4: Vermont Profile & Hazard Assessment

Vermont Profile

Vermont is located astride the Green Mountains at the center of three ranges of the Appalachians, with the Adirondacks to the west and the White Mountains to the east. Vermont encompasses 9,250 square miles of landmass.

Population Trends:

Geographically, Vermont is the sixth smallest state and the second least populated. The population of Vermont was 625,741 based on the 2010 Census and is estimated to have decreased to 623,657 in 2017, a decline of approximately 0.3%. As the maps below indicate (Figures 17 & 18), there have been relatively minor changes in population statewide since 2010. Some counties have experienced slight gains (most notably Chittenden, +3,965), and other counties have experienced decreases (most notably Rutland, -1,509).

Most Vermonters live in small, rural communities with populations of several hundred to several thousand people. The largest city is Burlington, with a population of 42,556 (2016 ACS estimate).

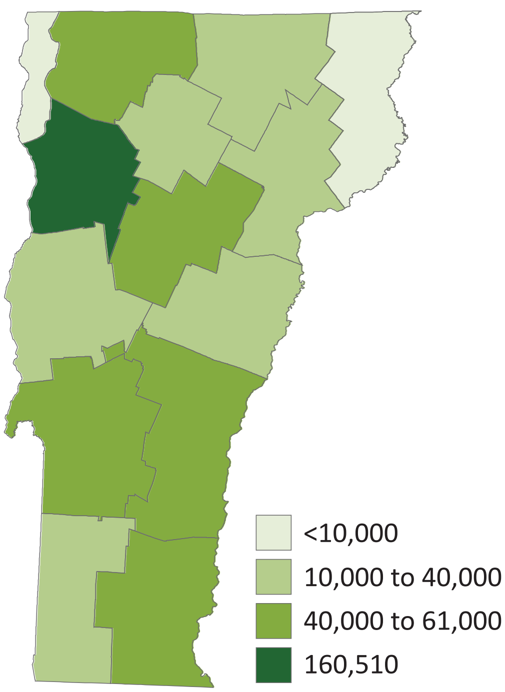

Figure 17: Vermont population by county map (2016)
Source: 2016 ACS 5-year estimates

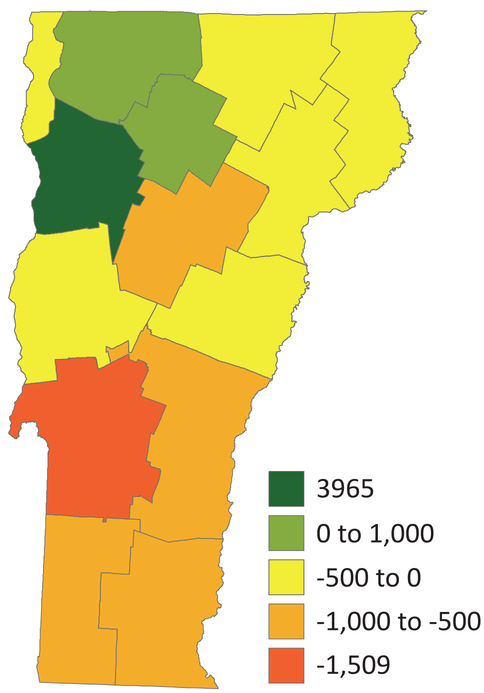

Figure 18: Vermont population change by county map (2010-2016)
Source: 2016 ACS 5-year estimates

Development Trends:

Historically, communities and infrastructure have often been sited in valleys and near water bodies, both globally and in Vermont. This development pattern was based on the assumption that rivers and coastlines would not shift or change course, which in turn relied on an assumption that climate conditions would remain relatively static. Today, with climate change models predicting increased precipitation and stronger storms in New England, many communities now find themselves and their infrastructure increasingly vulnerable to natural disasters like flooding. With the benefit of time, it is now understood that rivers and water bodies naturally adjust and change course, again threatening much of the infrastructure that lies in their path.

Between 2000 and 2010, there were no large-scale increases in either commercial or residential development in Vermont, with a total net increase of 28,157 housing units statewide. From 2010-2016, there has only been an estimated increase of 4,273 housing units (2016 ACS estimate) (Figure 20). Though this updated figure represents a shorter period of time for development, this trend, combined with population trends, suggests that the rate of new housing development in Vermont is declining.

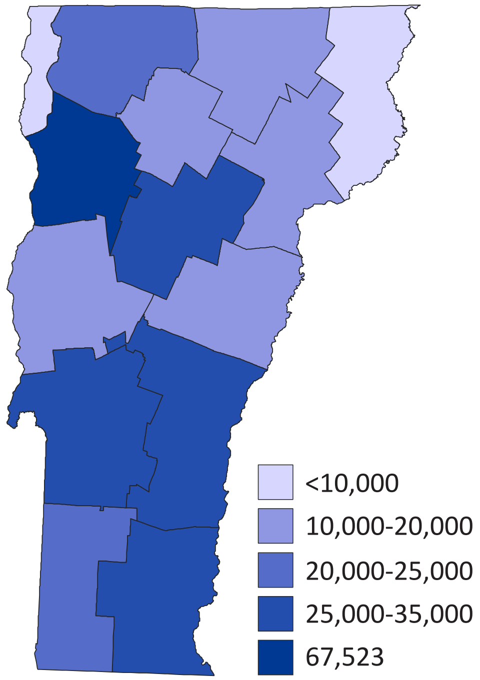

Figure 19: Housing units by county map (2016)
Source: 2016 ACS 5-year estimates

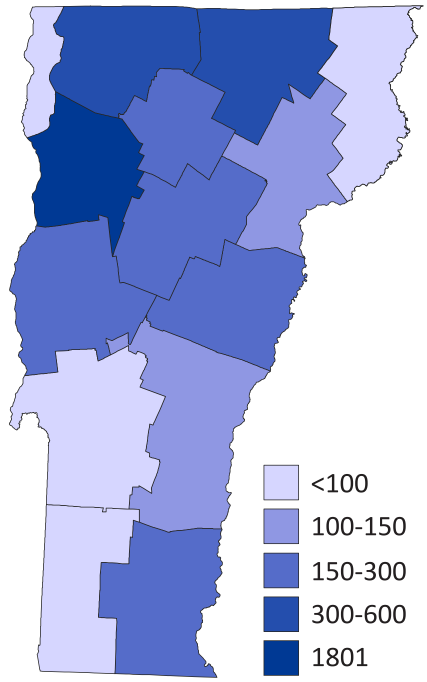

Figure 20: Housing unit change by county map (2010-2016)
Source: 2016 ACS 5-year estimates

A review of all Local Hazard Mitigation Plans that were approved by FEMA as of December 31, 2017 shows that the vast majority of communities report very little development, if any, since the 2013 State Hazard Mitigation Plan and that vulnerability has remained the same and is not projected to change. To get a better understanding of local development, VEM staff asked Regional Planning Commissions (RPCs) to note significant changes in development trends within their regions over the past five years and their impact on vulnerability, included in Table 12 below. Regions reporting no significant changes in development are not included.

