What *Dangers* Do We Face?

A Preliminary Multihazard Risk Profile For New York State

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Graduate Workshop, Fall 2006
May 7, 2007; MCEER-07-SP01

University at Buffalo
The State University of New York

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Introduction

New York State faces disasters within its boundaries. The main perception of disasters for many revolve around the September 11, 2001 attack on the World Trade Center; yet a greater disaster was the 1918 Spanish Flu, in which tens of thousands died. In recent years, disastrous floods, winter storms, and airplane crashes have occurred. The Hurricane Katrina disaster in 2005 reveals that a coastal storm surge is also a possibility in downstate New York.

New York State ranks as one of the top five states in terms of federally-declared disasters in the past 40 years (FEMA, 2006). Table 1-1 below illustrates a variety of disasters that NYS has endured. Flood-related events have caused approximately 77 percent of all federally-declared disasters in the state, while winter events and the cascading effects—at 15 percent—have made an impact as well.

Table 1-1 Historical Frequencies of FEMA Disaster Declarations in NYS, 1954-2006

Declared Disaster	Frequency
Flood-Related Events	40
Geophysical	1
Winter Events	9
Malicious	2
Power Shortage	1
TOTAL	**52**

Source: FEMA data

This preliminary New York State Multi-Hazard Risk Profile qualifies hazards, estimates their annual frequencies of occurrence in combination with magnitudes, and provides a comprehensive model for multi-hazard comparison. State and local decision-makers often have limited funds to allocate toward the disasters that hazards cause. The ultimate goal of this report is to assist them in determining the greatest collective dangers facing NYS in terms of mass casualties, mass destruction, and mass disruption.

This report seeks answers to the following questions: *Which hazards are most likely to occur in NYS? Which hazards would be most dangerous? How do we plan for disastrous events that are rare and full of uncertainty?* While vulnerability reduction is an important aspect of disaster alleviation, this report exclusively considers hazard mitigation.

An investigation of hazard assessments from NYS and other states uncovers that these resource documents are rarely available in a single, convenient form. Instead, profiles are often generic, piecemeal and created for just a few hazards.

This report was initiated during the 2006 fall semester at the University at Buffalo (UB). It was led by a 9-person planning studio in the Department of Urban and Regional Planning and was sponsored by MCEER.

The studio members made two presentations—one at UB and the other at The Nelson A. Rockefeller Institute of Government in Albany—in December.

This report strives to discover a way to fill a critical gap in disaster planning. It uses historical data and some expert estimates to present a direction toward comprehensive, multihazard risk profiling of NYS.

Federal, state, and local emergency managers are currently faced with many diverse hazards of increasing frequency and broad scope. For example, man-made and technological hazards now threaten our state as readily as natural hazards do. During the 1990s, federally-declared disasters in NYS were nearly twice as frequent as those in the 1980s (FEMA, 2006). In 2006 alone, the state experienced two major disasters—the June floods in eastern NYS and an October snowstorm in the western part of the state.

New York State now depends primarily on HAZNY methods for risk assessment. It is a "group process" method that depends on the judgments of participants to rank risks. Though such judgments are important in fields with uncertainty like disaster planning, governments should consider complimenting these judgments with quantitative analysis. This report identifies hazards in the following categories:

- Technological hazards include air crashes, hazardous material events, structural failures, and fire events
- Weather hazards include floods, tornadoes, winter storms, storm surges, and heat waves
- Geophysical hazards, also known as natural hazards, include earthquakes
- Epidemiological hazards include communicable infectious diseases, such as pandemic influenza
- Malicious hazards include human threats of mass harm, such as terrorism

We omit nuclear power plant accidents, technological blackouts, epidemics other than pandemic flu, and interstate warfare from our report due to lack of resources and time.

Hazards are conditions that cause the dangerous possibility of an extreme event. An extreme event is only considered a disaster when it involves sudden onset of mass casualties, mass destruction, or mass disruption that is concentrated in time and place. Some may consider car crashes, for example, to be "disasters" because they cause millions of annual casualties and injuries in the United States; yet, these types of disasters are not within the scope of our report because they lack a community-wide, disastrous effect.

Please note that what we have done here is create an illustration of what a risk scoring effort would look like for NYS. Because of limited time, resources, and opportunity to consult with experts, *this must not be considered a complete risk assessment* for NYS. Rather, we are setting a direction for improved risk assessment. Readers should be sure to note limitations within chapters and at the end of the report. They should also note that our primary recommendation *is not* that the scores be taken literally, but is rather the modest addition of an Office of Hazard Risk Assessment that would pursue this type of risk profiling on a consistent basis and in a systematic way.

Toward Better Risk Profiling for NYS

Emergency managers and disaster planners employ a variety of models in assessing risk from hazards. These models are often loosely defined, making it difficult to assess likelihood and magnitude. Estimates of magnitude are often qualitative or on a simple point-scale that do not measure differences in probability or damage.

While these models have been useful in identifying and comparing possible threats, they are of limited value. Often, they cannot be systematically revised based on new data. This report strives to take full advantage of available data.

Existing Models

The HAZards US, or HAZUS, risk assessment software model analyzes potential damage and loss due to flood, hurricane and earthquake events by combining scientific knowledge with Geographic Information Systems (GIS) technology. This model allows the user to visually display the potential damage to specific geographic areas. The model is limited due to certain assumptions that may affect accuracy of damage estimates and its application to only three possible hazards.

The Hazards New York, or HAZNY, risk assessment software model is different from the HAZUS model because it assigns a score ranging from zero to four hundred, dependent upon potential risk, to individual hazards upon the completion of a survey. The HAZNY survey includes questions regarding scope, frequency, impact, onset and duration. It does not include explicit definitions within some answer sets, and does not examine specific geographic areas or the likelihood of an event to happen within a specific area. The composition of the expert panels vary greatly and so do the results.

Conventional multihazard assessment is based on limited data and provides little quantitative information on relative risks.

Figure 2-1, shown on the following page, is taken from Amherst, New York. This figure shows the ranking of all hazard types, compared to one another, and corresponding risk scores. Again, it is not clear what data the ranking is based on.

Figure 2-2, shown on the following page, is an example of a conventional multihazard assessment, taken from Hawaii County, Hawaii's hazard assessment. Again here we see little basis in actual historic frequencies or probability estimates, along with vague terminology about hazard types.

The Group rated the 25 hazards as follows:

Hazardous Materials in Transit	316.3
Flood	305.5
Severe Storms	295.5
Earthquake	292.0
Ice Storm	290.8
Hazardous Material at Fixed Sites	290.3
Tornado	288.5
Transportation Accident	282.0
Winter Storm (Severe)	251.5
Fire	236.8
Oil Spill	231.8
Power Failure	230.8
Explosion	205.8
Structural Collapse	204.2
Extreme Temperatures	196.2

Figure 2-1 Risk Ranking from Amherst, NY, Hazard Analysis Report, October 2000

Hazard	Hazard Severity + Location + Frequency/Probability	Vulnerability Natural + Manmade + Systems	Total Risk Hazard Risk * Vulnerability /Capability	Page
Drought	Moderate	Low	Low	5
Earthquake	Moderate	High	Moderate -> High	8
Epidemic	Low -> Mod Severity Low -> Mod Probability	Low -> High Impact	Low	12
Flooding	Bear & Evans Cr. – high Sammamish R. – low L. Sammamish – low	Low Low Low	Moderate Low Low	15
Hazardous Materials	Low -> High	Low	Low ->Moderate	20
Heat Wave	Low	Moderate	Low	22
Landslide	High	Moderate	Moderate -> High	24
Terrorism	Low -> Moderate	Low -> Moderate (Depends on target)	Moderate	27
Wildfire	Low -> Moderate (Seasonal)	Low -> Moderate (Depends on if drought)	Low -> Moderate	29
Winter Storm	High	Low	Moderate	33

Figure 2-2 Excerpt from Hawaii County Multi-Hazard Mitigation Plan, May 2005

Our Approach

By contrast, our risk profiling approach intends to expand upon the existing model by assigning risk based upon historic frequency. It also provides a clear and concise list of mutually exclusive magnitude categories and hazard definitions.

Annual Frequency

Historic-based annual frequency for this report is defined as the average number of times per year that a hazard has occurred over a historic period. Magnitude is the degree of consequences (deaths, injuries, property or environmental loss, etc.) that may result from the event. Therefore, risk is calculated by multiplying the annual frequency by the magnitude of any particular disaster:

Risk = Annual Frequency x Magnitude

Annual frequency is used instead of annual probability, because some relatively low magnitude events occur on the average of more than once per year. Examples include fires, plane crashes, and hazmat releases.

Categorizing Magnitude

Magnitude is categorized in ascending levels of importance, from serious to catastrophic as shown in Table 2-1 on the following page. Criteria include: deaths, injuries, destruction costs, displacements, and disruptions. Number of deaths primarily determines magnitude.

In the instance that a hazardous event results in fewer deaths, but a significantly high number of disruptions or economic loss, the level of magnitude classification may be heightened to reflect this. For example, a fire resulting in five deaths may be initially categorized as Serious, but when combined with economic impact, may be recategorized as Severe.

Complete standardization of categorization was not possible as data within the hazard categories is repeatedly inconsistent, is often qualitative, or lacks required detail or exact numbers for standardization. For example, NCDC flood data by county had extremely variable quality of data. The numbers of households displaced would sometimes be numbered or in other cases, would be described as "many" or as "a whole neighborhood" without further detail. Economic loss data also seemed highly inconsistent and, in our judgment, unreliable.

Subjective judgment was relied on when applying this table to specific events for the following reasons: data was inconsistently available, sometimes given as verbal estimates and often unreliable. Using the available data to the best of our ability, we believe using data for rough estimates is superior to not using data at all.

The following destructive events can be used as benchmarks to familiarize the reader with categorization of magnitude:

Serious: Many fires fall into the serious category, with few deaths and lower amounts of monetary and physical damage. Compared to other disasters, the vast majority of fires are below "Serious" from a statewide perspective and are not considered in this report.

Severe: Most heat wave events are categorized as Severe, as hundreds of people in NYS have perished due to extreme temperatures.

Table 2-1 Magnitude Table

<table>
<tr><th>Magnitude Score</th><th>Magnitude Category</th><th>Deaths (in persons)</th><th>Injured or Displaced (in persons)</th><th>Destruction Cost (in dollars)</th><th>Disruption* (in people days)</th><th>Qualitative Variations</th></tr>
<tr><td>1</td><td>Serious</td><td>0-9</td><td>50-500</td><td>5-50 million</td><td>1,000s</td><td rowspan="5">• Psychological effects
• Trauma
• Shock
• Terror
• Unprecedented event
• Unusual weapons
• Loss of emergency services
• Infrastructure failure
• Undermining of social institutions
• Loss of government function
• Environmental destruction
• Long-term image transformation</td></tr>
<tr><td>10</td><td>Severe</td><td>10s</td><td>500-5,000</td><td>50-500 million</td><td>10,000s</td></tr>
<tr><td>100</td><td>Disastrous I</td><td>100s</td><td>5,000-50,000</td><td>500 million-5 billion</td><td>100,000s</td></tr>
<tr><td>1000</td><td>Disastrous II</td><td>1,000s</td><td>50,000-500,000</td><td>5-50 billion</td><td>millions</td></tr>
<tr><td>10000</td><td>Catastrophic</td><td>10,000s</td><td>500,000-5million</td><td>50-500 billion</td><td>10 millions</td></tr>
</table>

Disastrous I: The ice storm of 2003 is categorized as Disastrous I, although there was only one death, and no injuries, yet there was 57.1 million dollars in property damages, 8.6 million in crop damages, 402,500 people were disrupted for up to one week due to power outages, and it was a federally-declared disaster.

Disastrous II: The terrorist attack on September 11, 2001 annihilated the World Trade Center, killing approximately 3,000 individuals. It has been categorized as Disastrous II—rather than Catastrophic—due to the resilience of the social and governmental systems and the relative isolation of physical damage.

Catastrophic: Hurricane Katrina serves as a national example of a Catastrophic disaster, not only because of the number of deaths, but because of extensive disruptions in people-days and destruction. The Spanish Flu Epidemic of 1918 fits into this category as an example from NYS, killing at least 33,000 in NYC.

For each hazard, we calculated the frequency of each of a series, the frequency of a severe, and so forth through the frequency of a Catastrophic event. Then, we multiplied each Serious frequency by 1, Severe frequency by 10, up through Catastrophic frequency by 10,000. The "risk score" is the sum of these products (frequency by magnitudes).

Please note that in many cases a "—" is shown as the annual frequency. This indicates data may not have been available for certain magnitudes and/or data was not found for an event of such magnitude. In the future, analysis methods of "curve-fitting" could be used to estimate frequency where data is lacking. This should be done in further development of risk score projects, although it was not done for this report.

Data Collection and Limitations

Data was gathered from multiple sources per hazard. In many cases, information was not conveniently found in any one location. Examples of data sources include the United States Geological Survey, the Center for Disease Control, National Fire Protection Association, MIPT Terrorism Knowledge Base, National Oceanographic and Atmospheric Association and the National Weather Service, among others. All data sources will be explicitly cited within respective chapters. Years where data was available also varied across categories. For example, the National Climatic Data Center data on winter storms only consistently covered 11 years, while pandemic flu covered over 300 years.

Airplane Crash

According to the *New York State 2005 Annual Aviation Inventory Report,* there are 143 public airports in the state. The annual rate of airplane crashes in the US is much lower now since 2001 (NTSB database). Yet, there is a significant likelihood that major crashes will occur in NYS because of its large number of airports and busy air traffic in and around NYC. This section emphasizes crashes of statewide concern. Data on the September 11, 2001 airline crashes are excluded from this chapter.

Definitions

Airplane crashes occur due to weather conditions, mechanical failure or human error. They may also be intentional as part of a terrorist attack or a suicide attempt. Casualties may occur onboard an airplane or in the facilities or vehicles impacted by a crash.

An enplanement is the number of passengers traveling on any commercial flight. For this report, NYS enplanement data is collected from the *New York State 2005 Annual Aviation Inventory Report,* while US data is retrieved from the Federal Aviation Administration, (FAA) (NTSB Statistics). After a two-year decline in the wake of 9/11, the number of enplanements in NYS has increased gradually, reaching 34.5 million—5% of all US enplanements—in 2003.

Disastrous Air Crashes in New York State

The year 2001 was significant for aviation safety in NYS. Three major air crashes occurred in this year, causing more than 422 air and ground fatalities (NTSB database).

The most deadly airplane crash in NYS aviation history—excluding 9/11—was the Belle Harbor airplane accident. On November 12, 2001, a commercial airplane departed from John F. Kennedy (JFK) International Airport with two flight crewmembers, 7 flight attendants, and 251 passengers on board. The plane crashed into a residential area of Belle Harbor. All 260 people aboard the airplane and five people on the ground were killed. The airplane was destroyed by the impact and resulted in fire. According to the National Transportation Safety Board (NTSB), the probable causes of this crash were technical problems (NTSB database).

On July 17, 1996, an Airbus crashed into the Atlantic Ocean near East Moriches after taking off from JFK International Airport. All 230 people aboard including two pilots, two flight engineers, 14 flight attendants, and 212 passengers were killed, and the airplane was destroyed. The primary cause was a fuel-air explosion in the fuel tank (NTSB database).

Another tragic crash occurred on January 25, 1990, when a scheduled international passenger flight from Colombia to JFK crashed in a wooded residential area in Cove Neck, Long Island. After being in a holding position in poor weather conditions for over an hour, the plane ran out of fuel. Of the 158 persons aboard, 73 were killed (NTSB database).

Magnitude

The air transportation industry must consider all airplane crashes even if they do not cause fatalities or injuries—even those that occur to small private planes. While we recognize the importance of preparedness for all crashes, we focus only on large crashes that are of concern to state disaster planning. We define the magnitudes of airplane crashes as follows:

- *Serious:* 1-9 fatalities; damage or destruction of the aircraft
- *Severe:* 10-99 fatalities; complete aircraft destruction
- *Disastrous I:* 100-999 fatalities; complete aircraft destruction

We assume that an airplane crash cannot cause an event of greater magnitude (Disastrous II or Catastrophic) unless intentionally caused by a terrorist. If an airplane crashes into a large commercial area, high rise residential buildings, or public institution, it may cause many fatalities on the ground. In addition, on-the-ground damage may be extensive because of impact or fire. The number of casualties also depends on the location of the crash site and accessibility to responders.

Geographic Distribution

Research reveals that 16% of all major airplane crashes are low-impact crashes on the airport runway. Around 80% are high-impact crashes within two miles of the airport. The remaining 4% of crashes occur en route (City of Kent database). It follows therefore that the areas of the state most at risk are those with the most enplanements, as seen below in Figure 3-1.

