GIS in Water Resources Exercise #3 Solution

Part 1.

1.1 Hand Calculations

(i) The standard ESRI surface slope function

Grid size 10 m Diagonal distance= 14.142 m

47.5	48	47.7	50.6	48.3
45.1	45.8	46.8	48.6	47.6
45	46.1	46.4	47.9	47.4
45.4	46.1	47	48.6	47.7

dz/dx= -0.125
dz/dy= -0.0900

rise/run= 0.154029
Slope= 0.152828 radians
8.756408 degree

Aspect -2.19482 radians
-125.754 degree
Result as angle clockwise from North **234.2461** degree

(This is an Excel Object so you can click on it to see the formulas)

(ii) The 8 direction pour point model

ii) D8 Center cell 46.8

	With cells	Slope
Slope 1	48.6	-0.180
Slope 128	50.6	-0.269
Slope 64	47.7	-0.090
Slope 32	48	-0.085
Slope 16	45.8	**0.100**
Slope 8	46.1	0.049
Slope 4	46.4	0.040
Slope 2	47.9	-0.078

Maximum slope to cell in direction 16

Direction Encoding

32	64	128
16		1
8	4	2

(This is an Excel Object so you can click on it to see the formulas)

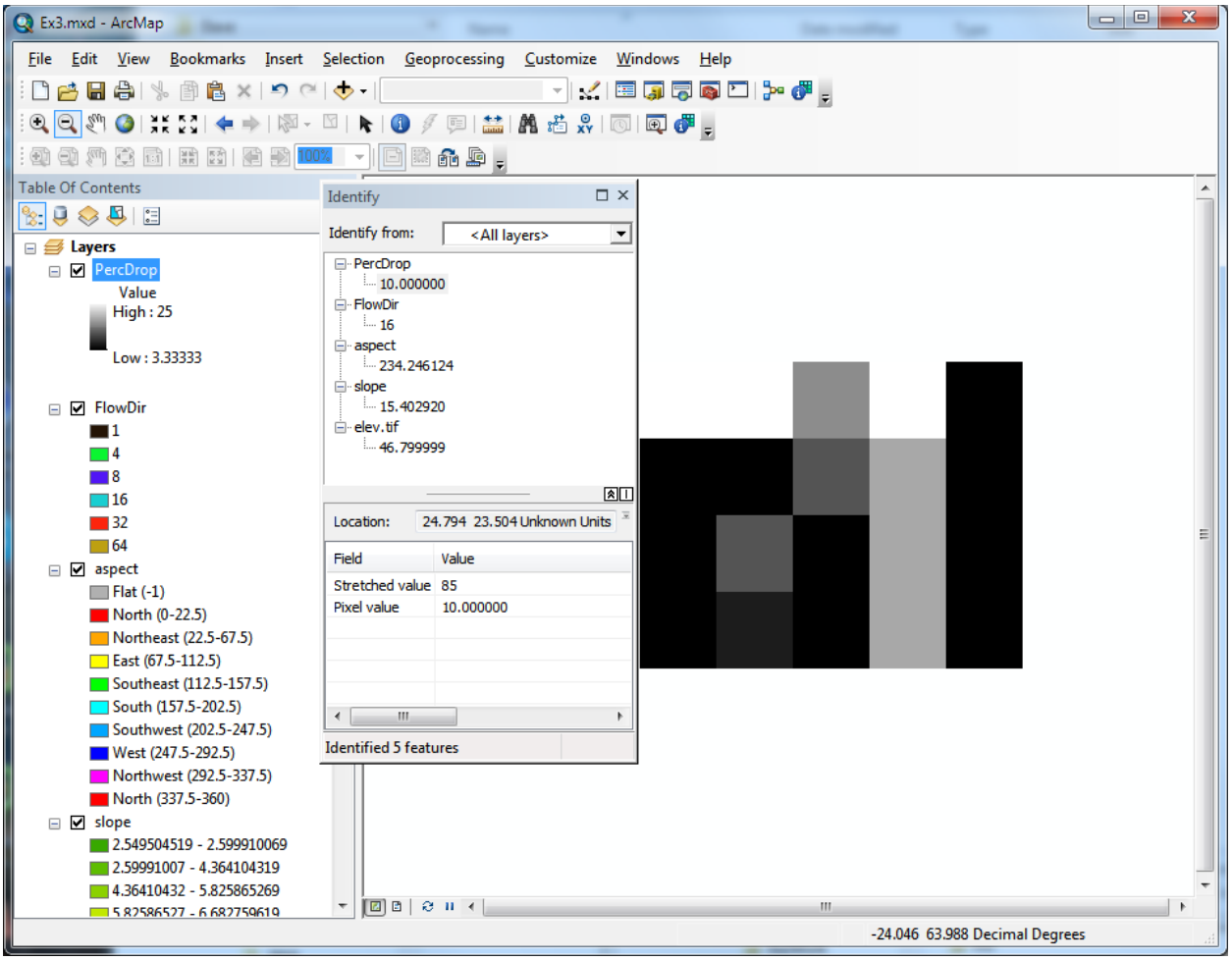
Note that the steepest 8 direction pour point model slope in direction 64 is:

