FINAL REPORT

VULNERABILITY OF INDUSTRIAL FACILITIES IN TEXAS TO COASTAL HAZARDS

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Introduction

Hurricane Harvey was one of the largest hurricanes to hit the U.S. in the past few decades and demonstrated the need for smart planning to avoid catastrophes spilling over to a greater loss of lives and vital infrastructure. A large part of that potential damage, especially for areas like the Galveston bay, is in the concentration of industrial land. Those areas have a huge potential for creating disastrous events like those seen during Harvey, which at the time lead to the largest air pollution leak from a hurricane event the U.S. has ever seen (Mosier 2019). It also has the potential for serious damage to the bay itself, with countless industrial sites holding numerous individual tanks that could spell disaster for the ship channel and surrounding ecosystems. Harvey isn't the only example of a hurricanes disruptive power on Texas' coast, however. Rita and Katrina also dislodged chemical tanks, destroyed others with high wind speeds, and generally caused massive damage to the Galveston Bay's industrial areas (Godoy 2007). In the future, multiple different scenarios for hurricanes like these could present themselves, which makes it difficult to narrow down the vulnerable areas. Using hydrological models though it is possible to simulate how hurricanes could crash into the coast and where the most damage would be dealt (Bass et al. 2018). Our project can use the research provided here to take a closer look at what hurricane storm surges really look like, and how they affect the Galveston Bay area. This is important in order to be able to pinpoint areas on the map where a hydrological model might indicate vulnerable areas in the bay. As this research also indicates, hurricanes can be devastating setbacks for major population centers like Houston that heavily rely on these industries for income and livelihood. Matters can only be made worse by chemical spills or industrial damage as surrounding areas face health risks and economic downturn.

Storm surge is a vital component when looking into the safety of the bay's infrastructure and the impact it could have on the surrounding area. Storm surges can have devastating effects, like those seen by Hurricanes Katrina and Rita (Godoy 2007). More recently however, we can look at Hurricane Harvey as an example of how destructive storm surges can be, as it caused billions of dollars of damage (Mosier 2019). These surges could cause tanks to spill chemicals or oil into surrounding areas which could affect people's livelihoods (Kiaghadi et al. 2018). Those spills could also have massive effects on the surrounding environment in the Galveston Bay (Yin et al. 2015). In order to discover how this damage can be avoided in the future, this project is centered on identifying and locating facilities that may be in danger of being damaged during a major storm surge so that those facilities can better prepare themselves against those risks in the future.

Methods

Data Collection

Topographic data

The elevation data and land cover for the region of Galveston Bay is going to be provided by the Houston-Galveston Area Council (H-GAC).

Land Parcels

The parcel data for the region of Galveston Bay is going to be provided by the Texas Natural Resources Information System (TNRIS).

Industrial Facilities

The Industrial facilities are going to be obtained from the Environmental Protection Agency's (EPA) Envirofacts database which provides facility information through a Facility Registry Service that identifies these locations through environmental interest such as regulations.

Flood, Storm, and Wind data

The storm surge data is going to include the different Hurricane risk zones which are established by analyzing the intensity of a surge through rainfall and wind. This data is being provided by Texas A&M University at Galveston campus and the Center for Texas Beaches and Shores.

Aboveground Petroleum storage tanks

The storage tanks are going to be provided by the Texas Commission on Environmental Quality (TCEQ) which is an agency that serves to protect the health of the public and the natural resources that pertain to the state.

Storm Surge and Wind Analysis

Using the data provided above, shapefiles with the storm and wind data were brought into ArcGIS Pro 2.4 to help separate and visualize the data. First, the information that was outside the study scope was clipped off, using the counties of Brazoria, Harris, Chambers, and Galveston around the Galveston Bay. Once that was done, the industrial facilities and petroleum locations were individually overlayed with the storm surge and wind data, and then clipped the locations into new shapefiles. The level of vulnerability was recorded by rearranging the symbology, and the locations and area of each facility or tank location is included in the visual.

