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Urban Hazards

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Cities are hazardous places. Despite the amenities that cities provide, there are inherent problems. The dangers arise from the locations chosen for settlements. For most American cities, original settlement sites were often places with characteristics that met certain needs: they provided natural resources (e.g., access to abundant water, transportation modes, energy sources, marketable goods [timber, fish, or coal], or places for refuge) or economic advantages. As settlement populations grew, agriculture was driven from land that became more valuable (or more profitable for the land owners if sold) for housing, transportation networks, or industrial uses than for growing food. Local fisheries also lost vitality, in part because of overexploitation, but also because local development reduced water quality and fish habitat. People still reside in places that provide access to many of these resources, though today access to distant sources has become easier and residential location is less directly tied to meeting basic needs because of improved urban and global transport systems and trade. In the United States and Canada, we are intellectually and spatially separated (and often consciously disconnected) from the impacts of our lives.

What we "need" has changed dramatically throughout history and other factors such as employment, local economies, social relationships, politics, social preferences, and environmental amenities increasingly drive contemporary residential "choices." For instance, *interesting* landscapes, *peaceful* settings, and *beautiful* views are pull factors in decision making among willingly relocating populations. Unfortunately, such attractions correlate with the most dynamic of natural environments: rivers that flood; coasts prone to storms, erosion, and tsunami; seismically and volcanically active mountain ranges with unstable slopes; or forested landscapes prone to fire. Or they may be places where economically active human landscapes contain certain dangers such as heavy traffic, industrial activities, or extraction of resources and/or people (criminals, terrorists, or enemies) or lifestyles and conflicts (such as with socially and politically alienated communities, drug users, or the mentally ill). For those with few options, these locations might be left over from the choices of the free, wealthy, or powerful segments of society. Each of these places holds some potential for "bad" things to happen.

In the twenty-first century, North American cities are susceptible to many environmental hazards, including droughts, floods, heat waves, earthquakes, ice storms, and volcanic eruptions. At first glance, many "natural disasters" in cities seem like natural disasters, forces of nature. But these events have impacts and effects that were mediated through the prism of socioeconomic power structures and arrangements. While there are certainly physical forces that can wreak havoc on our cities, disasters are first and foremost social experiences that often affect the poor more than the rich and reveal economic inequality, social injustice, and poor planning efforts. For example, following Hurricane Katrina's 2005 flooding of New Orleans, scholars Chester Hartman and Greg Squires wrote their 2006 book *There Is No Such Thing as a Natural Disaster*. The flooding of the city was a result of the poorly designed levees, a result of inadequate funding of public works. They argued that the effects of Hurricane Katrina were socially and racially determined: flooding disproportionately affected the poorest neighborhoods of the city, and the hardest hit neighborhoods were nonwhite. The racial and income disparities in the city were reflected in the spatial patterns of the flood damage. More than seven years after the disaster, vast areas in the Lower Ninth Ward, a predominantly African American neighborhood, remain unrestored (see figure 13.1).

North American cities face changing patterns and challenges of hazards and disasters. Advances in infrastructural engineering and notions of preferred landscapes generate technological issues that also change hazard patterns. There are general landscapes of risk in cities generated by natural processes (river and coastal flooding, hurricanes and other storms, and earthquakes), and at the same time there are ways urbanization augments hazards technologically and socially. Disasters reveal our social fault lines as well as our political failings. The primary aim of urban hazard management today is the quest for resilience.

Figure 13.1 Several years after Hurricane Katrina, vast areas of the Lower Ninth Ward are still not recovered and remain vacant. The lack of rebuilding suggests that political and social issues often underlie recovery efforts. *Source:* Google Maps.

CONCEPTS

The "bad things" that happen might be regarded as "risks," but risk simply refers to a probability (a "chance") that something negative could occur as processes occasionally become extreme or move beyond typical circumstances and present challenges. Box 13.1 lists a range of "extreme events." When negative outcomes vary spatially and affect people, we refer to them as "hazards." In scholarly terms, "hazard" is actually the probability that an "extreme" event will negatively impact people, their property, or their economic interests and is usually qualified by the extent, depth, or quantity of the impacts. Alternatively, a hazard's measure reflects the disaster potential. Here we define a disaster as an outcome of a hazardous event that exceeds a person's, place's, or system's ability to absorb it without upset.

Box 13.1 Assorted Urban Hazards in North American Cities

NATURAL HAZARDS

Geophysical

Earthquakes
Erosion
Landslides
Sinkholes
Subsidence
Tsunamis
Volcanic eruptions
Wildfires

Meteorological

Atmospheric inversions
Blizzards
Coastal inundation
Derechos
Droughts
Fog
Floods
Haboobs
Heat waves
Hurricanes and tropical storms
Ice storms
Severe thunderstorms
Tornadoes

Biological

Infestations
Invasive species
Plant and animal disease outbreaks
Vicious and disease-carrying pets and wildlife

TECHNOLOGICAL HAZARDS

Air pollution
Automobile accidents
Blackouts
Bridge collapses
Building collapses
Building fires
Chemical spills and airborne releases
Communication system failures
Dam failures
Electrical system failures
Energy crises
Industrial accidents
Internet failures
Levee failures
Occupational hazards
Pesticide exposures
Plane crashes
Radiation releases
Sunspots and solar activity
Train derailments
Ultraviolet radiation exposure
Water pollution

SOCIAL HAZARDS

- Carjacking
- Consumer product tampering
- Contagious disease outbreaks
- Domestic violence
- Epidemics
- Handgun violence
- Poverty
- Riots
- Road rage
- Serial killers and serial rapists
- Terrorism
- Theft
- Vandalism
- Violent crime

Geographical analyses of the probabilities that extreme events coincide with human landscapes identifies the places most in need of actions to reduce (or mitigate) disaster potential. These locations may or may not be distinguished as having the densest populations or the poorest neighborhoods. They also may *not* be closest to a risk-generating feature such as a coastline, fault line, riverbank, nuclear plant, interstate highway, or mental hospital. Spatially, the intensity of the impacts generated by extreme events may not reflect the geography of the sources of hazard because localities can have characteristics that cause them to respond differently to events, and therefore the geography of potential impacts must be examined carefully. Similarly, the communities in impacted locales might experience events differently because of their proximity to the "energy" of the event, individuals' personal characteristics, their economic and social wherewithal, their status in society, the built landscape surrounding them, and even a government's emergency response preparedness. These so-called vulnerabilities influence the distribution and the significance of impacts from extreme events.

Vulnerabilities associated with culture, religion, or education might influence how people perceive, interpret, or understand what is happening in an emergency. The relationships between and status of social groups might influence choices they make (or think they *can* make) in response to immediate and long-term threats. For instance, urban homeowners' associations, in order to maintain neighborhood property values, might restrict homeowners' choices or options for structural or spatial remedies to wildfire or seismic risks. Residents of poorer neighborhoods may have little control over the hazardousness of their neighborhoods because they may lack the economic wherewithal to manage it or the decision-making power associated with property ownership. The quality and strength of buildings, power grids, highways, or railroads can make elements of infrastructure more or less likely to be damaged or destroyed by specific events, and this influences the potential for disasters and disruption of a community. Training and practice by police, fire, or rescue personnel and emergency management agencies can diminish the impacts of events, and preparedness can vary over space and time. While vulnerability management can be used to manage hazard, it might have inadvertent negative consequences.

Cities tend not to wait passively for disasters to occur. Rather, they often attempt to manage hazard to mitigate disasters. People respond in diverse ways as they are guided by cognition or awareness and understanding, which may be incomplete or even wrong. Responses can prompt adaptation, minor or major adjustments, evacuation, planning and preparedness, permanent relocation, or even measures that attempt to eliminate the threat completely. For example, such measures could include straightening and deepening river channels, fortifying coastlines with seawalls, or passing laws to prevent "accidents." In few cases have hazards been eliminated. Such "elimination" efforts, however, tend to fall short and usually only change the geographies of risks or redistribute the risk to others. The exceptions are most apparent in locations where people (or whole communities) have been removed or economic activities have ceased and are no longer exposed to the hazard. For instance, the small community of Soldiers Grove (population 653 in 2000) in southwestern Wisconsin decided in 1977 to relocate the entire community above the floodplain and flood hazard zones associated with the Kickapoo River. The effort was completed by 1983, and the result was enhanced by a coincidental conversion to solar electrification. Similarly, residents of Gays Mills (population 625), a Kickapoo River neighbor to Soldiers Grove, committed to a similar relocation project in 2010 in order to remove the flood hazard from their midst. In these places, the potential for disaster has been eliminated because the hazard has been attenuated—but the risk has not.

Throughout the twentieth century, urban growth produced "hazards" by increasing human interaction with biophysical, geophysical, and ecological processes. This is a dialectical process. As people interact with natural processes, they cease to be natural, becoming a hybridized set of humanized natural processes. Labeling events as "natural disasters," in fact, mistakenly assigns their causes to nature. Hazards and disasters are caused by people, regardless of the source of the threat. Natural processes, technological processes, and social processes can generate hazards, but they are hazards because of human actions. Nature (even a "wild" animal) is dispassionate toward human beings. It is impartial in our interactions with it except insofar as an element of nature might strive to protect its own interest; it neither intends to harm people nor seeks to eliminate us. Disasters are entirely produced by *somebody's* actions, though they may not have been prompted by the actions of those disasters' victims. Often, the desires and actions of socially, politically, and economically powerful interests may generate riskscapes. Riskscapes are landscapes of probabilities for an extreme event. They impact marginalized populations, the politically or economically weak, or simply bystanders. Thus, the real roots of hazard are not biological, geological, or chemical processes but are the activities of actors who are often members of societies' elite groups. Disasters occur when people, health, or property are negatively impacted by extreme events or conditions. Without people and development, the potential for damage or loss of human life and/or property does not exist as extreme events would affect nothing of value to us. Without people, natural processes would simply continue as they have throughout time.

NATURAL, TECHNOLOGICAL, AND SOCIAL HAZARDS

Technological processes such as industrial and other activities can generate acute events that are of high energy, are discrete in time, and have an intense effect on the surroundings. Such processes can also generate chronic situations in which events are less intense, occurring over a long period of time, and produce constant, low-grade, and less apparent exposure to victims. Examples of acute events are releases of radioactivity from nuclear power facilities, intentional and accidental releases of toxic materials from industrial and commercial enterprises, explosions from many types of activities, and even deadly automobile accidents. Chronic problems include air and water pollution, exposure to pesticide residues, and first-, second-, and thirdhand tobacco smoke exposure, among many others. It is only when a death or a case of disease or injury is recognized as unusual, is suspiciously clustered in time, or is becoming too common do people go looking for its causes. Chronic exposures have, for the past half-century or so, come to be regarded as "environmental problems." Impacts are often delayed, unexpected, and unpredicted, but they diminish human health and cause long-term degradation of nature and ecosystems. They might clearly impact only a few people scattered over a region, which for most people mentally unlinks the impacts from their causes. By contrast, acute events are commonly regarded as technological hazards and may be managed in very different ways because of cognitively clear, direct links between events and negative impacts.

Natural and technological processes have traditionally been the object of study for hazard and disaster researchers. Studies of social processes that produce "social hazards" have been less common for this group of scholars. However, with the recent rise in awareness that terrorism can produce a hazard, social hazards have begun to be regarded as deserving of attention by hazards scholars and emergency managers. After countless centuries of death and destruction caused by man's inhumanity to man (as in wars, by murderers, by violence wrought by gun owners, and others), the terrorism acts committed on September 11, 2001, have compelled scholars to consider social problems as hazards. Though terrorism is relatively rare, other causes of social hazards are not. North American cities, in fact, force the "melting pot" of social relationships onto the front burner of the "stove of problems" with which managers must contend, through the concentration of people, the competitive motives of cultures in America, personal pursuits of power, and the augmentation of prejudice by self-interested actors. The resulting conflicts generate social friction and stress and lead to clashes and antisocial behaviors that are hazardous and complicate urban natural and technological hazard management.

URBAN HAZARDS AND DISASTERS IN NORTH AMERICA

Cities are rarely constructed in arbitrary locations with clear designs that reflect social goals or intentioned desires. The organic process of development of most cities is based on internal forces (investment and innovation) that spawn economic growth and external forces that spawn population growth, like in- or out-migrations between cities, between cities and the countryside, or between countries (immigration). More recent development in most cities has been premised on past patterns established for economic, strategic, and functional reasons but not on the patterns of risk that were established long before people came to occupy these places.

Floods

North American landscapes have always experienced floods, as have the cities that came to fruition on them. Settlers used the best available information about locations they could gather. Unfortunately, flood frequency and distribution, typical weather patterns, and climate extremes were (and still are) often very difficult to discern from recent conditions, and even long-term, detailed weather records could not enable perfect knowledge or prediction of future flood conditions. While locating settlements in floodplains is problematic, settlements also create flood problems where they may not have previously existed.

