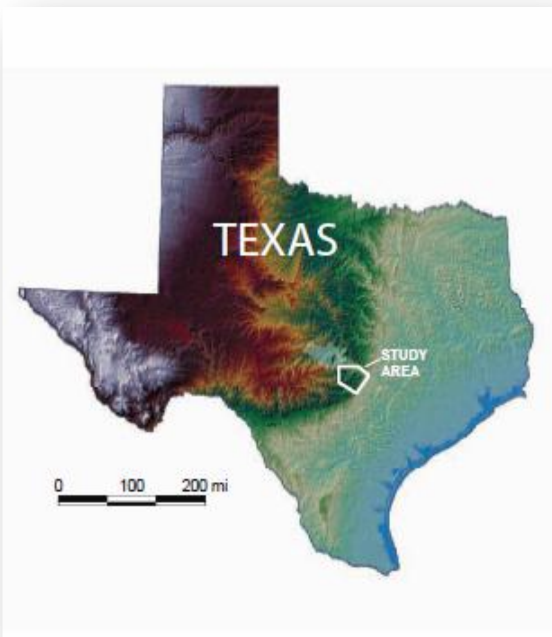
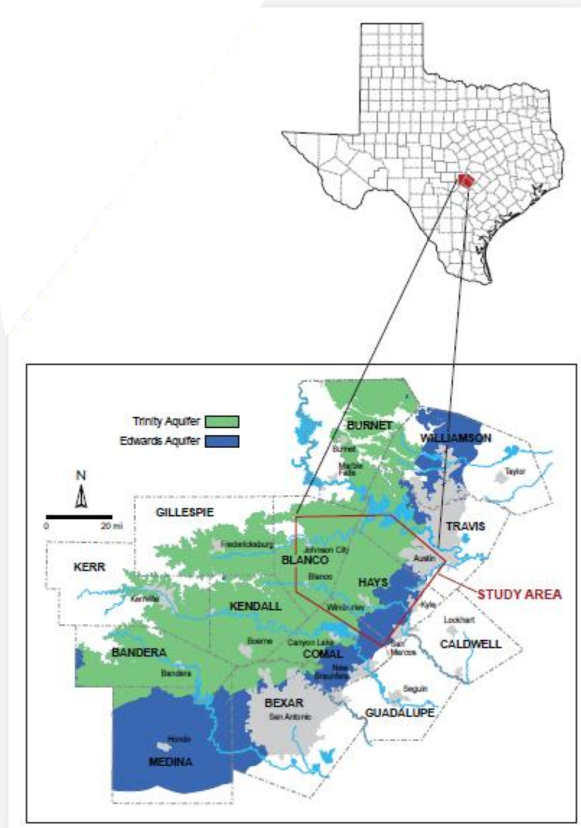
Water Volume Calculation of Hill Country Trinity Aquifer

Blanco, Hays, and Travis Counties, Central Texas





GIS and GPS Applications in Earth Science

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Introduction:

Trinity Aquifer is one of the major aquifers and one of the most extensive and highly used ground water resources in Texas. It extends across much of the central and northeastern part of the state. The Trinity aquifer discharges to a large number of springs, with most discharging less than 10 cubic feet.

The Trinity section dips gently to the south east until intersected by early Miocene – age faulting of the Blacons fault zone. It composed of several individual aquifers within trinity group, about 1000ft thickness and consists of 3 clastic - carbonate cycles. Mostly, carbonate rocks (Limestone and dolomite) with sandstone in between.

In order to calculate the volume of water in this aquifer, I have divided the whole section in two four members: Figure (1)

Upper member: Upper Glen Rose (Kgru)L and Lower Glen Rose (Kgrl) formations.

Middle member1: Hensel (Khe) formation.

Middle member 2: Cow Creek (Kcc) and Hammett formations.

Lower member: Sligo (Ksl) formation.

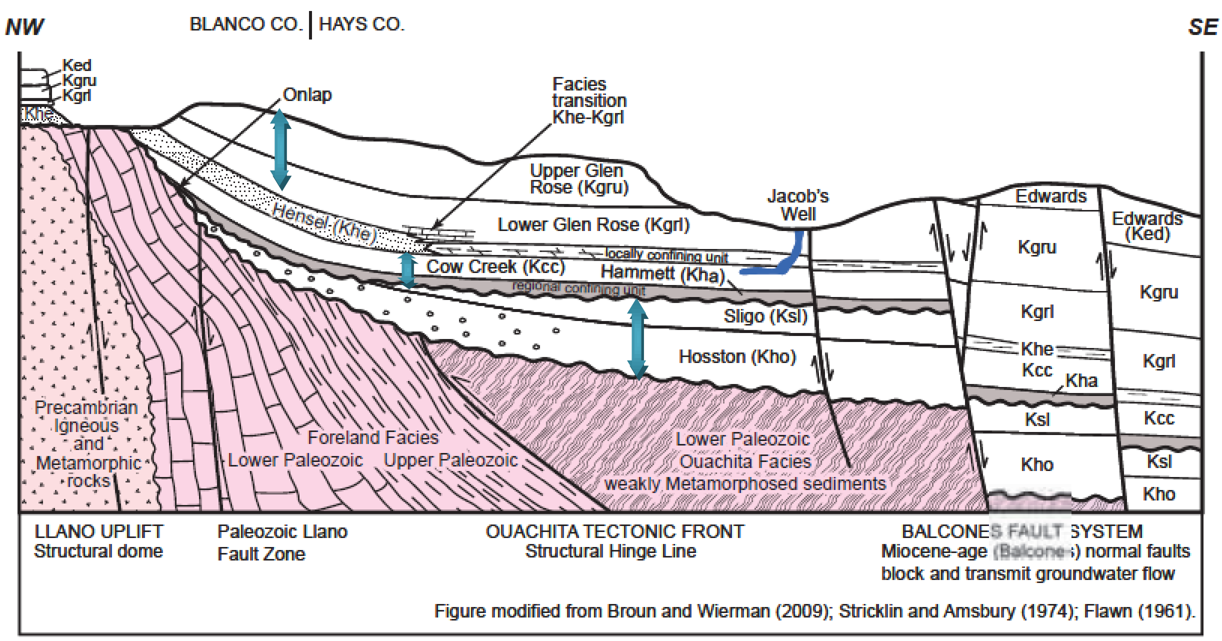


Figure 1: Schematic Geologic Cross section showing Trinity Group from Northwest to Southeast

Objectives of the project:

A study has been made by Wierman et al, 2010 on Hill country trinity aquifer within Blanco, Hays and Travis counties, central Texas. In this study, new data was collected from water wells as well was compiling the existing data to define the geologic structure and frame work of the aquifer. To understand the occurrence, movement and availability of ground water in the study area; surface and groundwater data were interpreted within the geologic, stratigraphic, and structural setting.

The objective of this project is to use the collected and updated data of 198 wells from the above mentioned study in order to calculate the volume of water in Trinity aquifer within Blanco, Hays and Travis counties. Furthermore, creating surfaces using the ArcGIS interpolation techniques to understand the artifact of gridding algorithm of the software and compare them with the hand contoured maps of the same study.

Data Collection:

The data for this project was collected from different sources:

1- **Capital Area Council of Governments**
   http://www.capcog.org/information-clearinghouse/geospatial-data/#aquifers
   - County boundaries: shapefile (I couldn't open the metadata link for counties)
   - Aquifer: ESRI Geodatabase and shapefile
     - *Geographic coordinate system name:* GCS_North_American_1983
     - *This dataset consists of the major and minor aquifers within the CAPCOG 10 county region (Hays,Travis,Bastrop,Blanco,Llano,Williamson,Caldwell,Fayette,Burnet, and Lee counties)*
     - *This data was created by TWDB and edited for redistribution by CAPCOG.*
   - City Limits: ESRI Geodatabase and shapefile
     - *Projected coordinate system name: NAD_1983_StatePlane_Texas_Central_FIPS_4203_Feet*
     - *Geographic coordinate system name: GCS_North_American_1983*
     - *This file was compiled from the city limits provided by CAPCOG by the ten county database coordinators*
   - Hydrology: ESRI Geodatabase and shapfile
     - *Map Projection Name: Lambert Conformal Conic*
     - *Data obtained from USGS/EPA National Hydrography Dataset. This metadata was created by CAPCOG and is not the original metadata*

2- **USGS: http://tx.usgs.gov/GAT/**
   - Faults: shape files
     - *Texas faults are from the Geologic Atlas of Texas, digital version available through the Texas Natural Resources Information Service*

3- **An Excel file from DVD:** D.A. Wierman, A.S. Broun, and B.B Hunt, 2010, Hydrogeologic Atlas of the Hill Country Trinity Aquifer, Blanco Pedernales Groundwater Conservation Districts, July 2010.

