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Drainage and Flood Analysis of New Orleans

Objectives

New Orleans was the most populated city of Louisiana and was located in the southeastern part of Louisiana, (*Louisiana 2010 census data*, 2010). The purpose of this project was to perform an analysis of New Orleans' drainage system. The analysis was spilt into two parts. The first part was an analysis of the drainage capacity of the pumping stations for different regions of the city. The second part was comparing the FEMA insurance flood maps to a recent major flooding event to see the accuracy of the maps. From these studies the project will determine which areas are at high risk for unpredicted flooding.

Background

New Orleans was not a traditional watershed because of the levees that completely encircled the city. Additionally most of New Orleans' elevation was near or slightly below sea level, so using gravity to drain the city was impractical (*Davis*, 2000). Pumping stations were constructed to remove all of the water in the city. There were 23 main pumping stations operating in different areas of New Orleans and some of the stations were considered to be the world's largest. A couple of the pumping stations are shown in Figures 1 and 2. Pumping stations might be added or improved by the Army Corps of Engineers based on flood events studies like the FEMA Flood Insurance Rate MAPS (FIRM). A FEMA FIRM showed which parts of the city were within the 100 year floodplain.

Figure 1: Old pumping station on Broad Street

Figure 2: New pumping station off I-10

In the last 2 decades there have been 2 major floods in New Orleans. In May 1995, some areas of New Orleans received up to 20 inches of rain within a 2 day period (*Turnipseed, Baldwin,* *Cooper, and Floyd*, 1995). The rainfall of the event was shown in Figure 3. One section of the city received over 12 inches of rainfall in 5 hours (*Ricks et al.,* 1997). The rain intensity overwhelmed the pumping stations and water overflowed in parts of the city. Unfortunately the areas flooded during this event were not available, so the other major flooding event that occurred, Hurricane Katrina, was compared to the FEMA flood maps instead.

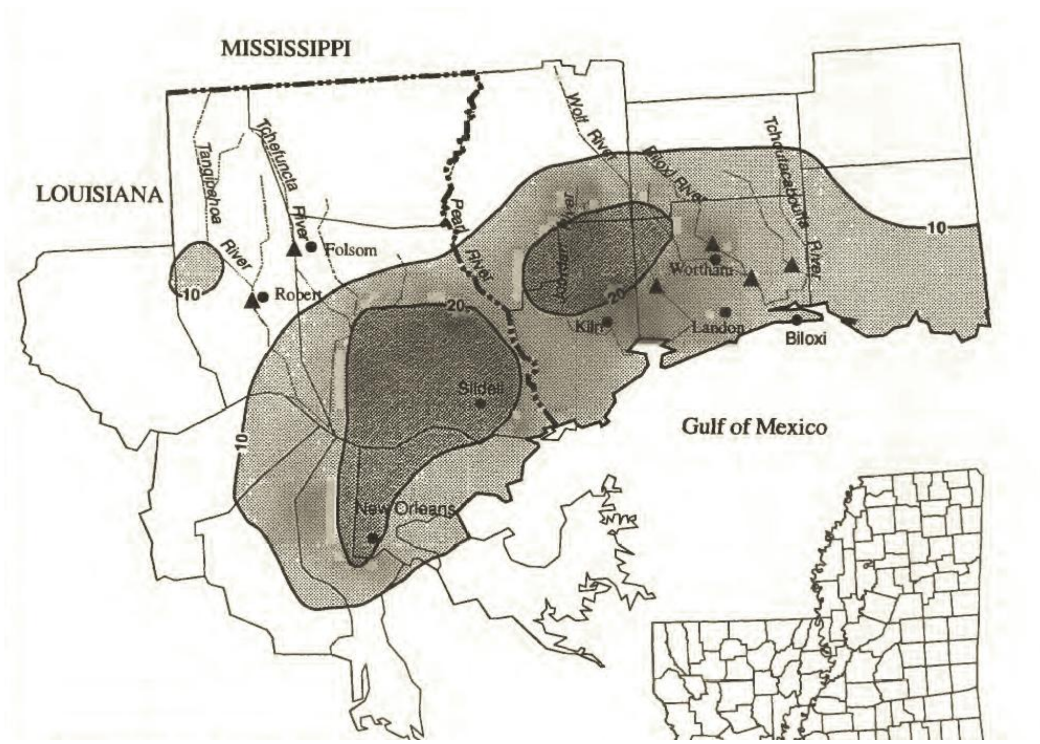

Figure 3: Rainfall totals of May 7-9, 1995 (*Turnipseed*, 1995)

