Flood Hazard Risk in Massachusetts

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Abstract

Floods are the most common occurring natural disaster and the severity and intensity of floods is only rising due to climate change. In this project I performed an analysis on publicly available information on flooding in the state of Massachusetts. The goal of my work in this project was to locate areas of higher flood concern. Factors that I analyzed include national flood hazard mapping, locations of bodies of water and coastlines, areas with high population numbers with flood exposure, and towns with the largest flood exposure. With my analysis I was able to pinpoint certain areas that have an increased exposure to flooding. Using my findings, emergency response planners will be better prepared to allocate their resources. It is nearly impossible to prevent a flood so people, businesses, and governments must have plans in place to mitigate any damages that occur due to a flooding scenario. The work in this project gives a great foundation of flood exposure analysis and can be used as a building block to more complicated studies. As is true with all natural disasters, the exposure is constantly growing so areas that are not of much concern now can become key areas in the future. Because of this it is important to constantly reevaluate flood exposure analysis as time goes on.

Introduction

Floods are the most frequent type of natural disaster and have affected more than 2 billion people worldwide between 1998 and 2017 (WHO, 2017). Floods cause both bodily injury and property damage when they occur. Flooding occurs when areas that are typically dry become submerged by water. The 3 most common types of flooding are flash floods, river floods, and coastal floods. Flash flooding occurs when there is rapid and excessive rainfall that causes water heights to rise. River flooding occurs when there is consistent rain or snow melt that forces the water over the capacity of the river. Coastal floods occur during storm surge events related to hurricanes and tsunamis.

In this report I will be looking at the flood exposure in Massachusetts. Massachusetts was chosen as the area of interest due to it being where I currently reside. In this project I will be analyzing areas of heightened flood risk throughout Massachusetts. Using the results of this project I will have a better understanding of where flood damage control measures should be in place and what areas of the state need to have flood response plans in place to mitigate potential damage during a flood scenario. With the increase in the number of floods occurring in the past several years it is important to understand the exposure. Climate change has resulted in more floods than ever before, and this number is not expected to drop. It is nearly impossible to prevent a flood from occurring so emergency responders need to have plans in place to mitigate potential damage during a flood. The results of my analysis will let disaster response planners know which areas they should focus their resources on.

Background

Coastal areas such as Massachusetts have an increased exposure to flooding due to risk associated with the ocean along with the typical flood exposures such as rivers and ponds. With the increasing threat of climate change, it has never been more important than now to reassess coastal flood risk. As the sea level rises, the potential for catastrophic flooding also rises. Older flood models only focus on the fluvial flooding hazards and neglect the coastal flooding hazards. It is now important to use a bivariate assessment framework to determine the probability of flooding. Moftakhari, et al have started to develop their own bivariate models to get a better understanding of the flooding potential for coastal areas (Moftakhari, et al, 2017).

As discussed above, a key focus on flood research has to do with climate change and its impact on coastal flooding. In Vitousek, et al (2017) study, the authors predicted that 10 to 20 cm expected sea level rise by 2050 will result in more than double the amount extreme water level events. Current flood modeling practices do not fully include the impact of waves rising with the sea level and because of this, models tend to underestimate the flood risk for coastal areas. In this study the authors combine wave and tidal models with rising sea levels to predict coastal flooding scenarios (Vitousek, et al, 2017).

Flood modeling and research has been a growing field primarily the past few years primarily driven by the increased flooding caused by climate change. With so many different studies being made on flood modeling and experimental work, the best studies can be lost in an influx of articles and journals. Mignot, Li, and Dewals (2019) have completed a study that combed through 45 scientific papers dedicated to urban flooding to help with future studies determine where to focus. In their paper the authors suggest that future experiments focus on the quantitative insights associated with urban flooding. With a focus on quantitative information, future analysis will be more successful in predicting flood scenarios (Mignot, Li, Dewals, 2019).

