EARTHQUAKES
CHAPTER 4.8

Although New York City does not sit on a seismically active fault line, earthquakes are a possibility. While the probability of a strong earthquake occurring is moderate, the risk is heightened by our population density, the scale of our built environment, the interdependencies of critical infrastructure systems, the age of much of our infrastructure, and the fact that much of our building stock was constructed before New York City adopted seismic design provisions for buildings in 1995.

WHAT IS THE HAZARD?

An earthquake is a sudden, rapid shaking of the ground caused when two blocks of earth slip past each other beneath the surface. Most earthquakes originate from pre-existing faults or from new breaks in the rocks that make up the earth's crust, along which rocks on either side move past each other. As the rock is strained, potential energy builds up. Eventually, it becomes so great that it is abruptly released in the form of seismic waves. These waves travel away from the earthquake's deep-underground source – the focus – causing shaking at the earth's surface that geologists and engineers call ground acceleration. The point on the earth's surface directly above the focus is called the epicenter.

How intensely the ground shakes depends on factors that include the amount of energy released, the depth of the earthquake focus beneath ground surface, how far from the epicenter the shaking is experienced, and the underlying soil type and bedrock. How intensely structures shake depends also on their height, weight, and design.

The strength of earthquakes can be expressed by the Moment Magnitude, which expresses the energy released at the source of the earthquake through recorded data. The Moment Magnitude scale replaced the Richter scale as a more accurate measure of the strength of an earthquake since the 1970s. The scale is logarithmic, which means that each one-point increase in the scale represents a 32 times larger energy release.

Earthquakes can trigger landslides and liquefaction of soils. Liquefaction occurs when loose, water-saturated soils become almost liquid due to intense seismic shaking and vibration during an earthquake.

Earthquakes and their aftermath can cause great destruction, trigger fires, damage buildings and infrastructure, interrupt community functions, and cause injuries and loss of life.

Aftershocks are earthquakes that follow the largest shock in an earthquake sequence. They are typically less intense than the main shock and can continue over weeks, months, or years after the initial earthquake is felt.

WHAT IS THE RISK?

The U.S. Geological Survey studies seismic conditions nationally and periodically produces maps to indicate where future earthquakes are likely to occur, the frequency of occurrence, and how hard the ground may shake. The latest maps, released in July 2014, show that on the East Coast, larger, more damaging earthquakes are possible than previous maps had shown.

Although strong earthquakes are uncommon in New York City, moderate magnitude earthquakes are possible. The older, harder bedrock found in the northeast generates high-frequency earthquake motions that can travel great distances before they subside. For example, earthquakes in Virginia in 2011 and Canada in 2013 were felt in New York City. The 2011 Virginia earthquake, with Moment Magnitude of 5.8, was felt more than 500 miles from its epicenter, making it the most-felt earthquake in modern U.S. history.

Unique geologic characteristics in our metropolitan area could create significant soil amplification effects. The two main factors of soil amplification are the sharp contrast of softer soils with very hard bedrock, and the bedrock motions, expected to be of relatively short duration and high frequency. Fast-shaking earthquakes are more common in the bedrock of eastern United States. Thus, if a soft soil above the bedrock is at shallow depths (say less than 100 feet), resonance can the fast shaking nature of the earthquake, affecting mostly short (2 to 5 stories) masonry buildings. On the other hand, a high rise building may resonant with deep soil deposits as they both tend to move slowly during an earthquake.

One of the strongest earthquakes to occur near New York City (thought to have originated somewhere between Brooklyn and Sandy Hook, New Jersey) occurred on August 10, 1884. Based on historical reports of the damage it did, it has been estimated to have been a 5.2 magnitude earthquake. Although moderate, it was felt from Virginia to Maine and damaged chimneys and brick buildings in New Jersey and New York City. Considering that the city was less developed then, if the same magnitude earthquake were to occur today, the damages would be far worse.

The historical earthquakes map shows the distribution of earthquake epicenters throughout the tri-state area from 1737 to 2014. Only two damaging earthquakes with a magnitude of 5.0 or greater have occurred in New York State. Many smaller earthquakes have been felt in New York City. For example, on January 18, 2001, a 2.4 magnitude earthquake was felt in Long Island City, Queens, and the Upper East Side of Manhattan near 125th Street. That earthquake affected an area with many unreinforced masonry buildings but caused little to no damage. Several residents mistook the earthquake for a manhole explosion. Engineers consider these events tremors and not strong ground motion earthquakes which are higher in magnitude (more than 4) and can cause structural damage.

In our metro area buildings must be designed to withstand the Maximum Considered Earthquake: that is, one with a two percent chance of happening at any point within a 50-year period. Such an earthquake would likely produce strong to very strong shaking and light to moderate physical damage, and significant interruptions in city functions. Historically, large earthquakes in New York City have had longer "return periods" – that is, they happen less frequently - on average about once in a hundred years.

