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Flood Hazard Map for Portions of Southeast Louisiana

INTRODUCTION

The City of New Orleans was constructed on the Mississippi River Delta. Through the course of nature, the Mississippi River will want to find the most direct route to the Gulf of Mexico but doing so would alter its present course through New Orleans. The Army Corps of Engineers forced the Mississippi River to maintain its current route by channeling the river through New Orleans. This resulted in the delta sinking and substantial marshland erosion. Marshlands are the City's first natural defense against major storms. "A combination of factors such as the gradual loss of elevation within the City due to high rates of subsidence in surrounding wetlands, and accelerated sea level rise, has further increased the vulnerability of New Orleans to flooding" (Masozera, Bailey, and Kerchner 301). "The wetlands and protective barrier islands that would dampen storm surges and waves during hurricanes have been lost, therefore increasing the risk of flood disaster in New Orleans and the surrounding area" (Masozera, Bailey, and Kerchner 301).

In August 2005, Hurricane Katrina landed onshore slightly east of New Orleans. Many locations in the New Orleans metropolitan area experienced severe flooding. In an attempt to lessen the loss of lives and property from future hurricanes, GIS is utilized to provide a flood hazard map of southeast Louisiana by indentifying high risk populations in relation to the bodies of water and levee locations. This is similar to a European Directive that required the production of integrated flood hazard maps "to establish flood hazard management plans focused on prevention, protection and preparedness" (Myronidis et al 102). An advantage of using GIS for flood management is that it visualizes the flooding as well as has the potential to estimate probable damages due to flooding (Solaimani 952).

Flood hazards are assessed through extreme events that exceed the design event of flood protection structures and failure scenarios such as dike breaches (Buchele et al 485). During Hurricane Katrina, a levee broke near the outskirts of the City which resulted in severe flooding of many residential neighborhoods. Since GIS is a useful tool that can be used to predict estimations of flood damage to single buildings or areas (Buchele et al 494), it is used in this case study to identify and rank flood areas based on proximity to water and levees as well as directional water flow. To mitigate devastation and wide-scale flooding in low lying areas for post-Katrina New Orleans neighborhoods, there was a proposal to return those areas to green space for ecological functions and stormwater management while relocating the citizens to higher ground (Fields 325). However, many people did not want their homes turned into green space so this proposal failed. Since these people did not want to relocate, a map is needed to identify higher elevation areas that would be safe to evacuate to during future hurricanes.

Ranking flooding vulnerabilities of coastal cities allows city managers and planners to plan future urban developments in low (flood) risk coastal areas (Shataee and Malek 293). It identifies "safe" areas to develop/rebuild neighborhoods following storms. The ranking of flood areas in New Orleans will dictate where mitigation efforts should be focused preceding future hurricanes. The purpose of this case study is to produce a flood hazard map for portions of southeast Louisiana based on the relationship between certain population demographics and existing infrastructure. Hopefully this map could aid the City's inhabitants in mitigation and evacuation efforts to minimize the loss of the life and property from future hurricanes.

PLANNING

There are many different factors to consider when producing flood hazard maps. During the initial planning stages of this case study, demographics of high risk populations were going to be analyzed against the existing infrastructure of Metropolitan New Orleans (Orleans and Jefferson Parishes). The most vulnerable populations to suffer from the negative effects of Hurricane Katrina were African Americans, people of limited income, single parents, and people suffering from chronic illnesses (Curtis, Mills and Leitner 327). To calculate the level of risk for these populations, each demographic data layer (age, race, mobility, disability, housing type and gender) would be rasterized, interpolated, and reclassified as low, moderate or high risk. The various reclassified layers would then be combined into one raster (through the raster calculator) to produce an overall classification of demographic flood risk.

The case study would then compare the demographics to the area's infrastructure such as the locations of levees, lakes, rivers, canals, and flood zones. Each infrastructure data layer would also be rasterized, computed through the raster calculator and reclassified into levels of risk. The various reclassified layers would then be combined into one raster (through the raster calculator) to produce an overall classification of infrastructure flood risks. To complete the analysis, the infrastructure flood risks data layer would be overlain on the demographic flood risks data layer to determine which areas in relation to populations were most at risk for severe flooding.

The overall planning process provided a good starting point from which to begin the analysis. However, as the case study progressed, some of the methods initially proposed to be used were dropped. There were also changes in what demographic and infrastructure data would be analyzed. The next section of the article describes how the case study is analyzed using GIS.