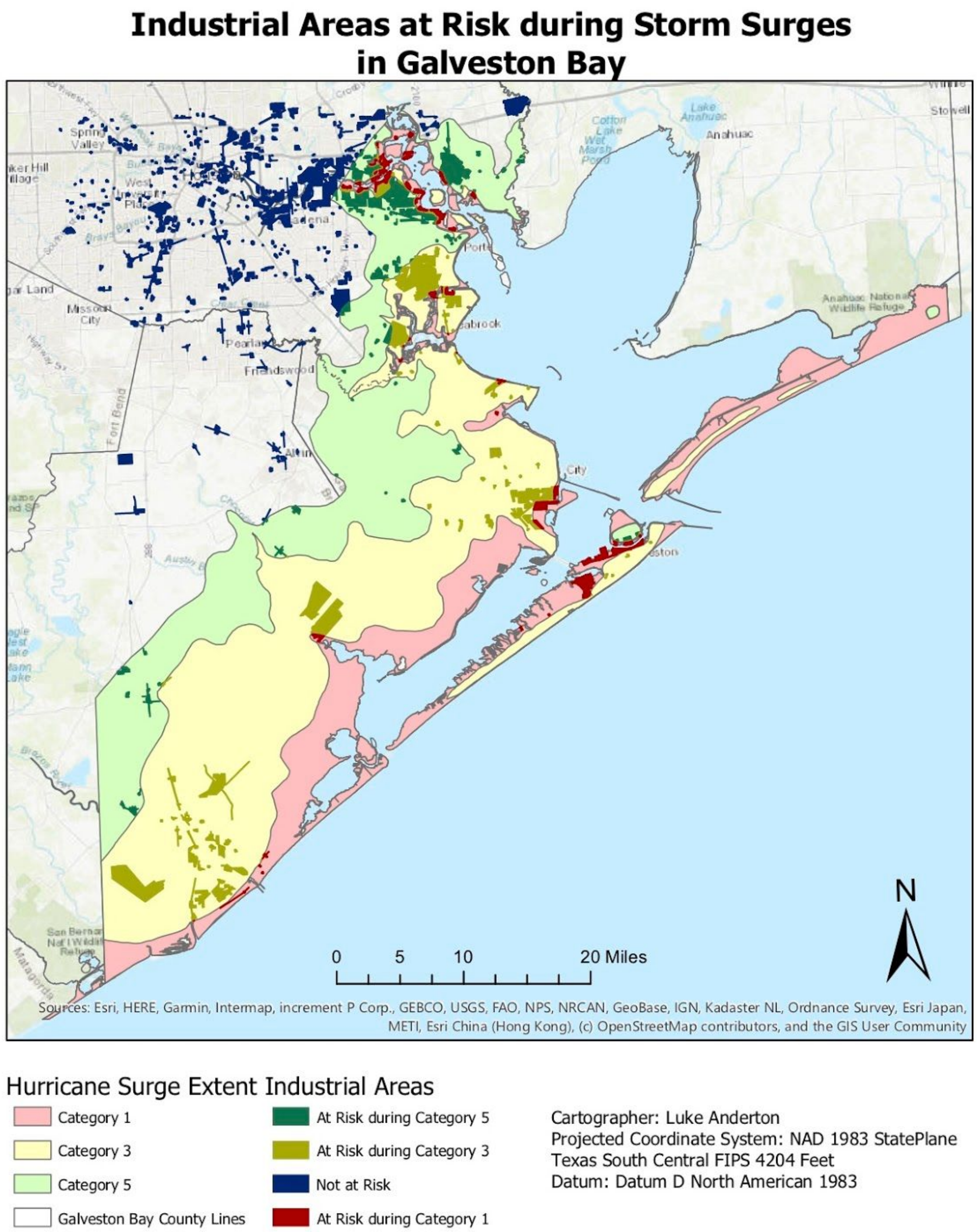
Flood Analysis

It is now time to analyze all the correct data has been collected to create a flood hazard map for the area around the Galveston Bay. ArcGIS Pro 2.4, was software of choice, to help visualize all this data to create a flood hazard map. The original DEM raster was considered a float raster and needed to be transformed into an integer raster. This step was completed by using the int spatial analysis tool. The land cover raster had twenty-two classes total, and this was difficult to deliver a good way to visualize the land cover. To help make the land cover DEM to look more pleasing to the eye, the reclassify tool was used to group the previous twenty-two classes into four different classes, water, residential, forest, and agriculture.

Now that all the data has been transformed, the next step is to combine all of the transformed rasters. This process can be done by creating a weighted suitability model. A weighted suitability model is a form of analysis to help visualize the most important raster cells of each layer's rank, that is ranked by the user. The weighted suitability model was made using the weighted overlay spatial analysis tool. The original DEM, for elevation, and the reclassed land cover DEM was entered into the weighted overlay tool. The tool uses a calculator that calculates the weight of each layer out of 100%, so the DEM and reclass land cover rasters were both ranked at 50%. The DEM elevation is in a range from -7 to 153 meters. These ranges were split into five different classes. These five classes help rank where it would be the best and worst spots for a flood. Class number 1 is the worst, and the classes gradually get better until the best class, class number 5. For the DEM classifications, the ranges of the classes go as, for class number 1 the range of elevations are between -7 to 13 meters, for class number 2 the range of elevations are 14 to 41 meters, for class number 3 the range of elevations are 42 to 81 meters, for class number 4 the range of elevations are 82 to 129 meters, and for class number 5 the range of elevations are 130 to 153 meters. For the reclassed land cover raster classifications, the water and agriculture were classed as class number 1, the residential was classed as class number 2, and the forest was classed as class number 3. These ranges and weighted percentage of each layer were used to find the areas around the Galveston Bay that is most likely prone to a flood.

The next step is to look at the vulnerability of the industrial facilities that around the Galveston Bay and coastal area if there was a flood to take place in the area. Since the weighted suitability model was still a raster, it had to be transformed into a polygon, so a select by location on the industrial facilities and petroleum storage tanks could be completed. Since the study area is around the Galveston Bay, not every industrial facility or petroleum storage tanks were needed, so the facilities and tanks were selected by location, and if intersected with the polygon that was created from the suitability model, then those facilities and tanks were used for the study. These selected facilities and tanks were then overlaid over the weighted suitability model to check if they were in a place of vulnerability from a flood.

