Chapter Three

3.0 Regional Risk and Vulnerability Assessment

44 CFR 201.6 (c) (2) A risk assessment that provides the factual basis for activities proposed in the strategy to reduce losses from identified hazards. Local risk assessments must provide sufficient information to enable the jurisdiction to identify and prioritize appropriate mitigation actions to reduce losses from identified hazards. The risk assessment shall include:

Chapter 2.4 identified the ten hazards on which this plan is based and briefly discussed why they were chosen. The purpose of Chapter 3 is to generally describe these hazards, recall past occurrences, assess region-wide risks, and identify region-wide vulnerabilities. This chapter should be used as reference and educational material for member municipalities, as well as the general public. Quantitative results of the Regional Risk Assessment were used when prioritizing Local Mitigation Actions in Chapter 5.

An additional section in this chapter, Chapter 3.1.4, addresses the National Flood Insurance Program (NFIP) on a regional level. The NFIP is also addressed at the municipal level in Chapters 4.1-4.16.

3.0.1 Regional Risk Assessment Overview

(i) A description of the type, location, and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.

The purpose of the Regional Risk Assessment is to rank the region's anticipated risk to each identified hazard, using five criteria: probability, impact, spatial extent, warning time, and duration. The Regional Risk Assessment also addresses historic incidences of each identified natural hazard.

Methodology

To conduct a proper risk assessment, NECCOG staff inventoried historic and scientific data to determine each hazard's expected impact, probability, spatial extent, warning time, and duration. The following sources were used when researching past events or predicting the impact and probability of future events:

The Storm Events Database- Compiled by the National Climatic Data Center (NCDC) at the National Oceanic and Atmospheric Administration (NOAA). This database contains records of a list of weather events, some dating into the 1950s. For many events, county-level data was used as a proxy for the NECCOG region. Property damage is expressed in 2011 US Dollars.

Hazus-MH software- A program used in conjunction with ArcMap GIS software by ESRI. Hazus-MH models hurricane, earthquake, and flooding events and was used in determining the spatial extent of flooding in the region. Hazus-MH was also important when assessing hazard vulnerability to tropical cyclones, earthquakes, and flooding.

Spatial Hazard Events and Losses Database for the United States (SHELDUS)- Created by the University of South Carolina's Hazard & Vulnerability Research Institute. Data from certain events dates to the 1960s; however, there is an information gap between 1985 and 1995. Like the Storm Events Database, much of the data is county-level and expressed in 2011 US Dollars.

Additional Sources- When the abovementioned databases were incomplete, additional sources from NOAA, the State of Connecticut, other government or non-profit entities, or research institutions were used.

Each hazard was given index values for the abovementioned criteria, which were then weighted and combined, giving each hazard a "Risk Factor Value" (RFV). The Risk Factor Value was then simplified to group hazards into "High Risk", "Medium Risk", and "Low Risk" categories. This method was adopted from an active plan for Huron County, Ohio, Huron County Multi-Jurisdictional Hazard Mitigation Plan 2011-2016, for its sound methodology and holistic approach to risk assessment. Full results from the assessment can be found in Table 3.0a and a matrix detailing its methodology is located in Table 3.0b.

Limitations

Historic data was valuable to the Regional Risk Assessment because it reveals trends and can allow planners to anticipate the impact of future events. However, natural hazards are dynamic and often unpredictable. Additionally, even the best data sets are not 100% accurate and often rely on incomprehensive collection techniques.

In the future, it may be found that different risk assessment methods are appropriate for the NECCOG region. Each subsequent plan should use the best, available techniques and data to limit oversight in the risk assessment process.

Hazard	Probability	Impact	Spatial Extent	Warning Time	Duration	RFV	Grouping
Lightning	4	3	4	4	1	3.4	High
Thunderstroms	4	3	4	4	1	3.4	High
Winter Storms/Nor'easters	4	3	4	1	2	3.2	High
Wind	4	2	4	4	2	3.2	High
Tropical Cyclones	3	4	4	1	2	3.2	High
Flooding	3	3	3	4	2	3	High
Tornadoes	1	4	2	4	1	2.4	Medium
Drought	2	1	4	1	4	2.2	Medium
Hail	4	1	2	1	1	2.1	Medium
Earthquakes	1	1	4	4	1	1.9	Low

Table 3.0a: Risk Factor Analysis results for the region's identified hazards

Criterium	Level	Degree of Risk	Index Value	Weight
Probability	Unlikely	<1% annually	1	30%
	Possible	1% - 20% annually	2	
	Likely	20% - 100% annually	3	
	Highly Likely	> 100% annually	4	
Impact	Minor	Few injuries; minor property damage	1	30%
	Limited	Minor injuries; More than 10% of property in affected area damaged or destroyed	2	
	Critical	Multiple deaths/injuries possible; More than 25% of property in affected area damaged or destroyed	3	
	Catastrophic	High number of deaths/injuries possible; More than 50% of property in affected area damaged or destroyed	4	
Spatial Extent	Negligible	Less than 1% of the region	1	20%
	Small	Between 1% and 10% of the region	2	
	Moderate	Between 10% and 50% of the region	3	
	Large	More than 50% of the region	4	
Warning Time		More than 24 hours	1	10%
		12 to 24 hours	2	
		6 to 12 hours	3	
		Less than 6 hours	4	
Duration		Less than 6 hours	1	10%
		Less than 24 hours	2	
		Less than 1 week	3	
		More than 1 week	4	

Table 3.0b: Matrix for establishing Risk Factor Values, adopted from Huron County Multi-Jurisdictional Hazard Mitigation Plan 2011-2016

3.0.2 Regional Vulnerability Assessment Overview

44 CFR 201.6 (c) (2)
(ii) A description of the jurisdiction's vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description shall include an overall summary of each hazard and its impact on the community. All plans approved after October 1, 2008 must also address NFIP insured structures that have been repetitively damaged by floods. The plan should describe vulnerability in terms of:
(A) The types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard areas;
(B) An estimate of the potential dollar losses to vulnerable structures identified in paragraph (c)(2)(ii)(A) of this section and a description of the methodology used to prepare the estimate;
(C) Providing a general description of land uses and development trends within the community so that mitigation options can be considered in future land use decisions.

For each identified hazard, an accompanying vulnerability assessment describes the anticipated, general effects of the hazard on communities in the region. Community-level vulnerability, where it may differ from regional vulnerability, was also assessed for each of NECCOG's member municipalities and can be found in Chapters 4.1-4.16.

Methodology

Historic records and local knowledge, acquired from the public, town government employees and elected officials, and other regional plans, were used to qualitatively describe anticipated effects of each hazard on the communities of the region. This qualitative assessment considers emergency response, crop property damage, health and safety risks, infrastructure threats, and effects on critical facilities.

To describe vulnerability quantitatively, FEMA's Hazus-MH software was employed. Hazus-MH contains databases that detail the region's critical facilities, and property value exposure (see Table 3.0c). Property value exposure is detailed in Table 3.0c and critical facilities are listed in Appendix 3X and, for each town, in Chapters 4.1-4.16.

Limitations

Hazus-MH data uses a standardized methodology to estimate potential building losses and total property exposure with open source building, demographic, and facilities data for the nation, comprising over 200 GIS layers. In the absence of current, uniform, regional tax data, this was the best method for quantitatively assessing vulnerability since it is standardized for the entire region. Each subsequent plan should consider the use of tax data, but ultimately use the best-available, defensible techniques and data to limit oversight in the Regional Vulnerability Assessment.

3.1 Flooding

Flooding, at any time of the year, is a common occurrence in the region. Northeastern Connecticut's abundance of rivers, and development patterns proximate to those rivers, makes flooding one of the more pertinent hazards affecting the region's communities. Floods are primarily the result of heavy or continuous precipitation exceeding the absorptive capacity of soil and the flow capacity of watercourses, blockages or blockage failures along watercourses, or the inability of man-made structures and systems (sewer systems, drainage areas, impervious surfaces) to handle an excess volume of water. They are generally classified into two categories: "flash floods", which are often caused by short-term, localized precipitation, and "general floods", which are often caused by long-term, wide-spread precipitation.

Floods are considered hazards when people and property are affected—even a relatively minor flood can pose risks. Floods cause damage in a number of ways, including undermining structures (buildings and infrastructure), mechanical and electrical damage, general water damage, drowning deaths or related injuries, or injury and damage caused by floating debris. According to NOAA, the national 30-year average number of flood deaths is 99, more than lightning (61), tornadoes (54), and hurricanes (49).

Flood levels are often measured in terms of probability over a given return period. As an example, a "100-year flood" is a flood level that has a 1% of being equaled or exceeded in a given year, while a "500-year flood" has a 0.2% chance of being equaled or exceeded. The flooded areas from these events can be expressed as the "100-year floodplain" and the "500-year floodplain", and are different for every watercourse.

3.1.1 Notable Occurrences

In 1938, the region experienced its most dramatic flooding during the Great New England Hurricane of 1938, a Category 3 hurricane that ravaged New England and New York. To this day, it remains the deadliest hurricane to affect New England since the 17th century[1]. Passing just south of northeastern Connecticut, the precipitation from the storm rose the Quinebaug and Shetucket Rivers to their, still, record discharge levels. The low-lying mill village of Rogers in Killingly was inundated by the Quinebaug River, as was West Thompson—where the river is now dammed[2].

Flooding from 1938 hurricane, occurred only two years after another serious flood in New England, the Flood of March 1936. The Flood of March 1938 was the result of nine days or rain, coupled with melting snow[3]. At the time, it was the greatest flooding in state history[4].

In August, 1955, two hurricanes hit New England in the course of one week. Some of the greatest damage in Connecticut occurred along the Quinebaug River. In Putnam, the Belding Hemingway Magnesium Plant caught on fire and railroads were destroyed[5]. The mouth of the river in Jewett City, Connecticut reached its peak height of 29 feet during this event[6].

More recently, a powerful storm in March threatened the Quinebaug River's peak level, bringing it to approximately 23 feet in Jewett City[7]. Upstream, in the NECCOG Region, the river rose above flooding stage, as did the Mount Hope River and several smaller rivers. One of the Quinebaug's major tributaries, the Moosup River, flooded streets in the village of Moosup. This flooding event was the result of snowmelt and heavy rain.

SHELDUS by the University of South Carolina and the NCDC's Storm Events Database contain records from historic flooding events in the region. These records can be found in Appendix 3B.

---

[1] Connecticut History Online, The Eye of the Storm: A Journey into the Natural Disasters in Connecticut
[2] Killingly Historical Society, The History of Killingly's Villages
[3] Archives & Special Collections at the Thomas J. Dodd Center, Going Beyond the Call: Southern New England Telephone Company's Response to Natural Disasters in Connecticut
[4] Connecticut History Online, The Eye of the Storm: A Journey into the Natural Disasters in Connecticut
[5] Connecticut State Library, The Connecticut Floods of 1955: A Fifty-Year Perspective
[6] The Day, Climate Change Suggests Floods Will Probably Happen Again
[7] The Day, Climate Change Suggests Floods Will Probably Happen Again

NOAA definitions of *flood* and *flash flood*

General Flood: An overflow of water onto normally dry land. The inundation of a normally dry area caused by rising water in an existing waterway, such as a river, stream, or drainage ditch. Ponding of water at or near the point where the rain fell. Flooding is a longer term event than flash flooding: it may last days or weeks.

Flash flood: A flood caused by heavy or excessive rainfall in a short period of time, generally less than 6 hours. Flash floods are usually characterized by raging torrents after heavy rains that rip through river beds, urban streets, or mountain canyons sweeping everything before them. They can occur within minutes or a few hours of excessive rainfall. They can also occur even if no rain has fallen, for instance after a levee or dam has failed, or after a sudden release of water by a debris or ice jam.

Figure 3.1a: General flooding versus flash flooding

Flood: 10/15/2005 07:30 – 15:00 EST

A low pressure system interacted with a plume of tropical moisture as the low slowly moved parallel to the Long Island and south Massachusetts coasts, resulting in excessive rain and flooding across north central and northeast Connecticut. Between approximately 4 and 8.5 inches of rain fell across the region. The county of Hartford was the hardest hit by this flood event, with much of the damage concentrated in the town of West Hartford... This flood event directly resulted in two fatalities in northern Connecticut. One fatality resulted when a women slipped and fell into the raging flood waters along the Natchaug River in Chaplin as she was watching the rapids. An elderly man was swept away and killed by flood waters when he attempted to leave his truck, which was stranded in flood waters from Roaring Brook in Stafford (Property Damage: $600,000; Fatalities: 1 (2 total)).

Flood: 02/13 16:50 EST – 02/14/2008 05:15 EST

In Windham, Routes 6 and 32 were flooded. Several streets and yards were flooded with six inches of water in Putnam. In the Moosup area of Plainfield, several yards were flooded. Freedley Road in Pomfret was closed due to flooding (Property Damage: $20,000).

Source: Storm Events Database, NCDC at NOAA

Figure 3.1b: Selected flood records from the Storm Events Database

3.1.2 Regional Risk Assessment

Probability

SHELDUS data from flooding in Windham County revealed that a total of 17 hazardous (causing damage to people or property) flooding events occurred between 1975 and 2014[8]. The most-significant event, in terms of damage, occurred in 1982.

[8] The years 1985 and 1995 contain incomplete data, some floods may not be accounted-for.

Flood data from the NCDC can belong to a number of flood types, only “flood” and “flash flood” events applied to the NECCOG region. Since flooding is often local and town-level data exists, NCDC data from New London and Tolland Counties were studied in addition to Windham County. Although data was sometimes duplicated or non-specific on the number of towns affected, it was determined that as many as 13 regional events affected NECCOG towns in the three counties since 1998. Additionally, the database included records of seven town-level flooding events between 1998 and 2014.

After reviewing data from these sources, it was determined that the yearly probability of a hazardous flood occurring in the NECCOG region is less than 100%. Although some years there may be no significant flooding; on average, the region experiences approximately one hazardous flood every two years. The index value for Probability is three out of four, or “likely”, meaning that there is an annual return rate between 20% and 100%.

Impact

The effects of flooding can be disastrous for people, their property, crops, and entire communities. One of the most disastrous, recent floods in the region, recorded in the Storm Events Database, was a flood in October, 2005 in which a woman drowned in the Natchaug River in Chaplin. This flooding event resulted in $600,000 in damage for Windham County alone. Historically, two of the most-notable events in the region and the state occurred in 1936 and 1955. The Flood of 1936 was caused by a nine-day rain event, coupled with melting snow, which crippled New England[9]. In 1955, Hurricanes Connie and Diane hit southern New England within a week of one another, resulting in over $350,000,000 in damage.

