Severe Flooding in Houston

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CE 394K: GIS in Water Resources

Term Project

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1. Houston's Recent Severe Flooding

In the past two years, Houston has experienced extreme flooding events on Memorial Day 2015 and April 2016, when the picture on the title page was taken from an office building. Each of these major floods resulted in the destruction of many homes, cars, and other property. The recent flooding has also resulted in loss of productivity for the city, as many people could not drive to work and some office buildings even had to be shut down for up to two weeks. **Figure 1** depicts how the severe flooding in Houston can cause such problems with transportation, as the excess precipitation can easily block all of the cars travling on a highway.

Figure 1. I-45 North blocked during Houston's Memorial Day 2015 flood event.[2]

To initially investigate the recent problems with Houston's flooding, streams from NHDPlus and raster data of the DEM were obtained. A part of Houston greatly affected by the recent flooding was the Buffalo Bayou Watershed. The park around the bayou was destroyed and there have been major cleanup and restoration efforts to rebuild its recreational

space and trails. After downloading shapefiles for the Harris County watersheds from the City of Houston open GIS database, it was easy to extract by mask for Buffalo Bayou Watershed and see the USGS digital elevation model's small changes in elevation for only the Buffalo Bayou watershed in **Figure 2.**

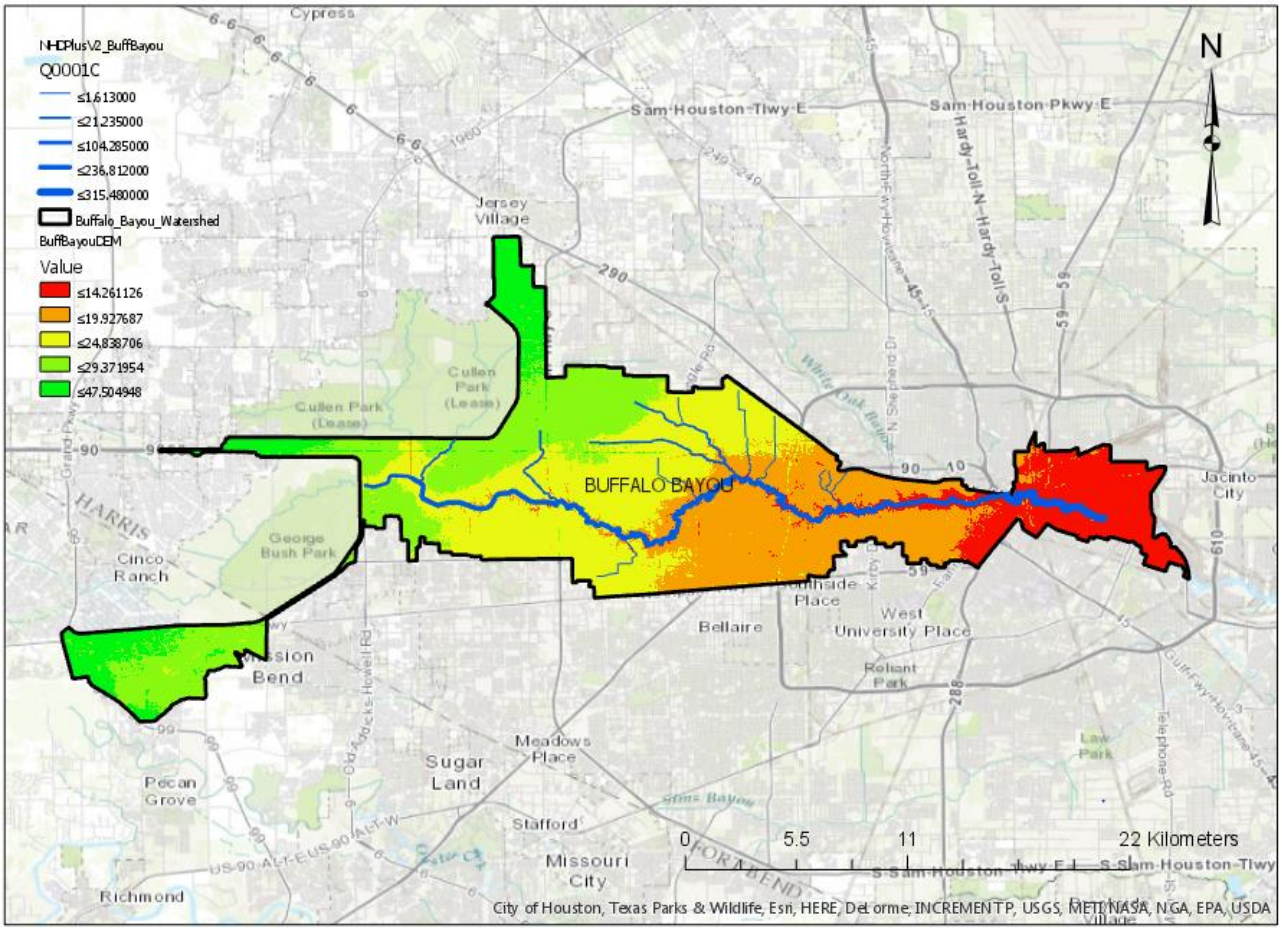

Figure 2. Buffalo Bayou Watershed with NHDPlus flowlines and extracted watershed DEM.

