

Planning for Climate Resilience
City of Asheville, North Carolina

Final Assessment Report

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THE CITY OF ASHEVILLE
NORTH CAROLINA

UNC ASHEVILLE | NEMAC
NATIONAL ENVIRONMENTAL MODELING & ANALYSIS CENTER

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Executive Summary

Asheville is vulnerable to multiple climate-related threats and hazards—particularly flooding, landslides, and wildfire—caused by extreme weather events such as extreme precipitation and drought.

Given its past and recent experience with impacts from extreme weather events and the scientific consensus that such events are increasing in frequency and are expected to become even more frequent and severe in the future, the City of Asheville determined that it was in its best interests to consider climate-related threats and hazards with a goal of becoming more resilient to them, and to integrate the results into its comprehensive planning process.

To this end, the city partnered with UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) to lead city staff through the first phase of a climate resilience planning process. Climate resilience planning considers ways that communities can prepare for climate-related impacts in order to protect people and community assets and best deliver key services.

Phase I of the planning process took place from June–December 2016, during which a 31-member team of city staff representing 14 municipal departments participated in six facilitated workshops and several working group sessions. The workshops and activities were designed by NEMAC to be aligned with the "Steps to Resilience" outlined in the U.S. Climate Resilience Toolkit (www.toolkit.climate.gov).

During Phase I, an assessment was completed during which the climate resilience project team considered seven primary threats (both riverine and nuisance flooding, landslides, wildfire, water shortage, heat waves, and supply chain interruption) and identified 14 key community assets (bridges, city-owned facilities, commercial property, critical infrastructure, energy supply chain, food infrastructure, industrial property, natural areas for habitat and conservation, parks and recreation, residential property, residents, roads, transit and greenways, and water supply).

Each community asset was assessed for its vulnerability and risk to each identified climate threat. The project team then worked to identify about 100 options that the city and stakeholders were willing to support. Participants determined appropriate evaluation criteria for city leadership to consider for implementation. Participants determined appropriate evaluation criteria for the options and began the important work of prioritization, also noting potential funding sources and suggestions for implementation leaders. The project team began to assess and prioritize the identified resilience-building options within Phase I's given time constraints. However, the remaining identified options required the team to revisit the prioritization exercise in Phase II before moving on to implementation.

The intent of Phase II, which commenced in early 2017, was to complete the prioritization of identified resilience-building options, compile a full prioritization report, and integrate the findings from this planning process into the city's comprehensive plan.

Introduction

Asheville is vulnerable to multiple climate-related threats and hazards—including flooding, landslides, and wildfire—caused by extreme weather events such as extreme precipitation and drought.

Past experience demonstrates just how vulnerable Asheville is to these hazards. In July 1916, the city was devastated by the most severe flooding event in its history. Dozens of lives and businesses were lost to the flood, and many homes and businesses were never rebuilt. More recently, in 2004 Asheville and the surrounding region experienced a series of heavy rainfall events that resulted in severe flooding and landslides, also resulting in the tragic loss of life, a considerable amount of damaged property, and significant loss of economic revenue due to business interruption.

Cities and communities across the United States are dealing with impacts from more frequent weather and climate-related threats. Since 1980, there have been more than 200 billion-dollar weather and climate-related disaster events in the United States. The scientific consensus, as reported in the third National Climate Assessment and in the nation's Climate Indicators, highlights the fact that the frequency of extreme weather events is increasing, and that they are expected to become even more frequent and severe in the future.

In order to become better prepared for impacts related to these events, communities are incorporating climate resilience and adaptation into their municipal planning. Climate resilience planning considers ways that communities can prepare for climate-related impacts to protect people and community assets and best deliver key services.

To become better prepared as it faces both existing hazards and a changing environment, the City of Asheville determined that it would be in its best interest to consider climate-related threats and hazards with a goal of becoming more resilient to them, and to integrate the results into its comprehensive planning process.

To this end, the city partnered with UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) to lead city staff through a series of workshops and activities aligned with the "Steps to Resilience" outlined in the U.S. Climate Resilience Toolkit (www.toolkit.climate.gov). This phased approach provides communities, municipalities, and organizations with a blueprint for climate resilience planning.

The application of the Steps to Resilience took place during a six-month period in 2016, during which a 31-member team of city staff representing 14 city departments participated in six workshops and several working group sessions.

The process began with an examination of how Asheville has been impacted by past climate-related threats and hazards, and how those threats and hazards are expected to change in

the future. Based on past threats and scientific consensus, the primary stressors and threats considered were:

- Major flooding
- Nuisance flooding
- Landslides
- Water shortages due to drought
- Wildfire
- Extreme heat events
- Supply chain interruptions

In addition to the potential threats, the team identified 14 key community assets. These included people, property and critical infrastructure, natural resources, and services upon which Asheville residents rely. Each community asset was assessed for its vulnerability and risk to each identified climate threat.

This report highlights an assessment of potential climate-related impacts, vulnerabilities, and risks for the City of Asheville that were identified during the planning process. The assessment phase of this work provided a foundation on which to evaluate existing policies and identify new options that reduce vulnerability and build resilience. These new options either (i) reduce exposure of assets to hazard events, (ii) increase the ability to cope with potential impacts, or (iii) support response and recovery following an event.

The final goal of this process was to evaluate options for specific geographic and management areas that are most vulnerable and at-risk, and to prioritize such options into actions that can be implemented in those areas.

Project Team

A climate resilience project team was assembled in June 2016, consisting of city staff representing 14 city departments. Additionally, a team from UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) provided facilitation through the climate resilience planning process, as well as technical support and scientific analysis to support the project. Project team participants are listed below.

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The climate resilience team met for six workshops between June and December, 2016:

June 23, 2016 | Workshop 1
August 4, 2016 | Workshop 2
September 8, 2016 | Workshop 3
October 5, 2016 | Workshop 4
November 10, 2016 | Workshop 5
December 1, 2016 | Workshop 6
July 27, 2016 | Workshop 1 Make-Up Session
August 29, 2016 | Workshop 2 Make-Up Session

In addition to the workshops, working sessions were held on September 23, September 30, October 13, and October 21, 2016. Information on this climate resilience planning process was presented to the public during an information session held on November 16, 2016.

What is Climate Resilience?

Many local governments are recognizing the need to build climate resilience, as extreme weather events are becoming more frequent and/or more severe than in the past. *Resilience* is defined as the capacity of a community, business, or natural system to prevent, withstand, respond to, and recover from a disruption.[1,2]

The initial step of climate resilience planning is to determine the climate threats on which to focus and to examine their potential impacts—how hazards negatively affect societal assets in a community. This step also involves considering trends and future changes in climate conditions.

Climate resilience involves three considerations: (1) building resilience to current climate variability or past hazard events; (2) building resilience to recently observed changing trends in climate; and (3) building resilience to future projected or expected changes in climate. Changes in climate will result in existing threats becoming more frequent or severe; therefore, building resilience to existing hazards is an effective approach to become better prepared for future change as well.[3]

Efforts to increase resilience are built on the foundation of understanding, and reducing, vulnerability. *Vulnerability* is a ubiquitous term often used to describe susceptibility to harm. In the context of building climate resilience, a vulnerability assessment is a structured process that identifies ways in which an organization or community is susceptible to harm from existing or potential hazards. Two main aspects of vulnerability are often considered, which include both physical and socioeconomic dimensions. Vulnerability assessments tend to have three main components: (1) exposure; (2) potential impacts; and (3) adaptive capacity.

Another key concept used in resilience planning is the understanding of risk. *Risk* involves the likelihood and consequence of a climate threat.

Together, the vulnerability and risk assessment of a resilience framework can serve to inform the development of strategies to reduce vulnerability or risk. By combining views of vulnerability and risk, efforts can focus on building resilience for the assets that are most susceptible and most likely to be impacted. This approach also complements risk-hazard mitigation activities and management practices.

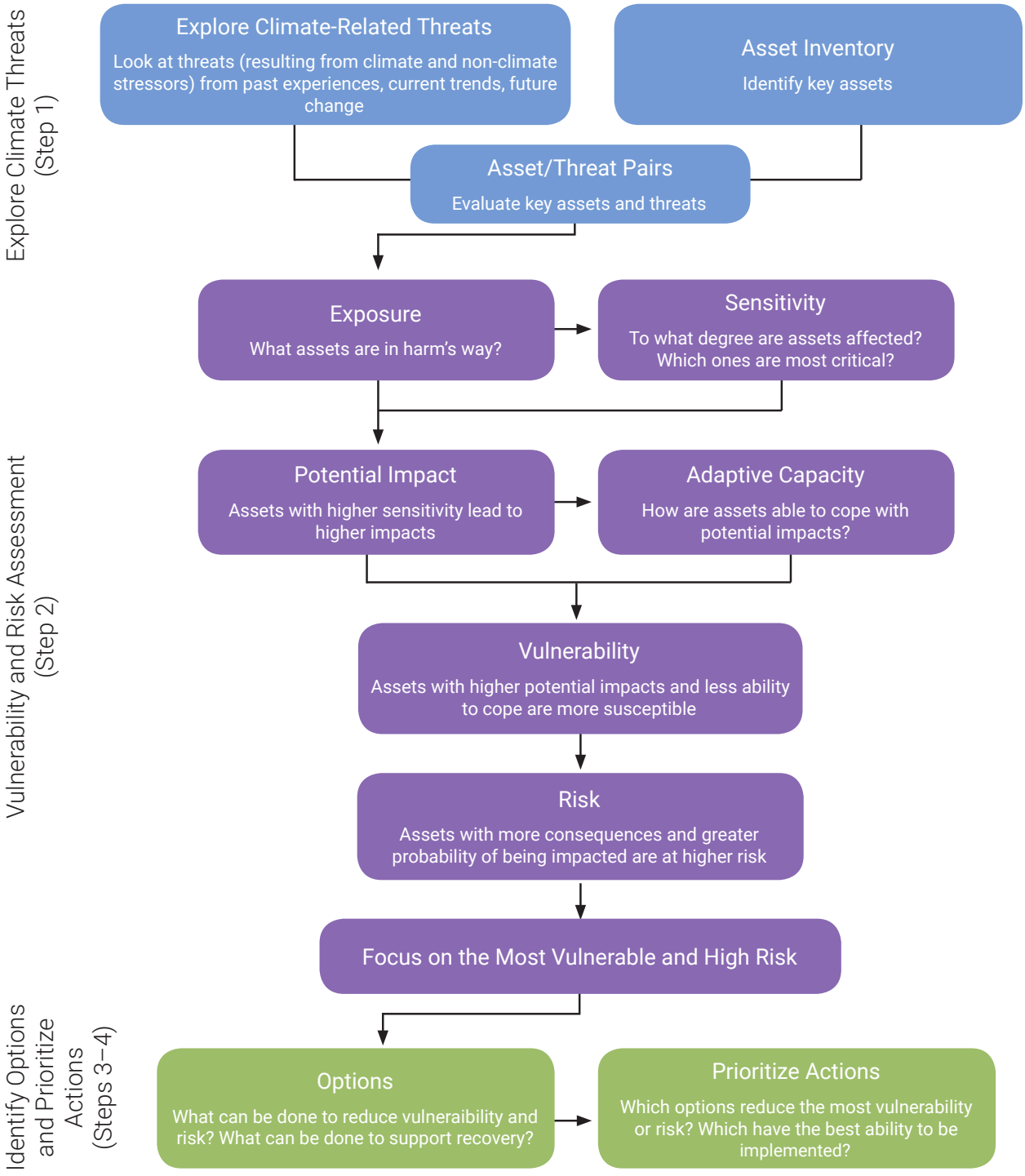
One of the primary distinctions in the climate-related efforts made by local governments is the difference between climate mitigation and climate resilience or adaptation. *Mitigation* refers to the reduction of greenhouse gases from the combustion of fossil fuels that are causing climate change. *Climate resilience or adaptation* refers to the efforts taken to cope with and withstand the impacts associated with existing climate-related hazard events or events attributed to climate change. Many local governments already focus on mitigation of climate change through other “green” initiatives, such as energy conservation. However, there is an increasing realization of the need to focus on resilience and adaptation, with the expectation that some degree of future change is unavoidable.

Another important aspect of resilience planning is to recognize the iterative nature of the process. Once strategies are implemented, it is necessary to monitor their effectiveness and to reiterate on the assessment of vulnerability and risk, and to identify new actions or strategies to build resilience.

Overview of the "Steps to Resilience"

The U.S. Climate Resilience Toolkit (www.toolkit.climate.gov) provides an iterative, five-step process for communities to follow when planning for climate resilience. This framework

Steps to Resilience and Supporting Components



integrates the components of climate resilience that can be used in existing municipal planning processes at the local level, and can be used to understand the characteristics of vulnerability and risk in a community, inform policy, and evaluate the effectiveness of strategies that are implemented.

Step One: Explore Climate Threats. Step One suggests that a community first research its past experiences with climate and weather events and explore regional climate trends and projections to understand how assets (people, infrastructure, services, or resources) may be threatened. Next is to identify stressors—both climate and non-climate—that cause or contribute to a threat or hazard event.

Step Two: Assess Vulnerability and Risks. Step Two starts with a vulnerability analysis. The purpose of this step is to understand how a community's assets are likely to be impacted by the climate threats identified during Step One. This assessment then becomes the foundation for developing options to build resilience in Step Three.

Vulnerability is defined as the susceptibility of societal assets to be impacted due to both physical and social factors. To define vulnerability, the analysis must first use the exposure assessment from Step One to examine both potential impact and adaptive capacity. This can be thought of simply as *vulnerability = potential impact − adaptive capacity.*[1,2,4]

Potential impact includes evaluating sensitivity, or the degree to which exposed assets are potentially affected.

Adaptive capacity is the ability to cope with identified impacts with minimal disruption or cost.

Vulnerability is then determined by considering both the potential impact and the adaptive capacity, with the most vulnerable having the highest potential impact and the lowest adaptive capacity.

For areas with high vulnerability, it is necessary to scope the level of risk. Risk depends on both probability and consequence—in other words, what is the chance of a loss? It is important to note that the scoping of risk at this stage is not the same as undertaking a detailed risk assessment, which can be a time- and cost-intensive process. Instead, risk scoping is an initial broad quantification of risk that can be used to compare general probabilities and consequences of certain threats occurring.

Step Three: Investigate Options. The ultimate goal of Step Three is to have actionable options to build resilience for the assets that are most vulnerable and at-risk. To be actionable, an option should have the potential of building resilience by (1) reducing exposure (removing assets from harm's way), (2) increasing adaptive capacity (increasing the asset's ability to cope with impacts), or (3) supporting response and recovery.

Step Four: Prioritize Actions. Step Three often yields a large number of options, and it can be difficult to evaluate and compare them all. Prioritization is a two-part process, the first of which involves looking at the actions that will have the most impact. The second part of the prioritization process is to determine criteria on which to rank the options.

Step Five: Take Action. Step Five can be viewed as the most important, as it involves implementing the plan to build community resilience. This step can take years to fully

implement, and it is critical for the community to monitor results as time passes—some of the assumptions made during the original analysis may have been faulty, or on-the-ground implementation may not have been completed. This is to be expected, and the community should be open to modifying its approach as needed.

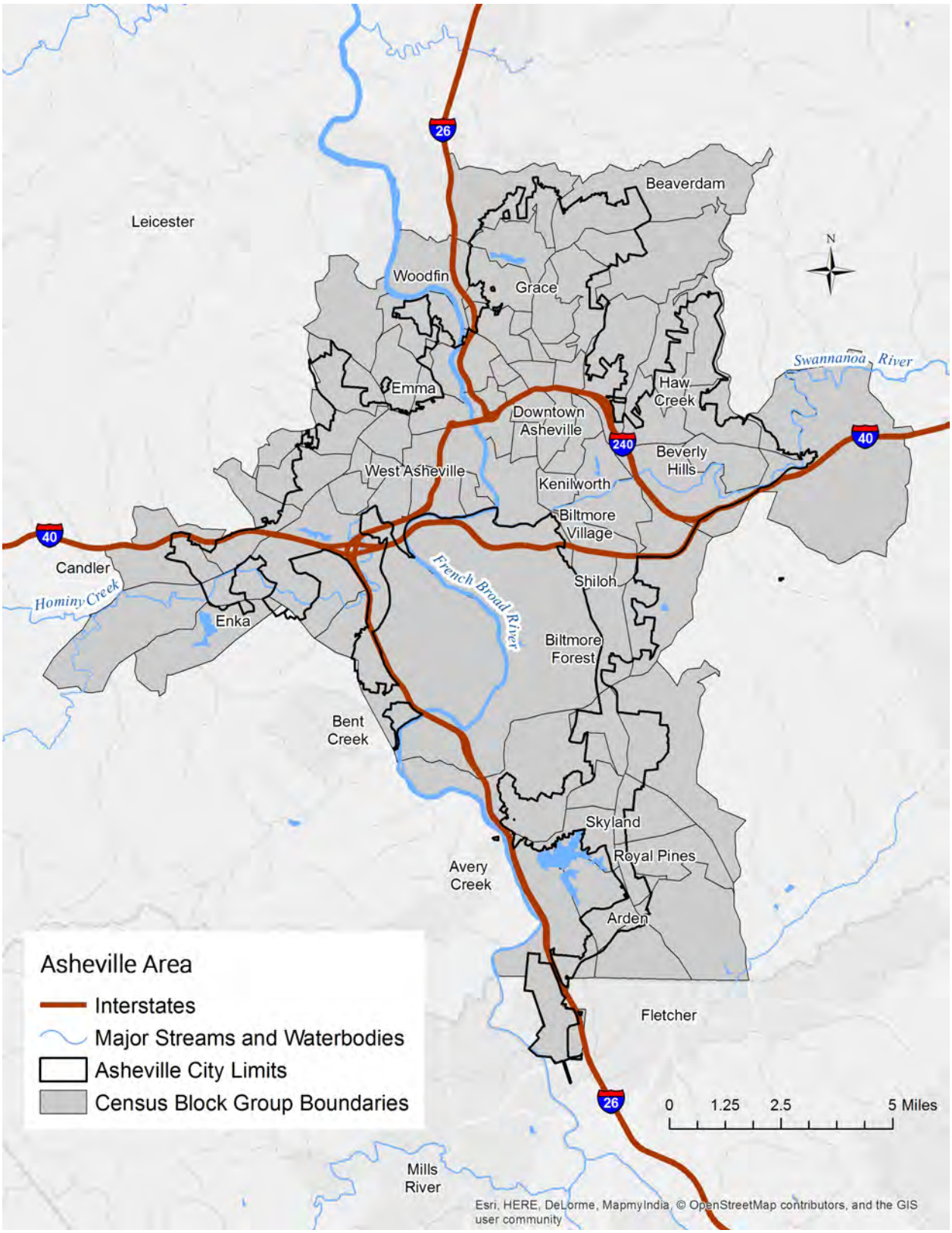
These modifications will sometimes require revisiting some of the earlier steps, re-examining options associated with key assets and threats, and keeping up with some of the non-climate stressors as well. Only through careful planning and monitoring will continued progress be made.

Overview of the City of Asheville

The city of Asheville, North Carolina, is located in the French Broad River Valley of Western North Carolina. With a population of almost 90,000, Asheville is the largest city in Western North Carolina and the 11th largest in the state. Asheville serves as an economic and cultural center both for the region and for the four-county statistical metropolitan area, which has a population of about 440,000.

At an elevation of approximately 2,100 feet, Asheville is shaped by and surrounded by mountains. The variable topography surrounding the city plays a major role in shaping the area's local weather and climate conditions. Indeed, one of the driest locations in the eastern United States is located nearby, as is one of the wettest.

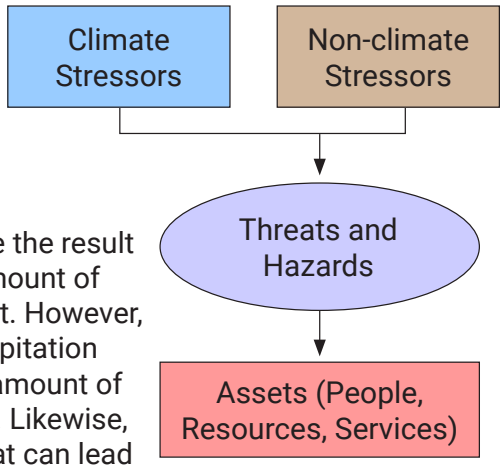
The climate resilience planning process focused on the City of Asheville municipal area. This area includes all city residents, businesses, infrastructure, and municipal operations and services. For planning purposes, the defined extent includes the city limits plus some additional areas located outside the city limits that lie within census block groups partially in or adjacent to the city limits. The map on the following page shows the official city limit boundary and the census block group boundaries that serve as the geographic extent of the "study area." One advantage of the use of the census block group geographic extent is that it allows the study to incorporate data and information from the U.S. Census Bureau. Therefore, any areas within the census block group boundaries are included in this report, while also recognizing that city interests and assets may also be located outside of this area.


Asheville Area
Interstates
Major Streams and Waterbodies
Asheville City Limits
Census Block Group Boundaries
Leicester
Beaverdam
Woodfin
Grace
Emma
Haw Creek
Swannanoa River
Downtown Asheville
West Asheville
Kenilworth
Beverly Hills
Biltmore Village
Candler
Hominy Creek
Enka
French Broad River
Shiloh
Biltmore Forest
Bent Creek
Skyland
Royal Pines
Avery Creek
Arden
Fletcher
Mills River
N
0 1.25 2.5 5 Miles
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Step One | Explore Climate Threats and Community Assets

Impacts related to climate threats must be evaluated and measured in a structured way so that participants can understand those impacts to make informed decisions. A conceptual model is one technique that can be used to explore the causal relationships between stressors, threats, and assets that are potentially affected.

The conceptual model template at right illustrates the relationships between climate and non-climate stressors, threats and hazards, and assets that may be affected. The arrows in the model are drawn to reflect the causal influences between these different components. This type of model can also be used to reveal strategies or actions that have the potential to reduce vulnerability and build resilience.



As shown in the template, climate threats and hazards are the result of climate and non-climate stressors. For example, the amount of precipitation (or lack thereof) in and of itself is not a threat. However, extreme precipitation is a climate stressor if enough precipitation falls in a given time, or in combination with a substantial amount of impervious surface, and can lead to the threat of flooding. Likewise, the lack of precipitation (drought) is a climate stressor that can lead to the threat of water shortage. Note, also, that threats and hazard events occur only where assets are potentially negatively affected. If an asset is potentially affected negatively by a threat (i.e., the asset is in harm's way), then it is considered exposed to that threat.

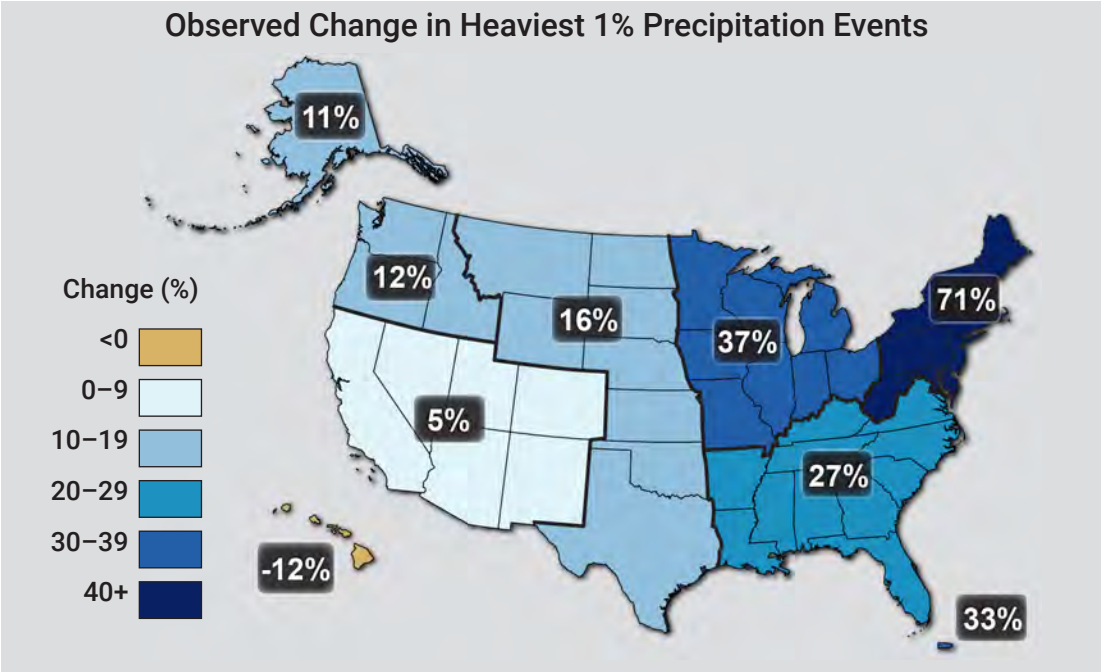
In this planning process, climate-related threats were identified by exploring the project team's institutional knowledge of past events (such as the flood events of 2004), the NOAA National Centers for Environmental Information Storm Events Database,[5] and regional climate trends and projections from the second and third National Climate Assessments.[6,1]

Additional resources used to explore climate threats for Asheville included:

- Information from the second and third National Climate Assessments was used as a basis for understanding some of the causal relationships between stressors (climate and non-climate) and the hazards that the community is facing.[6,1]
- A database created through an initiative by the North Carolina Interagency Leadership Team in 2010 provided information on stressors, impacts, and resources affected.[7]
- An example conceptual model constructed during a 2014 workshop conducted by the Southeast Sustainability Directors Network (in which Asheville was a participating member), based on flooding and landslide impacts in Asheville in 2004 (Appendix B).

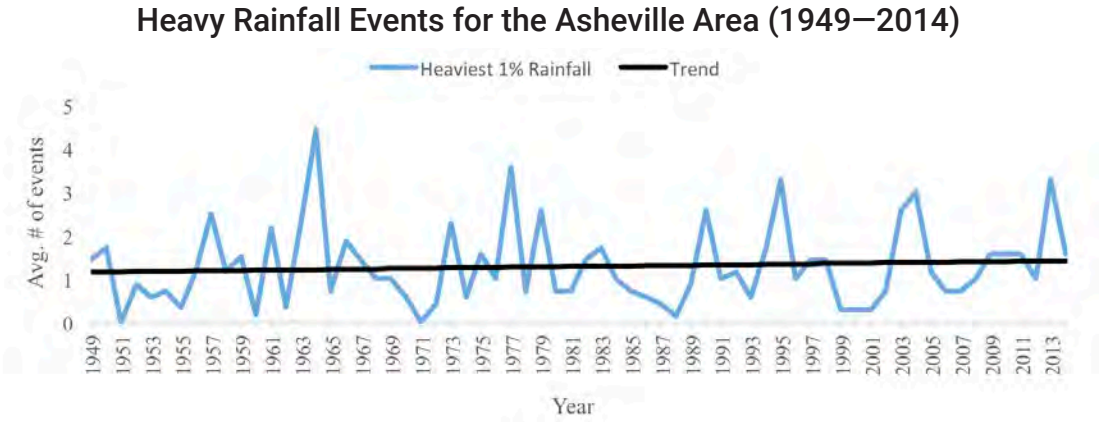
Climate and Non-Climate Stressors

Extreme precipitation is one of Asheville's main climate stressors. According to the third National Climate Assessment, from 1958 to 2012 the Southeast region experienced a 27 percent increase in heavy precipitation events.[1]



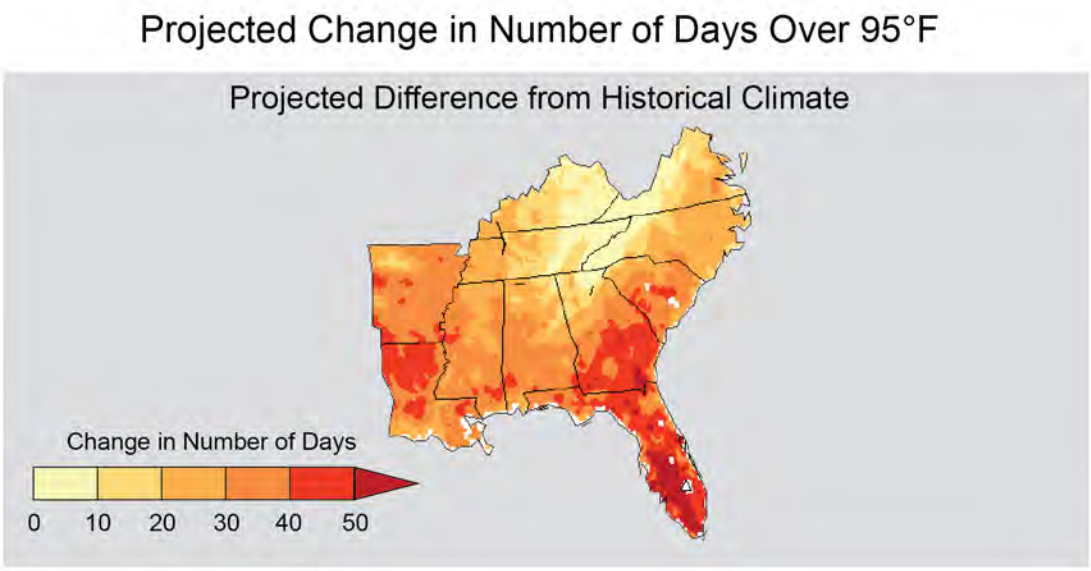
The map shows percent increases in the amount of precipitation falling in very heavy events (defined as the heaviest one percent of all daily events) from 1958 to 2012 for each region of the continental United States. The changes shown in this figure are calculated from the beginning and end points of the trends for 1958 to 2012. (Figure source: [1], updated from Karl et al. 2009.)

An analysis of the heaviest rainfall events specific to the Asheville area also shows an apparent increasing trend in the average annual number of these events from 1949 to 2014.



The graph shows the average number of heaviest 1% of all daily rainfall events in the Asheville area from 1949 to 2014 (66 years). The analysis was performed using data from seven Global Historical Climatology Network (GHCN) weather stations located within a 20-mile radius of downtown Asheville. The heaviest 1% daily precipitation events among all seven stations were analyzed using regular regression, a statistical method for trend analysis. The graph shows the average annual number of events (blue line) and the linear trend results of the analysis (black line). (Figure source: NEMAC.)

Another regional climate stressor is temperature variability. While the Asheville area has not experienced many extreme heat events in the past, projected changes in temperature variability show the potential for an increased number of days over 95°F for the region.[1]



This image shows the projected average number of days per year with maximum temperatures above 95°F in the Southeast region for 2041–2070 compared to 1971–2000, assuming emissions continue to grow (A2 scenario). The top map shows that the projected average increase in over-95°F days may range from 0 to 10 for most of the Western North Carolina region. (Figure source: NOAA NCDC/CICS-NC.[1])

Non-climate stressors are factors or conditions that contribute to the occurrence of a threat. For example, impervious surfaces are considered to be a non-climate stressor, as they are known to contribute to increased runoff, erosion, and flooding in urban areas and also to the urban heat island effect. According to land cover data from the 2011 National Landcover Dataset,[8] the area within the Asheville city limits is about 84 percent developed, and the area within the city limits that is also within the 100-year floodplain is approximately 75 percent developed. Other non-climate stressors for Asheville are related to population growth and demand for resources, such as water.

Both climate and non-climate stressors have the potential to change in the future and increase risk. Often, changes to *non*-climate stressors have a greater influence on climate hazards than do changes to climate stressors.

Climate Threats and Hazards

According to the Storm Events Database, there has been an estimated $108 million in damage from climatic and extreme weather events in Buncombe County, North Carolina—the county in which Asheville is located—between 1996 and 2014.[5] Events from flooding and landslides account for more than 97 percent of these damages (78.7 percent and 18.6 percent, respectively). Most of the hazards selected for this assessment are existing hazards that have impacted the community in the past and have the potential to change in frequency or severity in a changing climate.

The table below shows each climate threat considered for Asheville, along with its associated climate and non-climate stressors and expected future change in stressors that have an influence on climate threats. A discussion of each threat follows.

Climate threat	Climate stressor	Non-climate stressor	Expected future change
Flooding	Extreme precipitation	Impervious surfaces	• Increased frequency and severity of extreme precipitation • Increased development and more impervious surfaces
Landslides	Extreme precipitation	Steep slope development and vegetation removal	• Increased frequency and severity of extreme precipitation • Increased development
Wildfire	Drought	Fuels and vegetation; human-caused ignitions	• Increased frequency and severity of drought
Water shortage	Drought	Water use/demand	• Increased frequency and severity of drought • Increased population and water use/demand
Nuisance flooding, runoff, and erosion	Extreme precipitation	Impervious surfaces	• Increased frequency and severity of extreme precipitation • Increased development and more impervious surfaces
Extreme heat (heat waves)	Temperature variability	Impervious surfaces	• Potential for increased number of extreme heat days
Multiple supply chain threats	Tropical storms, precipitation	Energy use/demand	• Potential for increased frequency of tropical storms • Increased population and energy use/demand

Flooding

The French Broad and Swannanoa Rivers flow through Asheville. The frequency of flood events can be determined from stream gage data indicating the annual number of river flow events

above flood stage. The United States Geological Survey (USGS) maintains two stream gages in Asheville, one on the French Broad River just north of downtown and another on the Swannanoa River in Biltmore Village.

A high water event is when a river's height is bankfull, or the level above which the river begins to overflow.[9] The figures on the following page show the annual number of action stage and flood events for each of two stream gage locations. The colors indicate the categories, or stages, of the high water events: action stage (green), flood stage (orange), moderate flood stage (red), and major flood stage (dark red).

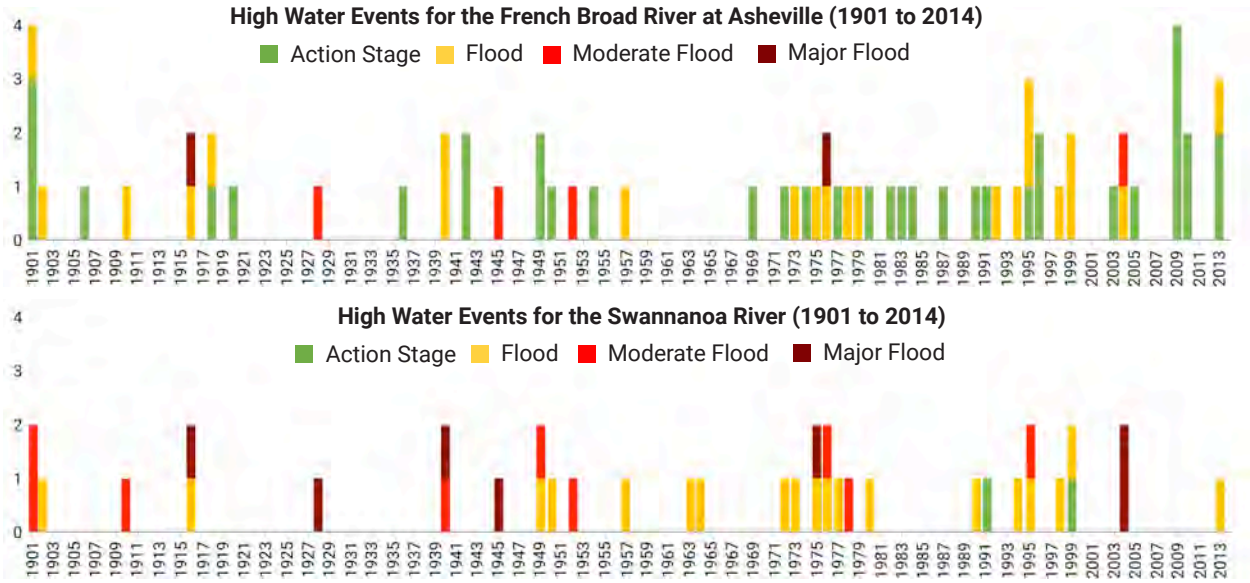
The hydrologic dynamics and characteristics are very different for these two rivers, so the number of events on each should not be compared. Nonetheless, it is interesting to see that events tend to be more severe at the Swannanoa River location than the French Broad River location.

In September 2004, Western North Carolina was significantly impacted by floods and landslides caused by two major hurricanes. Some of the major impacts to the Asheville area and surrounding counties included 11 lives lost, 140 homes destroyed, and more than 16,000 homes damaged. In total, the impacts resulted in more than $100 million in damages and the loss of freshwater supply in Asheville for several days due to a break in the water main from storm-induced erosion.

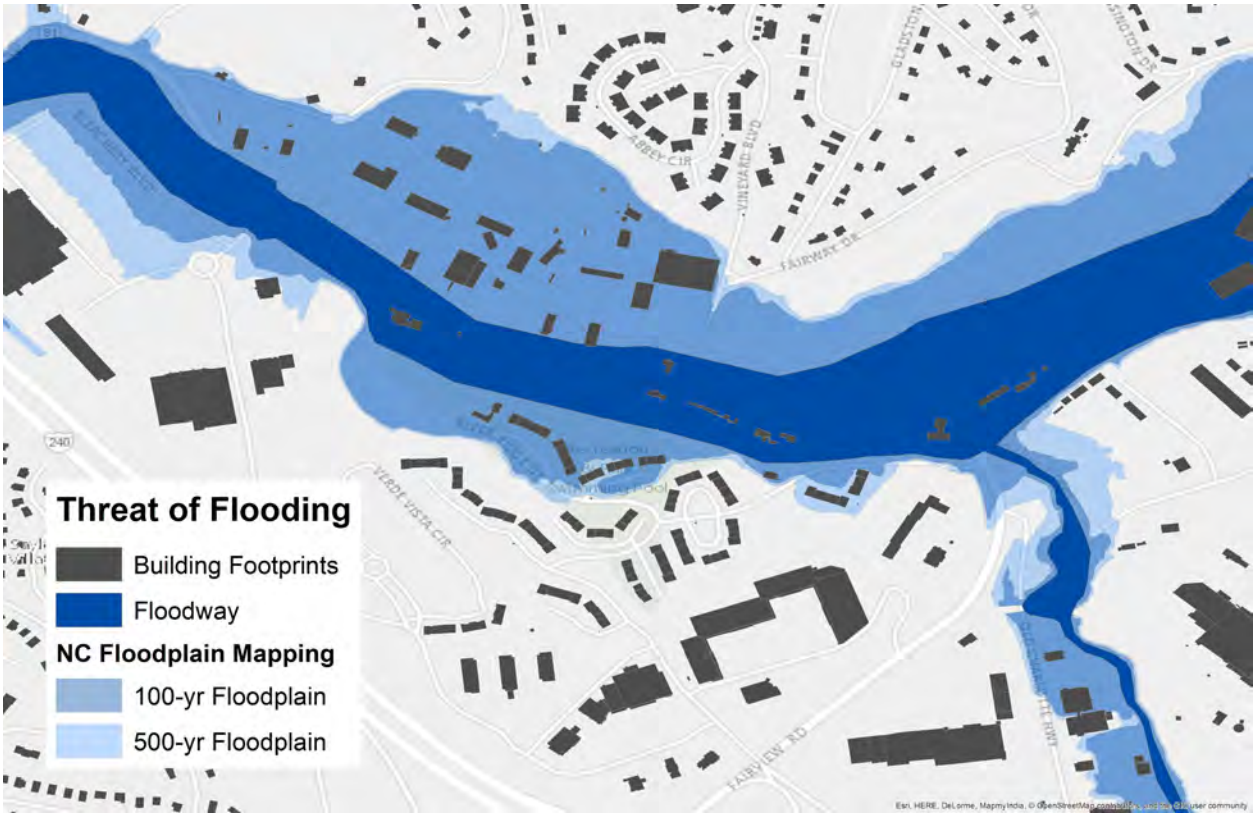
Severe storms are not unusual in Western North Carolina. In Asheville alone, several floods have occurred in the past 100 years, with two of the most serious in 1916 and 2004. The 1916 flood is estimated to have been an even more severe flooding event than the one in 2004. While the most severe flooding occurred in different areas, the 1916 storm was estimated to be a 500-year flooding event on the French Broad River, whereas the 2004 flood was estimated to be a 75-year flood event on the Swannanoa River.

These past events show how future storms and flooding events in Asheville have the potential to damage property and infrastructure and to threaten human safety. With the trend of increasing extreme precipitation events and with more development and impervious surfaces, Asheville can expect to see the potential for more flooding events in the future.

For purposes of this assessment, the threat of flooding was defined by the flood hazard areas as determined by the 2010 North Carolina Floodplain Mapping Program (NCFMP).[10] The figure on the next page shows the floodway, 100-year floodplain, and 500-year floodplain from the NCFMP for a section of the Swannanoa River in Asheville. Assets within any of these flood hazard zones were determined as being exposed to flooding. The different flood hazards zones were also used to determine different levels of risk: floodway (high), 100-year floodplain (medium), and 500-year floodplain (low). For more information, see the Assessment Framework and Methodology section under Step Two | Potential Impact, Vulnerability, and Risk Assessments.



