CE 394K GIS in Water Resources

Term Project

Flooding in the City of Houston during Hurricane Harvey

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FOR

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Dec.6, 2018

Contents

1. Background

Hurricane Harvey of 2017 is one of the costliest tropical cyclone on record, inflicting $125 billion in damage, primarily from catastrophic rainfall-triggered flooding in the Houston metropolitan area and Southeast Texas. In a four-day period, many areas received more than 40 inches (1,000 mm) of rain as the system slowly meandered over eastern Texas and adjacent waters, causing unprecedented flooding. The resulting floods inundated hundreds of thousands of homes, which displaced more than 30,000 people and prompted more than 17,000 rescues.

Figure 1 Houston during Hurricane Harvey. CNN

Because it will be too complex to map all of the Houston area, I chose to focus on Buffalo Bayou and see what I can do with that. The Buffalo Bayou watershed is primarily located in west-central Harris County with a small portion crossing into Fort Bend County. Rainfall within the 102 square miles of the Buffalo Bayou watershed drains to the watershed's primary waterway, Buffalo Bayou. Near downtown Houston, White Oak Bayou flows into Buffalo Bayou. Just east of downtown Houston near the Turning Basin, Buffalo Bayou becomes the Houston Ship Channel. Nearly 80 percent of the Watershed is urbanized yielding a high percentage of impervious land area. Problems associated with this level of urbanization include flooding, poor water quality (due to sedimentation, stormwater and agriculture), brownfields and loss of biotic habitat. Based on the 2010 U.S. Census, the estimated population of the Buffalo Bayou watershed is 444,602.

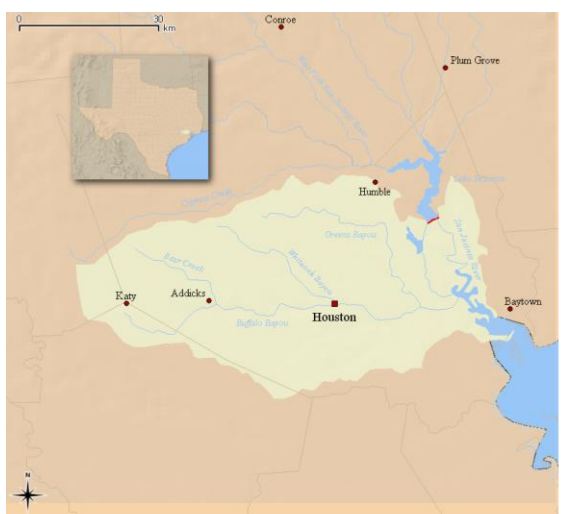

Figure 2 Map of the Buffalo Bayou and associated watershed, by Kuru

2. Objective

The object of this project is to create an hourly-interval flood map series of Houston during Hurricane Harvey in August 2017 using HAND method and other different ways available. In this project, I will try to use everything we have learnt in class during the semester and see if I can use them to solve some real problems.

3. Data Source

3.1 DEM Data

The DEM data is downloaded from USGS with 1/3 arcsec resolution for n30w095, n30w096, n31w095, n31w096, n31w097. Using *Mosaic to New Raster* tool to combine the DEMs, a boundary of Houston from H-GAC database with a 10km buffer *Extract by Mask* tool, the base DEM map is generated. The map displaying the elevations in the City of Houston and the surrounding area is displayed in Figure 2.

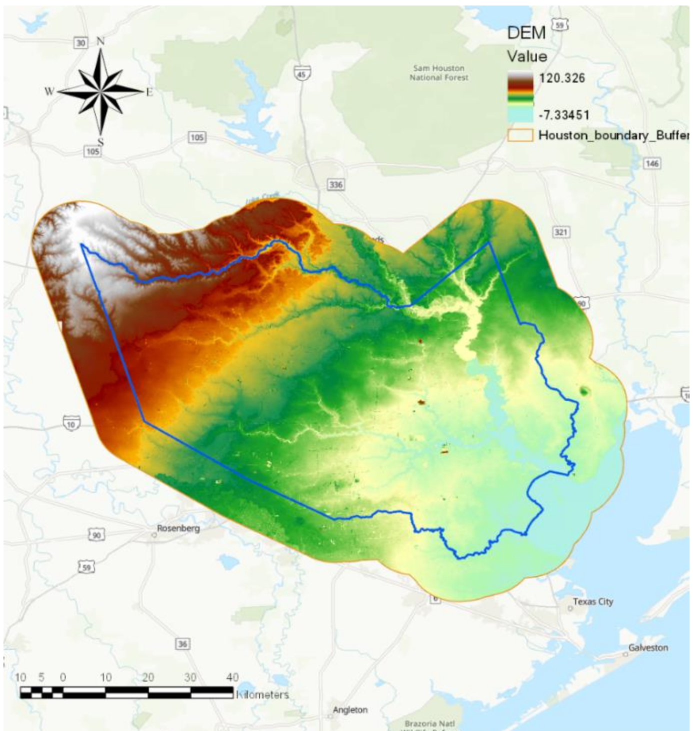

Figure 3 1/3 arcsec DEM for Houston City

HUC 12 sub watershed data are downloaded from NHD dataset, and following polygons: HUC12 120401040703, 120401040305, 120401040303 are aggregated to delineate a boundary of the Buffalo Bayou Watershed. A 2 km buffer around the boundary is also created around the boundary. All data are projected to a UTM zone 15 coordinate system for consistency.

