
ASSESSING THE VULNERABILITY OF THE TELECOMMUNICATIONS NETWORK TO IMPACTS FROM CLIMATE CHANGE: FOCUS ON NEW ENGLAND

by

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ABSTRACT

Climate change will not only alter the character of New England’s distinctive seasons, it will push the boundaries of severe weather in ways that will challenge current approaches in infrastructure siting and design. Wireless communications infrastructure is a highly integrated part of our daily lives, and it is critical for emergency communications in the event of natural disaster. A GIS analysis of the location of existing infrastructure and events potentially exacerbated by climate change, including flooding, hurricane inundation, and sea level rise shows that increased severity of events will impact more components of the existing infrastructure, including sites that serve highly populated areas. This analysis is limited by the availability of publically accessible, high resolution GIS data. It is critical that wireless site owners and developers consider future impacts of climate change in their siting decisions. It is also critical that the federal and state governments acquire and maintain the GIS data to make thorough analysis possible.

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OVERVIEW OF CLIMATE CHANGE IN NEW ENGLAND

Mark Twain once said “If you don’t like the weather in New England, wait a few minutes” (Quotations Book, 2006). It has been common knowledge among New England residents that the climate is highly variable, with four distinctive seasons and rapidly changing conditions taken for granted over the centuries. Winter is long and cold, spring is muddy and lush, summer is hot, and fall is awash in color from the changing foliage. While natural disasters including hurricanes, floods, ice storms, droughts, and the occasional tornado have occurred, the region is not under the perpetual threat of destructive tornados and tropical systems that have shaped life in the American Midwest and the Gulf Coast states. New England is well known for its nor’easters, coastal storms that are the product of a low pressure system originating in the gulf region and cold air from the Canadian Maritimes. In the middle of winter these storms have brought some of the area’s highest single-storm snow totals and caused wind damage and beach erosion. On the warmer ends of winter, they can cause flooding and wind-driven rain (Frumhoff, Mellillo, Moser, & Wuebbles, 2007), (Climate Change Research Center, 1998).

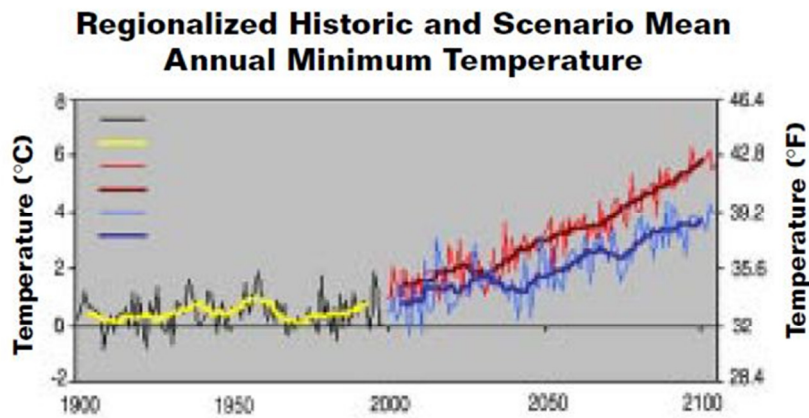
The infrastructure of New England has been designed to cope with seasonal variation in precipitation and temperature as well as the occasional nor’easter, and some of the oldest structures in the country have existed in this region since the colonial days. This may no longer be a sufficient approach. Climate change will not only change the character of New England’s distinctive seasons, it will push the boundaries of severe weather in ways that will challenge

current approaches in infrastructure siting and design. Without adequate planning, failures will become more common at a time when the infrastructure is needed the most.

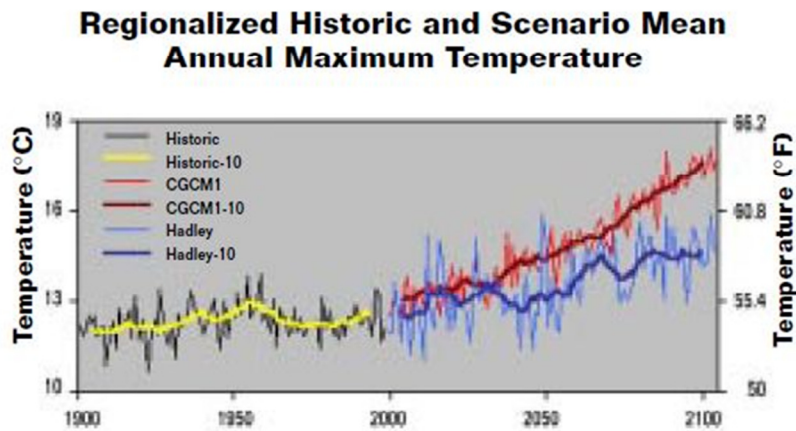
CHANGING TEMPERATURES

According to historical climate records, the temperature in New England has increased at a rate of 0.5 degrees Fahrenheit per decade since the 1970s. This increase has been more pronounced in the winter, which has been warming at an average rate of 1.3°F per decade since 1970. In addition to prolonging the growing season, the temperature increase reduces the snowpack and winter ice cover. More winter precipitation is now falling as rain. The Northeast Climate Impacts Assessment (NCIA) has projected that temperatures will increase between 2.5°F and 4°F in winter and 1.5°F and 3.5°F in summer through the mid-21st century regardless of any decrease in carbon emissions. Climate in the latter part of the century will be more significantly shaped by worldwide and regional emissions reductions, although a lack of significant reductions would result in a scenario where winter temperatures increase by 8°F to 12°F and summer temperatures by 6°F to 14°F (Frumhoff, Mellillo, Moser, & Wuebbles, 2007).

Figure 1: Increasing Temperature in New England



Graph of the 10-year running average of regional historic and modeled average annual minimum temperatures. There is no indication of a regional increase in minimum temperatures that departs from the range of exhibited variation. Both model estimates agree in predicting sustained increasing minimum temperatures that exceed expected variations. The Canadian model suggests greater increases in minimum temperatures than the Hadley model. Regional values were calculated by averaging the yearly mean values across all 128 VEMAP2 grid cell elements comprising the New England Region.



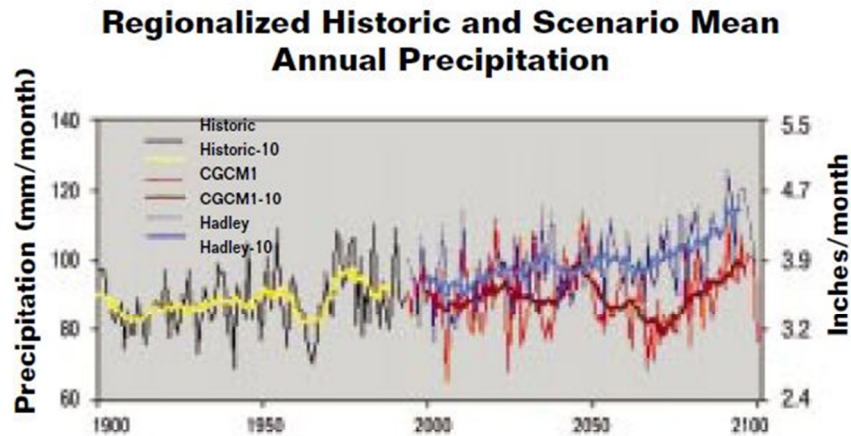
Graph of the 10-year running mean of regional historic and scenario average annual maximum temperatures. Model estimates agree in projecting sustained increasing maximum temperatures into the future that departs from the range of exhibited variation. The Canadian model suggests greater increases in maximum temperatures than the Hadley model.