The graphs show the annual number of action stage and flood events for two USGS stream gage locations in Asheville. Flood categories are used to describe severity of flooding and are determined for each gage location. Action stage is the level at which it is recommended that the National Weather Service or partner should prepare for hydrologic activity. Flood stage is the level at which waters begin to impact lives, property, and commerce. Moderate flooding is the level at which some structures or roads are inundated. Major flooding is the level at which extensive inundation of structures or roads occurs. (Figure source: NEMAC, data from USGS.)



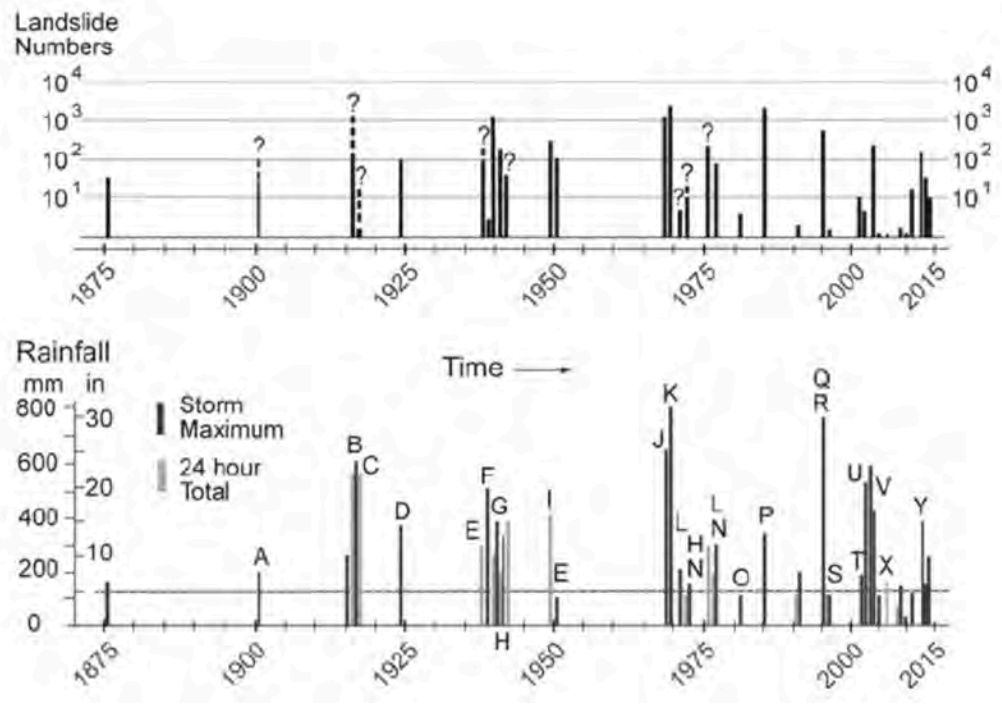
The map shows the flood hazard areas used to evaluate the threat of flooding. The map shows building structures along a section of the Swannanoa River corridor, some of which are in flood hazard zones. (Figure source: NEMAC.)

Landslides

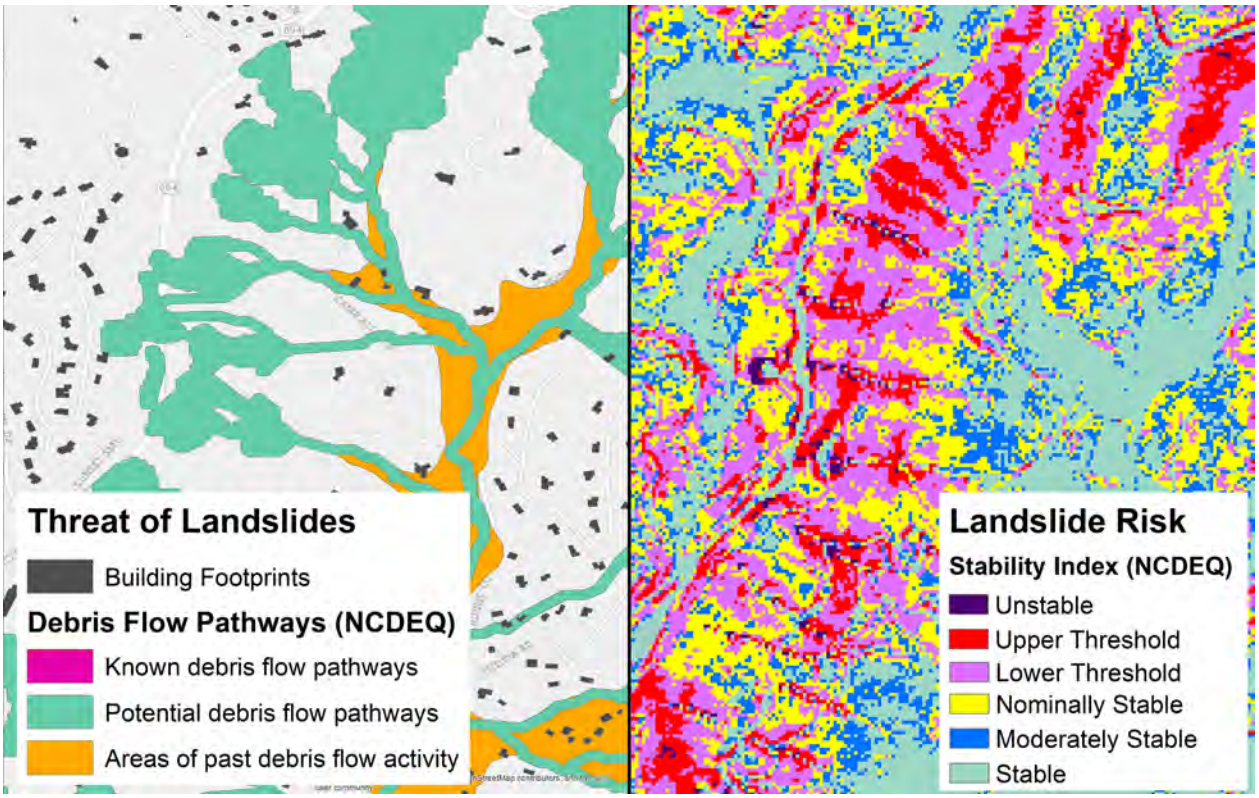
Landslides in Western North Carolina are, like flooding, associated with climate stressors related to the amount and timing of precipitation. The primary non-climate stressors contributing to the threat of landslides are development and the removal of vegetation on steep slopes.

Landslide events include debris flows, rock slides, mudslides, earth slides, and movements.[11] Most of the loss of life associated with the 2004 events was attributed to landslides that occurred throughout Western North Carolina. Research by scientists and North Carolina state geologists have explored how landslide events in Western North Carolina are often associated with certain thresholds of extreme precipitation. For example, it is estimated that four rainfall events in 2013 resulted in at least 300 landslide events in the region.[12] The chart below shows the rainfall amounts for selected storms that triggered landslides, mainly debris flows, in Western North Carolina from 1876 through 2013.

For purposes of this assessment, the threat of landslides was defined by potential debris flow areas as determined by the North Carolina Department of Environmental Quality (NCDEQ).[13] The figure on the following page shows the potential debris flow pathways for an area just east of Town Mountain Road in Asheville. Assets within any of these potential debris flow pathways were determined as being exposed to landslides. The NCDEQ Slope Stability Index was also used to determine different levels of risk: unstable and upper threshold (high), lower threshold (medium), and nominally stable, moderately stable, and stable (low). For more information, see the Assessment Framework and Methodology section under Step Two | Potential Impact, Vulnerability, and Risk Assessments.



The graphs show the association between amount of rainfall (bottom) and landslide numbers (top). Heavy rainfall events, especially those with at least 5-inch 24-hour totals, are associated with spikes in the number of landslide events. (Figure source: Wooten et al. 2016.)



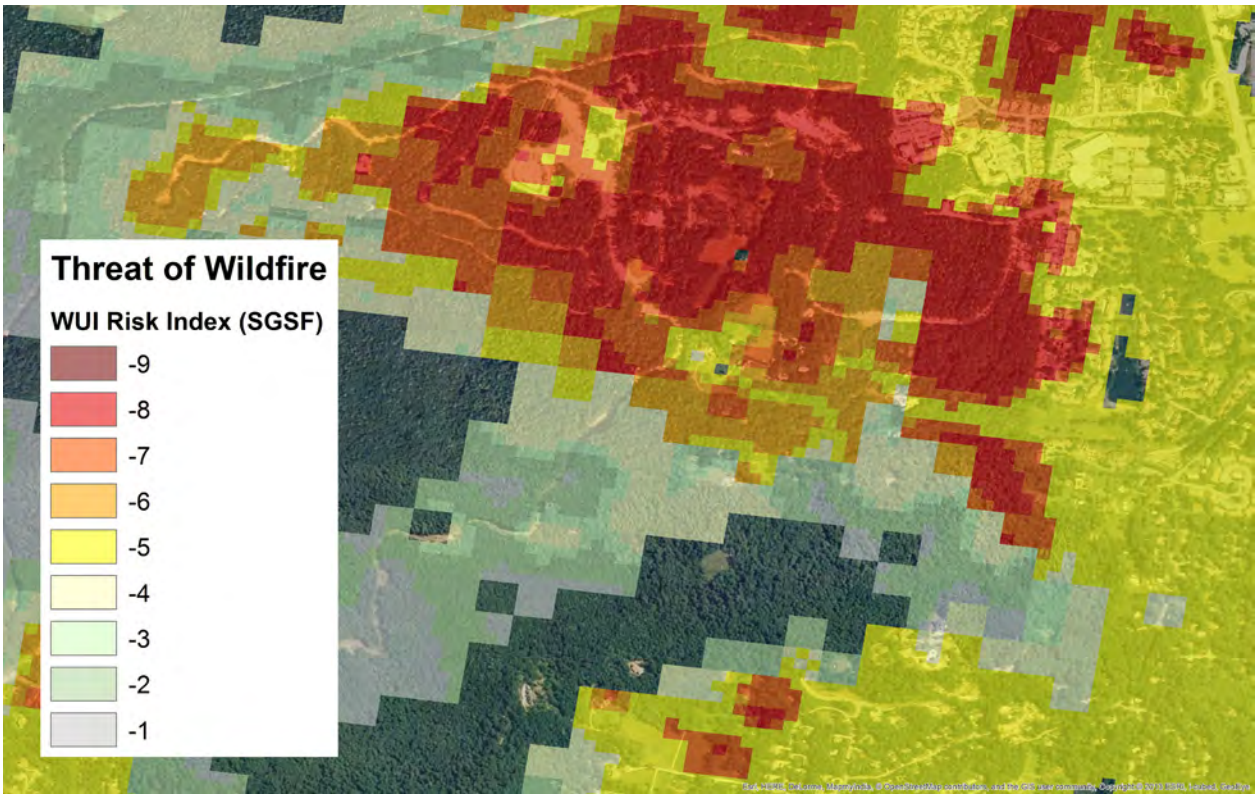
For the area of Chunns Cove, the map shows the potential debris flow pathways (left) and stability index map (right) used to evaluate the threat and risk of landslides. Any assets within the potential debris flow pathways were determined as being exposed to the threat of landslides. For example, the map at left shows building structures just east of Town Mountain Road in Asheville, some of which are in potential debris flow pathways. The stability index was used for determining different levels of risk (probability of landslides). (Figure source: NEMAC.)

Wildfire

Wildfire is a natural disturbance that provides benefits to ecosystems and natural systems, but it can become a threat when it negatively impacts communities and the assets we value. Drought conditions can lead to a greater chance of wildfire.

The primary non-climate stressor related to the threat of wildfire is the management of fuels and vegetation. Lack of active fuel management can contribute to a decline in fire-resilient ecosystems, an increase in wildfire burn severity, and increased risk of destructive wildfires that damage landscapes and threaten people and communities.

The threat of wildfire was defined by using the Wildland Urban INterface (WUI) Risk Index from the the Southern Group of State Foresters (SGSF).[14] The figure on the following page shows the WUI Risk Index for an area in south Asheville. Assets within any WUI area were determined as being exposed to the threat of wildfire. The SGSF burn probability was also used to determine different levels of risk to wildfire: values -9 (high), values between -6 and -8 (medium), and values between -1 and -5 (low). For more information, see the Assessment Framework and Methodology section under Step Two | Potential Impact, Vulnerability, and Risk Assessments.



The map shows the WUI Risk Index, which was used to evaluate the threat and risk of wildfire. Any assets within WUI areas were determined as being exposed to the threat of wildfire. (Figure source: NEMAC, data from the Southern Group of State Foresters.)

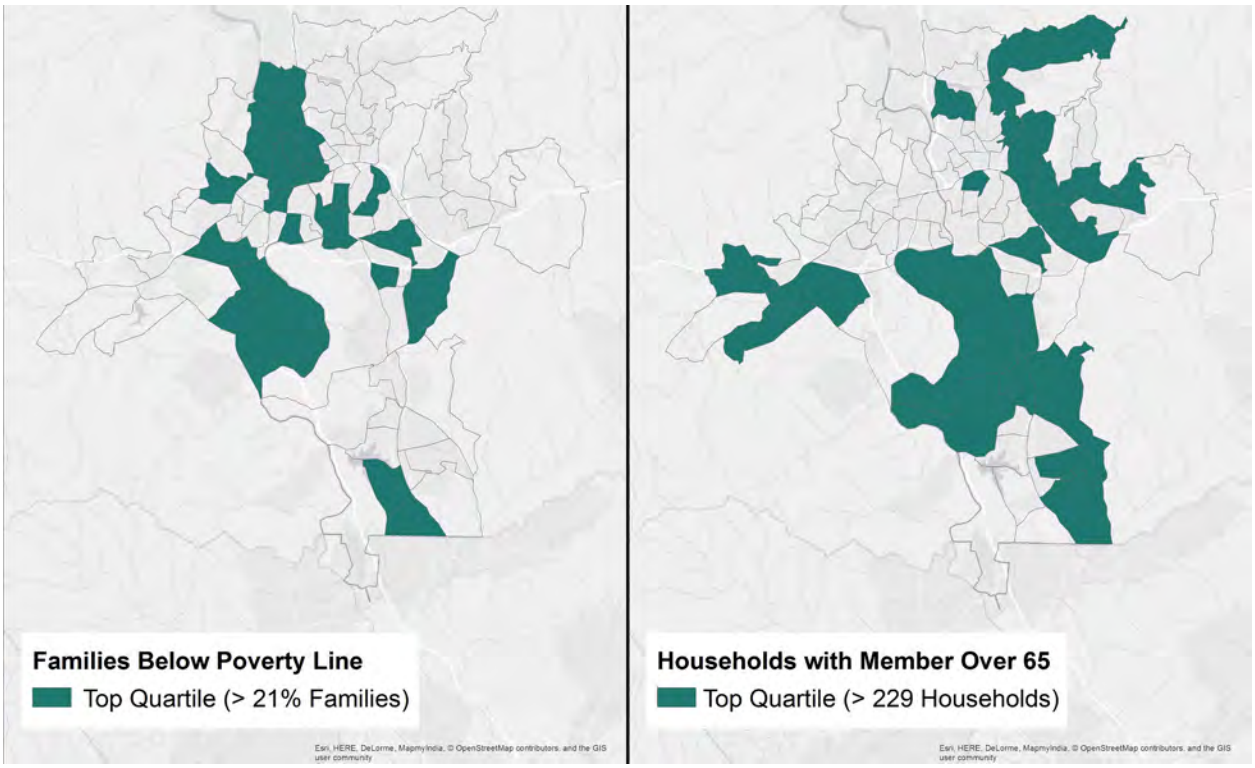
Water Shortage

The threat of water shortage is due to drought, or the lack of precipitation. Water shortages can impact the municipal water supply and cause stress to agricultural and natural systems, resulting in crop or tree mortality.

Since water shortage is not confined to specific areas, all areas within the city were determined to be exposed and potentially affected. Instead of using hazard areas, exposure to the threat of water shortage was evaluated by considering the assets that use or rely on the supply and availability of water.

Nuisance Flooding, Runoff, and Erosion

The threat of nuisance flooding (urban flooding), runoff, and erosion includes events caused by extreme or heavy precipitation that results in minor flooding or erosion from runoff, which is different from the threat of major riverine flooding.[1] NOAA defines nuisance flooding as events that overwhelm stormwater infrastructure and result in inconveniences, such as road closures and damage to infrastructure.[15] Nuisance flooding is often associated with coastal tidal flooding, but this assessment uses the nuisance flooding terminology to describe the minor flooding, runoff, and erosion that can occur after heavy precipitation. These events are usually less severe than major flooding, but can still cause significant impacts. Asheville has experienced more nuisance flooding and erosion-related issues in recent years after heavy precipitation events. This threat is also greatly influenced by the amount of development and impervious surfaces that contribute to runoff.



These maps show two socioeconomic metrics from the U.S. Census Bureau that were used in determining populations that are sensitive to extreme heat events. (Figure source: NEMAC.)

Due to the mountainous terrain and topography of the Asheville area, the threat of nuisance flooding, runoff, and erosion potentially affects all areas of the city.

Extreme Heat

Extreme heat events are periods of excessively hot and/or humid weather that can last for multiple days. This is the only threat with which Asheville has had little experience in the past.

For purposes of this assessment, sensitive populations—families below the poverty line and households with members over 65 years of age—were determined as being more sensitive to heat events.

Multiple Supply Chain Threats

Supply chains are the systems and infrastructure that support the transport of goods and services to the Asheville area. For example, Asheville is very dependent on supply chains for its energy production, fuel, and access to food. Supply chain infrastructure includes the energy pipelines and transportation networks, such as roads and railroads.

Multiple stressors and threats can result in supply chain interruptions, including tropical storm impacts to the Gulf of Mexico and coastal areas and landslide and flooding events that can interrupt transportation.

For the purposes of this assessment, supply chain threats were defined by events that can interrupt petroleum and natural gas pipelines, as well as road, highway, and rail infrastructure

leading into Asheville. These events include tropical storms affecting the Gulf Coast, and landslides and flooding events affecting the region.

Community Assets

Community assets were identified by considering the people, resources, and infrastructure in the City of Asheville, as well as the services those resources and infrastructure provide. Assets were considered that are both internal and external to the city's purview of operations. A total of 14 types of assets were identified by the project team, and are set forth below.

Bridges

This includes all bridge structures—but not culverts—carrying a road, including arterial, collector, and local road classes. Some bridges also serve as the single point of critical access to residential and other properties. There are a total of 181 bridges in the City of Asheville, which includes bridges owned and maintained by the state and by the City of Asheville.

City-Owned Facilities

This includes all city-owned facilities except for those associated with parks and recreation. City departments associated with city-owned facilities include public works, water resources, economic development, transportation and parking, and administration, to name a few. A total of 325 facilities were identified in this category.

Commercial Property

Commercial properties are non-residential properties that serve businesses and organizations. They also typically support commerce, jobs, and tourism. Citywide, there are a total of about 3,400 commercial properties.

Critical Infrastructure

Critical infrastructure includes facilities that deliver key services but are not city-owned, such as hospitals, utilities, some schools, and waste facilities. A total of 173 critical infrastructure properties were identified in the city.

Energy Supply Chain

Energy supply chains include energy supply, both for electrical power generation and for mobility. Most local energy needs come from the supply chains for gasoline, coal, and natural gas. These energy supplies must come from locations outside the city. Gasoline is delivered by tanker truck, coal for electrical generation by train, and natural gas is delivered by a single pipeline.

Food Infrastructure

Food infrastructure is defined for purposes of this assessment as food processing/distribution centers (such as the MANNA FoodBank) and locations where people access food (including

grocery stores, SNAP businesses, MANNA partner agencies and other food pantries, and restaurants). In the City of Asheville, there are a total of 387 food locations and 14 food distribution centers.

Industrial Property

Industrial properties include small businesses, factories, and companies that manufacture goods or materials. They are significant locations for local employment and often include distribution centers, which distribute goods to stores or directly to customers. Industrial properties and companies also serve as important sites of raw materials, such as gravel and concrete, for the city and support the local construction sector. There are 91 industrial properties citywide.

Natural Areas for Habitat and Conservation

This asset includes existing natural areas of conservation value. These areas were defined using North Carolina's Biodiversity/Wildlife Habitat Assessment,[16] which prioritizes aquatic and terrestrial habitat, landscape function, and connectivity. The assessment focuses on (1) the biodiversity of aquatic and terrestrial species and communities, (2) large-scale landscapes, including core wildlife habitats and habitat connectors, and (3) lands important to ecosystem processes, such as riparian buffers and wetlands. This asset does not include areas of low habitat quality that may have potential for land restoration. For the Asheville area, there are about 19,000 acres of natural land with conservation value, which makes up about 26 percent of the city area.

Parks and Recreation

Parks and recreation assets include all city parks and community centers. Some parks also serve as special facilities, such as for use by emergency services during an emergency event. There are about 153 city parks and recreation properties.

Residential Property

Residential properties include all single-family residences, multiple-family residences, low-income housing, apartments, manufactured houses, and mobile home parks. There are nearly 42,000 residential properties in the City of Asheville.

Residents

Residents include all people within the census block group area of the city, including sensitive populations. In the City of Asheville census block group area, there is a total population of about 123,000, which includes approximately 28,000 families and 53,000 households.

Roads

Roads include all major and secondary roads and considers the critical access they provide for emergency services. Roads were considered in two ways: (1) the road infrastructure potentially inundated and exposed to damage; and (2) the general number of parcels that could be

inaccessible by fire/emergency medical services. There are about 1,200 miles of roads in the Asheville area.

Transit and Greenways

Transit includes all city bus routes, and greenways include all existing and proposed greenways from Buncombe County's Greenway Master Plan. Together, these make up some of the multi-modal transportation assets of the city. There are 17 bus routes and 144 greenway segments in the city.

Water Supply

Water supply for the City of Asheville is provided by three intake points: North Fork Reservoir, Bee Tree Reservoir, and the Mills Gap intake on the French Broad River. The North Fork Reservoir provides about 70 percent of Asheville's water supply.

Exposure and Asset/Threat Pairs

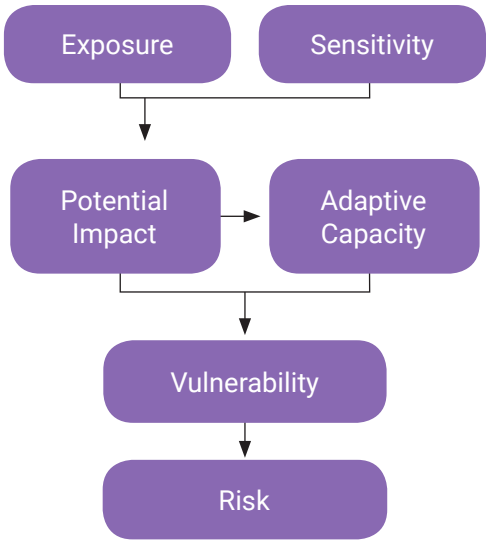
Once the climate threats and assets had been identified, the project team evaluated each identified asset to determine whether or not it is exposed to an identified climate threat. Exposure is the presence of assets in relation to a threat (assets that are in harm's way). This exposure determination was made based on the team's institutional knowledge and past historical events, and on exposure analysis of the available hazard information. Each unique combination of an asset and the threats to which it is exposed is referred to as an "asset/threat pair."

		Threats					
	Assets for analysis	Flooding	Landslides	Wildfire	Nuisance flooding	Water shortage	Extreme heat
1	Bridges	X					
2	City-owned facilities	X	X				
3	Commercial properties	X	X				
4	Critical infrastructure	X	X				
5	Food infrastructure	X					
6	Industrial properties	X	X				
7	Natural areas for habitat and conservation			X		X	
8	Parks and recreation	X					
9	Residential properties	X	X	X			
10	Residents/people				X		X
11	Roads	X	X				
12	Supply chains	X	X				
13	Transit and greenways	X					
14	Water supply/North Fork Dam					X	

Step Two | Potential Impact, Vulnerability, and Risk Assessments

Assessment Framework and Methodology

The project team applied an assessment framework to each asset/threat pair identified in Step One. Each asset/threat pair was evaluated separately, even though some hazards may be interrelated (e.g., drought and wildfire).



The flowchart at right shows each of the framework's core concepts and how they come together to help us understand potential impact, vulnerability, and risk. Each of these core concepts was explored in detail during the workshops and working sessions for Step Two.

Assessment Components

For most asset/threat pairs, the assessment framework was applied at the asset unit level. For example, residential and commercial properties were assessed at the parcel level, bridges were assessed at the bridge level, water supply was assessed at the water source level, and so on.

These core concepts were applied using a data-driven technique that involved multi-criteria decision analysis as well as spatial analysis.[17] This involved developing criteria, or rules, that were used to assign assets into ordinal classifications of "high," "medium," and "low." These rules were developed based on factors consistent with the framework concepts, and classifications were assigned using data attributes and spatial analysis. The classifications were then combined using a matrix approach to determine levels of vulnerability and risk.[18] The asset-level assessment resulted in levels of potential impact, vulnerability, or risk that are relative to each asset/threat assessment, although similar criteria were often applied across assessments. A discussion of how the concepts were applied at the asset level can be found in the following sections, along with the assessment summaries and assessment criteria descriptions.

Potential Impact

Potential impact is the degree to which an exposed asset (asset that is in harm's way) is potentially negatively affected by a climate-related threat. The level at which an exposed asset is negatively affected is also referred to as the asset's sensitivity. Assets that are not

exposed have no potential impact; thus, they are not vulnerable, or at-risk. Exposed assets were evaluated for levels of sensitivity, which were used in determining levels of potential impact.

Factors used to determine levels of potential impact were based on the asset's characteristics or on the level of impact due to service loss if the asset were to be affected.[19] For example, if inundation from flooding was the event, a property with a building structure in a flood hazard area has a higher potential impact than does a property that does not have a building in a flood hazard area. As another example, the inundation of a major road leads to a greater potential impact than the inundation of a minor secondary road.

Adaptive Capacity

Adaptive capacity considers how an asset is able to cope with a threat event or impact. An asset with adaptive capacity is able to withstand an impact with minimal disruption or loss. Measures of adaptive capacity can include physical elements, conditions, or designs in place that help an asset absorb an impact. Social factors also contribute to a community's ability to cope with loss from an event.

For example, a commercial building that has flood-proofed its foundation and raised its ground floor above flood levels has more adaptive capacity than a commercial building that has not done so. As another example, a park with facilities designed to withstand flood waters without damaging its infrastructure has adaptive capacity.

Vulnerability

Vulnerability describes the susceptibility of exposed assets based on the two core concepts described above: (1) *potential impact*—the degree to which an asset is affected; and (2) *adaptive capacity*—the ability the asset has to cope with a potential impact. Vulnerability, and its core concepts, can also be expressed as:

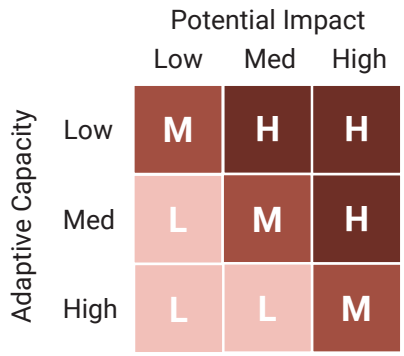
Vulnerability = (Potential Impact) – Adaptive Capacity

In this expression, vulnerability of an asset is the function of a potential impact (an asset's exposure and sensitivity to a hazard), which is offset by the asset's adaptive capacity. The table below shows example criteria used for determining levels of potential impact and adaptive capacity for commercial properties exposed to flooding. Levels of potential impact are based on the type of commercial building and whether the structure is potentially impacted. Therefore, this example assumes that a business-related structure in the floodplain should be assigned a "high" level of potential impact, whereas if only land (but no building) is in the floodplain, it would be considered a "low" potential impact. Levels of adaptive capacity are based on years associated with different building requirements for base height and flood-proofing; more recent years required more restrictive development requirements. For example, an asset is considered "low" adaptive capacity if it was built before 1980 and therefore not considered in more recent flood ordinances.

Level of classification	Vulnerability Assessment Component	
	Potential Impact	Adaptive Capacity
High	Structure in floodplain and business-related	Out of floodplain or built after 2010
Medium	Structure in floodplain and warehouse or storage	Built between 1981–2010
Low	No structure in floodplain (land only)	Built before 1980

The figure below is a matrix showing how these levels of potential impact and adaptive capacity were combined to determine three levels of vulnerability. Assets with high potential impact and low adaptive capacity are the most vulnerable. Assets with low potential impact and high adaptive capacity are the least vulnerable. For this assessment, only three levels were used for classifying vulnerability.

People's vulnerability to natural hazards and climate threats is primarily determined by social factors and existing socioeconomic vulnerabilities. Socially vulnerable populations are disproportionately affected by natural hazard events because they often are in closer proximity to the hazards, have fewer options for evacuating or otherwise moving out of harm's way before or during an event, and are less able to cope with or absorb financial loss following an event.[20] Several social vulnerability factors were incorporated into the analysis in assessing vulnerability, including household income, families living below the poverty line, unemployment, families participating in the Supplemental Nutritional Assistance Program, and reliance on public transportation. For this assessment, social vulnerability factors were considered at the census block group level.



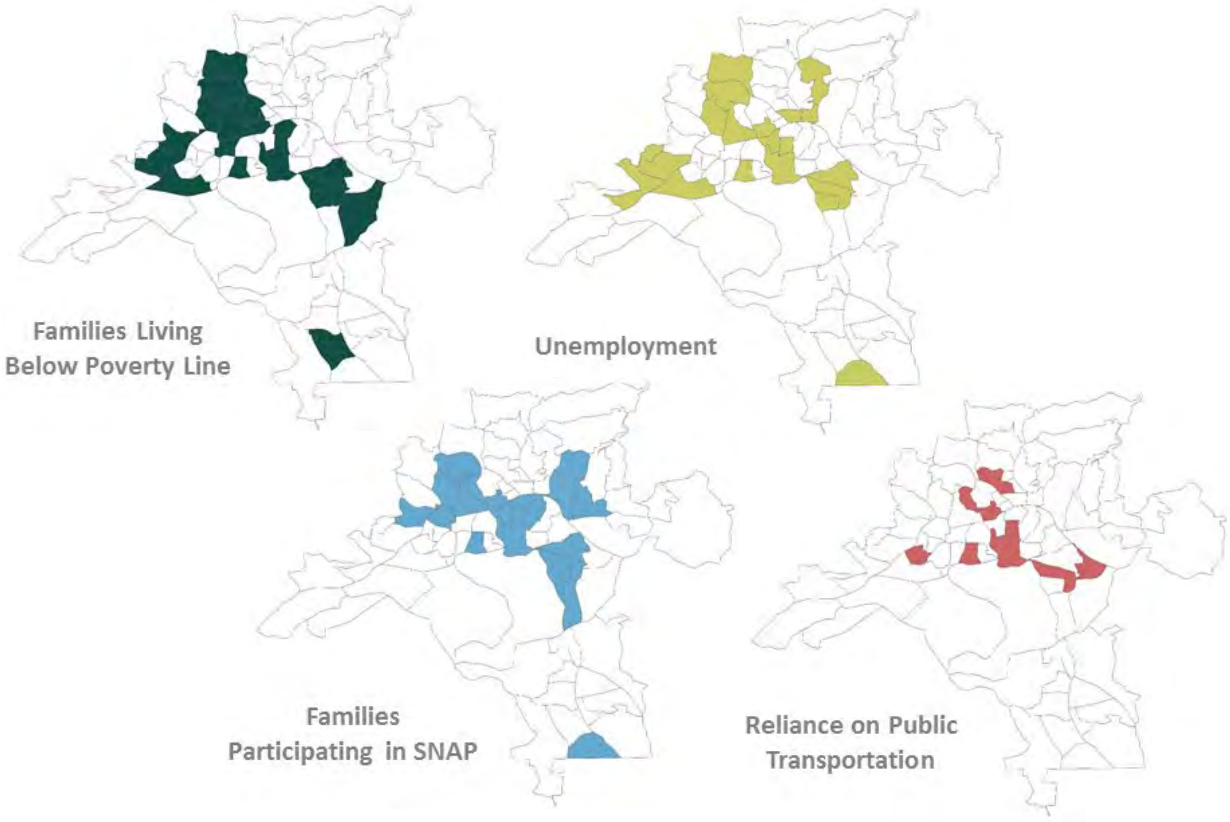
A vulnerability matrix is used to illustrate how levels of potential impact and adaptive capacity were combined to determine three levels of vulnerability, as indicated by the colors in the matrix.

Risk

Risk criteria were defined by both the probability and the consequence of a threat occurring. Probabilities were determined for each threat using annualized likelihoods of threat occurrence or relative levels based on known risk factors. For example, different flood hazard zones, such as the floodway, 100-yr, and 500-yr floodplains, were used to evaluate different probabilities for the threat of flooding. Therefore, an asset in the 100-yr floodplain has a great risk probability than an asset in the 500-yr floodplain. Risk consequence refers to negative outcomes or critical thresholds that indicate varying levels of significance if a threat were to occur. For example, assets with structures affected, or that have greater monetary value may have a greater consequence than assets with no structures affected, or that have lower monetary value. Risk, and its core concepts, can also be expressed as:

Risk = Probability x Consequence

Socioeconomic vulnerability Highlighting Census Block Groups in the Top Quartile



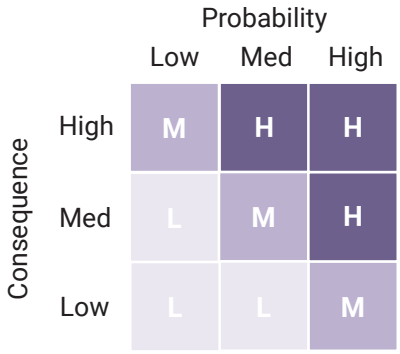
These maps show a few of the metrics from the U.S. Census Bureau that were used in considering socioeconomic vulnerability. Each map highlights the census block groups in the top quartile for each metric. (Figure source: NEMAC.)

It is important to note that this step was referred to as risk scoping, as no loss estimates were quantified. The criteria used for asset-level assessment of risk to each threat are illustrated in the table below.

	Risk Criteria	
Threat	Levels of Probability	Levels of Consequence
Flooding	**High:** Floodway **Medium:** 100-yr Floodplain **Low:** 500-yr Floodplain	**High:** Building structure affected/above median value **Medium:** Building structure affected/ below median value **Low:** No building structure affected
Landslides	**High:** Unstable and Upper Threshold **Medium:** Lower Threshold **Low:** Moderately Stable, Nominally Stable, and Stable	
Wildfire	**High:** Greater than 55% Burn Probability **Medium:** 33% to 55% Burn Probability **Low:** Less than 33% Burn Probability	

This table shows the information each type of assessment provides.

These levels of probability and consequence were then combined using a risk-matrix approach. The figure at right shows how the levels of probability and consequence combine to form levels of risk.



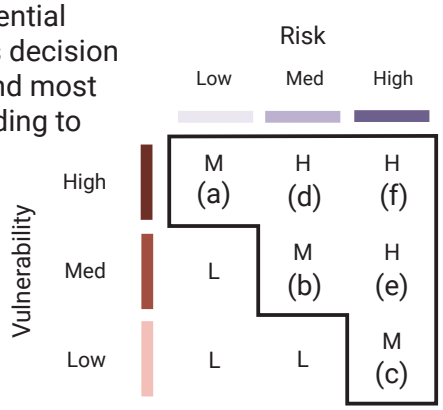
The matrix illustrates how the levels of probability and consequence were combined to determine levels of risk, as indicated by the colors in the matrix.

Combining Potential Impact, Vulnerability, and Risk

Each component of the assessment framework considers a different aspect of how assets might be affected by a climate threat. Potential impact only considers the degree to which an asset is impacted. Vulnerability considers how an asset might be impacted and its ability to cope if the threat event were to occur, and risk considers the probability, or likelihood, of the threat occurring and the general consequence of the threat (without considering factors that make it susceptible).

For this assessment, risk was usually combined with potential impact or vulnerability. Combining these concepts allows decision makers to evaluate which assets are most susceptible and most likely to be impacted, and also to consider options according to different levels of risk threshold. It also provides the ability to consider high impact/low probability events, or assets that are highly vulnerable but at low risk.

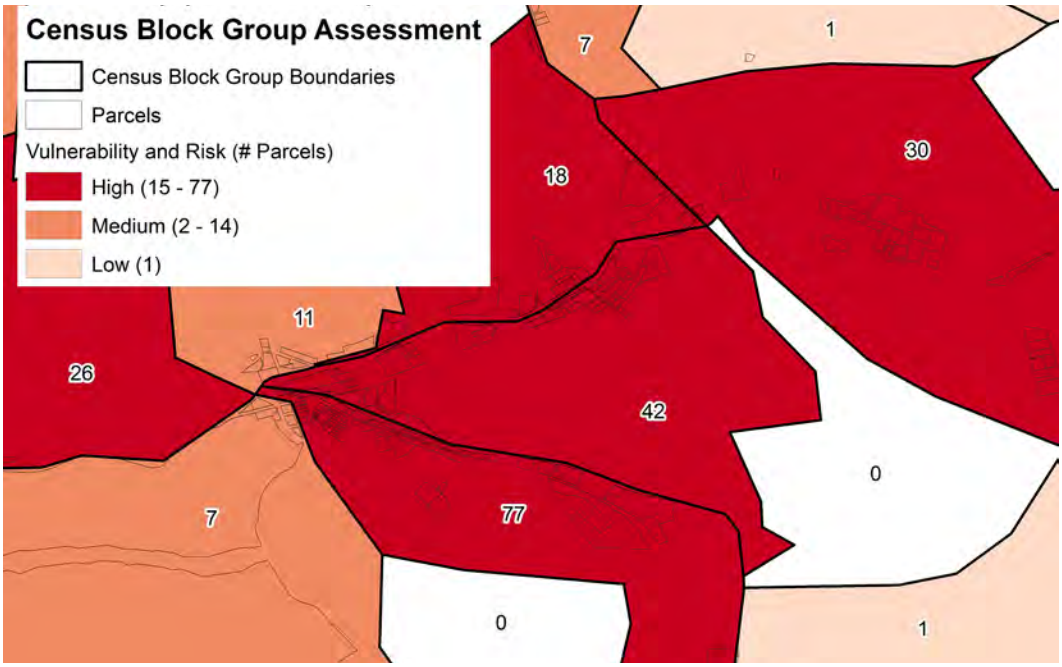
The combination of these concepts yields a third and final matrix. The figure at right illustrates the combined vulnerability and risk for an asset/threat pair. This matrix is accompanied by the number of assets (parcels in this case) for each vulnerability and risk combination: (a) high vulnerability and low risk; (b) medium vulnerability and medium risk; (c) low vulnerability and high risk; (d) high vulnerability and medium risk; (e) medium vulnerability and high risk; and (f) high vulnerability and high risk. Assets in the "f" category have the most susceptibility and the highest likelihood of being impacted, whereas parcels in the "a" category are also the most susceptible but have the lowest likelihood of being impacted. Assets with medium to high combined vulnerability and risk were identified in order to focus on those assets with the greatest amount of vulnerability and risk. This is illustrated in the figure at right: the categories within the solid black outline are those with medium to high combined vulnerability and risk. Assets that fell within these medium to high categories were then mapped at the census block group level, and were focused on for options to build resilience.



Final matrix showing an example of combining the concepts of vulnerability and risk. The black line highlights the medium to high combined vulnerability and risk categories that were focused on in the assessment; the numbers indicate the number of parcels citywide that fall into each category.

Census Block Group Level Summary

The resulting combination of potential impact, vulnerability, and risk that were assessed at the asset level were then expressed as maps at the census block scale. The number of assets



The map provides an example census block group-level assessment of vulnerability and risk, determined by the number of parcels with medium to high levels of vulnerability and risk located within the block groups.

with a medium to high potential impact or combined vulnerability and risk (depending on the assessment type) were quantified for every census block group.

