Think about the unthinkable:
Coastal comprehensive planning for better public outcomes after storm disasters

by

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A REPORT

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Abstract

The last 20 years have contributed to 4 of the top five most active hurricane seasons in the United States, three of them back-to-back. With these stronger storms comes more loss of life, injury to residents and responders, and more destruction of communities. Hurricanes are the most expensive natural disaster that the United States experiences. A single hurricane pass through a city in just a few hours, and still cost more in damages in that single day than a long-term wildfire that takes months to put out. The heightening levels of destruction, and the increasing frequency of large-scale hurricanes are leading many Americans to wonder if it is still safe to live along these coastal areas that are most frequently hit. Many different groups are working to address the need for better long-range planning before hurricanes. These groups are working together to create better solutions for evacuation, protection, and recovery, while working to address the root issues that individual cities face that make them each uniquely vulnerable to hurricanes, especially particular elements like storm surges and long-term flooding.

My objective was to provide planners with a framework to study different cities and their response to major storm disasters, and to analyze the different responses to determine best practices when planning for storms. In this report, I explored how two major U.S. coastal cities responded to storms, and which plans were most effective in protecting people for future storm events. A literature review explored frameworks from the Environmental Protection Agency that shaped my study. This provided the base framework for my analysis by identifying the focus areas of built environment, natural environment, society, governance, and risk.

My methodology was a combined approach of case study and comparative analysis. I began by identifying major cities that had experienced hurricanes in the 21st century and selected two for case study. I then completed a comparative analysis of the city's response to their two

different storms, and then to each other. Throughout this process, I identified areas of strength and weakness in the responses, as well as areas of change and improvement in between the storms.

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Introduction

Most historians agree that the Industrial Revolution started around 1750. Since then, we have seen a constant increase in the number of people living in cities, and a rapid leap forward in our technological capacity. However, this has come at a price. Since the start of the Industrial Revolution, the average global temperature has risen 1.4 degrees Fahrenheit. By the end of the 21st century, we might see temperatures rise by as much as 7 degrees Fahrenheit. This change may not seem like a lot, but it can mean a dramatic loss of the world's coastlines as the higher temperatures lead to rising sea levels, and a loss of glacial ice globally.

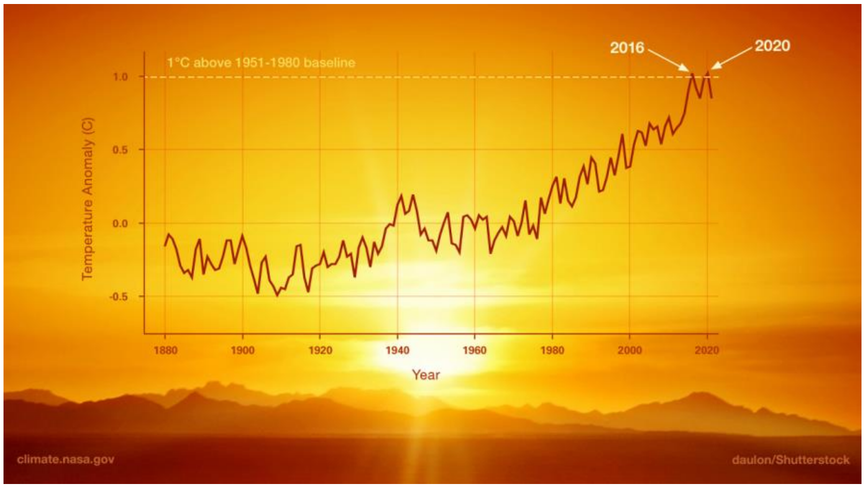

Figure 1: Rising Annual Temperatures 1880-2020 (NASA)

Although this temperature change impacts people around the world, we see it the most vividly in coastal communities, where the effect of rising temperatures correlates to rising tides. "Almost two-thirds of the world's cities with populations of over five million are located in areas at risk of sea level rise and almost 40 per cent of the world's population live within 100 km of a coast" (United Nations 2022). In the U.S. alone, coastal areas account for less than 10% of the total land mass for the country. However, this small amount of land also holds nearly 40% of the country's entire population (NOAA 2022). As we see temperatures rising, the ocean is warming up, which leads to thermal expansion and rising sea levels. We are also seeing glacier loss at an increasingly fast rate, accounting for upwards of 21% of the rising sea levels (Watts 2021). This rise in sea levels and increasing ocean temperatures leads to an increase in both the frequency and magnitude of coastal storms and hurricanes (Beatley 2009).

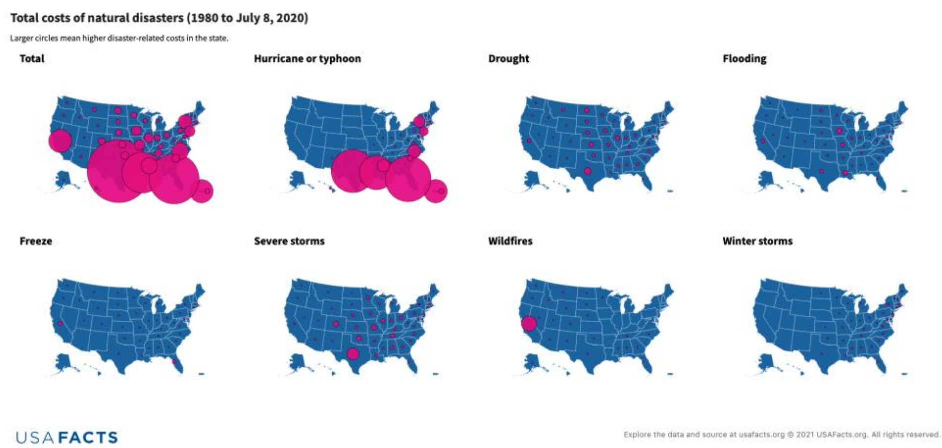

Figure 2: Total Cost of Natural Disasters in the United States 1980-2020 (USA Facts)

The last 20 years have contributed to 4 of the top five most active hurricane seasons in the United States, three of them back-to-back. With these stronger storms comes more loss of life, injury to residents and responders, and more destruction of communities. Hurricanes are the most expensive natural disaster that the United States experiences. A single hurricane passes through a city in just a few hours, and still cost more in damages in that single day than a long-term wildfire that takes months to put out (Figure 2). A single hurricane can cost a state hundreds of billions of dollars, and hurricanes generally hit more than one state. In the U.S., 2017 holds the record for most expensive hurricane season with $294 billion in damages, followed by 2005 with $236 billion. The 2021 season ranks third, followed by 2012 in fourth. In large part, these high-cost seasons are due to just one or two extremely powerful storms that caused more destruction than usual. In 2017, it was Hurricane Harvey that raised costs up to overtake the 2005 season. 2005 held its first place position for so long because of Hurricane Katrina. 2021 made it to third place because of the damages from

Hurricane Ida, and 2012 because of Hurricane Sandy. Other storms in those seasons added to the cost, but the large majority comes from a single storm (Rezal 2021).

The heightening levels of destruction, and the increasing frequency of large-scale hurricanes are leading many Americans to wonder if it is still safe to live along these coastal areas that are most frequently hit. Many different groups are working to address the need for better long-range planning before hurricanes. This includes both city and state officials across the Gulf Coast and Eastern Seaboard, as well as federal officials and agencies such as FEMA and the National Guard. All these people are working together to create better solutions for evacuation, protection, and recovery, while working to address the root issues that individual cities face that make them each uniquely vulnerable to hurricanes, especially particular elements like storm surges and long-term flooding.

Methodology

This report is aimed at answering the following questions:

1. Can comprehensive planning ensure better outcomes for our coastal cities in the face of 21st century storm-related flooding?
2. What factors would constitute effective comprehensive planning?

To answer these questions and fully understand the needs coastal communities have during storm events, I use two primary modes of data collection and analysis: case studies and comparable analysis. An illustration of my methodology can be found in Figure 4. The use of these two modes resulted in in-depth data about the different policies and practices that have been used historically, and the newer, modern solutions that have come to play in recent years to combat the increasing strength and number of hurricanes. Case study research provided the opportunity for an in-depth study on a single storm case, for a singular city. These storms and cities were selected because of their scale, and the amount of data and information available, as well as the length of time between the storms, which allowed for changes to be implemented. As the storms were nine and sixteen years apart, they both had the time needed to do studies, appropriate funding, and complete major large-scale projects. The cities were also deliberately selected to be in different regional parts of the country, to allow for broader comparisons, and not be limited to one small area that experiences hurricanes. In this report, I analyze New Orleans, Louisiana, and New York, New York, looking at the impact that different storms had on the cities, and how these cities changed and adapted to have more effective preparedness planning for future storms. Based on the city's responses and changes after the storms, I looked for commonalities and effective actions to provide holistic recommendations for any city in a hurricane risk area.

There are four case studies used in the report, with two storm case studies being on New Orleans, and two case studies being on New York. The selected studies for New Orleans were Hurricane Katrina (2005) and Hurricane Ida (2021), and the selected studies for New York were Hurricane Sandy (2012) and Hurricane Ida (2021). New Orleans as a city was chosen as one of the locations for case study because of its unique geography and the issues the geography can cause, which is covered in depth in chapter 3 of this report, as well as the fact that has been central in the conversations about hurricanes, hurricane preparedness, and hurricane response for as over a decade. The two case studies for New Orleans were chosen because they made landfall 16 years apart – to the day. The time between the two storms meant that the city, state, and federal level agencies all had time to assess the events of Katrina and make changes to their preparation and responses. New York as a city was selected because it sits outside the Gulf Coast area, in the Mid-Atlantic region. This is outside the area typically thought of as hurricane-prone, but New York has been hit by several hurricanes. New York was selected over other cities in the region due to its large population, the complex nature of its underground subway system and extensive maintenance tunnels, and the land reclamation that has artificially expanded the footprint of the city.

During the case study research process, I analyzed policies, public response, and best practices for planning for and responding to hurricane events in New Orleans and New York. The analysis process was used to understand the ways in which cities created systems of preparedness, and how they respond in conjunction with other organizations at the state and federal level, as well as with non-profit organizations. These case studies were necessary because, outside of Katrina, I was unable to find comprehensive review or analysis to determine what was done, what was done well, and what needed to change for better future planning and response across all categories. Any review that existed was focused on only one area, such as transportation. In creating an in-depth analysis of these four storms, I was able to highlight the areas of successful planning interventions, and areas where additional future planning is needed.