$$\frac{\text{center cell} - \text{side cell } 16}{\text{cell size}} = \frac{46.8 - 45.8}{10} = 0.10$$

D8 slope = **0.10**
D8 flow direction = **16**

1.2. Verifying calculations using ArcGIS

The values at cell A of Slope = 15.4%, Aspect = 234.25 deg, PercDrop = 10% and FlowDir=16 correspond to the hand calculations.

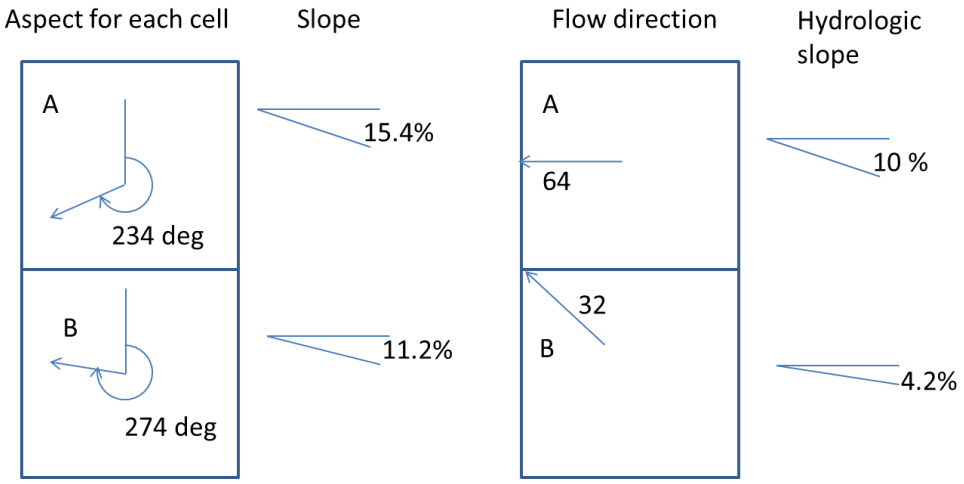


Other values are obtained similarly from identifying values in the ArcMap output.