Source: New England Regional Assessment Group, 2001. *Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change. New England Regional Overview.* U.S. Global Change Research Program, 96 pp., University of New Hampshire. Chapter 4: Future Climates of the New England Region.

INCREASING PRECIPITATION

Throughout the 1900s, average precipitation in New England has increased by about 4 percent. While historically the increase has been concentrated in the spring, summer, and fall, precipitation in the winter has also begun to increase. This is in large part due to climate warming, as more precipitation falls as rain instead of snow. By the end of the 21st century winter precipitation is predicted to increase by at least 10 and as much as 30 percent, if minimal reductions in carbon emissions are achieved. More significantly, incidences of heavy precipitation (defined by the NCIA as more than two inches of rain falling within 48 hours) will increase by 8 percent by 2050 and up to 13 percent by 2100. Average daily rainfall associated with these events, called precipitation intensity, will increase 8 to 9 percent by 2050 and 10 to 15 percent by 2100 (Frumhoff, Mellillo, Moser, & Wuebbles, 2007). There is some evidence that 1970 was a turning point for climate change in New England, with more statistically significant changes in precipitation measured between 1970 and 2005 than between 1954 and 2005 (Douglas & Fairbank, 2011) and more significant changes in flood frequency between 1970 and 2006 than between 1941 and 1970 (Armstrong, Collins, & Snyder, 2012).

Figure 2: Increasing Precipitation in New England



Graph of the 10-year running mean of regionalized historic and scenario average annual precipitation. There is a slight regional increase in the historic precipitation, however, large, rapid departures from any norm have occurred as exhibited by the mid-1960s drought. Model estimates do not agree in estimating potential future precipitation. The Canadian model suggests lesser increases in precipitation than the Hadley model.

Source: New England Regional Assessment Group, 2001. *Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change. New England Regional Overview.* U.S. Global Change Research Program, 96 pp., University of New Hampshire. Chapter 4: Future Climates of the New England Region.

INCREASE IN SEVERE WEATHER

Significant precipitation events are likely to occur during storms that are significant for other reasons, including damage caused by wind and ice. Nor'easters are a well-known component of a New England winter, and while hurricanes have made landfall in the region, more commonly the area is impacted by hurricanes that make landfall in the southern or mid-Atlantic states and track the coast north. These storms often lose intensity as they encounter colder waters, and impact New England as tropical storms or extratropical systems (Climate Change

Research Center, 1998). The last hurricane to make a direct landfall in New England was Hurricane Bob, which came ashore in 1991 as a category 2 with sustained winds of 115 miles per hour near New Bedford, Massachusetts and caused widespread damage (Commonwealth of Massachusetts, 2013).

While a statistically significant link has yet to be found between climate change and increased frequency of severe weather events like hurricanes, climate change has influenced the orientation of storm tracks in a way that could increase the impact on New England. Both nor'easters and hurricanes follow paths created by the jet stream, frontal boundaries, and high pressure systems. Since 1970, the most common track of extratropical systems including nor'easters has shifted to the north. Systems that might formerly have impacted the Mid-Atlantic States and skirted south of New England are now directly impacting New England. The New England states will be impacted by one additional system of this type every year on average by 2100 (Frumhoff, Mellillo, Moser, & Wuebbles, 2007).

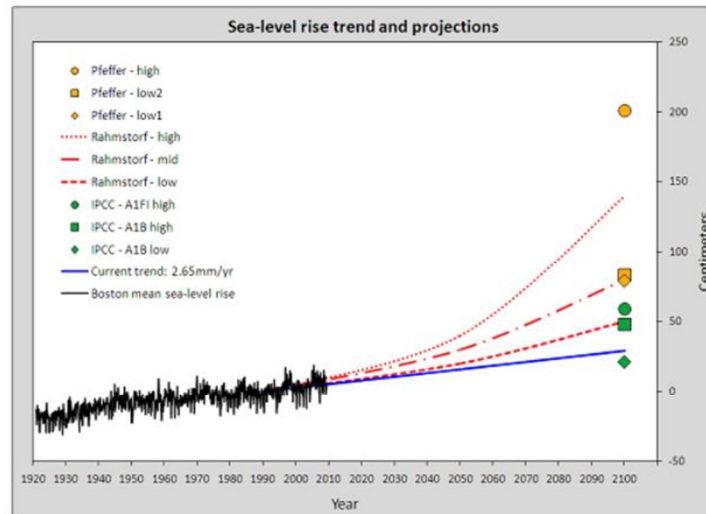
The warming of the oceans associated with climate change also appears to be increasing the average intensity of tropical systems. Hurricanes of the future may retain more tropical characteristics at more northerly latitudes, hitting New England with higher wind speeds and greater rainfall totals (Frumhoff, Mellillo, Moser, & Wuebbles, 2007).

SEA LEVEL RISE

Climate change is raising the oceans through two primary mechanisms, thermal expansion of the existing ocean water and melting of glaciers and polar ice sheets. The coast of New England

is heavily developed and densely populated. The maritime history of the area resulted in many large cities located directly on coastal ports, including Portland Maine, Boston, Bridgeport, New Haven Connecticut, and New London Connecticut. Future changes in sea level will have potentially disastrous impacts on the infrastructure of these areas, impacts that could be exacerbated by more intense tropical systems and more frequent coastal nor'easters. Sea levels are projected to rise as much as 4.5 feet by the end of the 21st century. Projections have been revised upwards several times as new climate data became available and may be revised upward again. Additionally much of New England is subsiding, meaning that local sea level rise is likely to exceed the global average by an amount that is locally variable and difficult to predict (Frumhoff, Mellillo, Moser, & Wuebbles, 2007).

Figure 3: Predicted Sea Level Rise (City of Boston)



Source: Massachusetts Executive Office of Energy and Environmental Affairs, 2013. *Climate Change Adaptation in Massachusetts and Its Impacts* <http://www.mass.gov/eea/air-water-climate-change/climate-change/climate-change-adaptation-in-ma.html>

OVERVIEW OF RESEARCH

Given the increasingly significant impact of climate change on the environment in New England, we should consider the effects on infrastructure that we take for granted in our daily lives. This study attempts to address the potential impacts of climate change on a part of our infrastructure that is relatively low-profile compared to roads, bridges, and power plants: the wireless communications towers and antenna networks that support many of our daily activities and interactions. Where possible, this study will use GIS analysis to directly compare potential impacts on the locations of the existing infrastructure, and where this is not possible this study will explain the data requirements for such analysis. State and local governments struggle to round up the expertise and funding to assess the risk for the most critical items like

power plants. Private companies typically keep their own infrastructure analysis private. However given the communications difficulties experienced recently during events like Superstorm Sandy, it is becoming clear that an integrated way to analyze the overall risk of the network is necessary. Wireless communications are no longer a luxury; they are a public safety requirement.

