In the Lower Manhattan Financial District Post-Sandy

Credit: Alexius Tan

# Sandy and Its Impacts

## 43 deaths… 6,500 patients evacuated from hospitals and nursing homes… Nearly 90,000 buildings in the inundation zone… 1.1 million New York City children unable to attend school for a week… close to 2 million people without power… 11 million travelers affected daily… $19 billion in damage…

By any measure, Sandy was an unprecedented event for New York City. Never in its recorded history had the city experienced a storm of this size. Never had a storm caused so much damage. Never had a storm affected so many lives. As of the writing of this report, individuals, families, businesses, institutions, and, in some ways, the city itself are still recovering from this devastating natural disaster and will continue to do so for years.

As it turns out, it took an improbable set of factors coming together in exactly the worst way to give rise to the catastrophic impacts of this storm. (*See sidebar: A Brief History of Sandy*)

There was, for example, the storm's timing. Its arrival on the evening of October 29 coincided almost exactly with high tide on the Atlantic Ocean and in New York Harbor (high tide arrived at the Battery in Lower Manhattan at 8:54 p.m., and the surge peaked there at 9:24 p.m.). This meant that water levels along much of the city's southern coastline already were elevated, with typical high tides about five feet higher than water levels at low tide. And, on the night of Sandy's arrival, it was not just a normal high tide but a "spring" tide, when the moon was full and the tide was at the very peak of its monthly cycle—generally up to half a foot higher than the average high tide. (*See maps: Water Levels Around New York City on October 29*)

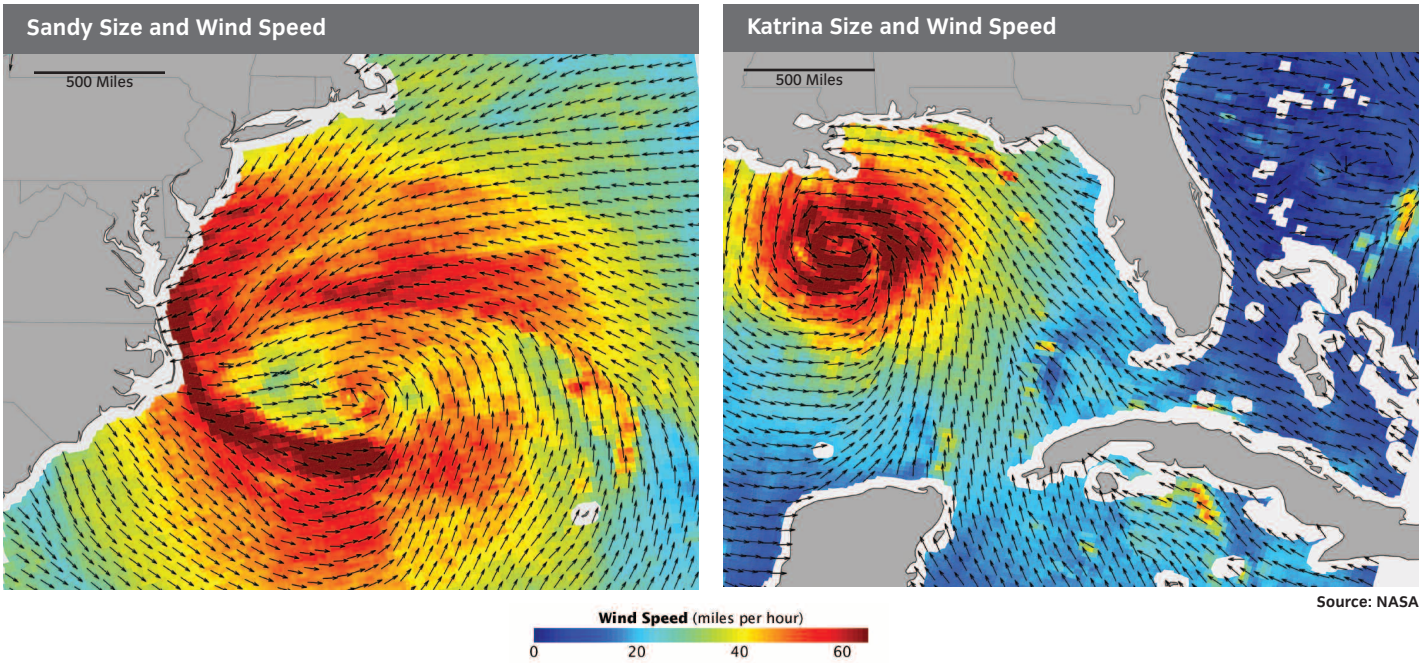
Then there was the storm's size. When Sandy made landfall, its tropical-storm-force winds extended 1,000 miles from end to end, making it more than three times the size of Hurricane Katrina. Storm size—the area over which strong winds blow—correlates closely with storm surge, the rise in water level caused by the storm's low pressure and the force of its winds pushing against the water. (*See graphic: Sandy Size and Wind Speed; see graphic: Katrina Size and Wind Speed*)

Because Sandy was such a massive storm, it generated a massive surge. And that surge, coming on top of the spring high tide, created a "storm tide" of over 14 feet above Mean Lower Low Water at the Battery, shattering the previous record of 10 feet, set when Hurricane Donna arrived in New York in 1960. (*See chart: High Water Events at Lower Manhattan*)

Finally, there was the unusual path Sandy took to the city's shores. Most hurricanes that approach the Northeast glance the coastline or curve east and head out to sea before they ever reach New York. But as Sandy came spinning north along the east coast of the United States, winds spiraling counterclockwise, the storm encountered weather systems that caused it to take a different course—one that would spell disaster for parts of the city. A high-pressure system to the north blocked the storm's advance. At the same time, a low-pressure system that was pushing eastward towards the Atlantic coast energized the storm and reeled it in. Steered between these two systems, Sandy made a westward turn—and headed straight for land just as it was increasing in intensity. At 7:30 p.m. on October 29, 2012, Sandy slammed into New Jersey head-on, seven miles north of Atlantic City, with maximum winds of 80 miles per hour.