Results



<u>Figure 1a:</u> Storm Surge Vulnerability in Galveston Bay

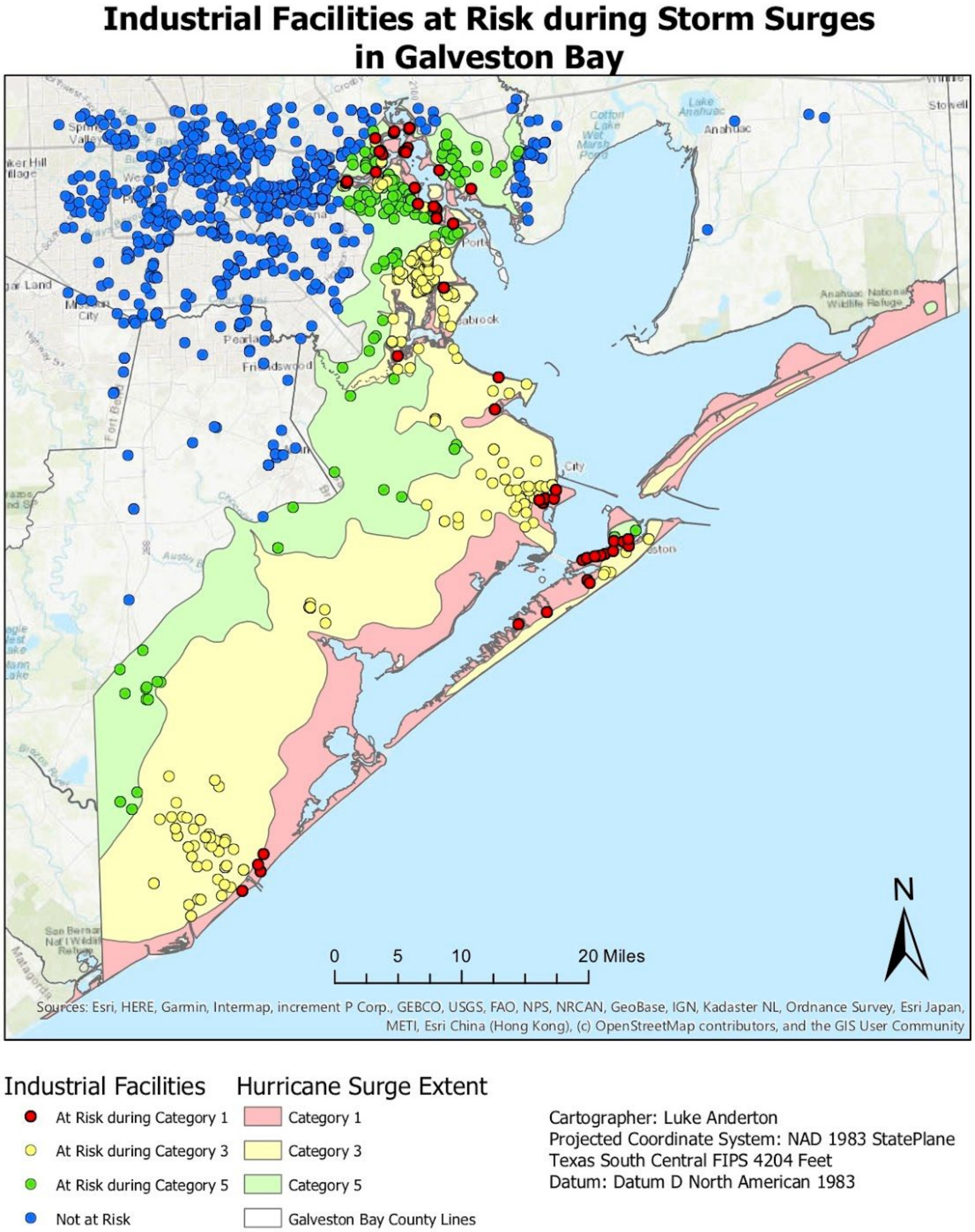
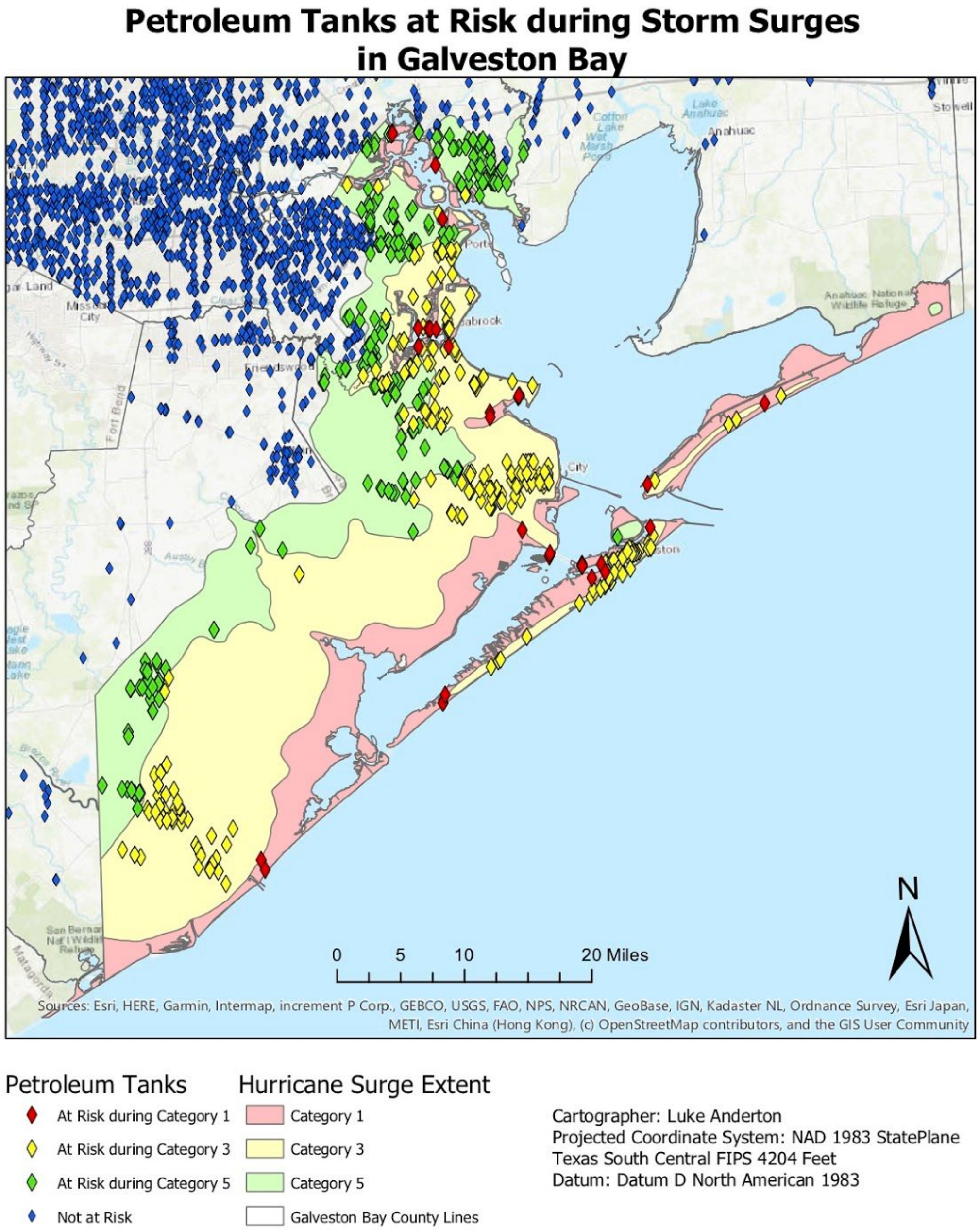