This analysis was guided by the 2017 Climate Resilience Screening Index (CRSI) that was created by the Environmental Protection Agency to help communities better understand the risks and vulnerabilities that they each face. The CRSI was designed to describe the state of the condition of resilience at the county level, provide a framework that might be useful for communities to expound upon the county information and create resilience scores, identify areas for management/action decisions, and help track changes over time at the county, state, region, and national levels. The CRSI criteria are based in five overall "domains" to describe overall resilience. Within the five domains are eleven topics of interest which break down into twenty-five candidate measurement categories [Figure 3]. By using these standardized criteria, I was able to create case studies that are comparable. The areas of greatest interest to me because of their wide scope and generalization that makes them applicable to all my case studies are:

CRSI Review Summary

Domains of Resilience	Topic of Interest	Candidate Measurement Categories
Natural Environment	Extent of Natural Areas	• Managed Lands • Ecosystem Type
	Integrity	• Condition
Society	Economy	• Economic Diversity • Employment • Insurance
	Critical Services	• Safety and Security • Social • Labor/Trade
	Characteristics	• Demographics • Health
Built Environment	Infrastructure Integrity / Continuity	• Communication • Transportation • Utilities
	Structure / Housing Characteristics	• Non-Residential • Residential • Shelter
Governance	Preparedness	• Planning • Investment
	Response	• Expenditure • Time
Risk	Losses	• Property • Human
	Hazard Exposure	• Geophysical • Technology Hazards

Figure 3: Climate Resilience Screening Index categories (EPA)

- Built Environment, with the interest topics of infrastructure integrity & continuity and structure & housing characteristics,
- Governance: with the interest topics of preparedness and response, and
- Risk: with the interest topics of losses and hazard exposure

In addition to the framework developed by the Environmental Protection Agency, I also used four major category areas that were defined by Craig Colten, Professor of Geography at Louisiana State University. Professor Colton has defined four major elements that determine the outcomes for cities during and after hurricanes. These elements, flood-proof architecture, protective structures and land use, local evacuation and multiple shelters, and the coordination of the organizational response, fall into the CSRI domains, and make it possible to analyze. I

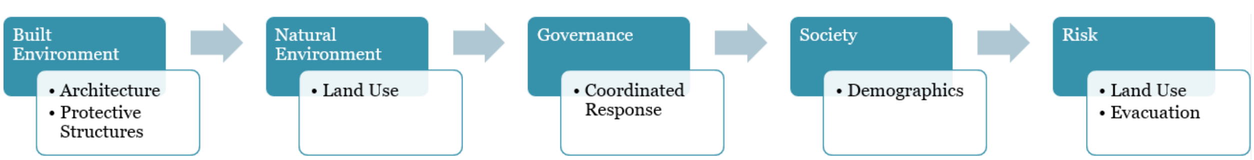

Figure 4: CRSI domains and Professor Colton's elements

matched these two criteria by fitting Professor Colton's elements into the broader domains using the additional topics and candidate measurements listed by the EPA. By matching Professor Colten's elements to these more detailed categories, I was able to pair my two criteria to complete my analysis.

The second phase of the methodology was comparable analysis. Comparable analysis is the process of comparing case studies to one another and distinguishing their similarities and differences. In this report, the comparison was made between the two storms for each city, and between each city's overall response. This comparison made it possible to highlight the areas that are consistently a weakness in preparedness and response, as well as identify specific practices and planning that was successful. The goal of this method is to create an overarching guide to best practices and pitfalls that cities should be aware of when working on their own hurricane preparedness plans.

Literature Review

Much of the literature that I reviewed initially was focused on climate change and creating a series of definitions for my different criteria. By looking at climate change, I was able to come to a better understand of why we are seeing changes in hurricane patterns in recent decades. In researching the different methods of determining resiliency, I was able to find the best criteria to move forward with my research.

Climate Change

Climate change has had a large impact on city resiliency, as the conditions that they were built to withstand have changed. Weather patterns have shifted, and storms have grown more destructive. "Climate change refers to long-term shifts in temperatures and weather patterns. These shifts may be natural, such as through variations in the solar cycle. But since the 1800s, human activities have been the main driver of climate change, primarily due to burning fossil fuels like coal, oil, and gas." (United Nations 2022). In creating cities and plans that are resilient, it is important to understand these shifts. Climate change serves as an umbrella term that encapsulates many changes happening globally. Climate change includes factors such as global warming, which is the long-term heating of Earth's surface observed since the pre-industrial period (between 1850 and 1900) due to human activities. There are several major effects of climate change. Some of these include the slow warming of the ocean, and changes in weather patterns.

Ocean Warming

One major effect of climate change is the overall global warming. Global warming refers to "the long-term heating of Earth's climate system observed since the pre-industrial period (between 1850 and 1900) due to human activities" (NASA 2023). Since this preindustrial period, the overall temperature of the planet has warmed about 1 degree Celsius above the previous average temperature. The ocean is the largest absorber of the increased heat levels. Ninety three percent of the excess heat generated since the 1970s has been absorbed by the ocean. This means ocean temperatures are rising. NOAA data shows roughly 0.13 degree increase in temperature every decade in the last century, and the average global temperature will rise 1-4 degrees Celsius by 2100. This warming is not evenly spread out across all of the ocean. Most of the warming effect can be seen concentrated in the Southern Hemisphere. Other areas of concentrated heat increase include the Gulf of Mexico, along the Eastern Seaboard and into the Bahamas (IUCN 2020). This means that the states along the east coast are more vulnerable to water encroachment, as the ocean continues to warm.

Storm Increase

With climate change and global warming comes increasingly strong storm systems. Ninety percent of disasters are now classed as weather- and climate-related (United Nations 2022), and of those disasters, hurricanes are among the largest and most destructive. These storm systems are more powerful and more destructive because they are able to absorb more heat energy from the warming waters caused by climate change. This means the hurricanes can travel faster, and create larger storm surges, which leads to more flooding. With water temperatures rising in areas that hurricanes have to pass through to make landfall in the United States, the danger is even higher. "Flooding of critical facilities is expected to increase by 1% to 19% for major hurricanes… [and] the present-day 1%-occurrence flood level was projected to become the 26%-occurrence flood level by 2100… For catastrophic-type hurricane surge events, flood elevations are projected to rise by as much as 0.5 m and 1.8 m by the 2030s and 2080s, respectively" (Mousavi, et.al. 2009).

Comprehensive Plans and Comprehensive Planning

A comprehensive plan is a long-term planning process and documentation for creating a broad, long-term vision for future land use and the built environment of communities. These plans are often written with a 20-year outlook. This allows for a time period that avoids the uncertainty of long-term economic and population growth patterns while also avoiding short-term thinking that can weaken a cohesive vision for the future.

Comprehensive planning typically refers to the process of determining the goals for a community's long-term development. For the purposes of my master's report, comprehensive planning refers to the practice of bringing multiple agencies and entities together to create a plan or series of plans to respond to and prepare for storm events. Although the plans generated by the process can and should include the comprehensive plan, or master plan, they should also include additional plans such as hazard mitigation plans and evacuation plans.

Storm Preparedness in Practice

There are many agencies involved in creating resilient cities in America, but one of the most involved is the Environmental Protection Agency. In 2017, the EPA created the Climate Resilience Screening Index, or CRSI, as a way for cities and counties to assess their own resilience across a broad range of areas. These areas are broadly grouped into five domains: Natural Environment, Society, Built Environment, Governance, and Risk. These five categories form the basis for any investigation into resiliency and preparedness. From those five categories, I will be using the four key elements of practical storm preparedness as defined by Craig Colten, Professor Emeritus of Geography at Louisiana State University. These elements – flood proof architecture, protective structures and land use, local evacuation and multiple shelters, and the coordination of the organizational response – fall into the CSRI domains and make it possible to compare different storms and different locations through the shared criteria (Colten 2008).

Flood-proof Architecture

Flood-proof architecture is defined by FEMA as: "Any combination of structural and non-structural additions, changes, or adjustments to structures which reduce or eliminate flood damage to real estate or improved real property, water and sanitary facilities, structures and their contents." Many places write some flood-proofing requirements into their building codes if the area has reoccurring flooding. This can include not allowing below-grade basements, requiring homes be elevated, or by encouraging ecological design, such as rain gardens. Different materials can also increase a building's flooding resilience.

Protective Structures

Protective structures refers to the use of sea walls, levees, dams, or other physical boundaries against flooding and storm surges. These structures are often multi-million or multi-billion-dollar projects. These structures decrease the likelihood that a flood will occur within the protected area, and they increase the sense of safety and security for people living in the protected areas. These structures do have a limited lifespan, usually around 50 years, before they need to be replaced. Increases in base sea level can also make these protective structures less effective. As the water level rises, the minimum storm surge needed to overtop these structures gets smaller, and new, taller, barriers are needed to ensure the same level of protection.

Land Use

Land use refers to the zoning of a community, and the decision of the local government to permit or forbid certain human uses of the land in different areas. Cities can choose to zone areas known to be prone to flooding as a park or nature preserve, in order to limit the destruction of property. They can also make efforts to restore areas back to their natural state through land reclamation and restoration programs.

Local Evacuation and Multiple Shelters

Evacuation procedures for cities are often run through multiple agencies. A city will have a set evacuation plan, and that will be bolstered by county or state plans. They will also be supported by the National Guard, FEMA, and the American Red Cross, as well as smaller local disaster recovery groups. Multiple shelters are important for evacuation plans, in order to support both those unable to evacuate, such as nursing homes, hospitals, or lower-income residents, and those who choose not to evacuate. Multiple shelters prevents overcrowding in any single shelter point, and ensures that if one shelter should fail, that alternative sites are available and accessible.

Coordination of the Organizational Response

Similar to the evacuation process, the overall organization response also falls to multiple agencies to coordinate. These agencies come from multiple levels –federal, state, and local –and they respond at different points. Some respond before a storm disaster, some after, and others are involved throughout the entire process.

Background

These studies take place in two cities in the United States. The first selected city, New Orleans, is in the Gulf Coast region, in the southeastern part of the country. The second city, New York, is in the Mid-Atlantic region, along the Eastern seaboard. It is important to understand both the geography and the history of these communities, in order to understand the factors that shaped their growth. Additionally, the community characteristics of the cities, such as total population and housing characteristics, as well as the changes that occur during the study periods, can tell us a lot about the impacts that major storms can have on cities.

New Orleans

New Orleans, Louisiana (NOLA) is located in the southeast corner of the State of Louisiana as seen in Figure 5, in Orleans Paris[1] . New Orleans is bordered to the north by Lake Pontchartrain, to the east by Lake Borgne, to the southeast and south by the Gulf of Mexico and has the Mississippi River to the south between the city and the coast. The city has an average elevation between 1-2 feet below sea level, with the city's lowest point being 6.5 feet below sea level, and the highest point is Laborde Mountain, an artificially constructed hill in city park that measures 49 feet above sea level, with 46 of that being artificially constructed. New Orleans is

Figure 5: Map of Louisiana (World Atlas)

[1]Louisiana was officially Roman Catholic under both France and Spain's rule. The boundaries dividing the territories generally coincided with church parishes. In 1807, the territorial legislature officially adopted the term "parish" to be used as the equivalent of other states' counties.

known for having such a high-water table that you cannot dig deep enough for graves, or deep foundations, without the holes immediately filling with water.

The land area that we now know as New Orleans was originally home to the Native American tribes known as the Woodland and Mississippian tribes. New Orleans as we know it today was originally founded by French settlers in 1718, under the governor Jean-Baptiste Le Moyne, Sieur de Bienville. He chose the location for the city because it was the first section of high ground above the Mississippi's mouth, which would allow for strong trade. This original founding site is now the oldest neighborhood in the city of New Orleans, known as the French Quarter. In 1722 New Orleans became the new capital, replacing Biloxi, which is located approximately 90 miles east. The same year that New Orleans became the capital, a hurricane destroyed most of the new city. They rebuilt the city in the grid pattern that we now know as the French Quarter. The city was ceded to Spain from 1762 until 1803, when it reverted back to French control, and 20 days later, it was US territory, as part of the Louisiana purchase. In the 20th century, new technology, including the ability to pump and drain swampland, massively expanded the city. New levees and canals meant that much of the new construction was located below sea level. There were several hurricanes in this time period that caused damage, but it was never considered catastrophic.