Additional flooding records in SHELDUS and the Storm Events Database show other instances of floods causing millions of dollars in damage—events like a 1982 storm that cost the region $14,772,727 and claimed one life. The index value for Impact is three out of four, or “Critical”, meaning that multiple casualties are possible or that 25% of the property in the affected area will be damaged or destroyed.

[9] Connecticut History Online, The Eye of the Storm: A Journey into the Natural Disasters in Connecticut

Spatial Extent

Flooding events are rarely isolated and their causes often affect the region as a whole, as opposed to a single town. Northeastern Connecticut's abundance of rivers and prominence of one major drainage basin—the Thames River Drainage Basin—create favorable conditions for flooding during heavy rain. Data from SHELDUS and the NCDC support the idea that flooding in northeastern Connecticut often occurs on a regional scale. More often than not, data was recorded on the county level and specifically mentioned serious flooding in more than one town. In the case of more serious flooding, such as a 100-year flood, it should be expected that every town will sustain property damage and, possibly, injuries or death. In this sense, the spatial extent of a flood is region-wide.

Looking more specifically at the geography of flooding, floodplains can be used to describe the exact percentage of land inundated by flood waters. Instead of relying only on historic data, 100-year and 500-year flood models created for Chapter 4 were used to study the spatial extent of floods. It was determined that __% of the region should be affected by a 500-year flood and that __% of the region should be affected by a 100-year flood, making the index value for Spatial Extent ___ out of four, meaning that ___.

Warning Time

When considering the warning time of floods, it is important to separate flash flooding from general flooding events. For the purposes of this plan, flash flooding—the more early-onset form of flooding—will be evaluated in respect to the warning time of floods. Flash floods are characterized by their lack of warning, and according to NOAA, "…can occur within a few minutes or a few hours of excessive rainfall. They can also occur if no rain has fallen, for instance after a levee or dam has failed…"[10] The index value for Warning Time is four out of four, meaning that there is typically less than six hours of lead time associated with hazardous flooding.

[10] National Severe Storms Laboratory, Severe Weather 101

Duration

Many factors influence the duration of a flooding event. The duration of rain event, the geography of a watercourse's drainage basin, geology and soil makeup of the affected area, topology, the carrying capacity of watercourses and underground utilities, and the presence of vegetation are all common variables. General flooding is typically longer-lived than flash flooding because it is associated with longer storm events and poor drainage. The Storm Events Database from the NCDC includes a record of a general flood that lasted over 20 hours in Windham County. For the most part, the database lacked durations for flooding. It should be expected that a major flooding event in northeastern Connecticut will last over 6 hours, making the index value for Duration, two out of four.

3.1.3 Regional Vulnerability Assessment

As mentioned earlier, flooding has the ability to destroy structures and utilities from physical damage, water damage, and damage from floating debris. Drowning deaths and related injuries are common threats to health and safety, especially from flash flooding. Additionally, fires are possible during floods and often result from electrical malfunctions. The resulting damages can have an immense impact on emergency response, especially if response-related facilities are, themselves, affected by the flood.

Vulnerability to flooding differs by town and by area within each town. A comprehensive analysis of town-level vulnerabilities to flooding, as well as town-level Hazus-MH modeling of 100-year and 500-year flooding events, can be found in Chapters 4.1-4.16. Town-level vulnerability assessments describe anticipated effects on critical facilities, people, and property.

3.1.4 The National Flood Insurance Program

Over 45 years ago, the United States Congress created the National Flood Insurance Program (NFIP) through the passage of the National Flood Insurance Act of 1968. The program, under control of FEMA, provides alternative, government-funded insurance to property owners at risk from flooding.

Local communities must adopt floodplain management ordinances in compliance with FEMA guidelines for property owners to be eligible. Local ordinances are intended to manage construction and land use in Special Flood Hazard Areas (SFHAs)—100-year flood zones and other special flood zones, depicted on Flood Insurance Rate Maps (FIRMs), drawn by FEMA. While scanned FIRMs are available online, maps for northeastern and northwestern Connecticut have not been combined and digitized into a GIS-friendly format. Voluntown is the only town in the region with a GIS-compatible FIRM (Figure 3.1c). Once a regional FIRM is completed, NECCOG expects to enhance its ability to share and produce NFIP-related information with its member towns. For the purposes of this plan, NECCOG relied on analysis from Hazus-MH for flood mapping; however, the maps produced display slightly different floodplain boundaries as FIRMs and should not be used to regulate activities or delineate the floodplain.

NECCOG's sixteen member towns, and Killingly's borough of Danielson, participate in the NFIP (Table 3.1a). Zoning regulations, town ordinances, and subdivision regulations are regulatory vehicles for ensuring NFIP compliance. Inland wetlands and watercourses regulations can also be used to mitigate a community's flood risks but rarely mention NFIP. Inland Wetlands and Watercourses Commissions[11], however, may be appointed to hear and decide requests for variances to local floodplain management ordinances. Each town's individual involvement in the program, and accompanying regulatory authorities, will be explained in Chapters 4.1.1-4.1.16.

There are two special grant programs—the Repetitive Flood Claims program and the Severe Repetitive Loss program—established under NFIP, that provide mitigation assistance to reduce future losses from structures that are continually impacted by flooding. In the NECCOG region, there are five Repetitive Loss (RL) structures and zero (0) Severe Repetitive Loss (SRL) structures (Figure 3.1d).

[11] The names for these commissions vary by town.

Town	Initial Flood Hazard Boundary Map Identified	Initial Flood Insurance Rate Map Identified	Current Effective Map Date	Began NFIP Participation
Ashford	11/8/1974	12/1/1981	12/1/1981	12/1/1981
Brooklyn	2/28/1975	1/3/1985	1/3/1985	1/3/1985
Chaplin	12/13/1974	1/6/1982	1/6/1982	1/6/1982
Canterbury	1/10/1975	10/16/1984	10/16/1984	10/16/1984
Eastford	3/15/1974	5/16/1983	5/16/1983	5/16/1983
Hampton	1/10/1975	12/4/1985	12/4/1985*	12/4/1985
Killingly	9/6/1974	1/3/1985	1/3/1985*	1/3/1985
Danielson (Killingly)	1/24/1975	11/1/1984	11/1/1984	11/1/1984
Plainfield	9/6/1974	6/17/1991	6/17/1991	6/17/1991
Pomfret	9/20/1974	4/17/1985	4/17/1985	4/17/1985
Putnam	9/6/1974	10/18/1988	10/18/1988	10/18/1988
Scotland	1/31/1975	12/4/1985	12/4/1985*	12/4/1985
Sterling	5/31/1974	3/4/1985	3/4/1985	3/4/1985
Thompson	5/17/1974	11/1/1984	NSFHA	11/1/1984
Union	12/4/1985	12/4/1985	12/4/1985*	12/4/1985
Voluntown	5/31/1974	6/3/1988	7/18/2011	6/3/1988
Woodstock	9/20/1974	11/1/1984	11/1/1984	11/1/1984
(*) No Elevation Determined - All Zone A, C, X				
(NSFHA) No Special Flood Hazard Area - All Zone C				

Table 3.1a: Community Status Report data regarding each town's participation in

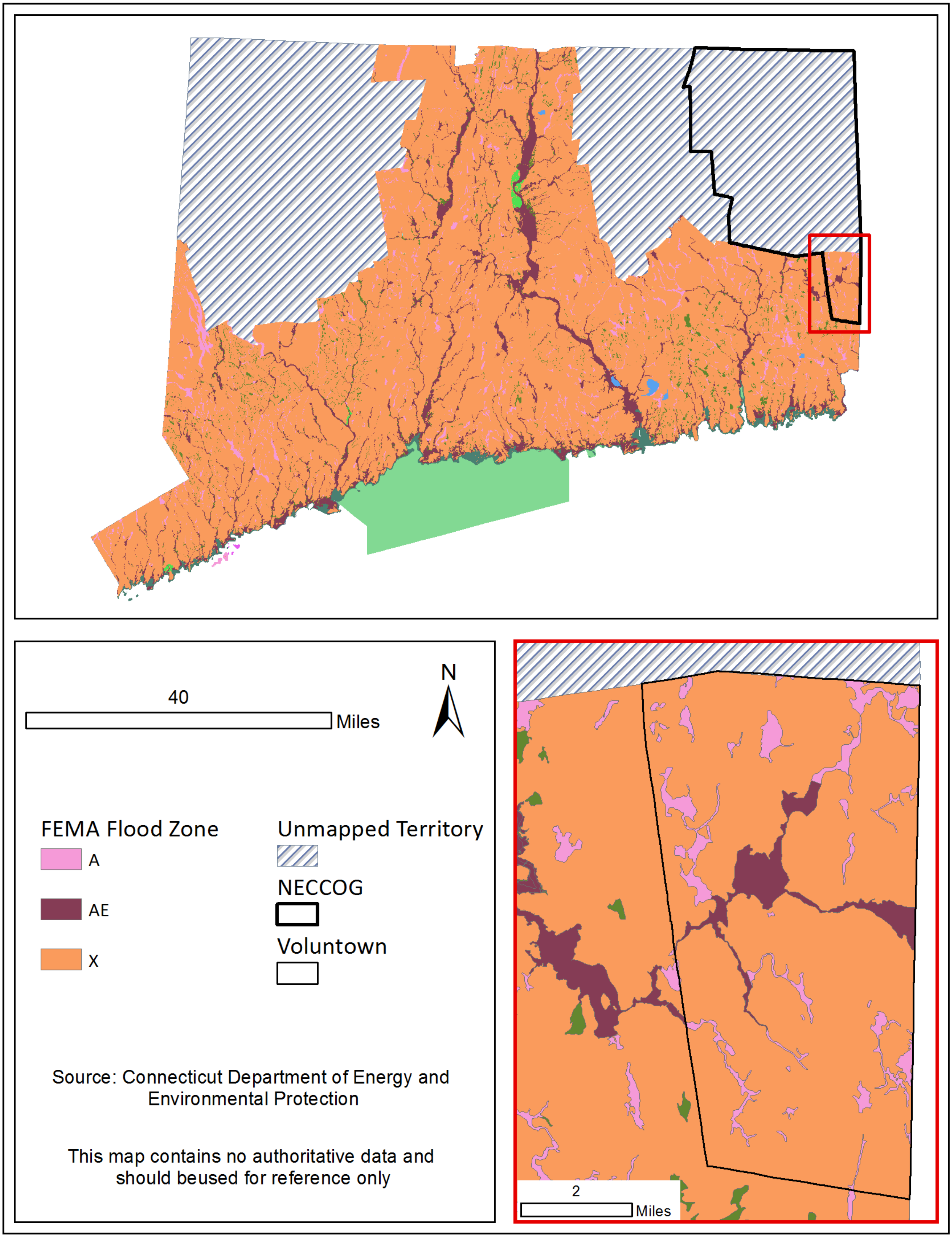


Figure 3.1c: **Digitized Flood Insurance Rate Maps**

Map Marker	Town	Village	Properties	Losses
A	Thompson	Quinebaug	1	2
B	Woodstock		1	2
C	Chaplin		1	5
D	Putnam		1	2
E	Plainfield	Central Village	1	3

There are five Repetitive Loss (RL) properties in the NECCOG region and no Severe Repetitive Loss (SRL) properties. The exact locations of these properties have been obscured to protect the interests of their owners. The shaded grid squares on the map represent the general location of each structure.

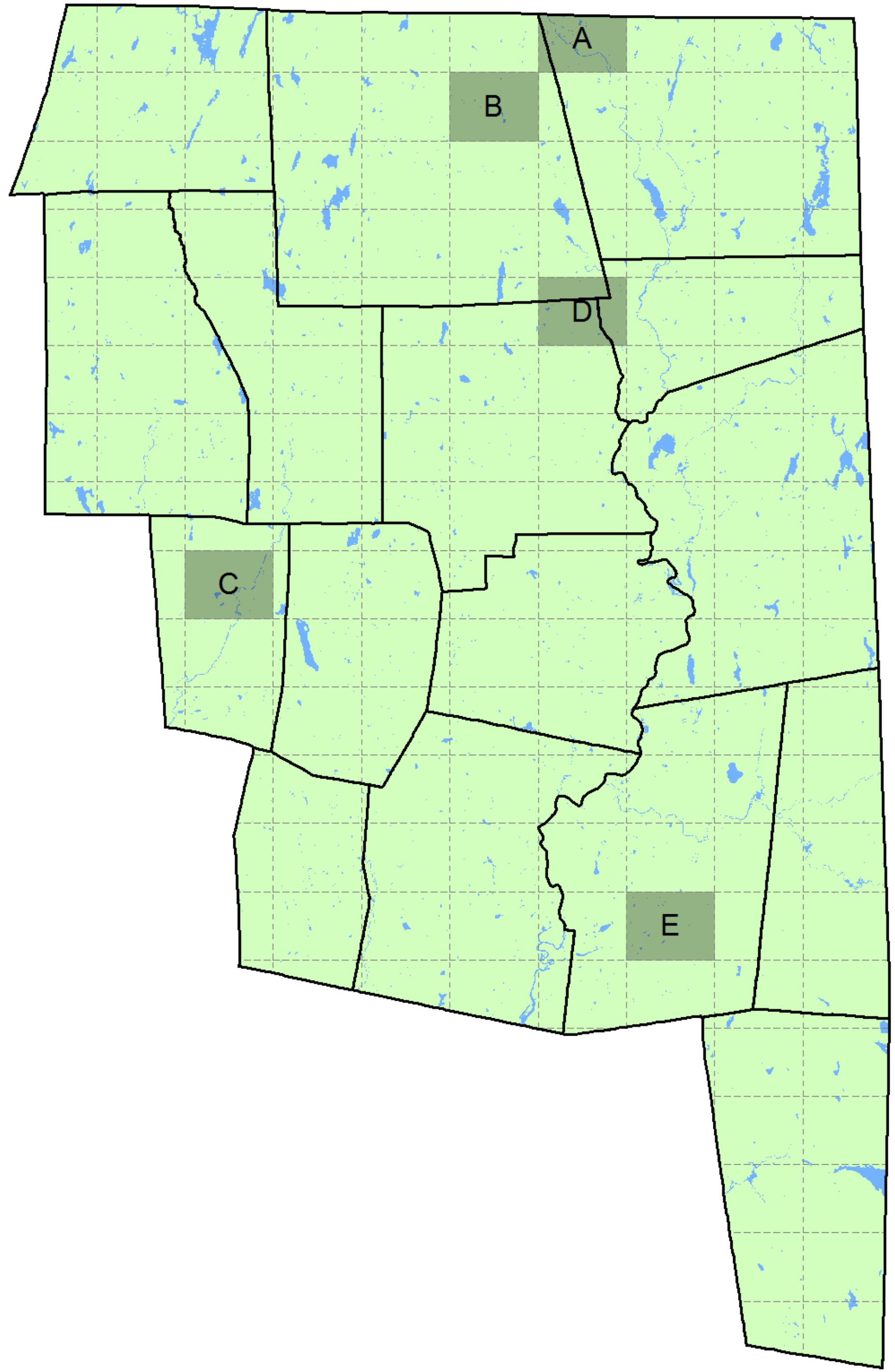
NECCOG Towns

General Location of Structures

10

Miles

N



Source: Connecticut Department of Energy and Environmental Protection; Property locations provided by State NFIP Coordinator

This map contains no authoritative data and should be use for reference only

Figure 3.1d: Approximate locations of Repetitive Loss structures

3.2 Wind

Wind occurs throughout the NECCOG region at all times of the year and often occur in association with a number of natural hazard events (winter storms, tornadoes, tropical cyclones, thunderstorms, hail storms). Wind events vary greatly in magnitude, geographic extent, and time of occurrence. Because of its unpredictability and reliance on dynamic, atmospheric activity, wind poses a distinct hazard to the region.