While Hurricane Katrina brought 4 inches of rain to New Orleans, the city flooded as result of the breached levees that line the city's canals system. These canals were all connected to Lake Pontchartrain (located north of the city), which was experiencing a storm surge from Katrina. The storm surge pushed the water level in the canals to heights it had never been before, overtopping some levees and breaking others that were unable to withstand the increased pressure. The water from those canals poured into the city until the water level in the city was balanced with water level of the lake. The water level balance was reached at 2.5ft above sea level on September 1, 2005 (*Mihelich*, 2005). The main locations of levee breaches were shown in Figure 4m (*Daweson*, 2005). All of the breaches occurred on the east bank of the Mississippi River, so New Orleans areas on the west bank of the Mississippi River received minimal to no flooding.

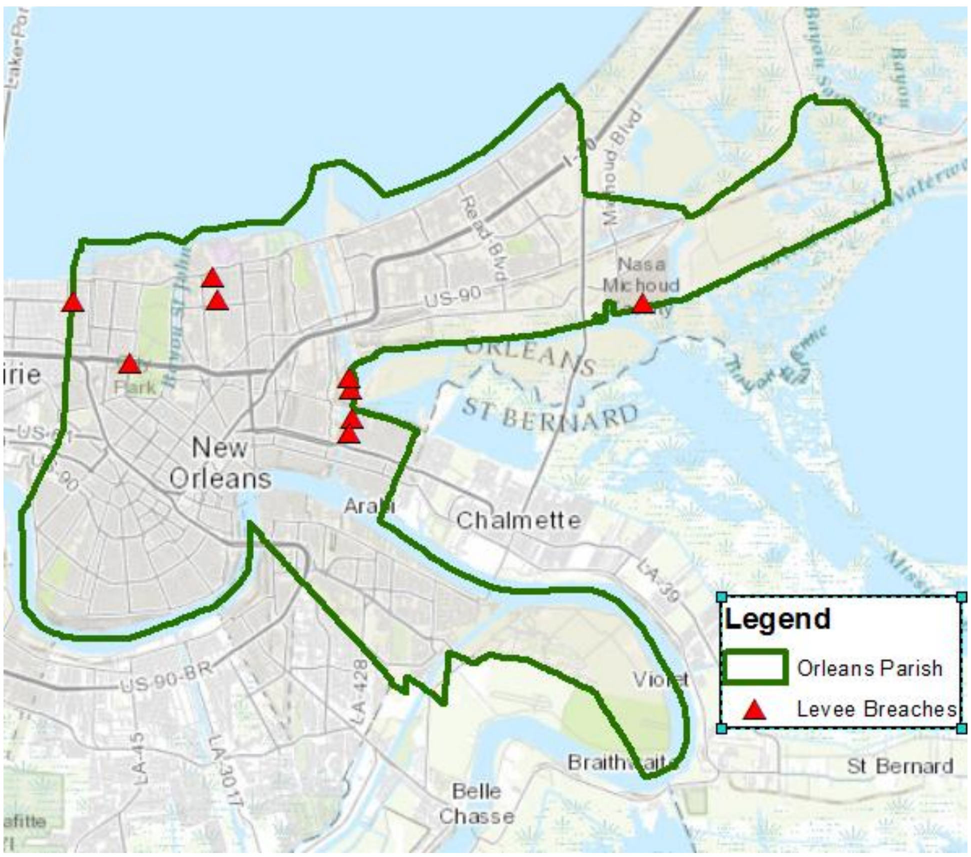

Figure 4: Location of New Orleans main levee breaches.

Methods

The data for this project was taken from a variety of sources and required preparation before it could be used in ArcGIS. The FIRM used was created by FEMA and was retrieved from Atlas: Louisiana GIS database. The DEM rasters were 1/9 arc second maps ordered from the USGS National Map Viewer, and the DEM of New Orleans' parish (Orleans parish) was isolated by GIS extracting tools. In Louisiana, the state was divided into parishes instead of counties. The pumping station locations and design capacity were found through reports and articles, and the locations were confirmed with Google maps (*New Orleans District*, 2009). An excel spreadsheet was prepared with the pumping station names, design capacity, and locations in decimal degrees. The pumping station table was converted into points with the display XY data tool, which was exported to create a feature class. The census data shapefiles were created by TIGER for the 2010 census but did not have census data attached to it. The data was available to download in table form from the American Fact Finder site, and the table had to be slightly modified in excel before it could be added to ArcGIS.