The storm's angle of approach put New York City in the path of the storm's onshore winds, the worst possible place to be. The winds earlier that day had been blowing in a generally southward direction in the New York area. However, as Sandy arrived, its winds shifted, instead moving in a generally northwesterly direction. It was this shift that helped push the storm's massive surge—and its large, battering waves—directly at the south-facing parts of the city.

As a result of all of these factors, Sandy hit New York with punishing force. Its surge and waves battered the city's coastline along the Atlantic Ocean and Lower New York Bay, striking with particular ferocity in neighborhoods across South Queens, Southern Brooklyn, and the East and South Shores of Staten Island, destroying homes and other buildings and damaging critical infrastructure. Meanwhile, the natural topography of the city's coastline channeled the storm surge that was arriving from




Source: NASA

# A Brief History of Sandy

Sandy was no ordinary hurricane. It was a meteorological event of colossal size and impact. It was a convergence of a number of weather systems that came together in a way that was disastrous for the New York area.

Sandy, however, began innocently enough—far from New York and almost three weeks before its arrival on the area's shores. It was October 11, late in the Atlantic hurricane season, when a tropical wave formed off the west coast of Africa. By October 22, the wave had evolved into a weather system in the Caribbean called Tropical Storm Sandy, the 18th named storm of the 2012 hurricane season. (*See map: Sandy Storm Path*)

A tropical storm is a cyclone—a system of clouds and thunderstorms rotating around a central "eye"—that originates in tropical waters and gets its energy from those warm waters. Sandy gained wind speed as it curled north. By October 24, it was a hurricane—a storm with wind speeds of at least 74 miles per hour (mph)—with an eye visible on satellite images. Sandy made landfall on Jamaica on October 24 as a Category 1 hurricane then intensified to a Category 3 hurricane before hitting Cuba on October 25, according to the National Hurricane Center.

While the storm moved across the Bahamas, it weakened to a Category 1 hurricane—but began to grow significantly in size. It continued to grow as it traveled north of the islands. After passing the Bahamas, Sandy turned northeast, beginning its trek through the Atlantic Ocean, paralleling the eastern coast of the United States. Its winds whirled counterclockwise, raising water levels all the way from Florida to Maine.

Although most hurricanes on a northward track along the US coast continue to hug the coast or eventually curve east and out to sea before they reach New York, Sandy encountered two other weather systems that caused it to shift direction and abruptly intensify yet again. One was a high-pressure system to the north that blocked Sandy's northward advance. The other was a low-pressure system pushing eastward over the southeastern United States that reenergized Sandy. Steered between these two weather systems, Sandy turned sharply west just as it was reaching another peak of intensity.

When Sandy made landfall in Brigantine, New Jersey, just north of Atlantic City, at 7:30 p.m. on October 29 with 80-mph winds, it was technically no longer a hurricane. Two-and-a-half hours before it had made landfall, the National Hurricane Center had reclassified Sandy as a "post-tropical cyclone" because the storm had evolved in such a way that it no longer possessed the technical characteristics of a hurricane: It lacked strong thunderstorm activity near its center; its energy did not come from warm ocean waters but from the jet stream; and it had lost its eye.

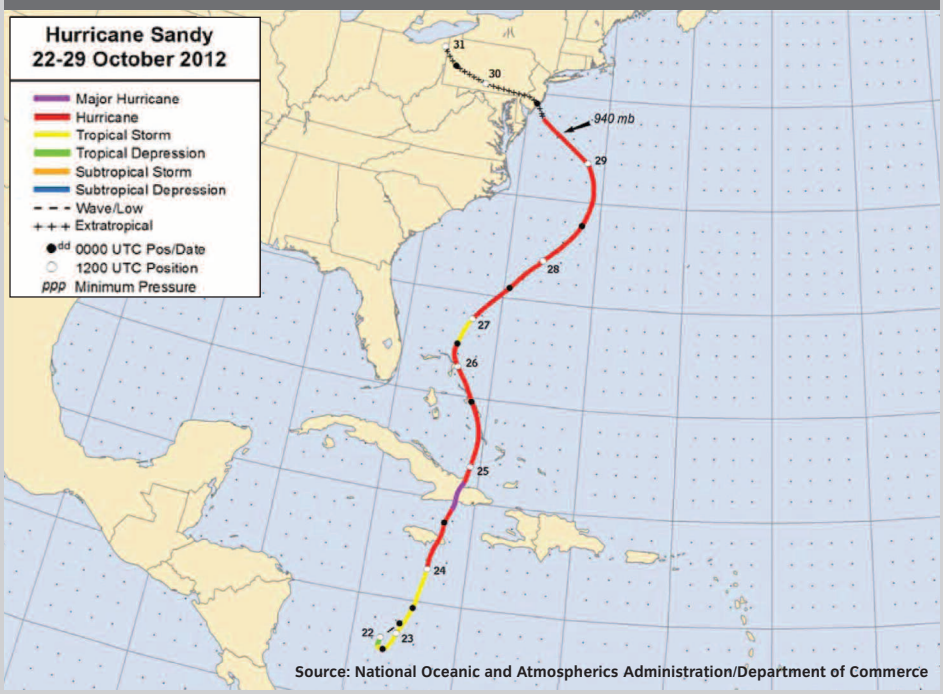
No matter what Sandy was called, though, the storm never lost its large wind field or its large radius of maximum wind (which is why weather experts still considered it a "hurricane strike" when it hit the New York region). In fact, when the storm made landfall, its tropical-storm-force winds extended 1,000 miles—three times that of a typical hurricane. It was those winds, as well as the storm's low pressure, that were responsible for its catastrophic storm surge.