State Well Grid Number	Name	Control Type	Abbreviation	y latitude (DD)	x longitude (DD)	y latitude (DMS)	x longitude (DMS)	Lat/Long Source	Elevation	Elevation Source	UGR Top Depth	UGR Top Elevation	UGR Isopach
Comal	11010 Hy 46	well	HW46	29.7882	-98.3121				1271		0	0	0
	57457-G1	well	G1	30.2618	-98.4939				1431		0	0	0
	6240 Hwy 290 West	well	6240	30.2362	-97.8581	30-14-10.3	97-51-29.3	well log	802	driller's log	110	692	443
	Anne Wynn	well	Ann	30.1223	-98.3861	30-7-20.2	98-23-10.1	well log	1345	driller's log	0	0	0
	AquaTx Well No. 23	well	Aqua	30.0391	-98.1437	30-02-20.6	98-08-37.2	well log	1050	GPS	0	0	0
57-63-7AP	Arrowhead Point Well No.1	well	Arr	30.0306	-98.2164	30-01-50.3	98-12-59.0	well log	990	earth google	0	0	0
58-49-7BD	Barsana Dhanm Well	well	Bars	30.1517	-97.9633	30-09-0-6.20	97- 57- 48	well log	932	earth google	23	909	220
57-63-9BW	Bass Well No. 1	well	Bass	30.0319	-98.1647	30-01-54.90	98-09-52.80	well log	1146	google earth	0	0	0
58-49-4FR	Belterra (Foster Ranch) Well No. 1	well	Belt1	30.1981	-97.9803	30-11-53	97-58-49	driller report	1083	estimate	0	0	0
	Beulah Well No. 1	well	Beu1	30.2142	-98.1118	30-12-51.1	98-08-14.3	Well log	1323	google earth	0	0	0
57-63-3BW	Bischoff Well No. 1	well	Bis	30.2417	-98.0167	30-14-30.0	98-01-11.0	driller's log	1032	earth google	0	0	0
Blanco	Blanco River	well	Blan	30.0946	-98.4323	30-05-40.6	98-25-56.2	well log	1316		0	0	0
Blanco	Bleakley No. 2	Well	Blek	30.2122	-98.1509	30-12-43.8	98-9-31	well log	1400	well log	0	0	0
58-49-5BZ	Bohm No.1	well	Bohm	30.1895	-97.9448				980		50	930	0
	Bous Well	well	Bou	30.1982	-98.2571	30-11-53.5	98-15-25.5	well log	1342	driller's log	0	0	0
68-08-8SP	Bridlewood Well No. 1	well	Brid1	29.8956	-98.0595	29-53-44.04	98-3-34.14	GPS	960	topo sheet est.	200	760	530
Blanco	Browning Ranch No. 1	well	Brow1	30.2562	-98.3346	30-15-22.3	98-20-04.7	well log	1168	earth google	0	0	0
Blanco	Browning Ranch No. 3	well	Brow3	30.2668	-98.3313	30-16-0.5	98-19-52.8	well log	1080	drillers log	0	0	0
BT3	Brushy Top Well No. 3	well	Bru3	30.1624	-98.3955	30-09-44.6	98-23-43.9	well log	1435	earth google	0	0	0
Blanco	Brushy Top No. 13A	well	Brus13A	30.1693	-98.4089	30-10-09.3	98-24-32.1	well log	1750		88	1662	347
Blanco	Brushy Top No. W3A	well	BrusW3A	30.1516	-98.4017	30-09-05.7	98-24-06.1	well log	1535		0	0	0
Blanco	Brushy Top No.16A	well	Brus16A	30.1642	-98.3954	30-09-51.3	98-23-43.3	well log	1485		0	0	0
Blanco	Brushy Top No.W1A	well	BrusW1A	30.153	-98.3957	30-09-10.8	98-23-44.6	well log	1484		0	0	0
57-56-2RB1	Burrus Well No. 1 (Deerfield Estates)	well	Burr1	30.2496	-98.0529	30-14-58.52	98-3-10.3		1148		0	0	0
68-08-4CR	Cielo Ranch Well No. 1	well	Ciel1	29.9253	-98.1196	29-55-31.1	98-7-10.7	GPS	1137		36	1101	487
Blanco	Cielo Springs 158	well	Cie	30.0855	-98.439	30-05-07.7	98-26-20.5	well log	1370		0	0	0
Blanco	Cielo Springs Fence	well	CieF	30.0737	-98.4161	30-04-25.2	98-24-58.1	well log	1397		0	0	0
58-49-613	Circle C Golf Course	well	CirC	30.1861	-97.9114	30-11-10	97-54-41	topo map	905	topo map	0	0	0
Comal	Co-1	well	Co-1	29.8008	-98.4997				1465		0	0	0
Comal	Co-2	well	Co-2	29.8339	-98.4578				621		0	0	0
68-08-4CW	Coats Well	well	Coat	29.8574	-98.0707				919		180	0	0
58-49-7CW	Colony Well No. 2	well	colo	30.1456	-97.9633				1060		20	1040	0
57-62-3cb	Corbula bed 150' S of Red Corral Ranch Rd 100' E of Blanco County line 2.0 miles S of RR 2325	outcrop		30.0841	-98.2795				1259.76		0	0	0
57-47-7cb	Corbula bed Hammett's Crossing Map 01	outcrop		30.25	-98.2428				1090		0	0	0
57-47-5cb	Corbula bed Hammett's Crossing Map 03	outcrop		30.2917	-98.1861				1060		0	0	0
57-47-6cb	Corbula bed Hammett's Crossing Map 04	outcrop		30.3078	-98.1431				1020		0	0	0
57-47-6cb2	Corbula bed Hammett's Crossing Map 05	outcrop		30.325	-98.1522				1000		0	0	0
57-55-1cb	Corbula bed Henly Map 01	outcrop		30.2314	-98.2464				1140		0	0	0

Table 1: Geologic data base for Hydrologic Atlas of the Hill Country Aquifer, July 2010

Method

- Import the excel file and convert it to ArcGIS format
- Project data in common predefined coordinate system: NAD_1983_UTM_Zone_14N
- Use Geostatistical Analyst to create surfaces
- Use 3D Analyst to create Tin and Convert Tin to raster
- Use raster calculator to create Isopach raster
- Calculate volume of rock from 3D special analyst tool
- Multiply volume of rock by average porosity of each formation

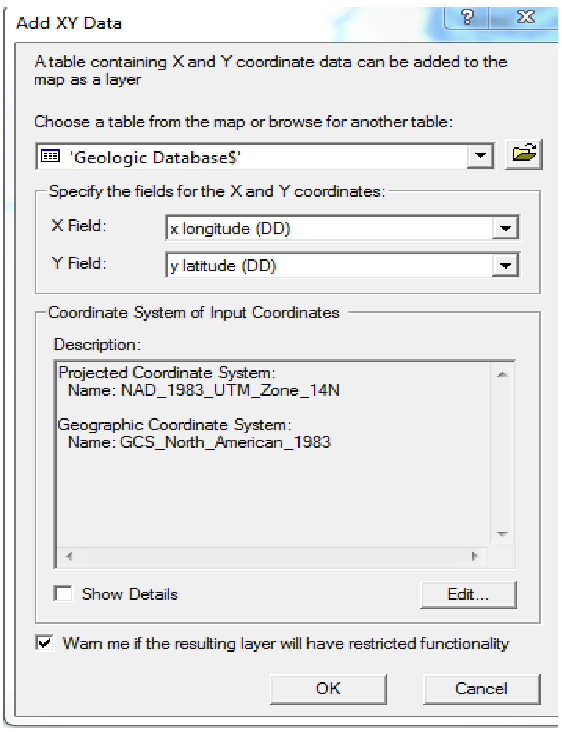
Data Processing:

1- Import Excel file:

From ArcMap, using the Add data botton  I added the xls. file, then add as XY data and convert it to shape file. The special references should be defined. In this case:

Projected coordinate system name: NAD_1983_UTM_Zone_14N

Geographic coordinate system name: GCS_North_American_1983



The import of the table is important to be done correctly, when I tried to QC the data, I realized that all the values of one of the columns are zero, I had to retype them in Arc Map because I wanted to create a surface from that column. To do that: Open the attribute table, then from Editor→ start editing and Start typing in the attribute table. This is time consuming because I had to QC all the data to make sure that all the values are correct ,it is not practical in case of having a huge dataset as well.

To avoid this problem, please see the following link that provides tips to use the correct format that is acceptable by ArcGIS:

http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Working_with_Microsoft_Excel_files_in_ArcGIS

2- <u>**Creating surface:**</u>

When I created surface from the points using interpolation methods in the special Analyst tool, there was no way to exclude the zero values that will be displayed as a flat area, and when convert it to raster, the minimum and maximum values exceeds the actual range. I had to find another way to create surface that will be discussed in the following section.