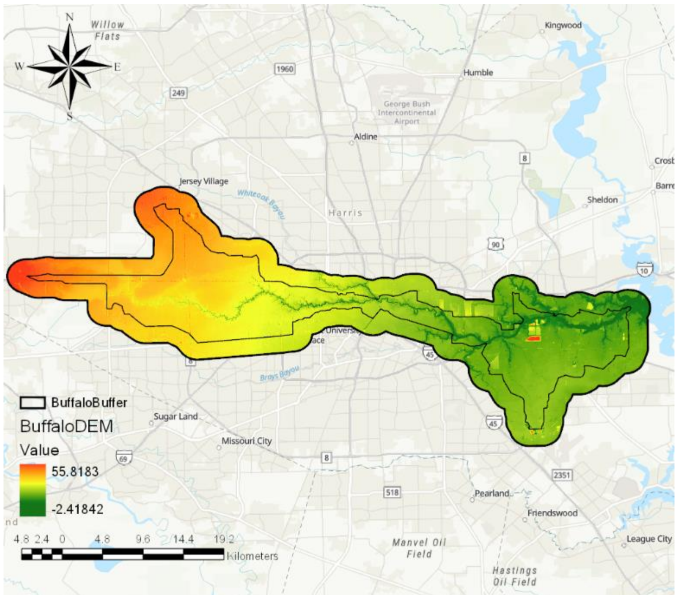

Figure 4 1/3 arcsec DEM for the Buffalo Bayou Watershed

3.2 Water Level Data

There are several different sources to get the water-level data, including the USGS stream gage data, and the NOAA coastal tide gage data.

First I need to decide which gages are located in my watershed. I selected all the sites contained in the buffer area and export them separately. Details are showed as Table 1 below.

Table 1 Infotmation about Stations in Buffalo Bayou Watershed

Stations	Source	Lat(Deg)	Long(Deg)
Buffalo Bayou at State Hwy 6 nr Addicks, TX	USGS	29.76938056	-95.64316667
Buffalo Bayou nr Addicks, TX	USGS	29.76166667	-95.60555556
Buffalo Bayou at W Belt Dr, Houston, TX	USGS	29.76194444	-95.5575
Buffalo Bayou at Piney Point, TX	USGS	29.74666667	-95.52333333
Buffalo Bayou at Houston, TX	USGS	29.76	-95.40833333
Whiteoak Bayou at Houston, TX	USGS	29.775	-95.39694444
Buffalo Bayou at Turning Basin, Houston, TX	USGS	29.74916667	-95.29083333
Little Whiteoak Bayou at Trimble St, Houston, TX	USGS	29.79277778	-95.36805556
Vince Bayou at Pasadena, TX	USGS	29.69444444	-95.21611111
Addicks Res nr Addicks, TX	USGS	29.79111111	-95.62333333
Manchester, TX	NOAA	29.727	-95.265
Morgans Point, Barbours Cut, TX	NOAA	29.682	-94.985