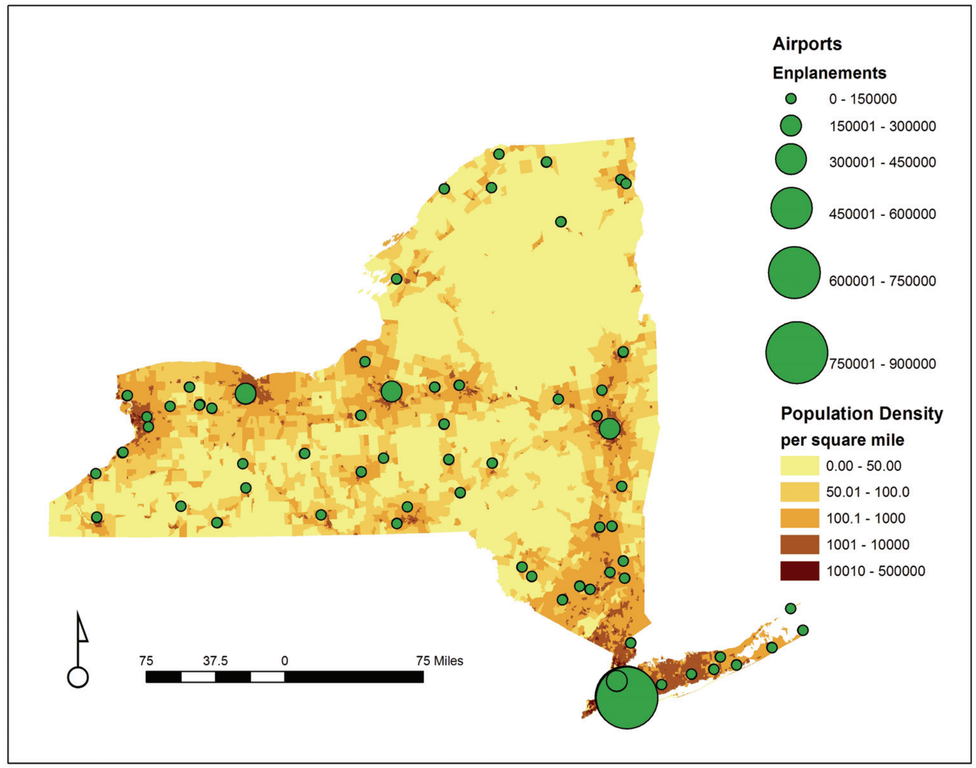


Figure 3-1 Public Airport and Population Density, 1986-2005

The most dangerous phases of a flight are takeoff, approach, and landing (ESPON). Therefore, areas near airports are most vulnerable to air crashes. Of the 143 public airports in NYS, the highest traffic is at NYC airports. Therefore, it also follows that the bulk of serious air crashes have occurred in the NYC metro area as seen in Figure 3-2 below.

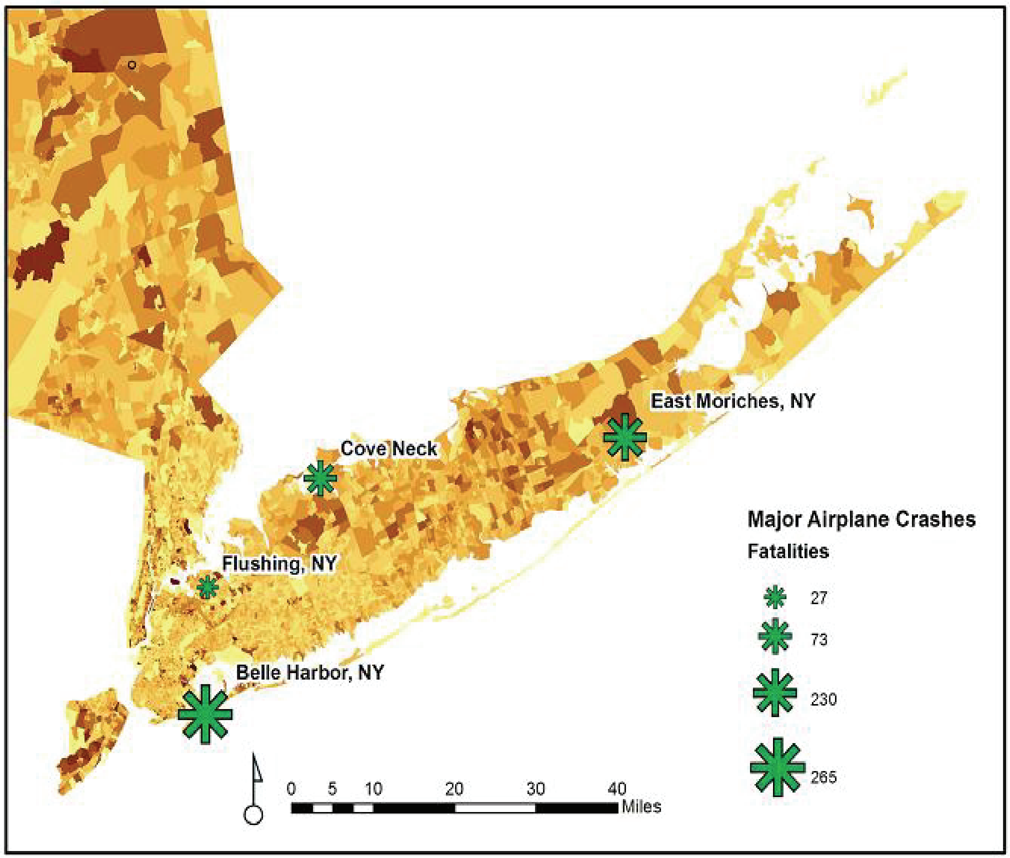


Figure 3-2 Geographic Location of Airplane Crashes, 1986-2005

Annual Frequency

Between 1986 and 2005, a total of 1024 incidents occurred in NYS, with 188 fatal accidents and an average annual frequency of 9.4. However, most of these are Serious incidents. Over the same period, there were two Severe crashes and two Disastrous crashes in the state. Based on this data, the annual frequencies of Serious, Severe, and Disastrous air crashes are 9.2, 0.1, and 0.1, respectively, as seen in Table 3-1 on the following page.

Risk Score

From our assigned weights for each sub-category of hazard type, the risk score for Serious, Severe, and Disastrous airplane crashes are 9.2, 1, and 10, respectively. The overall risk score of airplane crashes is 20.2 as seen in Table 3-1 on the following page.

Limitations

It may be argued that "Serious" accidents are local emergencies; however, for the sake of consistency across hazards, these are included in the risk score.

It is difficult to determine whether the past frequencies of occurrences provide reliable forecasts, because technologies and the organization of the US air travel industry are changing. A government-industry group working on improving safety for US commercial aviation has suggested that the number of departures is a better denominator (than enplanements) for measuring crash rates. This report focuses on annual enplanement data because of its availability.

Table 3-1 Airplane Crashes Annual Frequency and Risk Score, 1986-2005

	Serious*	***Severe***	***Disastrous I***	***Disastrous II***	***Catastrophic***	***Total***
Events	184	2	2	0	0	188
Annual Frequency	9.2	0.1	0.1	0	0	9.4
Magnitude Score	1	10	100	1,000	10,000	
Risk Score	***9.2***	***1***	***10***	***0***	***0***	***20.2***

Source: Aviation Accident Database, NTSB

Structural Failure

This section examines the risk of dam failure, bridge failure, and building failure in NYS. The state has 378 dams classified as high hazard. There were no failures of these dams in the past 25 years. New York State, one of the oldest and most populous states in the US, has comparatively older buildings and bridge stock. The available data could not provide estimates of loss or severity. Because of inadequate data, such failures were omitted from the risk profile yet provide general background discussion here.

Dam Failure

Table 3-2 Dam Failures in NYS, 1980-2000

Incident Date	Hazard Class	Nearest Town	Distance to Nearest Town (miles)	Height	River
9/1/1980	Low	Forestport Station	2	18	Little Woodhull Creek
3/22/1980	Significant	Tannersville	1	20	Allen Brook
1984	Low	Malone	0	10	Salmon River
6/14/1997	NA	NA	NA	NA	NA
1/9/1998	Low	Emeryville	3	13	East Branch Oswegatchie
6/8/1998	Low	Wethersfield Springs	2	11	East Koy Creek
6/27/1998	Significant	Peru	6	6	Furnace Brook
1/7/1998	NA	NA	NA	NA	NA
1/7/1998	Low	Lyons Falls	1	15	Moose River
11/27/1999	Low	Deer River	4	30	Deer River
9/17/1999	NA	NA	NA	NA	NA
9/17/1999	NA	NA	NA	NA	NA
9/17/1999	Significant	Spring Valley	NA	14	Pascack Creek
7/5/2000	NA	NA	NA	NA	NA

Source: NCTCOG

A dam failure is a partial or full collapse of the dam structure that results in downstream flooding. Dam failures can be caused by heavy rainfall and flooding, structural inefficiency, poor maintenance, or failure of upstream dams on the same waterway (NCTCOG 2004).

There have been catastrophic dam failures in the US. The largest failure took place at South Fork Dam in 1889 that killed 2,209 (FEMA website). In 1972, a privately owned dam on Buffalo Creek in West Virginia failed, resulting in 125 fatalities, more than 1,100 injuries and left more than 3,000 people homeless. In 1976, the Teton Dam failure in Idaho killed 11 people and destroyed over 4,000 homes and 4,000 farm buildings (FEMA website). Although NYS has areas at risk, the state has not experienced disastrous dam failures.

Each dam in the *National Inventory of Dams* (NID) is assigned a downstream hazard classification based on the potential for loss of life and damage to property if the dam fails. This classification does not consider the condition or structure of the dam or whether the dam is about to collapse (NCTCOG website). A dam is classified as having *high hazard* if its failure would cause fatalities and extensive economic loss (NPDP database).

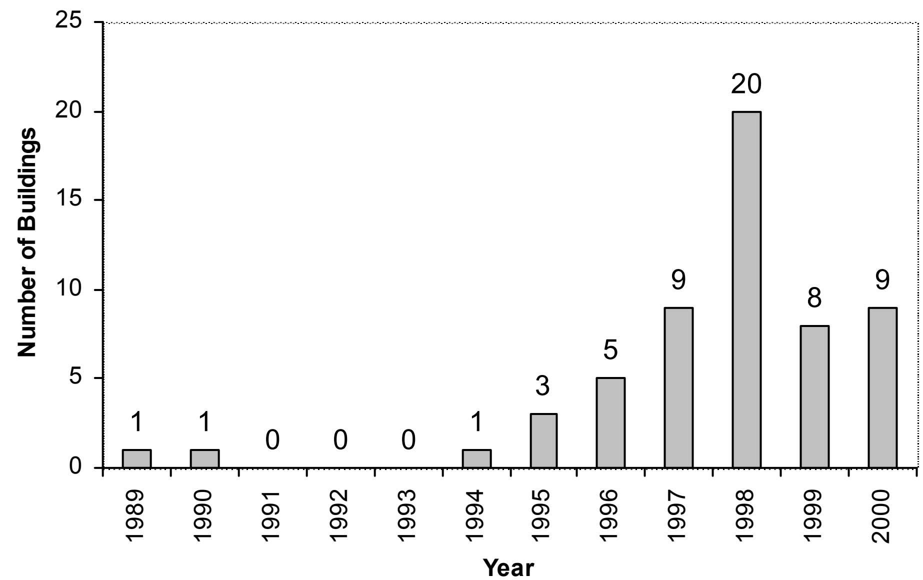
Of the total 1,971 dams in NYS, 378 dams are under high hazard classification. The rest are listed as having significant hazard or low hazard. This "high hazard" number represents 19% of total dams in the state. In the last 25 years, no fatal dam failure was recorded in NYS (NPDP database) as seen in Table 3-2 on the previous page.

These dam failures appear to have produced relatively little damage because the dams were relatively low in height and there were no downstream settlements. New York State has 378 dams labeled "high risk" and this hazard needs further investigation.

To estimate the risks to high risk dams in NYS, we have—despite the lack of local incidents--applied to NYS the national rates of failure for high risk dams. Because dams in NYS may not be similar to dams in the rest of the US, applicability of national data is questionable.

Building Failure

Studies reveal the failures of low-rise buildings other than single family dwellings are most frequent. Multi-story building failures are second in terms of frequency. Apartment buildings are the most prone to fail. External events such as rain, wind, snow, vehicular impact, collision and construction and maintenance deficiencies are the most frequent primary causes of building failures (Wardhana, 2003).



Source: Wardhana and Hadipriono

Figure 3-3 Number of Failed Buildings in NYS, 1989-2000

Table 3-3 States Ranked by Building Failure and Frequency,1989-2000

Rank	State	Failures	% of Total Failures
1	New York	57	25
2	California	29	13
3	Pennsylvania	16	7
4	New Jersey	10	4
4	Wisconsin	10	4
5	Illinois	9	4
5	Ohio	9	4
6	Georgia	8	4
7	Texas	7	3
8	North Carolina	6	3
9	Florida	5	2
9	Missouri	5	2
10	Louisiana	4	2
10	Massachusetts	4	2
10	Tennessee	4	2
10	Virginia	4	2

Source: Wardhana and Hadipriono

Historically, one of the most disastrous building collapse accidents happened in Kansas City. On July 17, 1981 the Hyatt Regency Hotel collapsed partially killing 114 people and injuring over 200 people (University of Alabama Birmingham website). Most recently in NYS, on June 27, 2006, a three story building collapsed in NYC, causing one death and nine others were rescued (CNN website). Another incident happened on July 10, 2006, when a building collapsed causing 15 injuries (CNN website). Several severe or disastrous building collapse accidents have happened in the US when buildings were under construction.

Authors Wardhana and Hadipriono (2003) have sought to inventory building collapses in the US, but achieved only partial collection of data. Their study is comprehensive in recording all building collapses in the US and did not take into account fatalities, injuries and economic loss. The study recorded 225 building failures in the US. Out of those, 57 were in NYS. They attribute the high rate of loss in NYS to older building stock as seen in Figure 3-3 on the previous page and Table 3-3 here.

Building collapse was omitted from the risk profile because data was not available for magnitude determination.

Bridge Failure

The major causes of bridge failure are floods, overload, collisions, improper design, improper detailing, faulty construction, material, and maintenance deficiency. Typically most failures occur during the bridge's service life (Wardhana, 2003).

On April 5, 1987, Schoharie Creek Bridge, a bridge on the New York Thruway, collapsed causing five vehicles to plunge into the river, killing ten (University of Alabama Birmingham, 2003). This was the most serious bridge failure in recent state history. The US as a whole has seen more severe bridge failures, including collapse of the Silver Bridge (West Virginia/Ohio) in 1967, killing 46. More recently, eight people died when barges and a tugboat struck the Queen Isabella Causeway, Texas, in 2001 (CNN website).

According to Wardhana and Hadipriono, the state with the highest number of bridge collapses is Iowa. Most of them are attributable to flooding in the Mississippi River basin in 1993. Surprisingly, NYS comes in second as seen here in Table 3-4.

Though NYS has significant numbers of bridge failures, it is assumed that most of them are caught by inspectors and do not pose life-threatening dangers. Bridge failures have been omitted from the risk profile because data was not available for magnitude determination. Overall, structural failure hazards by dams, buildings, and bridges in NYS deserve further study.

Table 3-4 States Ranked by Bridge Failure and Frequency, 1989-2000

Rank	State	Failures	% of Total Failures
1	Iowa	85	16.9
2	New York	64	12.72
3	Virginia	37	7.36
4	West Virginia	34	6.76
5	Arkansas	33	6.56
6	Maryland	29	5.77
7	California	22	4.37
8	Minnesota	18	3.58
9	Mississippi	14	2.78
9	Missouri	14	2.78
10	Georgia	13	2.58

Source: Wardhana and Hadipriono

Hazardous Materials Event

New York State has the second highest rate of hazmat events, including fixed site and mobile incidents, in the US according to data compiled by the US Department of Health and Human Services and the NYS Agency for Toxic Substances and Disease Registry (DHHS website).

While NYS events have all been relatively minor in scope, resulting in fewer than ten deaths each time, the possibility remains that a larger event could occur. The distribution of incidents is spread across the state, with Erie and Orange Counties having the highest rates. NYC falls in the second highest category of frequency. New York State has numerous fixed facilities that could potentially result in hazmat events. The possibility exists of a transportation event occurring at a higher frequency in NYS than most states in the nation due to patterns of thru-traffic.

According to the NYS Department of Health, Hazardous Substances Emergency Events Surveillance (HSEES) records from 1993 to 2005, there have been 46 incidents during that period that resulted in one or more death and 100 or more people evacuated (Welles, 2006). None of the hazmat events in NYS during this time resulted in 10 or more deaths or more than 500 people injured or evacuated in any single event. While NYS has experienced 1,330 evacuations, evacuated 103,653 people and lost 938,700 hours in people-hours due to hazmat events, these events have been spread out and not concentrated in a few events (Welles, 2006).

Hazmat events vary greatly. Explosions at fixed facilities can occur suddenly and leave little time for evacuation. Generally, they have a window of warning time for evacuations because of various internal systems to monitor chemical releases and because of fire alarms and other systems to monitor chemical releases. Because of these warning systems, the effects have historically decreased.

Definitions

Hazmat events are incidents that involve the release of hazardous materials. Human exposure to these materials can cause immediate injury or death and a host of long-term health risks. The release of these chemicals can also cause immediate environmental degradation, large scale building fires, property damage and loss, evacuations, and the temporary closure of highways and transport sites. According to the NYS Agency for Toxic Substances and Disease Registry and the Federal Emergency Management Agency (FEMA), hazardous materials involve numerous substances, ranging from medical waste and radioactive materials, to other chemicals such as chlorine, ammonia, mercury and lead (DHHS website).

Hazmat events fall under three broad categories. The first category is transportation related hazardous substance releases which may involve trucking accidents, railways, and air or water travel. The second category involves fixed facility events, where a specific site, such as a chemical plant or manufacturer, experiences the sudden release or explosion of hazardous materials. The third category of hazmat events is caused by human intent, such as a terrorist group, where hazardous materials are intentionally released to cause purposeful destruction. While hazmat exposure can occur in places such as neighborhoods, schools or factories over an extended period of time, this report does not explore issues surrounding long-term exposure.

