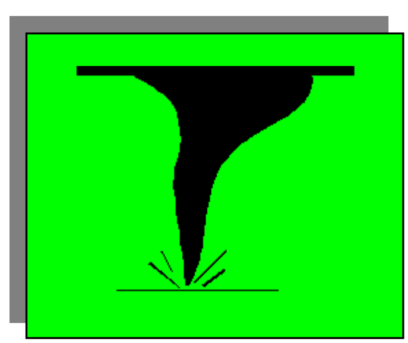
CHAPTER 2

NATURAL HAZARD IDENTIFICATION AND EVALUATION



2.0 GENERAL DESCRIPTION OF CONNECTICUT AND ITS NATURAL HAZARDS

The State of Connecticut had a 2000 population of 3,405,565 persons. Connecticut contains 169 towns within 8 counties (see map on next page, Figure 2-1) covering 5,543.6 square miles. The geography of Connecticut contains a wide variety of landscapes. From the shores of Long Island Sound in southern Connecticut, the land gently slopes upward to rolling hills across the southern half of the State. More rugged terrain covers the northwestern and northeastern areas of Connecticut with forested hills and mountains climbing to elevations of over 2,000 feet. The Connecticut River Valley cuts through the center of the state, and several deep river valleys cut through the eastern and western sections of the state. All of these rivers generally flow from north to south and into Long Island Sound.

There are approximately 8,400 miles of rivers and streams, 6,000 lakes and ponds, 4,300 dams, and 253 miles of shoreline in Connecticut. Because shoreline and riverine areas are relatively flat and easy to build upon, and because waterpower was a major source of industrialization during the 19th century, Connecticut's shoreline and riverine areas have been heavily developed for commercial, residential and industrial uses during the past 200 years.

The climate of Connecticut is moderate with annual rainfall averaging between 44 - 52 inches, and snowfall averaging between 30 inches at the coast of Long Island Sound up to 100 inches in the northwest hills. Temperatures range from highs in the 80's and 90's during the summer months, down to lows in the teens during the winter months. Transcontinental storms (low pressure systems), and storms that form near the Gulf of Mexico and along the East Coast deliver most of the annual rain and snowfall to the State. Heavy short-duration rains are also caused by thunderstorm activity in all but the winter season. Occasional hurricanes, which typically occur between June 1st to December 1st, deliver heavy rains of longer duration.

Approximately once in every ten years, a hurricane strikes Connecticut causing moderate to heavy damage. The extent and location of the damage varies greatly depending on the track, intensity and duration of the hurricane. The Connecticut hurricanes of the 1930's, 40's and 50’s were markedly more severe than the hurricanes that occurred between the 1960's and the 1990's.

Severe flooding occurs in Connecticut approximately once every 5 years. Flooding events in Connecticut are comprised of three types: coastal, riverine, and urban (see section 2.2 for a definition of each type). Deadly tornadoes also occur on average of once every ten years in Connecticut. The last major tornado to affect Connecticut occurred on July 10, 1989 in western Connecticut.

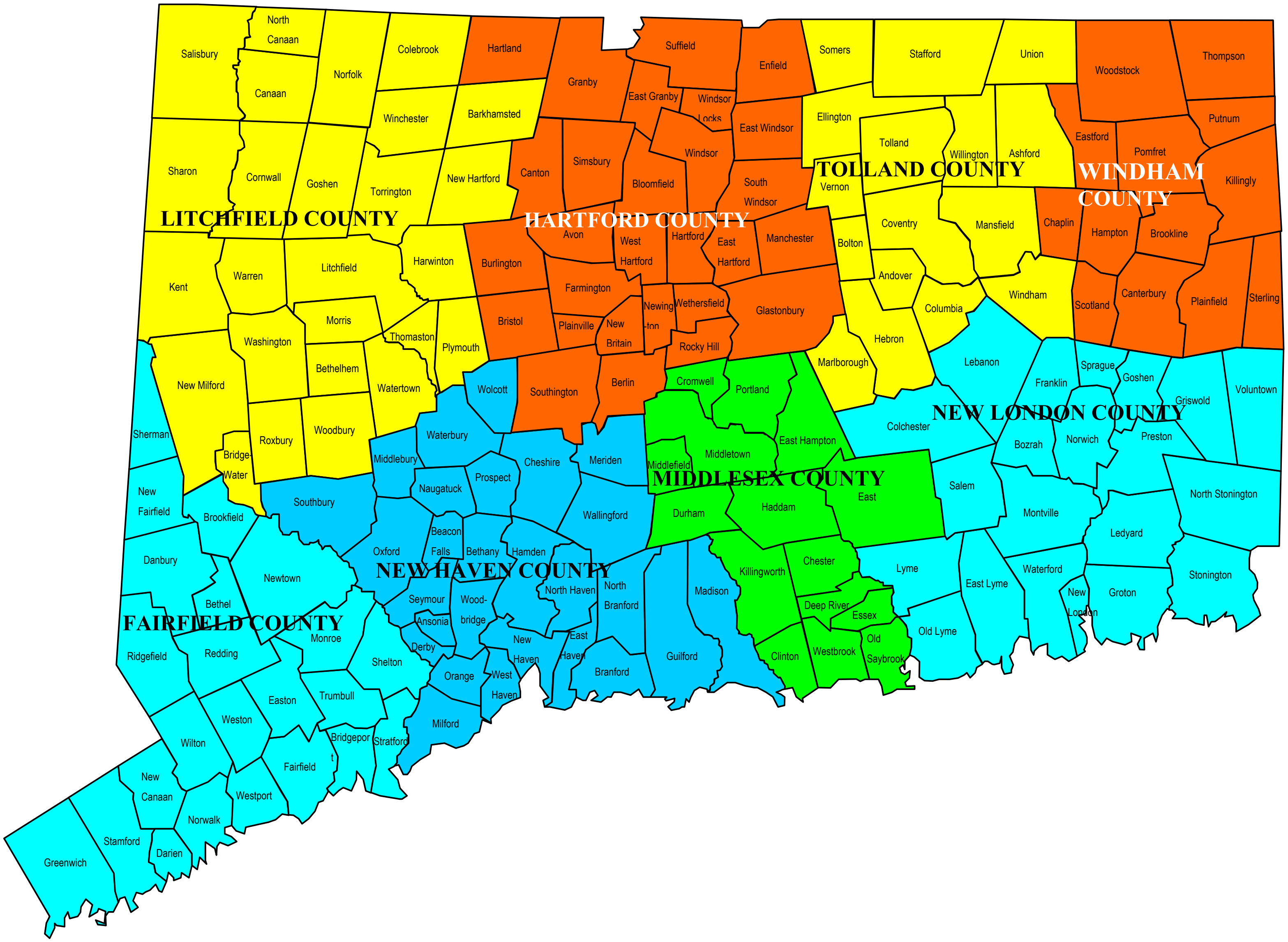
Severe winter storms, which result in over a foot of snowfall combined with either major coastal flooding or ice storms, have occurred seven times since 1973. Preventable fatalities during winter storms are almost always the result of drowning along the coast. Transportation gridlocks of up to 8 hours or more can occur during heavy snowstorms.

Urban flooding has become more prevalent in recent years as urban and suburban areas continue to grow and become too large for older, under-designed drainage systems. Urban flooding strikes most cities on an annual basis and is most often caused by slow moving heavy or severe thunderstorms.

Less frequent in Connecticut are droughts, forest fires and earthquakes that cause damage. Large-scale forest fires are rare in Connecticut. Fires are typically small underbrush and ground fires that rarely damage large numbers of buildings.

Connecticut experiences a magnitude 4.0 or greater earthquake once every 25 years on average. The chances of an earthquake greater than a 6.0 magnitude occurring in Connecticut are once in every 300 years. New England also receives a magnitude 5.0 earthquake every 60 years. The last such 5.0 quake occurred in upstate New York in 2002.

Figure 2-1: TOWN AND COUNTY BOUNDARIES IN CONNECTICUT



2.1 CONNECTICUT'S HISTORY OF AND FUTURE RISK FOR NATURAL DISASTERS

This section examines the types of natural hazards that impact Connecticut, their history and Connecticut's future vulnerability to each type of natural disaster. Tropical Storm Floyd is examined separately in Chapter 5.

2.1.1 HURRICANES

The Atlantic hurricane season begins on June 1st and ends on December 1st each year. A hurricane is a warm-core (having warmer air at its center) tropical cyclone. Hurricanes that affect Connecticut normally form in the tropical Atlantic, Caribbean, or Gulf of Mexico, typically between 15 - 30 degrees north latitude.

Hurricane History

The most intense hurricane to strike Connecticut occurred on September 21, 1938. Flooding, 130 MPH hurricane force winds and a coastal storm surge up to 12 feet high combined to cause the greatest disaster (in terms of lives lost) in the State's history. The hurricane tracked northward up the Connecticut River Valley with the greatest devastation occurring along the coast and east of the center of the hurricane. Shoreline railroad and highway traffic were inoperative for 3 weeks. Along the eastern seaboard the storm killed 600 persons (125 in Connecticut) and injured another 1,700. It destroyed over 9,000 structures, damaged more than 90,000, and resulted in extensive agricultural losses. The damages in southern New England were estimated to be $306 million (1938 dollars), and the damages in Connecticut were estimated to be $53 million (1938 dollars).

Another severe hurricane affected Connecticut on September 14 - 15, 1944. As in 1938, damage was sustained in almost every section of Connecticut. In the 1944 Hurricane however, injuries and storm damage were lower than in 1938 due to additional warning of the storm's approach and the fact that fewer structures were located in vulnerable areas due to the lack of rebuilding after the 1938 Hurricane. Even with the additional warning time, 7 persons were killed, and damages totaled $3 - 5 million (1944 dollars).

The next hurricane to strike Connecticut occurred on August 31, 1954. Hurricane "Carol" (naming of hurricanes began in 1950) tracked across the southeastern corner of the State. Three counties were declared disaster areas. Damages in the remainder of the state were relatively minor. Although Connecticut suffered no fatalities, property damage exceeded $53 million (1954 dollars).

In 1955 torrential rains fell from August 12 - 19, as the result of Hurricanes "Connie" and "Diane". Flood damage was extreme with multiple road/bridge washouts, loss of drinking water, destruction of power lines and loss of communication networks.

Fourteen out of 39 towns affected by the flooding in 1955 were declared health hazards. Seventy persons were killed and 4,700 were injured. The State was declared a disaster area. Two months later, on October 15 - 17, heavy rains again brought flooding to the state. Although the entire State was affected, 28 towns in the southwestern part of the State were the hardest hit. Over 4,200 families were evacuated because of the flooding and 23 persons died. The two flooding events in 1955 totaled an estimated 350 million (1955 dollars) in damage.

During the 1960's Connecticut was indirectly affected by several tropical storms and hurricanes. In 1976, Connecticut was hit by Hurricane Belle. Belle was a Category I hurricane, but still caused 5 fatalities, and some minor shoreline damage.

On September 27, 1985, Hurricane Gloria struck Connecticut, felling thousands of trees and causing minor structural damage. Gloria was a category II hurricane when it made landfall in the Westport area, however, Gloria did not cause flooding due to relatively light rain accompanying the storm. Debris cleanup and restoration of power were the major factors that lead to a disaster declaration for this "dry" hurricane.

On August 19, 1991 Hurricane "Bob" struck Rhode Island. Bob was a category III hurricane that formed in the Bahamas and moved up the eastern seaboard. Bob was a fast moving hurricane that weakened

Figure 2-2: THE SAFFIR-SIMPSON HURRICANE SCALE

The Saffir-Simpson Hurricane Scale is a 1-5 rating based on the hurricane's intensity at a given time. This is used to give an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on the slope of the continental shelf in the landfall region. Note that all winds are using the U.S. 1-minute average.

Category One Hurricane:

Winds 74-95 mph (64-82 kt or 119-153 kph). Storm surge generally 4-5 ft above normal. No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Some damage to poorly constructed signs. Also, some coastal road flooding and minor pier damage. Hurricanes Allison of 1995 and Danny of 1997 were Category One hurricanes at peak intensity.

Category Two Hurricane:

Winds 96-110 mph (83-95 kt or 154-177 kph). Storm surge generally 6-8 feet above normal. Some roofing material, door, and window damage of buildings. Considerable damage to shrubbery and trees with some trees blown down. Considerable damage to mobile homes, poorly constructed signs, and piers. Coastal and low-lying escape routes flood 2-4 hours before arrival of the hurricane center. Small craft in unprotected anchorages break moorings. Hurricane Bonnie of 1998 was a Category Two hurricane when it hit the North Carolina coast, and Hurricane Georges of 1998 was a Category Two Hurricane when it hit the Florida Keys and the Mississippi Gulf Coast.

Category Three Hurricane:

Winds 111-130 mph (96-113 kt or 178-209 kph). Storm surge generally 9-12 ft above normal. Some structural damage to small residences and utility buildings with a minor amount of curtainwall failures. Damage to shrubbery and trees with foliage blown off trees and large tress blown down. Mobile homes and poorly constructed signs are destroyed. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the hurricane center. Flooding near the coast destroys smaller structures with larger structures damaged by battering of floating debris. Terrain continuously lower than 5 ft above mean sea level may be flooded inland 8 miles (13 km) or more. Evacuation of low-lying residences with several blocks of the shoreline may be required. Hurricanes Roxanne of 1995 and Fran of 1996 were Category Three hurricanes at landfall on the Yucatan Peninsula of Mexico and in North Carolina, respectively.