Figure 1b: Storm Surge Vulnerability in Galveston Bay



<u>Figure 1c:</u> Storm Surge Vulnerability in Galveston Bay

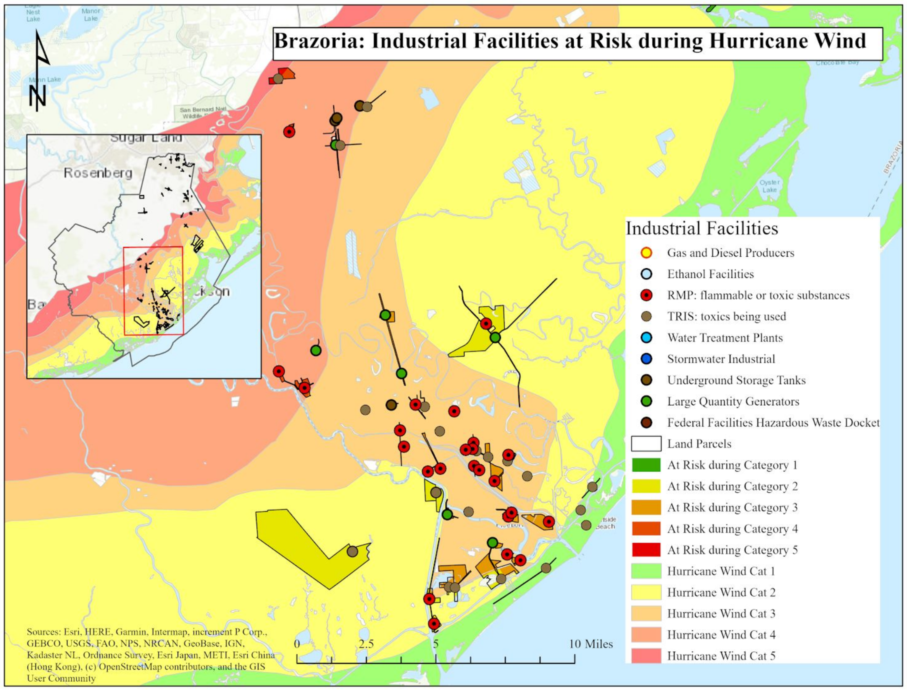


Figure 2a: Industrial Facilities at Risk during Hurricane Wind in Galveston

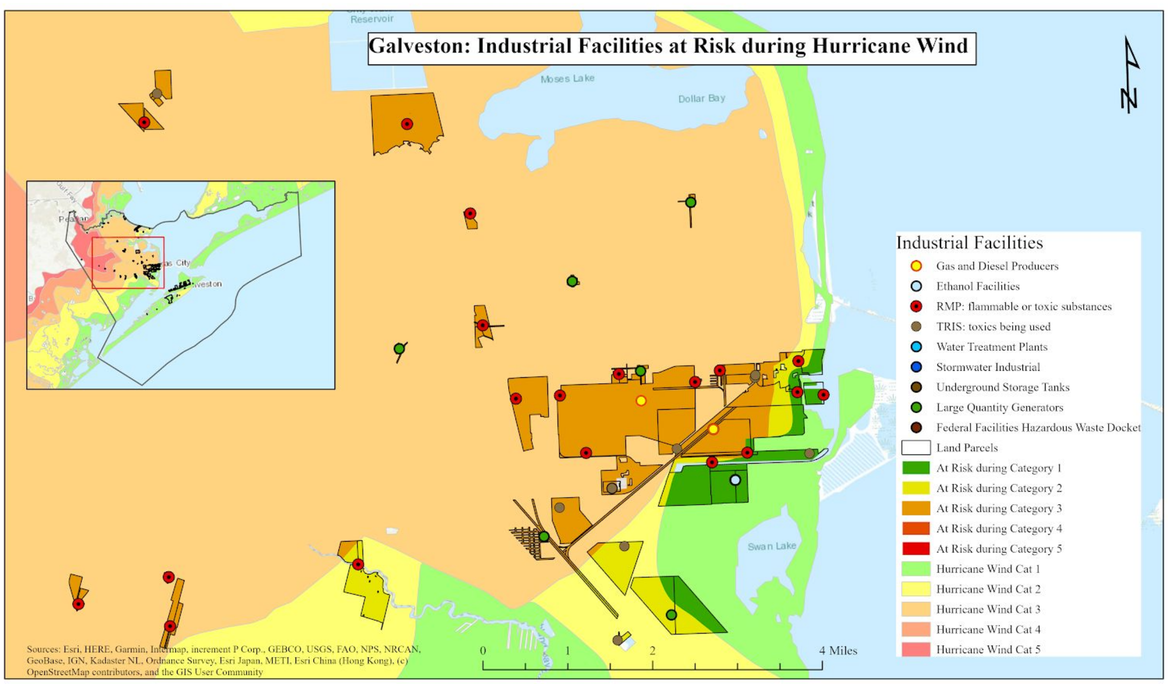