NOLA Demographics

At the beginning of the study period, in 2005, New Orleans had a population of 484,674 within the city boundary. Surrounding parishes that make up the greater New Orleans metropolitan area include St. Bernard's, Jefferson, St. Charles, Plaquemines, St. Tammany, and St. John the Baptist. By the end of the study period in 2021, these individual parishes would almost all see decreases in the population totals, and the area as a whole would see a loss of population. St. Charles Parish is located to the south and west of New Orleans city proper and is largely wetlands, and St. Tammany Parish is located on the northern side of Lake Pontchartrain. [Table 1] Today, the population of New Orleans is majority African American, with white/Caucasian making up the second largest group.

Table 1. **New Orleans metro area population changes 2000 – 2020**

	2000 Census	2020 Census	Total Change
Orleans Parish	484,674	383,997	-100,677
St. Bernard's Parish	67,229	43,764	-23,465
Jefferson Parish	455,466	440,781	-14,685
St. Charles Parish	48,072	52,549	+4,477
Plaquemines Parish	26,757	23,515	-3,242
St. Tammany Parish	191,268	264,570	+73,302
St. John the Baptist Parish	43,044	42,477	-567
NOLA Metro Total	1,316,510	1,251,653	-64,857

Within the city of New Orleans, the average household income was only $27,133, with 23.7% of families in the city living below the poverty line in 2000. By 2020, the average household income was $43,258, but 17% of families were still living below the poverty line. Although the number of individuals who report taking home incomes over $50,000 annually has increased since 2000, the majority of households still report annual incomes under $50,000. During this same time period, the number of people reporting to be married went down from 35.5% to 30.3%, meaning that more people were reporting their incomes as single individuals instead of married couples. Additionally, despite the 2020 numbers being collected in the beginning of a large number of layoffs generated by the SARS-CoV-2

Figure 6: NOLA annual income 2000 - 2020

pandemic, the percentage of the population reporting as unemployed went down from 5.5% unemployed and 42.2% being not in the labor force in 2000 to only 5.2% unemployed and 38.7% in the labor force in 2020. Educational attainment has also improved during this time period, going from 25.3% of people 25 and over having not completed high school or earned a GED to only 12.3%. At the same time, the number of people with some form of a degree, either an Associates, Bachelors, or Graduate degree, has gone from 29.3% to 43.4%, although what fields or areas of study these degrees are in is not clear.

Although some of this change comes from the natural migration of people around the country, and from efforts within the city to increase education and standards of living, much of the change is a part of Hurricane Katrina's lasting legacy. Many of those most heavily impacted by Hurricane Katrina were lower-income individuals and families. Most of these people were renters and did not receive money from the different programs for rebuilding property. A year after Hurricane Katrina decimated New Orleans, about 53 percent of displaced adults had returned to the city, but less than a third were living in the same home they'd lived in prior to Hurricane Katrina. For the roughly 40% of the population who did not return to New Orleans, their new homes were often far away from the city. Although Texas was the largest hub for refugees, especially in Huston, 25% of evacuees relocated at least 450 miles away, and 10% of evacuees relocated at least 830 miles away, the same distance as between St. Louis, MO and Denver, CO. Despite being a majority black city at the time of Hurricane Katrina, it was the white middle class who returned to the city first. These were the residents who had the financial means to rebuild their homes and their businesses. Even by 2012, seven years after Katrina destroyed their homes, many minority residents had not returned to the city, and many formerly black neighborhoods such as the Lower Ninth Ward remained largely empty.

NOLA Housing Demographics

An important area in understanding the vulnerability of a population in hurricane prone areas is housing. In New Orleans, many of the housing structures are old. This includes single family homes, townhomes, apartments, and condos. Across the board, most of the housing stock that is available in the city was built prior to 1980, meaning that they predate the Mount St. Helens eruption that occurred on March 27th, 1980, and were standing before John Lennon was shot on December 8th, 1980.

Table 2: Year housing structures were built NOLA

	2000	2020
2010 or later	0%	3.9%
2000 to 2009	0.4%	7%
1980 to 1999	10.8%	11.4%
1960 to 1979	28.7%	27.1%
1940 to 1959	30.5%	19.9%
1939 or earlier	29.7%	30.8%

These older structures do not have the modern safety features that newer construction has, and they are more prone to being destroyed by high winds or flooding during a storm event. Some of the oldest housing structures, including most of the 18th and 19th century buildings, in the city are located in the historic French Quarter. Since the French Quarter is located at the original site of the city, it is above sea level, and is protected from much of the flooding that the surrounding area is vulnerable to. In contrast, much of the post-World War II housing boom was located in low-lying areas that were extremely vulnerable to flooding and were protected only by the new levee systems being built. As of 2020, 77.8% of homes were more than 40 years old. The average lifespan of a house in the United States is 50 to 70 years, so most of the housing stock in New Orleans is coming close to end-of-life.

Many of the people living in the homes that were destroyed by the hurricanes also do not have the possibility of getting a buyout deal from the government or a large payout from insurance. In 2000, 53.5% of homes in New Orleans were renter occupied. In 2020, the number was down to 50.2%. However, this still means that half the people who live in New Orleans do not own the place where they live, and as such, are not eligible for the payouts, as those go instead to the owner of the property.

New York

New York, New York, (NYC) is located on the eastern edge of the State of New York as seen in Figure 7. It is bordered to the south by the Upper and Lower Bay's, and is divided into sections by the Newark Bay, the Hudson River, and the East River. To the north, the city is also bordered by water, with a series of bays running along Queens and Brooklyn. The eastern part of the Bronx is also bordered by additional bays, but the eastern portion of Queens is bordered by Long Island. The city has an average elevation of just 33 feet above sea level. The highest point is the naturally occurring Todt Hill, located on Staten Island, with a peak elevation of 401 feet above sea level. The lowest point in the city is 0 feet above sea level, where the beaches meet the Atlantic Ocean.

Figure 7: Map of New York (World Atlas)

The land that we know today as New York City was originally home to the Lenape, one of the tribes of the Algonquin people. The first Europeans settled on what we now call Governors Island in 1624, and in 1626, they purchased Manhattan Island from the natives. This settlement by the Dutch West India Company was named New Amsterdam, but in 1664, the

British seized the city and gave it the name we know today – New York City. By 1760, New York City had grown in size to become the second largest city in the Western Hemisphere, outpacing even Boston. After the American Revolution, New York City served as the nation's first capitol from 1785 until 1790, when D.C. became the new, permanent, capitol city. In 1825, the completion of the Erie Canal, which connects Lake Erie and the Hudson River, established the port city as the trading capital of the nation. In 1895, residents of the Bronx, Queens, Brooklyn, and Staten Island, voted to consolidate with Manhattan to form the five-borough city that we know today as New York City. This meant that New York City went from 60 square miles and a population just over 2 million on December 31, 1897, to a land area of 360 square miles, and a population of roughly 3,350,000 the next day, when the consolidation took effect.

NYC Demographics

At the beginning of the study period in 2012, New York City had a total population of 8,199,221. By the end of the study period in 2021, the city had grown to a total population of 8,736,047, an increase of 536,826 in just 9 years. New York City in 2010 was the 8th largest city in the world but had dropped to 48th largest in the world by 2021 as the populations in India and China have grown at a rapid rate, and more people are moving out of rural areas to cities in Bangladesh and Brazil. At the same time, New York City remained the largest city in the United States by around 4 million people. Most of the internal migration into New York City comes from New Jersey, California, Pennsylvania, and Florida.

The median household income in New York City in 2010 was $48,743. Eleven years later in 2021, that number had risen to $72,920. Adjusting the 2010 median income to account for inflation rates in 2021, there was still an increase in the median income of $14,079. The number of households living in poverty had also gone down, from 17% in 2010 to only 14% in 2021. The national poverty rate in 2021 was 11.6%, meaning that New York City is close to the national level. During this same time period, the reported marriage rate went from 41.3% to 42.3%, meaning

Figure 8: NYC median income 2010-2021

that the number of people reporting incomes as single-person households was stable during the 11-year study period. In 2010, New York City was reporting 55.8% employment status, and 7.0% unemployment rate. In 2021, as the SARS-CoV-2 pandemic continued to hold the average unemployment rate above the prior national average, New York City reported a 55.1% employment rate and 7.3% unemployment rate, so the workforce remained stable in the city. Education rates in the city did go up from 2010 to 2021. In 2010, 39.3% of the city was reporting having some form of advanced degree (associates, bachelors, graduate, or professional). By 2021, that number was up 7.6% to 47.5%.

NYC Housing Demographics

The vast majority of the housing stock that was available in the city in 2010 was built prior to 1980, with the 2000 contributing only 6% of the housing in the city. By 2021, the 2000s and 2010's combined were only capturing 11.6% of the housing market, only 3.1% more than the 1980's and 1990's combined.

Table 3: Year housing structures were built NYC

	2000	2020
2000 or later	6.0%	11.6%
1990 to 1999	3.4%	3.4%

1980 to 1989	4.2%	5.1%
1960 to 1979	20.4%	18.9%
1940 to 1959	25.7%	21.8%
1939 or earlier	40.3%	39.1%

Unlike many other U.S. cities, single-family homes do not make up a large portion of the housing market in New York City. Most of the city's housing comes in the form of condos, apartments, and townhomes – all different forms of high-density living. Although these housing types come with the benefits of housing more people per square mile, and provide the property owner with an income, it also means that the loss of one housing structure means the loss of many more homes. This means that any single building coming down takes out a much larger amount of the housing stock in the city, and much of that stock is aging. Although older buildings can be good places to live, they also come with additional maintenance needs, and can be dangerous if not kept up to standard.

New York city is also different from many other U.S. cities as its homeownership rate is incredibly low. In 2010, 67.9% of all housing units in the city were renter occupied. In 2021, that number had gone down only very slightly to 66.7%. This contributes to frequent moving between units and boroughs, so residents are not always aware of the flood risk for their current neighborhood. This high renter rate also means that in case of severe flooding or storm damage, occupants have more freedom to simply pack up and move somewhere in the city or move out of the city entirely.

New Orleans, Louisiana

Hurricane Katrina

Hurricane Katrina originated on August 23, 2005, as a tropical depression[2], which began to move westwards while growing in strength. It intensified into a tropical storm[3] as it traveled towards Florida, and two hours before making landfall at Hallandale Beach, in Broward County Florida, it officially strengthened to a hurricane. While passing over Florida, the storm lost energy and downgraded back to a tropical storm before entering the Gulf of Mexico, where the warm waters rapidly strengthened the tropical storm to a category 5 hurricane[4]. Hurricane Katrina would downgrade to a category 3 hurricane[5] before making landfall in Mississippi on August 29, 2005, where it tracked through the delta and passed over Lake Pontchartrain just to the east of the city of New Orleans. Hurricane Katrina would cause enough devastation to be the costliest hurricane ever at the time that it made landfall, and would maintain that title until 2017, when it would be tied, but not surpassed, by Hurricane Harvey. On April 6, 2006, the World Meteorological Organization retired the name Katrina from its list due to the large death toll and the shear amount of destruction that had been caused.