This research specifically explores hazmat events that involve sudden or rapid on-set, at a specific point in time, with a limited window of warning time and the potential for severe destruction. While 8% of reported hazmat incidents between 1993 and 2005 involved some form of intentional release, potential terrorist attacks taking place on hazmat facilities is of growing concern for the future. This research only explores accidental hazmat events and not premeditated human actions to release toxins (FEMA website). Fixed facility and transportation hazmat events are defined by the NYS Department of Health as the following:

> Fixed facility events are those which occur outdoors or inside the buildings on the premises of a facility or site. Some examples of fixed facilities are industrial sites, manufacturing plants, businesses, farms, schools, hospitals, and private residences. Transportation events involve ground, rail, water, air or pipeline transport and occur outside the boundaries of a fixed facility (NYSDOH).

Significant Historical Events

The most extreme hazmat event in the US took place in Texas City, Texas in 1947 (Minutaglio, 2003). The event involved an explosion from a fertilizer tank that resulted in thousands of immediate deaths and injuries along with others due to chemical exposure (Minutaglio, 2003). While industry practices and hazmat regulations have changed greatly since 1947 and NYS has fire departments and hazmat units better equipped to address such an event, disastrous hazmat events remain a possibility. Currently, NYS is second, directly behind Texas, in the greatest number of annual hazmat incidents (HSEES).

On November 10, 1979, a major railroad derailment occurred outside of Toronto, Canada in Mississauga, Canada, releasing multiple chemicals (Havey, 1980). Mississauga—Canada's ninth largest city located a few hours north of NYS—had to evacuate 218,000 people which included hospitals and nursing home residents, virtually closing the city for close to a week (Harvey, 1980).

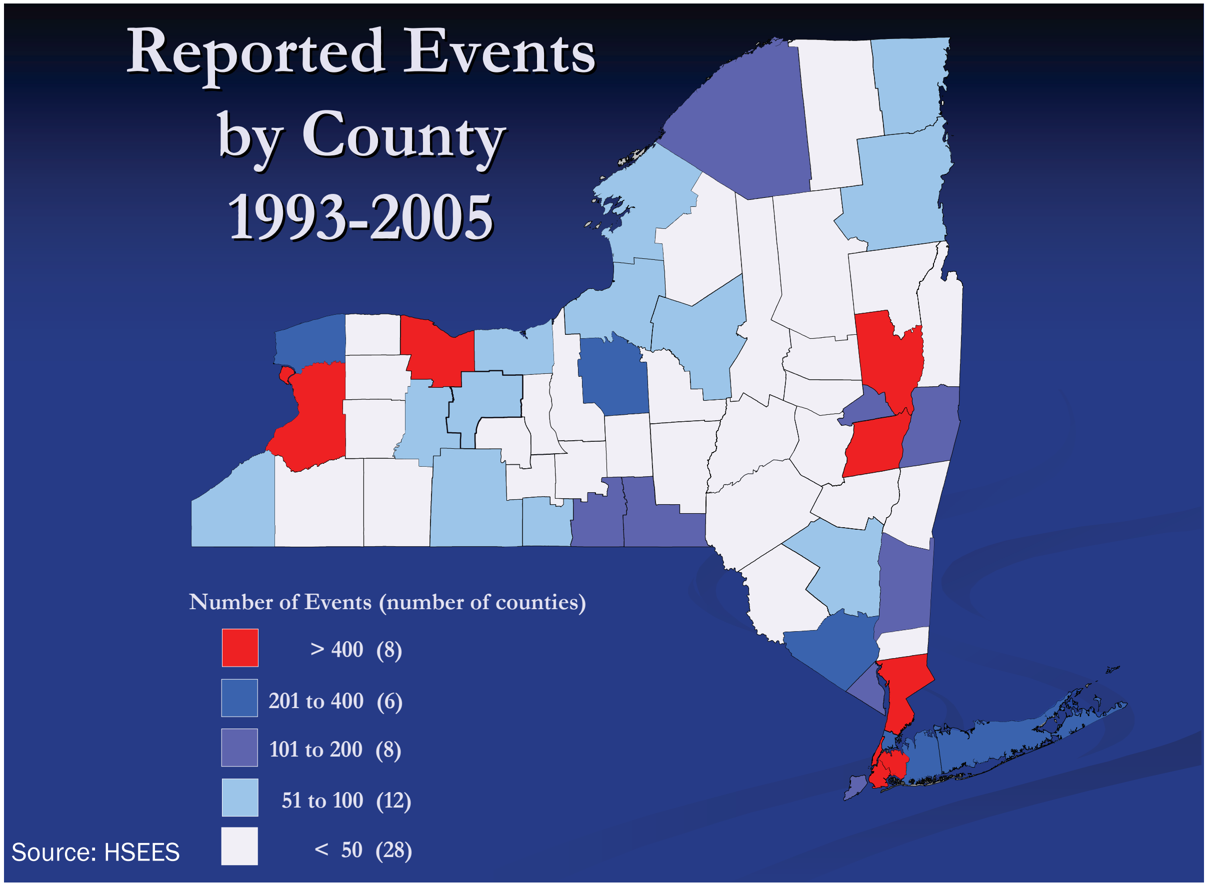


Figure 3-4 Geographic Distribution of HAZMAT Events by County

Magnitude

Harm from hazmat events can include not only economic loss, evacuations, traffic and other distributions, but also immediate and future death and injury from the exposure (Abrams, 1986). Small releases of hazardous materials occur regularly. In order to report an incident, the event must meet the federal definition of reportable hazmat events as defined by the Hazardous Substances Emergency Events Surveillance (HSEES). One of the most dangerous conditions in hazmat events is the potential release of multiple chemicals. However, 92% of hazmat events in NYS that occurred between 1993 and 2005 involved only one chemical (Welles, 2006).

Geographic Distribution

Hazmat events are spread across NYS. The risk of a fixed site event is concentrated most heavily in nine counties due to industry as seen in Figure 3-4 on the previous page. Between 1993 and 2005 there were 6,911 hazmat events at fixed sites in NYS: 21% piping, 15% outdoor events, 14% storage above ground, 14% ancillary processing equipment and 10% residences. NYS frequency of mobile hazmat incidents is second only to New Jersey (HSEES). Of the 2,611 mobile hazmat incidents in NYS between 1993 and 2005, 1,939 involved motor vehicles, 159 were rail, 28 were pipeline, and 27 were water events (Welles, 2006).

Annual Frequency and Risk Score

This report uses hazmat records from 1993 to 2005. This time period represents current conditions in industry, technology and governing legislation. Between 1993 and 2005 there were 46 hazmat events that resulted in at least one death but less than 10 according to records from HSEES. Forty-three resulted in death and three caused evacuations and injuries of 100 or more people. We classify these events as Serious. Over this 13-year period, the average annual frequency of hazmat events is 3.83, resulting in a risk score of 3.83 as seen in Table 3-5 below.

This risk score may be underestimating the potential impact of hazmat events. Further research that utilizes expert estimates, national trends and petroleum based hazmat events is needed to fully evaluate the possible dangers associated with hazmat events.

Limitations

Note that hazmat events are difficult to distinguish from fires. In hazmat events related to transportation, the wreck itself may cause death or injury that is compounded by the release of toxic substances. Also, immobile events may lead to structural failures. Hazardous mate-

Table 3-5 Hazmat Annual Frequency and Risk Score, 1993-2005

	Serious	*Severe*	*Disastrous I*	*Disastrous II*	*Catastrophic*	*Total*
Hazmat Events	46	—	—	—	—	46
Average Frequency per Year	3.83	—	—	—	—	3.83
Magnitude Score	1	10	100	1,000	10,000	
Frequency-Based Risk Score	***3.83***	**—**	**—**	**—**	**—**	***3.83***

rials can also result in long-term health problems and environmental damages that may not be immediately visible.

Past hazmat events may not be an accurate indicator of future events. Moreover, as policy to regulate hazardous substances changes, so will the occurrence of releases. The most severe events of the past may never occur again, and yet new risks may replace them.

Different agencies have different definitions of hazardous materials and the majority of studies focus on the reduction and dangers of toxic releases over time, as opposed to sudden releases. No single agency covers all hazardous substances releases or events.

This research uses data collected by the NYS Department of Health, HSEES, that does not include petroleum based events. Furthermore, while some experts would classify 9/11 as a hazmat event, this report, as stated earlier, does not look at hazmat events caused by terrorism.

Fire Event

The majority of fire events in NYS are efficiently controlled, contained and extinguished by local fire departments, preventing substantial damage or loss of life. There are several instances in which fires have been the cause of severe structural and environmental damage and multiple deaths. Though disastrous urban fires are largely a thing of the past, NYS must be prepared for damaging fires, as well as the possibility of severe wildfires. Fires occurring as a result of terrorist acts are not covered in this section, as such events are addressed within the terrorism section of this report.

Despite steady decrease in the number of civilian fire fatalities in NYS since 1985, fires caused by smoking—the number one cause of fire fatalities—has steadily increased. Arson is also becoming an increasing concern among fire prevention professionals and crime prevention agencies, as the number of arson incidents in the state has increased dramatically, specifically in Western New York and NYC. Fire damage is somewhat associated with hazmat crush events. For example, The Triangle Shirtwaist Company fire of 1911, which killed 145, the Bronx Social Club Fire of 1976, which killed 25, and the Happy Land Social Club fire of 1990, which killed 87, are three examples of fires where masses became trapped by the physical threat.

There is a downward trend in the occurrence of large loss and multiple-death fires statewide. The most recent available records from the NFPA state that in 2004, two of thirty-two multiple-death fires occurred in NYS, killing eleven. There were, however, no large-loss fires (over $5 million in damage) recorded in 2004 (FEMA website). The most vulnerable age groups in multiple death fires are the very young (ages 0-6) and the elderly (over 65). These victims also tend to be in lower income brackets.

Definitions

In this report, fires are classified as follows: residential, non-residential, and wildfires. The cause of the highest residential damage is smoking, of non-residential is arson, and of wildfires is arson and lightning.

History of Fires in New York State

In 2004, the National Fire Prevention Association compiled a list of the most notable fires in the US (NFPA, 2004). Three of these events occurred in NYS, the most notable being the Triangle Shirtwaist Company fire that occurred on March 25, 1911. This resulted in new legislation providing that all high-rises have adequate fire exits. Approximately 145 workers perished in the fire.

During the 1920's and 1930's, several large fatal fires occurred in institutions such as schools and hospitals, resulting in further development of building codes Renewed concerns about adequate exits, flammable decorations and public assembly fires were the result of tragic fires at the Bronx Social Club (1976, 25 lives) and Happy Land Social Club (1990, 87 lives).

Important steps took place in 1980 as a result of a fatal fire at the Stouffers Inn and Conference Center in Harrison, New York, leading to a comprehensive state fire initiative. The mandatory Statewide Uniform Fire Prevention and Building Code along with the establishment and preparedness of local fire professionals are critical defenses against fire damage.

Since 1903, there have been three occurrences of wildfire within of NYS, one posing a potential threat to a neighboring urban area (NIFC website). The Adirondack Wildfire of 1903 burned 637,000 acres of state land. The Sunrise Complex fire in Long Island, New York, 1995, although much smaller in scale (5,000 acres lost) NYS residents realized that "western-like" wildfires can occur in the East. The Sunrise Complex fire was declared a national fire emergency and required fire suppression aid from FEMA.

Magnitude

There are several indicators of the magnitude of a fire event: number of fatalities and injuries and the severity of injuries—including burns and smoke inhalations. Still another indicator is displacement from homes, businesses, and employment. The highest levels of displacement are in multi-unit residential dwellings along with commercial, industrial, and civic structures.

Geographic Distribution

Generally, county data collected over the past ten years by the NYS Office of Fire Prevention and Control clearly demonstrates that the most densely populated counties tend to experience higher numbers of fire incidents (NYSDOS OFPC, 2004). These counties are, in ranking order: Suffolk County, Nassau County, Westchester County, Erie County, and Monroe County.

While these are geographic areas of concentration in regard to urban structure fires, this does not prove any area in NYS to be any less susceptible to fire disasters. Fire is indiscriminate, and may strike rural as well as urban areas. The NYC area has the highest record of occurrences for fire events, including multiple-death catastrophic fires and large-loss fires (NYSDOS OFC, 2004).

Annual Frequency and Risk Score

From 1990 to 2005, there were 18 Serious residential fires, 17 non-residential Serious fires, and three Severe non-residential fires. The most Severe was the Happy Land Fire in 1990. Wild-fire data was available for 1903 to 2005 with two Serious and one Disastrous I. Results with risk scores are shown in Table 3-6 on the following page.

Limitations

Effects from prolonged exposure to fires may be as serious as chronic bronchitis, asthma, cancer or heart disease, dependent upon the mixture of particles, liquids and gaseous compounds within the smoke produced from the fire.

Fires are unpredictable due to human, technological, and environmental factors. Fire data originates in some fire departments and media reports where not all fires are reported. In general, it is difficult to determine which fires to categorize as disastrous. It is also difficult to differentiate cascading hazmat releases, crush events, and long-term health effects from fires.

Table 3-6 Earthquake Annual Frequency and Risk Score, 1877-2005

	Serious	*Severe*	*Disastrous I*	*Disastrous II*	*Catastrophic*	*Total*
Residential Fires (1990-2005)	18	—	—	—	—	18
Average Frequency per Year	1.125	—	—	—	—	1.125
Magnitude Score	1	10	100	1,000	10,000	----
Residential Frequency-Based Risk Score	1.125	—	—	—	—	1.125
Non-Residential Fires (1990-2005)	17	3	—	—	—	20
Average Frequency per Year	1.0625	0.1875	—	—	—	1.25
Non-Residential Frequency-Based Risk Score	*1.0625*	*1.875*	—	—	—	*2.938*
Wildfire (1903-2005)	2	—	1	—	—	3
Average Frequency per Year	0.0194	—	0.0097	—	—	0.029
Wildfire Frequency-Based Risk Score	***0.0194***	**—**	***0.9709***	**—**	**—**	***0.99***
ANY Fire	37	**3**	1	**—**	**—**	**41**
Average Frequency per Year	2.3125	**0.1875**	0.0625	**—**	**—**	**2.563**
Any Fire Frequency-Based Risk Score	2.3125	1.875	6.25			10.438

Source: NIFC

Winter Storm

New York State's weather patterns are affected by the Great Lakes and the Atlantic Ocean, which leaves NYS vulnerable for severe winter storms. The state is well prepared for severe winter weather events, as they are inevitable. They may affect certain areas of the state with a differing degree of severity given the geographic location and the local jurisdiction's ability to respond to the event.

Severe winter weather can be destructive and cost the state millions of dollars. Local New York State municipalities have a budget in place for dealing with winter events; however a significant storm can stretch their facilities to the limit. Dependence on electrically-managed furnaces has made communities more vulnerable.

A catastrophic winter weather event in NYS has not occurred in part because winter storms are handled effectively. This chapter focuses on winter storm events that produce significant damage and disruption. It does *not* consider average annual snowfall and precipitation to be hazardous, even though these events may claim lives and cost the state millions of dollars in damages.

Definitions

Synoptic weather occurs in a region for at least a time period of 12 hours (NWS Glossary). Alberta Clippers and Nor'easters are two types of synoptic storms effecting NYS. Alberta Clippers form when a low-pressure system forms over Alberta, Canada that travels southeastward into the US. These storms often bring cold air and move rather quickly; lake effect snow results under optimal conditions. Nor'easters take shape when intense areas of low pressure form off the Atlantic Ocean or the Gulf of Mexico on the East Coast. They may bring heavy rains, snow, strong winds and waves, ice and may cause blizzard like conditions (NWS Glossary).

Lake effect snow forms over the Great Lakes bordering NYS when cold air blows over a warm lake creating snow and releases the snow once the air mass runs into the land (NWS Glossary).

Blizzards occur when the temperature is at or below 20 degrees F, wind speeds are at least 35 mph, reduction of visibility's to a quarter mile or less for at least 3 hours, and blowing snow (due to the wind) is at least or greater than six feet in height.

Ice storms generate at least a half an inch of ice on the earth's surface. They form when rain hits objects on the surface that have a below freezing temperature, creating ice (NWS PowerPoint). Damage included downed power lines and outages, and impassable roads. Ice storms are particularly devastating to the natural and built environment. They are economically debilitating given the damage resulting from the storm.

Recent Devastating Winter Storms in NYS

The 2006 Lake Storm “Aphid”, known as the “October Storm” to residents of Erie, Genesee, Niagara, and Orleans counties, is the earliest-out-of-season snow event on record for the region. It was the sixth all-time greatest snowfall ever recorded at the Buffalo airport, at 22.6 inches. A series of unprecedented weather events led to a crippling heavy wet snowfall across the four counties, resulting in an unparalleled amount of damage. Almost one million people were without power, some for over a week. The trees, many with leaves, were completely devastated due to the weight of the snow. Power lines were down throughout the region. Schools, colleges, businesses, and other activities were cancelled for up to a week. Driving bans and states of emergency were common throughout the counties (NOAA website). On October 24, President George W. Bush declared Erie, Genesee, Niagara, and Orleans counties a federal disaster area (FEMA website).