Category Four Hurricane:

Winds 131-155 mph (114-135 kt or 210-249 kph). Storm surge generally 13-18 ft above normal. More extensive curtainwall failures with some complete roof structure failures on small residences. Shrubs, trees, and all signs are blown down. Complete destruction of mobile homes. Extensive damage to doors and windows. Low-lying escape routes may be cut by rising water 3-5 hours before arrival of the hurricane center. Major damage to lower floors of structures near the shore. Terrain lower than 10 ft above sea level may be flooded requiring massive evacuation of residential areas as far inland as 6 miles (10 km). Hurricane Luis of 1995 was a Category Four hurricane while moving over the Leeward Islands. Hurricanes Felix and Opal of 1995 also reached Category Four status at peak intensity.

Category Five Hurricane:

Winds greater than 155 mph (135 kt or 249 kph). Storm surge generally greater than 18 ft above normal. Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. All shrubs, trees, and signs blown down. Complete destruction of mobile homes. Severe and extensive window and door damage. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the hurricane center. Major damage to lower floors of all structures located less than 15 ft above sea level and within 500 yards of the shoreline. Massive evacuation of residential areas on low ground within 5-10 miles (8-16 km) of the shoreline may be required. Hurricane Mitch of 1998 was a Category Five hurricane at peak intensity over the western Caribbean. Hurricane Gilbert of 1988 was a Category Five hurricane at peak intensity and is the strongest Atlantic tropical cyclone of record.

When combined with the August floods, the two flooding events in 1955 totaled an estimated $1

IN DETAIL: COASTAL SHORE EROSION

Generally two types of events account for Connecticut's shoreline erosion. The first is the cumulative effect of tides, waves and wave-induced currents. The second are the compounding effects of hurricanes and winter storms that both cause repeated erosion along Connecticut's coastline. The recurrence interval of these damaging coastal storms is estimated to be 1.14 years.

Based on historical data, approximately 17% of Connecticut's shoreline is critically affected by erosion. Losses from erosion damage and the cost of erosion control measures is now estimated at 5 million dollars annually. Of this figure approximately 20% is for repair of existing erosion control structures.

The 1938 hurricane caused the greatest recorded damage to the shoreline. The storm track and storm surge combined with the normal high tide to destroy much of the existing shoreline by washing away barrier beaches as well as destroying thousands of shoreline properties.

The effects of shore erosion become severe when high tides are coupled with the storm surge from hurricanes or other significant coastal storms. This combination, may by catastrophic, as it was in the 1938 hurricane.

somewhat as it moved over the cooler waters north of the Carolina's. Bob made landfall as a strong category II hurricane in Newport, R.I. at 2:00 PM, on August 19th. Bob moved quickly through Rhode Island and Massachusetts. Tree damage in Connecticut was very light in western areas and light to moderate in eastern and central areas of the State. Flooding was also minor due to the fast forward speed of Bob and the short duration of the heavy rainfall.

On October 30th, 1991, a rare late season Hurricane "Grace" combined with a large non-tropical low-pressure system east of Maine to produce what has become known as the "perfect storm". Damage in Connecticut was light due to the protection of Long Island. However, moderate to heavy damage resulting from 30 – 50 foot seas occurred along the exposed coastlines from New Jersey to Maine. Another factor that made this storm very destructive was its six day duration.

On September 15th, 1999, Connecticut was affected by the remnants of Hurricane Floyd (by then a tropical storm). Damage from Floyd was greatest in the Danbury area of western Connecticut. Hurricane Floyd is covered in detail in Chapter 5.

Future Hurricane Risk

Hurricanes have the greatest destructive potential of all natural disasters in Connecticut. A moderate Category II hurricane can be expected to make landfall in Connecticut once every ten years. Based on the past frequency and intensity of hurricanes in the twentieth century, at least one major hurricane of Category III or IV may occur before 2040. Although winter storms cause more frequent coastal flooding and more annual damage, a single major hurricane (Category III or above) can cause 3 - 10 times that amount of damage.

2.1.2 WINTER STORMS (NOR'EASTERS)

A major winter storm (a.k.a Nor'easter) is typically an intense low-pressure system that forms either in the Carolinas or just off the mid-Atlantic coastline between November 1st and April 1st. These storms normally move in a northeastward direction to a position around 70 degrees north latitude, 40 degrees west longitude or about 80 miles south of Cape Cod.

The Nor'easter derives its name from the strong northeast winds that are characteristic during the storm.

History of Nor'easters

During the past 25 years there have been six major Nor'easters in Connecticut. These major winter storms can be as intense as a Category II hurricane, both in their low central pressure and the flooding they cause. These storms have claimed nearly a dozen lives during the past 25 years, and injured dozens of persons while causing millions of dollars in damages. Deadly winter storms have struck Connecticut in 1979, 1983, 1988, 1992, 1996 and 2003.

During the 90's two major storms hit Connecticut. The first and most intense was the December 10-13 Nor'easter of 1992. Three persons were killed as a result of the storm and 26 homes were destroyed. Tides in Long Island Sound were stacked up by the continued strong east/northeast winds reaching 55 mph. This "stacking" of water resulted in the third highest tide (10.16 Feet NGVD as measured at Bridgeport, CT) ever recorded in LIS and caused over 4.3 million dollars (1992) in damages to over six thousand homes. Inland areas received up to 4 feet of snow in Northeastern Connecticut. The heavy wet snow snapped tree limbs and power lines cutting power to 50,000 homes.

The next major storm to strike Connecticut occurred on January 8-9, 1996. Winter Storm "Ginger" brought up to 27 inches of snow to Connecticut and forced the state to shutdown for 24 hours. In terms of overall snowfall (outside Connecticut) this was the largest winter storm on the U.S. East Coast since 1888.

The last major winter storm occurred on February 17th, 2003. This storm was a very slow moving low pressure system with ample snowfall that blanketed the northeast U.S. from Washington to Boston with 1 – 3 feet of snow. This storm shut down most air travel for 24 – 36 hours.

Meteorology of Winter Storms in Connecticut

Although Connecticut is a small state of less than 100 miles long and 60 miles wide, the state has a very diverse winter climate. Average winter snowfall in central Connecticut is around 50 inches, however, snowfall at the coast is closer to 30 inches, and snowfall in the hills is close to 100 inches. This wide variation is the result of three factors:

1) the warmer waters in Long Island Sound and south of Long Island moderate the winter air mass and this mild air is drawn into coastal areas during winter storms. The mild air changes snow over to rain at the start of the storms and significantly reduces the total amount of snowfall.

2) the elevation of the northern hills combined with their distance from the coast results in colder temperatures, must less rain mixing in and greater snowfalls. In addition, the waters south of Long Island contribute moisture which is drawn into the storms and falls as snow in the hills. The effect of moisture being drawn into the storm can also lead to very intense heavy snowfalls with blinding conditions; and

3) in certain ideal conditions, as low pressure systems move off the mid-Atlantic or Carolina coast they will undergo explosive development. This development can occur in as little as 6 hours, and manifests itself as a sharp drop in central pressure in the area surrounding the storm. This sudden drop in pressure is the result of a large mass of air being lifted and expanded into the atmosphere. The sudden expansion causes the air to cool dynamically. This sudden cooling can change a borderline rain/snow event over to all snow very quickly.

The combination of these factors cannot always be predicted with precision by computer models in advance of a storm. Meteorologists and other experts must often ground-truth the computer models during the event and adjust the forecasts accordingly. One such storm occurred on March 4 – 7, 2001. A storm report from the NWS on this storm can be found at http://www.erh.noaa.gov/box/snow-info2.shtml.

Heavy Snowstorms in Urban Centers

During the early winter of 1988, several large snowstorms affected Connecticut at the height of traffic congestion in late afternoon. Traffic was gridlocked for up to 6 hours in some cases. As a result, the City of Hartford, in cooperation with several of the largest corporations in the City, prepared a snow gridlock plan. When heavy snow is anticipated for an afternoon rush hour, each corporation will send a certain number of employees home early to relieve congestion. This plan significantly reduced congestion in similar storm events later that winter.

On February 5th, 2001, a major snowstorm hit Connecticut at noon with very heavy snow. Up to 25 inches of heavy wet snow fell in a 10 hour period causing major traffic jams and gridlock as agencies and businesses shut down at noon. Traffic jams lasted up to 12 hours in some areas.

Future Risk of Major Winter Storms

Due to their more frequent occurrence winter storms cause more annual flood damage along Connecticut's coastline than hurricanes. The high frequency of major winter storms occurring on average once every 5 years means that they will be a continued threat to both the coast and inland areas from flooding and heavy snowfall. Gridlock plans for major cities need to be enforced and revised annually to prevent gridlock during major storms.

2.1.3 ICE STORMS

Ice storms occur when warm air overrides cold air (32° F or colder) at the surface during a winter storm. The warmer air typically above 1,000 feet changes the precipitation to rain. However, the rain freezes on contact when it reaches the ground because the surfaces are below freezing. Ice storms occur every year in Connecticut. Major ice storms are more rare because they require three factors: 1) temperatures well below freezing (28°F or colder), 2) cold temperatures for an extended duration (over 12 hours), and 3) greater than 1/2 inch of rain. The warmer waters of Long Island Sound and the waters south of Long Island mitigate these factors.

History of Ice Storms

Connecticut's most severe ice storm occurred on December 18, 1973. Ice storm "Felix" resulted in two deaths and caused widespread power outages, which lasted several days. In January 1998, Connecticut narrowly missed the worst ice storm ever recorded in New England. A slow moving low-pressure system pushed into cold air over northern New England on January 7. Freezing rain developed and continued for 4 days.

Damage was catastrophic in upstate New York, Vermont, New Hampshire, Maine and southeastern Canada. Eleven persons were killed in Canada. Ice coated power lines and trees to a thickness of 4 inches in some areas resulting in widespread destruction of power lines and forests. Even heavy-duty steel transmission towers were crushed under the weight of the ice on the power lines. This was widely considered to be a once in a thousand year event.

In November of 2002 an ice storm occurred primarily in Litchfield and western Hartford Counties. The storm resulted in 2.5 million dollars in public sector damages for removal of debris and protective measures. The state’s request for a disaster declaration was denied.

Future Risk of Ice Storms

An ice storm of the magnitude of the 1998 northern New England storm is not considered possible in southern New England due to the close proximity of the warmer waters of Long Island Sound and the Atlantic Ocean. However, repeats of the 1973 ice storm are certainly possible. A return interval was never calculated for the 1973 storm.

2.1.4 FLOODING

River Flooding

Since there is no distinct flood season in Connecticut, major riverine flooding can and has occurred in every month of the year. However, the spring snowmelt, and late summer/early autumn hurricanes are periods when riverine flooding is more likely.

Flood History

The winter of 1935/36 was cold and snowy and the usual January thaw of most winters did not occur. The "Great Connecticut River Flood" of March 1936 was the result of a combination of melting snow and moderately heavy rains over a 13-day period. The rainfall occurred in two peaks. The first peak occurred on March 11 – 12. This peak was the result of an apparent tropical system in the Gulf of Mexico that moved up the Appalachian mountains and merged with a low pressure system over western Quebec. On March 17 – 18 a strong low pressure system moved up the interior East Coast from Virginia to Connecticut and brought heavy rainfall to the entire region. Rainfall amounts of 6 – 8 inches occurred in Connecticut. Combined with melting snow a total of 10 – 30 inches of water flowed into rivers across the entire Northeast from Ohio to Maine and south to Virginia.

Three major rivers were affected in Connecticut, the Connecticut, Housatonic and Thames rivers. Each of these rivers reached all-time highs. The Connecticut River rose 8.6 feet higher than had been historically observed in the 300 year known history of the river.

The flood waters left some 10,000 Connecticut families homeless, contaminated drinking water supplies, brought the threat of typhoid and resulted in curfews in the flood ravaged communities. Across the northeastern U.S. 150 – 200 persons were killed and approximately 100 million dollars in damage was caused in New England alone. In Connecticut, the flood left several dead and $20 million (1936 dollars) in property damage.

From June 4 - 7, 1982 heavy rains fell over most of Connecticut totaling 3 - 16 inches during the 48-hour storm. The hardest hit area was south-central Connecticut where flood frequencies up to the 1,000-year flood event occurred according to the U.S.G.S. This precipitation occurred after a week of prolonged rainfall that had already saturated the ground. Dam failures in the hardest hit area around the mouth of the Connecticut River occurred in the towns of Chester, Haddam, Deep River, and Essex. A total of 30 dams failed or were partially breached during the storm.

Damages from the 1982 storm totaled $270 million (1982 dollars). Thirty-seven homes were destroyed and 1,500 suffered damage. About 200 commercial and industrial businesses suffered damage (including 4 privately owned sewage treatment plants). Eighteen state bridges and 25 municipal bridges also sustained severe damage. Eleven persons were killed during or after the storm. The SCS in cooperation with the DEP performed emergency watershed protection on 14 rivers and streams in Connecticut following the floods. This storm led to the installation of an automated flood warning system in the State of Connecticut in 1986.
Connecticut was struck again by flooding from May 28 - June 2, 1984. Rainfall amounts reported by the NWS Northeast River Forecast Center (NERFC) ranged from 5.90" inches in Bridgeport up to 9.94" in Weston. Due to the wide coverage area of the rainfall across most of New England, flooding occurred on all three large river basins (Housatonic, Farmington, and Connecticut) in Connecticut.