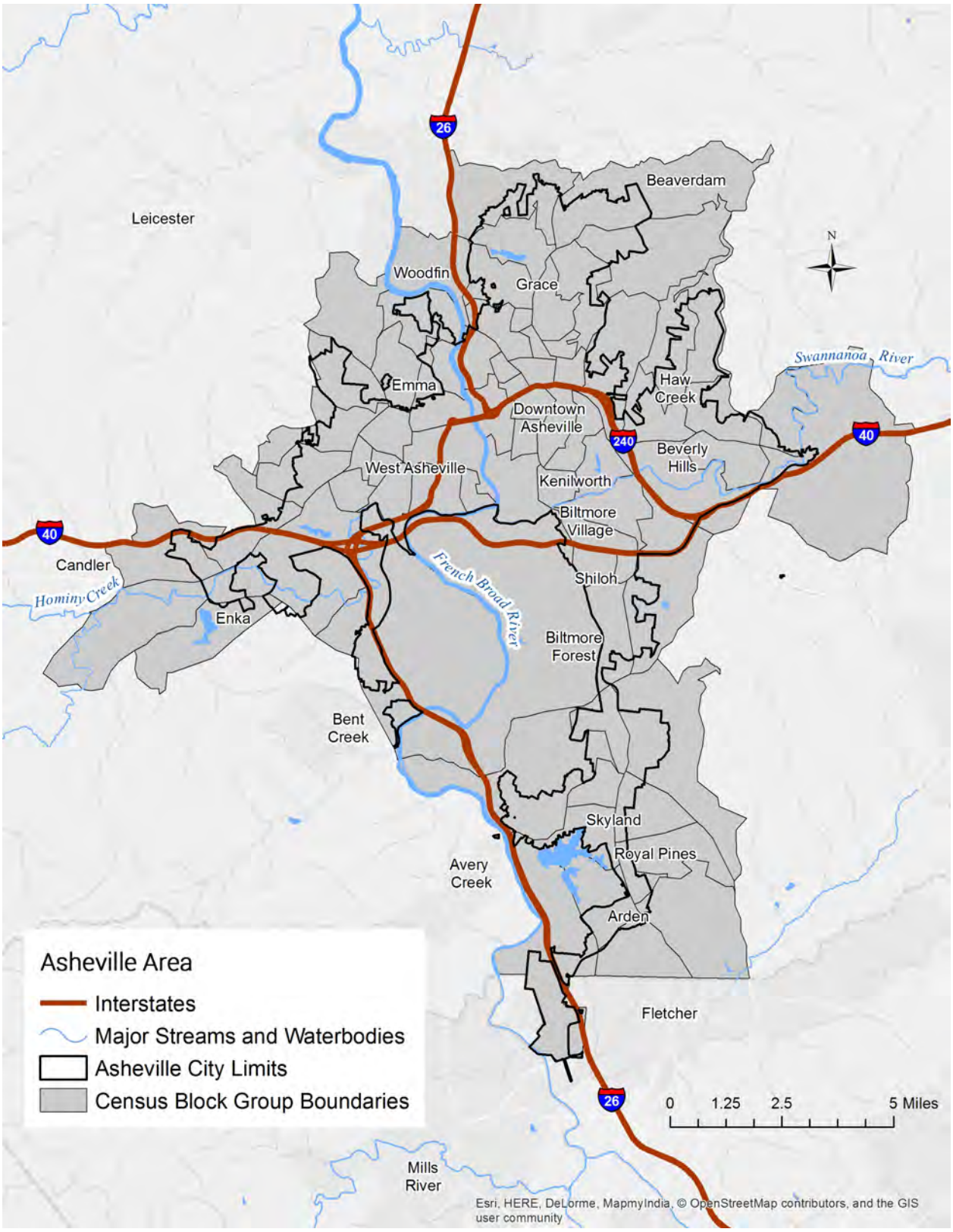
Census block groups were then classified, based on the number of quantified assets located within them, into levels of high, medium, and low. Census block groups in the upper quartile were classified as high, block groups in the interquartile (between lower and upper quartiles) were classified as medium, and block groups in the lower quartile were classified as low.

The figure below shows an example of how the census block group-level classification was determined based on the number of assets with medium to high combined vulnerability and risk.

Assessment Result Summaries

It is important to remember that the purpose of assessing assets and threats is to provide a foundation of information for building resilience. Different types of assessments were conducted based on available information and resources, but also based on the level of detail needed for identifying resilience-building options. Each type of assessment is made up of different components, each of which provides (or informs) insight about how an asset might be affected by a climate threat. For some assets, a potential impact assessment was sufficient, while others required the full complement of assessment components. The table below lists each assessment type conducted in this planning process, as well as their constituent components. The vulnerability and risk assessment type has the most components, which includes an understanding of potential impact, adaptive capacity, probability and consequence.

For example, bridges were assessed using only the potential impact assessment type because it was decided that the different probability (likelihood) levels were less important to distinguish and it was unclear what metrics could be used to evaluate the asset's ability to cope with the information that was available.


Leicester
Beaverdam
Woodfin
Grace
Emma
Haw Creek
Swannanoa River
Downtown Asheville
Beverly Hills
West Asheville
Kenilworth
Biltmore Village
Candler
Hominy Creek
Enka
French Broad River
Shiloh
Biltmore Forest
Bent Creek
Skyland
Royal Pines
Avery Creek
Arden
Fletcher
Mills River
N
26
240
40
Asheville Area
Interstates
Major Streams and Waterbodies
Asheville City Limits
Census Block Group Boundaries
0 1.25 2.5 5 Miles
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Assessment Type	Degree to which the asset is potentially affected (impacted)	Ability of asset to cope with potential impact	Probability (likelihood) of threat occurring and its consequence
Potential Impact	X		
Potential Impact & Risk	X		X
Vulnerability	X	X	
Vulnerability & Risk	X	X	X

The table below shows each asset/threat pair assessment along with its assessment type, assessment unit/scale, the total number of assets exposed to the threat (with the percentage of that asset citywide), and the total number of assets in the medium to high categories of the assessment (with the percentage of that asset in the medium to high categories citywide).

Asset	Assessment Type	Assessment Unit/Scale	Exposure (% Citywide)	Med-High (% Citywide)
Flooding				
Bridges	Potential Impact	Bridges	38 (21%)	20 (11.1%)
City-Owned Facilities	Potential Impact & Risk	Parcels	26 (8%)	18 (5.5%)
Commercial Properties	Vulnerability & Risk	Parcels	600 (17.4%)	450 (13.1%)
Critical Infrastructure	Vulnerability & Risk	Parcels	26 (15%)	6 (3.5%)
Food Infrastructure				
Distribution	Vulnerability & Risk	Parcels	6 (42.9%)	3 (21.4%)
Food Locations	Vulnerability & Risk	Parcels	65 (16.8%)	48 (12.4%)
Industrial Properties	Vulnerability & Risk	Parcels	24 (26.4%)	16 (17.6%)
Parks and Recreation	Vulnerability & Risk	Parcels	30 (19.6%)	8 (5.2%)
Residential Properties	Vulnerability & Risk	Parcels	1,550 (3.7%)	572 (1.4%)
Roads				
Infrastructure	Potential Impact	Road miles	63 (5.4%)	N/A
Critical Access	Potential Impact	Parcels	6,200 (14.8%)	N/A
Transit				
Bus Routes	Potential Impact	Routes	14 (82%)	N/A
Greenways	Potential Impact	Segments	85 (59%)	N/A
Water Supply/North Fork Dam	Vulnerability & Risk	Water Sources	1 (70%)	N/A
Landslides				
City-Owned Facilities	Potential Impact & Risk	Parcels	43 (13.9%)	31 (10%)

Asset	Assessment Type	Assessment Unit/Scale	Exposure (% Citywide)	Med-High (% Citywide)
Landslides				
Commercial Properties	Vulnerability & Risk	Parcels	563 (16%)	377 (10.7%)
Critical Infrastructure	Vulnerability & Risk	Parcels	36 (21%)	17 (9.9%)
Industrial Properties	Vulnerability & Risk	Parcels	34 (37%)	27 (29.3%)
Residential Properties	Vulnerability & Risk	Parcels	3,447 (8.2%)	1,831 (4.3%)
Roads				
Infrastructure	Potential Impact	Road miles	83 (7.1%)	N/A
Critical Access	Potential Impact	Parcels	8,700 (20.8%)	N/A
Wildfire				
Natural Areas for Habitat and Conservation	Vulnerability	Acres	71,400 (100%)	15,700 (22%)
Residential Properties	Vulnerability & Risk	Parcels	38,356 (91%)	4,795 (11%)
Water Shortage Due to Drought				
Natural Areas for Habitat and Conservation	Vulnerability	Acres	71,400 (100%)	19,000 (27%)
Water Supply	Vulnerability & Risk	Water Sources	3 (100%)	1 (33%)
Nuisance Flooding, Runoff, Erosion				
Residents/People	Vulnerability & Risk	People		
Extreme Heat				
Residents/People	Vulnerability	Families Over 65	3,308 (11.9%) 14,510 (27.4%)	
Supply Chain Threats				
Supply Chains (Energy/Fuel Supply)	Vulnerability & Risk	Supply		

Included on the following pages for each asset/threat pair are the top five areas within the city with medium-high combined vulnerability and risk. Accompanying each map is information about the threat, the community asset, and statistics indicating the number of parcels and the percentage of assets citywide that are exposed. These maps of vulnerability and risk were utilized by the project team as a foundation to develop actionable options, which are outlined in the next section of this report.

Asset/Threat Pair

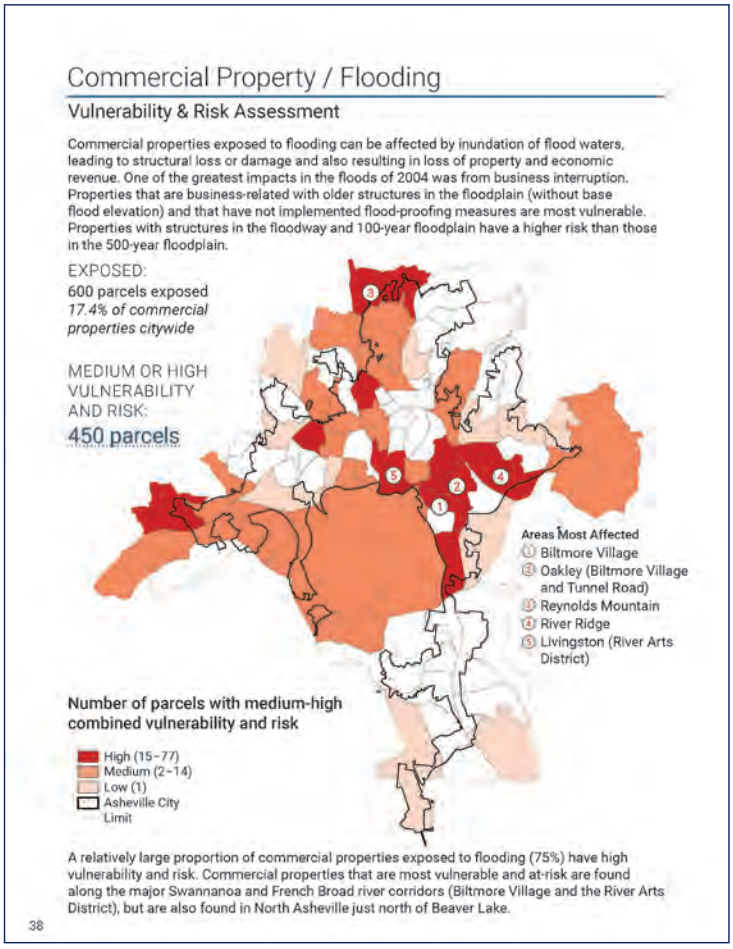
Exposure

Number and percentage of assets exposed citywide (in harm's way) to the threat

Assets with the most potential impact, vulnerability, or risk

Number of assets citywide with medium or high potential impact, vulnerability, or combined vulnerability and risk

Map showing the number of assets within each Census Block Group that have medium or high potential impact, vulnerability, or combined vulnerability and risk



Neighborhood Areas Potentially Most Affected

Neighborhood areas (based on Census Block Group boundaries) with the highest number of assets that are most potentially impacted, vulnerable and at risk

Asset/Threat Pair

Assessment Criteria

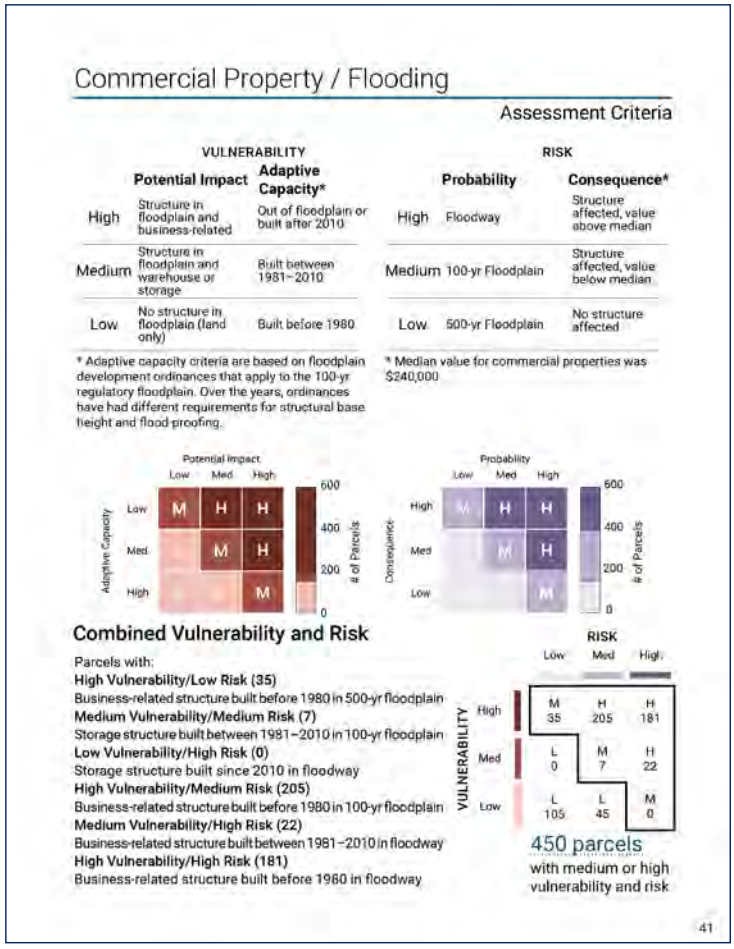
Rules used to assess levels of potential impact, adaptive capacity, and risk

Vulnerability and Risk Matrices and Charts

Matrix for each concept (Vulnerability and Risk) and a graphic showing distribution of vulnerability and risk for all exposed assets

Asset Descriptions

Descriptions of assets with medium to high combined potential impact or vulnerability and risk



Commercial Property / Flooding

Assessment Criteria

VULNERABILITY

	Potential Impact	Adaptive Capacity*
High	Structure in floodplain and business-related	Out of floodplain or built after 2010
Medium	Structure in floodplain and warehouse or storage	Built between 1981–2010
Low	No structure in floodplain (land only)	Built before 1980

* Adaptive capacity criteria are based on floodplain development ordinances that apply to the 100-yr regulatory floodplain. Over the years, ordinances have had different requirements for structural base height and flood proofing.

RISK

	Probability	Consequence*
High	Floodway	Structure affected, value above median
Medium	100-yr Floodplain	Structure affected, value below median
Low	500-yr Floodplain	No structure affected

* Median value for commercial properties was $240,000

Potential Impact (Low, Med, High) × Adaptive Capacity (Low, Med, High); # of Parcels (0, 200, 400, 600)

Probability (Low, Med, High) × Consequence (Low, Med, High); # of Parcels (0, 200, 400, 600)

Combined Vulnerability and Risk

Parcels with:

High Vulnerability/Low Risk (35)
Business-related structure built before 1980 in 500-yr floodplain
Medium Vulnerability/Medium Risk (7)
Storage structure built between 1981–2010 in 100-yr floodplain
Low Vulnerability/High Risk (0)
Storage structure built since 2010 in floodway
High Vulnerability/Medium Risk (205)
Business-related structure built before 1980 in 100-yr floodplain
Medium Vulnerability/High Risk (22)
Business-related structure built between 1981–2010 in floodway
High Vulnerability/High Risk (181)
Business-related structure built before 1960 in floodway

RISK (Low, Med, High) × VULNERABILITY (High, Med, Low)

VULNERABILITY \ RISK	Low	Med	High
High	M 35	H 205	H 181
Med	L 0	M 7	H 22
Low	L 105	L 45	M 0

450 parcels with medium or high vulnerability and risk

41

Matrix Showing Selection of "Medium to High"

Matrix showing how concepts are combined to produce levels of combined potential impact or vulnerability and risk. Also, the number of assets that fall into each category and the total number in medium to high.

Bridges / Flooding

Potential Impact Assessment

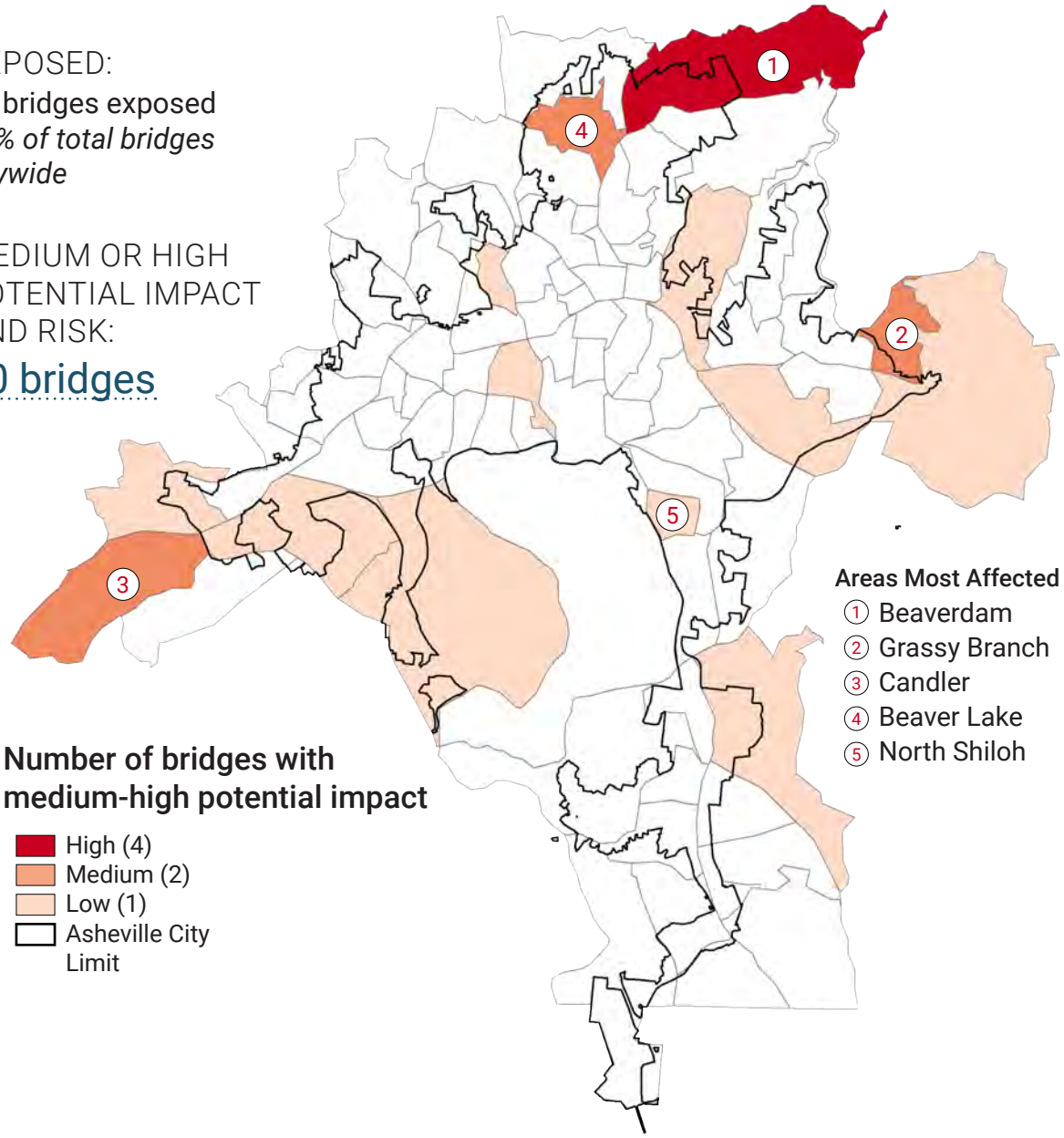
Bridges were assessed based on the type of road (major or secondary) and also whether they serve as the single point of critical access to residential or other properties. Bridges with a medium or high potential impact either serve a major road or serve as a critical point of access.

EXPOSED:

38 bridges exposed
21% of total bridges citywide

MEDIUM OR HIGH POTENTIAL IMPACT AND RISK:

20 bridges



The Beaverdam area has the highest number of bridges with high potential impact, with all four bridges serving as points of critical access. Other areas with critical access bridges include Grassy Branch (2), North Shiloh, Biltmore West/Bent Creek, and Chunns Cove. Bridges in other areas, including Candler and Beaver Lake, serve major roads.

Bridges / Flooding

Assessment Criteria

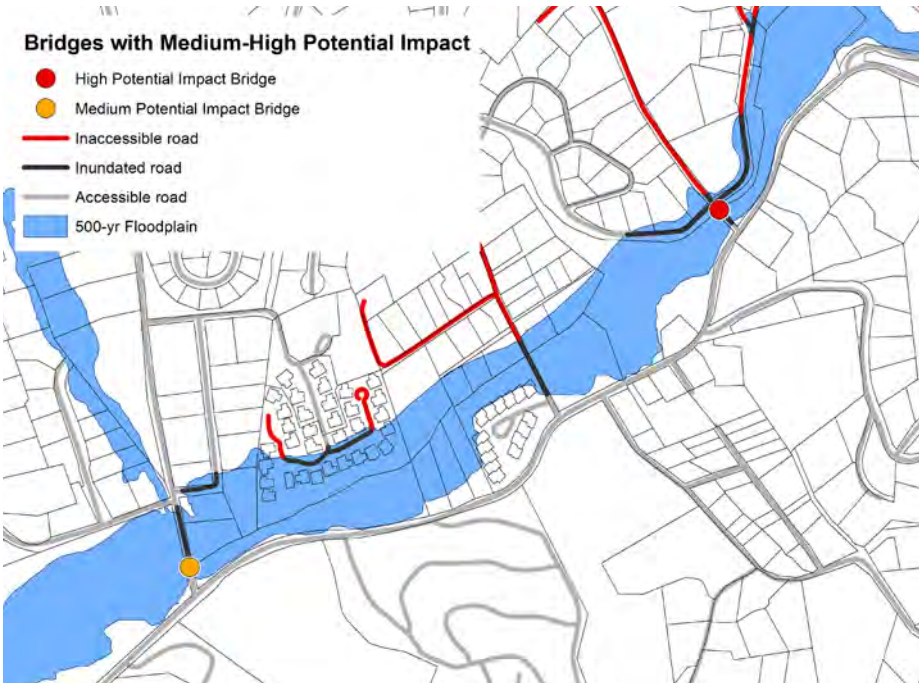
	Potential Impact (500-yr floodplain)
High	Bridge is major or secondary and serves as critical (single) point of access
Medium	Bridge serves a major road (arterial or collector), but is not a critical access point
Low	Bridge serves a secondary road (local), and is not a critical access point

Parcels with:
High Potential Impact (9)
Bridge serves as the only access point to residential or commercial properties and is in the 500-yr floodplain
Medium Potential Impact (11)
Bridge serves a major road and is in the 500-yr floodplain
Low Potential Impact (18)
Bridge serves a secondary road and is in the 500-yr floodplain

POTENTIAL IMPACT

Low	Med	High
18	11	9

20 bridges
with medium-high potential impact



The map above shows illustrations for a high potential impact bridge and a medium potential impact bridge. The high potential impact bridge is one that serves as the single access point; therefore, if inundated or damaged, roads and properties would have no other access. The medium potential impact bridge does not serve as the only access point to other roads or properties, but it does serve a major road.

City-Owned Facilities / Flooding

Potential Impact & Risk Assessment

This includes all city-owned facilities except for those associated with parks and recreation. City-owned facilities were assessed on whether the properties had structures in the floodplain and their level of risk. Properties with structures in the floodway and 100-year floodplain have higher risk than those in the 500-year floodplain.

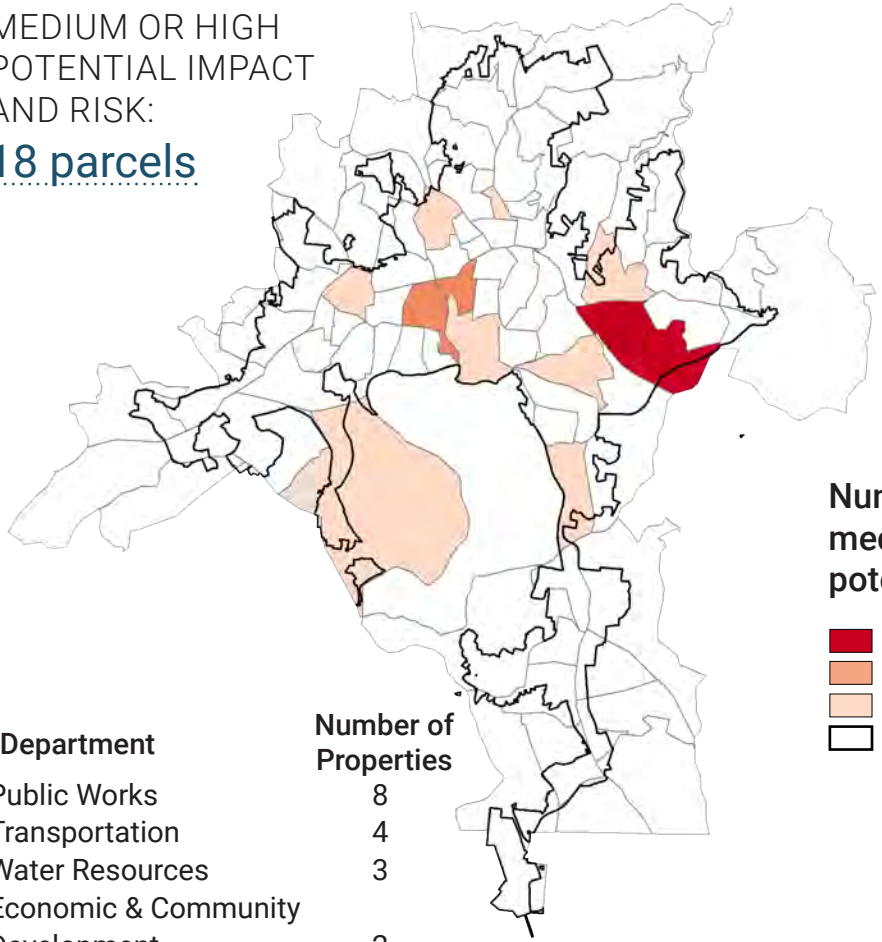
EXPOSED:

26 parcels exposed
8% of city-owned facilities citywide

MEDIUM OR HIGH POTENTIAL IMPACT AND RISK:

18 parcels





Number of parcels with medium-high combined potential impact and risk

- High (5)
- Medium (2)
- Low (1)
- Asheville City Limit

Department	Number of Properties
Public Works	8
Transportation	4
Water Resources	3
Economic & Community Development	2
Administration	1

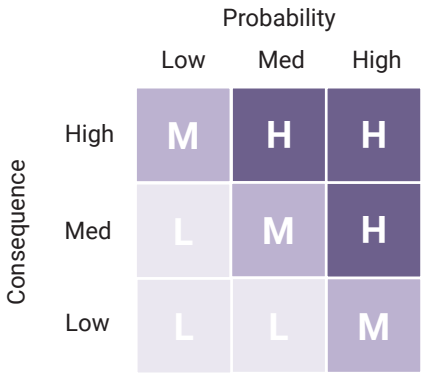
City-owned facilities include some properties outside of the city limit boundaries. The Public Works Department has the most facilities with high potential impact and risk to flooding. The River Ridge area has the greatest number of facilities with high potential impact and risk.

City-Owned Facilities / Flooding

Assessment Criteria

Potential Impact	
High	Structure in floodplain
Low	No structure in floodplain (land only)

RISK		
Probability		**Consequence**
High	Floodway	Structure affected
Medium	100-yr Floodplain	Structure affected
Low	500-yr Floodplain	No structure affected



Combined Potential Impact and Risk

Parcels with:
High Potential Impact/Low Risk (0)
Facility has structure in 500-yr floodplain
High Potential Impact/Medium Risk (7)
Facility has structure in 100-yr floodplain
Low Potential Impact/High Risk (5)
Facility has property (land only) in floodway
High Potential Impact/High Risk (6)
Facility has structure in floodway



18 parcels
with medium or high potential impact and risk

Commercial Property / Flooding

Vulnerability & Risk Assessment

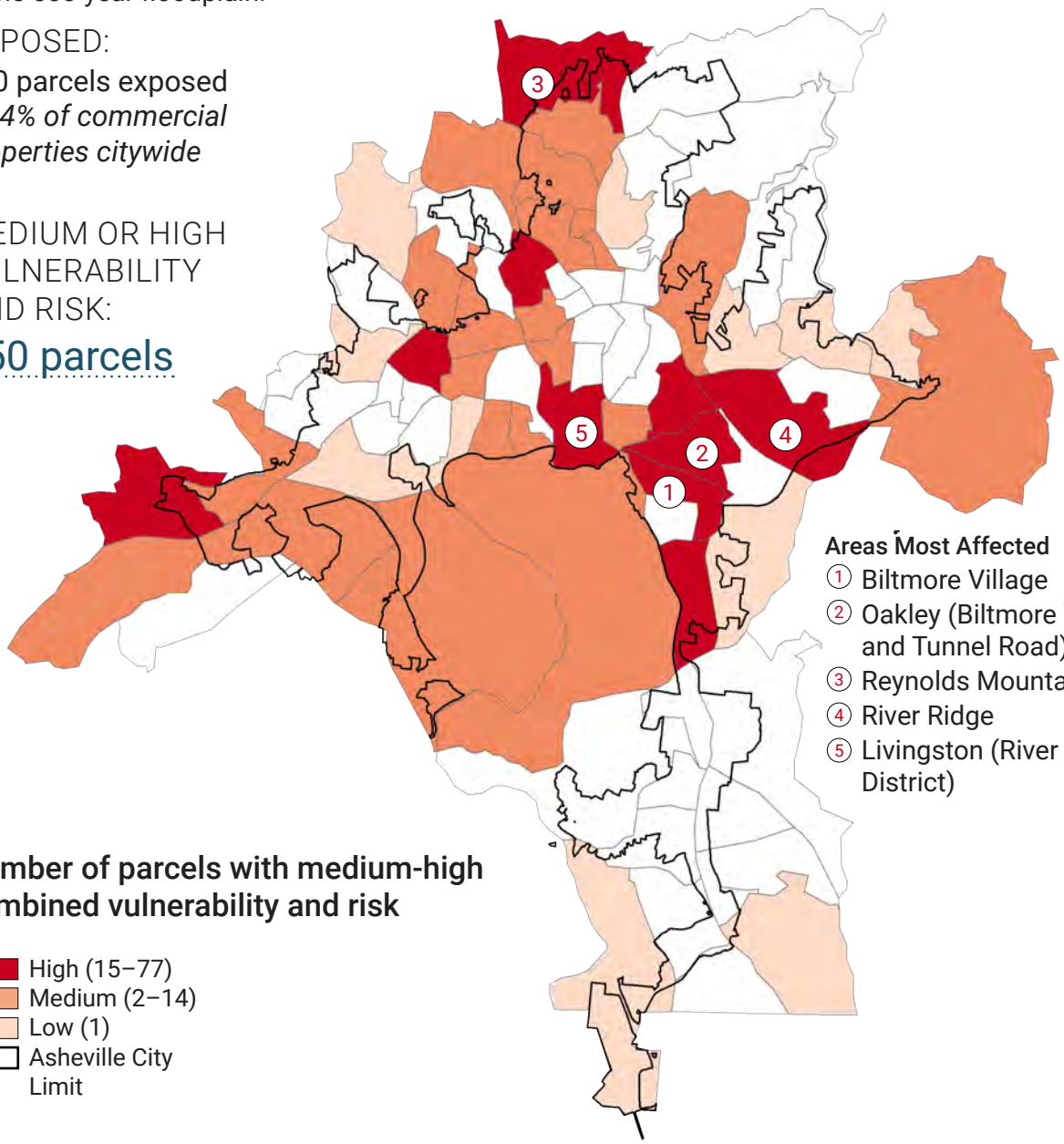
Commercial properties exposed to flooding can be affected by inundation of flood waters, leading to structural loss or damage and also resulting in loss of property and economic revenue. One of the greatest impacts in the floods of 2004 was from business interruption. Properties that are business-related with older structures in the floodplain (without base flood elevation) and that have not implemented flood-proofing measures are most vulnerable. Properties with structures in the floodway and 100-year floodplain have a higher risk than those in the 500-year floodplain.

EXPOSED:

600 parcels exposed
17.4% of commercial properties citywide

MEDIUM OR HIGH VULNERABILITY AND RISK:

450 parcels



A relatively large proportion of commercial properties exposed to flooding (75%) have high vulnerability and risk. Commercial properties that are most vulnerable and at-risk are found along the major Swannanoa and French Broad river corridors (Biltmore Village and the River Arts District), but are also found in North Asheville just north of Beaver Lake.

Commercial Property / Flooding

Assessment Criteria

VULNERABILITY

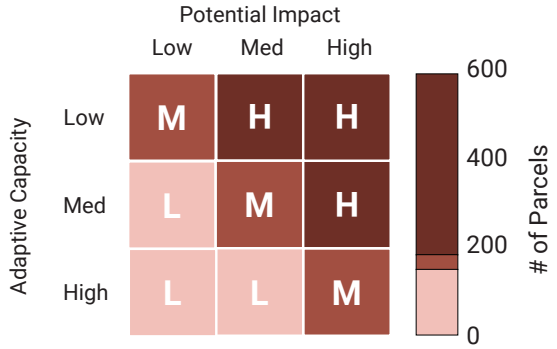
	Potential Impact	Adaptive Capacity*
High	Structure in floodplain and business-related	Out of floodplain or built after 2010
Medium	Structure in floodplain and warehouse or storage	Built between 1981–2010
Low	No structure in floodplain (land only)	Built before 1980

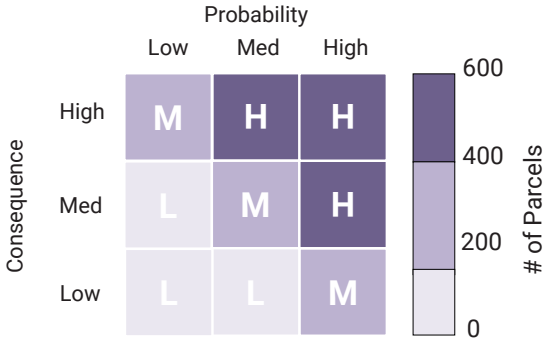
* Adaptive capacity criteria are based on floodplain development ordinances that apply to the 100-yr regulatory floodplain. Over the years, ordinances have had different requirements for structural base height and flood-proofing.

RISK

	Probability	Consequence*
High	Floodway	Structure affected, value above median
Medium	100-yr Floodplain	Structure affected, value below median
Low	500-yr Floodplain	No structure affected

* Median value for commercial properties was $240,000





Combined Vulnerability and Risk

Parcels with:

High Vulnerability/Low Risk (35)
Business-related structure built before 1980 in 500-yr floodplain

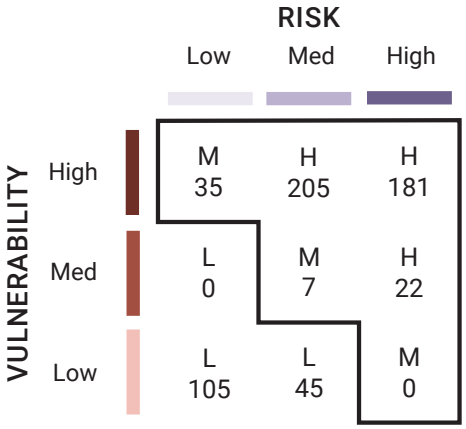
Medium Vulnerability/Medium Risk (7)
Storage structure built between 1981–2010 in 100-yr floodplain

Low Vulnerability/High Risk (0)
Storage structure built since 2010 in floodway

High Vulnerability/Medium Risk (205)
Business-related structure built before 1980 in 100-yr floodplain

Medium Vulnerability/High Risk (22)
Business-related structure built between 1981–2010 in floodway

High Vulnerability/High Risk (181)
Business-related structure built before 1980 in floodway



450 parcels
with medium or high vulnerability and risk

Critical Infrastructure / Flooding

Vulnerability & Risk Assessment

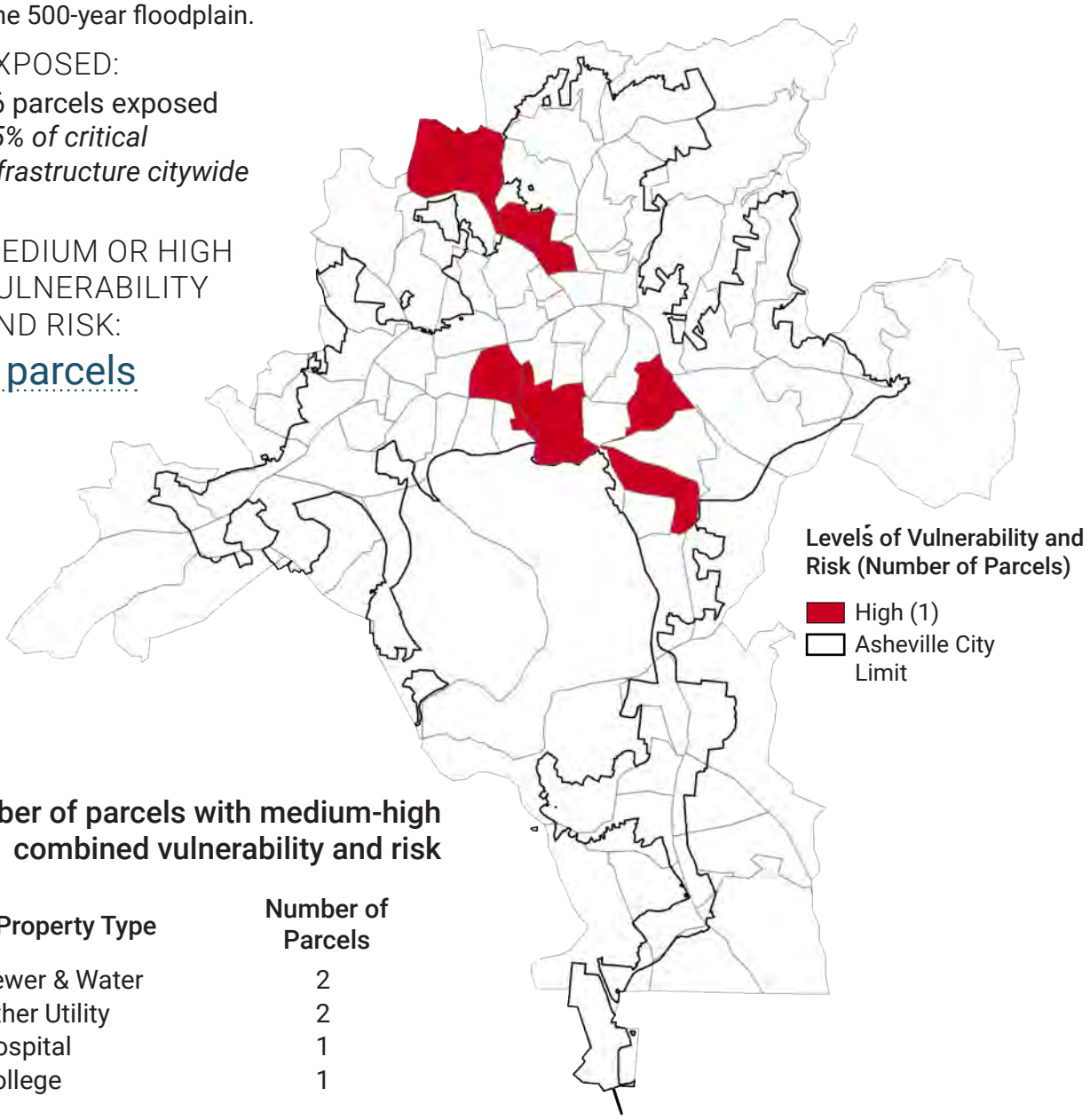
Critical infrastructure properties with older structures in the floodplain (with no base flood elevation) and that have not implemented flood-proofing measures are most vulnerable. Properties with buildings in the floodway and 100-year floodplain have a higher risk than those in the 500-year floodplain.

EXPOSED:

26 parcels exposed
15% of critical infrastructure citywide

MEDIUM OR HIGH VULNERABILITY AND RISK:

6 parcels



Number of parcels with medium-high combined vulnerability and risk

Property Type	Number of Parcels
Sewer & Water	2
Other Utility	2
Hospital	1
College	1

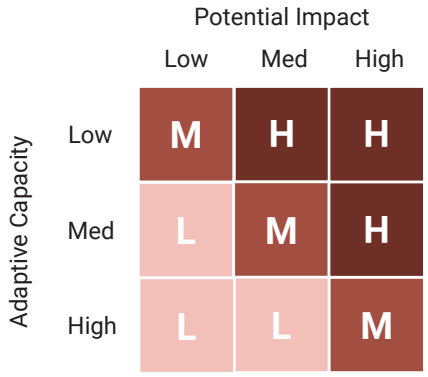
Out of the 26 critical infrastructure properties exposed, a total of six have medium or high combined potential impact and risk. These are properties that provide a critical service and where a structure on the property has a relatively high likelihood of being affected by flooding. Each of the six properties are located in a different census block group. The types of properties include utilities (sewer and water, telephone, and electricity), hospital, and college facilities.