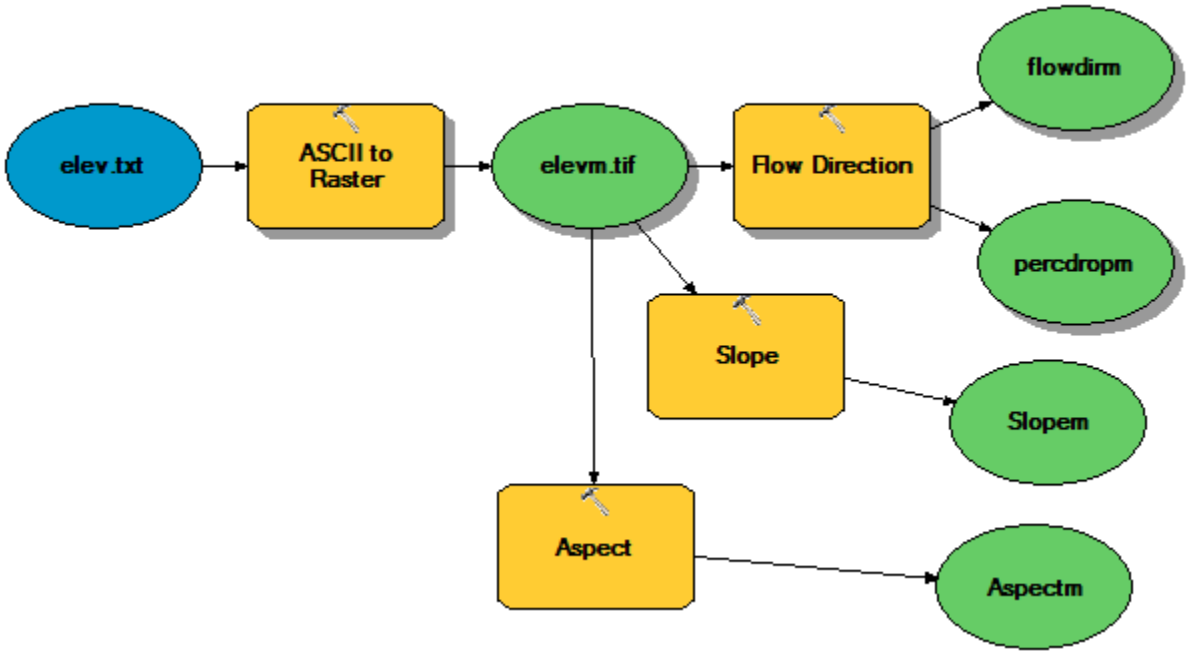
Table of ArcGIS computed quantities

Cell	A	B
Slope	15.403	11.159
Aspect	234.25	274.50
Hydrologic Slope (Percentage drop)	10%	4.24%
Flow Direction	16	32

Note that for the Cell B above ArcGIS (at least my version) reports 3.3%, so if students report 3.3% they should not be penalized. This appears to be a bug in ArcGIS, because based on the elevation values the percentage drop is 4.24%.



1.3 Model Builder model to do the above



This tool is available on http://www.neng.usu.edu/dtarb/giswr/2011/Ex3.tbx if you want to download and look at it.

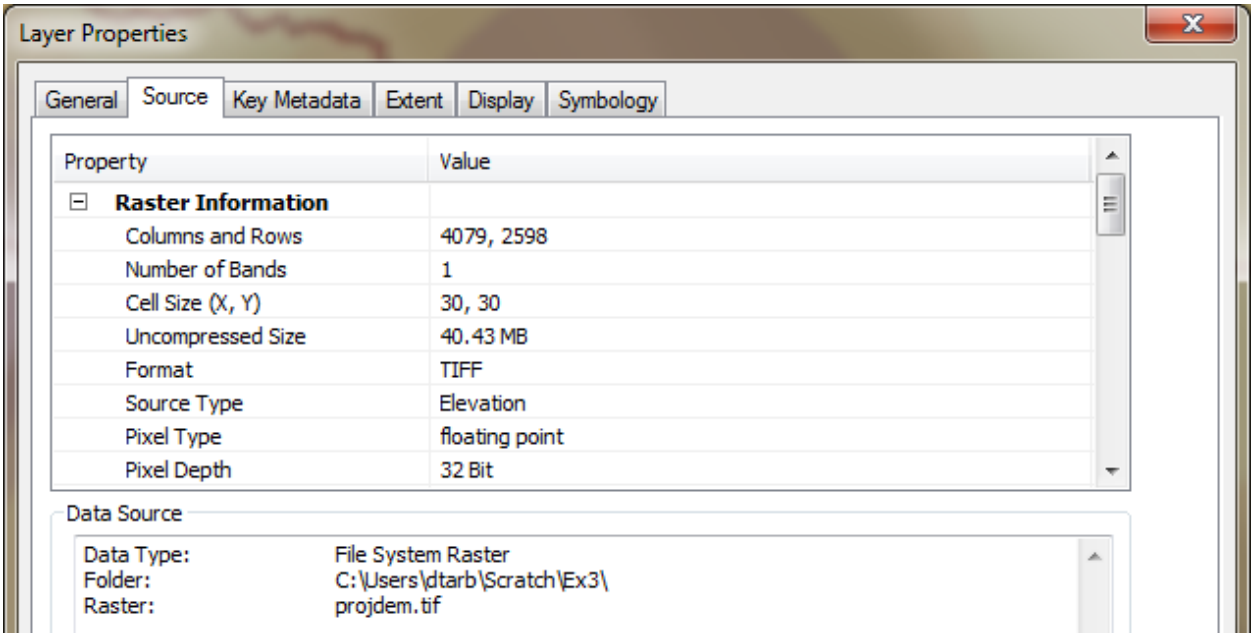
Table of data ranges from model output using the file demo.asc