Looking at the Buffalo Bayou watershed's digital elevation model (DEM) and the low variation between symbology classes in the legend, this is clearly an example of Houston's flat topography that could contribute to its flood problems. For example, the Memorial Day flooding affected both Houston and Austin, but the damage in Houston was greater from the same storm. With spatial analysis, the lower slopes of land in Houston were determined and compared to those of the Austin area to investigate the difference in severity of recent flooding in the two cities. Land cover information was also acquired and compared to see if Houston has more developed area than Austin, which would mean that the impervious surfaces likely further contribute to flooding problems.

2. Houston and Austin Spatial Analyses

The analysis starts with creating a shapefile for the Houston area by combining the Harris County watersheds with the Dissolve tool. Note that this also includes the Greater Houston area, as the city's perimeter is unusually shaped and crosses through all of these watersheds.

Figure 3. Houston area watersheds and shapefile.

The same sort of shapefile was made for the Austin area. This way, spatial analyses could be performed on both cities for comparison. By observing the number of watersheds in the area, Austin has a lot more natural drainage than Houston.

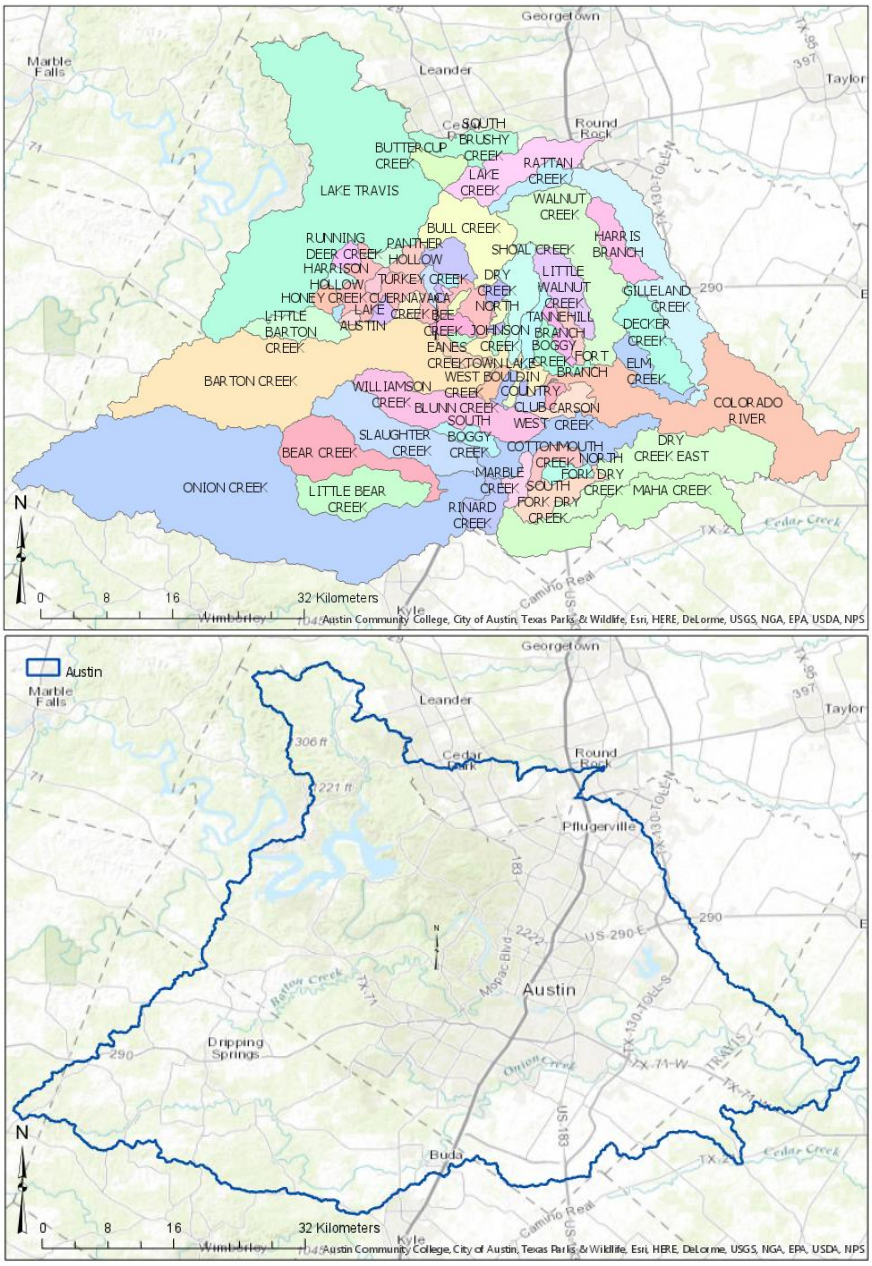

Figure 4. Austin area watersheds and shapefile.

The DEM for each area was found from USGS, and then Extract by Mask was used to keep the DEM within each shapefile. The original rasters acquired were for Houston-Galveston and a few counties surrounding Austin. Two adjacent rasters were obtained for

the Austin area and subsequently combined with the Mosaic Rasters Properties tool Blend function.

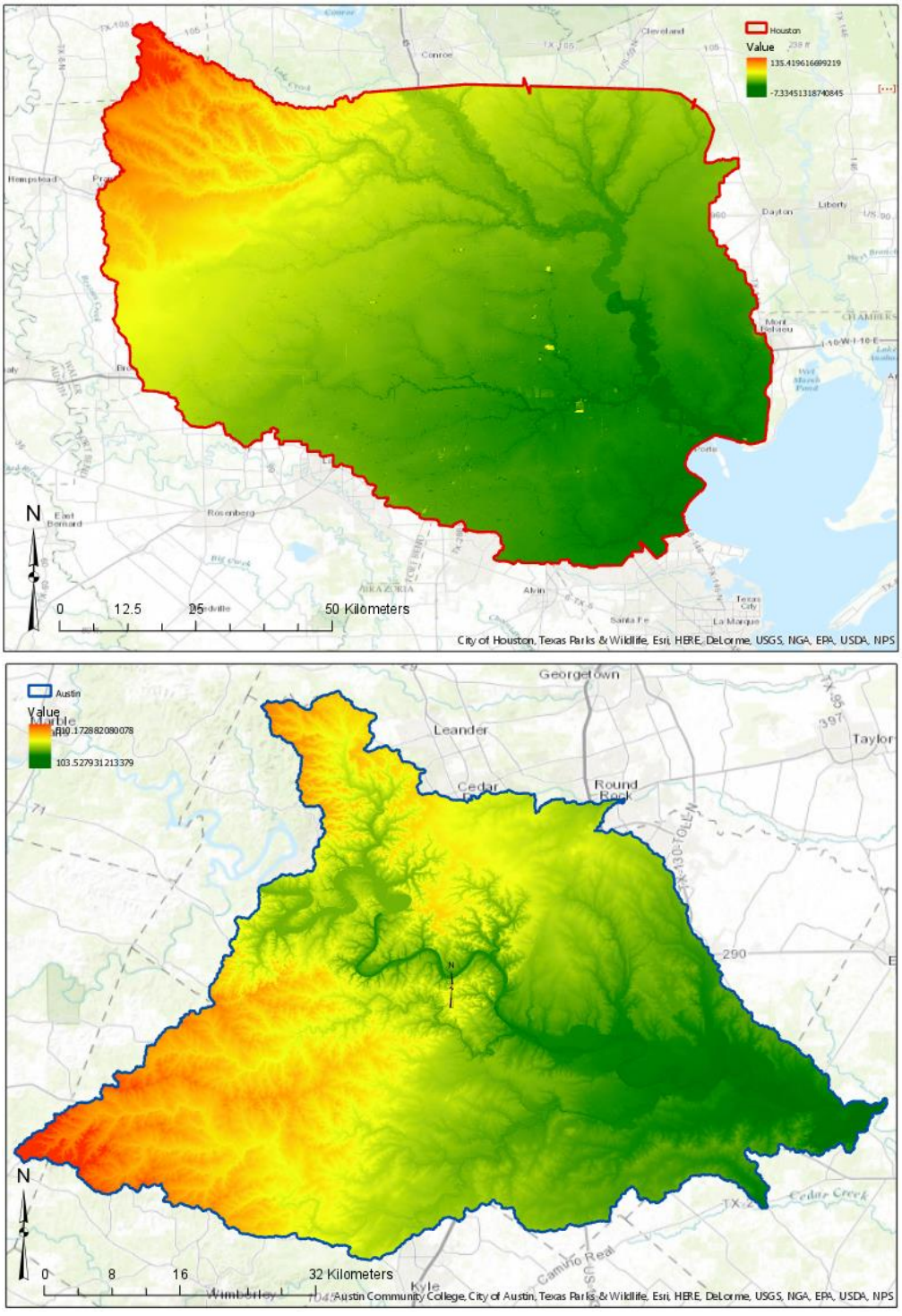

Figure 5. Houston DEM and Austin DEM.

