

**Pollution Discharge from Hurricane Florence:  
Examining how North Carolina is Impacted by Modern day Storms**

By

**Shane Beeson**

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Dr. Elizabeth Nichols

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**ABSTRACT**

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Hurricane Florence was a long-lived tropical cyclone that brought record-breaking rain amounts to North Carolina in September 2018 that the state had never seen before. With North Carolina still recovering in some locations from the flooding and destructive impacts Hurricane Mathew brought on the state in October of 2016, and with a projected frequency in hurricane intensity occurring in the Atlantic Ocean due to climate change, impacts from significant weather events like hurricane Florence and their effects on North Carolina need to be addressed. Utilizing the NCDEQ Incident Tracker for Hurricane Florence, discharge locations among municipal wastewater, industrial spills and agricultural lagoon breaches were recorded and mapped to examine discharge amounts released between these sectors and the demographic relationships within the state and how these impacted areas will increasingly become more vulnerable to the effects climate change is predicted to bring to North Carolina.

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## **Pollution Discharge and Hurricane Florence:**

### **Examining how North Carolina is Impacted by Modern day Storms**

#### **INTRODUCTION**

Hurricane Florence was a long-lived tropical cyclone that brought record-breaking rain amounts to North Carolina in September 2018 that the state had never seen before. Florence was ranked in as the wettest tropical cyclone to ever hit North Carolina and was recorded as the eighth wettest cyclone in US history. Florence moved at an incredibly slow pace after the storm made landfall causing extended surge events to take place along the North Carolina coast which when paired with extremely high rainfall totals of roughly 8 trillion gallons led to widespread discharge events across the state (Fig.1). These factors resulted in numerous locations experiencing widespread flooding, with many sites observed to have accumulated over 30 inches of precipitation from the storm (NCDC.NOAA, 2018). Rivers across North Carolina crested at new record levels, and the high rain accumulation and flooding from the storm placed many agricultural lagoons, municipal wastewater systems and industrial sites in jeopardy. A total of 146 confirmed waste sites resulted in discharge releases due to Florence, with municipal wastewater totaling 85 unique locations, 40 industrial spills and 21 individual overtopped agricultural lagoons along with 197 agricultural lagoons at risk of reaching freeboard level or higher (Fig.2) (NCDEQ.Dashboard, 2018).

With North Carolina still recovering in some locations from the flooding and destructive impacts Hurricane Mathew brought to the state in October of 2016, and with a general frequency in hurricane intensity occurring in the Atlantic Ocean, factors contributing to these events and their effects on North Carolina need to be addressed. The most significant driver that influences hurricane activity in the

Atlantic is climate change. Not only has it been shown that the intensity of hurricanes have increased due to climate change since the early 1980s, but the frequency and duration of these hurricanes have increased as well. Hurricane-associated storm intensity and rainfall rates are projected to increase as the climate continues to warm, resulting in a larger frequency of hurricanes of category 3 or higher (NCA.Global Change, 2014) (Bender, 2010).

Many of the locations impacted that resulted in waste discharged by hurricane Florence are situated in low-lying areas and are also situated near bodies of water by design as these systems are intended to discharge their final effluent into these waterways. The issue with these impacted locations is two-fold, because not only do flooding concerns from high precipitation amounts threaten to overburden and cause malfunctions at these locations, but these locations are often in areas of high poverty or in locations of financial disarray where updates to systems are hard to come by. These outdated systems are difficult to replace due to lack of funding (NC Health. Ross, 2018).

Addressing climate change and its impacts on these vulnerable systems is not uniform, however, which adds more complexity to the issue North Carolina faces from an increased storm presence in the years to come. Vulnerabilities and appropriate adaptation measures will need to be made on a regional or local scale to best fit the dilemmas facing each sector and location (Pryor, 2013). The dilemma of environmental injustice must also be addressed in these situations as well, as many of these impacted locations, especially those in the eastern portion of the state receive a disproportionate share of the negative environmental consequences when faced with these storm-related discharge events. Proper attention and consideration needs to be made to ensure that a given population or group is not subjected to pollution issues from these storms to an increased margin based solely on demographics of economic trends in a given region.

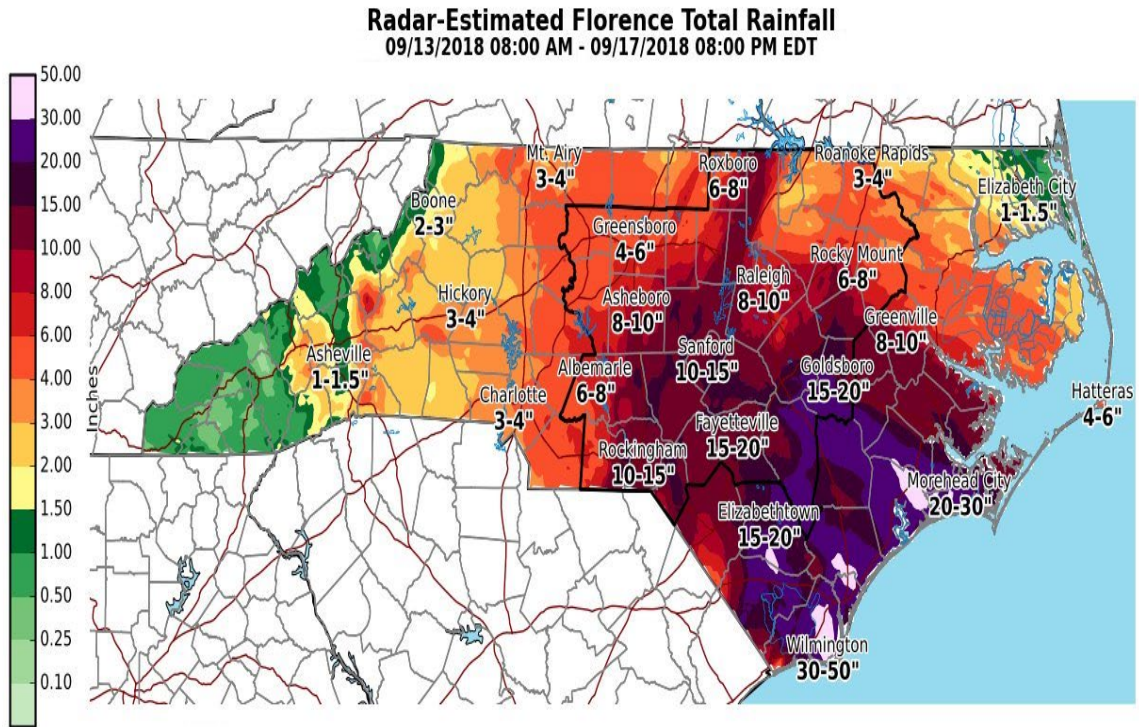
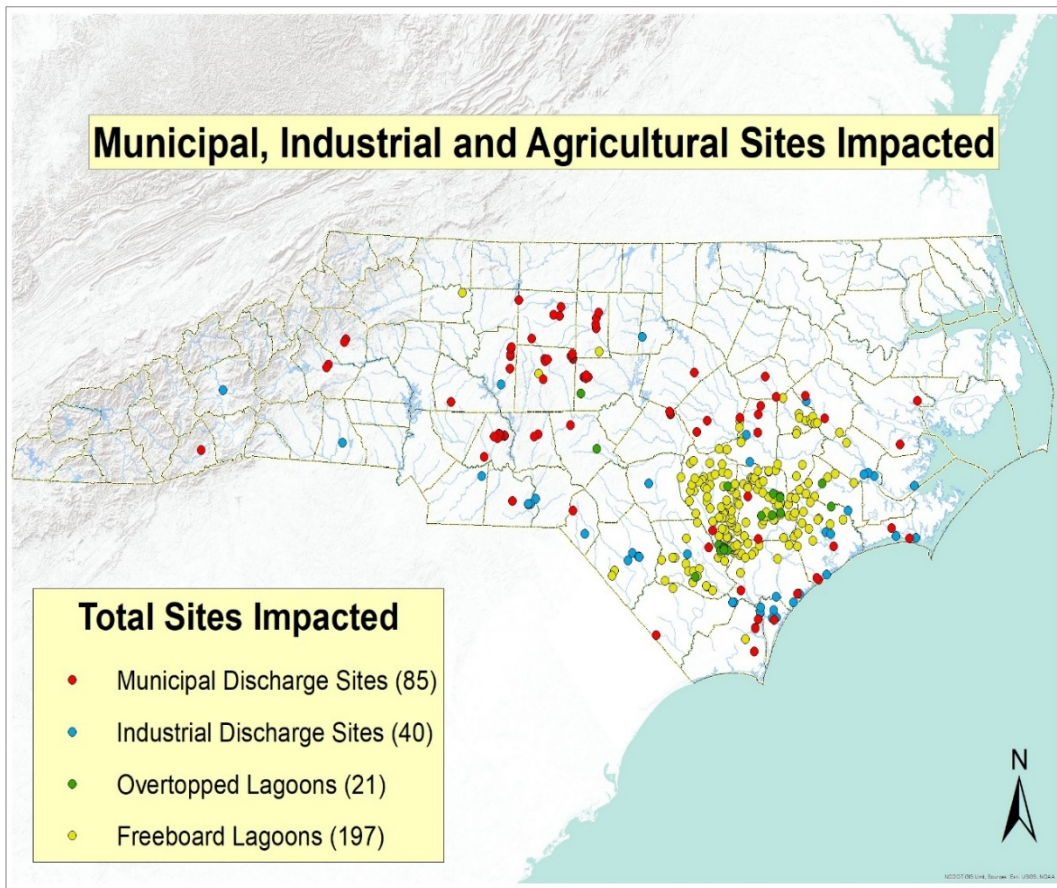