In addition to the feedback from RPCs, several communities were added to Table 12 below based on the review of currently approved LHMPs (for more information on this review process, see: State & Local Capabilities). Predominately, LHMPs report that little, if any, development has taken place since their previous Plan and that vulnerability has remained the same and is not projected to change.

Table 12: Changes in Development by Region

Region	Munipality	Changes in Development & Vulnerability
ACRPC	Middlebury	Mitigation project in East Middlebury creates a false sense of security. Development of athletic fields in the floodplain increased flood depths downtown.
BCRC	Bennington	Putnam Block hotel project will increase development downtown in the floodplain, though the project will include flood-proofing of new and existing buildings and is supporting a downtown.
CCRPC	Montpelier	Several developments are planned in the City of Montpelier within the floodplain, including a hotel and a distillery. All new development will be required to follow Montpelier's NFIP standards.
CCRPC	Jeffersonville Village	Vulnerable has been reduced due to FEMA-funded projects, including the Greenway Trail Bridge replacement project and floodplain restoration, and drainage improvements downtown that are currently underway.
CCRPC	Grand Isle	There has been a decline in agricultural use of land, a small amount of additional residential development along existing roadways and the shoreline, and some commercial development along Route 2. This development has not occurred in hazard-prone areas.

Continued on pg. 41

Region	Munipality	Changes in Development & Vulnerability
CVRPC	Barre City, Northfield, Middlesex	Home buyout projects have restored the floodplain to reduce and eliminate risk from flooding.
CVRPC	Plainfield	Home buyouts at risk from landslide and fluvial erosion have eliminated risk for specific properties.
NVDA	Concord, Maidstone, Westmore, Barnet	Conversion of seasonal homes to year-round use causes more use of old septic systems close to lakes – creating potential for contamination to surface waters. Roads that used to only be used seasonally are now used year-round.
RRPC	Brandon	Box culvert was built to allow the Neshobe River to pass through downtown during heavy flows and reduce vulnerability in town.
TRORC	Woodstock	Major infrastructure was rebuilt in floodplain after Irene; the village area is highly vulnerable to inundation and fluvial erosion.
WRC	Brattleboro	While no significant development has happened in Brattleboro according to their most recent LHMP, a pending Pre-Disaster Mitigation project for property buyouts and floodplain restoration on the Whetstone Brook will lower flood levels in Brattleboro.
WRC	Dover	Changes are expected due to Mount Snow Resort development, possibly including changes to flood patterns due to snowmaking water in a different watershed.
WRC	South Newfane	Home sales are lagging, due perhaps to flooding issues; the town may begin to depopulate.

The only significant development within State-owned buildings since 2013 was the Waterbury State Office Complex, which was awarded LEED Platinum designation in December of 2017. The complex was significantly damaged during Tropical Storm Irene in 2011 and was redeveloped to accommodate future flood predictions. The buildings now lie above the 0.2% annual flood level and incorporate dry flood-proofing to provide further protection from future flooding.

Transportation:

Vermont owns approximately 3,100 miles of State highway and there are 772 miles of federal highway within the State (Figure 21). Transportation systems that run north to south within the State are I-89 (northwestward from White River Junction to the Canadian border, serving both Montpelier and Burlington), I-91 (northward from the Massachusetts border to the Canadian border, connecting Brattleboro, White River Junction, St. Johnsbury, and Newport), and I-93 (northern terminus at I-91 in St. Johnsbury, connecting the northern part of Vermont with New Hampshire).

Other significant routes include U.S. Route 5 (running south to north along the eastern border of Vermont, parallel to I-91 for its entire length in the State), U.S. Route 7 (running south to north, along the western border of the State, connecting Burlington, Middlebury, Rutland, and Bennington) and Vermont Route 100 (running south to north almost directly through the center of the State, providing a route along the full length of the Green Mountains).

East-west routes include U.S. Route 2 (crossing northern Vermont from west to east, and connecting the population centers of Burlington, Montpelier, and St. Johnsbury), U.S. Route 4 (crossing south-central Vermont from west to east, from the New York border in the Town of Fair Haven, through the City of Rutland, and across to Killington and White River Junction), U.S. Route 302 (traveling east from Montpelier and Barre, into New Hampshire and Maine), Vermont Route 9 (running across the southern part of the State from Bennington to Brattleboro), and Vermont Route 105 (crossing the northernmost parts of Vermont and connecting the cities of St. Albans and Newport).

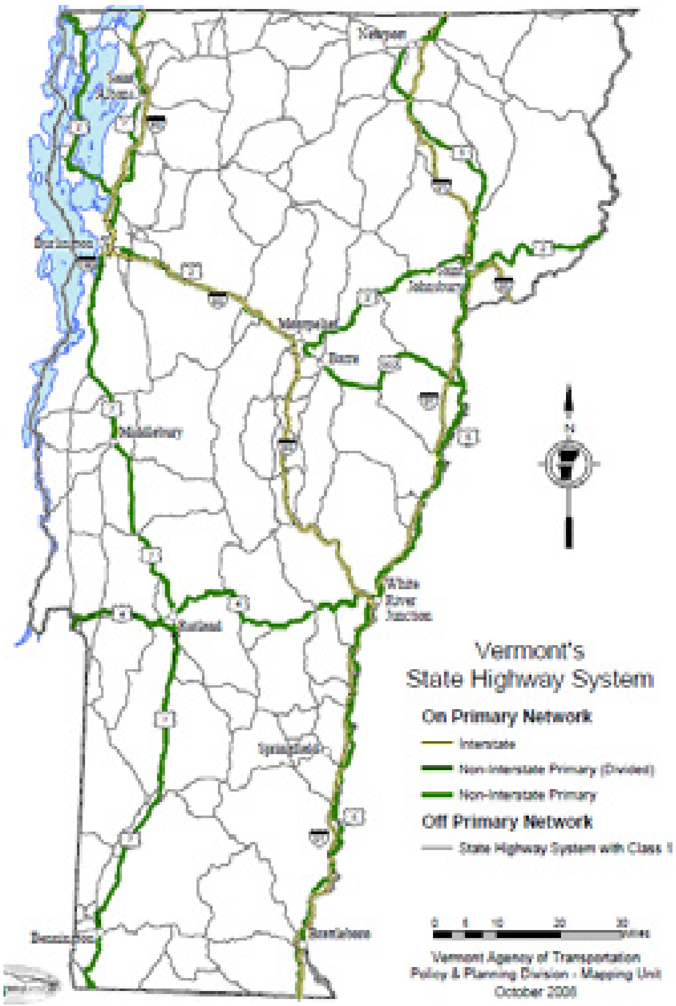

Figure 21: Vermont's state highway system map
Source: Vermont Agency of Transportation