After these rasters from the USGS National Elevation Dataset were extracted into a new DEM raster within each shapefile (**Figure 5**), a spatial analysis tool was created in ModelBuilder to obtain slopes from each city's DEM. The DEMs were already rasters, which made it simple to obtain slope values and then create slope rasters for each city.

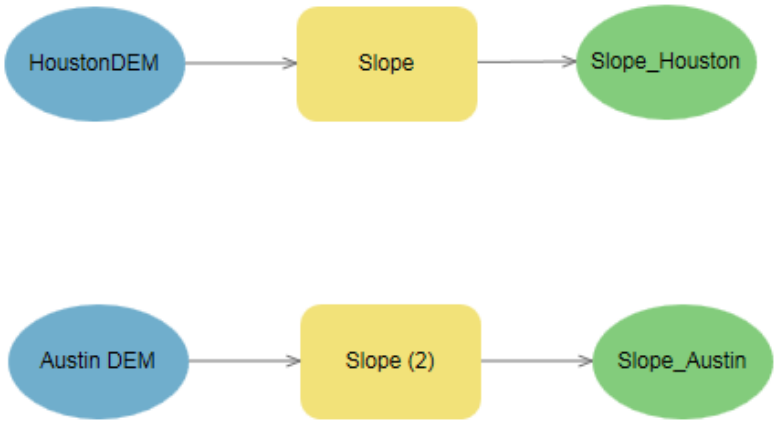

Figure 6. ModelBuilder tool for calculation of slopes for Houston and Austin.

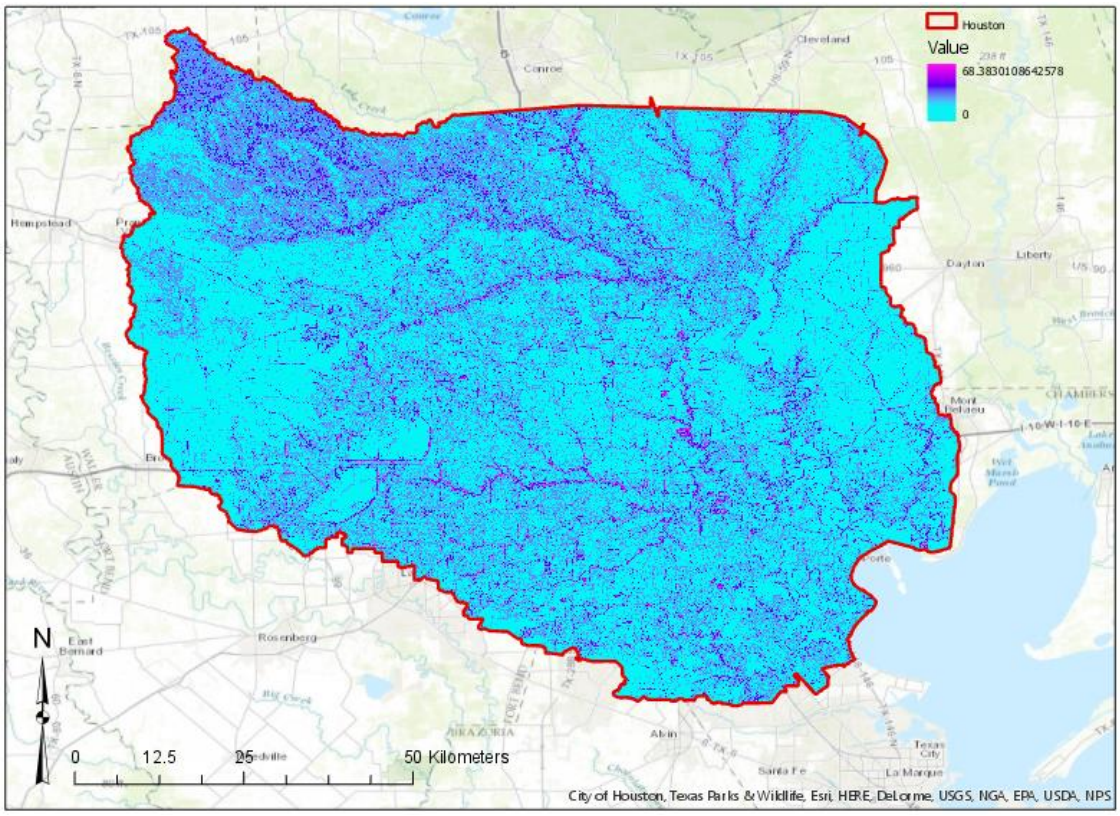

Figure 7. Houston slope values.