The Blizzard of 1977 is one of the most memorable and well-known winter storms to hit NYS, specifically Buffalo. On January 28, the storm struck covering the city in snow, bringing strong winds, greatly reducing visibility and bringing the city to a standstill for about four days. This occurred in late afternoon, and many people were stranded as the roads were impassable and 29 people perished. The National Guard helped clear the roads and return life back to normal. President Jimmy Carter confirmed the first federal emergency declaration for a snowstorm following the days after the storm (NOAA website).

The ice storm of 1998 hit January 4th, devastating northern NYS, New England, and southern Quebec. In the US, 37 counties were declared federal disaster areas by FEMA, including six NYS counties. The storm claimed ten lives in NYS. The impact was limited because of the rural nature of the counties as most were heavily forested. Montreal, Quebec was severely affected. The return period for an ice storm with a similar magnitude is estimated to be 100 years for Northern NYS and is comparable to a similar event in 1921 (DeGaetano, 2000).

Phases

The National Weather Service (NWS) has a variety of winter weather terms they use to issue warnings to the public, as follows:

- ***Winter Storm Outlook:*** alerts the public for the potential of a winter storm event within three to five days in the extended forecast
- ***Winter Storm Watch:*** the possibility of winter weather exists, such as heavy snow, sleet, and ice-this is typically issued 18 to 48 hours before the winter weather hits
- ***Winter Storm Warning:*** issued when there is a high degree of certainty that serious winter weather will develop
- ***Heavy Snow:*** defined as six inches or more within a 12-hour interval and/or nine inches or more within a 24-hour interval

Similar warnings are also issued for blizzards, high winds, wind chill, and lake-effect snow (NWS PowerPoint).

Unlike other hazards, winter storms can be forecasted days in advance, reducing the likelihood of a catastrophic outcome. Still, weather is often erratic, and predicting a winter storm accurately in advance is difficult. Doppler radar and other technologies have significantly improved forecasting accuracy. However, a storm may change its path or intensity making it extremely important to check the forecast often. Even with advanced technologies, forecasting is not completely accurate. As a result, storms can be unpredictable and may hit much harder than anticipated.

Geographic Distribution

Winter storms take on a wide array of sizes, scales, and localities, presenting difficulties when trying to generalize an overall pattern for the state. Certain areas of the state receive in excess of 200 inches of snow a year. New York State is home to three of the snowiest cities in the US—Syracuse, Buffalo, and Rochester (Cappella, 2003). Lake effect storms can have a massive impact on a localized area. These storms only affect certain areas of the state, particularly the region directly south, east, or southeast of Lake Erie and Lake Ontario.

The heaviest snowfalls in the state occur east of the Great Lakes. The highest elevations of the Tug Hill Plateau—directly east of Lake Ontario— receive about 200 inches of snow every year due in part to Lake Ontario.

An ice storm can occur anywhere in the state; however, some areas are more prone to devastating storms. Northern NYS is more susceptible to ice storms.

Magnitude

Winter storms can be characterized by snowfall, wind speed, freezing rain, ice accumulations, duration and other measurable factors, however determining their magnitude and total impact on the state proves difficult.

The Northeast Snowfall Impact Scale (NESIS) ranks storms that affect the Northeastern Urban Corridor, from Southern Virginia to New England. New York City is part of the Corridor and NYS may fall into the corridor depending on a storm's geographic scope. Rankings are based on the amount of snowfall, the area over which it occurred, and the number of people living in the affected area. The NESIS is useful for categorizing storms over the tri-state area. Because the parameters used to measure severity cover a greater geographic area than NYS, they are not utilized in this report.

The NOAA considers winter storms to be deceptive killers as deaths during such an event are indirectly related to the storm. According to the NOAA, of the deaths related to ice and snow, 70% occur in automobiles, and 25% are people actually caught in the storm (NOAA website).

Excess snowfall, strong winds, ice, and frigid temperatures make traveling nearly impossible and create many undesirable circumstances. The ice storm of 1998 resulted in one of the largest carbon monoxide poisoning events in US history. About 300 people had to be hospitalized in Maine (DeGaetano, 2000).

Homeowners face damage to their homes in the form of burst water pipes, possible flooding from quickly melting snowfall, damage to roofs due to a heavy snow load, heavy wind gusts may blow trees or other items onto homes causing damage. Other personal possessions such as cars may be stranded or abandoned due to unfavorable road conditions.

Disruptions caused by winter storms may have a great effect on people's daily life, the economy, and physical environment. Snowfall and ice may make the roads impassable for days at a time stalling commerce and daily activities.

Our magnitude table categorizes injuries and deaths; however given the low death and injury rates associated with winter storms, these factors do not affect a storm's ranking on the magnitude table. High death and injury rates are a valid possibility and their importance should not be forgotten. We classify storms from 1996-2006, quantified by the National Climatic Data Center (NCDC). For this report the qualitative factors were quantified according to NCDC. Assessment of storm impact is complicated, because deaths are indirectly related to the storm.

A federal disaster declaration automatically classifies a storm as severe. Categorizing storms based on NCDC data shifts a storm up a level on the magnitude table. Examples of Serious, Severe, and Disastrous I winter storms are listed below, citing qualitative variables used to determine magnitude; all data is from NCDC's online database.

- *Serious Winter Storm:* The 1996 heavy snow event on March 3rd and 4th is categorized as a Serious winter storm based on the following: one fatality and injury, 13,000 dollars in property damage, multiple road closures, traffic accidents, and the NYS Thruway was closed.
- *Severe Winter Storm:* The 2001 heavy snow event from December 24th through 29th is categorized as a Severe winter storm based on the following: no persons died or were injured, 23 million dollars in property damage, structural collapse, NYS declared a state of emergency, the National Guard was called in to assist, and additional factors.
- *Disastrous I Ice Storm:* April 4th and 5th 2003 was considered a Disastrous I storm based on the following: one person died, no one was injured, 57.1 million dollars in property damage, 8.6 million dollars in crop damages, 402,500 people were disrupted for up to a week due to power outages, trees and power lines were downed, structural damage, auto damage, NYS declared a state of emergency, federally declared disaster, school closing, emergency shelters were opened, and agricultural damage.

Annual Frequency and Risk Score

Annual frequency data is derived from the NCDC storm database for the following years: 1996-2006. We used these 11 years because the NCDC made available (in combined form) casualties and economic effects, only for this period. Frequency, magnitude, and risk scores results are in Table 4-1 on the following page.

Limitations

Available data sources lack comprehensive storm descriptions. Throughout the data, sources for the type of storm are not readily identified. The types of individual winter storms (i.e. Nor'easters or blizzard) events are not distinguishable and are classified under "winter storm" or "ice storm". Ice storms are the exception as they are categorized separately.

Property and crop damage seem to be under reported in the NCDC's storm data. The 1998 ice storm resulted in a total of $440.9 million in damage, but according to the NCDC property damage accounted for $23 million.

Further investigation is needed to provide accurate damage amounts adjusted for actual monetary impact. When utilizing the magnitude table, monetary damage amounts based on NCDC data are not heavily weighted when determining magnitude.

The NCDC's storm database only classifies snow and winter storm events after 1993. The sheer quantity of storms affecting the state per year is difficult to quantify in an effective manner; for example, 1996 has 875 events listed. Our judgment is used to classify possible disastrous or extreme events when querying the data (NCDC website). Given the complexity of New York's climate, further investigation is needed to quantify weather hazards on a regional basis. Each region's individual climate and weather patterns are different.

Table 4-1 Winter Storm Annual Frequency and Risk Score, 1996-2006

	Serious	***Severe***	***Disastrous I***	***Disastrous II***	***Catastrophic***	***Total***
Winter Storms, Except Ice Storm— NCDC	**6**	**4**	**1**	**—**	**—**	**11**
Average Frequency per Year	0.55	0.36	0.09	—	—	1.00
Magnitude Score	**1**	**10**	**100**	**1,000**	**10,000**	**—**
Frequency-Based Risk Score	*0.55*	*3.65*	*9.09*	—	—	*13.27*
Ice Storm Only—NCDC	**1**	**1**	**2**	**—**	**—**	**4**
Average Frequency Per Year	0.03	0.03	0.07	—	—	0.13
Frequency Based Risk Score	***0.03***	***0.33***	***6.61***	***0***	***0***	***6.98***
Winter Storms and Ice Storm—NCDC	**7**	**5**	**3**	**—**	**—**	**15**
Average Frequency Per Year	0.87	0.62	0.37	—	—	1.86
Frequency Based Risk Score	***0.87***	***6.20***	***37.19***	**—**	**—**	***44.26***

Source: NCDC data

The concept of global warming is highly debated; however any change in the earth's temperature will affect the weather patterns. This will have to be further investigated and closely watched in the coming years.

Flood

New York State experiences a disruptive flood approximately every year. Of all Presidential Disaster Declarations in NYS, from 1954 to 2006, 33% have been for floods (FEMA website). Based on this historic frequency, there is an annual likelihood of roughly 35% for a flood significant enough to be a Presidential Declared Disaster occurring in NYS.

According to the National Climate Data Center (NCDC), there were 2,101 flood events reported in NYS from 1993 to mid-2006. These floods resulted in 43 deaths, 33 injuries, $1.8 billion in property damages and $3.2 million in crop damages (US Army Corps of Engineers, 2003). This included 1,151 flash flood events, which accounts for 55% of total flood events. Consequently, flash floods are the most prominent flood type in NYS as seen here in Table 4-2. From 1993 to mid-2006, 26 flood related deaths in NYS occurred because of flash floods, accounting for 60% of total deaths caused by floods and 72% of property damage from floods (NCDC database).

Table 4-2 Flood Events, 1993-2006

Type	Number	Death	Injuries	Property Damage (millions)	Crop Damage (millions)
Urban/small Stream Flood	146	2	21	0.582	0
Flood	772	15	5	496.492	1.115
Flash Flood	1151	26	7	1309.944	2.06
Coastal Flood	32	0	0	12.25	0
Total	2101	43	33	1819.268	3.175

Source: NCDC data

The area most susceptible to flooding in NYS is the Delaware River Basin, centered in Delaware County. Severe flooding is not only a frequent event in the state, but it can also be a deadly one. Floods generally result in economic, environmental and physical destruction and disruption, rather than loss of life. While floods are a routine concern and threat to localities, many can be handled by the municipality where they occur and do not require state or national assistance. These smaller floods often do not affect settled areas or infrastructures and cause relatively low monetary damage. This chapter explores only serious (more severe) routine flooding caused by storms, we exclude flooding caused by coastal surges.

Definitions

According to the Federal Emergency Management Agency, a flood is “the accumulation of water within a water body and the overflow of excess water onto adjacent floodplain lands” (FEMA, 1997). Flooding can be separated into the following types:

- Riverine flooding:
  - Overflow from a river channel
  - Flash flood
  - Alluvial fan flood
  - Ice-jam flood
  - Dam-break flood
- Local drainage or high groundwater levels
- Fluctuating lake levels
- Debris flows
- Subsidence
- Coastal flooding, including storm surge (FEMA, 1997)

For flash floods, the lead time for a forecast is usually less than six hours. In areas that are prone to such floods, special warning systems are needed. However, flash floods can also occur within several seconds with little warning. In rapid riverine floods, the lead time is less than 48 hours (Sorensen, 2000).

Large Floods in New York State

The most recent large flood in NYS occurred in June 2006. Eighteen inches of rain fell in the Delaware Basin (and nearby areas). Nine inches fell just on June 27 and 28, on soil that was already saturated. Record high levels of rain fall were seen at several sites: West Branch Delaware River at Walton, West Branch Delaware River at Hale Eddy, and Delaware River at Callicoon. It has been labeled a 146 year flood event (Delaware County website). All major highways in the Binghamton area were closed due to the flooding including Interstate 81, Route 17, Route 26 and Interstate 88. All roads were closed in Delaware County. The flooding caused Interstate 88 to collapse, killing two truck drivers. In Sullivan County, one person was killed by the flooding when she was washed out of her home by the flood waters. In Chenango County, one man was killed by the flood waters. Over 9,000 were evacuated (NCDC database).

New York City is primarily susceptible to local drainage flooding and coastal flooding. In October 1996, an intense rainstorm deluged NYC and other parts of the metro area with up to 8.6 inches of rain, killing four people and cutting power to 341,000 homes in three states. Home flooding occurred in Queens, Bronx, and Brooklyn (NYC website).

Flood events are often very difficult to distinguish from other storm events. For example, a major ice storm and flood event hit northern NYS and New England in January 1998. Though this event was chiefly an ice storm, it exacerbated flooding, forcing the evacuation of more than 1,000 homes (NOAA, 1998).

Magnitude

For insurance and regulatory purposes, the usual way to evaluate flood hazards is by annual peak flows, classified as 10%, 2%, 1% and 0.2% recurrence intervals (10, 50, 100, and 500-year floods). At least ten recorded years are needed for such frequency analysis (FEMA, 1997). The standard evaluation of flood magnitudes is based on rainfall and saturation alone, but is not directly transferable to our magnitude classifications of Serious, Severe, Disastrous I, Disastrous II or Catastrophic. For the purposes of this report, we are assessing magnitude based not on rainfall, water levels or saturation, but death, injury and damage. For example, a 100-year flood on a rural stream may inundate no private properties or public infrastructures, causing little to no monetary damage and no threat to human life. While there may be environmental damage, the flooding is not destructive enough to be classified as Serious or higher.

The National Weather Service Manual uses the following flood categories:

- ***Minor Flooding:*** minimal or no property damage, but possibly some public threat.
- ***Moderate Flooding:*** some inundation of structures and roads near a stream. Some evacuations of people and/or transfer of property to higher elevations.
- ***Major Flooding:*** extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations.
- ***Record Flooding:*** flooding which equals or exceeds the highest stage or discharge at a given site during the period of record keeping (NWS, 2006).

The USGS estimates the level according to drainage area, basin storage, the percentage of the drainage area of topographic maps and mean annual precipitation, not according to actual damage (USGS 1993). It is difficult to translate this magnitude classification to actual NYS floods. We have attempted to use this information and make it more compatible with our definition of magnitude by obtaining NCDC data on floods that occurred between 1993 and 2006. These were chosen because the NCDC data was not available for an earlier period. While most of these floods received FEMA disaster designations, not all were declared disasters.

Geographic Distribution

According to data by the United State Geological Survey (USGS), NYS is divided into eight hydrologic regions. United States Geological Survey designates a state's areas of greatest flooding concern according to these basins (USGS, 1993). The Delaware River Basin is the most susceptible, followed by the Hudson River Basin. Based on hydrologic regions in NYS, Region 4 and Region 5 are the most susceptible areas among all regions, followed by Region 3.

Within the Delaware River Basin, Delaware County is particularly vulnerable because the population is concentrated in valleys or near rivers and bodies of water. Delaware County officials estimate that 5,500 people live in the 100-year Flood Zone (Delaware County 2005). Many live in mobile homes, which are more vulnerable to flood effects (Delaware County 2005). According to FEMA, Delaware County has received eight Presidential Disaster Declarations for flooding events between 1984 and 2006, giving it the highest record of flooding among all counties in NYS. Yet almost all counties in NYS may have floods. Altogether, 61 counties out of 62 have received a Presidential Disaster Declaration for flooding since 1984.

Annual Frequency and Risk Score

NCDC data for 1993-2006 was available on counties affected, deaths, injuries, damage to houses and businesses, road closures, bridge damage, numbers of people or households evacuated, and monetary damage. The data was highly incomplete and inconsistent. Because of the inconsistent data, judgments were made on how to classify the events. The classification was Serious if there was at least one death. Next, the extent of other damage was assessed. Where the additional damage or disruption was sufficient, the classification was raised to Severe or Disaster I. Given the quality of the data, classifications were imprecise.

For an additional source, FEMA disaster declarations for 1954-2006 were used. First, an average probability according to average occurrence was determined, then based on the average probability respectively, two risk scores from FEMA and NCDC data were computed. Finally, these scores were averaged. Based on flood occurrences from the two databases (FEMA and NCDC), the annual frequency of Serious, Severe, and Disastrous I floods were calculated as 0.56, 0.185, and 0.0824, respectively as seen in Table 4-3 on the following page. By multiplying the estimated magnitudes and annual frequencies, the overall risk score for flood is 10.65.

Table 4-3 Flood Annual Frequency and Risk Score (1954-2006, 1993-2006)

	Serious	***Severe***	***Disastrous I***	***Disastrous II***	***Catastrophic***	***Total***
Flood Events (FEMA 1954-2006, NCDC 1993-2006)	13.5	4.5	2	—	—	20
Average Frequency per Year	0.56	0.185	0.0824	—	—	0.827
Magnitude Score	1	10	100	1,000	10,000	—
Frequency-Based Risk core	*0.56*	*1.85*	*8.24*	—	—	*10.65*

Source: NCDC; FEMA data

Limitations

This estimate is subject to many limitations. The classification of event magnitudes is based on interpretations of inconsistent data. The period for which the magnitude data was available was only 1993-2006 (by NCDC data) or 1954-2006 (FEMA data). These are both small sample sizes. The final risk score is based on the average of the two estimates. We assume each to be an imperfect representation of "true flooding" propensity in NYS.

Damage estimates for local jurisdictions within a larger flood area tend to be extremely inaccurate. The frequency of future flood events in NYS may not reflect past frequencies. River modifications, changing land use, population change, and climate change can all affect likelihoods and intensities of floods.