VULNERABILITY

PEOPLE AT RISK

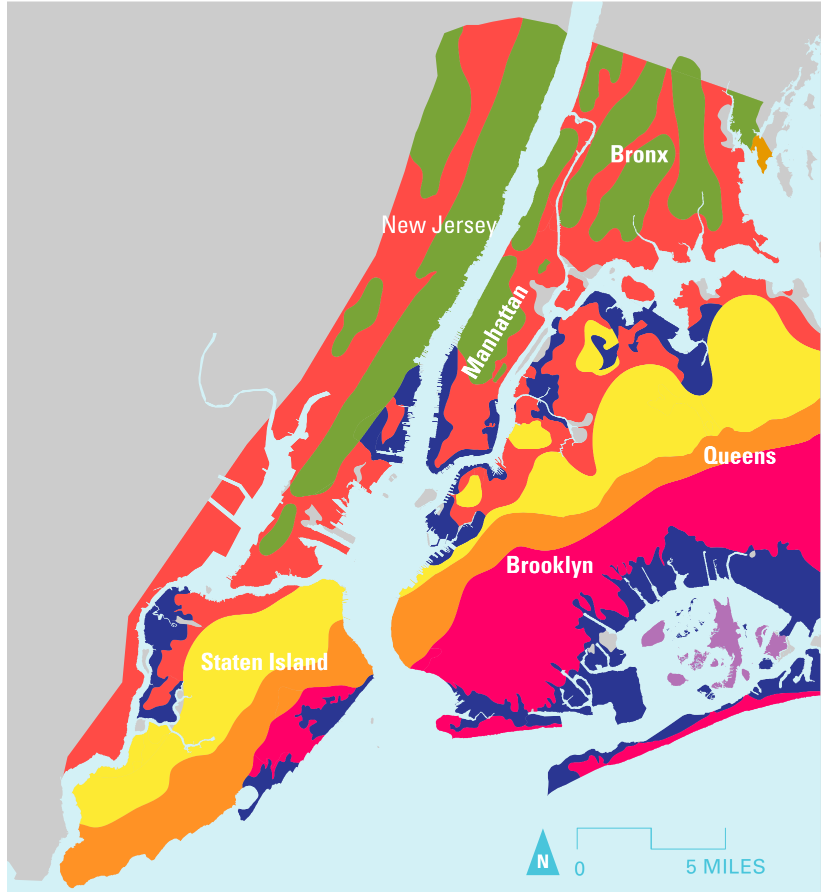
To glance at Chapter Three's survey of features of our city that are vulnerable to hazards is to grasp the extent of the damage that a severe or even moderate earthquake could do to the city.

Public safety is the paramount concern, because earthquakes occur with practically no warning, placing the population at immediate risk. Precisely because earthquakes have not occurred frequently here, the risk to public safety may be higher: the general public may not be as prepared or know how to respond. New York City's dense urban environment, which contains many high-occupancy buildings, amplifies our risk.

NYC AND EASTERN NJ GEOLOGICAL MAP

SOURCE: DEVELOPED BY MUESER RUTLEDGE CONSULTING ENGINEERS BASED ON THE ORIGINAL NYC FOLIO MAP OF 1902 (SEE TAMARO ET AL., 2000 AND MERRILL ET AL., 1902).

- ARTIFICIAL FILL
- ORGANIC SILT AND PEAT DEPOSITS
- GLACIAL OUTWASH DEPOSITS (SAND)
- GLACIAL LAKE DEPOSITS (VARVED SILT, CLAY & FINE SAND)
- TERMINAL MORAINE (SAND, GRAVEL, CLAY, SILT, BOULDERS & COBBLES)
- TILL (SAND, GRAVEL, SILT, CLAY)
- ROCK, WITH THIN TILL OVER ROCK