Figure 1: Radar Estimated Florence Total Rainfall (NCDc.NOAA, 2018)



**Figure 2: Municipal, Industrial and Agricultural Sites Impacted by Hurricane Florence**

## BACKGROUND

North Carolina has a thorough history of hurricanes causing havoc to various sectors and populations across the state as it is second on the list of states directly hit by hurricanes in the US. Hurricane Florence made landfall near Wrightsville Beach, North Carolina, on September 14th and upon landfall was a Category 1 hurricane with wind gusts reaching as high as 105 mph. As the storm eventually moved inland, inundation of susceptible and discharge prone locations led to disastrous scenarios resulting in wide-spread pollution releases from the continued flooding (NCEI.NOAA, 2018). Hurricane Florence was a storm like North Carolina had never experienced before, and as roughly 8

trillion gallons fell on North Carolina, municipal wastewater, industrial sites and agricultural lagoons were overwhelmed with heavy rainfall. With this much precipitation impact in such a relatively short amount of time, the pollution that was discharged into the environment was wide-spread as these systems could not handle the impacts of the widespread flooding. Discharge totals recorded from each of these three sectors were found using the NCDEQ Incident Tracker for Hurricane Florence (Available: <https://ncdenr.maps.arcgis.com/apps/webappviewer/index.html?id=c73b17df1fa8400998c69da505f36eb8>), Accessed September 28, 2018). Using this data, the address, amount and status were listed for each reported discharge and converted into x, y coordinates in order to manipulate the data into geospatial points in ArcGIS. By filling out a spreadsheet with each individual spill, tables were converted into geospatial data points in ArcGIS. Each incident was given a category, amount spilled, and status to go along with its identification allowing the various maps in this study to be made.

Confirmed total discharge amounts were determined from this data, with municipal discharges totaling 29,119,165 gallons, industry discharges totaling 6,510 gallons and an unconfirmed total of agricultural lagoon discharge. Out of these three sectors, municipal discharge amounts outpaced the others at a staggering rate (NCDEQ.Dashboard, 2018). These numbers present an interesting dilemma within themselves however as the amounts for both municipal and industrial discharge are largely still uncertain. With nearly half the discharge amounts unaccounted for in the municipal sector, and 80 percent of the spill amounts for industry still missing, actual totals are likely many times larger than currently shown in both sectors (Fig. 3). Municipal discharges resulted in a prominent showing across the piedmont to south-eastern Coastal Plain, where industry and agricultural were primarily located along much of Coastal Plain. Confirmed totals along with site status were also more common in the Piedmont compared to rural locations to the east resulting in greater uncertainty for rural locations where action had not been taken to resolve these discharge events (Fig. 4).