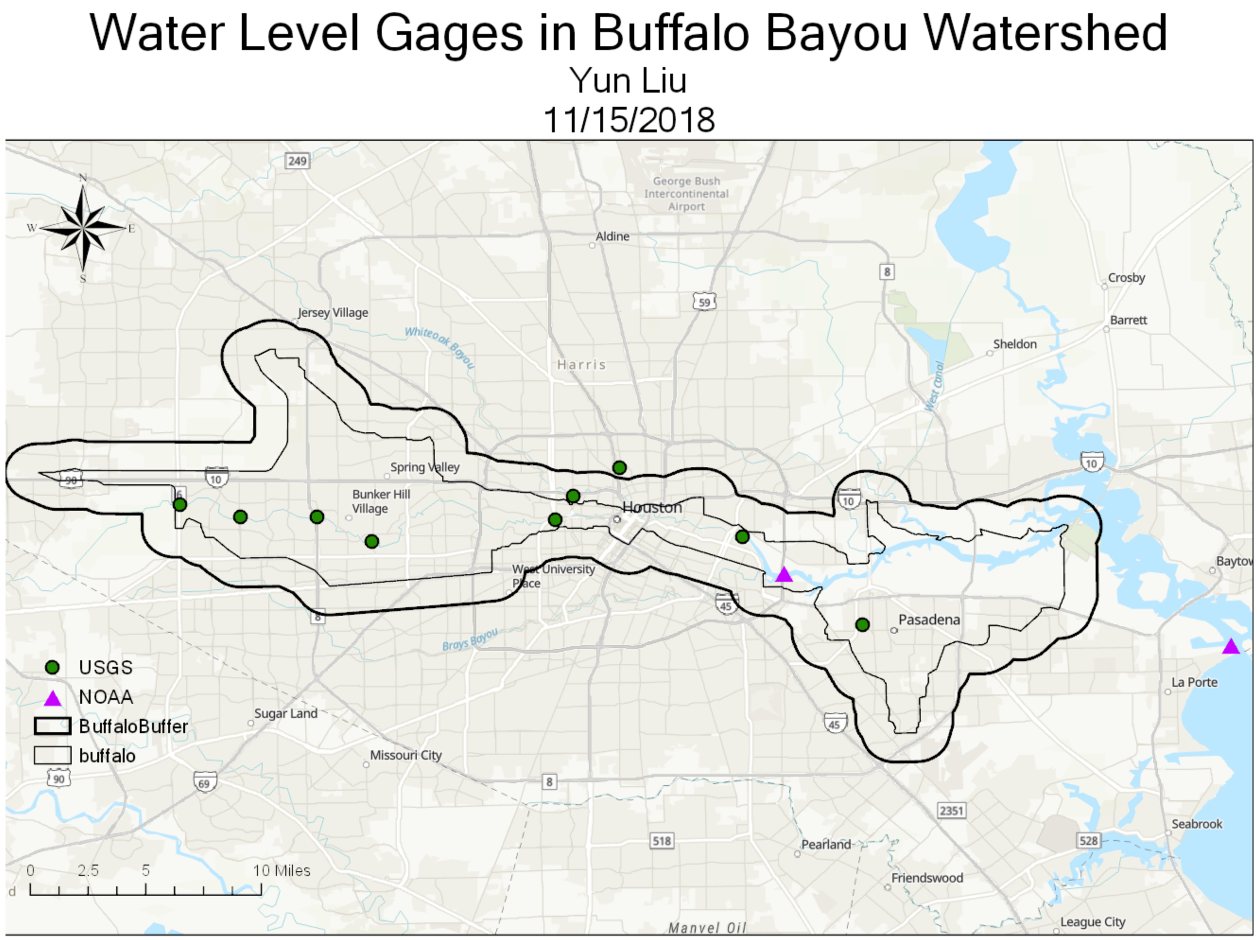

Figure 5 Water Level Stations in Buffalo Bayou Watershed

Next, I need to get the water level data of different gages at a certain time. I choose 12P.M. on Aug. 27, 2017 and 12P.M. on August 31, 2017 because that was basically when the flood hit Houston. It was a boring task which probably could be done by computer. After I have water level values from different gages at a certain time, a water surface could be generated.

3.3 NHD Flowlines etc.

Flowline and other hydrology data are downloaded from National Hydrography Dataset. The National Hydrography Dataset is a digital vector dataset of surface water in the US. Hydrographic features such as rivers, streams, canals, lakes, coastline, dams, and stream gages, as well as flow velocities and length are represented in this dataset.

4. Methods and Results

4.1 Interpolation Method

In order to get a water surface for the whole region, I must rely on the interpolation tools in ArcGIS Spatial Analyst Toolbox. There are several different kinds of interpolation methods are provided, and here the tool Kriging is used. The maps are shown as below in Figure 6.

Interpolated Water Surface at 12:00PM 8/27/2017

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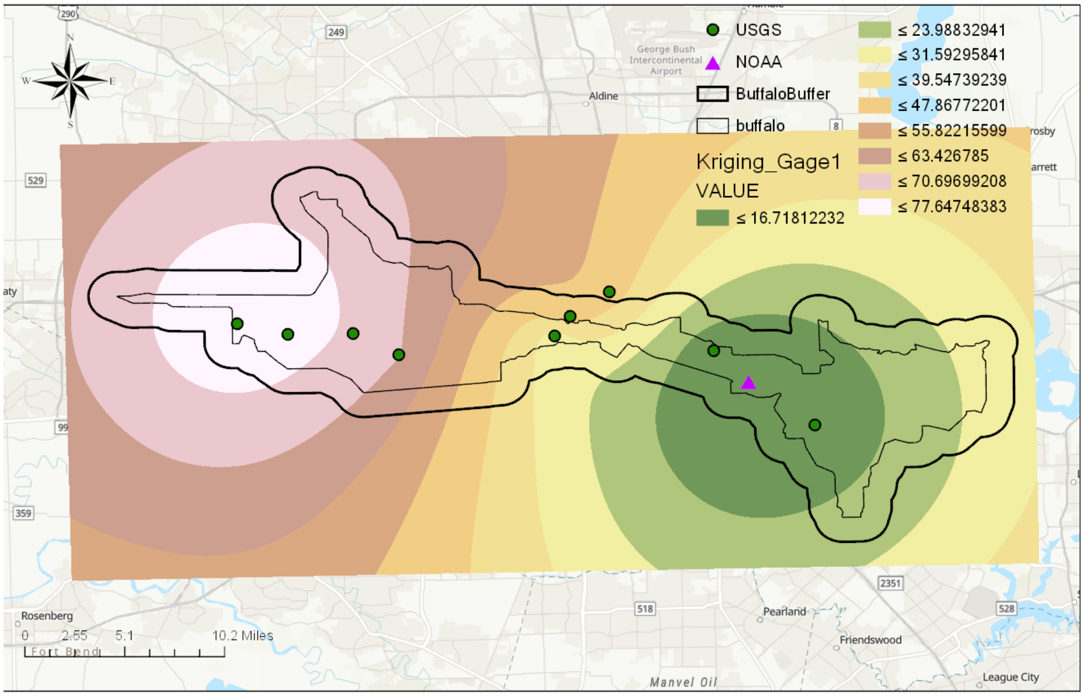
11/19/2018