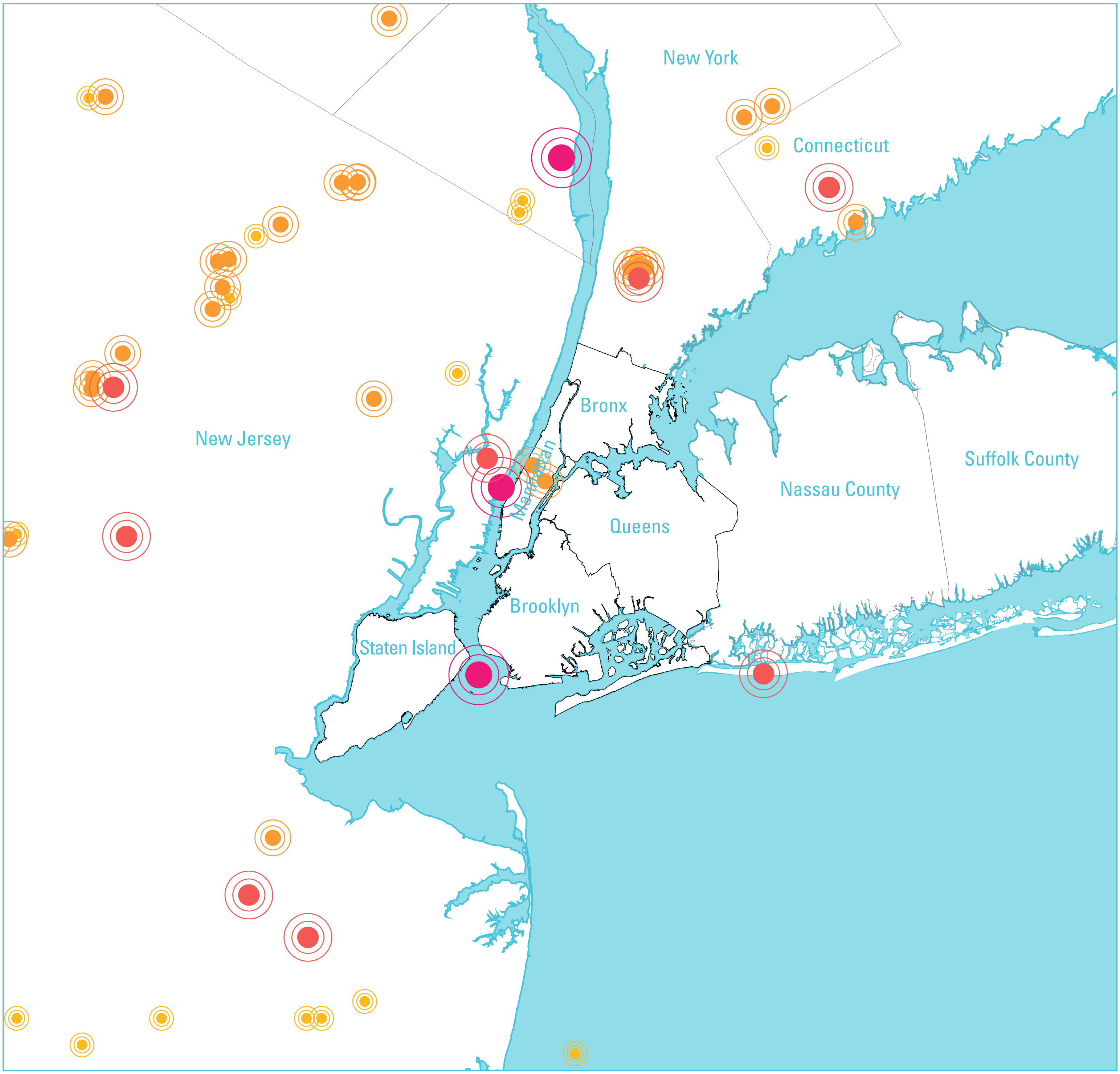
A moderate (magnitude 5.5 to 6) earthquake could cause downtime, injuries, and casualties in New York City. Typically mortality and injury peak within the first 72 hours of an earthquake. The biggest cause of death is building collapse: a study of 1,100 fatal earthquakes found that 75 percent of fatalities were due to this. According to FEMA, non-structural failures account for a vast majority of earthquake damage and can cause serious injuries or fatalities and make a building nonfunctional. Nonstructural components include items that are not part of the building's structural system such as heavy picture frames, mirrors over beds, hanging plants, heavy furniture (bookcases, filing cases, and china cabinets), light fixtures, electrical/mechanical equipment, elevators, and ceiling plasters. During an earthquake, these components may slide, swing or overturn because they are not tightly connected to the structure of the building.

Destruction of roads, bridges, and tunnels can cause injuries and fatalities, and the disruption of infrastructure and critical systems can cause its own cascade of impacts. Earthquakes can also generate fires as a result of seismic shaking, posing significant risk to people. Disruption of transportation can also place individuals dependent on these services at risk by hindering emergency and medical services.

Subsurface conditions, which vary widely in the five boroughs, can affect the amplification of an earthquake's ground motion. Conditions range from sound bedrock at ground surface to artificial fill. To create land that can be developed, large areas of the city have been filled to cover soft sediments and marshes. Examples are Manhattan's present-day Chinatown, which was built on fill that replaced a lake; the World's Fair site in Flushing, Queens; and JFK Airport, which was built on hydraulic sand fill on the south shore of Brooklyn.

The time of day an earthquake occurs can also increase impacts. Mortality rates rise if an earthquake occurs during weekdays between 9 AM and 5 PM, when people are likelier to be at work in large buildings or in school, or during the night, when people are home inside buildings. Other aftermath effects can include health risks from polluted water and spread of disease, and dramatic impact on the city and nation's economy.