Wind is the movement of air in the atmosphere, resulting from differences in air pressure. The force of wind is determined by the difference in pressure and the geographic extent of that difference. Meteorologists describe wind in a number of ways: direction and pattern of movement, speed, associated weather, and probability over a given return period (like flooding). A “gale force” wind, or anything greater, is typically considered to be a powerful and hazardous wind. Gale force winds are usually defined as sustained winds between of 33 and 47 nautical miles per hour (knots) or roughly 39 miles per hour. According to the Beaufort Scale, an index used to assess wind damage on land and effects at sea, a gale force wind produces high and long waves, breaks small branches on trees, and create difficult walking conditions. A “strong gale”, according to the scale, is between 47 and 54 knots and will begin to cause structural damage.

Wind causes damage by moving and disturbing objects, structures, and people in the environment. Some examples of this are: Uprooted trees covering the road, damaging houses, downing power lines, or hitting people, objects becoming airborne and colliding with structures or people, crop damage, or shingles being torn off of roofs.

3.2.1 Notable Occurrences

Northeastern Connecticut is in a region that is unlikely to be threatened by tornadoes; however, the have occurred and are expected to occur again. Additionally, powerful winter and summer storms, including hurricanes, are perennial threats to northeastern Connecticut, making strong wind a regular occurrence.

Three recent "High Wind" events from the Storm Events Database are documented in Figure 3.2a. A full inventory of past events is located in Appendix 3X. Chapter 3.6: Tropical Cyclones and Chapter 3.7: Tornadoes are additional sources for historic wind events. Full inventories of those events are located in Appendix 3X and 3X.

High Wind: 12/17/2000 11:00 – 22:00 EST

A rapidly strengthening low pressure system west of New England brought a period of damaging southerly winds to northern Connecticut, as lines of showers passed through southern New England. Following the passage of a strong cold front in the afternoon, increasing northwest winds caused additional damage. Peak wind gusts of nearly 60 mph were common in Hartford, Tolland, and Windham Counties. There were several reports of downed trees and wires, and several thousand electric customers were left without power.

High Wind: 12/01/2004 13:00 – 20:30 EST

Damaging wind gusts affected much of northern Connecticut as strengthening low pressure tracked across northern New England and a strong cold front moved through the region. Gusts estimated as high as 60 mph brought down trees and wires across the higher elevations of Hartford and Windham Counties. No injuries were reported. (Property Damage: $25,000).

High Wind: 01/31/2013 03:52 – 08:45 EST

The Automated Surface Observing System at Windham Airport in Willimantic (KIJD) recorded a wind gust to 58 mph. In addition, mesonet and amateur radio operators reported gusts to 60 mph in Thompson and North Grosvenor Dale. Several trees were downed onto wires in Woodstock. (Property Damage: $15,000).

Source: Strom Events Database, NCDC at NOAA

Figure 3.2a: Selected wind records from the Storm Events Database

3.2.2 Regional Risk Assessment

Probability

The probability of wind events is largely dependent on the probability of associated weather events because wind does not always occur on its own. Historic data on wind events was available through the Storm Events Database.

According to the NCDC, "high wind" above 30 knots (33mph) was reported on 16 separate (18 reported events) dates between 1996[12] and 2013 for Windham County. 180 separate dates (228 reported events) with weather events that featured winds in excess of 30 knots occurred after 1992 in Windham County. After reviewing NCDC data, it was determined that, accounting for wind-only and wind-coincident events, hazardous wind events have at least a 100% chance of occurring in any given year. This would give Probability an index value of four.

Impact

Hazardous winds events, whether alone or associated with another weather event, have the capability to greatly stress a community's resources, cause injury or loss of life, and cause wide-spread property damage. According to the Storm Events Database, in 2012, high winds of 53 knots from Hurricane Sandy were responsible for $483,000 in damage in Windham County. Additionally, the database contains a 2005 record of high winds—in a snow storm—downing tree limbs, injuring a Thompson man. Wind from this storm was responsible for $45,000 in property damage. Information used for analyses in Chapters 3.4-3.7 and 3.9 also served to determine the impact of wind. Historic data suggests that wind is capable of having a "Limited", but nonetheless noteworthy, impact on the region. The index value associated with wind's Impact is two out of four, because minor injuries can be expected alongside wide-spread property damage.

[12] Data on the "high wind" was not collected prior to 1996 for the region

Spatial Extent

Because hazardous winds can be associated with so many different weather events, the spatial extent of its damage is variable. In the case of a tornado, wind damage would largely be confined to the tornado's path. However, wind-only events and other wind-coincident events occur typically over a very large area—larger than the region—because they are associated with wide-spread, moving patterns of atmospheric pressure. For example, a low-pressure system in New England may bring thunderstorms that move in a northeasterly direction, across Connecticut and toward the Boston area. Wind associated with the moving storm front is likely to affect the whole of the state. Information from the NCDC supports this idea. 104 of 221 entries in the Storm Events Database were on the county level while many others were same-day reports from different towns. Information used for analyses in Chapters 3.4-3.6 and 3.9 was also useful in determining the spatial extent of wind. The index value for Spatial Extent is four out of four.

Warning Time

The warning time associated with extreme wind events in also dependent on the associated storm or weather conditions. For instance, wind associated with tornadoes will have less warning time than wind associated with hurricanes. The severity of wind associated with hurricanes, however, is often not fully realized until the hurricane has impacted the region. In most cases, the dynamic nature of the atmosphere and the unpredictability of associated weather events provides very little warning time hazardous winds.

Gale Warnings can be issued when an area is experiencing sustained wind exceeding 33 knots. Gale Watches are issued in advance, attempting to predict future wind based on atmospheric data, but with uncertainty as to the extent, exact locations, and timing of gale force winds[13]. Because of wind's unpredictability, Warning Time received an index value of four, meaning that it can't be reliably predicted in over six hours; this is especially the case with tornadoes.

[13] National Weather Service, National Weather Service Glossary

Duration

Some wind events in the Storm Events Database contained temporal data, although others displayed no data or incomplete data. Under the category, High Wind, the database contains 15 records over 13 days. When studying the duration of wind, three days of records were omitted due to incompleteness. The ten remaining events averaged 6 hours and 20 minutes, each. Because events averaged over six hours, the index value for Duration was assessed as two out of four. However, when associated with wide-spread weather systems and events like tropical storms and winter storms, powerful winds can persist for over a day.

3.2.3 Regional Vulnerability Assessment

As mentioned above, wind is capable of causing structural damage to buildings, disrupting infrastructure, downing trees, and threatening lives through structural damage, utility failure, and by creating dangerous projectiles. Hazardous winds are also extremely common in Connecticut and occur in conjunction with a number of other weather events. All people, critical facilities, and structures in the region should be considered vulnerable to the effects of wind.

3.3 Lightning

NOAA defines lightning as, “a rapid discharge of electrical energy in the atmosphere.” Although it is commonly associated with thunderstorms, lightning can occur whenever there is high electric potential between two regions in the atmosphere or the atmosphere and the earth. Lightning comes in three forms. Cloud-to-Ground (CG) lightning, as opposed to Intracloud (IC) and Cloud-to-Cloud (CC) lightning, is the most relevant form when planning for on-the-ground hazards. It occurs when wind, water particles, and hail create a negative electrical charge inside clouds. If a positive charge on the ground becomes large enough, the negative charge begins moving toward the ground, creating a conductive path along the way. If the two charges make a connection, an electrical current, lightning, moves through the conductive path. Between the years 2006 and 2013, lightning accounted for 261 deaths in the United States.[14] A large number of these deaths were preventable; many resulted from recklessness or ignorance of lightning safety.

Southern and Midwestern states, due to more-variable weather patterns, receive a far greater number of strikes per square mile, per year, than states in New England. Figure 3.3a: Cloud-to-Ground Lightning Incidence in the Continental United States (1997-2011), developed by Finnish company, Vaisala, offers a comparative and generalized representation of strike density in the continental United States. Despite northeastern Connecticut’s relatively low density of lightning strikes, lightning is nonetheless dangerous—especially without proper planning. Lightning has been known to disrupt key electrical infrastructure as well as cause fires, especially during droughts.

Lightning can be a product of many different storm events and has even been known to strike in snow storms. Thunderstorms, however, are characterized by the presence of lightning. When evaluating many of the risk factors of lightning, properties of thunderstorms were often taken into consideration. But because thunderstorms can have additional, hazardous properties, they are discussed in greater detail in Chapter 3.4.

[14] John S. Jensenius, Jr, A Detailed Analysis of Lightning Deaths in the United States from 2006 through 2013. National Weather Service

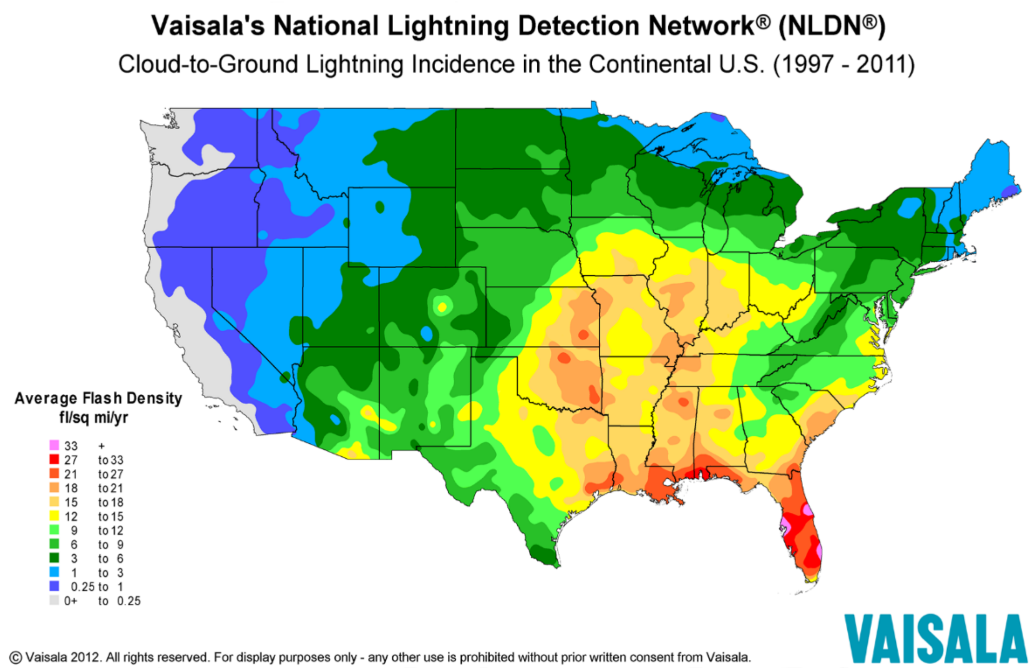


Figure 3.3a: Cloud-to-Ground Lightning Incidence in the Continental United States (1997-2011)
Source:
http://www.vaisala.com/en/products/thunderstormandlightningdetectionsystems/Pages/NLDN.aspx

3.3.1 Notable Occurrences

Lightning is an extremely common phenomenon in northeastern Connecticut's warmer months. In one lightning-producing storm, the region should expect multiple strikes. The Storm Events Database and SHELDUS contained limited records of lightning for the region, restricting it to incidences that caused quantifiable damage, or incidents that resulted in injury or loss of life (Appendix 3X). Figure 3.3b contains selected events from the database and descriptions of each event's impact.

Lightning: 07/19/1999 13:35 EST

Severe thunderstorms moved through northern Connecticut for the second day in a row, producing wind gusts over 60 mph. Some of the hardest hit areas had just begun to recover from the previous day's storms, including Coventry where there were many trees and power lines downed from thunderstorm winds. Bradley International Airport, in Windsor Locks, reported a wind gust to 60 mph as the storms moved through. Just over 1,000 customers in Hartford, Tolland, and Windham Counties were without power at the height of the storms. Lightning struck a house in Plainfield, causing some damage. (Property Damage: [not listed]).

Lightning: 08/21/2004 07:25 EST

Severe thunderstorms downed large branches in Southington and Ashford, and produced nickel sized hail in Ellington. Two men were struck by lightning while attending a Civil War reenactment in Woodstock (Injuries: 2).

Lightning: 07/24/2010 14:47 EST

A house was struck by lightning on Valentine Road (Property Damage: $10,000).

Source: Storm Events Database, NCDC at NOAA

Figure 3.3b: Selected lightning records from the Storm Events Database

3.3.2 Regional Risk Assessment

Probability

Lightning, relative to many other natural hazards, has a very high probability because it occurs in conjunction with a few different weather events.

Unfortunately, the Storm Events Database only contained records of lightning that caused injury, death, or property or crop damage. In the database, three events were reported for dates between 1999[15] and 2010 for Windham County (Figure 3.3b). Separate from the Storm Events

[15] Data on the lightning was not collected prior to 1996 for the region.