Flood recurrence intervals ranged from 25 - 75 years in these river basins. Damages to public and private structures and facilities totaled $38 million (1984 dollars). The Department of Housing reported that 177 homes suffered major damage and 715 homes suffered minor damage. Temporary housing was required for 700 families.

Although the 1984 flooding event had a 50-year return frequency on the Connecticut River, damage from the storm was greatly mitigated due to large scale flood control projects in Hartford and East Hartford. The establishment of Stream Channel Encroachment Lines (SCEL) in the 1960's also helped prevent development in the Connecticut river floodplain.

On June 5 - 6, 1992, a small but intense low pressure system moved northward from the North Carolina coast up the East Coast. A stationary front across Long Island blocked the northward movement of the storm and most of its moisture was wrung out over south central Connecticut. As much as 7-10 inches of rain fell in an 18-hour period killing one person and causing approximately $10 million (1992 dollars) in flood damages. The Small Business Administration (SBA) declared a flood disaster for this event and provided $612,500.00 in low interest loans to businesses affected by the storm.

Urban Flooding

Severe urban flooding can occur when thunderstorms with intense rainfall develop or stall over an urban center. These are typically summer thunderstorms that can drop 4 - 8 inches of rain over a small area in a matter of hours. Although not as costly in terms of damage or lives lost, urban street flooding is becoming more common in Connecticut because of increased development. On August 11 - 12, 2000 the Town of Stratford and the City of Bridgeport suffered severe urban flooding resulting from a thunderstorm that dropped as much as 7 inches of rainfall over a heavily urbanized area in less than 4 hours. This rainfall was the result of a wet micro-burst from intense slow-moving thunderstorms. A wet micro-burst is an intense downdraft out of the bottom of a thunderstorm that carries a large amount of water. Sixty businesses, 471 homes, and 3 high schools were flooded with as much as 6 feet of water. Damage totaled 5.9 million (2000) dollars, and the SBA declared a disaster, providing low interest loans. Flooding from this storm event exceeded the 500-year recurrence interval along Tanner's Brook in Stratford.

Future Risk of River Flooding

Major flooding of Connecticut's small rivers and loss of several lives can be expected once every 5 - 10 years during the 21st century. Major flooding of the larger rivers (Housatonic, Connecticut, Farmington) with some loss of life and several hundred million dollars in damage can be expected once every 30 years on average. Since the passage of flood regulations in 1968, and the creation of the Federal Emergency Management Agency (FEMA) in 1978, flood vulnerability in Connecticut has continued to increase but at a slower rate than it would have in the absence of regulation. In the future these regulations will serve to slowly eliminate floodprone buildings by requiring the elevation or removal from the 100 year floodplain buildings that are significantly flooded (50% or greater damage).

Future Risk of Urban Flooding

The urban flood risk will continue to increase steadily over the next several decades because many factors that affect urban flooding cannot be mitigated. These include large-scale urbanization combined with older undersized drainage systems that are so extensive that the cost to upgrade them is prohibitive as part of the post disaster mitigation. Urbanization will continue to create more impervious areas that channel increased runoff into under-sized catch basins causing flooding of low lying areas within towns and cities and along small urban brooks. Automated warning systems cannot effectively warn against the very rapid onset of urban flooding that occurs within 1 hour of the start of heavy rainfall.

2.1.5 ICE JAMS

An ice jam is an accumulation of ice in a river that restricts water flow and may cause backwater that floods low-lying areas upstream from the jam. Areas below the ice jam can also be affected when the jam releases, sending water and ice downstream. Ice jam damages can affect homes, buildings, roads, bridges and the environment (e.g., through erosion, sedimentation, bank scour or tree scarring, etc.)

According to the Special Report 94-7 Ice Jam Data Collection, by the US Army Cold Regions Research and Engineering Laboratory (CRREL) (March 1994), ice jams can be generally grouped into three categories: freezeup jams, breakup jams, or a combination of both. Each has different ice jam characteristics and associated mitigation and control.

The following description of the types of ice jams, and mitigation and control techniques has been taken all or in part from Pamphlet No. 1110-1-11, Engineering and Design Ice Jam Flooding: Causes And Possible Solutions, US Army Corps of Engineers, November 1994. Freezeup jams are composed primarily of frazil[1] ice (often described as

[1] Frazil ice consists of small particles of ice formed in highly turbulent, super-cooled water, such as river riffles,

slush ice), with some fragmented ice included, and occur during early winter to midwinter. The floating frazil may slow or stop due to a change in water slope from steep to mild because it reaches an obstruction to movement such as a sheet ice cover, or because some other hydraulic occurrence slows the movement of the frazil. Jams are formed when floating frazil ice stops moving downstream, forms an "arch" across the river channel, and begins to accumulate. Freezeup jams are characterized by low air and water temperatures, fairly steady water and ice discharges, and a consolidated top layer.

Breakup jams occur during periods of thaw, generally in late winter and early spring, and are composed primarily of fragmented ice formed by the breakup of an ice cover or freezeup jam. The ice cover breakup is usually associated with a rapid increase in runoff and corresponding river discharge due to a significant rainfall event or snowmelt. Late season breakup is often accelerated by increased air temperatures and solar radiation.

The broken, fragmented ice pieces move downstream until they encounter a strong intact downstream ice cover or other surface obstruction to flow (such as a dam or bridge), or other adverse hydraulic conditions such as a significant reduction in water surface slope. Once they reach such a jam initiation point, the fragmented ice pieces stop moving, begin to accumulate, and form a jam. The ultimate size of the jam (i.e., its length and thickness) and the severity of the resulting flooding depend on the flow conditions, the available ice supply from upstream reaches of the river, and the strength and size of the ice pieces.

Midwinter thaw periods marked by flow increases may cause a minor breakup jam. As cold weather resumes, the river flow subsides to normal winter level and the jammed ice drops with the water level. The jam may become grounded as well as consolidated or frozen in place. During normal spring breakup, this location is likely to be the site of a severe jam.

Combination jams involve both freezeup and breakup jams. Causes of all ice jams include river geometries, weather characteristics, and floodplain land-use practices such as bridge obstructions or dams.

Ice jam mitigation techniques include both structural and non-structural measures. Some are permanent while others can be deployed under emergency conditions when a jam has formed and flooding is occurring. Ice jam mitigation measures are described in Pamphlet No. 1110-1-11, Engineering and Design Ice Jam Flooding: Causes And Possible Solutions, US Army Corps of Engineers (November 1994).

The CRREL maintains a database of ice jam history, which draws largely from USGS river gauge information. This database includes 132 records of jams in Connecticut dating back to 1902. The database indicates that Connecticut experiences both freezeup and breakup type events. Other sources of information include historical accounts, newspapers, personal interviews and CRREL files. However these sources of data while providing important narrative information about ice events and related damage often lacks quantitative information of the type found in USGS sources.

Recent History of Ice Jams in Connecticut

Salmon River, East Haddam (Leesville)[2]

Ice jam related flooding has historically been a problem along the lower reach of the Salmon River in the Leesville area of East Haddam. Damaging ice jam occurred most recently in 2000 resulting in local road closure.

A similar event in 1994 was the result of a break-up of thick river ice in response to as sudden increase in discharge by snow melt and rainfall. The ice jam formed about a half mile downstream of the Route 151 bridge and progressed back to about 500 feet downstream of the dam. This jam caused water levels in the river to rise even more, flooding several homes and Powerhouse Road.

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during cold, clear winter nights when the heat loss from the water to the atmosphere is very high. As the frazil particles are transported downstream, they join together to form flocs that eventually rise to the surface where they form frazil pans or floes. Frazil ice is often described as *slush ice* because of its appearance. Pamphlet No. 1110-1-11, Engineering and Design Ice Jam Flooding: Causes And Possible Solutions, US Army Corps of Engineers (November 1994) Page 3-1.

[2] Section 22 Planning Assistance To States Program, Salmon River Ice Jam Investigation, US Army Corps of Engineers (December 1995).

Another ice jam event occurred in February 1982 when ice flowed over the dam and jammed at the Route 151 bridge. Many residents in the area believe the lowering of the dam and removal of its control gates has resulted in increased ice jam activity in the area below the dam. Historical evidence supports this presumption as similar winter jams occurred in January 1910 and 1940 when structural damage to the dam allowed ice to flow out of the impoundment. In each of these earlier cases the dam was repaired shortly after the damage occurred.

Based on available records for the Salmon River, it appears that severe ice jams events similar to 1982 and 1994 are likely to occur when ice thickness exceeds 9 inches and average daily discharge increases by 1,400 cubic feet per second (cfs) or more during a single day. Seasonal breakup events based on discharge and temperature records are related to one-day increases in stage, in excess of 1.5 times the ice thickness.[3] Also, tides (tidally influenced back water from the Connecticut River) appear to influence the ice jams location and the ice jams form both above and downstream of the Route 151 bridge.

Shetucket River, Sprague (Baltic)[3]

The Village of Baltic, is a section of Sprague located along the Shetucket River about 9 miles upstream from the Thames River confluence. The total drainage area at Baltic is 460 square miles. There are two hydro-electric dams which affect river discharge. The Scotland Dam is located about 4 miles upstream and the Occum Dam is located about 2.2. miles downstream from the Main Street Bridge (Route 97).

Since 1956, the town has experienced several ice jams during mid to late winter, usually in January and February. Prior to 1956, no ice-related flooding was recorded in the village, probably because Baltic Dam, which breached in 1955, controlled the ice upstream of the populated area of the village.

These breakup jams form when solid ice cover on the Shetucket River breaks up and moves downstream. It appears as though most of the ice that causes the problems in Baltic comes from a 2-mile river reach between the Scotland Dam upstream on the Shetucket River and the village. The slope of the river through this reach is very flat and the channel meanders, causing ice floes to lose momentum and slow down. In addition, the backwater of Occum Dam, located about two miles downstream of the village, causes thick and stable floes. As a result the ice jams tend to remain intact until sufficient pressure is built up behind them to dislodge the jam and move it downstream.

In the mid-1950's, the town requested assistance from the Army Corps of Engineers (ACOE) for non-ice related flooding. As a result an earthen flood control berm was built along the low-lying residential area. This berm has a top elevation of about 77.5 feet NGVD, and a top width of about 8 feet. Although the berm does not tie into high ground, it does provide protection against an approximate 10-year flood event.

On January 29, 1994, an ice jam occurred on the Shetucket River downstream of the Route 97 bridge in Baltic. The ice jam, about three-fourths of a mile in length, was grounded in numerous locations. Although the average ice thickness was 18 to 20 inches, the jam appeared to be about 8 feet thick in several locations. Floodwaters behind the jam overtopped the flood control berm and inundated 31 houses and 4 commercial businesses. One house was severely damaged when the ice broke through the masonry block foundation wall. Eventually, a channel opened under the ice to allow some discharge to pass the jam and the flood area drained, but the jam remained in place.

This severe ice jam flood prompted a post-disaster reconnaissance study by the Army Corps of Engineers. The Corps of Engineers estimated that the ice jam of 1994 resulted in flood damages of $526,000 for 31 residential properties and 4 commercial properties and estimated that the flood stages experienced during the January 1994 flood could occur as a result of ice affected flow approximately once in 12 years. The principal ice jam flood problem is located adjacent to Route 97. It extends a distance of about 2200 linear feet from a drainage culvert under Route 97 that drains a low area south of the state highway to an area upstream of the Blanchette Field at River Drive. It is estimated that there are 84 structures in the 500 year flood

[3] Reconnaissance Report, Shetucket River, Sprague (Baltic), Connecticut, Local Ice Jam Flood Protection, US Army Corps of Engineers (May 1995).

plain, 77 of which are residential structures, 4 are commercial structures and 3 are public buildings in this vicinity.

The ACOE study estimated that, based on ice jam affected flood stages experienced during the January 1994 flood, this event could occur at a recurring interval of once in 12 years for ice affected flow.

Future Ice Jam Risk

Although limited data exists regarding historic damages associated with ice jams, the twelve well-documented ice jams since 1961indicate that typical damages include road closures, bridge damages, evacuation, residential and commercial damage. Rivers in Connecticut susceptible to ice jam formation based on historic events are listed in Table 2-1.

	Table 2-1	
No.	**Rivers Susceptible to Ice Jams**	**Location**
1	Shetucket River	Baltic
2	Salmon River	East Haddam
3	Pomperaug River	Southbury
4	Yantic River	Norwich
5	Moosup River	Plainfield
6	Quanduck River	Sterling
7	Blackledge River	Marlborough
8	Willimantic River	Mansfield
9	Limekilm Brook	Bethel
10	Shepaug River	Roxbury
11	Blackberry River	North Canaan
12	Connecticut River	Hartford

2.1.6 FOREST FIRES

The state-wide system of programs and policies regarding the control of forest fires had its beginning almost 100 years ago. In 1905 the legislature established a formal system of locally-appointed forest fire wardens who were supervised by a State Forest Fire Warden.

