Monadnock Region Transportation Infrastructure Flood Vulnerability Assessment

Prepared by Southwest Region Planning Commission

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SWRPC | Southwest Region Planning Commission

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Cover photo of a road/stream crossing overtopped in July of 2021 taken by Henry Underwood.

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Definitions

The following terms are used widely in the following report.

Adaptation, in the context of this document, refers to the process of making changes to transportation infrastructure to minimize harm caused by changes in weather and climate.

Adaptive capacity refers to the system's ability to cope with existing climate variability or future climate impacts on an asset. For example, the transportation system has a low adaptive capacity to respond to an event if closure of an asset would result in significant detour lengths for drivers.

Asset refers to transportation-related infrastructure, such as culverts and bridges, that facilitates free water flow under a publicly maintained road.

Climate refers to the long-term precipitation and temperature patterns in a given location.

Criticality refers to the measurement of how critical or important an asset is to an area or group of constituents. Approaches to assessing criticality vary and can be based on criteria like daily traffic, access to jobs, degree of redundancy, and more.

Exposure refers to whether an asset or system is located in an area that has previously experienced flooding, is in a designated flood zone, or otherwise may be particularly at risk of flooding impacts.

Mitigation refers to efforts to reduce harm caused by a stressor like an extreme precipitation event or flood by increasing resilience or reducing risk.

Overtopping is when water flows over the top of the road fill at a surface of a bridge or stream crossing. In most cases it occurs during severe flooding events.

Risk is a measure that considers both the probability that an asset will experience an impact as well as the severity or consequence of the impact.

Sensitivity refers to how an asset is anticipated to fare when exposed to a climate variable. For example, a sensitive asset might experience overtopping during a period of increased waterbody flow.

Stream Crossing refers to a structure like a culvert or bridge, that carries a road over a river, lake, pond wetland, or small stream.

Substructure refers to components of a bridge which provide its foundation and stability. These components include the abutments, foundation, and more.

Superstructure refers to components of a bridge that support the live load traversing the asset. These include the deck (surface), guardrail, and more.

Vulnerability is a measure of how well an asset can cope with extreme precipitation events and is calculated as a function of an asset's or system's sensitivity to climate effects, exposure to extreme weather and climate effects, and adaptive capacity.

Background

The Southwest Region of New Hampshire is comprised of 34 municipalities including all of Cheshire County, 10 towns in Hillsborough County and 1 town in Sullivan County. Strong population growth in the mid to late 20th century gave way to slower growth in the first decades of the 21st century. Although our Region's population of 100,751 grew by 54% between 1970 and 2010, most of this growth occurred before 1990. While population growth has slowed significantly, over the last 100 years there was a broad expansion of the public highway system that formed a network of roads that stretches 1,862 miles over a 1,007 square mile area, supporting a mostly rural, decentralized population. This system, which provides people critical access to their homes, jobs, services, shopping and other needs, navigates over hills, through valleys, over rivers, and across thousands of stream crossings.

Over several decades, precipitation events have increased in severity, creating an unprecedented frequency and magnitude of stress on the public highway system. The trend of increased frequency and intensity of weather events is well-documented as indicated by a number of federal disaster declarations impacting the Region over recent decades. Between the first year federal disaster declarations were recorded in 1953 to present day, 34 out of 46 federal disasters declared in Cheshire, Hillsborough and Sullivan County happened in the 21st century, with a precipitation-related event accounting for 31 of all 21st century disaster events. [1] Many of these events resulted in costly road washouts, property damage, disruptions in economic activity, lack of access resources and even loss of life.

One of the most pressing threats to infrastructure in the Region is severe storms and flooding, accounting for over half of all disaster declarations in the tri-county area in the 21st century. Much of the Region's stormwater and roadway infrastructure such as culverts and bridges, which are aging and in need of repair, does not have the capacity to handle the extreme storms and flooding that have been occurring with increasing frequency. Ongoing and future changes to climate have the potential to compound these risks and could have a major impact on infrastructure and associated maintenance costs.

Infrastructure vulnerability has gained increasing attention among policymakers and the general public as these events have become more common. Until now, however, the Region has lacked a consistent, regionwide assessment to determine which transportation assets are most vulnerable, or more likely to be damaged or disrupted by these impacts.

The *Monadnock Region Transportation Infrastructure Flood Vulnerability Assessment* supports a variety of local, regional and state transportation-related planning documents that focus on associated topics like maintenance and asset, risk and hazard management. Examples of some key state and regional documents include the following:

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[1] Federal Emergency Management Administration. 2024. "Disaster Declarations for States and Counties." https://www.fema.gov/data-visualization/disaster-declarations-states-and-counties.

NHDOT's *Long Range Transportation Plan: 2010-2030*[2]*:*

Goal 6. System Preservation & Maintenance. Provide appropriate investment in existing and future infrastructure, facilities and equipment to maintain and preserve the physical condition and operability of the transportation system.

NHDOT's Evaluation Criteria for Hazard Risk and Hazard Mitigation in Ten Year Plan Project Nominations:

Hazard Risk

Are natural hazards in the project area documented in a plan, study, or database?

Have natural hazards previously impacted transportation infrastructure and/or mobility in the project area? How frequently?

Are natural hazard risks anticipated to increase in severity/impact (for example, due to anticipated impacts of climate change)?

Hazard Mitigation

To what extent does the project mitigate or adapt to known natural hazards in the project area? Does the project propose in-kind replacement of hazard-prone infrastructure?

Is the project responsive to stream characteristics, such as flood propensity, slope, bankfull width, and orientation to roadway?

Southwest Region Planning Commission's Long Range Transportation Plan, *Southwest Connects (2014-2035)*[3]*:*

Objective 3A: It will preserve mobility and reliability on backbone arterial highways.

[2] New Hampshire Department of Transportation. 2010. "NH Long Range Transportation Plan 2010-2030." https://mm.nh.gov/files/uploads/dot/remote-docs/2010-july-long-range-transportation-plan-complete.pdf.

[3] Southwest Region Planning Commission. 2014. "Southwest Connects: Southwest Region Transportation Plan 2014 - 2035." https://www.swrpc.org/wp-content/uploads/2021/03/Southwest-Connects-Southwest-Region-Transportation-Plan-FINAL.pdf.

Objective 3B: It will maintain access to pathways, roads, bridges, and railways by addressing causes of unreasonable delays and detours due to asset condition, design, failure or other restrictions.

Objective 4B: It will eliminate safety risks associated with poor transportation asset conditions.

Objective 4D: It will proactively mitigate potential dangers associated from severe storm events and other causes of potential hazards.

***Monadnock Region Future*[4]:**

Goal IV: The Region will be prepared for and have the capacity to withstand and recover from the impacts of natural and manmade hazards and other emergency situations.

Objective B: Prepare for disaster mitigation and emergency response through local planning and training.

Objective C: Ensure that the Region's critical infrastructure is capable of withstanding the impacts of potential threats and/or disasters.

Objectives

SWRPC had several objectives in mind when setting out to conduct the *Monadnock Region Transportation Infrastructure Flood Vulnerability Assessment,* including:

1. Assess the vulnerability of all publicly maintained bridges and culverts in Southwest New Hampshire to extreme precipitation events.
2. Raise public awareness about climate change-related risks to municipal and state-owned transportation assets.
3. Understand the vulnerability of Southwest New Hampshire's transportation system assets to climate change.
4. Identify and prioritize locations in the transportation network that are vulnerable to extreme precipitation events.
5. Identify short-term and long-term strategies (including projects) to address vulnerable infrastructure.
6. Publicize vulnerability information with decisionmakers.

[4] Southwest Region Planning Commission. 2015. "Monadnock Region Future: A Plan for Southwest New Hampshire." https://www.swrpc.org/wp-content/uploads/2021/03/MonadnockRegionFuture_RegionalPlan_FINAL.pdf.