Methods

The main dataset that I used for this project was the National Flood Hazard Layer (NFHL) dataset for Massachusetts that is published by the Federal Emergency Management Agency (FEMA). FEMA develops Flood Insurance Rate Maps to help insurance companies assess the flood exposure across the United States. The flood zones that I am interested in for this project are the 1% annual chance flood zones also known as Zone A or AE, and high-risk coastal areas also known as flood Zone VE. Using this data from FEMA gives us a great start of which areas will be affected by potential floods. Other data that I used from FEMA a dataset that showed which towns have flood zone data available.

I also used 2010 census data for the state of Massachusetts. The purpose of me obtaining this data was to get an idea of the amount of people that would be affected by a potential flood. I used data Census data on the block, block group, and tract level. The main datapoint I needed for these groups was the population of each.

Another dataset I used was the hydrologic information for the state of Massachusetts that was available on the MassGIS website. This dataset contained information on all major waterways across the state, such as ponds, lakes, rivers, and streams. I also used a dataset that included the coastline of Massachusetts.

To load each of my datasets into the pgAdmin software I used the PostGIS shapefile and DBF file Loader Exporter. Because each of the datasets I used were shapefiles, I was able to easily load each one in using the shapefile loader tool. Once each of the datasets were loaded into the pgAdmin database I was able to use the PostGIS package to analyze and manipulate the data. An example of the SQL used to create each data table can be seen in *figure 1* below.