Grid	Minimum	Maximum
Flow Direction	1	128
Hydrologic Slope (percentage drop)	0.067%	146.67%
Slope	0	148.79%
Aspect (degrees from north)	-1	360

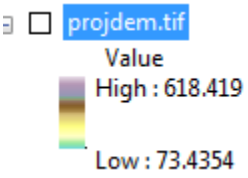
-1 for aspect is used to represent flat grid cells

Part 2.

Projecting the DEM

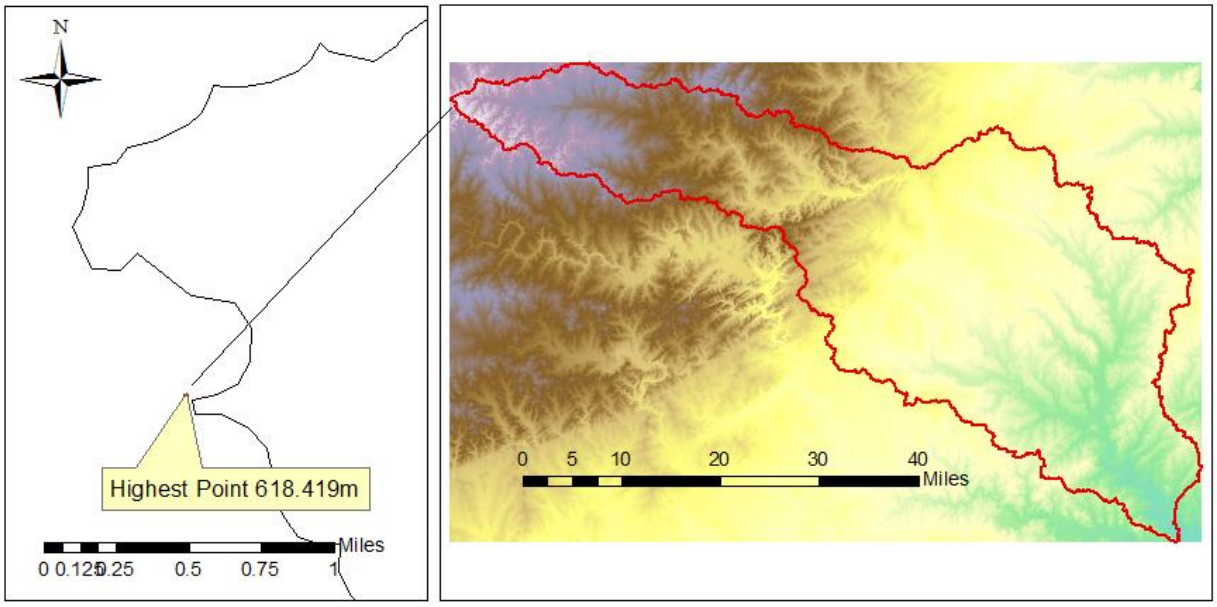


4079 columns, 2598 rows. The cell size is 30 m.The minimum and maximum elevations in the projected DEM 'projdem' are shown below.