Other Storm Events

Tornados and Wind Events

This section explores risks associated with thunderstorms, windstorms and tornados for NYS. While NYS experiences all of these storm types and they can all be disruptive, thunderstorms and windstorms have historically resulted in little damage or loss of life. Typically, thunderstorms are most dangerous when they produce flooding, which is discussed in the Flood chapter. Thunderstorms and windstorms are also most dangerous when conditions create tornados. Of these storm types, tornados create the most death, injury, disruption and economic loss and they therefore have a heavier concentration in this section.

Tornados occur in NYS, but their intensities have historically been low resulting in few causalities and injuries. Of the 352 tornados recorded in NYS since 1952, 75 (21%) have had an intensity rating between F-2 and F-4 (NCDC database). They are most likely to occur in the southern portion of the state, near the NYC area. New York State has little history of violent tornadoes (six documented F-4 tornados from 1952 to 2006) and no record of "incredibly damaging," or F-5 tornados. The NYC metro area has experienced F-0 or F-1 tornados, causing little damage and injury (NCDC database).

Definitions

The term severe local storm is defined by the NWS as, "a convective storm that usually covers a relatively small geographic area, or moves in a narrow path, and is sufficiently intense to threaten life and/or property" (NWS Glossary).

The NWS defines a thunderstorm as, "a local storm produced by a cumulonimbus clouds and accompanied by lightning and thunder" (NWS Glossary). There are four types of thunderstorms: single cell, multicell, multicell or squall line, and supercell. The cell refers to the updraft and downdraft component; cells may be separate, in a cluster or a line. Supercells are always classified as severe and may produce hail, flash floods, downbursts, and tornados (University of Illinois website).

A thunderstorm is considered "severe" (by the NWS) when it produces hail at least ¾ inch in diameter or has winds at least 57.5 miles per hour (50 knots) or produces a tornado (NOAA website).

According to the NOAA, a tornado is "a violently rotating column of air extending from a thunderstorm to the ground" (NOAA website). In some parts of the US, tornadoes can reach wind speeds of 300 miles per hour. Damage occurs from high wind speeds, flying debris, collapsing buildings and people caught in its path, as well as direct contact with the funnel or tornado (NCDC database).

Tornados

The most destructive tornado recorded in NYS since 1951 occurred in Saratoga County and northern Rensselaer County (NCDC database). A State of Emergency was declared for Saratoga and Rensselaer Counties by Governor Pataki and the National Guard was called in to assist in clean up. Combining damage in Saratoga and Rensselaer County, 345 homes and businesses were either destroyed or damaged. Electricity was out in some places for three to four days, wind gusts carried a roof 60 yards, roughly 25 cows were killed, power-lines and trees went down, and approximately 70 people were injured; there were no fatalities.

Phases

The National Weather Service (NWS) has a variety of severe storm terms they use to issue storm warnings to the general public, as follows:

- *Severe Thunderstorm Warning:* "is issued when either a severe thunderstorm is indicated by the WSR-88D radar or a spotter reports a thunderstorm producing hail 3/4 inch or larger in diameter and/or winds equal or exceed 58 miles an hour" (NWS Glossary).
- *Severe Thunderstorm Watch:* "is issued when conditions are favorable for the development of severe thunderstorms in and close to the watch area" (NWS Glossary).
- *Tornado Watch:* "is issued when conditions are favorable for the development of tornadoes in and close to the watch area" (NWS Glossary). These watches usually last about 4-8 hours.
- *Tornado Warning:* "is issued when a tornado is indicated by the WSR-88D radar or sighted by spotters; therefore, people in the affected area should seek safe shelter immediately" (NWS Glossary). A tornado watch does not have to be in effect for a tornado warning to be issued. They are typically issued for 30 minutes at a time. Tornados are generally accompanied by a short warning time.

Communities throughout the US and NYS have warning systems in place to alert citizens of tornadoes and tornado warnings when weather conditions could produce a tornado. This warning generally allows residents enough time to seek appropriate shelter during the onset of the storm; although this does not protect property, it greatly reduces death and injury. The peak tornado season in the Northern US, including NYS, is late spring through early summer and is most likely to happen between 3 p.m. and 9 p.m., but can occur at any time.

Magnitude

Thunderstorms and severe storms may lead to flooding. Flash floods and flooding from thunderstorms is the number one cause of all fatalities associated with the storm, about 140 people die annually nationwide (NOAA website). Lightning occurs in all thunderstorms and kills more people per year than tornados.

Straight line winds cause the majority of the wind damage. Wind speeds may exceed 100 miles per hour, and may occur in a downburst (NOAA website). A downburst is caused when air quickly descends beneath the storm, typically coming from one direction. Downbursts are classified as microburst or macroburst, and may cause the equivalent damage of a tornado.

The magnitude of tornados is determined using the Fujita Scale, which is based on a scale of F-0 to F-5 that assesses the classification based on damage.

An average year in the US produces 800 tornados, resulting in roughly 80 deaths and 1,500 injuries (NWS 1992). Tornados occur in NYS, but their intensities have historically been low resulting in few causalities and injuries.

Geographic Distribution

Thunderstorms are smaller in scope compared to other storms, such as winter storms and hurricanes. The average thunderstorm is 15 miles in diameter and lasts about 30 minutes (NOAA website). Thunderstorms affect the entire state, with varying degrees of severity.

Some regions in NYS are more susceptible to tornados than others. According to the US Geological Survey, the southeastern portion of the state, which includes NYC, is ranked as being a part of the continental US with the highest likelihood of a tornado and a portion of Western NYS is ranked in the high category (FEMA website). The National Severe Storms Laboratory (NSSL) ranks only a small portion of south NYS, outside of the NYC area, as high, most of Central NYS and part of Western NYS as moderate, and most of the Northern portion of the state as low (FEMA website). Southern, Central and Northern NYS each carry different probabilities by geographic distribution. Due to flying debris and high wind speeds, areas not immediately on the path of the tornado can also be damaged.

Annual Frequency and Risk Score

NOAA records report that from 1952 to 2006, there have been 352 tornados in NYS (NCDC database). This gives an average annual frequency of six tornados of any magnitude a year in the state as a whole, but only 75,or 21%, of those tornados were of a magnitude of

F2 or higher. Meteorologists generally classify tornados with a magnitude of F-2 or higher as severe. Using these records, the average annual frequency for a tornado with a magnitude of F2 or higher, anywhere in the state, is 1.36 (NCDC database) see Table 4-4. Of the 75 tornados with a magnitude of F2 or higher, six, or 2%, were categorized as F4, giving a likelihood, based on historic trends, of an F4 tornado occurring anywhere in the state to be approximately every 9 years (NCDC website). There is no reported record of an F5 tornado occurring anywhere in NYS.

Normally a tornado with a Fujita Scale rating of F-2 or higher would be considered destructive. In NYS there have been 75 tornados from 1952 – 2006 classified as F-2 or higher. However, most of these tornados did not produce damages beyond $1 – 2 million, deaths or more than 10 injuries. Therefore, this report uses a different magnitude scale. The magnitude scale assesses severity based on deaths, injury and major disruption. Eleven tornados recorded during this time period are thus categorized as Serious and two as Severe. The eleven Serious tornados resulted in at least one death and/or multiple injuries. In the cases of the two Severe tornados, one caused nine deaths, multiple injuries and economic loss; the other resulted in no deaths but caused major disruption from destroyed homes, businesses and power outages, 70 people were injured and it was a declared disaster.

Table 4-4 Tornados Annual Frequency and Risk Score

	F2 or Higher	*Serious*	*Severe*	*Disastrous I*	*Disastrous II*	*Catastrophic*	*Total*
Tornados	75	11	2	—	—	—	88
Average Frequency per Year	1.36	0.20	0.04	—	—	—	1.60
Magnitude Score	—	1	10	100	1,000	10,000	—
Frequency-Based Risk Score	—	*0.20*	*0.04*	—	—	—	*0.24*

Source: NCDC data

Eleven tornados meet the criteria to be categorized as Serious and two meet the criteria to be categorized as Severe but none fit into a higher category, based on NOAA records as seen here in Table 4-4. The average annual frequency of a tornado incident with an impact that is Serious is 0.2 and one with an impact that is Severe is 0.04. Of the two Severe tornados in NYS, one occurred in Orange County, outside of the NYC area. When the historic frequency is multiplied by the corresponding magnitudes of Serious and Severe, the total risk score for tornados in NYS is 0.57.

Table 4-5 Wind Events Annual Frequency and Risk Score

	Serious	*Severe*	*Disastrous I*	*Disastrous II*	*Catastrophic*	*Total*
High Wind Only Events	3	6	1	—	—	10
Average Frequency per Year	0.25	0.50	0.08	—	—	0.83
Magnitude Score	1	10	100	1,000	10,000	—
Frequency-Based Risk Score	**0.25**	**4.96**	**8.26**	—	**—**	**13.47**
Thunderstorm Wind Only Events	3	1	—	—	—	4
Average Frequency per Year	0.1	0.03	—	—	—	0.13
Magnitude Score	1	10	100	1,000	10,000	—
Frequency-Based Risk Score	**0.1**	**0.33**	**—**	**—**	**—**	**0.43**
All High Wind– excluding Tornados Events	6	7	1	—	—	14
Average Frequency per Year	0.69	0.81	0.12	—	—	1.62
Magnitude Score	1	10	100	1,000	10,000	—
Frequency-Based Risk Score	**0.69**	**8.1**	**11.57**	**—**	**—**	**20.36**

Source: NCDC Data

Table 4-5 illustrates the annual frequency and risk score for wind events in NYS. High winds are listed first with three Serious events, six Severe events, and one Disastrous I for a total risk score of 13.47. Thunderstorm wind events are listed next with a total combined risk score of 0.43. All wind events are then combined for a total combined risk score of 20.36.

Limitations

Data on tornados is clustered with other storms and floods and may not represent damages associated directly with tornados. The frequencies, number of tornados and level of loss reported by different agencies is sometime conflicting.

Data for Severe storms is not classified by definition of “severe storm” within NCDC’s online storm database. We separated high wind events from thunderstorm wind events in order to categorize other severe storms in NYS.

Enhanced placement of Doppler Radar Systems may provide greater warning time in the future and help to offset losses from an increase in storm frequency. Tornados can also cause cascading effects such as striking a power line or other structures that are not accounted for in this report. The tornado with the greatest number of fatalities (9 deaths in Orange County) only had a magnitude of an F1. Magnitude alone may not always be an indicator of potential injury and loss.

More than that, past events may not be a predictor of future events. Some scholars argue that weather patterns are changing and storms are increasing, which could potentially increase the rate and severity of storm events in the future.

Landfalling Hurricanes

Coastal storms consist of landfalling hurricanes, nor'easters, and tropical storms. They are typically characterized by heavy rain, high winds, and high surf. In NYS, coastal storms impact NYC and Long Island specifically, but upon hitting land can continue to wreak havoc on areas much further inland (flood effects are counted separately under the "flood" section).

The most reliable data set used is from NOAA and as such categorized coastal storms as landfalling hurricanes. The data did not report coastal storms as tropical storms or nor'easters in such a way that we could correlate each to our magnitude scale. Thus, the risk score is a reflection of only landfalling hurricanes and may not fully represent past coastal storms that have impacted NYC and LI. We based our assessment on historical frequency data that spans 105 years. During this period, there were 20 coastal storms that hit NYC and LI. These 'landfalling hurricanes' are categorized according to the hurricane scale known as the Saffir-Simpson scale. For this preliminary estimate, it was assumed that the magnitude of harm or damage corresponded directly to the 5-point Saffir-Simpson scale. Namely, the category Serious was assumed to correspond to Saffir-Simpson Category 1. Our category Severe was assumed to correspond to Saffir-Simpson Category 2, and so forth. Of the 20 recorded landfallling hurricanes , 16 were Category 3 (Disastrous I).

Table 4-6 Coastal Storm Annual Frequency and Risk Score

	Serious	*Severe*	*Disastrous I*	*Disastrous II*	*Catastrophic*	*Total*
Coastal Storms	**3**	**1**	**16**	**—**	**—**	**20**
Average Frequency per Year	0.03	0.01	0.15	—	—	0.19
Magnitude Score	1	10	100	1,000	10,000	----
Frequency-Based Risk Score	***0.03***	***0.10***	***15.24***	**—**	**—**	***15.36***

Source: NCDC - NOAA

For purposes of the risk score as seen in Table 4-6, coastal storms that are identified in the Storm Surge chapter were excluded. Likewise, any storms that were categorized by NOAA as tornadoes, severe storms (thunderstorms), or flooding events were not included.

Note that changes in the Earth's climate, global warming, and the El Nino/La Nina weather phenomenon all play a major role in the future likelihood of coastal storms in terms of intensity and frequency—but we were unable to assess how these will affect future probabilities.

Heat Wave

Harm from heat wave depends on factors such as age (elderly and very young), respiratory ailments, immobility (handicapped or otherwise), access to air conditioning, and taking certain medications. Exacerbating factors include heat-absorbing surfaces (i.e. concrete, pavement), the "heat island" effect, and lack of opportunity for relief from the blistering heat.

The National Weather Service (NWS) issues alerts and warnings as soon as they anticipate the onset of higher temperatures combined with high humidity. These warnings are given in an effort to alert the elderly and those responsible for the young to take precautionary measures.

Definitions

The NYC Department of Health and Mental Hygiene (DOHMH) defines heat wave as three consecutive days of temperatures of at least 100° followed by five consecutive days of temperatures of at least 90°.

As a result of the major heat wave in Chicago during the summer of 1995, the Cook County Medical Examiner's Office determined what constituted a death that was attributed to heat. A death was counted as the result of a heat wave if one of the following three criteria were met: 1) core body temperature greater than or equal to 105° F at the time of or immediately after death, 2) substantial environmental or circumstantial evidence of heat as a contributor to death. For example, the deceased was found in a room without air conditioning, with windows closed, and with a high room temperature, or 3) the deceased is in a decomposed condition without evidence of other cause of death (Center for Disease Control).

Historic Heat Waves

Over a 40-year period from 1936 through 1975, the effects of heat killed 20,000 people in the US. In 1980, a "disastrous" heat wave, according to the NOAA, claimed 1,250 lives the US. The death counts reflect direct casualties and not deaths which may have been advanced by the heat wave (NOAA).

During a period from July 11 to 27, 1995, summer heat caused 1,021 heat-related deaths in the US (NOAA). Of these, 629 occurred in Chicago and 28 in Milwaukee. The past decades have seen several major heat waves affecting the East Coast.

Magnitude

Magnitude for heat waves was determined by the number of deaths. Over the period from 1993 to 2006, there were five heat waves in NYS with deaths directly related to the heat. Two were classified as Serious, two as Severe, and one as Disastrous I.

We have tentatively identified the following heat waves occurring in NYS:

- 1995, 14 people died during a two week period in July when temperatures rose to 90° and higher, culminating at 102°in Central Park.
- 1999, 33 people died
- 2001, a high pressure system off the coast of South Carolina brought extreme high temperatures and high humidity to metro NYC. Temperatures reached 103° F for a short duration and the heat index maximized at 110°. There were 4 heat-related deaths in NYS as recorded by NWS during this event. Power outages were experienced by 21,000 people.
- July 2005, heat wave in NYC claimed or contributed to 100 deaths, according to city health officials (NYC DHMH). During the period of July 27 to August 5, an additional 60 deaths were considered as 'excess deaths' given the deceased had an existing ailment that was possibly exacerbated by the extreme heat.
- During August 1 to 4, 2006, the NYC chief medical examiner's office attributed 31 deaths to the heat.

Geographic Distribution

In a city where air is stagnant, heat traps pollutants, further compounding the effects of a heat wave on the human body. The "heat island" effect of heavily paved areas adds to increased temperatures. A great number of city deaths resulting from heat waves can be attributed to these factors (NOAA). The location of some city residents in high-rises makes it difficult for public officials to determine who is at risk. New York City is the most vulnerable city in NYS.

Annual Frequency and Risk Score

A central and consistent source of data for deaths attributed to heat wave events was not found. Typical "excess deaths" from routine high temperatures may be combined with surges in death from a heat wave event.. The annual frequencies and risk scores are shown on the following page in Table 4-7.

Limitations

Heat wave events may occur over several days. Social conditions may be a contributing factor to increased deaths due to heat. Further compounding the effect from the heat is one's age and overall health condition. The elderly tend to become fearful of the environment around them and as such, close windows to keep themselves safe. This exacerbates the effect of a heat event.

Inconsistencies in the definition of a heat "event" versus a heat "wave" lead to a tabulation of deaths for both, regardless of classification. Heat events were also identified by the highest recorded temperature (but without death counts) for a specific region in the state. It could not be determined whether the days having elevated temperatures were consecutive days or occurred over a period of non-consecutive days, weeks or months. Therefore, our frequencies may appear to be low which in turn provides a low risk score.

Table 4-7 Heat Wave Annual Frequency and Risk Score, (1993-2001, 2000-2006)

	Serious (x1)	*Severe (x10)*	*Disastrous I (x100)*	*Disastrous II (x1000)*	*Catastrophic (x10000)*	*Total*
Heat Wave Events (1993-2001) NCDC	2	1	—	—	—	3
Heat Wave Events (2000-2006) NYC DOHMH	—	1	1	—	—	2
Total Heat Wave Events (NCDC/NYC DOHMH)	2	2	1	—	—	5
Average Frequency per Year	0.143	0.143	0.071	—	—	0.357
Magnitude Score	1	10	100	1,000	10,000	----
Frequency-Based Risk Score	***0.143***	***1.429***	***7.143***	**—**	**—**	***8.714***

Source: NCDC and NYC DOHMH data

Storm Surge

The only susceptible locations to storm surge within NYS are NYC, Long Island (LI), and a small portion of the Hudson River valley. For a storm surge to affect Manhattan, a hurricane must have a certain angle of approach. The probability that a hurricane will cause a storm surge is less than the probability of a hurricane to occur.