IMPORTANCE OF WIRELESS COMMUNICATIONS INFRASTRUCTURE

We depend on mobile technology and instant communication in our everyday lives. From updating Facebook to calling the police, essential communications actions are now more portable than ever, and rely on a system of distributed wireless antennas and assorted infrastructure, including purpose-built towers and existing buildings, to support them. Cellular communications systems are increasingly replacing hard line connections among the general public (Blumberg & Luke, 2011).

Wireless phone communication dates to the 1940s when high powered and expensive sets first became available for automobiles. Due to their high cost and limited capacity and range, this type of communication was limited in its application to commercial or very wealthy (and patient) customers who had to wait up to 30 minutes for a live operator to connect a call. The modern cellular network, consisting of small handheld phones using digital signals that can range across geographic areas serviced by multiple antenna locations, came of age in the early 1990s (Webb, 1999). Since then the increased density of transmitting stations and antennas has allowed for an increase in battery life and subsequent decrease in phone size, as well as an increase in phone capability. Today mobile phones are almost ubiquitous, and their range and

features have allowed them to supplant or greatly enhance traditional radio services for police, fire, and other emergency responders. The advent of e911 services, including universal connection regardless of the network and GPS locations for wireless, make them crucial tools for the general public to provide and obtain information in an emergency.

Cellular signal coverage is almost universal in the United States. Antennas are mounted to towers as well as structures including buildings, water tanks, and stanchions supporting high-tension power lines. The necessity of universal coverage, particularly for densely developed urban and coastal areas, means that some of the sites are inevitably located in areas with less than ideal environmental conditions including floodplains and coastal inundation areas.

Events like 9/11 and Hurricane Katrina made it clear that America's first responders and public safety officials need a fully compatible, reliable wireless network with widespread coverage in order to function effectively during a disaster. Continued development of that infrastructure is a priority of the Federal Communications Commission as well as many state and local governments (Federal Communications Commission, 2012). Radio stations are also important outlets for public announcements during emergency situations.

CURRENT ENVIRONMENTAL CONSIDERATIONS IN SITING DECISIONS

NEPA AND THE 100 YEAR FLOODPLAIN

The National Environmental Policy Act of 1969 (NEPA) was established to ensure that the federal government considered the environment in its decision making. It did not ensure that environmental concerns trumped all other factors, but it forced the government to balance

environmental, social, and broader economic concerns with more traditional cost benefit analysis and political motivations for undertaking a project. A project does not have to be undertaken by the federal government directly to be covered under NEPA; any project that is in whole or partially-financed or licensed by the federal government also must comply with NEPA regulations (Executive Office of the President of the United States, 2013).

Construction of wireless telecommunications facilities triggers compliance under NEPA based on the requirement for a license from the Federal Communications Commission (FCC). 40 CFR section 1.1307(a)(6), Executive Order 11988 requires the Federal government to evaluate the potential effects of actions each Federal agency may take in a floodplain to “avoid adversely impacting floodplains wherever possible, to ensure that its planning programs and budget requests reflect consideration of flood hazards and floodplain management, including the restoration and preservation of such land areas as natural undeveloped floodplains, and to prescribe procedures to implement the policies and procedures of this Executive Order” (United States Archives - Federal Register, 1977). FEMA currently uses the 100-year floodplain as the standard, and is only concerned with construction in a 500-year floodplain if the project is defined as a "critical action." Currently cellular communications facilities do not fall under this designation (Federal Communications Commission, 2013).

The need to determine what constitutes a “100 year floodplain” came about with the advent of the National Flood Insurance Program (NFIP). Created by Congress in 1968, the aim of the NFIP was not only to provide flood insurance to areas where private companies had determined that it was not cost effective to cover or covered at unaffordable rates, it was also to encourage the

development of local building regulations that would ultimately reduce the risks of flood loss. Communities participating in the NFIP work with FEMA scientists to identify and map areas of flood risk. The resulting documents are Flood Insurance Rate Maps (FIRMs) (National Flood Insurance Program, 2011).

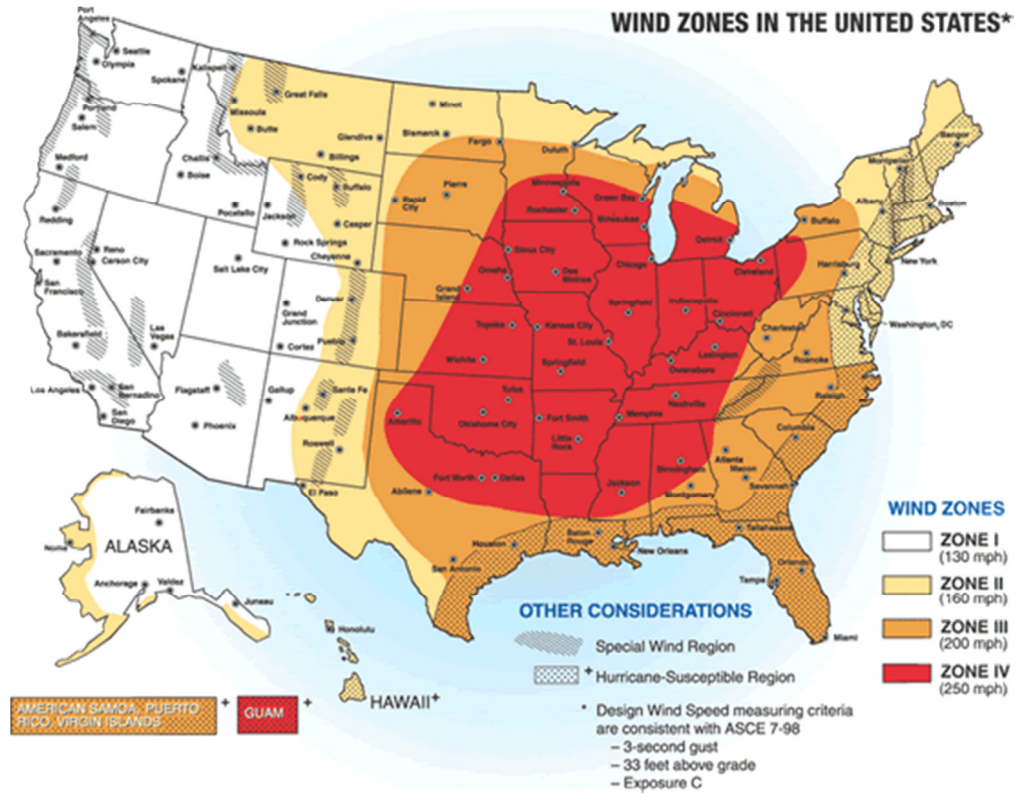
The 100 year flood event has a one percent chance of occurring in a given year, a determination based on an analysis of historic meteorological, hydraulic, and topographic data as well as existing development and any artificial flood control. The area inundated by a 100 year flood is the Special Flood Hazard Area (SFHA), and the elevation inundated is the Base Flood Elevation (BFE). Other flood hazard areas exist including the 500 year elevation (0.2 percent chance of occurring within a given year) (National Flood Insurance Program, 2011). Under the FCC's NEPA regulations, any communications tower construction located within a 100 year floodplain is not determined to be categorically excluded from additional environmental review, and must be presented for FCC review in an Environmental Assessment report (Federal Communications Commission, 2013). For practical purposes, the need to file an EA with the FCC can add months to the process of completing NEPA compliance on a new installation, and usually is a last resort when no alternative locations are available to achieve the same coverage. Constructing within a mapped 500 year floodplain, or otherwise adjacent to a 100 year floodplain, does not trigger the same environmental review and is no more unfavorable from a regulatory perspective than selecting a site far from a flood hazard area.

