorganized dataset. Further, I was able to show that the water level in Irion County is quite responsive to the overall surface elevation above mean sea level, and some level of quantification can be associated with this answer.

In the perfect world, I would have had a dataset with measurements taken at each water well at the same time. But, this is likely a good introduction to the real world, where dealing with imperfect data is common, and one must learn to do the best with what is provided. I think that I learned a great deal about working with GIS software from working on this project, and I am looking forward to continuing being an active participant in the field of GIS as it develops in the coming years.