These objectives were informed in part by the Federal Highway Administration's *Vulnerability Assessment and Adaptation Framework (3rd Edition).*[5]

Asset Data

Transportation assets include a number of types of infrastructure that are familiar to most including roads, bridges, airports, ports, and railways, among others. Other transportation assets that are sometimes overlooked include sidewalks, trails, drainage ditches, culverts, signs, guardrails, traffic signals and even naturally occurring or manmade wetlands, which can help mitigate flooding damage. Infrastructure of all kinds may be affected by, and vulnerable to, sudden severe weather events, as well as gradual impacts caused by climate change. For example, airports are susceptible to the impacts of heavy precipitation events. Flooding can damage aircraft and airfield infrastructure, as well as lead to flight delays and other operational hazards.[6] Individual or repeat extreme heat events may cause railways to "buckle" under otherwise normal railroad travel and operation.[7] More frequent freeze-thaw cycles may impact the operation of port infrastructure and may cause damage.[8]

Although transportation assets encompass numerous forms, functions, and purposes, the relatively small budget for the *Monadnock Region Transportation Infrastructure Flood Vulnerability Assessment* project made a comprehensive vulnerability assessment of all of these types of assets unrealistic. Additionally, thorough data, which is needed for accurate analysis, is typically only available for select assets. Therefore, based on a staff-level screening of the quality, completeness, and availability of data, the selected transportation assets to be studied were limited to our region's 2,262 publicly owned and maintained bridges and other stream crossings. These assets were additionally chosen for the focus of the *Assessment* due to their particular exposure to precipitation-driven inland flooding events, which are the most significant climate stressor to the Monadnock Region's transportation network. In accordance with Federal Highway Administration's *Vulnerability Assessment and Adaptation Framework (3rd Edition)*, SWRPC staff identified attributes associated with bridges and stream crossings that are important for understanding flooding event vulnerability:

- Age
- Condition
- Design life and stage of life
- Ownership
- Importance
- Geographic location
- Elevation information
- Current and historical performance and condition
- Level of use
- Replacement cost
- Maintenance schedule and costs
- Evacuation routes
- Emergency management/response costs
- Hydraulic performance
- Occurrence/location of maintenance events
- Flood history
- Structural design (as-built plans if available)
- Materials used in construction and repair
- Pavement quality (roughness/smoothness)
- Degree of redundancy in the system
- Availability of alternative routes

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[5] Federal Highway Administration. 2017. "Vulnerability Assessment and Adaptation Framework, Third Edition." https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/climate_adaptation.pdf.
[6] U. S. Department of Transportation. 2014. "Transportation Climate Change Sensitivity Matrix." https://www.fhwa.dot.gov/environment/sustainability/resilience/tools/.
[7] Ibid.
[8] Ibid.

Information on bridges came from the NHDOT Bureau of Planning and Community Assistance through their GIS data Quarterly Snapshot published on January 9, 2024.[9] The dataset includes all publicly owned and maintained bridges, including those that meet the state (10-foot span or greater) and federal (20-foot span) definitions. There are 477 bridges in our Region which are incorporated into this assessment. Information about stream crossings comes from the New Hampshire Stream Crossing Initiative.[10] Stream crossings may or may not meet the state or federal definition of a bridge. The Stream Crossing Initiative is a collaborative effort between the University of New Hampshire and the following New Hampshire state agencies: Department of Environmental Services, Fish & Game, Department of Transportation, Geological Survey, and Homeland Security and Emergency Management. There are 1,785 stream crossings in the region that are incorporated into this assessment that do not meet the state or federal definition of a bridge.

In Southwest New Hampshire, our bridges and other stream crossings represent some of the region's most vulnerable transportation infrastructure, particularly as the severity of storm events and flooding have increased in frequency. Scientists point to evidence that these increases are in part due to a changing climate.[11] In the next section, we explore climate change impacts to transportation infrastructure in general and some of the key climate data trends that are impacting the Northeast United States.

Summary of Climate Data

Climate refers to the average temperature, precipitation, and wind for a region over a period of at least 30 years.[12] In their 2021 Sixth Assessment Report, the Intergovernmental Panel on Climate Change determined that burning of fossil fuels has resulted in a period of unprecedented warming on a global scale, altering the climate.[13] Changes in climate often result in increased variability in weather events, as well as a shifts in the expected conditions of a region. Examples of these impacts may include changes in freeze-thaw cycles, average and extreme temperatures, wind patterns, increased drought, more frequent extreme precipitation events, increased flooding, and more.

The impacts of global climate change are far reaching and can have significant impacts on transportation assets which were not originally built to endure the weather conditions associated with shifts in climate.[14] Specifically, annual precipitation is predicted to increase by up to 15% in the Northeast by the

[9] NHDOT Bureau of Planning and Community Assistance. 2024. "GRANIT GIS Data Quarterly Snapshot." https://ftp.granit.unh.edu/NHDOT/GIS%20Data%20Quarterly%20Snapshots/2024/.

[10] State of New Hampshire. Accessed June 23, 2005. https://www4.des.state.nh.us/NH-Stream-Crossings/

[11] U. S. Global Change Research Program. 2023. "Fifth National Climate Assessment." U.S. Global Change Research Program, Washington, DC. https://nca2023.globalchange.gov/chapter/21/.

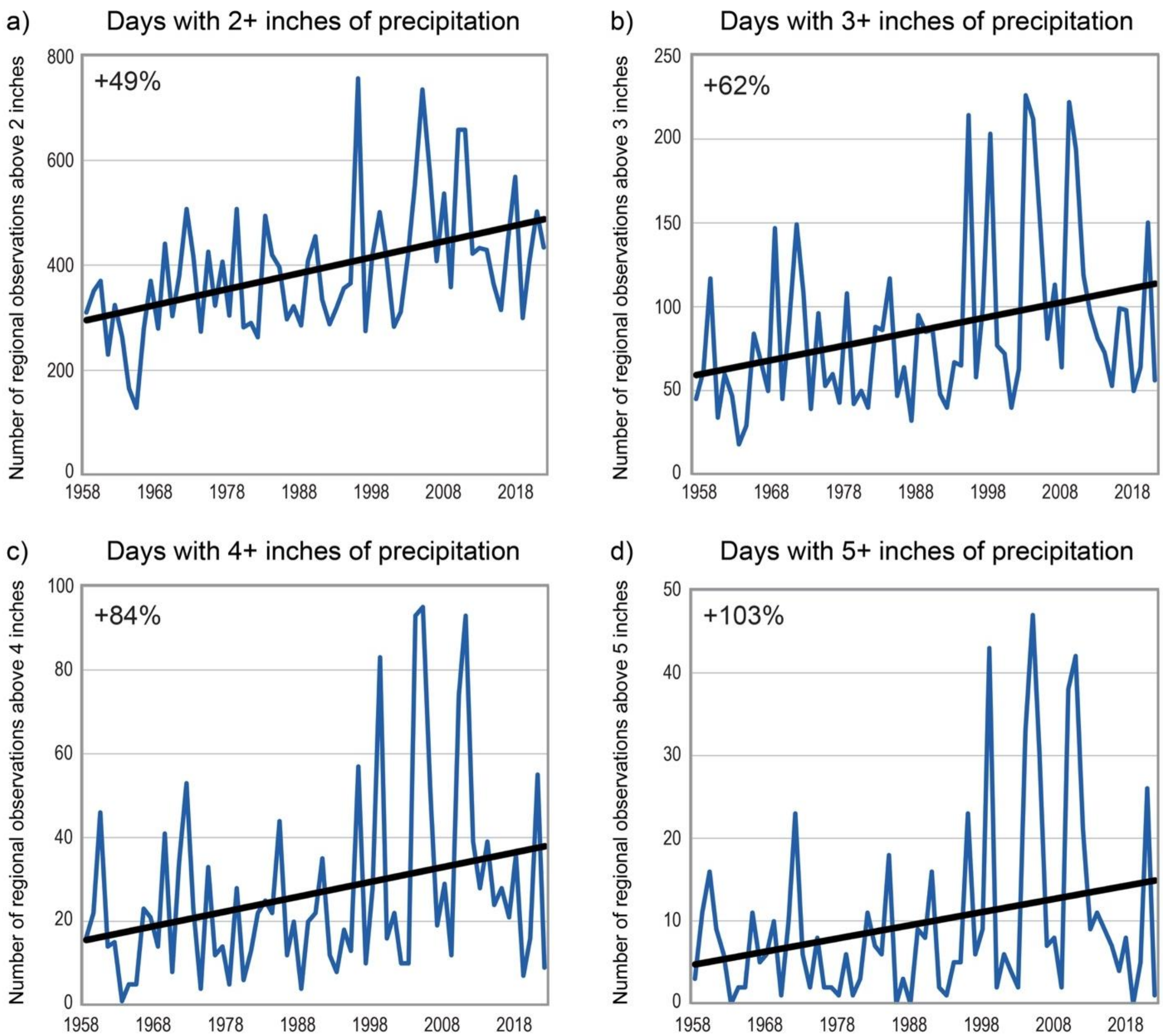
[12] The Intergovernmental Panel on Climate Change. n.d. "Glossary — Global Warming of 1.5 C." Accessed May 1, 2025. https://www.ipcc.ch/sr15/chapter/glossary/.