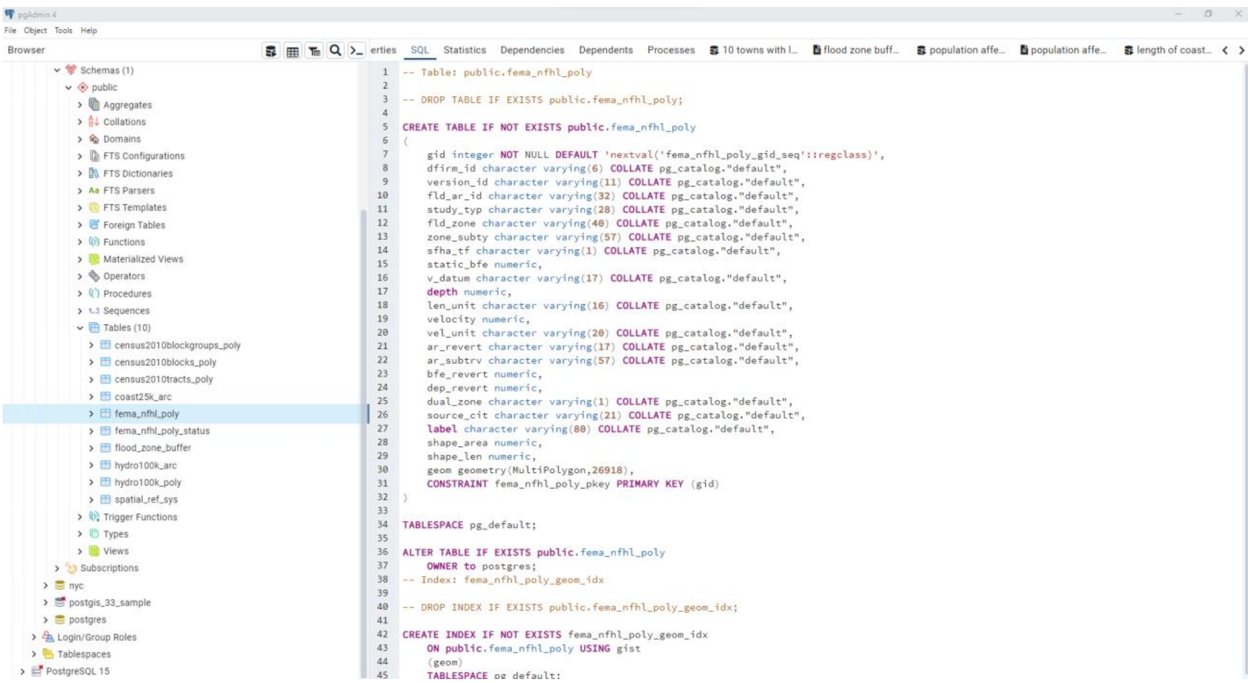

Figure 1: SQL for creation of FEMA NFHL table

There were several research questions that I wanted to answer in this project that ranged in complexity. The first question I had was which towns have the highest population values that are affected by critical flood zones (A, AE, VE). To complete this query, I would need to use information from the FEMA NFHL data table and the Census Block data table. I knew that I would be able to join these two data tables based on whether a census block intersected with a critical flood zone. Once the two datasets were joined, I would be able to select the town names and the sum of the populations for each town. I could then sort the data to show the populations that would be affected the most. Once I completed this analysis, I wanted to look further and perform a buffer on the critical flood zones. The reason I wanted to do this was because in a severe flood scenario, it is likely that the flood damage would go past the critical flood zone. The buffer that I used for this analysis was a 200-meter buffer. The reason I chose 200 meters is because that is what my current company uses when assessing flood exposures. With the new buffer flood zone dataset, I was able to repeat the analysis and see how many more people would be affected.

Another question I was interested in answering was which towns have the largest single flood zones. The reason for this analysis was that I was curious on how large an area could be affected by one flood event. To complete this query, I needed to use data from the NFHL data table and the NFHL town data table. I knew that I could join these two datasets on whether a town contained an entire flood zone. Once the datasets were joined, I was able to select the town names, the area of the flood zone, the perimeter length of the flood zone, the number of vertices, and the number of rings, and the type of flood zone. I was also able to order these results by the area value to determine where the largest flood zones are in Massachusetts.

Another question I was curious about was what the length of the coastline in Massachusetts was, including all the state's islands. I was interested in this information as I wanted to find out what the total distance of potential coastline flooding was. For this query all I needed was the Massachusetts coastline dataset. With this dataset I was able to select the sum of all the coastlines throughout the state.

Another question I was interested in answering was the number of flood zones in each town and how much of the town they take up. I was interested in this question as I wanted to compare flood zone sizes in each town. For this query I needed information from the FEMA NFHL dataset and the FEMA NFHL town dataset. For this query I would need to identify the number of flood zones that are completely within each town. Once I joined the two datasets, I was then able to select each town, the count of the number of flood zones for each town, the total area of flood zones for each town, and the sum of the area for each town.

Results

The first query that I ran was about the population of the census blocks that are affected by a critical flood zone. This query showed that Quincy had the highest population that was affected by a critical flood zone with 79,636 people. This number was over 15,000 more than the next town, which was Framingham. These results were surprising as Quincy is not the largest city in the state. The query and the results can be seen in *figure 2* below.