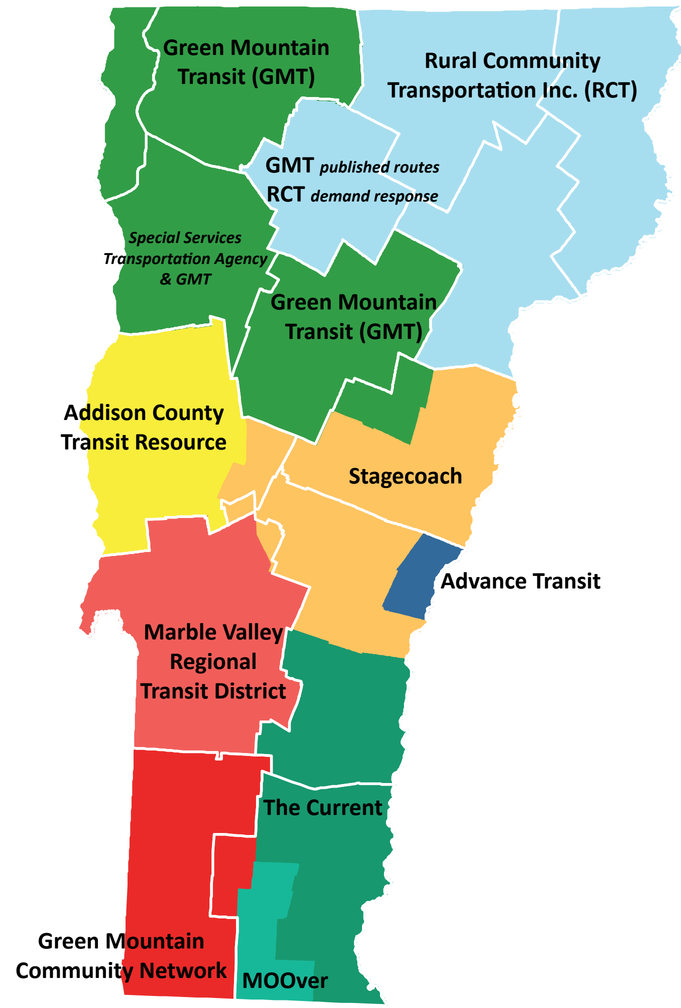

Figure 22: Vermont public transportation service areas map
Data Source: Vermont Public Transportation Association

A VTrans survey conducted in 2016 found that the vast majority of Vermonters (91%) travel in a personal vehicle frequently, with 88% commuting to work in a personal vehicle or carpool. The next largest transportation category was walking, with 45% of respondents walking as a means of transport multiple times per week or month[1]. Fourteen percent reported biking frequently, while 8% noted frequent use of public transportation.

Vermont is served by the Burlington International Airport (BTV). Vermont has eleven different bus companies (Figure 22), two ferry companies and three rail service lines throughout the State. The State of Vermont also has a program called Go Vermont[2], which is a resource for travelers who want to reduce the cost and environmental impact of driving. It provides information on bus routes, biking, or walking and features a free carpool/vanpool matching service and ridesharing tips. The State is served by Amtrak's Vermonter and Ethan Allen Express passenger lines, the New England Central Railroad, the Vermont Railway, and the Green Mountain Railroad. The Ethan Allen Express serves Rutland and Castleton, while the Vermonter serves Saint Albans, Essex Junction, Waterbury, Montpelier, Randolph, White River Junction, Windsor, Bellows Falls, and Brattleboro, with a planned extension to Canada.

1 http://vtrans.vermont.gov/sites/aot/files/planning/documents/planning/Existing%20Conditions%20%20Future%20Trends%206-7-17.pdf
2 https://www.connectingcommuters.org/

Vulnerable Populations:

Natural hazards can affect everyone in Vermont, but some populations may be more vulnerable to certain types of events or more significantly impacted during events. The Social Vulnerability Index (SVI)[3] defines overall vulnerability by summarizing four themes: socioeconomic status, household composition and disability, minority status and language, and housing and transportation. Figure 23 depicts this overall score by census block, broken into four relative categories of overall vulnerability.

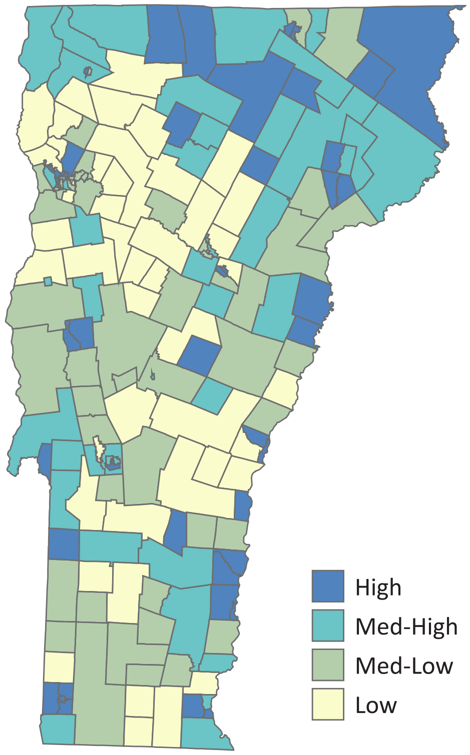

Figure 23: Social Vulnerability Index map (2016)
Source: https://svi.cdc.gov/map.aspx

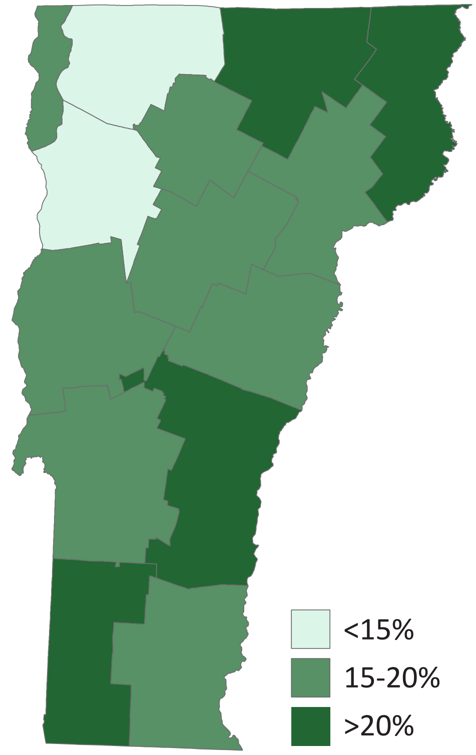

Figure 24: Vermont population over 65 map (2016)
Source: 2016 ACS 5-year estimates

Vermonters over the age of 65 is a specific demographic that is potentially more vulnerable to certain events, such as extreme heat. In 2016, 17% of Vermont was over the age of 65 based on estimates from the U.S. Census, above the national average of 14.5%. Figure 24 the percent population over 65 by county, with the most significant population in Essex County (23%, 1,408 people).