Results and Discussion

The pumping stations were divided into regions for analysis. These regions were created by dissolving the census tracts that were not separated by water bodies. The tracts that were divided by water drainage did not influence each other, so the tracts were analyzed separately. The locations of the pumping stations and the divided regions of Orleans Parish were shown in Figure 5. The Metro region of Orleans Parish (colored purple) was located on the east bank of the Mississippi River. The Metro region was the largest region and contained the most pumping stations. The next largest was the East region of the city and was separated from the Metro area by the Industrial Canal. The Lower 9th region (colored blue) was also separated from the Metro by the Industrial Canal and it was separated from the East region by the Intracoastal Waterway and swmaps. Algiers and Lower Algiers regions were both south of the Mississippi River and the Intracoastal Waterway divided them.

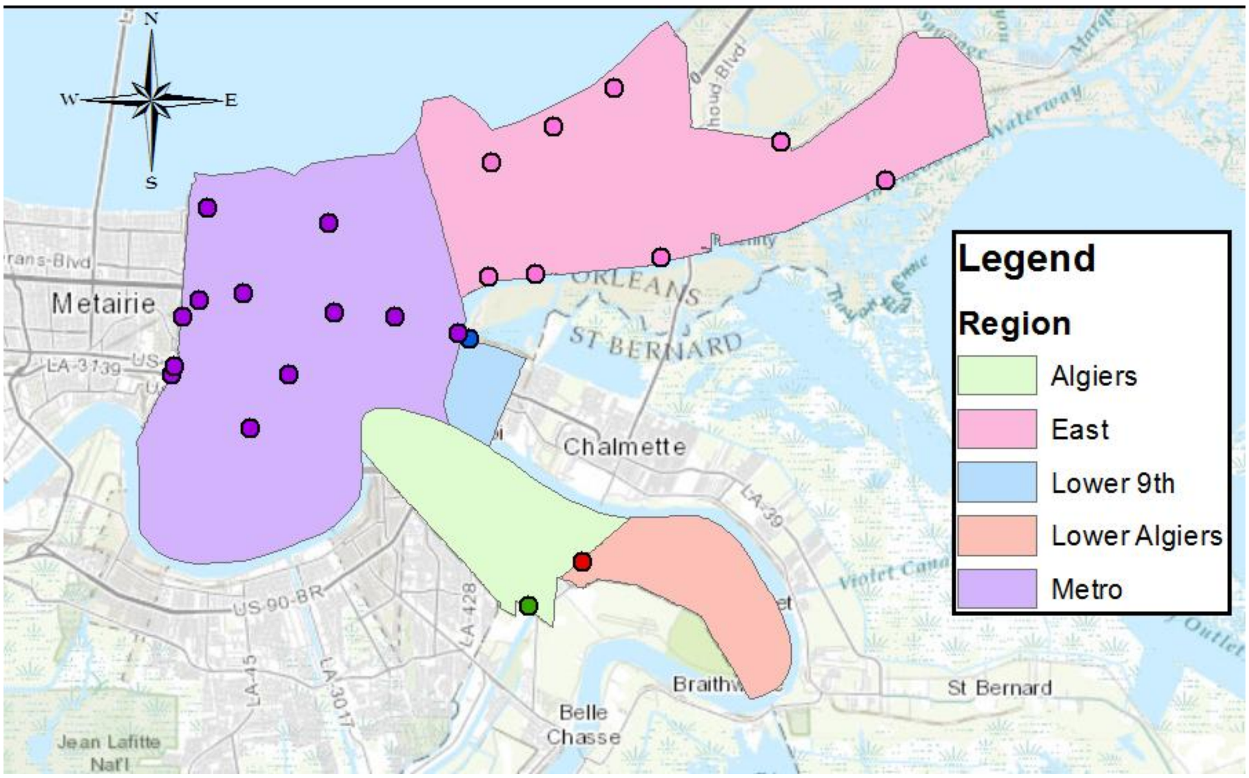

Figure 5: Pumping stations and regions

The drainage analysis was continued by comparing the pumping capacity of the regions. However, the regions have an unequal number of pumping stations and areas. To compare the total pumping capacity of each region was summed and then divided by the land area of the region. This ratio was called the pumping density and was given in Table 1. The table showed that the areas with the largest pumping density were the Metro and Lower Algiers regions, even though the East region had more pumping stations than Lower Algiers. Lower 9th Lower Algiers, and Algiers have only have only 1 pumping station, so if the station fails there was no major backup station for those regions, so these areas had a high risk of flooding.