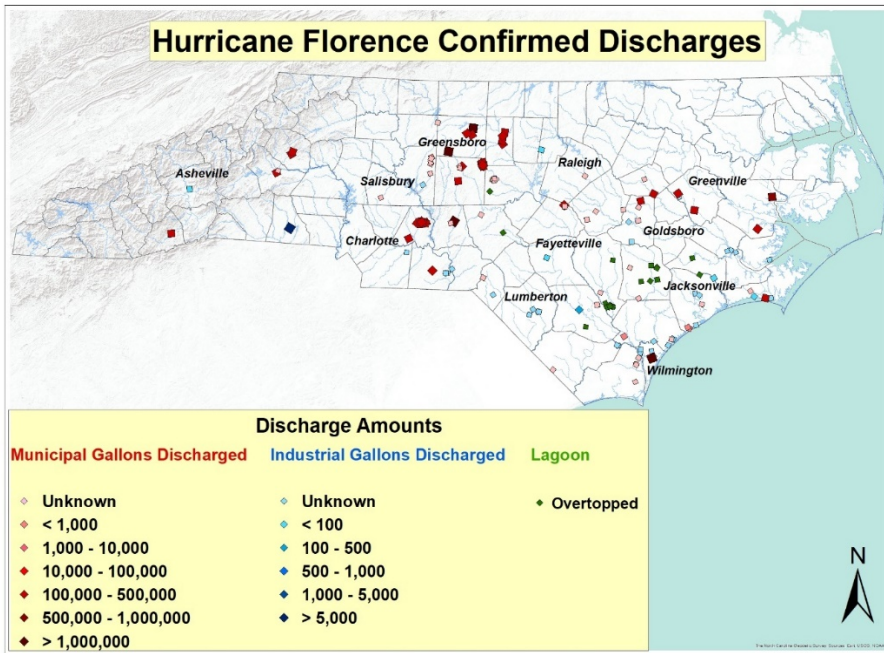


Figure 3: Hurricane Florence Confirmed Discharge Amounts

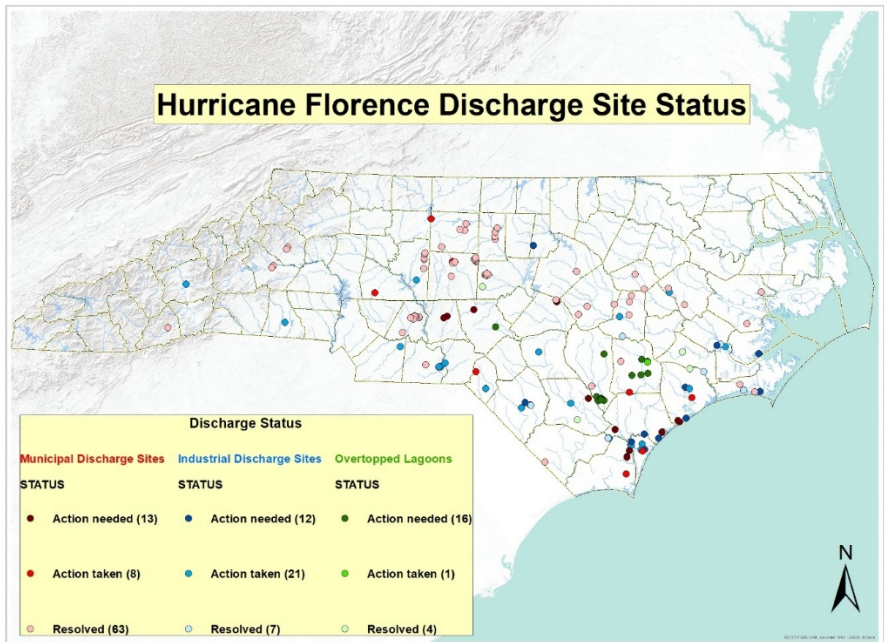


Figure 4: Hurricane Florence Discharge Site Status (9/28/2018)

Hurricane Florence and other recent storms that have hit North Carolina are what many studies show to be a new norm. These findings are especially troubling after the devastating aftermath Florence has caused to North Carolina, and as ocean temperatures continue to warm the likelihood of intense storms of similar or greater caliber are predicted to become much more likely (Holland, 2014). As our climate continues to become increasingly unstable, flooding associated with hurricanes and instances of high precipitation is predicted to increase and continue (Engel, 2017). Climate change vulnerability in these locations will need to be addressed as it is the degree to which a given location is susceptible to and unable to cope with, adverse effects of climate change including climate variability (McCarthy, 2001). When recognizing climate change vulnerability, the issue North Carolina faces with its coastal counties becomes clear as this region is not only one suffering from high poverty rates but is also at greater risk of hurricane damage and sea level rise (US Census. Quick Facts, 2018).

The predictions of storm events that we currently rely on will become increasingly inadequate as climate change alters how hurricanes in the Atlantic behave as well. This inadequacy can be seen recently in the damage and flooding from not only hurricane Florence but similarly with the flooding that transpired in Houston Texas from hurricane Harvey. Changes in the underlying climate compromises methods to assess flood risks. With anthropogenic climate change leading to a greater incidence of high intensity hurricanes, rising sea levels and a warmer ocean will pair together increasing the risk of flooding as hurricanes produce considerably more precipitation in the atmosphere (Emanuel, 2017). This increased uncertainty to not only predict hurricanes accurately, but to also not be able to prepare for their severity and side effects will combine to form issues leading to an increase in human, environmental, and monetary costs to communities and areas impacted by these storms (Engel, 2017). The impacts of recent North Carolina hurricanes (Tab. 1) show how dramatic the damage and cost associated with Florence was due largely in part to its extended duration which directly influenced the flooding along the Coastal Plain. With prediction models being outdated in relation to an unstable

climate like mentioned before, one problem North Carolina and coastal states in general now face is that the probability of major storms that result in 100-year, 500-year and 1000-year flood events are now happening more often than old models indicate the probability for. Prevention planning has not yet evolved to acknowledge that a 500-year flood like was once classified, for example, isn't a 1-in-500 chance anymore.

<b>Measure</b>	<b>Florence</b>	<b>Mathew</b>	<b>Floyd</b>
<b>Total Damage</b>	<b>\$16.7 billion</b>	<b>\$4.8 billion</b>	<b>\$7.0 -9.4 billion</b>
<b>Inches of Rain</b>	<b>122,080</b>	<b>82,000</b>	<b>87,000</b>
<b>Storm Surge (ft.)</b>	<b>25-35</b>	<b>18-20</b>	<b>17-20</b>
<b>Fatalities</b>	<b>40</b>	<b>28</b>	<b>51</b>
<b>Strongest Wind (mph)</b>	<b>105</b>	<b>80</b>	<b>100</b>
<b>Duration (days)</b>	<b>6</b>	<b>2</b>	<b>4</b>

**Table 1: North Carolina Hurricane Statistics as of 10/12/18 (NCOSBM,2018)**

## **MUNICIPAL DISCHARGE**

The Environmental Protection Agency (EPA) estimates that 34 billion gallons of wastewater is processed in the USA every day (EPA.Wastewater, 2018). During events like hurricane Florence, millions of gallons of untreated sewage and wastewater can overflow into communities across the state, posing significant health and environmental risks to the affected areas. Two of the primary pollutants associated with municipal waste are nitrogen and phosphorus which are found in human waste, food

and certain soaps and detergents (EPA. Nutrient Pollution, 2018). With floods, however, much of this nutrient pollution becomes diluted, but when too much nitrogen and phosphorus enter the environment, algae can grow at a rapid rate due to the increased nutrient presence and this growth often occurs faster than the ecosystem can handle (EPA. Nutrient Pollution, 2018).

Organic matter can be a significant source of pollution as well when municipal wastewater systems malfunction, resulting in a sanitary sewer overflow or other such failure that results in discharging during a hurricane or flood event (Fig. 5). Figure 5 shows sources of organic matter discharged after hurricane Florence and the dramatic impact can be noticeable and wide-spread at large scales. Raw sewage contains many disease-causing pathogens including viruses, bacteria, worms, and protozoa (Tab.2) (EPA. SSO, 2015). Vulnerable communities like children, the elderly, people with suppressed immune systems and poverty-stricken populations face added risk of contracting severe illnesses when exposed to sewage in this manner (Mowafi, 2004).