Nor'easters can also cause storm surges however, limited data was found. Almost all our data is on hurricane-based storm surges. Note only hurricanes that have been indicated to have caused serious or greater surges in NYS are discussed in this report. Hurricanes already listed under "landfalling hurricanes" are not double counted as these are discussed in Chapter 4.

New York State is vulnerable to hurricanes due to its landform. NYC and LI form a right angle which, according to NWS experts, causes water from a hurricane to accumulate and pile up at a relatively fast rate. The New York harbor further acts as a funnel due to the shallowness of the continental shelf and has some of the highest storm surge values in the country. A Category 3 storm making landfall in Florida may only have a 12-13 foot storm surge, whereas for NYC, a Category 1 storm can give the same depth in storm surge (NWS-NOAA).

Concern about storm surge in the metropolitan east coast region has increased because of observed sea-level rise near NYC (Gornitz, Center for Climate Systems Research). Warning time is a primary concern as there may only be hours of warning time before a hurricane hits NYC.

Definitions

A storm surge is a pushing of water toward the shore by the force of storm winds. The advancing surge combines with the normal tides to create a storm tide, which can rise above the mean water level by 15 feet or more. The storm surge may be caused by a hurricane, nor'easter or tsunami. For any one hurricane to cause a storm surge, the necessary conditions include high winds and low barometric pressure. Although extremely rare in the Atlantic, tsunamis may also occur.

Storm Surges in NYS

Storms reported to have caused storm surge in NYS are as follows:

- *1821:* A hurricane passed directly over parts of NYC pushing the tide up 13 feet in one hour and inundating wharves, causing the East River and the Hudson River to merge across lower Manhattan as far north as Canal Street. Since few people resided in Manhattan at that time, there were few deaths.

- *1858*: Category 1 hurricane affected New York during September.
- 1869: Category 1 hurricane affected New York during September.
- *1893:* Category 1 hurricane destroyed Hog Island, a resort island off Rockaway in southern Queens.
- 1894: Category 1 hurricane affected NYS, Connecticut, and Rhode Island during October.
- *1938:* Long Island Express - In terms of fatalities and property damage is one of the worst. In a matter of hours, 600 people were killed along the East Coast (10 in NYC), 3,500 were injured, and more than 75,000 buildings were damaged.
- *1954:* Hurricane Hazel, Category 4, produced a storm surge of 18 feet causing extensive damage and destruction to beaches located in Connecticut and ruining an entire business section of Garden City, Long Island.
- *1960:* Hurricane Donna created an 11-foot storm tide in the New York Harbor causing extensive pier damage and forcing 300 families to evacuate Long Island.
- *1992:* A powerful nor'easter immobilized NYC by shorting out the entire subway system. The storm further caused shut downs of the PATH transportation link between NYC and New Jersey; forced LaGuardia Airport to close; raised sea level at the southern tip of Manhattan by about eight-and-a-half feet; and flooded Battery Park Tunnel with six feet of water.
- *1999:* Hurricane Floyd, weakened to a tropical storm, brought sustained winds of 60 mph, dumping 10-15 inches of rain on upstate New Jersey and NYS.
- *2004:* The remains of Hurricane Frances in September flooded city subways, stranding passengers aboard trains that had to be stopped because of flooded tracks.

Table 5-1 Storm Surge in Relation to Hurricane Category and Magnitude Scale

Saffir-Simpson Category	Maximum Sustained Wind Speeds (m/s)	Minimum Surface Pressure (mb)	Storm Surge (m)	NOAA Classifications	Our Classifications
1	33 to 42	>980	1.0 to 1.7	Minimal	Serious
2	43 to 49	979 to 965	1.8 to 2.6	Moderate	Severe
3	50 to 58	964 to 945	2.7 to 3.8	Extensive	Disastrous I
4	59 to 69	944 to 920	3.9 to 5.6	Extreme	Disastrous II
5	>69	< 920	>5.6	Catastrophic	Catastrophic

Source: http://www.aoml.noaa.gov/

Magnitude

The height of the storm surge correlates with the Saffir-Simpson hurricane category which further correlates with maximum sustained wind speed, and minimum surface pressure. Figure 5-1 below shows the storm surge levels that are associated with each hurricane category according to the Atmospheric Oceanographic and Meteorological Laboratory.

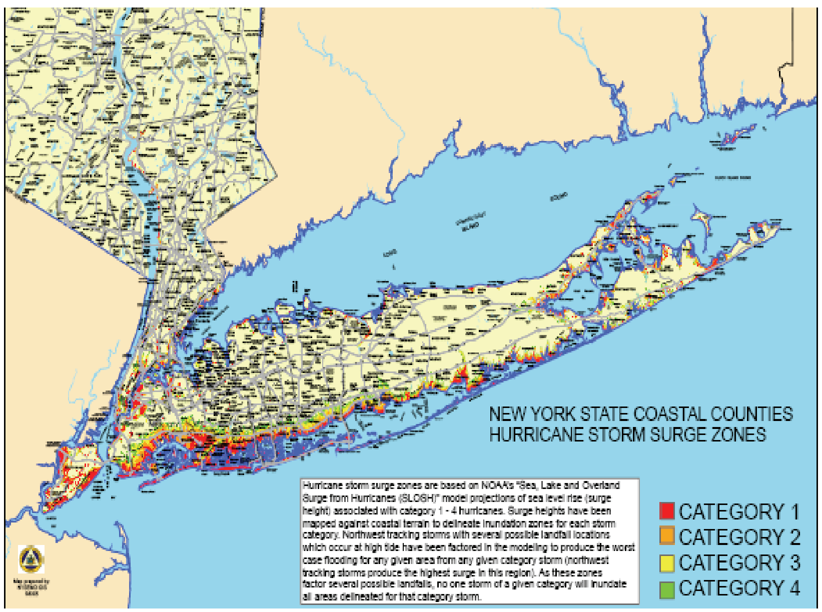


Figure 5-1 Storm Surge in Relation to Hurricane Category and Magnitude Scale

Source: NCDC and NYC DOHMH data

To classify magnitude, it is assumed the Saffir-Simpson categories correspond exactly to our magnitude categories. Thus Category 1 corresponds to "Serious" up to Category 5 which corresponds to "Catastrophic".

Over 155 years there were 12 hurricanes and one nor'easter that impacted NYC and LI with storm surges. The corresponding frequencies and risk scores can be seen on the following page in Table 5-2.

Geographic Distribution

The only areas of NYS exposed to storm surge are NYC, LI, and the a part of the Hudson River Valley.

Expert Estimate

NOAA has developed a computer model that can determine the level of a storm surge and the area of inundation. The model, known as SLOSH – Sea, Lake, and Overland Surge from Hurricanes – has helped forecasters understand to what degree areas could be inundated from a storm surge. This model predicted that if a Category 4 hurricane hit, John F. Kennedy International Airport would be inundated by 20 feet of water and sea water would pour through the Holland and Brooklyn-Battery tunnels and into the city's subways throughout lower Manhattan.

NYSEMO through NOAA prepared a storm surge inundation map that depicts the levels of water inundation that could occur in NYC and LI for three categories of hurricanes – Category 3, 4, and 5.

The frequencies of storms along the East Coast that have caused a storm surge have been studied and recorded using tide-gauge records from Atlantic City, New Jersey, and Charleston, South Carolina (Gornitz, Center for Climate Systems Research). For this report such data was unable to be used. Further work is needed to translate this work into future probability-based risk scores.

Limitations

According to the Director of Watch Command at New York City's Office of Emergency Management, the City has the potential to be impacted by a storm surge such that everything in lower Manhattan would be inundated, with some parts under water as much as 20 to 30 feet. A major hurricane can push water down from the Long Island Sound into the Upper East Side, South Bronx and northern Queens, flooding the areas severely. Though this is an extremely serious matter, probabilities of occurrence were unable to be obtained for this report.

Determining future occurrences of a hurricane, nor'easter, and/or earthquake that would cause a storm surge has proven to be very difficult. The Earth's climate is forever changing, as currently witnessed with global warming. Changes in the climate affect the intensity and frequency of storms along the Atlantic coast. The North America oscillation brings the El Nino and La Nina affect to the Atlantic coast affects weather patterns, temperatures, overall frequency and intensity of storms. Estimates for tsunami probability were not found.

Table 5-2 Storm Surge Annual Frequency and Risk Score

Explanation of Estimate	*Source*	*Serious*	*Severe*	*Disastrous I*	*Disastrous II*	*Catastrophic*	*Any*
Occurrence of Hurricanes and Nor'easters Along NYS Coast 1851-2005	NOAA	6	1	4	1	0	13
Average Annual Frequency		0.039	0.006	0.026	0.01	0	0.077
Individual Risk Scores by Magnitude		***0.04***	***0.06***	***2.58***	***6.45***	***0***	***9.14***

Earthquake

New York State was the third most seismically-active state east of the Mississippi River between 1730-1986, although it is far from any tectonic plate margins. Though there has been little physical damage and no lives lost over this period, the fact that NYS has three seismically-active areas is a cause for concern for long-term risks (MCEER website).

Measuring Earthquake Magnitude and Intensity

Magnitude is the term used to describe the amount of seismic energy released at the epicenter of an earthquake. It is represented by a single, instrumentally determined value, commonly known as the Richter Magnitude Scale. Generally, an earthquake at or below 2.0 is a “microearthquake” that goes unnoticed. A quake between 2.0 and 5.0 is considered moderate. Any quake at 7.0 or above on the Richter scale is typically labeled a “great” earthquake (USGS website).

Intensity is based on the observed effects of ground shaking on people, buildings and natural features and refers to the effects actually experienced at the place, according to US Geological Survey. The Modified Mercalli Intensity Scale is composed of 12 increasing levels of intensity that range from imperceptible shaking to catastrophic destruction. It is designated by Roman numerals and does not have a mathematical basis, rather an arbitrary ranking based on observed effects.

When considering prospective damage from an earthquake, one must consider damage that will depend on the built environment and total population.

Greatest Earthquakes in New York State

The August 10th, 1884 earthquake, registering a 5.5 on the Richter Scale, caused light damage in NYC. This earthquake raises the possibility of other such events in NYC. On September 5, 1944, the largest known earthquake to occur in NYS shocked residents in Massena, NY and Cornwall, Ontario. Registering at approximately 6.0 on the Richter scale it was a maximum intensity level of VIII. At its epicenter, even the strongest structures experienced damage. It disrupted the daily lives of residents, displacing them from their homes. The most recent notable earthquake occurred on April 20, 2002, in Plattsburgh, with a 5.1 magnitude; damage was relatively minimal (MCEER website).

Magnitude

Several variables effect the severity of damage including soil types, ground shaking patterns and acceleration, structural integrity and reactions, as well as time of day.

Peak ground acceleration (PGA) is a measure of how the earth shakes in a given geographic area. When soils are loosely packed or water-logged, there exists a potential risk of liquefaction which often results in severe structural damage (USGS website).

According to earthquake engineers, a building's response depends on building stiffness or flexibility, ductility, and damping. Building codes concerning resiliency during earthquakes did not exist until the 1980's and 1990's in NYS. Much of the built environment may be considerably vulnerable to damage as a result of a significant earthquake.

The amount of damage or number of casualties incurred from an earthquake event may differ greatly dependent upon the time of day. According to NYC Area Consortium for Earthquake Loss Mitigation (NYCEM), an earthquake of significant magnitude (6.0 or 7.0) occurring at 2:00 PM would result in significantly greater damage than if occurring at 2:00 AM, due to human activity (NYCEM website).

Geographic Distribution

Historically, earthquakes have occurred primarily in Northern NYS, Western NYS, and Metro NYC. Though northern NYS has a higher likelihood of larger magnitude earthquakes, the NYC area has a far larger exposed population as seen below in Figure 6-1.

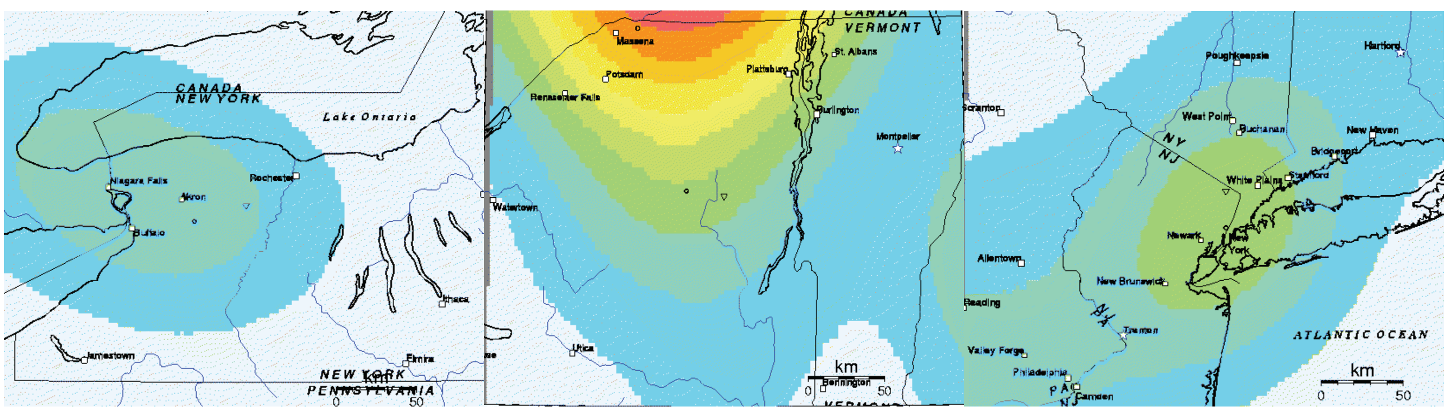


Figure 6-1 Earthquakes in Western NY, Northern NY, and Metro NYC

Source: USGS

Annual Frequency and Risk Score

Over the period of 1877 to 2005, there were eight earthquakes that we designate as serious or greater in NYS. Table 6-1 below shows their classifications and risk scores. Of the eight events, only the Cornwall-Massena was classified as Disastrous I due to its great disruption to the community.

USGS data gives seismological estimates for the annual likelihood of future earthquakes seen at right in Table 6-2. These were unable to be applied to our risk scoring approach as level of harm could not be estimated.

Table 6-2 Earthquake Probability Estimates for NYS

Earthquake Probability Estimates	5.0 Magnitude	6.0 Magnitude	7.0 Magnitude
Western NYS	*0.15%*	*0.02%*	-
Northern NYS	*0.50%*	*0.05%*	-
Metro NYS	*0.20%*	*0.01%*	-

Source: USGS

Table 6-1 Earthquake Annual Frequency and Risk Score, 1877-2005

	Serious (x1)	Severe (x10)	Disastrous I (x100)	Disastrous II (x1000)	Catastrophic (x10000)	Total
Earthquake Events	4	3	1	—	—	8
Average Frequency per Year	0.03	0.02	0.01	—	—	0.06
Magnitude Score	1	10	100	1,000	10,000	—
Frequency-Based Risk Score	***0.03***	***0.23***	***0.78***	***0***	***0***	***1.05***

Source: NCDC and NYC DOHMH data

Pandemic Flu

Pandemic influenza has the potential to infect and kill millions of people. Typically associated with high death toll, wide scale global spread, drastic disruption of critical services, great economic loss, and slow recurrence and recovery times, influenza pandemic may severely harm NYS.

Previous influenza pandemics occurred in 1918, 1957, and 1968. The Spanish Flu of 1918 affected roughly 28% of the US population (RMS website). At least 33,000 died in NYC alone (Santora, 2006).

In 2006, "H5N1", better known as avian flu, has become a global health concern. As of April 2006, 194 human infections have been reported globally. Of those infections, 109 have resulted in death. The overall case-fatality rate is 56%, as reported by the World Health Organization (WHO) in June 2006. As of November 2006, avian flu has not been reported in human populations in the US.

Epidemiological Events Other than Pandemic Flu

The epidemiological risk being addressed in this report is pandemic flu, however other epidemiological hazards exist. Recent outbreaks in the US include Severe Acute Respiratory Syndrome (SARS) and West Nile Virus. These outbreaks are examples of newly emergent diseases in North America.

SARS was first reported in Asia in February of 2003. Within months of initial detection, the virus had spread to numerous countries including the US. During the 2003 global outbreak, only eight people in the US had evidence of a SARS related death. Based on global 2003 figures, SARS has a case-fatality rate of 9.6%. In NYS, no definite cases of SARS infections have been confirmed. In 2003, 35 probable or suspected cases were identified in NYS (excluding NYC). So far in 2006 in NYC, 27 probable or suspected cases were identified (DHHS CDC website).

West Nile Virus is a seasonal epidemic in the Northeast in summer and early fall. Scientists believe West Nile Virus has been in the US since 1999 and in 2002 there were five fatalities in NYS of 82 confirmed infections. In 2006 in NYS, there have been 12 human infections and two deaths (NYS DOH website).