Vulnerability can also be economic. Vermont's median household income was estimated at $56,104 in 2016, slightly above the national average of $55,322. To better account for cost of living in Vermont, Vermont's Joint Fiscal Office develops a report biennially that determines a livable hourly wage for Vermonters[4]. This analysis estimates how much an individual would need to make, at a minimum, in order to live in Vermont based on a variety of family configurations and assuming employer-sponsored healthcare. The overall livable wage rate in 2016 was defined as $27,102 in individual income for a full-time worker in a two-person household without children. That equates to a household income of $54,205, which is just below the median household income for Vermont. The below table includes the various household types considered in the report and their corresponding livable wage figures.

Table 13: 2016 Basic Needs Budget Wages, Per Earner – Vermont's Basic Needs Budget

Family Type	Urban Annual Salary	Rural Annual Salary	Urban Household Salary	Rural Household Salary
Single Person	$36,691.20	$32,780.80	$36,691.20	$32,780.80
Single Person, Shared Housing	$30,076.80	$26,998.40	$60,153.60	$52,996.80
Single Parent, One Child	$61,360.00	$52,228.80	$61,360.00	$52,228.80
Single Parent, Two Children	$79,372.80	$67,641.60	$79,372.80	$67,641.60
Two Adults, No Children	$28,163.20	$26,020.80	$56,326,40	$52,041.60
Two Adults, Two Children (one wage erner)	$67,870.40	$63,793.60	$67,870.40	$63,793.60
Two Adults, Two Children (two wage erners)	$45,697.60	$42,328.00	$91,395.20	$84,656.00

Source: http://www.leg.state.vt.us/jfo/reports/2017%20BNB%20Report%20Revision_Feb_1.pdf

3 https://svi.cdc.gov/map.aspx
4 http://www.leg.state.vt.us/jfo/reports/2017%20BNB%20Report%20Revision_Feb_1.pdf

Climate Change

Over the past several decades, there has been a marked increase in the frequency and severity of weather-related disasters, both globally and nationally. Most notably, the Earth has experienced a 1°F rise in temperature, which has far-reaching impacts on weather patterns and ecosystems. This statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer), is known as climate change[5].

The Intergovernmental Panel on Climate Change (IPCC) forecasts a temperature rise of 2.5°F to 10°F over the next century, which will affect different regions in various ways over time. Impacts will also directly relate to the ability of different societal and environmental systems to mitigate or adapt to change[6]. Increasing temperatures are forecasted to have significant impacts on weather-related disasters, which will also increase risk to life, economy and quality of life, critical infrastructure and natural ecosystems. The IPCC notes that the range of published evidence indicates that the costs associated with net damages of climate change are likely to be significant and will increase over time. It is therefore imperative that recognition of a changing climate be incorporated into all planning processes when preparing for and responding to weather-related emergencies and disasters.

Most of the natural hazards identified below are likely to be exacerbated by changes in climate, either directly or indirectly. This section begins to review changes in our global and regional climate, which are further addressed in the hazard profiles, including:

- **Precipitation:** Inundation Flooding & Fluvial Erosion; Drought; Wildfire; Landslides; Snow Storm & Ice Storm
- **Temperature:** Extreme Cold; Extreme Heat; Drought; Wildfire; Invasive Species; Infectious Disease; Snow Storm & Ice Storm
- **Snow Cover:** Snow Storm & Ice Storm; Drought; Wildfire

The National Aeronautics & Space Administration (NASA) reports that global climate change has already had observable effects on the environment: glaciers are shrinking, sea ice is disappearing, sea level rise is accelerating, heat waves are occurring more frequently and intensely, river and lake ice is breaking up earlier, plant and animal ranges have shifted, and trees are flowering sooner. Though climate change is expected to have global reach, the impacts differ by region. While the southwestern United States is expected to experience increased heat, wildfire, drought and insect outbreaks, the northeastern region is predicted to experience increases in heat waves, downpours and flooding. Accordingly, consideration of climate change was identified as a key guiding principle of the 2018 SHMP, addressed in each of the pertinent hazard profiles and incorporated into all relevant mitigation actions.

Vermont's Annual Maximum and Minimum Temperatures (1960-2015)

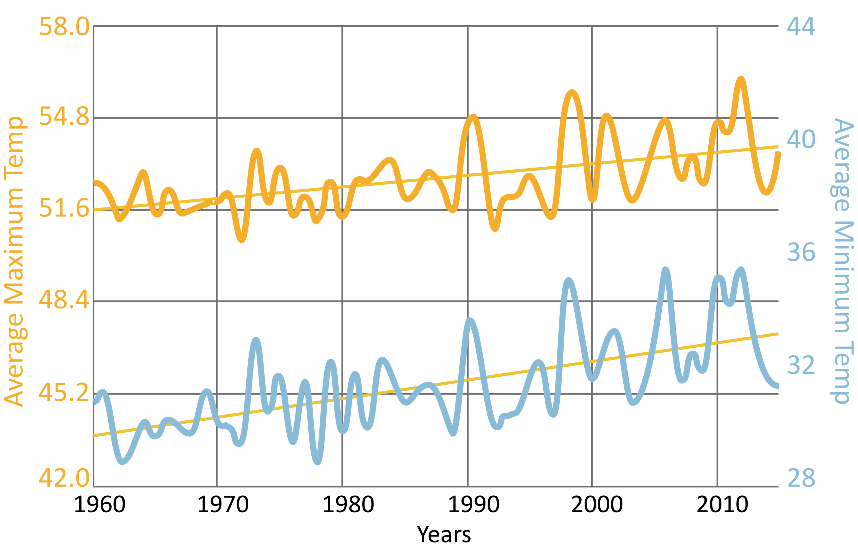

Figure 25: Vermont's annual maximum and minimum temperatures (1960-2015)
Data Source: climatechange.vermont.gov

5 http://www.ipcc.ch/
6 https://climate.nasa.gov/effects/

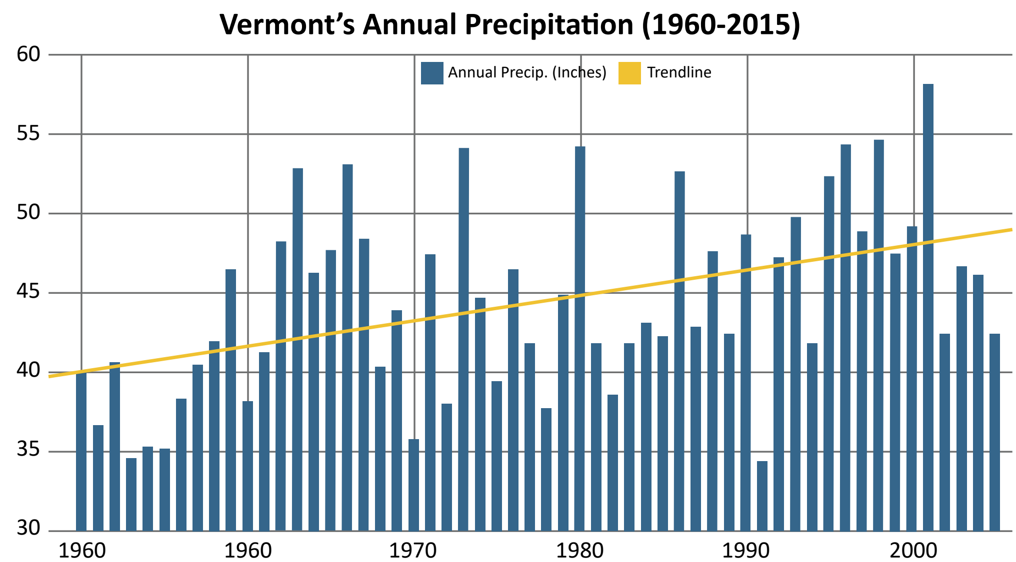

Figure 26: Vermont's annual precipitation (1960-2015)
Source: climatechange.vermont.gov