Figure 2b: Industrial Facilities at Risk during Hurricane Wind in Galveston

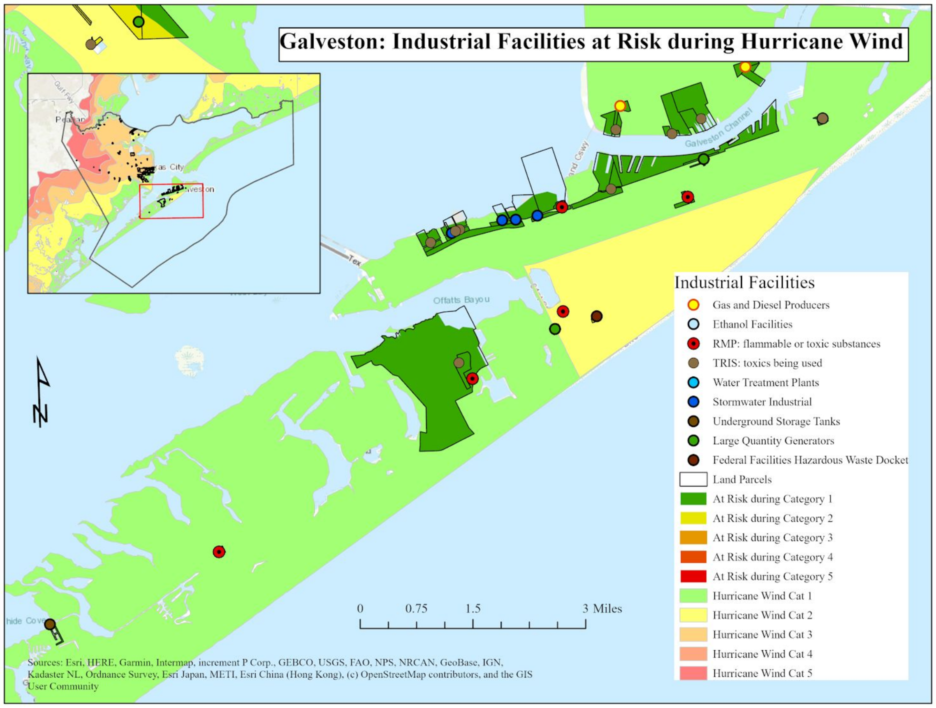


Figure 2c: Industrial Facilities at Risk during Hurricane Wind in Brazoria

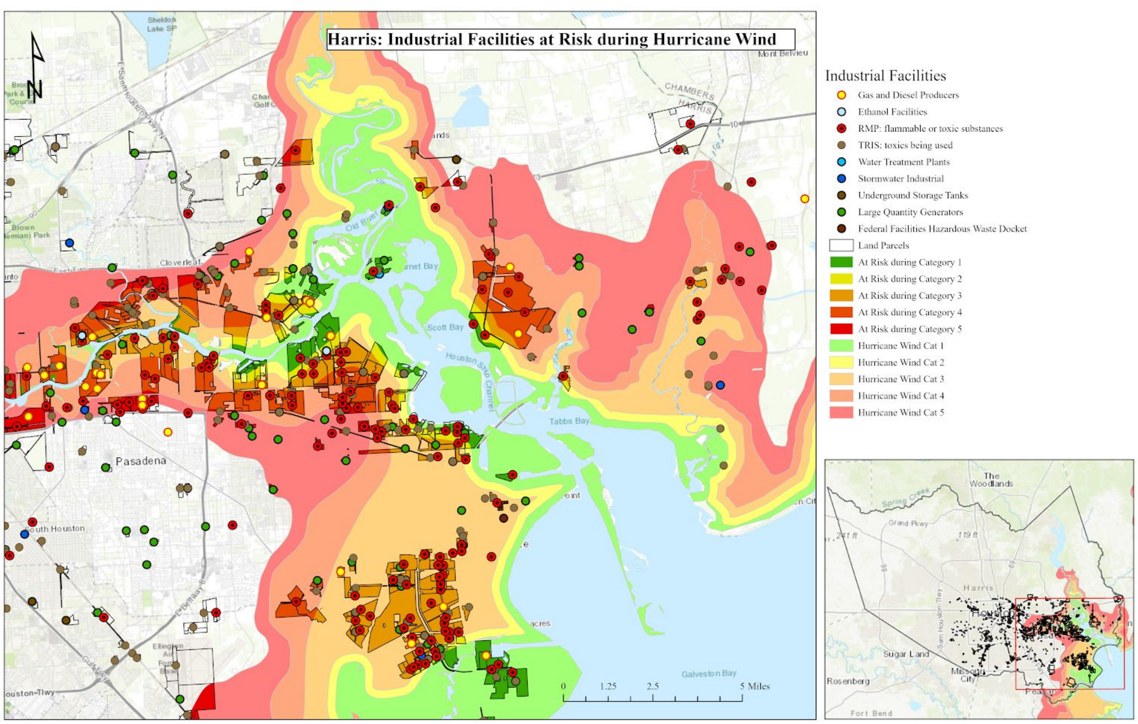


Figure 2d: Industrial Facilities at Risk during Hurricane Wind in Harris