WIND ZONES AND BUILDING CODES

FEMA has broken the United States down into four wind zones, based on the historical incidence of tornadoes recorded over the past 40 years and hurricanes recorded over the past 100 years. The New England states fall within Zone II, which has a design speed of 160 mph for a three second gust. Design speeds are incorporated into local building codes. Additionally, coastal New England is designated as a “hurricane susceptible region” and portions of the Berkshire Mountains extending from western Connecticut, through western Massachusetts and eastern Vermont/western New Hampshire are designated as a “special wind region.” These designations may result in local building codes mandating higher design speeds (Federal Emergency Management Agency, 2008). Different jurisdictions require varying types of permits for the construction of cellular communications facilities. Nearly all of them require a building permit for a freestanding tower structure, and require that structure to meet local building codes.

Tower manufacturers design structures to meet the county wind speed guidance published by the American Society of Civil Engineers. The ASCE basic wind speeds for New England range between 120 miles per hour in coastal hurricane prone areas to 90 miles per hour inland, with the same “special wind region” designation covering the Berkshire Mountains (Johannessen Consulting - Structural Engineering and Inspections., 2013). Standards are frequently updated.

Figure 4: Wind Zone Map



Source: Federal Emergency Management Agency

POTENTIAL IMPACTS OF CLIMATE CHANGE ON WIRELESS INFRASTRUCTURE

FLOOD DAMAGE

Flooding can be one of the most overtly destructive physical impacts of a natural disaster on the infrastructure located in its path, and wireless communications towers and associated equipment are no exception to this rule. Inundation by fast-moving floodwaters can physically move or topple over a tower or equipment platform. Slower moving waters can damage sensitive electrical components and radio cabinets, rendering a site inoperable.

Extreme precipitation events challenge the resilience of infrastructure, and the predicted likelihood and extent of a flood event is an important component of infrastructure siting and design. Climate change studies have projected an increase in precipitation events and the intensity of those events, which will result in increased incidents and severity of flooding. Historical data may not serve as an adequate benchmark when designing the infrastructure of the future.

SEVERE WEATHER

Severe storms including thunderstorms, hurricanes, and ice storms can also cause physical damage to infrastructure through direct wind damage or falling trees and other blown debris. The most common threat during severe weather is the loss of grid power. While some communications towers have diesel or propane generators that can provide backup power indefinitely with fuel supply replenishment, many have backup batteries designed to last only eight hours and some sites have no backup power at all. Fuel replenishment is not always

possible due to obstructed access (Ante, 2012). The projected northward realignment of storm tracks can be expected to increase incidents of wind damage throughout the New England area.

SEA LEVEL RISE AND HURRICANES

Many of the most densely populated areas of New England are located on the coast. Communications sites are installed at greater densities within these areas to provide the higher levels of bandwidth needed to support more calls and data transfers. While a large number of urban sites are collocations on rooftops or existing structures like billboards and water tanks, radio stations in particular need to maintain freestanding towers. Freestanding cellular communications towers can also be found in industrial areas and away from historic city centers. Sites located in close proximity to the coast are vulnerable to direct flooding from future sea level rise as well as increased flooding from a combination of sea level rise and impacts from hurricanes that maintain a higher level of severity further north than has been seen in the past.

WIND DAMAGE

The potential increase of severe weather as a result of climate change could result in wind speeds more commonly exceeding design parameters, making structures that were built based on published wind guidelines more likely to fail (Davies, 2011).

A SAMPLE GIS ANALYSIS: CONNECTICUT

METHODOLOGY

Geographic Information Systems (GIS) allow us to analyze infrastructure and environmental factors in a representation of the physical world that can be manipulated on a computer. These tools can be invaluable for visualizing risk and informing decisions about infrastructure siting in light of environmental parameters.

This study attempted to use existing publically-accessible data for environmental parameters related to climate change, along with publically available data on existing telecommunications infrastructure, to map areas of environmental concern and determine whether infrastructure might be located within areas where the impacts could be worsened by climate change. Analysis and mapping was conducted using ArcGIS software version 10.

Computer programs such as ArcGIS are increasingly powerful tools of analysis, but the end result is only as good as the data available. All of the New England states (for the purposes of this study Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont) support GIS data on the websites of state agencies, programs, or universities. States collect and publish data on varying timetables with varying degrees of coverage and multiple supported coordinate systems. Because of the differences in methodology in the data collection, it is not possible to make a direct comparison between analyses using one state's set of data and another state's set except in limited circumstances.

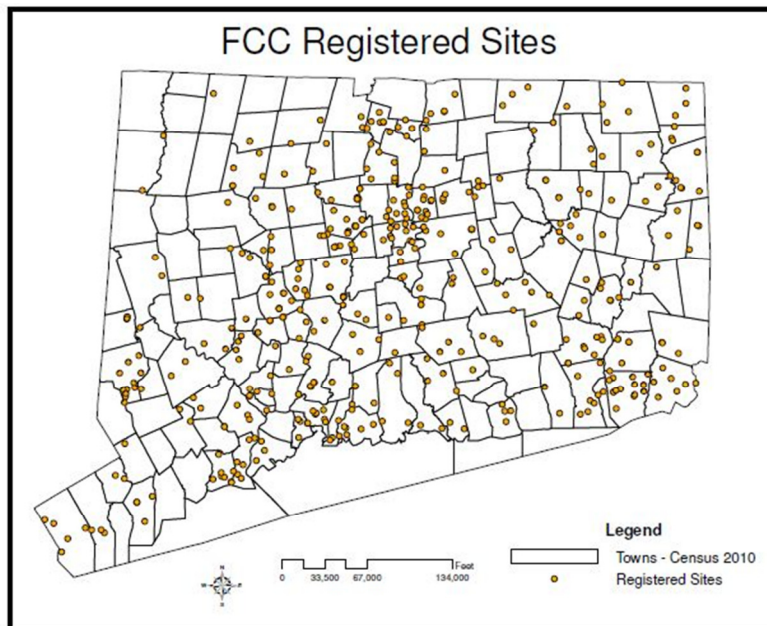
Some data is available on a national or regional scale. FEMA makes all digitally-available flood data for order through its online map service center. Digital flood coverage is not available for the entire United States. The FCC makes its database of registered communications sites available for download as a national shapefile. Each site is mapped by NAD83 coordinates with attributes including site registration number, registration date, owner, location, and construction status.

The Army Corps of Engineers (ACOE) has conducted hurricane inundation studies for all of the New England state coastal areas and makes the data files available on its New England District website.