Figure 5: USGS Imagery of Organic Matter Pollution from Hurricane Florence on 9/19/18 (NASA, 2018)

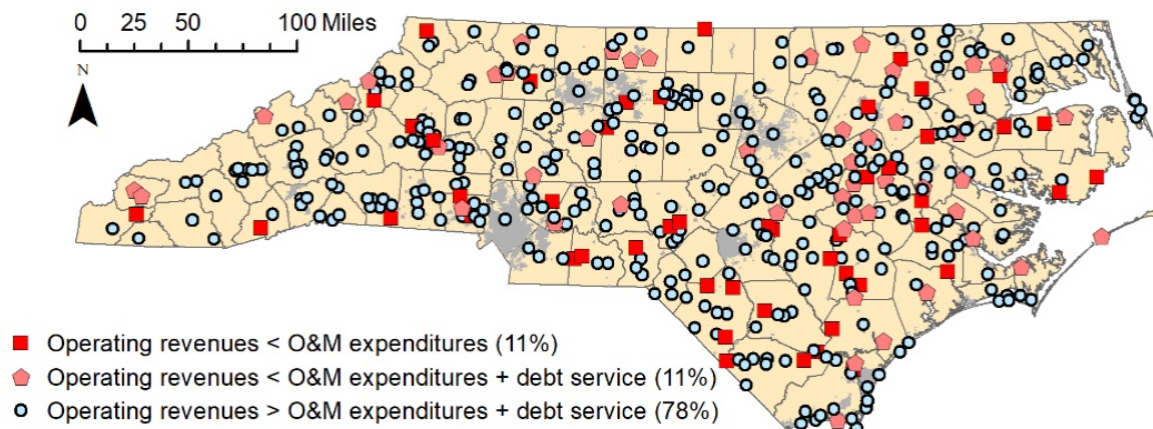
Organism	Health Effects
<b>Viruses</b>	<ul style="list-style-type: none"> <li>• Diarrhea</li> <li>• Gastroenteritis</li> <li>• Hepatitis</li> <li>• Meningitis</li> <li>• Pneumonia</li> <li>• Paralysis</li> </ul>
<b>Protozoa</b>	<ul style="list-style-type: none"> <li>• Abdominal Cramps</li> <li>• Intestinal Parasites</li> <li>• Severe Diarrhea</li> <li>• Ulcers</li> </ul>
<b>Bacteria</b>	<ul style="list-style-type: none"> <li>• Abdominal Pain</li> <li>• Cholera</li> <li>• Severe Diarrhea</li> <li>• Typhoid Fever</li> </ul>
<b>Worms</b>	<ul style="list-style-type: none"> <li>• Anemia</li> <li>• Chest Pain</li> <li>• Insomnia</li> <li>• Muscle Aches</li> <li>• Vomiting</li> </ul>

**Table 2: Raw Sewage Exposure (EPA. SSO, 2015)**

Sewage overflows in flood events are naturally due in part to sewer quality as well. When these systems are overburdened by precipitation, overflows are bound to occur. Hurricanes often cause widespread loss of electrical power of municipal treatment plants and pump stations as well, and if these systems have no independent backup generating systems, they are often forced to reroute untreated or partially treated sewage into receiving waters (Mallin, 1999). After Florence, countless water and sewer systems throughout North Carolina are now struggling with damages, and many of

these happen to be in areas of high poverty. Some of the damaged sewer systems impacted by hurricane Florence have been struggling since hurricane Matthew, two years ago and some were even underwater before either storm hit. With shrinking economies that make it difficult for coastal, rural and poverty-stricken areas to cover routine expenses and service the debt on their water and sewer infrastructure (NC Health. Ross, 2018) the damage Florence dealt to municipal systems was dramatic. This issue of poor communities along the eastern Piedmont and counties in the Coastal Plain dealing with reoccurring issues is a problem magnified by climate change (Fig.6).

### Cost Recovery in 449 Local Government-Owned Water and Wastewater Utilities during FY2016



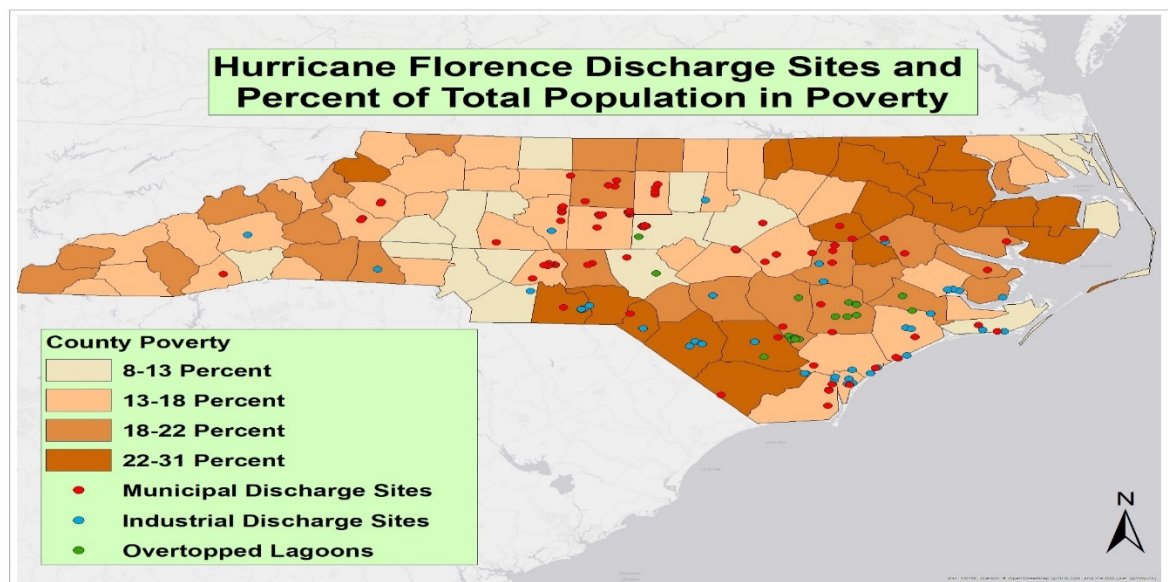
**Figure 6: Cost Recovery of Water and Waste Water Utilities (Environmental Finance Center North Carolina Water and Wastewater Rates Dashboard) (NC Health. Ross, 2018)**

When looking at figure 6 above, the data recorded from the Environmental Finance Center's North Carolina Water and Wastewater Rates Dashboard (Available:< <https://efc.sog.unc.edu/resource/north-carolina-water-and-wastewater-rates-dashboard>> Accessed November 18, 2018) show gray symbols on the map as municipal systems that have enough revenue to