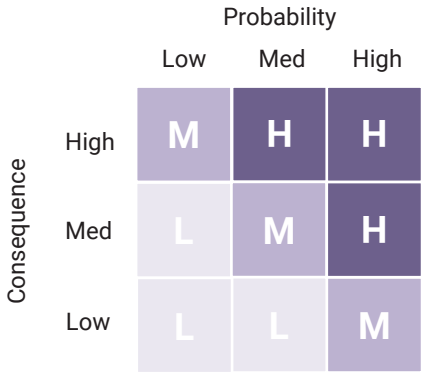
Critical Infrastructure / Flooding

Assessment Criteria

VULNERABILITY			RISK		
	Potential Impact	**Adaptive Capacity***		**Probability**	**Consequence**
High	Structure in floodplain	Out of floodplain or built after 2010	High	Floodway	Structure affected
Medium		Built between 1981–2010	Medium	100-yr Floodplain	Structure affected
Low	No structure in floodplain (land only)	Built before 1980	Low	500-yr Floodplain	No structure affected

* Adaptive capacity criteria are based on floodplain development ordinances that apply to the 100-yr regulatory floodplain. Over the years, ordinances have had different requirements for structural base height and flood-proofing.





Combined Vulnerability and Risk

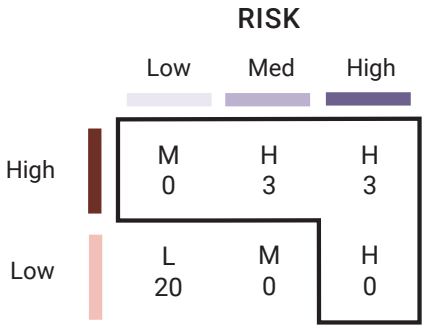
Parcels with:

High Potential Impact/Low Risk (0)
Structure in 500-yr floodplain

Low Potential Impact/High Risk (0)
No structure (land only) in floodway

High Potential Impact/Medium Risk (3)
Structure in 100-yr floodplain

High Potential Impact/High Risk (3)
Structure in floodway



6 parcels
with medium or high vulnerability and risk

Food Infrastructure / Flooding

Vulnerability & Risk Assessment

FOOD PROCESSING/DISTRIBUTION

3 parcels
with medium or high potential impact

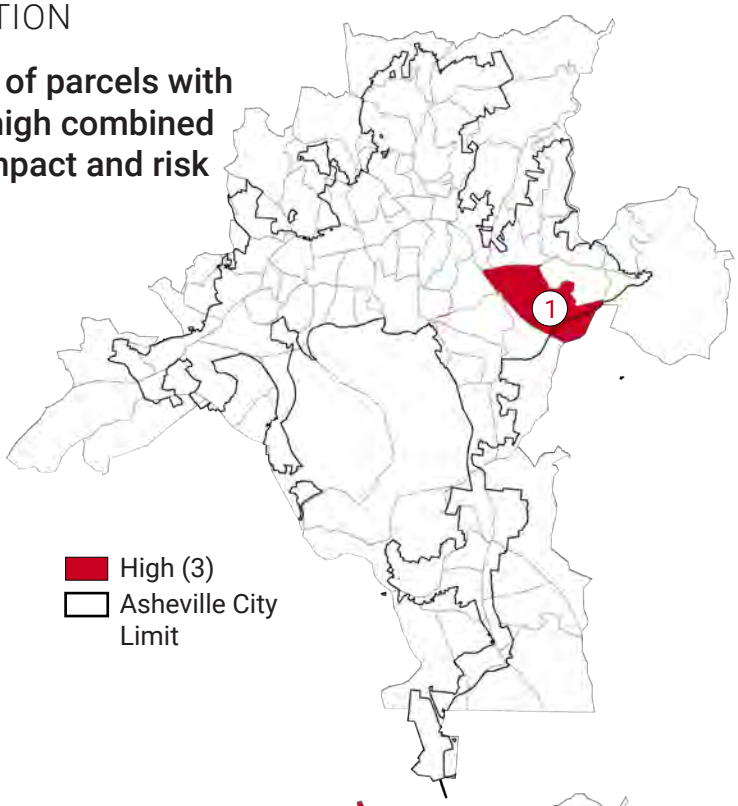
6 parcels exposed
42.9% of distribution parcels citywide

The three food distribution/ processing locations with high vulnerability and risk include the MANNA distribution center, which is on the Swannanoa River, and two community gardens that are in proximity to Azalea Road.

Areas Most Affected

① River Ridge

Number of parcels with medium-high combined potential impact and risk



FOOD LOCATIONS

48 parcels
with medium or high potential impact

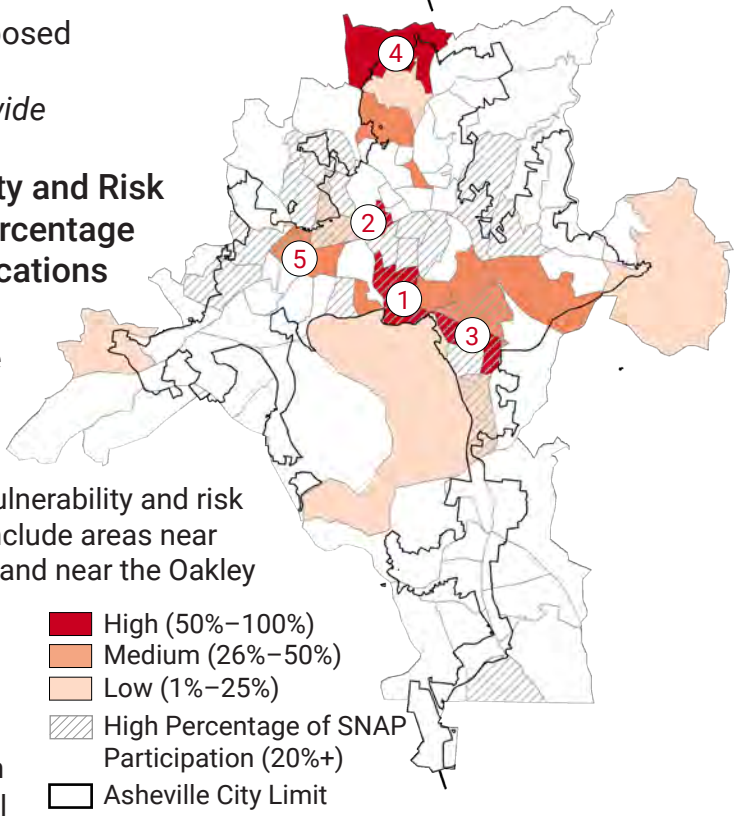
65 parcels exposed
16.8% of food locations citywide

Several areas where food locations have high vulnerability and risk are also areas with high participation in SNAP. The areas in dark red are where more than 50% of the food locations are highly vulnerable and at-risk, and include Livingston, Biltmore Village, and Courtland. Other areas with some vulnerability and risk and that have high SNAP participation include areas near the Emma community in West Asheville and near the Oakley and Shiloh communities in South Asheville.

Areas Most Affected

① Livingston
② Courtland / Hillcrest
③ Biltmore Village
④ Reynolds Mountain
⑤ Green Hill

Vulnerability and Risk Based on Percentage of Food Locations

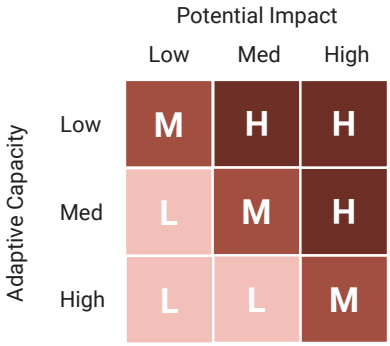


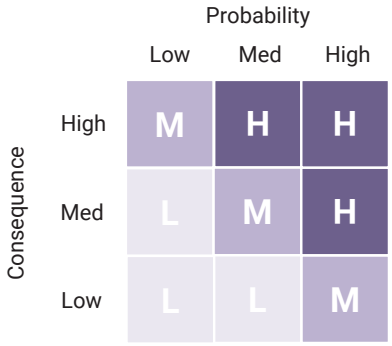
Food Infrastructure / Flooding

Assessment Criteria

	VULNERABILITY		RISK		
	Potential Impact	**Adaptive Capacity***		**Probability**	**Consequence**
High	Structure in floodplain	Out of floodplain or built after 2010	High	Floodway	Structure affected
Medium	Structure in floodplain	Built between 1981–2010	Medium	100-yr Floodplain	Structure affected
Low	No structure in floodplain (land only)	Built before 1980	Low	500-yr Floodplain	No structure affected

* Adaptive capacity criteria are based on floodplain development ordinances that apply to the 100-yr regulatory floodplain. Over the years, ordinances have had different requirements for structural base height and flood-proofing.





Combined Vulnerability and Risk

Parcels with:

High Vulnerability/Low Risk
Structure built before 1980 in 500-yr floodplain

Medium Vulnerability/Medium Risk
Structure built between 1981–2010 in 100-yr floodplain

Low Vulnerability/High Risk
Structure built since 2010 in floodway

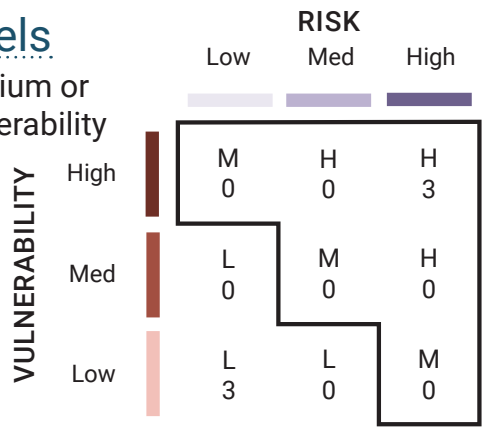
High Vulnerability/Medium Risk
Structure built before 1980 in 100-yr floodplain

Medium Vulnerability/High Risk
Structure built between 1981–2010 in 100-yr floodplain

High Vulnerability/High Risk
Structure built before 1980 in floodway

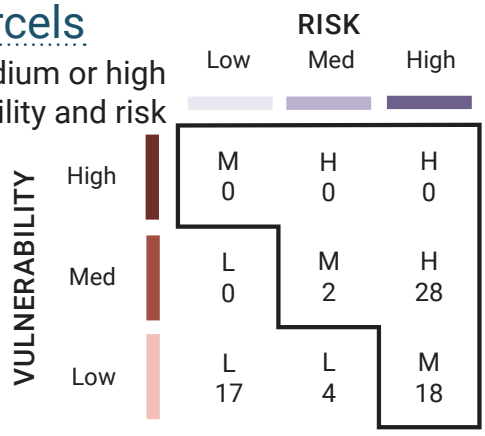
FOOD PROCESSING/DISTRIBUTION

3 parcels with medium or high vulnerability and risk



FOOD LOCATIONS

48 parcels with medium or high vulnerability and risk



Industrial Property / Flooding

Vulnerability & Risk Assessment

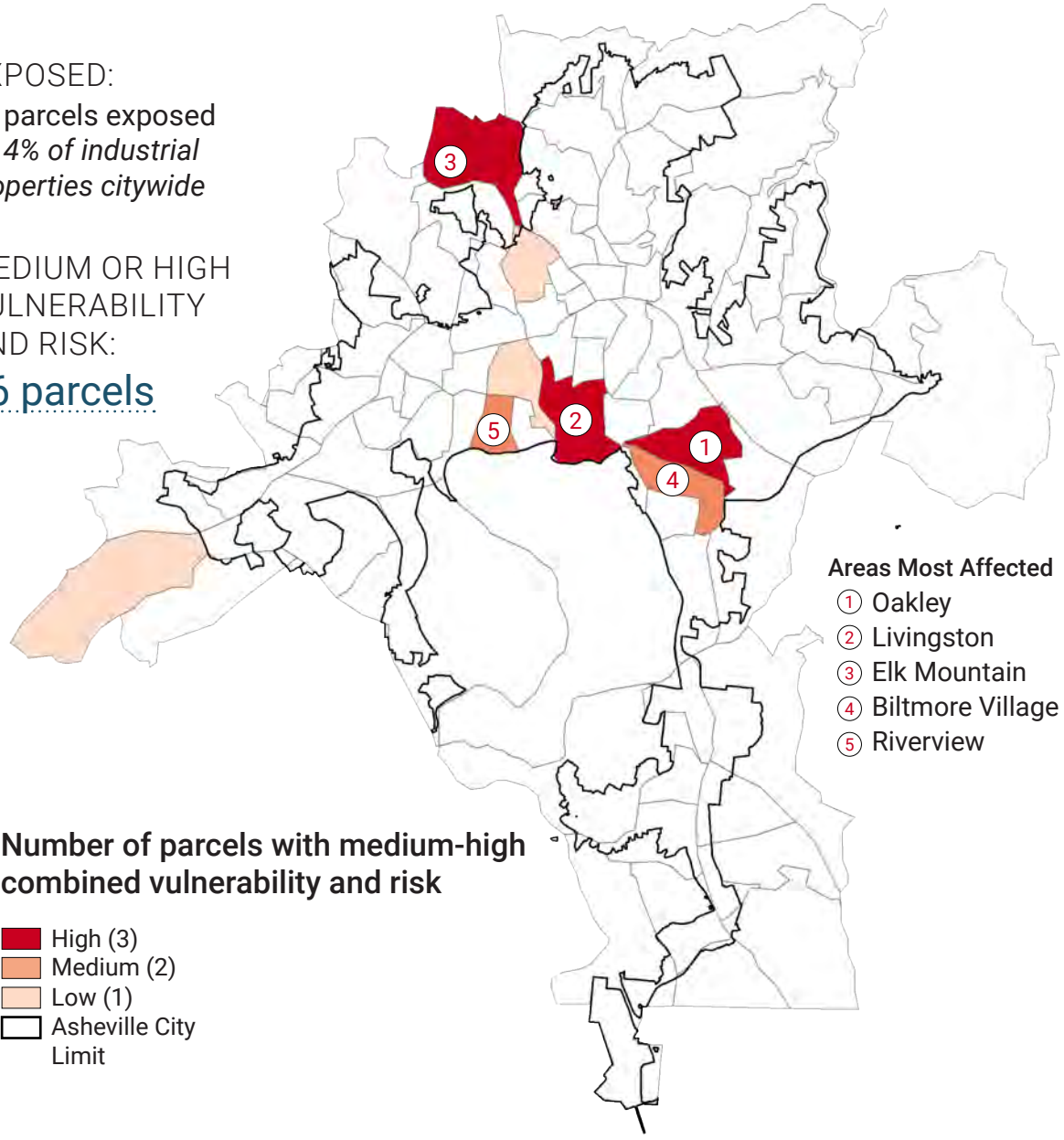
Industrial properties that serve as sites for raw materials (such as gravel and concrete) and that have structures in the floodplain without base flood elevation and that have not implemented flood-proofing measures are most vulnerable. Properties with structures in the floodway and 100-year floodplain have a higher risk than those in the 500-year floodplain.

EXPOSED:

24 parcels exposed
26.4% of industrial properties citywide

MEDIUM OR HIGH VULNERABILITY AND RISK:

16 parcels



Industrial properties at risk of flooding are found in just a few areas. They are located mainly in the same areas where Commercial Properties are at risk to flooding, so some of the options should be considered for both assets.

Industrial Property / Flooding

Assessment Criteria

VULNERABILITY

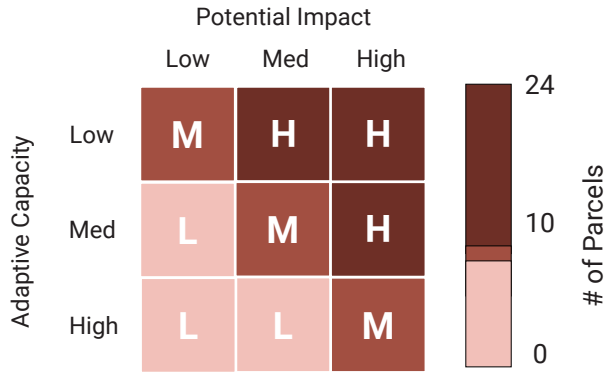
	Potential Impact	Adaptive Capacity*
High	Structure in floodplain and serves as a site for raw materials	Out of floodplain or built after 2010
Medium	Structure in floodplain	Built between 1981–2010
Low	No structure in floodplain (land only)	Built before 1980

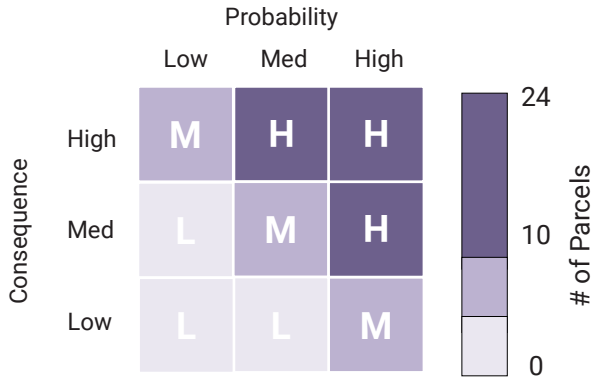
* Adaptive capacity criteria are based on floodplain development ordinances that apply to the 100-yr regulatory floodplain. Over the years, ordinances have had different requirements for structural base height and flood-proofing.

RISK

	Probability	Consequence*
High	Floodway	Structure affected, value above median
Medium	100-yr Floodplain	Structure affected, value below median
Low	500-yr Floodplain	No structure affected

* Median value for industrial properties was $240,000





Combined Vulnerability and Risk

Parcels with:

High Vulnerability/Low Risk (0)
Raw materials site with structure built before 1980 in 500-yr floodplain

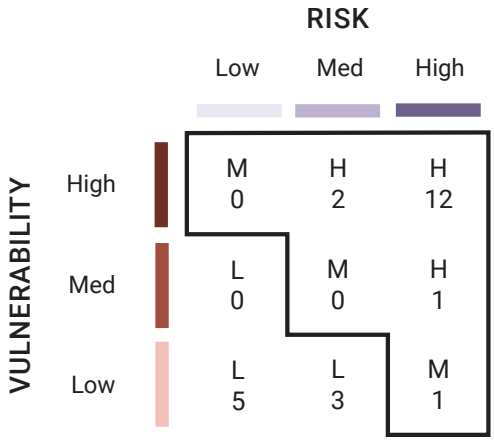
Medium Vulnerability/Medium Risk (0)
Structure built between 1981–2010 in 100-yr floodplain

Low Vulnerability/High Risk (1)
Structure built since 2010 in floodway

High Vulnerability/Medium Risk (2)
Raw materials site with structure built before 1980 in 100-yr floodplain

Medium Vulnerability/High Risk (1)
Single residence built between 1981–2010 in 100-yr floodplain

High Vulnerability/High Risk (12)
Raw materials site with structure built before 1980 in floodway



16 parcels
with medium or high vulnerability and risk

Parks and Recreation / Flooding

Vulnerability & Risk Assessment

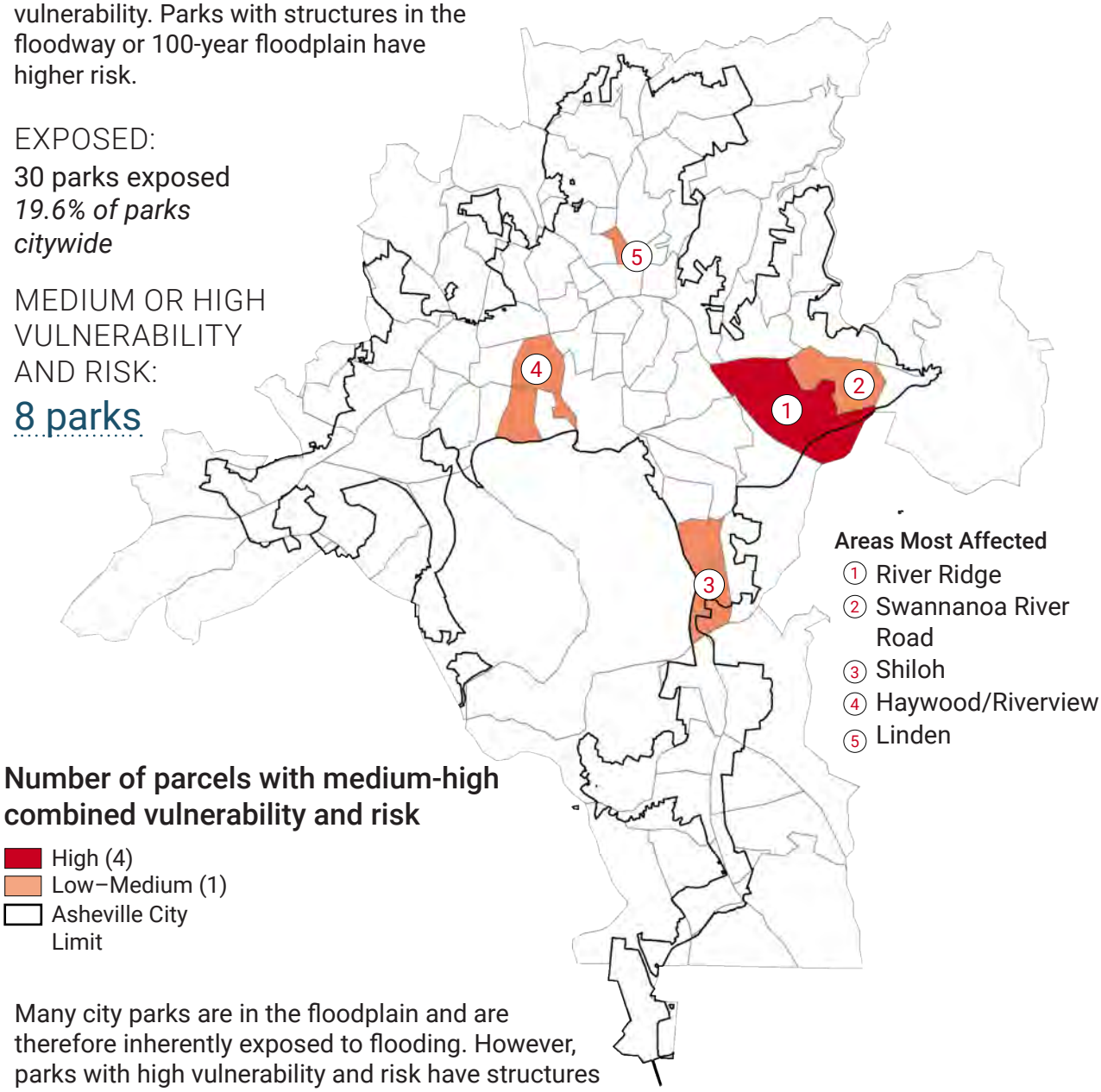
Parks and recreation assets include all city parks and community centers. Parks were evaluated based on their type of use and the expected cost and service interruption in a flooding event. Parks that serve as special facilities, such as for emergency service or community centers and that have structures in the floodplain have the highest vulnerability. Parks with structures in the floodway or 100-year floodplain have higher risk.

EXPOSED:

30 parks exposed
19.6% of parks citywide

MEDIUM OR HIGH VULNERABILITY AND RISK:

8 parks



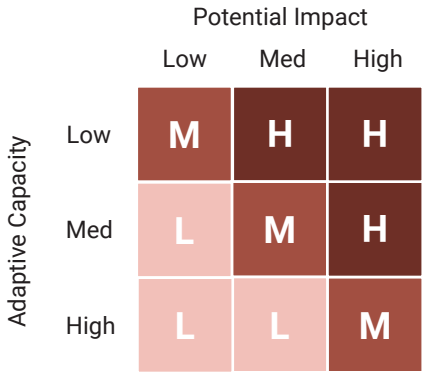
Many city parks are in the floodplain and are therefore inherently exposed to flooding. However, parks with high vulnerability and risk have structures or infrastructure that have the potential to be impacted by flooding events. The River Ridge area has the highest number of Parks and Recreation facilities with high vulnerability and risk. A few of these individual parks with high vulnerability and risk include Azalea Park Soccer Complex, Recreation Park, WNC Nature Center, Municipal Golf Course, and Shiloh Community Center.

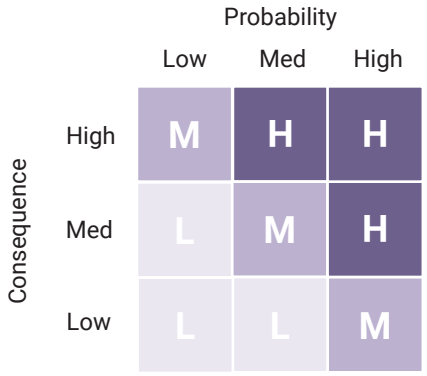
Parks and Recreation / Flooding

Assessment Criteria

	VULNERABILITY			RISK	
	Potential Impact	**Adaptive Capacity***		**Probability**	**Consequence***
High	Structure in floodplain and serves as special facility or community center	High cost and service interruption	High	Floodway	Structure affected
Medium	Special facility or community center with no structure in floodplain (land only)	Moderate cost and service interruption	Medium	100-yr Floodplain	Structure affected
Low	Not a special facility or community center and no structure in floodplain (land only)	Low cost and service interruption	Low	500-yr Floodplain	No structure affected

* Adaptive capacity criteria are based on recent past experiences with flood events and how they affected park and recreation facilities.





Combined Vulnerability and Risk

Parcels with:

High Vulnerability/Low Risk (0)
Special facility with structure in 500-yr floodplain

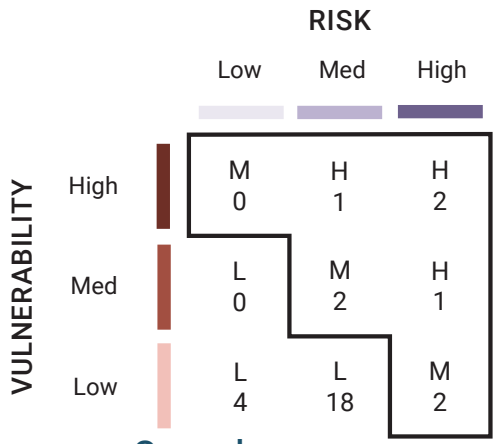
Medium Vulnerability/Medium Risk (2)
Special facility with property (land only) in 100-yr floodplain

Low Vulnerability/High Risk (2)
Non-special facility in floodway

High Vulnerability/Medium Risk (1)
Special facility with structure in 100-yr floodplain

Medium Vulnerability/High Risk (1)
Special facility with property (land only) in 100-yr floodplain

High Vulnerability/High Risk (2)
Special facility with structure in floodway



8 parks
with medium or high vulnerability and risk

Residential Property / Flooding

Vulnerability & Risk Assessment

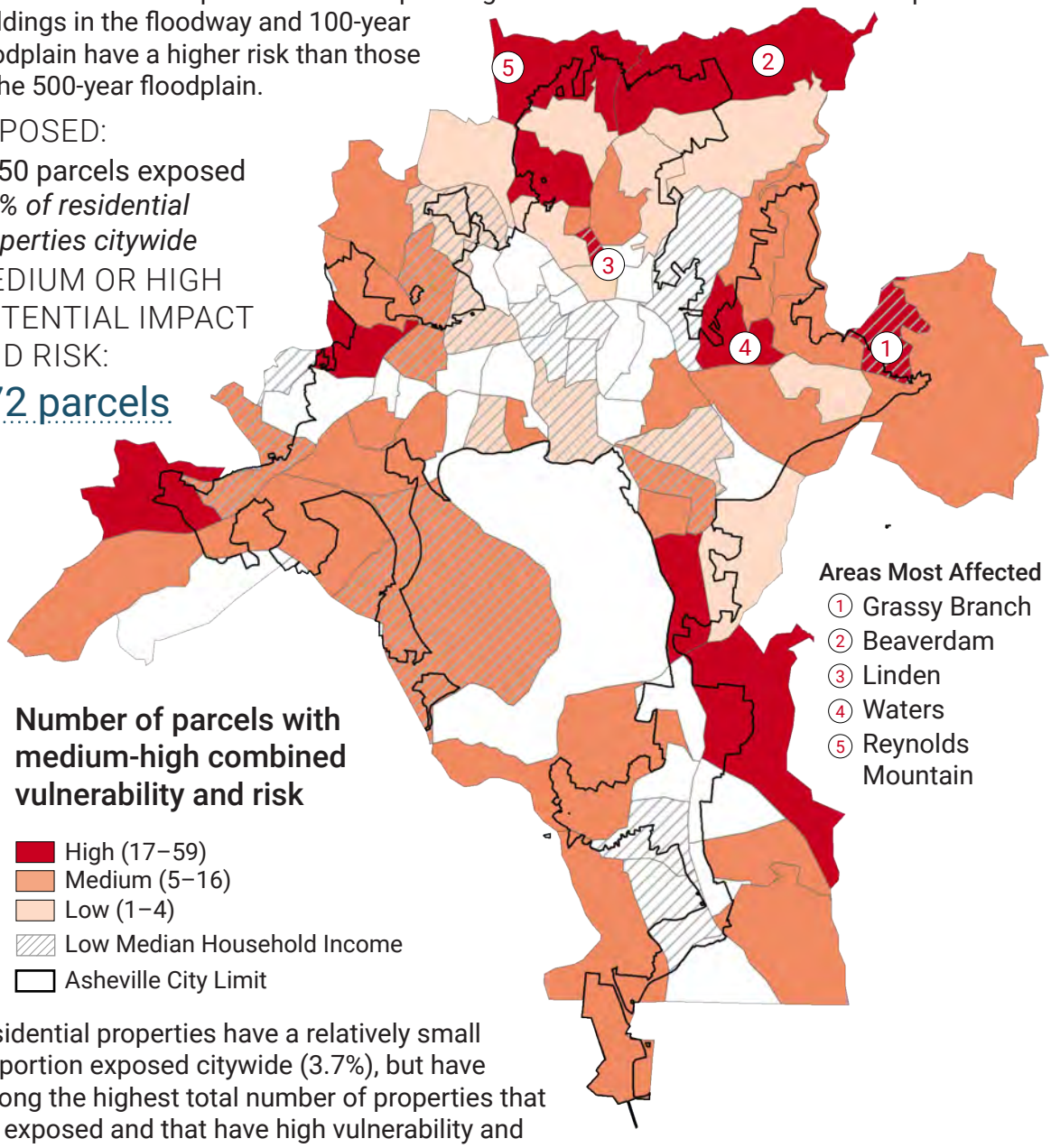
Residential properties were assessed based on the type of residence (e.g., multiple-residence, manufactured, or single-residence). Multiple-residence, apartment, manufactured, and mobile home park properties with older structures in the floodplain (with no base flood elevation) and that have not implemented flood-proofing measures are most vulnerable. Properties with buildings in the floodway and 100-year floodplain have a higher risk than those in the 500-year floodplain.

EXPOSED:

1,550 parcels exposed
3.7% of residential properties citywide

MEDIUM OR HIGH POTENTIAL IMPACT AND RISK:

572 parcels



Residential properties have a relatively small proportion exposed citywide (3.7%), but have among the highest total number of properties that are exposed and that have high vulnerability and risk. Areas with high vulnerability and risk for flooding are found across the city, mostly due to the potential for flooding along smaller streams and tributaries that eventually feed into the Swannanoa and French Broad Rivers. Some of these areas are in East Asheville (Haw Creek), North Asheville (Beaverdam Creek), West Asheville (Hominy Creek), and South Asheville (Sweeten Creek). A few of these areas with high vulnerability and risk are also areas with relatively low household income.

Residential Property / Flooding

Assessment Criteria

VULNERABILITY

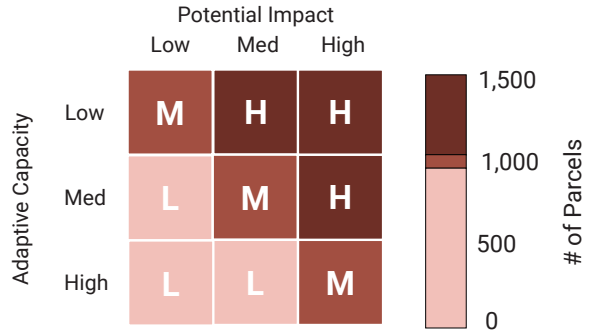
	Potential Impact	Adaptive Capacity*
High	Structure in floodplain and multiple-residence, apartment, manufactured house, or mobile home park	Out of floodplain or built after 2010
Medium	Structure in floodplain and single-residence	Built between 1981–2010
Low	No structure in floodplain (land only)	Built before 1980

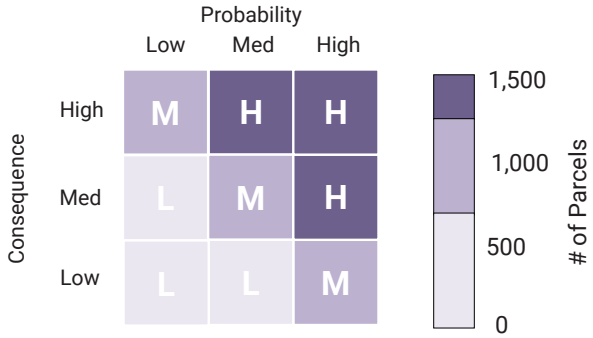
* Adaptive capacity criteria are based on floodplain development ordinances that apply to the 100-yr regulatory floodplain. Over the years, ordinances have had different requirements for structural base height and flood-proofing.

RISK

	Probability	Consequence*
High	Floodway	Structure affected, value above median
Medium	100-yr Floodplain	Structure affected, value below median
Low	500-yr Floodplain	No structure affected

* Median value for residential properties was $127,500





Combined Vulnerability and Risk

Parcels with:

High Vulnerability/Low Risk (66)
Multiple-residence built before 1980 in 500-yr floodplain

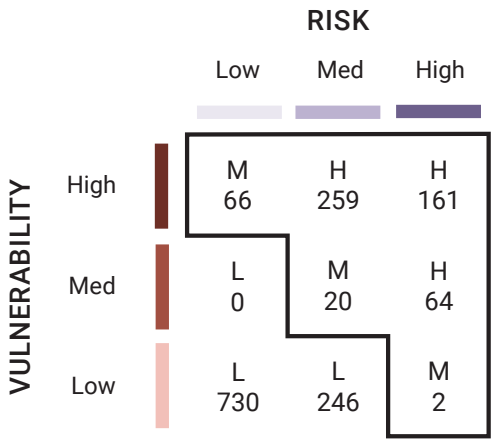
Medium Vulnerability/Medium Risk (20)
Single residence built between 1981–2010 in 100-yr floodplain

Low Vulnerability/High Risk (2)
Single residence built since 2010 in floodway

High Vulnerability/Medium Risk (259)
Multiple-residence built before 1980 in 100-yr floodplain

Medium Vulnerability/High Risk (64)
Single residence built between 1981–2010 in 100-yr floodplain

High Vulnerability/High Risk (161)
Multiple-residence built before 1980 in floodway



572 parcels
with medium or high potential impact

Roads / Flooding

Potential Impact Assessment

Roads were assessed based on the amount of road infrastructure potentially impacted and the critical access they provide for emergency services.

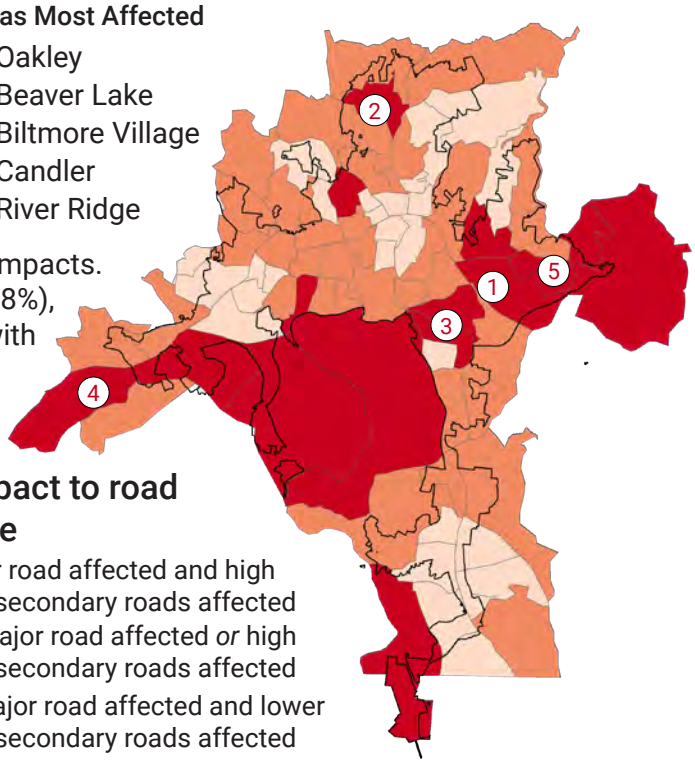
ROAD INFRASTRUCTURE

63 road miles potentially impacted *5.4% of roads citywide*

Inundated road infrastructure can cause temporary loss of transportation service, or flood waters can erode and damage roads resulting in more significant impacts. Most of the exposed roads are secondary (78%), with the rest being major (22%). The areas with a high ranking have the highest potential impact, where both a major road and a high proportion of secondary roads are potentially inundated by flooding. The medium-ranked areas are where either some major roads or a high proportion of secondary roads are potentially impacted.

Areas Most Affected

1. Oakley
2. Beaver Lake
3. Biltmore Village
4. Candler
5. River Ridge



Potential impact to road infrastructure

- High: Major road affected and high amount of secondary roads affected
- Medium: Major road affected *or* high amount of secondary roads affected
- Low: No major road affected and lower amount of secondary roads affected
- Asheville City Limit

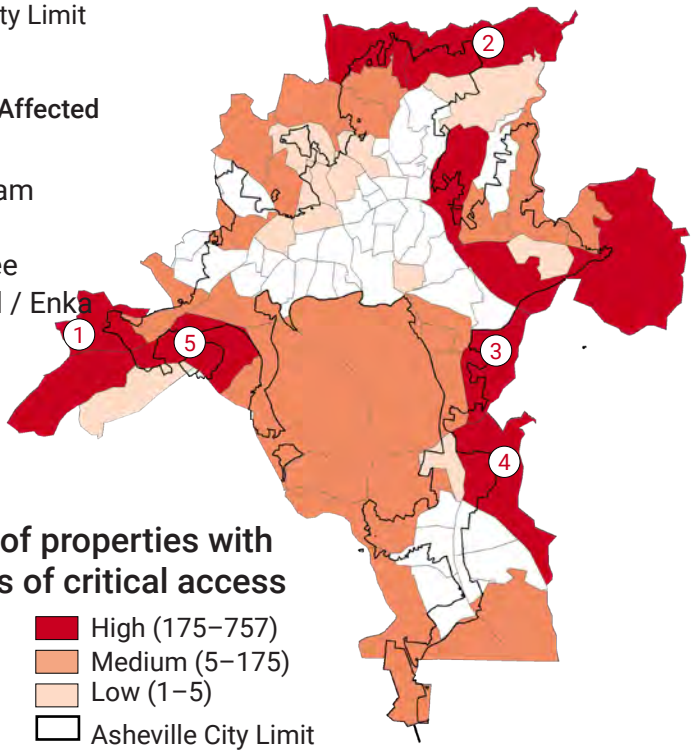
LOSS OF CRITICAL ACCESS

6,200 parcels with potential loss of critical access

One of the most important functions that roads provide is critical access for emergency services. Areas with potential loss of critical access are where a flooding event could result in properties being inaccessible by any Fire/EMS location due to impassable or damaged roads. The number of parcels affected (87% of which are residential) is for general purposes only, but the red areas are likely to have the highest number of properties with loss of critical access. Interestingly, these are not necessarily areas with a high proportion of road infrastructure affected.

Areas Most Affected

1. Asbury
2. Beaverdam
3. Busbee
4. Ballantree
5. Sand Hill / Enka



Number of properties with potential loss of critical access

- High (175–757)
- Medium (5–175)
- Low (1–5)
- Asheville City Limit

Roads / Flooding

Assessment Criteria

	POTENTIAL IMPACT (500-YR FLOODPLAIN)	
	Road Infrastructure	**Critical Access**
High	Any major road affected and high amount of secondary roads affected (>6%)	High number of non-vacant properties with potential loss of critical access for emergency services
Medium	Any major road affected or high amount of secondary roads affected (>6%), but not both	Moderate number of non-vacant properties with potential loss of critical access for emergency services
Low	No major road affected and lower amount of secondary roads affected (<6%)	Low number of non-vacant properties with potential loss of critical access for emergency services



The map above shows an illustration of road infrastructure potentially affected (inundated) and the potential loss of critical access to properties.

Transit and Greenways / Flooding

Potential Impact Assessment

Transit and greenways were assessed by considering potential impacts to city bus routes and to all existing and proposed greenways. Together, these make up some of the multi-modal transportation assets in the city.