Interpolated Water Surface at 12:00PM 8/31/2017

Yun Liu

11/19/2018

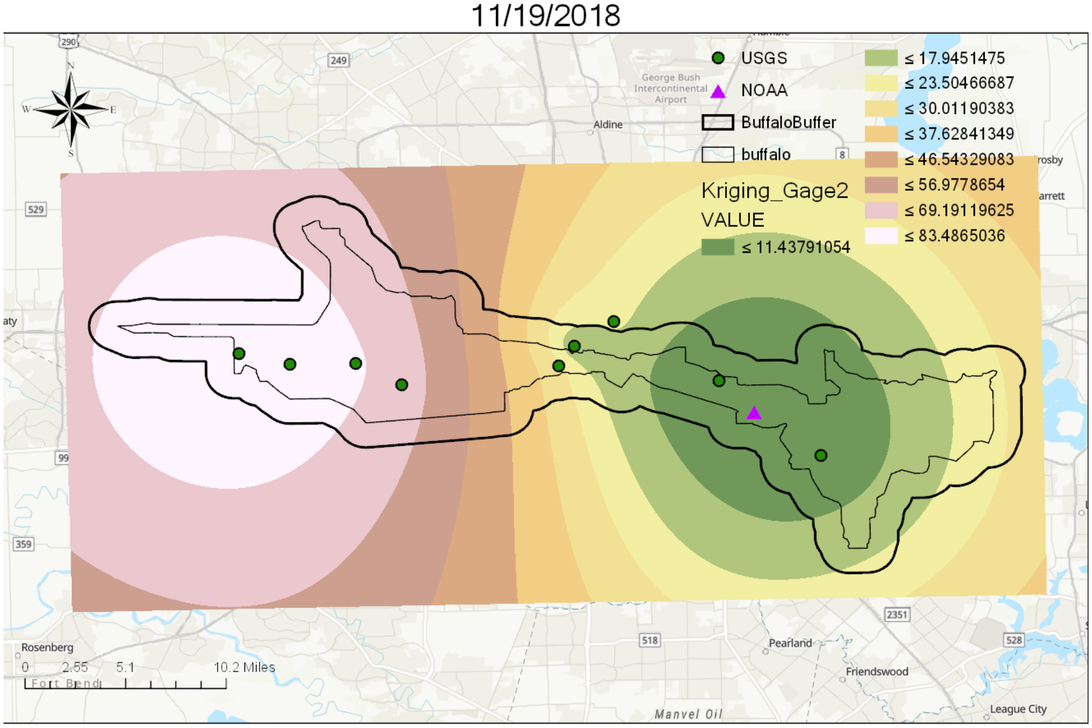


Figure 6 Interpolated Water Surface Map

Then by using the raster calculator tool and setting the condition as "Buffalo DEM"-"Water Surface "<0 and did the raster calculation. The output provided a raster file with values of 1 where the elevation is lower than water surface and 0 everywhere else. Setting the value 0 with no color, an inundation could be generated.