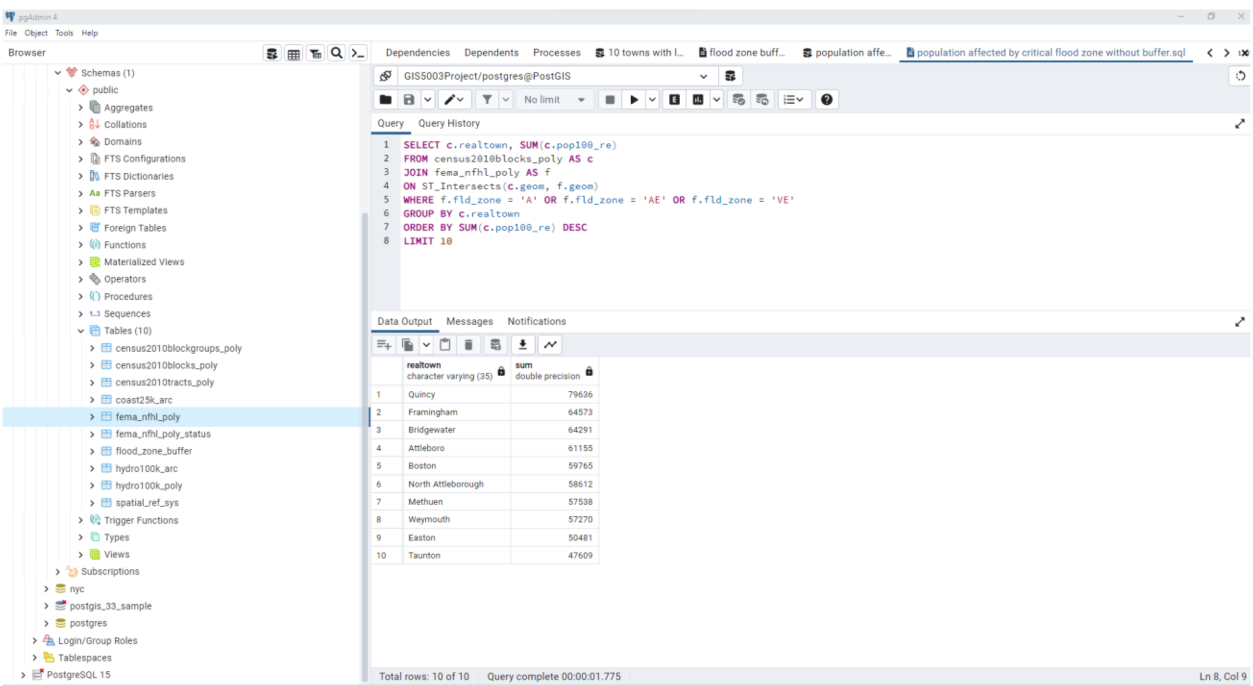

Figure 2: Town populations affected by a critical flood zone

Following these results, I was curious to how these results would change given a 200-meter buffer around each of the flood zones. The buffer did change the results, which was not surprising. Following the buffer Boston was the largest mover with now having 355,453 people affected by the population. This shot Boston up from number 5 in the original query to number 1 in the buffer query.

The creation of the buffer and the results of the new query can be seen in *figure 3* and *figure 4* below.