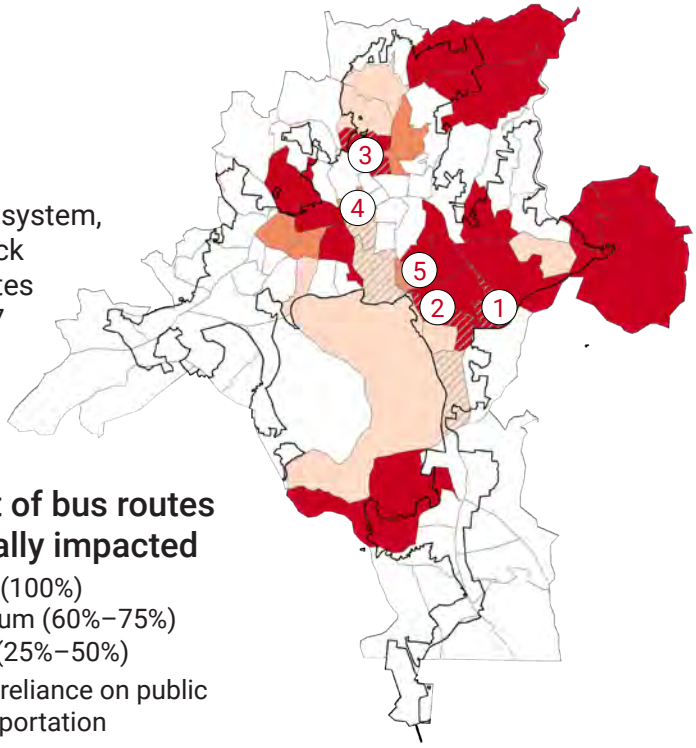
TRANSIT (BUS ROUTES)

14 routes exposed

82% of all routes citywide

Out of a total of 17 bus routes in the transit system, 14 are exposed to flooding. The census block groups are ranked by the percentage of routes affected within them. There are a total of 17 census block groups ranked as high, where 100% percent of the routes within them are potentially affected. Of these, three are areas with a high reliance on public transportation.

1. Oakley East
2. Biltmore Village
3. Riverside
4. Courtland/Hillcrest
5. Kenilworth



Percent of bus routes potentially impacted

- High (100%)
- Medium (60%–75%)
- Low (25%–50%)
- High reliance on public transportation
- Asheville City Limit

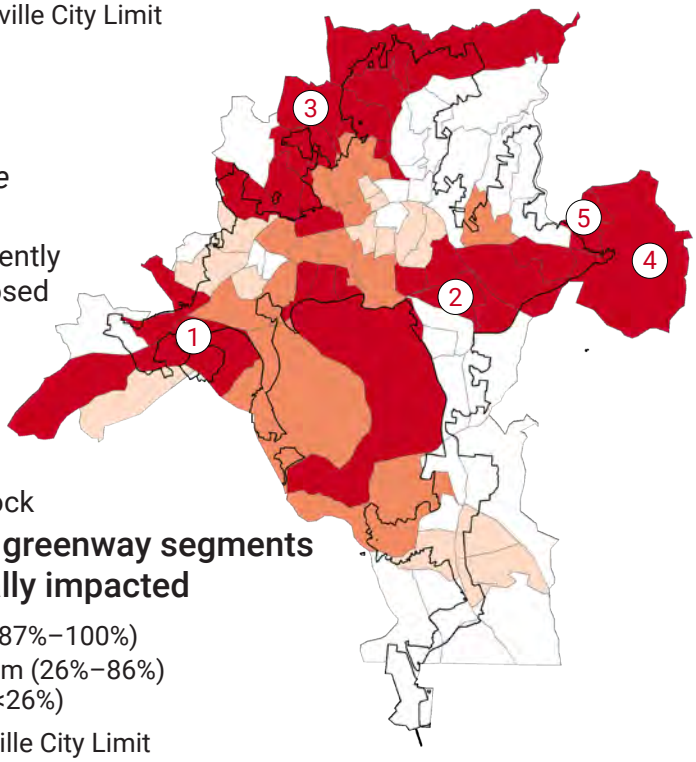
GREENWAYS

85 greenway segments potentially affected

59% of all greenways citywide

Similar to parks, many greenways are in the floodplain by design and are therefore inherently exposed to flooding. About 59% of all proposed and existing greenway segments are in the 500-year floodplain. Therefore, the multi-model function of these greenways would likely be interrupted in a major flood event. The proportion of the greenway segments potentially impacted within each census block group varies.

1. Sand Hill
2. River Ridge
3. Elk Mountain
4. Porters Cove
5. Grassy Branch



Percent greenway segments potentially impacted

- High (87%–100%)
- Medium (26%–86%)
- Low (<26%)
- Asheville City Limit

Transit and Greenways / Flooding

Assessment Criteria

	POTENTIAL IMPACT (500-YR FLOODPLAIN)	
	Transit (Bus Routes)	**Greenways**
High	100% of routes affected	86%–100% of greenways affected
Medium	60%–70% of routes affected	25%–85% of greenways affected
Low	Less than 60% of routes affected	Less than 25% of greenways affected

Water Supply and North Fork Dam / Flooding

Vulnerability & Risk Assessment

Water supply for the City of Asheville is provided by three intake points: North Fork Reservoir, Bee Tree Reservoir, and Mills Gap intake on the French Broad River. North Fork provides 70 percent of the water supply to the city.

EXPOSURE

Seventy percent of the local drinking water supply is provided by the North Fork Reservoir. The dam and associated infrastructure provides the reservoir's holding capacity. Past flood events and related erosion have shown the dam to be exposed to extreme precipitation and flooding events.

VULNERABILITY: HIGH

The construction of the dam over 60 years ago was sufficient at the time, but an increased demand for water and a greater exposure to possible dam breach has now made vulnerability high.

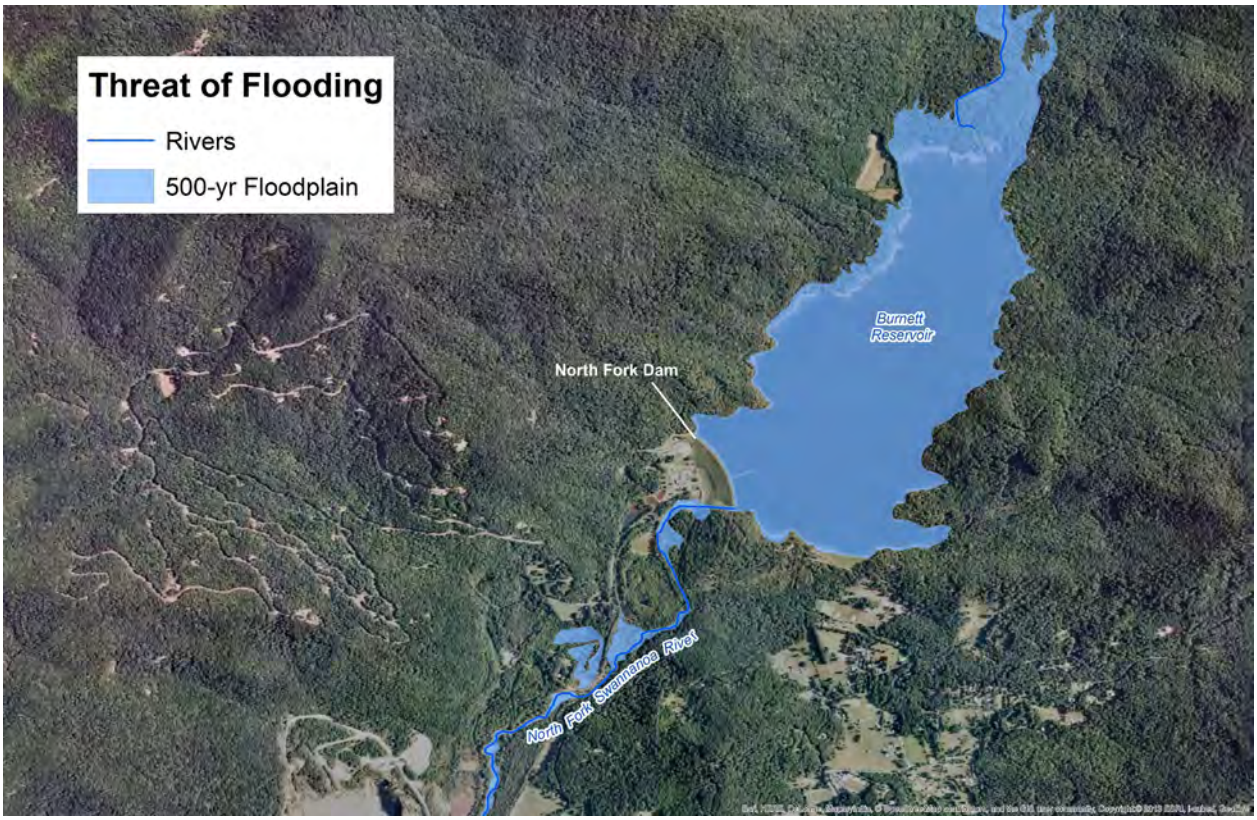
RISK: HIGH

The risk of a dam breach is high. The resulting flood would approximate a 500-year flood, with high velocity and the potential to cause massive damage downstream. This possibility, coupled with the impact of loss of drinking water for a substantial period of time, makes this a high risk.



Water Supply and North Fork Dam / Flooding

Assessment Criteria



This map shows the area of the North Fork Dam/Burnett Reservoir and the 500-yr floodplain. The pictures below show some of the impacts from the 2004 floods, which affected Asheville's main drinking water line.





Photos courtesy of Brown and Caldwell.

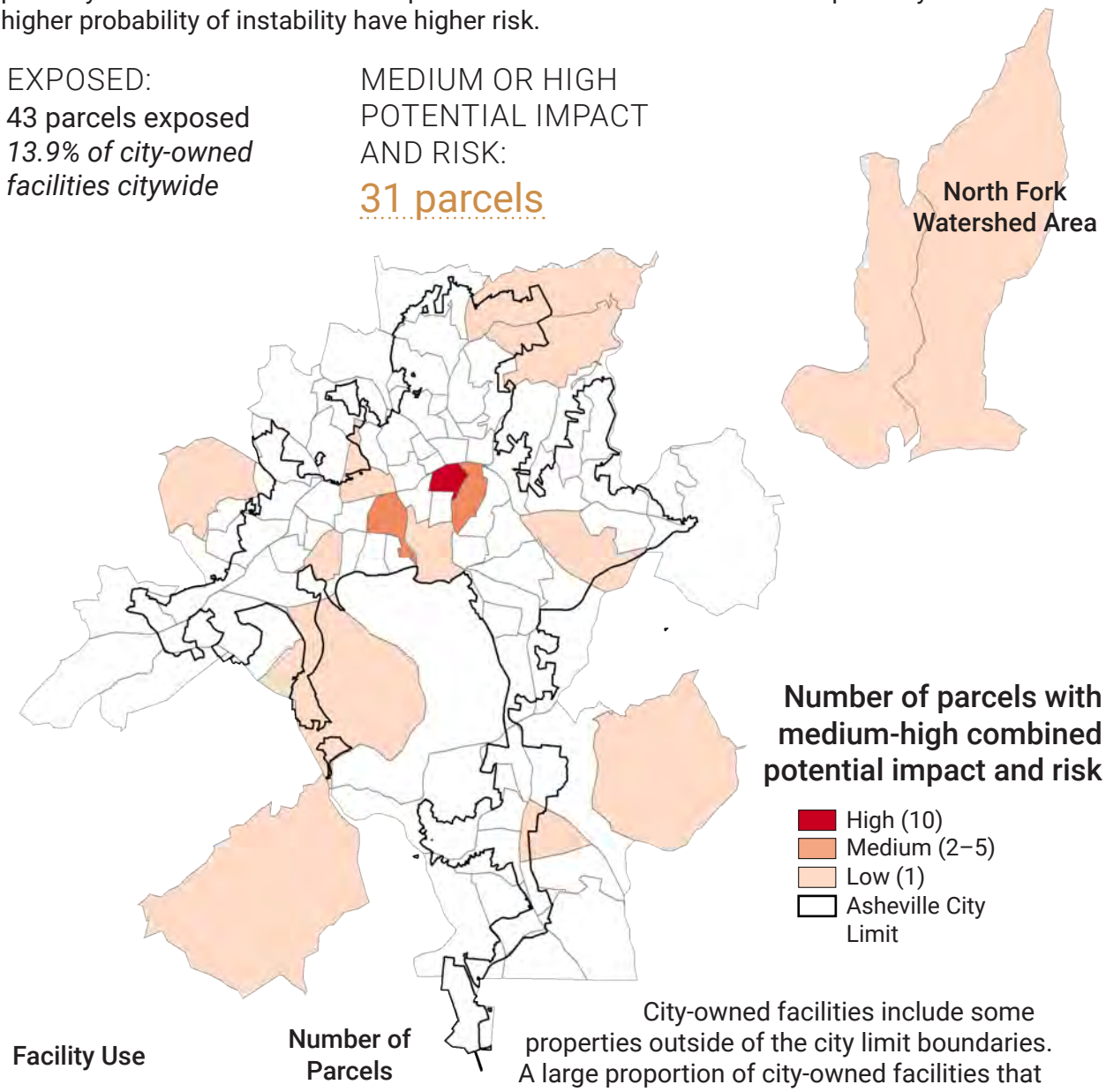
City-Owned Facilities / Landslides

Potential Impact & Risk Assessment

Includes all city-owned facilities except for those associated with parks and recreation. City-owned facilities were assessed on whether the properties had structures in debris flow pathways and their level of risk. Properties with structures in debris flow pathways with a higher probability of instability have higher risk.

EXPOSED:
43 parcels exposed
13.9% of city-owned facilities citywide

MEDIUM OR HIGH POTENTIAL IMPACT AND RISK:
31 parcels



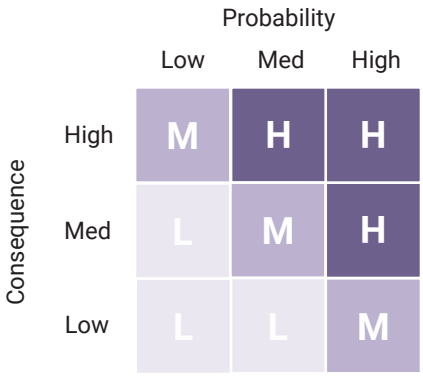
Facility Use	Number of Parcels
Public Works	11
Transportation	10
Water Resources	6
Economic & Community Development	2
Administration	2

City-owned facilities include some properties outside of the city limit boundaries. A large proportion of city-owned facilities that are exposed to landslides have a medium or high potential impact and risk (76%). The Public Works and Water Resources Departments have the most facilities with high potential impact and risk to landslides. Almost half (15) of these properties have structures in debris flow pathways, while the others are properties with high likelihood of debris flow activity.

City-Owned Facilities / Landslides

Assessment Criteria

POTENTIAL IMPACT		RISK		
			Probability	**Consequence**
High	Structure in debris flow pathway	High	Probability of instability >50%	Structure affected
		Medium	Probability of instability <50%	Structure affected
Low	No structure in debris flow pathway (land only)	Low	Probability of instability low	No structure affected



Combined Potential Impact and Risk

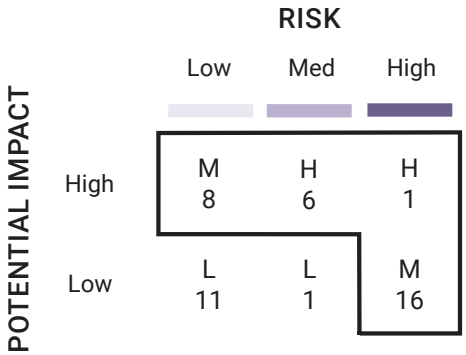
Parcels with:

High Potential Impact/Low Risk (8)
Facility has structure in debris flow pathway with low probability of instability

High Potential Impact/Medium Risk (6)
Facility has structure in debris flow pathway with medium probability of instability

Low Potential Impact/High Risk (16)
Facility has property (land only) in debris flow pathway with high probability of instability

High Potential Impact/High Risk (1)
Facility has structure in debris flow pathway with high probability of instability



31 parcels

with medium or high combined potential impact and risk

Commercial Property / Landslides

Vulnerability & Risk Assessment

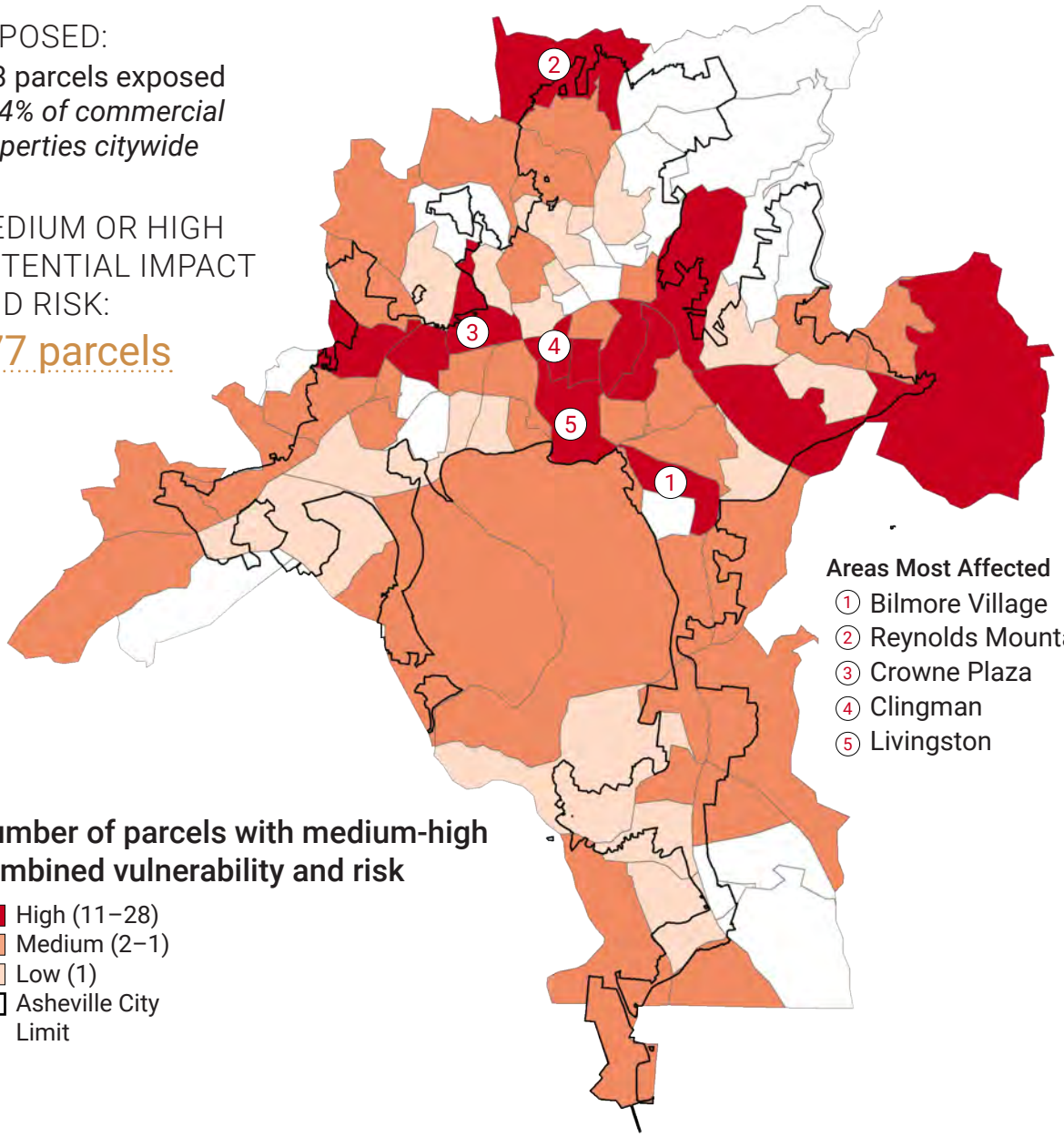
Commercial properties that are business-related with structures in debris flow pathways that were built without meeting current steep slope development requirements are most vulnerable. Properties with structures in debris flow pathways with a higher probability of instability have higher risk.

EXPOSED:

563 parcels exposed
17.4% of commercial properties citywide

MEDIUM OR HIGH POTENTIAL IMPACT AND RISK:

377 parcels



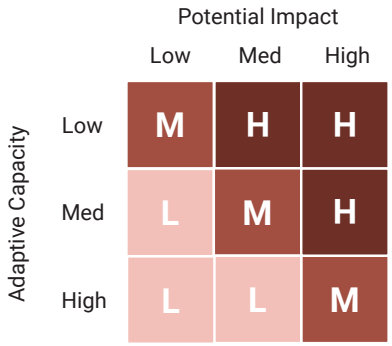
Commercial properties that are most vulnerable and at risk are found in some expected places along the Swannanoa and French Broad rivers (Biltmore Village and the Rivers Arts District), but are also in North Asheville just north of Beaver Lake.

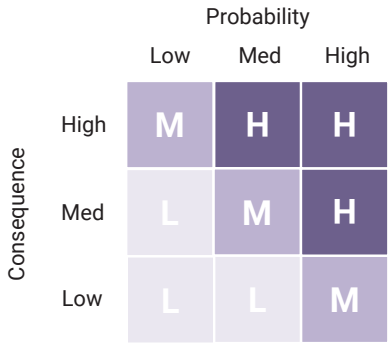
Commercial Property / Landslides

Assessment Criteria

	VULNERABILITY			RISK	
	Potential Impact	**Adaptive Capacity***		**Probability**	**Consequence**
High	Structure in debris flow pathway and business-related	No structure in debris flow pathway	High	Probability of instability >50%	Structure affected, value above median
Medium	Structure in debris flow pathway and warehouse or storage	Structure built after 2007	Medium	Probability of instability <50%	Structure affected, value below median
Low	No structure in debris flow pathway (land only)	Structure built 2007 or before	Low	Probability of instability low	No structure affected

* Adaptive capacity criteria are based on steep slope ordinances. Over the years, ordinances have had different requirements for development on steep slopes and vegetation removal.





Combined Vulnerability and Risk

Parcels with:

High Vulnerability/Low Risk (76)
Business-related structure built before 2007 in debris flow pathway with low probability of instability

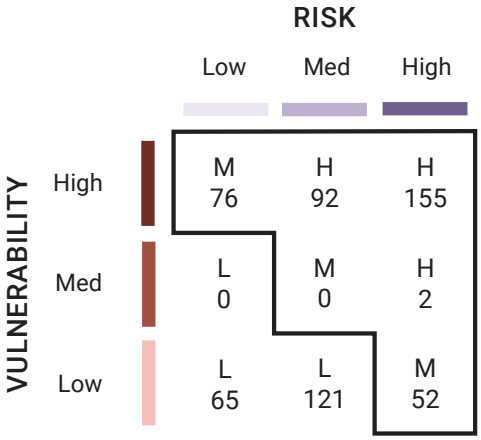
Medium Vulnerability/Medium Risk (0)
Business-related structure built after 2007 in debris flow pathway with medium probability of instability

Low Vulnerability/High Risk (52)
Storage structure built after 2007 in debris flow pathway with high probability of instability

High Vulnerability/Medium Risk (92)
Business-related structure built before 2007 in debris flow pathway with medium probability of instability

Medium Vulnerability/High Risk (2)
Storage structure built after 2007 in debris flow pathway with high probability of instability

High Vulnerability/High Risk (155)
Business-related structure built before 2007 in debris flow pathway with high probability of instability



377 parcels
with medium or high combined vulnerability and risk

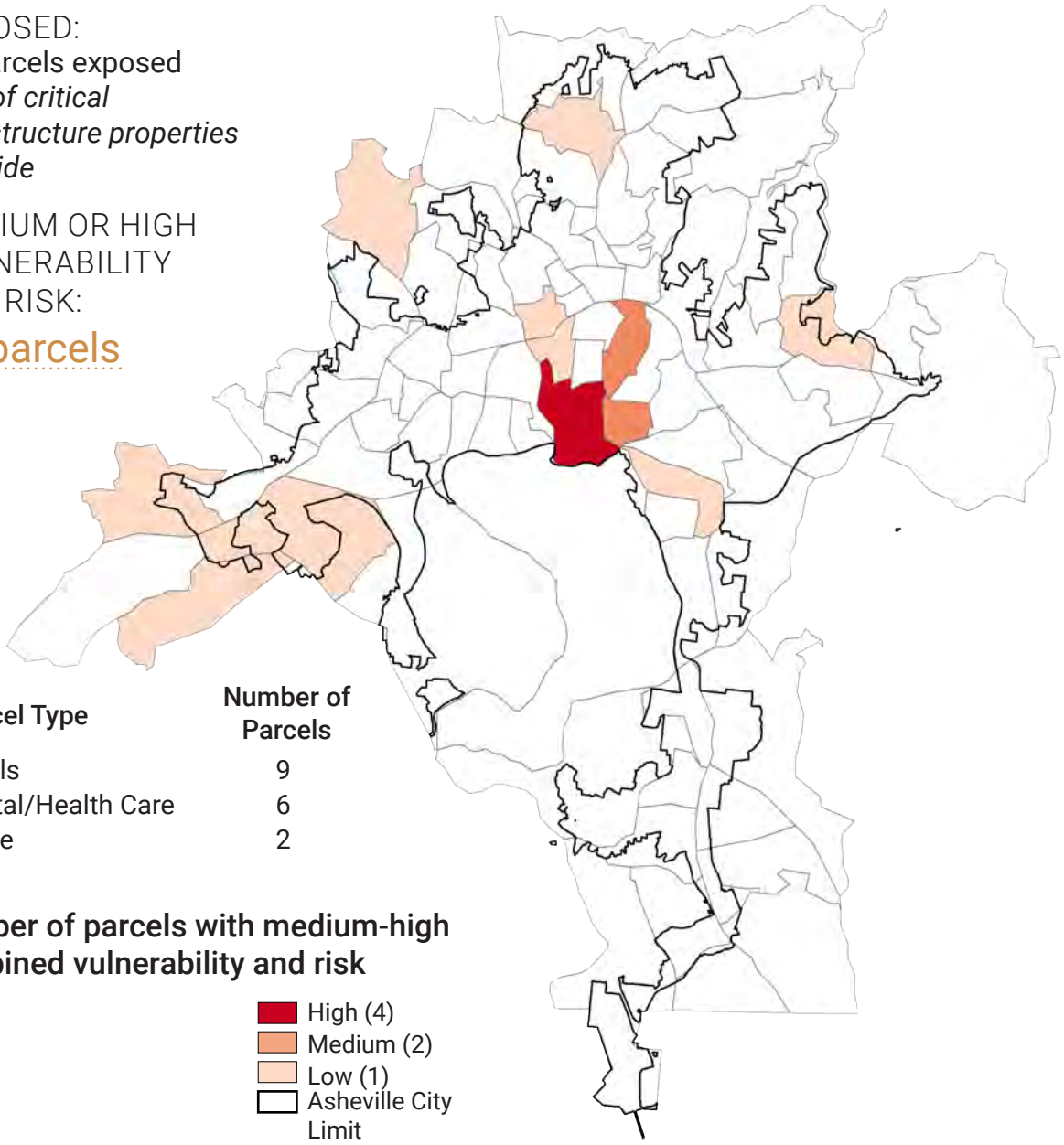
Critical Infrastructure / Landslides

Vulnerability & Risk Assessment

Critical infrastructure properties with structures in debris flow pathways that were built without meeting current steep slope development requirements are most vulnerable. Properties with structures in debris flow pathways with a higher probability of instability have higher risk.

EXPOSED:
36 parcels exposed
21% of critical infrastructure properties citywide

MEDIUM OR HIGH VULNERABILITY AND RISK:
17 parcels



Parcel Type	Number of Parcels
Schools	9
Hospital/Health Care	6
College	2

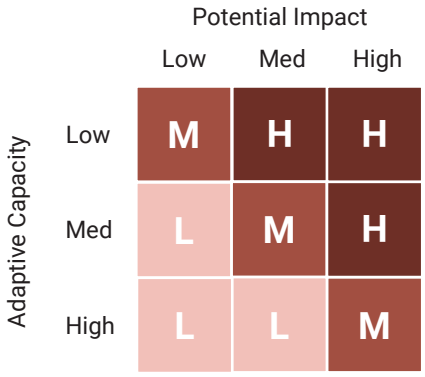
Out of the 36 critical infrastructure properties exposed, a total of 17 have medium or high combined vulnerability and risk. These are properties that provide a critical service and where a structure on the property has a relatively high likelihood of being affected by a landslide. The types of properties with high vulnerability and risk include schools, hospitals, and college facilities.

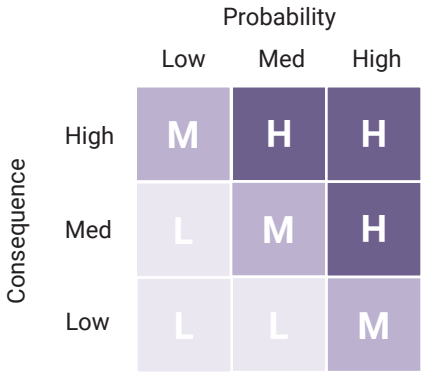
Critical Infrastructure / Landslides

Assessment Criteria

	VULNERABILITY		RISK		
	Potential Impact	**Adaptive Capacity***		**Probability**	**Consequence***
High	Structure in debris flow pathway	No structure in debris flow pathway	High	Probability of instability >50%	Structure affected
Medium		Structure built after 2007	Medium	Probability of instability <50%	Structure affected
Low	No structure in debris flow pathway (land only)	Structure built 2007 or before	Low	Probability of instability low	No structure affected

* Adaptive capacity criteria are based on steep slope ordinances. Over the years, ordinances have had different requirements for development on steep slopes and vegetation removal.





Combined Vulnerability and Risk

Parcels with:

High Vulnerability/Low Risk (0)
Structure built before 2007 in debris flow pathway with low probability of instability

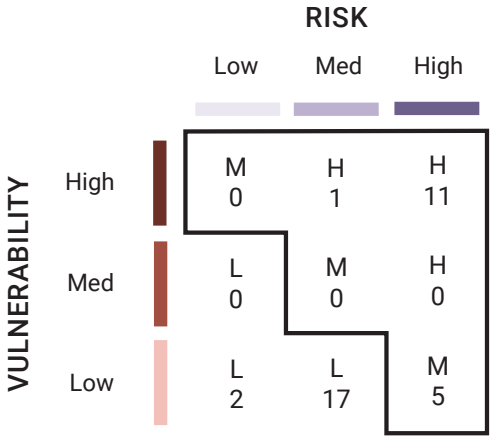
Medium Vulnerability/Medium Risk (0)
Structure built after 2007 in debris flow pathway with medium probability of instability

Low Vulnerability/High Risk (5)
Property (land only) in debris flow pathway with high probability of instability

High Vulnerability/Medium Risk (1)
Structure built before 2007 in debris flow pathway with medium probability of instability

Medium Vulnerability/High Risk (0)
Structure built after 2007 in debris flow pathway with high probability of instability

High Vulnerability/High Risk (11)
Structure built before 2007 in debris flow pathway with high probability of instability



17 parcels

with medium or high combined potential impact and risk

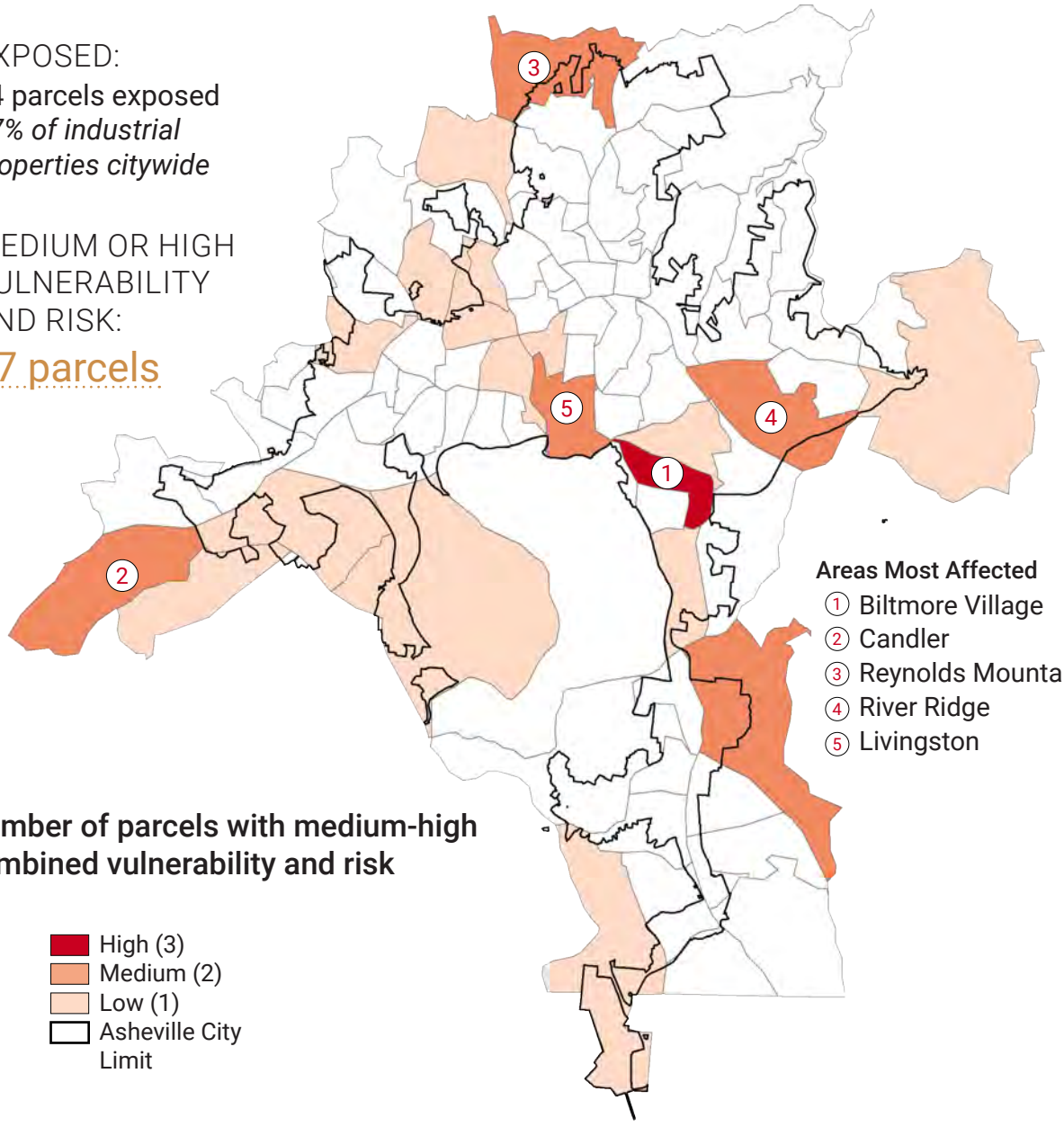
Industrial Property / Landslides

Vulnerability & Risk Assessment

Industrial properties that serve as sites for raw materials (such as gravel and concrete) and that have structures in debris flow pathways that were built without meeting current steep slope development requirements are most vulnerable. Properties with structures in debris flow pathways with a higher probability of instability have higher risk.

EXPOSED:
34 parcels exposed
37% of industrial properties citywide

MEDIUM OR HIGH VULNERABILITY AND RISK:
27 parcels



Industrial properties at risk of landslides are found in just a few areas. They are located mainly in the same areas where Commercial Properties are at risk to landslides, so some of the options should be considered for both assets.

Industrial Property / Landslides

Assessment Criteria

VULNERABILITY

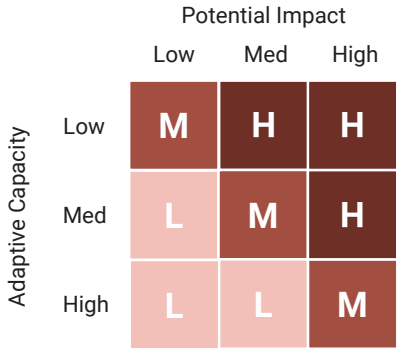
	Potential Impact	Adaptive Capacity*
High	Structure in debris flow pathway and raw material site	No structure in debris flow pathway
Medium	Structure in debris flow pathway	Structure built after 2007
Low	No structure in debris flow pathway (land only)	Structure built 2007 or before

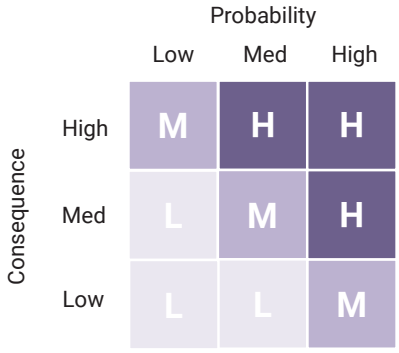
* Adaptive capacity criteria are based on steep slope ordinances. Over the years, ordinances have had different requirements for development on steep slopes and vegetation removal.

RISK

	Probability	Consequence*
High	No structure in debris flow pathway	Structure affected, value above median
Medium	Probability of instability <50%	Structure affected, value below median
Low	Probability of instability low	No structure affected

* Median value for industrial properties was $240,000.





Combined Vulnerability and Risk

Parcels with:

High Vulnerability/Low Risk (1)
Raw materials site with structure in debris flow pathway built before 2007 with high probability of instability

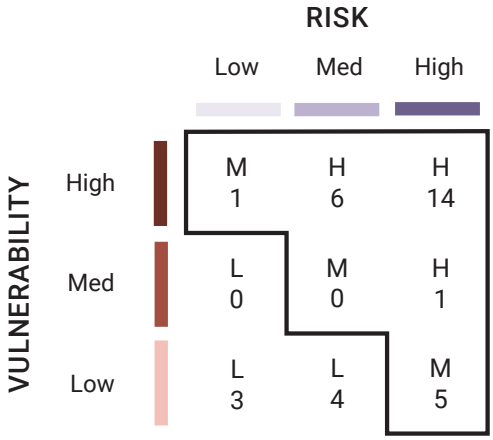
Medium Vulnerability/Medium Risk (4)
Structure built before 2007 in debris flow pathway with medium probability of instability

Low Vulnerability/High Risk (1)
No structure (land only) in debris flow pathwaywith high probability of instability

High Vulnerability/Medium Risk (6)
Raw materials site with structure built before 2007 in debris flow pathway with medium probability of instability

Medium Vulnerability/High Risk (5)
Structure built before 2007 in debris flow pathway with with high probability of instability

High Vulnerability/High Risk (14)
Raw materials site with structure built before 2007 with high probability of instability



27 parcels

with medium or high combined vulnerability and risk

Residential Property / Landslides

Vulnerability & Risk Assessment

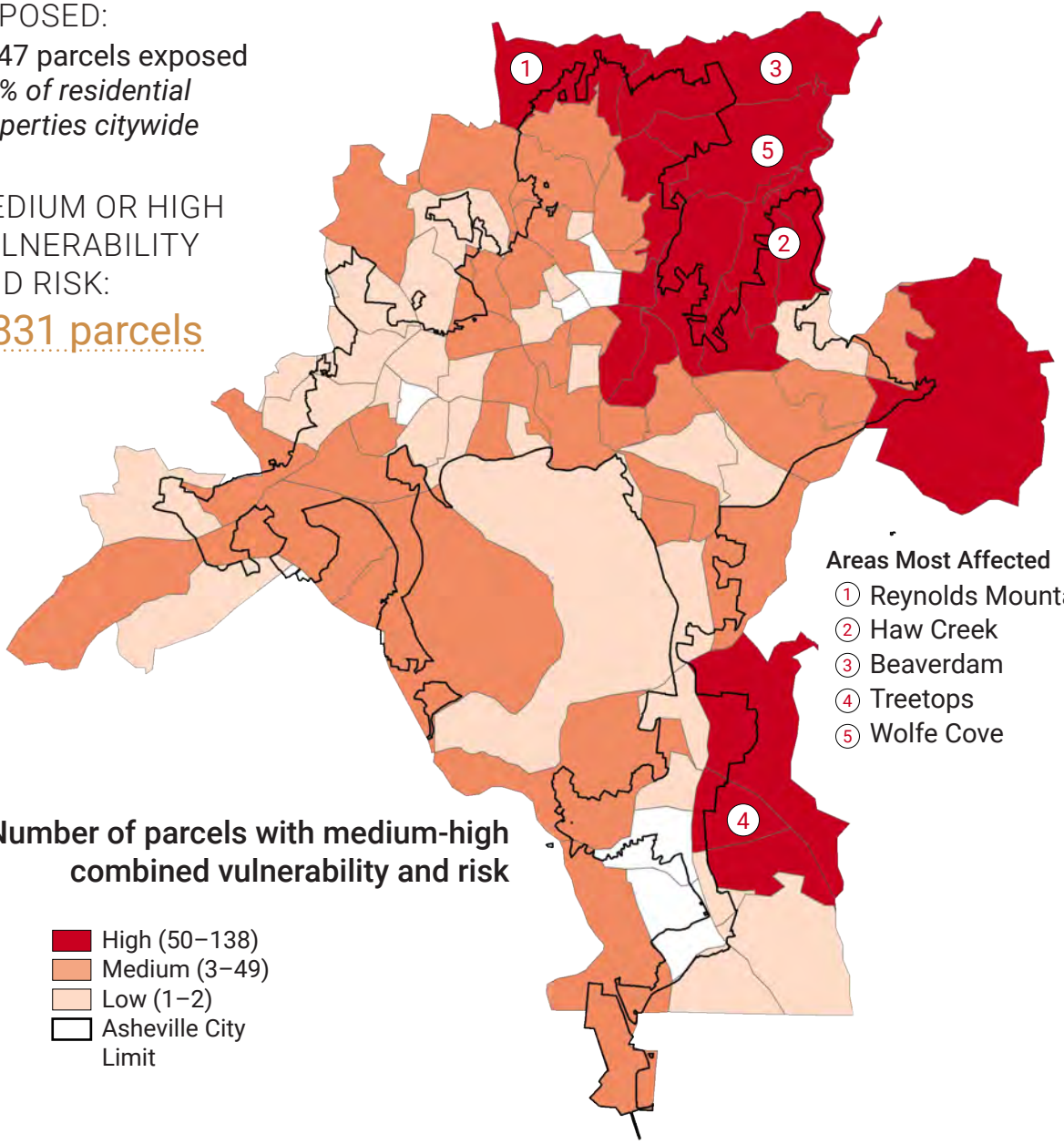
Residential properties were assessed based on the type of residence (e.g., multiple-residence, manufactured, or single-residence). Multiple-residence, apartment, manufactured, and mobile home park properties in debris flow pathways that were built without meeting current steep slope development requirements are most vulnerable. Properties with structures in debris flow pathways with a higher probability of instability have higher risk.