[13] Lemcke-Stampone, Mary D, Cameron P Wake, and Elizabeth Burakowski. 2021. "New Hampshire Climate Assessment 2021." The Sustainability Institute. https://scholars.unh.edu/cgi/viewcontent.cgi?article=1071&context=sustainability.

[14] Federal Highway Administration. "Vulnerability Assessment and Adaptation Framework, Third Edition." 2017. https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/climate_adaptation.pdf.cfm

end of the 21st century, particularly during the winter and spring.[15] Additionally, extreme precipitation events are occurring 60% more frequently now as compared to the mid-20th century, making inland regions susceptible to increased flooding risk.[16] *Figure 1* illustrates the increasing number of heavy precipitation days in the Northeast U.S. over previous decades showing increases for days with 2, 3, 4 and 5 inches of precipitation. Given these patterns, our expectation is that extreme precipitation events are among the most likely climate change stressors to continue to have a significant impact on the transportation assets within Southwest New Hampshire.

Figure 1: Trends in Extreme Precipitation in the Northeast. [17]

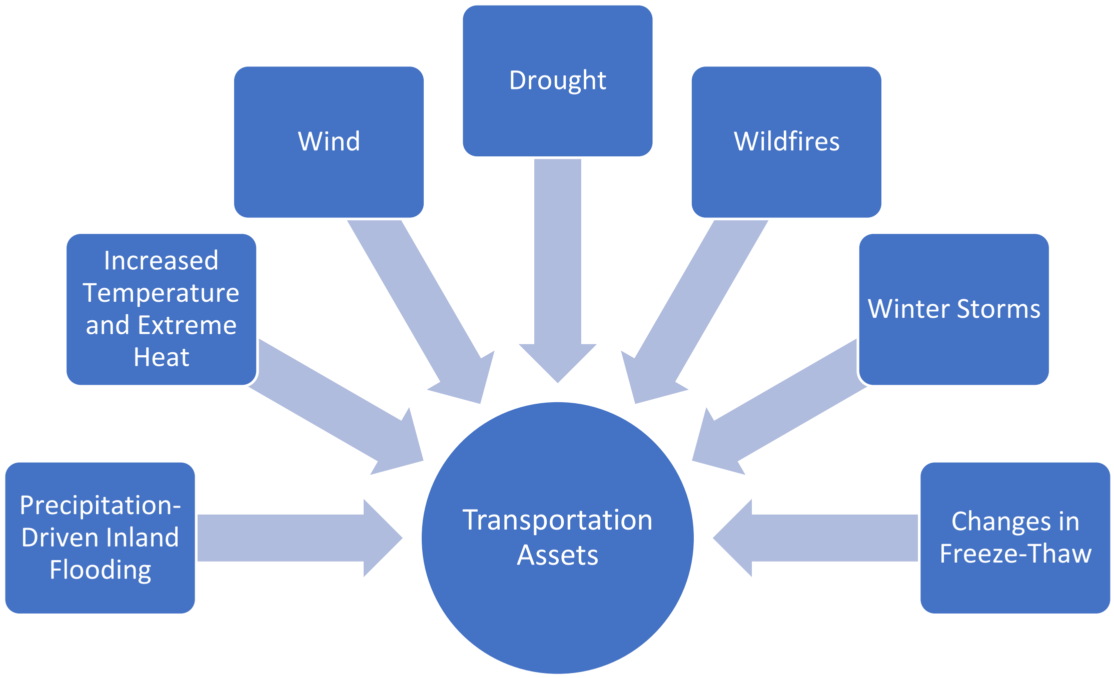


While the focus of this report is on severe storm events and flooding, other climate stressors can impact the Region's transportation assets as well. Some of these stressors may deserve additional study in the

[15] Lemcke-Stampone, Mary D, et al. "New Hampshire Climate Assessment 2021."
[16] Ibid.; U. S. Global Change Research Program. "Fifth National Climate Assessment."
[17] U. S. Global Change Research Program. "Fifth National Climate Assessment."

future. For now, we summarize some of these additional stressors in order to help build awareness about the broad impacts that climate stressors can have on our transportation system. Several of what the Federal Highway Administration calls "Climate Stressors of Concern" are depicted below in Figure 2 and then summarized below.

Figure 2 Climate Stressors of Concern[18]



Precipitation Driven Inland Flooding: Flooding, also referred to as precipitation driven inland flooding, often occurs because of extreme precipitation events. The typical metrics used to describe flooding include periods where greater than 1 or 2 inches of liquid precipitation fall within 24 hours; more than 4 liquid inches fall within 48 hours; and the wettest day of the year.[19] Data collected from 10 weather stations distributed throughout New Hampshire indicates that in most parts of the State the frequency of these events has increased over the last 50 years.[20]

Notably, data collected at the Keene weather station depicts a larger increase in the frequency of extreme precipitation events as compared to statewide data.[21] From 1901 to 1960, the Keene station measured an average of 6.9 days per year where over an inch of liquid precipitation fell.[22] The average number of days where over 2 inches of liquid precipitation fell in 24 hours was measured to be 0.7.[23] The average amount of liquid precipitation on the wettest day of the year during this period was determined to be 2.2 inches.[24] For the period of 1991 to 2020, the Keene station recorded an average of 10.9 days

[18] U. S. Department of Transportation. "Transportation Climate Change Sensitivity Matrix." 2014. https://www.fhwa.dot.gov/environment/sustainability/resilience/tools/.
[19] Lemcke-Stampone, Mary D, et al. "New Hampshire Climate Assessment 2021."
[20] Ibid
[21] Ibid.
[22] Ibid.
[23] Ibid.
[24] Ibid.

per year where over an inch of liquid precipitation fell, which represents an increase of 4.1 days from the prior period.[25] The average number of days where more than 2 inches of liquid precipitation fell within 24 hours was determined to be 1.8, an increase of 0.8 days compared to the 1901-1960 period.[26] For the 1991 to 2020 period, on average, there was 2.7 inches of liquid precipitation measured to fall within a 24-hour period, which is an increase of 0.6 inches from the 1901 to 1960 period.[27]

Extreme precipitation events may result in flooding which can have significant impacts on transportation assets, and this risk is exacerbated in New Hampshire since most transportation infrastructure was designed to withstand precipitation patterns pre-1971.[28] Flooding can damage bridges through several pathways. The superstructure, which refers to the structural parts of the bridge that make up the horizontal span supporting the traffic load and includes components like the deck, trusses, girders, and stringers, can be damaged by floating debris and the water itself.[29] The substructure, which supports the superstructure by transferring the load to the ground including components like abutments and piers can be impacted by flooding events that erode the stream bed surrounding the bridge supports[30]. When the stream or river is flooded and consequently has a very high flow rate, erosion can proceed rapidly and ultimately damage the substructure[31].

Roads can be damaged from a variety of flooding scenarios. Impact severity may depend on independent variables including road surface and pavement type (and its ability to withstand flooding), the proximity of the road to waterway crossings, and traffic volumes (i.e. the combined stress of traffic volume and flooding).[32] Damage can be as acute as total pavement and embankment failure, or may be more routine, such as surface defects or cracked pavement.[33] Unpaved roads may be washed out in extreme precipitation or flooding events.[34] Stormwater infrastructure built into the road such as drainage culverts or side drains can also be heavily impacted. Risks include the accumulation of sediment and debris, erosion, and structural damage, all of which can cause complete failure of the asset during extreme conditions.[35]

Increased Temperature and Extreme Heat: Average annual temperatures across New Hampshire have increased by approximately 3°F since 1901.[36] By the end of the 21st century, depending on the referenced climate model, this warming is predicted to increase by a factor of 5.2-9.5°F degrees above the 1901 average annual temperature.[37] Heatwaves, which refer to periods of abnormally hot weather,

[25] Ibid.
[26] Ibid.
[27] Ibid.
[28] U. S. Department of Transportation. “Transportation Climate Change Sensitivity Matrix.”
[29] Ibid.
[30] Ibid.
[31] Ibid.
[32] Ibid.
[33] Ibid.
[34] Ibid.
[35] Ibid.
[36] Lemcke-Stampone, Mary D, et al. “New Hampshire Climate Assessment 2021.”
[37] Ibid.