To ensure the uniformity of data, this study performed an example analysis of the state of Connecticut. Available data was taken from the two publically-available archives of GIS data for the state, the Connecticut Geospatial Information Systems Council and the Connecticut Department of Energy and Environmental Protection. State data for floodplains and hurricane inundation was crosschecked using the FEMA and ACOE datasets to ensure that the most complete available data was used. Data used for the analysis included basemaps of the state, town, and counties using the NAD 1983 StatePlane Connecticut FIPS 0600 Feet coordinate system, which is more accurate for small scale state and county level analysis than a global coordinate system, LIDAR-derived elevation contours at two-foot intervals, hydrology and major rivers, digital flood hazard maps, 2010 census data including town and county population, and worst-case hurricane surge inundation mapping.

FCC antenna structure registrations for the state of Connecticut were exported from the national dataset. It should be noted that this data set is not representative of all telecommunications structures located within the state, only those that meet the criteria requiring registration with the FCC or were voluntarily registered by their owners. A communications structure is required to be registered with the FCC if it is “taller than 200 feet above ground level or may interfere with the flight path of a nearby airport” as determined by the Federal Aviation Administration. Sites with a status of “terminated” or “dismantled” were eliminated from the dataset.

Figure 5: FCC Registered Sites in Connecticut



It should also be noted that FEMA digital flood data is not available for Litchfield County located in the northwest corner of the state, and Tolland and Windham Counties located in the northeastern portion. Registered antenna structures located within these counties were also

eliminated from the analysis to determine accurate relative percentages of structures located within and adjacent to flood zones.

Many factors determine which structures are more “important”: how many carriers or stations and different types of antennas they support, whether they support emergency government communications equipment, and the size of the population located within their given service area. Of these criteria, only population is discernible from publically-available GIS data. For the purposes of this study, 2010 census data was used to divide Connecticut towns into percentiles. Sites located within towns that had populations in the top 40 percent relative to statewide populations were categorized as “high capacity” sites. Sites located within towns that had populations between the top 60 percent and the top 40 percent were classified as “medium capacity sites.”

Table 1: High Capacity Site and Medium Capacity Site Locations

Population Percentiles	Towns in Connecticut
Top 20 percent (High Capacity)	Stamford, Hartford, Bridgeport, New Haven
Top 40 through Top 20 Percent (High Capacity)	Waterbury
Top 60 through Top 40 Percent (Medium Capacity)	West Hartford, Manchester, Greenwich, Norwalk, Fairfield, Danbury, Hamden, Meriden, Bristol, New Britain

Figure 6: Town Population Map

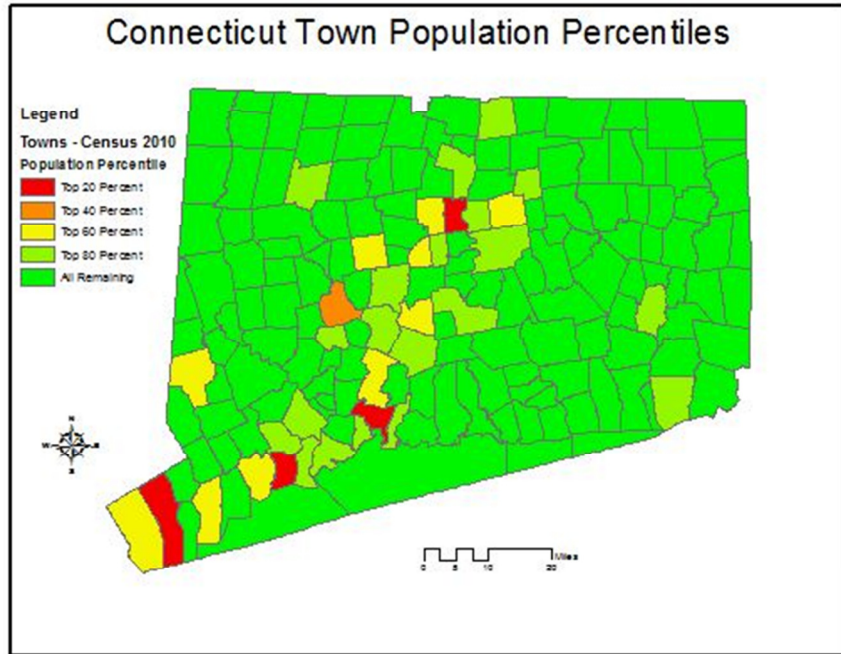
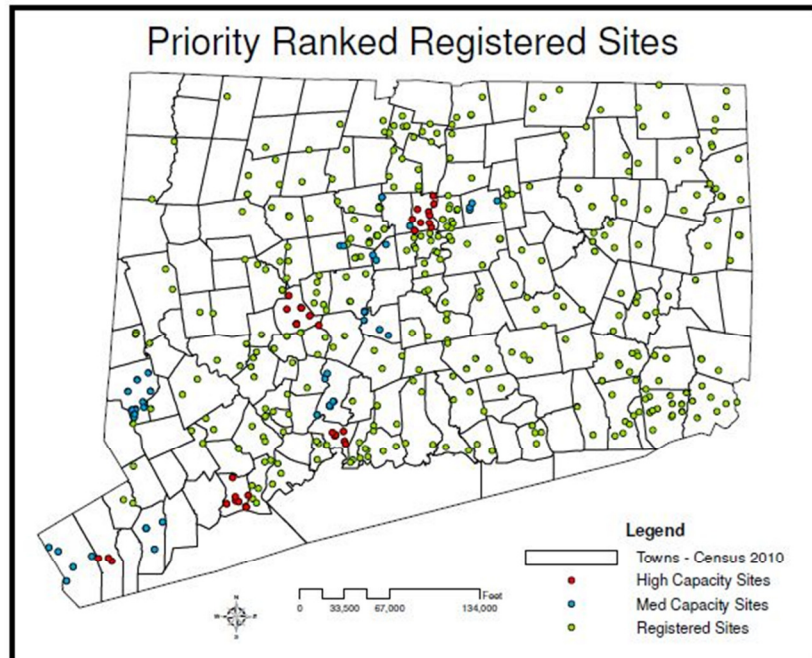


Figure 7: FCC Registered Sites Ranked by Importance



To determine the vulnerability of the existing sites to environmental impacts that could be exacerbated by climate change, several types of analysis were completed.

RESULTS

FLOOD POTENTIAL

The first analysis was run using flood inundation data from the state of Connecticut and FEMA. As previously noted digital flood data is not available for Litchfield, Tolland, and Windham Counties, so those counties were excluded from the analysis. Flood hazard areas mapped by this dataset include zones A, AE, AH, AO, V, VE, Zone X area of 0.2 percent chance of annual flooding (500 year floodplain), Zone X area of 1 percent chance of annual flooding (100 year floodplain) and Zone X, area protected by levee. Areas designated as in a floodplain but protected by a levee were included with the designated 500 year floodplain in this analysis because in the future, more frequent extreme precipitation events will stress levees and can create risks for these areas if the levees are not upgraded or adequately maintained.