EXPOSED:

3,447 parcels exposed
8.2% of residential properties citywide

MEDIUM OR HIGH VULNERABILITY AND RISK:

1,831 parcels



Residential Property / Landslides

Assessment Criteria

VULNERABILITY

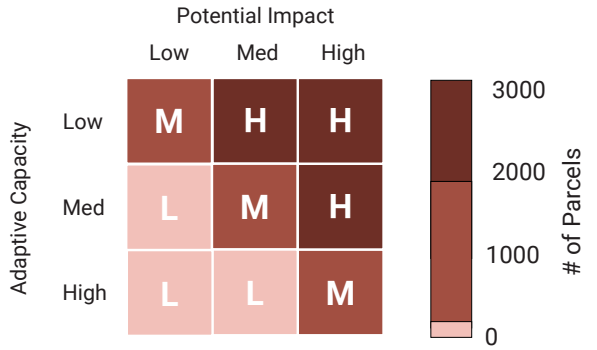
	Potential Impact	Adaptive Capacity*
High	Structure in debris flow pathway and multiple-residence, apartment, manufactured house, or mobile home park	No structure in debris flow pathway
Medium	Structure in debris flow pathway and single residence	Structure built after 2007
Low	No structure in debris flow pathway (land only)	Structure built 2007 or before

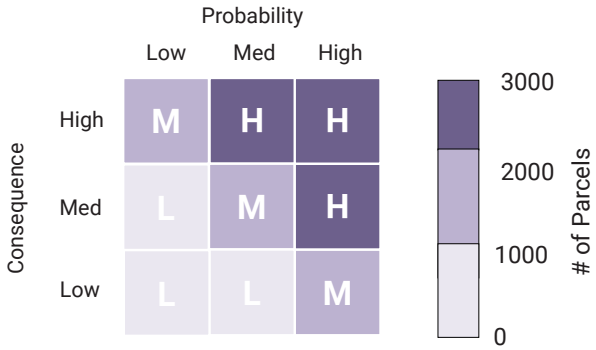
* Adaptive capacity criteria are based on steep slope ordinances. Over the years, ordinances have had different requirements for development on steep slopes and vegetation removal.

RISK

	Probability	Consequence*
High	Probability of instability >50%	Structure affected, value above median
Medium	Probability of instability <50%	Structure affected, value below median
Low	Probability of instability low	No structure affected

* Median value for residental properties was $127,500.





Combined Vulnerability and Risk

Parcels with:

High Vulnerability/Low Risk (381)
Multiple-residence structure in debris flow pathway built before 2007 with low probability of instability

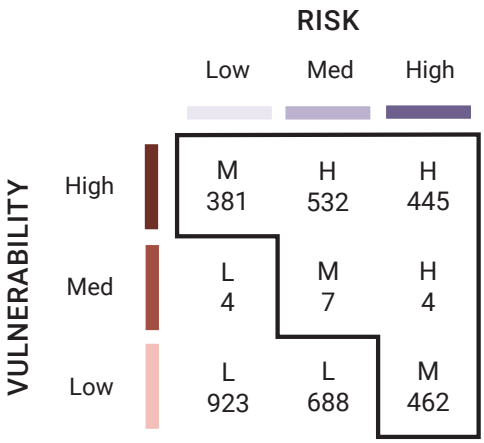
Medium Vulnerability/Medium Risk (584)
Single residence structure in debris flow pathway built before 2007 with medium probability of instability

Low Vulnerability/High Risk (11)
No structure (land only) in debris flow pathway with high probability of instability

High Vulnerability/Medium Risk (532)
Multiple-residence structure in debris flow pathway built before 2007 with medium probability of instability

Medium Vulnerability/High Risk (458)
Single residence structure in debris flow pathway built before 2007 with high probability of instability

High Vulnerability/High Risk (443)
Multiple-residence structure in debris flow pathway built before 2007 with high probability of instability



1,831 parcels

with medium or high combined vulnerability and risk

Roads / Landslides

Potential Impact Assessment

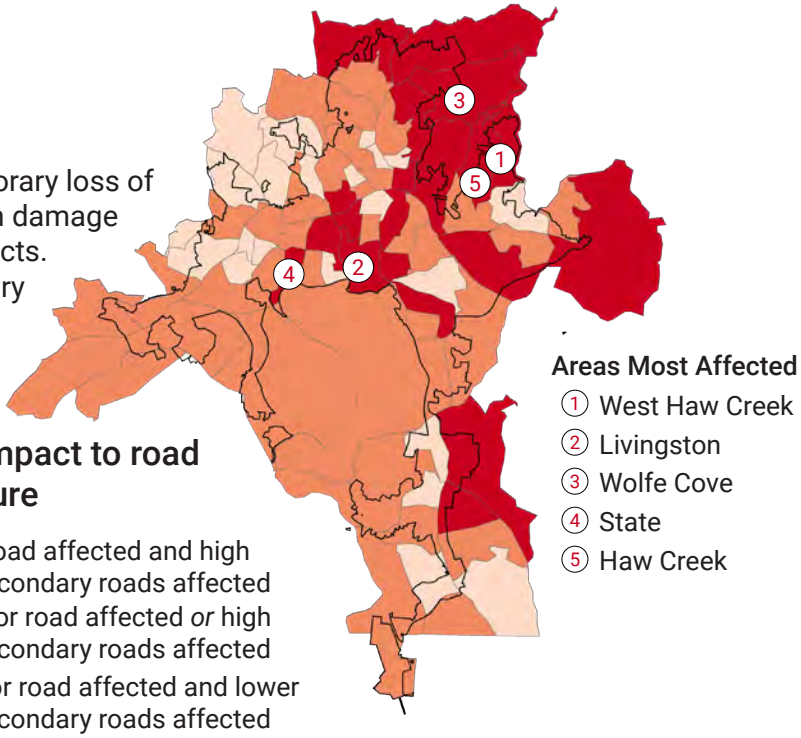
Roads were assessed based on the amount of road infrastructure potentially impacted and the critical access they provide for emergency services.

ROAD INFRASTRUCTURE

83 road miles potentially exposed

7.1% of roads citywide

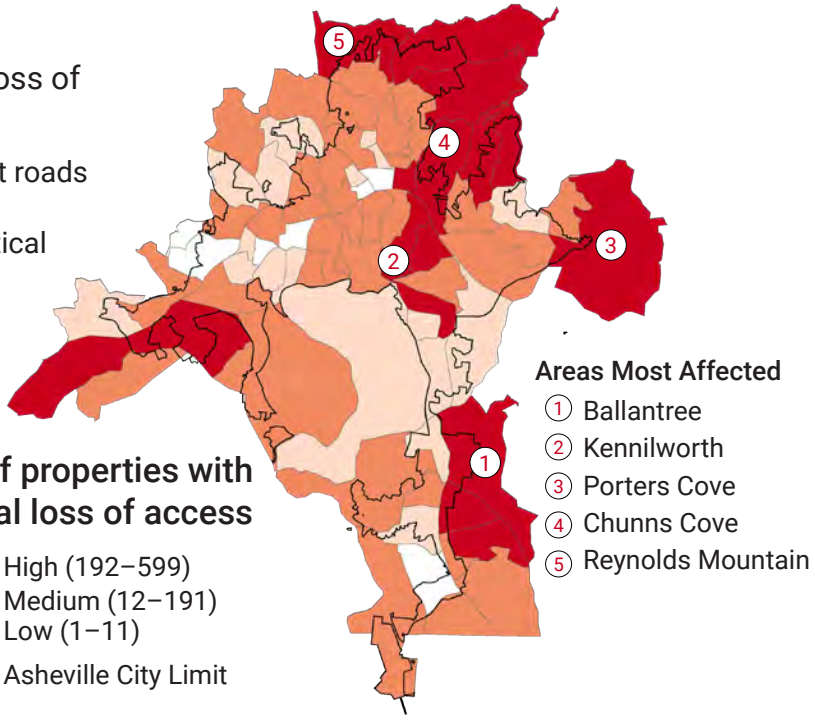
Debris from landslides can cause temporary loss of transportation service, or landslides can damage roads resulting in more significant impacts. Most of the exposed roads are secondary (67%), with the rest being major (33%). The areas with a high ranking have the highest potential impact, where both a major road and a high proportion of secondary roads are potentially affected by landslides. The medium-ranked areas are where either some major roads or a high proportion of secondary roads are potentially impacted.



LOSS OF CRITICAL ACCESS

8,700 parcels with potential loss of critical access

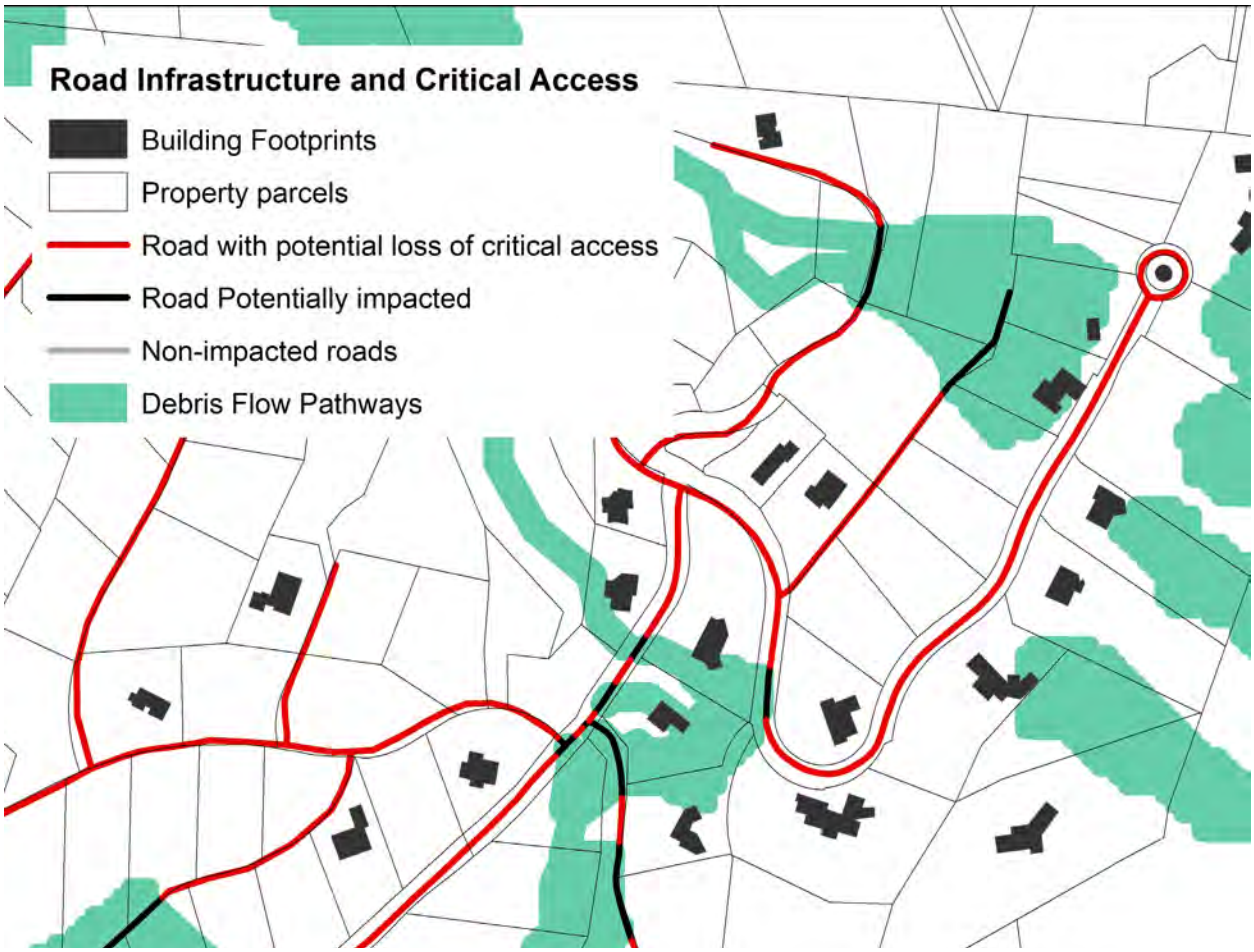
One of the most important functions that roads provide is critical access for emergency services. Areas with potential loss of critical access are where landslide events could result in properties being inaccessible by any Fire/EMS location due to impassable or damaged roads. The number of parcels affected (90% of which are residential) is for general purposes only, but the red areas are likely to have the highest number of properties with loss of critical access. Interestingly, these are not necessarily areas with a high proportion of road infrastructure affected.



Roads / Landslides

Assessment Criteria

	POTENTIAL IMPACT (POTENTIAL DEBRIS FLOW)	
	Road Infrastructure	**Critical Access**
High	Any major road affected and high amount of secondary roads affected (>7%)	High number of non-vacant properties with potential loss of critical access for emergency services
Medium	Any major road affected or high amount of secondary roads affected (>7%), but not both	Moderate number of non-vacant properties with potential loss of critical access for emergency services
Low	No major road affected and lower amount of secondary roads affected (<7%)	Low number of non-vacant properties with potential loss of critical access for emergency services



The map shows an illustration of road infrastructure potentially affected and the potential loss of critical access to properties.

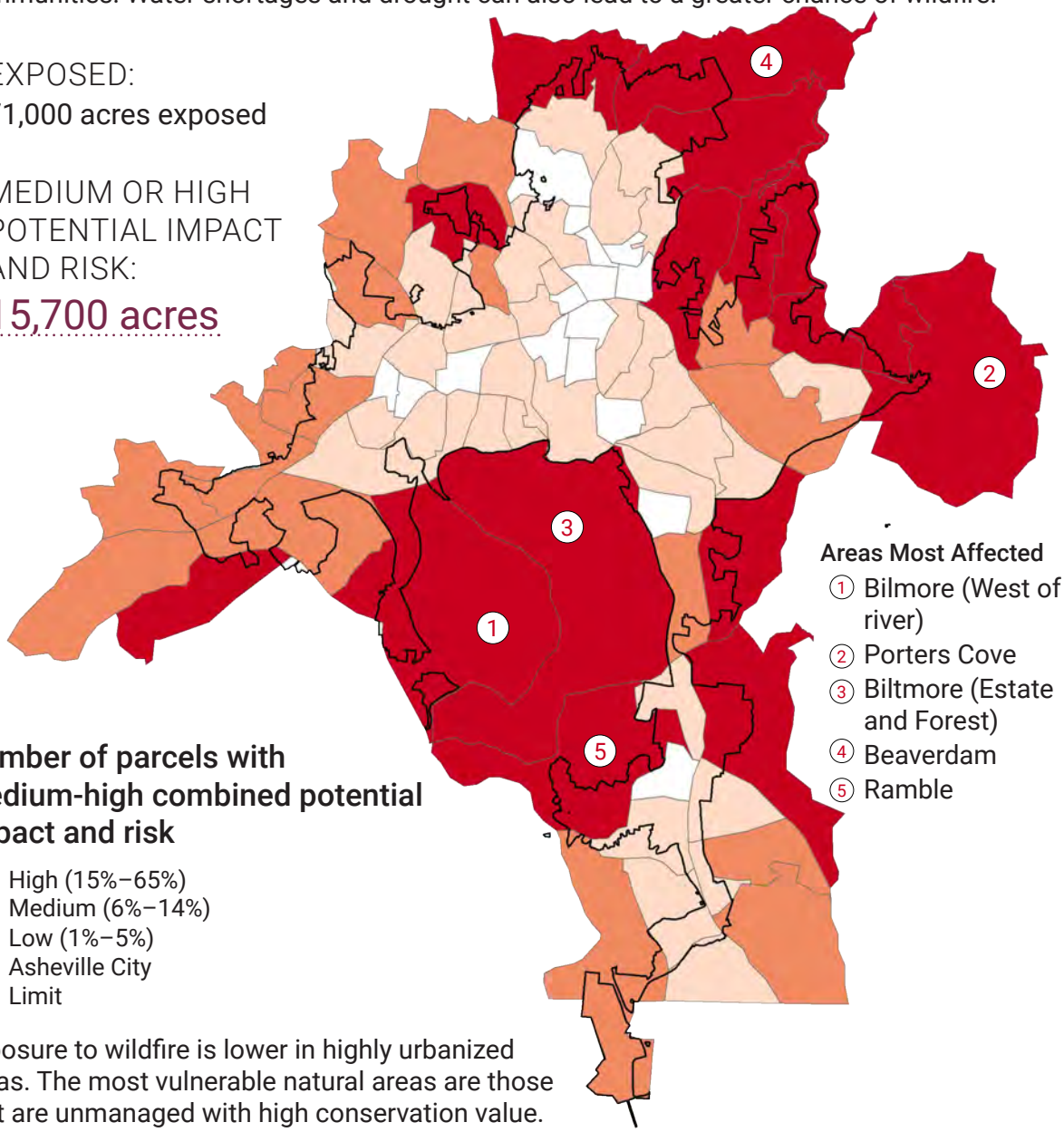
Natural Areas for Habitat and Conservation / Wildfire

Vulnerability & Risk Assessment

All natural areas with conservation value are exposed to wildfire. Lack of active management of fuels can contribute to a decline in fire-resilient ecosystems, an increase in wildfire burn severity, and an increased risk of destructive wildfires that damage landscapes and threaten people and communities. Water shortages and drought can also lead to a greater chance of wildfire.

EXPOSED:
71,000 acres exposed

MEDIUM OR HIGH POTENTIAL IMPACT AND RISK:
15,700 acres



Exposure to wildfire is lower in highly urbanized areas. The most vulnerable natural areas are those that are unmanaged with high conservation value. As expected, most large blocks of natural land with high conservation value are in the areas surrounding and outside of the Asheville city limits, with the exception of a few city parks and areas with high conservation value.

The more urbanized areas are within the city limits, where most census block groups are ranked low in terms of their total area percentage. However, most of the natural land in these urbanized areas is associated with riparian stream buffers, which are important for regulating stream flows and for maintaining water quality.

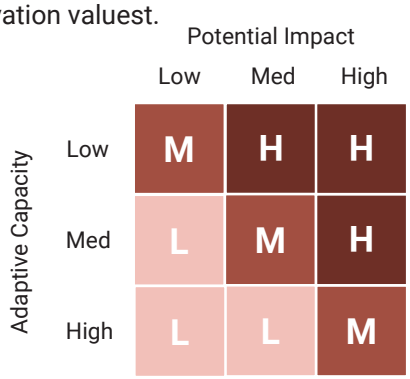
Natural Areas for Habitat and Conservation / Wildfire

Assessment Criteria

	VULNERABILITY		RISK
	Potential Impact*	**Adaptive Capacity****	**Probability**
High	High conservation value (7–10)	Area managed for disturbance and for biodiversity (GAP status 1 or 2)	>55% Burn Probability
Medium	Moderate conservation value (2–6)	Area managed for multiple uses, but not for biodiversity or habitat (GAP status 3)	33%–55% Burn Probability
Low	Low conservation value (1)	No known management	33% Burn Probability

* Potential Impact is based on NCDEQ's Biodiversity/Wildlife Habitat Assessment conservation valuest.

** Adaptive capacity criteria are based on GAP management status.



Combined Vulnerability and Risk

Parcels with:

High Vulnerability/Low Risk
Area with high conservation value and no known management
with low burn probability

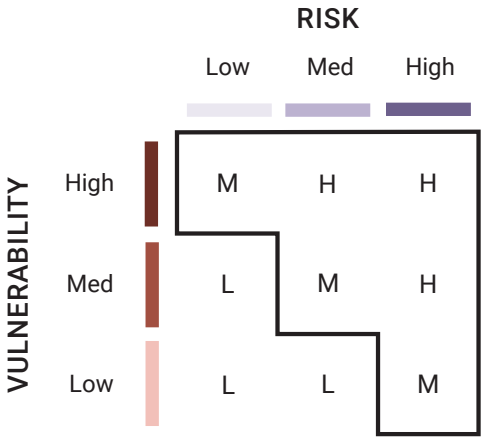
Medium Vulnerability/Medium Risk
Area with moderate conservation value managed for multiple
uses with medium burn probability

Low Vulnerability/High Risk
Area with moderate conservation value managed for disturbance
with high burn probability

High Vulnerability/Medium Risk
Area with high conservation value and no known management with medium burn probability

Medium Vulnerability/High Risk
Area with moderate conservation value managed for multiple
uses with high burn probability

High Vulnerability/High Risk
Area with high conservation value and no known management with high burn probability



15,700 acres
with medium or high combined vulnerability and risk

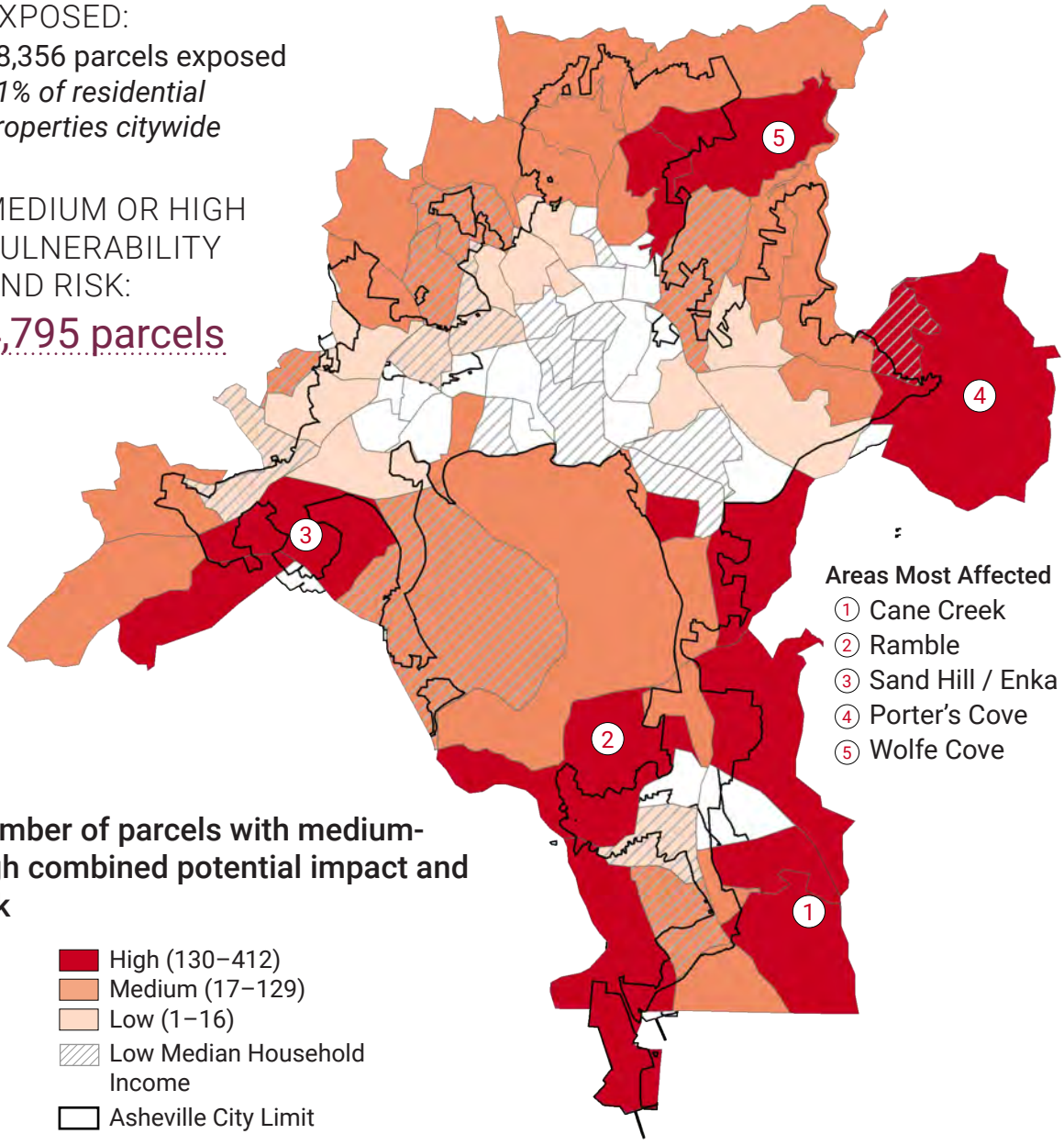
Residential Property / Wildfire

Vulnerability & Risk Assessment

Residential properties include all single-family residences, multiple-family residences, low-income housing, apartments, manufactured housing, and mobile home parks.

EXPOSED:
38,356 parcels exposed
91% of residential properties citywide

MEDIUM OR HIGH VULNERABILITY AND RISK:
4,795 parcels



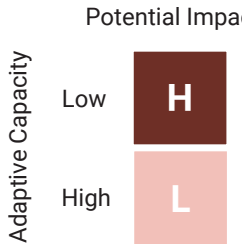
Vulnerability and risk for residential properties is the highest in Wildland Urban Interface (WUI) areas, some of which are also areas with steeper slopes. Homes in the WUI are in proximity to fire-prone vegetation and to forests with dead trees and branches that can serve as fuels for wildfire. Ignitions are usually human-caused, such as brush pile or backyard trash burning.

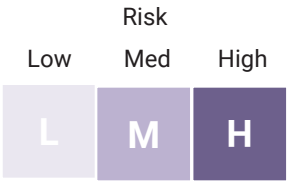
Residential Property / Wildfire

Assessment Criteria

	VULNERABILITY	
	Potential Impact	**Adaptive Capacity**
High	Property in WUI risk area	Property within 5-minute Fire/EMS drive time
Low	Property in WUI risk area	Property outside of 5- minute Fire/EMS drive time

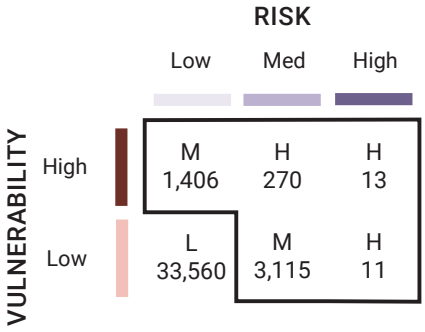
RISK	
High	High WUI Risk Index value (-9)
Medium	Moderate WUI Risk Index value (-8–-6)
Low	Low WUI Risk Index (-5–-1)





Combined Vulnerability and Risk

Parcels with:
High Vulnerability/Low Risk (1,406)
Property outside of 5-minute response time with low WUI risk
Low Vulnerability/High Risk (11)
Property within 5-minute response time with high WUI risk
High Vulnerability/Medium Risk (270)
Property outside of 5-minute response time with medium WUI risk
Low Vulnerability/Medium Risk (3,115)
Property within 5-minute response time with medium WUI risk
High Vulnerability/High Risk (13)
Property outside of 5-minute response time with medium WUI risk



4,795 parcels
with medium or high combined vulnerability and risk

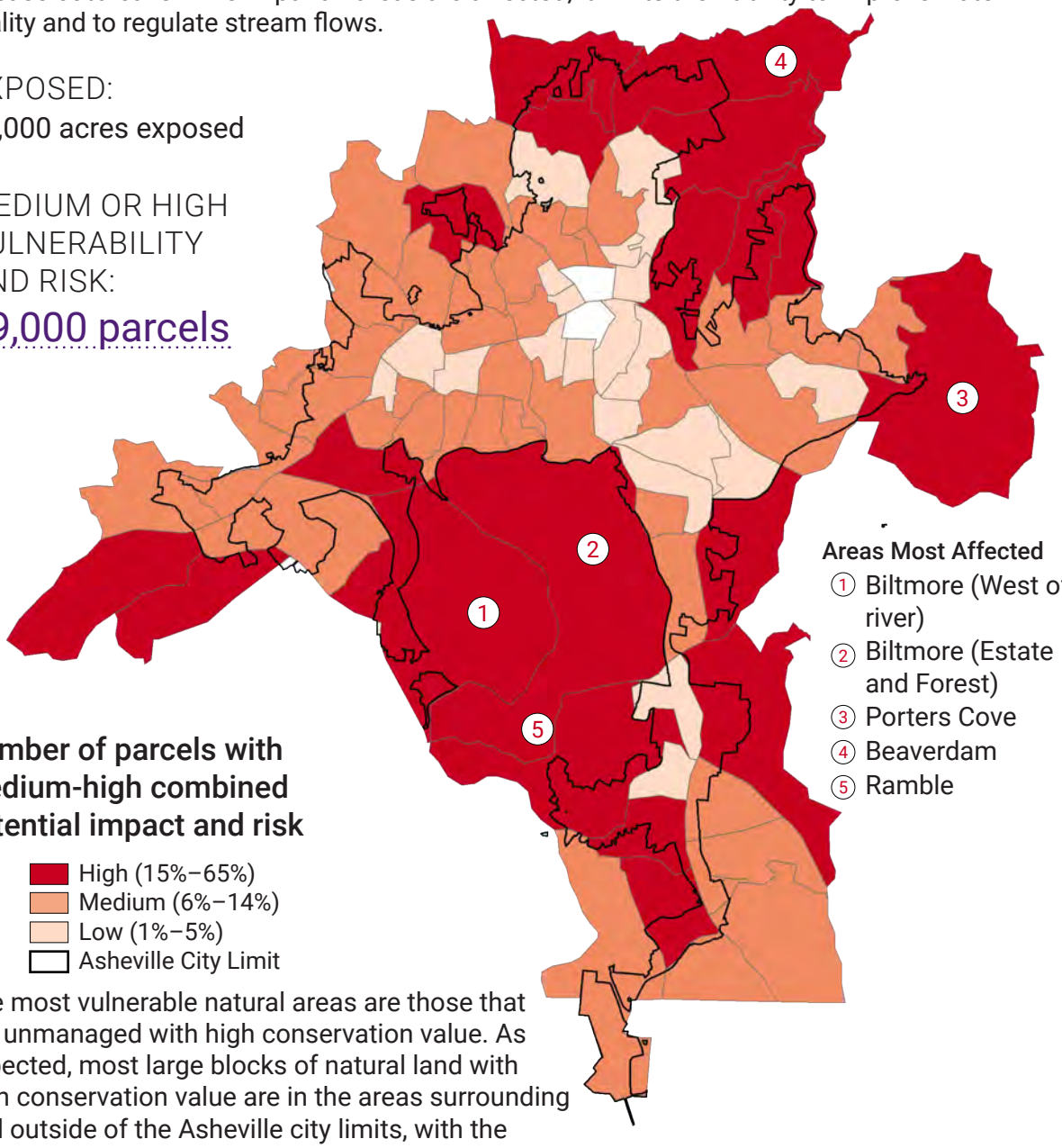
Natural Areas for Habitat and Conservation / Water Shortage Due to Drought

Vulnerability Assessment

All natural areas with conservation value are exposed to water shortages due to drought. In forested areas, water shortages can lead to greater susceptibility to insect infestations and disease outbreaks. When riparian areas are affected, it limits their ability to improve water quality and to regulate stream flows.

EXPOSED:
71,000 acres exposed

MEDIUM OR HIGH VULNERABILITY AND RISK:
19,000 parcels



The most vulnerable natural areas are those that are unmanaged with high conservation value. As expected, most large blocks of natural land with high conservation value are in the areas surrounding and outside of the Asheville city limits, with the exception of a few city parks and areas with high conservation value. The more urbanized areas are within the city limits, where most census block groups are ranked medium or low in terms of their total area percentage. However, most of the natural land in these urbanized areas is associated with riparian stream buffers, which are important for regulating stream flows and for maintaining water quality.

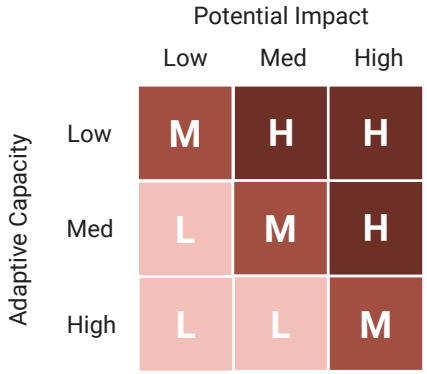
Natural Areas for Habitat and Conservation / Water Shortage Due to Drought

Assessment Criteria

	VULNERABILITY	
	Potential Impact*	**Adaptive Capacity****
High	High conservation value (7–10)	Area managed for disturbance and for biodiversity (GAP status 1 or 2)
Medium	Moderate conservation value (2–6)	Area managed for multiple uses, but not for biodiversity or habitat (GAP status 3)
Low	Low conservation value (1)	No known management

* Potential Impact is based on NCDEQ's Biodiversity/Wildlife Habitat Assessment conservation values.

** Adaptive capacity criteria are based on GAP management status.



Water Supply / Water Shortage Due to Drought

Potential Impact Assessment

Water supply for the City of Asheville is provided by three intake points: North Fork Reservoir, Bee Tree Reservoir, and Mills Gap intake on the French Broad River.

EXPOSURE

Buncombe County is one of the driest counties in North Carolina, receiving only about 40 inches of rain per year. This low rainfall, coupled with the lack of any viable regional aquifer that could be used for well waters, makes the City of Asheville's exposure to drought very high.

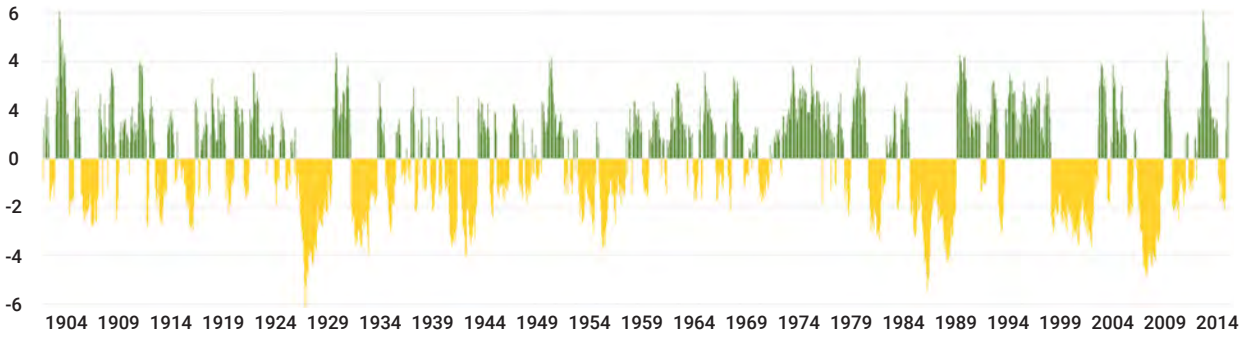
VULNERABILITY: MEDIUM

The city built adaptive capacity by adding two supply points in addition to North Fork Reservoir, reducing its overall vulnerability to drought and disruption of supply. Therefore, the vulnerability of water supply is medium.

RISK: MEDIUM-HIGH

Climate projections indicate that drought will continue to be a major threat to the City of Asheville. As demand on the city's water supply continues to grow, the threat of water shortage will increase, making the risk medium-high.

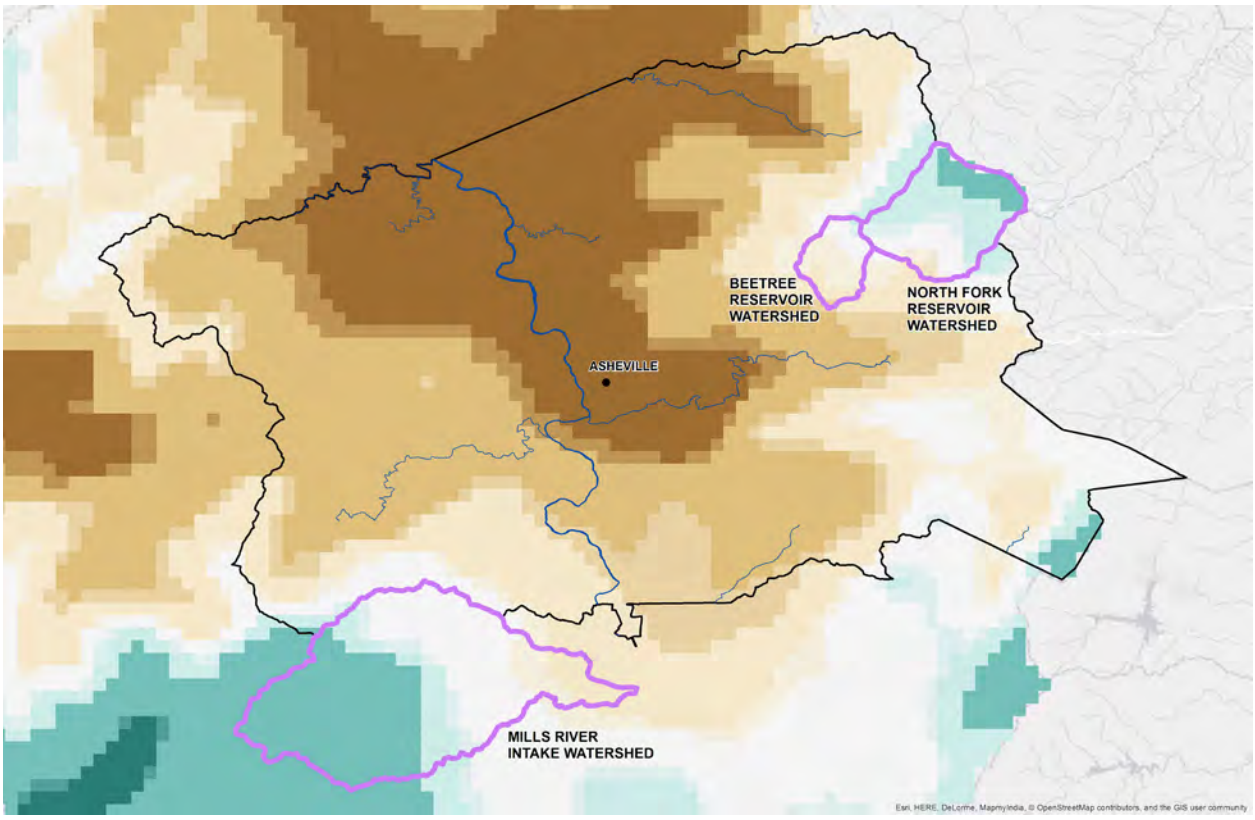
SOUTHERN MOUNTAINS, MONTHLY PALMER HYDROLOGICAL DROUGHT INDEX (PHDI) 1900–2015



Periods of drought are shown by the yellow bars. Note that Asheville experienced serious drought from 1997–2000, and then from 2005–2009. These two droughts were separated by the heavy precipitation events in 2004 that led to flooding.