ArcGIS Processing:

In order to calculate the volume of water in Trinity aquifer, we need to first calculate the volume of the rock and multiply the volume of rock by the average porosity of the formation, for this we need to have raster data and use raster calculator. So, **how to create raster from point features / well data?**

The following is the summery of the steps that I followed to create a raster from points and then calculate the volume:

- a- **Create a surface from the points using Geostatistical Analyst.**
- b- **Convert the surface to vector data.**
- c- **Convert the vector data to Tin.**
- d- **Convert the Tin to raster.**
- e- **Create Isopach raster using the raster calculator (subtract 2 rasters)**
- f- **Calculate the volume of rock for the Isopach raster using 3D Analyst→ Surface Analysis→ Volume--→Calculate statistics.**
- g- **Multiply the rock volume by the average porosity. (Volume of water in Aquifer=Volume of rock x average porosity of the formation)**

<u>**The above steps in detail:**</u>

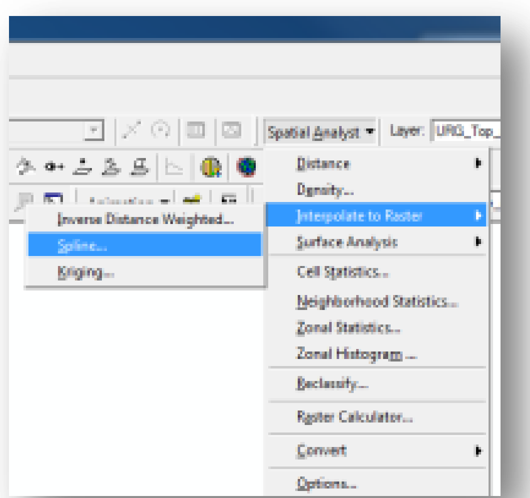
Creating Surface from the point features:

There are two ways to create a surface from the point features using the interpolation methods that we discussed in class (Inverse Distance weighted-IDW, Spline and Kriging).

The first way is from Spacial Analyst which is not friendly and the second is Geostatistical Analyst.

1- **Surface from Spatial Analyst:**

Spatial Analyst-→Interpolate to raster-→ spline

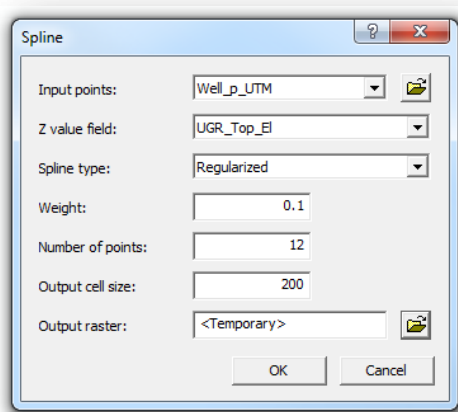


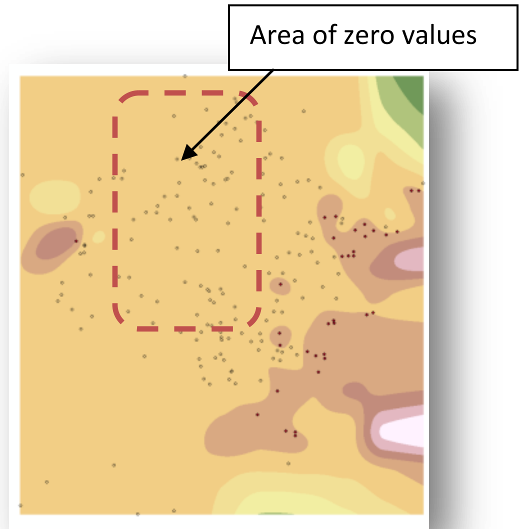
Input points: select the well data points

Z value fields: select the column that you want to create the surface from, in this case I selected the elevations for Upper Glen Rose formation UGR.

No of points: is the number of the neighboring points

Output raster: (where you want to save the rater to be saved permanently)



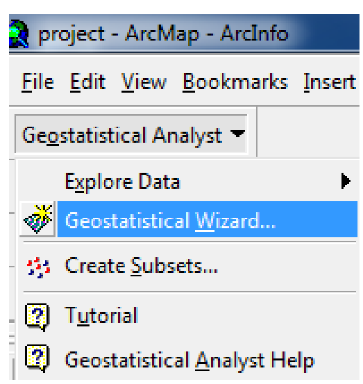


The area in the middle represent the zero values, it is pretty flat. This is not a reasonable surface because these wells with zero values are not penetrating this formation. Also, when this surface converts to raster, the maximum and minimum elevations exceed the actual range. **We need to find another way!!!!**

After applying different tools and methods, I realized that using the Geospatial analysis tool is the best solution to give us a raster with the actual maximum and minimum elevations.

2- Creating surface from Geostatistical Analyst tool:

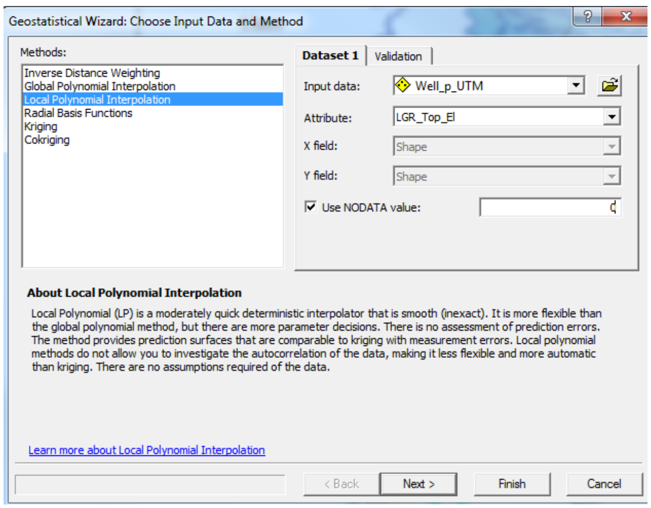
From Geostatistical Analyst-→ Geostatistical Wizard

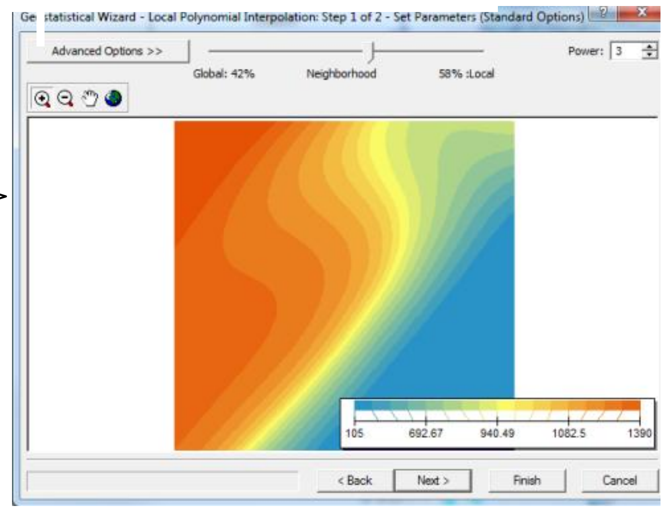


I used the Local Polynominal Interpolation method:

Input data: select the point shape file

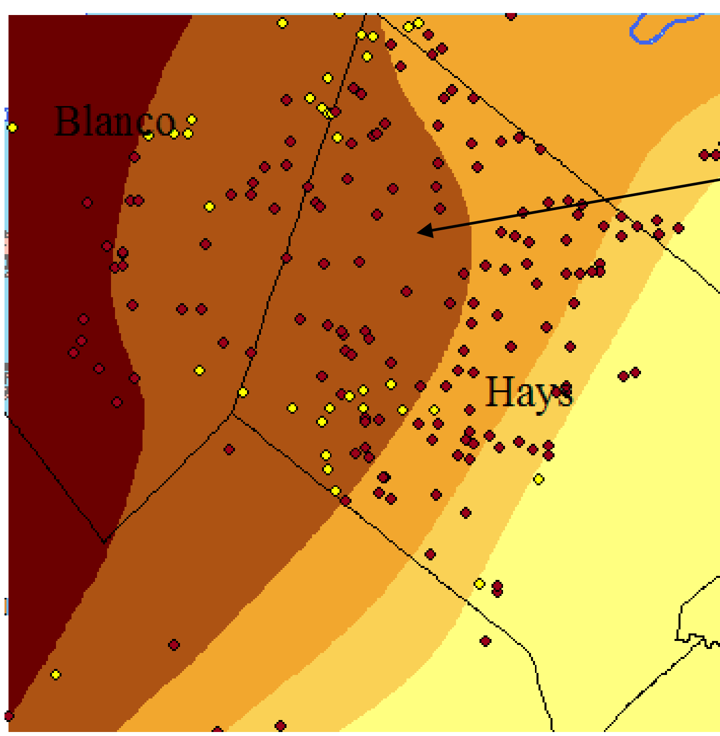
Attribute: select the column that you want to create the surface from (e.g, elevation)





Power and neighborhood to be defined.