The storm's angle of approach was also significant. Because Sandy came at the coast of New York at a perpendicular angle, its counterclockwise onshore winds drove the surge—and the surge's large, battering waves—directly into the city's coastline.

After landfall, Sandy slowed and weakened while moving through southern New Jersey, northern Delaware, and southern Pennsylvania. It finally lost its defined center while passing over northeastern Ohio late on October 31. For the next day or two, what remained of Sandy continued over Ontario, Canada before merging with a low-pressure area over eastern Canada and heading out to sea for good.

At that point, of course, New York still was reeling from the storm's effects—and was only beginning to cope with the extent of the damage.

**Sandy Storm Path**




Source: National Oceanic and Atmospherics Administration/Department of Commerce

## Sandy by the Numbers

**Sandy made landfall three times:** at Bull Bay, Jamaica, on October 24; at Santiago de Cuba, Cuba, on October 25; and finally at Brigantine, New Jersey, on October 29

**The storm's wind speed was 80 mph at landfall** in New Jersey.

**Its wind field extended for 1,000 miles.**

**In the US, $50 billion in total damages have been attributed to the storm**, making it more costly than any other storm except Hurricane Andrew in 1992 and Hurricane Katrina in 2005.

the ocean northward into New York Harbor, elevating water levels in Jamaica, Sheepshead, Gravesend, and Gowanus Bays, as well as in Upper New York Harbor and the East and Hudson Rivers. At the same time, the storm surge also was pushing water into Long Island Sound, and from there south.

In short, the ocean fed bays, the bays fed rivers, the rivers fed inlets and creeks. Water rose up over beaches, boardwalks, and bulkheads. It was an onslaught of water.

In total, a staggering 51 square miles of New York City flooded—17 percent of the city's total land mass. The floodplain boundaries on the flood maps from the Federal Emergency Management Agency (FEMA) in effect when Sandy hit had indicated that 33 square miles of New York City might be inundated during a so-called "100-year" flood, or the kind of flood estimated to have only a 1 percent chance of occurring in any given year. However, Sandy's storm tide caused flooding that exceeded the 100-year floodplain boundaries by 53 percent citywide. In Queens, the area Sandy flooded was almost twice as large as the floodplain area indicated on the maps. In Brooklyn, the area that flooded was more than twice as large as the floodplain. In certain communities, flooded areas were several times the size of the floodplains on FEMA maps. (*See map: Sandy Inundation*)

The urban character of New York City magnified the impact of the flooding. More than 443,000 New Yorkers were living in the areas that Sandy flooded when the storm struck. In all, 88,700 buildings were in this inundation zone—buildings containing more than 300,000 homes and approximately 23,400 businesses. Much of the city's critical infrastructure also was within flooded areas—including hospitals and nursing homes, key power facilities, many elements of the city's transportation networks, and all of the city's wastewater treatment plants.

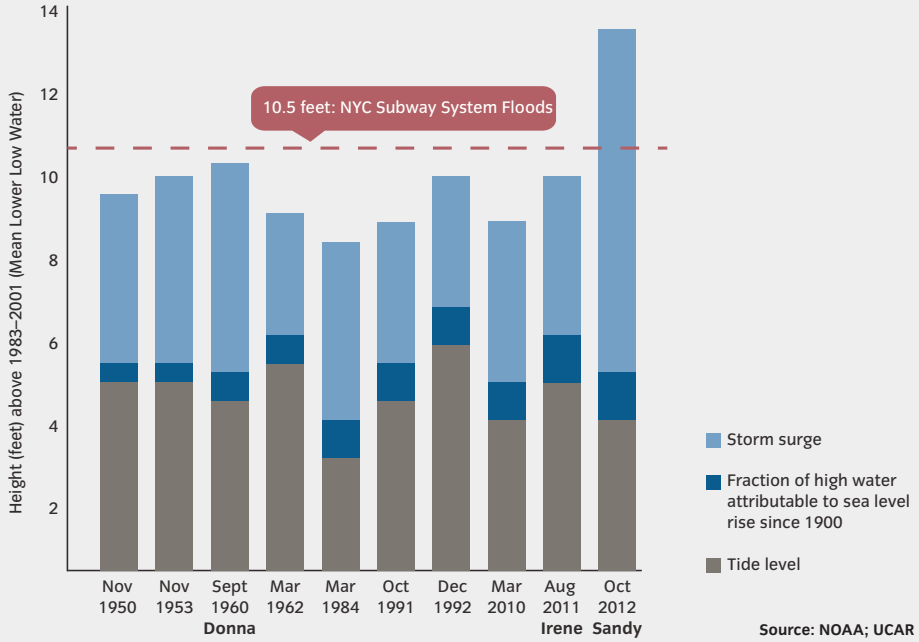
In many places, it was not only the extent of flooding that was significant; it was also the depth of floodwaters. Water heights of several feet above ground level were prevalent in many coastal areas. Near Sea Gate, on the Coney Island peninsula in Brooklyn, the water reached 11 feet above ground level, and at Tottenville on Staten Island, they rose to 14 feet.