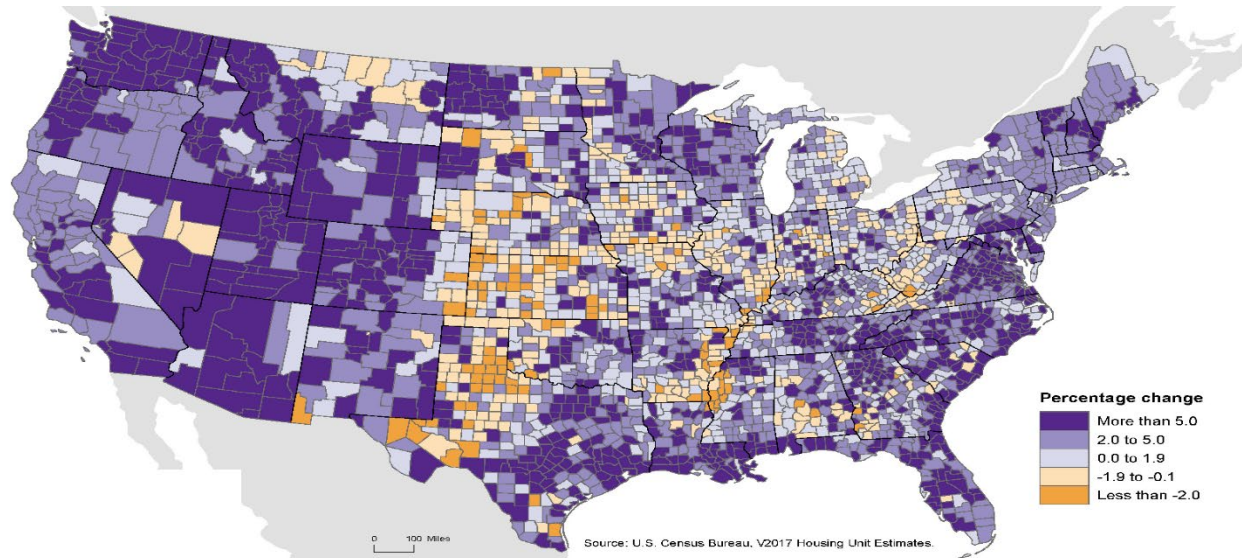
cover their expenses, the pink symbols show systems with enough revenue to cover their combined expenses and debts, and the red symbols represent those systems that do not have enough revenue to cover regular operating and maintenance expenses (NC Health. Ross, 2018). We can, therefore, see in figure 5 that most of the systems that fall into the category of not having enough revenue to cover maintenance are in the Coastal Plain. Looking at the discharge sites from hurricane Florence, by utilizing data from the USDA Department of Economic Research Service, an overview of poverty and discharge occurrences can be seen (Fig. 7) which shows that most systems unable to properly maintain their systems are in areas of high poverty.

With hurricanes Florence and Matthew causing damage to many of the municipal sites impacted in the east, action is needed in these vulnerable communities before they are placed in a state beyond repair. With climate change, sea level rise and increased rain accumulation from storms and hurricanes, issues surrounding sewers and municipal wastewater need to be appropriately addressed when it comes to the impact inflow and infiltration of water into these systems presents. A study conducted by Lawrence Cahoon at ECU showed significant increases in flow from sewage collection systems into wastewater treatment plants in eastern North Carolina driven by rainfall. Infiltration and inflow during these flooding events together exceed 10% of rainless flows into municipal sites in over 40% of the systems that were examined over a two-year period with approximately average rainfalls (Cahoon, 2017). Sanitary sewers that are not watertight due to cracks, faulty seals, and/or improper connections can receive exceptionally large amounts of infiltration and inflow during these wet weather events. These improper conditions are especially noteworthy for areas in North Carolina where revenue cannot be met to run maintenance on the local sewer systems. In these areas, large volumes of infiltration and inflow can cause overflows and/or operational problems at the wastewater site which can further cripple poverty-stricken areas suffering from storm damage (EPA. Municipal Wastewater, 2018)

The occurrence of failing municipal systems in eastern North Carolina due to flooding and the economy proves to be a precarious situation moving forward. This unstable situation becomes magnified when these factors are paired with the population fluctuation in and around these areas where poor counties face an out-migration of residents in poverty due to financial woes as well as new growth in the population of coastal areas due to recent surges in homeowners moving to the area (Fig.8). With figure 8, an increase in population to areas already heavily impacted and vulnerable to the effects climate change has on the municipal sectors in each community illustrates the importance of emergency planning and preparedness (US Census. Housing Units, 2018). This is especially true where housing units are increasing, and economic benefits could be aimed at properly treating damages to systems in these impacted areas. Water quality in these locations will become stressed and become adversely affected by unstable and intense weather events and through increased population pressures (Pryor, 2013) (Trenberth, 1999).



**Figure 7: Hurricane Florence Discharge Sites and Percent of Total Population in Poverty (USDA Economic Research Service. Percent of Total population in poverty, 2016)**



**Figure 8: Visualization: Percentage Change in Housing Units by County: 2010 to 2017 (US Census.**

**Housing Units, 2018)**

## **INDUSTRIAL DISCHARGE**

The industrial discharge resulting from hurricane Florence that was primarily focused on after the flooding was two coal ash spills at two Duke Energy Plants in Wilmington and Goldsboro respectively. The Sutton Coal Plant near Wilmington was where several breaches in containment ponds located onsite spilled into the nearby Cape Fear River. This plant was retired in 2013, but the site continues to have two coal ash pits and a cooling pond onsite (Huffman, 2018). This location is of utmost concern due to Wilmington's vulnerable location as an area prone to flooding and hurricane impact (Fig.9). Wilmington is part of a large portion of North Carolina's coastline cities with extreme vulnerability to sea level rise due mainly to its low elevation and to geological factors that are causing much of the coastline to sink (CDC. Coastal Flooding). With the increased likelihood of flooding in Wilmington and New Hanover County in general, the placement of these plants and discharge sites near

surface waters (Fig.10) leads to concerns for drinking water contamination, bodily exposure and threats to ecosystems as surface waters like rivers, wetlands, estuaries, and the ocean are all impacted due to the proximity of these spills (Fig.4).

Coal ash is a potential environmental contaminant and carcinogen. The environmental and health consequences of spills and leaks from coal ash containment facilities are extensively documented, and the EPA regulates coal ash due to its heavy metal content and instances where metals like arsenic leached out of unlined or inadequately lined landfills and ponds (Huffman, 2018). According to the EPA's peer-reviewed "Human and Ecological Risk Assessment for Coal Combustion Wastes," people that live in proximity to an unlined pond that contains coal ash that get their drinking water from a well have as much as a 1 in 50 chance of getting cancer from their drinking water (EPA. Coal Combustion Wastes, 2010). The metals and pollutants discharged by these facilities in this manner can cause severe issues in the form of cancer, lowered IQ among children, and malformations and reproductive harm in fish and various other wildlife. Many of these metals and pollutants remain in the environment for years after release, due to a high resistance to environmental degradation pathways (EPA. Effluent Guidelines, 2015). Due to the proximity to these facilities and their discharge events, low-income communities have a high exposure rate, or at least a greater exposure likelihood compared to other populations in part to a relatively high consumption of fish and contact with pollutants from power plant discharges. Low-income communities live near a disproportionate share of coal ash disposal facilities which stresses the importance of proper environmental regulations and ideas behind environmental justice as well (Physicians for Social Responsibility. Coal Ash, 2010).

