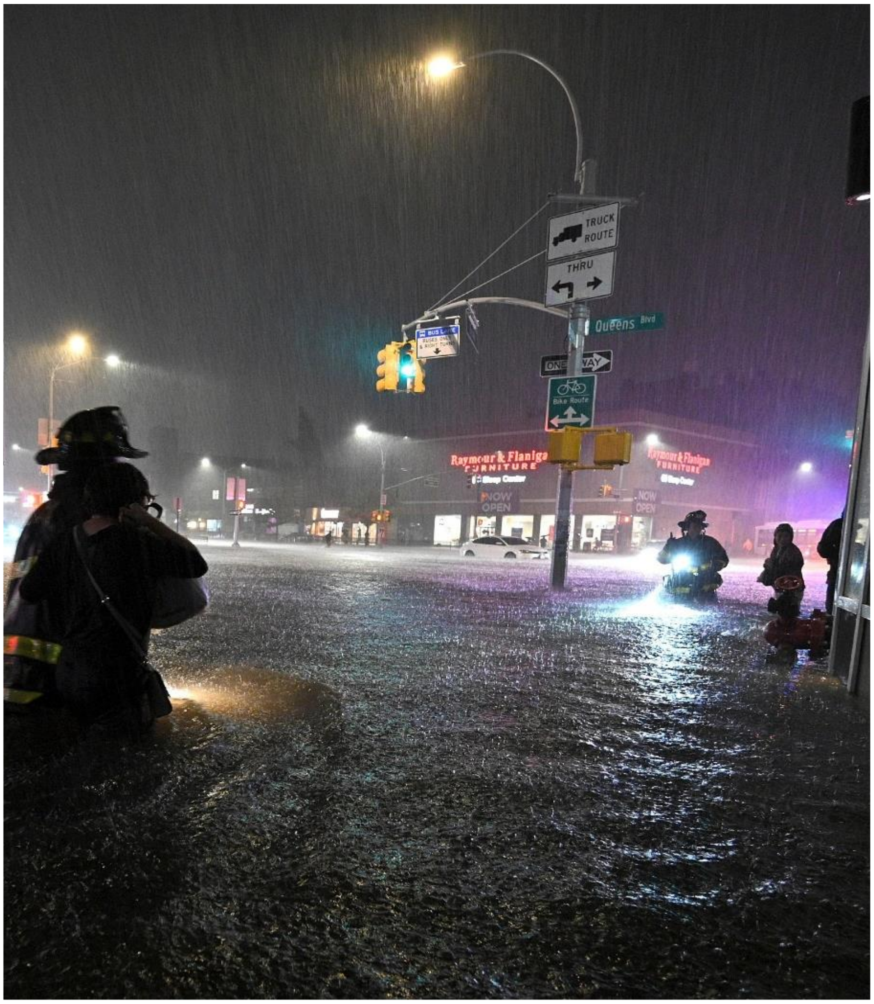




Mitigation Assessment Team Compendium Report

New York City: Effects of Hurricane Ida

Technical Reports and Fact Sheets

FEMA P-2333 / June 2023

FEMA

Unless stated otherwise, all photographs and figures in this report were taken by the MAT or developed for this report.

Cover photograph credit: Flooded street (Sipa USA via Associated Press); Flooded boiler room in the Bronx (Denise Ross); Other images (MAT)

Introduction

Remnants of Hurricane Ida moved through the New York City metropolitan area on September 1, 2021. They caused significant urban flooding and damage in many parts of the city. A presidential disaster was declared on September 13, 2021 (FEMA-4615-DR). As part of its response to the disaster, the Federal Emergency Management Agency (FEMA) Building Science Disaster Support program deployed a Mitigation Assessment Team (MAT) to New York City. The MAT assessed the damage. Its focus was on the urban flooding of below-grade spaces in residential buildings.

The primary objectives of the FEMA Building Science Disaster Support program are to improve both the resistance of buildings to natural hazards and the safety of building occupants. The program evaluates the key causes of building damage and failure and recommends solutions. The Team prepared three technical reports and four fact sheets, all of which are included here. These products focus on some construction and stormwater issues, which include the following:

- Surface runoff and urban flooding in urbanized areas
- Stormwater collection and drainage systems
- Effects of surface flooding on buildings
- Basement flooding in urbanized areas
- Early warning systems for urban flooding
- Egress (leaving) for occupants in at-risk basements
- Flood warning and flood risk mapping
- Steps owners and residents can take to reduce risks associated with urban flooding
- Ways to enhance policies and ordinances to reduce flood risks

Technical Report 1, Building Performance: Basement Buildings and Urban Flooding

This report describes the MAT's observations on buildings with basements. It recommends options for New York City and similar areas to prepare for future urban flooding events. The information is also useful for property owners, building managers, and design professionals. By applying mitigation measures to existing buildings and by designing safer new structures that resist hazards, cities can minimize the potential injuries and loss of life. This work will also reduce property damage in future natural hazard events.

Technical Report 2, Building Performance: Egress from Floodprone Basements

Technical Report 2 describes the MAT's observations on the egress of occupants from basements that are flooded when the capacity of a stormwater drainage system is exceeded. It summarizes some of New York City's requirements for building egress and emergency access. The report describes some ways to improve the safety of occupants in floodprone basements. It offers options to improve egress from floodprone basements.

Technical Report 3, Reducing the Effects of Urban Flooding in New York City

Technical Report 3 explains the basics of rainfall runoff, urban flooding, and urban stormwater drainage systems. It gives a summary of some of New York City's stormwater infrastructure programs and its work to address urban flooding. Applying mitigation measures to buildings and stormwater drainage systems can minimize the potential loss of life and injuries. It can also reduce property damage from future urban flooding events.

Fact Sheet 1, What Property Owners and Tenants Should Know About Urban Flooding

Fact Sheet 1 describes urban flooding and how it can create unsafe conditions and damage buildings. It also describes ways for property owners, tenants, and communities to minimize the damage from urban flooding. It explains how urban flooding differs from the flooding shown on the maps prepared by FEMA.

Fact Sheet 2, Flood Warning and Inundation Mapping

Fact Sheet 2 describes how flood warning systems, flood alerts, and flood inundation products convey flood risk information. It also explains how flood warning systems can improve flood awareness and public safety, and how they reduce the impacts of flooding.

Fact Sheet 3, Understanding Stormwater Runoff in Highly Urbanized Areas

Fact Sheet 3 describes how surface runoff relates to stormwater drainage systems. It also explains strategies and actions to reduce the impacts of urban flooding. The report highlights a number of these measures already underway in New York City.

Fact Sheet 4, What Property Owners and Tenants Should Know About Urban Flooding

Fact Sheet 4 summarizes all of the recommendations in the three technical reports. Local communities can use these by adopting new policies or adjusting existing policies. They can also amend or create new regulations.

Building Performance: Basement Buildings and Urban Flooding

Hurricane Ida NYC MAT Technical Report 1

June 2023

FEMA

Unless stated otherwise, all photographs and figures in this report were taken by the MAT or developed for this report.

Cover photograph credit: Flooded boiler room in the Bronx (Denise Ross)

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1. Introduction

Remnants of Hurricane Ida moved through the New York City metropolitan area on September 1, 2021, causing significant urban flooding and damage in many parts of the city. A presidential disaster was declared on September 13, 2021 (FEMA-4615-DR). As part of its response to the disaster, the Federal Emergency Management Agency (FEMA) Building Science Disaster Support program deployed a Mitigation Assessment Team (MAT) to assess damage. MATs are composed of federal and non-federal experts in building science and other relevant disciplines. These experts assess building performance after disasters, then incorporate lessons learned to make recommendations on improving the resilience of new construction and repairs and retrofits of existing buildings.

1.1. Report Objective

The primary objectives of the FEMA Building Science Disaster Support program are to improve the resistance of buildings to natural hazards and improve the safety of building occupants. Its work includes evaluating the key causes of building damage and failure, and recommending solutions. The remnants of Hurricane Ida produced widespread urban flooding, which led to flooding of numerous below-grade and basement areas. This report describes the MAT's observations related to buildings with basements. The observations were made during field investigations of selected sites in New York City. Figure 1 shows the locations visited by the Team.

This report provides information to help New York City and similar urban areas to prepare better for future urban flooding events. The information is also useful for property owners, building managers, and design professionals. By applying mitigation measures to existing buildings and by designing safer, hazard-resistant new structures, cities can minimize the potential loss of life and injuries, and reduce property damage from future natural hazard events. This report also offers a number of recommendations to improve the performance of buildings with floodprone basements and the safety of their occupants.

After deployment to New York City, the Team produced three technical reports and four fact sheets that relate to the effects of Hurricane Ida on the city. The documents focus on some construction and stormwater issues that were not considered in previous MAT investigations, including:

- Surface runoff and flooding in urbanized areas
- Stormwater collection and drainage systems
- Effects of surface flooding on buildings
- Basement flooding in urbanized areas
- Early warning systems for urban flooding
- Egress (leaving) for occupants of at-risk basements
- Flood warning and flood risk mapping

- Steps owners and residents can take to reduce risks associated with urban flooding
- Ways to enhance policies and regulations to reduce flood risk

Figure 1. Locations visited by FEMA MAT after Hurricane Ida

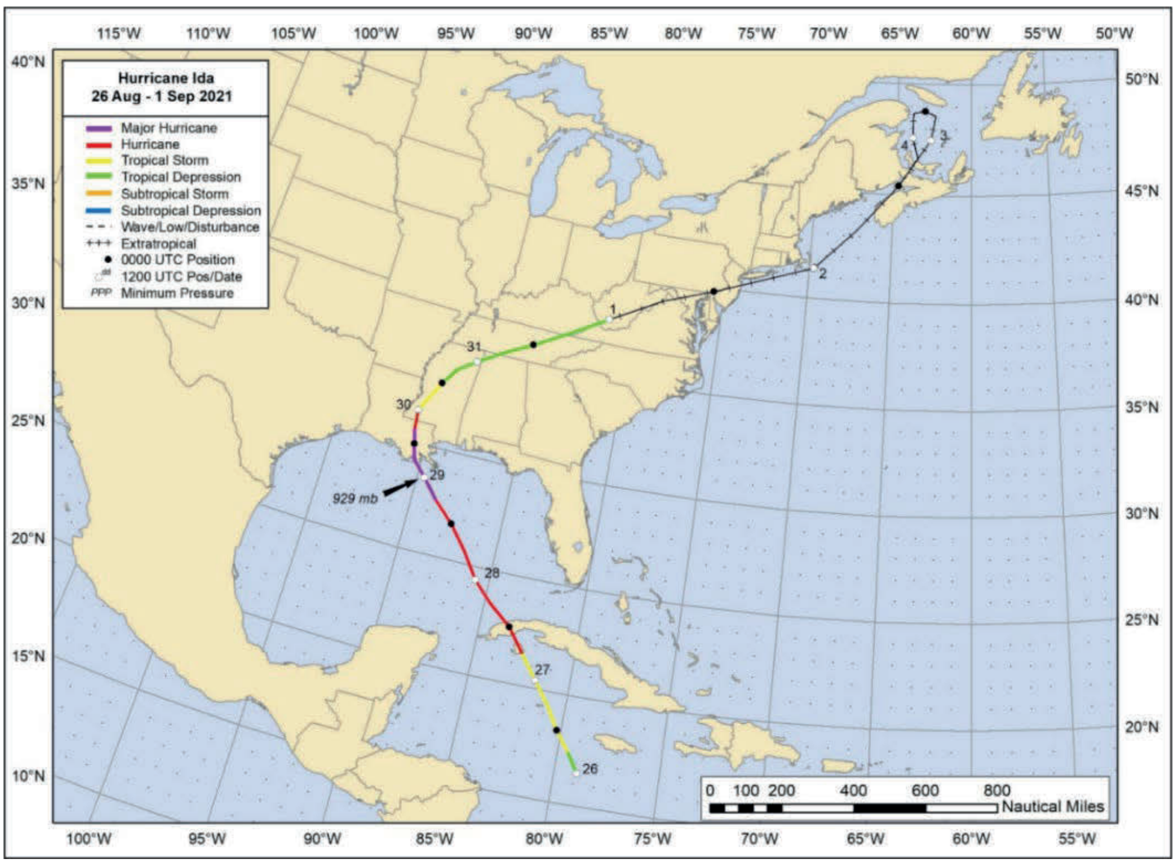
1.2. Hurricane Ida in New York City

On August 29, 2021, Hurricane Ida made landfall as a Category 4 hurricane in Lafourche Parish on the Louisiana coastline. This was only 50 miles west of where Hurricane Katrina made landfall on the same day in 2005. The storm generated high winds and storm surge, causing widespread damage to structures and to power and telecommunication infrastructure throughout the state. As Hurricane Ida moved inland beyond Louisiana (Figure 2), it produced heavy rain and unsettled weather in several states. The National Weather Service reported that extreme rainfall (Figure 3) caused flash flooding in New York and neighboring states.

New York City reported 13 fatalities attributed to the flooding caused by remnants of Hurricane Ida, while 26 fatalities were reported in New Jersey. Eleven of the fatalities in New York City were from drowning in the basements of single- and multi-family residential buildings.

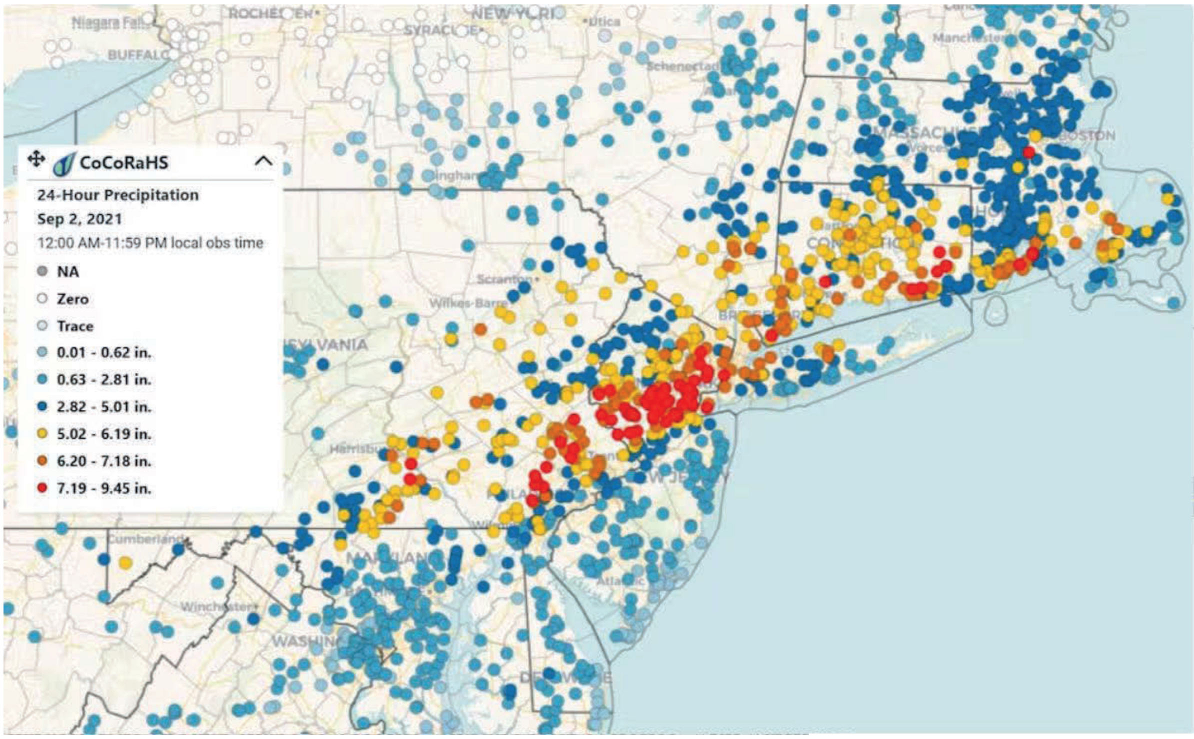
During the storm, the peak rainfall intensity in Central Park was 3.15 inches per hour, with a total of 7.13 inches of rain over a 24-hour period. At Newark, NJ, the peak precipitation rate was recorded at 3.24 inches per hour between 8 and 9 p.m. on September 1, 2021, with a total daily rainfall of 8.32 inches. It is important to note that the region was saturated because of heavy rainfall from the remnants of Tropical Storm Elsa in July, and Tropical Storm Fred and Hurricane Henri in August.

Heavy rainfall overwhelmed the stormwater drainage systems in many parts of New York City. Surface water accumulated, causing significant urban flooding in Queens, Brooklyn, the Bronx, and Staten Island. The city's storm drains (sewers) are designed to handle rainfall runoff resulting from approximately the 5-year intensity-duration-frequency precipitation event, where feasible. The 5-year event is 1.74 inches per hour for a 1-hour storm. The city considers several factors to determine feasibility of designing for that much runoff, including downstream constrictions. In areas where sewers were constructed before the 1970s, the system components may have been designed to carry the runoff from the 3-year event, which produces less runoff.



Source: National Hurricane Center

Figure 2. Storm track of Hurricane Ida from August 26 through September 4, 2021



Source: CoCoRaHS Mapping System

Figure 3. Total precipitation recorded over 24 hours, September 1-2, 2021, in New York and neighboring states

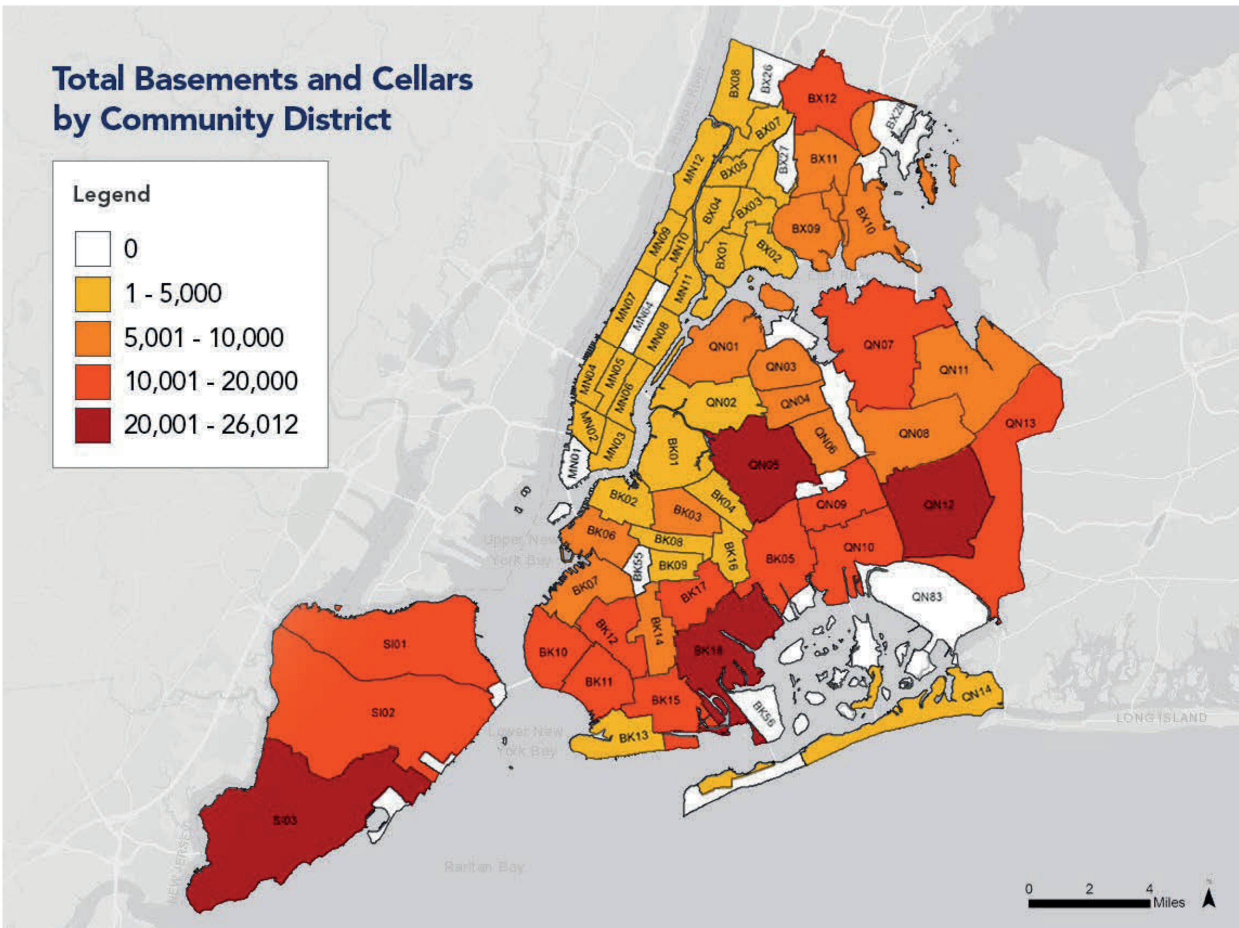
In some areas where the rainfall runoff exceeded the capacity of the stormwater drainage system, water flowed toward buildings, entering the basements, cellars, and below-grade spaces of numerous homes, multi-family buildings, and commercial buildings. The city generally does not allow dwelling units in basements, which are areas that are less than half a story below grade, unless specific requirements are satisfied. Cellars are subgrade areas with more than half a story below grade. The city does not allow cellars to be occupied. The basements of multi-family buildings are typically used to house equipment such as boilers and water heaters, and for storage.

Basements, Cellars, and Below-Grade Areas

This report uses “basement” and “below-grade area” to refer to any portion of a building that is below grade that is used for any purpose. The New York City Building Code defines “basement” and “cellar” in terms of how much of the “clear height (measured from finished floor to finished ceiling)” is below grade. A basement has less than 50% of the clear height below grade while a cellar has more than 50% of the clear height below grade.

In August 2022, the New York City Comptroller issued a report, “Bringing Basement Apartments into the Light.” The report estimated that one-, two- and three-family homes in the five boroughs have over 420,000 basements and cellars (Figure 4), although it does not estimate how many are occupied. The report states, “The Comptroller’s Office estimates that about 10%, or 43,000, basements and cellars … are currently facing some type of flooding risk. As storms intensify with climate change, the number of basements and cellars facing coastal and extreme rainfall flood risk is estimated to grow to 136,200, a third of all basements and cellars by the 2050s."

The heavy rainfall resulting as the remnants of Hurricane Ida passed over the city was one of many previous heavy rainfall events that flooded building basements. The city's 2009 Natural Hazard Mitigation Plan lists 60 urban flooding events between 1993 and 2007. Six of those events are reported to have flooded basements. Some events had citywide impacts, while others flooded basements in Queens (Brooklyn, Flushing, and Springfield Gardens). Notably, on January 3, 1999, people had to be rescued from basement apartments in Springfield Gardens when water rose nearly to ceiling height.



Source: NYC Comptroller's Office, 2022

Figure 4. Estimated number of basements and cellars in New York City by community district

1.3. Overview

SURFACE WATER SOURCES

Most sites the Team visited were buildings damaged by surface flooding associated with overwhelmed stormwater drainage system components. New York City staff reported that sewer drainage contributed to basement flooding in some buildings. The MAT field visits were performed 4 months after the event, and many sites had been cleaned before the visits. As a result, flooding from sewer backup was not apparent.

HOW SURFACE WATER ENTERED BUILDINGS

Rainfall runoff entered basements when surface water elevations reached the lowest point of entry at which water could flow into the buildings. In multi-story buildings, water typically entered through loading docks, exterior stairwells, and access ramps or through vent openings and street-level windows (Figure 5a and b). Secondary water entry points were seen where utility conduits penetrated foundation walls. The flow rate and volume from the secondary sources was judged to be significantly lower than those from surface water entry.

In some one- and two-family dwellings, water entered below-grade garages after street flooding reached the crests of driveways (Figure 5c). In others, it flowed down exterior basement access stairs as floodwater crested the stairway threshold (Figure 5d). Rectangular “slot” drains were observed at the base of driveways for many homes. Floor drains were seen at the base of the access stairs to many basement spaces, but most did not have sump pumps. These drains are intended to divert incoming water to the stormwater drainage system, with or without pumping. Team observations suggest that operating sump pumps could help limit accumulation of runoff from limited areas of driveways, access ramps, and exterior stairs. Most sump pumps installed in dwelling basements may have adequate capacity to remove some accumulated water. However, the typical sump pump is not designed for the volume of water that crested ramps and driveways and overtopped basement stairs, flowing into and filling many basements.

a. Ventilation openings near sidewalk level

b. Basement window sill near sidewalk level

c. Driveway sloping down to converted basement

d. Basement stairway threshold at sidewalk level

Figure 5. Examples of points of entry for surface flooding

STRUCTURAL PERFORMANCE

The Team observed a few failures of the walls of basements below one- and two-family dwellings. Some that did fail were constructed many years ago using methods and materials no longer allowed, such as unreinforced concrete or masonry that provide limited resistance to the lateral loads caused by exterior soil and water pressure. Others that failed used two styles of construction, including concrete masonry units or brick over concrete, which resulted in weak joints in the walls.

DRY FLOODPROOFING

Dry floodproofing refers to measures that make structures watertight, with all elements substantially impermeable and structural components with the capacity to resist flood loads. In addition, points where water may enter, such as joints and utility penetrations, must be watertight. Sump pumps must be installed in low areas to manage seepage. Guidance on planning considerations and designing dry floodproofing systems is in FEMA Technical Bulletin 3, Requirements for the Design and Certification of Dry Floodproofed Non-Residential and Mixed-Use Buildings, and P-936, Floodproofing Non-Residential Buildings.