From 1840 to 2011, major flood disasters have occurred in American and Canadian towns and cities at least seventy-eight times (table 13.1). This undoubtedly underestimates the pattern of urban flood hazards today, at least in part because the definition of "city" has evolved over the past two centuries. Major floods continue to occur in smaller cities, but they have not tended to be dramatically catastrophic in terms of either mortalities or monetary losses and have therefore been less noteworthy or simply not widely reported. Of the seventy-eight flood events in the table, fifty-four were produced primarily by prolonged or heavy precipitation. Many, thirty-five, were early spring (January through April) floods in which rain-melted snow added to the high rainfall amounts that occurred. Five hurricanes also played a role in ten urban floods in the US South and East. Furthermore, six dam, dike, and levee failures contributed to floods in fourteen more cities in the eastern, northern, and western United States and Canada. Each urban flood site possesses unique locational and situational characteristics, but occupants have played a major role in modifying the patterns, creating distinctly different flood riskscapes. The frequency of flood disasters in fact reveals how people have enhanced flood hazard in cities. Eleven flood disasters occurred prior to 1900. Twenty more occurred between 1900 and 1950. Thirty-two major floods struck North American cities between 1950 and 2000. And at least fifteen more disasters already occurred in the first eleven years of this century.

Every flood is different. Even when a specific city experiences two or more events, the distributions of the impacts of the events are never identical. Rainfall patterns, rates, and intensities might be dramatically different. Rainstorms might have followed extended periods of either drought or wetter-than-usual conditions. Soils, in places with absorptive soils that can store water, might be saturated and instead enhance runoff. As vegetation similarly slows runoff, its condition and abundance can also be a factor. All of these factors produce riskscapes.

But people also constantly change their urban landscapes, reducing the permeability of its surfaces and the absorbability of the built environment. These factors are constantly changing upstream and down, and predicting the next big storm (and its spatial extent, location, speed, and characteristics) is challenging because of the constantly evolving hazardscape. Some cities are becoming not only flood prone but flash-flood prone, in part because of economic interests that drive development of undeveloped land.

Table 13.1 Major Urban Floods in the United States and Canada, 1840 to Present

Location	*Year*	*Primary "Cause"*	*Location*	*Year*	*Primary "Cause"*
St. Louis, Missouri	1844	Heavy rain	Lawrence, Kansas	1951	Heavy rain
New Orleans, Louisiana	1849	Heavy rain	Kansas City, Kansas	1951	Heavy rain
Des Moines, Iowa	1851	Heavy rain	Kansas City, Missouri	1951	Heavy rain
Concord, New Hampshire	1852	Heavy rain	Salem, Oregon	1964	Heavy rain
Georgetown, District of Columbia	1852	Heavy rain	Clinton, Iowa	1965	Heavy rain
Philadelphia, Pennsylvania	1869	Hurricane	Rapid City, South Dakota	1972	Dam failure
Washington, District of Columbia	1869	Hurricane	Lansing, Michigan	1975	Heavy rain
Williamsburg, Massachusetts	1874	Dam failure	Flint, Michigan	1975	Heavy rain
Omaha, Nebraska	1881	Heavy rain	Kansas City, Missouri	1977	Heavy rain
Council Bluffs, Iowa	1881	Heavy rain	Linda, California	1986	Heavy rain
Johnstown, Pennsylvania	1889	Dam failure	Thornton, California	1986	Heavy Rain
Hepner, Oregon	1903	Heavy rain	Grand Forks, North Dakota	1987	Dike failure
Lansing, Michigan	1904	Heavy rain	East Grand Forks, Minnesota	1987	Dike failure
Kalamazoo, Michigan	1904	Heavy rain	Fargo, North Dakota	1987	Dike failure
Pittsburgh, Pennsylvania	1907	Heavy rain	Moorhead, Minnesota	1987	Dike failure
Albion, Michigan	1908	Heavy rain	Wahpeton, North Dakota	1987	Dike failure
Austin, Pennsylvania	1911	Dam failure	Breckenridge, Minnesota	1987	Dike failure
Columbus, Ohio	1913	Levee failure	Lewiston, Maine	1987	Heavy rain
Dayton, Ohio	1913	Heavy rain	Rumford, Maine	1987	Heavy rain
Chillicothe, Ohio	1913	Heavy rain	Mexico, Maine	1987	Heavy rain
Taylor, Texas	1921	Hurricane	Jay, Maine	1987	Heavy rain
Lowell, Massachusetts	1936	Heavy rain	Hartford, Connecticut	1996	Heavy rain
Cincinnati, Ohio	1937	Heavy rain	Olivehurst, California	1997	Levee failure
Louisville, Kentucky	1937	Heavy rain	Arboga, California	1997	Levee failure
Owensboro, Kentucky	1937	Heavy rain	Wilton, California	1997	Levee failure
Paducah, Kentucky	1937	Heavy rain	Manteca, California	1997	Levee failure
Aurora, Indiana	1937	Heavy rain	Modesto, California	1997	Levee failure
Columbus, Ohio	1937	Heavy rain	Fort Collins, Colorado	1997	Heavy rain
Dayton, Ohio	1937	Heavy rain	San Marcos, Texas	1998	Hurricane
Los Angeles, California	1938	Heavy rain	New Braunfels, Texas	1998	Hurricane
Manhattan, Kansas	1951	Heavy rain	Wilmington, North Carolina	1999	Hurricane
Topeka, Kansas	1951	Heavy rain	Bound Brook, New Jersey	1999	Hurricane

Location	*Year*	*Primary "Cause"*	*Location*	*Year*	*Primary "Cause"*
New Brunswick, New Jersey	1999	Hurricane	New Ulm, Minnesota	2010	Heavy rain
Houston, Texas	2001	Hurricane	Mankato, Minnesota	2010	Heavy rain
Beaumont, Texas	2001	Hurricane	St. Peter, Minnesota	2010	Heavy rain
New Orleans, Louisiana	2005	Hurricane and levee failure	Savage, Minnesota	2010	Heavy rain
Atlanta, Georgia	2009	Heavy rain	Shakopee, Minnesota	2010	Heavy rain
Warwick, Rhode Island	2010	Heavy rain	Henderson, Minnesota	2010	Heavy rain
Cranston, Rhode Island	2010	Heavy rain	Brandon, Minnesota	2011	Heavy rain
Johnston, Rhode Island	2010	Heavy rain	Minot, North Dakota	2011	Heavy rain

Box 13.2 "Flash-Flood Alley"

The Austin to San Antonio (Interstate 35) corridor in central Texas contains some of the fastest-growing US communities of the past decade. The population of the five-county region (Williamson, Travis, Hays, Comal, and Bexar) has grown from about 2.6 million to more than 3.4 million from 2000 to 2010, and the Round Rock-Austin-San Marcos Metropolitan Statistical Area is the eighth-fastest growing region of the country. While not a shocking fact, the implications might surprise. Population growth needs land development. This region straddles a geologic feature known as the Balcones Fault, and this is seen in a landscape feature: the Balcones Escarpment. The escarpment is uplifted limestone; its prominence separates the Blackland Prairie region (a southern extension of the Midwest prairies) from the Edwards Plateau (the southeastern portion of the high plains province called the "Texas Hill Country"). Because the Edwards Plateau is limestone and because climate and vegetation don't foster it, soil does not form quickly. Little soil is present in the eastern part of this region, and the land has little capacity to absorb rainfall or runoff.

The inactive fault is not the source of hazard in the region: the uplifted land creates the risk. The uplift (gradual in some places, abrupt in others) causes an elevation rise of up to three hundred feet. This small difference orographically lifts air masses moving westward off the Gulf of Mexico when cold fronts approach from the west. The more humid (and warmer) Gulf air contrasts with the arid, cooler desert air. A clash between the two often generates very heavy precipitation events of short duration. When Gulf air masses are weakening tropical weather systems (like hurricanes), the amount of precipitation in one storm can be extreme. It often equals the annual average precipitation of the region.

This has always occurred and is natural. However, new residents and their development must contend with this flash flooding, and hazards are abundant. More people mean a greater probability that people and property will be affected. Add the transformation of land as vegetation is removed for road, subdivision, and business construction and as impervious (nonabsorbent) cover is added. Rainfall runs off even faster. The runoff crosses the new developments and the road networks built across natural ephemeral stream channels. The channels turn into the occasional rivers that formed them, and fast-flowing water several feet deep can cross a road perpendicular to the traffic. Inattentive and overly confident drivers can find themselves floating downstream, and if they are lucky, they can escape with their lives (but probably not their cars). Some are not so lucky.

Between 1990 and 2004, more than 190 major flood events occurred in these counties, leading to at least thirty-five deaths caused by encounters with flooded roadways. An "untolled" (they are not often reported or even recorded by authorities) number of drivers and passengers have averted personal catastrophe by surviving their encounters. This region has seen neither major nor minor flooding (not even much precipitation) since 2008 because of a multiyear drought, and this is ominous. Flood risk has continued to increase as a result of landscape development over the past five years, and flood hazards will also climb as new residents (and new and youthful automobile drivers) will not know where to expect flooded properties and flooded roadways. Many will see "new" floodplains revealed for the first time.

Surface-water management has evolved throughout North America's development. Eighteenth- and nineteenth-century approaches primarily avoided floods and drained flooded lands. Innovations, such as mechanical dredges and pumping systems, aided such efforts later in the nineteenth century, but management simply attempted to move water out of or away from cities and into the countryside. Dams controlled some dynamic rivers by impoundment but were often primarily intended to generate energy. Not until the late twentieth century were dams used to protect cities. By contrast, levee enhancement and artificial levees in and around the Midwest, the South, and the West in the late nineteenth and early twentieth centuries was used to mitigate flood hazards. St. Louis and Kansas City, Missouri, and Brownsville, Texas, for instance, grappled with levee issues during the past century as these "improvements" were built to signal that these cities were safe and ripe for investment. Figure 13.2 shows a seawall in Galveston, Texas.

Commercial rivers received the most attention in the early twentieth century. The Ohio and Mississippi Rivers, for example, experienced numerous floods. The catastrophic Mississippi River flood of 1927 not only was a major watershed event in flood management but had major social and cultural ramifications as well. The most revealing element of the 1927 flood, however, was the dynamiting of levees downstream of New Orleans in order to "save" the city. Of course, the city that was saved was not really the people, but rather the economic interests of powerful local investors. The spaces of the poor and rural residents of Plaquemines Parish were sacrificed to the inundation. The Ohio River flood of 1937 also had significant impacts on river cities from Cincinnati to Paducah. The numerous major floods of the middle of the twentieth century led one geographer, Gilbert White, to delve

Figure 13.2 Seawall and beach, Galveston, Texas, ca. 1910.
Source: Library of Congress.

into American flood management, questioning the efforts to engineer floods from rivers and encouraging better decision making by floodplain occupants.

At the time, national policy toward flood disasters emphasized "bailing out" the victims of disasters rather than preventing disasters. After several decades of great expense, federal flood policies evolved to discourage risk taking (by reducing flood hazard). By the 1970s, the federal government encouraged loss protection through insurance rather than federal relief and reconstruction. Today, floodplain residents are "taxed" by compulsory participation in the National Flood Insurance Program. Unfortunately, this tax applies only to property buyers acquiring federally insured mortgages for flood-susceptible property. Those who owned and occupied floodplain properties before the program are not required to have flood insurance, so many at-risk floodplain residents are the next flood away from personal disaster and probable reliance on federal, state, private, and nonprofit relief. Indeed, countless millions of urbanites reside in locations of high flood risk today, and only by the luck inherent in probability have they not been impacted.

Hurricanes

In southeastern, midwestern, and eastern cities of North America, the annual season of tropical cyclone development raises the specter of flood disaster. Dozens of atmospheric low-pressure centers develop over warm subtropical waters of northern oceans during the summer and fall. Some evolve into so-called tropical depressions, tropical storms, and hurricanes. Paths and life spans of these storms are dictated by complex atmosphere-ocean interactions. Guessing where storms will go requires predictive models that are constantly fed data from monitoring and surveillance. Currently, these models are moderately successful.

North America's greatest death toll from any disaster was produced by a hurricane that struck Galveston, Texas, in 1900. At least six thousand people are believed to have died. While our technological capacity has evolved to detect and monitor hurricanes to allow time for warning of communities in their paths, precise and accurate prediction is still elusive. Only advancements in atmospheric science offer the improved prognostication of movements and strength of hurricanes. In the meantime, cities in cyclone-exposed regions must remain vigilant during hurricane "season" and should remove people from hazard-exposed locations.