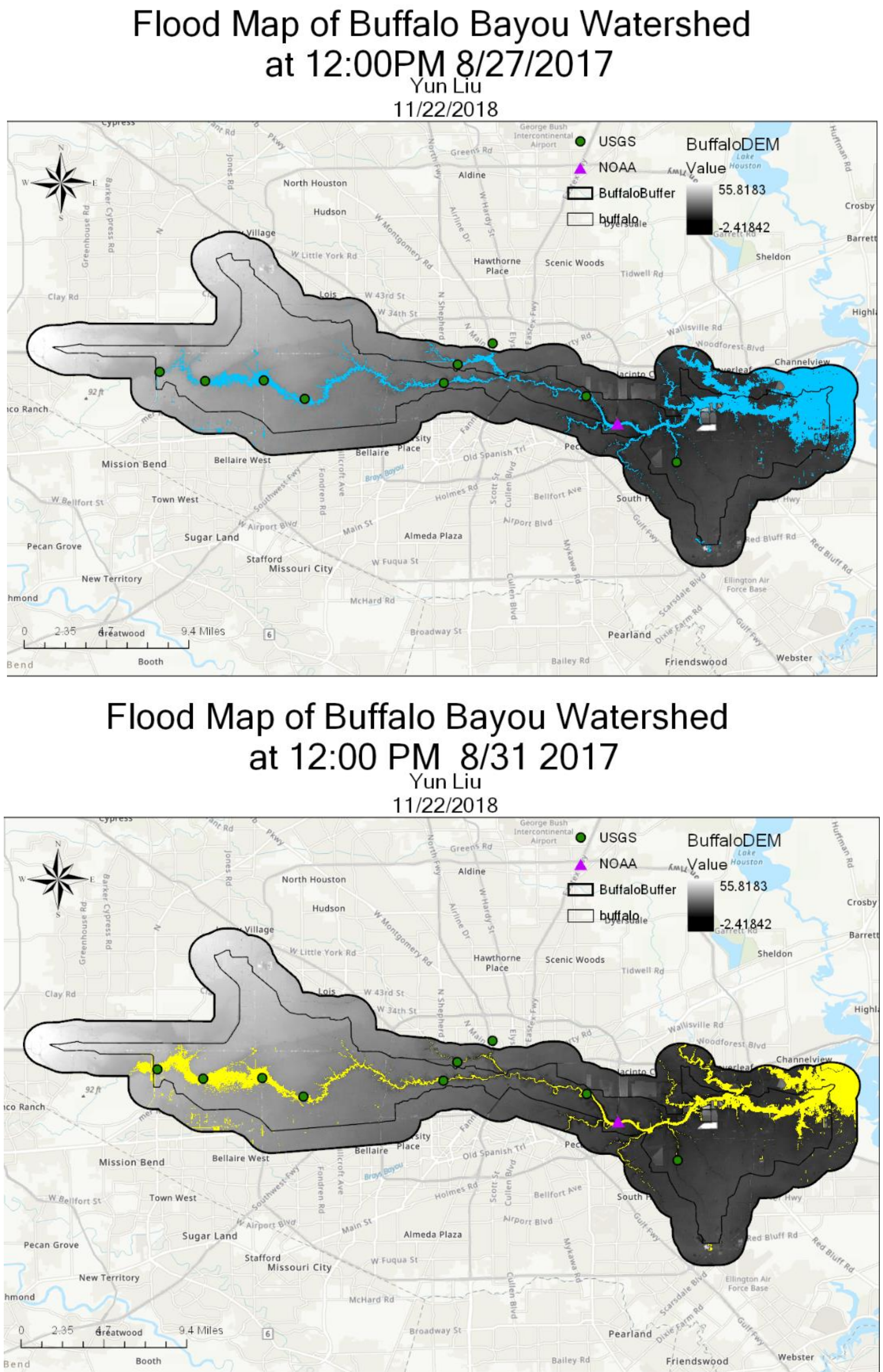


Figure 7 Flood Map of Buffalo Bayou Watershed

By changing the color and transparency, the two inundation maps are put together to show how the flood spread during those days. It is clear that the flooded area near the sea was shrinking while in interior area it was expanding.