Flood-proof Architecture

In New Orleans, late 19th century codes required that the lot be raised higher than the sidewalk. By the mid-20th century, as slab construction became more common, the codes added

[2] A tropical cyclone with maximum sustained surface winds of 38 mph winds or less

[3] Maximum sustained surface winds of 39-74 mph

[4] Category 5 hurricane: 157 mph or higher winds

[5] Category 3 hurricane: 111-129 mph winds

regulations that “Top of slab shall not be less than 18 inches above the highest point of the curb in front of the lot or site” (FEMA 2012). The city building codes also placed several limits on what basements could be used for. Over time, buildings were being constructed as low to the ground as possible as a money saving measure. This meant that by the time Katrina hit New Orleans, many of the structures, especially residential buildings, were not elevated high enough to be protected from flood damage. In large part this was a combination of the overwhelming building trend in the country being slab construction, and the growing faith in the extensive flood control devices being constructed around New Orleans. Despite this, certain people had continued to recognize the importance of raised construction in the city. Two decades prior to Hurricane Katrina, an engineer named James Janssen wrote: “It is a false economy of the most blatant form to save possibly a few dollars on construction of a new home or other building by basing it on a concrete slab poured directly on the native soil” (FEMA 2012).

Protective Structures

The existing levee system around New Orleans was started in 1965 following Hurricane Betsy. Betsy, the first tropical cyclone in the Atlantic basin area to reach one billion dollars in damages, was a category 4 hurricane when it made landfall in Louisiana, where its storm surge in Lake Pontchartrain breached several levees, including those around the lower Ninth Ward. After this storm, Congress passed the Flood Control Act of 1965. This act authorized the United States Army Corp of Engineers to design and build a number of projects aimed at flood prevention and the protection of cities. Some of these were related to ensuring clean water supply, while others focused on navigation and flood control. For the New Orleans area, the projects focused on conducting surveys for flood control purposes, including drainage and channel improvements, as well as building a flood protection system for Lake Pontchartrain and its vicinity. This project was meant to provide hurricane protection to the parishes of Orleans, Jefferson, St. Bernard, and St. Charles by building a new system of control structures, including concrete floodwalls and levees to replace those damaged or destroyed by Hurricane Betsy. It was designed with a particular focus on protecting areas around Lake Pontchartrain from flooding caused by a storm surge or rainfall associated with roughly a category 3 hurricane.

Work on the levee system began in that same year, with an original estimated completion timeline of thirteen years, and an original estimated budget of $85 million. This would allow for surveys of the area, designing and planning of a new levee system, and construction of the new levee walls. By 1982, costs had ballooned to $757 million, and the completion date had been pushed to 2008. In 2005, forty years after Hurricane Betsy had destroyed the old levee system, Hurricane Katrina hit the city. However, when Hurricane Katrina made landfall, there was still not a completed levee system around New Orleans. The project was sitting between 69%-90% complete, and the final completion had been moved to 2015. The work in Orleans Parish was estimated to be 90 percent complete. Jefferson Parish work was estimated to be 70 percent complete, with an estimated completion of 2010. In St. Charles Parish work was 60 percent complete with some gaps still remaining in the levees. Closure of these gaps was scheduled by September 2005. The new estimated cost of the project had grown to $738 million dollars, with the federal government being responsible for $528 million, and the local government being responsible for $210 million. Some of the delay had come from the need to rework parts of the design to accommodate the need for higher walls along three drainage canals that fed into Lake Pontchartrain in order to better handle storm surges. Other delays came from environmental groups raising concerns about the impacts of different portions of the project, to the point that the environmentalist groups brought up litigation against the Corp of Engineers. In December 1977, there was a court decision[6] that enjoined the Corps from constructing the barrier complexes and other parts of the project until a revised environmental impact statement was prepared and accepted. After the court order, the Corps completed a project reevaluation report and prepared a draft revised Environmental Impact Statement in the mid-1980s (GAO 2005).

There were 28 failures in the protective system in the first 24 hours after Katrina, and over 50 failures of the levees and flood walls protecting New Orleans, Louisiana, and its suburbs following the passage of Hurricane Katrina. Six of these were major breaches. The failures caused flooding in 80% of New Orleans. For areas like the Lakeview neighborhood, where many houses were built on minimally elevated slabs, the failure of the levee led to catastrophic flood damage. Some houses were completely detached from their slab foundations. (U.S. Army Corps of Engineers 2018). The massive failure of the levee systems across the city was deemed "the worst engineering catastrophe in US History" by the American Society of Civil Engineers in April of 2007. These breaches had a variety of causes, but many could be traced back to miscommunications in the Army Corp of Engineers, the New Orleans Levee Board, and between the two entities.

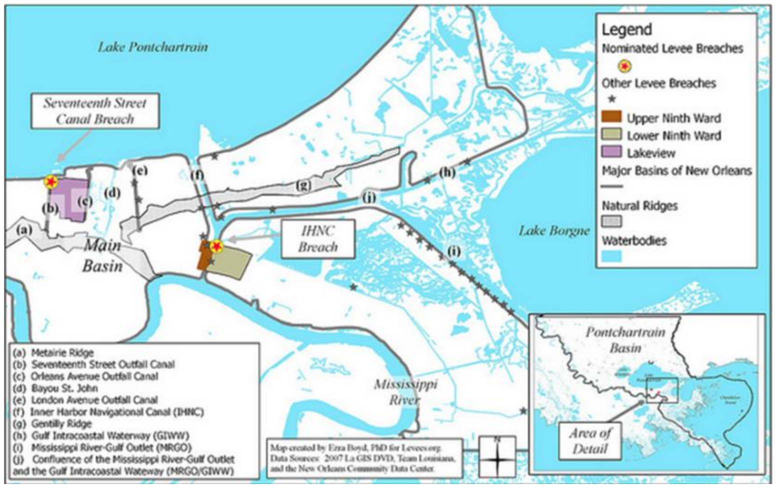

Figure 9: Map of breaches during Hurricane Katrina

The single largest failure on the part of the Corp was determining how deep the foundations needed to be. The Corp found their sheet piles needed to be 17 feet deep, but their

[6] Save Our Wetlands v. Rush, Civ. A. No. 75-3710 (E.D. La. Dec. 30, 1977)

own design drawings showed those piles had only been dug to a depth of 10 feet. The actual depth needed was between 31 to 46 feet, which led to catastrophic failures during Hurricane Katrina. There were also design decisions made to use what it known as an "I-wall" instead of a "T-wall" for the 17th street canal, London Avenue canal, and Orleans Avenue canal. T-walls are reinforced concrete retaining walls supported on piles, while I-walls are simple cantilever walls of sheet steel. As seen in Figure 10, T-walls are much more complicated to build, which means that they are also much more expensive to build. T-walls were used in New Orleans near bridges and gates, but I-walls were used extensively in all other areas in order to reduce the costs in the increasingly expensive project (Rodgers). The breaches that were seen during hurricane Katrina and in the immediate aftermath were exclusively in areas where I-walls had been used – there were no breaches of T-walls.

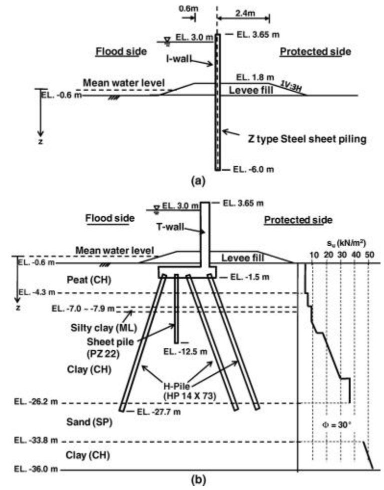

Figure 10: Levee designs, I-walls vs T-walls

Land Use

An average of 34 square miles of South Louisiana land, mostly marsh, has disappeared each year for the past five decades, according to the U.S. Geological Survey (USGS 2021). Today, South Louisiana is one of most intensively engineered places in the nation. Vast quantities of water are diverted or rerouted through a lacework of navigation corridors held in place by 2,000 miles of earthen, rock, and concrete levees. Walled off from the floodplains, the

Figure 11: Louisiana land loss 1952-2050 estimate

river can no longer provide enough silt to the delta to keep up with natural subsidence and sea level rise. About two-dozen dams also hold sediment back from the river and its tributaries. The Mississippi has historically relied on the river's natural switching between channels and deposition of new sediments in order to maintain the Louisiana coastline in a natural process that created the wetlands and barrier islands that protect more inland areas. The protective wetland in the Mississippi delta account for 30% of all coastal wetlands in the United States, but losses in the same region account for 90% of wetlands loss in the country. These wetlands are critical natural protective structures, as they naturally serve as a water storage area during floods, and when coastal wetlands are lost, so are wave and storm protections. They are also economically important for Louisiana, as they serve as nurseries for the rich fisheries in the area. Louisiana has roughly 30% of all US fisheries and provides 40% of the country's shrimp and oyster harvests every year.

At the time of Hurricane Katrina, there was a very small level of awareness regarding the importance of the natural wetlands. The Coastal Wetlands Planning, Protection, and Restoration Act was passed by Congress in 1990 creating a partnership between the Louisiana state government and five federal agencies: USACE, the U.S. Department of Agriculture, the U.S. Department of Commerce, the U.S. Department of the Interior, and the Environmental Protection Agency. Louisiana developed their first comprehensive wetlands restoration plan in 1993, and in 1998 Coast 2050: Toward a Sustainable Coastal Louisiana was published as the leading plan to restore and protect coastal resources. The Louisiana Coastal Area, LA—Ecosystem Restoration: Comprehensive Coastwide Ecosystem Restoration Study was published by USACE and the Louisiana Department of Natural Resources in 2004. These were beginning to guide efforts to restore the natural wetlands and swamps, but these efforts were still in early stages in 2005 when Katrina made landfall (Ocean Studies Board 2004).

There were also many older channels that were minimally used but still open that were being studied for permanent closing. For example, the Mississippi River Gulf Outlet, a little-used 40-year-old shipping channel connecting the Gulf of Mexico to the Mississippi River, is believed to have served as a funnel for Katrina's storm surge. The surge poured into Lake Pontchartrain and an industrial canal, where it overwhelmed levees, contributing to flooding in St. Bernard Parish and the Lower Ninth Ward of New Orleans. Like the many smaller oil and gas canals in the wetlands, the outlet also allowed saltwater intrusion and tidal action into freshwater ecosystems, killing vegetation, and turning the marsh into a stretch of open muddy water (Tibbetts 2006).

Local Evacuation and Multiple Shelters

Before Hurricane Katrina, the Mississippi's Emergency Management Agency (MEMA) urged coastal counties not to open local shelters to encourage people to evacuate north. MEMA described coastal county shelters as a "last resort." However, in spite of actively encouraging people to leave the city to take shelter, and not to stay in the city shelters, before Katrina made landfall in New Orleans, MEMA was reporting that Red Cross shelters were open in the coastal counties. The New Orleans city evacuation plan had residents leaving via car and head north, with all freeway lanes being one-way out of town, or to leave via city provided buses, but the bus evacuation was stalled. The original plan was for buses to drive people two hours north to shelter locations further inland, but the freeways were full of car traffic. Transportation infrastructure is neither planned nor designed to accommodate evacuation-level demand. The city of New Orleans Office of Emergency Preparedness made the call a day before Hurricane Katrina made landfall to redirect the buses to the Superdome in order to avoid the heavy traffic. The intention was to wait for Katrina to pass, and then immediately take people to the originally planned shelters. This led to rapid filling of the shelters, especially the Superdome (NPR 2005). There was no way to get those people out of the city after the storm, since every city bus was underwater and no longer usable. This led to around 100,000 people being trapped in the city in the days immediately after Katrina. FEMA had emergency response detachments, rapid needs assessment teams, and urban search and rescue teams stationed throughout the region to assist with evacuation and rescue. (House of Representatives Report 2006) However, these teams did not organize until after the storm, meaning that they were not helping with pre-storm evacuation, only post storm evacuation and rescue. FEMA did arrange for buses to be brought to New Orleans in order to facilitate the mass evacuation of the Superdome – but they failed to provide drivers with the security that they needed to safely drive into the city to collect people for evacuation.