Since 1842, hundreds of hurricanes and tropical storms have made landfall in the United States or Canada (figure 13.3). As with other natural processes, the patterns of hurricanes of the past do not determine future patterns of hurricanes. Examination of the list of past hurricanes reveals the chaotic temporal and spatial pattern of hurricanes and their tendencies over the past 160 years (table 13.2). For instance, 60 of the 167 (category 2 or stronger) land-falling hurricanes occurred between 1850 and 1900. In the next fifty years (up to 1950), only thirty-eight more made landfall on Atlantic and Gulf coasts. Forty-five more made landfall between 1951 and 2000, and eleven more have crossed North American coasts in the past twelve years. Not all of these hurricanes struck urban areas, but each storm had a potential to impact many small and large cities. Urbanization has expanded the area of potential exposure. The population of coastal regions has climbed dramatically during the past century and a half as well, and it is easy to understand that the hazard is ever greater. Today, twenty-one million North Americans live in urban areas along coasts at elevations ten meters or less above sea level, while more than 50 percent of the US population lives in coastal counties today. Coastal

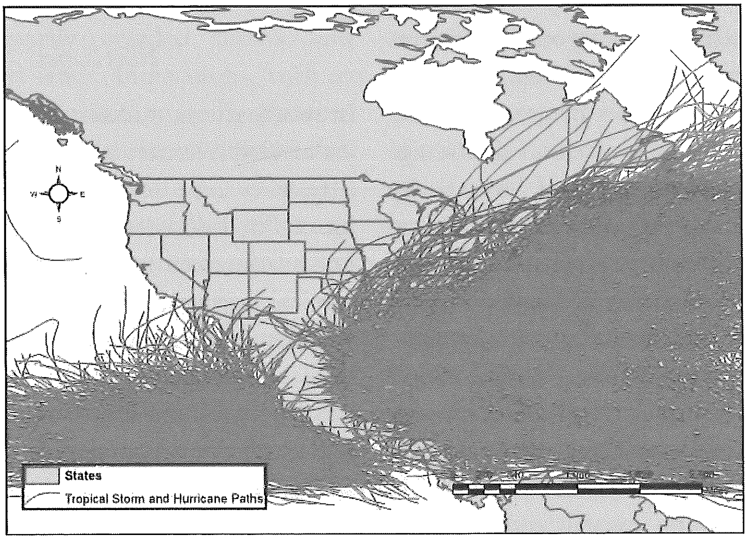

Figure 13.3 Paths of hurricanes and tropical storms in North America from 1842 to 2010. *Source:* International Best Track Archive for Climate Stewardship, National Climatic Data Center, National Oceanic and Atmospheric Administration. http://www.ncdc.noaa.gov/oa/ibtracs/index.php?name=ibtracs-data. Accessed April 26, 2012.

Table 13.2 "Strong" (Category 2 or Higher) Hurricanes in the United States and Canada, 1850–Present

*Date**	*Name*	*Category***	*States Affected****
8/23/1851	Unnamed	3	Florida
8/25/1852	Unnamed	2	Louisiana
8/26/1852	Unnamed	3	Alabama, Mississippi
10/9/1852	Unnamed	2	Florida
9/8/1854	Unnamed	3, 2	Georgia, South Carolina
9/18/1854	Unnamed	2	Texas
8/16/1855	Unnamed	3	Mississippi
9/16/1855	Unnamed	3	Louisiana
8/11/1856	Unnamed	4	Louisiana
8/31/1856	Unnamed	2	Florida
8/11–12/1860	Unnamed	3, 2	Louisiana, Mississippi, Alabama
9/15/1860	Unnamed	2	Louisiana, Mississippi
10/2/1860	Unnamed	2	Louisiana
9/1/1865	Unnamed	2	Louisiana
10/23/1865	Unnamed	2	Florida
7/15/1866	Unnamed	2	Texas
10/4/1867	Unnamed	2	Louisiana
8/17/1869	Unnamed	2	Texas
9/8/1869	Unnamed	3	Massachusetts
10/4/1869	Unnamed	2	Maine
8/16/1871	Unnamed	3	Florida
8/25/1871	Unnamed	2	Florida
10/7/1873	Unnamed	3	Florida
9/16/1875	Unnamed	3	Texas
10/20/1876	Unnamed	2	Florida
10/3/1877	Unnamed	3	Florida
9/10/1878	Unnamed	2	Florida
10/23/1878	Unnamed	2	North Carolina
8/18/1879	Unnamed	3, 2	North Carolina, Virginia
8/23/1879	Unnamed	2	Louisiana, Texas
9/1/1879	Unnamed	3	Louisiana
8/13/1880	Unnamed	3	Texas
8/29/1880	Unnamed	2	Florida

(*continued*)

Table 13.2 ***(continued)***

*Date**	*Name*	*Category***	*States Affected****
8/28/1881	Unnamed	2	Georgia
9/9/1881	Unnamed	2	North Carolina
9/10/1882	Unnamed	3	Florida
9/15/1882	Unnamed	2	Louisiana
9/11/1883	Unnamed	2	North Carolina
8/25/1885	Unnamed	3	South Carolina
9/25/1885	Unnamed	2	North Carolina
6/14/1886	Unnamed	2	Louisiana, Texas
6/21/1886	Unnamed	2	Florida
6/30/1886	Unnamed	2	Florida
8/20/1886	Unnamed	4	Texas
10/12/1886	Unnamed	3, 2	Louisiana, Texas
9/21/1887	Unnamed	2	Texas
8/16/1888	Unnamed	3	Florida
10/11/1888	Unnamed	2	Florida
8/28/1893	Unnamed	3	Georgia, South Carolina
9/7/1893	Unnamed	2	Louisiana
10/2–3/1893	Unnamed	4, 2	Louisiana, Mississippi, Alabama
9/25/1894	Unnamed	2	Florida
10/9/1894	Unnamed	3	Florida
7/7/1896	Unnamed	2	Florida
9/29/1896	Unnamed	3, 2	Florida, Georgia
10/2/1898	Unnamed	2, 4	Florida, Georgia
8/1/1899	Unnamed	2	Florida
8/18/1899	Unnamed	3	North Carolina
10/31/1899	Unnamed	2	South Carolina, North Carolina
9/9/1900	Unnamed	4	Texas
9/27/1906	Unnamed	2	Florida, Alabama, Mississippi
10/18/1906	Unnamed	3	Florida
6/29/1909	Unnamed	2	Texas
7/21/1909	Unnamed	3	Texas
9/20–21/1909	Unnamed	3, 2	Louisiana, Mississippi
10/11/1909	Unnamed	3	Florida

*Date**	*Name*	*Category***	*States Affected****
9/14/1910	Unnamed	2	Texas
10/18/1910	Unnamed	2	Florida
8/28/1911	Unnamed	2	South Carolina
10/16/1912	Unnamed	2	Texas
8/17/1915	Unnamed	4	Texas
9/29/1915	Unnamed	3, 2	Louisiana, Mississippi
7/5–6/1916	Unnamed	3, 2	Mississippi, Alabama, Florida
7/14/1916	Unnamed	2	South Carolina
8/18/1916	Unnamed	4	Texas
10/18/1916	Unnamed	2	Alabama, Florida
9/29/1917	Unnamed	3, 2	Florida, Louisiana
8/7/1918	Unnamed	3	Louisiana
9/10/1919	Unnamed	4	Florida
9/14/1919	Unnamed	3	Texas
9/21/1920	Unnamed	2	Louisiana
10/25/1921	Unnamed	3	Florida
7/27/1926	Unnamed	2	Florida
8/21/1926	Unnamed	3	Alabama
8/26/1926	Unnamed	3	Louisiana
9/18/1926	Unnamed	4	Florida
8/8/1928	Unnamed	2	Florida
9/17/1928	Unnamed	4	Florida
9/28/1929	Unnamed	3	Florida
8/14/1932	Unnamed	4	Texas
8/7/1933	Unnamed	2	Texas
8/23/1933	Unnamed	2	North Carolina, Virginia
9/4–5/1933	Unnamed	3	Florida, Texas
9/16/1933	Unnamed	3	North Carolina
6/16/1934	Unnamed	3	Louisiana
7/25/1934	Unnamed	2	Texas
9/3/1935	Unnamed	5	Florida
11/4/1935	Unnamed	2	Florida
7/31/1936	Unnamed	3	Florida
9/21/1938	Unnamed	3	New York, Connecticut, Rhode Island, Massachusetts

(continued)

Table 13.2 ***(continued)***

*Date**	*Name*	*Category***	*States Affected****
8/7–8/1940	Unnamed	2	Louisiana, Texas
8/11/1940	Unnamed	2	Georgia, South Carolina
9/23/1941	Unnamed	3	Texas
10/6/1941	Unnamed	2	Florida
8/30/1942	Unnamed	3	Texas
7/27/1943	Unnamed	2	Texas
9/14–15/1944	Unnamed	3, 2	North Carolina, Virginia, New York, Connecticut, Rhode Island, Massachusetts
10/19/1944	Unnamed	3	Florida
8/27/1945	Unnamed	2	Texas
9/15/1945	Unnamed	3	Florida
9/17–19/1947	Unnamed	4, 3	Florida, Louisiana, Mississippi
10/15/1947	Unnamed	2	Georgia, South Carolina
9/21/1948	Unnamed	3	Florida
10/5/1948	Unnamed	2	Florida
8/26/1949	Unnamed	3	Florida
10/4/1949	Unnamed	2	Texas
9/5/1950	Easy	3	Florida
10/18/1950	King	3	Florida
8/31/1954	Carol	3	North Carolina, New York, Connecticut, Rhode Island
9/11/1954	Edna	3	Massachusetts
10/15/1954	Hazel	4, 2	South Carolina, North Carolina, Maryland
8/12/1955	Connie	3	North Carolina
9/19/1955	Ione	3	North Carolina
9/24/1956	Flossy	2	Louisiana
6/27/1957	Audrey	4	Louisiana, Texas
9/27/1958	Helene	3	North Carolina
9/29/1959	Gracie	3	South Carolina
9/12/1960	Donna	4, 3, 2	Florida, North Carolina, New York, Connecticut, Rhode Island
9/11/1961	Carla	4	Texas
8/27/1964	Cleo	2	Florida
9/10/1964	Dora	2	Florida
10/3/1964	Hilda	3	Louisiana
10/14/1964	Isbell	2	Florida

*Date**	*Name*	*Category***	*States Affected****
9/8–10/1965	Betsy	3	Florida, Louisiana
6/9/1966	Alma	2	Florida
9/20/1967	Beulah	3	Texas
10/19/1968	Gladys	2	Florida
8/17/1969	Camille	5	Louisiana, Mississippi
8/3/1970	Celia	3	Texas
9/16/1971	Edith	2	Louisiana
9/8/1974	Carmen	3	Louisiana
9/23/1975	Eloise	3	Florida
9/3–4/1979	David	2	Florida, Georgia, South Carolina
9/13/1979	Frederic	3	Alabama, Mississippi
8/10/1980	Allen	3	Texas
9/18/1983	Alicia	3	Texas
9/13/1984	Diana	3	North Carolina
9/1–2/1985	Elena	3	Florida, Alabama, Mississippi
9/27/1985	Gloria	3, 2	North Carolina, New York, Connecticut, New Hampshire
11/21/1985	Kate	2	Florida
9/22/1989	Hugo	4	South Carolina
8/19/1991	Bob	2	New York, Connecticut, Rhode Island, Massachusetts
8/24–26/1992	Andrew	5, 3	Florida, Louisiana
9/12/1992	Iniki	4	Hawaii
8/31/1993	Emily	3	North Carolina
8/3/1995	Erin	2	Florida
10/4/1995	Opal	3	Florida
7/12/1996	Bertha	2	North Carolina
9/6/1996	Fran	3	North Carolina
8/27/1998	Bonnie	2	North Carolina
9/25/1998	Georges	2	Florida, Mississippi
8/23/1999	Bret	3	Texas
9/16/1999	Floyd	2	North Carolina
9/18/2003	Isabel	2	North Carolina
8/13/2004	Charley	4	Florida
9/5/2004	Frances	2	Florida
9/16/2004	Ivan	3	Florida, Alabama

(*continued*)

Table 13.2 ***(continued)***

*Date**	*Name*	*Category***	*States Affected****
9/26/2004	Jeanne	3	Florida
7/10/2005	Dennis	3	Florida
8/29/2005	Katrina	3	Louisiana, Mississippi
9/24/2005	Rita	3	Texas, Louisiana
10/24/2005	Wilma	3	Florida
9/1/2008	Gustav	2	Alabama, Louisiana
9/13/2008	Ike	2	Florida, Texas, Louisiana, Mississippi, Alabama

* Dates indicate the day of landfall. A range indicates the dates the storms entered new states.
** Category listed is determined by the strength of the hurricane as it made landfall or crossed into the next state or states listed.
*** States listed are those that experienced category 2 or higher sustained winds and are in order of the storm's passage.

counties comprise 17 percent of US land area, and most of this space is on the Atlantic and Gulf coasts, where hurricanes occur at least annually (on average). There is therefore significant potential for disaster.