Many storms have hit New York with higher winds than Sandy's 80-mile-per-hour peak wind gusts. Many storms have brought more rain than the half inch that Sandy dropped in parts of New York. However, Sandy's storm surge—and the devastation it caused—was unlike anything seen before. The surge, and the flooding and waves that came with it, had an enormous impact on the city.

## Sandy's Impact on New York

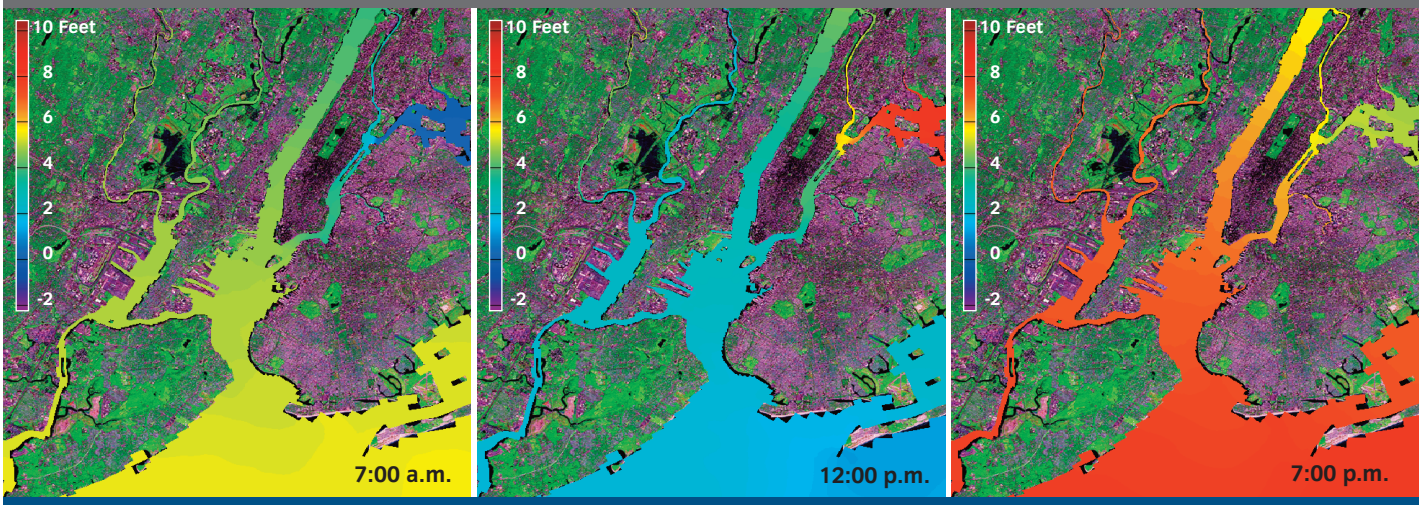
Any catalogue of the woes that Sandy brought to New York City must start with the tragic deaths of 43 people, the vast majority of whom perished from drowning in areas where waters rose rapidly as a result of the surge. Of these deaths, 23 occurred in Staten Island (including

**High-Water Events in Lower Manhattan**




Source: NOAA; UCAR

**Water Levels Around New York City on October 29**




**Tidal cycles are different in different parts of the Harbor—with lower water levels in Long Island Sound coinciding with higher levels in the Lower and Upper New York Bay and vice versa. On the evening of October 29th, just before the arrival of Sandy's surge, the tidal cycle was bringing higher tides to the City's south and lower tides to its north.**

Source: CMS at Stevens Institute of Technology

10 in the neighborhood of Midland Beach alone), with the remainder spread throughout Queens, Brooklyn, and Manhattan. The storm took an especially high toll on the young and old, with victims ranging from a 2-year-old boy to a man and a woman aged 90.

In other cases, the storm spared lives, but still turned them upside down. It destroyed homes that families had tended to over generations (of the hundreds destroyed or determined to be structurally unsound by the Department of Buildings (DOB), with over 60 percent in Queens and almost 30 percent in Staten Island). It impacted many businesses that New Yorkers had started from scratch (not just those in Sandy's inundation area, but 70,000 in areas that lost power during the storm). In some cases, it severely affected those with the fewest resources to draw on—residents of public housing developments, for example, since many of these developments are located on the coastline and were thus particularly vulnerable to extreme weather events. More than 400 New York City Housing Authority buildings containing approximately 35,000 housing units lost power, heat, or hot water during Sandy.