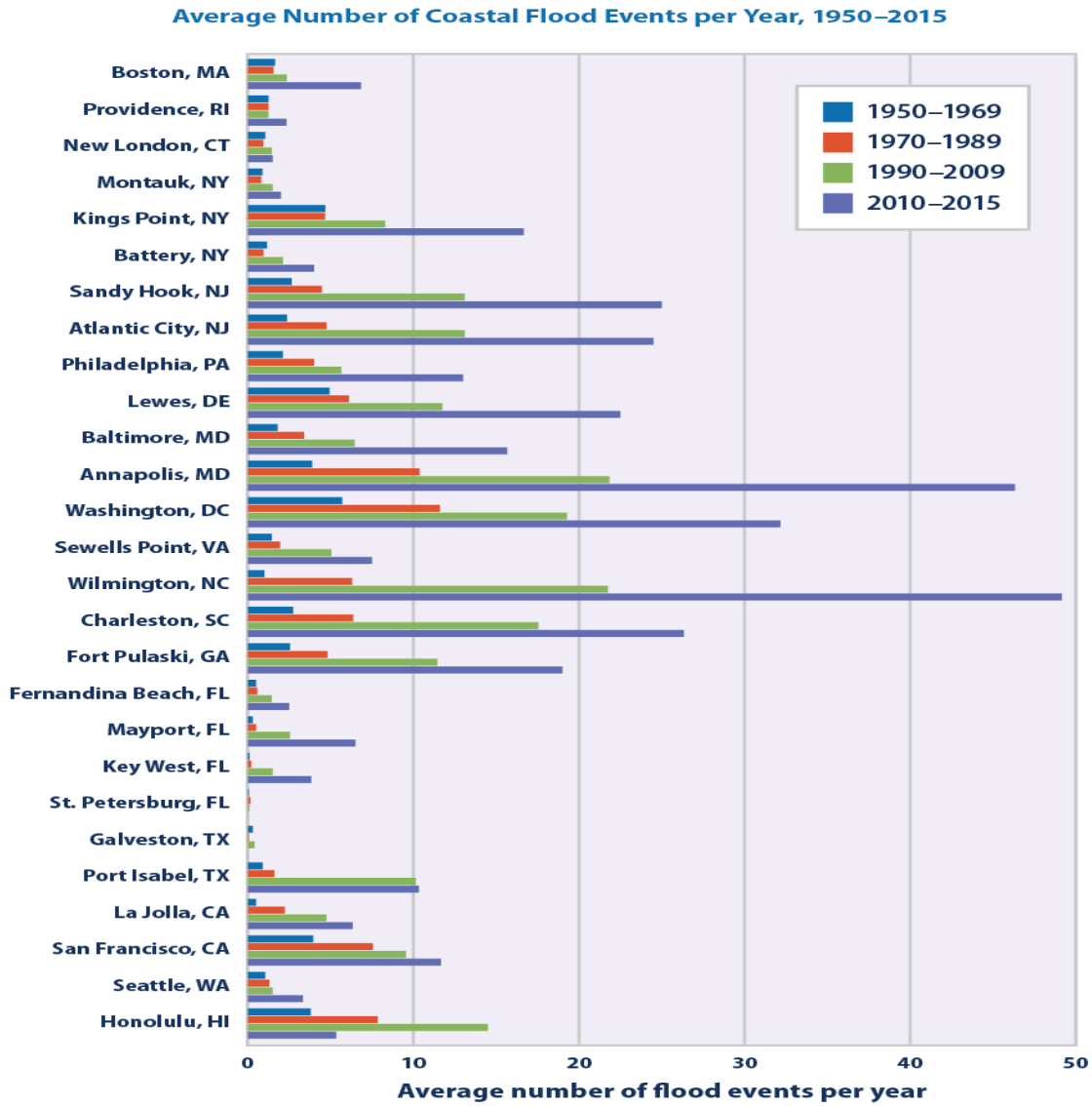


Figure 9: Average Number of Coastal Flood Events (NOAA. Sea Level Rise and Nuisance Flooding, 2016)

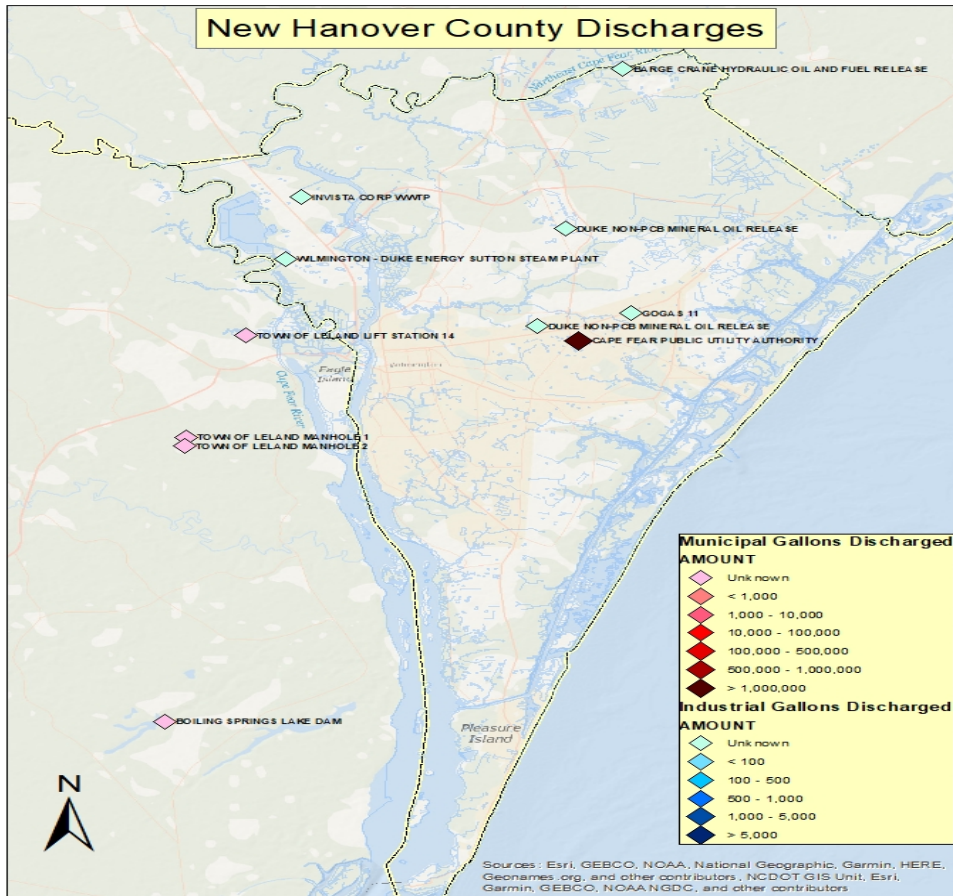


Figure 10: New Hanover County Discharge Map

**AGRICULTURAL DISCHARGE**

North Carolina’s history with agricultural lagoons and previous hurricanes is one of disaster and riddled with issues regarding discharges released from these sites and their impact on both public and environmental health. In 1999 when hurricane Floyd hit North Carolina, hog waste lagoons were flooded releasing 25 million gallons of waste into the environment through waterways nearby. A similar situation occurred with hurricane Mathew, and now with the destruction caused by Florence, the water

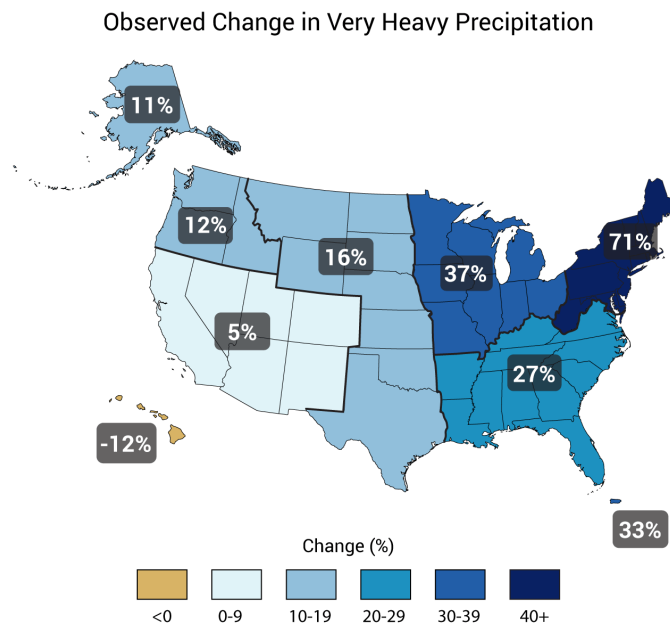
supply and quality in and around these locations has become contaminated once again like a vicious cycle that is only predicted to worsen (Holland, 2014).