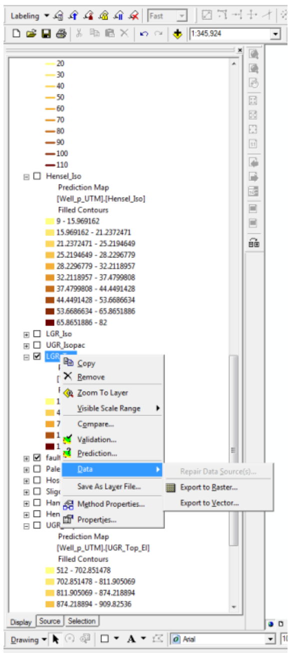
The resulted Surface looks like the following:

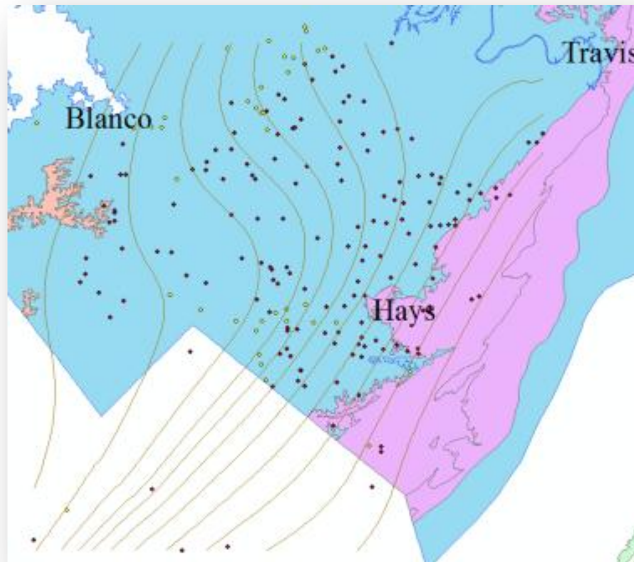


This surface is reasonable, no flat area in the middle and no bulls eyes

But we can’t use this surface to do calculations; it is not recognized as a raster. Next step is to convert this surface to vector:

Right click on resulted surface-→ Data-→ Export to vector

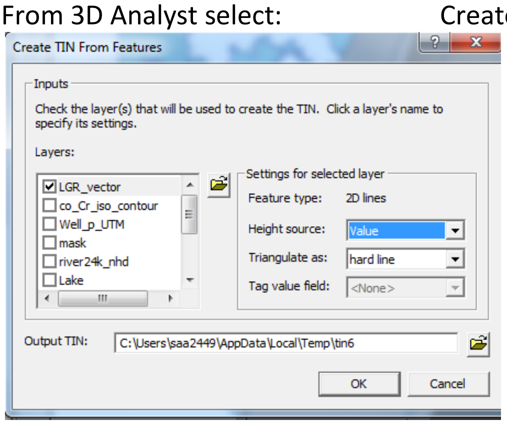


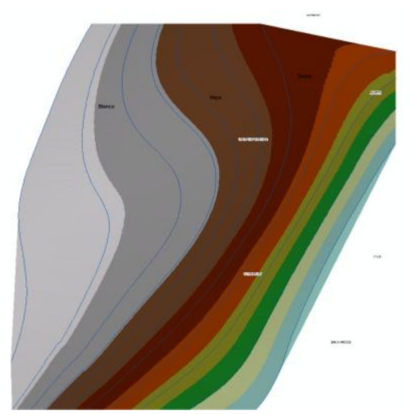


Vector from surface

Then Create a Tin from vector:

From 3D Analyst select: Create/Modify TIN-→ Create Tin from Feature

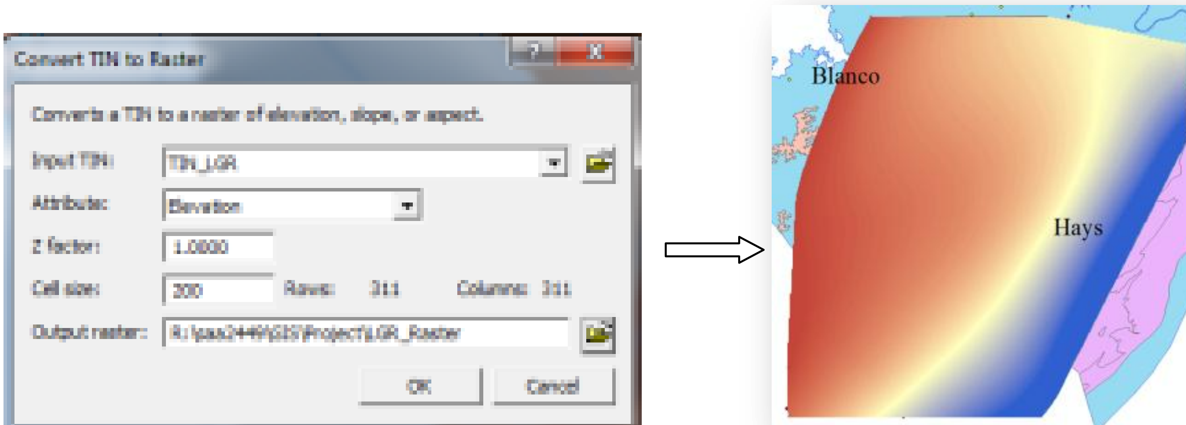




Tin from vector

Then Convert Tin to raster:

Spacial Analyst--→ convert-→ convert Tin to Raster



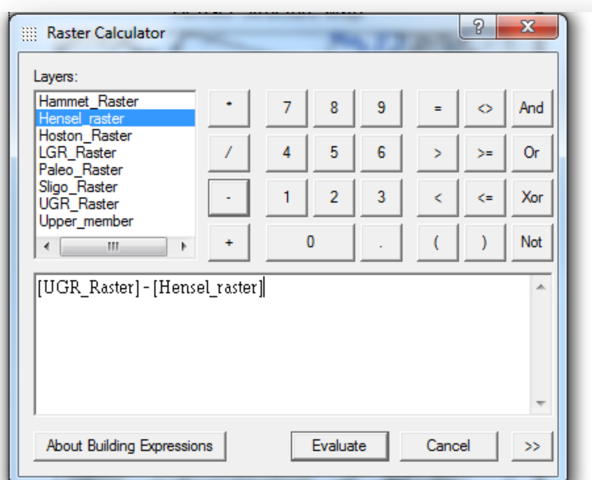
Finally, this raster has the actual elevations of the formation. Now we can start using raster calculator.

To calculate the volume of rock, we need to have Isopach/ thickness map. This means the top of the formation subtract from the bottom to calculate the thickness of a given formation. In this case, Trininty aquifier composed of several aquifiers, so, we need to divide the whole section to 4 members because they don't have different lithology that differ the porosity. Please see (figure 1).

Creating Isopach map/raster:

Spacial analyst -→raster calculator

For Upper member: GRU raster-Hensel raster-→ evaluate

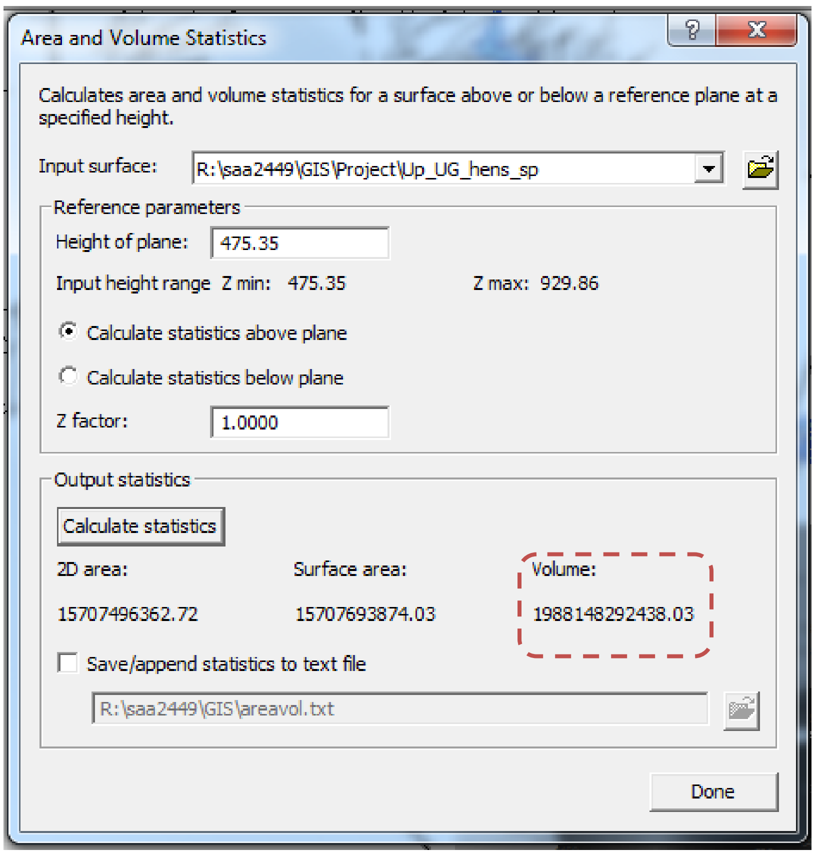


The new raster is Isopach, it was projected as NAD_1983_UTM_Zone_14N that makes problem in the X, Y and Z units. They should be all in feet or meter. In this case I changed the projection of the isopach to **NAD 1983_State plane_Texas_Central FIPS_4023_Feet.** Now the units are unified and all in feet and the z factor to be 1.

The Isopach can be used now to calculate the volume of the rock for the Upper member that composed of Upper Glen Rose (GRU) and Lower Glen Rose (LGR).