Damage to buildings could force thousands of people into interim housing. Some people could require permanent relocation. In the aftermath of an earthquake, long-term mental health risks may include post-traumatic stress, depression, and anxiety.



HISTORICAL EARTHQUAKES (1737 - 2014)

SOURCE: USGS; NYS DHSES

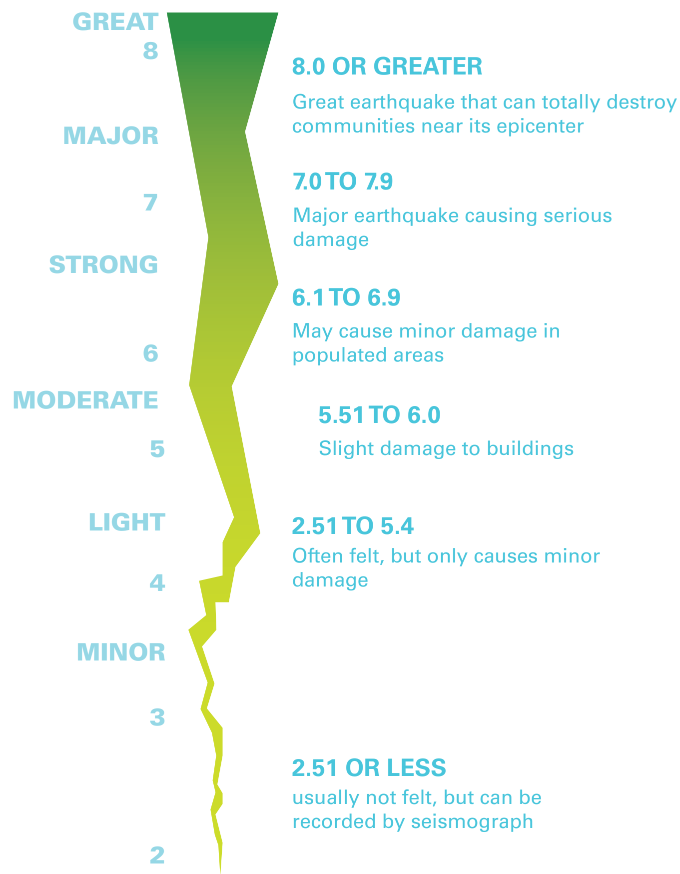
*NOT ALL PRE-1973 EARTHQUAKE EVENTS ARE DISPLAYED ON THE MAP

**EPICENTER LOCATIONS OF PRE-1973 EVENTS ARE APPROXIMATE ONLY

MAGNITUDE

EARTHQUAKE MAGNITUDE SCALE

SOURCE: UPSEIS/MICHIGAN TECH



BUILDINGS AT RISK

Although New York City has a low probability of large-magnitude earthquakes, potential damage could be physically extensive and costly, for reasons that include the following:

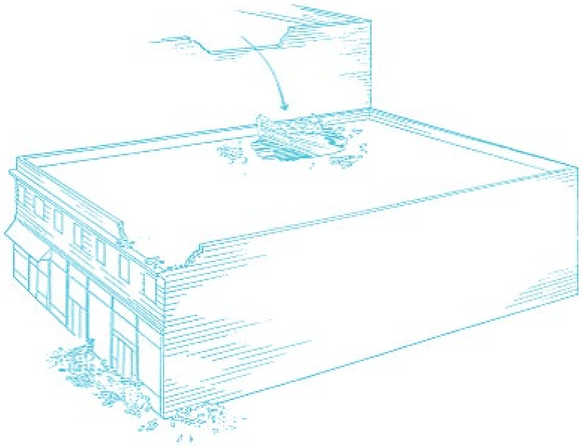
- New York City has nearly one million buildings.
- Dense built environment heightens risk.
- Most buildings were built before the City adopted seismic provisions in its Building Code, in 1995.
- Certain local building construction types are particularly vulnerable.
- Some of our commercial real estate, though built to modern seismic standards, is of such high asset value that damage to it could be costly.
- Interruption of functions (such as Wall Street) could affect not only NYC, but the US and world economies.

A 2008 analysis by FEMA of potential annualized building-related earthquake losses ranks New York State as the fourth most at-risk U.S. state and ranks the New York City-New Jersey-Long Island metro region as the twenty-first most at-risk metro region. Because of our high density of buildings, an earthquake could produce millions of tons of debris and cost billions of dollars' worth of damage to buildings.

Our high-rise buildings are less vulnerable to damage from earthquakes than low-rise buildings. For instance, earthquakes with slow moving waves that tend to damage taller buildings are less likely to occur in New York City. In addition, tall buildings designed to the 1995 Building Code are designed to preserve human life at a minimum in the event of a major earthquake and to preserve general occupancy conditions for less severe earthquakes.