Table 14: Observed Climate Trends – Vermont's 2017 Forest Action Plan

Parameter	Trend	Projections
Temperature		
Annual Temperature	Increase	By 2050, projected increase in average annual temperature by 3.7-5.8° F; by 2100, increase by 5.0-9.5° F.
Seasonal Temperature	Increase	By 2050, projected increase in average winter temperature (December, January, February) by 4.3-6.1° F; average summer temperature (June, July, August) by 3.8-6.4° F
Hot Days > 90°F	Increase	More frequent and more intense; by the end of the century, northern cities can expect 30-60+ days with maximum daily temperatures >90° F
Cold Days < 0°F	Decrease	Reduction in days with minimum daily temperatures <0° F
Variability	Increase	Greater variability (more ups and downs)
Hydrology		
Annual Precipitation	Increase	By the end of the century, projected total increase of 10% (about 4" per year)
Season Precipitation	Variable	More winter rain, less snow; by 2050, winter precipitation could increase by 11-16% on average; little change expected in summer, but projections are highly variable
Heavy Rainfall Events	Increase	More frequent and intense
Soil Moisture	Decrease	Reduction in soil moisture and increase in evaporation rates in the summer
Snow	Decrease	Fewer days with snow cover (by the end of the century, could lose one-fourth to more than one-half of snow-covered days); increased snow density
Spring Flows	Earlier, Reduced Volume	Earlier snowmelt, earlier high spring flows with reduced volume; could occur ten days to >2 weeks earlier
Summer Low Flows	Increase	Extended summer low-flow periods; could increase by nearly a month under high emissions scenario
Ice Dynamics	Changing	Less ice cover and reduced ice thickness
Extreme Events		
Flood Events	Increase	More likely, particularly in winter and particularly under the high emissions scenario
Number of Short-Term Droughts	Increase	By the end of the century, under high emissions scenario, short-term droughts could occur as much as once per year in some places
Storms	Increase	More frequent and intense (ice, wind, etc.)
Fire	Increase	More likely
Phenology		
Growing Season	Increase	By the end of the century, projected to be 4-6 weeks longer
Onset of Spring	Earlier	By the end of the century, could be 1 to almost 3 weeks earlier
Onset of Fall	Later	By the end of the century, could arrive 2-3 weeks later

Source: fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Vermont_Forests/Library/2017_VT_ForestActionPlan.pdf

Since 1960, the average annual maximum temperature in Vermont increased about 0.4°F per decade, while the average minimum temperature rose at 0.6°F per decade (Figure 25). Similarly, the average annual precipitation has risen 0.7” per decade since 1895 and 1.5” per decade since 1960[7] (Figure 26), suggesting increasing trends in both temperature and precipitation.

According to the 2014 National Climate Assessment, the average annual precipitation in the United States has increased by approximately 5%[8]. Of particular note, the Assessment also identifies the northern U.S. as being more likely to experience above average precipitation in the winter and spring, with even wetter conditions expected under a high greenhouse gas emissions scenario. In addition to higher annual precipitation in both the observed record and projected models, the northeastern United States is also projected to experience more frequent, heavier rainfall events. Since 1991, the incidence of these heavy precipitation events has been 30% above average[9].

Another climate change concern in Vermont is the potential for climate refugees. As portions of the U.S. become more arid and as sea levels continue to rise, Vermont may begin to see significant increases in population. One study on sea-level rise displacement projects over 4,000 migrants to Vermont from across the U.S., most predominately in Chittenden County. This study does not account for people moving from increasingly arid areas within the U.S. or from outside of the U.S., which may also increase net immigration. Based on the unpredictable nature and potential impact of an influx of climate refugees into the State, the Steering Committee decided to acknowledge climate refugees as a potential future hazard facing Vermont, to be reassessed during the next SHMP update.

HAZARD ASSESSMENT

A risk assessment is used to measure the potential loss of life, personal injury, economic impact, and property damage resulting from natural hazards by analyzing the vulnerability of people, the built environment, the economy and the natural environment. VEM staff used several methods to identify risks in Vermont, including the evaluation of historical data, consideration of changing climate trends, and feedback from stakeholders. This examination involved an extensive review of natural disasters in Vermont, both declared and undeclared. Man-made and technological hazards are covered extensively in the 2018 Vermont State Emergency Management Plan (SEMP), which follows a risk assessment methodology similar to that used in this Plan. Accordingly, the following sections of the risk assessment identify the natural hazards that Vermonters can expect to face over the next fifty years and beyond, and the mitigation strategies section reviews the actions underway or planned to address these hazards and risks. As noted in the 2013 SHMP, and confirmed again in this 2018 SHMP, the natural hazards not incorporated are coastal erosion, expansive soils, Karst topography, sinkholes, tsunamis and volcanoes. These hazards are considered non-significant, unlikely hazards in Vermont and therefore do not warrant extensive review and consideration in this Plan. Table 19 explains how each hazard addressed in the 2013 SHMP was considered in this Plan.

Hazard Events

One of the most significant changes from the 2013 Plan to the 2018 Plan is the way hazards are assessed. Instead of continuing to view hazards as events (e.g. hurricanes), the 2018 SHMP assesses the impacts of events (e.g. inundation flooding, fluvial erosion, and wind as impacts of a hurricane event), as it is the impacts, not the events, that can be mitigated. Table 15 represents the initial analysis of hazard events by the Steering Committee, which informed the creation of the hazard impact assessment.

7 http://climatechange.vermont.gov/our-changing-climate/dashboard/more-annual-precipitation
8 https://nca2014.globalchange.gov/report/our-changing-climate/precipitation-change
9 https://nca2014.globalchange.gov/report/our-changing-climate/heavy-downpours-increasing

Table 15: Hazard Events Assessment			
Hazard Events	**Hazard Type**	**Probability**	**Hazard Impacts**
Rainstorm/Thunderstorm	Meteorological	Highly Likely	Erosion; Inundation; Wind; Hail; Lightning
Winter Storm	Meteorological	Likely	Snow; Ice; Wind
Landslide	Geological	Likely	Inundation; Erosion
Drought	Meteorological	Likely	
Tropical Storm/Hurricane	Meteorological	Occasionally	Erosion; Inundation; Wind
Ice Jam	Meteorological	Occasionally	Inundation; Erosion
Tornado	Meteorological	Occasionally	Hail; Wind
Wildfire	Meteorological	Occasionally	
Earthquake	Geological	Occasionally	

Hazard Impacts

The Steering Committee ranked the natural hazard impacts associated with the events listed above. Table 16 presents that ranking, including the probability of occurrence and potential impact to infrastructure, life, economy and the environment. Table 17 details the hazard assessment ranking criteria.