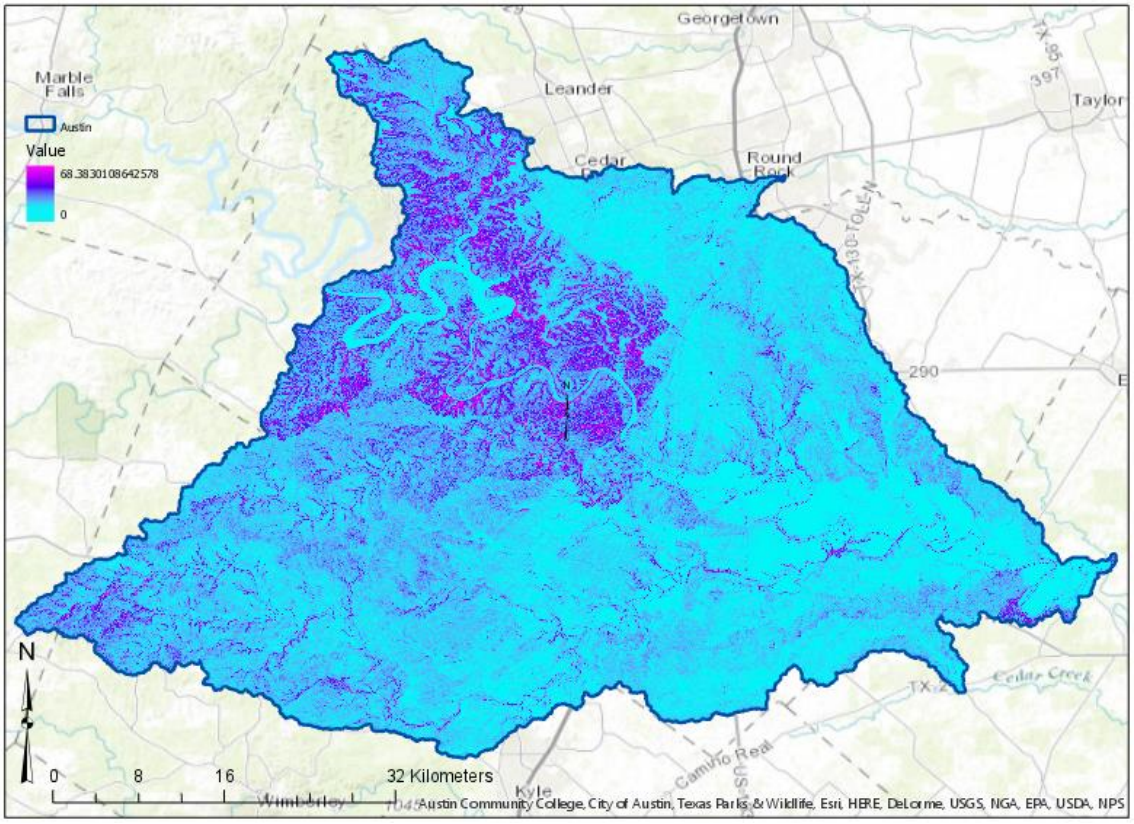

Figure 8. Austin slope values.

For a quantitative comparison, the ModelBuilder tool was taken a step further with the Zonal Statistics tool (**Figure 9**) to create a statistical table of the slope values for each city (**Table 1**). The tool was run twice to calculate the mean and standard deviation.