Existing structures not designed for earthquake loads are inherently vulnerable to seismic events. Unreinforced masonry buildings are most at risk because masonry cannot absorb tensile forces during an earthquake: rather than bending or flexing, they break or crumble. We have over 100,000 multi-family, unreinforced brick buildings, most of them between three to seven stories high and built between the mid-1800s and 1930s. Many New York City neighborhoods consist of rows of attached unreinforced masonry buildings. The buildings rely on each other for stability, so those separated by vacant lots are particularly vulnerable. Brooklyn has the largest number of unreinforced masonry buildings followed by Queens and Manhattan.

Even if there is little earthquake damage above ground, buildings may be uninhabitable because their foundations are damaged. Masonry loft buildings are vulnerable due to their lack of interior walls and greater floor-to-ceiling area. Many pre-code emergency response buildings such as fire houses and police stations are housed in unreinforced masonry structures that have not been retrofitted. They could sustain damage that would impede certain emergency services to function post-earthquake.



DANGERS OF UNREINFORCED MASONRY BUILDINGS DURING AN EARTHQUAKE
SOURCE: FEMA

A large portion of New York City's waterfront is built on reclaimed land, which is composed of fill with poor structural properties in the parts built at the colonial times until a few decades ago when controlled fill and construction procedures were applied. Additionally, new guidelines for protecting structures from flooding and increasing resiliency recommend elevating coastal buildings, creating a soft story base that permits floodwaters to pass through – for example, by supporting the first floor on piers. However, during an earthquake, the combination of a soft story base and poor subsurface conditions could shift most of the load to the foundation, concentrating most of the damage on the bottom story.

Over time, our city's stock of seismically vulnerable buildings is being replaced by new structures that conform to current seismic code standards. However, the small percentage of buildings that are historically landmarked will remain vulnerable unless retrofitted.

INFRASTRUCTURE AT RISK

Virtually all of the city's infrastructure – above ground and underground – is vulnerable to earthquakes: bridges, tunnels, the subway, railroads, water tunnels and water mains, utility lines (power cables, communication lines, natural gas lines, steam pipes), and wastewater treatment plants.

Soil liquefaction could result in large-scale ground failure that could damage pavements and building foundations and massively disrupt underground utilities. Structures built on liquefied soils could sink and settle. Damage to underground infrastructure usually occurs in areas where utility transmission lines such as pipes cannot withstand soil movements. Damage to them could trigger secondary impacts like water contamination, fire, and explosions. In addition, critical infrastructure systems have aged and have general maintenance problems that may make them vulnerable.

Our city is vulnerable to earthquakes that occur beyond our borders too. An earthquake that damaged the upstate reservoirs and aqueducts that supply our city's water could have severe consequences including the inability to suppress fires. The Indian Point nuclear power plant is sited 25 miles north of the City near the intersection of two seismic zones that are believed capable of generating a magnitude 6 to 6.5 earthquake.

Large-magnitude earthquakes that occur longer distances away, such as in Canada, can create low-frequency (slow-moving) shaking that can affect tall buildings and tanks.

THE ECONOMY AT RISK

For businesses, damage to buildings and to building contents, including equipment and warehouse and retail inventory, and damage to the infrastructure and critical systems upon which businesses depend, could disrupt operations and revenues, causing significant economic losses. Repairs and equipment and inventory losses not covered by insurance would be a further cost. Low-wage earners, in particular, could be unable to earn income because of downtime.

Damage to infrastructure and critical systems could disrupt government, institutions, healthcare services, and many other functions and facilities, causing economic dislocation not just for the city but the region. Recovery costs could be enormous.

Overall, severe effects on what is a global financial center could ripple through the global economy.

HOW DO WE MANAGE THE RISK?

Although earthquakes can occur suddenly and cannot be prevented, many strategies have been developed to reduce the risks associated with them. The body of knowledge that informs these strategies continues to grow, as seismologists, geologists, engineers, architects, and other professionals continue to pursue research to advance their fields.

The primary strategies involve building code seismic requirements and seismic design requirements for infrastructure. Inspections and maintenance play vital roles, too.

PROTECTING BUILDINGS: REGULATIONS, ENFORCEMENT, AND ENGINEERING STRATEGIES

In New York City, the Department of Buildings develops and updates building codes and enforces them through extensive administrative measures.

Modern building codes require that all new buildings be engineered to provide a minimum of life safety if a very rare, strong earthquake occurs and to ensure general occupancy conditions for less severe earthquakes. In New York City, existing buildings undergoing substantial modifications must meet this standard, too.

