# Building Performance: Basement Buildings and Urban Flooding

Hurricane Ida NYC MAT Technical Report 1

June 2023 (Revised May 2025)

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**

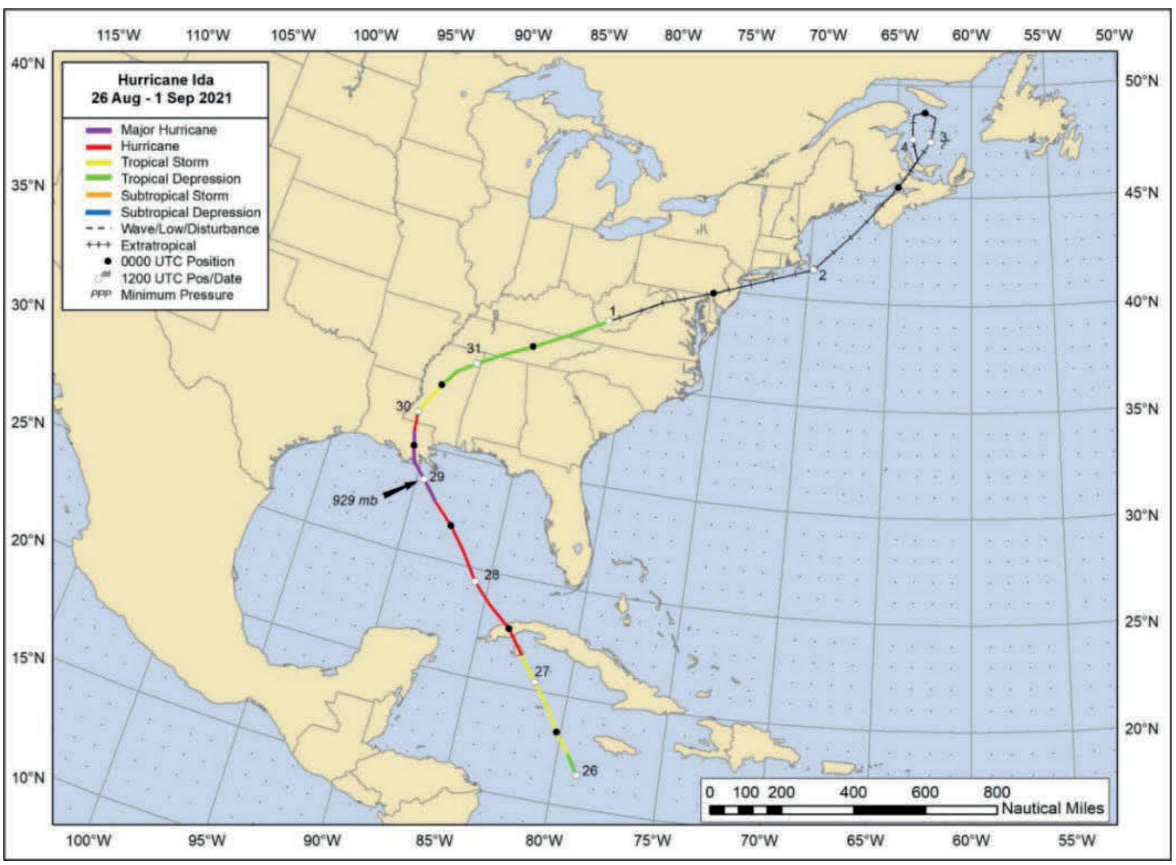
## 1.2. Hurricane Ida in New York City

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.