are lasting longer and are more severe in the Monadnock Region..[38] In the Northeast, by the mid-21st century, days with heat index values over 100°F are predicted to be three times as frequent as in 1901.[39] Bridge and road structural integrity will be at higher risk from sustained high temperatures caused by the thermal expansion of the paved surface.[40] Though less a concern in the Northeast as opposed to the Southeast and Southwest, paved surfaces may also soften when exposed to extreme temperatures for prolonged periods which can cause significant damage to the road surface.[41]

Wind: Outside of extreme precipitation events and other severe weather incidents, baseline wind conditions are unlikely to be affected by climate change. However, powerful storms such as hurricanes, tornadoes, and thunderstorms may occur more frequently because of climate change.[42] Strong wind conditions from such storms can be particularly detrimental to bridges.[43] Superstructure elements, including decks, may be stressed by strong wind conditions which can damage the bridge through excess horizontal loading.[44] High flow velocity can also damage the bridge substructure through erosion and scouring, which refers to the removal of sediment surrounding the supporting infrastructure.[45]

Drought: While climate change is predicted to increase precipitation in New Hampshire throughout the year, these increases are likely to be concentrated in the fall and winter.[46] Therefore, combined with an increase in summer temperatures, and the resulting potential decrease in soil moisture, it is likely that the state will experience more frequent short-term droughts.[47] Droughts do not pose a risk to bridge assets, but can contribute to the cracking and splitting of pavements, as well as damage to unpaved roads.[48]

Wildfires: Presently, wildfire risk in New Hampshire is relatively low compared to other portions of the United States. The predicted impact of climate change on wildfire risk in the Northeast is uncertain as wildfire risk is a product of numerous variables. These include climate factors such as precipitation, temperature, and soil moisture. Additionally, climate change may contribute to a regional shift in ecosystem composition that may be more favorable to wildfire conditions.[49] Wildfires can significantly damage transportation assets through several pathways. Road surfaces can be destroyed by such events, and rainstorms following wildfires can cause significant erosion and runoff which can damage

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[38] U. S. Global Change Research Program. "Fifth National Climate Assessment;" Kunkel, K. E. 2022. "State Climate Summaries for the United States 2022. NOAA Technical Report NESDIS 150." NOAA NESDIS. https://statesummaries.ncics.org/chapter/nh.
[39] U. S. Global Change Research Program. "Fifth National Climate Assessment.
[40] U. S. Department of Transportation. "Transportation Climate Change Sensitivity Matrix."
[41] Ibid.
[42] Narayanan, Rishya. 2023. "Climate Change Worsens Extreme Weather in New England." Conservation Law Foundation. August 31, 2023. https://www.clf.org/blog/climate-change-worsens-extreme-weather-in-new-england/.
[43] U. S. Department of Transportation. "Transportation Climate Change Sensitivity Matrix."
[44] Ibid.
[45] Ibid.
[46] Lemcke-Stampone, Mary D, et al. "New Hampshire Climate Assessment 2021."
[47] , Kunkel, K. E. "State Climate Summaries for the United States 2022. NOAA Technical Report NESDIS 150."
[48] U. S. Department of Transportation. "Transportation Climate Change Sensitivity Matrix."
[49] Lemcke-Stampone, Mary D, et al. "New Hampshire Climate Assessment 2021."

stormwater infrastructure.[50] Bridges can be damaged from post-wildfire rainstorms as loose debris can damage the foundation of the structures.[51]

Winter Storms: The number of snow-covered days and the amount of snowfall in New Hampshire has been decreasing.[52] As a result of climate change, New Hampshire is expected to receive more winter precipitation in the coming decades, but it climate forecasts are uncertain how much precipitation will fall as snow versus rain.[53] By mid-century, the statewide average maximum and minimum winter temperatures are expected to rise between 4.1-5.5°F and 5.4-7.2°F respectively.[54] Considering this expected shift in temperatures, it is fair to expect that the state will see a smaller proportion of its winter precipitation fall as snow. However, winter precipitation events can cause damage. For instance, winter storms can result in the saturation of soil through extreme snowmelt events. Snowmelt surrounding bridges may make the structures more susceptible to movement[55] particularly during freeze-thaw events.[56]

Changes in Freeze-Thaw: Thaw events, which refer to periods where temperatures rise above freezing during the winter months, are occurring more frequently in New Hampshire.[57] By the end of the century, the statewide number of thaw days, defined as those with minimum temperatures above 28°F, is expected to increase by a minimum of 20-35 days.[58] Freeze-thaw cycles are dangerous to a variety of transportation assets because of the potential for water to seep into asphalt and concrete through cracks that form over time. As this water freezes, it expands and exerts pressure on the asset which can lead to accelerated damage from otherwise normal wear.[59] Vulnerable assets include paved roads and bridges. More frequent freeze-thaw cycles may result in greater wear on these assets and an increased need for funding to repair the infrastructure.

While these additional climate stressors are expected to impact the Region's transportation assets, the remaining sections of the report focus on assets for which the Region has more complete data, and with a particular focus on how those assets are impacted by severe storm events and flooding.

Vulnerability Assessment Methodology

To assess the vulnerability of Monadnock Region, SWRPC utilized the Vulnerability Assessment Scoring Tool (VAST) published by the U. S. Federal Highway Administration (FHWA). Functionally, VAST is a macro-enabled Microsoft Excel spreadsheet which allows users to assess the vulnerability of transportation assets to different climate stressors. VAST can accept data from multiple time periods

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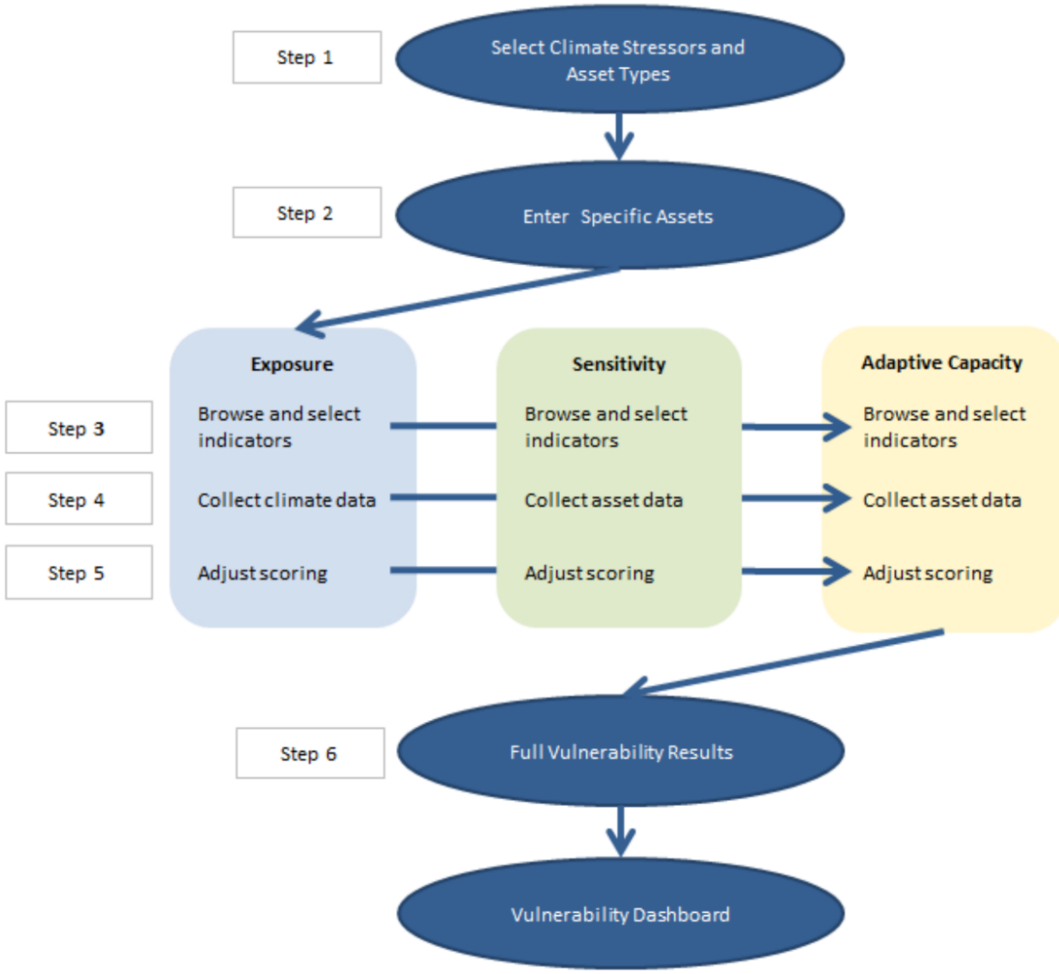
[50] U. S. Department of Transportation. "Transportation Climate Change Sensitivity Matrix."
[51] Ibid.
[52] Kunkel, K. E. "State Climate Summaries for the United States 2022. NOAA Technical Report NESDIS 150."
[53] Lemcke-Stampone, Mary D, et al. "New Hampshire Climate Assessment 2021."
[54] Ibid.
[55] U. S. Department of Transportation. "Transportation Climate Change Sensitivity Matrix."
[56] Ibid.
[57] Lemcke-Stampone, Mary D, et al. "New Hampshire Climate Assessment 2021.";Ganley, Rick, Mary McIntyre, Annie Ropeik. 2021. "As New Hampshire Warms, UNH Studies Effects Of More Freeze-Thaw Cycles." New Hampshire Public Radio. April 21, 2021. https://www.nhpr.org/climate-change/2021-04-21/as-new-hampshire-warms-unh-studies-effects-of-more-freeze-thaw-cycles.; Dave, Eshan. 2024. Presentation to Southwest Region Planning Commissioners. UNH Center for Infrastructure Resilience to Climate (CIRC).
[58] Lemcke-Stampone, Mary D, et al. "New Hampshire Climate Assessment 2021."
[59] U. S. Department of Transportation. "Transportation Climate Change Sensitivity Matrix."