The Team observed some commercial buildings with basements that are dry floodproofed and equipped with dry floodproofing panels. When installed in openings such as doorways and windows, these panels can substantially prevent water from entering the buildings. Manually installed dry floodproofing measures can require significant planning, organization, and manual labor, especially for large buildings. To be effective, installations must be started well before the anticipated onset of flooding. The large number of stored panels shown in Figure 6 suggests that if those responsible for installation wait too long when intense rain events could cause sudden surface flooding, they may not have time to prepare the building and safely evacuate basements.

Dry floodproofing of commercial buildings is permitted in FEMA-mapped floodplains. The same measures may be used to minimize flood damage for any building outside of FEMA-mapped floodplains. Many dry floodproofing systems include components that people must actively set up before the onset of flooding. The most common components that require human intervention are special panels and barriers that are designed to be installed in doorways and windows.

Figure 6. Dry floodproofing panels stored in basement of dry floodproofed building in NYC

1.4. Results of Basement Flooding

Many buildings in New York City have basements and other below-grade areas, including areas used for parking. In general, flooding that enters basements can damage equipment, interior flooring and walls, and contents. The types of equipment and contents vary depending on many factors, including whether the buildings are multi-story, commercial or residential, or one- and two-family dwellings.

When damaged by flooding:

- Electric service components and building service equipment in basements must be inspected and repaired or replaced (Figure 7).
- Water-damaged materials used for interior walls and floors must be replaced (Figure 8).
- Saturated contents typically cannot be recovered and must be disposed.
- Vehicles in below-grade garages may be damaged or total losses, depending on the depth of flooding.

Figure 7. Damage to equipment in flooded basements

Figure 8. Water-damaged interior surfaces and interior walls in basements

OCCUPIED BASEMENT UNITS

The adverse effects of basement flooding go beyond physical damage when below-grade areas are occupied, putting occupants at risk. Many occupied basement dwelling units in New York City satisfy the city's requirements for legal occupancy, including requirements for egress. However, other units have not yet satisfied those requirements.

During the rainfall caused by remnants of Hurricane Ida, basement flooding put occupants at extreme risk, since the water inflow was often through windows and down entry stairways (Figure 9). Sometimes those windows and stairways are the only ways that people can get out of basements. In addition, typical exterior doors to exit stairways open outward. When stairwells fill with runoff water, the hydrostatic pressure against doors can make it difficult, if not impossible, to open doors that swing outward. Compromised egress from occupied basement units can result in injuries and loss of life during flood events. The FEMA Hurricane Ida NYC MAT Technical Report 2, Egress from Floodprone Basements (FEMA P-XXXX), includes brief summaries of New York City's requirements and agency programs and responsibilities related to egress.

Source: Still image from video; Internet Clips, 2021

Source: Still image from video; Daily Mail, 2021

Figure 9. Surface water entering below-grade dwelling unit through window (left). NYPD officer searching flooded basement where three fatalities occurred (right).

RESIDENTIAL STRUCTURAL DAMAGE

Another consequence of the flooding of buildings with basements can be structural damage. The Team observed a single-family home in Queens with a collapsed basement wall that was constructed of unreinforced masonry blocks (Figure 10). Its collapse was likely the result of the low out-of-plane bending and shear capacity of the wall. This capacity was exceeded by lateral pressure of the soil, plus increased hydrostatic pressure on the exterior of the wall caused by the surface flooding. In addition to jeopardizing the structural integrity of the building supported by this wall, the collapse created a large opening. That opening may have allowed surface water to fill the basement rapidly.

One death in this basement was reported, although it is not known if it was due to trauma from the wall collapse or drowning.

That home and others like it in the neighborhood are approximately 100 years old. They were constructed before modern hazard-resistant building codes. Current building codes require new homes to have foundation drainage and basement walls reinforced to resist lateral earth pressure. The owners and occupants of these older buildings should be aware of the increased risk of basement wall collapse, which may allow a rapid flow of surface water into the basements. Those conditions can jeopardize the structural support for the house above and endanger occupants. Owners should also learn how to pump water out of basements to minimize damage to the basement walls.

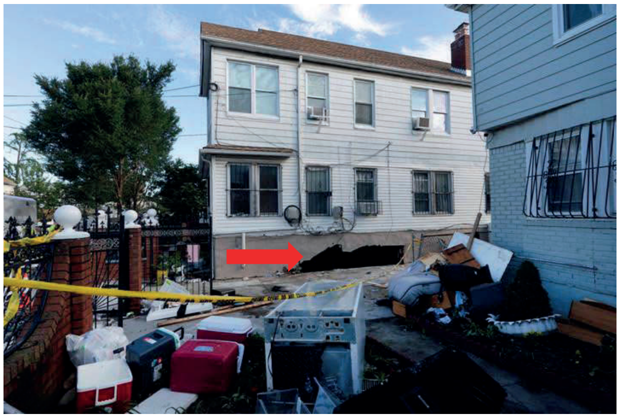
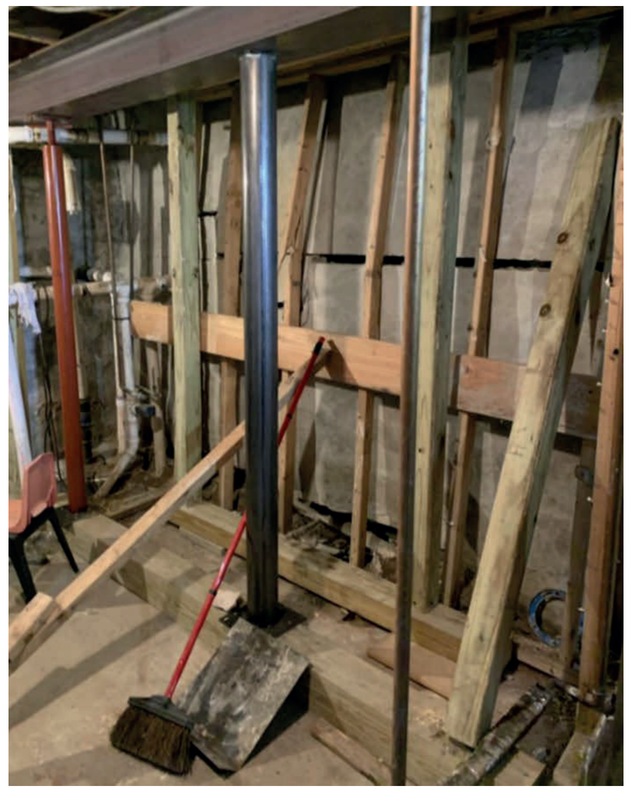


Figure 10. Failure of unreinforced masonry foundation wall at single-family home in Queens. Arrows point to a large opening in the foundation wall, as seen from the outside and inside of the building.



Source: Top left image by Mark Lennihan, Associated Press (AP)

2. Lessons from Prior Urban Flooding Events

This section summarizes MAT report findings and recommendations for three significant urban flooding events since 2003, including Hurricane Sandy, Hurricane Harvey, and the Midwest Floods of 2008. These events affected dry floodproofed buildings, buildings with basements, and underground utilities.

2.1. Hurricane Sandy in New Jersey and New York (FEMA P-942)

HOW THE FLOODING OCCURRED

Hurricane Sandy made landfall near Brigantine, NJ, on October 29, 2012. At that time, it was a 1,000-mile-wide post-tropical cyclone. For many locations visited by the MAT deployed by FEMA, the coastal flooding exceeded the Special Flood Hazard Area (SFHA) shown on maps prepared by FEMA. The SFHA depicts the 1-percent-annual-chance flood event. Flooding caused widespread damage to commercial and residential structures, critical facilities, and infrastructure. Most damage to low-rise buildings resulted from inundation.

PERFORMANCE OF FLOODED BASEMENTS AND BELOW-GRADE GARAGES

At many locations observed by the MAT, the water depths exceeded the curb and sidewalk elevations. Water flowed in through various openings, filling below-grade garages and basements. Structurally, the basements and below-grade areas of the low-rise buildings performed well. Most of the observed damage was to interior finishes and contents.

PERFORMANCE OF COMMERCIAL BUILDINGS WITH BASEMENTS

The MAT visited a number of commercial buildings with basements. Some were designed and constructed with dry floodproofing measures.

Manhattan Commercial High-Rise (1). This 24-story building in Lower Manhattan was built in 1971. The structure has a steel frame with masonry infill walls. The building's chief engineer stated that water entered through the lobby doors and the loading dock, and the first floor was inundated with more than 4 feet of water. Water spread throughout the first floor and inundated the basement, entering primarily through the elevator shaft. In the basement, the steam distribution system, water booster pumps, and other equipment in the mechanical room were damaged. This led to the building's loss of functionality.

Manhattan Commercial High-Rise (2). This 11-story commercial and office building was built in 1914. The water depth in the area was approximately 1 to 2 feet above street level. More than 40,000 gallons of fuel were stored in four tanks in the basement. The tanks serve more than 10 generators throughout the facility for various tenants. The fuel tanks and pumps that distribute fuel to the generators are inside a floodproofed enclosure. The basement also has six pumps (minimum capacity of 100 gallons per minute) to drain the basement in case of flooding. The building's chief engineer said that water initially entered the basement through a telecommunications utility point of entry. The six pumps successfully controlled flood levels throughout the basement, keeping the water level below 3 inches. Generators throughout the building remained operational during the storm and after, until the utility provider restored power service.

HURRICANE SANDY: SELECTED RECOMMENDATIONS RELATED TO DRY FLOODPROOFING AND BASEMENT FLOODING

- **Dry floodproofed buildings.** Consider amending regulations to require owners of buildings that rely on human intervention to implement dry floodproofing measures to submit periodic inspection reports to document installation and maintenance, emergency plans, and periodic installation practices. Recommendation 16.
- **Subgrade connections***.* In buildings that share subgrade connections (e.g., access tunnels, basements, underground parking), flood protection measures were recommended to keep the flooding of one building from spreading to connected areas or to other buildings. Recommendation 29b.
- **Below-grade spaces***.* Below-grade garages or basements are common in older construction in New Jersey and New York, including single family homes. Property owners should consider filling below-grade garages or basements of buildings in the SFHA. Recommendation 25c.

2.2. Hurricane Harvey in Texas (FEMA P-2022)

HOW THE FLOODING OCCURRED

Hurricane Harvey made landfall over San Jose Island, just north of Port Aransas, TX, on August 25, 2017. At landfall, the storm was a Category 4 hurricane with estimated sustained winds of 130 miles per hour. Hurricane Harvey caused widespread damage to buildings, power distribution systems, and water utility services. Historically heavy rainfall caused extensive sheet flow and riverine flooding in southeastern Texas. Houses built before communities adopted floodplain management regulations and Flood Insurance Rate Maps (FIRMs) were hit the hardest.

The damage caused by Hurricane Harvey flooding was extensive and significant. Flooding affected residential and non-residential buildings in the FEMA mapped SFHA, the 0.2-percent-annual-chance probability (500-year event) floodplain, and areas outside those floodplains. In Harris County and its municipalities, including the city of Houston, 22 percent of buildings experienced flood damage. Most of the damaged residences were slab-on-grade buildings, either built before the communities adopted floodplain management regulations or located outside the 0.2-percent-annual-chance floodplain. Some houses built in the 1980s and elevated to a lower base flood elevation than current floodplain regulations require were damaged. Recently constructed houses suffered minor damage (mainly insulation and drywall), mostly due to the use of materials that did not resist flood damage.

PERFORMANCE OF DRY FLOODPROOFING MEASURES FOR COMMERCIAL BUILDINGS

In Harris County, the MAT assessed the performance of dry floodproofing measures in non-residential buildings. The MAT visited non-residential buildings that were retrofit with dry floodproofing with FEMA funding after Tropical Storm Allison in 2001, and some that were dry floodproofed with private funding.

The failures that occurred at dry floodproofed buildings resulted from overtopped flood walls or barriers, structural failure of flood barriers, seepage through flood barriers and gaskets, and seepage through utility penetrations. For some buildings, insufficient planning and maintenance contributed to failures. As a result of the failures, critical building systems in basements and first floors were damaged and became inoperable.

The performance of dry floodproofing measures was highly variable, ranging from effective to complete failure. Where the dry floodproofing failed, critical building systems in basements and first floors were damaged and made inoperable. The MAT also observed numerous "near misses." In these cases, the dry floodproofing measures or human intervention prevented widespread flood damage. If flood levels had been only slightly higher, or if building managers had not acted before the flooding began, many of these successes would have been failures.

HURRICANE HARVEY: SELECTED RECOMMENDATIONS RELATED TO DRY FLOODPROOFING AND BASEMENT FLOODING

- **Dry floodproofing emergency plans, evaluation after flooding, and maintenance.** Owners and managers of dry floodproofed buildings should develop emergency operations plans. The plans should have implementation checklists based on timelines keyed to official severe weather warnings and watches. Owners or managers should also conduct periodic training exercises, timing how long each step or measure takes to deploy, and revise emergency plans if they identify deficiencies. In addition, owners and managers must maintain the dry floodproofing systems and inspect components annually. To ensure system functionality, periodic maintenance should include checking gaskets and seals, installation hardware and fasteners, and the condition of building elements to which dry floodproofing components will be attached. Recommendations TX-8a, TX-8b, and TX-8c.
- **Sump pumps.** Owners of dry floodproofed buildings should install sump pumps with floor drains system to collect seepage that may occur in floodproofed areas. Emergency power should be provided to run the pumps. Recommendation TX-6b.
- **Flood damage-resistant materials**. Flood damage-resistant materials should be used inside dry floodproofed buildings. Using flood damage-resistant materials is considered a best practice and helps minimize the damage and time needed to remove and replace interior finishes, especially if moisture accumulates in dry floodproofed areas or if flooding exceeds the design level of the dry floodproofing system. Recommendation TX-7.
- **Check valves and backflow preventers.** The Hurricane Harvey in Texas Recovery Advisory 1 recommends the installation of check valves in floor drains, and ejector systems with check valves or backflow preventers for combined stormwater and sanitary sewers. These devices are designed to allow wastewater to flow to the sewer system, while preventing wastewater from backing up into buildings when the sewer lines do not have the capacity to carry the flows downstream. Recommendation TX-6.

2.3. Midwest Floods of 2008 in Iowa and Wisconsin (FEMA P-765)

HOW THE FLOODING OCCURRED

In June 2008, several storm systems sequentially affected the midwestern United States. Much of the region received over 12 inches of rainfall. The Midwest also experienced wet conditions for several months prior to June. Therefore, the June rains fell onto saturated soils, which means most runoff flowed directly to streams. Resulting stream and river water levels reached historic highs across the region, particularly in areas of Iowa and southern Wisconsin.

In Iowa, numerous communities experienced flood crests that exceed historic levels. Some areas were flooded well outside of the SFHA shown on maps prepared by FEMA. Billions of dollars in damage occurred as homes, businesses, and critical facilities were inundated. The flood crested in Cedar Rapids more than 12 feet higher than the previous record. Flooding inundated more than 9 square miles. In Iowa City, surface water affected residential neighborhoods and the University of Iowa campus.

In Wisconsin, the Rock, Kickapoo, and Baraboo Rivers flooded above the record flood stage at multiple locations, causing extensive damage. As homes and roads flooded, residents were forced to evacuate. Sanitary sewer systems experienced high inflow and infiltration. Sewer backups were reported in many critical facilities. Several flooded manufacturing facilities were forced to lay off workers.

PERFORMANCE OF RESIDENTIAL BASEMENTS

The MAT observed failures of unreinforced basement walls in older homes. Most of the homes in FEMA-mapped floodplains were constructed before their communities adopted floodplain management regulations. Local floodplain management regulations adopted to satisfy the minimum requirements of the National Flood Insurance Program do not permit basements in residential buildings in mapped floodplains.

MIDWEST FLOODS: SELECTED RECOMMENDATIONS RELATED TO BASEMENT FLOODING

- **Repair damaged basement walls.** Unreinforced basement walls should be reinforced during repair, if the local floodplain management regulations do not require damaged homes with basements in the mapped floodplain to be brought into compliance. When damage is determined to be substantial damage (as defined in local floodplain management regulations), buildings must be brought into compliance. For residential buildings, compliance requires filling in basements and other below-grade areas. Recommendations #1 and #2.
- **Filling basements.** Property owners in SFHAs should consider filling basements with sand or reinforcing foundation walls, even if local floodplain management regulations do not require these mitigation measures. Communities should alert homeowners to the hazard involved in pumping water out of their basements too quickly. Owners of houses outside the SFHA should consider filling any basements with the potential for flooding. Recommendations #1 and #3.

3. Causes of Basement Flooding in New York City

3.1. Undersized Stormwater Drainage Systems

In 1970, New York City changed the design standard for drainage systems, increasing the volume of runoff that systems should handle from the 3-year storm event to the 5-year storm event. The 5-year storm has a peak intensity of 1.75 inches per hour. As remnants of Hurricane Ida moved through the region, the peak rainfall intensity measured in Central Park was 3.15 inches per hour.

The rainfall runoff during the storm overwhelmed the stormwater drainage system in many parts of the city. This resulted in the accumulation of surface water on roadways and sidewalks, particularly in lower lying areas (Figure 11). In some areas, the runoff overtopped curbs and entered many building basements and below-grade areas.

Source: Sipa USA via AP

Figure 11. Street flooding caused by the remnants of Hurricane Ida

3.2. Sewer Backup Flooding

Combined sewer systems carry both wastewater and stormwater to wastewater treatment plants. Combined sewers make up approximately 60 percent of New York City's stormwater drainage system. When the combined flows exceed the capacity of the system, a mix of stormwater and untreated sewage is discharged, or the mixture may back up into basements and below-grade areas of buildings if those areas have plumbing fixtures or floor drains connected to the sewer pipes.

The FEMA Mitigation Assessment Team did not observe basement flooding caused by sewer backup, but city staff reported that sewer drainage contributed to the flooding of some basements. MATs for other disasters in urban areas observed basement flooding associated with surcharged combined stormwater and sanitary sewer systems. This risk can be mitigated at individual buildings by installing backflow prevention valves in the sanitary sewer laterals that carry wastewater to the main sewer pipes. The city plumbing code specifies when backwater valves must be installed in any building. In particular, when compliance with the building code is required for buildings in flood hazard areas, automatic backwater valves are required to prevent release of sewage into floodwater and infiltration of floodwater into plumbing systems.

4. Public Awareness of Urban Flooding

WEATHER ALERTS AND EVACUATION ORDERS

New York City coordinates with the National Weather Service (NWS) to monitor severe weather events, including events that might produce heavy rainfall that results in urban flooding. The FEMA Hurricane Ida NYC MAT Fact Sheet 2, Flood Warning and Inundation Mapping (FEMA P-XXXX), describes the NWS Weather Radio and other federal initiatives related to severe weather.

The city develops robust ways to contact residents to inform and alert them about flood risks, including:

- **NotifyNYC.** Part of New York City Emergency Management, NotifyNYC provides New Yorkers alerts and messages about a range of occurrences, including emergency alerts and weather emergencies. The alerts are available in several languages. Learn more and sign up online to receive alerts at https://a858-nycnotify.nyc.gov/.
- **Rainfall Ready NYC.** The Department of Environmental Protection produced the Rainfall Ready NYC Action Plan, online at https://www.nyc.gov/site/dep/whats-new/rainfall-ready-nyc.page. The website has information to help people plan and prepare for storms, monitor conditions during storms, and recover rapidly after damaging events. A link allows people to sign up to receive alerts from the city's official source of information about emergencies, including weather emergencies.
- **FloodHelpNY.** A project of the Center for New York City Neighborhoods, Inc., which is supported by the city, FloodHelpNY is a primary resource for New York residents and businesses to learn about flood risks, flood retrofits, stormwater flooding, climate change, and flood insurance. The Community Flood Action Toolkit is designed to help building owners make informed decisions to reduce flood risk and lower the cost of flood insurance. Access the site at https://www.floodhelpny.org.

WATER SENSORS

As part of the FloodNet cooperative initiative, New York City plans to install 500 water sensors, primarily in public places susceptible to flooding. The intent of the sensor system is to inform city officials and others, who can then issue public warnings of the potential for damaging surface flooding. Access FloodNet online at https://www.floodnet.nyc to view real-time and historical flood data.

Another type of water sensor is commercially available. They can be installed in the basements of individual buildings. These sensors are typically located in the sump or lowest part of a basement and alert building managers and occupants when water is sensed. Some sensors are designed to register when the water level exceeds a threshold that indicates either that the sump pump is not functioning correctly, or the water level is rising too quickly for the sump pump to manage. In addition, some sensors are capable of automatically disconnecting sensitive equipment located in basements, to minimize safety risks and water damage. Sensors that sound alarms give basement occupants and owners early warning that water is rising in the sump. Like fire alarm systems, these sensors and alarms should have battery backup power to keep them functioning during power failures.

5. Recommendations

The FEMA Hurricane Ida NYC MAT Technical Report 3, Reducing the Effects of Urban Flooding in New York City (FEMA P-XXXX), provides an overview of many programs and initiatives to improve the city's stormwater drainage system. However, the city acknowledges that urban flooding problems are too big to resolve only through construction and green infrastructure measures that increase infiltration of rainfall. When heavy rainfall runoff overwhelms the drainage system in some parts of the city, occupants in floodprone basements will continue to face risks and buildings with basements will continue to experience flood damage.

The recommendations in this section are based on the MAT observations at selected sites visited after Hurricane Ida impacted New York City. They are intended to assist the city, building owners, residents, and others to enhance safety for building occupants and to reduce future basement damage and impacts from urban flooding.

Some recommendations suggest the city encourage or require building owners to take action. Requirements for actions could be triggered when owners apply for permits to do certain types of improvements, alterations, additions, or replacement of mechanical equipment. Encouragement may take many forms, from providing information to developing means of financial support, such as a grant program or other incentives.

5.1. Safety of Occupants in Basements

The FEMA Hurricane Ida NYC MAT Technical Report 2, Egress from Floodprone Basements, recommends that New York City continue its multi-faceted approach to improve awareness of flood risks and to warn building owners and residents. That report also recommends the city develop guidance and require or encourage building owners to examine their buildings with floodprone basements to determine appropriate ways to improve egress during emergencies. Building occupants, especially those who live in basements, must not assume that measures to keep water out of buildings means the buildings are safe when flooding occurs.

The recommendations in this section describe additional actions that the city and building owners can take to improve basement occupant safety.

RECOMMENDATION 1. WATER SENSORS IN BASEMENTS

The city could require or encourage owners of buildings with floodprone basements to install water sensors that are integrated with sump pump systems to warn occupants and emergency responders when water levels exceed the capacity of the pump. The sensors should have backup battery power. Like fire equipment, the systems should be tested annually.

RECOMMENDATION 2. RISKS OF UNREINFORCED BASEMENT WALLS

The city should consider whether it is feasible to identify one- and two-family homes with basements and cellars that were constructed before building codes required reinforced foundation walls and foundation drainage. Those older foundation walls may be susceptible to failing under hydrostatic and lateral earth pressures when soils become saturated. Then, if those homes are located in areas where urban flooding is a known risk, the city could inform owners and occupants of the risk of basement flooding and foundation wall collapse. Owners can be encouraged to seek advice from qualified professionals and contractors to learn more about whether their basement walls are at risk and options to minimize future damage.

RECOMMENDATION 3. SAFELY PUMPING FLOODWATER FROM BASEMENTS

The city should develop guidance and messaging to let building owners know how to safely pump floodwater from basements without risking structural damage. Building owners whose basements flood typically want to remove the water quickly so they can begin to clean up and identify needed repairs. However, rapidly pumping water out of basements can contribute to structural damage, especially if the soils surrounding the basement are saturated. FEMA and others advise draining or pumping flood basements slowly to equalize water pressure on both sides of basement walls. The recommended practice is to lower the water surface about 1 foot and wait 24 hours, then pump out another foot of water, repeating until the water is removed.

5.2. Improve Performance of Buildings with Floodprone Basements

The recommendations in this section describe actions that the city and building owners can take to reduce urban flooding of buildings with basements. Given past urban flood events and the city's awareness of areas where rainfall runoff from intense storms accumulates, the city may be able to identify owners of buildings with basements that are at risk of flooding.

RECOMMENDATION 4. ENCOURAGE BUILDING OWNERS TO ACT

New York City should evaluate options to encourage building owners to act to improve the performance of buildings with basements and below-grade areas that are known to be prone to urban flooding. Some options to consider include:

- Develop messaging and mechanisms to contact the owners and managers of buildings in areas where urban flooding has caused damage, with a focus on buildings with basements and below-grade areas. The messages should encourage them to first evaluate their buildings, and then decide whether to engage qualified professionals for more detailed inspections and assessments. The city can use the checklist in the FEMA Hurricane Ida NYC MAT Fact Sheet 1, What Building Owners and Tenants Should Know About Urban Flooding (FEMA P-XXX), as a starting point for a more detailed checklist for owners and managers.

- Develop training and inspection materials for building managers and design professionals to build on evaluations that may be undertaken by owners and managers. The materials should explain how to determine whether and how surface flooding enters buildings, and how to identify feasible mitigation options. Recommendation 6 refers to FEMA publications on dry floodproofing that are developed for use in FEMA-mapped Special Flood Hazard Areas. However, those publications also are useful for those who evaluate mitigation options for buildings at risk of urban flooding. Some options are described in Recommendation 5.