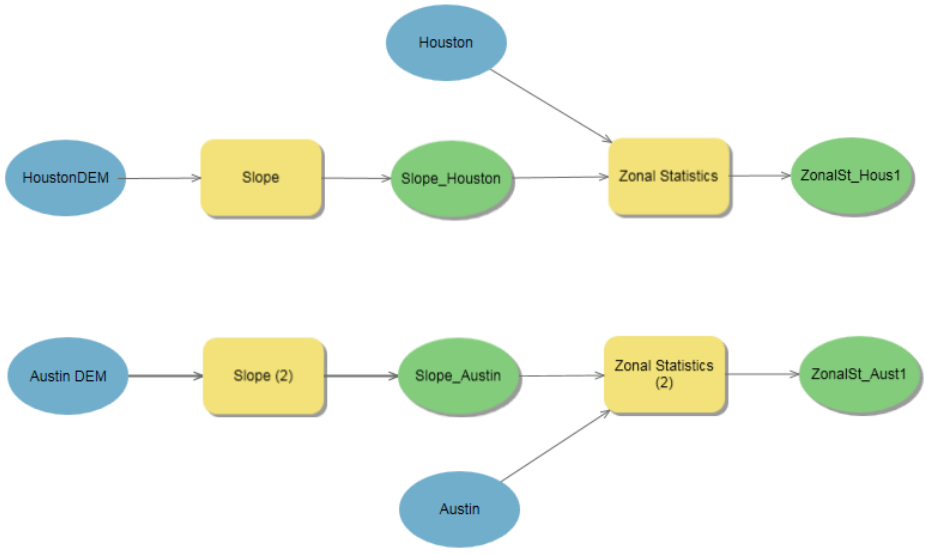

Figure 9. ModelBuilder tool for slope statistics.

Table 1. Slope Statistics.

	Mean (Slope %)	Standard Deviation (Slope %)
Austin	3.63	4.26
Houston	1.87	3.05

3. Land Cover for Houston and Austin

Information on the land cover of Houston versus Austin provided insight on whether Houston's urban development contributes to its extreme flooding. Land cover raster data was obtained from the Landscape ArcGIS server, and then extracted for the Houston and Austin shapefiles with Extract by Mask.

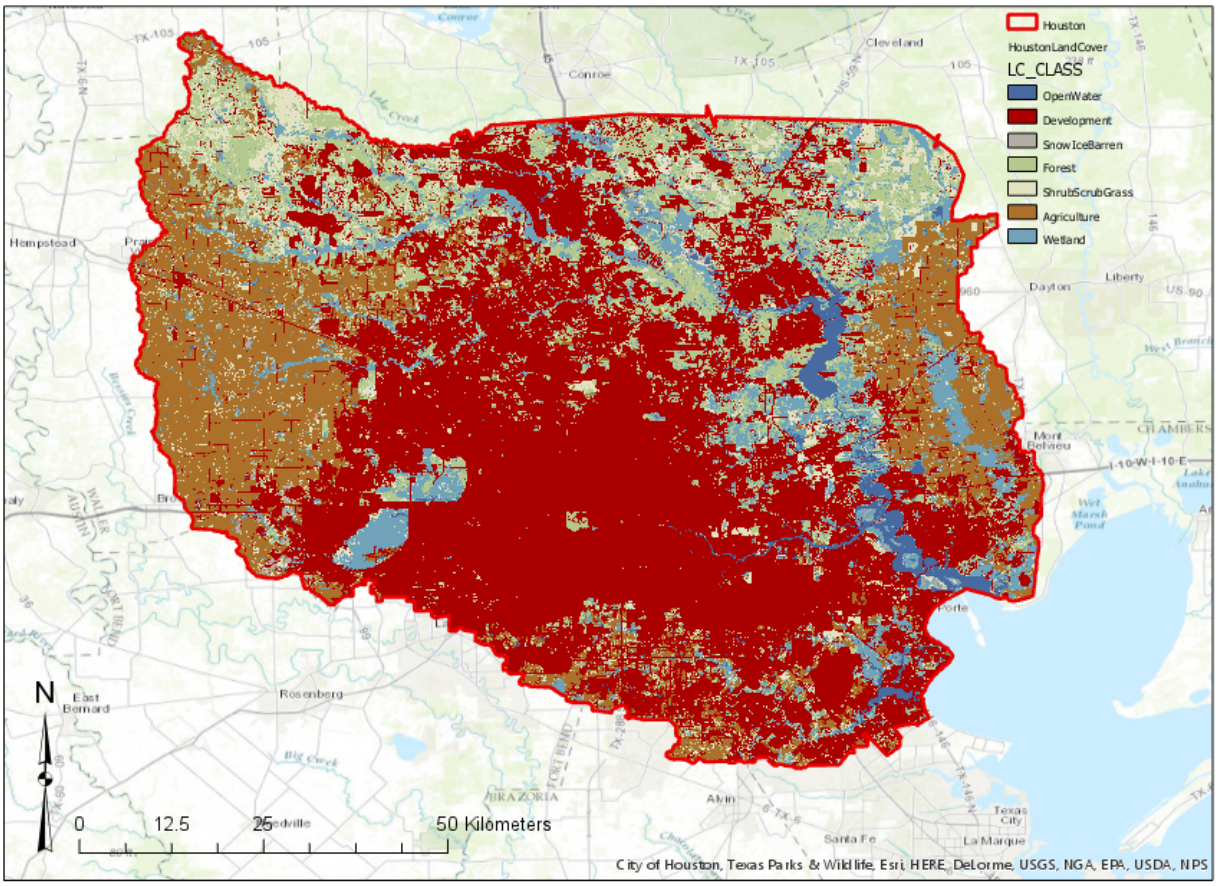

Figure 10. Houston land cover.