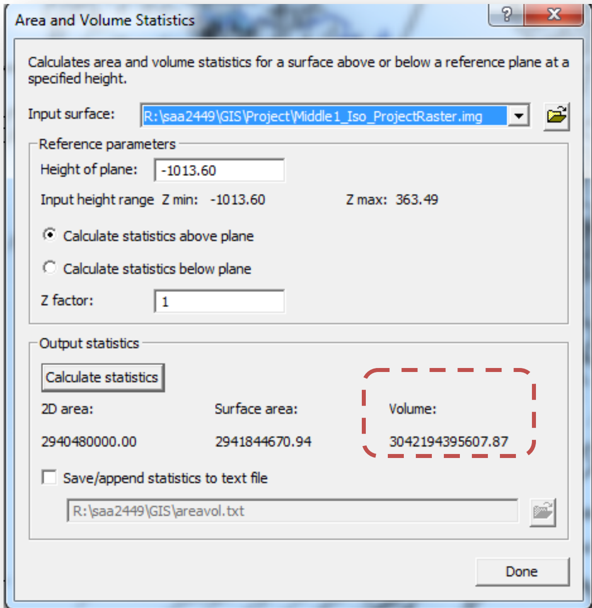
Open 3D analyst→Surface analysis-→ Area and Volume-→

Input the thickness raster-→ calculate statistics

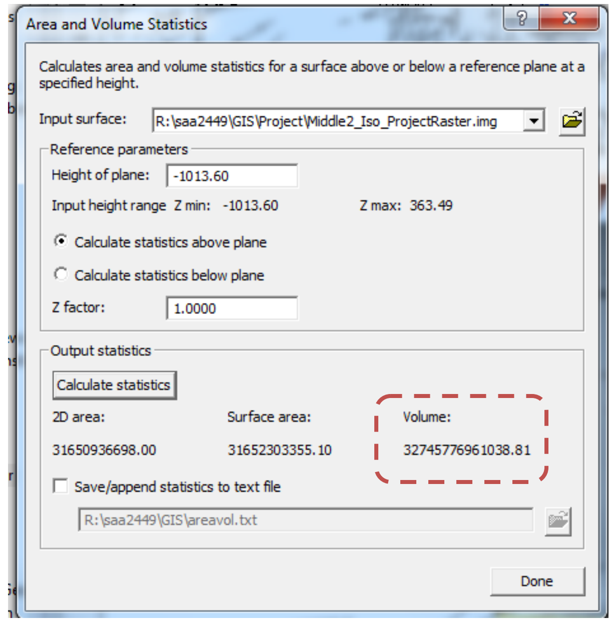


I repeated the above step 3 times to calculate the volume of the other three members that will be explained in Table 2

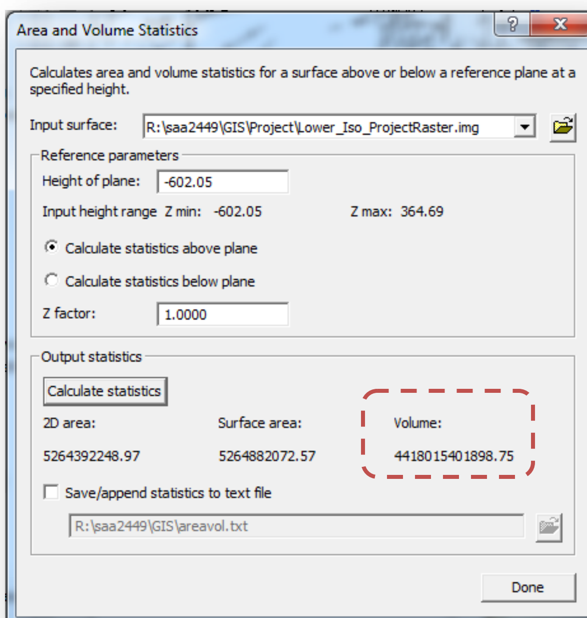
Middle member 1: Hensel (Khe)



Middle member 2: Cow Creek (Kcc) and Hammet (Kha)



Lower Member: Sligo (Ksl) and Hosston(Kho)



Now we have the volume of the rocks, we can find volume of water:

(Volume of water in Aquifer=Volume of rock x average porosity of the formation)

	Formations	Volume of rock (Cubic Feet)	Average porosity	Volume of water Cubic feet	Volume of water Cubic Meter	Volume of water Cubic kilometer
Upper member	Upper Glen Rose (KGRU)+Lower Glen Rose	1988148292438	0.06	119288897546	3377885426	3.377885426
Middle member 1	Hensel(Khe)	3042194395608	0.11	334641383517	9475988761	9.475988761
Middle member 2	Hammet(Kha)+Cow Creek	32745776961039	0.06	1964746617662	55635428800	55.6354288
Lower member	Sligo(Ksl)+Hosston(Kho)	4418015401899	0.06	265080924114	7506255894	7.506255894
Total				**2,683,757,822,839**	**75995558881**	**75.99555888**

Table 2: Volume of water calculation in Trinity Aquifer

The Total volume is approximately 76 cubic kilometers. Please note that this is a rough calculation or what is called back of the envelope calculation because:

- **The barriers such as (faults) have not been taken into account: This might be one of the short comings of ArcGIS, it doesn't work when you input the barriers using any of the methods when creating a surface.**
- **The average porosity is estimated: to have an accurate percentage, the average porosity should be calculated form type logs for each formation.**

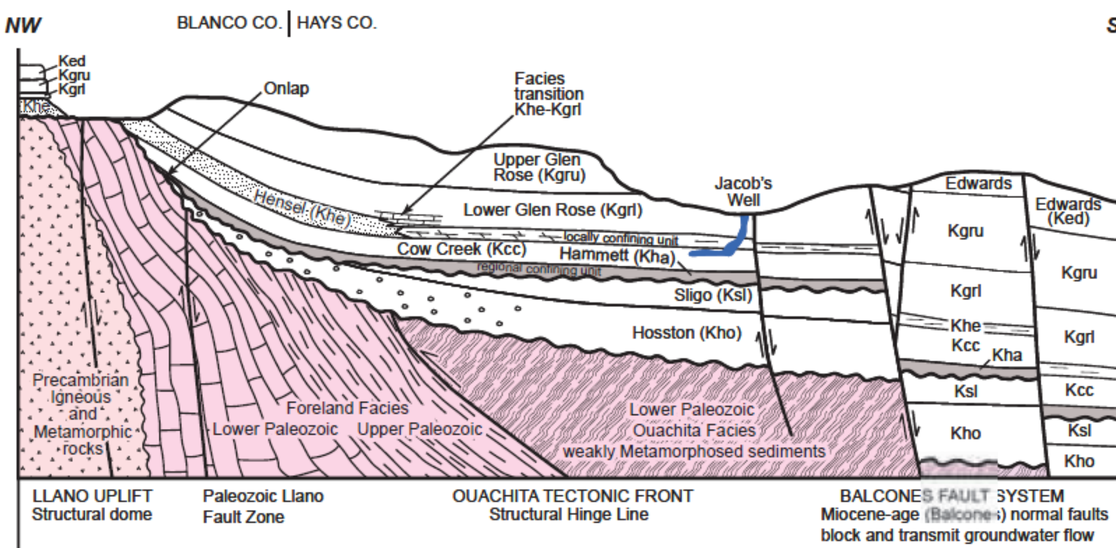
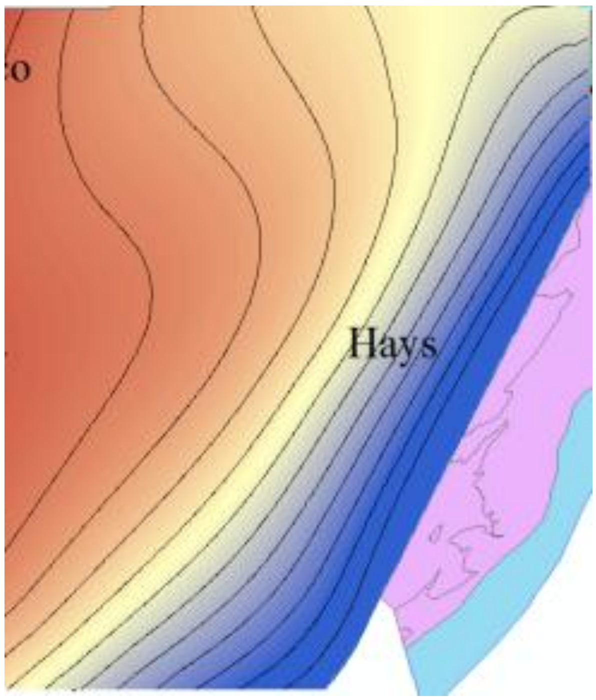


Figure modified from Broun and Wierman (2009); Stricklin and Amsbury (1974); Flawn (1961).

The Second objective of this project is to explore the potential of the software and understand what artifact of gridding algorithm does when a contour map of a surface creates and displays.

Using the rasters that I created for the surfaces, I have created counters as flows:

Spatial Analyst: Surface Analysis-→Contour



Contour lines of top of GRL formation.

I created structure maps for each aquifer. As discussed earlier, I couldn’t include the faults as barriers, so the offset of the faults will not be displayed. That is one of the differences between my maps and the hand contoured maps by Wierman et al, 2010 study. The following section is a comparison between the maps.

