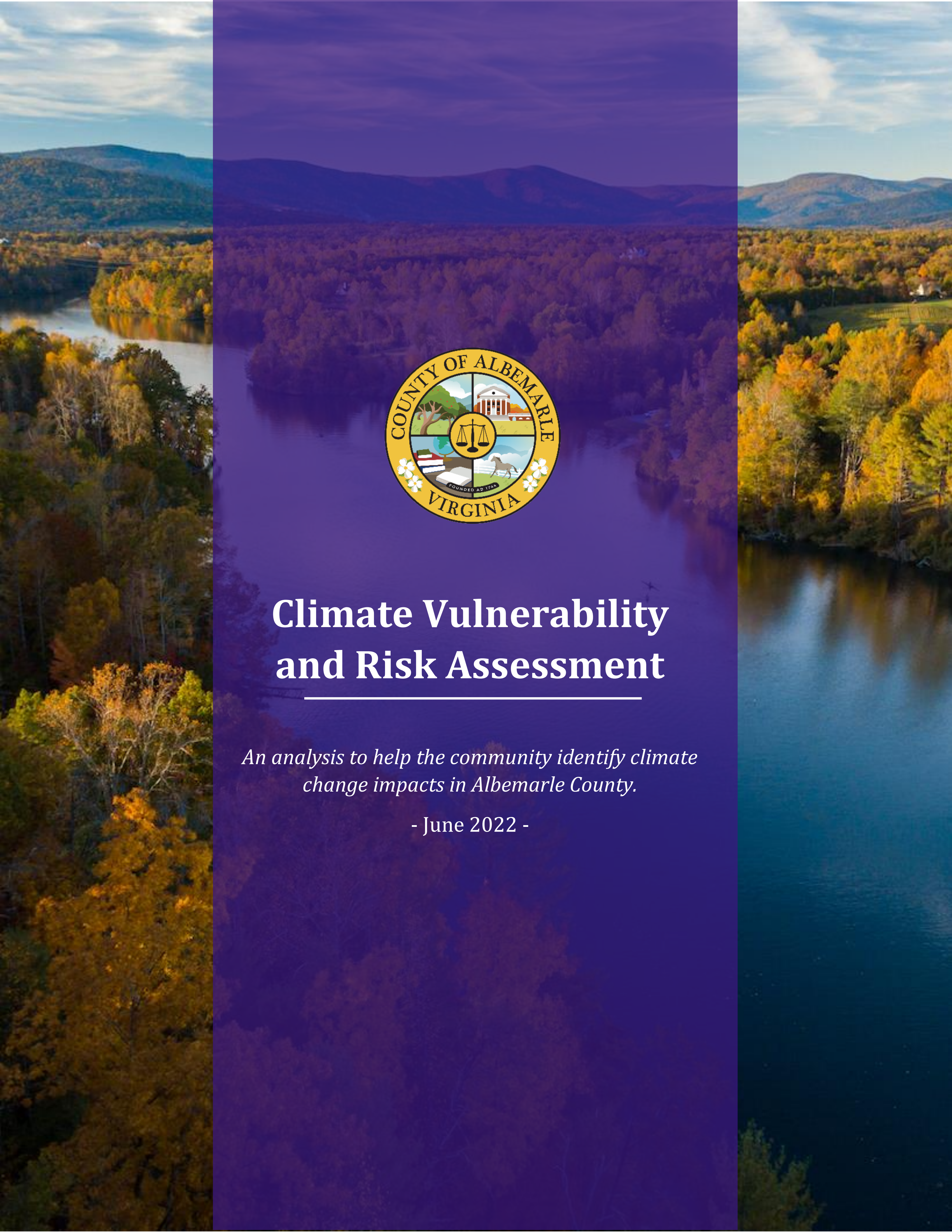

Climate Vulnerability and Risk Assessment

An analysis to help the community identify climate change impacts in Albemarle County.