At that point in history, Connecticut was largely rural. However, farms were gradually being abandoned as farmers and their families found better wages and easier living in the cities. These farms began to revert to a natural state - first to brush land and then to forest. Forest fires started and burned undetected for days. Once a fire was discovered, the efforts of the few, poorly-staffed, ill-equipped, rural volunteer fire companies were usually only effective in protecting houses and barns from approaching forest fires. Rural roads were largely gravel or dirt, and often deep ruts blocked fire fighters and their equipment from effectively managing a forest fire. Fire-fighting equipment was rudimentary, with very little equipment designed specifically for forest fire suppression.

The statutory foundations for today's forest fire control programs and policies were enacted by the legislature between 1905 and 1927. The death of great numbers of American chestnut trees from 1910 through 1925, due to the Chestnut Blight, led to an increase in the intensity of forest fires during that period. Created during this time was the State Forest Fire Warden system, establishment of a network of fire lookout towers, institution of a system regulating open burning, and the establishment of forest fire patrols.

In 1949, the unusually severe fire weather of the mid to late 1940's (1947 in particular) led the legislature to approve Connecticut's membership in a new, regional mutual aid organization for forest fire protection - the Northeastern Interstate Forest Fire Protection Compact.

The forest of Connecticut today is dramatically different from the Connecticut of 1905, or 1927, or the 1940's. The forest has grown older, the trees larger, and the forest is more extensive. The forest has reclaimed more than 500,000 acres of what was once farmland 90 years ago. But perhaps the most significant change that has occurred is what is now found in the forest – residential development. More and more, Connecticut's citizens are returning to live in or near woodlands and to nestle their homes in its quiet beauty. Once rural towns such as Newtown, Wallingford, and Burlington now can be classified as suburban towns, even though they yet retain much of their tree cover. The interface between humans and the forest is increasing yearly as sprawl extends further and further out from Connecticut's traditional urban cores.

The technology of forest fire fighting and the capabilities of fire fighting equipment have changed dramatically over the years. Advances in gear, equipment, training and technology have progressed. For instance the use of radio and cell phone communication has greatly improved fire fighting command capabilities, and the use of equipment such as air attack by helicopter water drops was unheard of in the 1940's.

These incremental changes to Connecticut's forests, society, and economy over the past 50, 70, or 90 years have significantly changed the face of wild fire control. In September of 1995 The Findings and Recommendations of the Select Committee on Forest Fire Control was published. This report analyzed the statewide system of forest fire control and made various recommendations much of which has been implemented.

Recent Forest Fire Experience in Connecticut

The Forestry Division of the DEP maintains statistical records concerning forest fire occurrence in the state. Reporting of forest fire is based upon the National Fire Incident Reporting System (NFIRS). This system came on line in 1997 and is administered through the State Fire Marshal's Office. This system has greatly improved the accuracy of reported data concerning forest fires (cause, size, etc.)

In Connecticut, approximately 600 acres per year are burned by wildfires (1994 through 2003).[4] This annually represents less than three one hundredths of a percent of the total forested acreage in Connecticut. Connecticut wild fire experience indicates that fires are small and detected early. During the last ten years only one wildfire occurred of slightly greater than 300 acres. The vast majority of wildfires are less than 10 acres in size. Arson is the number one known cause of forest fires. Almost one-half of all wildfires are intentionally set.

During the past ten years, the worst wildfire year in terms of both number of fires and total acreage burned occurred during 1999, which was the fourth hottest year of the past 100 years. One thousand seven hundred and thirty three (1733) acres burned and over 345 separate fires marked this hot and dry summer of 1999. This again points to the small and contained nature of most wildfires in Connecticut. The annual acreage of forests lost through wildfires has been declining dramatically over the past generation. Societal changes are leading to less backyard debris burning, and less uncontrolled or unsupervised interaction with forests and the natural environment as a whole. Statistics indicate that while Connecticut has an increasing urban/wildfire interface, there is not a large resultant wildfire problem.

Forest Fire Risk

Connecticut traditionally experiences high forest fire danger in the spring from mid-March through May. DEP's Division of Forestry continually monitors the danger of forest fire to help protect Connecticut's 1.8 million acres of forest land. Throughout the spring forest fire season, DEP sends daily advisories on forest fire danger levels to DEP's state park forest field staff, municipalities, fire departments and the media. Forest fire danger levels are classified as low, moderate, high, very high or extreme. In an average year, approximately 600 acres of Connecticut woodland are scorched by forest fires.

The DEP Forestry Division is now utilizing precipitation and soil moisture data provided through the Connecticut Automated Flood Warning System to compile forest fire probability forecasts during the spring fire season. This allows the Division to watch only the driest areas and has resulted in a reduction of both costs (measured in the thousands of dollars) and risk.

[4] Statistics on Connecticut forest fires complied from USDA Forest Service Annual Wildfire Summary Reports for 2003 through 1994.

2.1.7 TORNADOES

History of Tornadoes

Connecticut experienced 81 tornado incidents in the period from 1950-2003. These incidents have occurred throughout all of Connecticut in the months from April through October (see figure 2-3). These tornadoes have caused 590 million dollars in damage, claimed at least 7 lives and injured 700 persons. Connecticut averages approximately three tornadoes every two years.

The deadliest tornado on record to strike Connecticut occurred August 9, 1878 in central Connecticut. Although damage along its two-mile path was limited, it left 34 persons dead and injured over 100. Another deadly tornado occurred in Connecticut on May 24, 1962, in which one person was killed and 45 injured. The 1962 tornado destroyed 70 structures and heavily damaged 175 others along its 12-mile path. Total damages exceeded 5 million (2004 dollars).

On October 3, 1979, a tornado ripped a path through Windsor Locks, killing 2 persons, and injuring 10 others. It destroyed 12 homes, left another 40 uninhabitable and caused an estimated 214 million (1979) dollars in damages. As a result of this tornado, two towns were declared Federal disaster areas.

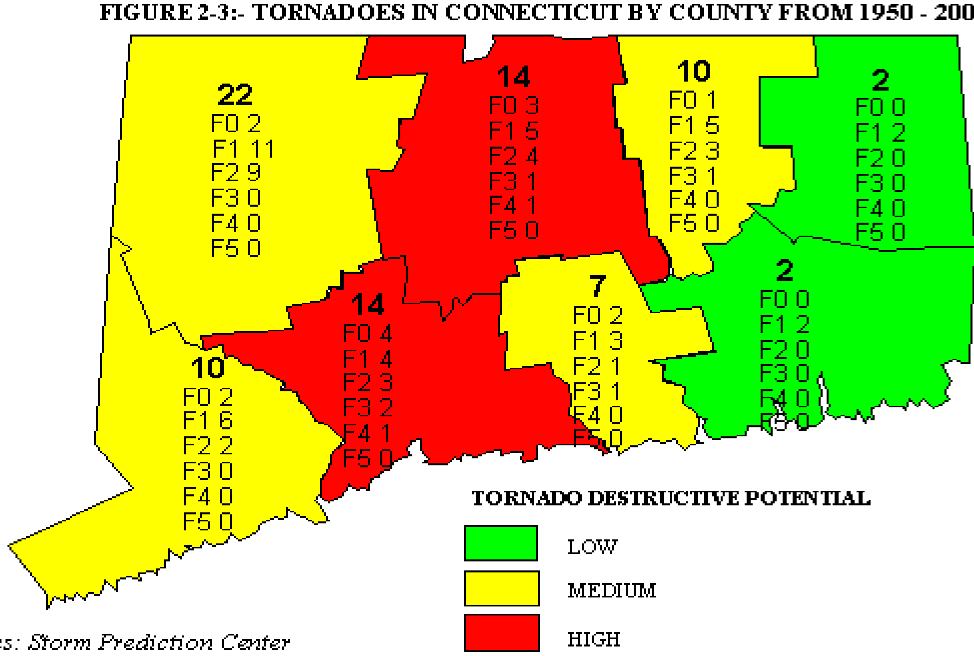
The most recent deadly tornado in Connecticut occurred on July 10, 1989. The tornado cut a path through western Connecticut, from Salisbury to New Haven in less than 1 hour. Two persons were killed and 67 homes were destroyed. Damages totaled 125 million (1989) dollars, and a Presidential Disaster (FEMA-837-DR-CT) was declared.

Future Tornado Risk

The pattern of occurrence and locations for tornadoes in Connecticut is expected to remain unchanged in the twenty-first century. The highest risk for tornadoes is expected in New Haven and Hartford counties. The second area of moderate to high risk is in Fairfield and New Haven counties. The counties of Middlesex, Tolland and Windham have a moderate risk and the county of New London can expect a low risk.

Figure 2-3 shows the number of tornadoes which have occurred in each county since 1950. Tornado intensities are measured by the Fujita Scale from F0 (lowest wind speed) to F5 (highest wind speed).

FIGURE 2-3:- TORNADOES IN CONNECTICUT BY COUNTY FROM 1950 - 2003



Sources: Storm Prediction Center
National Climatic Data Center

2.1.8 DROUGHT

Droughts have occurred periodically in Connecticut, most recently during 1964-1968 1981, 1987, 1988 and 2002. Droughts can vary widely in duration, severity, and local impact. They can have widespread social and economic significance that require the response of numerous parties.

While the agricultural drought of 1957 was the most disastrous to the State's agricultural interests it was also a severe meteorological drought for small reservoirs in the State. Other meteorological droughts of June 1929 through July 1932 and the mid-60's were also very serious. Connecticut experienced its drought of record during the 1960's with rainfall deficits reaching their highest levels in the spring of 1965. This drought severely restricted the ability of a number of water utilities throughout the state to continue to provide unlimited service to their customers.

Precipitation and Physiography[5]

Connecticut enjoys relatively abundant precipitation, which ranges from approximately 40 inches median annual along the coastal zone to a median-annual precipitation of over 53 inches in the western uplands. See map below which depicts median annual precipitation in Connecticut. The distribution of precipitation in both space and time is strongly influenced by physiography.[6]

MEDIAN ANNUAL PRECIPITATION IN CONNECTICUT 1951-1980

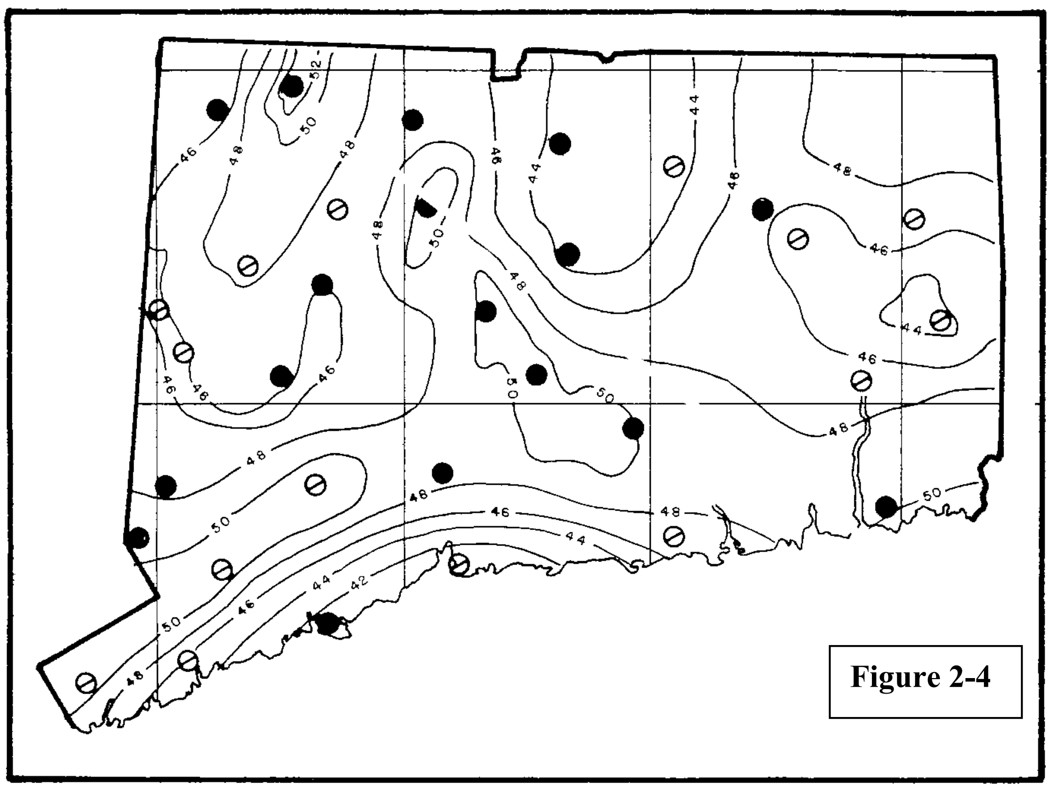


Figure 2-4 **:**Hunter, Bruce W. and Meade, Daniel B. Precipitation in Connecticut 1951 – 1980. Natural Resources Center, Connecticut Department of Environmental Protection, DEP Bulletin No. 6 (1983).page 14.

[5] Hunter, Bruce W. and Meade, Daniel B. Precipitation in Connecticut 1951 – 1980. Natural Resources Center, Connecticut Department of Environmental Protection, DEP Bulletin No. 6 (1983).

[6] Hunter, Bruce W. and Meade, Daniel B. Precipitation in Connecticut 1951 – 1980. Natural Resources Center, Connecticut Department of Environmental Protection, DEP Bulletin No. 6 (1983).