- Encourage design professionals and the special inspectors who conduct annual and triannual inspections of dry floodproofed buildings in Special Flood Hazard Areas in accordance with the New York City building code to learn how to evaluate buildings at risk of urban flooding to identify feasible mitigation options.

- Consider whether to provide financial assistance to building owners to have evaluations performed and to implement feasible mitigation options.

RECOMMENDATION 5. EVALUATE AND MITIGATE RISKS TO BASEMENTS AND BELOW-GRADE AREAS

Owners of buildings with basements and below-grade areas that are exposed to urban flooding should evaluate their buildings to determine how surface water enters those spaces and whether there are feasible and effective measures to keep water out and otherwise mitigate damage. Even if water can be blocked or diverted from entering basements and below-grade areas, occupants must evacuate all parts of buildings that might flood if the blocking measures are overwhelmed by more severe flooding.

The FEMA Hurricane Ida NYC MAT Fact Sheet 1, What Building Owners and Tenants Should Know About Urban Flooding, includes a simple checklist that can be used to screen how water gets into basements and what can be done to mitigate damage. More technical guidance for these evaluations is in the FEMA publications referenced in Recommendation 6.

Mitigation options to improve the performance of buildings with basements and below-grade areas that are vulnerable to flooding by rainfall runoff vary depending on site factors and building characteristics. Options that may be feasible include:

- Permanently raise the lowest points of entry for surface water. Points of entry include doorways, street-level windows and vents, loading bays, exterior basement stairways, ramps to below-grade parking, and driveways. Figure 12 shows how vents at grade level were retrofit with extended vent wells that raise the lowest point of entry several feet above the ground. The city's pluvial flood mapping project will produce anticipated flood elevations. Where feasible, those flood elevations should be used to determine how high to raise the entry points.
- Reinforce basements walls, or fill in basements, of homes with unreinforced concrete or masonry basement walls. Owners should consult with design professionals to evaluate feasibility and approach for these projects. The Hurricane Sandy Recovery Advisory 7, Reducing Flood Risk and Flood Insurance Premiums for Existing Residential Buildings in Zone A, offers some information on filling basements.
- Obtain temporary barriers and develop emergency implementation plans to deploy the barriers to block points of entry when permanent solutions are not feasible. A variety of temporary barriers are available from vendors. However, they are effective only when properly placed. For example, heavy plastic sheeting should be placed behind sandbags and the bags must be tightly stacked.
- Raise critical components of mechanical systems above basement floors and relocate electrical system components to higher locations. These measures are most effective when combined with measures to minimize the entry of surface water and installing backflow preventer valves in sumps and floor drains.
- Use materials that resist flood damage for basement interiors. FEMA Technical Bulletin 2, Flood Damage-Resistant Materials Requirements, lists materials that are acceptable and not acceptable in terms of resistance to water damage

Figure 12. Vents retrofit by extending vent wells above ground level

RECOMMENDATION 6. RETROFIT DRY FLOODPROOFING

Existing buildings in areas where surface flooding has entered basements and below-grade areas may be candidates for retrofit dry floodproofing measures. These measures involve making walls, floors, joints, and utility penetrations watertight, and installing temporary watertight panels and barriers at all building openings that are below the anticipated flood level. Sump pumps must be provided to manage seepage. Dry floodproofing measures should be designed for site-specific conditions. In general, retrofit dry floodproofing is not feasible or safe unless buildings are engineered or robust enough to resist flood loads.

Building codes and local floodplain management regulations have specific requirements and limitations that govern use of dry floodproofing in FEMA-mapped floodplains. When compliance with the code is required, the codes allow only non-residential buildings and non-residential portions of mixed-use buildings to be dry floodproofed. However, when compliance is not required, any building may be dry floodproofed. Owners should always work with design professionals who can evaluate building characteristics and site-specific conditions to determine feasibility. Owners should have their design professionals prepare maintenance plans and emergency operations plans that specify actions that must be taken when flood warnings are issued. FEMA publications for dry floodproofing (listed below) are written for buildings in SFHAs. However, the guidance may be useful for owners and design professionals who are considering retrofit options to keep surface flooding out of buildings with basements and other below-grade areas.

Building owners should be aware that dry floodproofing measures can fail or may be overtopped if water rises higher than the water depths used to design the measures. Occupants must evacuate every part of buildings that are dry floodproofed. Owners must understand that failure of the measures may result in significant damage. Failure is likely if the floodproofing measures are not maintained. Failure is also likely when people who must take action are not adequately trained. Observations by FEMA MATs after major flood events indicate many dry floodproofing systems do not function as designed because of poor maintenance. Also, the systems may fail when building managers or staff are not familiar with the steps to deploy dry floodproofing measures before flooding begins. Regular deployment exercises are necessary to ensure system components will be installed correctly and function as intended.

FEMA Publications for Dry Floodproofing

- FEMA Technical Bulletin 3, Requirements for the Design and Certification of Dry Floodproofed Non-Residential and Mixed-Use Buildings
- FEMA Technical Bulletin 6, Requirements for Dry Floodproofed Below-Grade Parking Areas Under Non-Residential and Mixed-Use Buildings
- FEMA P-936, Floodproofing Non-Residential Buildings

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For More Information

See the FEMA Building Science Frequently Asked Questions at https://www.fema.gov/emergency-managers/risk-management/building-science/faq.

Send questions on FEMA Building Science Publications to FEMA-Buildingsciencehelp@fema.dhs.gov or call 866-927-2104.

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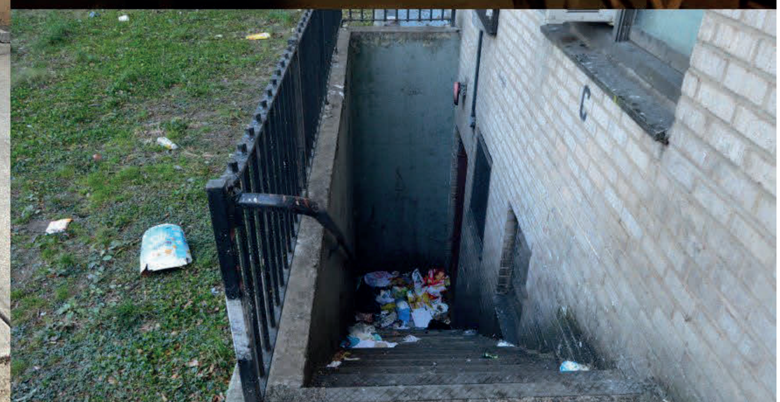

Building Performance: Egress from Floodprone Basements

Hurricane Ida NYC MAT Technical Report 2

June 2023

FEMA

Unless stated otherwise, all photographs and figures in this report were taken by the MAT or developed for this report.

Cover Image: Left-hand image shows a concrete driveway sloping down from street level to the front door of a basement apartment. The top right image shows an interior view of a basement wall with a small window located high on the wall. The bottom right image shows a staircase leading down from the sidewalk to a sub-grade area.

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1. Introduction

Remnants of Hurricane Ida moved through the New York City metropolitan area on September 1, 2021, causing significant urban flooding and damage in many parts of the city. A presidential disaster was declared on September 13, 2021 (FEMA-4615-DR). As part of its response to the disaster, the Federal Emergency Management Agency (FEMA) Building Science Disaster Support program deployed a Mitigation Assessment Team (MAT) to assess the damage. MATs are composed of federal and non-federal experts in building science and other relevant disciplines. These experts assess building performance after disasters, then incorporate lessons learned to make recommendations on improving the resilience of new construction and repairs and retrofits of existing buildings.

1.1. Report Objective

The primary objectives of the FEMA Building Science Disaster Support program are to improve the resistance of buildings to natural hazards and improve the safety of building occupants. Its work includes evaluating the key causes of building damage and failure, and recommending solutions. The remnants of Hurricane Ida produced widespread urban flooding, which led to flooding of numerous below-grade and basement areas. The Hurricane Ida NYC MAT Technical Report 1, Building Performance: Basement Buildings and Urban Flooding (FEMA P-XXXX), notes this type of flood damage has occurred many times in the past. That report also describes the impacts of basement flooding on life safety, buildings, and building utility systems and equipment. It includes a number of recommendations to address the safety of basement occupants and the performance of buildings with floodprone basements.

This report describes the MAT's observations related to the egress of occupants from basements flooded when the capacity of stormwater drainage systems is exceeded. The observations were made during field investigations of selected locations in New York City. Figure 1 shows the locations visited by the Team. This report offers a number of the New York City's requirements for building egress and emergency access. The report makes some recommendations to improve the safety of occupants in floodprone basements and options to improve egress from floodprone basements.

Basements and other below-grade areas that are prone to flooding by stormwater runoff should not be occupied unless deemed legal by the local jurisdiction. Building owners and occupants should be aware of the risks and know what to do when severe storm warnings are issued. Occupants of basements should have adequate ways to get out of their dwellings so they are not trapped when flooding occurs.

After deployment to New York City, the Team produced three technical reports and four fact sheets that relate to the effects of Hurricane Ida on the city. The documents focus on some construction and stormwater issues that were not considered in previous MAT investigations, including:

- Surface runoff and flooding in urbanized areas

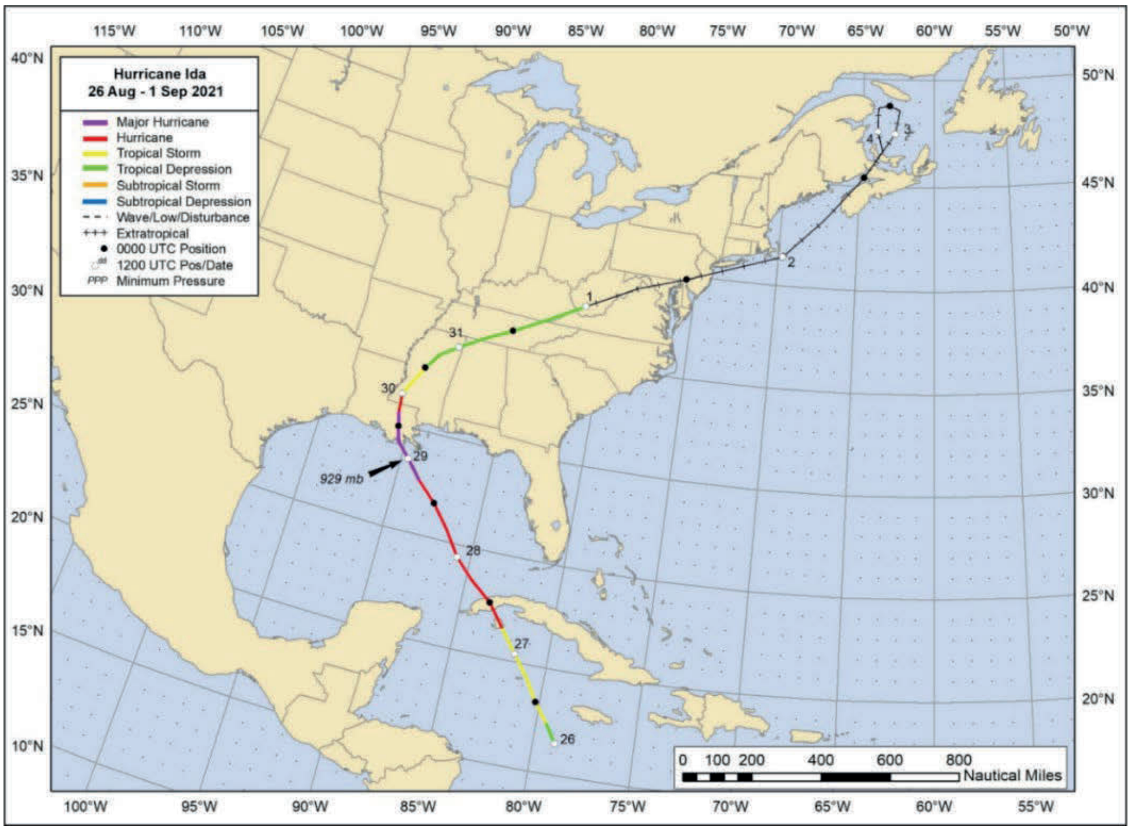
- Stormwater collection and drainage systems
- Effects of surface flooding on buildings
- Basement flooding in urbanized areas
- Early warning systems for urban flooding
- Egress (leaving) for occupants of at-risk basements
- Flood warning and flood risk mapping
- Steps owners and residents can take to reduce risks associated with urban flooding
- Ways to enhance policies and regulations to reduce flood risks

Figure 1. Locations visited by the FEMA MAT after Hurricane Ida

1.2. Hurricane Ida in New York City

On August 29, 2021, Hurricane Ida made landfall as a Category 4 hurricane in Lafourche Parish, on the Louisiana coastline. This was only 50 miles west of where Hurricane Katrina made landfall on the same day in 2005. The storm generated high winds and storm surge, causing widespread damage to structures and to power and telecommunication infrastructure throughout the state. As Hurricane Ida moved inland, beyond Louisiana (Figure 2), it produced heavy rain and unsettled weather in several states. In New York City, the peak rainfall intensity in Central Park was 3.15 inches per hour, with a total of 7.13 inches of rain over a 24-hour period. It is important to note that Hurricane Ida was preceded by the remnants of Tropical Storm Fred and Hurricane Henri, which saturated the city with heavy rainfall in August.

New York City reported 13 fatalities attributed to the flooding caused by Hurricane Ida. Eleven fatalities were from drowning in the basements of single- and multi-family residential buildings.



Source: National Hurricane Center

Figure 2. Storm track of Hurricane Ida from August 26 through September 4, 2021

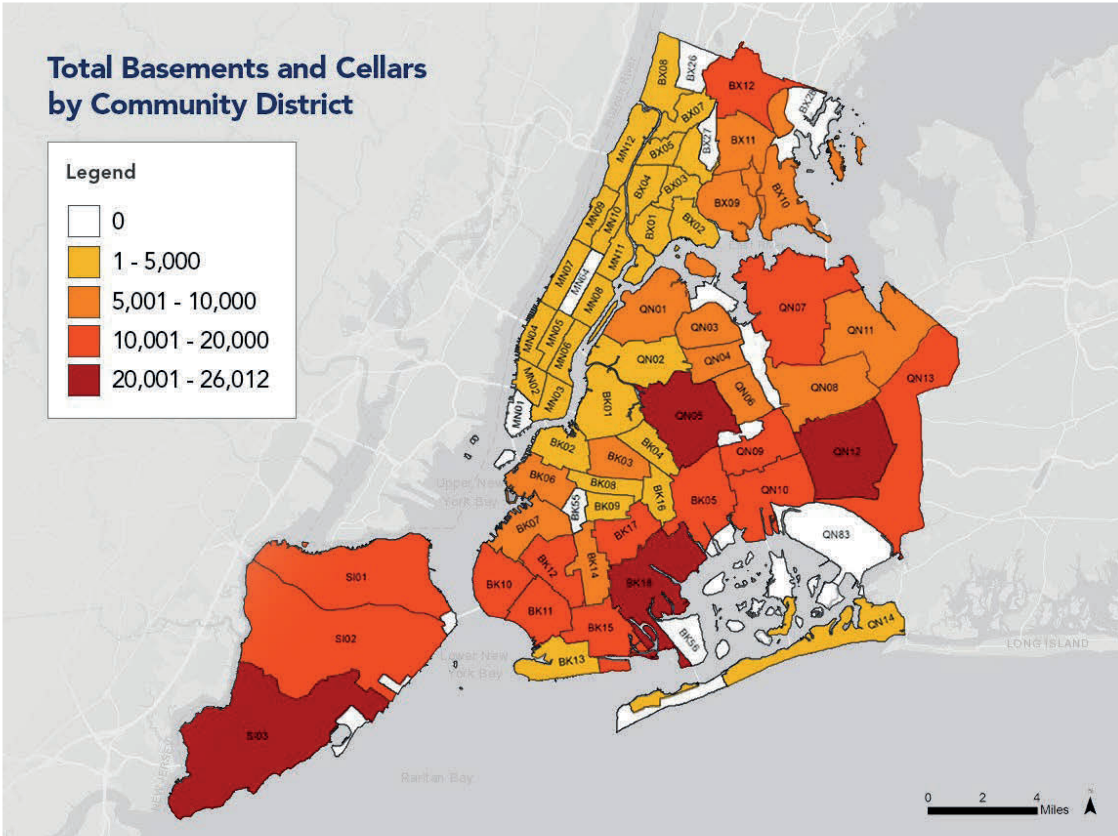
In some areas where the rainfall runoff exceeded the capacity of the stormwater drainage system, water flowed toward buildings, entering the basements, cellars, and below-grade spaces of numerous homes, multi-family buildings, and commercial buildings. The city generally does not allow dwelling units in basements, which are areas that are less than half a story below grade, unless specific requirements are satisfied. Cellars are subgrade areas with more than half a story below grade. The city does not allow cellars to be occupied. The basements of multi-family buildings are typically used to house equipment such as boilers and water heaters, and for storage.

Basements, Cellars, and Below-Grade Areas

This report uses “basement” and “below-grade area” to refer to any portion of a building that is below grade that is used for any purpose. The New York City Building Code defines “basement” and “cellar” in terms of how much of the “clear height (measured from finished floor to finished ceiling)” is below grade. A basement has less than 50% of the clear height below grade while a cellar has more than 50% of the clear height below grade.

In August 2022, the New York City Comptroller issued a report, “Bringing Basement Apartments into the Light.” This report estimated that one-, two- and three-family homes in the five boroughs have over 420,000 basements and cellars (Figure 3), although it does not estimate how many are occupied. The report states, “The Comptroller’s Office estimates that about 10%, or 43,000, basements and cellars … are currently facing some type of flooding risk. As storms intensify with climate change, the number of basements and cellars facing coastal and extreme rainfall flood risk is estimated to grow to 136,200, a third of all basements and cellars by the 2050s.”

Hurricane Ida is not the only storm to produce urban flooding that damaged buildings with basements. The heavy rainfall resulting as the remnants of Hurricane Ida passed over the city was one of many previous heavy rainfall events that flooded building basements. The city’s 2009 Natural Hazard Mitigation Plan lists 60 urban flooding events between 1993 and 2007. Six of those events are reported to have flooded basements. Some events had citywide impacts, while others flooded basements in Queens (Brooklyn, Flushing, and Springfield Gardens). Notably, on January 3, 1999, people had to be rescued from basement apartments in Springfield Gardens when water rose nearly to ceiling height.



Source: NYC Comptroller's Office, 2022

Figure 3. Estimated number of basements and cellars in New York City by community district

2. Hurricane Ida MAT Observations in New York City

2.1. How Surface Water Entered Basements

Rainfall runoff entered basements when surface water elevations reached the lowest point of entry at which water could flow into the buildings. In multi-story buildings, water typically entered through loading docks, exterior stairwells, and access ramps, or through street-level windows and vents. In some one- and two-family dwellings, water entered below-grade garages after street flooding reached the crests of the driveways. In others, it flowed down exterior basement access stairs as floodwater crested the stairway thresholds.

2.2. Risks To Occupants of Floodprone Basements

The MAT visited many buildings in New York City where surface water entered basements as Hurricane Ida move across the city. Only some of those basements were occupied during the event. The Team did not visit every building where occupants drowned. In addition, the Team did not evaluate whether egress from basements conforms to requirements established by the city for legal occupancy of basements.

Occupants of floodprone basements are at risk if they are unaware that their dwellings could flood during heavy rainfall events. Another aspect of risk may be the lack of a safe path, or obstacles on the path, for occupants to evacuate to safer locations.

BASEMENT OCCUPANTS MAY BE UNAWARE OF FLOOD RISK AND HOW TO RESPOND TO WARNINGS

During heavy rainfall events that cause urban flooding, water may enter basement areas through doorways, street-level windows and vents, driveway ramps, sewer backup, or utility penetrations in the foundation walls. Basement flooding may start with little warning, and water will continue to flow in as long as the water level stays high on the outside of the building. If the flow lasts long enough, basements and below-grade areas may fill up. Building owners and property managers may not know their buildings with occupied basements are vulnerable to urban flooding. New York City's initiatives to inform the public about urban flooding are summarized in Section 5 of this report.

MANY FLOODPRONE BASEMENTS LACK UNOBSTRUCTED WAYS TO ESCAPE

Many occupied basement dwelling units in New York City satisfy the city's requirements for legal occupancy, including requirements for egress. However, other units have not yet satisfied those requirements. The city's egress requirements are summarized in Section 3 of this report.

During the rainfall caused by remnants of Hurricane Ida, basement flooding put some occupants at extreme risk when water flowing through windows and exterior basement stairways obstructed the only way they had to escape (see Figure 4). Obstructed paths can result in injuries and loss of life. Exit paths may be obstructed in several ways, including:

- Exterior doors may open outward. When water accumulates against doors to exterior stairwells and driveway ramps, the hydrostatic pressure applied by water against doors can make it difficult, if not impossible, to open doors that swing outward. Similarly, water flowing through or accumulating against basement windows means people cannot escape through windows even if the windows are large enough to climb through.
- Basement windows may be too small or too high above the floor to be used for escape or may have security bars blocking escape if water against doors prevents them from opening (see Figure 5).
- Some basement areas do not have a defined path to escape. Some do not have direct paths to the exterior, and some have limited access to upper floors. When basements of one- and two-family dwellings are converted, the door at the top of interior stairs may be locked or secured and basement occupants are not able to leave that way.

Source: Still image from video; Internet Clips, 2021

Source: Still image from video; Daily Mail, 2021

Figure 4. Surface water entering below-grade dwelling unit through window (left); NYPD officer searching flooded basement where three fatalities occurred (right)

Figure 5. Basement window too high and too small for escape (left) and basement window with security bars (right)

3. Egress: Summary of New York City Requirements

The express intent and purpose of the New York City Building Code is to "provide reasonable minimum requirements and standards … in the interest of public safety, health, welfare and the environment …" Similarly, the intent and purpose of the New York City Fire Code is to "establish reasonable minimum requirements for life safety and property protection." And the purpose of the New York City Housing Maintenance Code is to enforce minimum standards of health and safety.

The city's codes have many general and specific requirements for means of egress and emergency escape and rescue openings (see definitions). Several factors govern when those requirements must be satisfied for both new construction and existing buildings. Safety of building occupants and emergency personnel are the reasons for these requirements. Occupants of buildings that have adequate means of egress, and emergency escape and rescue openings when required, are safer when evacuation is necessary. Evacuations may be necessary because of fire, flood, or other reasons.

New York City Code Definitions

Means of Egress. A continuous and unobstructed path of vertical and horizontal egress travel from any occupied portion of a building or structure to a public way. A means of egress consists of three separate and distinct parts: the exit access, the exit, and the exit discharge.

Emergency Escape and Rescue Opening. An operable window, door, or other similar device that provides for a means of egress and access of rescue in the event of an emergency.

Building owners and design professionals must determine which code requirements apply when they develop plans for new construction and proposals for work on existing buildings. The list below is not a comprehensive summary of all code requirements for means of egress and emergency escape and rescue openings. Requirements may differ depending on whether buildings are proposed for construction or are existing buildings proposed to be altered or have changes in occupancy classification. The following summarizes some requirements that pertain to occupancy of basements:

- **New Buildings.** The NYC Building Code specifies that buildings and portions of buildings must be designed to comply with the requirements for means of egress. Some buildings that are classified as residential must also have emergency escape and rescue openings provided in sleeping rooms. Where below-grade areas have sleeping rooms, each room must have an emergency escape and rescue opening. There are some situations where that requirement does not apply, depending on fire protection measures.

- **Multiple Family Buildings and Escape Openings.** The NYC Building Code requires certain residential buildings to provide emergency escape and rescue openings. These openings are required for buildings with multiple dwelling units and buildings with sleeping rooms below grade. The code requires below-grade areas that have window wells deeper than 44 inches to have permanently affixed ladders or steps to allow occupants to get out of the window wells.

- **Existing Buildings and Change of Occupancy.** The NYC Building Code requires assignment of an occupancy classification to each building or portion of a building (e.g., mercantile, assembly, residential). Proposed changes in occupancy classification are governed by the building code, including changes in occupancy classification to allow legal dwelling units in basements.

Changes in occupancy must comply with the code provisions for the proposed classification depending on a number of factors. Compliance includes satisfying the requirements for means of egress and, in some circumstances, the requirements for emergency escape and rescue openings. When a change of occupancy affects only a space, the rest of the building must be altered as necessary to protect the safety and welfare of the occupants. In general, the city allows work on buildings that complied with prior codes to be performed in accordance with those codes. Alterations for changes in occupancy may comply with a prior code provided no danger to general safety and public welfare is created.

- **Alteration of Existing Buildings.** The NYC Building Code governs alterations of existing buildings, including alterations to create legal dwelling units in basements. Depending on the amount of alteration proposed, the alterations and the altered portions of a building must be fully code compliant. In general, the city allows work on buildings that complied with prior codes to be performed in accordance with those codes. Compliance includes satisfying the requirements for means of egress. The requirements for emergency escape and rescue openings must be satisfied if the alterations are designed to comply with the current code. Alterations for changes in occupancy may comply with a prior code provided no danger to general safety and public welfare is created.

- **Illegal Residential Conversions.** The NYC Building Code states that it is unlawful to convert any dwelling for occupancy by more than the legally authorized number of dwelling units unless the conversion is in accordance with the code. This provision would apply to illegal conversion of basements to dwelling units. The code authorizes the city to inspect buildings when complaints of illegal conversions are submitted or violations are observed.