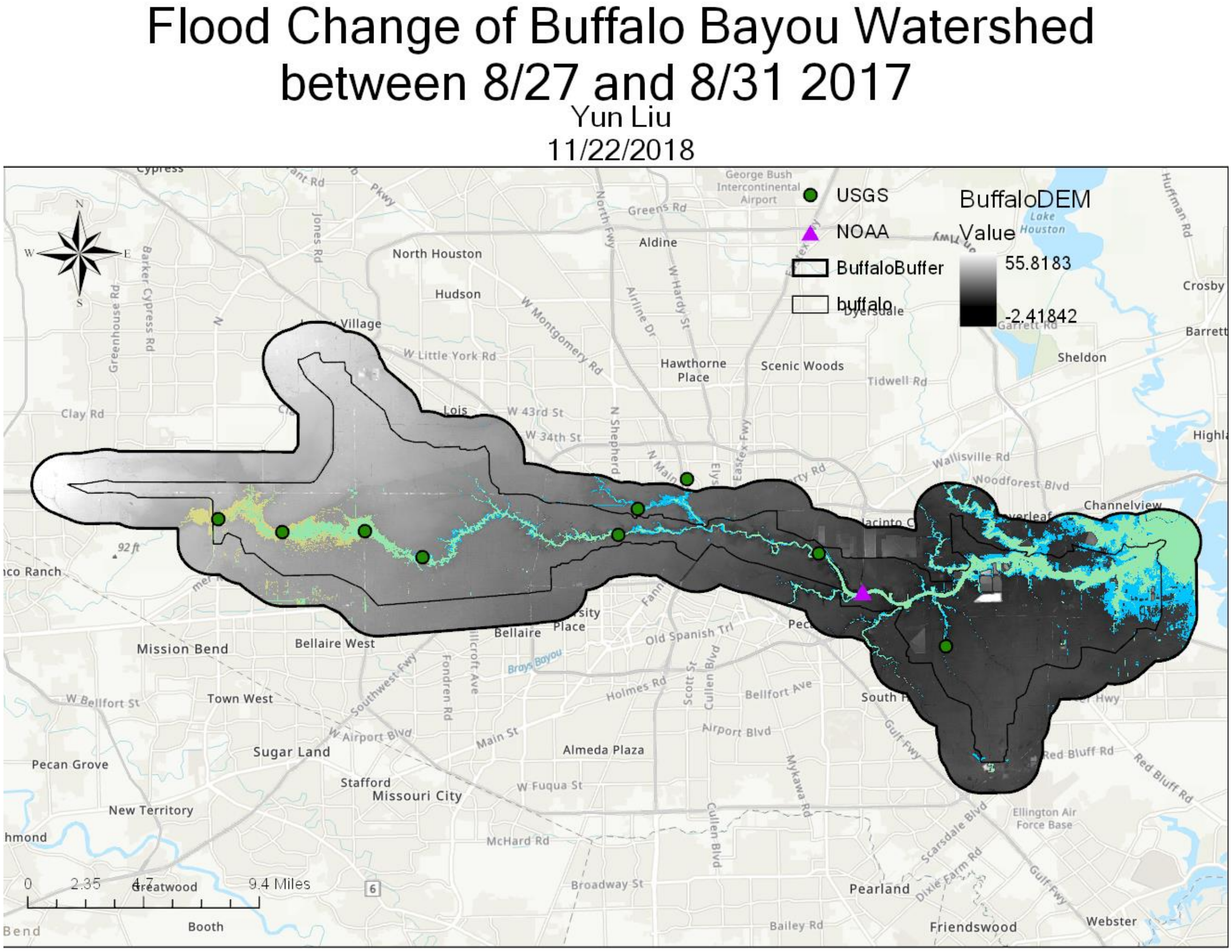


Figure 8 Flood Change in Buffalo Bayou during Hurricane Harvey

This method successfully carries out a flood map drawing mission with the help of ArcGIS. Deciding water-levels using interpolation methods is an easy and effective way to create flood map. However, since this method just consider the relationship of neighboring elements and use some mathematic functions to decide the values, without consider the physical mechanism behind the relationship. It is not the ideal method of flood mapping. Also, I take advantage of interpolation but don’t really understanding the mechanism of these methods. It is dangerous that we may produce some results that we are not even aware of.

4.2 HAND Method

When converting the dangling points to raster, even I have set all the environment parameters same as my DEM, the extent of the start points are very different from the set DEM.