1- **Lower Glen Rose Structure** Map by Wierman et al, 2010. Northeast structure rotates to east northeast in Travis Co. Normal faulting within the lower Miocene age BFZ truncated the mapped east west plunging nose. Please note the offsets of the faults

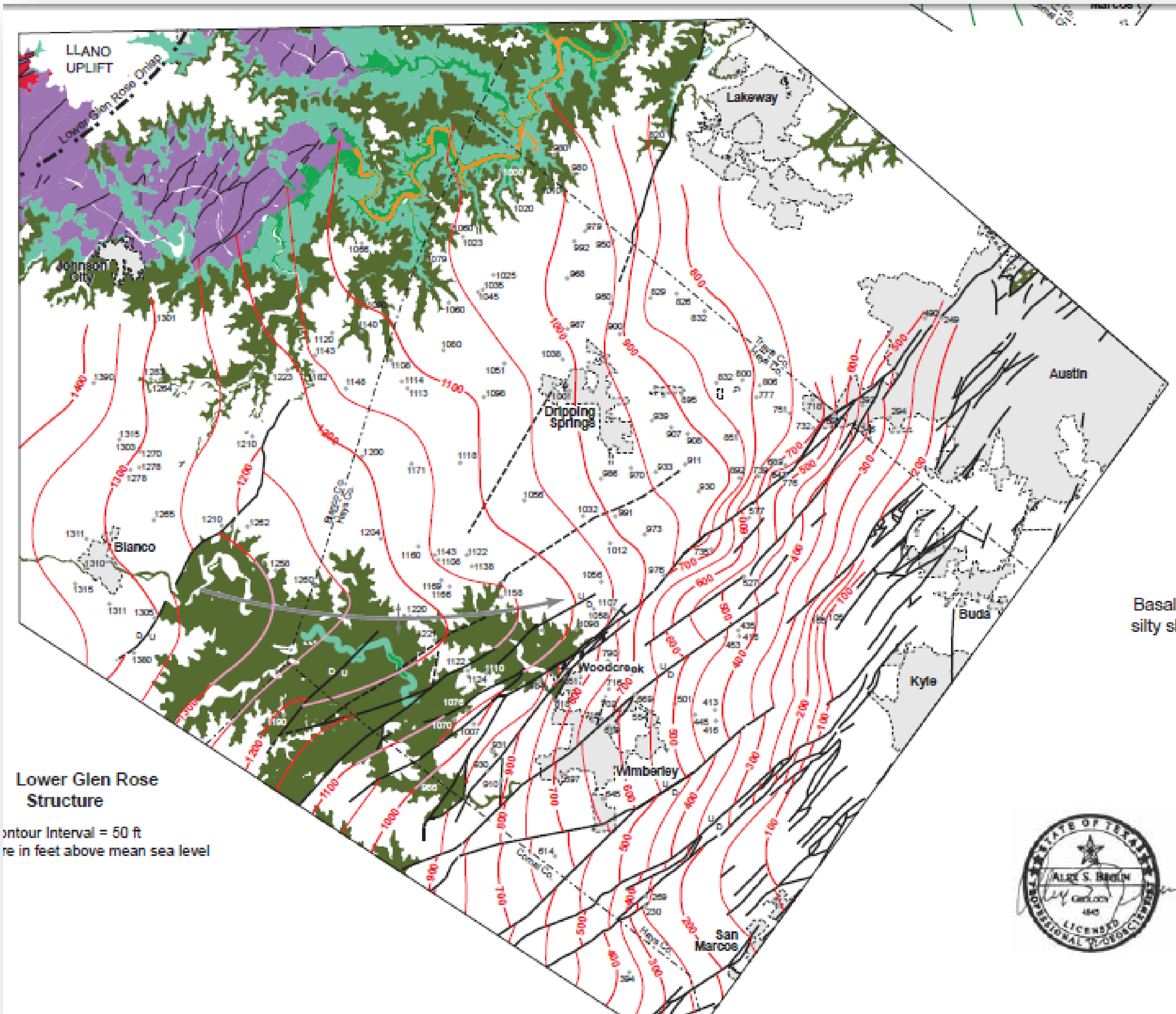


Figure 2: Hand contoured Lower Glen Rose Structure map by Wierman et al, 2010 Contour interval = 50 ft

The following is Lower Glen Structure map that I created using the interpolation methods by ArcGIS. Please note that the faults are shown here without being a barrier and showing offsets. In general, the map is displaying the trend (north east structure) and the same range of the highest elevations and lowest which is consistent with the hand contoured map

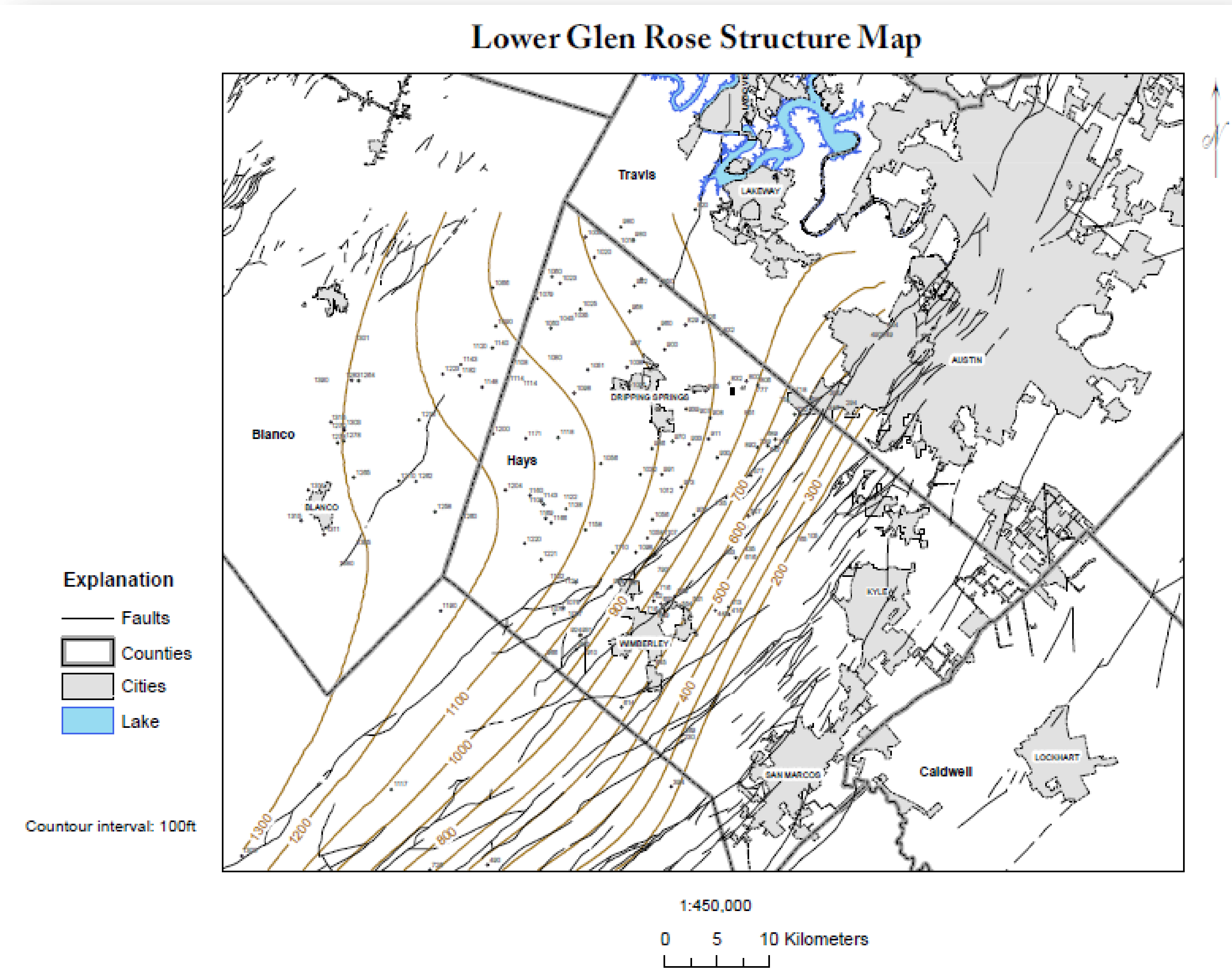


Figure 3: Lower Glen Rose Structure Map created by ArcGIS
Contour interval: 100ft

2- Hammett Structure Map: The map shows regular dip to the east-north east across the study area. Faulting along BFZ truncates the mapped plunging nose.