The evolution of seismic building code provisions

The first seismic provisions in New York City's Building Code were signed into law in 1995 and took effect in February 1996. The Department of Buildings further addressed structural vulnerability to earthquakes when it adopted the International Code Council's family of codes in 2008, as the New York City Construction Codes.

The 2008 Codes not only make buildings stronger but more flexible and ductile – able to absorb energy without breaking in a brittle manner. The Code's plan for the two-percent chance of a moderate earthquake occurring or being exceeded in a 50-year period. Specific soil type and the building foundation are taken into account, and seismic detailing is required to ensure that joints and structural connections and piping within a building hold up during an earthquake.

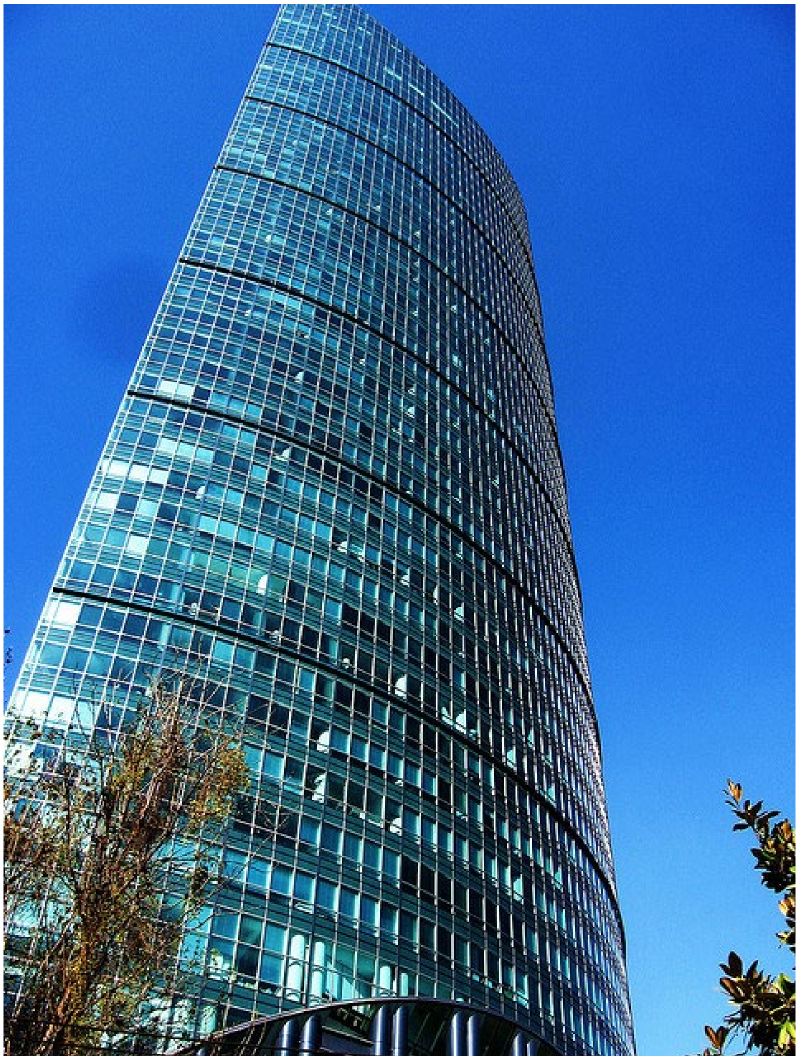
SOFT STORY BASE LOMA PRIETA
SOURCE: CIR ONLINE

Just as under the former City Building Code, under the 2008 Construction Codes critical facilities such as firehouses and hospitals must be designed to not only survive an earthquake but to also remain open and functional afterwards. The code permits unreinforced masonry for new buildings only in rare instances.

In 2014, the Department of Buildings revised the Construction Codes and moved toward a new concept: the risk-based approach, following the model of the American Society of Civil Engineers Standard 7-2010. This means that, instead designing against the probability of an earthquake happening, we are designing against the probability of a new structure collapsing or sustaining significant damage during an earthquake. The update also strengthens design requirements for soil liquefaction and takes into account the city's unique geologic conditions. Design must account for site-specific soil conditions and building foundations. It must ensure that joints and structural connections are flexible. Special detailing for electrical and mechanical systems, and building contents and architectural components is required.

Code enforcement

To ensure that buildings are built to code, new construction and major renovations cannot begin until the Department of Buildings has reviewed plans and issued work permits. The Department inspects properties after the construction



TORRE MAYOR

The Torre Mayor building in Mexico City is one of the strongest buildings in the world in terms of earthquake resistance. It was designed by New York City engineers to withstand 8.5 magnitude earthquakes on a site that has some of the worst soil conditions on earth. Its 96 viscous dampers work like car shock absorbers to block the resonating effects of both the lakebed on which the city sits and the building's own height.