- **Legal Occupancy of Cellars and Basement.** The NYC Housing Maintenance Code lists many requirements for legal occupancy of cellars and basements. Some requirements established by New York State vary depending on whether the below-grade spaces are in buildings with multiple dwellings, converted dwellings, or one- and two-family dwellings. Some requirements vary depending on when buildings were constructed. In general, all dwelling units in basements and cellars must have windows for lighting and ventilation. Minimum dimensions of those windows are specified, but not in terms of whether windows meet requirements for emergency egress.

- **Emergency Preparedness Plans.** The NYC Fire Code requires owners of certain buildings to develop fire protection and emergency preparedness plans for timely implementation of procedures in the event of a fire or non-fire emergency. Most buildings with multiple dwelling units must have fire and emergency preparedness plans and notices. The notices must be posted in each dwelling unit and at other locations. One purpose for these notices is to inform building occupants, building staff, and visitors about sheltering and evacuation procedures.

- **Posting Temporary Emergency Information.** The NYC Housing Maintenance Code requires owners of residential buildings, where at least one dwelling unit is not occupied by the owner, to post temporary emergency information. The notices must be posted in common areas to identify whether the building is located in a hurricane evacuation zone, the location of the nearest evacuation center, and other information about preparing for an anticipated weather event. The code requires removal of notices after passage of a weather emergency or natural disaster event. Figure 6 illustrates a permanent notice informing residents that the building is in hurricane evacuation zone 4.

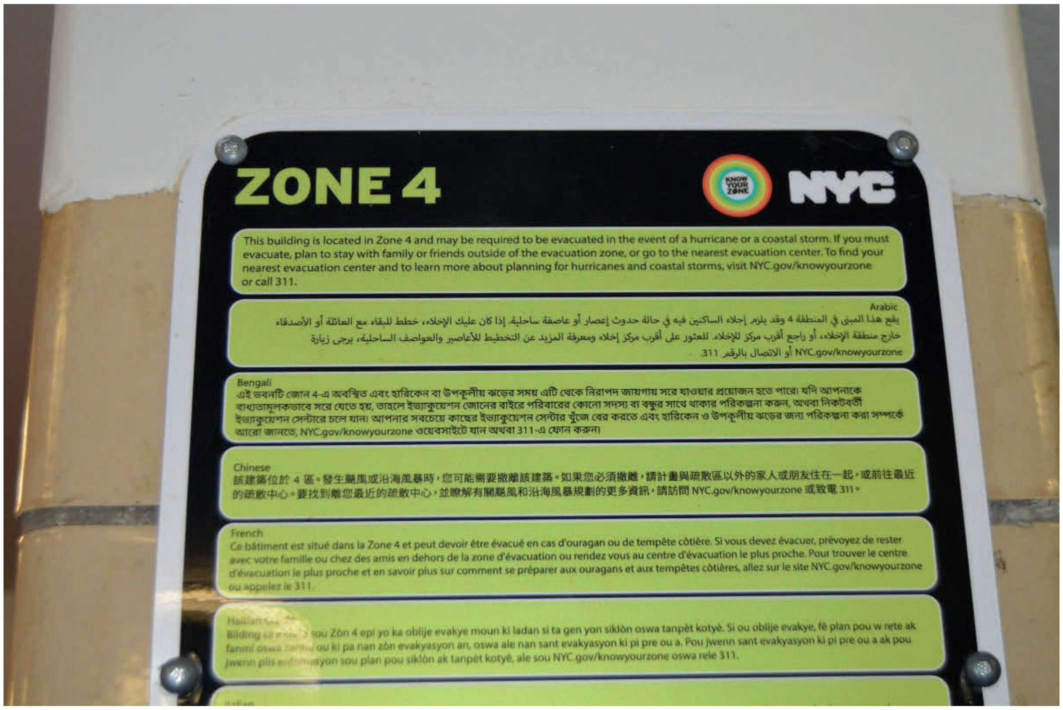


Figure 6. Hurricane evacuation zone notice posted at Sotomayor Houses in New York City

4. Occupied Basements: New York City Agencies and Initiatives

New York City, like most cities, has a shortage of safe, affordable housing. City leadership recognizes that basement dwelling units are part of its multi-faceted approach to long-term solutions. The following summarizes some city agencies and initiatives that pertain to occupancy of basements:

- The **Mayor's Office of Climate & Environmental Justice** works to implement policies that close the gap on environmental and health disparities by advancing access and inclusion for people at every level of the city's planning and decision-making process.
  - With the **Department of Environmental Protection** and **New York City Emergency Management**, the office is using a FEMA grant to study where installing backwater valves in sewer lines will be effective to reduce backflow of sewage into buildings. Buildings with basements and below-grade areas are most susceptible to sewage backflow when located in

parts of the city served by combined stormwater and sewage drainage systems. The study will examine social and physical vulnerability factors as part of recommending priority areas.

- The **Department of Buildings** enforces the New York City Building Code and Construction Codes.
    - The department reviews permit applications and plans for compliance, inspects construction for compliance, identifies and resolves violations of the codes.
    - The NYC Quality of Life Unit is part of the department. The unit conducts field inspections in response to complaints of illegal conversions performed without first obtaining permits and approvals. Reported locations are inspected to identify potentially hazardous conditions. The city offers several tips to help tenants recognize whether a unit is an illegal dwelling. One suggestion for tenants to check is whether there is an adequate means of egress (way out). Tenants of legal units should be able to get to all available exits either directly from the unit or a public hallway.
- The **Department of Housing Preservation and Development** is charged with promoting quality and affordability in the city's housing, and diversity and strength in the city's neighborhoods. The city supports legalization of existing basement apartments and development of affordable dwelling units to increase the supply of housing and meet its fair housing goals. The department enforces the New York City Housing Maintenance Code to maintain minimum standards for health and safety. The department has many programs and initiatives. Some of the department's initiatives have bearing on occupied basements.
    - The department's basement apartment conversion pilot program identified a barrier to conversion is the state Multiple Dwelling Law. Without changes to the law, the high cost of conversions will continue to obstruct legal conversions. If changes are enacted by the legislature, the department will reexamine implementation of a city-wide conversion program.
    - The department conducts in-home assessments of 1-4 family homes and multi-family buildings. The materials used by staff may be expanded to include resilience, energy efficiency, and deferred maintenance needs. When funded, the HomeFix program provides eligible owners access to low- or no-interest and potentially forgivable loads for home repairs.
- **New York City Emergency Management** coordinates citywide emergency planning and response for all types and scales of emergencies.
    - The office manages NotifyNYC to provide New Yorkers alerts and messages about a range of occurrences, including emergency alerts and weather emergencies.
    - After Hurricane Ida, the office developed enhanced communications to basement occupants to inform them about pending emergencies and urge evacuation. Delivery of the enhanced messaging will be guided by a database of occupied basements and whether those occupied basements are in areas identified as prone to urban flooding.

5. Public Awareness of Urban Flooding

New York City develops robust ways to contact residents to inform and alert them about flood risks, including:

- **NotifyNYC.** Part of New York City Emergency Management, NotifyNYC provides New Yorkers alerts and messages about a range of occurrences, including emergency alerts and weather emergencies. The alerts are available in several languages. Learn more and sign up online to receive alerts at https://a858-nycnotify.nyc.gov/.
- **Rainfall Ready NYC.** The Department of Environmental Protection produced the Rainfall Ready NYC Action Plan, online at https://www.nyc.gov/site/dep/whats-new/rainfall-ready-nyc.page. The website has information to help people plan and prepare for storms, monitor conditions during storms, and recover rapidly after damaging events. A link allows people to sign up to receive alerts from the city's official source of information about emergencies, including weather emergencies.
- **FloodHelpNY.** A project of the Center for New York City Neighborhoods, Inc., which is supported by the city, FloodHelpNY is a primary resource for New York residents and businesses to learn about flood risks, flood retrofits, stormwater flooding, climate change, and flood insurance. The Community Flood Action Toolkit was designed to help property owners make informed decisions to reduce flood risk and lower the cost of flood insurance. Access the site at https://www.floodhelpny.org.

6. Recommendations

The FEMA Hurricane Ida NYC MAT Technical Report 1, Building Performance: Basement Buildings and Urban Flooding, offers recommendations to encourage building owners to evaluate options to mitigate flooding of basements and below-grade areas. However, even if buildings are modified to keep water out of basements, some risk remains if heavy rainfall events produce rainfall runoff that rises higher than the level of protection. Similar risks are present when owners and occupants place temporary barriers to block points of water entry. Building occupants, especially those who live in basements, must not assume that measures to keep water out mean the buildings are safe when flooding occurs.

The recommendations in this section are based on the MAT observations at selected sites visited after Hurricane Ida impacted New York City. The Team did not visit every building where occupants drowned. In addition, the Team did not evaluate whether egress from basements conforms to requirements established by the city for legal occupancy of basements. The recommendations are intended to assist the city, building owners, residents, and others to enhance safety for building occupants, especially those who live in basements.

Some recommendations suggest the city encourage or require building owners to take action. Requirements for actions could be triggered when owners apply for permits to do certain types of improvements, alterations, additions, or replacement of mechanical equipment. Encouragement may take many forms, from providing information to developing ways to financially support actions, such as a grant program or other incentives.

RECOMMENDATION 1. COMMUNICATION WITH BASEMENT OCCUPANTS

New York City should continue its multi-faceted approach to improve awareness of flood risks and to warn building owners and residents. The urban flooding caused by Hurricane Ida demonstrated the specific risks experienced by those who occupy floodprone basements and other below-grade areas. The city should explore options to focus specific messages to those residents, including tailoring messages for basement occupants for delivery through NotifyNYC and the NYC Alerts 911 system, and continue concerted efforts to tell residents how to sign up to receive alerts.

RECOMMENDATION 2. AUGMENT INSPECTIONS OF ILLEGAL CONVERSIONS

The NYC Department of Buildings, Quality of Life Unit, should add a flood vulnerability element to the potentially hazardous conditions that are checked in response to complaints of illegal conversions. The added element would apply when complaints identify dwelling units in basements and cellars in buildings located in areas known to be prone to surface flooding. The inspectors should do the same check when buildings are located in FEMA-mapped floodplains.

RECOMMENDATION 3. EXAMINE OPTIONS TO IMPROVE EGRESS FROM FLOODPRONE BASEMENTS

New York City should develop guidance for building owners to examine their buildings with floodprone basements to determine appropriate ways for occupants to leave when emergency conditions are expected. The guidance for multiple family buildings should encourage owners to identify space where basement occupants can shelter. For one- and two-family dwellings, the guidance should advise occupants to evacuate to safe locations when warnings are issued. The city should consider establishing a requirement for building owners to perform this examination, for example as part of requests for legal occupancy of floodprone basements or any other alteration that requires building permits.

For specific buildings, the feasibility of options to improve how occupants get out of basements is depends on building characteristics. Options to consider include:

- Provide interior routes to the first floor of multiple family buildings. Where space is limited, options might include spiral stairs, ship ladder stairs, or alternating tread stairs.
- Replace existing small or fixed basement windows with windows that open and are large and accessible enough for occupants to be able to climb out. Windows with sills that are more than 44 inches above the floor should have ladders permanently affixed to walls.
- Modify doors that lead to exterior basement stairs or driveway ramps when the doors open outward, by installing small “blow-out” panels over openings made near the bottom of doors. These lightly-attached panels installed on the inside of doors will break off as water rises against them, allowing water to flow in. This will relieve the pressure of water accumulating in stairwells,

which can prevent occupants from escaping. This option is similar to flood openings required to relieve water pressure against walls of buildings constructed in FEMA-mapped floodplains.

- Install water sensors that are integrated with sump pump systems to warn occupants and emergency responders when water levels exceed the capacity of the pump. The sensors should have backup battery power. Like fire equipment, the systems should be tested annually.

- Explore the feasibility of installing wireless speakers in the common areas of multiple family buildings with floodprone basements, to broadcast warnings when intense rainfall and flooding events are predicted and provide basement occupants more time to evacuate.

RECOMMENDATION 4. SUPPLEMENT ASSESSMENTS FOR BUILDINGS WITH FLOODPRONE BASEMENTS

New York City should consider supplementing the in-home assessments offered by the Department of Housing Preservation and Development to include information for owners of buildings with basements when those buildings are located in areas known to experience urban flooding. Similarly, the city should consider supplementing the inspections conducted when complaints of illegal conversions of basements and cellars are submitted or violations are observed. The supplementary material could include:

- A checklist similar to the checklist for owners and tenants included in the FEMA Hurricane Ida NYC MAT Fact Sheet 1, What Building Owners and Tenants Should Know About Urban Flooding (FEMA P-XXXX). That checklist can help those making assessments and inspectors determine whether basements are prone to flooding.

- A checklist for those making the assessments and inspectors to look at whether egress from floodprone basements can be improved.

RECOMMENDATION 5. REQUIRE PERMANENT POSTING OF EMERGENCY INFORMATION

The New York City Housing Maintenance Code should be modified to require owners of residential buildings, where at least one dwelling unit is not occupied by the owner, to post permanent notices of emergency information. The current code requires owners to post information prior to weather emergency and natural disaster events, and to remove the posting after passage of emergencies. Permanent notices should be posted in buildings located in hurricane evacuation zones, FEMA-mapped floodplains, and areas known to be prone to surface flooding. When the buildings have basement dwellings, the notices should specifically inform basement occupants of risks, the importance of evacuating before the onset of flooding, and how to sign up online to receive weather alerts from NotifyNYC.

RECOMMENDATION 6. SUPPLEMENT FIRE PROTECTION AND EMERGENCY PREPAREDNESS PLANS AND NOTICES

The New York City Fire Code specifies when fire protection and emergency preparedness plans and notices are required. The code also specifies the content of those plans and notices, which must address fire and non-fire emergencies. The city should develop example language for buildings with multiple dwelling units to address flood emergencies. The flood emergency language should be required for multi-family buildings with occupied basements when the buildings are located in FEMA-mapped floodplains and areas known to be prone to surface flooding.

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Reducing the Effects of Urban Flooding in New York City

Hurricane Ida NYC MAT Technical Report 3

June 2023

U.S. DEPARTMENT OF HOMELAND SECURITY

FEMA

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1. Introduction

Remnants of Hurricane Ida moved through the New York City metropolitan area on September 1, 2021, causing significant urban flooding and damage in many parts of the city. A presidential disaster was declared on September 13, 2021 (FEMA-4615-DR). As part of the response to the disaster, the Federal Emergency Management Agency (FEMA) Building Science Disaster Support program deployed a Mitigation Assessment Team (MAT) to assess the damage. MATs are composed of federal and non-federal experts in building science and other relevant disciplines.

1.1. Report Objective

The primary objectives of the FEMA Building Science Disaster Support program are to improve the resistance of buildings to natural hazards and improve the safety of building occupants. Its work includes evaluating the key causes of building damage and failure, and recommending solutions. The remnants of Hurricane Ida produced widespread urban flooding that overwhelmed the stormwater drainage system in many parts of New York City. As a result, many streets, low-lying areas, underpasses, and some parts of the subway system flooded.

Urban Flooding:

The inundation of property in a built environment, particularly in more densely populated areas. Urban flooding may be caused by rainfall that runs off large amounts of impervious surfaces and overwhelms the capacity of stormwater drainage systems.

During Hurricane Ida, floodwater entered and damaged many buildings with below-grade and basement areas. The Hurricane Ida NYC MAT Technical Report 1, Building Performance: Basement Buildings and Urban Flooding (FEMA P-XXXX), notes this type of flood damage has occurred many times in the past. That report also describes the impacts of basement flooding on life safety, buildings, and building utility systems and equipment. It includes a number of recommendations to address the safety of basement occupants and the performance of buildings with floodprone basements. The Hurricane Ida NYC MAT Technical Report 2, Building Performance: Egress from Floodprone Basements (FEMA P-XXXX), includes brief summaries of New York City's requirements and agency programs and responsibilities related to egress.

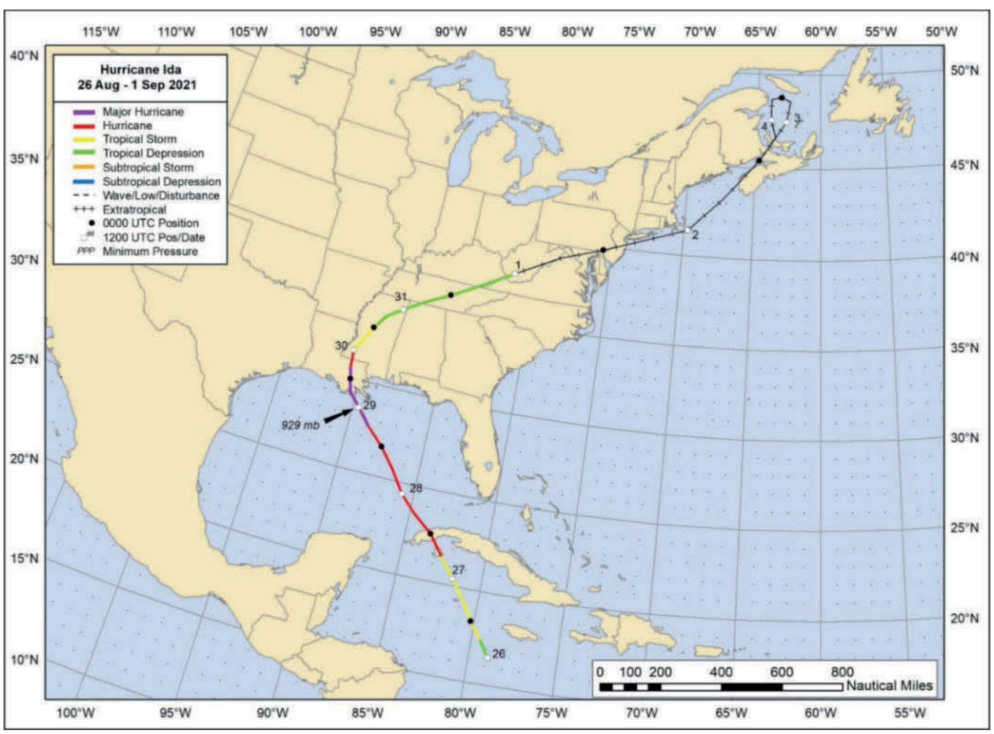
This report briefly explains the basics of rainfall runoff, urban flooding, and urban stormwater drainage systems. It gives a summary of some of New York City's stormwater infrastructure programs and its initiatives to address urban flooding. Applying mitigation measures to stormwater drainage systems and existing buildings can minimize the potential loss of life and injuries, and reduce property damage from future urban flooding events.

After deployment to New York City, the Team produced three technical reports and four fact sheets that relate to the effects of Hurricane Ida on the city. The documents focus on some construction and stormwater issues that were not considered in previous MAT investigations, including:

- Surface runoff and flooding in urbanized areas
- Stormwater collection and drainage systems
- Effects of surface flooding on buildings
- Basement flooding in urbanized areas
- Early warning systems for urban flooding
- Egress (leaving) for occupants of at-risk basements
- Flood warnings and flood risk mapping
- Steps owners and residents can take to reduce risks associated with urban flooding
- Ways to enhance policies and regulations to reduce flood risks

1.2. Hurricane Ida in New York City

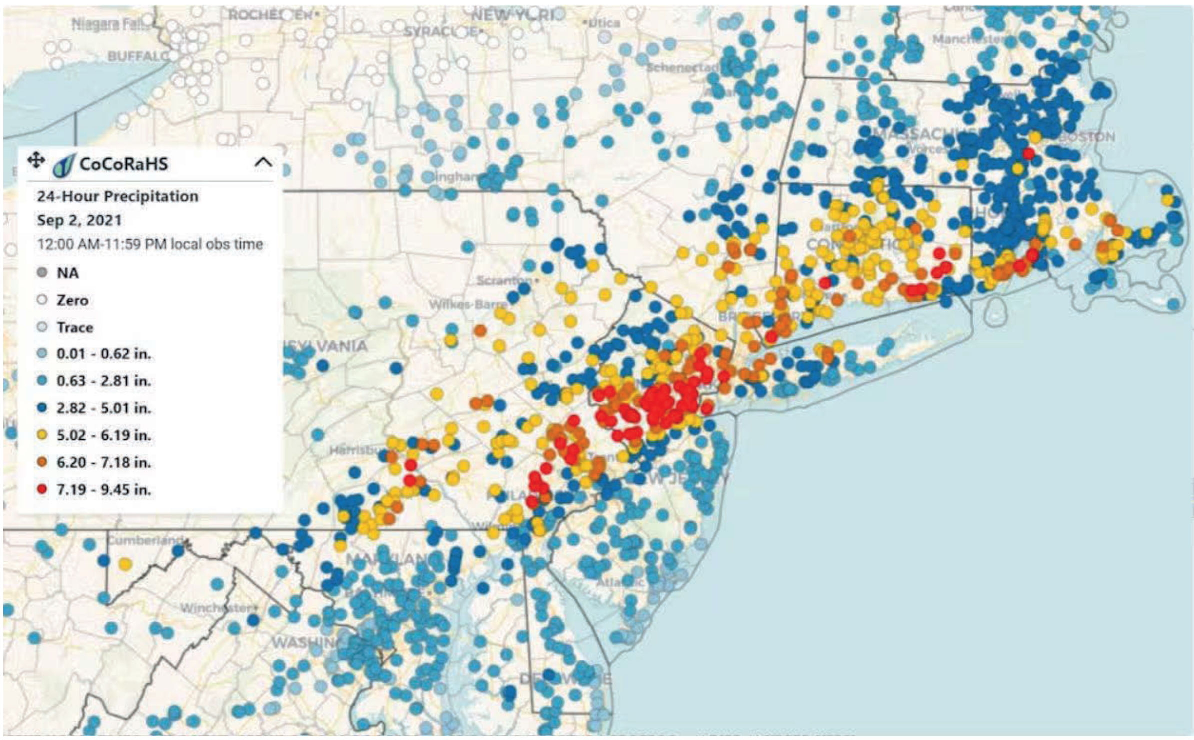
On August 29, 2021, Hurricane Ida made landfall as a Category 4 hurricane in Lafourche Parish, on the Louisiana coastline. This was only 50 miles west of where Hurricane Katrina made landfall on the same day in 2005. The storm generated high winds and storm surge, causing widespread damage to structures and to power and telecommunication infrastructure throughout the state. As Hurricane Ida moved inland, beyond Louisiana (Figure 1), it produced heavy rain and unsettled weather in several states. The National Weather Service reported extreme rainfall (Figure 2) caused flash flooding in New York and neighboring states.



Source: National Hurricane Center

Figure 1. Storm track of Hurricane Ida from August 26 through September 4, 2021

During Hurricane Ida, heavy rainfall overwhelmed the stormwater drainage systems in many parts of New York City. Surface water accumulated, causing significant urban flooding in Queens, Brooklyn, the Bronx, and Staten Island. The peak rainfall intensity in Central Park was 3.15 inches per hour, with a total of 6.95 inches of rain over a 24-hour period. It is important to note that Hurricane Ida was preceded by the remnants of Tropical Storm Fred and Hurricane Henri, which saturated the city with heavy rainfall in August.



Source: CoCoRaHS Mapping

Figure 2. Total precipitation recorded over 24 hours, September 1-2, 2021, in New York and neighboring states

In some areas of the city, the rainfall runoff exceeded the capacity of the stormwater drainage system. Runoff accumulated in streets and low-lying areas (Figure 3). It entered the basements, cellars, and below-grade areas of numerous homes, multi-family buildings, and commercial buildings. Surface water entered through exterior stairways, street-level windows, once it rose above the stair thresholds or windowsills. In multi-story buildings, water typically entered through loading docks, exterior stairwells, access ramps, or through street-level vents and windows.

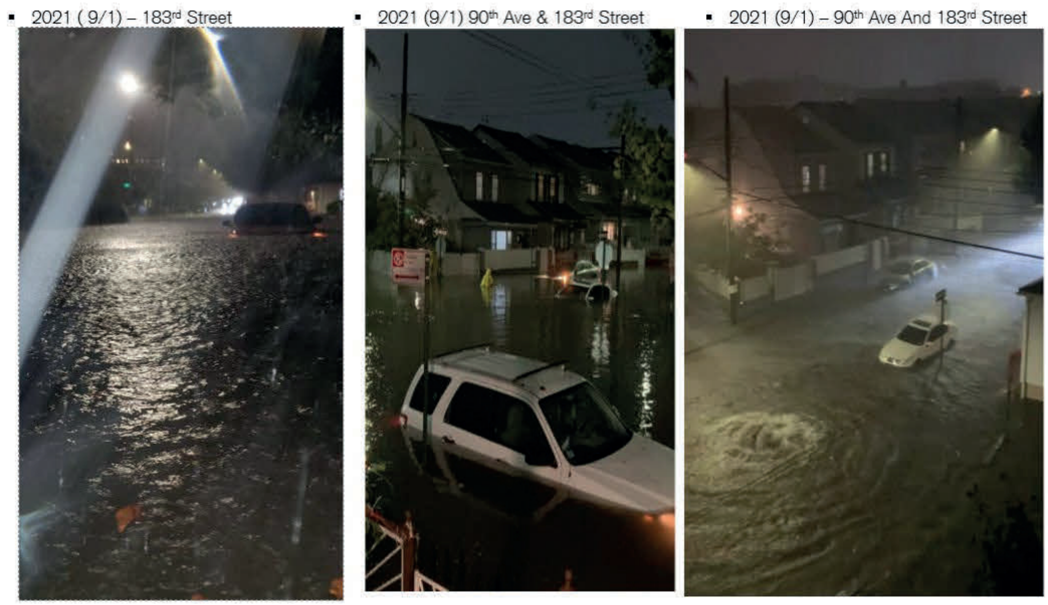


Figure 3. New York City street flooding during Hurricane Ida

2. Rainfall Runoff and Urban Flooding Basics

Cities and highly urbanized areas have many buildings and paved surfaces, including streets, parking lots, and sidewalks. When rain falls on the ground, the water can soak in. But when rain falls on buildings and paved surfaces, it runs off without soaking in. When rainfall runoff does not drain away from low-lying areas, or does not drain away quickly, the accumulated water is called urban flooding. Urban flooding also occurs when curbs, gutters and other parts of stormwater drainage systems cannot contain the flow of water from extreme or heavy precipitation. These drainage problems are also called stormwater flooding, local flooding, or nuisance flooding.