which allows users to assess current and future vulnerability due to climate change. SWRPC used the model to assess asset vulnerability from severe storm events and flooding, the major concern in the Monadnock Region, with data representing current conditions.

VAST functions by assessing three different components of vulnerability: Exposure, Sensitivity, and Adaptive Capacity. Exposure refers to the degree that an asset is located in a vulnerable location or has a history of flooding. Sensitivity describes an asset's ability to mitigate effects from a flooding incident. Adaptive Capacity illustrates the predicted significance to the transportation network if an asset were to be damaged from flooding. For each component of vulnerability, the VAST user assigns specific indicators derived from geographic data (for exposure) and asset data (for sensitivity and adaptive capacity). For example, a layer representing flood history is one of the selected Exposure indicators, while the condition of an asset's inlet and outlet are examples of Sensitivity indicators. Scores for each indicator are averaged with user defined weights to provide an overall category score. The category scores are then averaged with additional user defined weights to generate each asset Vulnerability score. *Figure 3* provides an overview of the model inputs and the components of vulnerability which are used to calculate each vulnerability score.

In addition to Vulnerability scores, VAST calculates a damage score for each asset. Damage scores are created by averaging each asset's Exposure and Sensitivity scores while ignoring the Adaptive Capacity score. This provides a more specific calculation to represent the risk for each asset without incorporating the risk to the greater transportation system into the output.

Figure 3: VAST Scoring Diagram[60]



Components of Vulnerability

The indicators that were used for Exposure, Sensitivity and Adaptive Capacity in the *Monadnock Region Transportation Infrastructure Flood Vulnerability Assessment* are identified and described in *Figure 4* and *Tables 1-3* on the following pages. The scoring methodology is also provided in *Tables 1-3* which explains the standardization of each indicator's data to the VAST numeric scale of 0-4 (with 4 representing the most significant Exposure, Sensitivity, or Adaptive Capacity). Higher scores are indicative of assets that are at higher risk with respect to each component of vulnerability. Higher Exposure scores, for example, tend to show assets with a history of flooding and close proximity to Federal Emergency Management Agency Special Flood Hazard Areas. High Sensitivity scores occur for assets that are documented as being in poor condition. A high Adaptive Capacity score is reflective of an asset which is a particularly sensitive link in the transportation network. For example, an asset that would result in a long detour in the event of a closure would likely have a higher Adaptive Capacity score than an asset with a short detour.

[60] Federal Highway Administration. "Vulnerability Assessment and Adaptation Framework, Third Edition."

To calculate the value of each component of vulnerability, indicators were collectively represented on a 100-point scale and assigned a proportion of the total number of points or a "weight". Weights were determined by SWRPC staff based on the perceived importance of each indicator as well as the quality of the data.

Furthermore, the three components of vulnerability are weighed against each other to calculate the asset's complete vulnerability score. *Figure 4* illustrates the relative weights for the indicators as they constitute the components of vulnerability, as well as the weights of each component as used to calculate each asset's total vulnerability score. When an indicator is missing for a particular asset, the share of its weight is distributed proportionally to the other indicators which make up that component of vulnerability. For example, if an asset does not have a value to represent Waterway Adequacy, the weights for Special Flood Hazard Areas and Past Experience with Flooding would be redistributed to be 54.3% and 45.7% respectively. Values for these two indicators would then be used to calculate the asset's Exposure score.

Figure 4: Component of Vulnerability (Exposure, Sensitivity, Adaptive Capacity) and Indicator Weights

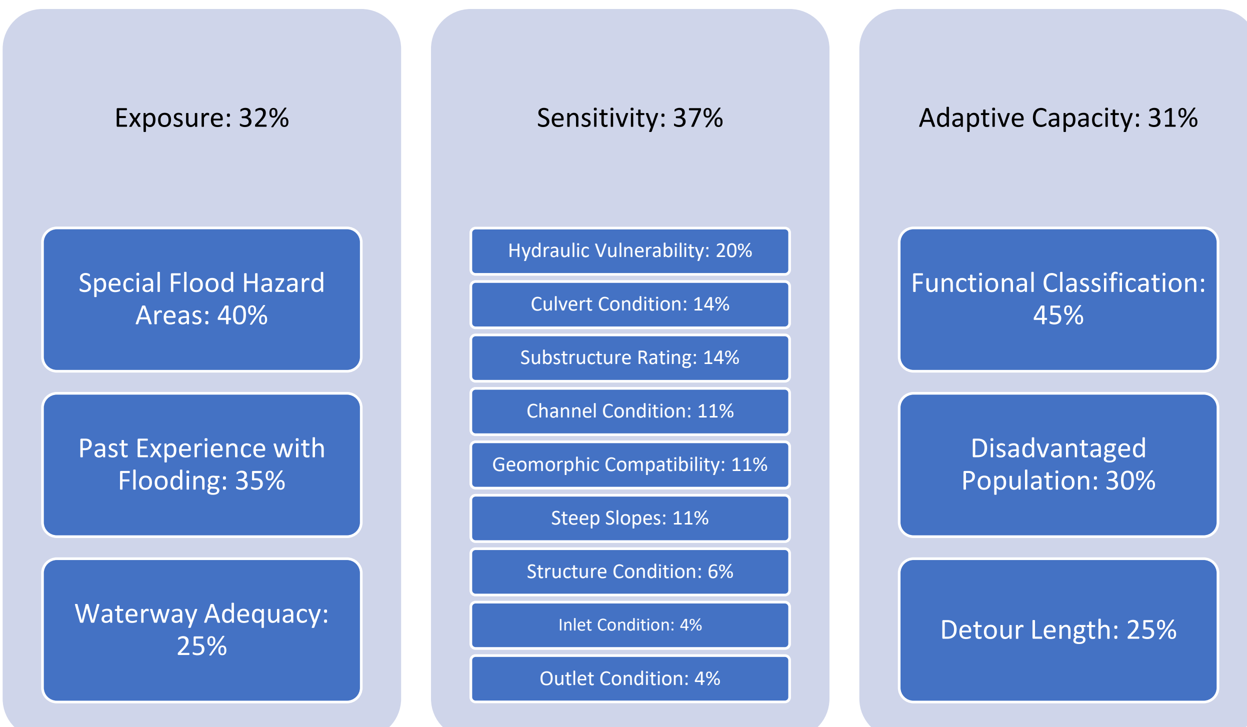


Table 1: Exposure Indicators

Indicator	Data Sources	Scoring Methodology	
Waterway Adequacy	National Bridge Inventory (NBI) Item 71. This item considers the frequency of overtopping to various parts of the bridge as well as how overtopping impacts bridge traffic.	9 Above Desirable	1
		8 Equal Desirable	1
		7 Above Minimum	2
		6 Equal Minimum	2
		5 Above Tolerable	3
		4 Tolerable	3
		0 Bridge Closed	4
Past Experience with Flooding	A merged dataset encompassing indicators from four different flood history databases: Waze Flood Alerts[61], NHDOT 511 Reports, NHDOT FEMA Declared Events Data[62] and New Hampshire Geological Survey (NHGS) Flood Hazard Geodatabase features. Road segments which overlapped with these features were identified to select assets.	No intersection of any identified flood indicators.	Not Exposed
		Any intersection with at least one identified flood indicator.	4
Special Flood Hazard Areas (SFHA)	Federal Emergency Management Agency (FEMA) Public and Preliminary Flood Insurance Rate Maps.	Not within or near a 100-year or 500-year flood zone.	Not Exposed
		Within 100’ of 500-year flood zone.	1
		Inside a 500-year flood zone, but not within 100' of a 100-year flood zone.	2
		Within 100’ of a regulatory floodway or 100-year flood zone.	3
		Inside a regulatory floodway or 100-year flood zone.	4