Database, the NCDC compiles Raw Flash Data into a separate database that records the locations of individual lightning flashes. A county-level summary of this data revealed that there were lightning strikes on 805 separate days, in Windham County, between January, 1986 and May, 2013 (Appendix 3X). This data suggests that lightning has at least a 100% chance of reoccurring each year. This makes the probability of lightning, "Highly Likely", or an index value of four out of four.

Impact

Lightning has a great capacity to cause injury, loss of life, or cause property damage. According to the NCDC, lightning from a 2004 storm injured two in Woodstock. Data from SHELDUS documents that two people have been killed by lightning in the region since 1960. Also, a 1977 event resulted in $185,714 in lightning-related damages, while wind and lightning from a 1979 storm caused $1,969,697 in property damage.

The potential for death and injury, as well as the destructive power of lighting—causing electrical malfunctions and potentially fire—gives it an index value of three out of four.

Spatial Extent

Since lightning is associated with large-scale weather events like thunderstorms and hurricanes, its spatial extent is large and determined by the spatial extent of other storms. The index value for lightning's spatial extent was assessed as four out of four, meaning that more than 50% of the region will be affected.

Warning Time

The warning time associated with lightning is dependent on the warning time of thunderstorms. Chapter 3.4.2 discusses "Thunderstorm Warnings" and "Thunderstorm Watches". The index value associated with lightning's warning time is four out of four, meaning that there is typically less than six hours lead time associated with lightning.

Duration

The duration of lightning is also dependent on the duration of thunderstorms. Chapter 3.4.3 discusses the duration of thunderstorms. The index value associated with lightning's duration is one out of four, meaning that lightning typically lasts less than six hours.

3.3.3 Regional Vulnerability Assessment

According to 2006 study, conducted by NOAA, 64% of lightning fatalities in the United States occurred while people were participating in outdoor leisure activities[16]. Because lightning strikes are unpredictable and can happen at any moment, over a large area, all people and property in the region are vulnerable to lightning; however, lightning rarely causes property damage aside from damage to electrical infrastructure.

[16] National Oceanic and Atmospheric Administration, NOAA Study Finds Fishing Tops U.S. Lightning Death Activities

3.4 Thunderstorms

Thunderstorms are a common occurrence throughout the region, particularly in warmer months. Thunderstorms, by their name, are characterized by the presence of thunder—the audile effect of lightning. However, lightning only partially describes a thunderstorm's threat to people and property. According to NOAA, "Many hazardous weather events are associated with thunderstorms. Under the right conditions, rainfall from thunderstorms causes flash flooding, killing more people each year than hurricanes, tornadoes or lightning. Lightning is responsible for many fires around the world each year, and causes fatalities. Hail up to the size of softballs damages cars and windows, and kills livestock caught out in the open. Strong (up to more than 120 mph) straight-line winds associated with thunderstorms knock down trees, power lines and mobile homes. Tornadoes (with winds up to about 300 mph) can destroy all but the best-built man-made structures."[17] There are four types of thunderstorms: multi-cell storms, squall line storms, supercell storms, and single-cell storms. Supercell storms are typically the most hazardous, but are not as common in New England. A collection of thunderstorms that acts as a system, although rare, is a mesoscale convective system (MCS). Historically, only a few MCSs have impacted the region.

Thunderstorms are caused by rising, warm, moist air that forms a cumulonimbus cloud. Water droplets and ice create the potential for lightning as described in Chapter 3.3, then fall to earth as rain or hail. A downdraft caused by the cooling effect of precipitation accounts for a thunderstorm's strong wind, and eventually causes the storm to dissipate.

---

[17] National Oceanic and Atmospheric Administration, Severe Weather 101

3.4.1 Notable Occurrences

In July, 1999, powerful storms made their way through the state, bringing lightning, rain and strong winds. In Ashford, wind gusts were measured at 55 knots, and in Plainfield, a house was struck by lightning. The Storm Events Database did not record property damage for this storm; however, it should be expected that damage did occur. Over 1,000 people in northern Connecticut—including Windham County—were left without power.

A type of mesoscale convective system, called a “bow echo”, hit Windham County in May, 2007. This storm downed trees across Ashford, Eastford, Pomfret, Killingly, and Putnam. It was estimated that hundreds of trees came down in one section of Pomfret. Winds from this storm were estimated to be as high as 80 mile per hour.

Figure 3.4a contains additional dates and descriptions of records from the Storm Events Database. A more-complete listing of events from the Storm Events Database and SHELDUS is located in Appendix 3X. Historic lightning events are covered in Chapter 3.3.1.

Thunderstorm Wind: 08/10/2001 12:50 EST

Severe thunderstorms brought damaging winds to parts of northeast Connecticut. In Tolland County, trees and wires were downed in Coventry and Andover. In Windham County, the storms downed trees and wires in Thompson and Plainfield.

Thunderstorm Wind: 07/22/2003 17:00 EST

A severe thunderstorm downed large tree limbs and wires in Ashford and Putnam. Dime sized hail was also reported in Putnam. (Property Damage: $5,000).

Thunderstorm Wind: 07/07/2009 14:00 EST

Trees on Ashford and Westford Roads [in Eastord] were downed by thunderstorm winds. (Property Damage: $5,000).

Source: Storm Events Database, NCDC at NOAA

Figure 3.4a: Selected thunderstorm events from the Storm Events Database

3.4.2 Regional Risk Assessment

Probability

Thunderstorms are a common occurrence in mid-latitude regions. Northeastern Connecticut typically sees several hazardous thunderstorms each year and many minor thunderstorms. County-level data from SHELDUS revealed that between 1960 and 1985[18], 53 hazardous thunderstorms affected the region. The NCDC's Storm Events Database does not contain "Thunderstorm" records but separate records for "Thunderstorm Wind", "Lighting, "Marine Thunderstorm Wind", and other weather conditions related to thunderstorms. Although these data sets served the Regional Vulnerability Assessment, they were not used in calculating probability.

Data from SHELDUS suggests that thunderstorms have at least a 100% chance of reoccurring each year, making it "Highly Likely" and giving it an index value of four.

Impact

Strong winds (Chapter 3.2) account for much of the property damage associated with thunderstorms. Hail (Chapter 3.9), although less-likely in New England, can also account for a large percentage of a thunderstorm's damage. Flooding (Chapter 3.1) and lightning (Chapter 3.3), on the other hand, pose the most significant threats to the safety of people.

Data from the Storm Events Database revealed 58 records, spanning 39 days, between 1991 and 2014[19] for "Lightning" and "Thunderstorm Wind". Between 2002[20] and 2014, these two weather events accounted for $525,000 in property damage. Wind was responsible for damage in most instances, with individual events accounting for over $100,000 in property damage. As mentioned in Chapter 3.3, lightning accounted for two deaths in 1974 and 1977 as well as two injuries in one day in 2004.

---

[18] Because data between 1985 and 1995 was incomplete, the sample size was restricted to pre-1985 data.
[19] Events data prior to 1990 is less-consistently recorded in the database.
[20] The first recorded instance of property damage.

Considering the historic casualty rates of lightning and the damaging effects of wind, the anticipated impact of thunderstorms on the region is "Critical" or an index value of four. It is expected that multiple injuries and/or multiple deaths could result from a severe storm.

Spatial Extent

Individual thunderstorms are a byproduct of larger-scale weather events that move across the region with small geographic variations. The number and intensity of storms is dependent on atmospheric and on-the-ground conditions, and can range from one small, localized storm to multiple large storms that sweep across the region. In the case of multi-cell thunderstorms, if proper conditions are present in one part of the region, it is likely that they are present, or will be present, in most other parts of the region. Squall line storms, on the other hand, can hundreds of miles long and supercell storms can be up to ten miles in diameter[21].

The spatial extent of thunderstorms was given the indexed as four out of four, meaning that more than 50% of the region could be affected by thunderstorms in a given storm event.

Warning Time

The National Weather Service issues Severe Thunderstorm Warnings and Severe Thunderstorm Watches. A Severe Thunderstorm Warning is issued when a thunderstorm producing wind gusts greater than 58mph and/or hail greater than 1" in diameter has been spotted or detected with radar. A severe Thunderstorm Watch is issued when conditions for a thunderstorm exist in an area. Although the weather patterns that provide the conditions for thunderstorms can be tracked and modeled further in advance, it is often unsure if, where, and when thunderstorms will develop. Barbara Watson of NOAA writes, "[Thunderstorms] can develop in less than 30 minutes, allowing little time for warning."[22] Because of their unpredictability, the warning time for thunderstorms as given an index value of four, meaning that there is typically less than six hours lead time before the storm.

---

[21] National Severe Storms Laboratory, Severe Weather 101

[22] Barabara Watson, Virginia Thunderstorms and Lightning

Duration

Thunderstorms in northeastern Connecticut typically come and go quickly, unless associated with hurricanes or tropical storms. The four types of thunderstorms last anywhere from 20 minutes to over one hour[23]; however, a multi-cell storm may be part of a system that lasts two or more hours, but this is a short-duration event comparted to some other natural hazards. Mesoscale convective systems have been known to last over 12 hours but are not typical to the region. Because thunderstorms in northeastern Connecticut typically last less than six hours, their duration was given an index value of one.

3.4.3 Regional Vulnerability Assessment

The region experiences a number of violent thunder storms each year. With these storms comes the potential for safety risks and property damage from lightning, hail, wind, rain and flooding, and even tornadoes. Regional vulnerability to these weather events is discussed in Chapters 3.1-3.3, 3.7, and 3.9.

[23] National Severe Storms Laboratory, Severe Weather 101

3.5 Winter Storms/Nor'easters

Winter storms are common occurrences in northeastern Connecticut and can bring different combinations of individually hazardous weather conditions including snow, cold temperatures, rain, freezing rain, ice, sleet, and high winds. Winter storms have the potential to cause significant threats to safety on roadways, interrupt electric and other utilities, cause flooding, or cause structure damage or collapse. Additionally, extreme cold is often exacerbated by these effects of winter storms, such as utility failure, and can pose a significant threat to the public. Older-aged, poor, homeless, and disabled populations are especially at-risk during the winter. They can be threatened by even minor winter weather events.

Nor'easters, explained below, are meteorological phenomena, relevant to this chapter and natural to the region.

Nor'easters

Nor'easters are large-scale, rotating storms that affect the Atlantic coasts of the United States and Canada. They typically bring heavy precipitation and high wind, causing blizzard conditions (see below). Nor'easters are commonly associated with winter storms; however, they can occur at other times of the year (typically between November and April). A famous example of a nor'easter is the Blizzard of 1978 in New England and the northeast. This nor'easter left many without heat, water, and electricity and greatly stretched the region's resources. According to NOAA's Neal Strauss, the storm accounted for approximately 100 lives[24].

Blizzards

A blizzard is a specific combination of snow and wind. A Blizzard Warning is issued by the National Weather Service when winds or frequent gusts reach or exceed 35mph and falling or blowing snow reduces visibility to within ¼ mile[25].

---

[24] Neal Strauss, The Great Northeast Blizzard of 1978 Remembered 30 Years Later in Southern New England
[25] National Weather Service, National Weather Service Glossary

3.5.1 Notable Occurrences

The Blizzard of 1888 was one of the most impressive storms in Connecticut's post-industrial history. Snow accumulations totaled between twenty and fifty inches across the state, over a three-day period[26]. Accompanying the snow were gale force winds and cold temperatures.

Ninety years after the Blizzard of 1888, the Great Northeast Blizzard of 1978 broke Boston and Providence's 24-hour snowfall records, caused over $25,000,000 in damage, and crippled activity in southern New England[27]. In Hartford, the flat roof of the Hartford Civic Center collapsed under the weight of the snow. Governor Ella T. Grasso ordered the closure of all roads in the state[28].

A strange and destructive storm occurred on October 30, 2011. The 2011 Halloween Nor'easter was an unseasonable snowstorm in New England and the Mid-Atlantic, making it particularly destructive. Because most trees were still in-leaf, falling trees and broken branches caused power outages that lasted as many as eleven days in Connecticut[29]. Of the 39 people killed in the storm, ten were in Connecticut—the highest of any state[30].

Winter Storm Nemo, also known as the February 2013 Nor'easter, was the most-recent, major storm to affect northeastern Connecticut. Over 22 inches of snow fell in Hartford and over 24 inches in Boston[31]. According to the Storm Events Database, 22 to 26 inches of snow fell across Windham County. The database also reported that thunderstorms were common during the height of the storm.

Details of selected records from the Storm Events Database can be found in Figure 3.5a. Appendix 3X contains a list of database records from the Storm Events Database and SHELDUS.

[26] Connecticut History Online, The Eye of the Storm: A Journey into the Natural Disasters in Connecticut
[27] Neal Strauss, The Great Northeast Blizzard of 1978 Remembered 30 Years Later in Southern New England
[28] Connecticut State Library, Ella Giovanna Olivia (Tambussi) Grasso
[29] Federal Energy Regulatory Commission & the North American Electric Reliability Corporation, Report on Transmission Facility Outages During the Northeast Snowstorm of October 29-30, 2011
[30] Journal Inquirer, Death Toll From Storm Rises to 10
[31] USA Today, Slow Recovery for Northeast after Epic Blizzard

Heavy Snow: 03/31/1997 15:00 EST – 04/01/1997 09:00 EST

Heavy snow and strong winds produced near-blizzard conditions across the area during the early morning hours of April 1st. Snowfall totals of 12 to 21 inches were reported. Some totals included: Putnam, 21 inches; Union, 18.5 inches; and Mansfield, 16 inches. About 98,000 electric customers lost power statewide when the heavy, wet snow knocked down tree limbs and power lines. Most of the estimated dollar damage was from snow removal and restoration of power/removal of debris. (Property Damage: [not listed]).

Winter Storm: 01/08/2005 07:00 EST

Low pressure quickly strengthened as it passed south of New England and brought a mix of snow, sleet and freezing rain to much of interior southern New England. North central Connecticut was especially hard hit by freezing rain, where as much as one half inch of glaze brought down trees, tree limbs and power lines. There was no estimate of how many customers lost power, but dozens of accidents were reported as a result of icy roads. (Property Damage: $50,000).

Winter Storm: 02/01/2011 07:00 EST

A total of 6 inches of snow fell across Windham County over the two day period. Damage amounts are for the roof collapses of some 28 structures that occurred following heavy snowfall that totaled 86.4 inches by the end of the snow season. Most of this snow fell from December 26 through February 2 and most roof collapses occurred during or shortly after the February 1 and 2 snow storm. (Property Damage: $500,000).