METHODOLOGY

This case study employs raster based analyses to identify high risk flood locations utilizing land elevation in association with levees and bodies of water. It compares those rasters against demographic and water flow rasters to highlight at-risk populations living within high flood risk areas. Raster based analyses are used in this case study because they "can delineate topographic geological material types by utilizing land cover and slope maps" (Kenny 52), and slope might be an important factor in the analyses.

The analysis commences by obtaining the demographic and parish boundaries data, setting their projections then clipping to the extent of the study area. The study area encompasses eight southeast Louisiana parishes: Jefferson, Lafourche, Orleans, Plaquemines, St. Bernard, St. Charles, St. John the Baptist and St. Tammany. GIS is used to identity where vulnerable populations reside within these parishes. Populations of elderly people (65 years old +), disabled people (physically and mentally), and single guardians of children (<18 years old) are the high risk focus groups that would be most likely to suffer the negative impacts of severe storms should flood hazard maps not exist. The densities of these populations are studied per square mile.

Researchers Raber and Tullis used GIS to produce a water surface elevation map of the inundated areas along the Mississippi Gulf Coast resulting from Hurricane Katrina (221). They applied a modified or “cost-weighted” distance interpolation algorithm in GIS to model the physical nature of the storm surge along the Gulf Coast (Raber and Tullis 221-222). Similar to Raber and Tullis’ method, interpolation (inverse distance weighted method) is used in this case study to identify the levels of risk (low, moderate, and high) for the population densities of the high risk focus groups.

The demographic data need to be converted from polygons to points before they can be interpolated. Each population density is interpolated, reclassified into three classes, and then symbolized using the equal interval classification method: low population densities, moderate population densities, and high population densities. Once complete, the raster layers representing the three reclassified population densities are entered into the “raster calculator” to produce a single raster layer of demographic risk. Once this data layer is made permanent, it is reclassified into three classes and symbolized using the equal interval classification method. The resulting *Demographic Flood Risk* data are symbolized as low risk population densities, moderate risk population densities or high risk population densities.

Once the demographics are analyzed, the focus of the case study changes to the area’s infrastructure. Data on the parishes’ levees, elevation, and bodies of water are obtained, projected and clipped to the extent of the study area. Since the file sizes of the elevation data are so large, a mosaic of the data needs to done. Half mile buffers are added to both the levees and bodies of water. Zonal Statistics are run on the buffered levees in association with land elevation. The resulting raster layer is reclassified into three classes and symbolized using the equal interval classification method: low levee elevation, moderate levee elevation, and high levee elevation. Zonal Statistics are also run on the buffered bodies of water in association with land elevation. The resulting raster layer is reclassified into three classes then symbolized using the equal interval classification method: low water elevation, moderate water elevation, and high water elevation.

Another condition to consider in evaluating flood risk is the directional flow of water. Using Spatial Analysis' focal flow and aggregate tools, the areas that would have large quantities of water flowing into them can be identified. The output of this analysis is reclassified into three classes then symbolized using the equal interval classification method: low water flow, moderate water flow, and high water flow.

Once the analyses of the infrastructure data are complete, the raster layers representing the four reclassified flood risk factors (demographics, levees, bodies of water, and water flow direction) are entered into the "raster calculator" to produce a single raster layer of flood risk. Once this data layer is made permanent, it is reclassified into five classes and symbolized using the equal interval classification method. The resulting *Levels of Flood Hazards* data are symbolized as low flood risk, moderate flood risk, intermediate flood risk, high flood risk, or severe flood risk.

To further analyze the populations located within the "severe flood risk" category, the *Levels of Flood Hazards* data need to be converted from a raster into polygons. Using the "select by attributes" and "select by location" applications, one can intersect the demographic block groups with the severe flood risk areas. This identifies the population density percentages of elderly, disabled people, and single guardians residing within "severe flood risk" areas.

RESULTS

It is important to produce flood maps and web mapping services in accordance with the needs of the general public (Hagemeier-Klose and Wagner 563). Therefore, the flood hazard map produced from this case study's analyses clearly identifies the areas of risk based on severity: low, moderate, intermediate, high and severe. This allows city managers, planners, government officials and lay people access to a map that can be easily understood.