Precipitation is considered extreme or heavy when the amount of rain or snow from an event substantially exceeds what is considered to be normal. These events can be measured by their frequency, their return periods (the chance that the event will be equaled or exceeded in a given year), or the amount of the precipitation in a certain period. It is common to describe storms in terms of the inches of rain falling in one hour or over a 24-hour period.

Urban flooding from extreme or heavy rainfall or rapidly melting deep snow can overwhelm drainage systems and damage property. In vulnerable areas, buildings may be damaged when this runoff enters basements or below-grade areas (such as parking garages). The property damage may be structural, non-structural, or both. It can include damage to building service equipment and contents. Also, the flooding of basements and below-grade areas puts people’s lives at risk if they get trapped without a way to escape.

Extreme Rainfall Runoff in New York City

The New York City Mayor's Office of Climate & Environmental Justice reports that extreme rainfall events, such as Hurricane Ida, are becoming more frequent. The city considers a rainfall event to be extreme if more than 1.74 inches of rain fall in Central Park. During Hurricane Ida in 2021, the peak rainfall intensity in Central Park was 3.15 inches per hour. This is nearly double the intensity-duration value the city has used to design its stormwater infrastructure since about 1970. Hurricane Ida produced significant surface flooding in Queens, Brooklyn, the Bronx, and Staten Island. In all those areas, the capacity of the stormwater drainage systems was exceeded.

3. Urban Stormwater Drainage System Basics

Communities build stormwater drainage systems to collect and convey surface runoff to minimize impacts on buildings, infrastructure, streets, and other property. The components of a drainage system include curbs and gutters, drainage swales and ditches, inlets where water flows into catch basins, and below-ground stormwater pipes. The whole system is intended to carry rainfall runoff and snow melt to a stream, river, or tidal body of water.

In general, there are two types of stormwater systems:

- **Combined sewer systems.** These systems use a single set of pipes to carry flows from sanitary sewer systems and stormwater runoff to waste treatment plants for processing (Figure 4). During normal rainfall events, well-maintained combined sewer systems function effectively. During extreme rainfall events, combined systems can "surcharge," which refers to flows that exceed the capacity of the system. Surcharged systems may create backup flows that enter the plumbing systems of buildings. Combined systems are built with bypass locations that allow excess flows to discharge into receiving streams, rivers, or tidal waters without treatment. These points are identified as combined sewer outfalls. They are governed by regulations on water quality treatment.

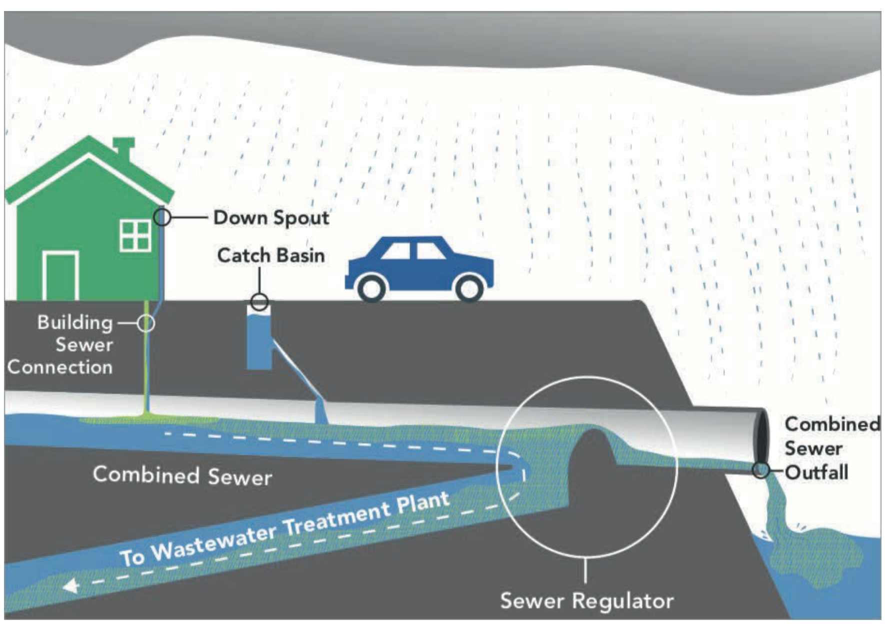


Figure 4. Schematic of Combined Sewer System

- **Separate stormwater**

sewer system. These systems use two sets of pipes that separate sanitary sewer flows from stormwater flows. Because the systems are separate, heavy stormwater runoff does not overwhelm wastewater treatment plants. This minimizes overflow sewage discharges to receiving waters.

For years, many cities designed their stormwater drainage systems to handle the runoff from what is called the "5-year storm" or the "10-year storm." The intensity of the rainfall associated with those storm frequencies varies by location. Cities and urbanized areas recognize that, as rainfall runoff increases, the stormwater drainage infrastructure will be challenged in several ways:

- As storms get more intense and occur more frequently due to climate change, the rainfall runoff will exceed the capacity of the drainage system more frequently.
- As systems get older, they may not perform as intended. This is especially true in areas where buildings and impervious surfaces have been added, which increases the amount of runoff and may contribute to property damage and safety hazards.
- Drainage systems must be inspected and maintained to keep them working properly. Maintenance typically includes removing debris and leaves, cleaning out catch basins and stormwater pipes, and making repairs.
- The use of rain gardens, stormwater ponds, special paving materials, and other features is increasing. These measures help runoff soak into the ground instead of flowing to stormwater systems. Methods and features that reduce rainfall runoff by increasing infiltration are often called "green infrastructure."

Stormwater Drainage Systems in New York City

- About 60% of New York City is served by combined sewer systems. The other 40% has separate stormwater and sewer systems.
- In most areas of the city where storm drains were built before 1970, the drainage system components were designed to handle the runoff from a 3-year storm event.
- In areas where stormwater drainage systems were built after 1970, the components are designed for a higher-impact event, using the intensity-duration values for a storm with a 5-year return period (equivalent to 1.75 inches per hour for a 1-hour storm).

4. New York City Stormwater Infrastructure and Initiatives

New York City has an extensive program to monitor and maintain its stormwater drainage and sewer systems. To function properly, stormwater infrastructure must be inspected, maintained, and repaired. Especially in areas where extreme storms produce urban flooding that damages buildings, debris and leaves must be removed from inlets and catch basins. The city inspects and maintains its system using a data-driven approach.

The city routinely identifies where improving the stormwater infrastructure in certain areas can increase its capacity. Increased capacity is needed, as more extreme storms are expected in the future. The city examines inefficient inlets and underground pipes to see if improvements are feasible. However, the city recognizes that, in many areas, the stormwater sewers cannot be enlarged.

Physically increasing the capacity of a stormwater drainage system is expensive. Even where feasible upgrades are identified, implementation may take decades. Given the acknowledged importance of addressing many problem areas subject to urban flooding, the city established a long-term vision to increase its stormwater resilience. The vision merges traditional stormwater approaches with plans for a citywide network of blue and green infrastructure. This network would intercept more rainfall runoff before it reaches the stormwater drainage system.

4.1. Pursue the Long-Term Vision

In 2022, New York City updated its approach to managing stormwater. It released “Increasing Stormwater Resilience in the Face of Climate Change: Our Long Term Vision.” In 2021, back-to-back storms with heavy rainfall—Hurricanes Henri and Ida—spurred the city to take action. It reaffirmed that its stormwater infrastructure was never intended to manage frequent events with such intense rainfall runoff. Highlights of this plan are available at: https://www.nyc.gov/assets/dep/downloads/pdf/climate-resiliency/increasing-stormwater-resilience-in-the-face-of-climate-change.pdf. The highlights include:

- Upgrade and rehabilitate the sewer system, using historical records, topography, and the likelihood of future flooding to prioritize areas for work (see Section 4.2)
- Keep the stormwater on private property (see Section 4.3)
- Promote infiltration and green infrastructure (see Section 4.4)
- Expand Bluebelts and daylight historic streams and wetlands (see Section 4.5)
- Implement “cloudburst” management Infrastructure (see Section 4.6)
- Adapt to climate change, provide online Stormwater Flood Maps, and administer Rainfall Ready NYC, an action plan with short-term steps that the city and its residents can take to prepare for urban flooding (see Section 5.1)
- As a part of FloodNet, install sensors, monitor flood conditions, and increase awareness (see Section 5.2)

4.2. Upgrade and Rehabilitate the Sewer System

New York City's stormwater drainage system includes more than 7,000 miles of sewers and many other components. As a whole, it is not intended to handle the rainfall runoff from extreme storms. In addition, some parts of the city do not have fully built systems. The city uses a variety of factors to prioritize areas to upgrade the system in order to relieve urban flooding. These factors include the projected sea level rise and environmental justice for residents.

The city has a long-term objective to upgrade and rehabilitate all systems to the current design standard. That standard calls for the system to handle the runoff from 1.75 inches of rain in one hour. As of mid-2023, the city is evaluating the adequacy of that standard, given the growing frequency and intensity of extreme storms.

On the first anniversary of Hurricane Ida, Mayor Eric Adams announced a suite of stormwater initiatives. He highlighted completed and ongoing projects in several parts of the city, including upgrading and increasing the size of sewers, building new stormwater drainage systems, raising some streets, and separating combined sewer systems to increase capacity and improve water quality, Read more at https://www.nyc.gov/office-of-the-mayor/news/637-22/mayor-adams-dep-honor-first-anniversary-hurricane-ida-suite-stormwater#/0.

4.3. Retain Stormwater on Private Property

A significant initiative in New York City's long-term vision is to increase retention of rainfall runoff on private properties. In 2022, the city adopted amendments to its Unified Stormwater Rule. The amendments change requirements for how to manage stormwater on newly built or rebuilt properties. Hydrologic and hydraulic models estimate that by 2030, this rule change will reduce combined sewer overflows citywide by approximately 360 million fewer gallons. This will also help improve the health of New York Harbor.

The changes to the Unified Stormwater Rule modified the rate of flow for house and site connections to the city's combined sewer system. The city must determine sewer availability and approve any new connections to the system. Sewer certifications may be required when a site is altered or renovated in a way that increases sanitary flows or stormwater flows. To meet the new requirements, developers will use a variety of measures to retain or detain stormwater onsite and to increase rainfall infiltration into the ground. Some of those measures are described in Section 4.4. Find more information at https://www.nyc.gov/site/dep/water/stormwater-management.page.

4.4. Promote Infiltration and Green Infrastructure

Increasing infiltration of rainfall runoff through various methods is an effective way to reduce the amount of runoff that flows to and through stormwater management systems. The term "green infrastructure" refers to a variety of ways to increase infiltration. New York City has built or encouraged thousands of green infrastructure installations. Green infrastructure offers significant benefit in areas of the city served by combined sewer systems because the measures help reduce the number and frequency of untreated sewer overflows to receiving waters. Combined sewers are described in Section 3.

The types of green infrastructure installed in New York City include rain gardens, infiltration basins, stormwater greenstreets, green roofs, blue roofs, permeable paving, subsurface detention systems, and rain barrels and cisterns. Figure 5 illustrates two of these methods. The city offers some financial incentives to developers and owners to install green infrastructure on private property. Learn more about these measures at https://www.nyc.gov/site/dep/water/types-of-green-infrastructure.page. The site also has an interactive map to show where green infrastructure measures have been installed.

Figure 5. New York City site with porous pavement and green roof

4.5. Expand the Bluebelt Program

"Bluebelts" are developed as components of New York City's drainage system. They are ecologically rich and cost-effective ways to handle rainfall runoff from streets and sidewalks. Areas with Bluebelts do not have to rely entirely on traditional stormwater drainage system components, such as underground pipes. The program preserves natural drainage corridors including streams, ponds, and wetlands. It enhances those

Source: NYC *Water*

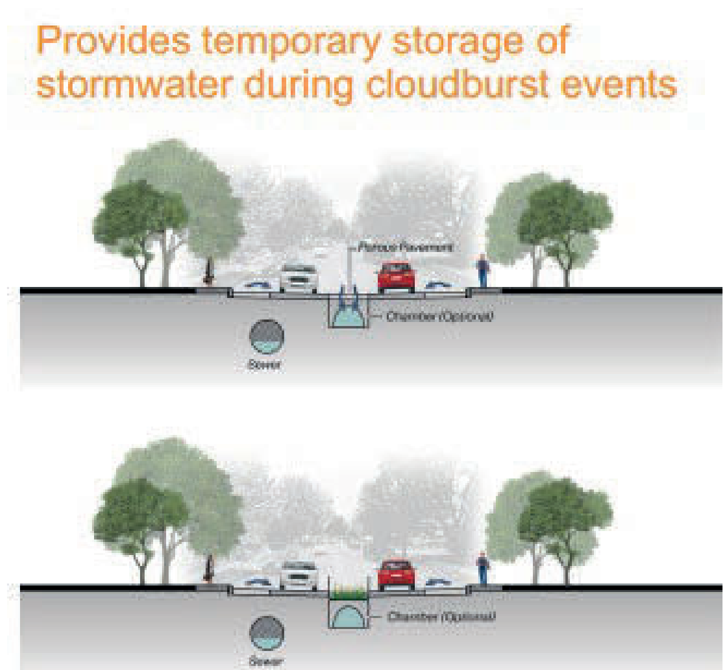
Figure 6. Sweet Brook Bluebelt

features to allow them to perform their functions of conveying, storing, and filtering runoff. Bluebelts also provide open green space and diverse habitat for wildlife (see Figure 6). Bluebelts are part of the city's initiatives to prepare for heavier rains due to climate change. Learn more at https://www.nyc.gov/site/dep/water/the-bluebelt-program.page.

Prior to the first Bluebelt initiative in Staten Island, very few streets in the Sweet Brook area had catch basins or storm drains. Streets often flooded during heavy rainstorms. The Bluebelt project modified drainage in several ways, including adding catch basins to direct rainfall runoff to wetlands. As of mid-2023, the city has more than 75 separate Bluebelts at locations throughout the city.

4.6. Implement Cloudburst Management

A "cloudburst" is a sudden, heavy downpour, where a lot of rain falls in a short time. It is another term for extreme or heavy precipitation that substantially exceeds what is considered normal. In New York City, cloudburst management combines methods, including green infrastructure, to absorb, store, and transfer stormwater (see Figure 7). In this way, it reduces the strain on the city's stormwater drainage system. The goal is to minimize flooding and damage to property and infrastructure.



Source: NYC DEP

Figure 7. Two ways to provide median storage

The city considers many factors when planning cloudburst management projects. Factors include a site's existing physical features, available space, below-ground conditions, existing utility infrastructure, and whether it is possible to connect runoff to green infrastructure. The city also looks at local social and economic factors in each area that may incorporate special amenities and public open spaces. Learn more at https://www.nyc.gov/site/dep/environment/cloudburst.page.

5. Increasing Public Awareness of Urban Flooding

The effects of urban flooding vary, ranging from water ponding in low areas to unsafe conditions for pedestrians and drivers and damage to buildings. FEMA NYC MAT Fact Sheet 1, What Building Owners and Tenants Should Know About Urban Flooding (FEMA P-XXXX), briefly explains how flooding differs from the flood hazard areas shown on FEMA flood maps. It also describes safety risks and how flooding affects buildings and occupants.

New York City is working to increase public awareness of urban flooding and the risks and effects of urban flooding. This section highlights initiatives that support that goal.

5.1. AdaptNYC, Stormwater Flood Maps, and Rainfall Ready NYC

AdaptNYC is New York City's plan to adapt to climate change. Adapting requires citywide, multi-generational efforts. It also requires significant investment. The initiative will improve how the city communicates about flooding risks. One focus is on neighborhoods in low-lying areas with poor drainage and insufficient stormwater drainage systems. The goal is to help people understand the potential risks of flooding. The city hopes to raise awareness of urban flooding caused by extreme rainfall events. Learn more at https://climate.cityofnewyork.us/initiatives/adaptnyc/.

The city developed an online tool to generate Stormwater Flood Maps. The maps depict a range of scenarios to show how stormwater and coastal flooding patterns may change over time. The tool allows users to see the flood risks for scenarios with and without sea level rise. Rising sea levels will keep some storm drain outfalls from fully draining. This will cause those storm drains to back up, which will increase street flooding. It also creates the potential for sewer backups into buildings. The map in Figure 8 shows an extreme stormwater flood scenario (about 3.5 inches of rainfall in one hour), with the 2080 projected sea level rise. Access the maps at https://climate.cityofnewyork.us/challenges/extreme-rainfall/.

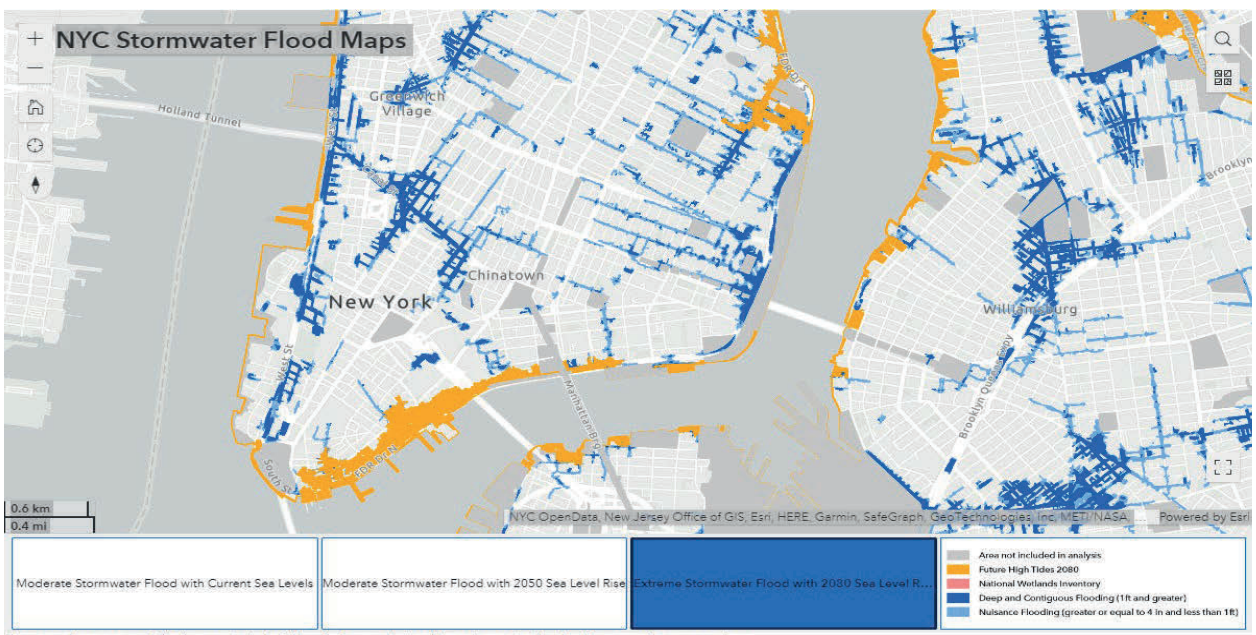


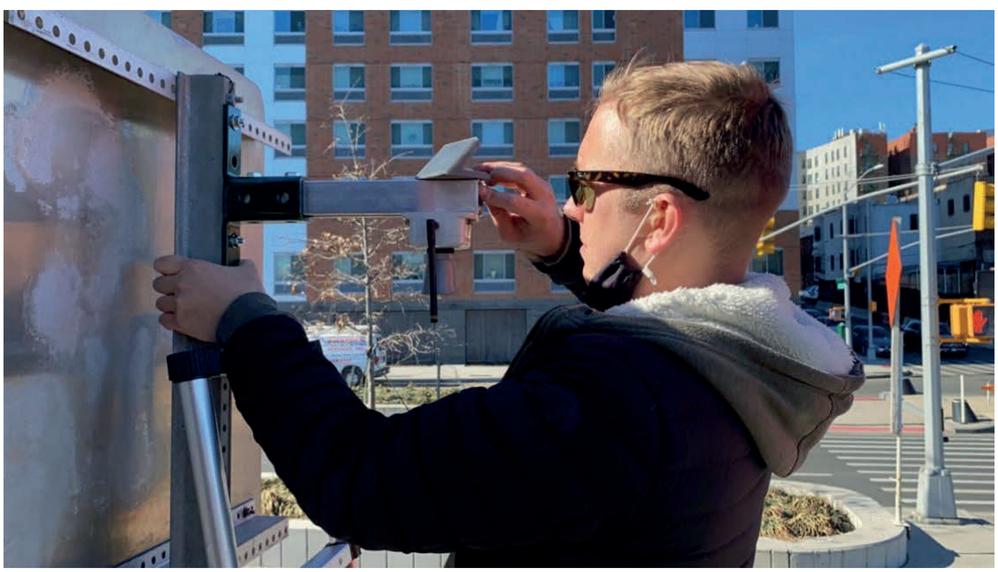
Figure 8. NYC Stormwater Flood Map for Extreme Stormwater Flooding with 2080 Sea Level Rise

Rainfall Ready NYC Action Plan engages the public through a website. The website explains actions the city takes to plan and prepare for urban flooding. For example, it informs residents and owners about flood risks and offers resources to help them protect their properties. The city monitors conditions in real time and communicates with the public about hazards. The website advises people on ways to plan and prepare for intense storms, monitor conditions during storms, and recover rapidly after damaging events. People can sign up to receive alerts from the city's official source of information about emergencies, including weather events. Learn more and sign up at https://www.nyc.gov/site/dep/whats-new/rainfall-ready-nyc.page.

5.2. FloodNet

New York City uses a variety of tools to monitor flood conditions, including traffic cameras, social media, 311 complaints, and other sources. One resource is FloodNet, a cooperative of communities, researchers, and the city government. This group works to better understand the frequency, severity, and impacts of flooding in the city.

As part of FloodNet, the city is installing sensors to detect flooding from any source in real time. The sensors will be installed throughout the city in public places that are prone to flooding (see Figure 9). The sensor system is designed to inform city officials, who can then issue public warnings of the potential for damaging surface flooding. The network is slated to have 500 sensors by 2027, to give both officials and residents real-time flood information. It will also maintain a hyperlocal historical record of flooding that can be used to inform future mitigation work.



Source: NY1/Ari Ephraim Feldman

Figure 9. New York University researcher installs a flood sensor on a traffic sign located on Sheridan Boulevard, near the Bronx River, in the Crotona Park section of the borough

6. Recommendation

This Technical Report briefly summarizes some of New York City's stormwater infrastructure programs and initiatives. The city acknowledges that the urban flooding problem is too big to resolve through construction alone. Instead, the city is using green infrastructure and other measures to supplement the stormwater drainage system. These measures are vital to increase the infiltration of rainfall to reduce the amount of runoff that flows to and through the stormwater management systems.

The city has made major investments in stormwater infrastructure and green infrastructure. It also has several programs to require or encourage owners to retain stormwater on their properties and increase infiltration. Despite this, many buildings will remain vulnerable to damage by urban flooding. Buildings with below-grade areas and basements have the greatest risk because they may fill up once water finds a way in.

Hurricane Ida MAT Technical Report 1, Recommendation 4, describes options for the city to encourage property owners to act. Some options to consider include:

- Develop messaging and mechanisms to contact the owners and managers of buildings in areas where urban flooding has caused damage, with a focus on buildings with basements and below-grade areas. The messages should encourage them to first evaluate their buildings, and then determine whether to engage a qualified professional for a more detailed inspection.

- Develop training and inspection materials for building managers and design professionals to build on evaluations that may be undertaken by owners and managers. The materials can explain how to determine whether and how surface flooding enters buildings, and how to identify feasible mitigation options.

- Encourage design professionals and the special inspectors who conduct annual and triannual inspections of dry floodproofed buildings in Special Flood Hazard Areas in accordance with the New York City building code to learn how to evaluate buildings at risk of urban flooding to identify feasible mitigation options.

- Consider whether to provide financial assistance to building owners to have evaluations performed and to implement feasible mitigation options.

Hurricane Ida MAT Technical Report 1, Recommendation 5, briefly describes the benefits of evaluating flood risk to buildings with basements and below-grade areas. It describes a number of mitigation options to keep water out of those areas. The feasibility of each option depends on site factors and building characteristics. Options include:

- Permanently raise the lowest points of entry for surface water. Points of entry may be doorways, street-level windows and vents, loading bays, exterior basement stairways, ramps to below-grade parking, and driveways.

- Reinforce basements walls, or fill in basements, of homes with unreinforced concrete or masonry basement walls.
- Obtain temporary barriers and develop emergency implementation plans to deploy the barriers to block points of entry when permanent solutions are not feasible.
- Raise critical components of mechanical systems above basement floors and relocate electrical system components to higher locations, and install backflow preventer valves in sumps and floor drains.
- Use materials that resist flood damage for basement interiors.