- June 2022 -

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Acknowledgements

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We would like to acknowledge the following groups for their contributions to this Report:

- Albemarle County Environmental Services
- Albemarle County Community Development
- Albemarle County Fire Rescue
- Albemarle County Water & Sewer Authority
- City of Charlottesville Water & Sewer Authority
- Rivanna Water & Sewer Authority
- Thomas Jefferson Planning District Commission
- USDA Farm Service Agency, Louisa Service Center
- USDA Natural Resources Conservation Service, Louisa Service Center
- Virginia Cooperative Extension
- Virginia Department of Forestry

Executive Summary

Impacts from climate change are already being felt in Virginia, from rising sea levels on the coast to increasingly severe flash floods and heat waves inland. Based on the latest scientific research, we expect observed changes in the Virginia Piedmont to worsen over the coming years and decades.

Albemarle County needs to prepare for the drastic shifts in temperatures, precipitation, and seasonal patterns that climate change is bringing to our region. These shifts will bring shocks and stressors to our local community, economy, environment, and infrastructure.

To adapt to climate change, build resilience to the shocks it will bring, and reduce harmful impacts to our community, we need to engage in thoughtful, inclusive planning that centers community members who will be most affected. Several recent County documents, including the Comprehensive Plan (2015) and the Climate Action Plan (2020), call on staff to create a climate adaptation and resilience plan to prepare for and to alleviate the challenges brought by climate change.

The first step in planning for resilience is to understand the specific climate change risks that we will face here in Albemarle County. This report, the *Climate Vulnerability and Risk Assessment*, provides a comprehensive overview of those risks.

What This Report Is

To assess climate change related risks for Albemarle County, the *Climate Vulnerability and Risk Assessment* identifies which natural hazards exacerbated by climate change will affect our region, who and what in our community will be most exposed to these hazards, and where there is greater vulnerability to adverse impacts.

Specifically, this report analyzes five areas of information related to how climate change will affect us in Albemarle County:

1. major ***changes to temperature and precipitation*** by 2050 and 2075 that will drive acute shifts in weather patterns and exacerbate natural hazards that we experience;
2. the primary ***hazards*** that our community is most likely to face on those time horizons, including extreme heat, drought, wildfire, flooding, pests and disease, and disruptions to seasonal weather patterns;
3. the groups and areas of our community that will be most ***exposed*** to these hazards, which may vary by hazard (e.g., a drought will affect the whole county, whereas a flash flood might affect a specific part of the county);
4. social, economic, ecological, and infrastructural conditions that may make some community members, businesses, and habitats more ***vulnerable*** to these hazards; and
5. the harmful ***impacts*** that are likely to occur when a hazardous event takes place.

Key Concepts

The report analyzes the interaction among several conditions, trends, and likely events, defined below. Unless otherwise noted, these definitions are drawn from Chapter 19 of the report *Climate Change 2014: Impacts, Adaptation, and Vulnerability* by the Intergovernmental Panel on Climate Change (IPCC).

Climate Change "refers to long-term shifts in temperatures and weather patterns. These shifts may be natural, such as through variations in the solar cycle. But since the 1800s, human activities have been the main driver of climate change, primarily due to burning fossil fuels like coal, oil and gas. Burning fossil fuels generates greenhouse gas emissions that act like a blanket wrapped around the Earth, trapping the sun's heat and raising temperatures" (United Nations, "What Is Climate Change?").

Hazards include "the potential occurrence of a natural or human-induced physical event or trend… that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources." In this report, we discuss five hazards exacerbated by climate change that are most relevant to Albemarle County; these include:

Extreme Heat includes temperatures that are much hotter and/or more humid than average, as well as unseasonable weather. In the summer, this can cause heat-related illness, and in the late winter and early spring, this can cause damage to orchards and other agriculture.

Drought includes a prolonged period of abnormally low rainfall, which can lead to lower surface and ground water levels.

Wildfire includes a destructive fire that can quickly spread over brush and forested land.

Flooding includes fluvial (or riverine) flooding caused by excessive or intense precipitation.

Disease and Pestilence includes pests and diseases that harm people, woodland, and agriculture.

Exposure refers to the "presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected" by hazards, specifically those exacerbated by climate change.

Vulnerability encompasses the "propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt."

Impacts "refer to the effects on natural and human systems of extreme weather and climate events and of climate change."

Risk refers to the "potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur."