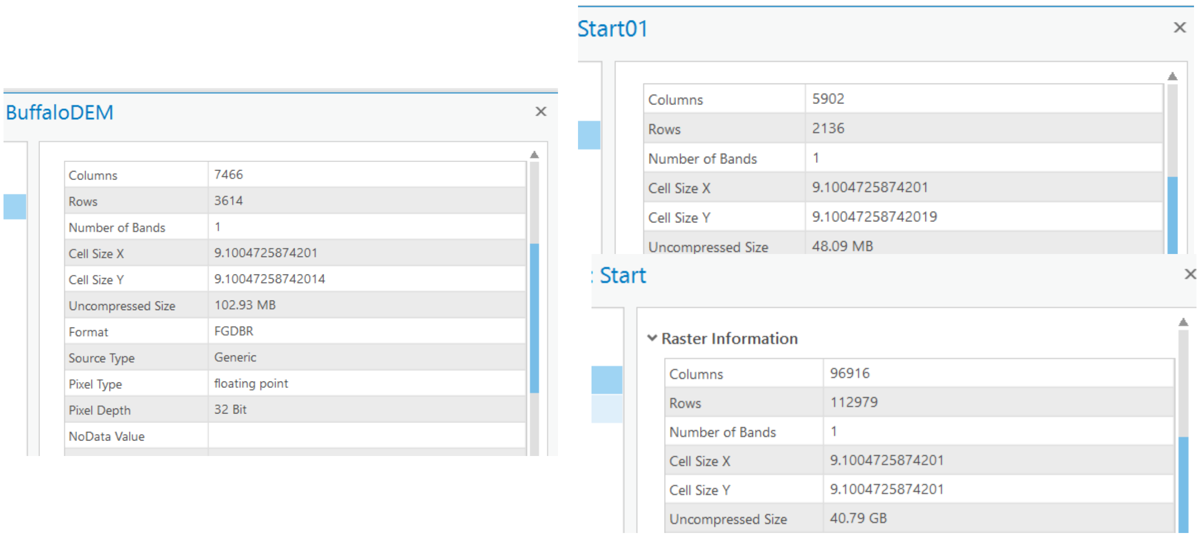


Figure 9 Extents of DEM and Start Point Raster

I found both the Start raster contains all the points I need, but the extent is not correct. So I used the second one which contains more information than I need, and use *Extract by Mask* to get the resulting raster the same dimensions as the DEM. Finally, an inundation map with water depth of 3, 5, and 12 meters was generated.

However, there are still several problems with this map. The stream generated from flow accumulation is cut off at shown area, which leads to unreasonable small value of flow accumulation downstream and HAND data lost in that area. Therefore, it is doubtful whether this map is accurate and reliable.

Figure 10 Stream Cut-off in HAND Map

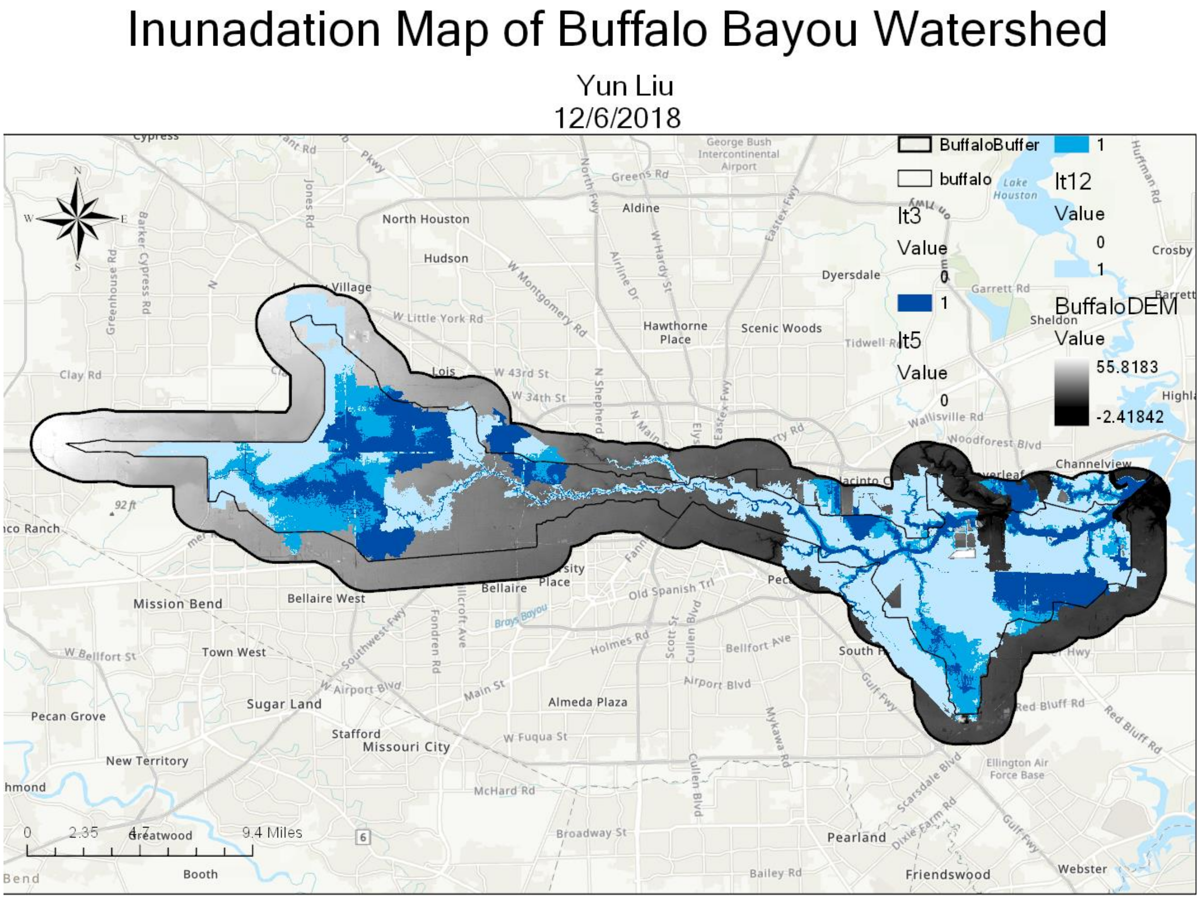


Figure 11 Inundation Map of Different Water Levels

4.3 GeoFlood

The third method is tried to be used in this project, GeoFlood, is a method designed for mapping real-time inundation extents using high-resolution terrain inputs at low computational cost. It couples the effective Height Above Nearest Drainage (HAND) method, which quantifies the relative height of each land surface cell above its nearest stream bed cell, and GeoNet, a channel extraction method designed for high-resolution lidar-derived terrain data.