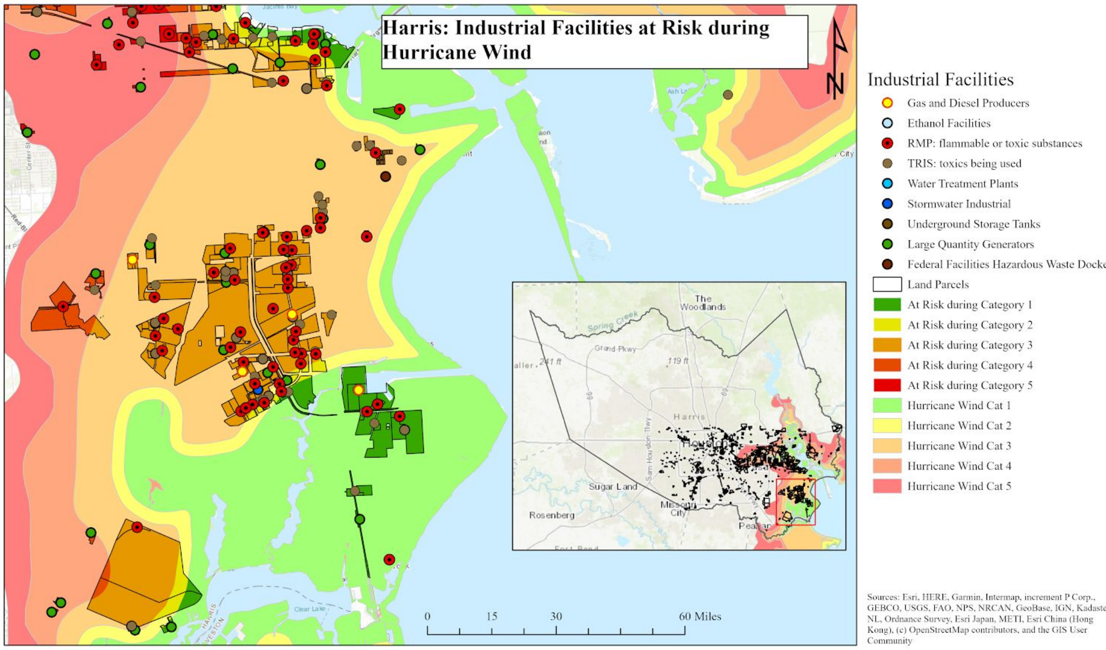


Figure 2e: Industrial Facilities at Risk during Hurricane Wind in Harris

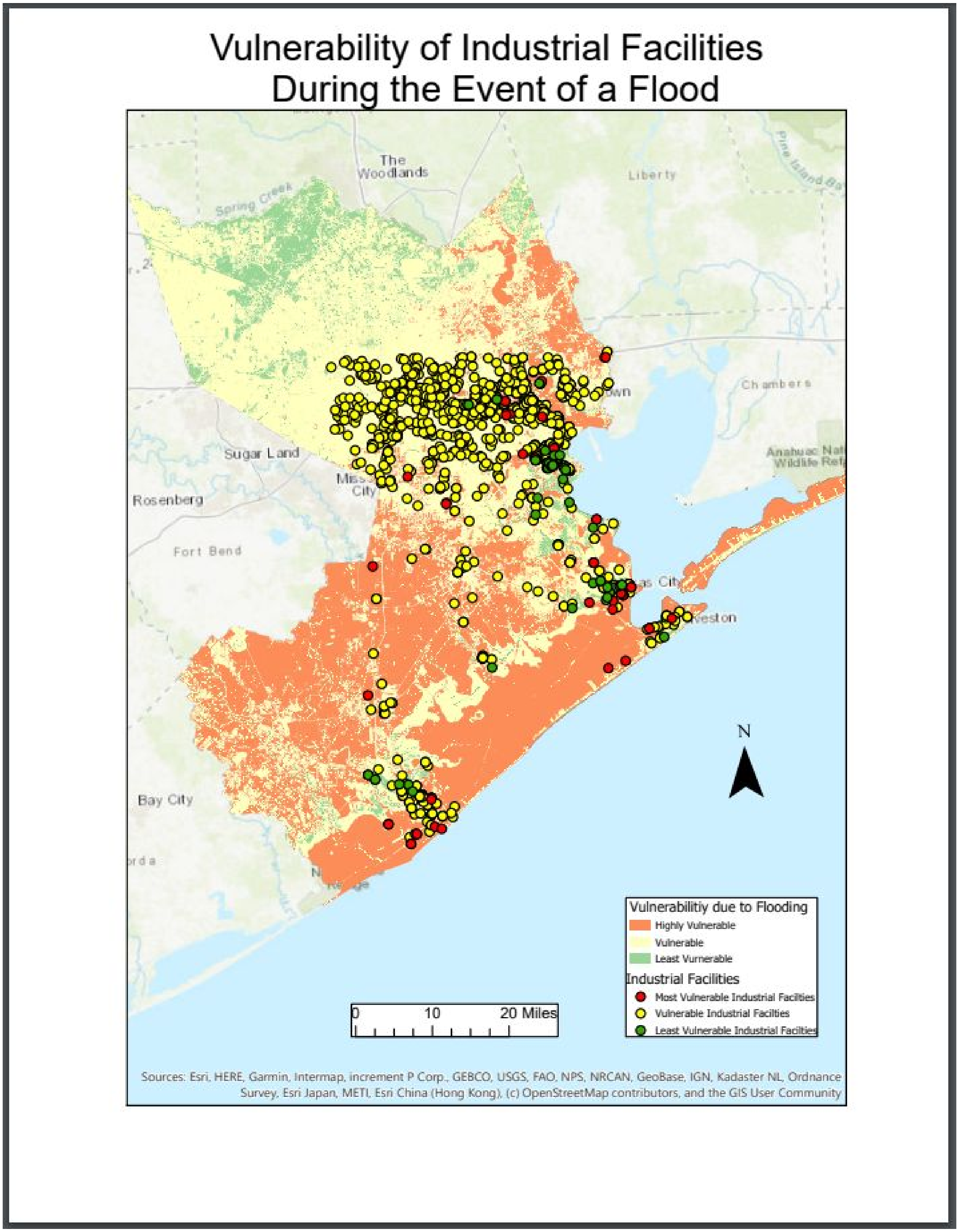


Figure 3a. Vulnerability of industrial facilities in the event of a flood in Galveston, Harris, and Brazoria counties, Texas.