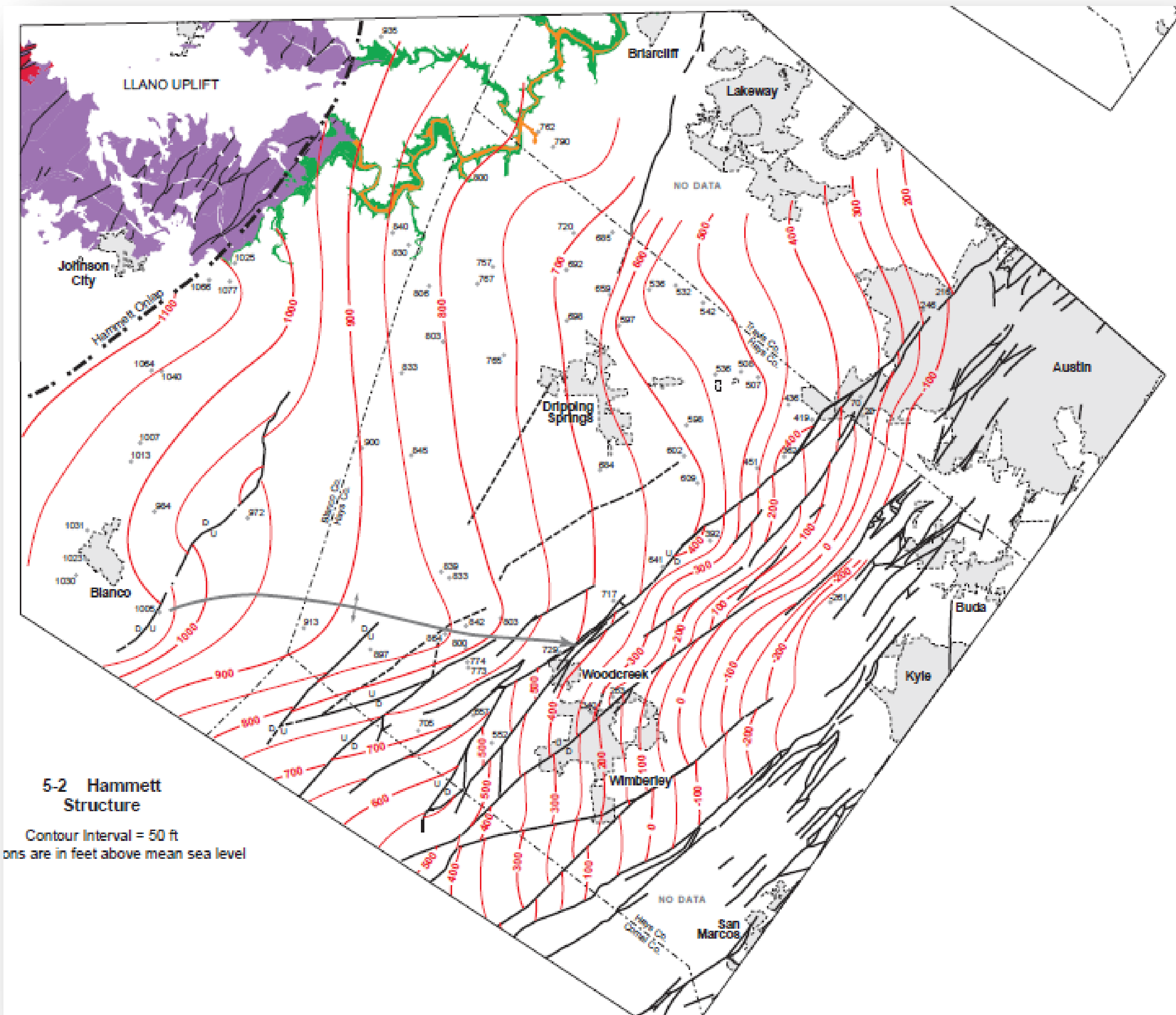


Figure 4: Hammett structure Hand contoured map by Wierman et al, 2010. Contour interval: 100ft

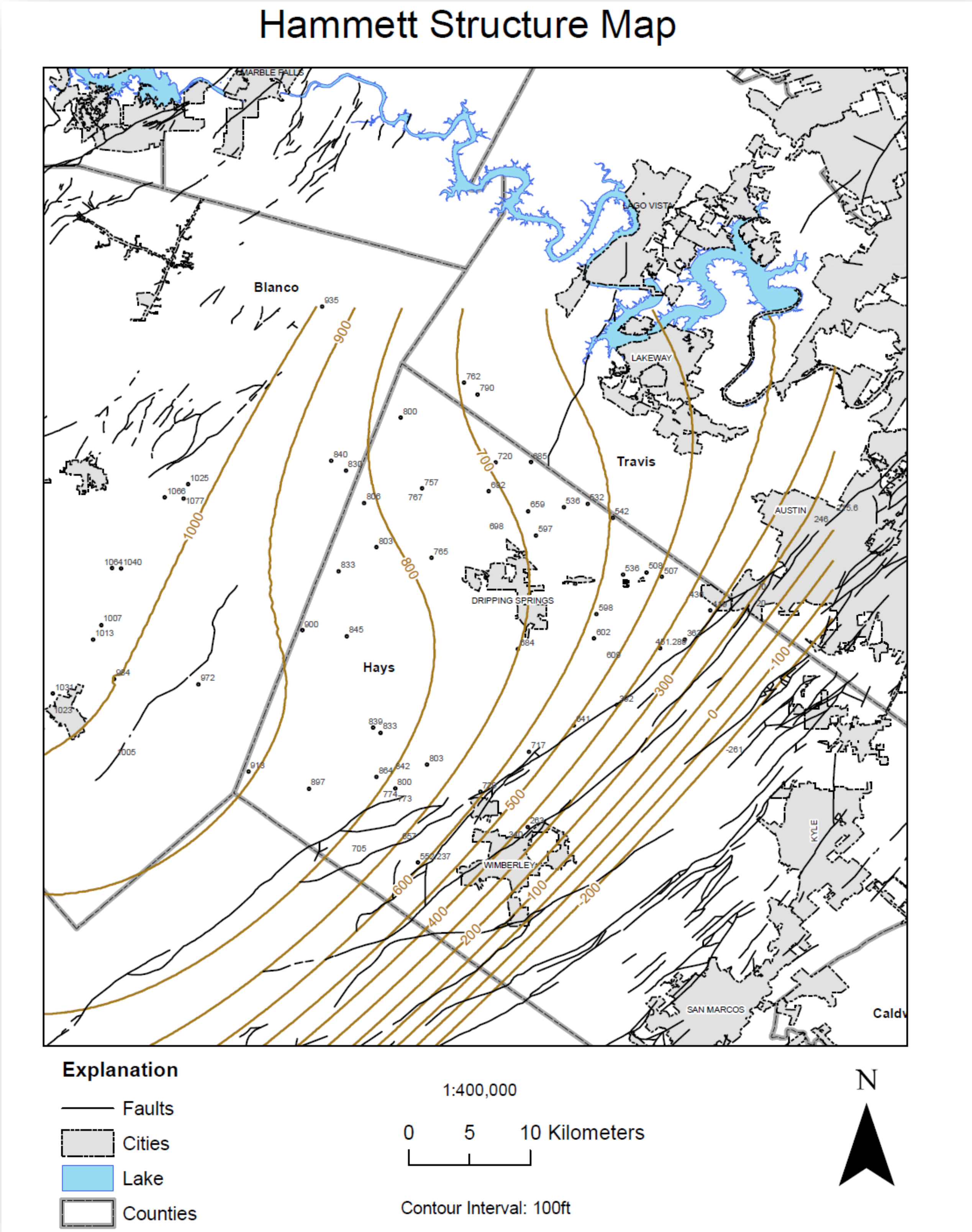


Figure 5: Hamett Structure map using ArcGIS. Contuor interval: 100ft

3- Hensel structure map Eastward trending structural dip in Blanco County. My map is giving a general trend of the structure.