Table 16: 2018 Hazard Assessment							
Hazard Impacts	**Probability**	**Potential Impact**					**Score*:**
		Infrastructure	Life	Economy	Environment	**Average:**	
Fluvial Erosion	4	4	3	4	4	3.75	15
Inundation Flooding	4	4	3	4	2	3.25	13
Ice	3	3	3	3	2	2	8.25
Snow	4	1	3	2	1	1.75	7
Wind	4	2	2	1	1	1.5	6
Heat	3	1	3	2	2	2	6
Cold	3	1	3	2	2	2	6
Drought	3	1	2	2	3	2	6
Landslides	3	3	2	1	2	2	6
Wildfire	2	3	3	3	2	2.75	5.5
Earthquake	2	3	3	3	2	2.75	5.5
Invasive Species	2	1	1	2	3	1.75	3.5
Infectious Disease Outbreak	2	1	3	2	1	1.75	3.5
Hail	3	1	1	1	1	1	3

*Score = Probability x Average Potential Impact

Table 17: Hazard Assessment Ranking Criteria		
	Frequency of Occurrence: Probability of a plausibly significant event	**Potential Impact:** Severity and extent of damage and disruption to population, property, environment and the economy
1	Unlikely: <1% probability of occurrence per year	Negligible: isolated occurrences of minor property and environmental damage, potential for minor injuries, no to minimal economic disruption
2	Occasionally: 1–10% probability of occurrence per year, or at least one chance in next 100 years	Minor: isolated occurrences of moderate to severe property and environmental damage, potential for injuries, minor economic disruption
3	Likely: >10% but <75% probability per year, at least 1 chance in next 10 years	Moderate: severe property and environmental damage on a community scale, injuries or fatalities, short-term economic impact
4	Highly Likely: >75% probability in a year	Major: severe property and environmental damage on a community or regional scale, multiple injuries or fatalities, significant economic impact

The hazards and explanations of their relative probability and impact scores are detailed in the individual hazards assessment sections below. While these hazards are profiled individually, this Plan and the hazard assessment sections recognize that hazards do not occur in silos; many of the hazards are inter-related and often occur in tandem. To highlight the most significant relationships, the fluvial erosion and inundation flooding assessments were combined, as well as the ice and snow storm assessments. Each individual hazard assessment section also references the other pertinent hazards and their content, when applicable.

Table 18: Causal Relationships Between Hazard Impacts

Secondary Hazard Impact (Result) / Primary Hazard (Causal)	Fluvial Erosion	Inundation Flooding	Ice	Snow	Wind	Heat	Cold	Drought	Landslides	Wildfire	Earthquake	Invasive Species	Infectious Disease	Hail
Fluvial Erosion	—	X							X			X		
Inundation Flooding	X	—												
Ice			—											
Snow				—										
Wind					—									
Heat						—		X		X		X	X	
Cold							—							
Drought								—		X				
Landslides									—			X		
Wildfire										—				
Earthquake									X		—			
Invasive Species									X			—	X	
Infectious Disease													—	
Hail														—

Beyond the potential of simultaneous occurrence, several of the hazards also have the potential to *cause* other hazards. Causal relationships are identified in Table 18 (with causal hazards identified in green and resulting hazards identified in blue) and further addressed in pertinent hazard assessment sections. Combined with the projected increases in both precipitation and temperature, this assessment highlights the more significant compounding impacts that Vermont can anticipate in the future due to climate change.

Table 19: Hazard Assessment Changes from the 2013 SHMP

Hazards Addressed in 2013	Hazards Addressed in 2018
Flooding and Fluvial Erosion	**Inundation Flooding; Fluvial Erosion**
Terrorism	Man-made hazards removed.
Earthquakes	**Earthquake**
Infectious Disease Outbreak	**Infectious Disease**
Hurricanes/Tropical Storms	Hazard impacts seperated (**Inundation Flooding; Fluvial Erosion; Wind**)
Tornadoes	Hazard impacts seperated (**Wind; Hail**)
Nuclear Power Plant Failure	Man-made hazards removed. Vermont's only nuclear power plan has been decommissioned.
Landslides/Rockslides	**Landslides**
Severe Thunderstorms	Hazard impacts seperated (**Inundation Flooding; Fluvial Erosion; Wind; Hail**)
Wildfires	**Wildfire**
Dam Failure	Hazard impacts seperated (**Inundation Flooding; Fluvial Erosion**)
Severe Winter Storms	Hazard impacts seperated (**Ice; Snow**)
Hail	**Hail**
Ice Jams	Hazard impacts seperated (**Inundation Flooding; Fluvial Erosion**)
Drought	**Drought**
Rock Cuts	Man-made hazards removed.
Invasive Species	**Invasive Species**
Extreme Temperatures	Hazard impacts seperated (**Heat; Cold**)

Jurisdictional Vulnerability

In conjunction with the risk assessment, VEM staff conducted a vulnerability assessment, which predicts the extent of damage that may result from a hazard event of a given intensity in a given area and considers damage to the existing and future built environment, the natural environment, and populations within Vermont. Vulnerability was determined by identifying the threats posed to people, property, the environment, and the economy. Hazard-specific vulnerability is detailed further in the individual hazard profiles.

Though a small state, Vermont's topography and mountainous setting can result in geographic isolation during severe storms, which can have significant localized impacts. A localized storm can drop a significant amount of water into a small watershed, devastating one town or cutting it off from the rest of the State, while causing no damage to an adjacent town on the other side of a mountain. The mountainous areas in Vermont vulnerable to these phenomena are numerous. Because of the steep mountain topography, damage from frequently occurring extreme weather events in any specific location may occur often or only once in a lifetime, which makes it difficult to plan for and responding to events.

Coupled with this topographic isolation, the rural nature of the State can also result in isolation from necessary emergency response efforts. Most communities in Vermont have an identified local Emergency Operations Center (EOC) and/or shelter for its residents, should an event warrant their opening and often require a back-up energy source, typically in the form of generators. In order to keep these critical facilities functioning in times of need, VEM is regularly contacted for equipment and training requests and financial assistance. Other critical facilities that have applied for funding through the State are wastewater treatment plants and fire departments, which require back-up energy sources during events that may result in community-wide power loss (e.g. flooding, wind storm, ice/snow storm), or which require flood-proofing to reduce vulnerability to flood damage.