Figure 8: Sites Located Within Floodplains (all counties except Litchfield, Windham, and Tolland)

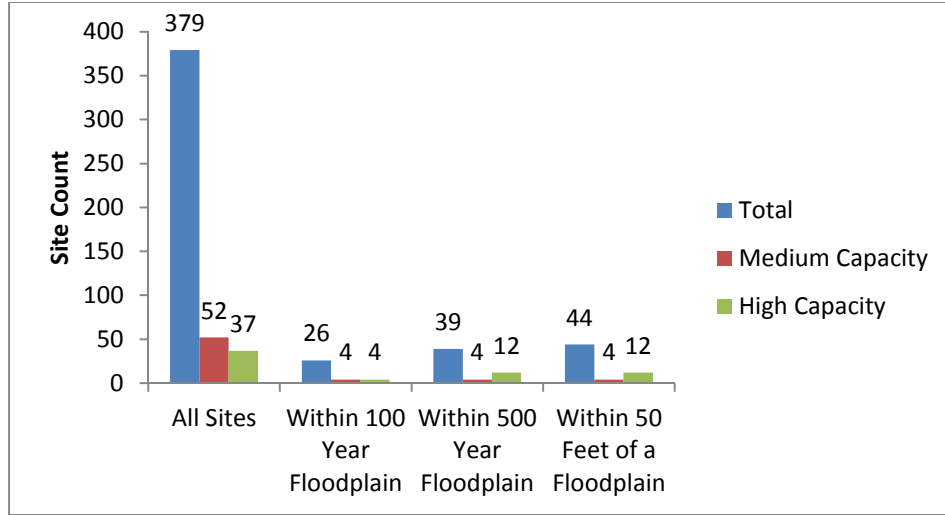
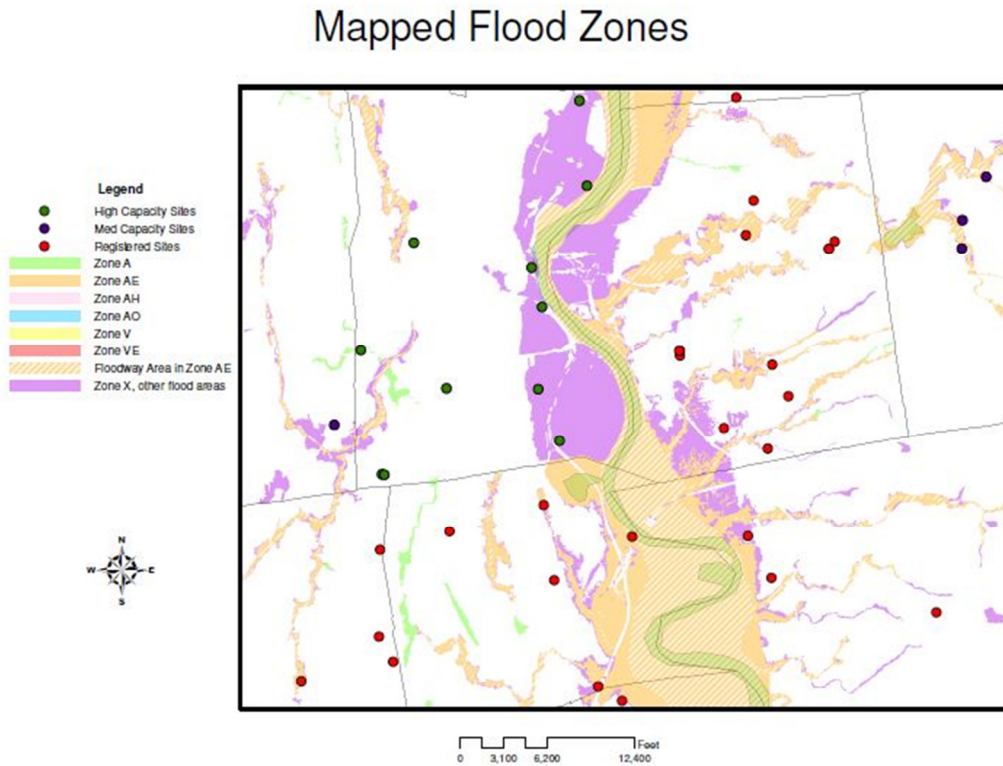


Figure 9: Flood Areas and Registered Sites Located Along the Connecticut River in Hartford



Only six percent of sites analyzed are located within a mapped 100 year floodplain, and of those sites only eight serve medium to high density populations. However, when mapped 500 year floodplains and areas located within 50 feet of a mapped floodplain boundary are included, the percentage of affected sites increases to 11.6 percent, with 4 sites serving medium density populations and 12 serving high density populations. Climate change could result in flood impacts to nearly twice the number of sites that are currently flagged as vulnerable.

HURRICANE INUNDATION

The second analysis was run using the hurricane inundation data available from the state of Connecticut. This data was published by the US Army Corps of Engineers in 2008. The data includes projected hurricane inundation areas for hurricane categories 1-4. Site located within each of the hurricane inundation categories were inventoried. Note that for each successively more intense hurricane category, sites were considered to be inundated if they were located within a less intense category inundation area (so if a site would be inundated during a Category 2 storm, it was also presumed to be inundated during a Category 3 storm):

Table 2: Sites within Mapped Hurricane Inundation Areas

Hurricane Category	Number of Sites	
Category 1	Total	3
	Medium Capacity	0
	High Capacity	1
Category 2	Total	9
	Medium Capacity	1
	High Capacity	4
Category 3	Total	17
	Medium Capacity	1
	High Capacity	7
Category 4	Total	18
	Medium Capacity	1
	High Capacity	7

Figure 10: Sites within Mapped Hurricane Inundation Areas

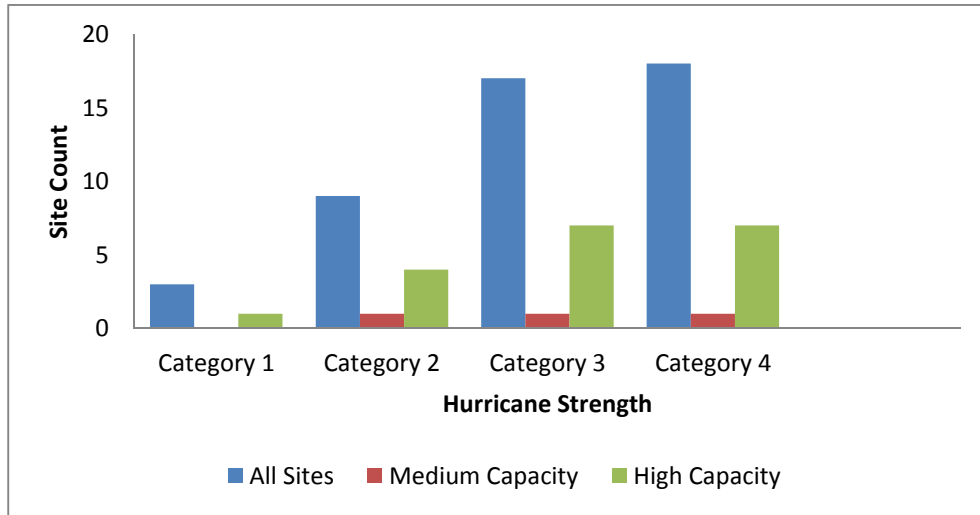
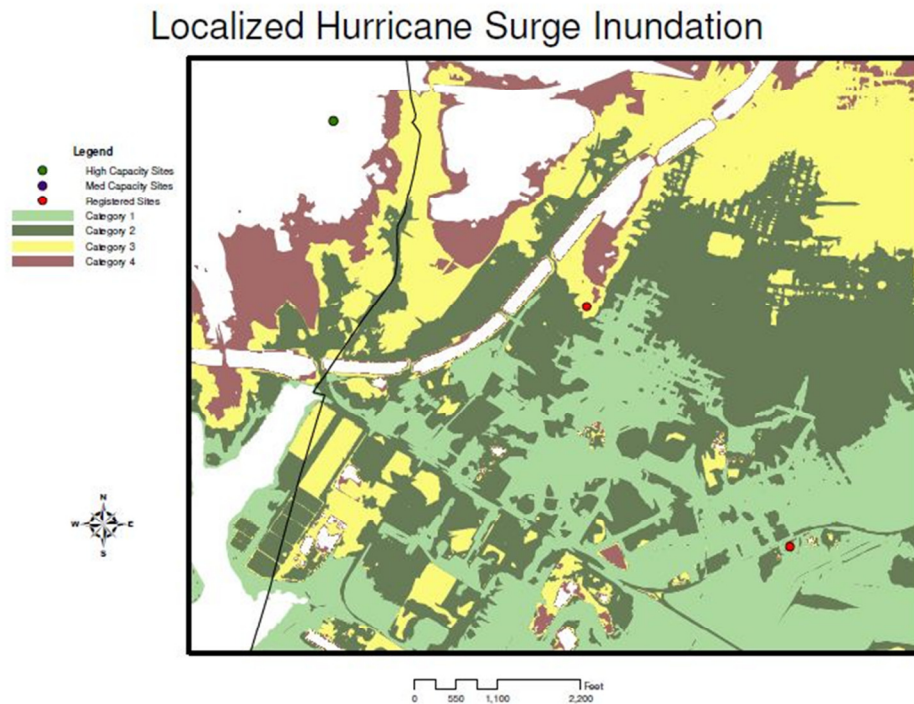