The results of the analyses indicate that as the severity of flood risk increases, the amount of area within each risk category decreases. This means that the areas characterized by severe flood risks are smaller per square mile than the areas characterized by low flood risks. The low and moderate flood risk areas are the two largest categories spanning most of southeastern Louisiana. The low risk category is the largest category because it includes the portions of Lake Pontchartrain and the Gulf of Mexico that lie within the parish boundaries being analyzed. The intermediate and high flood risk areas are located along levees and the Mississippi River boundaries. The severe flood risk areas appear to be located slightly west of downtown New Orleans, along the Mississippi River levees.

Particular focus is placed on the high risk populations dwelling within severe flood risk zones. Table 1 displays the total population densities for the high risk populations in relation to the overall population density for the study area.

Table 1

High Risk Population Densities within Study Area		
Demographic	**Population Density per Square Mile**	**Percentage of Total Population**
Total Population Density for Study Area	*7,403,727*	**-**
Disabled Populations	2,991,536	40.41
Elderly (65+) Populations	908,082	12.27
Single Guardian Populations	444,098	6.00

As the Table 1 indicates, the population density of disabled people comprises almost half of the total population density within the study area at approximately 40%. The population densities of elderly and single guardians comprise approximately 12% and 6%, respectively. Other than the disabled populations, the other two high risk populations have small percentages of people living within the study area.

Table 2 displays the total population densities for the high risk populations living within the severe flood risk areas in relation to the overall population density for the study area.

Table 2

High Risk Population Densities living within Severe Flood Risk Areas		
Demographic	**Population Density per Square Mile**	**Percentage of Total Population**
Total Population Density for Study Area	*7,403,727*	**-**
Disabled Populations	614,511	8.30
Elderly (65+) Populations	190,586	2.57
Single Guardian Populations	82,187	1.11

The population densities for the high risk populations are smaller in the severe flood risk category than they are in the overall study area. The percentages of the population densities for the disabled, elderly, and single guardians living within severe flood risk zones are approximately 8%, 3% and 1%, respectively.

CRITICAL ANALYSIS

The case study highlights the populations that are most at risk from flooding and compares their habitat locations with the locations of water, levees and directional water flow. The analysis combines the densities of elderly, disabled, and single guardian populations into one risk factor, entitled *Demographic Flood Risk*. However, multiple analyses could have been run using each demographic separately. These populations are chosen because they are more likely to experience difficulty in evacuating and/or preparing their properties for impending storms. The analysis could have also been run using actual population figures rather than densities per square mile.

It is determined that the percentages of elderly, disabled, and single guardian population densities located in severe flood risk areas are lower than the overall percentages of the total population densities for each demographic. This is interesting because one would assume that the percentages would be higher than the total population density percentages. This results from the assumption that severe flood risk areas would be in areas of lower property values. Areas with lower property values typically have higher percentages of elderly, disabled and single guardian population densities as these groups are more likely to be lower income.

However, this case study proves otherwise. Since I am a New Orleans area native, I am familiar with the geography of the areas located within the severe flood risk zones. These areas are characterized by affluent neighborhoods. The main area is known as the Garden District which is an historic part of the City that is populated by high income citizens and historical preservation sites. This is not an area where most elderly, disabled or single guardians reside. However, this analysis could employ positivist techniques to determine what actual demographics characterize this area.

Half mile buffers are used around the levees and bodies of water data to provide a more compressive analysis of those populations that would experience flooding should the levees break or the bodies of the water overrun their banks. Since there are many bodies of water in the area, only half mile buffers are used to limit the possibility of buffers overlaying each other. However, this analysis could be conducted employing no buffers or buffers of different distances.

The concept of slope is considered in the analysis to determine the areas that are most at risk from downhill water flow. The results of the slope analysis indicate that most of the topography in the study area is relatively flat. Slope values primarily exist along the levees; therefore, slope does not play a factor in the overall analysis. To determine the areas where water flowing into them would be problematic, the focal flow and aggregate applications contained in ArcMap's Spatial Analyst toolset are used. This analysis is able to produce a flood risk factor of the amount of water flowing into an area. The higher amount of water flowing into an area increases the area's flood risk.

CONCLUSION

This case study is an example of how local knowledge plays an equal part with technology in studying flood risk areas. Unfortunately, "work in science and technology studies shows that conflicts between local residents and state officials and/or scientists are in part based on their different types of knowledge about a place, with state-centered scientific knowledge generally considered to override local knowledges" (Cidell 1202). This case study utilizes GIS technology to analyze and rank flood risks for southeast Louisiana. However, since I am a New Orleans native, some local knowledge assists in analyzing the GIS results. Hopefully, this flood hazard map will assist government officials and local inhabitants in planning mitigation efforts for future hurricanes.

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