Hurricanes can bring a range of problems to urban areas. While tropical storms can also cause major flood events, hurricanes add the hazards of high sustained winds (anything above seventy-four miles per hour creates a "hurricane"), tornadoes, and storm surge. Passage of the storm does not necessarily end the event. Transportation, power, and emergency response can all be debilitated by the storm. Box 13.3 describes New York City's experience with Superstorm Sandy and the complex risks associated with all phases of the hurricane event.

Box 13.3 New York Hurricane Hazard and Inundation Risk: Superstorm Sandy

New York City and its metropolitan region is a so-called megacity (an urban system with at least ten million people and a density exceeding two thousand people per square mile). The challenges of managing risk and hazard in such large cities (of which there are more than twenty today) often exceeds the capacity of local governments and regional management agencies.

In late October 2012, a tropical cyclone formed in the western Atlantic and quickly grew to a very large and destructive hurricane. Hurricane Sandy was the tenth hurricane of 2012, and the second major hurricane of that year. It made landfall first near Kingston, Jamaica. It moved back into the Caribbean Sea and strengthened, making landfall in Cuba as a category 3 storm. Several days later, Sandy curved north-northwest, gathered strength again, and merged with a storm moving over the eastern United States. The merge made it turn northwest, turning it into the Northeastern Seaboard. It was a category 2 when it made landfall along the coast of the northeastern United States on October 30 (see figure 13.4). In the

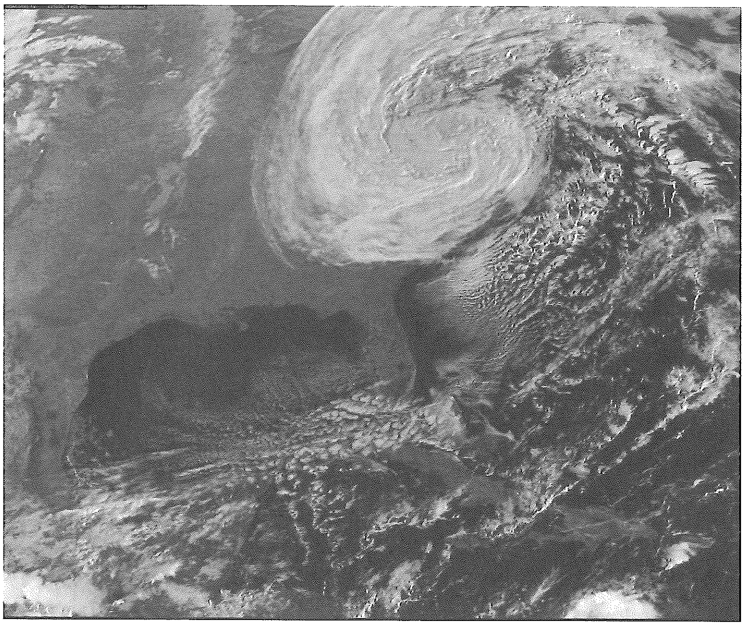

Figure 13.4 Superstorm Sandy makes it way to the northeastern United States, 2012. *Source:* NOAA.

United States, Hurricane Sandy affected twenty-four states but wrought most of its damage in New Jersey and New York. Damage in the United States was estimated at over seventy-one billion dollars. The severe and widespread damage the storm caused, as well as its unusual merge with a frontal system, led the media to nickname the hurricane "Superstorm Sandy."

In New York City, its storm surge flooded streets, tunnels, and subway lines, cutting power in and around the city. Flooding would be produced not because of the heavy rainfall rates or runoff from inland areas that can be expected but because hurricanes circulate counterclockwise in the northern hemisphere, and their greatest flood threat is found in the upper-right quadrant of the storm, where sustained winds and the low pressure of the atmosphere in the storm system lift and push the surface of the ocean forward, ahead of the storm. Storm "surge" is a major threat to coastal islands, bays behind barrier islands, and estuaries where freshwater rivers enter the salty ocean. If the path of a storm is oriented "just right" relative to the coast, it can cause devastating flooding, and this can be exacerbated further by coincidence with a period of high tide.

Several days before the storm hit, government weather forecasts noted that there was a 90 percent chance that the East Coast would be impacted by the storm. The governor of New York declared a state of emergency, as did New Jersey. The Federal Emergency Management Agency (FEMA) coordinated with state and other emergency management partners in states along the coast. Preparations began in New Jersey when residents on barrier islands were told to evacuate and the Atlantic City casinos were closed. In New

York and Pennsylvania, major airline carriers cancelled all flights into and out of major airports, and some of the railroads suspended service. In New York City, schools, bridges, tunnels, and subways were closed, and emergency management worked to evacuate low-lying portions of the islands of the city while people could still do so safely. Even the New York Stock Exchange closed for two days.

The storm caused widespread flooding and power outages. Some 4.8 million people were without power in the first days after the storm. A week later, nearly a million were still without power. Lines were down, and many substations were flooded by storm surge. One explosion at a substation on the East Side of Manhattan plunged the lower third of that borough into darkness for days. In New Jersey, the city of Hoboken flooded; and many coastal communities were devastated. At least thirty-seven people in New Jersey were killed. In New York, the East River overflowed its banks, flooding large sections of Lower Manhattan. Battery Park, for example, had a water surge of almost fourteen feet. Seven subway tunnels were flooded. The storm also damaged or destroyed more than one hundred thousand homes on Long Island. Several months after the storm, significant recovery work remained. Sandy highlighted the fragility of the aging American infrastructure, particularly the electricity network. In many Northeast communities, utilities have not buried power lines, which means that falling trees, branches, and debris from heavy winds can easily knock out power lines.

Superstorm Sandy helped reignite debate about the relationship between climate change and intense weather events. Sandy may be little more than the coincidental alignment of a tropical storm with another storm. But many believe that the storm was enhanced by global warming because of the abnormally warm sea surface temperatures offshore the East Coast of the United States. Warming oceans and greater atmospheric moisture are intensifying storms, while rising sea levels are worsening the effects of storm surge.

The track of this hurricane could have generated a worse disaster for New York City. It may be only a matter of time until a category 3 or stronger hurricane makes landfall in a region of very high population. Storm surges of storms greater than a category 3 will devastate the region, particularly when the surges are enhanced not only by a contemporaneous high tide but also by sea-level rise generated by climate change. Damages caused by hurricane winds and tornadoes spawned by hurricanes will make conditions even more dangerous. Mitigation by residents is vital to prevent disasters, but this always becomes especially difficult when many residents have developed dismissive attitudes to the warnings and suffered no consequences from doing so. Megacities possess megachallenges that are made even more complicated by the many people who cling to their beliefs of invincibility. Perhaps people have to experience disasters before they adopt attitudes that promote safety and self-preservation.

Although among climate scientists climate change is regarded as a certainty, how climate change will alter the geography of hurricanes is difficult to predict and diminishes scientific confidence about future hurricane predictability. This is publicly expressed as *uncertainty*. Fewer hurricanes might form (lowering risk), or more will form (heightening risk). They might be stronger (heightening risk) or weaker (lowering it). We may see a significant northward shift of these storms. Fewer might strike land (hazard might be lowered), or more might (heightening hazard). Perhaps the hazard will intensify as larger cities to the northeast (such as New York, Philadelphia, Toronto, Montreal, or Boston) or even on the West Coast (San Diego or Los Angeles, for instance) experience more and stronger hurricanes, some maybe for the first time. Because of their inexperience with full-strength hurricanes (rather than tropical storm or even tropical depressions), these cities may experience catastrophes. These cities are not likely to have developed hurricane disaster management plans, nor to have required building codes for these events.

Coastal Erosion

While the atmosphere is highly dynamic and constantly changing in its redistribution of heat and moisture around the globe, oceans are also dynamic and in constant motion; visible changes along coastlines may seem less abrupt to terrestrial residents. The most dynamic zone of the earth's surface however, is where land interacts with ocean. Ports were established on North American coasts to promote trade, facilitate naval power, and extract ocean resources. These cities depend upon regularity of the near-shore ocean bottom to enable safe passage of ships. The physical shape of most coastlines is unfortunately dictated by the supply and distribution of sediments (sands and finer-grade materials) derived from eroding lands and the entrained load transported seaward by rivers, from coastal zones "upstream" (laterally along the coast from the direction of longshore currents) or from offshore ocean sediments driven ashore by wave action. These sources of sediment vary over time, and major shifts in any can suddenly change the near-shore bottom, causing sedimentation of shipping lanes near a coast. Changes of the amount of sediment carried in rivers that flow into either bays behind barrier islands or directly into the ocean can change coastal beaches and wetlands that receive that sediment. In some coastal areas, beaches and wetlands provide buffers against land-falling hurricanes for the cities that may be located inland (see box 13.4).

Unwilling to accept prevailing environmental conditions, some cities have also attempted to engineer "their" coastlines to solve "their" problems. Unfortunately, they tend to only change their problems, not eliminate them, often disturbing downstream beaches. For instance, cities dredge ship channels through breaks in barrier islands to achieve sufficient depth for boat traffic. Dredging requires substantial monetary investment to sustain. The passage of major storms often rearranges sediments because of increased erosion onshore (upslope from the coast) and wave transport from offshore. Some cities build jetties (one or even a pair of long piles of stones dropped in lines jutting into the sea perpendicular to the coastline) instead of or in addition to dredging, intending to block or impair the flow of sediment laterally

Box 13.4 New Orleans, Katrina, and Coastal Erosion

Hurricane Katrina in 2005 unfortunately revealed, among myriad social and political problems, the socially constructed geography of inequity in exposure and social vulnerabilities of the residents of the city of New Orleans, as well as the structural vulnerabilities of the engineered environment that was built to protect New Orleans, Louisiana, from the ravages of hurricanes and Mississippi River floods. Levees were breached east of the city as a powerful storm surge flowed up the channel referred to as the Mississippi River Gulf Outlet (or MR-GO). Drainage and ship channels within the city were also inundated by storm surge from Lake Ponchartrain and the Industrial Canal as the hurricane passed just east of the city and winds drove the lake and river waters from the east and north into the "bowl" occupied by New Orleans. This disaster generated the largest loss of life (1,836 deaths) in the United States related to a natural phenomenon (as opposed to epidemics, acts of terrorism, or wars) since a 1928 cyclone that devastated Puerto Rico and southern Florida (killing more than three thousand Americans).

Katrina was a powerful hurricane. As it approached the coast of Louisiana in late August 2005, it was a category 5 hurricane with sustained winds exceeding 175 miles per hour. The storm surge predicted for the coast was expected to be twenty-nine feet or higher. Fortunately, during the early morning hours of August 28, before the hurricane made landfall in Louisiana, the sustained winds had diminished to 125 miles per hour, and the 120-mile-wide storm was recategorized to "only" a category 3 status.

While New Orleans occupies a high-risk position (in terms of flooding) as much of the city lies one to two feet below sea level and the height of the Mississippi River levees as the river passes through the city is twenty feet above sea level, its exposure to hurricanes and tropical storms from the Gulf of Mexico has been mitigated by the downstream deposition of the sediment that is carried past the city by the river. New Orleans is about fifty miles northwest of the Gulf of Mexico, and coastal beaches, barrier islands, estuarine wetlands, and thousands of square miles of marshes, swamps, and rural agricultural land established on riverine sediment help to buffer the city from storms off the Gulf. The sediment has poured from the channels of the bird's-foot delta over the ages. The entrained sediments are driven back toward the coastline by ocean waves, and they circulate in the littoral system. Historically, the intervening land south and east of New Orleans had been growing at accelerating rates over the past two centuries (enhanced by farming-generated erosion throughout the Mississippi-Missouri-Ohio River system). However, that trend has slowly reversed during the past few decades by efforts to manage the rivers' flows.

Levees, flood-control structures, dams, and locks all reduce the capacity of any river to carry sediment. Slower flow cannot carry as much sediment, and the result of the construction of these technologies is that less has been reaching the Mississippi's mouth at the Gulf. To this sediment starvation of coastal Louisiana, we must factor in the impacts of resource extraction activities in the coastal plain. The pumping of oil and natural gas from subsurface geological structures, the displacement and pumping of saltwater from local groundwater in order to improve land for agriculture, and the pumping of freshwater for consumption by small towns and cities in the region have collectively led to subsidence of the land surface and saltwater inundation of the coastal plain. Estuarine vegetation has a limited resistance to saltwater exposure, and it can be destroyed by constant and even permanent exposure to ocean water. Wave action increasingly erodes the vulnerable coastal land, and the Gulf creeps northward toward New Orleans. And adding future changes to the height of sea level resulting from climate change augments flood risk and several hazards that result from less coastal buffering capacity.