The following graphic from the IPCC's *Climate Change 2014* report depicts these concepts and the relationships among them:

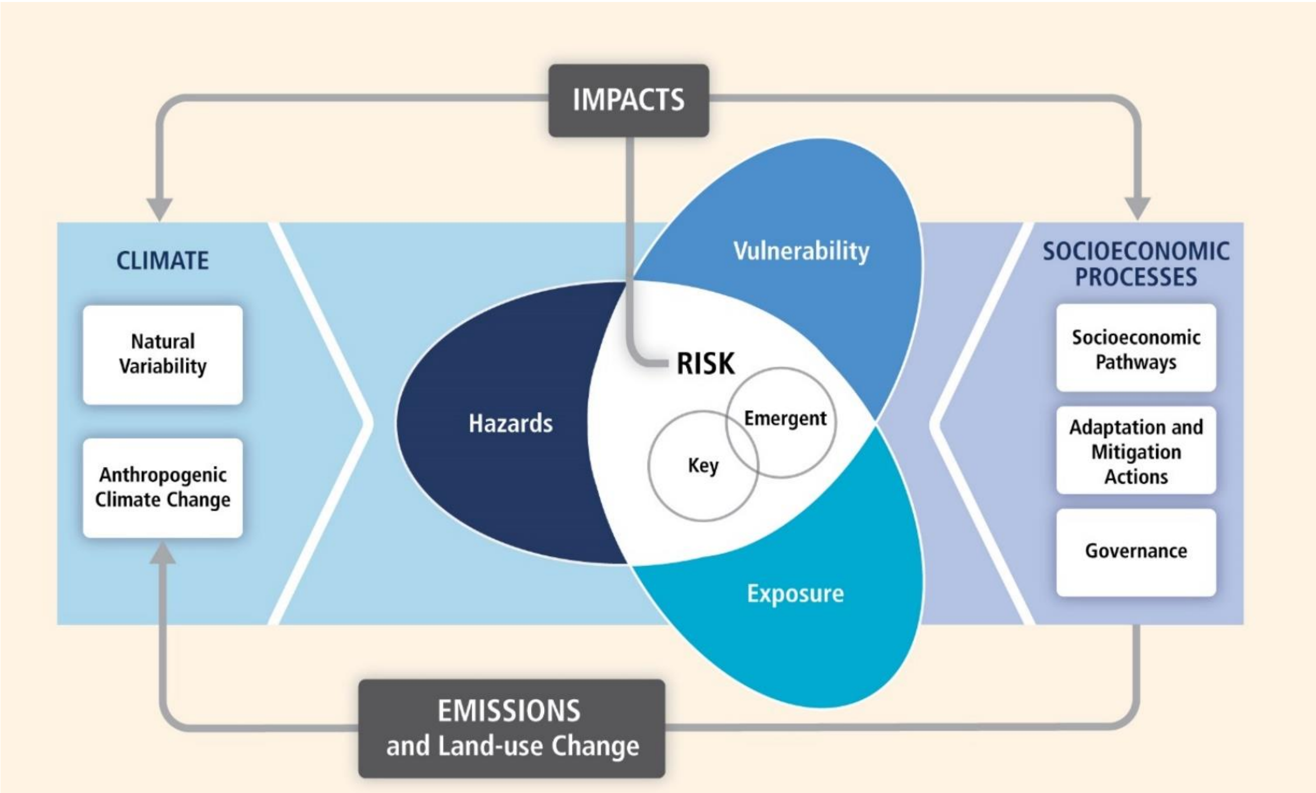


Figure A: Replica of Figure 19-1, Chapter 19: Emergent Risks and Key Vulnerabilities, in Climate Change 2014: Impacts, Adaptation, and Vulnerability *(*IPCC AR5 WG2 A, 2014*, p. 1046).*

Climate change (shown on the left) produces and exacerbates specific **hazards**—including individual *events* and *trends* over time. **Socioeconomic processes** (at right)—which can include "a broad set of factors such as wealth, social status, and gender"—and to some extent climate change (left) produce **exposure** and **vulnerability**. Hazards, exposure, and vulnerability are the three factors that directly produce the **risk** (center) of adverse **impacts**. The graphic shows that the overall system can be a cyclical process, in which impacts can in turn affect climate change and socioeconomic processes.