Water Supply / Water Shortage Due to Drought

Assessment Criteria



Water Supply Watersheds and Average Annual Precipitation

- Major Rivers
- Water Supply Watersheds
- Buncombe County

Average Annual Precipitation (1981-2010) (Inches)

- 36 - 40
- 41 - 45
- 46 - 50
- 51 - 55
- 56 - 60
- 61 - 80
- 81 - 100

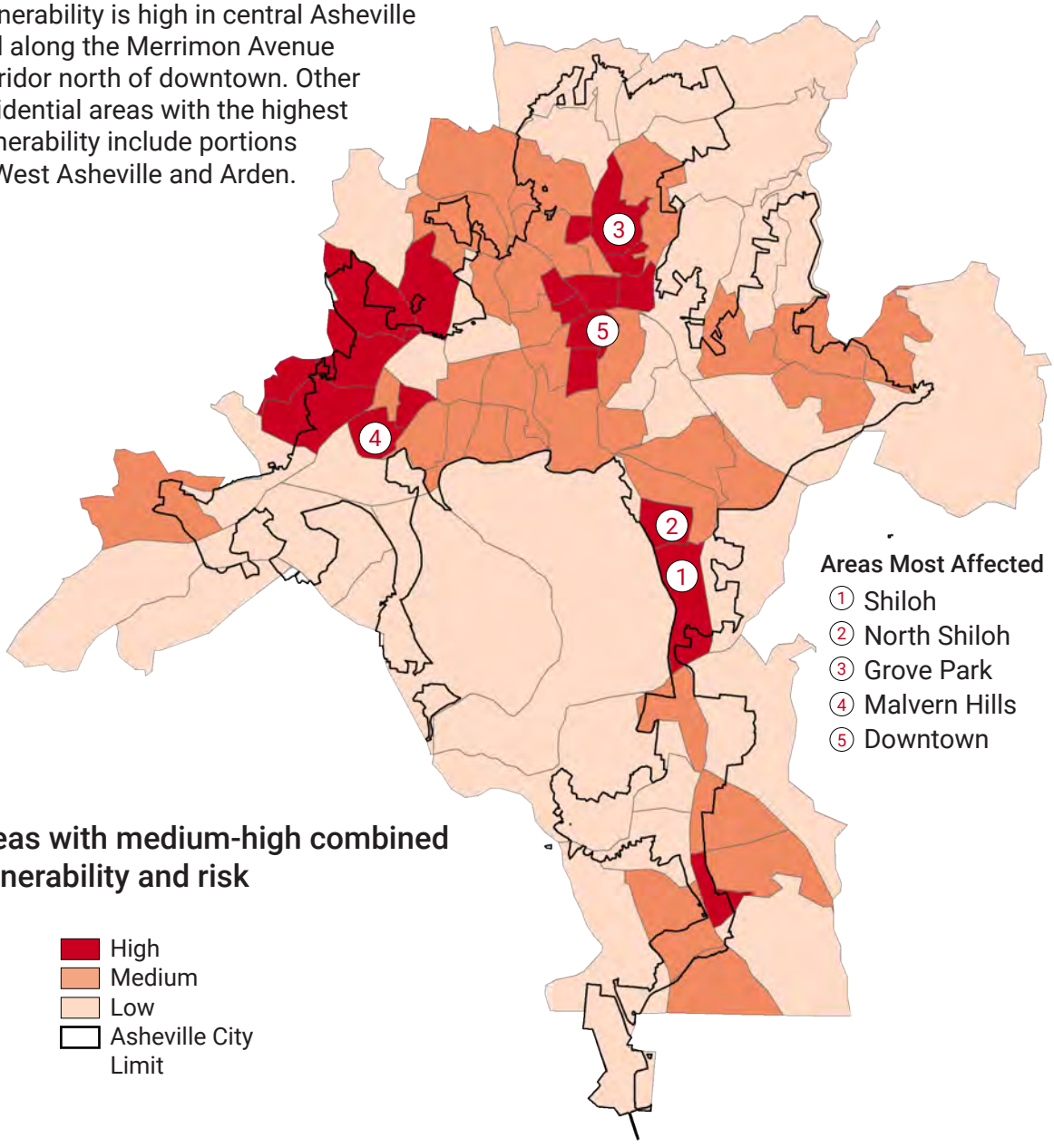
This map shows the regional exposure to water shortage by showing Asheville's drinking water watersheds and their relation to average annual precipitation. The dark brown color signifies 40 inches of average annual rainfall, while the turquoise is the upper limit of more than 60 inches per year. The French Broad Valley (where Asheville is located) is in a "rain shadow"—the surrounding mountains, with their higher elevations, receive more rainfall (due to the orographic effect). In addition, there are no deep continuous aquifers to provide reliable groundwater sources for wells. The North Fork Reservoir was established in the 1950s to provide a sustainable source of water due to this drought exposure. Increasing demand from a growing population and a changing climate that could bring more severe droughts is increasing the exposure (and therefore risk) of water supply sources for the region.

Residents / Nuisance Flooding, Runoff, Erosion

Vulnerability & Risk Assessment

All residential areas are exposed to nuisance flooding, runoff, and erosion. Areas with highest population density and the most impervious surfaces were determined to have the highest potential impact. The existing amount and condition of stormwater infrastructure was evaluated by determining a particular area's capacity to cope with runoff from heavy precipitation events. Areas with the highest vulnerability and risk are areas with high population density, high impervious surface area, and that have either a relatively low amount of stormwater infrastructure or where there is a relatively high amount of infrastructure with a high likelihood of failure that is also in proximity to densely populated areas.

Vulnerability is high in central Asheville and along the Merrimon Avenue corridor north of downtown. Other residential areas with the highest vulnerability include portions of West Asheville and Arden.



Residents / Nuisance Flooding, Runoff, Erosion

Assessment Criteria

VULNERABILITY

	Potential Impact	Adaptive Capacity
High	High total population density and high level of impervious surface	Low amount of high-priority infrastructure, or high amount of total stormwater infrastructure
Medium	Medium-high total population density or medium-high level of impervious surface	Moderate amount of high-priority infrastructure, or moderate amount of total stormwater infrastructure
Low	Low population density and low level of impervious surface	High amount of high-priority stormwater infrastructure (high consequence and high likelihood of failure), or relative low amount of stormwater infrastructure

RISK*

	Probability	Consequence
High	High likelihood of failure	Proximity to densely populated areas

* Risk criteria based on stormwater criticality assessment of high consequence due to proximity to densely populated areas and high likelihood of failure base on infrastructure material, age, condition, and potential population increase

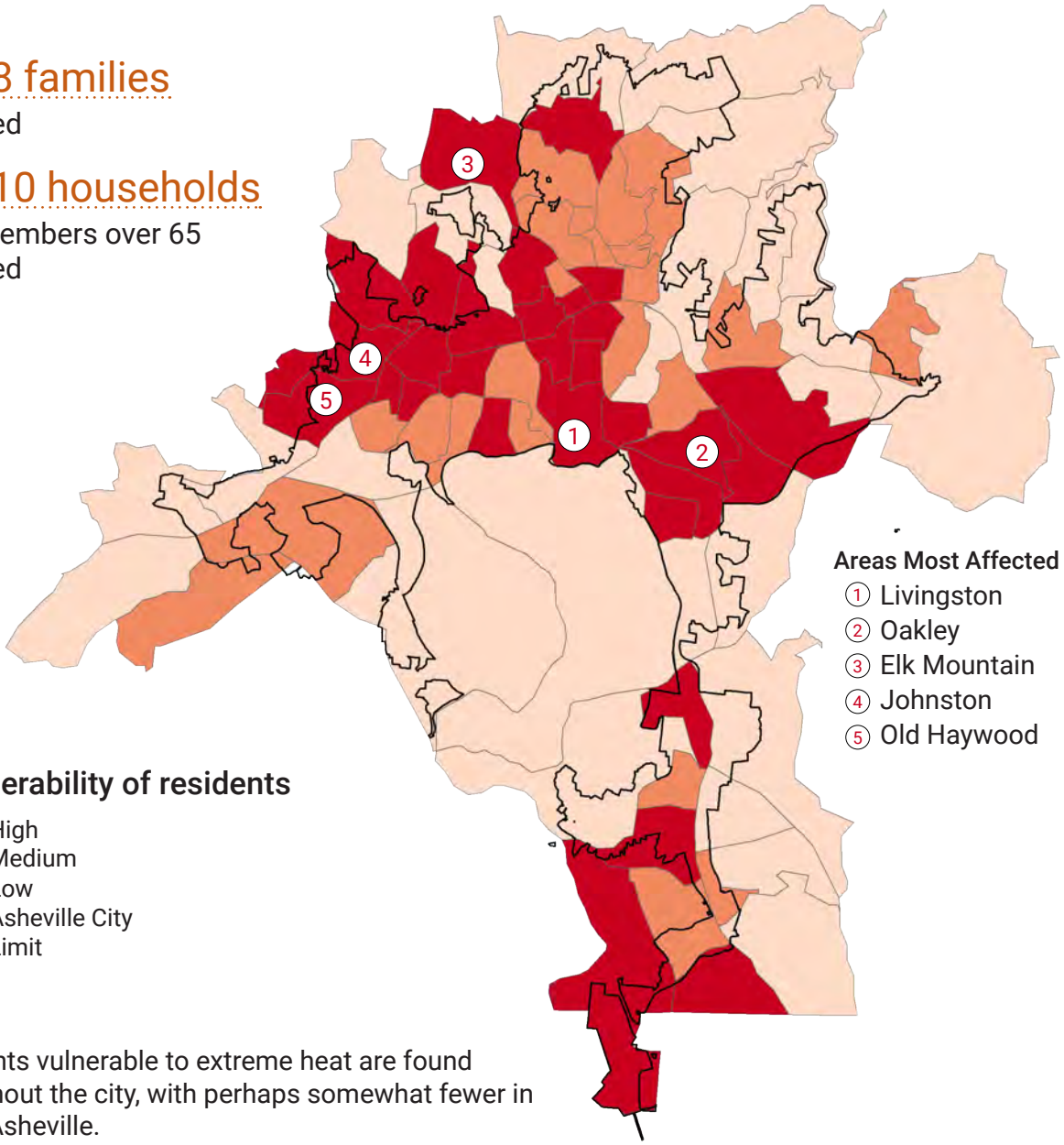
Residents / Extreme Heat

Vulnerability Assessment

The vulnerability of residents to extreme heat considers sensitive populations, including families living below the poverty line and households with members 65 years of age and older that live in proximity to developed land cover, as being exposed to a potential extreme heat event. The amount of tree canopy was used as a measure of adaptive capacity to an extreme heat event. Therefore, sensitive populations in areas with a high percentage of developed land cover and low tree canopy are most vulnerable to negative health effects from heat stress due to the urban heat island effect.

3,308 families
exposed

14,510 households
with members over 65 exposed



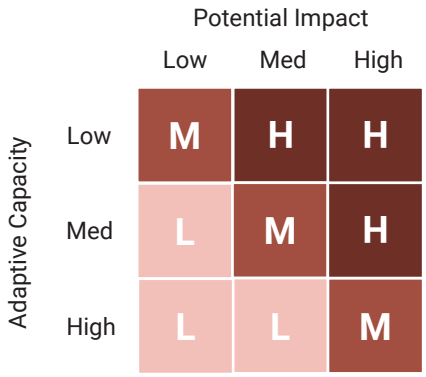
Residents vulnerable to extreme heat are found throughout the city, with perhaps somewhat fewer in North Asheville.

Residents / Extreme Heat

Assessment Criteria

VULNERABILITY

	Potential Impact	Adaptive Capacity
High	Highest number of sensitive populations and high percentage of developed land cover (>85%)	High average Tree Canopy (>62.2%)
Medium	Lower number of sensitive populations or lower percentage of developed land cover (62.5%–85%)	Moderate average Tree Canopy (38.8%–62.2%)
Low	Lower number of sensitive populations and low percentage of developed land cover (<62.5%)	Low average Tree Canopy (<38.8%)



Energy Supply Chains / Multiple Threats

Potential Impact Assessment

Asheville's energy supply is very exposed, both for electrical power generation and for mobility. A combination of climate and non-climate stressors have historically shown how vulnerable these supply chains are, and the risk is increasing. Multiple stressors and threats can result in supply chain interruptions, including tropical storm impacts in the Gulf of Mexico and coastal areas, landslides, and flooding events.

EXPOSURE

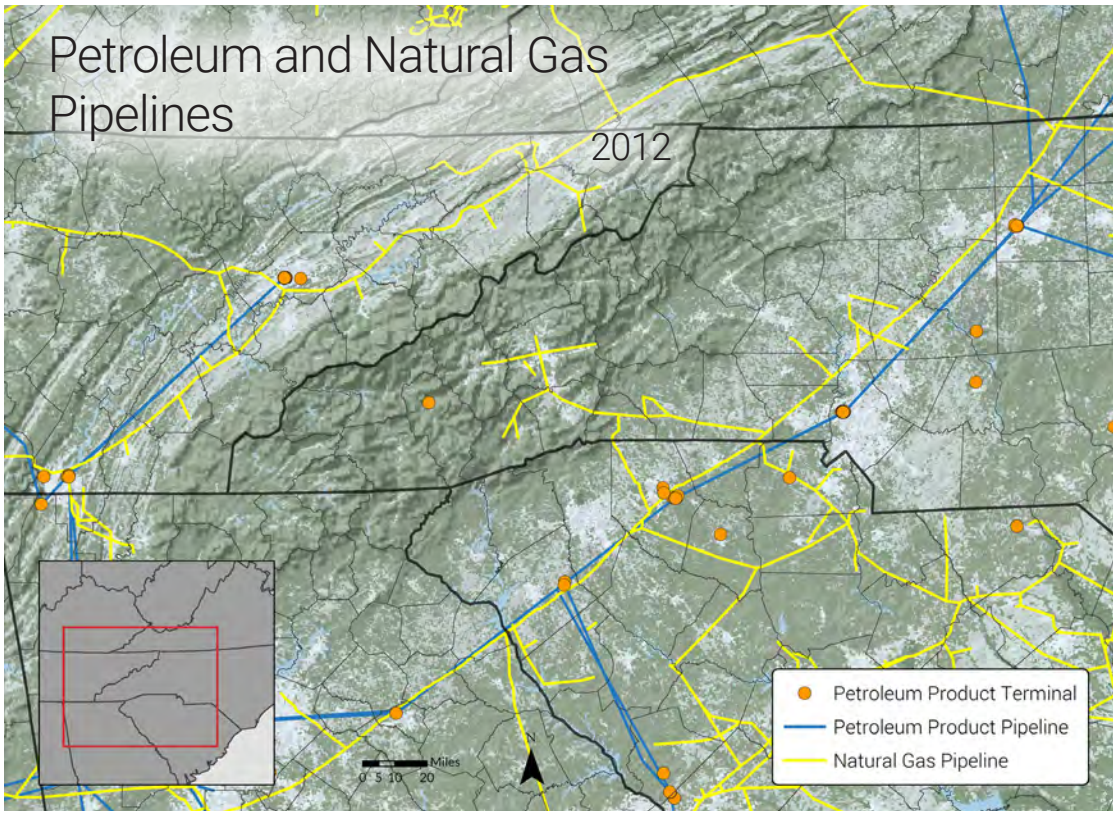
Most of our local energy needs are linked to hydrocarbons, either directly or indirectly. Because neither Asheville (nor other locations in North Carolina) produce their own oil and gas, this supply must come from other locations. Gasoline is delivered by tanker truck, coal for electricity generation is delivered by train, and natural gas is delivered through a single pipeline. All of these transportation routes have high exposure.

VULNERABILITY: HIGH

Recent gasoline shortages locally due to a disruption in the Colonial Pipeline in Alabama show the vulnerability of this supply chain. In addition, with Asheville being at the end of a supply chain that must compete for products with Charlotte, Atlanta, and Raleigh, it is difficult to obtain sufficient supplies during times of shortage. Vulnerability is high.

RISK: MEDIUM-HIGH

The consequences of a supply disruption include a large economic impact. Most of the workers in Asheville commute long distances to work using gasoline for individual cars. Disruption of coal or gas supply means that the local power plant cannot provide electricity. This is high risk.



Energy Supply Chains / Multiple Threats

Assessment Criteria

ENERGY USE AND DEMAND IN NORTH CAROLINA

(from Western North Carolina Vitality Index)

With no local deposits of coal, petroleum, or natural gas, the vast majority of energy resources for North Carolina's mountain region must be imported.

U.S. government data indicates that electric power generation companies in North Carolina spend an amount equivalent to nearly one percent of the state's total economic output on fossil fuels mined in other states. Most of the coal is mined in West Virginia and Kentucky, and the petroleum products come in by pipeline from the Gulf Coast.

The energy sector in North Carolina is the largest consumer of water, as nuclear, coal, and natural gas power plants require large amounts of water for cooling. Also, any future changes to precipitation patterns will have significant implications for hydroelectricity in Western North Carolina.

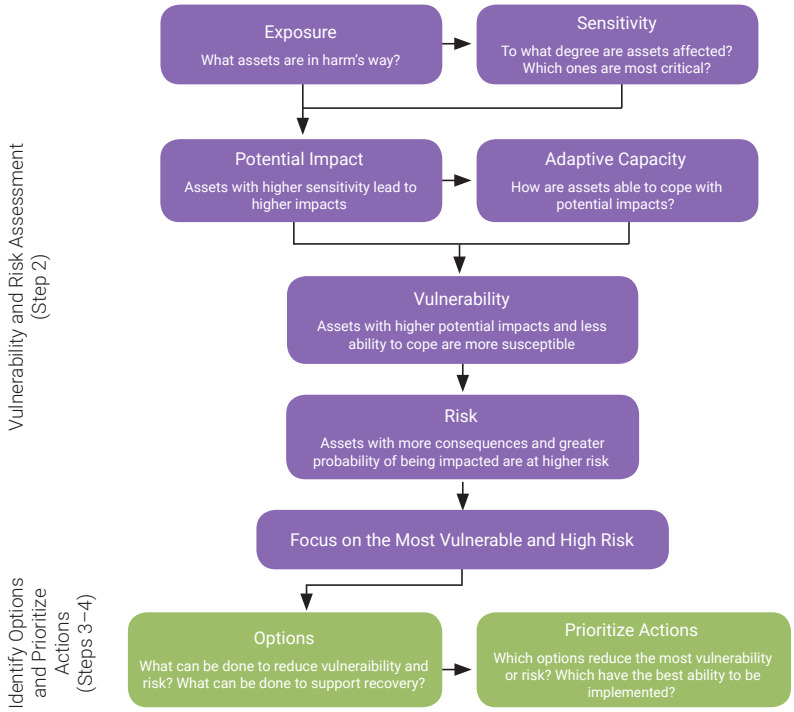
Energy demand and energy costs are expected to increase into the near future in Western North Carolina. A greater share of family income will have to be budgeted for this rising cost, whether it is for gasoline for our cars or heat and light for our houses.

As of 2008, the 27-county mountain region of North Carolina hosted 2,435 megawatts of electricity generation capacity—8.3 percent of the state's total generating capacity. Half the region's generating capacity was powered by coal, about 31 percent by water, and 17.4 percent by natural gas. The region's counties are home to 39 percent of the state's hydroelectric power capacity, 9.4 percent of the state's coal-fired capacity, and about 5 percent of natural gas-fired generation.

Step Three | Options to Build Resilience

The assessment in Step Two showed that some assets are more vulnerable than others. By the end of Step Two, members of the project team were able to begin asking questions related to their tolerance of risk and vulnerability, and were also able to identify specific assets and areas with higher risk or vulnerability as potential areas in which to build resilience.

The ultimate goal of Step Three is to have actionable options to build resilience for the assets that are determined to be most vulnerable and at-risk. To be actionable, an option should have the potential of building resilience by either (1) reducing exposure (removing assets from harm's way), (2) increasing adaptive capacity (increasing the asset's ability to cope with impacts), or (3) supporting response and recovery. Options also may build resilience by being proactive in dealing with future change.



The project team considered these questions during Step Three:

- What are the key vulnerabilities and risks that need to be addressed?
- What are the future changes that need to be considered? (These include not only climate-related changes, but also non-climatic changes such as population growth, demographic change, economic projections, etc.)
- What have other communities done to address similar issues?
- Are there vulnerabilities and risks that cannot be addressed?
- For a given option, what is the expected benefit?

In facilitated group brainstorming exercises, the project team worked to identify possible solutions and explored what other, similar groups have done.

Step Three often yields a large number of options, and it can be difficult to evaluate and compare them all. The project team examined 14 key assets and seven threats identified during the Step Two workshops, and used the vulnerability assessment and risk scoping exercises to create more focused resiliency options. While many options were identified as being applicable citywide, some options were examined for smaller, neighborhood-level or similar scales. There were also seven types, or themes, of options identified, including:

- Hazard mitigation and emergency response
- Further analysis
- Ordinances and design standards
- Infrastructure
- Communication, education, and outreach
- Natural areas
- Supply chains

From this effort, the project team developed a comprehensive list of 125 options and strategies for the city to consider to address resilience (see Appendix C). These options and strategies were then carried forward to Step Four: Prioritizing Actions.

Step Four | Prioritized Actions

The prioritization process determined criteria on which to evaluate the options and strategies. The prioritization criteria considered by the project team included:

- Cost/benefit (impact of option),
- Synergy with the comprehensive plan,
- Political feasibility, and
- Financial feasibility.

During the prioritization workshops, the final criteria were used to evaluate the 125 options and strategies identified in Step Three. In addition to those criteria, the team also noted for each option potential stakeholders, whether it was an existing effort, and suggestions for implementation leads.

To complete the prioritization exercise, participants assigned a red, green, or yellow value—similar to a traffic light—to indicate how the options fit with each criteria. Then the higher-level strategies were identified.

Options	Cost/benefit	Comprehensive plan	Political feasibility	Financial feasibility
Option 1				
Option 2				
Option 3				
Option 4				

Active efforts and strategies

In the process of identifying and prioritizing resilience strategies, it was important to recognize steps that the city has already taken and strategies that the city and stakeholders are already working to implement. The findings of the assessment support continuing these efforts and strategies to help build resilience:

- **Hazard mitigation and emergency response planning.** The City of Asheville is a participating member of the Buncombe Madison Regional Hazard Mitigation Plan,

which was prepared in coordination with FEMA Region IV and the North Carolina Department of Emergency Management. City departments also address potential threats and hazards by working through the four phases of emergency response, which include mitigation, preparedness, response, and recovery. In addition, the city has implemented a rapid emergency notification service to alert citizens of hazard events.

- **City-led initiatives for further analysis.** A few examples of city-supported initiatives include:
  - A tree canopy and gap analysis, through the Asheville Tree Commission and Public Works, which seeks to better protect and preserve Asheville's trees.
  - The Energy Innovation Task Force, which is working to research and recommend energy efficiency and demand-side management programs.
  - The Flood Damage Reduction Task Force, appointed by the Asheville City Council in 2006, is made up of members from city staff, the development community, and private property owners. The task force's mission is to establish a regional approach and long-range plan for flood damage reduction, floodplain protection, and watershed management.
- **Development ordinances and design standards.** The city has ordinances for floodplain and steep slope development. The city's floodplain ordinance, a part of the Unified Development Ordinance, was last updated in 2010 to exceed FEMA standards, which helped the city achieve a 10 percent discount on flood insurance premiums for property owners in special flood hazard areas. For steep slope areas, the city has special requirements for removal of vegetation. The city also has proactive fire programs and building codes that follow the North Carolina Building Code for fire protection.
- **Partnerships and programs to further water conservation.** The City of Asheville participates and partners with organizations, such as the Mills River Partnership and others, to preserve and protect watersheds.
- **Plan and respond to protect homes and critical access points on steep slopes.** With the resources available, city departments work to maintain safety and access on city-maintained roads that can be susceptible to landslides or slope failures.

Summary of Options for Building Resilience in the City of Asheville

The following is a summary of findings from the prioritization effort for the climate resilience assessment, including high-level strategies that fit within the seven themes identified in Step Three. See Appendix C for a detailed list of identified options that fall within these strategies.

Based on the criteria used for prioritization, the strategies included are organized into three categories:

- Strategy identified as currently having a high priority for building resilience and that can be implemented based on current resources.
- Strategy identified as currently having a high priority for building resilience, but will require more stakeholders or resources.
- Strategy identified as currently having lower priority for building resilience and will require more stakeholders or resources

Hazard mitigation and emergency response

Provide information on all identified assets and threats to Emergency Management in order to update hazard mitigation plans
Work closely with Communication & Public Engagement (CAPE) to improve internal communications across city departments during hazard events
Work with Water Resources Department and CAPE to promote water conservation during periods of drought
Work with Emergency Management to enhance response and recovery programs associated with identified climate threats
Assess and plan for secondary and alternative access for all multimodal transportation routes
Create policy to address controlled burning requests to better mitigate wildfire risk

Further analysis

Conduct additional studies as necessary to determine detailed strategies for flood and landslide hazard mitigation

Ordinances and design standards

Work with Stormwater Services to enhance stormwater management in accordance with identified strategies outlined in the climate assessment and comprehensive plan

Ordinances and design standards

Increase use of stormwater and flood control measures identified in the climate assessment prioritization table
Modify the Unified Development Ordinance as it pertains to flooding in accordance with the climate assessment prioritization table
Modify the Unified Development Ordinance as it pertains to steep slopes in accordance with the climate assessment prioritization table

Infrastructure

Build resilience into existing city owned buildings and properties as it pertains to flood and heat threats identified in the climate assessment prioritization table
Upgrade stormwater infrastructure systems and enhance capacity through green infrastructure utilizing strategies identified in the comprehensive plan
Continue to build further capacity into water supply
Continue to improve water supply and distribution systems
Analyze mechanisms to improve road and bridge infrastructure as needed in order to reduce exposure and build adaptive capacity

Communication, education, and outreach

Promote climate resilience concepts and best management practices through public education and communication strategies
Develop partnerships to help promote green infrastructure strategies identified in the comprehensive plan

Natural areas

Increase adaptive capacity though improvements to landscape resilience

Supply chain

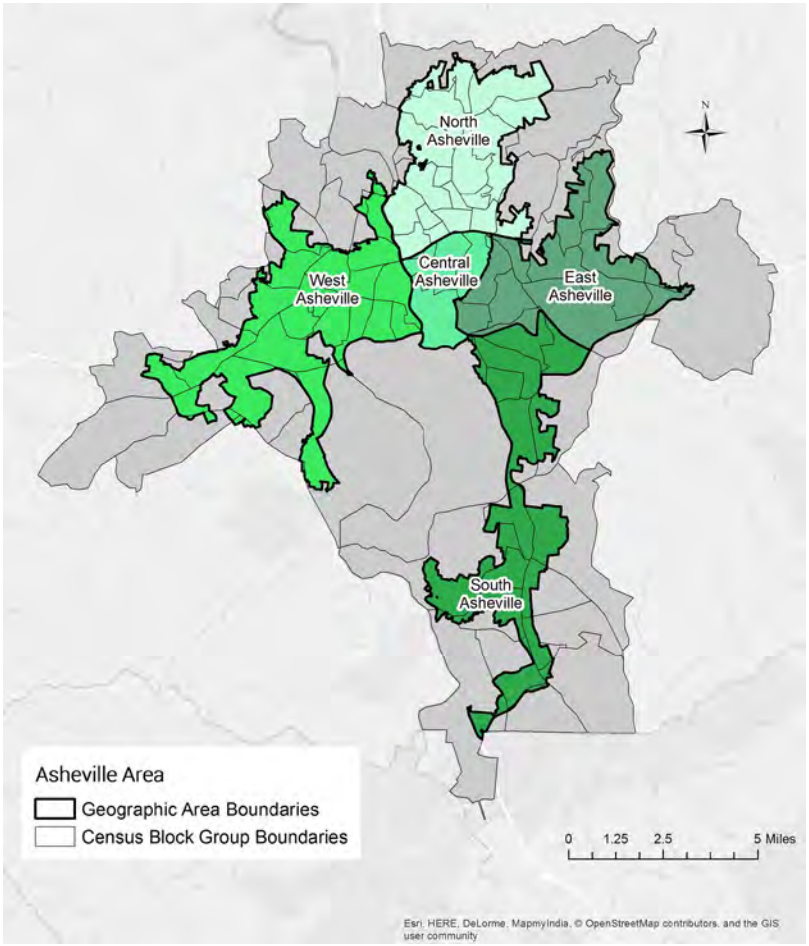
Prepare and plan for supply chain interruptions through partnerships with appropriate regional entities
Promote regional partnerships to build resilience

Geographic Areas | Vulnerabilities, Risks, and Options

As referenced in the introduction to this report, the options identified from the climate resilience planning process will be integrated into the city's comprehensive plan, *Living Asheville: A Comprehensive Plan for Our Future*.

The comprehensive plan uses a synergistic approach in its organization, and while it is primarily built around the six themes of a Livable Built Environment, a Resilient Economy, Harmony with the Natural Environment, Healthy Communities, Interwoven Equity, and Responsible Regionalism, there are no single topic chapters. Instead, the plan utilizes twelve overarching aspirational principles to help inform the development of more specific goals and strategies within the six themes.

These principles, which emerged through the public engagement process, are outlined in Book 1: Introduction. One of these twelve aspirations, Plan and Design with Nature in Mind, directly points to the need for Asheville to actively address the effects of climate change and calls for the implementation of the options and strategies outlined in this report. Throughout Book 2: Themes, there are also specific goals and strategies that address issues related to climate change. These include topics such as erosion control, flooding, stormwater management, development standards, and regional cooperation, to name a few.



The map shows the five geographic areas used for the City of Asheville's comprehensive plan. (Figure source: NEMAC.)

Additionally, it is recognized that many of the challenges facing Asheville, including vulnerability to certain climate threats, are better understood at the local level. Thus, the comprehensive plan characterizes the five geographic areas of the city and describes the unique strengths, threats, and challenges that pertain to these localized areas in a section called Plan Geographies, found in Book 3: Physical Strategies and Land Use.

Citywide

Water Shortage Due to Drought

Due to its leeward location in a central valley of the Southern Appalachian Mountains, Asheville is exposed to water shortages associated with drought. The central valley of the French Broad River—where Asheville is located—is one of the driest areas in the Southeast, receiving less than 40 inches of rain a year, whereas the higher mountains around Asheville can receive nearly twice that amount due to the orographic effect. Additionally, the geology of Asheville, with its very old, solid, and hard rock formations, prevents the absorption of water and makes it difficult to drill wells that could provide dependable high-flow quantities of groundwater.

In order to meet its water needs, Asheville has historically relied on the construction of reservoirs to retain runoff from the surrounding mountains. The majority of Asheville's freshwater currently is derived from the North Fork Reservoir, which was constructed in the 1950s. The reservoir usually holds about six billion gallons of water and drains a protected watershed of about 22,000 acres. During periods of drought (such as in 2002 and again in 2007–2008), the reservoir dropped to precariously low levels, but with water conservation measures in place the city was still able to meet local water needs.

As the region continues to grow, the demand for water has also grown. This need, coupled with the potential for more frequent and severe drought conditions, has resulted in the addition of the Bee Tree Reservoir and the French Broad intake at Mills River. While Asheville has built a degree of adaptive capacity into the system with these additional intake points, the continued increase in demand may eventually require further investment.

Beyond the increase of reliable water sources, the city is also pursuing the replacement of old water pipes throughout the system. A great quantity of water is lost as the water moves from its source to its destination due to old leaking pipes. These leaks are costly to the city not only because of the waste of water resources, but also due to the sinkholes and other related hazards that often result. One option to build resilience in this area would be to better map and locate the damaged pipes using subsurface monitoring.

Water Supply/North Fork Dam and Reservoir

Related to the issue of water supply discussed above is the robustness of the North Fork Dam. The dam actually serves two main hazard mitigation roles: it creates the reservoir for critical water supply, and also serves as the primary flood mitigation feature for the Upper Swannanoa River.

The mountain tops receive much more rain than the valleys, and it is not unusual for the mountains to receive over ten inches of rain in a 48-hour period. Without the dam, these types of precipitation events would cause major flooding along the Swannanoa River all the way from Black Mountain to Biltmore Village.

Unfortunately, the dam is an earthen dam created almost 70 years ago. If the dam were to be overtopped during an extreme precipitation event, subsequent erosion could cause a 500-year flood event.

To build resilience, the city has worked with an engineering firm to design a concrete dam to replace the earthen dam. This is one of the highest-ranked options that arose from this planning effort, and work is scheduled to begin in June 2017.

Energy Supply Chains

Asheville does not have any local hydrocarbon supply and limited alternative energy. Thus, all of the fuel for powering the city's electrical generation and transportation system must be brought in by road or rail.

The main source for gasoline and diesel fuel is the Colonial Pipeline, which runs from the Gulf Coast refineries to the Northeast through Atlanta, Greenville, Charlotte, Raleigh, and Richmond. When hurricanes or man-made factors disrupt the flow of supply through the pipeline, there is almost an immediate supply shortage in Asheville. Although these disruptions have not had a critical impact on Asheville in the past, the disruptions could become more common. A longer disruption would have a severe impact on the economic vitality of our region because most people rely on a steady supply of gasoline to power the vehicles that transport them to work. Possible options to build resilience could include negotiating more supplier contracts with vendors that link into the Northeast Pipeline, creating a more local set of storage tanks, and converting more of the city fleet to alternative fuels.

A related issue is the supply of natural gas. At the current time, there is only one major natural gas line that supplies our region. With Duke Energy's plans to switch the existing coal-burning power plant to natural gas, our community's exposure to supply disruption comes with much higher risk. The city should negotiate with Duke Energy and PSNC Energy to construct another gas pipeline into the mountains.

Wildfire

An increasing citywide risk is the vulnerability of residential properties to wildfire. Of all the threats to which residential properties are exposed, the assessment demonstrates that the threat of wildfire is the greatest (91% of residential properties exposed). While the vulnerability and risk may not be as high, it does show the potential for wildfire impacting residential areas. The large fires of 2016 that impacted the Gatlinburg, Tennessee, area highlight the seriousness of this risk. Homes with the highest risk are those on the city's periphery and those that are located on steep slopes. These homeowners should invest in making their properties more resilient to this threat, utilizing programs such as the National Fire Protection Association's Firewise Communities Program.

Flooding

The flooding assessments show that a major flooding event would have widespread impacts on the community. While only about 3.7% of residential properties are exposed to flooding, this still represents more than 1,500 residences. More than a third of these (572) have relatively high vulnerability and risk. Most of the residential properties at risk to flooding are along secondary streams and tributaries, such as along Sweeten Creek, Hominy Creek, and Beaverdam Creek. Commercial properties are also highly exposed, with about 13% of all commercial properties citywide having vulnerability. Transit assets are also highly exposed to flooding, as are food infrastructure assets (food locations in particular). The combination of these two assets being impacted in a major flood event would have large consequences on areas of the city where people rely on public transportation for access to food and services. Flooding would also have large impacts on road infrastructure and bridges and would result in up to approximately 6,000 properties being rendered inaccessible by emergency departments.

The City of Asheville is in the process of implementing actions to build resilience to impacts from flooding. Since 2004, the city has reduced exposure through property buyouts and has implemented flood control measures along the Swannanoa River in East Asheville. Still, a major challenge Asheville continues to face is increasing risk of flooding due to more development and impervious surfaces that contribute to flood events.

Landslides

Many assets in the City of Asheville are also exposed to landslide events. Some areas of the city in proximity to steep slopes have greater vulnerability and risk than other areas, particularly where buildings are in potential debris flow pathways. Industrial properties have the highest proportion of parcels with high vulnerability and risk (33%). Commercial properties, residential properties, critical infrastructure, and city-owned properties also have high vulnerability and risk.

The City of Asheville already has steep slope development ordinances that limit vegetation removal on steep slopes. A challenge Asheville continues to face is development pressure, and could consider zoning changes that would limit development on steep slopes, especially in high landslide risk areas.

Central Asheville

Central Asheville includes Downtown, the River Arts District and Livingston.

Landslides

In addition to the above, Central Asheville also has vulnerability to landslides. In such an event, access to critical infrastructure—including Mission Hospital and several schools—would be impacted. This emergency management plan should recognize this vulnerability.

Downtown: Extreme Heat and Vulnerable Populations

Asheville's Downtown area was established on a hill elevated above the French Broad River. Due to this siting, it experiences very little exposure to flooding, landslides, or wildfire. However, Downtown is heavily developed with a large amount of paved surfaces and reflective buildings, which causes this area to have higher daytime temperatures than other parts of the city. For this reason, people at risk will experience a greater exposure to extreme heat. Options being considered to build resilience include planting more trees in this urban zone, documenting vulnerable populations that live Downtown, and creating an educational program about proactive personal resilience to extreme heat.

River Arts District: Vulnerability to Flooding

The River Arts District (RAD), like Downtown, also has exposure to heat extremes and shares the related options to build resilience. Flooding, however, is a much larger threat to this area. This area was decimated by the historic 1916 flood and, at the time, the neighborhood was the heart of the city's commercial, industrial, and transportation sectors.

The RAD area has flooded five times over the past 100 years, so it is clear that exposure to flooding cannot be lowered. However, the area lies in the heart of the city and is currently the focus of a redevelopment effort having become popular for its concentration of working artist studios occupying the many older industrial buildings. The key to responsible development would be to build adaptive capacity into the neighborhood's every asset. The city is moving forward proactively in requiring that all

new building meet its floodplain ordinance, which requires that the base floor elevation be two feet above the level of the 100-year floodplain.

In addition to enforcement of its building ordinances, transportation solutions should consider alternative routes for key services during times of flooding, and design of greenways and similar recreation should include solutions that will limit erosion during periods of high flow. Finally, if any new residential property is planned for the RAD, access routes to the buildings should be designed so that they are above the 500-year floodplain.

Livingston: Food Access Vulnerability

This area that includes south-central Asheville and east of the river is a food desert, as categorized by the U.S. Department of Agriculture, and residents must travel out of the neighborhood to obtain groceries or prepared food. During a flood event, many of the transportation corridors and transit routes would be affected. The emergency management plan should recognize this vulnerability and utilize a facility in the neighborhood as a local food distribution site during periods of recovery.

North Asheville

Many of the properties with high risk for landslides are located in North Asheville. To avoid increase of this risk from new construction, the current steep slope ordinance should be revised to add other metrics beyond elevation and slope. Some of these additional metrics include housing density, land disturbance, tree removal/retention, and accessibility could emergency vehicles and personnel.

Reynolds Mountain: Vulnerability to Multiple Hazards

Located in the northernmost part of the city, the neighborhoods around Reynolds Mountain command wonderful views of Asheville to the south, but achieve these views through greater exposure to both landslides and wildfire. In addition, there are many flood-prone commercial structures located next to the river in this area. Residents and emergency management plans should recognize these vulnerabilities.

Beaverdam: Flooding Risk to Residential Properties

Some of the most vulnerable bridges in the city are located in the Beaverdam neighborhood. The bridges are aging, and were designed to handle less frequent and less severe flood events than we now experience. A prioritized option is two-fold: (1) undertake a study to determine which bridges in the neighborhood require replacement; and (2) begin reconstruction of each bridge according to the resulting prioritized list.

Town Mountain: Vulnerability to Landslides

On Town Mountain, roads that are exposed to high landslide hazard risk should be strengthened. This will also lower the exposure of residences downslope of these high-hazard zones. Many homes in this area, like on Reynolds Mountain, were constructed prior to the steep slope ordinance and are therefore much more sensitive to slope disturbance and failure.

The Merrimon and Charlotte Street Corridors are primary transportation and commercial corridors in North Asheville. Thankfully, they are not as vulnerable to the primary climate risks as other areas of the city.

East Asheville

In recent years, East Asheville—more than any other area of the city—has experienced considerable losses from flooding. The 2004 floods had a substantial impact on East Asheville, with the largest impact on the commercial sector. In addition to its vulnerability to riverine flooding, nuisance flooding is also of great concern; heavy precipitation events tend to overwhelm the area's existing stormwater system. Additionally, the neighborhoods in Chunns Cove and Porters Cove are vulnerable to landslides.

Tunnel Road Commercial Corridor: Vulnerability to Flooding

The Tunnel Road commercial corridor is the highest-ranked area for vulnerability to flood impacts on the industrial sector and the second-highest vulnerable area for flood impacts on the commercial sector. However, like Biltmore Village, this area is evolving to lower risk. The new Walmart shopping complex is a good example of flood-resilient building, and the clearing of the Swannanoa River channel has helped. A new apartment complex under construction south of the Swannanoa River is being built to comply with code; however, the new complex is in all likelihood introducing a greater risk for vulnerable populations with regard to access during periods of flooding.

Azalea Park and River Ridge: Flood Vulnerability for Public Works Facilities, Parks and Recreation, and Food Access

The Public Works Department has the most facilities with high exposure and risk to flooding, and the River Ridge area contains the largest number of these. A prioritized option is two-fold: (1) first, a study should be conducted to determine which facilities have the highest risk; and (2) implementation of adaptive capacity should begin on each facility according to the resulting prioritized list.

The three food distribution/processing locations with high vulnerability and risk include the MANNA Foodbank distribution center on the Swannanoa River and two community gardens in proximity to Azalea Road. One option being considered is to develop a plan for alternative food distribution/processing sites for use in an emergency. MANNA FoodBank, as a key stakeholder, should be brought into this discussion.

Azalea Park continues to have high exposure to flooding, and the city is working to develop more adaptive capacity for the facilities in this park, which are heavily utilized. The Grassy Branch neighborhood is an area of high residential property risk for flooding.

South Asheville

South Asheville is dominated by the Hendersonville Road corridor and the neighborhoods along it. Flooding along Sweeten Creek, wildfire risk for the homes on the mountainside to the east of the corridor, and nuisance flooding in several areas (e.g., Dingle Creek) are some of South Asheville's primary vulnerabilities.

Biltmore Village: Vulnerability to Flooding

The commercial properties of Biltmore Village are the most vulnerable and at risk of flooding, but the area has more recently increased its adaptive capacity having experienced extensive redevelopment since the 2004 floods, with new structures built to meet the more strict floodplain regulations. Following the 2004 floods, several old structures were removed and newer buildings constructed in their place with much greater adaptive capacity. Examples include a mixed retail building (currently housing stores such as Chico's and Williams-Sonoma) and the Grand Bohemian Hotel. In addition, the building housing Zoës Kitchen restaurant was rebuilt to meet the new building code.

The road system throughout the Biltmore Village area is at high risk of flooding. As experienced during the 2004 flood event, this limits critical access for emergency responders and for residents of Kenilworth and nearby neighborhoods. As more dwellings are constructed in this area, greater attention should be paid to the exposed roads and development of alternative access points.

With regard to nuisance flooding in Biltmore Village, one of the options discussed was to replace the area's high-risk (old) stormwater system. The Swannanoa Watershed Flood Mitigation Study created as a result of the 2004 flood event indicates the system's location. Once replaced, the new stormwater system will be able to handle greater runoff volumes caused by the increase in frequency and severity of heavy precipitation events.