New Orleans is losing its protective cushion. It is believed that the impacts of Katrina may have been worsened by diminished natural mitigation capacity. As coastal wetlands shrink, so does the region's capacity to absorb the blow of hurricane landfall. As the coastline "moves" closer to New Orleans, the power unleashed by strong tropical cyclones will be less attenuated, and New Orleans will become less habitable.

along the shoreline. Jetties create "swirls" upstream of the jetties that dump the sediment offshore, starving the downstream coastline, which is then eroded by normal wave action. The coast downstream of the jetty wastes away as the beach retreats inland. In response, downstream residents often construct groins, shorter hydraulic structures comprising rock piles set at strategic angles to the coast and cemented with concrete designed to catch the eroding sediment and thereby save their beach or shoreline. These create pocket beaches that are periodically enriched artificially with dredged sand from offshore, satisfying local residents but, of course, starving downstream beaches of sediment. Contagious reactions continue to echo as the original decision reverberates on and on down the coast. Eventually, people on some segment of coast decide that the loss by erosion is too great a risk to their properties as the sea floods or threatens coastal properties, and they attempt to harden "their" shore to "eliminate" erosion of "their" coastline. Often communities will construct a seawall, a concrete abutment that is built vertically above the mean waterline to prevent direct wave action on the properties along the coastline. Galveston, Texas, did this, for example, after the infamous hurricane of 1900. Seawalls accomplish what coastal dunes might do naturally, but they provide no sand for accretion into a beach. Construction and periodic nourishment of an artificial beach is expensive and must be repeated *ad infinitum*. If not, the seawall will eventually receive the full energy of ocean-generated waves, and the near-shore bottom will deepen. Ultimately, the seawall could be undercut, requiring the battle to start anew with costly renewed vigor.

Add to this "normal" battle against the sea the impact of climate change. Atmospheric warming causes ocean warming. Warming water expands. Add freshwater melt from ice caps and glaciers, and the result is sea-level rise. Rising seas translate into coastal-zone flooding and shrinking land surface. Approximately twenty-one million urbanites in North America reside within about thirty feet of current-day sea level. As discussed in the previous chapter, significant climate-change-induced magnifications of coastal flood hazards will occur and will be very difficult to manage as they evolve. Among the exposed cities at great risk, the New York, Los Angeles, and Miami metropolitan areas are the most likely to experience extensive coastal inundation.

Aside from the direct impacts to buildings and to residential spaces and the permanent displacement of people, seawater floods will also destroy infrastructure and urban infrastructure through corrosion caused by saltwater. Roads, railways, and subways could be flooded, damaged, or destroyed by rising seas. Airports, seaports, and trucking facilities in low-lying areas might also be submerged. Dikes may be the only recourse to holding back the sea, and cities (like New Orleans, Miami, and New York) already poised for greater catastrophe given that they are at or below sea level will endure epic challenges unless they somehow adapt or adjust to predictions.

Severe Weather: Tornadoes, Blizzards, and Heat Waves

Among the most dramatic natural hazards of the atmosphere are extreme weather events that produce tornadoes, ice storms, blizzards, and heat waves. While these can occur anywhere and occur preferentially in no special types of landscapes, the city does magnify their threats.

Destructive windstorms, for example, cannot be prevented, but their effects are manageable. One great twentieth-century achievement is technology enabling detection and tracking of tornadoes. Increased warning time and advance communication of imminent storms has saved many lives. Improved radar and preparedness have made mass casualties from tornado outbreaks less likely. Destruction caused by storms, however, is not easy to avoid. Though generally moving west to east, the path of a tornado is rather arbitrary from the perspective of residents, as tornadoes are seemingly guided mostly, if not entirely, by atmospheric dynamics rather than by the characteristics of the landscape. Windproofing efforts such as hurricane clips on the roofs of houses can prevent damage in weaker storms, but a direct "hit" by a tornado frankly makes windproofing of most structures irrelevant. Education programs that encourage wind-resistant design of shelters or construction of safe rooms in homes for refuge are probably the most effective activities for mitigation of damages and prevention of deaths and injuries from tornadoes in cities and their surroundings.

The damages wrought by blizzards and ice storms that interrupt transportation, collapse power lines, or prevent emergency response can be mitigated by prestorm emergency response planning. Having working and effective equipment to plow snow from roads or restore power quickly is vital and requires not just financial resources but also adequate foresight by city managers. Ironically, it is not the cities prone to blizzards, ice storms, or windstorms that are most likely to experience disasters. The communities having little experience will be less prepared for response. Cities in the southeastern United States, for instance, are far less experienced with regard to unusual winter storms. It may not be realistic or financially feasible for all cities to prepare for rare events, so usually, many simply take their chances and weather the consequences.

Heat waves are defined as extended periods of unusual, constant, and extreme heat and are most often associated with cities. Development replaces natural land cover with artificial surfaces that behave differently when sunlight falls on them. City surfaces are made of unnatural heat-absorbent materials like concrete and blacktop macadam (covering parking lots, airports, and road networks) and roofing materials (such as dark shingles and tar). Increased absorption enhances the normal amount of solar radiation that will be converted from the high-energy, shorter wavelengths of incoming solar radiation (or insolation) into longer wavelengths as they are reradiated to the lower atmosphere, thus warming it. In this way, cities effectively create "heat islands" in local and regional weather patterns. The urban heat island is the distinct warming of urban areas compared with surrounding rural areas. In the average US metro region, for example, urban areas are 4 to 18 degrees Fahrenheit (2 to 10 degrees Celsius) warmer than surrounding rural areas. Warmer cities also mean hotter buildings that may be insufficiently ventilated or cooled without technology. Air conditioning is usually used to respond to this these days, but using more air conditioning raises the urban demand for electricity and can result in blackouts that ironically disable the cooling systems used to make such places livable. The city of Chicago, for example, has an active policy of encouraging the vegetation of commercial roofs through grants, tax breaks, and other financial inducements to developers and builders.

Heat waves are particularly dangerous in homes and buildings that can't staunch the heat or for residents who can't afford to cool them. The most likely to suffer are the most vulnerable: the elderly, the infirm, the poor, and those who are socially isolated from public assistance. Heat waves affect people in rural areas as much as in urban areas, but recent heat waves in Chicago (1995), New York and the cities of the Middle Atlantic states (1999, 2001), the entire eastern half of Canada and the United States (2002, 2006), and Los Angeles and much of California (2006) produced mass casualties among their vulnerable populations. The 1995 heat wave that struck the city of Chicago lasted for over a week with temperatures that reached over one hundred degrees every day. By July 20, more than seven hundred people had died. It was referred to in the press as a "natural disaster," an unfortunate outcome of a freak meteorological condition. But in his 2002 book *Heat Wave*, Eric Klinenberg found that deaths were greatest among elderly people living on their own. The tragedy was not simply a natural disaster but the outcome of the social isolation of seniors, retrenchment of public assistance, and declining neighborhoods. Most victims were seniors who lived alone with few visits from public health officials. This underscores a key theme in this chapter: the disaster was not the result of high temperatures but of high temperatures as mediated through a complex set of social and political relationships.

The problem of heat in cities will worsen with global climate change. Nighttime low temperatures are expected to rise as the atmosphere also humidifies resulting from increased evaporation caused by rising temperatures. Physiological stresses caused by daytime heating will increase because of the lack of nighttime relief. Heat-related death rates in cities will rise and may be magnified, particularly by air pollution.

Earthquakes

Although "where" earthquakes will strike is easier to predict than where weather events will occur, the *timing* of earthquakes is unpredictable; there also seems to be no presaged warning. The scientific understanding of the workings of the earth's crust has improved exponentially since the 1850s, and detection and monitoring technologies and networks have improved our understanding of the risk patterns. Fault lines in the crust reveal stressed zones at the interfaces of earth's tectonic plates. These are usually seismically active areas and provide information about the direction and speed at which the plates are moving above the mantle. These tend to indicate something about the potential for an earthquake. Occasionally, however, faults that are located near the edges of plates are not visible at the surface, and this leaves us blind to their existence. These blind faults pose significant danger, particularly for urban areas in places like the Pacific Northwest. Past earthquakes and volcanic features are indicators of seismic regions produced by convergence of plates or by midplate "hot spots." These spots are usually far from plate boundaries and have caused major earthquakes in the US mid-South and coastal southeast. Plate movement is not smooth and constant, however, and plates do not generate quakes with any apparent temporal or spatial regularity. Therefore, releases of built-up pressures on faults are not predictable, and the best management responses we can take are avoiding development in earthquake-prone areas, engineering the city to adapt to the risk, and mitigating the impacts of earthquakes.

Earthquakes have been important in the histories of several North American cities (table 13.3). While seismic zones have generated disasters infrequently in our region, they are very important to our cities. Today, Seattle, Washington, Vancouver, British Columbia, Portland, Oregon, and Memphis, Tennessee, are poised for unprecedented disasters should the "big ones" occur, as seismologists suggest. The damages depend on the progress of mitigation and activities to retrofit existing infrastructure. Other Pacific Coast cities including Anchorage, Alaska, San Francisco, California, and Los Angeles, California, have had earthquakes relatively recently. One earthquake does not completely eliminate the potential for another in the same region soon after the first, and in some regions of the world, large earthquakes are relatively frequent. The second greatest "natural" disaster in the United States in terms of loss of life occurred in San Francisco in 1906 (see figure 13.5). The city was devastated not only by earthquake but also by uncontainable conflagration. The same city experienced another destructive but weaker earthquake in 1989. If events similar to our past earthquakes were to occur today, the impacts could be devastating. And if the past reveals risk, cities of the East and the Rocky Mountains should be prepared: major earthquakes struck Charleston, South Carolina (1886), and Denver, Colorado (1873).

Today, most North America cities have earthquake risk, but most are rather low probabilities and involve only weak earthquakes. The only region unlikely to see a strong earthquake is north-central North America, where the bedrock is an igneous formation known as the Canadian Shield (figure 13.6). The perimeter of this region has experienced a number of sizable earthquakes, for instance, in the St. Lawrence Valley of Canada, but significant quakes to the north and west are rare. The biggest threat today seems to be in the Pacific Northwest, where residents face the prospects of a quake that could be greater than a 9.0 Richter-scale magnitude (see box 13.5).

Table 13.3 Major (> 6.0 Richter Magnitude) Earthquakes in the United States and Canada, 1800–Present

Location	*Date*	*Magnitude*	*Location*	*Date*	*Magnitude*
New Madrid, Missouri	12/16/1811	7.0	Lompoc, California	11/4/1927	7.1
New Madrid, Missouri	12/16/1811	7.7	Grand Banks off Newfoundland	11/18/1929	7.2
New Madrid, Missouri	1/23/1812	7.5	Eureka, California	6/6/1932	6.4
New Madrid, Missouri	2/7/1812	7.7	Long Beach, California	3/11/1933	6.4
San Bernardino County, California	12/08/1812	6.9	Parkfield, California	6/8/1934	6.1
Ventura, California	12/21/1812	7.1	Helena, Montana	10/19/1935	6.3
Northeast Arkansas	1/5/1843	6.3	Helena, Montana	10/31/1935	6.0
Fort Tejon, California	1/9/1957	7.9	Timiscaming, Ontario	11/1/1935	6.1
Hayward, California	10/21/1868	6.8	San Francisco Bay, California	6/10/1936	6.5
Lake Chelan, Washington	12/14/1872	7.4	Maui, Hawaii	1/23/1938	6.8
California/Oregon Coast	11/23/1873	7.3	San Francisco, California	6/11/1938	6.8
Denver, Colorado	11/08/1882	7.3	Imperial Valley, California	5/19/1940	7.1
Charleston, South Carolina	9/1/1886	7.3	Vancouver Island, British Columbia	6/23/1946	7.3
Imperial Valley, California	2/24/1892	7.8	Haida Gwaii, British Columbia	8/22/1949	8.1
Vacaville, California	4/19/1892	6.4	Puget Sound, Washington	4/13/1949	7.1
Charleston, Missouri	10/31/1895	6.6	Kona, Hawaii	8/21/1951	6.9
Calaveras fault, California	6/20/1897	6.3	Kern County, California	7/21/1952	7.3
Mendocino County, California	4/15/1898	6.8	Fallon-Stillwater area, Nevada	7/6/1954	6.6
Eureka, California	4/16/1899	7.0	Stillwater, Nevada	8/24/1954	6.8
San Jacinto, California	12/25/1899	6.7	Eureka, California	12/21/1954	6.5
Parkfield, California	3/3/1901	6.4	Prince William Sound, Alaska	3/28/1964	9.2
Cook Inlet, Alaska	12/31/1901	7.1	Puget Sound, Washington	4/29/1965	6.5
Fairbanks, Alaska	8/27/1904	7.3	Parkfield, California	6/28/1966	6.1
San Francisco, California	4/18/1906	7.8	San Fernando, California	2/9/1971	6.6
Calaveras fault, California	7/1/1911	6.5	Sitka, Alaska	7/30/1972	7.6
San Jacinto, California	4/21/1918	6.8	US-Mexico border, Imperial Valley, California	10/15/1979	6.4
Vancouver Island, British Columbia	12/6/1918	7.2	Humboldt County, California	11/8/1980	7.2
Eureka, California	1/31/1922	7.3	Loma Prieta, California	10/18/1989	6.9
Parkfield, California	3/10/1922	6.1	Landers, California	6/28/1992	7.3
Humboldt County, California	1/22/1923	7.2	Northridge, California	9/1/1994	6.7
Charlevoix, Quebec	3/1/1925	6.2			
Santa Barbara, California	6/29/1925	6.8			
Monterey Bay, California	10/22/1926	6.1			