[61] Waze Data Feed specifications - Waze Partners Help

[62] eCFR :: 23 CFR Part 667 -- Periodic Evaluation of Facilities Repeatedly Requiring Repair and Reconstruction Due to Emergency Events

Table 2: Sensitivity Indicators

Indicator	Data Source	Scoring Methodology	
Culvert Condition	This item (NBI Item 62) evaluates the alignment, settlement, joints, structural condition, scour, and other items associated with culverts. The rating code is intended to be an overall condition evaluation of the culvert.	9 Excellent	1
		8 Very Good	1
		7 Good	1
		6 Satisfactory	2
		5 Fair	2
		4 Poor	3
		3 Serious	3
		2 Critical	4
		1 Closed – Failing	4
Channel Condition	This item (NBI Item 61) describes the physical conditions associated with the flow of water through the bridge such as stream stability and the condition of the channel, riprap, slope protection, or stream control devices including spur dikes.	9 Above Desirable	1
		8 Equal Desirable	1
		7 Above Minimum	2
		6 Equal Minimum	3
		5 Above Tolerable	3
		4 Tolerable	3
		3 Intolerable – Correct	4
		0 Bridge Closed	4
Substructure Rating	This item (NBI Item 60) describes the physical condition of piers, abutments, piles, fenders, footings, or other components. Rating only applies to bridges.	9 Excellent	1
		8 Very Good	1
		7 Good	1
		6 Satisfactory	2
		5 Fair	2
		4 Poor	3
		3 Serious	3
		1 Closed – Failing	4
Hydraulic Vulnerability[63]	This item (NH Statewide Asset Data Exchange System (SADES) Item 101) describes how well a stream crossing transports flows during storm events (in this case 10-year event).	No Rating – Wide Span	1
		No Rating – Road Elevation	1
		Pass	1
		Vulnerable	3
		Overtop	4
Geomorphic Compatibility[64]	This item (SADES Item 99) describes the long-term compatibility of a stream crossing with river channel.	Fully Compatible	1
		Mostly Compatible	2
		Partially Compatible	3
		Mostly Incompatible	3
		Fully Incompatible	4

[63] New Hampshire Stream Crossing Initiative. "How We Evaluate Crossings." Accessed June 27, 2025. https://www4.des.state.nh.us/NH-Stream-Crossings/index.php/how-we-evaluate-crossings/.
[64] Ibid.

Indicator	Data Source	Scoring Methodology	
Steep Slopes	The average slope in the catchment of each stream crossing calculated using NHGS Stream Crossing Catchments and NH GRANIT LiDAR-derived slope.	1-12 degrees	1
		12-15 degrees	2
		15-17 degrees	3
		17-41 degrees	4
Structure Condition	The condition of the inside of the conduit: SADES Item 65.	Good	1
		Fair	2
		Poor	4
Inlet Condition	The condition of the external structural features (both the headwall and wing walls) surrounding the crossing inlet: SADES Item 33.	Good	1
		Fair	2
		Poor	4
Outlet Condition	The condition of the structural features (both the headwall and wing walls) at the crossing outlet: SADES Item 70.	Good	1
		Fair	2
		Poor	4

Table 3: Adaptive Capacity Indicators

Indicator	Data Source	Scoring Methodology	
Detour Length	The detour length should represent the total additional travel for a vehicle which would result from the closing of the bridge. Represents the number of kilometers for the expected detour. NBI Item 19.	0-1 kilometers	1
		1-3 kilometers	2
		3-6 kilometers	3
		6-99 kilometers	4
Functional Classification	The FHWA functional classification of roadways defines the role each element of the roadway network plays in serving these travel needs.	3, other principal arterial	4
		4, minor arterial	3
		5-6, major and minor collector	2
		7, local road	1
Disadvantaged Population	Defines assets in an area of relatively higher or lower "disadvantage" based on transportation access, pollution, socioeconomic status, and other factors using the Final Index Score from USDOT's Equitable Transportation Community (ETC) Explorer.[65]	73-97	4
		49-73	3
		25-49	2
		0-25	1

For instances when an indicator did not have a value or otherwise had a value not defined in *Tables 1-3*, VAST would proportionally redistribute the weight of that indicator to the other indicators in the component score. In these cases, VAST would classify other inputs as "No Data" which would not contribute to the vulnerability scores of the assets but would rather proportionally increase the weights of the other indicators within that component.

[65] United States Department of Transportation, "Equitable Transportation Community Explorer (ETCE)," accessed June 27, 2025, https://www.transportation.gov/sites/dot.gov/files/2023-02/ETCE-Technical-Documentation.pdf.

Results

Table 5 displays the 50 assets with the highest Vulnerability Scores listed in order. A table of results with all assets included, as well as an interactive map displaying the assets, is available on SWRPC's webpage: www.swrpc.org/vulnerability-assessment. *Table 4* provides a key for the data shown in *Table 5*. Score categories are developed from a "natural breaks" distribution of each score (the Jenks optimization algorithm), which identifies natural groupings or clusters within a dataset based on the data's inherent structure, aiming to minimize variance within each class and maximize variance between classes.

Table 4: Vulnerability Assessment Data Results Key

Field Name	Meaning
Street Name	Local road name or route number.
Town Name	Name of municipality.
Route Number	Route number(s).
Ownership	Entity that owns and maintains the asset.
Asset ID	A unique identifier used by SWRPC for this project.
Data Availability	Refers to the proportion of indicators that have data for the given asset.

		Highest	High	Medium	Lowest
Vulnerability Score	The model-produced vulnerability score for each asset.	2.32 – 4.00	1.78 – 2.32	1.37 – 1.78	0 – 1.37
Exposure Score	A measurement of previous flood history or current predisposition to flooding events.	2.85 – 4.00	1.95 – 2.85	0.90 – 1.95	0 – 0.90
Sensitivity Score	Refers to the condition of the asset which may include the need for repairs.	3.33 – 4.00	2.38 – 3.33	1.57 – 2.38	0 – 1.57
Adaptive Capacity Score	Describes the ability of the transportation network to continue operating in the event of damage or closure to the asset.	3.10 – 4.00	2.25 – 3.10	1.50 – 2.25	0 – 1.50
Damage Score	A rating based off an asset's Exposure and Sensitivity scores to measure the expected impact or likelihood of storm effects.	2.57 – 4.00	1.87 – 2.57	1.21 – 1.87	0 – 1.21

Table 5: Vulnerability Assessment Results Overview (Top 50 Vulnerability Scores)