Ballentree/Sweeten Creek: Vulnerability to Flooding

Homes in the Ballentree subdivision along Sweeten Creek are vulnerable to flooding, and new development in this area should include plans for greater adaptive capacity in their design. Related to this issue is the loss of critical access for emergency responders and residents, as homes along the Sweeten Creek corridor can be cut off by flooding.

Treetops/Sweeten Creek Road: Vulnerability to Landslides

Many of the homes south of the Blue Ridge Parkway along Sweeten Creek Road and the Treetops subdivision are vulnerable to landslides. This vulnerability applies to both the structures and access routes. Many homes here have only one access road—if impacted by a landslide, those residents would be isolated.

West Asheville

West Asheville has the lowest vulnerability and risk to climate-related threats in the city. This is not to say that the entire area is devoid of risk: neighborhoods along the French Broad River are exposed to flooding, and the steeper slope areas around Richmond Hill have landslide and wildfire risk.

Candler: Flooding Risk to Residential Properties

Like the Beaverdam neighborhood, some of the most vulnerable bridges in the city are located in Candler. The bridges are aging, and were designed to handle less frequent and less severe flood events than we now experience. A prioritized option is two-fold: (1) undertake a study to determine which bridges in the neighborhood require replacement; and (2) begin reconstruction of each bridge according to the resulting prioritized list.

Next Steps

This process is a collaborative effort across departments and stakeholders, and plans for community involvement are a priority for a successful completion of this effort. To that end, the city's first steps following the prioritization effort include an initiative to promote communication, education, and awareness of the results of this climate resilience planning process. This initiative is underway and involves various city departments.

To move toward implementation, the project team will need to determine specific tasks required for the approval, implementation, and long-term maintenance of the identified options for action, as well as how each action will be monitored and evaluated.

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Appendix A | Glossary

Asset (also called socioeconomic asset, or resources and services) — These are things that people value, including people, infrastructure, and ecosystems.

Adaptive capacity — The ability of a person or system to adjust to a stressor, take advantage of new opportunities, or cope with change.

Climate stressors — Events and trends related to weather, climate, and climate change that have an important, generally negative, effect on exposed systems.

Ecosystem services — Benefits that humans receive from natural systems.

Exposure — The presence of people, assets, and ecosystems in places where they could be adversely affected by hazards.

Hazard (Threat) — The potential occurrence of an event that may cause injury, illness, or death to humans, damage to assets or infrastructure, or adverse effects on ecosystems.

Impacts — Effects on natural and human systems due to extreme weather, climate events, and climate change. Impacts are also referred to as consequences or outcomes.

Non-climate stressors — Events and trends outside of the climate system that affect human and/or natural systems. Non-climate stressors can increase vulnerability to climate-related threats.

Projection (climate) — Potential future climate conditions calculated by computer-based models of the Earth system. Unlike predictions, projections are based on sets of assumptions about the future (using scenarios) that may or may not be realized. In other words, there is uncertainty related to projection information.

Potential impact — The degree to which exposed assets are potentially affected by a climate threat based on their levels of sensitivity.

Resilience — The capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from a disruption.

Risk — The potential for consequences when something of value may be partly or completely damaged or lost. Risk is often evaluated by the probability of a hazardous event's occurrence multiplied by the impacts that would result if it did happen.

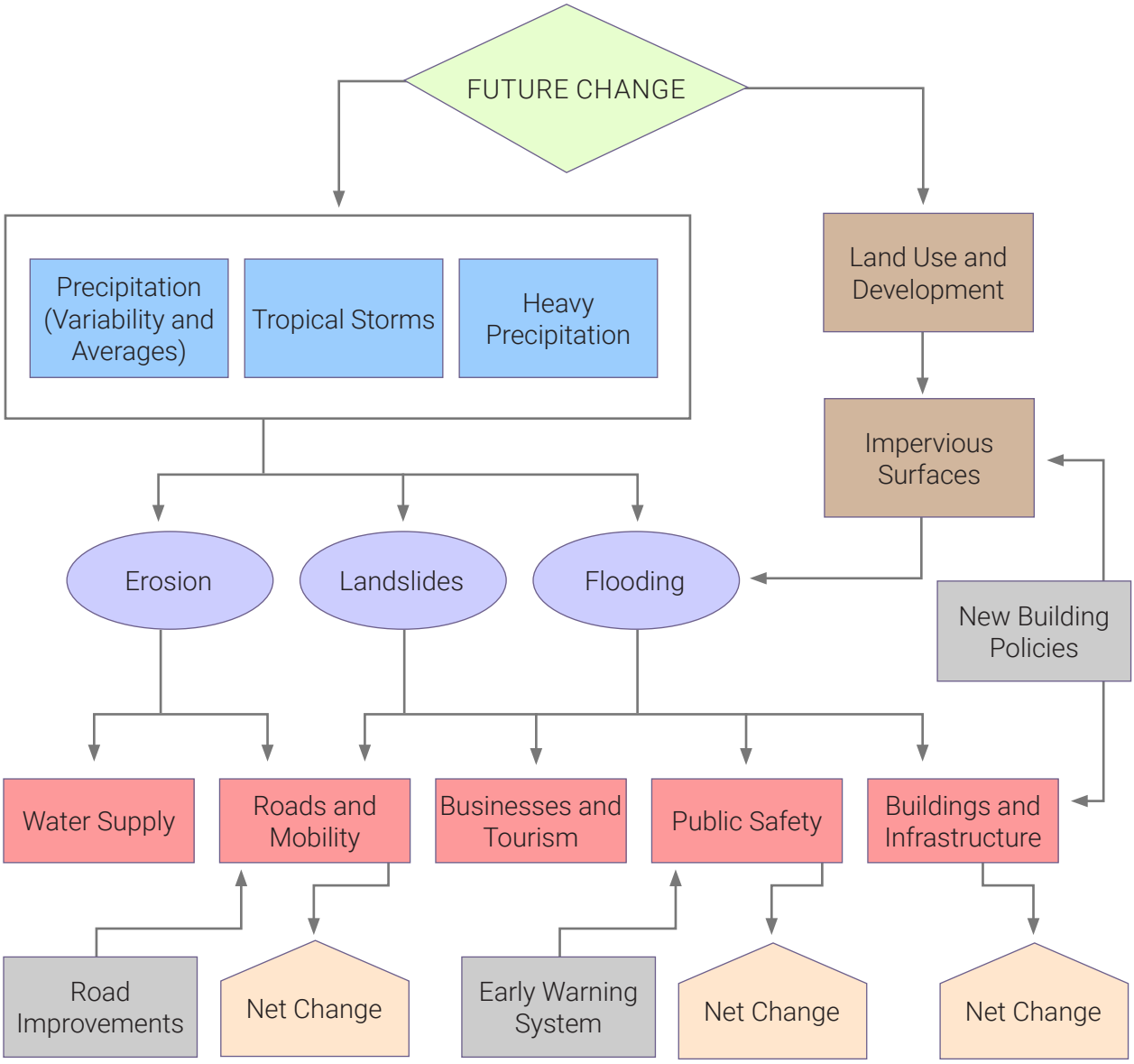
Sensitivity — The degree to which a system, population, or resource is affected by climate impacts (including extreme weather) or changing climate conditions.

Uncertainty — A state of incomplete knowledge indicating the degree to which future climate is unknown. Uncertainty about future climate arises from the complexity of the climate system and the ability of models to represent it, as well as the inability to predict the decisions that society will make.

Vulnerability — The propensity or predisposition of human and other systems to be adversely affected by climate change. Vulnerability encompasses concepts such as susceptibility to harm and lack of capacity to cope or adapt.

Appendix B | Example Conceptual Model

This conceptual model for the City of Asheville was constructed for workshops held by the Southeast Sustainability Directors Network, of which Asheville is a member. Using the conceptual model template, this model shows the relationships between stressors, the selected hazards, and societal assets. In addition to flooding and landslides, the model also shows storm-induced erosion (as a result of flooding). This conceptual model includes efforts the City of Asheville has undertaken subsequent to the 2004 floods to mitigate future flood events.



Appendix C | Options

ID#	Threat	Asset	Option	Location (Census block, City-Wide etc. *See maps)	Focus of option	Type of Activity (Strategy, Active Project, Possible Project, Analysis needed)	Action Lead Department	Stakeholders	Active Effort	CRITERIA (3= "green light"; 2="yellow light"; 1="red light")			
										Cost/Benefit (Impact of option)	Comp Plan	Ability to Implement	
												Political Feasibility	Financial Feasibility
									Active or not (Y/N)	Does this option address vulnerability and risk to a large degree? Does this option address more than one threat and/or asset? Does implementing this option now avoid costs in the future?	Does this option align with the City's comprehensive plan?	Is there political will to implement this option? Are there active stakeholders?	Is there funding now or an ability to be funded?
Hazard Mitigation and Emergency Response													
PLANS													
1	**Provide information on all identified assets and threats to Emergency Management in order to update hazard mitigation plans**												
1f	**Flooding**	Food Locations	Mobile food markets connecting to food distribution centers and grocery stores	City wide	Increase adaptive capacity	Analysis Needed	Office of Sustainability	Economic Development	N	1	1	2	1
1g	**All threats**	All assets	Consider providing information to City/County (Regional Hazard Mitigation Plan) hazard mitigation plan	City wide	Reduce exposure	Project	Fire and Rescue	Emergency Managers	Y	3	3	3	3
	Flooding	All assets	Consider providing information to City/County (Regional Hazard Mitigation Plan) flood hazard mitigation plan	City wide	Reduce exposure		Fire and Rescue		Y	3	3	3	3
	Landslides	Bridges/Roads/Critical Access	Consider providing information to City/County (Regional Hazard Mitigation Plan) landslide hazard mitigation plan	City wide	Preparedness, response, recovery		Public Works		Y	3	3	3	3
	Flooding	Food Locations	Connect the City's emergency response plan to the Regional Hazard Mitigation Plan for food supply and points of distribution.	City wide	Response	Strategy/plan	Fire and Rescue		Y	3	3	3	2
2	**Work closely with Communication & Public Engagement (CAPE) to improve internal communications across city departments during hazard events**												
2a	**Flooding**	Bridges and Roads	Improve internal communications across departments during flood events	City wide	Response, recovery	Strategy	Public Works	CAPE	Y	3	1	3	3
17	**Work with Water Resources Department and CAPE to promote water conservation during periods of drought**												
17a	**Water Shortage Due to Drought**	Water Supply	Update Water Shortage Response Plan to include historical data—water usage vs water shortage response—do we need to change thresholds or change response?	City wide	Increase adaptive capacity		Water Resources		Y	3	3	3	3
RESPONSE AND RECOVERY													
4	**Work with Emergency Management to enhance response and recovery programs associated with identified climate threats**												
4a	**Flooding**	Critical Infrastructure, including Parks and Rec Buildings	72 hour resilience for all city infrastructure."- (Generator (and/or solar with battery backup) (COOP) -supplies and storage -points of relocation *ops and loc center" Training for all city departments about our response.	121 Shiloh Rd./ Grant ctr.	Response, recovery	Data or Planning Required [Strategy]	Parks and Recreation	Fire and Rescue	Y/N	2	2	2	1
4b	**Flooding**	Transit - Greenways	Focus on restoration and maintenance after flood	City wide	Response, recovery	Project	Parks and Recreation	Transportation Division	Y	3	2	3	3
4c	**Extreme Heat**	Residents and People	Temporary relocation of vulnerable populations during extreme heat events (follow same model as code purple/extreme cold)	City wide	Reduce exposure	Strategy	Fire and Rescue	Buncombe County	Y	3	2	3	2
19	**Assess and plan for secondary and alternative access for all multimodal transportation routes**												
19a-1	**Flooding and Landslides**	Bridges and Roads	Assess adequate secondary access	City wide	Adaptive capacity, response and recovery	Strategy	Public Works		N	2	1	1	1
	Flooding	Bridges and Roads	Assess adequate secondary access	City wide	Adaptive capacity, response and recovery	Strategy	Public Works		N	2	1	1	1

	Landslides	Bridges and Roads	Determine other points of access				Public Works		N	2	1	1	1
19a-2	Flooding	Bridges and Roads	Create detours and educate public on alternative access and evacuation plan (i.e. prepare to be temporarily stranded)	City wide	Response and recovery	Possible Project	Public Works - Streets Division	CAPE + Fire and Rescue	Y	3	2	3	2
19a-3	Flooding	Transit - Bus Routes	Create detour/alternate bus routes map and create communications plan for reduced service (Use I-ride, ABC alert)		Increase adaptive capacity	Possible Project	Transportation	CAPE + Fire and Rescue	Y	2	1	3	3
19b-1	Flooding	Greenways	Evaulate greenways located in flood prone areas	City wide	Response and recovery, adaptive capacity	Strategy	Transportation	IT/GIS	N	1	1	2	2
19b-2	Flooding	Greenways	Plan for and communicate alternate routes/info source if closed due to flooding	City wide	Increase adaptive capacity	Strategy	Transporation	IT/GIS	Y	1	1	3	2
19c	Flooding	Food Locations	More frequent transit options and food routes	Sensitive populations	Increase adaptive capacity	Strategy	Transit	Office of Sustainability	N	2	2	3	2
19d	Landslides	Greenways	Plan for alternate routes/info source if closed due to landslides		Increase adaptive capacity	Strategy	Parks and Recreation + Transportation	CAPE	N	1	1	1	1
FUEL MANAGEMENT													
5	**Create policy to address controlled burning requests to better mitigate wildfire risk**												
5b	Wildfire	Residential Property	Identify locations of controlled burns and keep in database		Adaptive capacity/reduce risk	Plan/strategy	Fire and Rescue		N	2	1	2	3
5d	Wildfire	People and Places	Policy about how to address controlled burn requests and requirements of the owner moving forward (furture use of the property) (future purpose and timeline)	City Parks, US forests, Parkway, Biltmore	Adaptive capacity, exposure	Policy	Fire and Rescue		N	3	2	2	2
Further analysis													
6	**Conduct additional studies as necessary to determine detailed strategies for flood and landslide hazard mitigation**												
6a	Flooding	City-Owned Facilities	Detail exposed assets and determine whether they house critical functions to determine next steps	Citywide	Reduce exposure	Project	General Services	Facilities + Real Estate	Y	2	1	2	3
6b	Flooding	Bridges and roads	Incorporate information on bridge and road vulnerability into CIP Planning process	City wide	Adaptive capacity, response recovery	Strategy	Public Works	Finance Department	Y/N	3	2	3	2
6c	**Flooding; Nuisance Flooding, Runoff, Erosion**	All Properties	Develop watershed plans to guide infrastructure and improvement projects							3	3	3	3
	Flooding	Commercial / Industrial/ Residential Properties	Watershed plans: prioritize plans; influence zoning	City wide	Exposure	Project/Strategy [Project]	Public Works	Stormwater Division	Y	3	3	3	3
	Nuisance Flooding, Runoff, Erosion	Residential Properties	Watershed Plans - infrastructure evaluations - Prioritize plan for improvement projects -Infrastructure - Stream Restoration	City wide	Exposure, Adaptive capacity	Project/strategy							
6d	Flooding	Commercial / Industrial/ Residential Properties	Create flood maps based on build out of watershed (use Charlotte as example), update ordinance to reflect support planning and policy regulation	City wide	Exposure	Project	Pubilc Works + Stormwater		N	2	1	1	1
6e	Flooding	Bridges and roads	Localized flood mitigation master plan to identify detailed mitigation options such as storage areas, stream restoration w/ relocation	City wide	Adaptive Capacity, exposure	Strategy	Pubilc Works + Stormwater	Cross Jurisdictional (County and town within the County)	Y	3	3	3	3

6f	Flooding	Food Distribution	Determine how to work with 80% of centers not exposed (plan for use in emergency) >> Prepare, educate and train city staff to increase response time to climate related threats >Design of practice excersise	Swannanoa River Road/River Ridge area	Increase adaptive capacity	Strategy	Land of Sky?	Office of Sustainability	Y/N	2	2	3	2
6h	Landslides	Critical Infrastructure	Detail exposed assets and determine whether they house important assets to determine next steps (critical access)	City wide	Reduce exposure	Strategy + Analysis Needed	IT	Public Works	N	3	1	3	2
6i	Landslides	All Properties	1) Detailed data analysis of landslides for infill and development and the impacts of updip (upslope)/downdip (downslope) (debris flow pathway) (look at shallow tranlational slopes from NC maps)>> additional regulation/ordinance update	City wide	Reduce Exposure	Strategy + Analysis Needed	Planning Department		N	3	3	3	3
6j	Landslides	Bridges and Roads	1) Detailed data/research for roads, parcel and access points (identify, etc.), Emergency response would be included		Adaptive capacity	Public Works - Steets Division	Fire and Rescue		N	3	2	3	3
6k	Nuisance Flooding, Runoff, Erosion	Residential Properties	Enhance data collection and identify locations of re-occuring nuisance flooding areas	City wide	Reduce Exposure	Active project	Stormwater		Y	3	3	3	3
6m	Nuisance Flooding, Runoff, Erosion	Residential and Commerical	Work with MSD to identify infiltration and inflow issues within sewer lines to reduce sewer entering stormwater system	City wide	Adaptive capacity	Active project	Stormwater	MSD	Y	3	3	3	3
6o	Extreme Heat	Residents and People	Design of built environment, tree canopy, transportation (how to move). Opening community centers, education, water, building social/community plans, how elders work within community neighbor networks. >>design of built environment and increase tree canopy	City wide	Increasing adaptive capacity	Active project	Fire and Rescue		Y	3	3	3	2
Ordinances and Design Standards													
7	**Work with Stormwater Services to enhance stormwater management in accordance with identified strategies outlined in the climate assessment and comprehensive plan**												
7a	**Flooding; Nuisance Flooding, Runoff, Erosion**	Residents and All Properties	Increase stormwater management, requirements for retaining water							2	2	1	3
	Flooding	Residential Properties	Increase stormwater management, requirements for retaining water	Haw Creek/ RAD/ Biltmore Village	Adaptive capacity	Strategy	Public Works - Stormwater Division + Planning and Urban Design	CIP	N	2	3	1	3
	Flooding	Commercial Properties	Increase stormwater management, requirements for retaining water	City wide	Adaptive capacity	Strategy	Public Works - Stormwater Division + Planning and Urban Design	CIP	N	2	3	2	3
	Nuisance Flooding, Runoff, Erosion	Residents/People	Increase stormwater management, requirements for retaining water	Haw Creek/ RAD/ Biltmore Village	Adaptive capacity	strategy	Planning and Urban Design + Public Works - Stormwater		N	2	3	2	3
7b	Flooding	Residential Properties	Limit/control amount of impervious surfaces Max. infiltration (look at zoning regulation if can't add to stormwater ordinance)	City wide	Adaptive Capacity	Strategy	Stormwater Division	Finance Department	Not a new idea but not an active effort	2	3	1	2
7d	Nuisance Flooding, Runoff, Erosion	Commercial Properties	Enhance existing stormwater ordinance to detain 25-yr storm		Exposure	strategy	Planning and Urban Design + Public Works - Stormwater		N	2	2	1	3
7e	Nuisance Flooding, Runoff, Erosion	Commercial Properties	Ordinance that looks at hydrologic matching pre-/post development, commercial development (generally like LID)		Exposure	strategy			N	2	2	2	2
7f	Nuisance Flooding, Runoff, Erosion	Commercial Properties	Create opportunity - encouragement for hydrologic matching (storm EZ) for LID	City wide	Adaptive capacity	Strategy			N	2	1	3	2

7g	Nuisance Flooding	Commercial Properties	Zoning regulations become more restrictive: "max impervious areas"	Medium-High Vulnerability areas	Exposure	Strategy			N	3	2	2	2
7h	Nuisance Flooding, Runoff, Erosion	Residential and Commerical	Reduce threshold for stormwater quantity control - Increase quality control -Storm EZ- hydrologic matching - improve incentives for current roles to increase quantity and infiltration	city wide	Adaptive capacity	Strategy			N	2	2	3	2
7i	Nuisance Flooding, Runoff, Erosion	Residential and Commerical	Stream Restoration- Increase buffer Increase stream flooding capacity Affected by fluctuations of volume	City wide	Adaptive capacity	Strategy/ project	Planning and Urban Design	Stormwater	N	2	3	1	3
8	**Increase use of stormwater and flood control measures**												
8a	Flooding	Residential Properties	Increase/require use of Low Impact Developments (LIDs)	Vulnerable areas	Increases adaptive capacity by providing filtration and storage	Strategy	Planning and Urban Design			2	3	1	3
8b	Flooding	Commercial/ Residential Properties	Incentivize use of Low Impact Developments (LIDS)	City wide	Adaptive Capacity	Strategy + Analysis Needed	Planning and Urban Design		N	2	3	3	3
8c	Flooding	Residential Properties	Increase stream buffer (distances structures and increases storage) AND consider improvements to streams	City wide	Adaptive Capacity [Or, is this Reduce Exposure?]	Strategy	Planning and Urban Design		Not a new idea but not an active effort	3	2	2	3
8d	Flooding	Commercial/ Industrial/ Residential Properties	Stream restoration in gullys most affected by fluctuations in volume to reduce flooding	City wide	Adaptive Capacity	Possible Project	Stormwater?		Not a new idea but not an active effort	3	2	3	2
8f	Flooding	Commercial / Industrial/ Residential Properties	Increase and improve stream buffers with cross-community collaboration and watershed plans	City wide/ Regional	Adaptive Capacity	Strategy	Planning and Urban Design	Nonprofit Organizations?	N	3	3	1	3
8g	Flooding	All Properties	Preservation of open space in flood prone areas	City wide	Exposure	Strategy	Planning and Urban Design		Y	3	3	3	3
8i	Nuisance Flooding, Runoff, Erosion	Residential Properties	Program to encourage urban landscaping, pervious surfaces, and down spout disconnection disconnected impervious	City wide	Adaptive capacity	Project	Office of Sustainability		N	3	2	3	3
8j	Nuisance Flooding, Runoff, Erosion	Residential Properties	Max impervious surface for residential sites	City wide	Exposure	Strategy			Not a new idea but not an active effort	3	2	1	3
8k	Nuisance Flooding, Runoff, Erosion	Residential Properties	Encourage land conservation easement to be held by local non-profit	Steep slopes, city wide	Adaptive capacity, exposure	strategy	Nonprofit Organizations	General Services - Real Estate Division	N	3	3	3	3
9	**Modify the Unified Development Ordinance as it pertains to flooding**												
9a	Flooding	Residential Properties	Minimize low income housing in the floodplain; provide/reduce incentives (city funded), financial assistance for low income housing	City wide	Exposure	Strategy	Economic Development - Community Development	General Services - Real Estate Division + Strategic Devleopment Office	N	3	2	2	3
9b	Flooding	Residential Properties	Revise flood ordinance to add other metrics for new building (use suggestions from CRS)	Medium-High Vulnerability areas	Exposure, Adaptive Capacity	Project			N	3	2	2	2
9f	Flooding	Residential/ Commercial Properties	Increase flood freeboard to 4' (or above current 2' + BFE)	City wide	Exposure	Strategy			N	2	2	1	3
9h	Flooding	Commercial Properties	Limit fill in floodplain [in proximity] to critical infrastructure	City wide	Adaptive Capacity	Strategy			N	3	2	2	3

9j	Flooding	Industrial Properties	Discourage building in flood-prone areas	Flood hazard areas	Reduce exposure	Strategy	Planning and Urban Design		N	2	2	2	3
9l	Flooding	Commercial/ Industrial/ Residential Properties	Update ordinance to require access roads elevated 2' above BFE in the floodplain (floodway, 100yr, 500 yr)	City wide	Exposure, Response and recovery	Strategy	Planning and Urban Design		N	1	1	1	1
9m	Flooding	All Properties	Bring City owned property into compliance regardless of improvement threshold. *Dependant upon ability to relocate the service. Begin regulation of 500 year flood zones (all private and city owned properties.	City wide	Adaptive Capacity	Project	General Services	Real Estate	N	1	1	1	1
10	**Modify the Unified Development Ordinance as it pertains to steep slopes**												
10a-1	Landslides	Residential Properties	Evaluate the City's steep slope ordinance and consider amendments to reduce the impacts to downslope residential properties (i.e. consider lesser elevation threshold for development that triggers the ordinance)	Areas identified over a certain elevation	Adaptive Capacity	Strategy, Ordinance change	Planning and Urban Design		N	3	3	3	3
10a-2	Landslides	Residential Properties	Revise steep slope ordinance to add other metrics beyond elevation and slope (reduce density, land disturbance, and prohibit tree removal)	Vulnerable areas, steep slopes	Lower exposure and increase land's capacity to be resilient	Strategy, Ordinance change	Planning and Urban Design		N	2	3	3	3
10d	Landslides	Commercial Properties	Improve soil stability (improve root mass/plant vegetation, limit grading activity)	Identified via debris flow maps	Increase adaptive capacity	Strategy	Planning and Urban Design	Public Works	N	2	2	2	3
Infrastructure													
BUILDINGS AND PROPERTY													
12	**Build resilience into existing city owned buildings and properties as it pertains to flood and heat threats**												
12a	Flooding	Residential Properties	Develop program to buy out repetitive loss or high-risk properties	City wide	Response and Recovery	Project	General Services - Real Estate	Finance Department	N	2	1	1	1
12b	Flooding	City-owned Facilities	Relocation of facilities	Flood hazard areas	Reduce exposure	Possible Project	General Services - Real Estate	Departments identitied though analysis	N	1	1	1	1
12c	Flooding	Food Distribution	Relocation of facilities	Swannanoa River Road/River Ridge area	Increase adaptive capacity	Project		City would be a partner or advocate	N	2	2	2	1
12d	Flooding	Industrial Property	Flood-proof existing structures	Flood hazard areas	Increase adaptive capacity	Possible Project			N	1	1	1	1
12f	Extreme Heat	Residents and People	Climate control retrofits (fans, A/C) for sensitive populations	City wide, Sensitive Poplulations	Reduce exposure	Possible Project	Office of Sustainability	Buncombe County	Y	2	2	2	2
13a	Flooding	Commercial Properties	Build adaptive capacity into any new asset put into the RAD and Biltmore Village, and other vulnerable commercial areas	City wide	Increasing adaptive capacity	Strategy	Planning and Urban Design		Y	3	3	3	2
Stormwater system													
14	**Upgrade stormwater infrastructure systems and enhance capacity through green infrastructure utilizing strategies identified in the comprehensive plan**												
14a	**Flooding and Nuisance Flooding, Runoff and Erosion**	Residential Properties, Commercial Properties, Residents and People, Public Safety	Improve capacity, replace/add to stormwater system	Linden, Edwin (urban areas), CIty wide	Builds adaptive capacity: Outdated infrastructure cannot keep up with impervious surfaces	Project			Y	3	3	3	3

14d	Nuisance Flooding, Runoff, Erosion	Residents and People	Green infrastructure, green roofs, rain barrels (trees, improve stormwater infrastructure, improve LID/green infrastructure)	City wide	Adaptive capacity, risk	Strategy			Y	3	3	3	1
14f	Nuisance Flooding, Runoff, Erosion	Public Infrastructure	Incorporate green infrastructure in complete streets or other capital improvements	City wide	Adaptive capacity, exposure	Strategy	Public Works/CIP	Finance/CIP	Y	3	3	3	3
Water Supply and Distribution													
15	**Continue to build further capacity into water supply**												
15a	Water Shortage Due to Drought	Water Supply	Build additional storage (expand)- reservoirs, build additional tanks	Greater Buncombe Co., parts of Henderson Co.	Adaptive capacity, response recovery	Project, planning and strategy	Water Resources Department		N	1	1	1	1
15b	Water Shortage Due to Drought	Water Supply	Add capacity to North Fork Reservoir—determine viability	North Fork Dam	Increase adaptive capacity	Active Project	Water Resources Department		Y	3	3	3	3
15c	Water Shortage Due to Drought	Water Supply	Agreements with FEMA to truck water in (before need occurs and correctly)	Greater Buncombe Co., parts of Henderson Co.	Adaptive capacity, response recovery	Project, planning and strategy	Water Resources Department	Fire and Rescue	Y	3	3	3	3
16	**Continue to improve water supply and distribution systems**												
16a	Flooding	Water Supply/Water Infrastructure/North Fork Dam	- Hardened dam (in progress) - Harden areas at supply line -Provide redundant supply lines or reinforce -move existing supply lines	North Fork and pump stations	Capacity - minimal response/ recovery	Project/Plan	Water Resources Department		Y	3	3	3	3
16b	Water Shortage Due to Drought	Water Supply	Capital improvements, infrastructure replacement, enhancement in areas of increased population	Greater Buncombe Co., parts of Henderson Co.	Adaptive capacity, response recovery	Project, planning and strategy	Water Resources Department		Y	3	3	3	3
16c	Water Shortage Due to Drought	Water Supply	Encourage everyone to fix leak (non revenue water loss), more education of water conservation measures (Water Wise)	Greater Buncombe Co., parts of Henderson Co.	Adaptive capacity, response recovery	Project, planning and strategy			Y	3	3	3	3
Roads and Bridges													
18	**Analyze mechanisms to improve road and bridge infrastructure as needed in order to reduce exposure and build adaptive capacity**												
18a	Flooding	Bridges and Roads	Replace older bridges and elevate if possible or explore other design solutions	City wide	Adaptive Capacity, Response Recovery, Exposure	Strategy	Public Works Streets Division		Y	3	2	2	1
18b-1	Landslides	Bridges and Roads	Set aside money to addressing hardening roads (savings fund)	Vulnerable areas	Exposure, risk	Activity	Public Works Streets Division	Finance/ CIP	N	3	2	2	1
18b-2	Landslides	Bridges and Roads	Harden/ stabilize roads (retaining walls, vegetation, etc.) prior to event	Vulnerable areas	Exposure, risk	Strategy	Public Works Streets Division	Finance/ CIP	Y	3	2	2	1
Communication, Education, and Outreach													
20	**Promote climate resilience concepts and best management practices through public education and communication strategies**												
20b	Flooding	Bridges and Roads	Education of community and property owners about access issues in case of flood (use Google, Waze)	City wide	Response and recovery	Active project			In progress	3	2	3	3
	All Threats	Commercial/ Industrial/ Residential Properties	Education toolkit to build resilience on personal properties around flooding to sensitive populations (expand stormwater education; work with neighborhood coordinator; hub for information; outdoor storage; low income weatherization; floodproofing) >> ALL THREATS	City wide	Adaptive Capacity	Project			N	3	3	3	3
	Nuisance Flooding, Runoff, Erosion	Residential Properties	Education on water detention methods like green roofs, rain barrels to general public	City wide	Adaptive capacity	Strategy			N	3	3	3	3

20c	Nuisance Flooding, Runoff, Erosion	Residents and People	Program to leave lawns wild, thick, heavily planted	Vulnerable areas, all	Reduce runoff/erosion (exposure)						2		
	Extreme Heat	Residents and People	Education on extreme heat		Increases understanding, reduces exposure				N	3	2	3	3
	Landslides	All Properties	Highlight and communicate: impacts of steep slopes, protect vegatation/vegetation management, emergency plan, food and water storage, multi-hazard risk tool			Project			N	3	2	3	3
	Wildfire	Residential Property	Implement Fire Wise Communities Program	High-hazard areas	Reduces exposure				N	3	1	3	3
	Water Shortage Due to Drought	Water Supply	Reduce water use								3		
	Landslides	Commercial Properties	Develop early warning system for landslides (education and prevention)		Reduce exposure						1		
	Extreme Heat	Residents and People	Develop early warning system for extreme heat (education and prevention)		Reduce exposure						1		
20i	Extreme Heat	Residents and People	Community check-in (elderly)		Increase adaptive capacity				N	3	1	2	1
21	**Develop partnerships to help promote green infrastructure strategies identified in the comprehensive plan**												
21b	Nuisance Flooding, Runoff, Erosion	All properties	Build partnerships for opportunities for green infrastructure and/or voluntary (Green Opportunities, Riverlink, etc.)	City wide		Strategy			Y	3	2	3	3
21c	Wildfire	All Properties	ISO 3(helps with insurance)		Adaptive capacity, exposure and risk	Certification			Y	3	1	3	2
Natural Areas													
22	**Increase adaptive capacity though improvements to landscape resilience**												
22a	Water Shortage Due to Drought	Natural Areas	For stream restoration projects, have a mix of water-loving and drought-resistant, native plants		Increase adaptive capacity				Y	3	3	3	1
22b	Water Shortage Due to Drought	Natural Areas	Develop a monitoring program for insect infestation and disease outbreaks		Increase adaptive capacity				N	2	1	2	1
Supply Chains													
23	**Prepare and plan for supply chain interruptions through partnerships with appropriate regional entities**												
23a	Supply Chain Interruption		Prioritize fuel supply and consumption,routes in case of fuel shortage due to outside event		Increase adaptive capacity	Active project			Y	3	1	3	3
23b	Supply Chain Interruption	Public	For fuel (liquid), understand local food supply conditions (meet with Ingles)	City/Region	Adaptive capacity	Analysis needed			N	2	1	1	1
	Supply Chain Interruption	Public	For fuel (liquid), determine alternative food delivery (electric train, conv. train)	City/Region	Adaptive capacity	Plan/Project			N				
	Supply Chain Interruption	Public	For fuel (liquid), determine: what presently exists? what's need to operate? how much is needed in storage for how many days?	All of asheville and region	Adaptive capacity and resilience	Analysis needed			N				
	Supply Chain Interruption	Transit	(Asset: Transit) Determine how residents can get around? Develop emergency routes	City of Asheville	Adaptive capacity				N				
23f	Supply Chain Interruption	Transit	When City buys new assets, require Staff to consider how the purchase could address supply chain interruptions and resilience? (ie. alternative fuel buses/electric buses, etc.)			Active project			Y	3	3	3	2
24	**Promote regional partnerships to build resilience**												
24a	Supply Chain Interruption	Businesses	(Asset: Businesses) Coordinate with Land of Sky to extend assessment for 5 surrounding counties (regional evaluation of supply chain interruption)	Regional	Adaptive capacity				N	3	3	3	3

Appendix D | Data Sources

Threats

- Floodplain mapping: North Carolina Floodplain Mapping Program (2010)
- Potential Debris Flow Pathways: North Carolina Department of Environmental Quality (2009)
- Slope Stability Index for Buncombe County, NC: North Carolina Department of Environmental Quality (2009)
- Wildfire Burn Probability: Southern Group of State Foresters

Assets

- *Biodiversity/Wildlife Habitat Assessment*: North Carolina Department of Environmental Quality and North Carolina Natural Heritage Program, https://ncnhde.natureserve.org/content/data-download (accessed September2016)
- *Bridges*: NCDOT Structure Locations, https://connect.ncdot.gov/resources/gis/pages/gis-data-layers.aspx (accessed August 2016)
- *Building footprints (structures)*: North Carolina Floodplain Mapping Program and Buncombe County GIS
- *Bus routes:* City of Asheville, http://data.ashevillenc.gov/datasets/71c2756c24834b0ba241d54c12762422_11 (accessed October 2016)
- *Families living below poverty line and households with member over 65 years of age*: U.S. Census Bureau, American Community Survey 2014 5-year estimates
- *Food distribution locations:* Land of Sky Regional Council, Buncombe County GIS, and City of Asheville
- *Food locations:* Buncombe County GIS; U.S. Department of Agriculture Food and Nutrition Service, http://www.fns.usda.gov/pd/supplemental-nutrition-assistance-program-snap (accessed September 2016); City of Asheville, http://data.ashevillenc.gov/datasets/8443a628d9df48e881a356a804da190b_0 (accessed October 2016)
- *Impervious surface*: National Land Cover Database (2014)
- *Managed Areas/GAP Status*: North Carolina Department of Environmental Quality, North Carolina Natural Heritage Program
- *Parcels*: Buncombe County GIS, https://www.buncombecounty.org/Governing/Depts/GIS/DataDownload.aspx (accessed May 2016); City of Asheville Facility Inventory (accessed October 2016)
- *Park parcels:* Buncombe County GIS; City of Asheville, http://data.ashevillenc.gov/datasets/127fd263dfc64a73a2c2815c9d65b1d5_0 (accessed October 2016); City of

Asheville Facility Inventory (accessed October 2016)

- *Population density*: U.S. Census Bureau, American Community Survey 2014 5-year estimates
- *Reliance on public transportation:* U.S. Census Bureau, American Community Survey 2014 5-year estimates
- *Roads*: Buncombe County GIS; City of Asheville
- *Stormwater infrastructure*: City of Asheville City Wide Drainage Assessment (accessed August 2016)

Appendix E | NEMAC Contributors

James (Jim) Fox is the Director for UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC). In that position, he serves as the team leader and principal investigator for several major collaborations, including the USDA Forest Service's Eastern Forest Environmental Threat Assessment Center (EFETAC), NOAA's Climate Program Office and National Centers for Environmental Information, the North Carolina Institute for Climate Studies, and state, county, municipal, and regional governments in the southeastern United States. Jim holds undergraduate degrees in Geology/Geophysics and Communications and a Master's Degree in Information Technology for Informal Education. He specializes in systems thinking: integrating vast amounts of data, converting that data into information using visualization and storytelling, and using that information to support complex decision making through risk analysis. Prior to joining NEMAC, Mr. Fox performed complex risk analysis in the offshore oil exploration business. He has produced animations and visualizations for national parks and earth science museums nationwide, including the major museums in Denver and Houston. He returned home to Asheville in 2002 to pursue his passion of utilizing community collaborations and computer technologies to aid in complex decision making. Over the years, he has designed and taught many workshops with a foundation in hands-on learning through application of tools to real life problems.

Matt Hutchins is a Research Scientist and Environmental Change Project Lead with UNC Asheville's NEMAC. He has been a part of the NEMAC team since 2009, and specializes in Geographic Information Systems (GIS) and spatial databases, web technologies, and vulnerability and risk assessment. Matt has worked with federal partners, local and state governments, and communities to support them in making informed decisions on issues related to the impacts from climate change and extreme weather, wildfire, and other environmental threats. Matt combines his knowledge in environmental science, climate change, and decision science with technical skills to create data-driven web applications, develop and facilitate workshops, and to develop materials that help groups use information to better understand and deal with the challenges they face. He holds a B.S. in Environmental Studies from UNC Asheville and a Masters of Liberal Arts and Sciences with a concentration in Climate Change and Society, also from UNC Asheville. In his Master's thesis, he developed an assessment framework for understanding climate-related vulnerabilities and to implement climate adaptation activities at the local level.

Karin Rogers is the Director of Operations and a Research Scientist at NEMAC. Her work involves both the day-to-day operations of NEMAC and working with NEMAC's federal, local, and state partners to effectively deliver and communicate their science for more informed decision making. As Director of Operations, Karin manages NEMAC's organizational and funding program, which involves overseeing external grants, contracts, and agreements and individual program and project budgets. She works closely with funding agents and UNC Asheville staff to execute the financial and operational goals for each NEMAC project. She fosters relationships with NEMAC's external funders and stakeholders, including the USDA Forest Service, NOAA's National Centers for Environmental Information, NOAA's Cooperative Institute for Climate and Satellites-North Carolina, and various regional, state, and local partners. As Research Scientist, Karin is interested in the application of scientific information in the realm of decision making. Her work has focused on various technology transfer methodologies, including group facilitation and training, scientific graphic design, and statistical applications used in decision support. Her knowledge of environmental science, decision science, and team dynamics helps groups use

scientific information to better understand and face the challenges of a changing environment. Previously, she worked as a Research Coordinator at the University of Georgia Department of Crop and Soil Sciences, researching issues related to water quality and nonpoint source pollution. Karin received her M.S in Geology with a concentration in Fluvial Geomorphology from the University of Georgia, and her bachelor's degree in Geology from Union College in Schenectady, NY.

Caroline Dougherty works as part of NEMAC's web development team, creating data visualizations and the interfaces with which to present them. She is also responsible for the graphic identity of NEMAC's projects and works extensively with assorted design programs. She also assists in the management of NEMAC's web presence, now completely based in Drupal. Caroline is a graduate of UNC Asheville with a B.A. in Multimedia Arts and Sciences, concentration in interactive design, and a minor in Literature. She holds a graduate certificate in Climate Change and Society through UNC Asheville's Master of Liberal Arts and Sciences program.

Nina Flagler Hall is NEMAC's Lead Science Editor and a Research Scientist. As such, she is responsible for overall editorial management and for synthesizing and coordinating the content of scientific and technical decision-making tools and visualizations produced by NEMAC to assure that quality information is conveyed to an appropriate audience, with particular attention to conceptual clarity, accuracy, and format. Nina also oversees the development and implementation of NEMAC's digital storytelling products, and works with the team on the development of digital content management systems. She is interested in the processes of facilitated group decision making, and has worked with several NEMAC partners on local and regional planning projects. She has been with NEMAC since 2009. Nina holds an Masters of Liberal Arts and Sciences from UNC Asheville with a focus on sustainability and local food systems, and a B.A. in English Literature from Lewis & Clark College in Portland, Oregon.