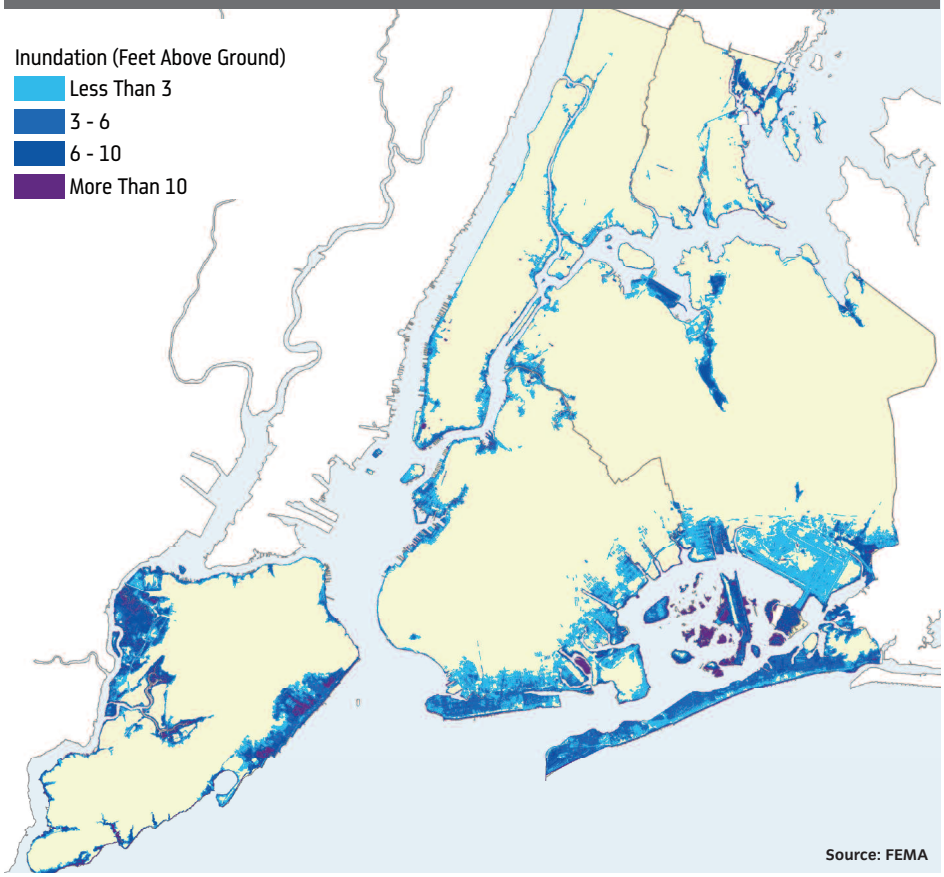
Meanwhile, facilities and services that are crucial to the well-being of all New Yorkers fully or partially shut down for the duration of the storm, and in some cases, for long periods afterwards. Disruptions to some systems (such as power) affected the functioning of others (healthcare, transportation, and telecommunications, among others). The trials of some communities (flooding and power outages in hubs like Southern Manhattan) created tribulations for others (those living elsewhere who could not work because their offices could not open). The storm was a reminder of how interconnected the city's systems are.

It also highlighted significant vulnerabilities in many of these systems and in certain geographic areas of the city. Below are brief summaries of some of the major impacts of the storm on the city's coastline, buildings, infrastructure, and selected neighborhoods. Further information, analysis, and initiatives can be found in the relevant chapters of the report.

**Coastline and Waterfront Infrastructure**

During Sandy, the coastline of the southern half of the city felt the full force of the storm. Ocean-facing areas generally experienced the destructive impact of waves reported to be 12 feet or more, along with flooding, while other coastal areas experienced only flooding, though the damage from that flooding was still serious and long-lasting.

**Sandy Inundation**




Although barges and other "floating" infrastructure played a key role in the city's recovery from Sandy, damage to "fixed" waterfront infrastructure was extensive. The storm damaged boardwalks, landings, and terminals. Waves and retreating waters caused coastal erosion, with New York's beaches losing up to 3 million cubic yards of sand or more citywide, including 1.5 million cubic yards on the Rockaway Peninsula alone.

Though the storm surge generally devastated areas that it touched, the city's nourished beaches, dunes, and bulkheads did help to mitigate its impact, particularly where these protections were combined to form multilayered defenses.

*For more on coastal protection, see Chapter 3.*

**Buildings**

Building damage from Sandy was widespread and in many cases severe. In some areas, storm surge and rising floodwaters pushed houses right off their foundations or caused walls to collapse. Elsewhere, floodwaters filled basements and ruined electrical and other building systems, as well as personal possessions. As of December 2012, DOB had tagged nearly 800 buildings as having been structurally damaged or destroyed across the five boroughs, with tens of thousands more impacted, including buildings containing nearly 70,000 housing units that were registered with FEMA and determined to have sustained some level of damage. Over 100 of the lost homes and businesses were destroyed by storm-related fires, which were often electrical in nature, caused largely by the interaction of electricity and seawater.

Overall, there were several predictors of how the storm impacted New York's building stock. Some of these predictors related to the characteristics of the inundation that buildings faced. Not surprisingly, shoreline areas that experienced the strong lateral forces of waves had many more damaged buildings than areas with still-water flooding only. Other predictors related to a building's physical characteristics (such as building height and construction type) as well as age, which, in turn, determined the regulations in force when the building was constructed. Overall, older, 1-story, light-frame buildings suffered the most severe structural damage—representing just 18 percent of the buildings in the areas inundated by Sandy, but 73 percent of all buildings tagged as structurally damaged or destroyed by DOB as of December 2012.

Although high-rise buildings did not generally experience as much structural damage, they

Boardwalk damage in the Rockaways

Credit: Daniel Avila/NYC Parks

often lost mechanical building equipment housed in basements, rendering buildings uninhabitable and leaving residents stranded on upper floors and businesses closed until repairs could be made.

*For more on buildings, see Chapter 4.*

**Insurance**

For many New Yorkers, insurance issues have compounded the problem of building damage from Sandy, with the extensive flood damage from the storm focusing attention on flood insurance. Most large commercial properties obtain insurance, including flood insurance, through the private market. Although most homeowners in New York City have homeowners insurance, these policies typically do not cover flood damage, and homeowners and small business owners seeking flood coverage generally purchase policies through the National Flood Insurance Program (NFIP), which is administered by FEMA.