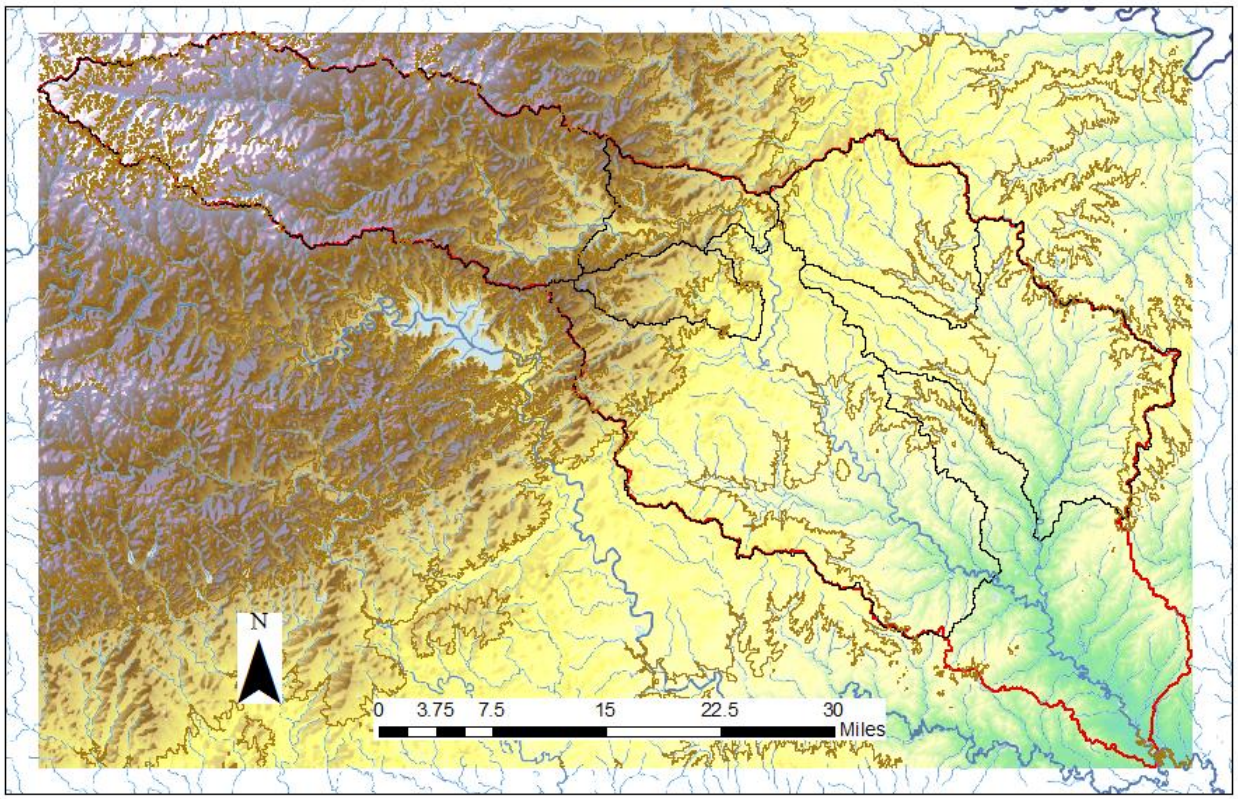
Exploring the DEM

Highest elevation point in the San Marcos DEM



Contours and Hillshade

San Marcos Topography



The layout above uses 80 m contours and the hillshade effect associated with the DEM to illustrate the San Marcos Topography. The Basin boundary (red) and subwatersheds (black) are shown.