Table 1: Region properties

Region	Number of pumping stations	Land Area (km^2)	pumping density (cfs/km^2)
Algiers	1	26.0	179.1
East	8	82.1	59.2
Lower 9th	1	5.8	318.5
Lower Algiers	1	17.5	95.5
Metro	12	106.4	341.3

The range of the regions' pumping density was illustrated in Figure 6. The Figure showed that the Metro and Lower 9th regions had significantly more pumping capacity than the East and Lower Algiers regions. This showed that if the pumping stations were operational, the Metro and Lower 9th regions were the least likely to flood while the East and Lower Algiers regions were the most likely to flood, so East and Lower Algiers were at a high flood risk. An analysis of the region's population density was also done to determine which how many people are affected per km^2 of flooding. The pumping stations were studied by region so the census data was similarly summarized. In Figure 7, the Metro and Algiers regions are have the highest population density while Lower Algiers has the lowest.

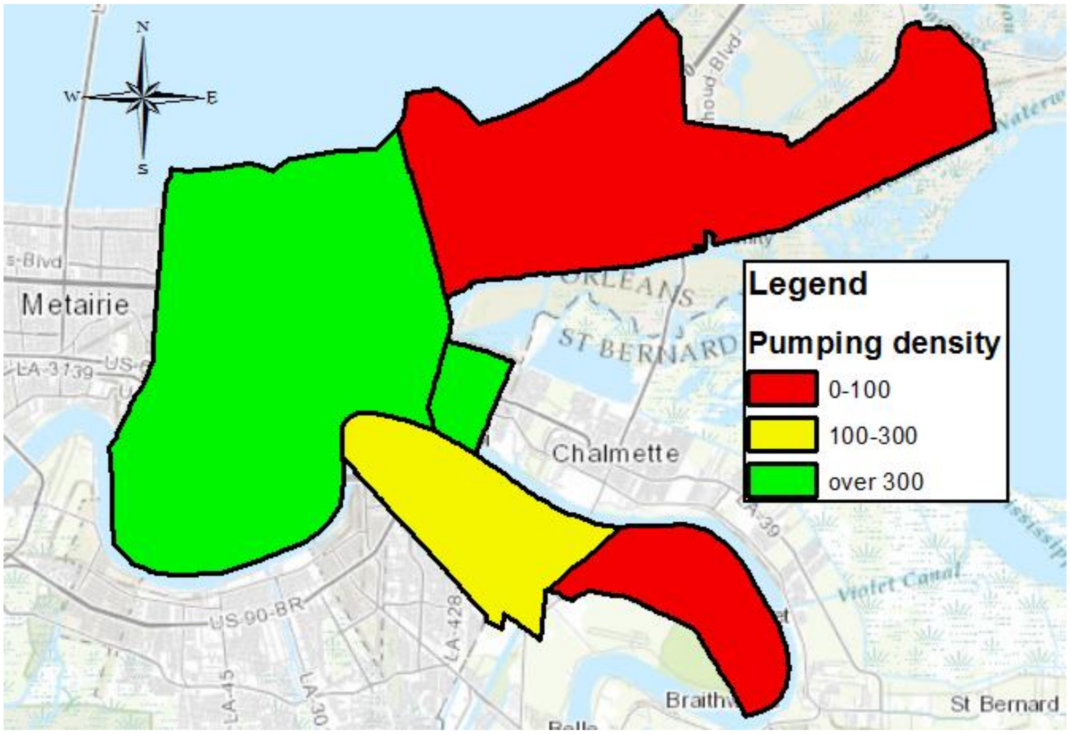

Figure 6: Pumping Density

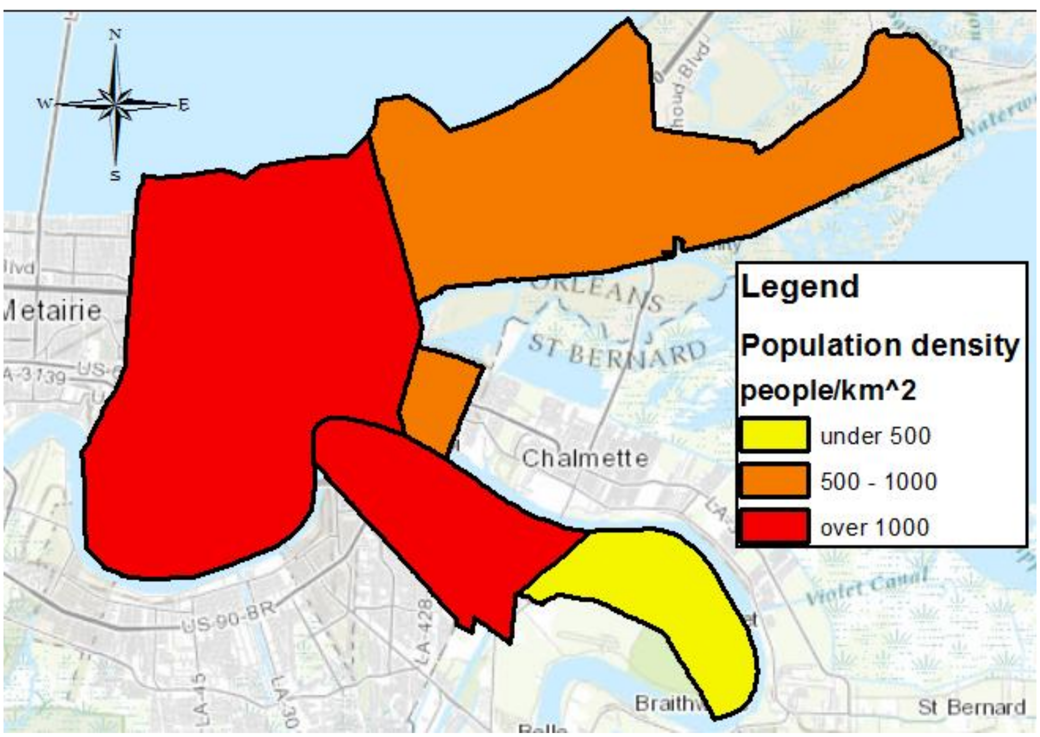

Figure 7: Population Density

For the second part of the analysis a comparison of the FEMA maps to the regions flooded during Katrina was done to identify which regions flooding were underestimated. The following figure was the FEMA FIRM for Orleans Parish used for flooding analysis. The pink regions were categorized as A zones and were areas that FEMA considered at risk for a 100 year flood event. The orange areas were categorized as X zones and were areas that FEMA considered to be outside of the floodplain of a 100 year flood event. The majority of Orleans Parish appeared to be in the A zone. However the map showed more than the metropolitan area because this map also included the wetlands present in Orleans Parish. So the wetland areas were extracted and removed from the map.

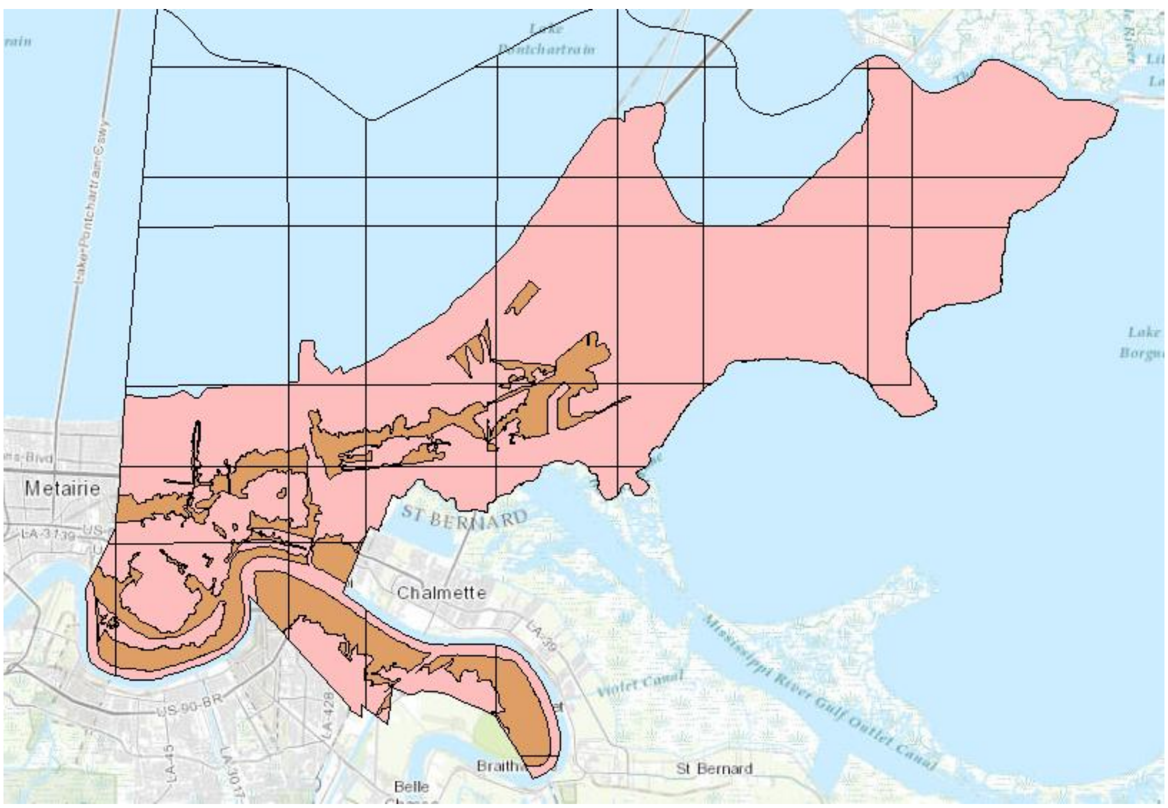

Figure 8. FEMA FIRM of Orleans Parish.