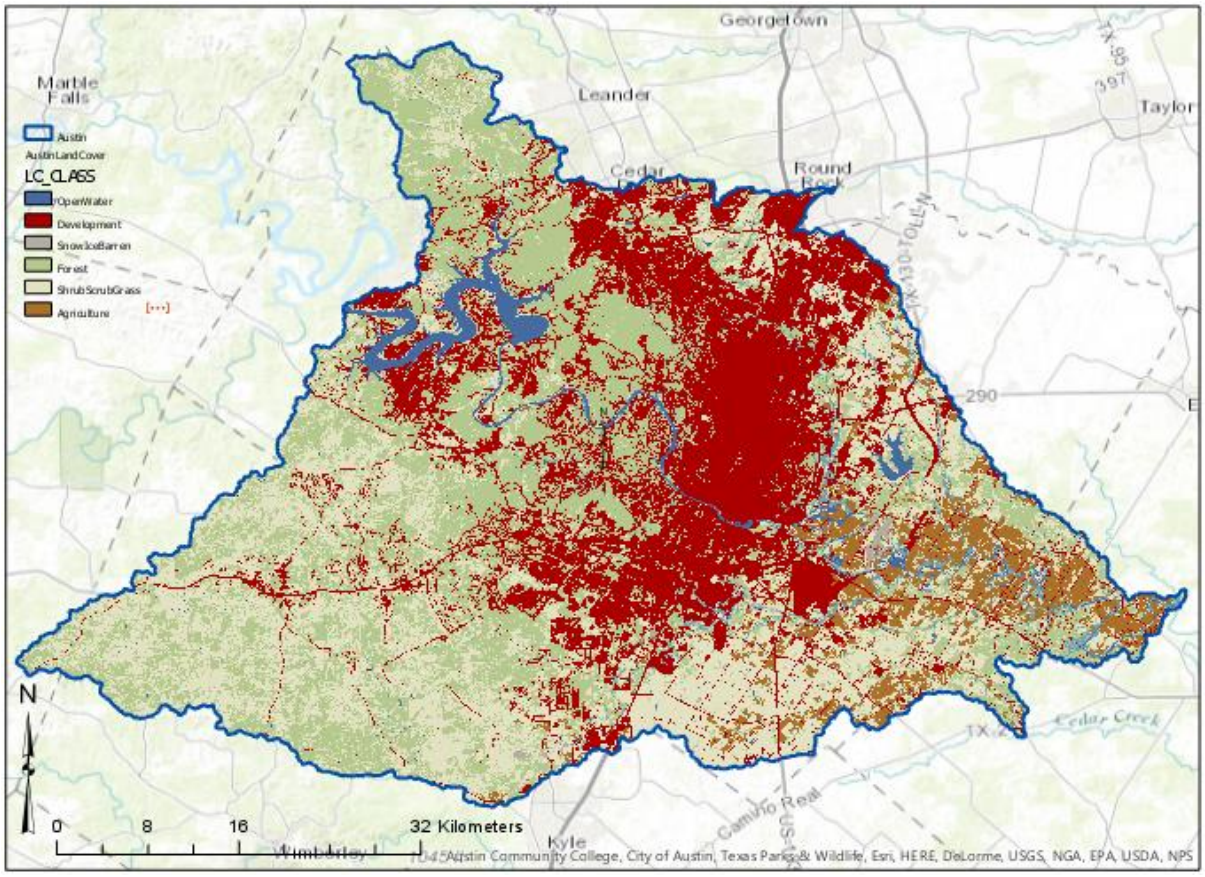

Figure 11. Austin land cover.

With a quick comparison of the maps, there appeared to be a greater fraction of developed land in the Houston area. To further validate this observation, statistics on the area of each land cover class were examined. The Summary Statistics tool was used and automated in ModelBuilder to perform simultaneous geoprocessing for both cities **(Figure 12).** Calculated values for areas and percent of area for each land cover class are listed in **Tables 2 and 3**.