Zonal Average Calculation

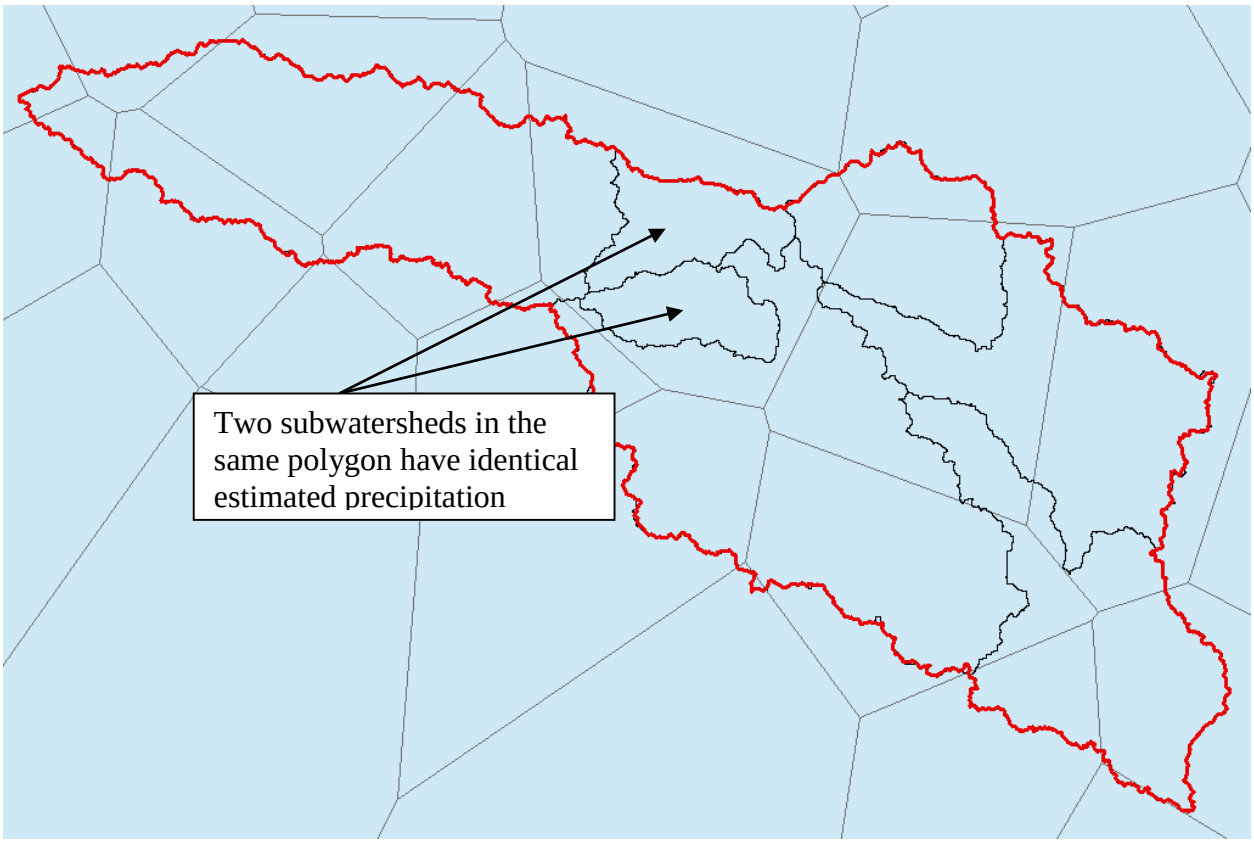
HydroID	Name	Elevation Range (m)	Elevation mean (m)
330	Plum Ck at Lockhart, Tx	137.2	189.9
331	Blanco Rv at Wimberley, Tx	372.8	418.6
332	Blanco Rv nr Kyle, Tx	212.3	288.6
333	San Marcos Rv at San Marcos, Tx	218.3	266.2
334	Plum Ck nr Luling, Tx	115.2	152.0
335	San Marcos Rv at Luling, Tx	310.7	183.5

The subwatershed with highest mean elevation is Blanco at Wimberley (Note the point with the highest elevation is near the upper end of this subwatershed). The largest elevation range is found in the Blanco at Wimberley subwatershed too.