Road Name	Town Name	Owner	ID	Vulnerability Score	Exposure Score	Sensitivity Score	Adaptive Capacity Score	Damage Score	Data Availability
NH 124 (Mountain Rd)	JAFFREY	State	2516	3.5	4.0	4.0	2.4	2.4	70%
NH 9	KEENE	State	1328	3.5	3.5	4.0	2.8	1.8	92%
NH 119 (Richmond Rd)	WINCHESTER	State	1381	3.5	3.5	4.0	2.8	1.5	59%
River Rd	WESTMORELAND	Local	2166	3.3	4.0	4.0	1.8	1.0	68%
NH 9	KEENE	State	1146	3.3	1.9	4.0	4.0	2.2	37%
NH 12	KEENE	State	1413	3.3	1.9	4.0	4.0	2.6	70%
NH 10 (Keene Rd)	WINCHESTER	State	1635	3.3	3.5	2.6	4.0	2.2	37%
NH 119 (Ashuelot Main St)	WINCHESTER	State	1672	3.3	4.0	3.1	2.8	2.2	37%
NH 10 (Manning Hill Rd)	WINCHESTER	State	2174	3.2	1.6	4.0	4.0	3.5	70%
NH 12	WESTMORELAND	State	2375	3.2	1.9	4.0	3.6	2.3	70%
NH 9	CHESTERFIELD	State	2548	3.2	1.9	4.0	3.6	2.2	51%
NH 12	WESTMORELAND	State	2606	3.2	1.9	4.0	3.6	3.5	64%
NH 12	WESTMORELAND	State	2644	3.2	1.9	4.0	3.6	1.6	37%
NH 12	WESTMORELAND	State	2645	3.2	1.9	4.0	3.6	1.1	37%
NH Route 123 N	STODDARD	State	1495	3.2	4.0	3.8	1.6	1.3	70%
Shaker Farm Rd S	JAFFREY	Local	2262	3.2	3.5	4.0	1.8	2.7	76%
River Rd	WESTMORELAND	Local	2392	3.2	3.5	4.0	1.8	1.0	68%

NH Route 12	MARLBOROUGH	State	1417	3.2	3.5	2.5	3.6	1.8	86%
NH 137 (Bennington Rd)	HANCOCK	State	792	3.1	3.5	3.1	2.8	1.7	82%
NH 9 (Keene Rd)	ANTRIM	State	2436	3.1	3.5	2.0	4.0	0.9	61%
NH 119 (Richmond Rd)	WINCHESTER	State	1380	3.1	3.5	3.0	2.8	1.8	37%
NH 12(Monadnock Hwy)	SWANZEY	State	2666	3.1	3.5	3.0	2.8	1.9	37%
Jaquith Rd	HARRISVILLE	Local	1887	3.1	4.0	4.0	1.0	1.6	37%
NH 31, NH 9 (Keene Rd)	ANTRIM	State	2804	3.1	3.5	1.9	4.0	1.3	51%
NH 119 (Northfield Rd)	HINSDALE	State	352	3.1	3.5	3.3	2.4	2.1	70%
Reed Rd	MARLOW	Local	1278	3.0	3.5	4.0	1.4	2.5	70%
NH 10	MARLOW	State	1685	3.0	4.0	3.0	2.0	1.2	61%
Old Dublin Rd	HANCOCK	Local	559	3.0	3.5	3.3	2.2	1.3	70%
NH 119 (Brattleboro Rd)	HINSDALE	State	21	3.0	4.0	2.6	2.4	0.9	54%
NH 10	MARLOW	State	1615	3.0	3.5	3.4	2.0	1.2	66%
NH 9	CHESTERFIELD	State	2345	3.0	3.5	2.0	3.6	2.2	37%
NH 9 (Keene Rd)	ANTRIM	State	747	3.0	1.6	3.3	4.0	0.8	70%
Heath Rd	JAFFREY	Local	2435	3.0	4.0	3.0	1.8	2.5	51%
NH 9	KEENE	State	1059	3.0	1.9	4.0	2.8	1.3	56%
NH 9	KEENE	State	2240	3.0	1.9	4.0	2.8	1.1	37%

US 202	BENNINGTON	State	775	2.9	3.5	2.3	3.2	2.2	57%
Willard Pond Rd	HANCOCK	Local	547	2.9	3.5	3.1	2.2	2.8	70%
Lost Rd	WINCHESTER	State	1425	2.9	3.5	3.0	2.2	0.5	37%
Branch Rd	ROXBURY	State	2412	2.9	3.5	4.0	1.0	1.3	37%
NH 12	WESTMORELAND	State	2671	2.9	1.7	3.3	3.7	1.8	37%
Gilsum Rd	SURRY	State	52	2.9	3.4	3.2	2.1	1.0	86%
NH 31 (Clinton Rd)	ANTRIM	State	2928	2.9	3.3	2.6	2.9	2.6	51%
Washington Pond Rd	MARLOW	Local	1386	2.9	3.5	3.6	1.4	2.4	57%
Jaquith Rd	HANCOCK	Local	904	2.9	3.5	3.0	2.2	1.0	68%
Jaquith Rd	HANCOCK	Local	905	2.9	3.5	3.0	2.2	1.1	70%
NH 124 (Mountain Rd)	JAFFREY	State	829	2.9	3.5	2.8	2.4	1.6	95%
Depot Rd	HANCOCK	Local	853	2.9	3.5	2.9	2.2	1.7	82%
Sargent St	HINSDALE	Local	357	2.9	3.5	3.3	1.8	2.2	57%
NH 9	STODDARD	State	1246	2.9	3.5	2.4	2.8	1.3	37%
Horseshoe Rd	CHESTERFIELD	Local	635	2.9	4.0	2.8	1.8	1.4	70%

Response Options

With vulnerability scores generated for each asset, the goal for the *Monadnock Region Transportation Infrastructure Flood Vulnerability Assessment* is to help prioritize and inform responses to flooding threats. Broadly, there are typically 3 kinds of response options for these threats: adaptation, mitigation, and in-kind replacement. The latter, in-kind replacement, refers to rebuilding an asset to the same specification prior to flooding impacts and is not recommended in most cases. Mitigation refers to responding to the flooding threat in a manner that removes the risk in the future. For example, mitigation could look like upgrading a stream crossing to a bridge, or, in an extreme example, moving a bridge from a vulnerable location to a location that is less exposed. Mitigation is typically an effective response, but it often carries a high price tag. Adaptation is a method of response which works within the current asset structure to lower the risk of flooding effects. Adaptation is typically the most cost-effective method of response to an environmental stressor and is therefore the focus of this section.

Due to the high number of culverts and bridges evaluated, it was not possible to identify individual response options for every stream crossing. General strategies for adapting to or mitigating vulnerability to extreme weather are identified by the FHWA in their *Vulnerability Assessment and Adaptation Framework* guide and should be considered for the assets identified in this report.[66]

- Engineer new assets to withstand environmental conditions anticipated in the future (e.g., use construction materials better suited to higher heat days);
- Retrofit existing assets to accommodate impacts (e.g., add barriers to prevent water incursion into tunnels, harden roadway embankments);
- Increase redundancy of the system to ensure transportation services provided by infrastructure can be supplied by other means/alternatives (e.g., build alternative access routes at higher elevations);
- Institute intensive maintenance schedules (e.g., more frequent cleaning of drains);
- Incorporate findings into asset management plans and systems;
- Integrate findings into systems planning (e.g., site new facilities outside of expanded floodplains where their potential for climate-related damage is reduced); and
- Improve operations plans for weather emergencies.

As illustrated in the list above, methods to address vulnerable transportation assets can be broken down broadly into three categories: natural, structural, or policy-based. Furthermore, they can be implemented regionally or in a site-specific manner. For some assets, a simple solution such as a more intensive maintenance schedule to clear a frequently clogged system could be all that is needed. In a more extreme case, a better solution may be to permanently move an asset to a new location that is less vulnerable to extreme weather, which is a mitigation response. In between these two kinds of solutions lie many intermediate steps in a spectrum of varying complexity and scale. Site-specific solutions, like the reinforcement or reconstruction of specific assets, are a necessary priority to strengthen weak points within the transportation network. For areas that are flood-prone, such as assets along a river that floods more and more often, system-wide improvements should be planned to help build future resilience within the network.

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[66] Federal Highway Administration. "Vulnerability Assessment and Adaptation Framework, Third Edition."

In addition to implementing specific improvements to individual problematic assets, planning for system-wide resilience should consider a range of higher-level changes. An example would be for NHDOT and municipalities to apply more rigorous engineering standards when building new assets and retrofitting existing structures. Another example is to actively plan to increase the redundancy of the transportation system to mitigate the effects of specific asset failure. In the Monadnock Region, and others with very rural populations, this may be particularly important to reduce the likelihood of communities being isolated from help during future severe weather events. The effects of 2024 Hurricane Helene in rural portions of Appalachia are illustrative to the dangers of populations being highly isolated in the transportation network. Following this storm, many communities were cut off from the transportation network for weeks as flooding destroyed stream crossing infrastructure.[67]

[67] Seminera, Makiya. 2024. "In Remote Mountain Communities Cut off by Helene, Residents Look to the Skies for Aid." AP News. October 9, 2024. https://apnews.com/article/hurricane-helene-north-carolina-national-guard-7dd82ee953d8da9098996231f619cbce.