Method

The basic approach of this assessment is to consider the interaction between what climate change will bring to our region and how that will affect the people, natural environment, built environment, and economy specific to Albemarle County. We do this by considering the intersection of climate-related hazards and specific conditions on the ground. Sometimes this literally takes the form of a layered map. For example, in Figure 73 we depict the areas of the county most likely to experience extreme heat superimposed on a countywide geographic distribution of buildings in poor condition or without central cooling in order to identify areas that will be more affected by the hotter heat waves anticipated in the future.

Using the formal concepts introduced above, the method involves considering climate-related *hazards*, *exposure* to those hazards, and *vulnerability* to the hazards' effects in conjunction with one another. We identify likely hazards based on what several climate models in aggregate predict for our region in the coming decades—extreme heat, drought, wildfire, flooding, and pests and disease. We identify exposure and vulnerability to these hazards based on a review of numerous socioeconomic indicators for Albemarle County. Putting these together, we quantify predicted impacts for the years 2050 and 2075 and under two future climate change scenarios—*low* emissions and *high* emissions.

When we display this information in tables, charts, and maps, we highlight key observations for the reader to consider. Each chapter contains a detailed description of the data used and how we present it. We retrieved all the data for this report from publicly accessible databases, County datasets, or partner organizations.

How to Read the Report

Most of the chapters of this report follow a similar structure. Understanding that structure will help readers navigate the information and locate sections of interest.

The **Introduction** presents the purpose of this report, outlines the topics covered within it, and defines key terminology. It largely mirrors the Executive Summary.

Chapter 1: Albemarle County provides information and data about the county's (1) population, (2) natural environment, (3) built environment, and (4) economy. These four categories form the basis of information about conditions in the county that may contribute to exposure and vulnerability to hazards exacerbated by climate change. Subsequent chapters on specific hazards will reference these four categories when discussing exposure and vulnerability. Chapter 1 could be understood as corresponding to the *socioeconomic processes* depicted at right in the IPCC 2014 graphic shown above.

Chapter 2: Climate Change presents predictions over time for changing temperature and precipitation patterns in Albemarle County, based on multiple climate change models. Chapter 2 corresponds to the *climate* system depicted at left in the IPCC 2014 graphic shown above. These broad shifts in regional climate patterns set the stage for specific hazards discussed in subsequent chapters.

Chapters 3-7 cover the following climate-related hazards in order: extreme heat, drought, wildfire, flooding, and pests and diseases. These chapters follow a similar structure to one another, outlined below:

- ***Background:*** This section provides contextual information about the hazard in question and related concepts.
- ***Current and Future Conditions:*** This section discusses the specific predictions for the hazard in question, based on the broader climate models presented in Chapter 2. The material in this section corresponds to the likely *hazards*, one of the direct factors for risk in the IPCC 2014 graphic.
- ***Exposure:*** This section provides a brief overview of how the county's population, natural features, built environment, and economy may be exposed to the hazard. Only those categories that are explicitly exposed to the hazard are discussed in this section, which represents one of the direct factors for risk in the IPCC 2014 graphic.
- ***Vulnerability:*** This section examines potential vulnerabilities to the climate-related hazard that may worsen the impacts for some groups or parts of the community, addressing each of the four categories introduced in Chapter 1: (1) population, (2) natural environment, (3) built environment, and (4) economy. The section represents one of the direct factors for risk in the IPCC 2014 graphic.
- ***Potential Impacts:*** This section combines the previous information of each chapter and describes the impacts that will likely occur in the event of a given hazard. We categorize impacts by the same four categories introduced in Chapter 1 and discussed in the section on vulnerability: (1) population, (2) natural environment, (3) built environment, and (4) economy. The section corresponds to the central risk item in the IPCC 2014 graphic.

Throughout the report, we use several visual icons to help the reader identify the hazards and aspects of the community that will be impacted.

Hazards				
Extreme Heat	Drought	Wildfire	Flooding	Pests & Disease

Community Category			
People	Natural Environment	Built Environment	Economy

Conclusions

Average temperatures in Albemarle County will rise significantly over the coming decades. That will lead to hotter summers and warmer winters. Events and trends associated with the hazards discussed in this report will include longer, hotter heat waves that pose public health risks and shifting seasonal patterns that bring early blooms, late spring frosts, and early fall frosts, which can harm agriculture and our broader natural environment. Long-term average warming will produce longer dry spells between rainfall and more intense precipitation when it does rain, yielding the dual prediction of increased drought and flooding. Warmer temperature averages year-round, increasing heat waves, and longer dry spells will increase the risk of wildfire in our region (although that risk will remain low compared to other parts of the United States). Longer summers and warmer winters will increase the prevalence of pests that can spread disease to humans, animals, and plants.