6. Calculation of Area Average Precipitation using Thiessen Polygons

HydroID	Name	Precipitation (in)
330	Plum Ck at Lockhart, Tx	36.37
331	Blanco Rv at Wimberley, Tx	37.83
332	Blanco Rv nr Kyle, Tx	40.48
333	San Marcos Rv at San Marcos, Tx	40.48
334	Plum Ck nr Luling, Tx	36.52
335	San Marcos Rv at Luling, Tx	37.59

The highest mean precipitation is found for the San Marcos River at San Marcos and Blanco River near Kyle watersheds. These are identical, because they are both in the same polygon.



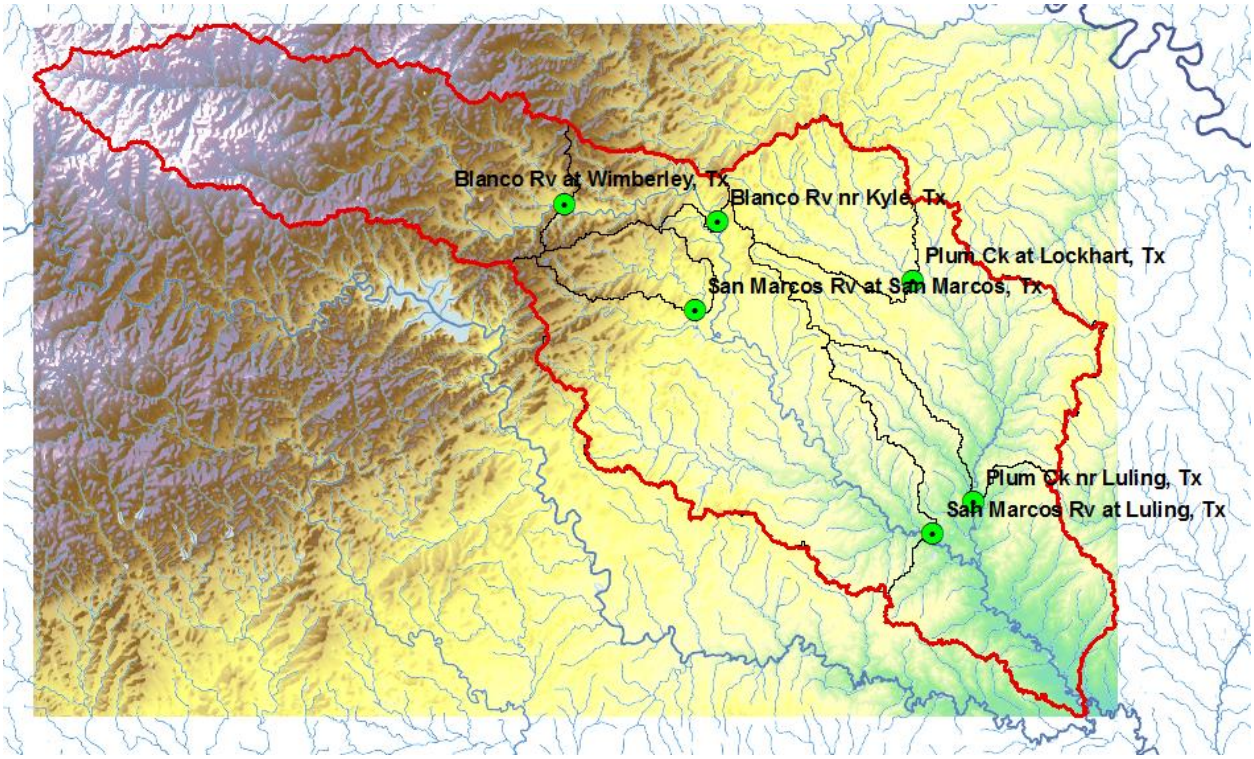
7. Estimate basin average mean annual precipitation using Spatial Interpolation/Surface fitting

HydroID	Name	Mean Precip (in) by Tension Spline
330	Plum Ck at Lockhart, Tx	36.22
331	Blanco Rv at Wimberley, Tx	37.89
332	Blanco Rv nr Kyle, Tx	39.79
333	San Marcos Rv at San Marcos, Tx	39.66
334	Plum Ck nr Luling, Tx	36.46
335	San Marcos Rv at Luling, Tx	37.99

Blanco Rv nr Kyle, TX has the highest mean precipitation estimated from Tension Spline Interpolation.