In January 2003, a 7.6 earthquake shook the city. This building survived undamaged, and occupants did not know a tremor had occurred.

process is completed and then issues a final Certificate of Occupancy when the completed work matches plans that the Department has approved for new buildings or major alterations.

Engineering strategies

Architects and engineers employ a variety of methods to design and engineer new buildings and retrofit older ones to meet strict seismic standards. Some engineering strategies include strengthening how building elements are connected to increase flexibility, reducing building mass to reduce seismic forces, and strengthening foundations located in poor soil to ensure stability.   Other strategies include incorporating viscous dampers throughout the building to absorb seismic energy or employing techniques that isolates the earthquake movement from the foundation to the structure.

For existing unreinforced-masonry buildings, adding, and in some cases preserving, structural elements that increase the structure's ductility – its ability to absorb energy without failing in a brittle manner – is another strategy. For example, steel reinforcement should be added where possible. Connections between structural elements can be strengthened by anchoring walls to the roof and walls to the foundation. This increases the structure's ability to transfer loads during an earthquake.

Parapets are often the most damaged element of an unreinforced building. Anchoring them with bolt diagonal steel struts and repairing the mortar on parapets can help reduce seismic risk. So can replacing unreinforced masonry parapets with reinforced masonry parapets and anchoring them to the building.

Preserving, rather than demolishing, interior walls in older loft buildings keeps those buildings safer.

Many times, simple, common sense solutions are enough to improve seismic performance and dramatically reduce the seismic risk. For example, to protect a building's contents, furniture can be anchored or bolted to the walls.

Guidelines for protecting coastal buildings from flooding and coastal storms, raise seismic safety issues: attention to the vulnerabilities of elevated buildings. For buildings with a soft story base, one of the easier solutions is to add bracing or shear walls to take the extra load. Another method is to make the columns and piles bigger or stronger.

For all buildings, routine maintenance is essential to reducing earthquake impacts. This means keeping roofs secure and in good condition, securing cornices and aluminum panels, repointing mortar regularly (especially on parapets and chimneys), and fixing all cracks.

Among the initiatives now under way in New York City, the Department of Administrative Services is installing new mechanical equipment to resist seismic forces in 55 City-owned buildings. The Department of Education is conducting a seismic study of its tall buildings and is retrofitting buildings to exceed current Construction Code seismic provisions. The Health and Hospitals Corporation is retrofitting several hospital facilities to meet code seismic standards.

PROTECTING INFRASTRUCTURE: GOVERNMENT GUIDELINES, INSPECTIONS, AND ENGINEERING STRATEGIES

Earthquakes can damage major infrastructure like bridges, tunnels, sewers, water supply systems, and wastewater treatment plants that were not designed to withstand earthquakes. New infrastructure is required to be designed to meet seismic loading, and older infrastructure is required to be retrofitted to meet those standards. Federal, state, and local governments all play roles in managing aspects of seismic safety for infrastructure.

Seismic guidelines for infrastructure govern retrofitting of older bridges and tunnels and other facilities, and the design of new ones to safe standards.

Protecting bridges

After the 1989 Loma Prieta earthquake which caused extensive damage to bridges in Northern California, many states in the central and eastern part of the country began adopting seismic provisions for highway bridges. In New York, many bridge owners hired seismologists to assess the risk of this hazard to our bridges. The Federal Highway Administration administers seismic retrofits of bridges through local authorities, under an inspection and rehab program mandated by Congress in 1991. To this end, the New York City Department of Transportation developed Seismic Criteria Guidelines in 1998 that have been updated since then to include up to date knowledge.

> For all buildings, routine maintenance is essential to reducing earthquake impacts.

Since 1985, FEMA has been sponsoring earthquake engineering research by the National Earthquake Hazards Reduction Program (NEHRP). Their latest publication FEMA P-750: NEHRP Recommended Seismic Provisions for New Buildings and Other Structures was released in 2009. These recommended provisions are the primary source of seismic design requirements for new buildings and other structures throughout the nation. The goal of these provisions is to assure that seismic performance will:

- avoid serious injury and loss of life,
- avoid loss of function in critical facilities,
- minimize structural and nonstructural repair costs where practical to do so

Seismic assessment of bridges in the New York City requires evaluating the bridge for performance standards based on whether the bridge is determined critical, essential, or other. Retrofitting older bridges or designing new bridges should be accomplished by designing to the level of damage expected from the earthquake, to allow for the repairs needed after the event. The New York City Department of Transportation, which owns and maintains 789 bridges, is in the process of implementing seismic retrofits of all their critical, essential and other bridges.

SEISMIC ISOLATORS ON THE JFK AIR TRAIN

One of the more common methods of seismic protection in bridges and structures is seismic isolation. It protects bridges or structures by isolating the earthquake movement from the foundation to the structure. This is accomplished by mounting isolators (rubber and steel bearings) between the bridge deck and its piers, or the building and its foundation. The isolators absorb the earthquake energy and minimize the energy transferred to the structure. In New York City, this method has been used in the JFK Light Rail system.