When Sandy struck, however, most New York City property owners affected by the storm did not have adequate flood insurance—or any flood insurance at all. This was the case for a variety of reasons. For example, more than half of all buildings and about half of the residential units in the area flooded by Sandy were outside of FEMA's 100-year floodplain—so the owners of these buildings were probably unaware of the risks that they faced and, at any rate, were not required by the terms of their mortgages to have flood insurance (since Federally backed mortgages require such coverage only for buildings in the 100-year floodplain). Even among those in the floodplain, many were not insured for flood damage (less than 50 percent of residential buildings in the pre-Sandy 100-year floodplain had flood insurance). This was either because they did not comply with, and their mortgage lenders did not enforce, the terms of their mortgages (about one-third of residential buildings with Federally backed mortgages in New York when Sandy hit did not have flood insurance), or because they did not have mortgages in the first place. Meanwhile, in many cases, those who were insured discovered, after Sandy, that they were not covered for certain losses, such as damages in basements.

Going forward, premiums in the private insurance market may increase in the near term, particularly in flood-prone areas, but the private insurance market overall, despite large losses from Sandy, is expected to remain competitive, with signs, as of the writing of this report, that the market may already be stabilizing. Because of reforms to the NFIP enacted before Sandy, however, property owners insured by the NFIP are likely to see large and permanent increases in flood insurance premiums—unless changes to the NFIP are enacted.

*For more on insurance, see Chapter 5.*

**Utilities**

Sandy dealt a serious blow to the city's utilities—particularly its electric utilities, due in part to the fact that some of the most important utility infrastructure is on the waterfront. Close to 2 million people lost power at some point during the storm, with almost a third of these customers in Manhattan. In fact, parts of Lower Manhattan and Brooklyn even lost power prior to Sandy, when Con Edison preemptively disconnected them from the city's grid to protect equipment and reduce potential downtime. Almost all areas south of the Empire State Building followed when floodwaters inundated several of the city's substations in Southern Manhattan. On Staten Island and in the Rockaways, meanwhile, 120,000 customers lost power due to substation damage, while all around the city, strong winds took down overhead lines, affecting another 390,000 customers.

Generally, damaged substations were repaired quickly, with power restored to most customers in Manhattan, for example, within four to five days. Repairing damage to the whole overhead system, though, took almost two weeks, even with the help of thousands of utility workers from other states. Damage to electrical equipment within buildings took considerably longer in many cases, leaving some places in the Rockaways and other hard-hit areas without power or heat for weeks as crews of electricians and plumbers, many of them sent by the City free of charge as part of its Rapid Repairs program, went door-to-door to check and repair equipment.

Other utility systems experienced varying degrees of disruption. Con Edison's steam system, which services 1,700 large buildings in Manhattan, including major hospitals, was unable to supply steam to one-third of its customers when the storm inundated four of the system's six plants and flooded utility tunnels. It took nearly two weeks to restore service to these customers.

The natural gas system generally performed better, although 84,000 customers lost service, mostly in Brooklyn, where National Grid shut off gas valves close to the coast to isolate flooded pipes from the rest of its distribution system. Within hard-hit areas, each affected customer had to be checked by plumbers before service was restored, which took several weeks.

*For more on utilities, see Chapter 6.*

**Liquid Fuels**

For many New York City drivers, the post-storm period might have brought back memories of the oil crises of the 1970s. For days and weeks, long lines were the norm at gas stations that still had fuel. Although initial reports suggested that stations primarily closed because they did not have the power to pump gas, in fact over 90 percent of the city's gas stations were outside of the areas of the city that experienced widespread power outages. Instead, the real problem was that the stations had no gas to pump. This was due to severe breakdowns in the supply chain serving New York caused by

storm damage to fragile infrastructure in New Jersey and on the New York City waterfront.

The storm shut down refineries for several weeks, stopped marine and pipeline deliveries for three to four days, and damaged storage terminals. As a result, for four days after the storm, the system received no new supply, and for almost a month after that, supply was limited. As soon as drivers returned to the roads, long lines at gas stations followed. Within one week of Sandy's landfall, less than 20 percent of stations were able to sell fuel at any given time.

Working with the Federal government and the State National Guard, the City set up a fueling program for critical and public service fleets including emergency responders, utility vehicles, ambulances, and school buses. Regular consumers had to wait several weeks for the system to recover fully, though license plate-based rationing did reduce lines and a host of regulatory waivers helped bring supply back into balance with demand.

*For more on liquid fuels, see Chapter 7.*

Charging cell phones in the East Village

Credit: Matt Kane

**Healthcare**

Sandy placed an unprecedented strain on the city's healthcare system as a whole, and disrupted services in affected communities across New York. Six hospitals closed—four in Manhattan, one in Brooklyn, and one on Staten Island—requiring City and State health officials, co-located at the City's Office of Emergency Management, to coordinate the evacuation of nearly 2,000 patients. Hospitals that remained open—frequently owing to the heroic efforts of staff, who pumped out or diverted water, repurposed lobbies to serve as inpatient rooms, and siphoned gasoline from vehicles to run generators—struggled to meet the needs of incoming patients.

Nursing homes and adult-care facilities were also affected by flooding and power outages. Twenty-six facilities closed and five partially closed, resulting in the evacuation of 4,500 patients. At the community level, flooding caused over 500 buildings with doctors' offices, clinics, and other outpatient facilities to close. Many patients who could not reach their normal providers had to postpone care or sought help at hospital emergency rooms, further straining the entire system.