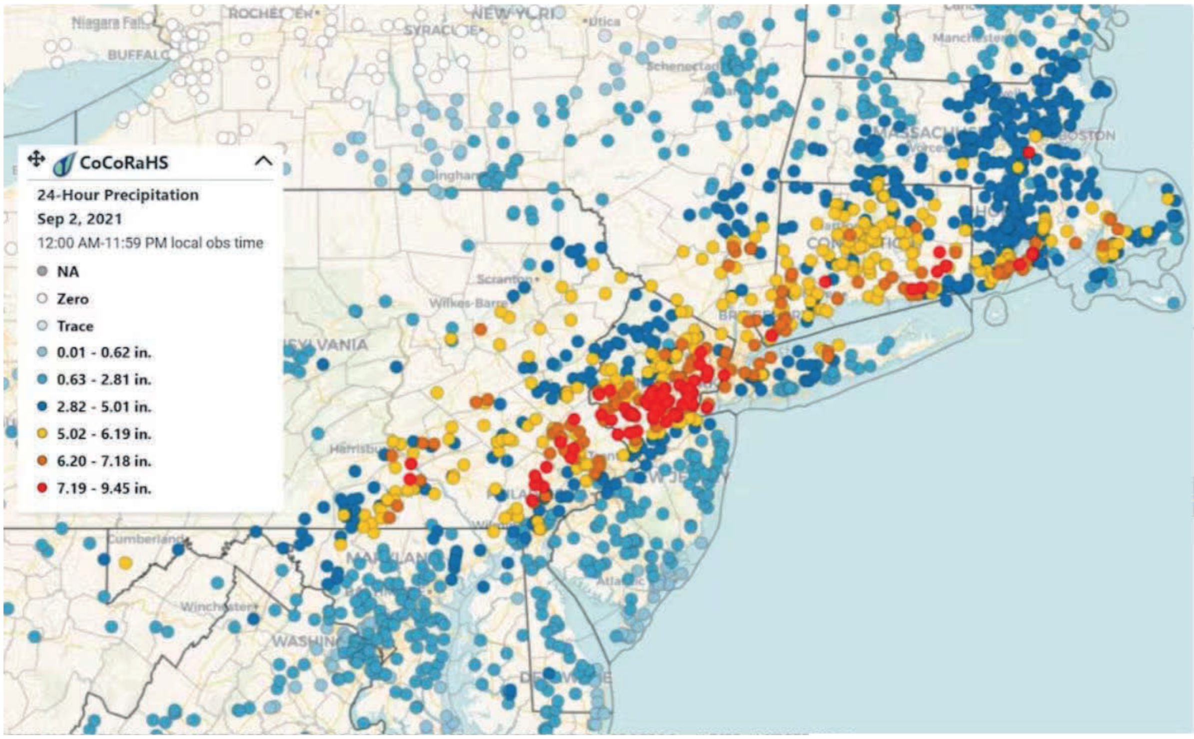
During the storm, the peak rainfall intensity in Central Park was 3.15 inches per hour, with a total of 7.13 inches of rain over a 24-hour period. It is important to note that the region was saturated because of heavy rainfall from the remnants of Tropical Storm Elsa in July, and Tropical Storm Fred 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**