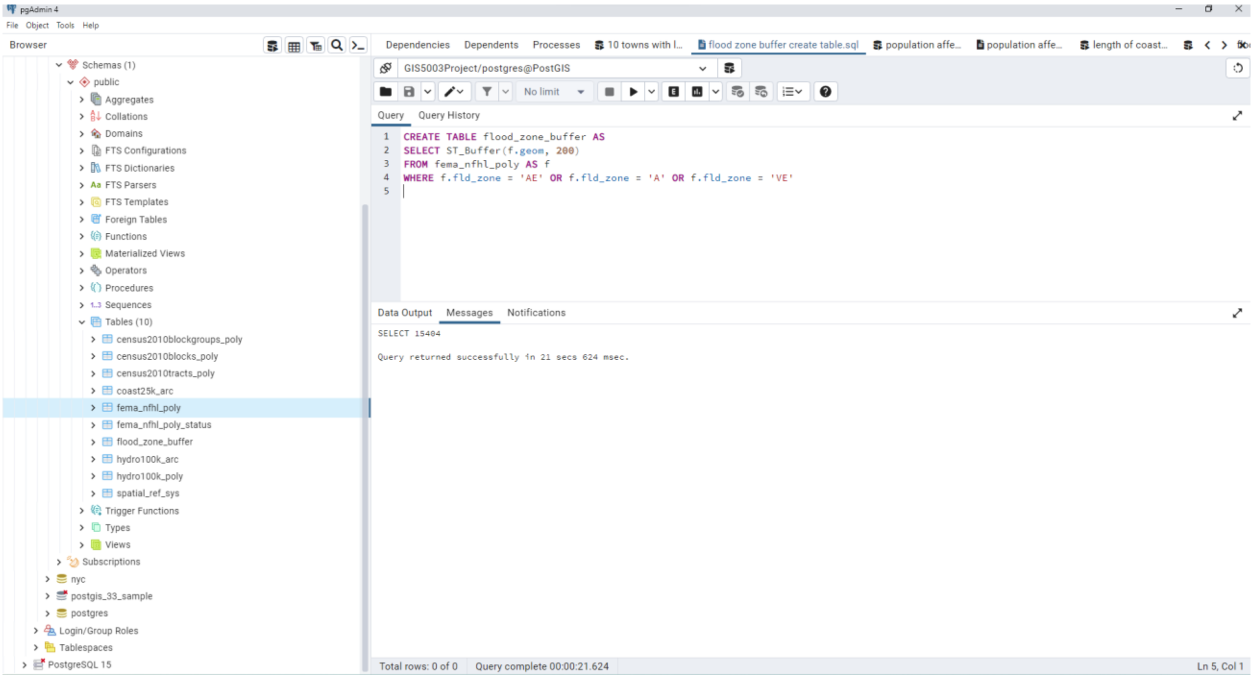

Figure 3: Create 200-meter buffer around critical flood zones

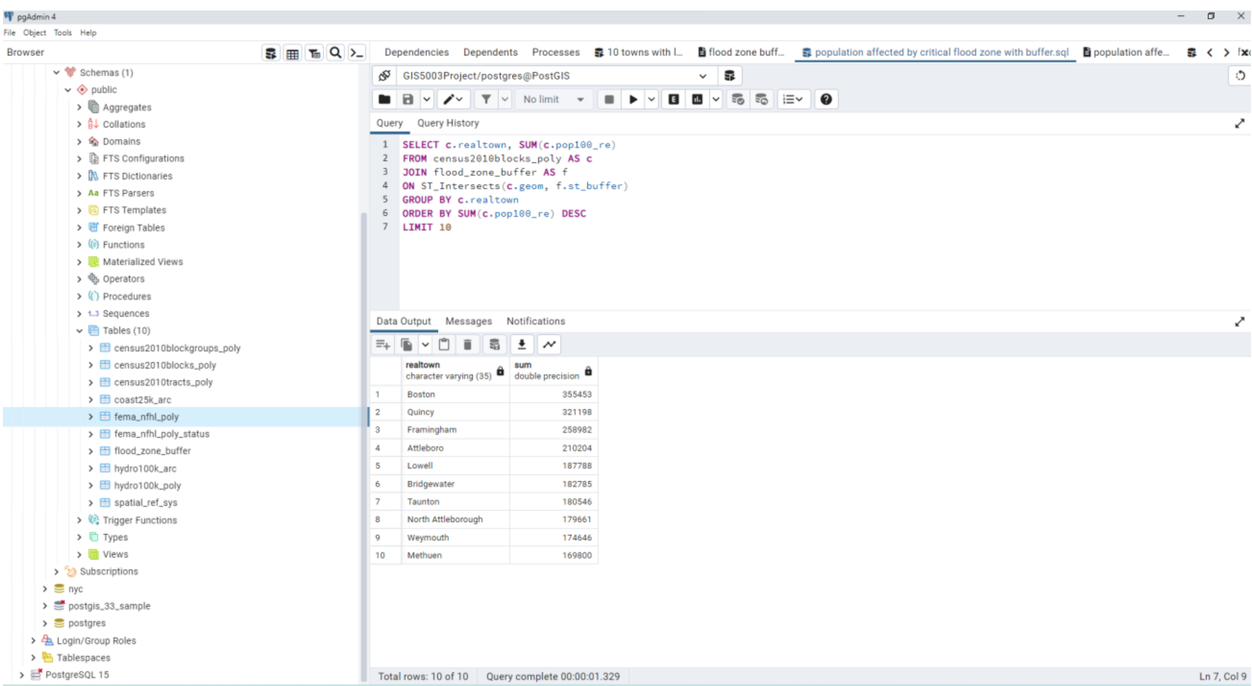

Figure 4: City populations affected by 200-meter flood zone buffer

The next query that I was interested in was the largest flood zone throughout the state and which towns these were in. These results showed that Webster had the largest flood zone with an area of 5,530,233 square meters. This flood zone also had the largest perimeter being 36,212 meters in length. This flood zone was made up of 2919 vertices and had 8 rings. This flood zone is much larger than all other flood zones in Massachusetts. Another interesting note from this query was that both Dartmouth and Marshfield have two flood zones that are in the top 6 largest in the state. The results from this query can be seen in *figure 5* below.