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For More Information

See the FEMA Building Science Frequently Asked Questions at https://www.fema.gov/emergency-managers/risk-management/building-science/faq.

Send questions on FEMA Building Science Publications to FEMA-Buildingsciencehelp@fema.dhs.gov or call 866-927-2104.

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What Building Owners and Tenants Should Know About Urban Flooding

This fact sheet describes urban flooding and how it can create unsafe conditions and damage buildings. It also describes actions that building owners, tenants, and communities can take to minimize damage from urban flooding. Urban flooding differs in some ways from the flooding shown on maps prepared by FEMA.

What is Urban Flooding?

Cities have many buildings and paved surfaces, such as streets, parking lots, and sidewalks. When rain falls on the ground, the water can soak in. But when rain falls on buildings and paved surfaces, it runs off without soaking in. When rainfall does not drain away from low-lying areas, or does not drain away quickly, the accumulated water is called urban flooding. Urban flooding also occurs when curbs and gutters cannot contain the flow. Other descriptions used for this type of flooding include stormwater flooding, local flooding, and nuisance flooding. Urban flooding is not the same as flood hazard areas shown on FEMA Flood Insurance Rate Maps, called "FIRMs."

Storms that produce heavy and intense rainfall happen more often in recent years than they did in past decades. This is one of the effects of climate change. Many other factors can also make urban flooding severe enough to create unsafe conditions and cause problems.

Some of those factors are:

- Most urban stormwater drainage systems in the United States were not built to handle the amount of runoff from increasingly intense storms and associated heavy rainfall.
- Many stormwater drainage systems are decades old and may not be well maintained.
- Trash and leaves that accumulate in gutters, storm drains, and catch basins can block the flow of runoff, which sometimes prevents the water from draining away quickly.

What is a stormwater drainage system?

Stormwater drainage systems include curbs and gutters, inlets where water flows into catch basins, and the below-ground storm sewer pipes that are designed to carry runoff to a treatment plant, stream, river, or tidal body of water. Some urban systems use rain gardens, stormwater ponds, and other features to help runoff soak into the ground.

Can Urban Flooding Cause Safety Risks?

Yes, there are some safety risks caused by urban flooding. Pedestrians and drivers sometimes encounter flooding that is risky. People should be cautious about walking in or driving through high water. Here are some possible risks from urban flooding:

Fast-flowing water can knock pedestrians off their feet.

Passenger cars may float in water only 12 to 24 inches deep, especially if it is flowing fast.

Stormwater collects in low spots on roads and streets, like underpasses. Cars and trucks can stall when engines get wet.

Stormwater might flow into subgrade parking garages and trap people and vehicles.

Stormwater might flow into basements. Flooded basements can trap, drown, and electrocute people, and damage buildings and their contents.

Depending on the drainage system, storm drain manhole covers might shift, causing pedestrians to trip or fall.

How Does Flooding Affect Buildings and Occupants?

Whether flooding is caused by coastal storm surges, high water in rivers and streams, or urban flooding, the floodwater can damage buildings and affect occupants. Even shallow flooding can cause damage by:

- Saturating wood floors and wood wall framing, which can warp and will usually need to be replaced
- Saturating wall coverings and insulation, which usually need to be removed and replaced
- Saturating furniture and belongings, which usually have to be replaced
- Inundating furnaces and water heaters, which usually have to be replaced
- Cracking basement walls and floors when the ground around the basement gets saturated
- Creating conditions that allow mold to grow, which can cause health risks

How is Urban Flooding Different than the Floodplains on FEMA Maps?

Whether your home or business is in or outside of a FEMA-mapped Special Flood Hazard Area does not indicate your level of risk from urban flooding. Urban flooding differs in several ways from the Special Flood Hazard Areas shown on the FEMA maps:

- Urban flooding happens more frequently than the severe flooding that inundates the areas shown on FEMA maps.
- Urban flooding can be a problem in any low-lying area, even if there is no body of water nearby. Many low-lying areas are not identified by FEMA as Special Flood Hazard Areas.

- Most communities with urban drainage problems do not regulate how buildings are built in areas where urban flooding can be severe enough to cause damage.

Learn more about New York City's stormwater resiliency and flooding.

AdaptNYC. AdaptNYC is the city's plan to adopt to climate change. It helps people understand the potential risks of flooding. Access the site at https://climate.cityofnewyork.us/initiatives/adaptnyc/.

Stormwater Flood Maps is an on online tool to generate maps to show a range of scenarios to show how stormwater and coastal flooding patters may change over time. Access the site at https://climate.cityofnewyork.us/challenges/extreme-rainfall/.

FloodHelpNY is a primary resource for New York residents and businesses to learn about flood risks, flood retrofits, stormwater flooding, and flood insurance. The Community Flood Action Toolkit is designed to help property owners make informed decisions to reduce flood risk and lower the cost of flood insurance. Access the site at https://www.floodhelpny.org.

Rainfall Ready NYC Action Plan. The plan explains actions the city takes to plan and prepare for urban flooding. Access the site to learn more and sign up for alerts at https://www.nyc.gov/site/dep/whats-new/rainfall-ready-nyc.page.

NYC Flood Hazard Mapper. The NYC Flood Hazard Mapper gives a full overview of the coastal hazards that threaten the city today. The Mapper also shows how those hazards are likely to increase in the future because of climate change. (The Mapper does not show areas where urban flooding occurs.) Access the Flood Hazard Mapper at https://www.nyc.gov/site/planning/data-maps/flood-hazard-mapper.page.

Learn more at www.fema.gov. Click on Flood & Maps to learn about federal flood insurance, floodplain management, flood maps and flood risks, including information for homeowners, renters, and business owners.

What Can Building Owners and Tenants Do to Minimize Problems from Urban Flooding?

The first step owners and tenants can take to minimize damage from urban flooding is to find out whether rainfall runoff can get into their buildings. You can use the checklist below to identify possible problems. If you identify ways that water can get into your building, you should talk to an architect, engineer, or someone with experience to learn about options to retrofit or modify your building. Some of the options noted in the checklist must be authorized by building permits before starting work. Talking with an experienced design professional is especially important if a building's subgrade areas are occupied because the residents could be at risk.

Checklist to Identify Possible Building Damage from Urban Flooding

Answer these questions:	*Then decide what to do:*
☐ Are nearby street gutters and catch basins blocked by trash and leaves?	If yes, check the city street sweeping schedule. Clean up trash and leaves before the next storm.
The next time it rains, watch where the runoff flows: ☐ Could runoff flow toward your building? ☐ Has your building had water in it before?	If the answer to either question is yes, answer the next question about how water might get into your building.
Are there any obvious places where water could flow into your building? Answer the following questions:	Walk around your building, take notes on what you see, and take photographs. Use this checklist to identify possible problems.
☐ Are any window wells, exterior basement stairways, or loading bays below the ground level? Do driveways or parking garage ramps slope down below the surrounding ground level?	Does it seem feasible to permanently block any opening where water can enter? Could you use a barrier to block openings in an emergency, such as properly placed sandbags with plastic sheeting? How will occupants know when to block those openings?
☐ Are there cracks between the building and the sidewalk or paving that might allow water to flow down the outside of the basement wall?	Could caulking be added or should old caulking be removed and replaced?
☐ Are any doorways at or near the ground level where water could enter even if the water is only 1 or 2 inches deep?	Would placing a watertight barrier help keep water out? If yes, consult with an architect or engineer to see if a barrier can be installed in the doorway. Alternatively, check with your city to learn the correct way to fill and stack sandbags with plastic sheeting to hold back the water.
☐ Look in all parts of your basement. Can you see any cracks in the walls, the floor, or where the walls join the floor? Is there evidence of water seeping through cracks?	Cracks could indicate existing damage due to lateral earth pressure on the outside of the wall. Some older homes have unreinforced basement walls that can buckle or collapse. Solutions to these problems usually require the advice of an architect, engineer, or experienced contractor.
☐ Does your basement have a sump pump? Has water ever backed up through the floor drain?	Talk to an experienced plumbing contractor about whether a backflow preventer or backwater valve would help.
☐ If the basement is occupied, do the occupants know to heed storm warnings, monitor possible street flooding, watch for water coming in to the basement, and to leave immediately?	Update your emergency preparedness plans to include flood safety. Make sure that basement occupants realize they are at risk if they stay in a basement when heavy rainfall and potential flooding is anticipated.
☐ If the basement is unoccupied, can flooring and wall coverings be removed? Can those materials be replaced with flood damage-resistant materials?	Read *FEMA Technical Bulletin 2, Flood Damage-Resistant Materials Requirements*, which lists typical construction materials. These materials range from those that are highly resistant to flood damage, to those that have no resistance.

Do Communities Regulate Development in Areas with Urban Flooding Problems?

Most communities do not regulate areas with known urban flooding problems. Although most cities keep reports of urban flooding problems, few prepare maps to show where those problems occur. Some areas with urban flooding problems are also shown on FEMA maps as Special Flood Hazard Areas. In those areas, enforcing the floodplain management regulations will also reduce damage by urban flooding.

To protect new buildings that are proposed in areas with urban flood problems, communities can adopt requirements. They can specify that lowest floors must be a certain height above the nearest storm drain inlet or crown of the nearest road. They can require builders to direct rainfall runoff away from buildings. Another option is to prohibit basements and subgrade areas unless the buildings are floodproofed to keep rainfall runoff out of those areas. Communities can consider ways to encourage the owners of at-risk existing buildings to evaluate options to keep water out of their buildings.

What Flood Hazards are Shown on FEMA FIRMs?

FEMA produces studies and maps to identify normally dry lands along streams, rivers, lakes, coastal waters, and some low-lying areas that are expected to flood. The maps are Flood Insurance Rate Maps (FIRMs). They show Special Flood Hazard Areas that are expected to be under water when a “base flood” occurs. The base flood has one chance in 100 of being equaled or exceeded in any given year. Sometimes, this flood is called the “100-year flood,” but that is misleading, because severe flood events can happen more frequently.

Cities, towns, and counties that participate in the National Flood Insurance Program (NFIP) use FEMA studies and maps to regulate development in Special Flood Hazard Areas. Those communities adopt and enforce specific floodplain management requirements for buildings and structures to reduce the amount of building damage when floods occur. The requirements specify that the lowest floors of new buildings (and some older buildings, when those buildings are improved or repaired) must be elevated to at least the flood elevation shown on the FEMA maps. Also, residential buildings must not have subgrade (basement) areas.

Do NFIP Flood Insurance Policies Cover Damage Caused by Urban Flooding?

Damage caused by urban flooding might be covered by NFIP flood insurance policies. NFIP policies pay claims when damage is caused by a “general condition of flooding,” which is defined as flooding that covers two or more acres of normally dry land area and affects two or more adjacent properties. The NFIP offers flood insurance coverage for all buildings in communities that participate in the program. NFIP policies can be purchased for buildings that are not in the Special Flood Hazard Areas shown on FEMA maps. The coverage has some limitations, including what is covered in basements and other subgrade areas.

Building owners can purchase policies to cover flood damage to buildings, contents, and personal property. Unit owners and tenants can purchase policies to cover flood damage to contents and personal property. Most standard property insurance policies available from private insurance companies do not cover flood damage. However, many property insurance companies partner with the NFIP to provide flood insurance.

> Buy an NFIP policy by contacting your insurance company or agent. Or go to www.floodsmart.gov or call NFIP Direct Customer Care at 800-638-6620.

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Flood Warning and Inundation Mapping

This fact sheet describes how flood warning systems, flood alerts, and flood inundation products convey flood risk information. It also describes how flood warning systems can improve flood awareness and public safety, and reduce impacts from flooding.

How Do Flood Warning and Mapping Systems Improve Flood Awareness and Reduce Risk?

Flood warning and mapping systems are useful to provide situational awareness for key questions before and during flood events:

- How high might the floodwater rise?
- When might floodwater be deepest?
- Where will the water go?
- What property and people are in the areas where flooding is predicted?
- What advice and information will help people at risk of flooding respond effectively?
- How can we best give at-risk people that information?

The benefits associated with flood forecasting and warning are linked with methods used to disseminate warnings and the response actions taken by the public and supporting agencies (both voluntary and official). Depending on several variables, the benefits include reduced physical damage and losses – and improved public safety – compared with what might occur if warnings are not issued.

Physical flood damage, also called direct losses, includes the cost to repair damage caused when floodwater contacts property. Buildings may be damaged, vehicles destroyed, and building contents and personal belongings saturated and contaminated.

Losses that are more difficult to measure are called indirect losses. The most significant indirect losses are loss of life and injury. Examples of other indirect losses include loss of income when businesses must shut down to repair damage and replace equipment and inventory, and when residents must pay for alternative housing while repairs

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are made. Communities experience indirect losses when tax income is reduced and when state and federal disaster assistance requires local matching funds.

Advanced knowledge provided by flood warning systems can give people more time to act and reduce losses. The more lead-time available, the more effective these actions will be.

- Warning those who live and work in low-lying areas to evacuate
- Emphasizing the urgency of evacuating basements
- Moving vehicles to higher ground
- Pre-event maintenance of stormwater systems, such as cleaning gutters and inlets
- Installing flood fighting measures (e.g., sandbags, property flood barriers)
- Moving building contents to somewhere above the estimated flood level or out of floodprone areas
- Shutting down equipment that serves buildings
- Shutting off electric and gas service to minimize the potential for fires and explosions
- Providing evacuation assistance to facilities that serve people with mobility limitations, including hospitals and nursing homes
- Pre-positioning fire and rescue services near known problem areas
- Establishing traffic controls to facilitate evacuation and prevent inadvertent travel into hazardous areas
- Scheduling closure of schools and transporting students out of floodprone areas
- Deploying components of dry floodproofing systems designed to minimize building damage
- Timely operation of flood control structures (e.g., gates, temporary flood defenses) to prevent inundation of property and land

Why Are Flood Warning and Inundation Mapping Effective?

The **National Weather Service (NWS)**, an agency of the National Oceanic and Atmospheric Administration (NOAA), produces generalized weather and flooding information. Communities can use NWS forecasting products to establish local flood warning programs. Timely collection of more detailed information on local rainfall and stream levels may allow communities to develop more accurate and reliable predictions of floods than those available from the NWS.

Many communities develop local warning systems or participate in regional systems, while others rely on forecasts issued by the NWS and mapping products available from the U.S. Geological Survey (USGS). Local officials in communities that experience flooding should learn how using available flood warning products and inundation mapping may be an effective way to reduce flood damage and address safety risks. State emergency management agencies, water resources departments, and local NWS offices may provide technical support.

The NWS reports that floods are the main cause of weather-related deaths in the United States, with flash floods causing many of the deaths. The U.S. has averaged more than 85 flood deaths each year over the past 30 years, with that number increasing to more than 100 deaths a year since 2015. Of these, an average of 37 are attributed to flash floods. Flash floods can occur with little advance notice.

Weather researchers, meteorologists, and hydrologists have greatly increased their ability to estimate weather and flooding events over time. However, research indicates there is a knowledge gap between these professionals and the general public, specifically with regard to flood risk and flood awareness. With advances in internet mapping technology, state and local officials who are responsible for issuing flood alerts and warnings have increasingly turned to flood inundation mapping to provide geographic context to real-time flooding and predicted flood events.

What Are Flood Warning Systems and Flood Inundation Mapping?

Flood warning system programs managed by communities or regional authorities can be effective at providing customized products, including scalable solutions and alerts, such as reverse 911 notifications. Those now in use have been credited with saving scores of lives and preventing millions of dollars of damage. In situations when flash flooding occurs very quickly following heavy rains, warning systems provide lifesaving evacuation notices and notify authorities to close low-lying roads and bridges. Even with advanced warning, people in areas prone to flash flooding may not have enough lead time to protect their property and still evacuate safely.

FLOOD WARNING SYSTEMS

Flood warning systems provide information to allow individuals and decision-makers to make informed decisions about whether to take emergency action before a flood event (e.g., evacuation, closing roads). Some flood warning systems provide real-time data on flood conditions, while others use real-time data to estimate future flood conditions several hours or days in advance.

Flood alert components of warning systems are designed to notify residents, businesses, and decision-makers when pre-defined actions should be taken. These alerts are targeted to specific locations and are pushed out, rather than requiring people to monitor a website or news reports. A flood alert that is driven by a flood warning system with estimates of anticipated flooding may be able to give people enough time to evacuate or move possessions out of harm’s way. Alerts and warnings can be distributed through text, email, social media, websites, warning signs and signals, or through radio, television, and news outlets.

FLOOD INUNDATION MAPPING SYSTEMS

Flood inundation mapping systems are used to display the anticipated extent of flooding based on real-time or estimated flood levels. The flood extents are overlaid on other mapping layers, such as road networks, aerial photography, and building maps to provide recipients enough information on which to act, including evacuation or protecting property.

Where Can You Find Flood Warnings and Inundation Mapping?

NOAA NATIONAL WEATHER SERVICE

Forecasters in local NWS offices use the Advanced Weather Interactive Processing System (AWIPS) to display and forecast weather and to create and distribute weather warnings. Issued warnings can be delivered via multiple avenues including:

- Wireless Emergency Alerts on mobile phones
- NOAA Weather Radio (described below)
- Emergency Alert System (described below)
- Integrated Public Alert and Warning System
- NOAA Weather Wire Service
- Emergency Managers Weather Information Network
- Interactive Weather Information Network
- NOAAPORT

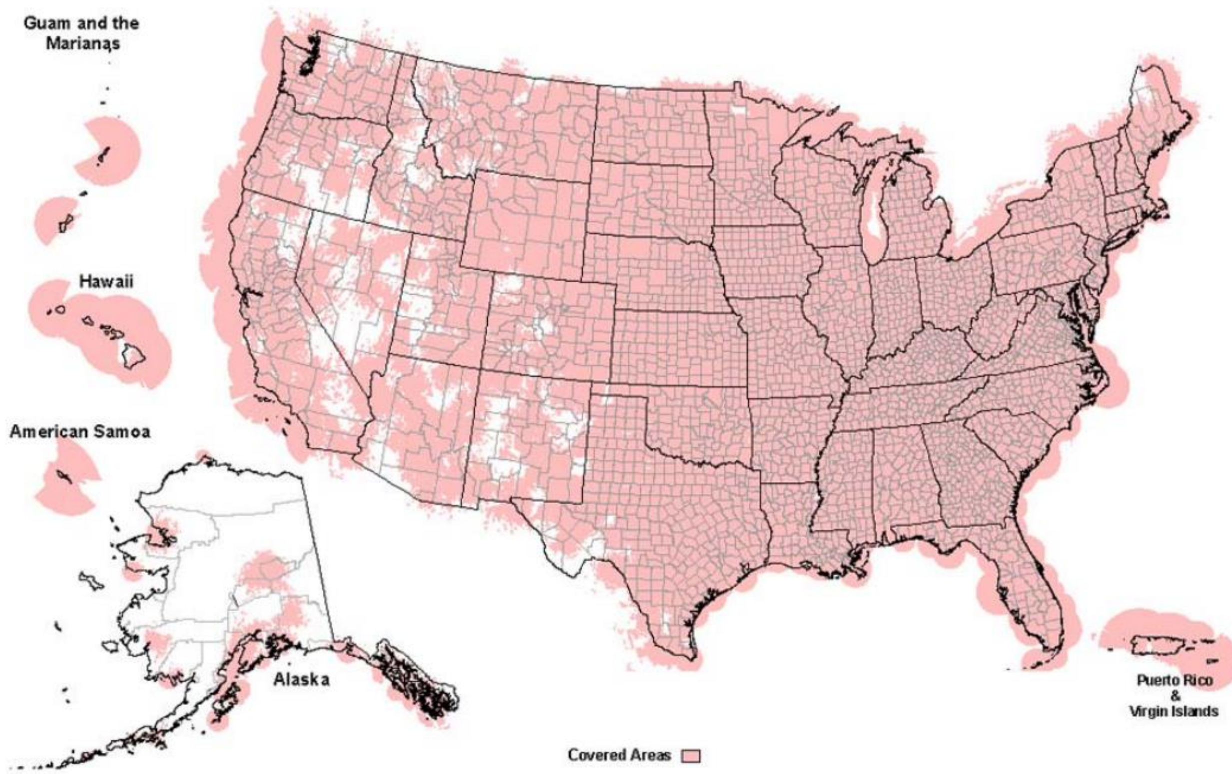
NOAA Weather Radio: NOAA Weather Radio (NWR) is a nationwide network of 1,025 radio stations covering all 50 states, adjacent coastal waters, Puerto Rico, U.S. Virgin Islands, and the U.S. Pacific Territories (see map). NWR broadcasts continuous weather information directly from NWS offices to areas served by those offices. Broadcasts include NWS warnings, watches, forecasts, and other hazard information. Working with the Emergency Alert System, NWR is an "All Hazards" radio network that broadcasts warnings and post-event information for all types of hazards, including natural hazards (e.g., earthquakes, avalanches), environmental hazards (e.g., chemical releases, oil spills), and public safety messages (e.g., AMBER alerts, 911 telephone outages).

All Hazards NOAA Weather Radio
NOAA's National Weather Service

Many retail outlets such as electronics, department, sporting goods, and boat and marine accessory stores and their online catalogs carry NOAA weather radio receivers. NWR broadcasts are found in the VHF public service band at these seven frequencies (MHz): 162.400, 162.425, 162.450, 162.475, 162.500, 162.525, and 162.550.

NOAA Emergency Alert System: The Emergency Alert System (EAS) is the Nation's public warning system. Broadcasters, cable television systems, wireless cable systems, satellite digital audio radio service providers, and direct broadcast satellite providers are required to provide communications capability for the President to address the American public during national emergencies. FEMA is responsible for national-level activation of the system, including tests and exercises.

The EAS is activated most frequently for imminent and dangerous weather conditions. The system is also activated to enable state and local authorities to communicate important non-weather emergency messages, such as AMBER alerts and Civil Emergency Messages. With the exception of national-level activation, it is voluntary for participating radio and television stations to relay the messages.



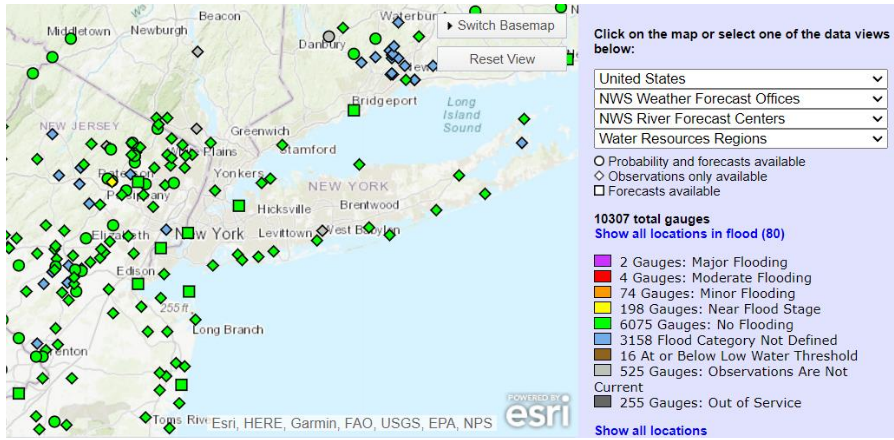
NOAA Weather Radio Covered Areas

NOAA ADVANCED HYDROLOGIC PREDICTION SERVICE

The Advanced Hydrologic Prediction Service (AHPS) is an essential component of the NOAA climate, water, and weather services. AHPS is a web-based suite of accurate and information-rich forecast products that display the magnitude and uncertainty of occurrence of floods or droughts, from hours to days and months in advance of occurrence. The graphical products have useful information used by many economic and emergency managers. These products enable government agencies, private institutions, and individuals to make more informed decisions about risk-based policies and actions to mitigate the dangers posed by floods and droughts.

The NWS AWIPS (described above) uses sophisticated computer models and large amounts of data from many sources such as automated gages, Geostationary Operational Environmental Satellites (GOES), Doppler Radar, and weather observation stations. The system produces hydrologic forecasts for almost 4,000 locations across the U.S. These forecasts are developed by NWS River Forecast Centers and widely distributed.

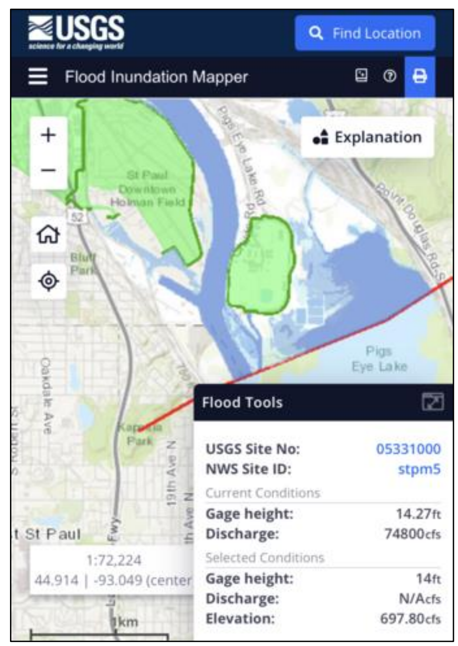
The current set of AHPS products covers forecast periods ranging from hours to months. AHPS yields valuable information about the chances of flood or drought that is presented through user-friendly graphical products. Flood forecasts, including how high a river may rise and when it is likely to reach its peak or crest, are shown through hydrographs. A hydrograph illustrates how water elevations rise and fall over time. Other information produced includes the probability of a river exceeding minor, moderate, or major flood levels; the chance of a river exceeding certain level, volume, and flow of water at specific points on the river during 90-day periods; and a map of areas surrounding the forecast point that provides information about major roads, railways, landmarks, and other features that are likely to be flooded, along with levels of past floods.