*For more on healthcare, see Chapter 8.*

**Telecommunications**

Sandy caused outages across phone, wireless, cable, and Internet services. Short-term outages affected the greatest number of customers and were a direct result of power loss, which knocked out cable and Internet service in homes and businesses immediately.

Wireless service was also affected when backup batteries powering cell sites ran down, generally four to eight hours after grid power was lost, reducing or eliminating service to over a million cell customers in New York City. Even customers with working cell networks found that charging mobile devices was a challenge in areas without power, though many businesses and cell companies set up charging stations in affected areas.

Meanwhile, flood damage at critical facilities in Southern Manhattan, Red Hook, and the Rockaways disrupted landline and Internet service throughout the neighborhoods they served for up to 11 days. Generally, providers with modern networks and hardened facilities were able to restore service faster, while those that had not adequately protected facilities from flooding faced longer and more extensive outages.

In coastal areas, flood damage to building telecommunications equipment and cabling caused long-term outages, with some providers using flood damage as an opportunity to swap in new, more resilient equipment rather than simply fixing in-place infrastructure—a benefit to customers over the long term, but frequently at the cost of considerable short-term inconvenience. For example, in commercial buildings in part of Southern Manhattan, Verizon opted to replace corroded copper cables with fiber. The result was that in a sample of 172 buildings, nearly 60 percent did not have service fully restored 60 days after Sandy, with 12 percent still out after 100 days.

*For more on telecommunications, see Chapter 9.*


A gas station line in Sunnyside, Queens

Credit: Brian Kingsley

**Transportation**

During Sandy, many highways, roads, railroads, and airports flooded. At the same time, all six East River subway tunnels connecting Brooklyn and Manhattan were knocked out of service by flooding, along with the Steinway Tunnel that carries the 7 train between Queens and Manhattan, the G train tunnel under Newtown Creek, the Long Island Railroad and Amtrak tunnels under the East River and the PATH and Amtrak tunnels under the Hudson River. Major damage occurred to the South Ferry subway station in Lower Manhattan, as well as to the subway viaduct connecting Howard Beach, Broad Channel, and the Rockaways. Service also was disrupted on the Staten Island Ferry, the East River Ferry, and private ferries. The loss of ferry service during and after Sandy stranded some 80,000 normal weekday riders, while the loss of subway service stranded another 5.4 million normal weekday riders.

Exacerbating flooding was the loss of electrical power, which made it difficult to pump out tunnels, clean up damaged subway stations, and begin restoring service. The difficulty in "dewatering" the tunnels further increased the damage from Sandy, as sensitive mechanical, electrical, and electronic equipment soaked in corrosive salt water. In addition to subway tunnels, flooding closed three vehicular tunnels into and out of Manhattan, interrupting the commutes of 217,000 vehicles.

Although major bridges reopened as soon as winds dissipated and portions of the transportation network not directly flooded experienced little damage, over 500 miles of roads suffered significant damage and the subway system remained out of service in the days after the storm, even as crews worked around the clock to restore service. This led to significant gridlock on roads and bridges into Manhattan as people tried to return to work by car. The commuting challenges led City and State officials to implement temporary measures to manage travel and congestion. These measures included restrictions on single-occupant vehicles using bridges and tunnels across the Hudson and East Rivers, increased East River ferry service, and the successful "bus bridges"—an above-ground replacement for the subways that sent hundreds of buses back and forth on the bridges between Brooklyn and Manhattan. These measures enabled over 226,000 commuters to cross the East River—almost triple the number able to cross before they were in place.

One week after Sandy struck, many subway lines had been fully or partially restored, but some elements of the system remained closed much longer, with repairs projected to take months and even years. However, the opening of A train service to Broad Channel and the Rockaways just prior to the release of this report shows the strong commitment of the region's transportation agencies to the restoration of service as quickly as possible.

*For more on transportation, see Chapter 10.*

**Parks**

The Department of Parks & Recreation (DPR) closed all City parks the day before Sandy, and the parks remained closed after the storm while DPR worked continuously to complete park inspections, reopening many facilities within three days—aided by legions of volunteers who helped bag debris and gather fallen branches. However, nearly 400 parks were damaged significantly and remained closed for major repairs. Across the city approximately 20,000 street and park trees were damaged or downed. Beaches and waterfront park facilities were hard-hit by storm surge, erosion, and coastal flooding, with two miles of scenic boardwalk destroyed primarily in the Rockaways as well as in Coney Island and on the East Shore of Staten Island.

Notwithstanding this loss, many DPR facilities—including beaches, wetlands, and other natural areas—played a role in protecting adjacent communities, serving as a buffer for these areas. In addition, some newer parks, which designers had planned with extreme weather risks in mind, weathered the storm with comparatively little damage. For example, Brooklyn Bridge Park generally fared well because of its elevation and use of resilient coastal edges and plantings. Meanwhile, the new park being constructed at the center of Governors Island—on a site elevated with fill—also largely was protected from Sandy's surge.

*For more on parks, see Chapter 11.*

**Water and Wastewater**

High-quality drinking water continued to flow uninterrupted to New York City during and after Sandy. However, in areas with power outages, the pumping systems in high-rise buildings ceased to function, leaving residents on upper floors with empty taps and no way to flush toilets. Meanwhile, a fire in Breezy Point in Queens caused significant disruption to that neighborhood's private water distribution system.