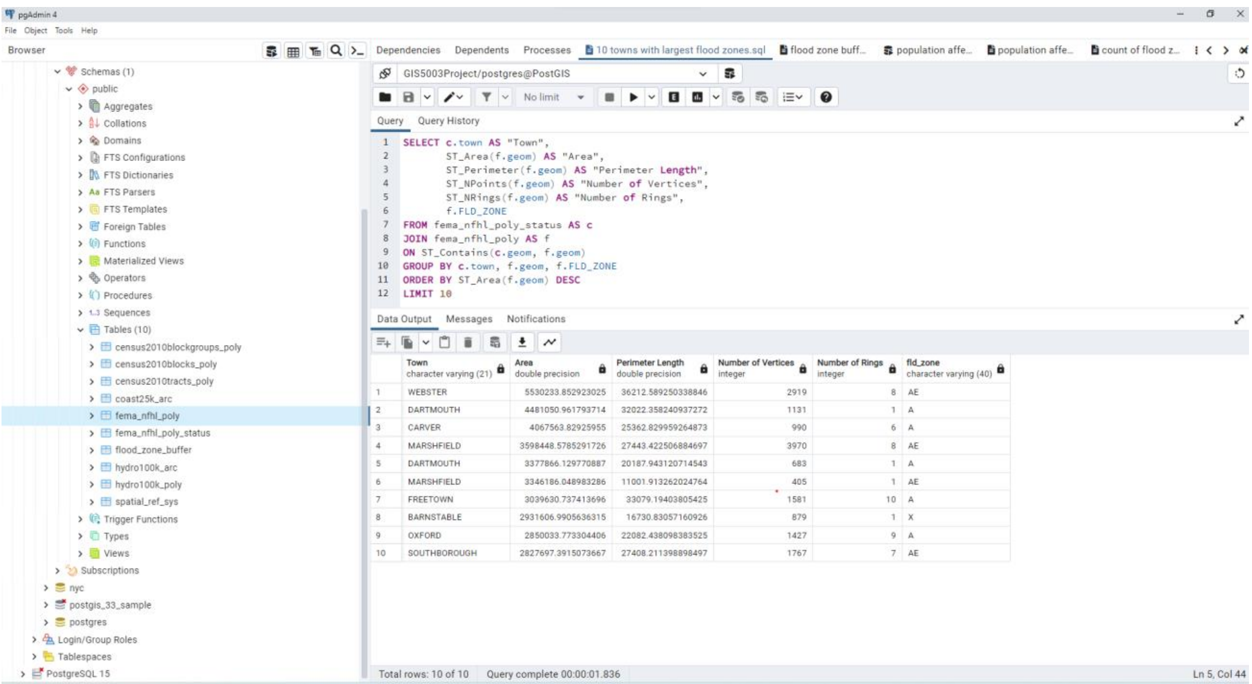

Figure 5: Largest flood zones in Massachusetts

The next query that I had was the length of coastline in Massachusetts including all islands. The results from this query showed that Massachusetts has a coastline of 4,500,435 meters. This entire area is at risk to coastal flooding which can be more catastrophic when compared to flooding that occurs inland from rain or inland bodies of water. With climate change Massachusetts will need to put more resources to this critical coastline to protect itself from coastal flooding and storm surge. The results of this query can be seen in *figure 6* below.