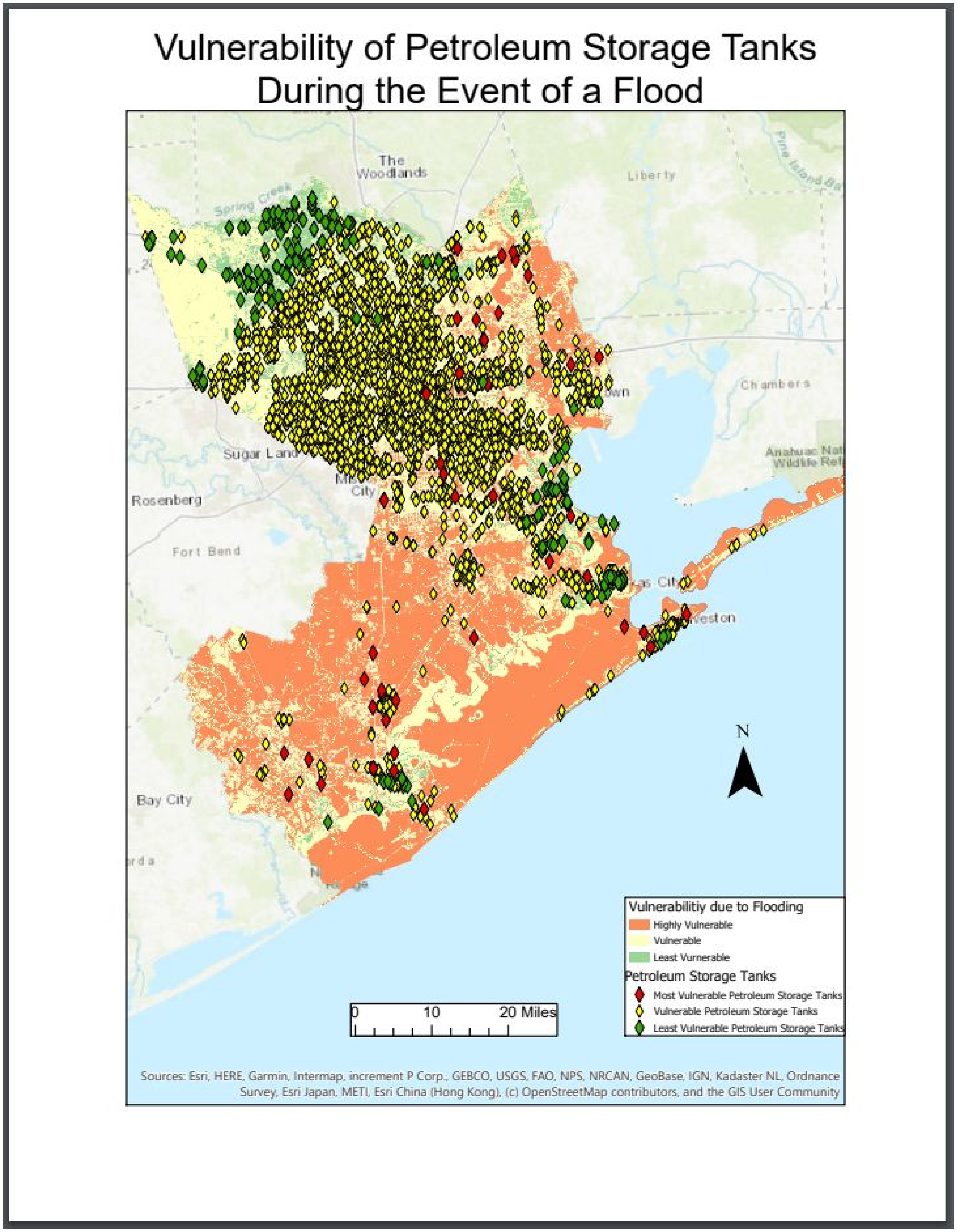


Figure 3b. Vulnerability of petroleum storage tanks during the event of a flood in Galveston, Harris, and Brazoria counties, Texas.

Discussion

The figures above are representative of the bulk of the analysis done regarding this project. For the purpose of simplicity, the results have also been split into three separate categories: storm surge, wind, and flooding risks. Storm surge results, pictured in figure 1, can be broken down into three different sections in terms of how much industrial land is at risk, including locations, actual land area, and petroleum tank locations. The industrial land which consisted of hazardous waste, oil and gas, water treatment and various other facilities were compared with the storm surge data for hurricane categories 1, 3, and 5. The number of facilities affected by any level of hurricane was approximately 82 or 5.4% of the facilities in the four surrounding counties. For category 3, 31% and for category 5, 48%. The total amount of land coverage which was estimated using the same methods, was calculated to be around 3,814.60 acres of the recorded 55,675.89 acres used in the data. For this, 6.8% of the land would be affected during any category of hurricane, 38.5% would be affected during a hurricane of category 3, and 59.7% of the land would be affected during a category 5 hurricane. As for the petroleum tanks, only 1.0% would be affected during any level, 8.8% would be affected during category 3, and 16% would be affected during category 5. The data suggests that despite having a large number of petroleum tanks in the four counties surrounding the Galveston Bay, they are less near the coast or in harmful areas. It is alarming that a vast majority of the Greater Houston area's industrial facilities would be placed at risk in the face of a hurricane of category 5. Especially as this isn't taking the long term effects of flooding into account.

The industrial facilities that were found in this area at a Hurricane Wind category 5 accumulated to a total of 1,201 sites. These facilities were categorized by a specific affiliation towards an environmental interest. This included gas and diesel producers, ethanol facilities, flammable or toxic substances, water treatment plants, stormwater industrial, underground storage tanks, large quantity generators, and hazardous waste. In the Hurricane Wind category 1, there are 520 facilities that are at risk from wind damage which contain hazardous waste, gas and diesel, large quantity generators, ethanol, and flammable/toxic substances. These facilities are relatively close to the coast which shows a high vulnerability in taking damage if a strong hurricane were to hit the area around Galveston Bay. With each category increasing in area for hurricane wind, the number of facilities at risk increase which is a cause of concern for the communities and the environment around them.