Source: Storm Events Database, NCDC at NOAA

Figure 3.5a: Selected winter storm events from the Storm Events Database

3.5.2 Regional Risk Assessment

Probability

In the NCDC's Storm Events Database, all reported events were filed as "Heavy Snow", "Winter Weather", or "Winter Storm"; the designation "Blizzard" was never used in Windham County. Data for these three event types is available since 1996. The database contains records for 72 county-wide events in the 19 year period, meaning almost four major events—on average—per year.

This data suggests that winter storms have at least a 100% chance of reoccurring each year. This makes them “Highly Likely”, giving winter storm probability an index value of four out of four.

Impact

The impact of winter storms is largely determined by the physical ability of its precipitation to disrupt infrastructure, limit movement, cause flood-related damage, and damage structures. Common injuries and deaths result largely from car crashes. As of 2008, about 70% of injuries, due to ice and snow, resulted from vehicle accidents. And 25% of these accidents occurred during the storm. Other injuries and deaths can be contributed to extreme cold and wind chill. 50% of cold-related injuries affected people over 60 years old, and 20% occurred in the home[32].

NCDC and SHELDUS data was incomplete in regards to injury and death statistics related to winter storms. To prove the impact of winter storms, recent news articles were examined and cross referenced with NCDC records. A recent two-day storm dubbed, Winter Storm Nemo brought multiple feet of snow to Connecticut and New England. According to official reports of the storm, the NEMO accounted for five deaths in Connecticut alone[33]. Additionally, the NCDC reported that this storm damaged or destroyed more than 140 agricultural structures in Connecticut. Another recent and historic storm, the Halloween Nor’easter, resulted in ten fatalities in Connecticut and 39 total fatalities on the east coast. The NCDC reports that roughly 830,000 customers in the state were without power, some for as long as 11 days[34]. This storm was particularly damaging because of its timing.

[32] U.S. Department of Commerce, National Oceanaic and Atmospheric Administration & National Weather Service, Winter Storms: The Deceptive Killers
[33] CNN, Live Blog: Reports of Five Deaths in Connecticut, Governor Says
[34] Federal Energy Regulatory Commission & the North American Electric Reliability Corporation, Report on Transmission Facility Outages During the Northeast Snowstorm of October 29-30, 2011

Considering casualty rates of recent winter storms in Connecticut and the wide-spread effect on property and agriculture, the anticipated impact of future winter storms on the region is “Critical” or an index value of three. It is expected that multiple injuries and/or multiple deaths could result from a severe storm. It is also expected that wide-spread property damage and disruption of critical facilities is possible.

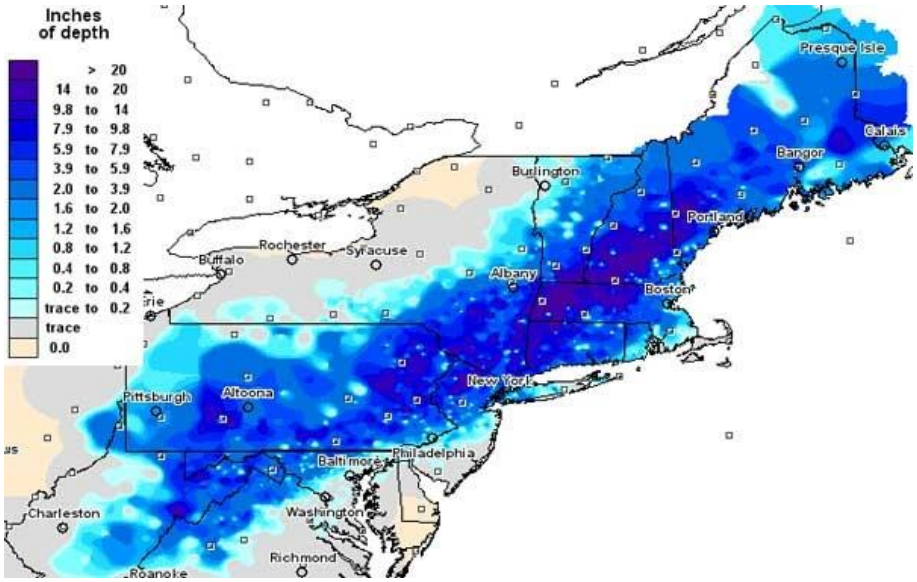


Figure 3.5b: 2011 Halloween nor’easter snowfall totals
Source: http://www.weather.com/outlook/weather-news/news/articles/recalling-snowtober-to-remember_2011-11-01

Spatial Extent

Winter storms of significant size occur almost-exclusively on a multi-state or multi-region basis. Westerly winds that define weather patterns in New England bring storms that cross much of the continental United States. Although, topography and atmospheric conditions may cause local variations in a storm’s intensity, their spatial extent is great.

Figure 3.5b shows snowfall totals in the northeastern United States following the 2011 Halloween Nor'easter. This storm resulted in a swath of snowfall from Maine to West Virginia. Central New England received the most-intense snowfall while nearby Rhode Island and Cape Cod received relatively little.

Using RFCA, winter storms' spatial extent is "Large" or an index value of four, meaning that more than 50% of the northeastern Connecticut could be affected by a single winter storm. In reality, this only partially describes the spatial extent of winter storms.

Warning Time

The large spatial extent of winter storms lends itself to very high warning time. It is common that school closures and closures of other community buildings or businesses will be decided a day in advance of a storm.

The National Weather Service issues Winter Storm Outlooks, and Winter Storm Advisories. Winter Storm Outlooks are predictions that communicate a storm is likely within 2-5 days. Winter Storm Advisories are the most-immediate, warning people that a winter storm is affecting the area and that they should take necessary precaution. Because of this, the index value for a winter storm's warning time was assessed as one out of four, meaning that there is usually more than 24 hours warning before an event.

Duration

The NCDC's Storm Events Database provided severe winter storm data for 72 separate events since 1996 in Windham County. In a sample of 19 events (all events between 2010 and 2014), the average duration of a winter storm was 16.9 hours and storms ranged between 39 and six hours. Using this data, a winter storm's duration was assessed an index value of two out of four, meaning that a typical storm lasts less than one day.

3.5.3 Regional Vulnerability Assessment

Winter storms are extremely common in Connecticut and occur every year. A major threat to health, safety, and property, from winter storms, is unsafe driving conditions resulting in potentially deadly and costly accidents. Utility failures can also pose a significant threat, especially to those that rely on electric heating.

All property, people, and critical facilities in the region are vulnerable to winter storms. It should be expected, however, that elderly and special populations are more vulnerable to winter storms because they may lack the individual capabilities to respond to snow and ice and may remain isolated, or because elderly populations are often more susceptible to the effects of cold weather. It should also be expected for areas at higher elevation to be experience increased frequency and severity of winter stroms.

3.6 Tropical Cyclones

Tropical cyclones have the greatest destructive potential of all natural disasters in Connecticut, due to their probability, size, and the destructive combination of high winds, damage from debris, storm surge and coastal erosion, and heavy rain and flooding. Tropical cyclones include hurricanes, tropical storms, and tropical depressions (Table 3.6a)—extremely large, rotating systems of low pressure that originate in the tropics and are continually fed by moisture when moving over the ocean. Tropical cyclones rotate around an "eye", and the region of the storm immediately surrounding the eye—they "eyewall"—is the most intense. In New England, tropical cyclones arrive from the south, often tracking along the Atlantic coastline and affecting other states. Because of a tropical cyclone's size, one can be disastrous for an area without passing directly over that region.

Tropical cyclones are categorized by wind speed; hurricanes range from Category 1 hurricanes to Category 5 hurricanes. Tropical storms have lower wind speeds than hurricanes (below 74mph) but can be equally destructive. Table 3.6a shows storm classifications by wind speed, according to the Saffir-Simpson Hurricane Wind Scale, and estimated return periods for the different storm classifications.

Category 3, or greater, hurricanes are rare in New England. The Great Colonial Hurricane of 1635 is thought to be the region's most severe. Today this storm is estimated to be a "Category 3.5", judging by historic records[35]. The cooler waters of the North Atlantic reduce the strength of particularly violent storms; southern states, the Caribbean, and the Gulf Coast are more vulnerable to these storms.

[35] Brian R. Jarvinen, Storm Tides in Twelve Tropical Cyclones (Including Four Intense New England Hurricanes)

Clasification	Maximum Sustained Winds (nmph)	Central Pressure (mb)
Tropical Depression	<34	
Tropical Storm	34 - 63	
Category 1 Hurricane	64 - 82	>980
Category 2 Hurricane	83 - 95	965 - 979
Category 3 Hurricane	96 - 112	945 - 964
Category 4 Hurricane	113 - 136	920 - 944
Category 5 Hurricane	>136	<920

Table 3.6a: Saffir-Simpson Hurricane Wind Scale and estimated return periods for hurricane eye to come within 50 nautical miles
Source: http://www.nws.noaa.gov/os/hurricane/resources/TropicalCyclones11.pdf;
http://www.tulane.edu/~sanelson/Natural_Disasters/tropical_cyclones.htm

3.6.1 Notable Occurrences

As mentioned above, Category 3, 4, and 5 hurricanes are rare in New England. Nonetheless, the region has been affected by a number of severe hurricanes and other tropical cyclones throughout its history.

The Great Colonial Hurricane of 1635 is thought to be the most powerful in the region's history, and was perhaps a Category 4 or 5 hurricane before reaching New England[36].

The Hurricane of 1938, mentioned in Chapter 3.1, was also a Category 3 hurricane and still is the deadliest and most powerful hurricane, of recent history, to impact New England. This storm made landfall directly south of Windham County.

[36] Brian R. Jarvinen, Storm Tides in Twelve Tropical Cyclones (Including Four Intense New England Hurricanes)

More recently, in 2011 and 2012, Connecticut and the Atlantic coast experienced significant impact from two tropical events: Hurricane Irene and Super Storm Sandy (Hurricane Sandy). Both of these storms brought torrential rain, causing localized flooding which exacerbated response and accounted for property damage; however, most notable in terms of impact from these events was the loss of electrical power and communications due to high winds. Specifically, fallen trees or tree limbs were to blame for these utility failures—a factor that continues to account for a large amount of storm damage since northeastern Connecticut's nearly 1,200 miles of roadways are primarily tree-lined. The under-management of trees along roadways was brought to reality by these storms. During both events, the region had towns with no passable roads. Trees along public roadways contributed significantly to power outages and the duration of those outages, limited emergency response, and impaired public safety.

Other notable hurricanes for the region include: The Great Atlantic Hurricane in 1944; Hurricane Carols and Edna in 1954; Hurricane Bob in 1991; and Hurricane Floyd in 1999.

Tropical Storm: 08/28/2011 05:56 EST – 08/28/2011 13:30 EST

Trees and branches were downed in Moosup (Lake Street) and Plainfield (Route 12, Major and Gendron Roads, Huntington Estates). An amateur radio operator recorded gusts to 57 knots (66 mph) on their home weather station in Thompson. The Automated Surface Observing System at Windham Airport (KIJD) recorded sustained wind speeds of 24 knots (28 mph) and gusts to 44 knots (51 mph). (Property Damage: $20,000,000).

Source: Storm Events Database, NCDC at NOAA

Figure 3.6a: Selected tropical cyclone events from the Storm Events Database

3.6.1 Regional Risk Assessment

Probability

It is difficult to model return rates for tropical cyclones. Data sources typically focus on one storm type and methodology varies. As mentioned above, Category 3, 4, or 5 hurricanes are extremely rare in New England. The return rate for these hurricanes off of Block Island, RI—the nearest measurement station—is once every 52 years, about 2%, while the overall hurricane return rate is once every 6 years, about 17%[37].

According to the National Weather Service Forecast Office in Boston, MA, 49 tropical cyclones impacted New England between 1900 and 1997[38]. This means that there is roughly a 44% chance of a tropical storm or hurricane impacting New England in a given year. It should be noted, however, that rising sea-surface temperatures in the North Atlantic contribute to increased cyclonic activity[39]. If warming trends continue, increased frequency and intensity of storms could place Connecticut at a much higher risk.

When reviewing data from numerous sources it “Likely”. This means that the annual probability of tropical cyclones in northeastern Connecticut is greater than 20%, giving it an index value of three.

Impact

Tropical cyclones typically have a larger impact on coastal regions. High winds cause storm surge and tidal extremes that can flood and inundate communities built along the shore. The Hurricane of 1938 caused coastal flooding that lifted houses off of their foundations, moving them miles. Cyclones also tend to lose strength after moving over land. Northeastern Connecticut, however, is not very far inland; the strength of a cyclone should differ greatly after moving thirty miles inland.

---

[37] National Hurricane Center, Tropical Cyclone Climatology
[38] National Weather Service Forecast Office, Boston, Massachussets, New England Hurricane Climatology
[39] World Meteorological Organization, International Workshop on Tropical Cyclones, Statement on Tropical Cyclones and Climate Change

Although northeastern Connecticut is safe from coastal flooding. The number of rivers and streams in the region, its rolling topography, and the prominence of one major drainage basin—the Thames River Drainage Basin—creates a great chance of inland flooding. The low-lying villages along the Quinebaug River, Shetucket River, and their tributaries, could potentially see historic flooding in an extreme cyclonic event. Similarly, Vermont experienced historic flooding in 2011 during Hurricane Irene. Rolling topography and development along rivers proved catastrophic for many low-lying areas in the southern portion of the state, with some areas experiencing flooding that exceeded records set by the Hurricane of 1938[40].

Northeastern Connecticut is also very vulnerable to a cyclone's high wind speeds. Mentioned earlier, the presence of trees along minor and major roadways poses a threat to mobility, utilities, response, and safety. Records presented in Chapter 3.2 cite instances of sub-hurricane-force winds causing tens of thousands of dollars in utility-related damages.

Considering the wide-spread, damaging, and life threatening potential of hurricanes and tropical storms in Connecticut and the New England region, as well as modeling of future events using Hazus-MH (Chapter 3.6.3), these storms are a major priority for hazard mitigation efforts. The anticipated impact of a powerful tropical cyclone on northeastern Connecticut is "Critical" or an index value of three. It is expected that multiple injuries and/or multiple deaths could result from one of these storms.

Spatial Extent

A storm's gale radius is a measurement, in nautical miles, of the distance of the furthest gale force wind from the center of the storm, in each quadrant (northeast, southeast, southwest, and northwest) [41]. The gale radius of a recent event, Hurricane Sandy was examined when considering the spatial extent of tropical cyclones. When Hurricane Sandy made landfall in 2011, the gale radii of its four quadrants were

[40] WCAX, VT Communities Inundated by Irene Flooding
[41] Colorado State University, The Tropical Meteorology Project

estimated to be 460nm, 370nm, 400nm, and 490nm, respectively. Smaller, tropical storms and tropical depressions should be expected to be encompass a reduced area, but still affect the entire region.