Figure 11: Hurricane Inundation Areas (Bridgeport-Stratford Area)



There is a correlation between increase in hurricane intensity and a rapid increase in the number of coastal sites affected, with only three registered sites located within the inundation

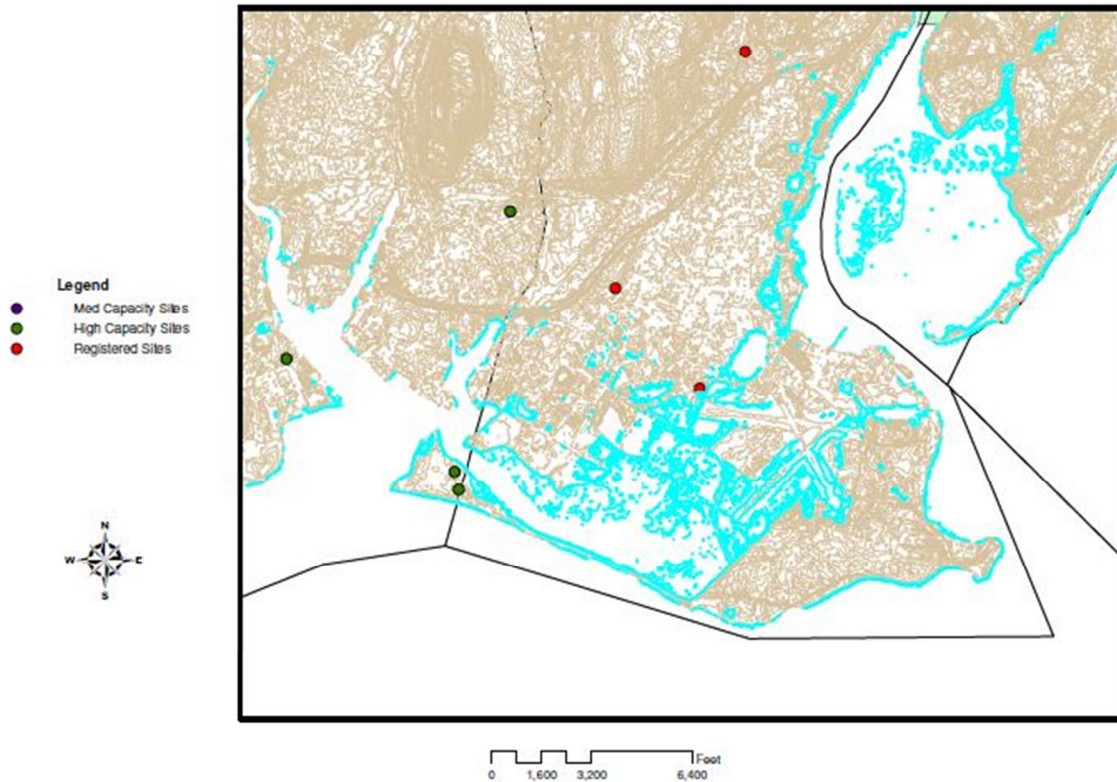
area of a Category 1 storm (only one of which serves a moderately or highly populated area) and 18 sites located within the inundation area of a Category 4 storm (eight of which serve moderately or highly populated areas). More intense and possibly more frequent direct hurricane impacts will increase the portion of the existing network affected.

SEA LEVEL RISE

The State of Connecticut has mapped two foot contours generated from Triangulated Irregular Networks based on Light Detection and Ranging (LIDAR) data collected in 2000. To assess the potential impact from future sea level rise of up to one meter or higher, coastal elevations below the four-foot above mean sea level contour were mapped. Currently, no active registered antenna sites are located within this area. It is possible, particularly in densely developed coastal urban areas, that unregistered antenna sites are present in these areas.

Figure 12: Four foot AMSL Elevation and Registered Sites Located in Bridgeport/Branford

Potential Sea Level Rise - Bridgeport/Branford



DATA REVIEW

State government and major land grant universities are the largest source of GIS data for the New England Region (see Appendix A for a list of websites), with selected data sets available from federal agencies including FEMA and the ACOE. The following data categories were used, or would have been helpful, to complete analysis of the type used in this report.

Digital Flood Coverage – Digital Flood Insurance Rate Map (DFIRM) GIS data is currently not available for all counties in all states. In New England, areas without coverage include the

northwestern and northeastern corners of Connecticut, western Massachusetts, northern New Hampshire, and portions of Vermont and Maine. While areas without coverage generally include less populated areas of the states, achieving universal coverage is critical to analyzing widely distributed infrastructure like wireless communication sites.

Digital Elevation Data – High resolution LIDAR elevation data has the precision needed for analyzing potential risk related to sea level rise and flooding. Plans are underway to expand or acquire LIDAR-based coverage in New Hampshire and Vermont.

Hurricane Inundation Mapping – the Army Corps of Engineers has conducted hurricane inundation studies of the New England coast as part of its hurricane evacuation plan development. This data is not directly available on every state website, but can be accessed through the ACOE website.

High Wind Area/Wind Damage Vulnerability – currently, Massachusetts and Rhode Island have developed wind mapping suitable for determining preferential locations for wind farms. However, the New England states have not developed a dataset indicating more precise areas of wind damage hazard or vulnerability beyond that provided by FEMA and the American Society of Civil Engineers.

Historic Natural Disaster Data – Vermont currently maintains a publically-available data set showing damage recorded during the Ice Storm of 1998. Development of additional GIS data sets that document damage from hurricanes, tornadoes, floods, and winter storms will enable the analysis of historic patterns and areas of increased vulnerability.