The following are a sample of the report's specific forecasted impacts for Albemarle County for the year 2050 under the *high* emission scenario:

- We will experience triple the number of days with temperatures above 95°F and five to nine times as many days with evening temperatures greater than 75°F, which can exacerbate heat illness. Approximately 37,000 additional people will be exposed to heat island effect, and rates of heat illness will double.
- The probability of a major drought occurring will increase sixfold, and average annual agricultural losses due to drought will increase more than two-and-a-half times.*
- Financial losses from will increase more than two-and-a-half times, and the need for shelters for displaced people will increase more than sixfold.
- The number of days when more than two inches of rain falls is expected to double, and the amount of rainfall associated with a 100-year, 24-hour storm will increase from 10.3 to 12 inches.*
- We will experience an additional month per year of mosquito activity, increasing the prevalence of vector-borne illness.

*Note: Increasing likelihood of drought and extreme precipitation may come as a surprise to readers. Climate models predict less frequent rain throughout the year but more precipitation during individual storms.

The following tables and charts provide a summary of the relevant vulnerabilities, risks, and predicted impacts for our community that are discussed in detail in the report's chapters.

The following table lists the most relevant vulnerabilities for each climate-related hazard that we identified across the four categories of people, natural environment, built environment, and economy. Awareness of these vulnerabilities will inform efforts to engage our community and build resilience to climate change.

	PEOPLE	NATURAL ENVIRONMENT	BUILT ENVIRONMENT	ECONOMY
EXTREME HEAT	• Elderly and children • Below poverty line • No air conditioning • Poor health • No vehicle access • Emergency responders • Pets	• High chill requirement orchards • Heat intolerant plant varieties • Long-haired livestock • Livestock without access to shade	• Buildings in poor or very poor condition • Uninsulated buildings • Non-heat-tolerant rail, bridges, and roads	• Agriculture, forestry, fishing, and hunting • Construction • Manufacturing • Quarrying, oil and gas extraction • Recreation
DROUGHT	• Elderly and children • Below poverty line • Poor health • No vehicle access • Those with shallow wells	• Younger trees • Drought intolerant plant varieties • Sandy soils and soils without clay • Farms not using rotational grazing	• Businesses requiring large amounts of water • Businesses with a supply chain dependent on water • Water utilities	• Agriculture • Manufacturing • Mining, Quarrying, oil and gas extraction • Recreation
WILDFIRE	• Elderly and children • Below poverty line • Poor health • No vehicle access • Those living and working in secluded areas (limited roads in and out)	• Farms without adequate water supply • Farms with fuel storage adjacent to equipment, buildings, and livestock • Orchards and vineyards without fire breaks	• Buildings and infrastructure located in wildland-urban interface (WUI) • Businesses and homes without defensible zones	• Forestry • Hunting • Recreation • Businesses located in wildfire high hazard area
FLOOD	• Elderly and children • Below poverty line • Poor health • No vehicle access • Those required to travel for work	• Grazing land in floodplain • Barns and storage buildings in floodplain • Agriculture susceptible to long duration floods	• Mobile homes and buildings with short foundations such as slab on grade. • Buildings and infrastructure exposed to flooding without flood-proofing	• Businesses requiring employees or customers to travel through flooded roadways • Businesses directly exposed to flooding
PESTS/ DISEASE	• Elderly and children • Below poverty line • Pre-existing health conditions • People working outdoors • Pet exposure	• Trees stressed due to drought conditions • Damaged trees from animal browsing, wind, lightning, flooding, wildfire	• Grass and brush height around buildings • Dryer landscaping without standing water	• Agriculture, forestry, fishing, and hunting • Recreation

Figure B provides a visual depiction of the risk equation defined by the IPCC as the "probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur." The *highest risk* occurs when higher hazard probability occurs in conjunction with high impact in the event of a hazard. The *lowest risk* occurs when lower hazard probability and lower impact occur together. *Medium risk* occurs when a hazard is highly probably but the impact is relatively low or when a hazard is not likely to occur but the impact would be high if that hazard did occur.