A tropical cyclone's spatial extent is "Large" or an index value of four, meaning that more than 50% of the northeastern Connecticut could be affected by an event. But, like winter storms, this only partially describes the spatial extent of large systems.

Warning Time

Similar to winter storms, the large spatial extent of tropical cyclones suggests very high warning time. Weather professionals and radar systems are dedicated to tracking and monitoring potential storms before they become cyclonic. When a potentially threatening storm develops. The National Weather Service tracks it and models its trajectory. The National Weather Service also issues "watches" and "warnings" for tropical storms and hurricanes. A Tropical Storm Watch or a Hurricane Watch is issued 48 hours in advance of a storm's possible onset, meaning that storm is possible in a given area. Tropical Storm Warnings and Hurricane Warnings are issued when a storm is expected within 36 hours. Extreme Wind Warnings are short-term warnings for winds in excess of 115mph are expected within one hour for a region[42].

The warning time associated with tropical cyclones was assessed an index value of one, meaning that there is usually more than 24 hours warning before an event.

Duration

When estimating the duration of a tropical cyclones on the region, it is necessary to consider the size of a storm and the average forward speed of past storms (Table 3.6b). At northeastern Connecticut's latitude (41^{o} N), the average forward speed of a hurricane is 30.6mph or 26.6 knots. Given that Hurricane Sandy's average estimated gale radius was 430 miles when it made landfall, it would have taken roughly 28 hours to pass over a given point if traveling in a straight line[43].

---

[42] National Hurricane Center, Hurricane Preparedness - Watches & Warnings
[43] Colorado State University, The Tropical Meteorology Project

Because typical tropical cyclones in northeastern Connecticut last under 24 hours but over six hours, their duration was assessed an index value of two

Latitude	Speed (knots)	Number of Cases
0^o - 5^o	14	186
5^o - 10^o	11.9	4678
10^o - 15^o	10.4	7620
15^o - 20^o	9.4	7501
20^o - 25^o	9.4	8602
25^o - 30^o	10.8	6469
30^o - 35^o	14.6	3397
35^o - 40^o	21	1120
40^o - 45^o	26.6	246
45^o - 50^o	27.8	34
50^o - 55^o	27.8	15
55^o - 60^o	30.1	1

Table 3.6b: Forward speed of hurricanes
Source: http://www.aoml.noaa.gov/hrd/tcfaq/G16.html

3.6.3 Regional Vulnerability Assessment

Although tropical cyclones tend to cause more-severe damage to coastal regions, damage and threats to health and safety from hurricanes, tropical storms, and tropical depressions is always great and demands planning and attention from inland regions as well. High winds and flooding are major concerns from tropical cyclones and can result in major property damage, wind or flooding-related deaths or injuries, utility failures, and interference and damage to transportation infrastructure that results in population isolation and impairment of emergency response.

The entire region is vulnerable to tropical cyclones, while populations and structures within floodplains are at increased vulnerability. Regional vulnerability to wind and flooding is discussed in Chapters 3.1 and 3.2.

Modeling of a 100-year hurricane event, for each town, using Hazus-MH software, was conducted and the results are described in Chapters 4.1-4.16.

3.7 Tornadoes

A tornado, sometimes referred to as a “twister” or “cyclone”, is defined by NOAA as, “A violently rotating column of air, usually pendant to a cumulonimbus, with circulation reaching the ground. It nearly always starts as a funnel cloud and may be accompanied by a loud roaring noise. On a local scale, it is the most destructive of all atmospheric phenomena.” Tornadoes are most-commonly associated with supercell thunderstorms but can also be formed absent of supercells and even in tropical cyclones. Tornadoes produced from supercell thunderstorms are typically the most dangerous, lasting longer than one hour and being fed by the storm’s updraft.

Tornados have historically been measured in terms of estimated wind speed from damage to man-made structures. The Fujita-Pearson Scale (Table 3.7a) designates estimated tornado events F0, F1, F2, F3, F4, or F5 with F5 being the most-intense. Today, the Enhanced Fujita Scale

Fujita Scale	Wind (mph)	Damage
F0	>73	Light- some damage to chimneys, shallow-rooted trees pushed over.
F1	73 - 112	Peels surface off of roofs, moving automobiles blow off roads
F2	113 - 157	Roofs torn from house frames, cars lifted off of ground
F3	158 - 207	Roofs and some walls torn from well-constructed homes, trains overturned
F4	208 - 260	Well-constructed houses leveled, cars thrown
F5	261 - 318	Strong-framed houses leveled, trees debarked

Table 3.7a: Fujita Scale with damage descriptions
Source: http://www.spc.noaa.gov/faq/tornado/f-scale.html

Enhanced Fujita Scale	Wind (mph)
EF0	65 -85
EF1	86 - 110
EF2	111 - 135
EF3	136 - 165
EF4	166 - 200
EF5	>200

Table 3.7b: Enhanced Fujita Scale
Source: http://www.spc.noaa.gov/efscale/ef-scale.html

(Table 3.7b) has replaced the Fujita-Pearson Scale. It accounts for differences in construction quality and uses a modified index to estimated wind speed. The Enhanced Fujita Scale designates events as EF0, EF1, EF2, EF3, EF4, or EF5 based on Degree of Damage (DOD) data.

Despite their infrequent occurrence in the region, the seriousness and specific challenges related to tornados demand great attention. Tornadoes have killed as many as 519 people in one year, in the United States and, according to NOAA, 59 EF5 or F5 tornadoes have occurred in the United States since 1950[44][45].

3.7.1 Notable Occurrences

The two most significant tornado events in Windham County took place one year apart, in 1786 and 1787[46]. On August 23, 1786, a tornado touched down in Sturbridge, MA and traveled southeastward through Woodstock, Pomfret, and Killingly. One person was killed in Woodstock, and another in Killingly. The tornado also destroyed 20 homes and 63 barns in the region[47].

Less than one year later, August 15, 1787, the northeast experienced a tornado outbreak, with six storms in 3.5 hours across the states of Connecticut, Rhode Island, Massachusetts, and New Hampshire. The Four-State Tornado Swarm did not kill anyone in Windham County, but two people were killing in Wethersfield, Connecticut[48].

Nearby counties in Connecticut, Rhode Island, and Massachusetts have recently experienced severe tornadoes, similar in intensity to the two in 1787 and 1876. These tornadoes are discussed in Chapter 3.7.2. Figure 3.7a includes descriptions of the Storm Events Database's three entries for Windham County.

---

[44] AON Corporation, United States Tornado History
[45] Storm Prediction Center, F5 and EF5 Tornadoes of the United States
[46] Colonial Sense, New England Weather
[47] Thomas Grazulis, Significant Tornadoes 1586-1870
[48] Thomas Grazulis, Significant Tornadoes 1680-1991

Tornado: 06/24/1985 11:45 EST

A small tornado touched down in rural, northeastern Connecticut in the town of Woodstock at 1:45 P.M. E.D.T. and moved on a generally east-southeastward track through the towns of Woodstock, Pomfret. Putnam and Killingly. The funnel moved along at generally treetop level throughout its course, tearing up thousands of trees but doing relatively light structural damage. In Woodstock, a 200-ft. long, concrete block chicken coop was totally demolished. A number of homes along the path of the tornado were damaged by falling trees. Five sheds were demolished near Ballouville, and an apartment building there lost parts of its roof. In Killingly, a portion of a roof to a factory was blown off. Damage was estimated at about $600,000 along the total track of the storm, which was a confirmed tornado by NWS investigation. It was the 6th tornado to be reported in Windham County during the past three hundred years. (Property Damage: $2,500,000).

Tornado: 08/26/1985 12:45 EST

A small tornado moved through a camping area, damaging tents, trailers, and fences before moving eastward across the state line into Rhode Island. No injuries were reported and damage was held to a minimum since the vortex roved along at tree-top level. The occurrence wa5 confirmed by National Weather Service investigation. The total path length in both states was 1.5 miles. (Property Damage: $250).

Tornado: 07/14/1992 16:30 EST

A small tornado touched down in a wooded area just off Route 12. No structures were damaged.

Source: Storm Events Database, NCDC at NOAA

Figure 3.7a: Selected tornado events from the Storm Events Database

3.7.2 Regional Risk Assessment

Probability

Tornadoes are significantly rarer to southern New England than most other regions in the continental United States. The United States, however, has a very high incidence of land-born tornadoes when compared to other countries. It appears that Windham County experiences fewer tornados, on average, than almost all other Connecticut counties—New London County has the least, with only has 2 records in the Storm Events Database. Counties in central and western Connecticut had far higher incidence of tornados, and Litchfield County in northwestern Connecticut recorded 22 separate events in the Storm Events Database.

The Storm Events Database keeps tornado records as late as 1950, longer than any other weather event. An assessment of the database's records revealed that Connecticut had experienced 73 separate events since 1950. Of these 73 events, two were F4 tornados, and neither one affected a NECCOG town. Windham County had three entries in the database, two from 1985 and one from 1992. An entry for a F1 tornado in June, 1985 mentioned that it was the sixth tornado in Windham County in 300 years. Nearby Worcester County, Massachusetts had 37 records corresponding to 28 separate events since 1950. Worcester County's most extreme tornado was a F4 event in 1953 that claimed 90 lives. Kent and Providence Counties in northwestern Rhode Island combined for seven separate tornados, including a record of a F2 tornado that formed in nearby Burrillville.

After assessing the database's records, it was determined that the probability of a tornado affecting northeastern Connecticut is about 10% or "Possible", giving it an index value of two out of four.

Impact

Unlike other states where tornadoes are more common and pose an immediate threat, Connecticut does not have designated tornado shelters[49]. However, the Connecticut Department of Emergency Management and Homeland Security does provide all public schools in the state with radios for National Weather Service broadcasts. This system for advanced warning allow some mitigation of a tornado's effect on the population. A tornado's effect on property, however, is much more difficult to mitigate. According to the Enhanced Fujita Scale, EF2 tornadoes can cause serious damage to homes (Table 3.7a). According to NOAA, during an F4 tornado, "Well-constructed houses [will be] leveled…", and during an F3 tornado, "Roofs and some walls torn off well-constructed houses…"[50]

[49] Department of Energy and Environmental Protection & Department of Emergency Service and Public Protection, 2014 Connecticut Natural Hazards Mitigation Plan Update
[50] Storm Prediction Center, Fujita Tornado Damage Scale

Year	County	State	Intensity	Deaths	Injuries	Property Damage (2011 USD)
1953	Worcester	MA	F4	90	1228	250,000,000
1979	Hartford	CT	F4	3	500	250,000,000
1985	Windham	CT	F1			600,000
1985	Windham	CT	F1			250
1986	Providence	RI	F2			2,500,000
1989	New Haven	CT	F4		40	250,000,000
1992	Windham	CT	F1			
2011	Hampden	MA	EF3	4	200	227,600,000

Table 3.7c: List of significant, nearby tornadoes and Windham County tornadoes
Source: Storm Events Database, NCDC at NOAA

The most significant tornado to affect Windham County, in recent history, occurred in 1985, starting in Woodstock then traveling southeast through Pomfret, Putnam, then Killingly. This F1 tornado resulted in $600,000 in property damage[51], destroying a chicken coop and damaging homes and businesses (Table 3.7c). A short distance away, in northern Worcester County, a famous 1953 F4 tornado claimed 90 lives, resulted in 1228 injuries, and caused a quarter of a billion dollars in property damage. Tornadoes in Hartford and New Haven counties each accounted for a similar amount of property damage but claimed less lives and fewer injuries. These F4 tornados are extremely rare in the area are destructive due largely to a lack of preparedness. Recently, a 2011 tornado that began in Springfield, Massachusetts and traveled across much of the state, claimed four lives and injured 200 people. This smaller EF3 tornado claimed accounted for greater property damage than the previous F4 tornados.

[51] Price adjusted to 2011 dollars.

Considering the historic impact of tornadoes in Windham County and on surrounding regions—totaling as many as 90 deaths in a single event—the potential impact of tornadoes on the region was assessed as “Catastrophic”, or an index value of four. A high number of injuries and deaths are possible from tornadoes and over 50% of homes in a tornadoes path could be destroyed.

Year	County	State	Intensity	Width (yd)	Length (mile)
1951	Middlesex	CT	F3	33	Not Specified
1954	Tolland	CT	F3	33	0.3
1962	New Haven	CT	F3	120	9.3*
1962	Hartford	CT	F3	120	2.3*
1971	New Haven	CT	F3	200	Not Specified
1979	Hartford	CT	F4	1400	11.3
1989	New Haven	CT	F4	100	3
* Different segments of the same tornado					

Table 3.7d: Path sizes for significant Connecticut tornadoes
Source: http://www.ncdc.noaa.gov/stormevents/

Spatial Extent

As mentioned earlier, tornadoes are extremely localized phenomena. A tornado’s path of destruction is normally very thin and the path’s length is small in comparison to many other weather hazards. The record for widest recorded tornado path comes from a 2013 event in Oklahoma. A tornado in El Reno had a path width of 2.6 miles, barely eclipsing an event in Hallum, Nebraska with a width of 2.5 miles[52]. It should be noted, however that tornadoes of this size are very uncommon, even in heavily affected areas.

[52] National Climatic Data Center, Storm Events Database

An inventory of serious tornado events in Connecticut (Table 3.7d) revealed that no tornadoes exceeded 1400 yards (roughly 0.8 miles) in width. The median width of these tornadoes was only 120 yards (roughly 0.07 miles). The maximum path distance belonged to a 1962 event that ran 11.6 miles through Hartford County and New Haven County. The 1979 tornado in Hartford County had the greatest path area, just under nine square miles. Considering that the NECCOG region has an area of over 560 square miles, a Connecticut-record tornado is likely to affect less than 2% of the entire region. The spatial extent of a tornado received an index value of four, meaning that it is "Small".

Warning Time

The National Weather Service issues Tornado Watches when tornadoes are possible in an area—normally due to violent thunderstorms—and Tornado Warnings when a tornado has been spotted. According to NOAA, the average lead-time for a Tornado Warning is 13 minutes before strike[53]. This short lead-time contributes to the destructive nature of tornados, making it difficult to prepare find shelter before a tornado strike. Since there is less than six hours of warning time before a tornado, this criteria received an index value of four.