Jurisdictional Risk Assessments:

In an effort to validate the risk assessment completed by the Steering Committee, and as one of the metrics used to assess local vulnerability, VEM staff asked RPCs to rank the same list of hazards based on the perceived

Table 20: Hazard Assessment Ranking by Regional Planning Commission

Hazard Impact	Average	ACRPC	BCRC	CCRPC	CVRPC	LCPC	NRPC	NVDA	RRPC	SWCRPC	TRORC	WRC
Inundation Flooding	2.2	9	1	2	1	2	1	1	2	1	2	2
Fluvial Erosion	2.3	3	2	1	2	4	3	5	1	2	1	1
Snow	4.5	12	3	4	3	1	5	2	7	3	6	3
Ice	4.6	1	9	6	4	5	2	3	4	9	3	5
Wind	5.1	2	4	3	6	6	4	6	3	6	4	12
Cold	7.4	17	8	5	5	3	13	4	5	4	10	10
Invasive Species	8.0	4	6	10	10	9	11	13	8	--	5	4
Landslides	8.4	7	12	13	8	7	6	8	10	7	8	6
Wildfire	8.8	6	11	9	7	11	9	10	13	5	9	7
Drought	9.3	11	7	11	12	10	8	9	11	8	7	8
Hail	9.5	10	14	12	9	8	7	7	6	11	11	9
Infectious Disease	10.0	5	5	7	14	12	10	12	12	--	12	11
Heat	11.1	8	10	8	13	13	14	11	9	10	13	13
Earthquake	13.1	12	13	14	11	14	12	14	14	12	14	14

Table 21: Hazards Addressed in Local Hazard Mitigation Plans Approved as of December 31, 2017		
Hazard	**Approved LHMPs**	**Percent of Approved LHMPs**
Flooding	165	97.1%
Winter Storms	132	79.4%
Fluvial Erosion	122	71.8%
Ice Storm	95	55.9%
High Wind	87	51.2%
Flash Flood	69	40.6%
Wildfires	47	27.6%
Hurricanes/Tropical Storms	42	24.7%
Thunderstorms	42	24.7%
Hail	39	22.9%
Landslides	39	22.9%
Extreme Cold	36	21.2%
Ice Jams	36	21.2%
Lightning	31	18.2%
Dam Failure	29	17.1%
Infectious Disease Outbreak	29	17.1%
Earthquake	27	15.9%
Drought	24	14.1%
Invasive Species	22	12.9%
Tornado	20	11.8%
Extreme Temperatures	19	11.2%

vulnerability in their respective regions. RPCs ranked vulnerability on a scale from 1-14, with 1 being the most significant and 14 being the least significant. Table 20 represents the responses from each RPC, with an average score based on all responses, ordered from most to least significant. The results of this analysis closely matched the hazard ranking completed by the Steering Committee, further confirming Vermont's most significant hazards (i.e. Fluvial Erosion, Inundation Flooding, Ice and Snow).

At the end of 2017, 170 of the 281 jurisdictions in Vermont had FEMA-approved Local Hazard Mitigation Plans (60.5%). In a review of these approved plans, VEM mitigation staff identified natural hazards that were addressed by more than 10 individual jurisdictions (Table 21). The analysis also confirms that the most significant concerns at the State level are consistent with reality at the regional and local levels, with Flooding, Winter Storms and Fluvial Erosion and Ice Storm ranking as the most significant hazards.

In addition to ranking hazard significance, RPCs also listed the communities within their regions that are most vulnerable to natural hazards and explained what makes them vulnerable. The responses are represented in Table 22. VEM staff used this local vulnerability information to inform the assessment of each hazard and the mitigation strategy (see: Mitigation Strategy).

Table 22: Local Vulnerability by Regional Planning Commission		
RPC	**Municipality**	**Vulnerability**
ACRPC	Bristol	Village was built on unstable gravel deposit prone to landside; large forest products industry threatened by invasive species.
ACRPC	Goshen	Most of town is within the Green Mountain National Forest and vulnerable to wildfire.
BCRC	Bennington	Significant amount of structures in floodplain, including downtown Bennington, vulnerable to flooding and fluvial erosion.
BCRC	Pownal	Over 100 mobile homes in the floodplain, vulnerable to flooding and erosion.
BCRC	Manchester	Second largest town in the region, which was cut off during Irene and is still vulnerable to flooding and fluvial erosion.
BCRC	Woodford	Over 40 homes in river corridor that are not in the flood zone. Town has not adopted river corridor protection and is vulnerable to erosion.

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RPC	Municipality	Vulnerability
CCRPC	Bolton, Huntington, Richmond, Underhill, Westford	Steep roads vulnerable to fluvial erosion and flooding.
CVRPC	Barre City, Montpelier	Downtowns in floodplain prone to flooding and ice jams, vulnerable populations at risk due to cold, critical facilities potentially at risk, limited capacity to handle and store large volumes of snow.
CVRPC	Plainfield	Vulnerable to flooding due to topography and soils, debris jam potential, and public infrastructure in need of upgrade. Limited transportation routes and potential for isolation. Proximity to the Marshfield Dam.
CVRPC	Duxbury	Vulnerable to flooding due to topography and soils. 90% forested landcover, which is at risk of wildfire. Lack of dry hydrants; rural community with remote locations and vulnerable populations; potential for long-term power outages.
CVRPC	Waterbury Town/Village	Downtown location and critical facilities prone to flooding and near Waterbury Dam, age and condition of infrastructure, vulnerable populations, potential for long-term power outages.
LCPC	Johnson	Vulnerable to flood inundation and ice jams due to low lying downtown.
LCPC	Jeffersonville/Cambridge	Population in the floodplain vulnerable to inundation flooding and ice jams.
LCPC	Stowe	More densely developed along river, vulnerable to flood inundation and wind.
NRPC	Highgate	Forested land cover at risk of inundation and fluvial erosion, power lines vulnerable to ice, winds from the west gain strength over lake.
NRPC	Montgomery	Soils and topography create risk of flooding and erosion, power lines vulnerable to ice, remoteness and forested land cover, winds from the west gain strength over lake.
NRPC	Enosburgh Town	Fluvial erosion and inundation risk, power lines vulnerable to ice, forested land cover, winds from the west gain strength over lake.
NRPC	Isle La Motte	Island landform vulnerable to flood inundation, one road connects island to neighboring town, remote, power lines vulnerable to ice, winds from the west gain strength over lake.
NRPC	Swanton Town/Village	Pre-flood regulations development at risk of flood inundation, power lines vulnerable to ice, winds from the west gain strength over lake.
NVDA	Hardwick, Lyndonville, St. Johnsbury	Regional centers with high amount of development subject to flooding and fluvial erosion.
NVDA	Concord, Brownington, Barnet	Development and Infrastructure (roads) in flood zone and river corridor vulnerable to flooding and fluvial erosion.
RRPC	Mendon, Brandon, Pawlet, Rutland City	Infrastructure in the river corridor vulnerable to flooding and fluvial erosion.
SWRPC	Cavendish	Location and topography cause risk of inundation and erosion.
SWRPC	Chester	Critical facilities and infrastructure at risk of inundation and slope failure.
SWRPC	Windsor, West Windsor	Critical facilities vulnerable to inundation, erosion and drought.
SWRPC	Ludlow	Location puts infrastructure at risk from flooding.
TRORC	Stockbridge	Steep slopes that were damaged by Irene at risk of fluvial erosion, road infrastructure located near water bodies vulnerable to inundation risk.
TRORC	Woodstock, Newbury and Village of Wells River, Granville	Major public and private infrastructure located near waterways and vulnerable to erosion and inundation.
TRORC	Rochester	Major public and private infrastructure located near waterways and easily isolated during storm events, at risk of inundation and erosion.
WRC	Jamaica, Newfane	Historic development pattern cause vulnerability to fluvial erosion and inundation.
WRC	Marlboro	Topography and development patterns create a risk of fluvial erosion.
WRC	Wilmington, Wardsboro	Location of downtown and historic development pattern cause a risk of flooding and fluvial erosion.