The DEM (Figure 9) was added for the flood analysis. The census shapefile was used as a mask to limit the DEM to the urban areas of Orleans Parish. The DEM shows that most of the city's elevation was below 0.5 m (colored red). The highest areas of the city (colored dark green) were actually the some of the levees and the areas built upon the natural levees created by the Mississippi river.

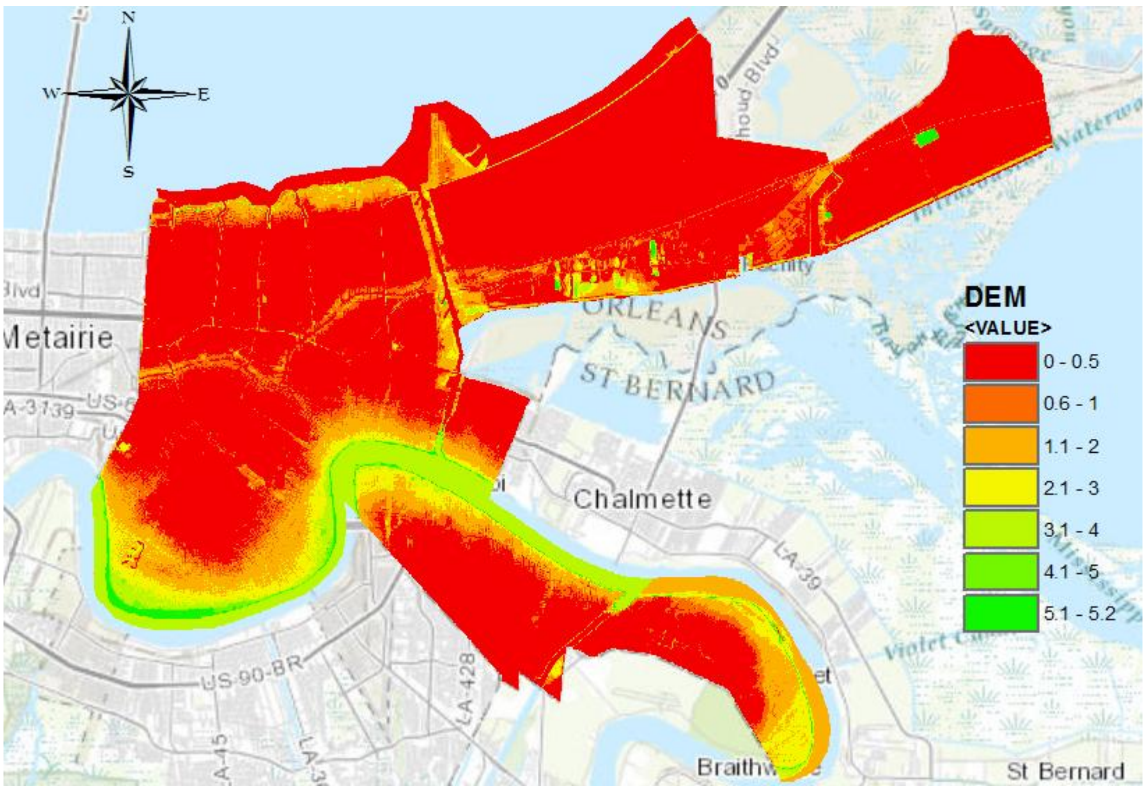

Figure 9: DEM of Orleans Parish urban areas

In the beginning of September, the water height of Lake Pontchartrain was 2.5ft so the areas of New Orleans considered flooded would be the places with an elevation less than 0.76m. From Figure 9, those regions would be the red areas and some of the orange areas. However, the regions of Algiers and Lower Algiers did not flood during Katrina. To separate the DEM raster, 2 layers were created: one with Algiers and Lower Algiers regions and the other with Metro, East, and Lower 9th regions. The DEM of the Algiers and Lower Algiers regions were extracted and marked as no flood. The rest of the DEM was divided by the extract by attributes tool. The tool created the flooded region by the formula “VALUE” <=0.76 and the no flooded region as “VALUE” > 0.76. In Figure 10 the flooded area was blue and the not flooded area was orange.