Protecting other infrastructure

The City Department of Environmental Protection is conducting several projects to increase seismic protection of our wastewater treatment system. The agency is retrofitting wastewater treatment facilities and methane gas storage systems to withstand seismic activity, because most of these facilities were designed and built prior to current seismic standards. To reduce the impact of seismic activity on our sewer system, the agency has been inspecting and repairing structural deficiencies in some of its major sewers.

The Department is conducting a study to assess the seismic resiliency of our water supply system (water tunnels, piping, clean water pump stations, dams, shafts, and tanks) and to determine seismic design standards for it. Study findings will help prioritize areas in the distribution system that needs retrofits to meet seismic standards. City Water Tunnel 3 (described in the Water Shortage hazard profile) is designed to strict seismic standards.

Applying the City's seismic guidelines, the MTA, which is administered by New York State, is currently incorporating seismic requirements into its bridge and tunnel restoration projects in New York City.

Entergy Corporation, the operator of the Indian Point nuclear plant, states that the plant was designed to withstand an earthquake greater than the strongest earthquake probable for the area. In 2008, a safety evaluation confirmed that the plant's seismic design was sound and safe.

RESEARCH AND PROFESSIONAL EDUCATION

Collaboration among seismologists, geologists, engineers, architects, and emergency managers is essential to managing earthquake risks. Further research into the potential impacts of earthquakes on our city will expand our knowledge base and help promote awareness. This research may include earthquake impact modeling of New York City's unique built environment, taking into account our large stock of older buildings, soil conditions, and geological characteristics, to estimate potential physical and economic losses. The new seismic hazard maps released in July 2014 by the U.S. Geological Survey will inform future research.

The American Institute for Architects and the New York-Northeast Chapter of the Earthquake Engineering Research Institute held a series of programs ("Consider the Quake: Seismic Design on the Edge") in early 2014 to inform New Yorkers about seismic risk exposure for NYC buildings and how well the city is prepared to deal with earthquakes. The series included workshops on how to design buildings to withstand an earthquake.

The New York City Area Consortium for Earthquake Loss Mitigation, formed in 1998, created an educational guide to create public awareness of seismic risk in New York, New Jersey, and Connecticut. The guide, developed between 1998 and 2003, contains risk and loss estimates for the tri-state area; soil information for use in quantifying seismic hazard; information on Manhattan's building inventory, for estimating local impacts; models of earthquake scenarios and their probable consequences; an assessment of individual essential facilities; and recommendations for how to reduce potential damage and losses.

The Next Generation Attenuation is a multi-disciplinary research project coordinated by the Pacific Earthquake Engineering Research Center. It includes researchers from organizations in academia, industry, and government. They are working to develop a consensus for new ground motion prediction equations, hazard assessments, and site responses for the Central and Eastern North-American region.

The Earthquake Engineering Research Institute recently established a New York–Northeast chapter to increase awareness of earthquake risk and to offer educational resources on how to reduce earthquake risk, at all levels of expertise in the fields of engineering, geoscience, architecture, planning, and the social sciences.

The Multidisciplinary Center for Earthquake Engineering, in collaboration with the Structural Engineering Association of New York, initiated studies to better understand the vulnerabilities of unreinforced masonry buildings in New York City. Working with the State University of New York at Buffalo, the Multidisciplinary Center is currently testing the shaking table prototypes of unreinforced masonry structure in order to develop pre-engineered solutions for New York City's building stock.

PUBLIC EDUCATION AND OUTREACH

Because many New Yorkers are not aware of the local risk of earthquakes and will not have a warning when one happens, promoting awareness and preparedness is essential.

NYC Emergency Management's Ready New York campaign encourages New Yorkers to be ready for all types of emergencies, to develop a disaster plan, and to keep informed of hazards that may impact the City. Our *Ready New York Earthquake Safety Guide* explains what to do when an earthquake strikes and immediately afterwards.

NYC Emergency Management's *Ready New York Reduce Your Risk Guide* includes longer-term strategies that homeowners and residents can implement to reduce the impacts of an earthquake.

Because earthquakes can inflict not just physical but psychological harm, mental health services are essential to response and recovery. The NYC Department of Health and Mental Hygiene's Mental Health First Aid education program informs the public about mental health problems, warning signs, the forms those problems can take, and the kinds of treatments commonly available.

FEMA and the Northeast States Emergency Consortium organize annual Great Northeast Shakeout drills to encourage organizations, households, and agencies to practice how to be safer during an earthquake. It is also an opportunity for groups to update their preparedness plans, restock supplies, and secure their homes and workplaces to prevent damage and injuries.