Figure 13.5 San Francisco after the earthquake and fire of 1906. (Photo by Arnold Genthe, 1906, courtesy of Library of Congress)

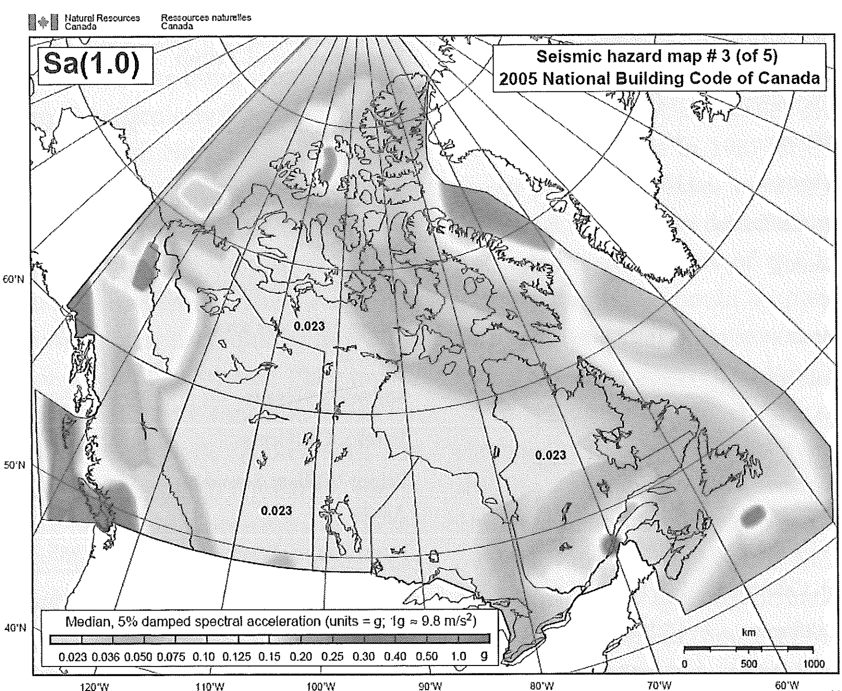

Figure 13.6 Map of seismic risk in Canada indicating where there exists a 2 percent probability that an earthquake producing peak ground acceleration of one Hz (or a wave of one cycle per second) will occur in the next fifty years. *Source:* Natural Resources Canada. http://www.earthquakescanada.nrcan.gc.ca/hazard-alea/zoning/NBCC2005maps-eng.php. Accessed April 26, 2012.

Box 13.5 Earthquake Hazards in Seattle, Washington, and Victoria and Vancouver, British Columbia

On January 26, 1700, the greatest known earthquake to strike Canada and one of the strongest to strike North America in modern times occurred along the undersea Cascadia thrust fault off the west coast of Vancouver Island, British Columbia. The earthquake has been retrospectively measured as having had a magnitude of 9.0 on the Richter scale and is considered a "great quake" (of which there have been thirteen over the past six thousand years). The primary hazard that an offshore earthquake of this size would pose is a tsunami risk for coastal cities of the Pacific Basin. A similar quake striking in the same proximity today would certainly cause great destruction in cities and towns throughout the Puget Sound region of the United States and southwestern British Columbia, Canada.

An even greater hazard to this region than such great quakes (which are almost certain to occur again in the very near future) is the probability of weaker, though still very destructive, earthquakes that originate along faults located beneath the cities of Seattle and Vancouver. These onshore earthquakes can be shallow or deep in the crust and can release Richter magnitude 7 levels of energy. Five have occurred within about four hundred miles of Seattle and Victoria during the past 130 years: in 1872 (a shallow quake) and then in 1918, 1929, 1946, and 1970 (deeper quakes). In 2001, a 6.8 magnitude earthquake called the Nisqually Quake caused two billion dollars in damage to Seattle. This was a deep quake that did not hit Seattle as strongly as the others, but it was felt over a much wider area. The proximity of the moving Pacific, North American, and Juan de Fuca crustal plates (that generate deep and megathrust events) and hundreds of faults (that generate very strong shallow quakes) to the built environment makes the Pacific Northwest (and Canada's Southwest) extremely likely to suffer a significant catastrophe in the near future. (It is said that there is an 84 percent chance that an earthquake of 6.5 magnitude or greater will occur here in the next fifty years and a 21 percent chance that a "structurally damaging" earthquake will impact the southern end of Vancouver Island in the same time frame.)

As has been discussed, the presence of people makes hazard from the natural risk. Seattle, for instance, currently has a population exceeding six hundred thousand and is surrounded by urbanized areas of more than eight thousand square miles that contain more than 3.4 million people. Similarly, Vancouver has about six hundred thousand residents, and its metropolitan population is almost 2.9 million people spread over only 1,100 square miles. Victoria, the capital of British Columbia, has a population of about eighty thousand and a metropolitan population of nearly 350,000 in an area of about 270 square miles. These cities were established during the latter half of the nineteenth century in this active and seismically complex region. The most important questions that must be faced are related to efforts to improve seismic engineering and safety of structures in the built environment and the preparation of residents should the expected occur.

The Seattle Fault is an east-west trending fault line that generated a very large earthquake a little more than a millennium ago. It runs through Seattle from Bremerton to Issaquah beneath areas that have very loose sediments overlying the bedrock. Unconsolidated earth and rock debris have the tendency to move when shaken violently, and this causes them to behave much like a liquid. This process is called liquefaction. The implications of liquefaction were most clearly seen in the effects of the 1989 Loma Prieta earthquake in the Marina district of San Francisco. Aside from loss of structural stability for buildings, particularly in places where urban space was created with artificial fill, slopes can fail (chiefly in places where structures have been constructed above the slope), and landslides can rearrange the land surface, particularly in areas like the Pacific Northwest that have significant topographical relief. The humid environment will also contribute to this liquefaction and the slide susceptibility of these urban areas.

The most critical challenges involve the collapse of structures and breakage or failure of, in particular, critical infrastructure. Fortunately, communities, states, and provinces in this portion of both countries have aggressively undertaken mitigation. Seismic retrofits of homes (particularly low-income residential structures), redesign, retrofitting and reconstruction of critical infrastructure (like fire stations, fire boats, bridges, automatic gas shut-off valves, the water system, dams), and upgrading of building codes have been supported logistically and financially by the city of Seattle in the past few years. Community preparedness has also been a focus, not only among the general population, but among the most vulnerable populations (the elderly and disabled, linguistically isolated populations, and the poor) as well. Since 2004, Vancouver has completed more than 137 seismic mitigation projects to schools and many other buildings as well. The provincial government updated its earthquake response plan (in 2008), coordinating the responsibilities of individuals, communities, the province, First Nations, and the federal (Canadian) government. City building codes, provincial building codes, and national building codes are in effect throughout the province. A national building code for earthquake mitigation, in particular, was promulgated in 1995. British Columbia adopted the national code in 1998 and amended it to fit unique BC circumstances. And the city of Vancouver adopted and modified these into the city's seismic building code in 1999. The overall effect of these efforts will be determined only when the next strong tremor hits. Officials and some residents of the region can say, whatever the outcome of the next event, that they did not wait to take action. It seems the region is taking the earthquake hazard seriously.

Tsunamis are ocean waves generated by displacement of water either through changes in the shape of the sea floor or by large landslides into the ocean, sometimes caused by earthquakes under the ocean floor. The potential impacts of tsunamis (that are seismically generated) add substantial risk of powerful, fast-moving inundation of coastal cities by long-wavelength waves, as demonstrated in rather recent disasters: for example, in northern Japan in 2011, the coastlines surrounding the Indian Ocean in 2004, and the Chilean coast in 1960. Most coastal cities of the United States and Canada have been relatively untouched by tsunamis, but historically, tsunamis have devastated Anchorage, Alaska, the Hawaiian Islands, Newfoundland, and other North American regions (table 13.4). While these events presage what can happen, they do not necessarily dictate the impact locations of future tsunami. Virtually every city that fronts on a coastline possesses tsunami risk. Future coastal inundations will depend on the strength and location of earthquakes, the geophysical impacts of these events, and the degree that the ocean attenuates sudden displacement. The population distribution along the coastlines in the United States certainly magnifies the hazard. Technological advancements in detection of wave energy transmission within the Atlantic Ocean and Pacific Ocean basins are the only tools we have to enable evacuation of coastal regions to high ground inland, but in very dense and normally traffic-choked regions, this may mitigate only a small number of the deaths caused by a future tsunami disaster.

Table 13.4 Known (and Possible) Historic Tsunamis Affecting the United States and Canada, 1700–Present

Location of Tsunami Impact	*Cause of Tsunami*	*Date*
Vancouver Island, British Columbia	9.0 M_w Cascadia earthquake	1700
Delaware River "swell"*	?	11/14/1840
Island of Hawaii, Hawaii	Landslide on Mauna Loa triggered by 7.5–8.0 M_w	1868
Maine	earthquake on island	11/17/1872
Longport, New Jersey*	?	6/9/1913
Puerto Rico	?	10/11/1918
Rockaway Park, Queens, New York*	?	8/6/1923
Coney Island, New York*	?	8/8/1924
Maine	?	1/9/1926
Burin Peninsula, Newfoundland	?	11/18/1929
Atlantic City, New Jersey*	7.2 M_w Grand Banks, Atlantic Ocean earthquake	8/19/1931
Aleutian Islands, Alaska/Hilo, Hawaii	?	4/1/1946
Lituya Bay, Alaska**	7.8 M_w Aleutian Islands earthquake	7/9/1958
Hilo, Hawaii	8.3 M_w Alaska Panhandle earthquake	5/22/1960
Alaska, British Columbia, Washington,	9.5 M_w Valdivia, Chile earthquake	3/27/1964
Oregon, and California	9.2 M_w Anchorage, Alaska earthquake	5/19/1964
Northeastern United States*	?	5/18/1980
Spirit Lake, Washington (freshwater)**	Landslide created by eruption of Mount St. Helens	7/4/1992
Daytona Beach, Florida*	?	

M_w: moment magnitude
* Possible tsunami
** Denotes "megatsunami," a tsunami that has initial wave heights much larger than normal tsunamis and that originate not from tectonic activity but from landslides or volcanic eruption

Fires

Fire has always been vital to living in cities, particularly for cooking and the heating of dwellings. The Industrial Revolution greatly enhanced the role of combustion in urban growth and improved the lives of many by using combustion of fossil fuels for manufacturing, in high-temperature refining and smelting furnaces, and eventually in the internalizing of combustion in engines. Both industrialization and faster transportation aided urban population agglomeration, employment opportunities, and improved quality of life. The extraction of energy from fossil materials from the earth diminished our reliance on wood and brought us into the high-energy industrial world of today. Coal (in the eighteenth and nineteenth centuries) and petroleum and natural gas (in the twentieth) were new sources of energy enabling the use of new materials and the development of new processes that built cities.

Fire was also a major problem for North American cities from their beginnings. At least seventy-seven times, major multibuilding, extensive fires dating from the earliest European settlements in North America burned cities; at least eleven of these fires were intentionally set (for a number of reasons during wars) (table 13.5). As early settlements had comparatively low density, dwellings, outbuildings, and commercial operations were usually separated enough that fires in wooden structures were not contagious. Only seven of the seventy-seven extensive, major fires occurred during more than a century prior to the beginning of the nineteenth century. As settlements grew and towns and cities emerged, central business districts intensified construction and commercial and industrial activities. Eight fires occurred between 1800 and 1849. In landscapes of wood and brick structures, urban fire hazards increased. As long as cities were constructed of combustible materials, widespread fire was problematic. Communities began to address this problem with fire brigades that were motivated to fight to contain the fires, and thus the damages, and prevent greater disasters.