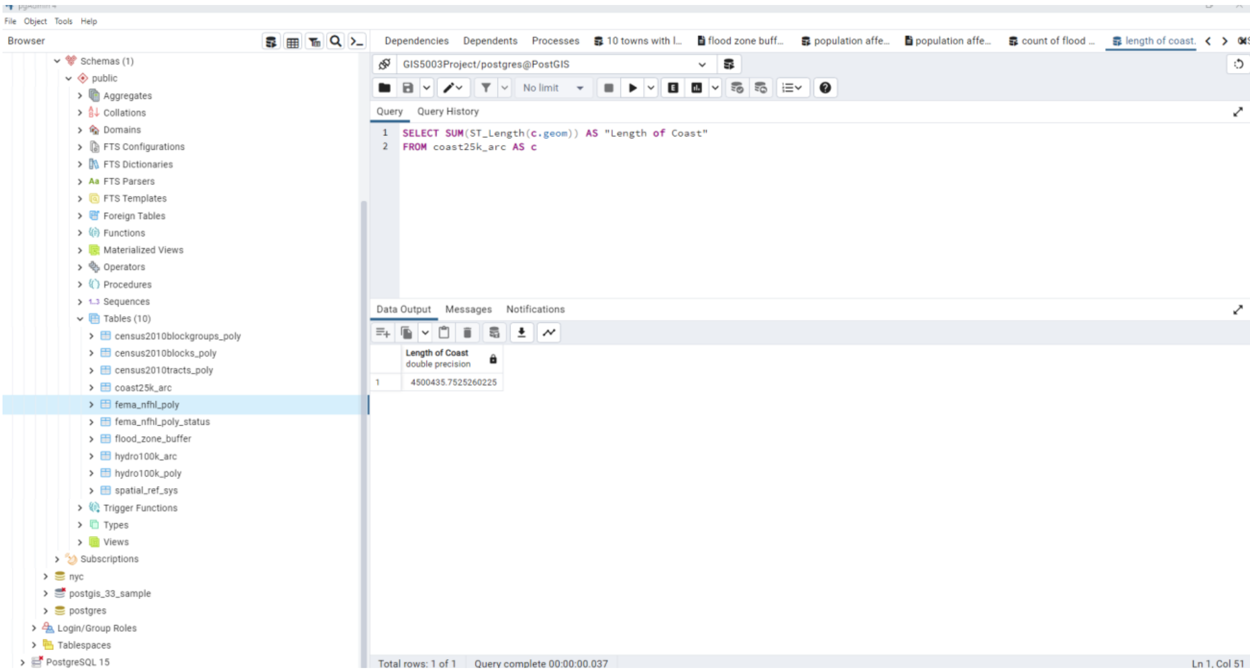

Figure 6: Length of coastline in Massachusetts

The next query that I ran was the count of all flood zones in each town and the areas that these flood zones take up in the town. This query gave interesting results as the highest number of flood zones in a town was 622 and the lowest number was 3. It was also interesting as Woburn had 611 flood zones which was number 2 on the list but only had 2,085,892 square meters of flood zone area. The other towns that were in the top 5 of total number of flood zones all had areas over 10,000,000 square meters. So even though Woburn has the second highest number of flood zones, these zones do not take up much of the towns area. This query is also valuable as it compares the total flood zone area to the town's total area. Using this information local governments can assess how much of their town is under risk of a flood. The results of this query can be seen in *figure 7* below.