Though these have relatively few casualties in North America, there is considerable concern that other emergent diseases will be more deadly. It is difficult to find probabilities and magnitudes of these types of epidemiological hazards. A fuller risk assessment than we can conduct would undoubtedly include an assessment of this risk. Bioterrorism as an epidemiological disaster is not discussed in this report.

Definitions

Pandemic influenza is described by the US Department of Health and Human Services as, "…virulent human flu that causes a global outbreak, or pandemic, of serious illness. Because there is little natural immunity, the disease can spread easily from person to person." (DHHS website)

According to the US Food and Drug Administration:

> A pandemic is a global disease outbreak. A flu pandemic occurs when a new influenza virus emerges for which people have little or no immunity and for which there is no vaccine. The disease spreads easily person-to-person, causes serious illness, and can sweep across the country and around the world in a very short time." (UDFDA website)

Every year in the U.S., approximately 5-20% of the population becomes infected with common or *seasonal* influenza. Of this number, roughly 36,000 people die (NYS DOH website). Seasonal influenza is considered to be an on-going health problem which the US health system is prepared for dealing with on an annual basis and is not considered in this report. By contrast, pandemic influenza leads to a rapid, devastating surge in cases over a relatively short period of time.

Pandemic Influenza in New York

The Spanish Flu of 1918 is the most extreme influenza pandemic recorded in US history. Unlike the common flu which affects children, the elderly, and the sick, this virus found a new unexpected host in the immune systems and lungs of otherwise healthy 15-45 year olds (Encyclopedia of NYS website). During the final months of World War I, training camps were crowded with soldiers returning home from war. These military camps are believed to have been the hub of origination of the virus in the US. As soon as the outbreak was recognized, municipalities began quarantining and controlling the in- and-out-migration of residents. Overall, more than 500,000 New Yorkers were infected with the Spanish flu and at least 33,000 died (Encyclopedia of NYS website).

Table 7-1 Pandemic Flu Events Since 1700

Date
1729-1730
1732-1733
1781-1782
1830-1831
1833
1836-1837
1847-1848
1889-1890
1918-1919
1957
1968

Phases

The World Health Organization defines possible phases of pandemic. They range from Inter-Pandemic Phase to Pandemic Phase. All levels are significant, but we will focus on Phases 3 and seen below in Table 7-2.

- *Phase 1—Inter-Pandemic Phase:* Very low risk of human cases. Virus is virtually non-existent, or at least not a threat to the general population.
- *Phase 2—Inter-Pandemic Phase:* A new virus has been detected but is not present in humans at all. Though the threat of human transmission is slightly higher than Phase 1, it is still not an active threat to the general population.
- *Phase 3—Pandemic Alert:* No human-to-human spread of pandemic influenza has been reported in the general population. In rare instances, human-to-human spread has occurred due to very close contact between infected humans, as was the case in Southeast Asia. Human infections have come from a new subtype of the virus.
- *Phase 4—Pandemic Alert.* Limited human-to-human transmission is present in small clusters and spread is highly localized. The new virus subtype is not well adapted to humans.
- *Phase 5—Pandemic Alert:* Human-to-human spread is still localized but is not present in larger clusters yet. The virus has become better adapted to humans and presents a higher risk of infection.
- *Phase 6—Pandemic:* Pandemic influenza is now circulating in the general population. Transmission is increased and sustained and no human is safe from the effects.

Table 7-2 Phases of Pandemic Flu

Inter-Pandemic Phase ***New virus in animals, no human cases***	Low risk of human cases	1
	Higher risk of human cases	2
Pandemic Alert ***New virus cases, human cases***	No or very limited human-to-human transmission	3
	Evidence of increased human-to-human transmission	4
	Evidence of significant human-to-human transmission	5
Pandemic	Evidence and sustained human-to-human transmission	6

Source: NCDC and NYC DOHMH data

As of 2005, according to the WHO, the US has been categorized in a Phase 3 Pandemic Alert Period based on current global trends. Though no human infections have been identified in the US, there is a small chance that humans may be infected within the next year.

Magnitude

According to the CDC, in the first 6 weeks of a Phase 6 pandemic (WHO website), the following may occur in the US (Duchin , 2005):

- 1.2 million become ill
- 245,000 - 612,000 clinically ill
- 180,000 - 470,000 seek outpatient medical visits
- 24,000 – 57,000 hospitalized
- 600 – 2,700 die

Within 4 to 6 months the following may occur in the US:

- Up to 200 million infected
- 40 - 90 million clinically ill
- 20 - 46 million seek outpatient medical visits
- 360,000 – 9,600,000 hospitalized
- 104,000 – 2,200,000 die.

Economic loss in the United States in this event is estimated to be between $71 billion and $166 billion (Duchin 2005). Furthermore, as of 2006, it takes 6-8 months to reproduce flu vaccine for a new strain of virus and supplies would be severely limited (Duchin 2005). These are close to worst-case scenarios. An actual pandemic may occur at any of a number of magnitudes.

In this report risk scores have been proportionally calculated based on the NYS proportion of national population.

- ***Serious to Severe to Disaster I Outbreak:*** Bird to human transmission with a low-level of severity. Also known as the best-case scenario with the lowest impact in human fatalities. In NYS 2,300 to 3,000 would die. This is also the number of people that die annually in for an average seasonal flu-- 2,700 died in NYC alone from seasonal influenza in 2003 (NYCDHMH website). Since this is an amount that our health system deals with annually, we are not considering it in our study and are only considering outbreaks that have reached the Disaster II level and above.
- ***Disastrous II Outbreak:*** The virus can now spread from human to human but the infection rate is below maximum due to aggressive quarantines and surveillance. The main victims would be the immune-depressed, elderly, babies and children. Hospitals and medical facilities will be greatly stressed and first responders will be most at risk of contracting the virus. In NYS, 1,000 to 9,999 would

die. (Please note that our category combines two magnitude categories provided by CDC.)

- *Catastrophic Outbreak:* The worst-case scenario of human-to-human transmission with a very high human infection rate. This event would mimic the 1918 Spanish Flu event. In NYS, deaths could range from 10,000 to 130,000 (CDC website).

Annual Frequency and Risk Score

Since 1700, there have been 10 to 13 influenza pandemics in the world, but we have used 11 in our classification. Three of those have occurred in the past century (Table 7-1). Only one, the Spanish Flu, is considered catastrophic.

The total risk score presented by pandemic influenza is 65.15. This result consists of 10 for Disastrous II and 1 for Catastrophic, as shown below in Table 7-3.

Table 7-3 Pandemic Flu Annual Frequency and Risk Score, 1700-2006

	Serious (x1)	*Severe (x10)*	*Disastrous I (x100)*	*Disastrous II (x1000)*	*Catastrophic (x10000)*	*Total*
Flu Events	0	0	0	10	1	11
Average Frequency per Year	0	0	0	0.033	0.003	0.036
Magnitude Score	1	10	100	1,000	10,000	----
Frequency-Based Risk Score	0	0	0	**32.57**	**32.57**	**65.50**

Source: CBO

Expert Estimates

Because of the volatile nature of this hazard expert, probability estimates were examined for a pandemic flu outbreak.

The US Congressional Budget Office (CBO) states that there is a 3% to 4% probability that pandemic influenza can occur in any given year. Researchers at the CDC similarly believe that one pandemic flu event occurs every 33 years in the US (CDC website). GlobalSecurity.org identifies 11 pandemic influenza events that have occurred between 1700 and 2000 (Table 7-1). According to the data, each of the 11 outbreaks had over 1000 fatalities, qualifying it as at least Disastrous II. Professor Baruch Fishoff brought together a panel of medical experts and asked what they thought the likelihood of human-to-human transmission is of avian flu in the next three years. Their estimates also came out to an annual probability of 0.033.

Risk Management Solutions (RMS), a private firm, states there is a possibility that the next pandemic flu will be greater than the 1918 pandemic flu. The RMS model incorporates over 1,800 pandemic influenza scenarios that take into account such factors as likelihood of occurrence, infectiousness, and lethality, demographic impact, country of outbreak, vaccine production, and national countermeasures. The RMS model estimates a 20% probability of the next Influenza pandemic being worse than the 1918 pandemic flu. Potentially 30,000 to 400,000 more deaths in the US could be expected than already estimated.

J. Michael Steele, Professor of Statistics and Operations and Information Management at the Wharton School of Economics writes there is a 20% chance of a pandemic flu outbreak in 2006. Dr. Steele has based his figure on many different factors including current trends that exist globally, and the lethality of the avian flu virus strain, H5N1 (Steele). Please note that we assume that a pandemic flu must have a greater number of fatalities than normal seasonal influenza outbreaks do.

Our report could not determine how much weight to put on these alternative expert estimates for classification purposes. Future risk research for NYS should carefully weigh the results from epidemiological risk panels.

Limitations

Users of this data should know that historic documents are partial and problematic. The extent of historic illnesses is not well-documented. Everyone is working with a small sample, creating many possibilities for sample bias. In addition, note that expert estimates of future annual probability vary greatly from up to as much as 20%. Greater variations can be found from other sources. Finally, note probability of an outbreak next year depends on the development of the pathogen this year. As this is written, we may be in a particularly high-risk year, because we are in the pandemic alert period. For practical purposes, probability of occurrence and risk scores should be evaluated frequently. Reliable estimates would require consultation with a committee of public health and epidemiological health specialists.

Terrorism

In the wake of 9/11 and the anthrax attacks, New Yorkers are justifiably worried about terrorism. Yet, the idea of forecasting terrorism is highly controversial and problematic.

Terrorism—unlike a natural disaster—involves intelligence and intent. Currently, there are dramatically fewer international terrorist incidents in NYS as compared to the 1980s; yet terrorist attacks are becoming more lethal. Before the 1990s, terrorism did not threaten to cause a catastrophic level of damage and loss of life. Now, a growing percentage of terrorist attacks are designed to kill as many people as possible (FBI, 2004). Al-Qaeda—the most well-known transnational terrorist organization—represents a growing trend toward hatred of the United States.

Conventional explosives remain the weapons of choice for most terrorists; some terrorist groups now show an interest in acquiring the capability to use weapons of mass destruction (FBI, 1999).

Definition

The term "terrorism" lacks a universal definition. Our report is primarily concerned with acts of terror in which the intended damage and mass casualties pass a certain threshold. Our definition is most aligned with the U.S. National Counter Terrorism Center (NCTC) definition, which describes terrorism as "premeditated; perpetrated by a subnational or clandestine agent; politically motivated, potentially including religious, philosophical, or culturally symbolic motivations; violent; and perpetrated against a noncombatant target" (NCTC, 2006). Note that in following this definition for this report, acts of war against the US and NYS are excluded.

According to the Federal Bureau of Investigations (FBI), there are two primary types of terrorism: domestic and international. Domestic terrorists act without foreign direction. International terrorists transcend national boundaries. The FBI further divides terrorist-related activity into two main categories: incidents and preventions. A terrorist incident is a successful act of terrorism, while a terrorist prevention is successfully interdicted through investigative activity (FBI, 2004).

Potential terrorist tactics include conventional and suicide bombings, chemical-biological-radiological-nuclear (CBRN) weapons of mass destruction, airline attacks, infrastructure attacks, and arsons. Tactics such as kidnappings, assassinations, and cyberterrorism are excluded from this study. Major effects of terrorist events include loss of life, injuries to people and property, disruption of services, and psychological damage.

Recent Terrorist Incidents in New York State

As shown below in Table 8-1, there have been preventions, foiled attacks and allegations leading to arrests—each apparently intended to cause large-scale damage. Historically, the most threats involved Islamic fundamentalists in NYC.

Table 8-1 Terrorist Attacks, Preventions, and Arrests in NYS, 1993-2006

Year	Perpetrators	Incident
1993	"Blind Sheik"; radical Islamists	NYC World Trade Center vehicle bombing; convictions
1993	"Blind Sheik"; radical Islamists	NYC landmark bomb plot foiled; convictions
1997	al-Qaeda	NYC subway bomb plot foiled; convictions
2001	al-Qaeda	NYC World Trade Center airline attacks
2001	Unknown	NYC *Anthrax* mailings; unsolved
2002	"Lackawanna Six"	Buffalo material support to al-Qaeda foiled; convictions
2003	al-Qaeda	NYC weapons smuggling foiled; convictions
2003	al-Qaeda	NYC bridge surveillance operations foiled; convictions
2004	US Residents of Foreign Origins	NYC subway bomb plot foiled; conviction
2004	US Residents of Foreign Origins	Albany material support to Ansar al-Islam; convictions
2006	al-Qaeda	Transatlantic aircraft plot foiled; arrests
2006	al-Qaeda	NYC Holland Tunnel bomb plot foiled; arrests

Source: MIPT website; Sudnik 2006

The September 11, 2001 attack on the WTC in NYC represented the most deadly and destructive terrorist attack in history and claimed more lives than all previous acts of terrorism in the US combined. It was the first successful act of international terrorism carried out in the US since the 1993 bombing of the WTC. After unsuccessful efforts against the United States in the 1990s, the Al-Qaeda terrorist network finally succeeded with a highly-coordinated suicide attack on September 11, 2001. The network used four hijacked U.S. aircrafts as weapons against business and government targets. This incident resulted in the deaths of nearly 3,000 innocent people along with thousands of injuries (FBI, 2004).

The anthrax mailings during the fall of 2001 represent the first fatal terrorist use of a deadly biological agent in the US. These multiple incidents involved the sending of anthrax spores through the US postal system. Common targets included government and media officials. Several deaths and multiple hospitalizations were recorded. The investigation into these anthrax incidents continues (FBI, 2004).

It should be understood that there are various phases to a terrorist attack seen below in Table 8-2. In an analysis of the threats that NYS faces, even unsuccessful attempts should be considered part of databases. The Advancing National Strategies and Enabling Results Corporation (ANSER)—a public-service research institute offering technical and analytical information to government agencies—provides a systematic, conceptual framework of phased responses to terrorism (ANSER website). This framework has been widely accepted because it is objective and considers time.

Table 8-2 Framework of Phased Responses to Terrorism

Pre-Attack	Preemption	Directly attack terrorist operations including motivations, organizational structure
	Protection	Exercise physical security and access control procedures to limit extent of terrorist damage
	Preparation	Increase citizen knowledge and participation to send clear message of preparedness to terrorists
	Prevention	Stop individual terrorist attacks, limit extent of damage, and reduce psychological ramifications
During Attack	Crisis management	Set in motion the actions to take immediately—information gathering and investigation—to end a terrorist attack
	Consequence management	Limit damage inflicted at the immediate scene of the attack through rescue and assistance
Post-Attack	Interdiction	Employs tools—intelligence, military, diplomatic—to affect the terrorist infrastructure; similar to pre-attack preemption
	Attribution	Associate specific terrorist as legally-bound criminal linked to an attack
	Recover	Restore public safety, psychological confidence, and “normalcy”
	Information	Fully share information between the target population and its government
Long-Term	Isolation	Physically cut terrorist access—financial and physical—to active supporters and sponsors
	Retribution	Allow direct retaliation against or asymmetrical punishment of terrorist
	Prosecution	Focus on the criminality and illegitimacy of the terrorist and terrorist objectives
	Reconstitution	Restore function and eliminate evidence within the target site or system
	Dissuasion	Directly respond to terrorist through a psychological and physical offensive

Source: ANSER 2005

Magnitude

Our magnitude scale for terrorism is primarily focused on fatalities. Secondary measurements include injuries, displacements, destruction costs, disruption, and our personal qualitative judgments. For quantitative analysis, the Memorial Institute for the Prevention of Terrorism (MIPT) database was examined for the years 1980 to 2005. This report only uses data from 1990 to 2006.

Contrary to expectations, the majority of incidents labeled as "terrorism" are minor, causing slight damage. Commonly, these are attributed to animal rights and environmental extremists. These incidents usually target equipment and laboratories rather than people.

The largest number of terrorist-related deaths occurred from 9/11 and explosions comprised 99% of all deaths from terrorist incidents in the state from 1980 to 2005. The second most lethal incident was the 1993 WTC bombing that comprised only 0.2% of all terrorist-related deaths during this time. Other terrorist incidents such as arson, shootings, robberies, and the spread of a biological agent led to deaths in NYS. The largest number of terrorist-related injuries in NYS also occurred in the 9/11 explosions. The second largest number of injuries, 1,042, occurred in the 1993 vehicle bombing at the WTC (MIPT website).

Disruptions from a terrorist attack can be minimal or widespread. Terrorism has the capability to completely shut down the core services in any given area. Transportation, buildings, electricity generation, Internet capabilities, and production facilities are all potential targets for terrorists.

Categorizing Magnitude

The following are examples of terrorist events based on our magnitude table:

- *Serious Event:* A typical arson event from the Animal Liberation Front —an example of special-interest extremists—typically causes minimal structural and financial damage with no deaths and few injuries.
- *Severe Events:* The anthrax mailings of 2001 are categorized as "severe", not only because of deaths and injuries (two and nine, respectively), but because of the extensive social and economic disruption.
- *Disastrous I Threat::* The first WTC attack killed 6, injured 1042, and caused extensive disruptions.
- *Disastrous II Threat::* The 9/11 airline attacks are considered Disastrous II because the most severe damage was localized and not considered catastrophic.
- *Catastrophic Threat::* We do not categorize any threats as "catastrophic".

Geographic Distribution

Terrorism has the potential to occur anywhere at anytime throughout NYS. International terrorism is typically based on intelligence, intent and attention, threats are typically aimed at large, densely-populated urban centers that have a mass of critical infrastructure and many media outlets.