By contrast, Sandy's storm surge had a major impact on the city's wastewater treatment system. Ten of 14 wastewater treatment plants operated by the Department of Environmental Protection (DEP) released partially treated or untreated sewage into local waterways (though water quality samples showed impacts to be minimal due to dilution from the enormous volume of water flowing through the Harbor from the surge). In addition, 42 of 96 pumping stations that keep stormwater, wastewater, or combined sewage moving through the system were temporarily out of service because they were damaged or lost power.

While many facilities in neighboring municipalities were impaired for several weeks, New York City was treating 99 percent of its wastewater within just four days of the storm's end, and 100 percent within 2 weeks.

As for the city's stormwater and combined sewers, though Sandy was not a major rain event and the sewers generally performed as designed during the storm, the unprecedented volume of the surge was beyond the capacity of the system to handle. As the surge finally


**Station out of service due to subway system shutdown** Credit: MTAPhotos

receded, the system did help to drain floodwaters, though the sand and debris left by the surge did slow this process.

*For more on water and wastewater, see Chapter 12.*

**Other Critical Networks**

Thankfully, New York's food supply chain continued to function reasonably well during and following the storm. This supply chain is made up of wholesale distributors, which bring food to the city and often store it in warehouses, and retailers, which supply food directly to New Yorkers. The city's food distributors depend heavily on transportation networks to make deliveries and electricity for their refrigeration systems, so they experienced a slight strain when the area's bridges were temporarily closed and power outages were at their peak. Fortunately, though, Hunts Point, the city's largest food distribution center—and a key distribution point for much of the fresh food that comes into the city—largely was unaffected.

Location dictated Sandy's impact on food retailers. For example, when power went out in Southern Manhattan, many supermarkets and bodegas lost perishable food. Meanwhile, many food retailers in Coney Island and Brighton Beach (almost 30 supermarkets and 50 bodegas) and nearly all retailers in the Rockaways and Broad Channel were affected by storm surge or flooding. Unless they had generators, these retailers were also without power and also lost inventory. Many food pantries—an important source of nourishment for the city's vulnerable populations often located in the basements of churches and other buildings—similarly experienced flooding. This left some areas without access to food within a reasonable distance.

The City and FEMA stepped in and over a three-month period gave out almost 4 million meals from hot-food distribution sites in areas such as South Queens and Southern Brooklyn.

New York City's solid waste system, too, generally functioned well, despite some damage to its facilities, its vehicle fleet, and New York City's rail network. Truck-based collection resumed almost immediately after the storm, even though many Department of Sanitation workers themselves had homes damaged by the storm. In addition to diligently removing the regular daily volume of solid waste, these employees managed to cart away over 400,000 tons of excess debris from waterlogged homes and businesses—to widespread acclaim.


**Blackout in Chelsea from Southern Manhattan power outage** Credit: Dan Nguyen

Because some facilities responsible for receiving New York City's solid waste were affected by the storm, the City made contingency plans for disposal—for instance, diverting over 10 percent of the city's residential and institutional solid waste from a waste-to-energy facility in New Jersey to other facilities. Rail transport of solid waste also experienced disruptions. Important lines were down for five days on Staten Island and in the Bronx, during which time solid waste was stored in containers or shipped out on transfer trailers.

*For more on food supply and solid waste, see Chapter 13.*

**Communities**

While Sandy affected neighborhoods all across New York City, the storm hit five coastal areas particularly hard—the Brooklyn-Queens Waterfront, the East and South Shores of Staten Island, South Queens, Southern Brooklyn, and Southern Manhattan. Three of the five areas (the East and South Shores of Staten Island, South Queens, and Southern Brooklyn) were directly exposed to storm surge and destructive waves along the shore, and all experienced widespread inundation. Across the five areas—which are home to 685,000 people—physical and economic damage was extensive and long-lasting.

Building damage in these areas was pervasive and in many cases devastating. Neighborhoods in South Queens, Southern Brooklyn, and along the East and South Shores of Staten Island accounted for over 90 percent of the buildings in Sandy-inundated areas citywide and over 70 percent of the buildings tagged by DOB as having been seriously damaged or destroyed citywide as of December 2012. Buildings along the Brooklyn/Queens Waterfront and in Southern Manhattan, meanwhile, often lost critical building systems, expensive mechanical equipment, and personal property and inventory located on ground floors. Residents of high-rise buildings—including elderly New Yorkers and those with physical limitations—found themselves, in many cases, stranded on upper floors when their buildings lost elevator service. Many of these impacts were felt particularly acutely by residents of public housing developments located on the waterfront.

Across these communities, there was also damage done to critical infrastructure, often affecting not just these communities, but the city as a whole. For example, many of Southern Manhattan's vehicular tunnels were inundated during the storm, resulting in their closure for up to three weeks following Sandy, eliminating key connections between New York City and New Jersey and between New York's boroughs. Southern Manhattan's subway tunnels flooded as well, and most subway lines were down between three and seven days, impairing the system citywide. Wastewater treatment plants in several neighborhoods also saw flooding and damage, and all five communities experienced power outages.

The recovery of these neighborhoods is vital not only to the people who live and work in them, but to the city as a whole. This report would not be complete without plans to address the vulnerabilities that Sandy exposed in these areas and that climate change likely will exacerbate in the future. The initiatives in this report aim to help these communities stand strong again.

*For the Brooklyn-Queens Waterfront, see Chapter 14. For the East and South Shores of Staten Island, see Chapter 15. For South Queens, see Chapter 16. For Southern Brooklyn, see Chapter 17. For Southern Manhattan, see Chapter 18.*