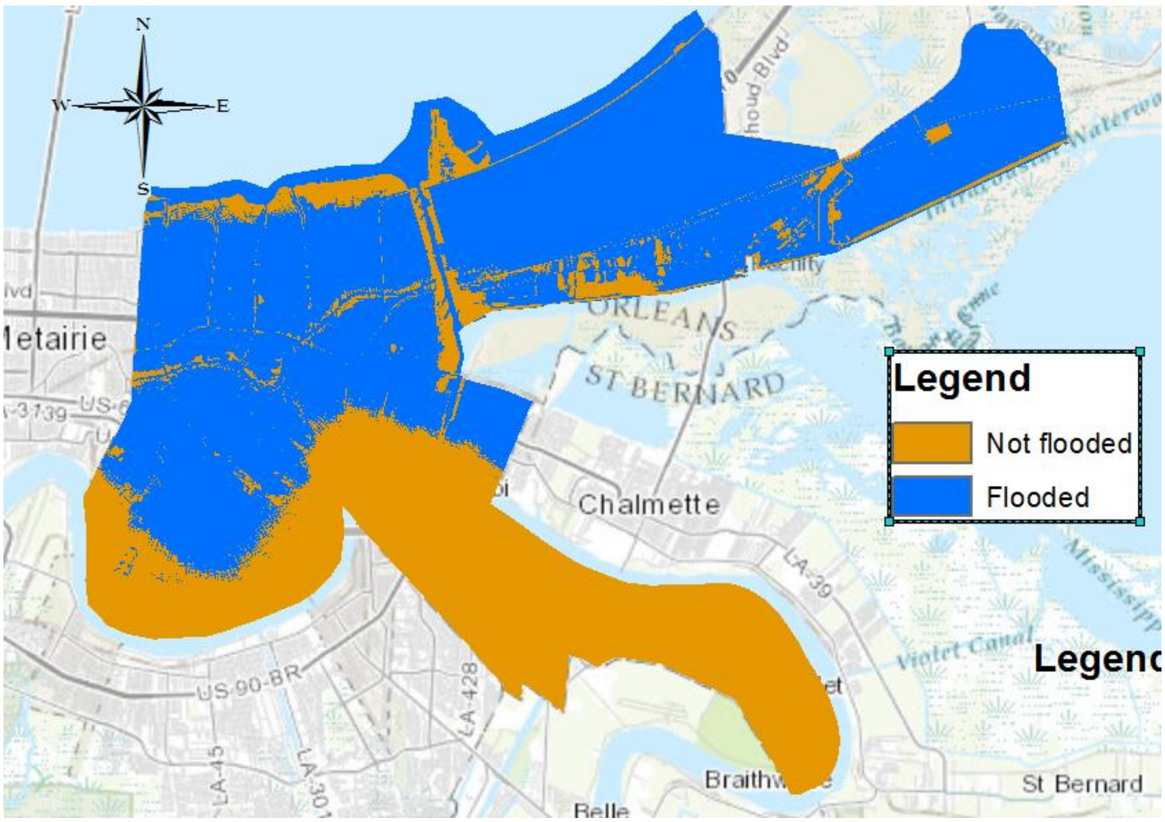

Figure 10: Inundated areas after Katrina

Two Layers were created from the FEMA FIRM to separate X and A areas of the FIRM for a comparison of the FIRMS and where flooding occurred in 2005. The differences between what was predicted for an extreme event and what occurred in 2005 were displayed in Figure 11. The A areas were used as a mask for the not flooded region raster to find what areas were predicted to flood but did not. These areas were colored yellow in Figure 11. Conversely, the X areas were used as a mask for the flooded regions to find where flooding was not probable but occurred in 2005. These areas were colored purple in Figure 11. The rest of the area in the figure behaved as predicted by the FIRM map (colored green). There was a bit of error in Figure 11 because the Mississippi River, which was higher than the water height of Lake Pontchartrain, was taken as area than did not flood. So the sections of the Mississippi River in yellow should be disregarded. Figure 11 showed significant flooding where it was not expected in regions on the east bank of the Mississippi River, especially in the East and Lower 9th region. Both regions had substantially more unexpected areas that flooded than areas that were expected to flood and did not. The discrepancy here shows that the Lower 9th and East regions would have more unpredicted flooding. While significant flooding occurred in the Metro as well, it was somewhat balanced by areas that were not levees that were predicted to flood but did not, so the total amount of flooding in the region did not change.