The distribution of precipitation in Connecticut may be roughly divided into four major physiographic zones.[7] A coastal zone, extending two to ten miles inland from Long Island Sound is characterized by low elevation, low relief hills, and numerous small bays, inlets, and tidal marshes.

The central lowlands zone extends north to south through central Connecticut from Massachusetts to the coast and ranges up to 20 miles in width. This lowland includes parts of three major river valleys; the Connecticut, the Farmington, and the Quinnipiac. Topography is generally flat with the exception of narrow north-south ridges that rise abruptly to elevations as much as 700 feet above the lowlands.

The eastern and western uplands are characterized by hills and valleys. Elevations in eastern Connecticut range from 250 feet to over 1,000 feet above sea level. The uplands of western Connecticut range in elevation from 250 feet to over 2,000 feet above sea level, and the area is characterized by considerable and abrupt topographic change.

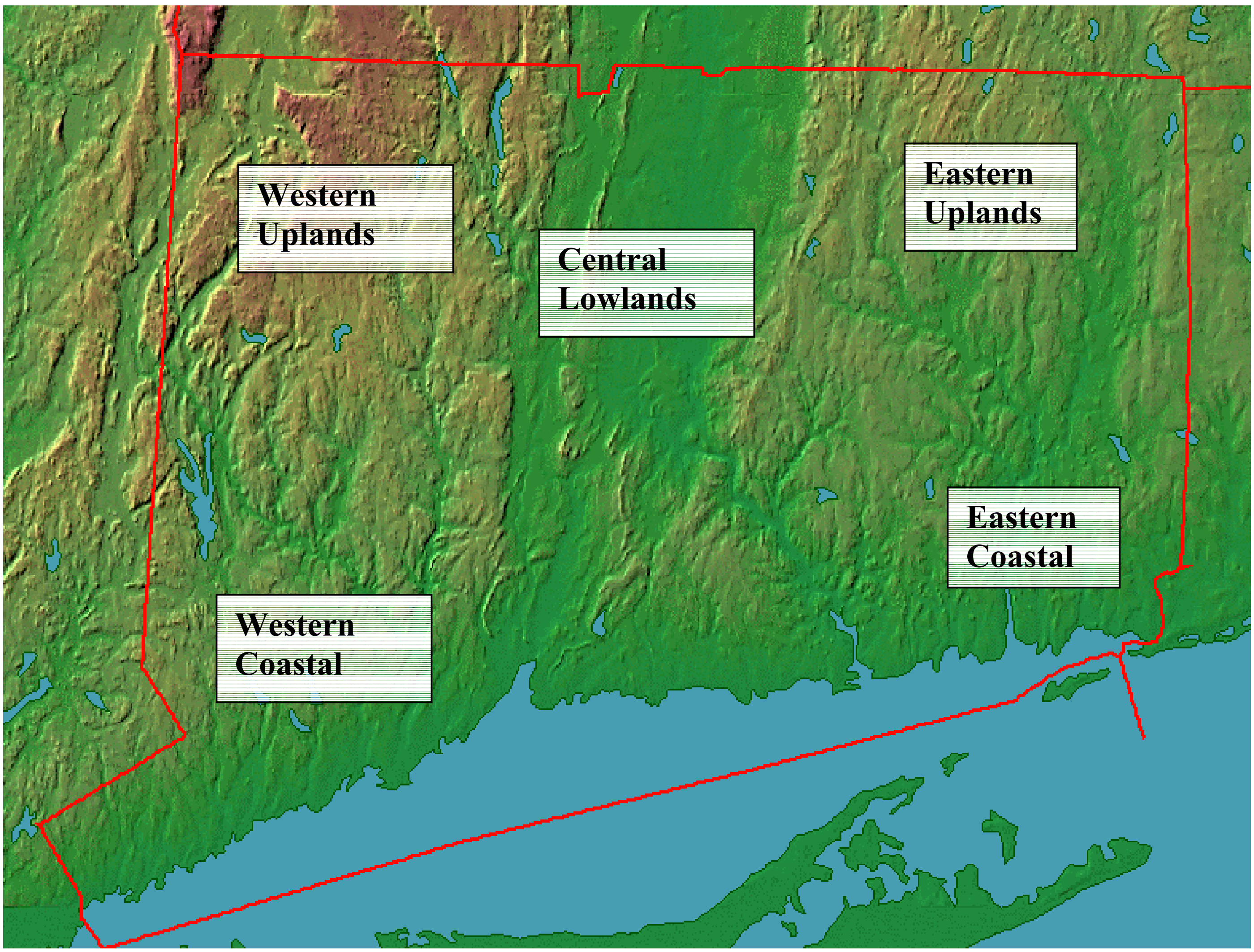


Figure 2-5 Connecticut Physiographic Zones

[7] Hunter, Bruce W. and Meade, Daniel B. Precipitation in Connecticut 1951 – 1980. Natural Resources Center, Connecticut Department of Environmental Protection, DEP Bulletin No. 6 (1983).

Drought Categories

Donald A. Wilhite, director of the National Drought Mitigation Center, and Michael H. Glantz of the National Center for Atmospheric Research categorized the definitions of drought in terms of four basic approaches to measuring drought: meteorological, agricultural, hydrological, and socioeconomic. The first three approaches deal with ways to measure drought as a physical phenomenon. The last deals with drought in terms of supply and demand, tracking the effects of water shortfall as it ripples through socioeconomic systems. Each of the four basic categories of drought are discussed below (taken generally from the National Drought Mitigation Center web site except where otherwise noted.)

Meteorological drought is usually an expression of precipitation's departure from normal over some period of time. These definitions are usually region-specific, and presumably based on a thorough understanding of regional climatology. Meteorological measurements are the first indicators of drought. In Connecticut basic measures of meteorological drought include precipitation deficits and the Palmer drought severity index.

Agricultural drought occurs when there isn't enough soil moisture to meet the needs of a particular crop at a particular time. Agricultural drought happens after meteorological drought but before hydrological drought. Agriculture is usually the first economic sector to be affected by drought. The key to agricultural drought is not only its severity but also its timing. In Connecticut, agricultural droughts tend to be most serious when the plants are forming or filling their seeds, generally in mid-summer (*Drought, Forests and Agriculture in Connecticut*, Dr, David Miller, UCONN, 2002).

One of the most significant historic agricultural droughts in Connecticut occurred during 1957. It was a short intense period of precipitation deficit that corresponded with the growing season. "Precipitation from May 3 to October 3 ranged from 7 to 8 inches in the extreme northeast to 14 to 16 inches in southern hilly areas away from the immediate coast. Statewide precipitation during the period averaged 55 percent of normal."8

Hydrological drought refers to deficiencies in surface and ground water supplies. It is measured as streamflow and as lake, reservoir, and groundwater levels. There is a time lag between lack of rain and less water in streams, rivers, lakes, and reservoirs, so hydrological measurements are not the earliest indicators of drought. When precipitation is reduced or deficient over an extended period of time, this shortage will be reflected in declining surface and subsurface water levels.

Although all droughts originate with a deficiency of precipitation, hydrologists are more concerned with how this deficiency plays out through the hydrologic system. Hydrological droughts are usually out of phase with or lag the occurrence of meteorological and agricultural droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system such as soil moisture, streamflow, and ground water and reservoir levels. As a result, these impacts are out of phase with impacts in other economic sectors. For example, a precipitation deficiency may result in a rapid depletion of soil moisture that is almost immediately discernible to agriculturalists, but the impact of this deficiency on reservoir levels may not affect hydroelectric power production, drinking water supply availability or recreational uses for many months.

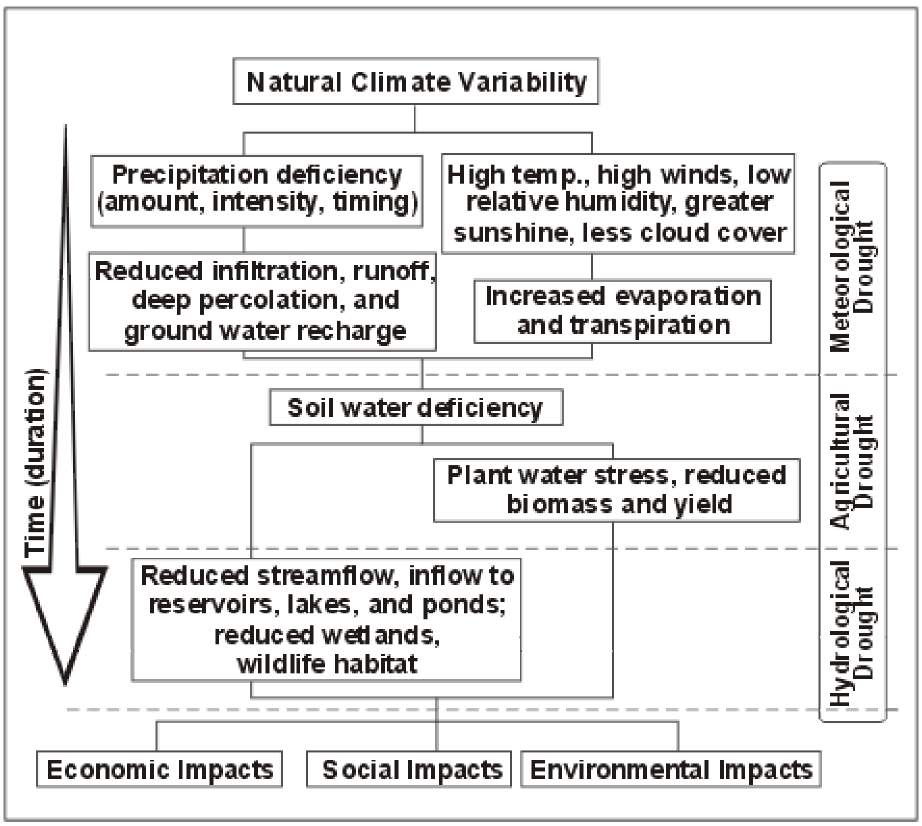
Hydrological Drought and Land Use

Although climate is a primary contributor to hydrological drought, other factors such as changes in land use (e.g., deforestation), land degradation, and the construction of dams all affect the hydrological characteristics of the basin. Because regions are interconnected by hydrologic systems, the impact of meteorological drought may extend well beyond the borders of the precipitation-deficient area. For example, the Southwest Regional Pipeline interconnects most of the major public water supply systems in Fairfield County, Connecticut. This promotes supply sharing, and system redundancies and results in mitigating the effect of a hydrological drought on any one system. However, since the

[8] Brumbach, Joseph J. The Climate of Connecticut. State Geological and Natural History Survey of Connecticut, Bulletin Number 99, (1965). P.109

entire Fairfield county coastline area is dependent upon large reservoirs located further inland, meteorological drought inland may severely affect the sources of supply resulting in the need for drought restrictions in the coastal service areas even if these areas are not experiencing meteorological drought. Land use change is another one of the ways human actions alter the frequency of water shortage even when no change in the frequency of meteorological drought has been observed. For instance as the degree of imperviousness increases due to development, recharge of groundwater is lessened and low-flows in streams which depend upon this groundwater infiltration are reduced.

Figure2-6: ***Sequence of Drought Impacts***



From the National Drought Mitigation Center

Sequence of Drought Impacts

The sequence of impacts associated with meteorological, agricultural, and hydrological drought further emphasizes their differences. When drought begins, the agricultural sector is usually the first to be affected because of its heavy dependence on stored soil water. Soil water can be rapidly depleted during extended dry periods. If precipitation deficiencies continue, then people dependent on other sources of water will begin to feel the effects of the shortage. Those who rely on surface water (i.e., reservoirs and lakes) and subsurface water (i.e., ground water), for example, are usually the last to be affected. A short-term drought that persists for 3 to 6 months may have little impact on these sectors, depending on the characteristics of the hydrologic system and water use requirements.

When precipitation returns to normal and meteorological drought conditions have abated, the sequence is repeated for the recovery of surface and subsurface water supplies. Soil water reserves are replenished first, followed by streamflow, reservoirs and lakes, and ground water. Drought impacts may diminish rapidly in the agricultural sector because of its reliance on soil water, but linger for months or even years in other sectors dependent on stored surface or subsurface supplies. Ground water users, often the last to be affected by drought during its onset, may be last to experience a return to normal water levels. The length of the recovery period is a function of the intensity of the drought, its duration, and the quantity of precipitation received as the episode terminates.

Socioeconomic drought refers to the situation when water shortages begin to effect people and their lives. It associates economic good with the elements of meteorological, agricultural, and hydrological drought. For instance when a hydrological drought becomes so severe as to result in use restriction or prohibition against non-essential uses, some businesses may be adversely affected. Some economic goods such as hydro power are dependent upon the weather and resultant stream flow. Due to variations in climate, some years have high supplies of water, but other years the supply is very low. A socioeconomic drought takes place when the supply of an economic good cannot meet the demand for that production, and the cause of this short-fall is weather related (water supply).

2.1.9 POWER GRID DISRUPTION/ GEOMAGNETIC STORMS

During the summer of 2003 a severe blackout occurred across the northeastern United States due to a series of power system overloads in western New York and the eastern Great Lakes region. The resulting blackout lasted for over 24 hours in some cities and caused severe disruptions of communications and transportation services in New England.