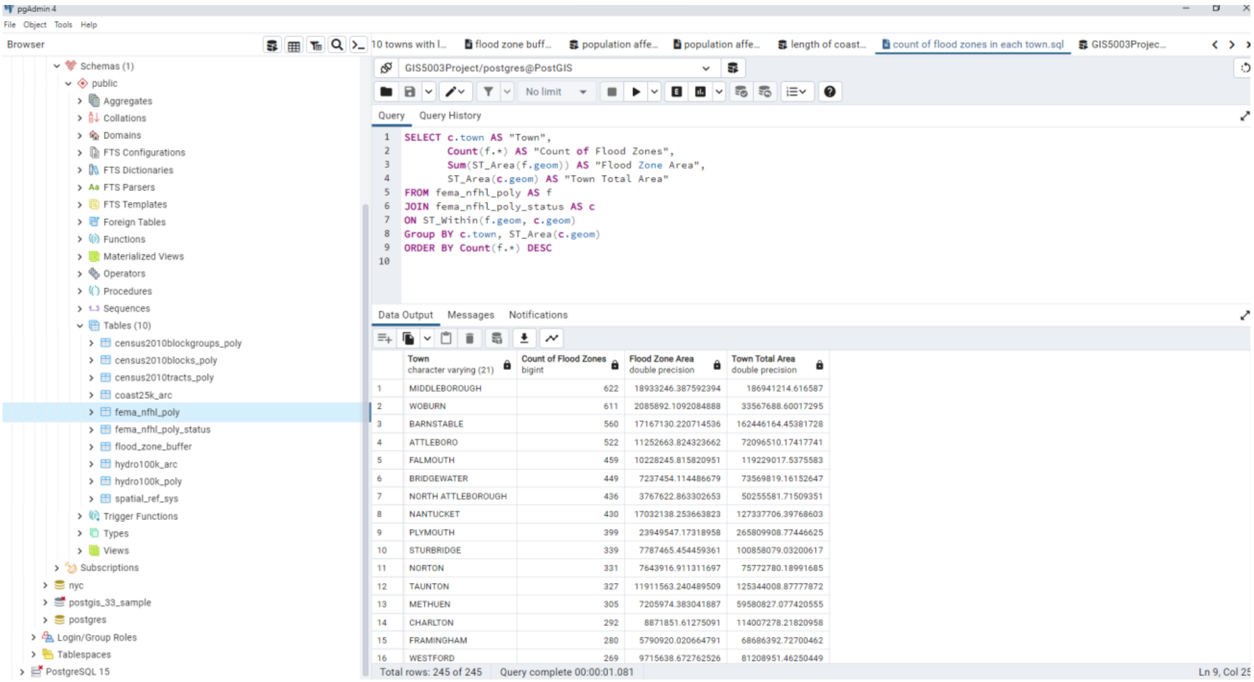

Figure 7: Number of flood zones in each town

Discussion

The results of the queries that were posed in this project give valuable insight into flood the FEMA designated flood zones in Massachusetts. With the results of these queries emergency planners can get a better idea of the areas they need to put increased focus on for emergency response. My query on the census blocks that are impacted by critical flood zones will let decision makers understand the amount of people that are at risk of a flood in each town. These results could be further drilled down to pick out which areas have the highest population and largest exposure. This query was just scratching the surface for what can be accomplished in flood emergency planning. Other queries such as the largest flood zones could be further investigated to determine why these flood zones are so large. This could investigate the nearby bodies of water, the slope of the land, the annual precipitation, and more.

There were several queries that I tried running that were not possible due to the large data sets and the computational requirements of the queries. One example of this was a query where I tried comparing locating all flood zones within a radius distance of a census block. Because both datasets were so large, pgAdmin still did not return a result even after running for 15 minutes. For that specific query I was trying to look at a larger picture by including all census blocks with all flood zones. I should have chosen one specific census block to locate flood zones within a distance to the specific block. I think with further time I would be able to create a process where one block is selected and flood zones within a specified distance will be returned. I think that my current analysis serves as a good foundation for further and more advanced flood studies within Massachusetts.

Conclusion

In this project I investigated publicly available Massachusetts flood information to get a closer look into key areas of flooding concern in Massachusetts. I posed several queries that scratched the surface of analysis in these areas. My findings highlight areas that emergency response planners should focus on when allocating flood response and prevention resources. Floods are the most common natural hazard and will continue to grow in severity as long as the climate keeps changing. In recent years the number of catastrophic flooding has been consistently rising. A key area of concern are coastal areas such as Massachusetts. This project pinpointed several areas that have large flood risks. These areas included highly populated areas with flood exposure and flood exposure that is increased due to the size of the area's flood zone and in turn the size of surrounding waterways. My goal for this project was to take available information and perform analysis to help pinpoint key areas of concern. I was able to use PostGIS to answer several queries of varying intensity. As I said in the discussion section above, this work only scratches the surface of flood studies and can be built on by others. As I found in my literature review, the subject of flood modeling and analysis has a lot of eyes on it right now and is continuing to grow. It is almost impossible to prevent a flood, so it is best to prepare to mitigate potential flooding damages in areas that are likely to flood based on advanced models. I look forward to continuing my work on floods as I improve my GIS skillset.

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