Runoff Coefficients

The following map shows stream gages at the outlet of each subwatershed



This indicates the following subwatersheds which comprise each watershed

Watershed	**Subwatersheds**
Plum Ck at Lockhart, TX	Plum Ck at Lockhart, TX
Blanco Rv at Wimberley, TX	Blanco Rv at Wimberley, TX
Blanco Rv nr Kyle, TX	Blanco Rv nr Kyle, TX Blanco Rv at Wimberley, TX
San Marcos Rv at San Marcos, TX	San Marcos Rv at San Marcos, TX
Plum Ck nr Luling, TX	Plum Ck nr Luling, TX Plum Ck at Lockhart, TX
San Marcos Rv at Luling, TX	Blanco Rv nr Kyle, TX Blanco Rv at Wimberley, TX San Marcos Rv at San Marcos, TX San Marcos Rv at Luling, TX

Runoff ratio calculations are in the following spreadsheet (embedded object so you can see calculations in electronic version)

Subwatershed Precip from Thiessen Polygons

#	Name	Area (m^2)	Mean Precip (in)	Precip Volume (ft^3)
1	Plum Ck at Lockhart, Tx	2.91E+08	36.37	9.485E+09
2	Blanco Rv at Wimberley, Tx	9.21E+08	37.83	3.125E+10
3	Blanco Rv nr Kyle, Tx	1.49E+08	40.48	5.416E+09
4	San Marcos Rv at San Marcos, Tx	1.27E+08	40.48	4.599E+09
5	Plum Ck nr Luling, Tx	5.21E+08	36.52	1.708E+10
6	San Marcos Rv at Luling, Tx	9.8E+08	37.59	3.305E+10

Watersheds

#	Name	Flow (cfs)	Flow Volume (ft^3)	Subwater-sheds that comprise watershed	Precip volume subwater-shed sum	**Runoff ratio**
1	Plum Ck at Lockhart, Tx	49.00	1546322400	1	9485325535	**0.16302**
2	Blanco Rv at Wimberley, Tx	142.00	4481179200	2	3.1254E+10	**0.14338**
3	Blanco Rv nr Kyle, Tx	165.00	5207004000	2, 3	3.667E+10	**0.14200**
4	San Marcos Rv at San Marcos, Tx	176.00	5554137600	4	4598624672	**1.20778**
5	Plum Ck nr Luling, Tx	114.00	3597566400	1, 5	2.6562E+10	**0.13544**
6	San Marcos Rv at Luling, Tx	408.00	12875500800	2, 3, 4, 6	7.4322E+10	**0.17324**

In the top table Precip volume is Mean precip * Area divided by 12 x 0.3048^2 to obtain volume in ft^3. In the bottom table Flow volume is obtained from flow in cfs by multiplying by 365.25*24*3600*3600. The subwatersheds that comprise each watershed are identified and precip volume obtained by summing these. Runoff ratio is then flow volume/precip volume.

The runoff ratio for the San Marcos river at San Marcos is anomalously high due to flow from springs that are fed by precipitation that recharges the Edwards Aquifer outside the watershed. This anomalous high flow attenuates downstream. Plum Creek at Lockhart is also in the vicinity of where the Edwards aquifer outcrops and has a slightly higher runoff ratio so likely gets some spring contributions too. Over all the other watersheds, runoff ratio is pretty consistent between 0.11 and 0.15, which seems about right for this region.