Coordination of the Organizational Response

Local first responders were quickly overwhelmed by Hurricane Katrina, and the National Response Plan did not adequately provide a way for federal assets to quickly supplement or supplant first responders. The response plans at all levels of government lacked flexibility and adaptability, which often led to delayed responses by agencies across all levels. “Officials at all levels seemed to be waiting for the disaster that fit their plans, rather than planning and building scalable capacities to meet whatever Mother Nature threw at them.” (House of Representatives Report 2006). The response to the Katrina catastrophe revealed – all too often, and for far too long – confusion, delay, misdirection, inactivity, poor coordination, and lack of leadership at all levels of government.

One major issue was communication between the different agencies, and within each individual agency. Katrina inflicted widespread destruction on communications and electrical infrastructure. Cellular towers were down, land lines were submerged, and there was no power, making telephone and wireless communications largely impossible in the areas most heavily affected by the hurricane. Even radio communication was mostly down, with the emergency radio systems going down just a few hours after cellular signals went down. The Governor of Mississippi at the time, Haley Barbour, summed up the lack of communications: "My head of the National Guard might as well have been a Civil War general for the first two or three days because he could only find out what is going on by sending somebody. He did have helicopters instead of horses, so it was a little faster, but the same sort of thing". The National Communication System, managed by the Department of Homeland Security, was responsible for ensuring communication during an Incident of National Significance. Before Hurricane Katrina, they had never had to repair the land mobile radio (LMR) systems that are operated by local governments and used by first responders. There was no operational plan in place to systematically assess an incident's impact on the LMR systems and respond to local governments' communications needs for operability or interoperability during emergencies and there was no plan for how to get widely damaged systems back online.

Hurricane Ida

Hurricane Ida originated as a tropical wave[7] on August 23, and by August 26, had evolved into a tropical depression. Later that day, the storm officially grew into a tropical storm, and was given the name Ida. The next day, August 27, Ida was officially declared a hurricane

[7] An inverted trough (an elongated area of relatively low pressure) or cyclonic curvature maximum moving east to west across the tropics. These can lead to the formation of a tropical cyclone.

shortly before it hit western Cuba. On August 28th, as Ida reached the warm waters of the Gulf of Mexica, it rapidly strengthened to a category 4 hurricane[8]. On August 29th, 2021, the 16th year anniversary of Hurricane Katrina's landfall in Louisiana, Hurricane Ida made landfall. Ida would lose energy steadily, and on August 30th, would be downgraded to a tropical depression, and on September 1st, would be downgraded again to a post-tropical cyclone[9] as it tracked through the northeastern United States. Hurricane Ida would become the fifth-costliest tropical cyclone on record globally, and the fourth-costliest Atlantic hurricane in the United States. Due to the damages and deaths both in the United States and in other impacted countries, the World Meteorological Organization officially retired the name Ida from future use on April 27, 2022.

Flood-proof Architecture

In the aftermath of Hurricane Katrina, many people saw a need for changes in the construction practices in New Orleans. Local geographer Richard Campanella, who was studying the development of urbanism in the city observed; "Raised houses individualize flood protection. All structures, particularly residences, should be raised on pilings or piers. This tradition prevailed in New Orleans for over 200 years, only to be abandoned after World War II in favor of cheap concrete slabs poured at grade level. Living at grade places too

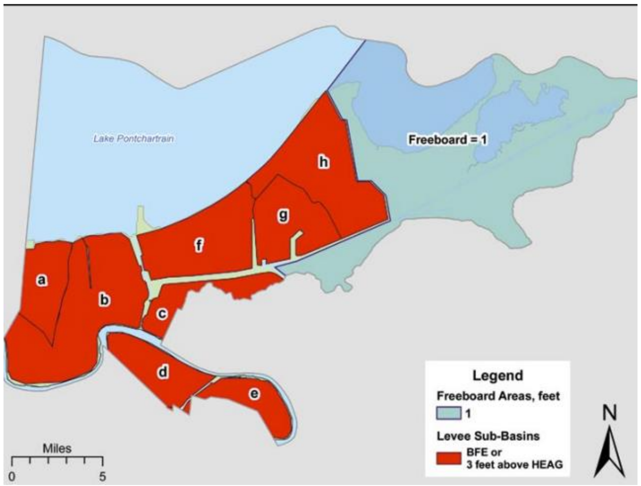

Figure 12: FEMA housing base elevation

[8] Category 4 hurricane: 130-156 mph winds

[9] A cyclone that no longer possesses sufficient tropical characteristics to be considered a tropical cyclone. Post-tropical cyclones can continue to carry heavy rains and high winds.

much faith in flood-control and drainage infrastructure. Building above the grade empowers the individual to play a role in minimizing personal flood damage should other systems fail". FEMA created an Advisory Base Flood Elevation that they recommended all homes be built above, which in New Orleans is 3 feet above the highest elevation point on site for areas protected by the levees, and 1 foot outside the levee protected areas. Following Hurricane Katrina, FEMA and the Louisiana Office of Community Development's Hazard Grant Mitigation Program created a mitigation grant program to assist homeowners in paying to elevate their houses. By the time Hurricane Ida made landfall, over $500 million had been spent in mitigation grant in New Orleans in order to make the buildings more resilient.

In addition to the buildings, there were several important systems that needed to have their structures updated. In particular, the power and water systems lacked the appropriate infrastructure to survive Hurricane Ida's windspeed. The eight power transmission lines into the city that are owned and managed by the private energy company Entergy, were all torn down by the high winds, leaving the city without power. This came after years of Entergy aggressively resisting any and all efforts by regulators, residents and advocates to improve its infrastructure, and repeated failures to modernize the grid after other major storms. High winds also uprooted trees, leading to burst water and sewer pipes, and a lack of power meant that water treatment facilities were running on the little power they could receive from generators until the power grid could be restored.

Protective Structures

In the aftermath of Hurricane Katrina, one of the clear immediate priorities was rebuilding the levee system. The old system had large sections that were damaged, with multiple breech points in most of the canals and levee walls. In order to create a plan for designing, funding, and building a new system to control flooding and protect the city, the Hurricane & Storm Damage Risk Reduction System was created by Congress. Consisting of the five parishes of Orleans, Jefferson, St. Bernard, St. Charles, and Plaquemines, this system was meant to replace the old system that had been designed and funded under the 1965 Flood Control Act. The design of the new system had a goal of being a 100-year level risk reduction system, meaning that it was designed to protect against 100-year storm events, or events that have a 1% chance of occurring or being exceeded every year. This is a lower level than the previous system, which was designed around the goal of a 200-year risk.

Figure 13: Map of levee system improvements (New York Times)

There have been several major projects that have been completed through the Hurricane & Storm Damage Risk Reduction System. Of the 78 pump stations located in the system boundaries, 33 received funding and contracts for repairs, all of which were completed as of 2018. The 17th Street, Orleans Avenue, and London Avenue canals which all saw damaged during Katrina have all received 100-year level interim structures at their outfall points, and all three locations have survived and been successful during Hurricanes Gustav (2008), Isaac (2012), and Ida (2021). The Inner Harbor Navigation Canal – Lake Borgne Surge Barrier began construction in May 2009 with a goal of reducing surge from Lake Borgne and the Gulf of

Mexico. Comprised of a barrier wall with three gates, the completed barrier stretches 1.8 miles, with a top elevation of 26 feet, and is the largest structure of its kind in the world, earning itself the nickname “The Great Wall of Louisiana”, and coming with the price tag of $1.2 billion. The Gulf Intracoastal Waterway-West Closure Complex, which prevents storm surge from entering the Harvey and Algiers Canals, eliminated the need for 25 miles of levees, floodwalls, floodgates, and pumping stations. Construction began in August 2009, and was completed in September 2011, with a total cost of nearly one billion dollars. It now stands as the world's largest drainage pump station, floodwalls, sluice gates, foreshore protection and an earthen levee. In total, the entire Hurricane & Storm Damage Risk Reduction System comes together to form the 133-mile Greater New Orleans perimeter system, and also contains approximately 70 miles worth of interior risk reduction systems like pumps and canal closures (Army Corp of Engineers 2018).

The total cost of this system was $14 billion dollars – and it is already seeing problems. With an annual maintenance cost of $33.8 million just to keep the system working, having to spend even more on the system is not the most popular thought. However, in 2019, just as many of the largest projects were finalizing, the Army Corp of Engineers was already warning that the earthen levees needed to be reinforced. The soft undersoil, consisting of peat, sand, and clay, that had caused issues in the old system was now being compacted under the weight of the new system, and was sinking. And with the new system being built to a lower standard, the risk of overtopping is higher. In 2021, when Ida

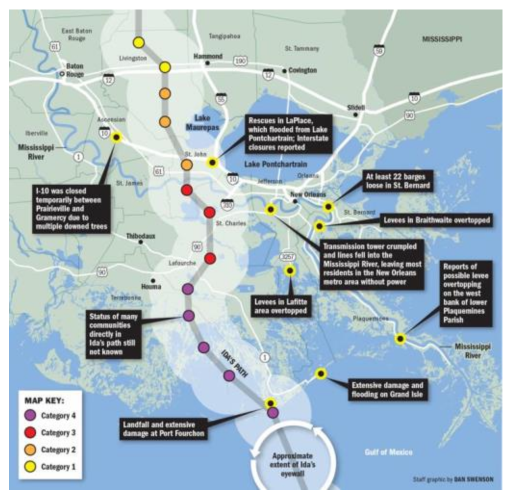

Figure 14: Map of Hurricane Ida damage

hit the city, both the regional director of the Southeast Louisiana Flood Protection Authority and the Governor of Louisiana stated to the press that the system would not breach – and they were right. The system suffered no breaches during the entirety of Hurricane Ida, but there were places that were overtopped in many surrounding communities. In many ways, Ida showed a fundamental truth about levees – no matter how sturdy a wall is, or high a wall is built, nature will always overtop it.