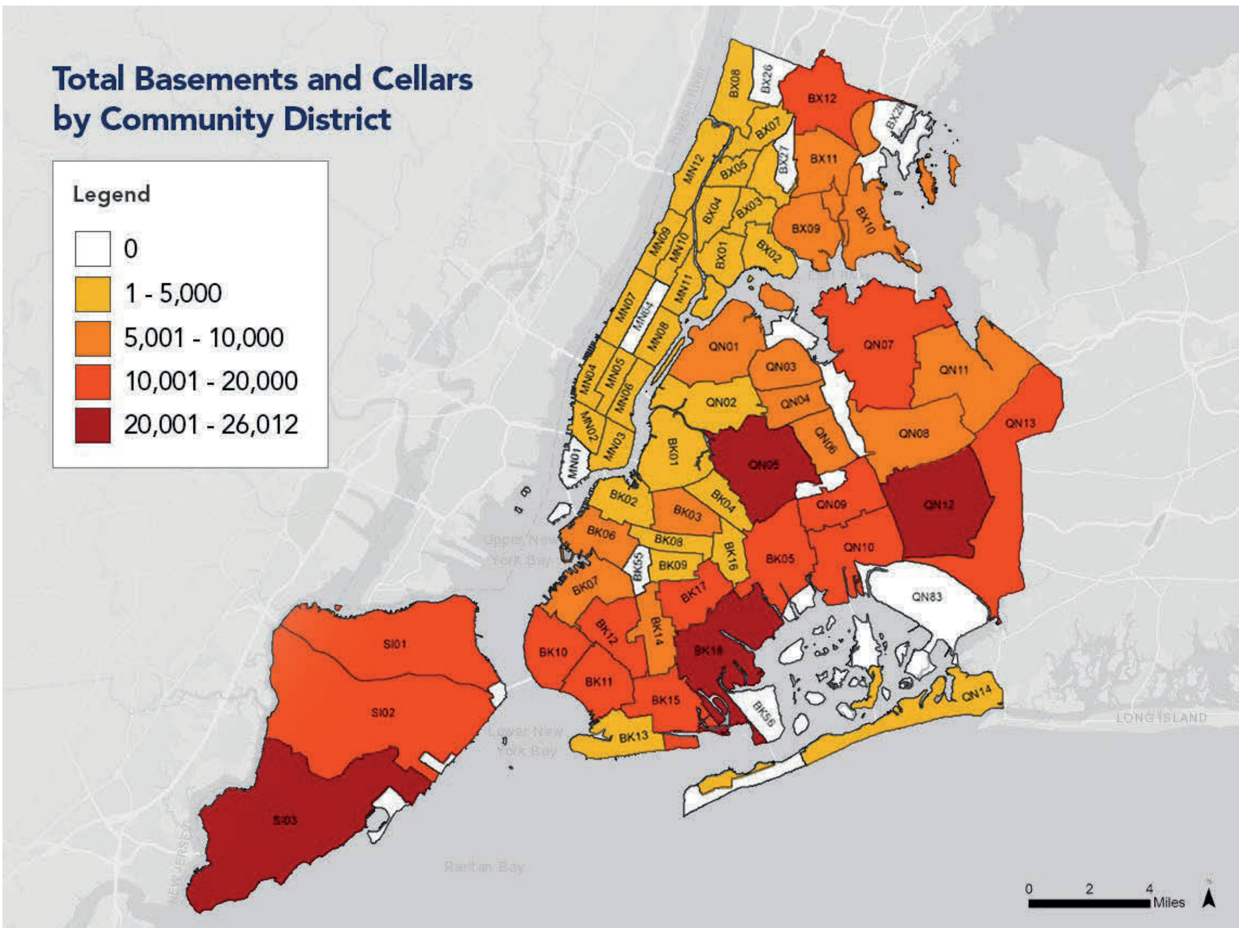
In some areas where the rainfall runoff exceeded the capacity of the stormwater drainage system, water flowed toward buildings, entering the basements, cellars, and below-grade spaces of numerous homes, multi-family buildings, and commercial buildings. The city generally does not allow dwelling units 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, 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-2333), 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.

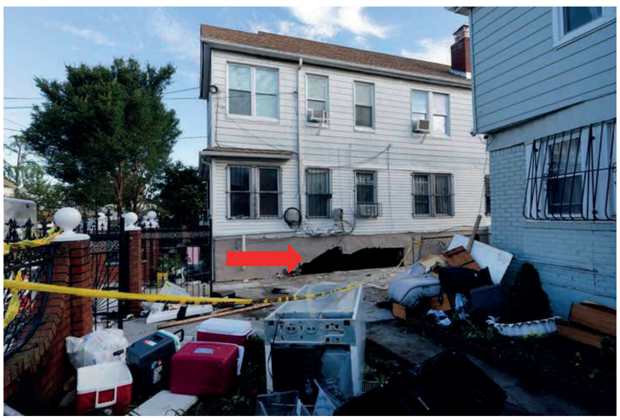


**Figure 10. Failure of unreinforced masonry foundation wall at single-family home in Queens. Arrows point to a large opening in the foundation wall, as seen from the outside and inside of the building.**

*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-2333), 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, future conditions, 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-2333), 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-2333), 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.

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