North Carolina is ranked second in the United States in pork production coming in just behind Iowa. Current inventory accounts for roughly 9 million hogs which translates to slightly less than 14% of the total inventory of the entire country (NASS.USDA Agriculture Overview, 2017). These agricultural sites where hogs are located are what are referred to as confined animal feeding operations or CAFOs, and it is in these lagoons that concentrated waste containing numerous health and environmental concerns reside. Contaminants like pathogens, antibiotics, hormone residues, heavy metals and nutrients are located within the hog waste, and each presents a dangerous threat (Cole, 2000).

Thousands of confined animal feeding operations are in eastern North Carolina and are primarily found in areas of high poverty. The fecal waste pit and spray field waste management systems used by these operations are highly susceptible to flooding in low lying regions such as eastern North Carolina which leads to an increased risk when storms like Florence brings substantial amounts of precipitation onto these vulnerable communities (Wing, 2002). Roughly 3,300 permitted hog lagoons are in North Carolina and inspected by NCDEQ. State environmental standards require that lagoons be built to withstand 24 hours of rain (NCDEQ. Swine Waste Management System Permit,2016), but the threat of continuous rain for multiple days like what occurred during the span of hurricane Florence, highlights the severity that climate change brings to these sites with research showing an increased presence in wetter hurricanes with more extreme rainfall. With higher levels of precipitation becoming more common, discharge events look to become exceptionally problematic for these locations. Looking at Figure 2, any of the 197 lagoons that reached freeboard status had the potential to overflow if slight variations had occurred in Florence's path. With so many sites in jeopardy in the Coastal Plain, North Carolina is left gambling on not only which of the countless CAFOs will be impacted, but how many with each coming storm. Watersheds across eastern North Carolina where the water table is near the surface

are exceptionally vulnerable from the discharge from these lagoons. This pollution is incredibly detrimental to the public when drinking water is contaminated in this manner (Wing, 2002).

With the location of so many of these agricultural lagoons and CAFOs in jeopardy from the impact of events like hurricane Florence and other such storms to come, it becomes clear that although only 21 lagoons overtopped, since 1958, the amount of precipitation during heavy rainstorms has increased by 27 percent in the Southeast (Fig. 11), and the trend toward increasingly heavy rainstorms is likely to continue leading to scenarios with widespread flooding seeming more and more likely to impact more and more CAFOs in the future (EPA, Climate Change NC, 2016).



**Figure 11: Percent Increase of Precipitation from Heavy Events from 1958-2012 (Karl, 2009)**

## HURRICANE FLORENCE DEMOGRAPHIC IMPACTS

One of the major issues revolving around discharge events from hurricane Florence and other significant storms is the impact this pollution has on the public health in areas of high poverty and locations where there is an inherent disparity in environmental health outcomes and situations for

populations in these areas. This dilemma is referred to as Environmental Injustice which is where a group of people whether it be race, color, national origin, or income bear a disproportionate share of the negative environmental consequences resulting from industrial, governmental and commercial operations or policies (Nicole, 2013).

One of the misunderstandings about environmental injustice is that the term suggests a malicious or at least discriminatory intent regarding the location of the hazards in question. Although that may unfortunately exist in some cases, several studies have come forth arguing that a given industry or government simply followed the path of least resistance in choosing sites where people were often less likely to object or where land was cheap (Nicole, 2013). When placement of a new factory or agricultural site comes into discussion, the location of these facilities is heavily influenced by not only where land is inexpensive, but also where employment leans heavily towards manual labor (Nicole, 2013). These categories listed above are often where poor people live and it's no different in North Carolina. Placing these sites in these areas becomes even more noticeable as an environmental injustice issue because racial and ethnic minorities are disproportionately poor, which is especially noticeable in the eastern part of the state, where sites that threaten the livelihood of human populations and the environment are directly impacted by their proximity to CAFOs and the like. In the end, no matter the reason, the situation nevertheless results in environmental injustice if areas high in poverty rates and high minority populations are disproportionately affected (Mohai,2009).

The environmental injustice taking place in North Carolina is predominantly seen through CAFOs and agricultural lagoons, this is due in part to the clustering of these sites in low-income communities along the Coastal Plain. The data collected through the NCDEQ Incident Tracker for Hurricane Florence resulted in numbers that reinforce and support the claim that environmental injustice is taking place in North Carolina regarding agricultural lagoons, as well as spills in the municipal and industrial sectors. Data regarding high poverty tracts across North Carolina was pulled from the Workforce Innovation and

Opportunity Act (WIOA) and the US Department of Labor to explore any relationships between discharge events and areas of high poverty through ArcGIS and the Florence data found from the DEQ Incident Tracker (Fig. 12). When compared with areas of high poverty in this manner, the discharge events from hurricane Florence occurring in these locations resulted in 60 percent of all municipal discharge events taking place in high poverty tracts, 72.5 percent of all industrial discharges taking place in high poverty tracts and 90.5 percent of all agricultural discharges taking place in high poverty tracts. The top 4 counties contributing to the total amount of confirmed municipal discharge amounts all occurred in areas of high poverty as well. These top counties resulted in 86 percent of the total discharged amount with 25,034,700 gallons spilled of the total 29,119,165 in high poverty locations (Tab. 3). These percentages throughout the three sectors and the confirmed total amounts mainly in the municipal sector lend well to the research that environmental injustice in North Carolina is occurring based on socio-economic lines.

North Carolina is one of the most studied states regarding environmental injustice due in part to the clustered location of CAFOs located in the eastern half of the state where high poverty rates, inadequate health care, and unemployment occur together in close association. A prominent crescent-shaped band can be seen reflecting much of this area (Fig. 7) that has its roots connected to when slaves worked on plantations in these locations (Baharanyi, 1992). After emancipation, many freed slaves continued to work as sharecroppers and tenant farmers in this region and now today many black residents that live in this region still experience poor living conditions. The citizens in the eastern Coastal Plain not only face economic woes but also lack the political capacity to resist and bear the socio-economic, environmental, and health-related effects that swine waste inflicts when lagoons are overburdened leading to contamination events like those that occurred after hurricane Florence (Nicole, 2013).