Telecom Infrastructure – Three of the New England states (Maine, New Hampshire, and Vermont) maintain GIS data layers showing FCC registered antenna sites located within their boundaries. However, with last updates ranging from 2011 to 1998, these layers are too old to be useful. The most comprehensive, updated list is the national dataset located on the FCC’s website.

Table 3: Data Availability for the New England States

Data Category	Connecticut	Maine	Massachusetts	New Hampshire	Rhode Island	Vermont
Digital Flood Coverage	Partial	Partial	Partial	Partial	Complete	Partial
Digital Elevation Model	LIDAR-based	LIDAR - based	LIDAR - partial	Non-LIDAR	LIDAR	LIDAR - partial
Hurricane Inundation	Yes	Yes	Yes (ACOE only)	Yes (ACOE only)	Yes	N/A
Wind Speed	No	No	Yes (FEMA map)	No	Yes (for windpower)	Yes
Other Natural Disaster	No	No	No	No	No	Ice Storm (1998)
Telecom Infrastructure	No	Updated 1998	No	Updated 2007	No	Updated 2011

LIMITATIONS OF THE DATA

This type of analysis is only scratching the surface of what we should know to accurately predict the impacts of climate change on existing and future communications infrastructure. Important considerations about the limits of this analysis include:

- The FCC's antenna structure registration system is not a comprehensive list of communication sites. Many cellular communication towers are less than 200 feet tall, and are not required to be registered with the FCC. The major carriers including Verizon Wireless, AT&T Mobility, Sprint and T-Mobile keep detailed network inventories that are not publically available. Registration of all communications sites would develop a database adequate for third party analysis. Absent a public database, the FCC could require that major cellular carriers and emergency communications networks at the state or local level be required to conduct and publish a network vulnerability analysis.
- FEMA flood hazard mapping is not available in digital format for all counties. Universal digital flood mapping is crucial to developing a risk analysis of site locations using GIS systems.
- Hurricane inundation data provided by the ACOE is not broken down into hurricane categories. Further refining the inundation data will allow for risk associated with potential increases in hurricane intensity to be evaluated.
- Creating national standards for state data inventories, including coordinate systems and data maintenance/update schedules, will allow regional or national standardization of risk assessments.
- While sea level rise studies and mapping have been undertaken for selected urban areas like Boston, the vast majority of the coast has not been measured, and a comprehensive set of data showing coastal impacts of sea level rise under different scenarios has not been published.

- Wind zone maps are readily available online; however, most states have not published more detailed state level wind data that would be suitable for structural engineering analysis. Existing published wind data is focused on the potential for wind turbine operation, and includes wind speeds measured at 30 meters or higher, above the height of some communications infrastructure.

LESSONS FROM HISTORY

The existing communications and radio networks are highly reliable under normal conditions; however, past performance during natural disasters has exposed the existing vulnerabilities that will become even more pronounced with climate change.

During the Ice Storm of 1998, one communications tower, 8 broadcast towers, and 10 two-way radio towers failed in New Hampshire and Vermont due to wind and ice loading. Many other towers survived the storm, but went offline when their backup fuel supplies ran out in the face of widespread power outages (Jones & Mulherin, 1998).

In 2005, the Independent Panel Reviewing the Impact of Hurricane Katrina on Communications Networks issued recommendations that cellular network providers increase the amount of backup power available for sites, due to widespread outages experienced during Katrina. The FCC proposed a rule requiring 24 hours of backup power at central communications offices and eight hours at antenna sites. This rule was abandoned following criticism by carriers and the Bush White House that installing such backup systems would be prohibitively expensive (Silva, 2008).

As many as 1,400 tower sites in Virginia, New Jersey, New York, and North Carolina, three broadcast radio stations, and an unknown number of coastal sites were reportedly damaged and knocked offline by Hurricane Irene in 2011. Major carriers including AT&T and Verizon reported problems with flooding, downed trees, loss of grid power, and abnormally high call volume (Hamblen, 2011).

According to the FCC, at the height of Hurricane Sandy in 2012, 25 percent of all cell towers throughout 10 states were offline due to the storm. Reported causes included flooding, loss of grid power, inability to access the sites and replenish fuel to generators, antenna misalignment due to wind damage, and physical site damage from debris (Burt, 2012). Two days after the storm, 19 percent of sites remained offline and AT&T and T-Mobile had implemented a network sharing agreement in the New York area to compensate for reduced capacity in their individual networks (Smith, 2012).

LOOKING FORWARD: FUTURE CONSIDERATIONS FOR SITING

In the race to expand our communications network to serve a growing and data-hungry population, it is tempting to do the minimal amount of environmental review necessary to select a site and get the structure online. Our currently mandatory environmental review for these types of facilities consists of compliance with NEPA and local building and zoning regulations. These regulations are tied to currently mapped floodplains, wind zones, and hurricane inundation areas that are based on analysis of historic data.

Climate change studies of the New England region show us that the historic baseline is changing, with increased temperatures and precipitation, more severe weather, and rising sea levels. Some of these impacts are evident through recent severe weather events that have caused significant damage to communications infrastructure built in compliance with existing regulations. We depend on this infrastructure to get assistance during the very events that are most apt to render it useless. It is critical that network owners and wireless carriers develop a far-sighted approach to choosing sites that will protect them. Consideration should be paid to whether a structure is located within an area of historically “moderate” risk, like a 500 year floodplain, or adjacent to these areas, because yesterday’s moderate risk areas are becoming the high risk areas of the future. It is not inconceivable that a Category 3 or 4 hurricane could make landfall in New England, particularly on south-facing coasts such as those of Connecticut, Long Island, and Cape Cod. Sea levels are rising while much of New England is subsiding, and both coastal communications sites and the highly populated areas they serve will be vulnerable to inundation and increased storm damage.

GIS analysis is potentially a very effective tool at predicting future network vulnerability, but as this analysis has shown if the required data is outdated, not detailed enough, restricted in coverage, or just not available, such efforts will be greatly limited in scope. It is critical that our state and federal governments invest in resources to develop and maintain highly accurate, detailed environmental data sets that are available for public and academic research. This money will be well spent, because it will enable the establishment of future network locations that ride out the storm and operate safely for many years to come, keeping critical lines of communication open when we need them the most.

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APPENDIX A: PUBLICALLY AVAILABLE GIS DATA RESOURCES FOR THE NEW ENGLAND STATES

Connecticut

Connecticut Environmental Conditions Online <http://cteco.uconn.edu/>

Connecticut Geospatial Information Systems Council <http://www.ct.gov/GIS/site/default.asp>

Connecticut Department of Energy and Environmental Protection
http://www.ct.gov/dep/cwp/view.asp?a=2698&q=322898&depNav_GID=1707

Maine

Maine Office of GIS (MEGIS) <http://www.maine.gov/megis/>

Massachusetts

Massachusetts Office of Geographic Information (MassGIS)
<http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/>

New Hampshire

New Hampshire GRANIT <http://www.granit.unh.edu/>

Rhode Island

Rhode Island Geographic Information System (RIGIS) <http://www.edc.uri.edu/rigis/>

Vermont

Vermont Center for Geographic Information (VCGI) <http://www.vcgi.org/>