One of three causes are usually responsible for major blackouts; 1) human error, 2) inadequate system design and safeguards, and 3) geomagnetic storms. Although the frequency of blackouts caused by human error and inadequate system design cannot be predicted with certainty, geomagnetic storms are somewhat more predicable. Geomagnetic storms occur when solar flares appear on the sun. These solar flares eject ionized gas into space, some of which moves towards earth. When this gas comes into contact with the earth's magnetic field, electromagnetic currents are formed, which can disrupt power lines, and cause blackouts. Table 2-2 shows the expected return frequency for geomagnetic storms:

Table 2-2: Effects of Geomagnetic Storms

Category/ Scale	Effect	Frequency
G 1 Minor	Weak power fluctuations on grids. No communications effects	2.3 Days
G 2 Moderate	Moderate power fluctuations on grids. HF interferance at high latitudes.	6.7 Days
G 3 Strong	Voltage corrections may be required on grids, some false alarms.	20 Days
G 4 Severe	Potential widespread voltage control problems may trip out key assets from Grid.	40 Days
G 5 Extreme	Widespread voltage control problems. Some complete system collapses causing blackouts. Possible satellite disruption and failure. High frequency (HF) radio communications not possible on sunlit side of earth .	2.75 years
Source: NASA Space Weather Scales		

Future Risk of Power Grid Disruption Due to Geomagnetic Storms

During normal demand, the northeast power grid is not highly vulnerable to geomagnetic storms on the scale from G1 – G4. However, extreme (G5) events may cause blackouts in limited areas during normal demand.

During peak demand, the state becomes much more vulnerable to G3 and G4 events. If these lesser events occur during a late summer afternoon when demand is at it's greatest, blackouts may result. The relatively frequent occurrence (every 20 – 40 days) of these storms will coincide with peak demand periods several times each year. Some disruption may occur during these periods.

The worst case scenario would involve a G5 event which occurs during a peak demand period. The relatively infrequent occurrence (every 2.75 years) of G5 storms and the relatively short periods of peak demand (20 days each summer for 12 hours per day) combine to make this type of event relatively rare.

2.1.10 EARTHQUAKES

Earthquakes are caused by the shifting of sections of the Earth' s crust along faults, fractures that break up large sections of bedrock into separate units. There are many more inactive faults than active ones. Most of the faults in Connecticut were made millions and millions of years ago. Connecticut is considered to be a moderate seismic risk as defined by the Federal Emergency Management Agency. However, the term, "moderate" relates to the fact that earthquakes in the State have a relatively long reoccurrence interval and not that the earthquake magnitudes or impact on the population is necessarily moderate. According to the Northeast States Emergency Consortium there have been a total of 137 recorded earthquakes in Connecticut from 1568 – 1989.

The magnitude of an earthquake is a measure of the amount of energy released. Each earthquake has a unique magnitude assigned to it. This is based on the amplitude of seismic waves measured at a number of seismograph sites, after being corrected for distance from the earthquake. Magnitude estimates often change by up to 0.2 units, as additional data are included in the estimate.

Table 2-3: Richter Earthquake Magnitude Scale

Magnitude	Description
M = 1 to 3	Recorded on local seismographs, but generally not felt.
M = 3 to 4	Often felt, no damage.
M = 5	Felt widely, slight damage near epicenter.
M = 6	Damage to poorly constructed buildings and other structures within 10's km.
M = 7	*"Major"* earthquake, causes serious damage up to ~100 km (recent Taiwan, Turkey, Kobe, Japan, and California earthquakes).
M = 8	*"Great"* earthquake, great destruction, loss of life over several 100 km (1906 San Francisco).
M = 9	*"Rare"* great earthquake, major damage over a large region over 1000 km (Chile 1960, Alaska 1964.)
M = 10	Very rare in the world. Complete destruction.

The Richter scale is logarithmic, that is an increase of 1 magnitude unit represents a factor of ten times in amplitude. The seismic waves of a magnitude 6 earthquake are 10 times greater in amplitude than those of a magnitude 5 earthquake. However, in terms of energy release, a magnitude 6 earthquake is about 31 times greater than a magnitude 5.

The intensity of an earthquake varies greatly from site to site depending on the distance from the earthquake epicenter, ground conditions, and other factors.

Earthquake History in Connecticut

A significant earthquake occurred in Newbury, Massachusetts in 1727, and was felt from Maine to Delaware. On May 16, 1791, the citizens of Moodus, Connecticut experienced a violent shaking of the earth. Although this earthquake was felt from New York to Boston, only minor damage occurred in Moodus.

Another severe quake occurred in the early morning hours of November 18, 1755, near Cape Ann, Massachusetts. This quake registered nearly 7.0 on the Richter scale and caused considerable damage in Boston.

More recently there have been several quakes within states neighboring Connecticut. During 1982, there was an earthquake swarm near Albany, NY, just as there was one that year in Moodus. The Albany quakes were eight miles deep. Earthquakes near Moodus rarely exceed one mile in depth. Other quakes of the eighties and nineties have occurred in north central New York, New Hampshire, Massachusetts and New Brunswick, Canada. Buildings constructed in Connecticut were not required to be tolerant to seismic activity prior to 1975. During the 1980's, several of the old factory structures were converted to condominiums, health clubs, or other occupied uses. Connecticut updated its building codes to include the new BOCA codes for seismic activity in 1992.

2.1.11 TIDAL WAVE (TSUNAMI) HISTORY

Tidal waves along the East Coast are rare (100 year) events and are caused by two types of natural events: offshore earthquakes causing submarine landslides; and backwash from intense hurricanes or severe thunderstorms.

The last documented case of a tidal wave along the Atlantic coast induced by an earthquake occurred in Nova Scotia in 1929. An offshore earthquake triggered a massive underwater landslide in the Grand Banks offshore, which produced a tidal wave that killed 28 persons in Nova Scotia.

There were two hurricane-induced tidal waves in New Jersey during the 20th century. These were not storm surges caused by the land-falling hurricanes, but were the result of wind-driven water being forced offshore by strong northwest winds. When the winds suddenly slackened off, the water rushed back into the coast resulting in waves 25 - 50 feet high. This happened in 1938 and again in 1944. Five persons were killed in the 1944 wave.

The landmass of Long Island provides protection to most of the Connecticut coastline from tidal waves and hurricane-induced waves of the type that have struck New Jersey.

2.2 CONNECTICUT'S VULNERABILITY TO NATURAL HAZARDS

Since flooding is the principal cause of loss of life and property damage in Connecticut, it is given the greatest emphasis in natural hazard mitigation planning efforts. Most of the natural disasters that have affected Connecticut in the past 100 years have involved flooding which could be caused either directly or indirectly by heavy rainfall or due to other factors such as rapid snowmelt or high winds stacking up water along the coast. This section outlines Connecticut's vulnerability to these hazards as well as ice storms, tornados, forest fires, geomagnetic storms, hurricanes, tsunamis and earthquakes in terms of property damage potential, loss of utilities and loss of life. Discussion of other indicators of state vulnerability and the impact of no action are included within this section of the plan.

Although Connecticut may be affected by all of the hazards listed above, flooding continues to be the major cause of damage.

2.2.1 FUTURE HURRICANE VULNERABILITY

Hydrology of Long Island Sound

Since the end of the last ice age, Long Island has sheltered most of the Connecticut coastline from large sea waves produced by hurricanes, winter storms and tidal waves. However, the shape and directional orientation of Long Island Sound creates other flooding hazards unique to the Connecticut coast.

During storm events in which there is a strong easterly or northeasterly component to the wind that lasts more than one tide cycle, water piles up in the Sound and is unable to appreciably flow out due to the pressure of the wind. Coastal flooding, particularly in the western end of the Sound, is the result. Although the threshold for significant flooding is approximate, the following criteria are used to determine if flooding will occur:

1) Winds of greater than 30 mph lasting more than 12 hours;

2) Wind direction in a range from the northeast (45 degrees) to the east southeast (120 degrees); and

3) Astronomical high tides.

The combination of these three factors can lead to moderate to major flooding in Long Island Sound. The last event to combine all three factors occurred in December 1992.

There are three other factors that may lead to increased vulnerability to coastal flood events resulting from hurricanes. First, it is generally acknowledged that temperatures will continue to slowly warm in the 21st century. This may slightly increase the risk from powerful hurricanes because the warmer air will lead to warmer ocean water, which in-turns provides more energy for the development of powerful hurricanes.

Second, Connecticut's population continues to increase. From 1950 - 2000 the State's population increased 70%. Most of this increase has occurred in the suburbs surrounding major cities. Population in most of Connecticut's cities has dropped since 1950.

Coastal population increases at around 33% have been about half that of the state average (see figure 2-7 on page 2-27). This is primarily due to the fact that the majority of the coastline had already been heavily developed by 1950.

In contrast, and the third factor is the markedly above average growth that has occurred in east coastal New Haven county and all of coastal Middlesex county. These areas are highly vulnerable to a repeat of the 1938 hurricane because they are once again highly developed in an area subject to a direct strike from a hurricane.

The inland effects of future hurricanes will also be significant for several reasons. Although Connecticut adopted the latest BOCA building codes in the early 90's, these changes affect only new construction or renovations. Most of the existing housing stock in Connecticut was built before 1990 and is unaffected by the code changes. In general building codes have been revised following each major disaster in Connecticut during the 20th century.

Because much of the existing housing stock predates the code improvements, it is highly susceptible to roof and window damage from high winds. Also, a large number of homes (about 32,000) in Connecticut are within the 100-year floodplain. Because the expense of mitigating these vulnerabilities all at once would be extreme and cost-prohibitive, the older homes will continue to be damaged and it is expected that most will be removed from of the housing stock over the next 100 years due in part to substantial damage, but also due to simple aging of the structures and changes in demands from housing markets regarding the style, type and size of housing units desired.

During the next 45 years the state population is expected to increase by 49% (according to the U.S. Census Bureau's middle series estimate) to 4,866,855 by 2050. All areas of growth and development expand the state's vulnerability to natural hazards such as hurricanes.

An increasingly major impact of hurricanes is on public and private communications. As our state becomes more dependent on the Internet and mobile communications (cellular, paging, and email) for commerce, the disruptions caused by power outages and damaged communications lines will increase. In addition, many persons now rely on these vast communications networks to pay bills, schedule appointments and conduct their lives. When Hurricane Bob struck Connecticut in 1991, the Internet, as we know it, didn't exist and cell phones and pagers were only just beginning to become common. A major hurricane has the potential of causing complete disruption of power and communications for up to 3 weeks rendering many cell phones, pagers, computers and the Internet inoperative. Workplace productivity greatly depends on computers and the Internet and would be severely affected. Personal communications and many emergency communications systems now rely on cell phones and these systems would also be severely affected, although the exact impact cannot be calculated empirically. This remains a significant but quantitatively unknown risk in Connecticut.

In addition, stronger regulations and hazard mitigation targeted at coastal and riverine floodplains should help to lower the vulnerability to flooding (only in floodplain areas) relative to the vulnerability to high winds (all exposed areas) during the next 50 years, although flooding is expected to remain the prime threat.

2.2.2 FUTURE VULNERABILITY TO MAJOR WINTER STORMS

Connecticut will become increasingly vulnerable to major winter storms during the next 20 years due to our increasing population and its heavy dependence on transportation. Connecticut's dense population and aging transportation network may result in severe gridlock during winter storms. The State is especially vulnerable to two types of winter storm: 1) rapid onset of heavy snow over urban areas and 2) icing of roadways as a result of lighter snow events that lead to freezing of water on roadways.

The roadway effects of either type of winter storms cannot be effectively mitigated, however, the use of timed releases from work, and pre-storm closing of schools has mitigated the resulting disruption to the transportation network. The costs associated with transportation disruptions and the loss of work and school time may continue to increase.

2.2.3 FUTURE VULNERABILITY TO ICE STORMS

The vulnerability to ice storm damage is not easily mitigated. Future costs resulting from ice storms may increase as the power and transportation infrastructure grows more dense in the valley locations susceptible to icing.

2.2.4 FUTURE VULNERABLITY TO ICE JAMS

Connecticut remains vulnerable to ice jams in areas where ice jams have traditionally occurred in CT see list. In addition, as older mill dams are breached or removed, attention must be given to the effects of these actions on ice conditions.
More information concerning the type of jam, source of ice, local and remote causes of the jam, river morphology and hydrology at jam locations, meteorological and hydrological condition that lead to ice jam formation and statistical frequency, of such jams is needed when developing an ice jam control strategy. DEP intends to seek grant funding for

technical assistance from CRREL in performing an ice jam summary and analysis for Connecticut similar to one performed for the state of New Hampshire. In addition, when DEP becomes aware of an ice jam (regardless of whether or not it causes damages), we intend to file report forms to CRREL for the centralized national database.

2.2.5 FUTURE VULNERABILITY TO FOREST FIRES

As the existing forests continue to change in age, structure and species composition and become more fragmented, wildfire danger will continue to be an issue. The problem of the urban/forest interface is also present, although not to the degree that it exists in western states. The urban/forest interface (homes and buildings constructed in and on the borders of forests) is muted somewhat in Connecticut by societal factors such as declining backyard debris burning, and less uncontrolled or unsupervised interaction with forests and the natural environment as a whole. Other factors which mute the urban/forest interface problem in Connecticut are fuel-loading levels which are significantly less than other parts of the country; weather patterns producing median annual precipitation of greater than 42 inches which is well distributed throughout the year; and a landscaping preference which emphasizes large expanses of lawn around buildings.