Prioritization and Decision-making

One of the main strengths of VAST is that it synthesizes data from many sources to develop each asset's vulnerability score, which can provide a more robust assessment of an asset's risk to extreme weather. However, the score should not be used in isolation. When prioritizing infrastructure projects and identifying assets most at risk of extreme precipitation, utilizing multiple sources of information is critical. Accordingly, SWRPC's goal is to share this data with communities and infrastructure stakeholders to help inform decision-making. The scores should not supplant local knowledge of the transportation system, but rather, to support informed decisions about project prioritization.

One way vulnerability scores can be used is to support project nominations for the NHDOT Ten Year Plan (TYP). Nominations can be put forward by SWRPC and other stakeholders. SWRPC's Transportation Advisory Committee ranks TYP nominations based on specific criteria, including a project area's hazard risk and a project's anticipated hazard mitigation impact. Since this can be a competitive process, having supporting documentation for project need and impact can be important. Vulnerability scores can also be included in local Hazard Mitigation Plans which must be updated every 5 years to be eligible for certain FEMA grant programs.

Challenges

The most significant challenges encountered by the SWRPC team during this project were those associated with the collection and preparation of many kinds of data from various sources, scales and accuracies. In fact, the process of developing the asset points themselves was complex, as they were formed by joining NH State Stream Crossing data to the federal National Bridge Inventory. A significant data "cleanup effort" was required, such as when bridge data was attributed to an incorrect stream crossing. Additional challenges were associated with efforts to create a flood history. Since there are no comprehensive existing data sources for this information, the project team sourced data from multiple different sources and aggregated the information. Similar difficulties were experienced when assessing the proximity of assets to FEMA Special Flood Hazard zones. FEMA splits the Monadnock Region into numerous geographic sections which are updated on different schedules. This meant that different versions of the data had to be utilized for different assets.

Updates

For the scope and timeline of this project, the results of the *Monadnock Region Transportation Infrastructure Flood Vulnerability Assessment* are an important initial step towards understanding which stream crossings may be most at risk from extreme precipitation events. There are a number of future actions which could expand this effort and build on its initial findings. First, since the conditions associated with the assets will change over time, updating the model in the future should be a priority. Future data sources may additionally become more accurate which will help refine the model outputs. A realistic time frame for re-running the model with updated data, or for utilizing an updated model to build on this study, might be in 2030.

When conducting a future update, SWRPC should consult NHDOT's recently published *Resilience Improvement Plan*, which includes a vulnerability assessment of state transportation assets, along with other helpful information.[68] Comparison of the *Monadnock Region Transportation Infrastructure Flood Vulnerability Assessment* to the *Resilience Improvement Plan* may inform future actions and refine future

model usage. There are other ways to build in the Report ahead of any update efforts as well, including conducting assessments of criticality and risk, as defined by FHWA.[69]

Assessing infrastructure criticality refers to the incorporation of qualitative local knowledge of the transportation system into the overall project approach. This can be an important way to identify the most important assets to prioritize for implementation projects, particularly when managing large sets of data. It can also be an important method to increase local knowledge about the project and achieve greater buy-in from stakeholders. Assessing risk builds on the vulnerability score attributed to each asset by calculating two additional metrics: the probability of an asset being affected by severe weather and the potential consequences of this impact. Better understanding the risk associated with each asset's vulnerability score can additionally help prioritize future funding and study.

[68] New Hampshire Department of Transportation. 2025. "New Hampshire DOT Resilience Improvement Plan." Concord, New Hampshire. https://mm.nh.gov/files/uploads/dot/remote-docs/nhdot-resilience-improvement-plan.pdf.
[69] Federal Highway Administration. "Vulnerability Assessment and Adaptation Framework, Third Edition."

References

1. Federal Emergency Management Administration. "Disaster Declarations for States and Counties." March 21, 2024. https://www.fema.gov/data-visualization/disaster-declarations-states-and-counties.
2. Federal Highway Administration. "Vulnerability Assessment and Adaptation Framework, Third Edition." 2017. https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/climate_adaptation.pdf.
3. Federal Highway Administration. "Vulnerability Assessment Scoring Tool User's Guide." June 2015. https://www.fhwa.dot.gov/environment/sustainability/resilience/tools/scoring_tools_guide/vast_users_guide.pdf.
4. Ganley, Rick, Mary McIntyre, Annie Ropeik. 2021. "As New Hampshire Warms, UNH Studies Effects Of More Freeze-Thaw Cycles." New Hampshire Public Radio. April 21, 2021. https://www.nhpr.org/climate-change/2021-04-21/as-new-hampshire-warms-unh-studies-effects-of-more-freeze-thaw-cycles.
5. Kunkel, K. E. 2022. "State Climate Summaries for the United States 2022. NOAA Technical Report NESDIS 150." NOAA NESDIS. https://statesummaries.ncics.org/chapter/nh.
6. Lemcke-Stampone, Mary D, Cameron P Wake, and Elizabeth Burakowski. n.d. "New Hampshire Climate Assessment 2021." *The Sustainability Institute*. https://scholars.unh.edu/cgi/viewcontent.cgi?article=1071&context=sustainability.
7. Narayanan, Rishya. 2023. "Climate Change Worsens Extreme Weather in New England." Conservation Law Foundation. August 31, 2023. https://www.clf.org/blog/climate-change-worsens-extreme-weather-in-new-england/.
8. NHDOT Bureau of Planning and Community Assistance. 2024. "GRANIT GIS Data Quarterly Snapshot." https://ftp.granit.unh.edu/NHDOT/GIS%20Data%20Quarterly%20Snapshots/2024/.
9. New Hampshire Department of Transportation. 2010. "NH Long Range Transportation Plan 2010-2030." https://mm.nh.gov/files/uploads/dot/remote-docs/2010-july-long-range-transportation-plan-complete.pdf.
10. New Hampshire Department of Transportation. 2025. "New Hampshire DOT Resilience Improvement Plan." Concord, New Hampshire. https://mm.nh.gov/files/uploads/dot/remote-docs/nhdot-resilience-improvement-plan.pdf.
11. New Hampshire Stream Crossing Initiative. n.d. "How We Evaluate Crossings." Accessed June 27, 2025. https://www4.des.state.nh.us/NH-Stream-Crossings/index.php/how-we-evaluate-crossings/.
12. Seminera, Makiya. 2024. "In Remote Mountain Communities Cut off by Helene, Residents Look to the Skies for Aid." AP News. October 9, 2024. https://apnews.com/article/hurricane-helene-north-carolina-national-guard-7dd82ee953d8da9098996231f619cbce.
13. Southwest Region Planning Commission. 2014. "Southwest Connects: Southwest Region Transportation Plan 2014 - 2035." https://www.swrpc.org/wp-content/uploads/2021/03/Southwest-Connects-Southwest-Region-Transportation-Plan-FINAL.pdf.

14. Southwest Region Planning Commission. 2015. “Monadnock Region Future: A Plan for Southwest New Hampshire.” https://www.swrpc.org/wp-content/uploads/2021/03/MonadnockRegionFuture_RegionalPlan_FINAL.pdf.
15. The Intergovernmental Panel on Climate Change. n.d. “Glossary — Global Warming of 1.5 °C.” Accessed May 1, 2025. https://www.ipcc.ch/sr15/chapter/glossary/.
16. U. S. Department of Transportation. 2014. “Transportation Climate Change Sensitivity Matrix.” https://www.fhwa.dot.gov/environment/sustainability/resilience/tools/.
17. U. S. Department of Transportation Bureau of Transportation Statistics. 2024. “National Bridge Inventory.” https://geodata.bts.gov/datasets/usdot::national-bridge-inventory/about.
18. U. S. Global Change Research Program. 2023. “Fifth National Climate Assessment.” U.S. Global Change Research Program, Washington, DC. https://nca2023.globalchange.gov/chapter/21/.
19. Wake, Cameron P, Elizabeth A Burakowski, Peter Wilkinson, Katharine Hayhoe, Anne Stoner, C Keeley, and Julie LaBranche. 2014. “Climate Change in Southern New Hampshire: Past, Present and Future.” *The Sustainability Institute*. https://scholars.unh.edu/cgi/viewcontent.cgi?article=1002&context=sustainability.