Example of stream gage location map showing real-time conditions.

UNITED STATES GEOLOGICAL SURVEY

The **USGS Flood Inundation Mapper (FIM) Program** helps communities protect lives and property by providing tools and information to help them understand their local flood risks and make cost-effective mitigation decisions. The program focuses on partnering with communities to develop flood inundation libraries and provide online access to flood inundation maps along with streamflow data, flood forecasts, and potential loss estimates.



USGS Flood Inundation Mapper during Minor Flooding Level in St. Paul, Minnesota (April 7, 2020).

The flood inundation libraries can be used for:

- Preparedness through development of "what-if" flooding scenarios
- Timely disaster response
- Aiding in damage assessments during flood recovery
- Input data for risk assessments for flood planning and mitigation
- Displaying flood extents based on real-time and forecast information

For more information on the USGS FIM Program, visit: https://www.usgs.gov/mission-areas/water-resources/science/flood-inundation-mapping-fim-program#overview.

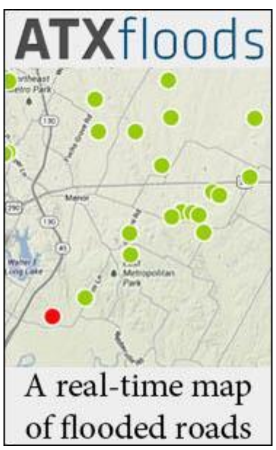
STATE AND LOCAL GOVERNMENTS

Increasingly, state and local government agencies are developing networks of flood gages and inundation mapping programs to augment the NWS and USGS products. These programs use NWS forecasts, gage data, and locally available data to produce flood warnings, alerts, and web-based inundation mapping. Five local programs are described below.

City of New York, NY, FloodNet: FloodNet is a cooperative of communities, researchers, and New York City government agencies working to better understand the frequency, severity, and impacts of flooding in the city. The data and knowledge gained can be used by local residents, researchers, city agencies, and others to advocate around and work to reduce flood risk. FloodNet brings together innovative sources of information on street flooding impacts in neighborhoods that are vulnerable to high tides, storm surge, and stormwater runoff. Real-time flood sensors were developed by the FloodSense project at New York University and the CUNY Advanced Science Research Center. The sensors provide information on the presence, frequency, and depth of hyperlocal street-level flood events to a range of stakeholders, including policymakers, government agencies, citizens, emergency response teams, community advocacy groups, and researchers.

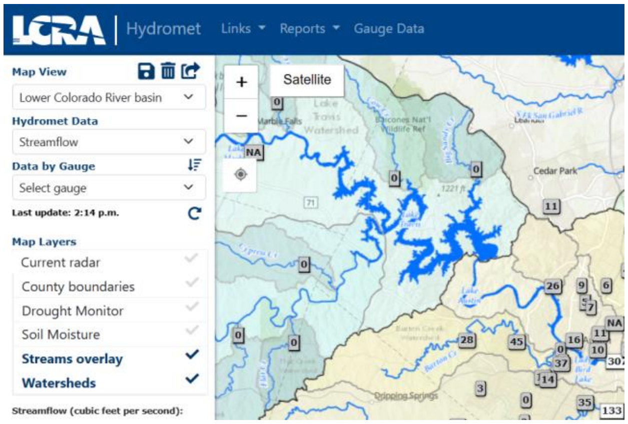
New York City maintains web sites to provide information to residents, property owners, and businesses. FloodHelpNY is a primary source for information about flood risks, flood retrofits, stormwater flooding, and flood insurance. In addition to explaining actions the city takes to plan and prepare for urban flooding, Rainfall Ready NYC is where people can sign up to receive alerts about emergencies, including weather events.

For information about NYC initiatives, visit: https://www.floodnet.nyc/, https://www.floodhelpny.org, https://www.nyc.gov/site/dep/whats-new/rainfall-ready-nyc.page



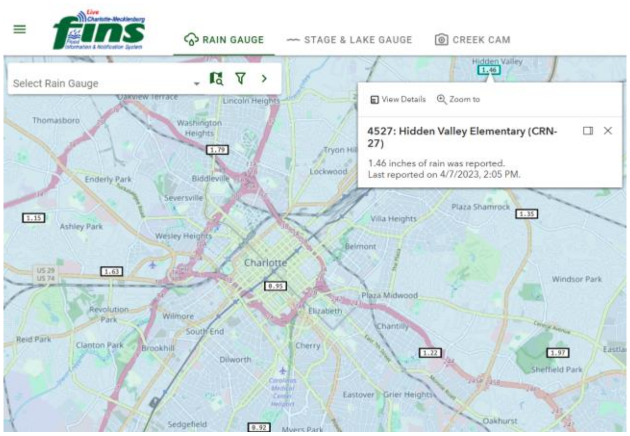
City of Austin, TX, Flood Early Warning System (ATXfloods): ATXfloods, established in 1985, is maintained by the City of Austin Flood Early Warning System team. It was built in large part to monitor flooded roadways in Austin and the eight surrounding counties. The system uses 130 gages and cameras to monitor water levels in creeks and at low-water crossings. Individuals can sign up online to receive flood alerts via email, text message, or phone call. In addition, Austin has placed flashing lights and automated barricades at 15 low-water crossings to prevent motorists from driving into high water.

For more information about ATXfloods, visit: https://www.austintexas.gov/department/flood-early-warning-system



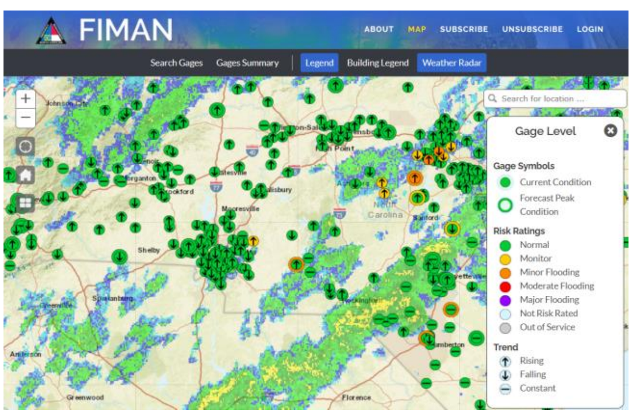
Lower Colorado River Authority Flood Operations Notification Service (LCRA FONS): Because releases from flood control dams on Highland Lakes and Bastrop Dam in Central Texas can cause flash flooding, the Lower Colorado River Authority operates a flood alert system to warn residents living below Lake Austin when flood releases are occurring. Individuals can sign up online to receive flood alerts via email, text message, or phone call when flood operations begin. The notification service supplements NWS warnings. It prompts individuals and businesses to take mitigative action in advance of flooding and to evacuate.

For more information about LCRA FONS, visit: https://www.lcra.org/water/floods/floodgate-operations-notification-system



City of Charlotte, NC, Flood Information and Notification System (FINS): FINS is a partnership involving the City of Charlotte, Mecklenburg County, and the USGS. FINS Live continually monitors real-time rain and stream gage levels along creeks throughout the area. Emergency responders and the public are notified when there is a potential or actual flooding concern.

For more information about FINS, visit: https://finslive.mecklenburgcountync.gov/?gauge=rain&period=PT24H



North Carolina Flood Inundation Mapping and Alert Network (FIMAN): The FIMAN website contains inundation maps for selected sites across North Carolina, as well as along some entire river basins. Flood risk information is provided for areas with inundation maps. For each incremental rise in floodwater, Geographic Information System libraries display pre-developed flood mapping extents. Buildings, roads, and infrastructure that could be impacted are identified. Information on water depth at each affected building is displayed, along with estimated damage costs.

For more information about FIMAN, visit: https://fiman.nc.gov/

How Are Federal Flood Warnings and Inundation Maps Developed?

The NWS is the primary source of water and climate data, and weather forecasts and warnings in the U.S. With 122 Weather Forecast Offices, 13 River Forecast Centers, nine National Centers, and other support offices, the NWS collects and analyzes more than 6.3 billion observations per day, and releases about 1.5 million forecasts and 50,000 warnings each year. Forecasters build their datasets and resulting forecasts with observations from surface stations, weather balloon readings, and satellite data to input to numerical weather, water, and climate models. Forecasters communicate this information and potential impacts to the public, emergency managers, and other key stakeholders to help them make decisions that save lives and protect property.

For more information on NWS forecasts and services, visit: https://www.weather.gov/about/forecastsandservice.

FLOOD WARNINGS

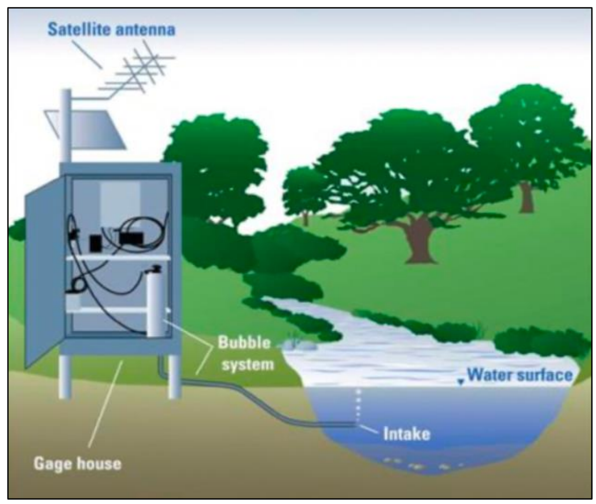
Flood warning systems have three components: data collection, computer modeling using the data, and establishing flooding thresholds for dissemination of flood watches and warnings. Each component is described in more detail below.

Data Collection

The NWS collects weather data from rain gages, stream gages, and remote-sensing sources. A large network of cooperative observers also collects and reports data to NWS.

Rain Gages: Rain gages operated by NWS are usually located at manned sites where local observers check readings daily and perform regular maintenance. The USGS collects precipitation data at about 3,400 locations around the country. About one quarter of the rain gages are co-located with stream gages.

Stream Gages: The USGS collects data from more than 10,000 stream gages nationwide. A stream gage is a structure installed beside a stream or river that contains equipment to measure and record water levels (called gage height or stage) of the stream. Streamflow volume (also called discharge) is computed from measured water levels using a site-specific relationship (called a stage-discharge rating curve) developed from onsite water level and streamflow measurements made by USGS hydrographers.



Typical USGS stream gage installation
Credit: L.S. Coplin, USGS

Remote Sensing Data: In addition to actual measurements taken by rain gages and stream gages, data are collected from national and local Doppler Radar systems and GOES satellite data. These data provide large-scale weather information such as precipitation total estimates and forecasted precipitation.

For more information about USGS water data, visit: https://waterdata.usgs.gov/nwis/rt

Computer Modeling

NOAA uses complex computer models and large amounts of data from a wide variety of sources, including automated gages, satellites, Doppler Radar, weather observation stations, and the computer and communications system called AWIPS. The NWS provides hydrologic forecasts for almost 4,000 locations across the U.S. The forecasts are developed by the NWS River Forecast Centers and distributed by NWS field offices to a range of customers. The computer models provide several products to aid forecasters, including anticipated precipitation (timing and amounts), river and stream hydrograph forecasts (water levels over time), weekly chance of exceeding certain stage and flow levels, and graphical probabilistic forecast guidance.

Communicating Flood Risks to the Public

The NWS uses four flooding thresholds of increasing risk to communicate predicted conditions to the public. The NWS also uses known information at specific locations on certain streams and rivers to signal flood levels and potential impacts to define the level of flooding expected. The levels of flooding are:

- **Bankfull Stage:** When streams and rivers begin to overflow their banks.
- **Action Stage:** When the NWS and others begin monitoring flood levels and begin mitigative actions.
- **Flood Stage:** When flooding begins to pose risks to life, property, and commerce.
- **Minor Flood Level:** When flooding is occurring, but there is no anticipated building damage or more than minor overtopping of roads.
- **Moderate Flood Level:** When floodwater is inundating buildings and roads near the stream or river and evacuation and moving property to higher ground may be needed. When this level is reached, the NWS issues Flood Warnings.
- **Major Flood Level: When** flooding is causing extensive inundation of buildings and roads. Significant evacuations and emergency actions may be needed.

1 FLOOD WATCHES

Issued when conditions are favorable for flooding to occur.

2 FLOOD ADVISORIES

Issued when flooding is expected, and caution is needed to avoid threats to life and property.

3 FLOOD WARNINGS

Issued when flooding is imminent or already occurring.

4 FLASH FLOOD WARNINGS

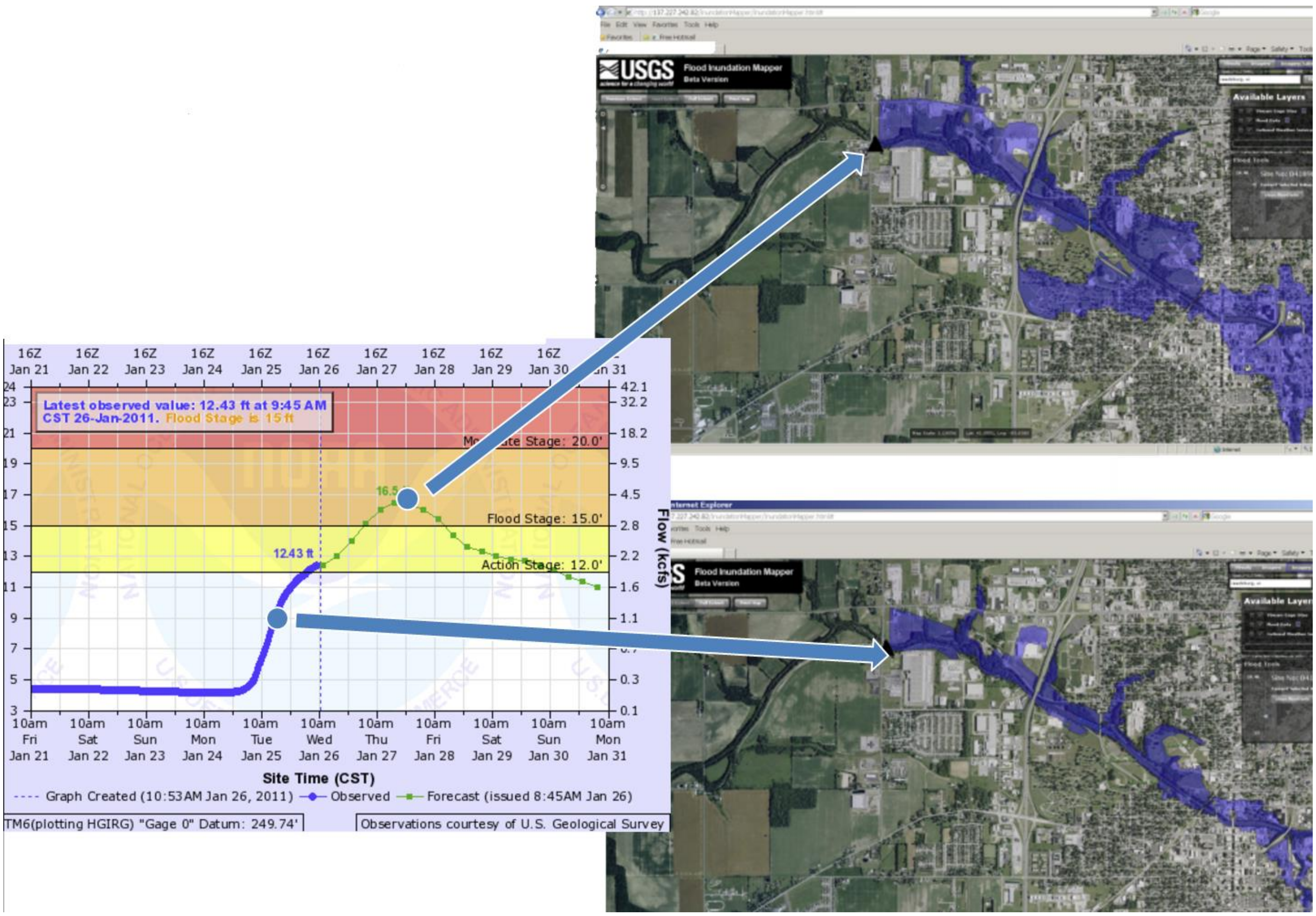
Issued when a flash flood is imminent or already occurring.

FLOOD INUNDATION MAPPING

According to the USGS, several agencies and partners develop flood inundation mapping products and systems to provide the geographic context of flooding. Flood inundation mapping systems use hydrologic and hydraulic models to map different flood levels. This is often created as a “library” of flooding extents that illustrate areas predicted to be impacted by flood levels of different severity, usually in equal increments such as every foot of water above a level established at a nearby stream gage. To allow users to easily view at-risk areas in relation to known landmarks, the maps of flooding extents are combined with other GIS layers, including aerial photography, street and road networks, building locations, and topography.

In online applications, the library of flooding extents is displayed based on input from gage readings or from flood peak forecasts. The NWS image below shows the correlation of a flood level from a USGS gage hydrograph (lower image) and a forecasted flood peak (upper image). The combination of the gage reading, flood forecast, the flood “libraries,” and GIS layers allows the flooding to be depicted spatially and, as shown in the example, users can see buildings and infrastructure that are in the mapped flood extent.

For more information on USGS Stream Gage Hydrographs and Inundation Mapping, visit: https://water.weather.gov/ahps/



USGS Stream Gage Hydrograph and Inundation Mapping

For More Information

Local officials should contact their state emergency management agency, state or regional water resources departments, and their local NWS office to learn more about flood warning and inundation mapping systems. To learn what resources may be available in your community, citizens should contact their local emergency management office or their community's floodplain administrator.

For More Information

See the FEMA Building Science Frequently Asked Questions at https://www.fema.gov/emergency-managers/risk-management/building-science/faq.

Send questions on FEMA Building Science Publications to FEMA-Buildingsciencehelp@fema.dhs.gov or call 866-927-2104.

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Scan the QR code to visit the Building Science Branch of the Risk Management Directorate in the FEMA Federal Insurance and Mitigation Administration at https://www.fema.gov/building-science.

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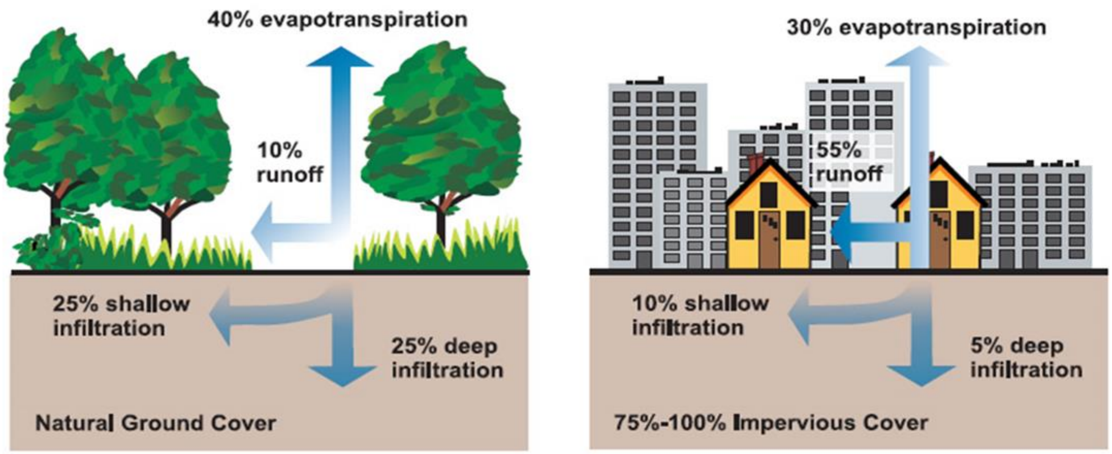
Understanding Stormwater Runoff in Highly Urbanized Areas

This fact sheet explains stormwater runoff, stormwater drainage systems, and ways communities manage runoff and reduce the impacts of urban flooding. The stormwater runoff from increasingly intense storms can overwhelm urban drainage systems, causing extensive flooding and widespread damage, injuries, and loss of life.

What is the Connection Between Surface Runoff and Stormwater Drainage Systems?

Stormwater or surface runoff is a component of the Earth's water cycle. Precipitation falls and either seeps into the ground or flows along the surface of the ground. If it seeps into the ground below the top layers of soil, groundwater aquifers may be replenished. In urbanized areas, surface runoff first collects in stormwater drainage systems, brooks, streams, and rivers, then flows to ponds, lakes, and the ocean. Water evaporates from the ground and those bodies of water. Trees, grass, and other vegetation also take water from the soil and transpire it to the atmosphere. In the atmosphere, the water condenses and forms clouds. Precipitation falls from clouds to the Earth's surface, continuing the water cycle.

Most of the rain that falls on areas with buildings, streets, parking lots, sidewalks, and other paved surfaces runs off more quickly than the rain that falls on parks, gardens, green spaces, forests, and farmland. In cities and highly urbanized areas, the runoff collects in urban stormwater drainage systems.



Source: Federal Interagency Stream Restoration Working Group

Relationship between impervious cover and surface runoff

FEMA

How is a Storm Defined?

Storms are typically identified based on wind velocity, rain intensity, duration, and the area impacted. Agencies such as the National Oceanic and Atmospheric Administration (NOAA) use other factors, including barometric pressure, to indicate the potential severity of storms. Federal, state, and local agencies use storm characteristics to indicate potential property damage and to encourage people in affected areas to be prepared, to take precautions for safety, to anticipate flooding and high winds. The NOAA National Hurricane Center uses the Saffir-Simpson Hurricane Wind Scale to classify the severity of winds and storm surge flooding produced by tropical storms and hurricanes.

Storms are also classified in terms of recurrence intervals. A recurrence interval is the expected time between occurrences of a storm of a particular severity. The probability or chance of a storm of a certain magnitude occurring in any given year is the inverse of the recurrence interval. The lower the probability or chance of occurrence, the more severe the storm. Statistical probability statements may create misunderstandings. In reality, a storm event of any magnitude may occur every year, or even multiple times in one year. Depending on state and local requirements, engineers use the following probabilities (and associated recurrence intervals) for various purposes, including designing urban stormwater systems and evaluating whether existing systems have adequate capacity to carry anticipated rainfall runoff amounts:

- 100-percent chance of occurring in a year (1-year storm)
- 20-percent chance of occurring in a year (5-year storm)
- 10-percent chance of occurring in a year (10-year storm)
- 1-percent chance of occurring in a year (100-year storm)
- 0.2-percent chance of occurring in a year (500-year storm)

What is the Recent History of Significant Rainfall Amounts for New York City?

The NOAA National Centers for Environmental Information reports that the average annual precipitation for the New York City urban area is 47 inches of rainfall, plus 25 inches of snow. Over the past decade, the time of year and amount of rainfall for the maximum 1-day totals have varied significantly (see table). On September 1, 2021, Hurricane Ida produced the most significant daily total amount of rain (7.13 inches) and the most intense hourly rate of rainfall (3.15 inches per hour).

Maximum Daily Total Rainfall Amounts in New York City from 2010 to 2021
(Source: Current Results – Weather and Science Facts)

Date of Storm	Inches	Date of Storm	Inches
March 13, 2010	3.86	January 23, 2016	2.31
August 14, 2011	5.81	October 29, 2017	3.03
April 22, 2012	2.45	August 11, 2018	2.90
June 7. 2013	4.16	October 16, 2019	1.83
April 30, 2014	4.97	July 10, 2020	2.54
January 18, 2015	2.10	September 1, 2021	7.13

What is a Stormwater Drainage System?

Communities build stormwater drainage systems, sometimes called stormwater sewer systems, to collect and convey surface runoff. Doing this minimizes local flooding which can disrupt traffic, damage buildings, and damage personal and public property. Drainage system components include curbs and gutters, drainage swales and ditches, inlets where water flows into catch basins, and below-ground stormwater pipes. The whole system is intended to carry rainfall runoff and snow melt to a stream, river, tidal body of water, or treatment plant. Some cities and urban areas use rain gardens, stormwater ponds, special paving materials, and other features to help runoff soak into the ground instead of flowing to their stormwater drainage systems.

When stormwater drainage systems are sized to carry anticipated runoff from frequent storms, the adverse impacts on traffic, buildings, and people are minimized. To function properly, drainage systems must be maintained. Communities need to inspect their systems, remove debris and leaves, clean out catch basins and stormwater pipes, and make repairs to keep the system working properly.

When older stormwater drainage systems were designed to carry smaller amounts of runoff, or if they are poorly maintained, they may not be able to handle the runoff from increasingly intense rainfall events. As a result, streets flood, soil and plantings wash away, and water may get into buildings, especially buildings with basements, cellars, and below-grade areas. The resulting accumulation of floodwater can damage walls, flooring, furnaces, appliances, furnishings, and personal property. Buildings with basements may be at a high risk of flooding if they are not protected from storm drain backup through floor drains, or if surface runoff can flow into the below-grade areas. Stormwater seeks the easiest path to enter buildings, which may be through foundation cracks, windows and vents that are close to the ground, exterior stairways, and driveways. Depending on how long water is able to enter, some basements may completely fill.

As urban stormwater drainage systems get older, they may not work as well as originally designed, especially if not maintained. Plus, as storms get more intense and rainfall amounts increase due to climate change, there will be more runoff water than some systems can convey. Having more buildings and impervious paving increases the amount of surface water runoff, and as rainfall runoff volumes increase, the drainage systems may not be able to handle the flows.