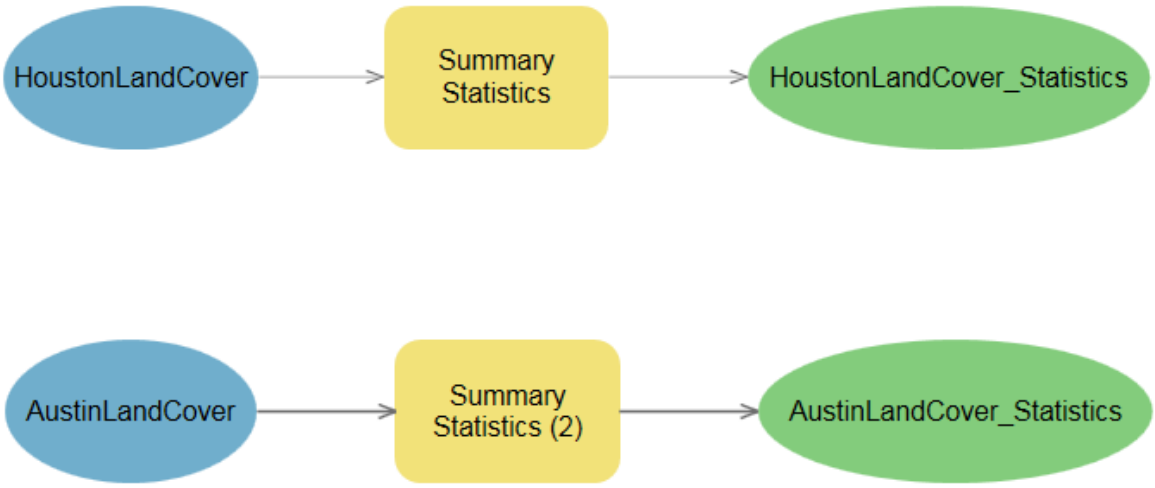

Figure 12. ModelBuilder tool for Houston and Austin land cover statistics.

Table 2. Houston land cover.

Land Cover Class	Area (km^2)	% of Total Area
Agriculture	1811.62	18.44%
Development	4767.53	48.54%
Forest	1333.52	13.58%
Open Water	232.80	2.37%
ShrubScrubGrass	699.29	7.12%
Barren	61.92	0.63%
Wetland	915.23	9.32%

Table 3. Austin land cover.

Land Cover Class	Area (km^2)	% of Total Area
Agriculture	221.54	5.65%
Development	1046.83	26.70%
Forest	1297.45	33.09%
Open Water	94.80	2.42%
ShrubScrubGrass	1172.24	29.90%
Barren	19.03	0.49%
Wetland	69.07	1.76%

4. Comparison of Houston and Austin Analysis Results

As predicted, the slope values of Houston's land surface are generally lower overall than those of Austin. The median slope of Houston with one standard deviation was calculated to be

1.87±3.05%, while that of Austin was 3.64±4.26%. Not only was the median slope for Austin almost twice as steep as Houston's, there was also a higher standard deviation. Houston also had a greater percentage of developed land despite the Houston shapefile having a larger area than Austin's. Almost half of Houston land cover was developed, 48.54%, while Austin was 26.70% developed. The percentage of developed land in Houston was almost twice that of Austin, which means Houston's amount of impervious concrete cover is much higher.

5. Conclusions

Drainage in Houston is problematic because the flat landscape essentially prevents precipitation from flowing to another location. Lower slopes, such as those in Houston, mean that there is less energy from gravity to allow for water to flow. As a result, the surface runoff in Houston usually does not move far, or goes to a bayou which eventually overflows in a destructive flood event. Furthermore, the higher percentage of land cover also causes Houston to flood to a greater degree than Austin. The impervious area of the concrete used in land development does not allow for the seepage that other land cover classes such as grass, agriculture, and forest do. The slopes and land cover of Houston contribute to its flooding, and this is supported by the lower slope values and higher developed land cover of Houston when compared to Austin.

References

[1]"Elevation Products." Elevation Products | Earth Resources Observation and Science (EROS) Center. USGS, n.d. Web. Nov. 2016.

[2]"Extreme Weather Proves Deadly in Texas, Oklahoma." *Environmental News Service*. ENS, 26 May 2015. Web. Nov. 2016.

[3]"GIS and Maps." *City of Austin, Texas GIS Maps/Downloads*. N.p., n.d. Web. 18 Nov. 2016.

[4]*Houston Open GIS Data*. The City of Houston, n.d. Web. Oct. 2016. <http://cohgis.mycity.opendata.arcgis.com/>.

[5]"NHDPlus High Res Data." N.p., n.d. Web. Nov. 2016. <ftp://rockyftp.cr.usgs.gov/vdelivery/Datasets/Staged/Hydrography/NHD/State/HighResolution/GDB/>.

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