Land Use

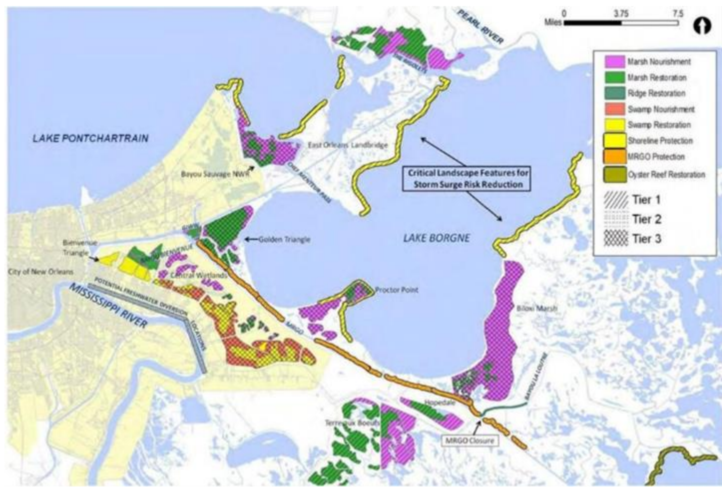

Figure 15: Wetlands restoration plan, Army Corp of Engineers

In the years following Hurricane Katrina, awareness about the importance of the natural wetlands buffer system in the New Orleans area grew. The two largest threats to the wetlands in Louisiana are human dredging or draining and saltwater intrusion. Human actions like draining and dredging wetlands and swamps for oil and gas exploration or expanding buildable land quickly ruins the habitats, and saltwater intrusion slowly damages the ecosystem and kills off the flora and fauna as the salt levels rise. One of the first actions taken after Katrina was deauthorizing a major channel known as the Mississippi River Gulf Outlet. During hurricane Katrina, the outlet acted as a “hurricane highway”, providing the storm a way to travel up inland without losing water. With the closing of the outlet, a dam was also built to stop saltwater intrusion in the area.

Protective measures for existing wetlands have also expanded heavily in the decade and a half after Katrina leading up to Ida. In November 2005, the state of Louisiana appointed an agency for the protection and restoration of the coastline, where for the first time the restoration of wetlands was included as a task. In the New Orleans masterplan for 2010, wetlands had a central role in the chapter covering green infrastructure and resilience. Before Hurricane Ida made landfall in 2021, the state had made strides to restore the wetlands, but Ida's damages included in destruction of 106 square miles of wetlands, primarily to the south of New Orleans. New Orleans now aims to promote the protection and restoration of wetlands through land use planning, regulation, acquisitions of land, co-ordination within both public and private domains, financial aid, and the establishment of new local regulations. In the chapter of their master plan dedicated to Land Use Planning published by the city of New Orleans in 2019, wetlands are mentioned 12 times, with a focus on protection, preservation, and restoration. In 2023, the Board of the Louisiana Coastal Protection and Restoration Authority (CPRA) unanimously approved the 2023 Coastal Master Plan. Since 2007, the plan has driven investment of over $21.4 billion in coastal protection and restoration projects, benefitting over 55,807 acres of habitat, 369 miles of levee improvements, and 71.6 miles of restored barrier islands and headlands across the coast to help reduce risk to coastal communities and the ecosystems that sustain them.

Local Evacuation and Multiple Shelters

Evacuations for Hurricane Ida were very different from the evacuation that took place during Hurricane Katrina. Advancements in storm tracking technology and in personal cell phones allowed residents of the city to live track the storm with meteorologists and make informed evacuation decisions. No official evacuation order was ever given to the city, but it is estimated that between 50% to 70% of the city chose to evacuate voluntarily. Orleans Parish plans to improve in two areas of evacuation and sheltering in place based on their Ida experience. First, the city aims to speed up assisted evacuations. The aim is to improve the ability to evacuate those who are more medically vulnerable and fragile, as well as those who are mobility impaired, such as wheelchair users, who require additional assistance in evacuating. Second, the city is shoring up its post-storm resources, working to have 15 generator-supported cooling centers - up from eight, including the Convention Center, ready to help residents quickly after a storm. These shelters are critical, as power can be down for weeks at a time after a hurricane, and most hurricanes hit New Orleans between July and October, which are among the hottest months of the year for the city. Evacuation was impaired during Ida by the SARS-CoV-2 pandemic, as many hospitals were unable to evacuate since there were no beds available for their patients in other cities. At the time of Hurricane Ida, the Delta variant of SARS-CoV-2 had a strong grip on the Deep South, limiting hospital capacity across the region. People evacuating also had to plan to bring additional supplies outside of the usual hurricane kits, such as masks, and had to try and social distance in shelter locations that were not designed for pandemic regulations.

Figure 16: Evacuation Locations, NOLA 2021

Coordination of the Organizational Response

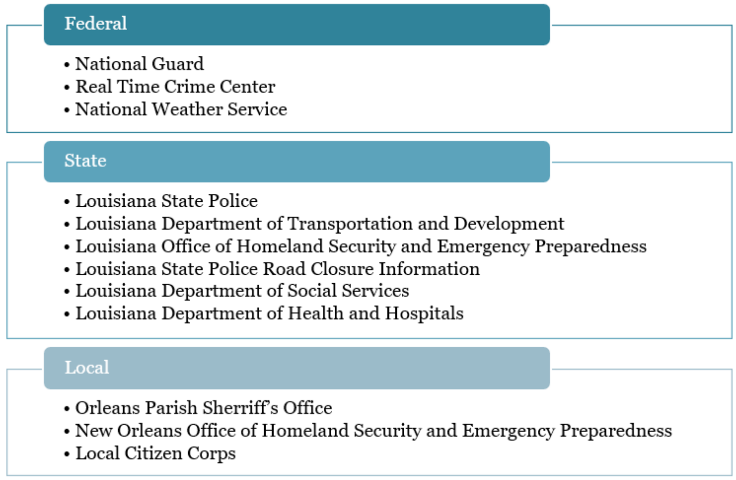

Figure 17: Agency Organization Chart

Unlike in 2005 when Hurricane Katrina made landfall, responding agencies already had plans for how to respond to Hurricane Ida. Many of the response plans that were created in the decade and a half following Katrina were collaborative documents between multiple response agencies. The Orleans Parish Sheriff's Office (OPSO), New Orleans Office of Homeland Security and Emergency Preparedness (NOHSEP), Real Time Crime Center (RTCC), Louisiana State Police (LSP), and National Guard came together to create a Hurricane Response plan that focused on ensuring the safety of those who did not evacuate during and after the storm. The American Red Cross, Louisiana Department of Transportation and Development, Louisiana Office of Homeland Security and Emergency Preparedness, Louisiana State Police Road Closure Information, National Weather Service, Louisiana Department of Social Services, Louisiana Department of Health and Hospitals, and the many Local Citizen Corps came together to create the official Emergency Evacuation and Shelter guide.

New York, New York

Hurricane Sandy

Hurricane Sandy originated from a tropical wave on October 22, 2012, and strengthened rapidly, becoming a named tropical storm just six hours later. On October 24th, Sandy was officially declared a hurricane before making landfall briefly in Jamacia. After making landfall, Sandy re-emerged and strengthened to a category 2 hurricane[10]. On the 25th, Sandy strengthened to a category 3 before making landfall in Cuba, which weakened it back to a category 1 hurricane[11]. On October 27th, Sandy did briefly weaken, as was classified as a tropical storm, before strengthening back to a category 1 hurricane. Two days later, after having made its way up the Atlantic, Hurricane Sandy made a "left hook", and made landfall for the first time in the United States near Brigantine, New Jersey. At the time of landfall, Sandy was officially considered to be a post-tropical cyclone, with hurricane force winds. Sandy's impact was heightened as it was a full moon, meaning that water levels in the area were already naturally heightened by the tides. Sandy would eventually be absorbed after moving further west and inland by another extratropical storm on November 2. On April 11, 2013, the World Meteorological Organization officially retired Sandy from its list of hurricane names, in large part due to the widespread loss of life caused outside of the United States, and the damages caused in all impacted countries, including Cuba, Haiti, Jamacia, Puerto Rico, the Dominican Republic and The Bahamas.

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[10] Category 2 hurricane: 96-110 mph winds

[11] Category 1 hurricane: 74-95 mph winds

Flood-proof Architecture

At the time that Hurricane Sandy made landfall, housing in New York City was widely unsuitable for a storm of that magnitude. More than 69,000 residential units were damaged as a result of Hurricane Sandy. Some neighborhoods were hit especially hard, such as Breezy Point, Queens, and Oakwood Beach, Staten Island, where hundreds of homes were destroyed by either flooding or fires. In addition, many thousands of New Yorkers were temporarily displaced from their homes due to power outages or other service interruptions, and more were left with costs they could not afford. In some neighborhoods, more houses had been completely torn down by the storm than left standing, and entire streets of houses were gone. In other neighborhoods with higher density housing units, basement areas were heavily flooded; 19,699 multi-family units, such as townhomes and apartments received grants for repairs after Hurricane Sandy. Many of the hardest hit high-density areas were lower-income areas, and after the storm, 234 public housing units required repairs. Much of this damage was because there was no codified requirement for the housing units to be built to any degree of hurricane preparedness. These houses and multi-family structures had no special design considerations for hurricanes and could have been built in any U.S. city without appearing out of place.

Protective Structures

New York harbor has naturally occurring barrier islands that serve as an organic sea wall to limit storm surges from the Atlantic Ocean into the harbor. However, these islands are inhabited, and they don’t have additional sea walls to protect them. Many of these islands have also been intentionally built out, which means that there are portions of the barrier islands with a lowered ability to block storm surges. The city of New York had, at the time of Hurricane Sandy, a series of bulkheads along its coasts in order to limit flooding, but these bulkheads were old, and had limited effectiveness against the large storm surges that occurred during Hurricane Sandy.

The subway system in 2012 had identified several stations that were at highest risk of flooding prior to Hurricane Sandy. In order to prepare, the Metropolitan Transportation Authority discontinued all services prior to the storm's arrival and made sure to barricade most subway stations that were in danger of flooding. Despite these efforts, many stations were flooded. Numerous subway lines remained closed for days while emergency repairs were made. In some cases, individual stations were down for months as the flood damage was so severe that the stations were rendered unusable.

Land Use

New York City is infamous for having built out its natural coastline to expand its waterfront and create additional square milage. In areas farther to the outskirts of the city, many of the neighborhoods were built out on drained coastal wetland areas. Coastal wetlands capture carbon 50 times faster than rainforests, by enclosing dead organic matter in mud before it can begin to rot. Wetlands play host to aquatic plants, endangered mammals, and about half of all North American bird species. More than 85 percent of global wetlands have been lost since 1700, according to the United Nations. The power of wetlands in the natural protective system is the ability to capture and absorb water. The complex network of roots that form wetlands allow them to act “like natural tubs or sponges” for floodwater.

Figure 18: New York city wetlands and shoreline

The combination of the expanded land into the harbor and the loss of the wetlands in the area has led to less absorption of water, and the rising sea levels have threatened the artificially constructed shorelines of the city. When Hurricane Sandy hit, there was no legislation or planning in place to protect the few remaining wetlands, and there was nothing in place regarding the expansion of the shoreline.

Local Evacuation and Multiple Shelters

When Hurricane Sandy hit in 2012, the city was divided into three levels of evacuation zones. Zone A homes had mandatory evacuations for Category 1 hurricanes, Zone B for Category 2 hurricanes, and Zone C for category 3 and 4 hurricanes. There was no mandatory evacuation zones prepared for Category 5 hurricanes. Hurricane Sandy prompted a mandatory evacuation for Zone A residents, which included five hospitals and eight nursing homes. The city had been preparing evacuation plans for years, and had run a test evacuation in 2010, and had a real evacuation in 2011 with Hurricane Irene. However, evacuation did not run smoothly for Hurricane Sandy. Many residents in New York city relied on the subway systems for their main mode of transit, and the Metropolitan Transportation Authority closed the subway system in preparation for the storm's arrival. This led to residents being stranded with limited ability to evacuate in a quick, efficient manner.