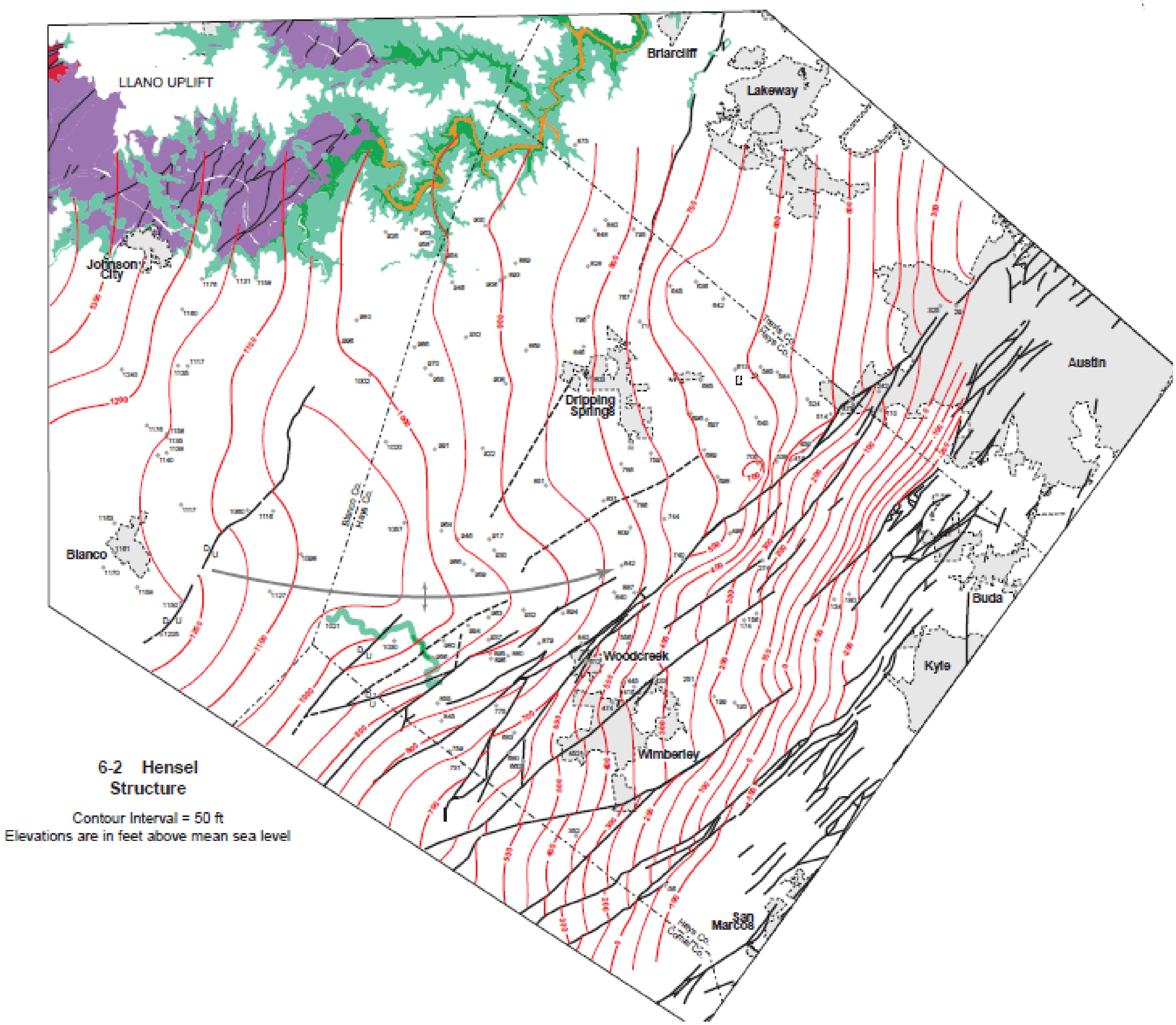


Figure6: Hensel structure Hand contoured map by Wierman et al, 2010. Contour interval: 50 ft

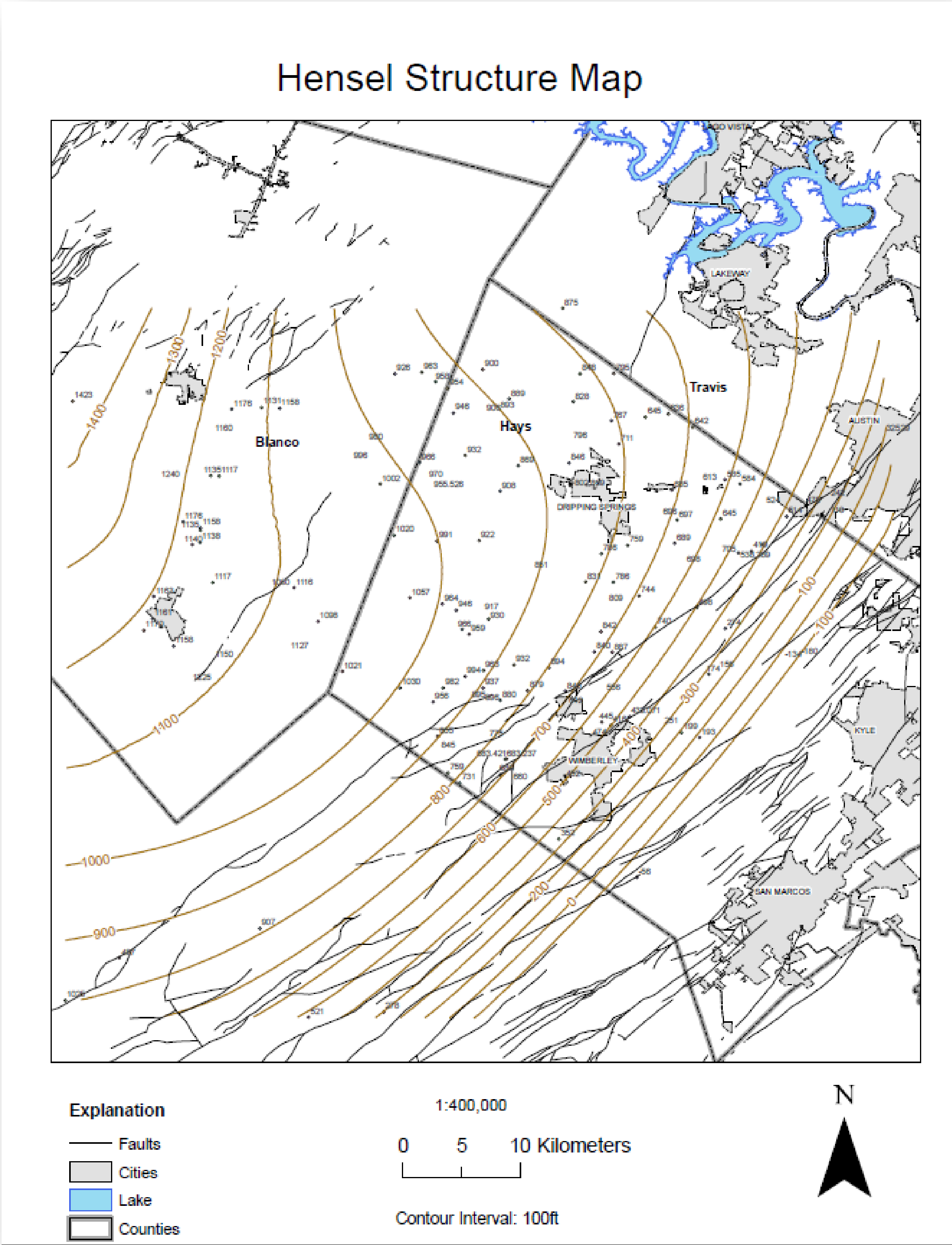


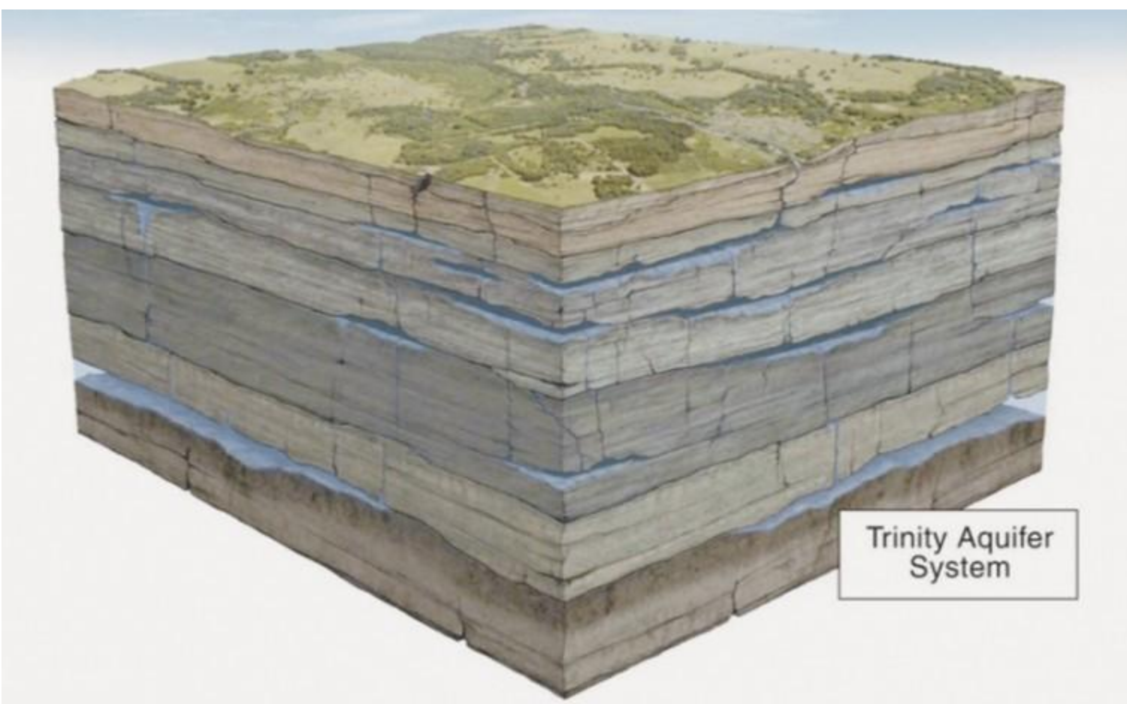
Figure7: Hensel structure created by ArcGIS. Countour interval 100ft.

Conclusion:

Trinity Aquifer is one of the major aquifers and one of the ground water resources in Texas. It would be interesting if we know the volume of the water in this major aquifer. In this study, I used data from previous studies and used different tools of ArcGIS to calculate the volume of water in trinity aquifer which is approximately 76 cubic kilometers. This study area is within Blanco, Hays, and Travis Counties, Central Texas

This is a rough calculation without taking the barriers into consideration. Also, the used average porosity is estimated. The accurate percentage of the porosity should be found in type logs. If we find a way to include the barriers, ArcGIS will be a very useful tool to find a reasonable estimation of the volume of water in an aquifer which is an important resource.

There are tools to create structure and Isopach maps from point features in ArcGIS. We need to explore to find the way that gives the best or the more realistic display of the structure. After applying a number of tools, I realized that Geostatistical analyst method is a good method to create a surface with no zero values of the points and gives reasonable a trend.



References

D.A. Wierman, A.S. Broun, and B.B Hunt, 2010, Hydrogeologic Atlas of the Hill Country Trinity Aquifer, Blanco Pedernales Groundwater Conservation Districts, July 2010.

http://www.twdb.state.tx.us/GwRD/GMA/PDF/TrinityAquifer.pdf

http://www.capcog.org/information-clearinghouse/geospatial-data/#aquifers