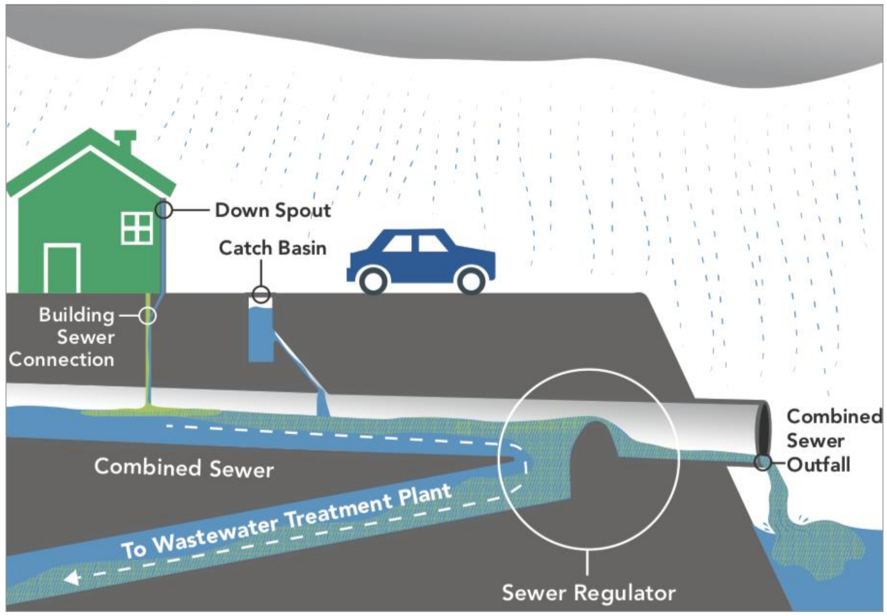
How do Combined Sewer Systems Work?

Combined sewer systems are designed to carry flows from sanitary sewers and stormwater runoff. They convey the flows to wastewater treatment plants, where cleanup occurs. During normal rainfall events, well-maintained combined sewer systems function effectively. However, during extreme rainfall events, the conveyance system is built with bypass locations that allow the flows to be discharged into receiving streams, rivers, or tidal waters without treatment. These discharge points are identified as combined sewer outfalls. They are governed by

Source: NYC Department of Environmental Protection regulations on water quality treatment. Some parts of many highly urbanized areas, including New York City, have combined sewer systems.

Heavy stormwater runoff can trigger combined sewer systems to surcharge. Surcharges occur when the amount of wastewater is too much for the system to carry. When surcharges occur, wastewater backs up in the system. Surcharges can lead to performance failures during extreme rainfall events, resulting in:

- Surcharged sanitary sewers, which may create backup flows that enter the plumbing systems of buildings.
- Lift station and pump station capacity may be reduced or pump systems may fail and lose power.



Schematic of combined sewer system (NYC DEP)

What Happens When Rainfall Runoff Exceeds the Capacity of a Stormwater System?

Intense rainfall can trigger various conditions depending on the capacity of the stormwater drainage system to carry runoff. That capacity is defined in terms of the drainage system design standards in use at the time the system components were constructed. It is not unusual to find older systems that have less capacity to carry increased rainfall runoff as more intense storms occur. While most urban stormwater drainage systems handle flows under normal rainfall, they may not have adequate capacity to function under intense rainfall. The result is urban flooding.

> **Urban Flooding**
>
> The inundation of property in a built environment, particularly in more densely populated areas. Urban flooding may be caused by rainfall that runs off large amounts of impervious surfaces and overwhelms the capacity of stormwater drainage systems.

There are many ways that urban flooding increases hazards and damage:

- Surcharged stormwater systems
  - Pressure on the pipe network can damage components
  - Shifted manhole covers are risks to people on sidewalks and streets
- Sanitary backflow from combined sewer systems
  - Backs up into buildings, especially basements and below-grade spaces, through plumbing fixtures and floor drains
  - Environmental damage when sewage flows into streams, rivers, and tidal waters

- Building damage:
  - Basement wall and floor cracking and failures
  - Damaged machinery, equipment, contents, and finishes
  - Utility failures
- Building occupant hazards:
  - Basement and lowest floor flooding can trap people
  - Health problems caused by mold, bacteria, and pollutants carried by floodwater
- Street and road hazards:
  - Risks to drivers if cars hydroplane on wet streets or when moving water pushes cars off roads
  - Washed out roadbeds where the erosion of culverts or underlying soils is enough to affect roadbed integrity (undermining), creating failures such as potholes, sinkholes, and shoulder collapse
  - Bridge failures caused by erosion and scouring of the soil adjacent to a pier or abutment, resulting in instability and potential collapse

How do Communities Regulate Storm Drainage Performance Standards?

Communities throughout the United States establish requirements for their stormwater drainage systems. The requirements account for the impact of property use in the community, whether areas are densely developed with large amounts of impervious areas or less intensely developed. More heavily developed areas have larger volumes of stormwater runoff flows to their stormwater systems.

Typically, stormwater design requirements set limits on the conditions allowed for projects, both redevelopment projects and new developments. The minimum standards usually are based on flow rates, velocity controls, and local benchmarks, such as how much increased runoff is allowed under certain conditions. Impermeable surfaces prevent the infiltration of rainfall, increase pollutant levels in the runoff, increase rainfall runoff which can cause erosion, increase urban flooding, and create flood hazards downstream. Flooding and erosion are primary impacts if runoff is not managed as development changes the characteristics of the land.

Many cities use the 5-year storm (20 percent chance of occurring in any given year) to determine the volume of rainfall runoff, and others use the 10-year storm (10 percent chance of occurring in any given year). Over time, many cities have changed their design standards to accommodate the increasing frequency and intensity of storms. In New York City, the standard design criterion for new and replacement stormwater drainage systems is the intensity-duration values for the 5-year storm (equivalent to 1.75 inches of rain in 1 hour). Engineers evaluate the amount of rainfall runoff generated when that amount of rain occurs. That volume of water is then used to plan the number of catch basin inlets and to calculate the size of the sewer pipes needed to manage stormwater.

What Strategies and Actions Can Reduce the Impacts of Urban Flooding?

Strategies evaluated by cities to manage stormwater infrastructure balance what is a practical performance or design standard and what would be needed to manage flows from extreme rain events. Each community that decides to reduce the impacts of urban flooding will seek a balance between costs and benefits as they set performance standards for their stormwater infrastructure.

Cities consider a range of methods to control peak runoff rates, reduce pollutant flows, and effectively manage runoff volume. Failure to address these objectives can lead to negative impacts on the overall stormwater drainage system. Managing the peak runoff rate is critical to reduce the erosive impacts that can lead to failure of other drainage system components and natural systems. Limiting pollutants in the flow contributes to the overall environmental quality of the receiving streams, rivers, and ocean. Managing runoff volume reduces the occurrence of surcharging of the system (exceeding the system capacity).

Managing existing stormwater drainage systems to optimize both capacity and the ability to protect people and property is important in the long term. The foundation is an asset management system that identifies all components and allows local officials to monitor maintenance needs. With a management system in place, secondary steps can be effectively addressed to sustain the performance and extend the life of the system components. Communities can take a number of actions to maintain and improve their stormwater drainage systems, including:

- Cleaning and maintaining components on a regular schedule and checking known problem areas after significant storms
- Replacing damaged components and upgrading undersized portions, based on a risk assessment that considers age, material, and projected useful life of the components
- Expanding or adding catch basin inlets to eliminate spot flooding where the underground conveyance system can handle additional flows
- Increasing the size of pipes to improve capacity, starting downstream in a conveyance line to avoid creating new constraints in flow
- Increasing infiltration using tools such as green infrastructure
- Increasing upstream detention capacity to reduce velocity and flow rates

Many cities develop strategies to increase infiltration and retain or reuse stormwater runoff to reduce the negative impacts of urban flooding. Over the past several decades, many communities have preserved or increased the amount of green space which soaks up runoff from buildings and impervious surfaces. Tree canopy, greenways, rain gardens, and other natural systems (often referred to as “green infrastructure”) are key practices used to reduce urban flooding.

Cities use many of the green infrastructure best practices described in the table below. An introduction to types of green infrastructure used in New York City is online at https://www.nyc.gov/site/dep/water/types-of-green-infrastructure.page.

Green Infrastructure Practices Can Reduce Rainfall Runoff by Improving Infiltration

Practice	Description of Practice	Example
Bio-retention Areas (also called Rain Gardens and Porous Landscape Detention)	A low-lying vegetated area is underlain by a sand bed with an underdrain pipe. A shallow surcharge volume exists above the bio-retention area, for temporary storage of runoff. During storms, the accumulated runoff ponds in the vegetated area and gradually infiltrates the sand bed. The underdrain gradually dewaters the sand bed, discharging the runoff to a nearby channel or stormwater drain.	 Streetside rain gardens (NYC)
Tree Box Filters	A concrete box with a soil medium filtration system for trees. Runoff is collected and retained, then filtered through the vegetation and soil. The water is then either consumed by the tree or flows to the stormwater drainage system.	 Along sidewalks, streets, or parking lots (U.S. Environmental Protection Agency)
Infiltration Basins	A basin below a grassed or concrete surface that collects stormwater. Openings in the basin walls allow water to flow to an underlying stone layer. The water then infiltrates into the ground.	 Infiltration basin below concrete sidewalk (NYC)

Practice	Description of Practice	Example
Bioswales	A vegetated channel to collect and convey runoff. Its underground components store, filter, and infiltrate stormwater. Bioswales typically are planted with dense grasses over a layer of sand, a layer of gravel, and an underdrain pipe.	 Alternative to gutters, pipes, and ditches (Fairfax County, VA)
Permeable Pavements	Open graded asphalt or concrete, with reduced fine material and special binder, allows for the rapid through-flow of water. Stormwater runoff flows through voids between the aggregate and into the ground. Paver blocks also are used to make permeable paving surfaces. An aggregate sub-base is installed below that surface to filter and store runoff. “Grass-blocks” let grass grow in spaces formed in concrete pavers.	 Permeable paving allows infiltration (NYC)
Green Roofs	Green roofs can be installed on new or existing buildings, even some gently sloping roofs. They can use either a layered soil system or a modular system in which plants are pre-grown. Green roof plants should be hardy, self-sustaining, and drought resistant. A lightweight soil mix is used to reduce the structural load on the roof. Roofs that are designed to handle snow loads are usually suitable for a green roof.	 Green roofs absorb and retain rainwater (Fairfax County, VA)

Practice	Description of Practice	Example
Blue Roofs	Blue roofs are designed to detain stormwater without vegetation. Roof drain inlets are modified to allow rain to pond on the roof and be gradually released.	 Blue roofs detain rainwater (NYC)
Rain Barrels	Rain barrels catch and store stormwater from building roofs. The water can be used to water gardens, trees, and lawns.	 Rain barrels store roof runoff (U.S. Environmental Protection Agaency)
Bluebelts	A New York City initiative, the Bluebelt program reduces runoff to lower peak flow demand on the stormwater drainage system. Projects may involve catch basins and underground drains. Runoff is directed to wetland areas where it is naturally filtered.	 Sweet Brook Bluebelt (NYC)
Cloudburst Management	A New York City initiative, cloudburst management uses a combination of methods to absorb, store, and transfer stormwater to minimize flooding. It combines “grey” infrastructure, like pipes and underground tanks, and green infrastructure techniques. Some projects include amenities and open spaces for public use.	 Planned sunken basketball court (NYC)

How Can Communities Inform the Public About Urban Flooding?

One of the biggest challenges communities have when managing stormwater drainage systems is to gain community support to invest in the inventory, modeling, repair, replacement, rehabilitation, and maintenance of the conveyance and treatment components. Stormwater systems are “silent” infrastructure, usually out of sight and unnoticed until it rains. In extreme rain events that damage property, citizens and business owners ask a lot of questions about why and how the flooding occurred. Educating the public about stormwater is an ongoing challenge because the post-storm urgency and focus on stormwater must compete with many other important services delivered by communities.

Communities that develop outreach tools and techniques using common terms and language can effectively share basic need-to-know facts, engaging their target audience through clear, correct, concise, and complete information. It is best to avoid jargon and acronyms, and use simple concepts and words that translate easily into other languages. Reaching people where they live and work encourages a partnership in learning. This improves the usefulness of the information for the end user. Many communities build on neighborhood resources to reach the broadest audience.

Urban flooding can cause safety risks and damage buildings, personal property, and vehicles. When cities determine those risks are present, they may include the following messages in their public outreach initiatives:

- Preventive measures protect life and property from damage by urban flooding, with an important target audience of those who live in basements. People have drowned when trapped in flooded basements.
- Encourage everyone to recognize the risks when urban flooding occurs, including homeowners, renters, businesses, community centers, public transport users, daycare operators, and schools.
- Evacuation procedures and early warning signs, with an emphasis on preplanning safe routes from homes, schools, businesses, transportation systems, and churches. Families can identify a reporting location so each member will know where and how to obtain shelter.
- Key messages for all:
  - Have an emergency plan and kit. State emergency management agencies sponsor campaigns to encourage families and businesses to prepare for emergencies. New York City’s comprehensive initiative is online at https://www.nyc.gov/site/em/ready/ready-new-york.page.
  - Connect to emergency notification systems.
  - Follow the evacuation advice of emergency officials.
  - Be aware of local weather conditions before leaving home, and when driving or walking.
  - Do not walk or drive through floodwater. “Turn around, don’t drown!” is the National Weather Service safety campaign, online at https://www.weather.gov/safety/flood-turn-around-dont-drown.

Hurricane Ida NYC MAT Fact Sheet 1 describes what building owners and tenants should know about urban flooding and what they can do to minimize problems, especially if they know that stormwater runoff has flooded their buildings in the past.

- Begin to clean up as soon as floodwater recedes and it is safe to enter buildings. Follow the guidance from local and public safety officials, especially to learn how to pump water out of basements without causing more damage to basement walls.

For More Information

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Considering Policies and Regulations to Reduce Risks Caused by Urban Flooding

Remnants of Hurricane Ida caused significant urban flooding and damage in New York City in September 2021. This fact sheet summarizes the recommendations from technical reports FEMA prepared after that event. Communities use different mechanisms to put recommendations into practice. They may adopt new policies or adjust existing ones. Depending on the nature of a recommendation, communities may adopt new regulations or amend existing ones.

Hurricane Ida in New York City

During Hurricane Ida, heavy rainfall overwhelmed the stormwater drainage systems in many areas. Surface water accumulated in streets and low-lying areas throughout New York City, causing significant urban flooding in Queens, Brooklyn, the Bronx, and Staten Island. In some areas, floodwater entered and damaged homes and multi-family buildings with below-grade areas and basements. New York City reported 13 fatalities attributed to the flooding, including 11 people who were trapped in flooded basements.

FEMA Hurricane Ida New York City Mitigation Assessment Team Technical Reports

As part of the Federal Emergency Management Agency response to significant urban flooding and damage resulting from Hurricane Ida, the FEMA Building Science Disaster Support program deployed a Mitigation Assessment Team (MAT) to assess damage. FEMA publishes reports to document what MATs observe and recommend. Table 1 summarizes the MAT's three technical reports for this event.

FEMA

Table 1. Summary of Three NYC MAT Technical Reports

Hurricane Ida Technical Reports	*Summary*
Report 1: Building Performance: Basement Buildings and Urban Flooding	Technical Report 1 provides information to help New York City and similar urban areas prepare better for future urban flooding events. The information is also useful for property owners, building managers, and design professionals. The report offers a number of recommendations to improve the performance of buildings with floodprone basements and the safety of their occupants.
Report 2: Building Performance: Egress from Floodprone Basements	Technical Report 2 describes the MAT's observations related to the egress of occupants from basements flooded when the capacity of stormwater drainage systems is exceeded. It briefly summarizes some of New York City's requirements for building egress and emergency access. The report makes recommendations to improve the safety of occupants in floodprone basements and options to improve egress from floodprone basements.
Report 3: Reducing the Effects of Urban Flooding in New York City	Technical Report 3 explains the basics of rainfall runoff, urban flooding, and stormwater drainage systems. It summarizes some of New York City's stormwater infrastructure programs and its initiatives to address urban flooding.
Download the Hurricane Ida NYC FEMA technical reports and fact sheets at: FEMA P-2333, 2023. New York City: Effects of Hurricane Ida	

Tools to Put Recommendations into Practice: Policies and Regulations

Communities can put recommendations into action by adopting new policies or adjusting existing ones. Depending on the nature of a recommendation, communities may adopt new regulations or amend existing ones.

POLICIES

In general, policies are statements of intent, guidelines, and directions for implementing objectives. Policies may interpret statutory or regulatory requirements and state how a community will fulfill those requirements. They do not impose legally enforceable requirements. Some policies might be framed as standard operating procedures and practices. They are followed to be consistent in implementing requirements. Examples of community policies include:

- **Comprehensive Plans:** Comprehensive plans are used by communities to express long-term objectives related to growth and development.

- **Resolutions:** Elected bodies often pass resolutions to establish policy, and sometimes to set objectives that community staff can pursue within existing authorities.

- **Multi-Hazard Mitigation Plans:** Communities develop multi-hazard mitigation plans to identify hazards, assess risks, and evaluate strategies and actions to mitigate risks. The plans satisfy federal requirements for certain types of disaster assistance and grants for mitigation projects. The actions and activities described in these plans include policies. Examples of policy actions include exploring grant funding opportunities, executing public information initiatives, obtaining better information about risks, and studying alternatives to reduce specific risks associated with a hazard.

- **Stormwater Master Plans and Stormwater Design Manuals:** Stormwater master plans developed by communities typically examine flooding problems caused by rainfall runoff that exceeds the capacity of existing stormwater drainage systems. Design manuals outline how the community and developers can design measures to manage rainfall runoff when required by stormwater management regulations. Examples of policy actions that may be identified in plans include finding drainage solutions through existing public works authority and budget, and establishing incentives for developers to use green infrastructure measures.

REGULATIONS

Government regulations establish rules and mandates, typically to impose requirements on the public. The types of regulated activities and the action a person or entity proposes usually determine whether that person or entity must comply with the requirements. Examples of regulations include:

- **Building Codes:** Building codes specify how buildings and structures must be designed and constructed to provide reasonable levels of safety, public health, and general welfare. Fire codes, which may be separate, specify requirements specific to fire safety and emergency preparedness.

- **Housing Maintenance Codes;** Housing maintenance codes typically set minimum standards for health and safety, fire protection, light and ventilation, cleanliness, repair, and maintenance to protect tenants. Enforcing these minimum standards preserves safe housing, minimizes deterioration of housing, and improves living conditions.

- **Stormwater Management Regulations:** These regulations usually specify which property owners and developers must manage increases in rainfall runoff caused by proposed changes to the land. These changes include construction of buildings and impervious surfaces, such as parking lots and driveways.

Putting Recommendations into Practice Through Policies and Regulations

The Hurricane Ida NYC MAT technical reports include FEMA's recommendations based on the MAT's observations and evaluation of a number of relevant New York City codes, programs, and initiatives. The recommendations address the safety of occupants in floodprone basements and ways to improve the performance of buildings with floodprone basements and below-grade areas. Some recommendations suggest actions for building owners. Others suggest actions for New York City.

New York City will determine which recommendations may warrant taking action. Action by the city may be to adopt or modify one or more policies and programs. Some actions may require adoption or amendment of regulations and building codes. Table 2 summarizes the recommendations in Technical Reports 1, 2, and 3. Table 2 also indicates whether a recommendation might be put into practice by policy or regulation. If the city decides that any of these actions are appropriate to pursue, it will also determine the appropriate mechanism.

Table 2. FEMA Hurricane Ida MAT Recommendations: Options to Put into Practice

Source	*Summary of Recommendations*	*Policy*	*Regulation*
Technical Report 1	Recommendation 1. Water Sensors in Basements. Require or encourage owners of buildings with floodprone basements to install water sensors that are integrated with sump pump systems to warn occupants and emergency responders when water levels exceed the capacity of the pump.	Yes	Yes
Technical Report 1	Recommendation 2. Risks of Unreinforced Basement Walls. Identify one- and two-family homes with basements and cellars that were constructed before building codes required reinforced foundation walls and foundation drainage. Inform owners and occupants of the risk of basement flooding and foundation wall collapse if exposed to urban flooding.	Yes	No
Technical Report 1	Recommendation 3. Safely Pumping Floodwater from Basements. Develop guidance and messaging to let building owners know how to safely pump floodwater from basements without risking structural damage.	Yes	No
Technical Report 1	Recommendation 4. Encourage Building Owners to Act. Evaluate options to encourage building owners to improve the performance of buildings with basements that are known to be prone to urban flooding. Some options include:	Yes	No

Source	*Summary of Recommendations*	*Policy*	*Regulation*
	▪ Develop messaging and a checklist for owners and managers to evaluate their buildings to decide whether to engage qualified professionals for more detailed inspections and assessments. ▪ Develop training for building managers and design professionals to conduct inspections and identify feasible mitigation options. ▪ Encourage design professionals and dry floodproofing special inspectors to learn how to evaluate buildings and identify mitigation options. ▪ Consider providing financial assistance to owners of buildings in areas prone to surface flooding to have evaluations performed and implement feasible mitigation options.		
Technical Report 1	Recommendation 5. Evaluate and Mitigate Risks to Basements and Below-Grade Areas. Owners of buildings with floodprone basements should consider feasible options to keep surface flooding out and mitigate damage. Options include: ▪ Permanently raise the lowest points of entry for surface water. ▪ Reinforce basement walls, or fill in basements, of homes with unreinforced concrete or masonry basement walls. ▪ Obtain temporary barriers and develop emergency implementation plans to deploy the barriers to block points of entry. ▪ Raise critical components of mechanical systems above basement floors and relocate electrical systems to higher locations. ▪ Use materials that resist flood damage for basement interiors.	Yes	No
Technical Report 1	Recommendation 6. Retrofit Dry Floodproofing. Some buildings in areas where surface water has entered basements and below-grade areas may be candidates for retrofit dry floodproofing measures. These measures should be designed for site-specific conditions. Owners should be aware that dry floodproofing measures can fail or may be overtopped if water rises higher than the depths used for design. Failure is likely if the measures are not maintained or if those who are responsible are not adequately trained to deploy measures that require action.	No	No
Technical Report 2	Recommendation 1. Communication with Basement Occupants. Focus messages to occupants of floodprone basements, tailor messages for delivery through NotifyNYC and the NYC Alerts 911 system, and continue to encourage residents to sign up to receive alerts.	Yes	No
Technical Report 2	Recommendation 2. Augment Inspections of Illegal Conversions. Add a flood vulnerability element to the potentially hazardous conditions that the NYC Quality of Life Unit checks in response to complaints of illegal conversions of dwelling units in basements and cellars that are known to be prone to surface flooding and when the buildings are in FEMA-mapped floodplains.	Yes	No

Source	*Summary of Recommendations*	*Policy*	*Regulation*
Technical Report 2	Recommendation 3. Examine Options to Improve Egress From Floodprone Basements. Develop guidance for building owners to examine their buildings with floodprone basements to determine appropriate ways for occupants to leave when emergency conditions are expected. The guidance for multiple family buildings should encourage owners to identify spaces where basement occupants can shelter. For one- and two-family dwellings, the guidance should advise occupants to evacuate to safe locations when warnings are issued. Consider whether to require owners to perform this examination. Specific building characteristics will determine whether one or more options to improve emergency egress are feasible. Options that may be feasible include: ▪ Provide interior routes to the first floor of multiple family buildings. ▪ Replace existing small or fixed basement windows with windows that open and are large and accessible enough for occupants to be able to climb out. ▪ Modify doors that lead to exterior basement stairs or driveway ramps when the doors open outward by installing small “blow-out” panels near the bottom of doors. ▪ Install water sensors that are integrated with sump pump systems to warn occupants and emergency responders when water levels exceed the capacity of the pump. ▪ Explore the feasibility of installing wireless speakers in the common areas of multiple family buildings with floodprone basements, to broadcast warnings.	Yes	Yes
Technical Report 2	Recommendation 4. Supplement Assessments for Buildings with Floodprone Basements. The in-home assessments offered by the NYC Department of Housing Preservation and Development should be supplemented include information for owners of buildings with basements in areas known to experience urban flooding. Consider supplementing the inspections conducted when complaints of illegal conversions of basements and cellars are submitted or violations are observed.	Yes	No
Technical Report 2	Recommendation 5. Require Permanent Posting of Emergency Information. Rather than posting emergency information temporarily, the NYC Housing Maintenance Code should require owners of residential buildings to post permanent notices. The notices should be required when buildings with basements are in FEMA-mapped floodplains and areas known to be prone to surface flooding.	No	Yes
Technical Report 2	Recommendation 6. Supplement Fire Protection and Emergency Preparedness Plans and Notices. Develop example language to address flood emergencies for inclusion in fire protection and emergency preparedness plans and notices required to be posted in buildings with multiple dwelling units, especially for buildings with occupied basements	Yes	Yes

Source	*Summary of Recommendations*	*Policy*	*Regulation*
	in FEMA-mapped floodplains and areas known to be prone to surface flooding.		
Technical Report 3	Reinforces recommendations in Technical Reports 1 and 2 that the city should evaluate options to encourage or require building owners to act to reduce risks of flooding of occupied basements.	Yes	Yes

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