Four charts appear in Figure B, each reflecting the risk associated with the four community categories: people, natural environment, built environment, and economy. Each chart plots the five hazards by the respective hazard's probability and the impact if that hazard occurs. Readers will see that the risk level is not necessarily the same across all parts of the community or for all hazards.

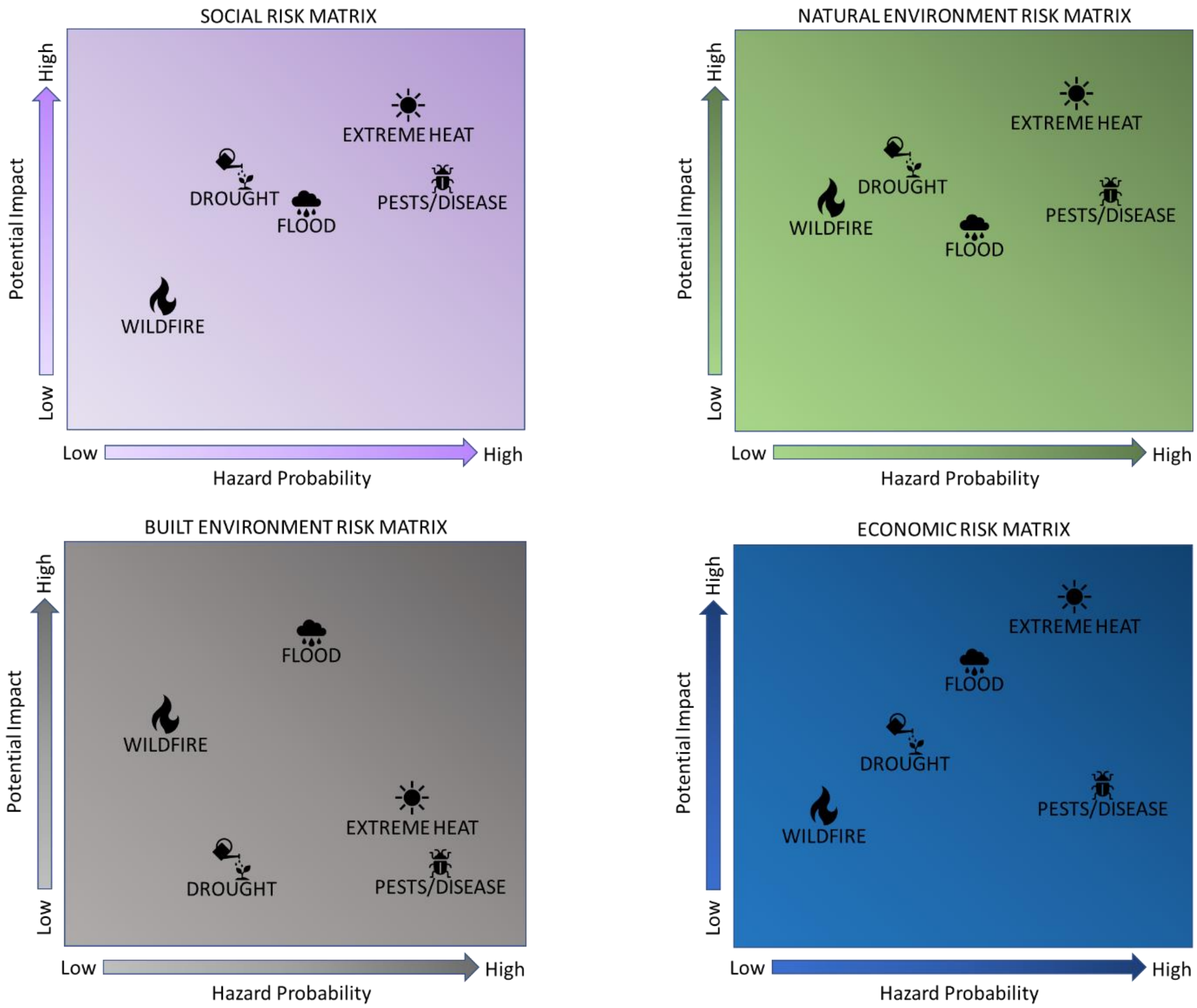
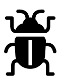


Figure B: Visual depiction of the risk equation defined by the IPCC as the "probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur."