The flooding results, pictured in Figure 3a and 3b, show the vulnerability of industrial facilities and petroleum storage tanks in the event of a flood within Galveston, Harris, and Brazoria counties. There are a total of 1,445 industrial facilities that were within the study area. There are 50 industrial facilities that are located in the most vulnerable to flood area. There are 1,315 industrial facilities that are located in the vulnerable to flood area. There are 80 industrial facilities that are located in the least vulnerable to flood area. There are a total of 3,275 petroleum storage tanks that were within the study area. There are 44 petroleum storage tanks that are located in the most vulnerable to flood area. There are 3,047 petroleum storage tanks that are located in the vulnerable to flood area. There are 184 petroleum storage tanks that are located in the least vulnerable to flood area.

There were several challenges facing this project, including data and scope issues. The storm surge and wind data didn't cover a significant portion of Chamber county, meaning a large section of the Galveston Bay was unchecked. Unfortunately there was not another source for the storm surge data to cover the missing county. The project also used flooding estimations that were based on elevation, and storm surge and wind data that came from the CTBS in Galveston, so the accuracy of vulnerability is entirely relative to other stations. Whether or not facilities get damaged would also depend on the local topography, drainage, and security measures taken by each individual facility which were not accounted for in this analysis.

Conclusion

In *NOS Experimental Galveston Bay Nowcast/Forecast System: Storm Surge Studies*, NOAA was able to signify that we need to provide further attention to the drainage areas that persist in the Galveston Bay which plays a crucial factor in sediment transport and morphological change near the coast. The critical point for these areas is reducing flood vulnerability which can be devastating if a future storm surge happens without any solutions in place (Richard, 2007). As seen in the figures above, there are a number of facilities that may be at serious risk during major flooding events. This report incorporates a baseline broad overview of the facilities that could face risk, and their vulnerability based on several storm related factors in the Galveston Bay. Should further interest in the subject drive research to continue, it would benefit from accumulating more extensive flood and storm data to cover further down the coast, as well as accumulated the risks related to each category laid out in this document in order to have a more comprehensive view of which facilities are most vulnerable to storm damage.

References

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