The prevention emphasis in local fire departments has historically been on fire in the home, with forest fire addressed peripherally. There is a spread of woodland/suburban interface as the population of the state moves from the traditional urban cores out to former farmland and the suburban sprawl continues. However, while the interface of humans with forested areas is increasing, the actual risks appear relatively low in Connecticut as 1) the wildfire/forest fire prone areas are becoming fragmented; 2) the annual incident of forest fires is very low; 3) the problematic interface areas (such as zoning regulations which may permit driveways too narrow for fire trucks) are very site specific based upon Connecticut home rule of government. Local fire departments in a home rule state such as Connecticut focus their efforts during interface fires on residential and commercial structure protection. The State Fire Marshall and the DEP Division of Forestry - Fire Prevention Unit are well aware of the urban/wildfire interface issue and through the Connecticut Rural Fire Council is discussing interface issues.

Moderating any vulnerability to forest fire in Connecticut is DEP's fire fighting capability. Personnel from the State Parks and the Forestry Division form the backbone of the state fire fighting staff. The Division of Forestry also maintains a 70-person fire-fighting crew for possible assignment to assist the U.S. Forest Service in the suppression of large forest fires anywhere in the nation. This Connecticut Interstate Fire Crew is utilized in-state, as well, and is available for mutual aid to states in the Northeast.

2.2.6 FUTURE VULNERABILITY TO TORNADOES

The frequency of tornadoes in Connecticut will continue to range from most occurrences in the western and northwestern area of Connecticut, down to least occurrences in southeastern, Connecticut.

Although the frequency of occurrences may be greater in western Connecticut, vulnerability may not be greatest in that part of the State because of the relatively low population density there. When the frequency of occurrences and the population density are combined, the highest vulnerability to damage exists in Hartford and New Haven counties.

The lowest vulnerability to tornado damage will likely continue to be along the southeast coast. Although this area is very densely populated, the frequency of tornado activity is low with only one confirmed tornado during the past thirty years in New London County.

Although tornadoes pose a real threat to public safety, their occurrence is not considered frequent enough in Connecticut to justify construction of tornado shelters.

2.2.7 FUTURE VULNERABILITY TO DROUGHT

Despite the relative abundance of water resources in Connecticut, there is not always enough water to meet needs in certain areas, particularly during drought. All areas of Connecticut are vulnerable to various categories of drought.

There are two major factors contributing to drought vulnerability in Connecticut: (1) seasonal variation in water availability. Both streamflow and ground water levels vary seasonally, and typically are highest during the spring and lowest during the late summer and early fall. Streamflow and groundwater levels are a function of recent climatic conditions. Most water users have limited ability to vary water needs in response to meteorological or agricultural droughts; and (2) growth and shifting demand. Connecticut continues to grow and change, and its economic expansion naturally results in changes in how much water is needed and where it is needed. While population projections prepared by the office of Policy and Management (draft version 91.2, prepared for public water supply planning purposes) indicate that statewide population growth over the next forty years is not likely to be significant, people continue to leave the cities and move to suburban and rural areas, thereby creating new or additional demand for public drinking water in areas traditionally served by private residential wells. This results in increased vulnerability to a hydrologic drought condition.

The effects of hydrologic drought can be mitigated through the development of interconnections and supply sharing between and amongst public water supply purveyors. The Southwest Regional Pipeline extends from Bridgeport to Greenwich and interconnects a number of municipal and private investor owned water systems. The ability to share water results in ground water dependent water systems being able to use reservoir storage from others during short-term meteorological droughts. Currently a project known as the Thames River Regional Pipeline is under consideration for southeastern Connecticut and proposed to share water between five New London county communities.

2.2.8 FUTURE VULNERABILITY TO GEOMAGNETIC STORMS

Connecticut's dense population, and high level of dependency on communications, technology and transportation makes the state vulnerable to the affects of a large-scale blackout. The most likely causes for future power blackouts are human error and system design deficiencies.

A less likely but far more damaging and widespread blackout can be caused by geomagnetic storms. A rare combination of a G5 geomagnetic storm coinciding with a peak power demand period could potentially bring down much of the Connecticut power grid. Such a large-scale blackout could take days and even weeks to restore full power.

2.2.9 FUTURE VULNERABILITY TO EARTHQUAKES AND TSUNAMIS

The USGS has determined that Connecticut has a 1 in 10 chance that at some point during a 50-year period an earthquake would cause ground shaking of 4 to 8 percent of the force of gravity. This amount of shaking may cause minor damage resulting from items falling from shelves and very minor damage to buildings (broken windows, doors jamming shut).

If the state should be struck by a 5.0 quake, it is assumed the damage caused would be similar to the 5.1 quake that occurred in upstate New York in 2002. "In upstate New York, items were tossed off shelves, plaster was cracked, windows broken and chimneys were also cracked, with a few chimneys collapsing. Minor landslides also occurred which closed one state road, and a power substation suffered minor damage temporarily cutting power to 3,500 customers."[9]

The chances of a tsunami affecting Connecticut directly are extremely low because of the protection provided by Long Island.

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[9] Seismo-Watch, Inc. - Report: April 24, 2002
P.O. Box 18012 , Reno, NV 89511-8012
http://www.seismo-watch.com

2.2.10 OTHER INDICATORS OF STATE VULNERABILITY TO FLOODING

Location of Flood Prone Lands

While the DEP has no precise measure of the total acreage of land within the state's flood prone areas, studies have been performed of basins where flood warning systems have been installed.

Flood audits have been conducted along the Norwalk, Rippowam, Quinnipiac, Yantic, Wepawaug, Still, Farm, and a portion of the Connecticut River. Roughly 1,100 buildings have been identified by the flood audit program as being directly affected by flooding within Connecticut's floodplains.

Eighteen other basins have also been identified in the Operational Guide on Flood Warning (DEP/IWRD, 2000) as subjects of further study.

Connecticut Coastal Vulnerability Assessment – 1983

In December 1983 the Department of Environmental Protection published a Study of Coastal Vulnerability to Flooding. This study was a pre-cursor to modern Hazard Mitigation Plans. The intent of the study was to provide the State and its coastal communities with a better understanding of flood hazard potential, development of improved forecasting and warning routines, emergency operations plans, zoning changes to discourage development in high hazard areas, assistance to private home owners, and enhancing the National Flood Insurance Program (NFIP). The study looked at the total number of structures located in coastal hazard zones, reviewed local zoning regulations, numbers of uninsured properties, and gathered information on flood awareness. The study determined that there were a total of 34,679 structures located in coastal high hazard zones. It was determined that only a small fraction of coastal properties suffering damages were insured through the National Flood Insurance Program.

Western Connecticut Coastal Study

A study for Long Island Sound from Westport to East Haven was conducted by the Army Corps of Engineers in 1990. Major recommendations of the study included: 1) raising of structures in coastal high hazard zones above the 100-year wave elevation at selected sites; 2) modifying of town constructed protection works; and 3) improving forecasting, warning and evacuation plans.

The Corps of Engineers did a similar study of eastern Long Island Sound in 1993. If future predictions of sea level rise and the greenhouse effect prove accurate, vulnerability along Connecticut's coastline will increase at a faster rate than current coastal development suggests.

Corps of Engineers – SLOSH (Sea, Lake and Overland Surges from Hurricanes) Study

The SLOSH computer program is a numerical computer model, developed by the National Weather Service, for the Corps of Engineers (COE), and designed to forecast the rise in water level caused by the wind and pressure forces of a hurricane. This rise in the water surface, which accompanies a hurricane, is referred to as the storm surge. The SLOSH model computes the storm surge over water and along the coastline and extends the computations inland over the coastal flood plain. The results of the model can be utilized along with topographic information to determine hurricane flood inundation zones.

The SLOSH model calculates three inundation zones. The three zones correspond to Hurricane Categories I & II, III, and IV respectively on the Saffir/Simpson scale.

Connecticut also studied the population of coastal areas. Tables 2-4 and 2-5 show the numbers of persons living in zones I-II and III-IV within Connecticut's 25 coastal towns and cities. The SLOSH model and hurricane evacuation study were completed in April 1994. Transportation, population and resources were studied and this data was made available to each coastal town. The towns were expected to implement evacuation plans utilizing the data. The model and study data determined how much time is required for each municipality to evacuate its population. The average evacuation (clearance) time along the coast is 7 hours.

Connecticut now has a coastal population of over 1 million people, and most of this coastal population would need to be evacuated in a major hurricane.

For inland flooding areas, FEMA's National Flood Insurance Program (NFIP) has mapped all major riverine floodplains within Connecticut.

These inland riverine study areas include:

- Housatonic River Basin (Corps of Engineers) – 624 structures (exclusive of Naugatuck River Basin).

- South Central Connecticut Coastal Basin (Corps of Engineers) 1340 (excluding municipalities directly abutting coastline).

Approximately three-fourths of these structures are within the 100-year floodplain, and the remainder are within the 500-year floodplain.

The following list of facts underscores Connecticut's ongoing vulnerability to flooding. Most of this data was provided by FEMA through the NFIP.

a. There are flood prone lands in every community.
b. The annual total paid in premiums for flood insurance policies in force under the NFIP was $17,902,841.00 as of March 31, 2000.
c. As of March 31, 2000, 29,170 flood insurance policies were in force, totaling over four billion dollars in coverage provided by flood insurance.
d. Since 1978, the NFIP has paid out over 92 million dollars in flood claims in Connecticut.
e. 146 municipalities each have over $1,000,000 of flood insurance policies in force.

Sea Level Rise

Experts at the National Oceanic and Atmospheric Administration have estimated (through several studies and papers) that sea level will rise by approximately 35 cm (14 inches) by the year 2050.[10] In Connecticut there is no data on the slope of the coastal floodplain that is detailed enough to determine what affect this will have. Thus, these data need to be compiled to gain an accurate picture of the affect of sea level rise.

What we do know is that any rise in sea level may lead to a corresponding rise in the actual base flood elevation; however, the rise is expected to be slow. FEMA mapping may need to be updated periodically to reflect the change in sea level.

For example, a 1-foot rise in sea level may make the actual 100-year flood elevation coincide with the existing 500-year flood elevation as depicted on the NFIP maps. Thus lands prone to coastal flooding will be subject to more frequent flooding events than currently predicted.

2.2.11 POTENTIAL IMPACT OF NO-ACTION

Connecticut will continue to bear flood losses of 70 – 90 million dollars annually until sufficient or significant action is taken to reduce damages. Growing coastal populations (see figure 2-7) further increases the potential for damage.

[10] Douglas, Bruce C. - 1995 Global sea level change: Determination and interpretation; NOAA, National Oceanographic Data Center, Washington, D.C., US National Report to IUGG, 1991-1994, Rev. GeopHys. Vol 33 Suppl., © 1995 American Geophysical Union