While firefighting as an institution can be traced back to the Roman Empire, modern firefighting began during the eighteenth and nineteenth centuries. Early American approaches to fire prevention included materials management such as the outlawing of wooden chimneys and thatched roofs and the establishment of volunteer surveillance teams and fire brigades, which usually moved water in buckets toward a fire. After the creation of pressurized city water systems and then the introduction of pumper trucks, fitted with coal-fueled, steam-powered pumps and able to transport equipment to the conflagrations, the business of professional firefighting emerged. Cincinnati, Ohio, became the first American city to employ full-time firefighters in 1853; creating a regular roster of experienced firemen who were more efficient and adept at suppressing fire. Throughout the nineteenth century, however, brigades remained voluntary and were often committed to particular neighborhoods, to particular ethnic groups, or even to particular political parties and politicians. Despite increasing vigilance, twenty-one major fires burned North American cities between 1850 and 1899. Citywide fire departments did not formally emerge until the twentieth century.

One of the most famous fire epics occurred in Chicago in 1871. Although Mrs. Catherine O'Leary and her cow were publicly blamed for starting the fire, the exact cause and origin

Table 13.5 Major Deadly Urban Fires in the United States and Canada, 1600–Present

Location	*Year (and cause if not accidental)*	*Location*	*Year (and cause if not accidental)*
Jamestown, Virginia	1608 (burned purposely during war)	Vancouver, British Columbia	1886
Jamestown, Virginia	1676 (burned purposely during war)	Seattle, Washington	1889
St. John's, Newfoundland	1696	Bakersfield, California	1889
Montreal, New France	1734	Lynn, Massachusetts	1889
New York City, New York	1776	St. John's, Newfoundland	1892
New Orleans, Louisiana	1788	Hinckley, Minnesota	1894
New Orleans, Louisiana	1794	Windsor, Nova Scotia	1897
Detroit, Michigan	1805	New Westminster, British Columbia	1898
Buffalo, New York	1812 (burned purposely during war)	Ponce, Puerto Rico	1899
York, Upper Canada	1813 (burned purposely during war)	Sandon, British Columbia	1900
Portsmouth, New Hampshire	1813	Jacksonville, Florida	1901
Washington, District of Columbia	1814 (burned purposely during war)	Baltimore, Maryland	1904
St. John's, Newfoundland	1817	Toronto, Ontario	1904
St. Louis, Missouri	1849	San Francisco, California	1906
Toronto, Ontario	1849	Chelsea, Massachusetts	1908
Montreal, New France	1852	Oscoda/Au Sable, Michigan	1911
Troy, New York	1862	Salem, Massachusetts	1914
Atlanta, Georgia	1864 (burned purposely during war)	Matheson, Ontario	1916
Columbia, South Carolina	1864 (burned purposely during war)	Halifax, Nova Scotia	1917
Richmond, Virginia	1865 (burned purposely during war)	Atlanta, Georgia	1917
Portland, Maine	1866	Tulsa, Oklahoma	1921 (burned during riot)
Chicago, Illinois	1871	Astoria, Oregon	1922
Peshtigo, Wisconsin	1871	Timiskaming District, Ontario	1922
Port Huron, Michigan	1871	Berkeley, California	1923
Boston, Massachusetts	1872	Lilooet, British Columbia	1931
St. John, New Brunswick	1877	Texas City, Texas	1947
Ocala, Florida	1883	Brentwood-Bel Air (Los Angeles), California	1961
		Boston, Massachusetts	1964
		Chelsea, Massachusetts	1973

(*continued*)

Table 13.5 ***(continued)***

Location	*Year (and cause if not accidental)*
Chelsea, Massachusetts	1974
Lynn, Massachusetts	1981 (caused by a bombing)
Buffalo, New York	1983
Philadelphia, Pennsylvania	1985 (authorities dislodging an anti-government group)
Oakland Hills, California	1991 (wildland-urban interface fire)
Highland, California	2003 (wildland-urban interface fire)
San Bernardino, California	2003 (wildland-urban interface fire)
San Diego, California	2003 (wildland-urban interface fire)
San Diego, California	2007 (wildland-urban interface fire)
Los Angeles, California	2007 (wildland-urban interface fire)
Orange, California	2007 (wildland-urban interface fire)
Temecula, California	2007 (wildland-urban interface fire)
Malibu, California	2007 (wildland-urban interface fire)
Los Angeles, California	2008 (wildland-urban interface fire)
Corona, California	2008 (wildland-urban interface fire)
Chino, California	2008 (wildland-urban interface fire)
Yorba Linda, California	2008 (wildland-urban interface fire)
Anaheim Hills, California	2008 (wildland-urban interface fire)
Brea, California	2008 (wildland-urban interface fire)
Altadena, California	2008 (wildland-urban interface fire)
Los Angeles, California	2009 (wildland-urban interface fire)
Bastrop, Texas	2011 (wildland-urban interface fire)

of the fire remains uncertain. On October 8, a small fire started in an alley and quickly turned into a widespread conflagration. The spread of the fire was accelerated by the overuse of wooden structures, a recent drought, and strong winds. The fire lasted until the morning of October 10, when a light rain helped douse the remaining flames. The fire killed three hundred people and left more than one hundred thousand homeless. Much of the downtown was destroyed. Yet within five years, the city was rebuilt and celebrated by hosting the 1893 Columbian Exhibition that showcased the rebuilt city. Chicago survived the great fire of 1871 to come back bigger and more confident than ever, creating insurance and fire companies and instituting new building codes that planned for and negated a repetition of the tragedy. Cities that survive disasters often respond by creating better institutional arrangements that mitigate a repeat of the fire hazard.

Though numerous cities established professional fire departments by the *fin de siècle*, most used horse-drawn trucks. Communication and transportation were vitally needed improvements but were in their infancy, particularly in newer cities. The city of San Francisco, for instance, was said to have had the most modern firefighting organizations in the country in 1906. Their system alerting teams to fires was noteworthy as telegraphs were linked to local stations, and they were able to arrive at the scenes with sufficient speed to extinguish the blazes. At the time of the magnitude 7.9 earthquake in 1906, responders were disabled from response as the tremor destroyed the city's water system and no water emerged from neighborhood hydrants. Furthermore, collapsed buildings blocked access throughout the city. Anything that wasn't destroyed by the earthquake succumbed to fire; most of the city burned to the ground.

Telegraphs, though widely distributed by 1900, did not reach private residences or every neighborhood. Telephone systems were coming into vogue but did not reach the urban middle and lower classes. Critical to effective urban fire suppression was speed: speed of detection, rapid communication to responders, and swift arrival of firefighters at a scene reduced damage and limited disruptions. These abilities improved during the first two decades of the 1900s. By the end of World War I, most fire trucks were motorized, and most cities had telephonic coverage. But despite these improvements, seventeen more major urban fires occurred between 1900 and 1949.

The spatial extent of major fires in cities was shrinking, but the problem was not so much under control as it was changing. Only eight more spatially extensive urban fires occurred prior to 2000, but the problem was replaced by structure fires.

Two technological developments altered the geography of the fire hazard in North American cities: development of iron- (and later steel-) framed structures providing vertical construction and the improvement of the elevator. The heights of all wooden and stone structures were constrained by stability and strength issues, but iron girding allowed stories to be placed above the traditional four- or five-floor limit. Potential users of buildings also set a limit: few desired to climb more than three or four flights of stairs, particularly if they were carrying possessions. Elevators changed the practical issues impeding acceptance of taller buildings and enabled the skyscraper.

Skyscrapers challenged firefighting anew. Fighting fires in the upper stories of ten-story (or more) buildings required significant modifications of fire suppression strategies, equipment, and evacuation plans. Fires tended to spread upward. Getting water and fire-suppressing chemicals to upper stories was challenging. Building occupants were growing exponentially in number with the height of the buildings, and moving them rapidly past fires and out of buildings was tricky. Climbing down stairs is slow and increases exposure to heat and flames. The elevator, which enabled vertical construction of housing, was not the alternative for escape. People were unwittingly opting for "risky" places for residence or employment as they were enamored with solutions for their need for space in cities, views provided by elevation in buildings, or the seclusion that height provided (table 13.6).

A more recent development of urban fire risk has emerged at the perimeter of many cities. While North America's urban systems have dramatically increased in population over the twentieth and twenty-first centuries, the areal extent of cities has also grown. Both exposure and vulnerability to fires ignited in wildlands have risen dramatically in recent years.

The North American appreciation of nature has grown over the twentieth century. North American suburbs hark back to the gardens of the royalty of Europe, and per-

Table 13.6 Major Deadly Structure Fires in the United States and Canada, 1800–Present

Structure	*Location*	*Year*
Richmond Theater	Richmond, Virginia	1811
The White House and Capitol	Washington, DC	1814
US Patent Office, Blodget's Hotel	Washington, DC	1836
Building	Mayagüez, Puerto Rico	1841
Sts. Michael and Augustine Roman Catholic Churches	Philadelphia, Pennsylvania	1844
Brooklyn Theater	Brooklyn, New York	1876
US Patent Office	Washington, DC	1877
Washburn "A" Flour Mill	Minneapolis, Minnesota	1878
The Rotunda, University of Virginia	Charlottesville, Virginia	1895
Windsor Hotel	Manhattan, New York	1899
Hoboken Docks	Hoboken, New Jersey	1900
Iroquois Theater	Chicago, Illinois	1903
Collinwood School	Cleveland, Ohio	1908
Parker Building	New York City, New York	1908
Rhoads Theater	Boyertown, Pennsylvania	1908
Friedlander Leather Remnants Factory	Philadelphia, Pennsylvania	1910
Triangle Shirtwaist Factory	New York City, New York	1911
Equitable Life Assurance Building	New York City, New York	1912
Factory	Binghamton, New York	1913
St. John the Baptist School	Peabody, Massachusetts	1915
Centre Block of Parliament Buildings	Ottawa, Ontario	1916
Norman State Hospital	Norman, Oklahoma	1918
Mayagüez Theater	San Juan, Puerto Rico	1919
Cleveland School	Camden, South Carolina	1923
Babbs Switch Schoolhouse	Oklahoma	1924
Laurier Palace Theater	Montreal, Quebec	1927
Cleveland Clinic	Cleveland, Ohio	1929
Study Club	Detroit, Michigan	1929
Ohio Penitentiary	Columbus, Ohio	1930
Terminal Hotel	Atlanta, Georgia	1938
Rhythm Night Club	Natchez, Mississippi	1940
Cocoanut Grove	Boston, Massachusetts	1942
Knights of Columbus Hotel	St. John's, Newfoundland	1942
Gulf Hotel	Houston, Texas	1943

Structure	*Location*	*Year*
Hartford Circus	Hartford, Connecticut	1944
Empire State Building	New York City, New York	1945
LaSalle Hotel	Chicago, Illinois	1946
Winecoff Hotel	Atlanta, Georgia	1946
St. Anthony's Hospital	Effingham, Illinois	1949
Mercy Hospital	Davenport, Iowa	1950
Littlefield Nursing Home	Largo, Florida	1953
Charles Berg Laboratories	Philadelphia, Pennsylvania	1954
Larkin Warehouse	Buffalo, New York	1954
Warrenton Nursing Home	Warrenton, Missouri	1957
Our Lady of the Angels School	Chicago, Illinois	1958
Fretz Building	Philadelphia, Pennsylvania	1963
Golden Age Nursing Home	Fitchville, Ohio	1963
Hotel Roosevelt	Jacksonville, Florida	1963
Surfside Hotel	Atlantic City, New Jersey	1963
Dale's Penthouse Restaurant	Montgomery, Alabama	1967
Florida State Prison	Jay, Florida	1967
Pioneer Hotel	Tucson, Arizona	1970
Blue Bird Café	Montreal, Quebec	1972
Hotel Vendome	Boston, Massachusetts	1972
National Archives	St. Louis, Missouri	1973
Upstairs Lounge	New Orleans, Louisiana	1973
Gulf Refinery	Philadelphia, Pennsylvania	1975
Barson's Overbrook Restaurant	Philadelphia, Pennsylvania	1976
Retirement Home	Goulds, Newfoundland	1976
Beverly Hills Supper Club	Southgate, Kentucky	1977
Younkers Department Store	Des Moines, Iowa	1978
Opémiska Community Hall	Chapais, Quebec	1979
Extendicare Ltd. Nursing Home	Mississauga, Ontario	1980
MGM Grand Hotel	Las Vegas, Nevada	1980
Keansburg Boarding Home	Keansburg, New Jersey	1981
Dorothy Mae Apartments	Los Angeles, California	1982
Northwestern National Bank	Minneapolis, Minnesota	1982
Dupont Plaza	San Juan, Puerto Rico	1986

(*continued*)

Table 13.6 *(continued)*

Structure	*Location*	*Year*
Ford Automobile Dealership	Hackensack, New Jersey	1988
First Interstate Tower	Los Angeles, California	1988
Happy Land	Bronx, New York	1990
One Meridian Plaza	Philadelphia, Pennsylvania	1991
Worcester Cold Storage	Worcester, Massachusetts	1999
World Trade Center	New York City, New York	2001
Charleston Sofa Super Store	Charleston, South Carolina	2007
Alma College	St. Thomas, Ontario	2008
Quebec City Armory	Quebec City, Quebec	2008
Governor's Mansion	Austin, Texas	2008
Deli	Buffalo, New York	2009

haps that is the status to which suburbanites aspire. The fear of nature-dominated spaces has diminished for many North Americans, and the greening of cities and expansion into less-developed landscapes for seclusion and peace demonstrate this. The outcome of this is that it has led to unintentional exposure to wildfire, producing tens of billions of dollars in property loss and equivalent expenditures for fire suppression. Since 2000, sixteen major, historic fires originated and burned within the so-called urban fringe.