Vermont Economic Resiliency Initiative (VERI) Priority Areas:

In 2015, the Agency of Commerce and Community Development (ACCD) completed the Vermont Economic Resiliency Initiative (VERI) report[10]. The report was developed to help Vermont communities better manage their flood risk and included an analysis that defined the top 32 communities where flooding risk is high, based on economic activity, at-risk infrastructure, and at-risk non-residential buildings. ACCD completed more detailed analyses for the top six communities, for which projects were defined that would reduce vulnerability and prioritize investment: Barre City and Town, Brandon, Brattleboro, Enosburg Village and Town, and Woodstock. In additional to these top communities, many of the priority areas have seen increased investment in mitigation work, as noted Table 23.

Table 23: Economic Centers with Infrastructure and Commercial Buildings at Risk (VERI)

Municipality	Economic Activity Ranking	2011 Population Estimate	Infrastructure Vulnerability Ranking	Vulnerable Commercial Buildings	Notes	Mitigation Progress in 2018
Brattleboro	4	11,978	6	73	Designated Downtown, Critical Employer	Buyout of Melrose Terrace and subsequent floodplain restoration along Whestone Brook underway
Montpelier	7	7,868	11	300	Designated Downtown, Critical Employer	USACE Silver Jackets VT team awarded funding for updating floodmapping in 2017
Hartford	10	9,952	7	45	Designated Downtown	Several buyouts post-Irene
Barre City	15	9,066	12	169	Designated Downtown	Several buyouts, drainage upgrade projects
Ludlow	16	1,963	43	84	Tourism	Large drainage improvement project and several buyouts
Morristown	17	5,277	51	46	Designated Downtown, Critical Employer	N/A
Woodstock	19	3,047	24	140	Tourism	N/A
Cambridge	20	3,695	26	35	Tourism	Large floodplain restoration and drainage improvement projects underway
Enosburg	57	2,800	65	10	Agriculture	Drainage project along Tyler Branch
Hardwick	65	3,003	22	55	Agriculture	N/A
Essex	22	19,713	66	12	Critical Employer	N/A
Brandon	24	3,943	30	26	Designated Downtown	Large drainage improvement project and several buyouts
Castleton	27	4,695	63	21		N/A
Rockingham	28	5,255	45	14	Designated Downtown	N/A
Arlington	31	2,308	8	15	Critical Employer	Large flood mitigation project at a camp along the Battenkill
Barton	32	2,805	3	68		N/A
Berlin	33	2,886	9	61	Critical Employer	Buyout post-Irene
Chester	34	3,153	16	24	Critical Employer	Several buyouts

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10 http://accd.vermont.gov/community-development/flood/veri

Municipality	Economic Activity Ranking	2011 Population Estimate	Infrastructure Vulnerability Ranking	Vulnerable Commercial Buildings	Notes	Mitigation Progress in 2018
Randolph	36	4,788	36	22	Designated Downtown	N/A
Springfield	37	9,373	19	154	Downtown, Critical Employer	N/A
St. Johnsbury	39	7,594	23	126	Designated Downtown, Critical Employer	Buyout
Lyndon	44	5,971	21	39	Critical Employer	N/A
Barre Town	48	7,937	61	29		N/A
Londonderry	50	1,758	42	31		Several buyouts, generators and flood-proofing projects
Richmond	51	4,108	52	21		Several structural elevation projects
Bradford	54	2,804	5	16	Designated Downtown	N/A
Cavendish	55	1,367	14	11		N/A
Northfield	59	6,221	28	40	Critical Employer	Significant buyouts along Dog River
Burke	63	1,751	48	22	Tourism	N/A
Bethel	70	2,022	1	38	Critical Employer	Several buyouts post-Irene
Fairfax	71	4,319	17	12		N/A
Johnson	74	3,472	41	57	Critical Employer	N/A

Source: http://accd.vermont.gov/community-development/flood/veri

Vulnerability of State-Owned Buildings:

Buildings and General Services (BGS), through a 2018 SHMP subgrant, is the lead agency for a statewide assessment of State-owned buildings located either in the FEMA-mapped floodplain and/or the river corridor. This assessment, which included all State-owned and leased properties, considered both criticality of the buildings' functions and the vulnerability of the structures based on location.

As the two most significant hazards identified in this Plan, the BGS risk assessment project focused primarily on fluvial erosion and flood inundation vulnerability. Further, assessing risk based on these hazards was fairly straightforward, as BGS could access both State and FEMA mapping data specific to fluvial erosion and inundation flooding. Using these data, BGS assessed vulnerability of an individual structure according to its proximity to the FEMA-mapped 100- and 500-yr floodplains, as well as the river corridor. An overall vulnerability score was assigned to each structure using a point system outlined in the Appendix to Section 3. Structures were then assessed according to their criticality to the following State functions:

- Emergency Operations
- Government Operations
- Public Safety
- Public Health
- Public Service
- Economic Activity
- Cultural Resources

BGS then used the scores for criticality and vulnerability to determine building prioritization for developing mitigation measures. The risk assessment also includes information on each building's current function, construction type and year, number of floors, building replacement cost, cost of personal property and cost of computer equipment. A detailed description of this risk assessment, prioritization process and alternatives analysis for the top priority State-owned structures can be found in the Appendix to Section 3.

Though the BGS project focused primarily on fluvial erosion and inundation flooding, the data acquired are pertinent to all natural hazards profiled in this Plan that could impact State-owned or leased structures. That is, a building's replacement cost will be the same regardless of what hazard was responsible for its destruction. Similarly, a building's criticality score does not differ hazard-to-hazard. Further, without high fidelity hazard mapping data for all natural hazards, determining true vulnerability of a structure based on proximity to a clearly delineated hazard area is very difficult. The full list of all State-owned buildings and their replacement costs as defined above in is the Appendix to Section 4.