This crescent-shaped band, and eastern North Carolina in general, are predominantly rural areas, have communities that are considerably isolated from one another and have climate-sensitive sub-populations that have low access to health care (Kearney, 2018). This region has historically had the highest mortality and prevalence rates of discernable health disabilities and highest incidence rates of several significant chronic health conditions and diseases in North Carolina (ECU, 2014). This high risk of illness in areas like eastern communities in North Carolina and their relationship to agricultural lagoons and CAFOs need future studies to determine factors that influence these communities having higher all-cause and infant mortality, mortality due to kidney disease, anemia, tuberculosis and higher hospital admissions of infants (Kravchenko, 2018). In the research conducted by Kravchenko, establishing causality with exposures from hog CAFOs and the occurrence of these health impacts was not met, but the people living in southeastern North Carolina communities located near hog CAFOs had poorer outcomes for a variety of health conditions when compared to residents of North Carolina communities located in zip codes without hog CAFOs (Kravchenko, 2018). Instances like these that show how poverty not only lends itself toward ill health in these populations, but ill health can also further sink people into poverty. This relationship puts others in proximity at risk of becoming poor as well in a double-edged situation that links detrimental health impacts associated with contaminants found in these lagoons with well-being. This link between public health, CAFOs and discharge events in general is of utmost concern to prevent further decline of impacted communities when hurricane like events devastate these populations.

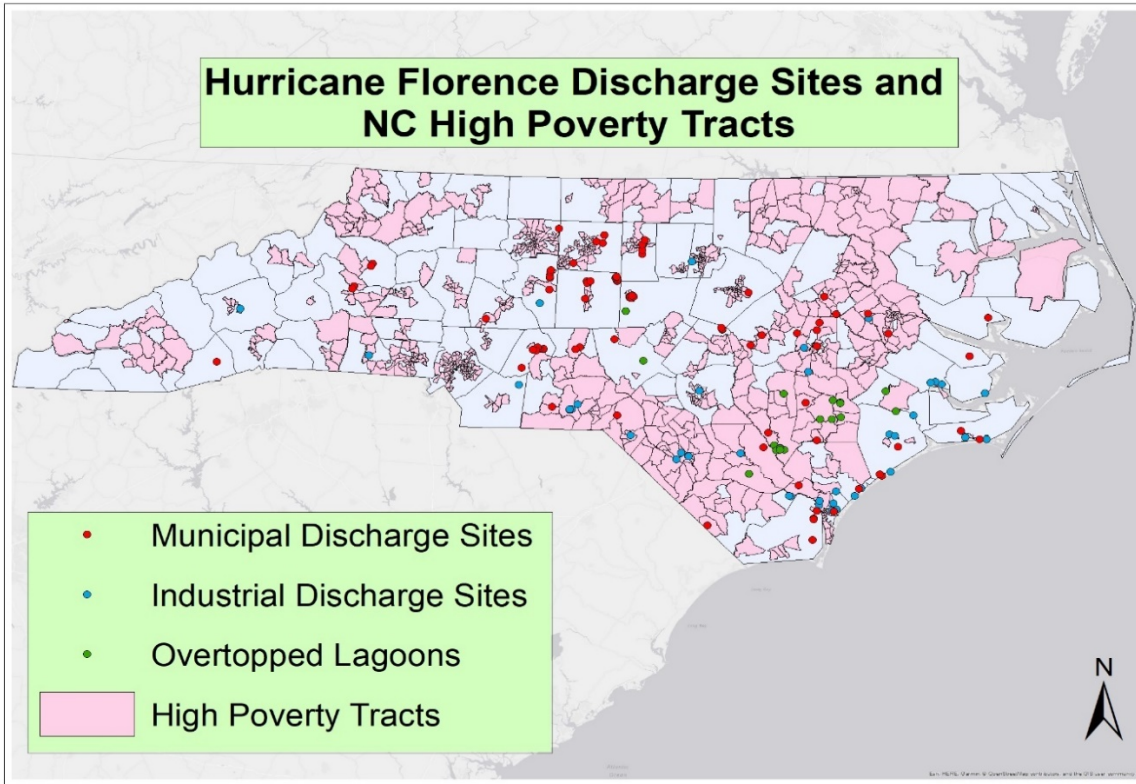


Figure 12: Hurricane Florence Discharge Sites and High Poverty Tracts

North Carolina Counties	Municipal Confirmed Discharge Totals (gal.)
Montgomery County	17,000,000
New Hanover County	5,000,000
Guilford County	2,574,000
Stanley County	460,700

Table 3: Highest Confirmed Municipal Discharge Totals from Hurricane Florence Per County

**DISCUSSION**

The impact hurricane Florence had on North Carolina shows that serious efforts are needed to not only engage communities and stakeholders in the topic of hurricane preparedness, but to also

increase general public awareness across the state in environmentally sustainable practices that promote both climate change awareness and understanding. Past attempts at explaining the threats climate change brings, will hopefully be realized through the wrath Florence cast across the state allowing windows of opportunity to form and point to a future where proper action can be undertaken to protect systems that threaten public and environmental health and quality across the state.

The impact that hurricane Florence had on the state was and will continue to be a tremendous obstacle to overcome. Without proper measures to ensure scenarios like this are lessened and better prepared for, communities will weaken, some to the point where rebuilding could become impossible. This failure to prepare for future changes in weather patterns will further stress the state as it manages other impacts from climate change and populations floundering from improper protections not being instated.

Like in the case of systems damaged by hurricane Mathew before it, those systems damaged by hurricane Florence will continue to be at risk for future storms whenever they occur. As climate change continues to influence storm presence and severity in the Atlantic and contribute to sea-level rise, vulnerable communities across the state that are wide-spread and diverse will be impacted in dramatically different ways, warranting proper regional and localized management plans to be made to protect public and environmental health from future catastrophes. Locations throughout the Coastal Plain will be tested as once classified 500-year and 1000-year flood are brought from storms that are becoming more and more likely.

Hurricane's like Florence will overburden the state with increased heavy rain events, duration and intensity and studies show that these factors are likely to continue. Using a database like DEQ's Hurricane Tracker and other mapping and incident collecting information systems, occurrences in these situations can be mapped, and aid in the study of how to combat the impact storms like Florence can

deliver to vulnerable communities prone to discharge events and flooding. These projections are vital, but funding and realizing climate change models and climate science in forecasting threats from flooding and rising seas will ultimately be key to solving these issues. Proper attention must be directed towards strengthening and ensuring the integrity of our infrastructure and vulnerable systems at risk from these massive storms across the state as well. Future studies need to be conducted to trace health risks from living in proximity to CAFOs in order to hopefully further push funding of handling environmental injustice across the state in rural portions of the Coastal Plain.

## **CONCLUSION**

With 60 percent of all municipal discharge events, 72.5 percent of all industrial discharge events and 90.5 percent of all agricultural discharges taking place in high poverty tracts, environmental injustice was reinforced in this study as it occurred so starkly across socio-economic lines. The top 4 counties contributing to the total amount of confirmed municipal discharge amounts all occurred in high poverty tracts as well, with 86 percent of the total discharged amount spilled in these vulnerable communities. With 25,034,700 gallons of municipal waste spilled of the total 29,119,165 in areas facing poverty and other such disadvantages show a desperate need for action against environmental injustices taking place across the state. Although tackling the case of environmental injustice is a praiseworthy goal, it is none the less one of involving utopian-like feats that will require enormous efforts to create noticeable and meaningful change to level the playing field on demographic disparity across the state. Overcoming this difficulty must be a priority in order to reach people in need, especially those that are typically underserved. and All the while alleviating pollution occurring in and around poverty-stricken locations as well as implementing methods to protect these places from future harm resulting from heavy weather events.

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