FIGURE 2-7: COASTAL CONNECTICUT TOTAL POPULATION CHANGE 1950-1999

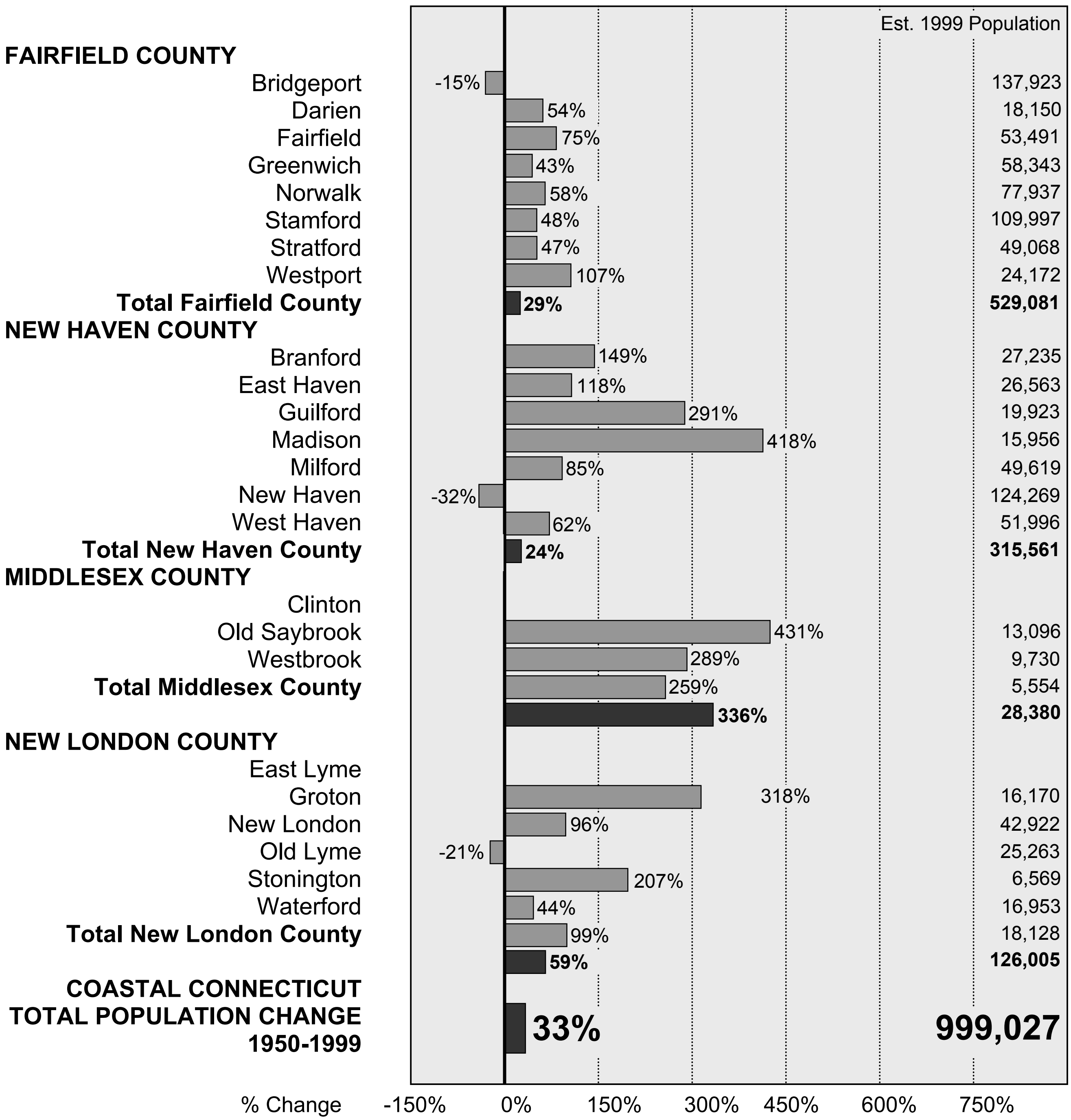


TABLE 2-4 - VULNERABLE COASTAL POPULATION (ESTIMATED TO 2000) CATEGORY I & II HURRICANES & SEVERE WINTER STORMS[1]						
Coastal Community	**Permanent Population**	**Seasonal Population**	**Mobile Home Population**	**Permanent Population living in Evacuation Zones**	**Seasonal Population living in Evacuation Zones**	**Total Vulnerable Population**
Greenwich	**61,101**	**618**	**11**	**6,702**	**52**	**6,765**
Stamford	**117,083**	**380**	**33**	**4,323**	**11**	**4,367**
East Lyme	**18,118**	**2,811**			**922**	
Waterford	**19,152**	**374**	**171**	**3,204**	**129**	**3,504**
New London	**25,671**	**262**	**18**	**2,348**	**18**	**2,384**
Groton City	**10,100**	**74**	**0**	**498**	**11**	**509**
Groton Town	**40,000**	**1,359**	**1,764**	**2,606**	**483**	**4,853**
Stonington	**17,906**	**1,016**	**466**	**4,985**	**561**	**6,012**
TOTALS	**1,045,861**	**21,439**	**5,139**	**154,966**	**10,448**	**170,553**

[1]*The population data in tables 4 and 5 is based on 2000 Block Census Data for Connecticut. The original 1988 data was updated to 2000 using the newer population data from the Connecticut Register and Manual and was linearly extrapolated across all categories to 2000.*

TABLE 2-5 - VULNERABLE COASTAL POPULATION (Estimated to 2000[1]) CATEGORY III & IV HURRICANES						
Coastal Community	Permanent Population	Seasonal Population	Mobile Home Population	Permanent Population living in Evacuation Zones	Seasonal Population living in Evacuation Zones	Total Vulnerable Population
Greenwich	61,101	618	11	12,933	94	13,038
Stamford	117,083	380	33	4,984	11	5,028
Darien	19,607	129	11	4,018	65	4,094
Norwalk	82,951	223	96	12,844	53	12,993
Westport	25,749	496	179	6,245	152	6,576
Fairfield	57,340	612	11	15,006	354	15,371
Bridgeport	139,529	167	30	42,864	108	43,002
Stratford	49,976	323	20	15,480	283	15,783
Milford	52,305	880	461	25,669	629	26,759
West Haven	52,360	58	97	17,969	29	18,095
New Haven	123,626	265	19	27,108	57	27,184
East Haven	28,189	162	11	14,589	162	14,762
Branford	28,683	966	686	17,251	925	18,862
Guilford	21,398	852	54	7,244	647	7,945
Madison	17,858	1,799	12	5,164	1,269	6,445
Clinton	13,094	1,220	595	5,362	1,004	6,961
Westbrook	6,292	1,617	361	3,337	1,232	4,930
Old Saybrook	10,367	2,160	11	8,239	2,215	10,465
Old Lyme	7,406	2,616	11	2,865	1,789	4,665
East Lyme	18,118	2,811	11	6,779	2,031	8,821
Waterford	19,152	374	171	4,518	160	4,849
New London	25,671	262	18	4,362	72	4,452
Groton City	10,100	74	0	4,408	31	4,439
Groton Town	40,000	1,359	1,764	6,695	763	9,222
Stonington	17,906	1,016	466	6,096	657	7,219
TOTALS	1,045,861	21,439	5,139	282,029	14,792	301,960

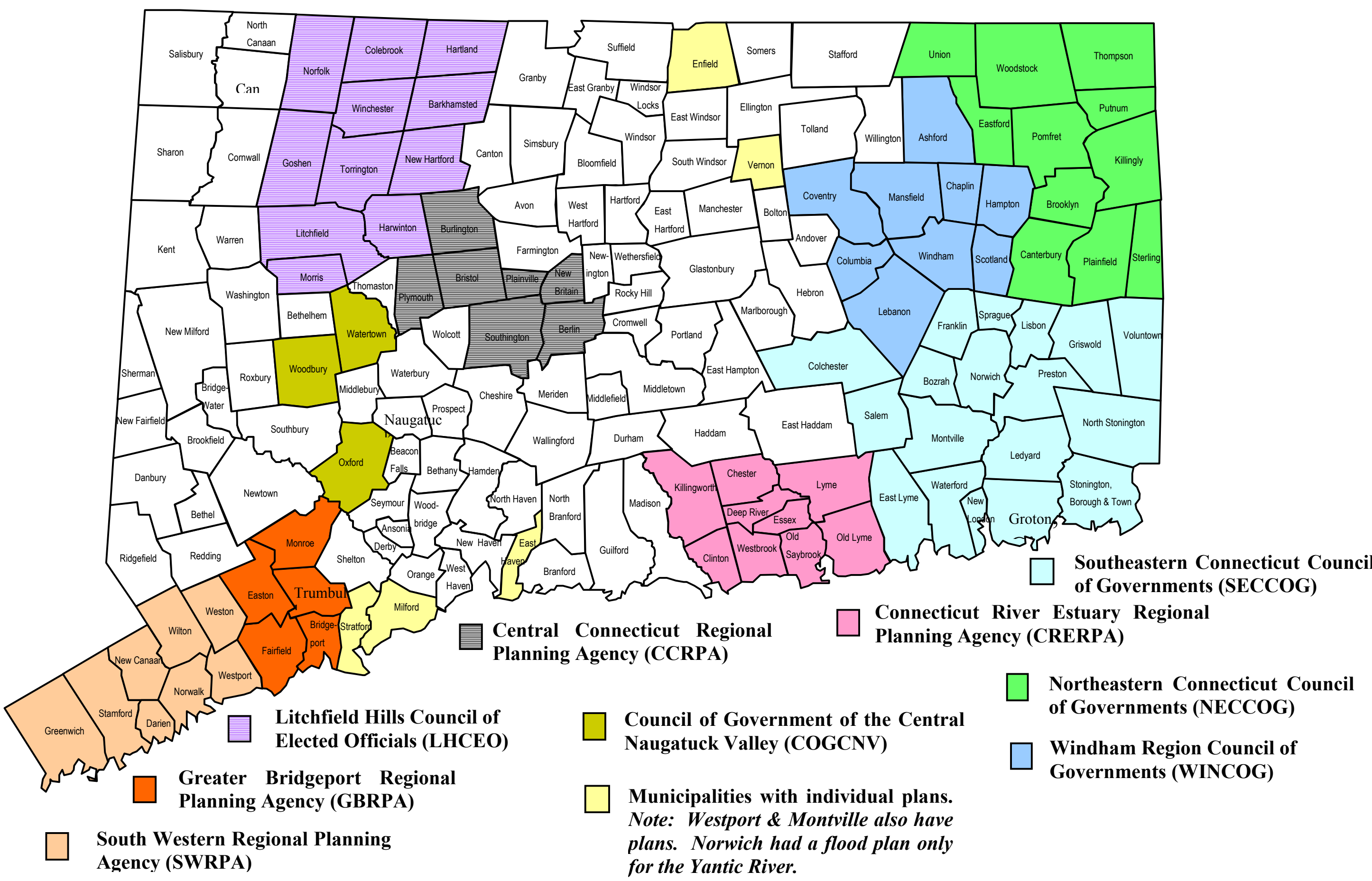
[1]The population data in tables 4 and 5 is based on 2000 Block Census Data for Connecticut. The original 1988 data was updated to 2000 using the newer population data from the Connecticut Register and Manual and was linearly extrapolated across all categories to 2000.

2.3 LOCAL AND REGIONAL RISK ASSESSMENTS

Connecticut is a relatively small state with a strong home rule tradition. There are 169 towns (municipalities) in 8 counties in Connecticut although county government is largely non-existent, and the towns function in much the same way as counties do in larger states. Regional Planning Organizations in Connecticut provide county level or inter-county planning services (see section 1.8 for more details). See Figure 2-1 on page 2-2 for a map of Connecticut's towns and Counties.

In Connecticut's continuing effort to get approved local plans for all of its jurisdictions, various local and regional risk assessments have been completed. See Figure 2-8 below for a map of towns with approved and pending local hazard mitigation plans. The actual plans are included as separate amendments to this state plan.

Figure 2-8: **Local and Regional Natural Hazard Mitigation Plans in Connecticut**
Connecticut



2.4 HAZUS MH DISASTER SIMULATIONS

HAZUS Multi-Hazard (MH) is a geographic information system based regional loss estimation model developed by FEMA and the National Institute of Building Sciences. The primary purpose of HAZUS MH is to provide loss estimates for earthquakes, hurricanes and flood hazards.

The DEP in cooperation with the Northeast States Emergency Consortium (NESEC) performed a hurricane and earthquake disaster simulation using the HAZUS MH model. The data used for the simulations was taken solely from the HAZUS MH database provided by FEMA.

If the HAZUS building coordinates were determined to be greater than 200 meters from the apparent location of a facility, the DEP corrected the locations using a hand-held GPS. Corrections were made to the locations of schools, hospitals, police, fire and emergency management facilities.

The region used for the simulation contained the entire state of Connecticut (815 census tracks totaling 4,962.77 square miles). HAZUS MH estimated that a total of 941,000 buildings (residential and non-residential) are contained within the state with a total replacement value of 222.7 billion dollars. The value of transportation and utility lifeline systems was estimated by HAZUS MH to be 83 billion and 10.3 billion dollars respectively.

2.4.1 HURRICANE SIMULATION

The hurricane simulation modeled a repeat of the 1938 hurricane on the current infrastructure. The 1938 hurricane represents the most destructive natural disaster in Connecticut's history for which records are available.

During a re-occurrence of the 1938 hurricane (a strong category III with 130 mph sustained winds moving north at 60 mph) the model estimates that about 269 thousand buildings will be at least moderately damaged. The model also estimated that a total of 22 million tons (44 billion pounds) of debris would be generated by the storm. Of that amount, brick and wood comprises 23.71%, reinforced concrete/steel comprises 0.31% with the remainder being tree debris. The model estimated that it would require 880,000 truckloads (at 25 tons per truckload) to remove the debris potentially generated by the simulated hurricane.

Total hurricane damages to buildings and infrastructure is estimated by HAZUS to be approximately 37 billion dollars. Damage to governmental buildings in Connecticut is estimated by HAZUS to be 1.39 billion dollars. Economic loss resulting from the hurricane was estimated at 6 billion dollars. For a county by county breakout of information on the hurricane simulation and resulting damages, please see Appendix G.

2.4.2 EARTHQUAKE SIMULATION

The earthquake simulation modeled a magnitude 5.0 (on the Richter scale) earthquake centered in Moodus, Connecticut. This location was selected based on the historical frequency of minor earthquakes in Connecticut.

During a magnitude 5.0 (on the Richter scale) earthquake centered in Moodus, the HAZUS MH model estimates that about 1,273 buildings will be at least moderately damaged. The model also estimated that a total of 64,000 tons of debris would be potentially generated by the simulated earthquake. This is based upon the models estimation that approximately ninety percent of the buildings in Connecticut are of wood frame construction.

Since fires are often generated by earthquakes due to broken gas lines, the model also estimates that 24 fires will result from the earthquake in Connecticut. These fires are predicted to cause 5 million dollars in damage and displace 79 persons.

Total building and economic losses from the 5.0 earthquake were estimated to be 594 million dollars. Damage to governmental buildings in Connecticut is estimated by HAZUS to be 1.4 million dollars. For a county by county breakout of information on the earthquake simulation and resulting damages, please see Appendix G.

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Hurricane Flood of September, 1938 – U.S. Geological Survey, Water Supply Paper 867 dated 1940.

Floods of August - October, 1955 – U.S. Geological Survey, Water Supply Paper 1420 dated 1960.

Southern New England Telephone History via the University of Connecticut library website. http://www.lib.uconn.edu/online/research/speclib/ASC/SNETdisaster/1955.htm