In the past 25 years, according to MIPT, 80.7% of terrorist incidents in NYS occurred in NYC. Another 18.2% took place in the surrounding areas of NYC. Only 1.1% of the incidents occurred in Upstate NY, represented by a bombing in Schenectady, NY (MIPT website).

In our use of expert estimates, we assume a locational factor for events in NYS as compared to the nation as a whole. New York State contains approximately 8 percent of the US population—mainly because of the population density in NYC. This percentage was doubled to 0.16 for the following reasons:

- NYC is internationally-known as a symbol of American capitalist interests.
- NYC has been attacked more frequently than any other city in the US.
- NYC may be a natural target because it contains numerous tall buildings, mass assembly centers, media outlets, and transportation hubs.
- NYC may be an anonymous source of shelter for malicious agents
- Historically, 86 total terrorist threats—both incidents and preventions—have occurred in NYS out of 483 total for the entire US (MIPT website). This equals a frequency of 18 percent for NYS, comparable to our locational factor.
- The DHS Homeland Security Advisory System has been raised a total of 9 times with two of these times raised specifically for New York City threats (DHS website). This equals a comparable frequency of 22 percent for NYC.

Annual Frequency and Risk Score

The annual likelihood of a terrorist incident—as opposed to a natural disaster—is difficult to estimate because of variables such as intelligence, secrecy, strategic decision-making, and the uncertainty of human intent.

Historic-Based Frequencies

Estimates were first collected for annual frequencies based on historic data from MIPT. Recent frequencies—from 1990 to 2006—are more representative of recent terrorism. For our frequency estimates, 1980 to 1989 from MIPT data was omitted. The historic-based annual frequency of any terrorist event was calculated to be 1.5: 1.31 times per year for Serious events and 0.06 each for Severe, Disastrous I and Disastrous II events as seen on the following page in Table 8-3.

Probability-Based Expert Estimates

Because of rapidly-changing conditions and changes in the capabilities of US homeland security, terrorism deserves special attention. Historic frequencies are an insufficient basis for judging terrorism likelihoods, thus expert estimates of future probabilities were also examined.

The Lugar Survey on Proliferation Threats and Responses places the probability of an event—like 9/11—anywhere in the world at 50% within the next 5 years (Lugar, 2005).

In another study by the Center for American Progress study, 35 out of 100 experts agree that a disaster with the magnitude of 9/11 will occur within the next year somewhere in the US. In the same group of experts—79 believe that it will happen in the next 5 years. Fifty-seven out of 100 think that a disaster on the scale of the London bombing will occur in the next year. This information could not be translated into frequency and magnitude due to the way it was presented for this report (CAP, 2006).

One estimate from a Risk Management Solutions (RMS) terrorism model was used. The model estimated the probability of a CBRN attack on the US in 2004 to be 33%. RMS did not specify magnitudes (Willis, 2005). Our locational factor for NYS was applied to derive an annual probability of any terrorist attack for next year to be 0.05, with Disastrous I and II and Catastrophic each split equally at 1.71%. This report realizes a large assumption was made applying the 2004 estimate to the upcoming year, as well as dividing magnitudes up equally between three categories.

Expert estimates may exist, but were not available to us. Estimates should be derived from disparate expert groups that are neither politically-inclined nor communicate with each other. One of the central reasons for recommending the NYS Risk Office is to provide resources to acquire and compare multiple estimates.

Scores for each event magnitude of terrorism are derived by multiplying the magnitude score by the average annual frequency for each magnitude shown in Table 8-4. The total risk score for terrorism in NYS, based on historic frequencies is 70.69—with scores for Serious, Severe, Disastrous I, and Disastrous II at 1.31, 0.625, 6.25, and 62.5, respectively (Table 8-3). The expert probability-based risk score is

189.81—with scores for Disastrous I, Disastrous II, and Catastrophic at 1.71, 17.1 and 171, respectively, seen on the right in Table 8-4. Note the probability-based risk score is more than double the historic-based risk score.

Limitations

Terrorism risk cannot be estimated based on historical frequency alone. A Terrorism Risk Insurance Act was recently passed, forcing insurance companies to estimate terrorism loss. These estimates were not available for this study.

Table 8-3 Terrorism Annual Frequency and Risk Score, 1990-2005

	Serious (x1)	*Severe (x10)*	*Disastrous I (x100)*	*Disastrous II (x1000)*	*Catastrophic (x10000)*	*Total*
Terrorist Events	21	1	1	1	0	24
Average Frequency per Year	1.31	0.0625	0.0625	0.0625	0.00	1.5
Magnitude Score	1	10	100	1,000	10,000	----
Frequency-Based Risk Score	***1.31***	***0.625***	***6.25***	***62.5***	***0.00***	***70.69***

Source: MIPT website

Table 8-4 Terrorism Expert Estimate of Future Probability and Risk Score, 2004

Explanation of Estimate	*Source*	*Serious*	*Severe*	*Disastrous I*	*Disastrous II*	*Catastrophic*	*Any*
US Est. Prob. Attack, 2004 *(NYS Location Factor of .16)*	RMS	___	___	*.0171*	*.0171*	*.0171*	*.0512*
Magnitude Score		1	10	100	1,000	10,000	----
Probability-Based Risk Score		***0***	***0***	***1.71***	***17.1***	***171***	***189.81***

Source: Willis 2005

Limitations arise from the inconsistent sources and estimation methodologies on which the MIPT database depends. The likelihood of a catastrophic event—that would most likely have raised our risk score—was unable to be estimated.

Finally, the propensity for terrorism is constantly changing, various non-state groups change in their intentions and capacities. US Homeland Security is changing. For these reasons, terrorism risk estimates should be regularly reviewed.

Recommendations, Findings and Limitations

Recommendations

This risk score approach is a one-step improvement beyond current risk assessments. Such information can improve homeland security, disaster mitigation, and emergency management decision-making in NYS. Risk scores can be used to allocate budgets within and between agencies, develop priorities, and inform agency spending. For example, the risk scores may help make decisions on what type of emergency exercises to hold. These risk scores are not expected to *drive* policy, but rather to *inform* it.

Homeland security policy-making and agency decision-making are complex and include many negotiated agreements. New York State does not have a single disaster-related budget, but rather spreads it among state emergency management offices, the Office of Homeland Security, the Department of Health, and other agencies. Funds also have to be distributed between the state and localities. Proposed levels should take into account prior year investments, single year projects, and multi-year projects. In addition, policy-making should take into account not only risks, but vulnerabilities, which have not been addressed in this report. The levels of vulnerability include: agency preparedness and capabilities, population, critical infrastructure, and transportations assets. Despite the many complications, better risk knowledge should lead to better decisions.

Our results take only a modest step toward providing such risk information. For NYS to sufficiently take advantage of hazard assessment and policy-making, the following suggestions are recommended.

State Risk Office

The State Risk Office would collect data, organize it, and interpret it. The office would provide the data to "Delphi" and other group methods, evaluate methodologies, draw up reports and guidebooks, and help local jurisdictions develop their own hazard analyses. An alternative to a permanent State Risk Office would be a trial 5-year State Risk Project that would tackle these issues. The office would refine this methodology; centrally collect the best, most up-to-date data sources; undertake regular revisions; and standardize the classification of magnitudes.

Expert Panel

Where data is unavailable, the State Risk Office should turn to panels of experts to further assess hazards with rapidly-altering conditions—such as bioterrorism, radiological terrorism, pandemic flu, and storm surge. These types of panels are necessary because past frequencies alone are not adequate to assess future likelihoods.

State Risk Board

The State Risk Office would submit draft reports to a State Risk Board. It would be composed of respected leaders from different disciplines and from various sectors of society. Based on its collective wisdom, the Board would approve or adjust the risk report so it could be released to the public.

Findings

Historical accounts and data were gathered on several hazard types: airplane crashes, hazardous materials events, fire, winter storm, flood, other storm events (tornado, severe storm and landfalling hurricane), heat wave, storm surge, earthquake, pandemic flu and terrorist events. Each distinct hazard type has been given an annual frequency based on records of historic events and a corresponding Risk Score. The Risk Score uses the historic frequency of the event and then multiplies the average according to the magnitude of events. This section assembles and compares the illustrative Risk Scores. Readers should note the numerous limitations and challenges involved in these estimates and data collection, as described in previous chapters and in the final section of this chapter.

In keeping with our definition of disaster, events that cause mass causalities, destruction, and disruption, are only considered. Routine, day-to-day emergencies, no matter the aggregate number of associated deaths per year, are not considered here.

A particularly important consideration when viewing these Risk Scores is that they are based on state-wide events and threats. These are the results of multihazard risk profiling for the state as a whole. Any individual jurisdiction within NYS will face different risk profiles. Hazard types do not occur at equal rates or magnitudes among municipalities or regions within NYS.

Our results, based on historic frequencies of events, are shown in Table 9-1 on the following page. It shows the illustrative Risk Score results by discrete hazard type. In the graph (Figure 9-1), the colors illustrate the magnitude level to which scores were attached. Therefore, scores with darker colors indicate higher levels of magnitude and scores with lighter colors indicate lower levels of magnitude. Each bar shows the findings for all categories by hazard type – Serious, Severe, Disastrous I, Disastrous II, and Catastrophic.

Table 9-1 NYS Frequency-Based Risk Scores

Hazard Types	Serious	Severe	Disastrous I	Disastrous II	Catastrophic	Overall Score
Airplane Crash	9.20	1.00	10.00	0.00	0.00	20.20
Hazmat	3.54	0.00	0.00	0.00	0.00	3.54
Fire	2.21	1.86	0.97	0.00	0.00	5.04
Winter Storm	0.87	6.20	37.19	0.00	0.00	44.26
Flood	0.56	1.85	8.24	0.00	0.00	10.65
Tornado	0.2	0.36	0.00	0.00	0.00	0.56
Severe Storm	0.69	8.10	11.60	0.00	0.00	20.39
Costal Storm	0.03	0.10	15.24	0.00	0.00	15.37
Heat Wave	0.14	1.43	7.14	0.00	0.00	8.71
Storm Surge	0.04	0.06	2.58	6.45	0.00	9.13
Earthquake	0.03	0.23	0.78	0.00	0.00	1.04
Pandemic Flu	0.00	0.00	0.00	32.57	32.57	65.15
Terrorism	1.31	0.63	6.25	62.50	0.00	70.69
TOTAL	**3.87**	**18.95**	**89.02**	**101.52**	**32.57**	**245.95**

Note that pandemic flu and terrorism have the highest relative risk scores. Terrorism is the highest, with a risk score of 70.69; followed by pandemic flu with a risk score of 65.50.

Whether pandemic flu or terrorism deserves such a large share of the risk profile is a controversial subject. When all weather related and geophysical events are combined into one category of natural disasters and all technological failures are added together into a technology category, there are different results. As shown in Figure 9-1 on page 71, "natural disasters" become a more significant portion of the total risk profile than terrorism or pandemic flu. Technological failures also become a larger portion of the NYS Risk Profile. A technological failure, for the purposes of this report, includes airplane crashes, fires, and hazmat events. It excludes structural failures and bridge collapses, due to the unavailability of data.

In many of these hazard types, significant concern was raised and considered about the use of historic frequency to predict future likelihood. Note that Storm Surge has a relatively low Risk Score based on historic frequency, which may not accurately portray future magnitudes and likelihoods. Changes in climate and weather patterns can increase the severity and frequency of hurricanes. Rising sea levels can also increase the impact of hurricanes and therefore the potential and severity of sea surges. Conversely, greater preparedness and changes in land use may decrease the impact.

Earthquakes, especially in a dense urban environment like NYC, could cause mass destruction. Large earthquakes in NYS are rare, but one major earthquake in today's built environment could potentially cause levels of destruction not indicated in this report. Therefore, earthquakes may also pose a risk score that is greater than estimated. For hazmat events, we were unable to estimate the probability of events that have a magnitude that is severe or higher. This was not possible because NYS lacks historical events, other than the attacks on the WTC, which is discussed under terrorism. While a severe hazmat event is rare, it remains a possibility.

The limitations of using past events to predict future magnitudes and likelihoods are also demonstrated in pandemic flu. Pandemic flu is deeply affected by changing conditions, such as the global mobility of people and medical advancements. Risk scores were unable to be calculated based on expert estimates of pandemic flu risk, although some estimates are described in Chapter 7.

Terrorism is also a product of rapidly changing technology and political conditions. In the case of terrorism, we were able to obtain one expert estimate. This expert estimate increased the overall likelihood and severity of terrorism. The risk score changes when we include an expert estimate that is a better factor for changes in the environment, technology, policy and other areas of potential influence. Readers are reminded that these results were obtained with an analysis done with little time and resources. Only this one hazard type includes an expert estimate and a fuller on-going study is recommended with the proposed "New York State Risk Office" to generate results that offer greater confidence.

Limitations of This Study

The preparation of these illustrative multihazard risk scores for NYS posed many challenges. Data was collected from various reporting agencies, each using varied reporting standards. All data is subject to variations in the definitions and accuracy of the collection agency. Especially under weather events, we found it difficult to know how various extreme events were classified by the reporting agency. For example, one weather event might be classifiable as landfall hurricane, sea surge, and flood. Each event was classified under what we took to be its primary hazard effect, to avoid double counting, but this often proved to be difficult.

The sample of years varied widely, from just over a decade (winter storms, terrorism), to centuries (pandemic flu). In some, the sample was small just because of limited data collection. In others, such as winter storms, a small number of years was used because they were the only years impact data (by which we measured magnitude) was available. In still others, such as terrorism, we felt that only the period since 1990 represented current threats. Of course, all samples are inadequate representations of some larger true propensity.

Our data commensurable by assigning magnitudes (of harm or damage or impact) on a logarithmic scale from 1 to 10,000. Because the data varied in quality, with numbers of deaths being an inadequate criterion in itself, our judgment was heavily depended upon for classification. In many instances, there was cause for debate about how an event should be classified. With small sample sizes, these decisions significantly affected our final scores.

Past frequencies are only partial indicators of future propensity. Land use change (flooding), climate change (hurricane, storm surge), demographic and medical change (pandemic flu), and political and technological change (terrorism) all affect future propensities.

Annual frequency estimated from historic data and probability-based estimates from expert panels are, strictly speaking, not mathematically comparable. (The former could include multiple events per year, while the latter is typically expressed as "at least one per year.") However, for the few instances in which these two types of estimates were compared, this mathematical problem was disregarded assuming that in practice the distinction would have a small effect on our preliminary calculations.

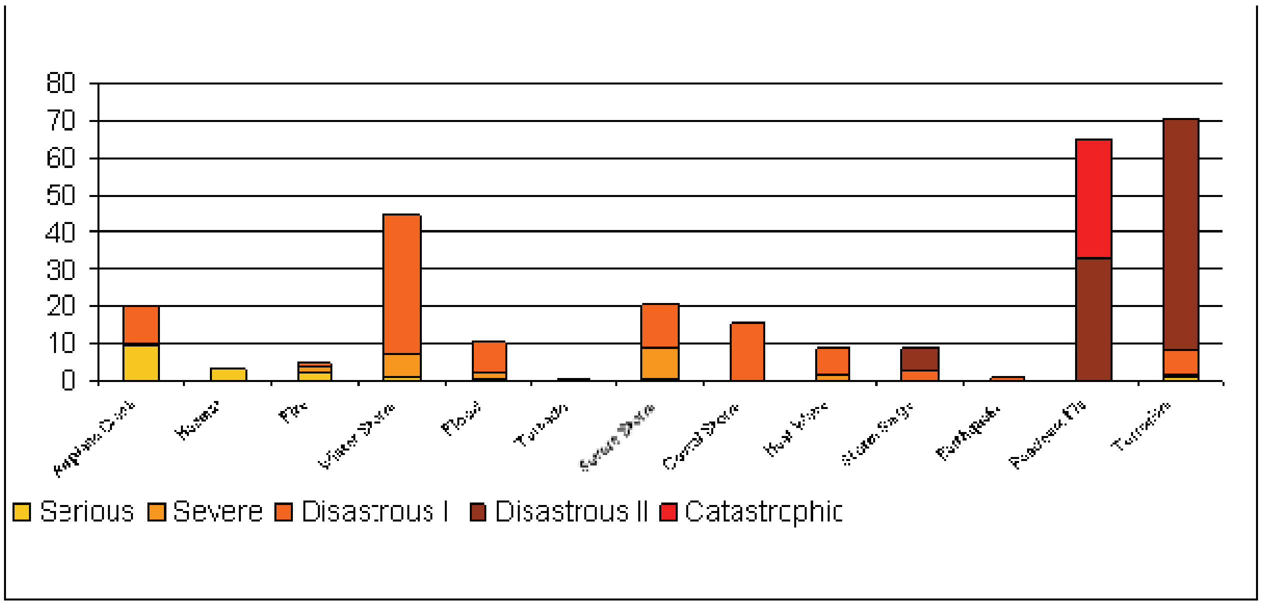


Figure 9-1 NYS Multihazards Based on Hazard Type

Our results also suffered from missing data within magnitude categories. Techniques of curve fitting could be used to fill in gaps, but were not attempted for this report. Estimates of disaster risk should also assess local preparedness (how well first responders, hospitals, and governments are ready to tackle the event) and vulnerabilities (including special vulnerabilities by age, health, and disability). This was not attempted for this report.

These limitations further reinforce our recommendation: that better risk scoring for NYS depends on the establishment of the proposed State Risk Office.

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