The city also had 73 evacuation centers and evacuation shelters in place prior to Hurricane Sandy making landfall. Centers were located at high schools, churches, parks, colleges, and even two racetracks. Some of these centers could be used as

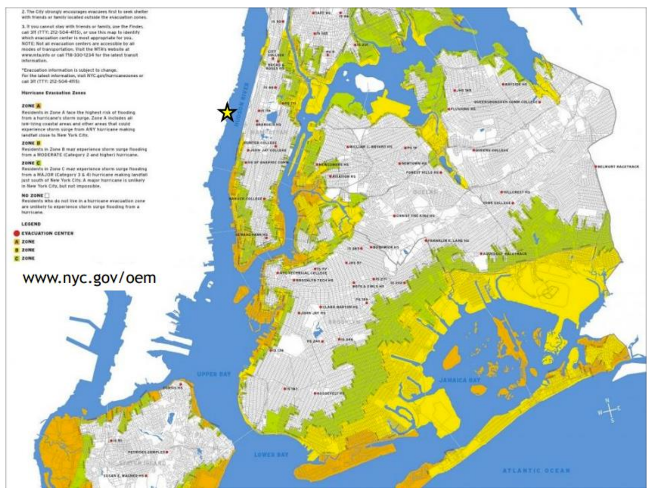

Figure 19: NYC evacuation zones and shelter locations 2012

shelter locations, but their primary purpose was to serve as a space to gather before evacuating further. New York City's shelter system housed approximately 6,800 evacuees in 73 shelters during Hurricane Sandy. One of the weaknesses of the evacuation and shelter plan was that it was designed based on old FEMA flood maps from the 1980s. FEMA maps had indicated flooding would occur on roughly 33 square miles, but by the end of the storm, 51 square miles of New York City had been inundated, with the 100-year floodplain being exceeded by over 50% citywide. Rising sea levels over the decades after the creation of the maps led to inaccurate mapping of evacuation zones, and put additional stress on centers, as they had more people evacuating than expected. The shelters were also only designed to serve as temporary locations and were not meant to house people for longer than three days, with no shower or laundry facilities in the shelters. When the expected three-day period was up, there were still many people unable to return to their homes due to flood damage and continued power outages across the city.

During the lead up to Hurricane Sandy making landfall, as well as during the storm and in its immediate aftermath, the city intensified its efforts in communication outreach. The Office of Emergency Management sent Notify NYC alerts via landline, mobile, text, email, and Twitter to more than 165,000 residents. The City sent more than 2,000 tweets and gained more than 175,000 social media followers during the storm, including a 71% increase in followers of the NYC Mayor's Office Twitter feed. During the storm, the City pushed out information through as many channels as possible. Major television networks, radio channels, third-party websites, NYC.gov, and the Mayor's Office and Mike Bloomberg YouTube channels carried live press conferences while City Twitter feeds reinforced the most critical messages. The mayor's press office issued frequent updates on the storm's progress and sent text press releases to their distribution lists that include more than 100 ethnic and community-based press outlets—ranging from Russian newspapers to Chinese television stations to Spanish-language radio. To reach the deaf and hard of hearing community, sign language interpreters signed all live press conferences and the City actively encouraged major networks to provide closed captioning during mayoral press conferences. All of this effort was to ensure that all residents, regardless of their age, language, or income, were able to stay up to date on the most important information about Hurricane Sandy.

Coordination of the Organizational Response

During Hurricane Sandy, many agencies were responding individually, with little coordination between them. The Red Cross stations did not coordinate with the Office of Emergency Management, and FEMA didn't coordinate with either of them. The national guard and coast guard were under different chains of command and were not coordinated with each other. Each group was very effective in their own area, but their overall effectiveness was limited by the fact that they were not working as part of a larger system to respond to the needs of the city. In the immediate aftermath of the storm, the city determined that there was a need to resolve inconsistencies in city databases and ensure that all city agencies had access to and operated from the same information. The Mayor's Office of Data Analytics, the Mayor's Office of Operations, and the Department of Information Technology and Telecommunications also found they needed to develop a training program for agency staff and other relevant personnel on the availability and use of city data sources.

Hurricane Ida

Shortly after landfall, Ida turned north northwestward, with its intensity steadily decreasing as it moved inland. Ida weakened to a tropical storm before moving into southwestern

Mississippi. The cyclone weakened to a tropical depression as it moved into northeastern Mississippi. The system then accelerated northeastward across northwestern Alabama, central and eastern Tennessee, and portions of Kentucky and Virginia before reaching southern West Virginia. Ida began an extratropical transition as it moved through the Tennessee Valley, and the system became an extratropical low as it moved over West Virginia later that day. Once it became extratropical, Ida moved through West Virginia, northern Virginia, and central Maryland to southeastern Pennsylvania where it acquired gale-force winds over the Atlantic east of the center. Ida continued east northeastward across northern New Jersey and into the Atlantic just south of Long Island, New York, to near Nantucket, Massachusetts on September 1st.

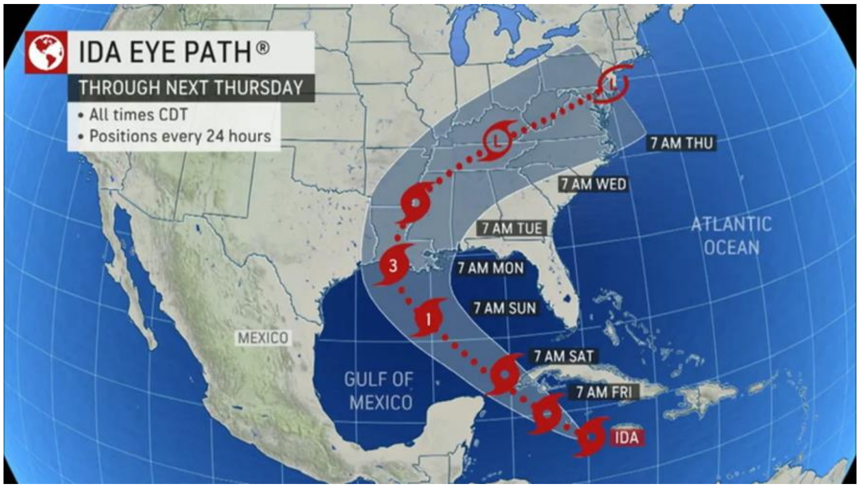

Figure 20: Tracking Hurricane Ida across U.S.

Flood-proof Architecture

After Hurricane Sandy, many people saw a need to build in a way that was more flood-proof. Although the city did not change their building codes to require any sort of additional protection or hurricane-proofing features, many private developers and design firms moved to create buildings that were adapted to survive hurricanes and major storms. Some apartment and condo buildings are now designed with elevated utilities, placing them up several stories to prevent them from flooding and ensure that the building will still have utilities after the storm. Other buildings, including hotels, have moved to designing their lobbies with flood-resilient materials like granite and concrete instead of wood and carpet, so that the space can be quickly dried out after flooding and be usable without major renovations. The New York City Housing Authority entered into emergency contracts with electrical contractors to install generators and/or build temporary switch boxes and restore connections to the grid, since lack of power was one of the greatest limitations in getting back into homes after Sandy. The housing authority also improved communication with the public regarding post-storm fire safety and reoccupation of dwellings and provided clear guidance on the proper steps to safely reoccupy a residence or business. Many people were able to get back into their homes after Ida on a much shorter timeline than they had been able to return to their homes after Sandy.

Protective Structures

After Hurricane Sandy caused catastrophic flooding across New York City, a large effort was put into place to ensure that the city was better protected against storm surge flooding. One of the largest efforts in creating a storm barrier has been focused on the creation of new green barriers, especially oyster reefs. New "oyster castles" serve as an organic, natural way to filter the water and protect the city against storm surges. A single oyster can filter 30 to 50 gallons of water a day. They are also a native storm protection that used to exist in large numbers in the harbor area. When Henry Hudson sailed into New York harbor in 1609, some 350 square miles of oyster reefs stretched in all directions. In early American history, the world came to think of New York as a great port where people ate local oysters. Their millions of discarded shells helped build the city, as they were used in the streets as an early paving system, and for a

Figure 21: Oyster castles creating an oyster reef

century, oysters were the city's most popular food. The enormous harvest was overfished and killed by sewage and pollution, while the shoreline turned into piers and landfill. By 1927, the last of the New York City oyster beds officially closed for business. Harbor oysters had become too contaminated to eat.

Oyster castles are interlocking blocks made from a blend of concrete and oyster shells. They serve as a surface for juvenile oysters, or spat, to grow on, which is crucial when there aren't enough naturally occurring shells to start to a reef. Oyster castles work well for shoreline restorations because they can be configured in multiple ways. Blocks can easily be added to extend the length of the shoreline and stacked to the perfect height to reduce wave energy and provide shoreline protection. These oyster reefs are currently installed by nonprofit programs, but they do incorporate elements of the city comprehensive plan, as they increase waterfront resiliency.

An extensive amount of work was also put into creating a new flood protection system for the subway. After Hurricane Sandy, it cost $5 billion to get the subway fully back online, and the city spent $20 million annually on water mitigation efforts. In order to limit the amount of flooding during future storms, the city looked to prevent water from getting in via stations and underground tunnels. One of those methods is called the Flex-Gate (Figure 23), a big sheet of waterproof fabric designed to cover subway entrances and keep the

Figure 23: Flex Gate at Franklin Street Station

Figure 22: Testing the resilient tunnel plug

water out. The first sketch for the Flex-Gate was created in 2013. It was partly inspired by the roll-up metal doors used over shop windows in New York City at night. Eight months after that first design was sketched, engineering firm ILC Dover was installing a prototype Flex-Gate on Canal Street in lower Manhattan. By 2015, they had built 23 more, and installation continued at a rapid pace after that. Another new technology being used in the subway system that was designed in response to Hurricane Sandy is called the resilient tunnel plug (Figure 22). The tunnel plug acts as a big balloon that inflates to plug up a tunnel and was seen as effective in preventing water from entering underground tunnels during Hurricane Ida.

There is also a new proposal in the works after Hurricane Ida – a $119 billion sea wall. The wall would be a 6-mile-long impermeable barrier, and it is highly controversial. The potential locations of the barrier are directly around the island of Manhattan, which would essentially act as a 20-foot-tall wall right at the edge of the island. This is not a popular option as it would only protect one borough and push the water into the other boroughs. The other option is to build the wall at the entrance of the harbor. This would prevent any loss of views and water access in the boroughs. However, building a giant wall and sea gate at the entrance of the harbor has the potential to trap large amounts of pollution in the harbor and kill off the delicate ecosystem that is just starting to come back after decades of heavy pollution.

Land Use

Figure 24: Areas of Buyout (Wall Street Journal)

After Hurricane Sandy, there were many places that were completely destroyed by the flooding. Oakwood Beach became the face of these neighborhoods after Sandy completely destroyed the neighborhood that was built over old wetlands. The Governor's Office of Storm Recovery worked with FEMA to generate a buyout plan for flooded neighborhoods, where the houses would be purchased at their pre-storm value. Those properties would then be returned to nature as part of a program to increase the natural buffer in flood-prone zones around New York City. Oakwood Beach became the first urban managed retreat in the United States, and as an enhanced buyout area being funded by a federal grant, all structures were removed and the land was to be used for environmental purposes, including wetlands restoration. The state of New Yok passed a law in 2015 reaffirming that buyout land should "be dedicated and maintained in perpetuity as open space for the conservation of natural floodplain functions."