Duration

Tornadoes are relatively short-lived compared to other natural hazards in the region. The longest United States tornado was the Tri-State Tornado in 1925. This tornado affected the states of Missouri, Illinois, and Indiana, lasting over three and a half hours. Tornadoes in Connecticut, however, are very short-lived and last only a few minutes. This criteria received an index value of four, meaning that tornadoes last less than six hours.

[53] National Oceanic and Atmospheric Administration, Tornadoes 101

3.7.3 Regional Vulnerability Assessment

Tornadoes are extremely destructive and can occur anywhere in the region, with very little warning. Communities in New England are typically ill-equipped for tornado mitigation and response when compared with communities in the southern or central United States. History, however, has shown that tornadoes are a realistic threat to the region and have resulted in catastrophic losses to people and property by destroying structures and creating wind-driven projectiles. As reviewed in Table 3.7c, a F4 tornado in Worcester County resulted in 90 deaths in 1953.

It should be assumed that all people and property in the region are vulnerable to tornadoes; however, a tornado in an urbanized or built-up area will be particularly destructive. Towns with large population centers and clustered development are uniquely vulnerable to the effects of tornadoes.

3.8 Drought

Drought differs from many of the region's other hazards because it is a long-onset condition, brought on by unusual weather patterns across the continent. A drought occurs when there is deficiency in an area's water supply over an extended period of time, resulting from below-average precipitation. The effects of drought differ based on a specific town's water needs. In agriculture, soil moisture affects crop growth and stored water is typically used for irrigation. Thus, rural economies that are dependent on agriculture could be stressed when needing to conserve water. Higher-population cities, on the other hand, could be forced to place restrictions on public, commercial, or industrial water consumption. In extreme cases, famine, war, and wildfires have occurred around the world as results of drought.

According to NOAA, there are four types of drought. A "meteorological drought" is the broad term used to describe long-term dryness resultant of weather conditions. "Hydrological drought", "agricultural drought", and "socioeconomic drought" are terms that describe droughts as they impact different systems. The Drought Severity Classification (Table 3.8a), developed by the National Drought Mitigation Center (NDMC), categorizes droughts according to different indices that measure their individual effects.

Connecticut's population density and presence of agriculture and industry makes it vulnerable to the social, environmental, and economic effects of a major drought. Luckily, the region's climate makes drought unlikely and rarely serious. Northeastern Connecticut, and other rural parts of the state, could be at increased risk due to a lack of public drinking water. Much of the region is dependent on well water and these homes are more likely to experience shortages than municipally supplied homes.

According to the *2014 Connecticut Natural Hazards Mitigation Plan Update*, climate change could be responsible for more-intense heat waves and variations in continental weather patterns. It should be recognized that drought conditions could be more prevalent in the future if climate change persists.

Drought Severity	Return Period (years)	Possible Impacts	Drought Monitoring Indicies: Standardized Precipitation Index (SPI)	NDMC Drought Category	Palmer Drought Index
Minor Drought	3 - 4	Short-term dryness slowing growth of crops or pastures; fire risk above average	-0.5 to -0.7	D0	-1.0 to -1.9
Moderate Drought	5 - 9	Some damage to crops or pastures; fire risk high	-0.8 to -1.2	D1	-2.0 to -2.9
Severe Drought	10 - 17	Crop or pasture losses likely; fire risk very high	-1.3 to -1.5	D2	-3.0 to -3.9
Extreme Drought	18 - 43	Major crop and pasture losses; extreme fire danger	-1.6 to -1.9	D3	-4.0 to -4.9
Exceptional Drougth	44+	Exceptional and widespread crop and pasture losses; exceptional fire risk	less than -2	D4	-5.0 or less

Table 3.8a: Drought Severity Classification chart
Source: http://droughtmonitor.unl.edu/AboutUs/ClassificationScheme.aspx

3.8.1 Notable Occurrences

According to the Northeast Regional Climate Center at Cornell University, the "Central Climate Division" of Connecticut, which includes northeastern Connecticut, has experienced 8 severe or extreme droughts, lasting two months or more, since 1895[54]. According to the NRCC, the longest of these droughts lasted 28 months—36 months according to the Connecticut Drought Preparedness and Response Plan—and occurred between the years 1964 and 1966[55].

[54] Northeast Regional Climate Center, Northeast Drought
[55] Interagency Drought Working Group, Connecticut Drought Preparedness and Response Plan

Drought: 04/12/2012 7:30 EST

The U.S. Drought Monitor declared severe drought (D2) over Windham County from April 12 through April 24. This was deemed a meteorological drought due to precipitation levels approximately one half of normal.

Source: Storm Events Database, NCDC at NOAA

Figure 3.8a: Selected winter storm events from the Storm Events Database

The storm events database included one record of a severe drought in Windham County. This drought was a Severe Drought and occurred in 2012 (Figure 3.8a).

3.8.2 Regional Risk Assessment

Probability

The Storm Events Database contains records of droughts as late as 1996. Six separate droughts were recorded for the state of Connecticut since then—including one for Windham County. All four counties in southern Connecticut experienced droughts in April, May, and June of 2002. According to Kevin McCarthy at the Connecticut Office of Legislative Research in 2003, major droughts in Connecticut occurred in the years 1964-1968, 1981, 1987, and 2002[56].

Considering future probability of drought, a drought is "Possible" or an index value of two out of four. The historic incidence of drought in the region suggests that there is less than 20% chance, but greater than 1% chance, of a drought occurring in a given year in northeastern Connecticut.

[56] Kevin McCarthy, OLR Backgrounder: Nor Any Drop to Drink

Impact

Droughts are a unique hazard in that they generally do not cause direct property damage. Additionally, droughts in developed countries do not typically cause loss of life or injury. The vulnerability of a region to drought, however, can vary based on its reliance on water for agriculture, economy, and subsistence. In 2003, *Connecticut adopted the Connecticut Drought Preparedness and Response Plan.* This plan establishes a framework for drought monitoring and response. Then in December, 2008, the Connecticut Office of Policy and Management (OPM) issued *Managing Water in Connecticut*, a report that examines the current management of public water resources in Connecticut and explores options for improvements.

The Connecticut's drought between the years 1964 and 1966 proved to slow forage production, hay and pasture yields, to about 60% of normal, and corn silage yields to 80-85% of normal. Tree fruits, some vegetable crops, corn, and strawberries saw slight yield reductions and heavier yield reductions where irrigation was not applied[57].

Windham County's recent, 2012 drought did not cause any damage according to the Storm Events Database. No other records in the database, from Connecticut counties, included crop damage; although, this is likely inaccurate. Considering the history of drought the state, its potential impact on the northeastern Connecticut was assessed as "Minor" or an index value of one.

Spatial Extent

Despite slight, year-to-year fluctuations in precipitation and variations in water usage across the region, it is expected that all towns in northeastern Connecticut will be affected by a severe drought. This idea is supported by historic records in the Strom Events Database and from the NRCC. A drought's spatial extent is expected to be "Large" or an index value of four, meaning that it will affect over 50% of the region.

Warning Time

[57] Byron E. Janes & Joseph J. Brumbach, The 1964 Drought in Connecticut

As mentioned earlier, drought results from long-onset conditions and changes in weather patterns. Monitoring weather—temperature, humidity, wind, and amount of precipitation—allows advanced notice of drought conditions. Forecasting of local weather is increasingly accurate and typically available for seven day periods, with accuracy increasing for more immediate forecasts. Using current and past weather forecasts while monitoring water usage and availability can allow property owners, business owners, municipalities, utility companies, and farmers to plan for droughts.

Another resource for monitoring and anticipating drought conditions is the Drought Severity Classification from the National Drought Mitigation Center. The Drought Severity Classification for the entire United States is updated on a weekly basis and uses indexes—such as the CPC Soil Moisture Module—to assess drought levels. Monitoring the weekly drought level, stakeholders will be able to anticipate the next week's drought level if conditions persist, worsen, or improve. Additionally, the Connecticut Drought Preparedness and Response Plan established a monthly, criteria-based assessment of drought levels in the state. The Drought Advisory stage is the earliest warning for drought conditions and roughly corresponds to D1 on the Drought Severity Classification.

The warning time associated with drought is long, and was assessed at an index value of one, meaning that there is typically more than 24 hours' notice associated with the hazard. In reality, the warning time for a drought is much longer.

Duration

Droughts are often long-lived compared to other natural hazards. A severe drought must persist long enough to have an impact on the region's economy, environment, agriculture, or people. Of all of the region's identified hazards, droughts last the longest.

The duration of drought was assessed an index value of four, meaning that a drought typically lasts more than one week.

3.8.3 Regional Vulnerability Assessment

Drought can occur throughout the year and its severity is determined by extremely dynamic, climatological processes that may be exacerbated by climate change.

It should be expected, however, that drought will mostly impact people that are reliant on agriculture and people that rely on water from underground wells. In Connecticut, non-irrigated crops have seen yield reductions during severe droughts, implying that more significant droughts could result in far greater losses. Dried wells can weakening fire response and force people to seek water from other sources if they are not connected to public water utilities.

3.9 Hail

Hail is a weather condition that is associated with a number of previously identified hazards—thunderstorms, winter storms/nor'easters, and tropical cyclones. But hail, like lightning and wind, is worthy of recognition because of its distinct threats to people and property. Hail is a specific form of solid (ice) precipitation, at least 5mm in diameter. The American Meteorological Society defines hail as, "Precipitation in the form of balls or irregular lumps of ice, always produced by convective clouds, nearly always cumulonimbus."[58]

Any storm that produces hail is known as a hailstorm. Hailstorms are born from storms that feature convective updrafts—typically thunderstorms. Convective air currents cycle ice pellets through different altitudes in storm clouds. A hailstone increases in size as it stays trapped in these convective currents, gaining a layer each cycle, until it can no longer be supported and falls to the ground. Heavier hailstones fall more quickly than lighter hailstones of the same shape, increasing the risk to people and property. The largest hailstone in the United States fell in South Dakota and had a diameter of 8 inches[59]. States that are known for tornadoes or violent and frequent thunderstorms are more vulnerable to damaging hail.

Hail is commonly known for damaging cars and their windows, the windows and roofs of homes, and other materials that are capable of being dented or shattered by falling ice; however, crops can be equally vulnerable to hail storms. According to the National Weather Service, hail is responsible for about $1,000,000,000 in damage to property and crops each year in the United States[60]. The National Weather Service will issue a Severe Thunderstorm Warning in the presence of hailstones greater than 1" in diameter. This is the size at which hail begins causing extensive damage. Much smaller hail can cause crop damage though, depending on the sensitivity of the crop.

---

[58] American Meteorological Society, Meteorology Glossary
[59] National Oceanic and Atmospheric Administration, 'Volleyball' from the Sky
[60] National Weather Service Forecast Office, Columbia, South Carolina, Hail

3.9.1 Notable Occurrences

Connecticut's most destructive hail storm on record in the Storm Events Database occurred in June, 1995. This storm includes individual records from the towns of Vernon, Ellington, Manchester, Lyme, Deep River, and Old Saybrook. Ellington, in particular, sustained an estimated $200,000 of damage. In Deep River and Old Saybrook, 2.75" ("baseball" sized) hailstones fell.

In Windham County, hail from records in the Storm Events Database did not exceed 1.75" ("golf ball" sized). This size hail was recorded in 1972, 2004, and 2012. In 1979 and 1999, there were reports of 1.5" hailstones ("walnut" or "ping pong ball" sized). Although no property damage was recorded in the database, it should be expected that these events caused damage. Selected event narratives from the Storm Events Database are listed in Figure 3.9a.

Hail: 05/01/1997 17:45 EST

Thunderstorms moved in from the southwest during the early evening and one particular thunderstorm cell produced the first significant convective weather event of the season. Dime size hail was reported by the local fire station personnel in North Windham and in Woodstock, near the Thompson line, as reported by the Connecticut State Police. There were no reports of damage.

Hail: 08/05/1999 13:48 EST

Severe thunderstorms produced large hail and damaging winds in northern Connecticut. In Hartford County, the storms produced quarter size hail in Unionville, and downed trees and large branches in Farmington, Unionville, Hartford, and Burlington. As the storms moved across Windham County, they produced hail as large as ping pong balls in Pomfret, and hail the size of quarters in Killingly. Thunderstorm winds also downed trees in Pomfret.Hail: 05/25/2014 14:46 EST

Dime size hail fell from 2:46pm to 2:49pm, then nickel to quarter size hail fell.

Source: Storm Events Database, NCDC at NOAA

Figure 3.9a: Selected winter storm events from the Storm Events Database

3.9.1 Regional Risk Assessment

Probability

Reviewing records from the Storm Events Database by NCDC, Windham County towns experienced 24 days with 36 recorded hail events in the past 21 years (since 1994). The database kept records on all instances of hail greater than 0.5” diameter. Additionally, ten days with hail greater than 1” in diameter, over 12 separate events were recorded. Considering the frequency of hail, it was determined that hail is “Highly Likely” and its probability was assessed an index value of four. On average, hail should occur at least once per year in the region.

Impact

The Storm Events Database contained no records of property or crop damage from hail. Since hailstones beyond 1.75” in diameter were not recorded, it is likely that damage was only negligible and was never reported. Reviewing the narratives of individual records, there were also no reports of property damage from hail. The impact of hail was assessed as “Minor”, an index value of one. Negligible property damage and few—if any—injuries should be expected in northeastern Connecticut.

Spatial Extent

The most wide-spread hail storm recorded in the Storm Events Database for Windham County occurred on July 18, 2012. Hail from this storm was recorded in the towns of Ashford, Eastford, Pomfret, Putnam, and Thompson. There were also many records of two-town events, and one three-town event in the database. Most entries, however, involved only one town. Using RFCA, a hail storm’s expected spatial extent is “Small”, and was assessed an index value of two. It should be expected that between 1% and 10% of the region will be affected by a given event.

Warning Time

The storm systems that produce hail can be predicted and tracked using radar, hail cannot be detected until it is formed. According to NOAA, hail inside of thunderstorms is a great reflector of radar energy, allowing meteorologists to detect its presence and size with some accuracy[61]. Radar detection or spotting of hail greater than 1” in diameter will trigger a Severe Thunderstorm Warning for an area. Hail formation, however, is not a long term process. According to the Insurance Institute of South Africa, hail stones can grow between 1mm and 20mm (roughly 0.75”) in approximately 30 minutes[62].

Like the thunderstorms that produce hail, its warning time was assessed an index value of four, meaning that there is typically less than six hours’ notice associated with the hazard.