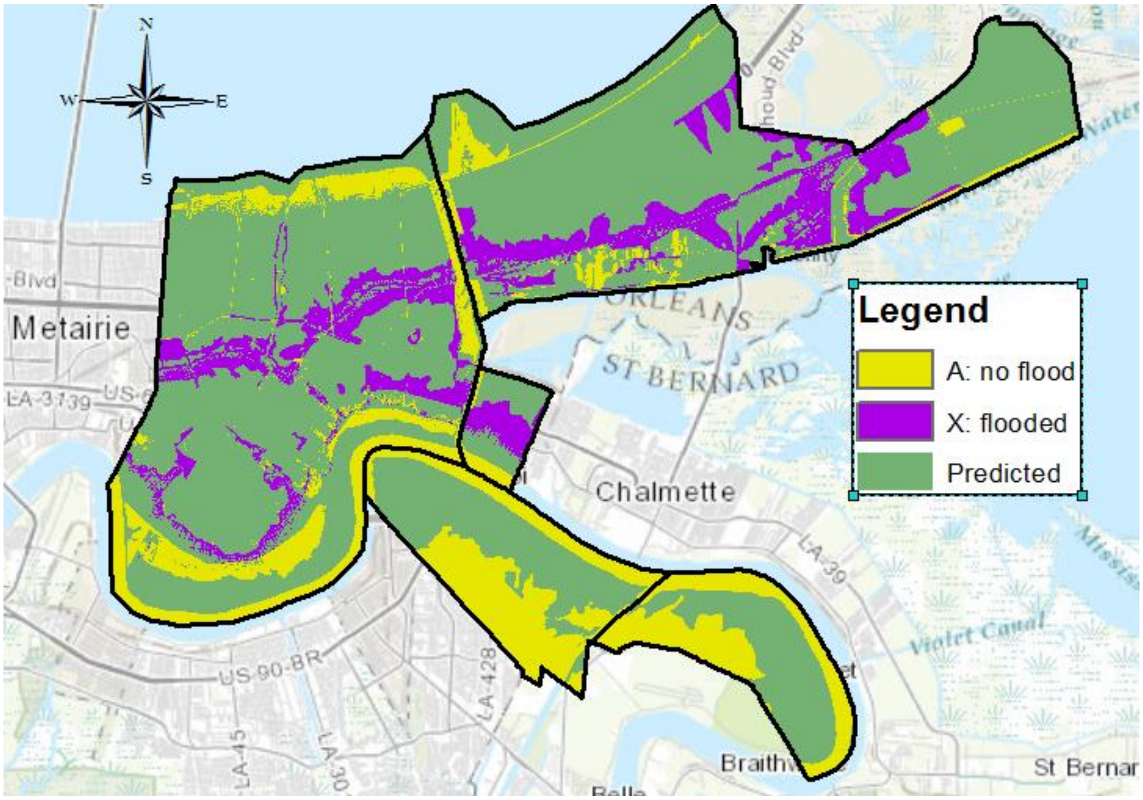

Figure E: FEMA comparison to flooding

Conclusion

The first section of the analysis revealed that the East and Lower Algiers regions were areas that had the lowest pumping density in New Orleans. However, the East region has 8 pumping stations so if there is one or multiple failures, there are other stations that will continue to pump water out of the East. The same is not true of Algiers, Lower Algiers, and Lower 9th regions, which have only 1 pumping station each. If any of these stations are faulty during a rain event, there was no other main pumping station to rely on. So Algiers, Lower Algiers, and Lower 9th regions have a high flood risk.

The FEMA FIRM and Katrina flooding comparison showed which areas of New Orleans flooded during Katrina that was not predicted. Overall, the East and Lower 9th regions had the most unpredicted flooding from Katrina. The Metro area had unpredicted flooding as well, but it also had significant areas of no flooding where flooding was predicted. Combining the results shows that the East, Lower 9th, and Lower Algiers had the highest risk for unpredicted flood (all had the lowest parameters for 2/3 of the analysis) and the Metro region had the lowest risk for large unpredicted flooding. This was a concerned because Lower 9th region had a high population density and East region had a medium population density with a large area, so high risk of unpredicted flooding in these regions affect a large population.

There were a few directions where this analysis can expand. If the flood data from the May 1995 event was obtained, it could be compared to FEMA FIRM to see the unpredicted flooding for a rainfall event. The drainage analysis may be done at per pumping station level with the exact district each pumping station services. With land use and soil types, the infiltration rates may be calculated, which would give the runoff. The critical rainfall event for the area may then be calculated from the runoff and the pumping capacity. Finally the critical rainfall event may then be compared to see where the drainage capacity of Orleans Parish is the weakest.

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