However, a year after Hurricane Ida swept through and proved the value and effectiveness of these buyout areas as natural buffers, the wetlands were sold, and the promise of the land never being developed was broken. Construction began in October 2022, but the legality of building a clubhouse and stadium on the property is being litigated. If the construction does move forward, it will destroy the effectiveness of the buffer. The wetlands area had the potential to store upwards of 9 million gallons of floodwater during storms, and the sports complex has plans to put in foundations to prevent water absorption of that level in their fields to make them more playable. Many of the residents who sold their homes in the buyout program with the understanding that their property would be given to nature feel betrayed by the project, and many felt lied to.

Local Evacuation and Multiple Shelters

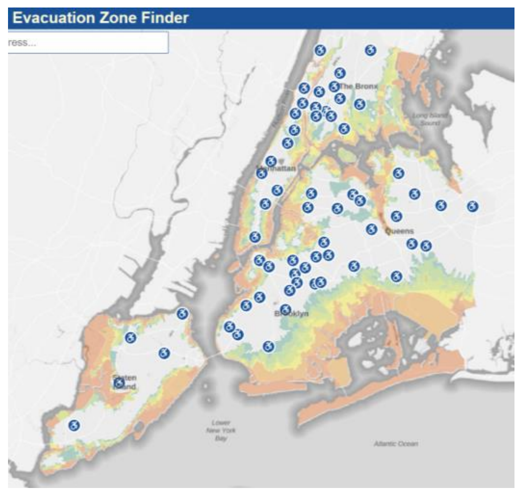

Figure 25: New evacuation zones and shelters NYC

After Hurricane Sandy, New York City restructured their evacuation zones as part of the new Coastal Storm Plan expanded from 3 zones to 6 zones in an effort to better categorize the vulnerability level of each area of the city. Part of the effort to redo the evacuation zones include a program called Know Your Zone, which worked to make it easy for any residents or visitors to look up the zone they were in by address quickly and easily. Know Your Zone also encouraged business to display stickers of their zone number in storefront windows to passerby's were aware of the area zone easily. Another initiative was the creation of evacuation guides that were published in 13 languages: English, Spanish, Chinese, Russian, Arabic, Bengali, French, Haitian Creole, Italian, Korean, Polish, Urdu, and Yiddish. The workbook was designed to guide users through establishing a support network, capturing important health information, evacuation planning, and gathering emergency supplies. It was also designed for first responders or caregivers to help people with disabilities have access to their functional needs during an emergency.

The shelter program also was revamped after Hurricane Sandy. The New York City Hurricane Evacuation Zone Finder interactive map that allows people to find the evacuation zone also is updated with any current evacuation orders for the city and shows all the possible locations people can go for shelter. These shelters now come with indicators listing if they are handicap accessible, so people who need those amenities know which shelters to avoid when possible. When an individual shelter location is selected, a list of all amenities available at that location pop up. These include entrance accessibility, restroom accessibility, accessible sleeping and eating areas, and special charging stations for medical devices.

Hurricane Ida evacuation was mostly successful. However, there were still deaths, mostly people who were dwelling in basement units and chose not to evacuate or were unable to evacuate. Many of those deaths were in neighborhoods that saw sudden flash flooding, as opposed to a slower, gradual rise in water levels. The speed of the water was unforeseen and was unfortunately faster than evacuation notices and emergency response crews. This led to pushes for legislation to ensure that water catch basins are maintained better to prevent this sort of rapid flooding. The law would mandate the city establish a flash flood emergency evacuation plan for multiple-dwelling tenants in flood zones to prevent deaths like those that resulted from Hurricane Ida.

Coordination of the Organizational Response

Two of the key areas that were reworked after Hurricane Sandy were the coordination of different groups of responders and the restoration of critical services by responders. All of this work was centered around the goal of better coordination of relief to affected areas and to vulnerable or homebound populations, including more efficient deployment of volunteers and donations to residents and business owners. The city made an effort to purchase additional public safety equipment, including additional light towers and inflatable boats in order to facilitate rescue operations. They also developed a comprehensive plan to expedite power restoration to multi-family public and private housing, and a plan to establish inter-agency teams in advance of a coastal storm or other emergency.

Before Ida, there was also a major effort to expand NYC Service's emergency preparedness plan and to pre-identifies partners with the capacity to manage volunteers in various roles on a large scale and across multiple affected areas. This included the creation of a volunteer transportation plan and improved communications outside of hurricane season about GoPass, the City's screening process for volunteers to allow them to work in sensitive environments and with vulnerable populations. New York also work to build relationships with major retailers to identify specific supplies needed in the wake of a disaster, while updating and expanding the city's unsolicited donations plan to manage the intake and distribution of material goods.

Recommendations and Conclusion

Recommendations

Based upon the two cities I investigated, I have found that comprehensive planning practices are very effective in creating more resilient and better prepared cities, which leads to better outcomes when storm-related flooding does occur. By joining agencies together, and created a series of plans that are interconnected, cities are more aware of their areas of vulnerability, and agencies are able to coordinate between each other in order to cover the weaknesses of any single plan or agency. One single plan or department is unable to fully plan for and prepare for the sheer scope of a storm. Joint planning and coordination ensure that every aspect can be planned for, and it ensures that no area is left without a plan, procedure, and response.

There are several strategies that constitute effective comprehensive planning and upgraded technology. Several strategic actions are recommended in the following section. Planning better building practices, to ensure that more structures are able to survive storms is critical to long-term storm protection. Adapting the comprehensive plan includes building requirements to ensure that buildings are required to meet certain standards to be more survivable during storms. Changes in building codes can mean higher initial construction costs for new buildings, but they will ensure that the building does not have as much damage to repair after a storm.

By growing in a deeper understanding of the natural buffers against storms, cities are able to become more prepared and resilient. Nature did everything right without human intervention in creating systems of buffers and water storage areas. Water will always win against human engineering, and as author Margaret Atwood wrote in her 2005 novella The Penelopiad "Water always goes where it wants to go, and nothing in the end can stand against it." Water will always take the path of least resilience, and will run down slopes to the lowest available elevation. By working with natural systems, cities are able to increase their resilience and become better prepared for storm events. In order to improve their outcomes from storms, cities need to work to revitalize failing natural buffers and install protections for vulnerable natural buffers. In order to do this efficiently, I recommend that cities adapt their comprehensive plan to include a focus on protecting natural areas.

Cities can also ensure better outcomes by working with multiple agencies before storms hit to create effective plans for evacuation and shelter. It also is clear that it is critical to adapt plans as technology changes, becomes available, and/or becomes affordable. The rapid changes in available technologies in the last 50 years means that plans that are even just 10 years old are no longer up to the standard for modern technology, as they fail to account for new changes in electric vehicles, advancements in engineering safety, and new AI modelling capabilities. By remaining up-to-date on technology, cities are able to ensure clear communication for citizens and responders.

Finally, it is very important that cities are open to working with community leaders and local community experts. People who live in a city tend to be very familiar with both their field of expertise and with the needs and weaknesses of their home. Community engagement strategies, especially open forums, allow stakeholders to have input in the planning process. Informed citizens are better prepared when disasters strike. By working with local experts, it is easier to identify areas for improvement. It is also important to work with local leaders, as they have the best understanding of the needs and attitudes of their communities. Local leaders will know what plans would be best received by the people they represent and can help to explain plans to their communities in a way that outsiders cannot, since they have a different connection to the community.

Conclusion

At the beginning of this report, I asked two questions of my research.

1. Can comprehensive planning ensure better outcomes for our coastal cities in the face of 21st century storm-related flooding?
2. What factors would constitute effective comprehensive planning?

Now, for the purpose of this report, comprehensive planning refers to the practice of bringing multiple agencies and entities together to create a plan or series of plans to respond to and prepare for storm events. This includes many documents including city master plans, evacuation plans, and coastal protection plans.

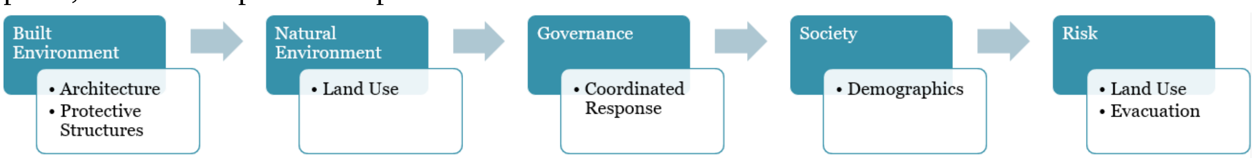

Figure 26: Figure 4, repeated. CRSI domains and Professor Colton's elements

For New Orleans, the most effective comprehensive planning involved working with a mix of natural and manmade strategies. The process of restoring the wetland as part of an increasing awareness of the importance of natural systems works in tandem with the manmade protective levees and floodwalls to block flooding. By using the built and natural environment in tandem, they strengthen the resilience of the city. Alone, each of the two strategies does offer some protection, but when they are combined, they create an integrated system that holds and blocks the water. In the same way, the combination of improved transportation and evacuation, and the coordination of the organizational response serve to improve each other. Alone, the process of updating the transportation plan for evacuation will improve the end result by getting more people out of the danger zone more efficiently and lowering the risk of living in the city but cannot be fully effective. Likewise, coordinating the organizational response is beneficial on its own, as it improves response time, but does not solve all problems. By combining the evacuation with coordinated response, not only will more people get out of the city in an effective manner, but they will also be aware of where the shelters further inland are, and those who cannot or choose not to leave are aware of shelter locations in the city. I believe that New Orleans strategy of adding multiple agencies to the planning process, and their growing focus on natural protective strategies make for more effective comprehensive planning.

Up in New York, the processes of unbuilding heavily flooded neighborhoods to return them to nature and the creation of natural buffers with oysters has been greatly increasing the water retention of the land while breaking the waves before they hit the shore. The natural environment has been used to great effect in New York, with a lower overall cost in comparison to built environment projects like sea walls. These projects combine with smaller manmade projects like flood protects for the subway to greatly reduce flooding to critical structures. However, the built projects for the subway only protect those systems, and do not help reduce flooding in housing.

Between the two cities, I believe that both have shown that the natural environment will be a growing area for cities to focus on when they look to improve their protections against future storms. As the sea continues to rise, manmade protections like levees and seawalls will protect cities, but they will be vulnerable to the water’s rise, as they are a set height. I also believe that building codes for housing need to be reconsidered and changed to make them less vulnerable to flooding. Both cities recognized the dangers of different housing after the first storm, but neither made any changes. In addition, I feel that bringing multiple interest groups together in creating the response plans allows for the most effective response when disaster does strike. Without this coordination, the response can be jumbled and slow. By coordinating the response, every agency is aware of exactly what their job is during a storm and is able to do it efficiently.

This report did have some limitations that I want to acknowledge. This study only looked at two cities, both of which were larger cities, and both of which are generally considered to be Democratic cities. In expanding this research, it would be beneficial to look at smaller coastal communities, as well as looking at cities and towns that lean Republican in order to understand better how size and political affiliations can impact a place's planning and response to hurricanes. This study also did not include any interview component, but if this research were to move forward, I feel that interviews would help to expand the information available. Finally, this study also did not involve any personal trips to the sites, and I feel that further research would benefit from site visits to better understand the areas.

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