However, the program failed to generate a correct river segment shapefile which will be inputs for following steps, so I only came up with a HAND map. Interestingly, the HAND map also shows a cut-off of the stream in the same area as in the previous method. I would try to solve this problem in the future.

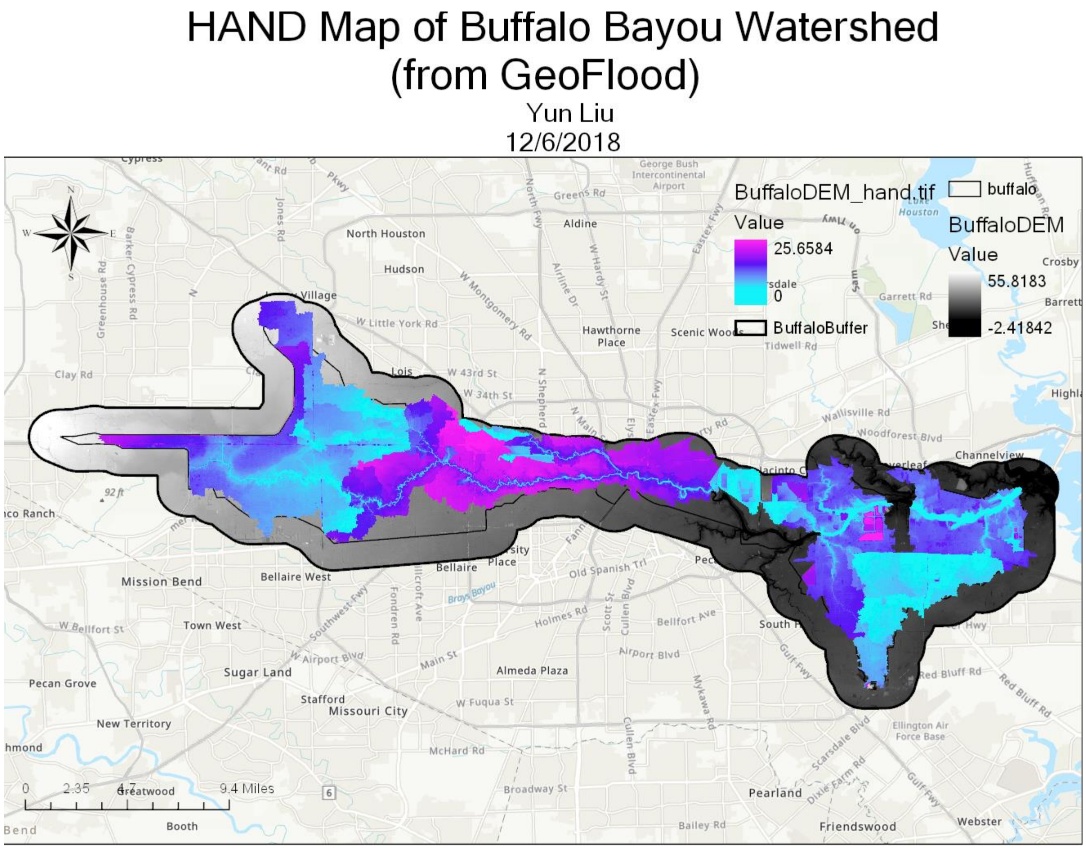


Figure 12 HAND Map generated in GeoFlood

5. Discussions

The project successfully generates a flooding map of Buffalo Bayou during Hurricane Harvey via interpolation method in ArcGIS. However, when using methods relating to HAND, it encountered some problems which is not solvable for me currently. Hopefully by using DEM data from another source or changing some parameters, a more reasonable inundation map could generate in the future.

During the process, a lot of assumptions about the geological and hydrologic conditions are made to simplify the question. If we want to get the ideal flood map, we must consider hydraulics and hydrology parameters, building a model considering sea-wave and other effects, to decide a more precise water surface and inundation situation.

GeoFlood is an accessible tool for anyone with some basic knowledge of GIS. But it is designed to use water-level data from National Water Model, which makes it difficult to be used to generate inundation map of past events.

ArcGIS is a useful tool not only for hydrologist but also any researcher whose study related to spatial distribution. It helps to make data visualizable and be communicated more efficiently. But it is very important to understand the mechanisms of each tool before using it. Otherwise even the result is plausible, the reliability and accuracy of it is still questionable.

HAND maps could be used to determine the most vulnerable area and help modify flooding preparedness and response system. And real-time inundation mapping is an important tool for recovery works. So it is significant to pursue a better, faster and easier way to generate these maps.

References

"Buffalo Bayou Watershed Overview". Harris County Flood Control District. December 2013. Retrieved 26 February 2017.

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