Widespread residential wildfire threats are a recent development resulting from traditional American forest fire management. Suppression of fire was practiced by federal and state agencies throughout the twentieth century largely to protect forest resources. Economics motivated agencies to spot and extinguish fires in forests as quickly as possible to save timber resources and profits. Over time, management learned to appreciate other forest values in managing for wildlife and other wildland uses. Unfortunately, fire exclusion served to stockpile fuel for future fires. Fire risk has risen and continues to rise every year there is no fire. The most recent fires have been more intense and more difficult to control than past "natural" fires. It is now apparent that building near public or private forestlands is unwise, and analysis of current development reveals that the wildfire hazard is extraordinarily high around some cities. From 1990 to 2007, sixteen catastrophic wildfires have destroyed more than twelve thousand residential dwellings. Many additional smaller fires (with proportionate impacts on smaller communities) have occurred as well. While past fires seem heavily biased toward California and the western states, it should be noted that the risk is high throughout the eastern United States as well. Fires in Florida during the first decade of the twenty-first century have threatened smaller communities, and other cities in the East will be impacted by wildfires eventually (see figure 13.7). Fire is now being managed under a new regime that not only recognizes the ecological role it plays in making healthy ecosystems but also manages the stock of fuels in forests.

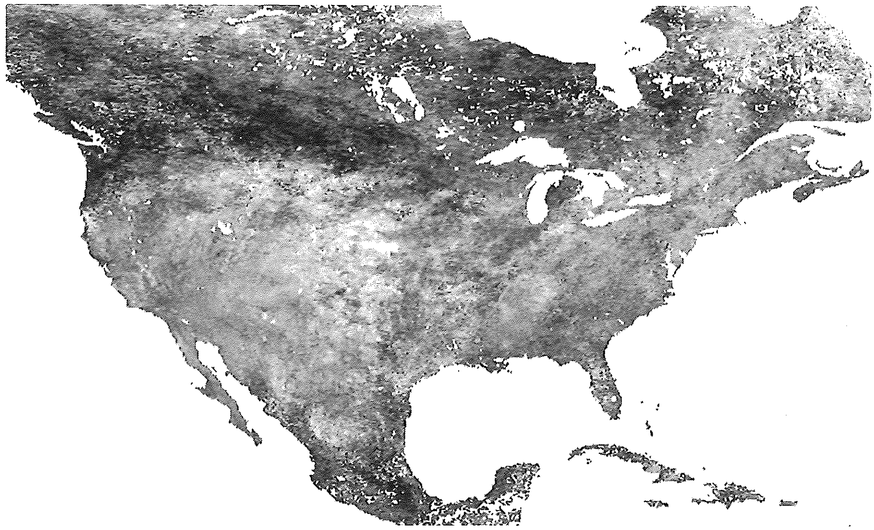

Figure 13.7 In this NASA map of land-surface temperature anomalies, the intensity and scope of the heat wave in the western United States is clearly visible (shown in lightest gray/white)—especially over Colorado, southwest Nebraska, and parts of Wyoming. *Source:* NASA map based on data gathered from June 17–24, 2012, from the Moderate Resolution Imaging Spectrometer (MODIS) on NASA's Terra satellite.

Enhancing this hazard in the urban fringe are vulnerabilities built into the landscapes over the past few decades. Box 13.6 discusses how society has created such hazards. Curvilinear streets in suburban subdivisions with limited ingress and egress are intended to enhance exclusivity and promote seclusion. They inadvertently make evacuations difficult and complicate firefighting. Heavy vegetation also limits residential fire awareness and vigilance, leaving it more susceptible to fast-moving fires. Furthermore, developments in areas with complex terrain and a lot of relief (i.e., with hills, canyons, or valleys) can be very dangerous for similar reasons, but the risk there is heightened by wildfire dynamics and local conditions produced by fires. Because of the diversity of geographies of residential development throughout North America, there can be no single one-size-fits-all approach to managing the urban-fringe fire problem short of completely removing the exposed from places of high risk.

Box 13.6 Geographic Perspectives on Urban Hazards

Many urban hazards result from endeavors for private profit that ignore the costs (or externalities) to others, from actions that are temporally shortsighted, or from behaviors that are ignorant of the long-term implications. The lack of spatial awareness, spatial thinking, or spatial planning is revealed in the negative social outcomes of disasters and catastrophes. While some human actions can be discouraged or even made illegal, many are simply problems when they are undertaken in certain contexts. As discussed in this chapter, it is both individuals and society that create hazard by participating in natural, technological, or social processes in ways that threaten health, welfare, or property; many of these processes are tied to the landscapes and locations in which they occur. For example, human occupancy of places where flooding, seismic and volcanic activities, drought, and frost can occur or are commonplace ought to be avoided or "occupied" very carefully. Built landscapes that possess hidden vulnerabilities (like structures that are built of highly flammable materials or that house potentially incendiary or explosive activities) ought to be publically identified, reorganized, restricted, or managed with heightened vigilance in order to diminish the likelihood of disaster. But human demands are unceasing, and there is usually significant reticence to "surrender" to nature or geography, particularly if a space or place has economic value.

Geographers often strive to reveal the patterns of activities and processes (both natural and human, visible and invisible) that occur on earth. Through geographical analysis using geographic tools such as geographic information systems, remote sensing, spatial statistical analysis, and geographical insights, geographers can expose and clarify the implications of present-day decisions and prospects for future disasters. Geographers can illuminate the places where future disasters might occur, identify the locations more likely to experience disasters sooner and places that might be more severely impacted, and uncover the most vulnerable populations, places, systems, and processes in a region of heightened risk.

Because cities tend to be defined by the spatial reach of the urban political unit in which management decisions are (or can be) made, they can be regarded as a purposeful system that organizes its own internal operations. Ideally, a city can rectify recognized problems and may be able to avoid disruptions and disasters. However, cities of North America are organic systems that have evolved in place over decades or centuries; they do not exist in vacuums, and they have historical inertia in their political, economic, and social systems that tends to slow down solutions to recognized spatial problems (hazards, vulnerabilities, exposures). Hazard management may require years or decades of unraveling of past spatial decisions before commencing with effective hazard mitigation and sustainable redevelopment. Geographers possess skills to sort out the legal, social, political, and economic resistance to spatial change and can, theoretically, encourage urban systems to evolve toward safer, less expensive, and more efficient organization. Geographers do this by gathering spatial data, analyzing the patterns of geophysical, meteorological, biological, technological, and sociological processes and their interactions, and providing decision-making guidance to planners and others in urban, state, and national governmental agencies. By fostering the development of spatial awareness, understanding the workings of complex systems, sensitivities to manifold issues and social problems, and effective communication skills, geographers can actively contribute to the solutions of many urban hazard problems.

CONCLUSIONS: URBAN VULNERABILITY AND URBAN RESILIENCY

Ultimately, the age-old notion that the city is an effective refuge from the threats of nature (or enemies of any type) is constantly disproved. Indeed, there are many threats derived from natural processes that are in some way or another intensified by urban development. Nature infuses cities with the raw materials of civilization, but the resources come with costs. Hazards are the cost of "living" that can be magnified or attenuated by our choices.

The distribution of risks from flooding, severe storms, earthquake activity, and wildfires, among the many other things that can do harm, is constantly changing spatially and temporally, and the idea of eliminating risk completely is impractical. What can be managed is the hazard. We can reduce the implications of events that occur with planning and preventive decisions. Vulnerability intensifies the impacts of hazard events if our differential characteristics are ignored. The susceptibility of cities and their populations to hazards can be managed as well.

Recently, urban hazard managers have become more focused on managing urban vulnerabilities. Their goal is to reduce destructive impacts and limit disruption caused by extreme events. Reducing exposure of hazard-vulnerable people, communities, systems, infrastructures, or even government agencies to hazards will assist this effort. Whereas twentieth-century hazard managers sought urban disaster *resistance* by creating hardened, theoretically impenetrable systems and structures, the twenty-first-century manager now strives for disaster *resilience*. Resilience is accomplished by enabling the capacities of people, communities, infrastructure, and systems to absorb the impacts of extreme events so that hazards impinge less on lives, social systems, and urban infrastructure. Resiliency building suggests that we can preferentially control disaster impacts so that our communities will quickly return to normal after an event.

In the twenty-first century, urban planners are challenged to develop hazard management plans that involve the following stages of disaster management:

- Emergency response to quell the emergency and rescue the victims during the period from the occurrence of the event to days or weeks afterward;
- Restoration of infrastructure, systems, and services over the next few weeks to months in order to make the disaster-impacted region at least livable for the emergency-sheltered populations and returning evacuees;
- Reconstruction of the destroyed buildings and urban infrastructure to at least predisaster quality during the first few months to first few years of the postdisaster period to "recover" from the disaster; and
- Redesign, reorganization, replacement, and redevelopment of the city with rebuilding projects to mitigate future hazards, to eliminate social and structural vulnerabilities, and to create a resilient city undertaken during the few years or decade following the disaster.

Such "resilient" cities express the power of hope and opportunity in the face of adversity.

North American systems are designed for and primarily driven by capitalist economics. The understanding of the problems (and the hazards we face) is filtered through a capitalist (neoliberal) perspective. Hazard mitigation choices are also limited by the values inherent in this perspective; therefore, places tend to change only incrementally and only after disasters. Prevention is known to be less costly economically (and certainly in terms of mortalities and casualties) than is reaction, recovery, reconstruction, and after-the-fact mitigation, but our society tends to play the odds. The vulnerable, the marginalized, and the powerless often experience the consequences of the decisions made by elites and the powerful. Urban disasters in North America will continue to occur according to the geographies of economics and ethics, and only when preventive actions and fundamental restructuring of urban spaces are undertaken will they begin to diminish. That time is unlikely to come soon, at least willfully, before disaster.

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"A sparkling contribution to our knowledge of the urban issues facing the United States and Canada in this second decade of the twenty-first century. The editor has assembled a team of leading scholars, masterfully integrating their highly accessible chapters to maximize students' understanding of the rapidly changing metropolitan scene. Among the cutting-edge topics covered are changing approaches to urban geography, the latest impacts of globalization on cities and suburbs, the emergence of new social identities on the urban landscape, and the troubling effects of the ever-widening income gap. Especially valuable is the emphasis given to urban dimensions of the natural environment, which points toward the next big thing in researching and teaching about North American cities—urban sustainability. I wholeheartedly recommend this volume to anyone teaching courses in the urban-related social and environmental sciences as well as planners and policymakers concerned with the forces that continue to reshape the American metropolis."
—**Peter O. Muller**, University of Miami

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"North America became a majority-urban realm early in the twentieth century. The world became a majority-urban planet early in the twenty-first century. Urbanization has rearranged populations everywhere, forced the creation of new living environments, overworked the networks of transportation and communication, and challenged local governments to provide jobs and services. None of this has happened without problems of continental proportion, and there is no better way to get a handle on those issues than by delving into *Cities of North America*." —**Donald J. Zeigler**, Old Dominion University

This timely text provides a comprehensive overview of the dramatic and rapidly evolving issues confronting the cities of North America. Metropolitan areas throughout the United States and Canada face a range of dynamic and complex concerns—including the redistribution of economic activities, the continued decline of manufacturing, increased social polarization, and the need to plan a sustainable future. The book explores how the combined processes of urbanization and globalization have added new responsibilities for city governments at the same time that leaders are grappling with planning, economic development and finance, justice, equity, and social cohesion. Introducing contemporary spatial arrangements and distributions of activities in metropolitan areas, this clear and accessible book covers economic, social, political, and ecological changes. It is also the only text to include the physical geography of urban areas. Bringing together leading geographers, it will be an ideal resource for courses on urban geography and geography of the city.

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US and Canadian Cities

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