Duration

Hail storms are typically short-lived and dependent on the carrying capacity of hail-producing clouds. It is unusual for a hailstorm to last more than 15 minutes, even in regions that experience the most severe hail[63]. Records in the Storm Events Database typically lacked information on the duration of specific events in Windham County. A handful of records documented storms lasting five minutes or less in single towns. A recent storm in May, 2014 lasted 15 minutes in the town of Brooklyn and three minutes in the town of Woodstock.

Using this data, the duration of a hail storm was assessed an index value of one, meaning that it will last less than six hours.

[61] National Weather Service Forecast Office, Columbia, South Carolina, Hail
[62] Deon E. Terblanche, The Impact of Hail: A Global Perspective
[63] Nolan J. Doesken, Hail, Hail, Hail!: The Summertime Hazard of Eastern Colorado

3.9.3 Regional Vulnerability Assessment

Mentioned above, hail causes damage to surfaces, and materials that can be easily broken, cracked, or dented; windows, cars, and metal roofs are commonly affected by hail damage. Hail can also cause damage to crops by bruising, stem breakage, and leaf damage.

The entire region is vulnerable to hail damage. Denser, urban areas should expect greater damage to property and threats to health, while rural areas are more vulnerable to crop losses.

3.10 Earthquakes

Earthquakes are violent vibrations in the Earth's crust, resulting from a release of localized tension, caused by crustal plates moving or subducting. As earthquake energy is released, it quickly radiates outward as waves, shaking and rolling the ground, potentially undermining, damaging, and collapsing buildings and structures, damaging roads and underground utilities, and downing power lines and trees. Extreme earthquakes can cause landslides, slumps, tsunamis, and avalanches. Additionally, smaller earthquakes or "aftershocks" can occur after a large earthquake, as crustal plates reset and change position. Fortunately, seismic (relating to earthquakes) activity is very low in Connecticut, and earthquakes of significant magnitude do not pose a probable threat to the region.

An earthquake in Connecticut would be classified as an "intraplate" earthquake, which occurs at the interior of a crustal plate. Ninety percent of the world's earthquakes are "interplate" earthquakes and occur at plate boundaries[64]. The origin of an earthquake is deep underground and its location is known as the "hypocenter". The "epicenter" is the location, on the Earth's surface, directly above the hypocenter. Distance from these centers is an important factor when determining the severity of an earthquake at a given location; all other things being equal, a closer earthquake will have a greater impact. Another important factor is geology; bedrock geology and soil geology play important roles in the conduction of earthquake energy. Stable areas, sitting on solid bedrock experience less-destructive shaking than areas with underlying soils that are loose, unconsolidated, or partially saturated.

The Richter Scale was developed in the 1930s to measure the energy released by earthquakes. It is a logarithmic scale with a base of 10, meaning that each scalar value is an order of magnitude (10x) greater than the preceding value and an order of magnitude less than the proceeding value. Typically, earthquakes greater than 5.0 magnitude can cause damage to structures. 5.0 on the Richter Scale roughly corresponds to V on the Modified Mercalli Intnsity Scale (MMI), commonly used to measure earthquake intensity by describing peoples'

[64] National Oceanic and Atmospheric Administration, Earthquakes

perceptions and expected damage to buildings and goods; the MMI uses 12 Roman numeral values from I to XII. The Moment Magnitude Scale (MMS) is the current scale used to measure magnitude, replacing the Ritcher Scale. A comparison of the three scales can be found in Table 3.10a.

Connecticut and New England have experienced few earthquakes in the past; however, the destructive nature of severe events suggests that steps should still be taken to protect the region's population and property. The entire region could either experience an earthquake directly or feel the effects of one from a considerable distance away. So far, earthquakes are unpredictable; however, they are extremely clustered,

MMI	Description	Richter Scale	MMS
I	Only felt by instruments	2	
II	Felt by few, especially on upper floors	2.5	
III	Felt indoors; vibrations similar to a large truck	< 3	> 2
IV	Felt indoors by many; dishes, windows may move	3.5	
V	Felt by most; tall objects may fall	< 4	> 3
VI	Felt by all; light damage	4	
VII	Very noticable; damage to weaker buildings on fill	< 5	4
VIII	Walls, monuments, bookcases fall; soil liquefaction	< 6	5
IX	Buildings shift off of foundations; ground is cracked	< 7	< 6
X	Most structures severly damaged; rails bent	7	
XI	Few structures standing; large fissures in ground	7.5 - 8	< 7
XII	Total damage; objects thrown into the air	8.5	7.0 - < 8.0

Table 3.10a: Modified Mercalli Intensity scalar values and descriptions compared to approximate Ritchter and Moment Magnitude scalar values
Source: http://scearthquakes.cofc.edu/?page=eqsize

globally, and probabilities for future events can be mapped. Figure 3.10a shows the probability for a damage-causing (magnitude 5.0 or greater) earthquake occurring in southern New England.

3.10.1 Notable Occurrences

Since 1950 there have been 15 earthquakes of at least 1.0 magnitude in Connecticut, and one off of the coast in Long Island Sound, ranging between 1.7 and 3.8 in magnitude[65]. None of these earthquakes occurred in a NECCOG town.

The most severe earthquake in Connecticut's history occurred on May 16, 1791 in Moodus, Connecticut, a village in the town of East Haddam, near the mouth of the Connecticut River[66]. It is now believed that his earthquake would have registered VII in intensity, using the MMI scale[67]. Later, in the nineteenth century, Connecticut experienced four separate earthquakes between 1837 and 1875.

An intensity V earthquake in southern Connecticut cracked plaster walls and damaged items. Recently, across the Connecticut River from Moodus, in the town of Chester, was the epicenter of a 2.0 magnitude earthquake in 2008[68]. According to the *2014 Connecticut Natural Hazard Mitigation Plan Update*, this Connecticut's most recent, noticeable earthquake.

Notable earthquakes that occurred outside of the state, but were still realized by Connecticut residents include: an intensity VII event in Massachusetts, in 1727; a magnitude 5.0 event in Canada, in 2008; and a magnitude 5.8 event in northern Virginia, in 2011[69][70]. Although Connecticut did not sustain any damage from Virginia's 2011 earthquake, it halted play at the New Haven Open at Yale tennis tournament and

[65] United States Geological Survey, Connecticut Earthquake History
[66] United States Geological Survey, Connecticut Earthquake History
[67] Department of Energy and Environmental Protection & Department of Emergency Service and Public Protection, 2014 Connecticut Natural Hazards Mitigation Plan Update
[68] Department of Energy and Environmental Protection & Department of Emergency Service and Public Protection, 2014 Connecticut Natural Hazards Mitigation Plan Update
[69] United States Geological Survey, Connecticut Earthquake History
[70] Department of Energy and Environmental Protection & Department of Emergency Service and Public Protection, 2014 Connecticut Natural Hazards Mitigation Plan Update

prompted an evacuation of the Cullman-Heyman Tennis Center[71]. Additionally, shaking was felt as far north as Quebec, Canada and Chicago, Illinois[72].

3.10.2 Regional Risk Assessment

Probability

Earthquakes that occur, or are felt, in Connecticut are rarely intense enough to cause damage. The most recent, nearby earthquake of significant magnitude occurred in August, 2011 in Virginia. This 5.8 magnitude earthquake was felt in Connecticut but was of little significance.

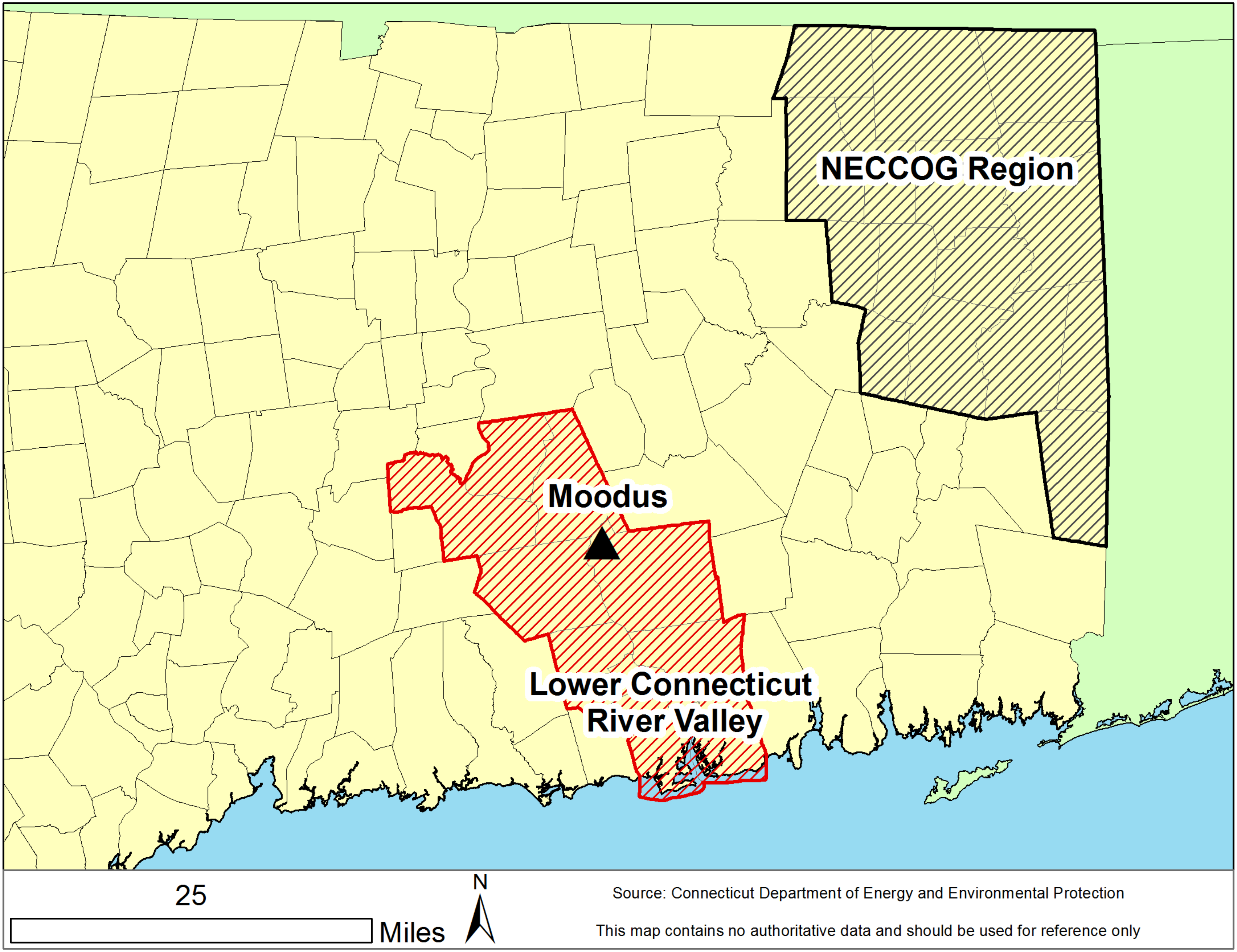
For the purpose of this risk assessment, Figure 3.10a shows that the yearly probability of a 5.0 magnitude, or greater, earthquake occurring within 50 kilometers of Connecticut is between 0.00 and 0.01.

The probability of a damaging earthquake occurring in the next year is “Unlikely”, or an index value of one, meaning that an earthquake of 5.0 magnitude has an annualized return rate of less than 1%. Although there is a slightly higher probability—based on historic events—that a smaller earthquake will occur in Connecticut, these earthquakes have typically posed little or no threat to people or property.

Impact

Although the maximum potential impact of an earthquake is extremely high, it is expected that future earthquakes in Connecticut will cause minimal—if any—destruction. The 1791 earthquake in Moodus, remains the state’s most severe. It was reported that sequential vibrations in the earth lasted much of the night, stonewalls and chimneys were damaged, and that fissures were left in the ground[73]. The areas surrounding

[71] http://www.huffingtonpost.com/2011/08/23/earthquake-new-haven-open-evacuation_n_934470.html
[72] http://earthquake.usgs.gov/earthquakes/dyfi/events/se/082311a/us/index.html
[73] http://earthquake.usgs.gov/earthquakes/states/connecticut/history.php



<u>Figure 3.10b</u>: **The NECCOG region in relation to Moodus, Connecticut and the Lower Connecticut River Valley**

New London Counties are roughly one hour's drive from most NECCOG towns (Figure 3.10b).

Considering the historic lack of deadly and destructive earthquakes in Connecticut, northeastern Connecticut in particular, an earthquake's potential impact was assessed an index value of one, or "Minor". Meaning that, at most, few injuries and minor structure damage would be expected.

Spatial Extent

When compared to the short-lived and unpredictable nature of the hazard, earthquakes have an extremely large spatial extent. Historically, earthquakes as distant as Ontario, Canada have been felt in Connecticut. The recent 5.8 magnitude earthquake in Virginia was felt as far north as Augusta, Maine[74].

An earthquake's spatial extent was assessed an index value of four, or "Large". If an earthquake occurred a NECCOG member town, it would affect over 50% of the region; however, this does not fully describe the spatial extent of earthquakes.

Warning Time

Mentioned above, there is no current method for predicting earthquakes[75]. The warning time associated with earthquakes was assessed an index value of four, meaning that there is less than six hours' notice before an earthquake.

---

[74] Portland Press Herald, Mainers Report Feeling Tremors and Wondering What's Shaking
[75] Robert J. Geller, David D. Jackson, Yan Y. Kagan & Francesco Mulargia, Enhanced: Earthquakes Cannot be Predicted

Duration

In the case of more-extreme earthquakes on crustal boundaries, aftershocks can occur long after the initial earthquake[76]. However, an earthquake in Connecticut should be short-lived and produce small aftershocks, if any. An earthquake's duration was assessed an index value of one, meaning that they last less than six hours.

3.10.3 Regional Vulnerability Assessment

Earthquakes cause damage by ground shaking that stresses the structural integrity of buildings and infrastructure. Common results of earthquakes are foundation and wall cracking, road cracking, and objects falling and breaking. Particularly strong earthquakes can cause buildings and bridges to collapse and destroy key infrastructure. It should be expected, however, that an earthquake in Connecticut or a nearby area will not cause severe damage.

The entire region is vulnerable to the effects of an earthquake, although damages may vary by town. Modeling of a __ magnitude earthquake, for each town, using Hazus-MH software, was conducted and the results are described in Chapters 4.1-4.16.

[76] GNS Science, How Long Does an Earthquake Last?