Finally, the following table summarizes the report's quantitative findings for 2050 and 2075 and for the two emissions scenarios. The third column (Current) provides annual averages over periods spanning ten to fifty years, depending on the impact variable. Columns 4-7 project impacts for each year and emissions scenario, with the exception of flooding (only modeled for 2075 high emissions).

Hazard	Annual Impacts	Current (Avg. Annual)	2050 – Low Emissions	2050 – High Emissions	2075 – Low Emissions	2075 – High Emissions
	Heat Illness (People)	22	+73%	+100%	+123%	+173%
	Livestock Losses	Minimal	Not Modeled	+$100K-$150K	Not Modeled	+$250K-$300K
	Extreme Heat Agriculture Loss	$357,508	+16%	+69%	+59%	+142%
	Frost Agriculture Loss	$581,589	+30%	+41%	+41%	+77%
	Fruit Set Failure Agriculture Loss	$21,317	+99%	+149%	+139%	+288%
	Air Conditioning Cost - Residential	$7,842,744	+112%	+134%	+184%	+260%
	Air Conditioning Cost - Other Bldgs.	$1,805,278	+112%	+134%	+184%	+260%
	Transportation Loss	$0	$0	+$20K-$30K	+$20K-$30K	+$125-$175K
	Economic Impact due to Heat	$20,000,000	+499%	+587%	+570%	+792%
	Drought Agriculture Loss	$289,317	+84%	+177%	+146%	+223%

Hazard	Annual Impacts	Current (Avg. Annual)	2050 – Low Emissions	2050 – High Emissions	2075 – Low Emissions	2075 – High Emissions
	Water Costs	$206,953	+149%	+274%	+304%	+431%
	Algae Bloom Costs	$103,100	+31%	+44%	+57%	+83%
	Business Loss	$203,490	+84%	+177%	+146%	+223%
	Displaced Population (People)	0.36	+317%	+567%	+456%	+983%
	Public Shelter Requirements (People)	0.03	+233%	+567%	+567%	+900%
	Wildfire Agricultural Loss	$6,800	+84%	+177%	+146%	+223%
	Wildfire Building Loss	$137,726	+84%	+177%	+146%	+223%
	Wildfire Utility Loss	$2,500	+84%	+177%	+146%	+223%
	Wildfire Economic Loss ($)	$24,934	+84%	+177%	+146%	+223%
	Displaced Population (People)	2	Not Modeled	Not Modeled	Not Modeled	+120%
	Public Shelter Requirements (People)	0.8	Not Modeled	Not Modeled	Not Modeled	+138%
	Flood Agriculture Loss	$118,526	Not Modeled	Not Modeled	Not Modeled	+150%
	Flood Building Loss	$503,131	Not Modeled	Not Modeled	Not Modeled	+301%
	Flood Economic Loss	$799,527	Not Modeled	Not Modeled	Not Modeled	+182%
	Human Lyme Disease (Cases)	40	+43%	+43%	+75%	+80%
	Other Tick/Mosquito-Spread Human Disease (Cases)	13	+38%	+46%	+77%	+77%
	Pests/Disease Agricultural Loss	$69,928	+5%	+6%	+7%	+9%

Next Steps

Climate change will have significant impacts on the people, natural and built environments, and economy of Albemarle County. Taken together, these projected impacts illuminate the urgency and importance of climate adaptation and resilience planning, as well as continuing to implement the County's Climate Action Plan. Understanding the information in the Climate Vulnerability and Risk Assessment will enable staff to facilitate a more equitable and inclusive planning process, and ultimately to create a plan with more effective adaptation and resilience strategies.

The information in this report will inform climate adaptation and resilience planning in two ways: First, we will use the findings to support community engagement early in the planning process, conducting targeted outreach to groups in our community who may be more vulnerable to the impacts of climate change. Second, the report's findings will allow us to develop data-driven, project-based strategies to build community resilience.

Introduction

Impacts from climate change are already being felt in Virginia, from rising sea levels on the coast to increasingly severe flash floods and heat waves inland. Based on the latest scientific research, we expect observed changes in the Virginia Piedmont to worsen over the coming years and decades.

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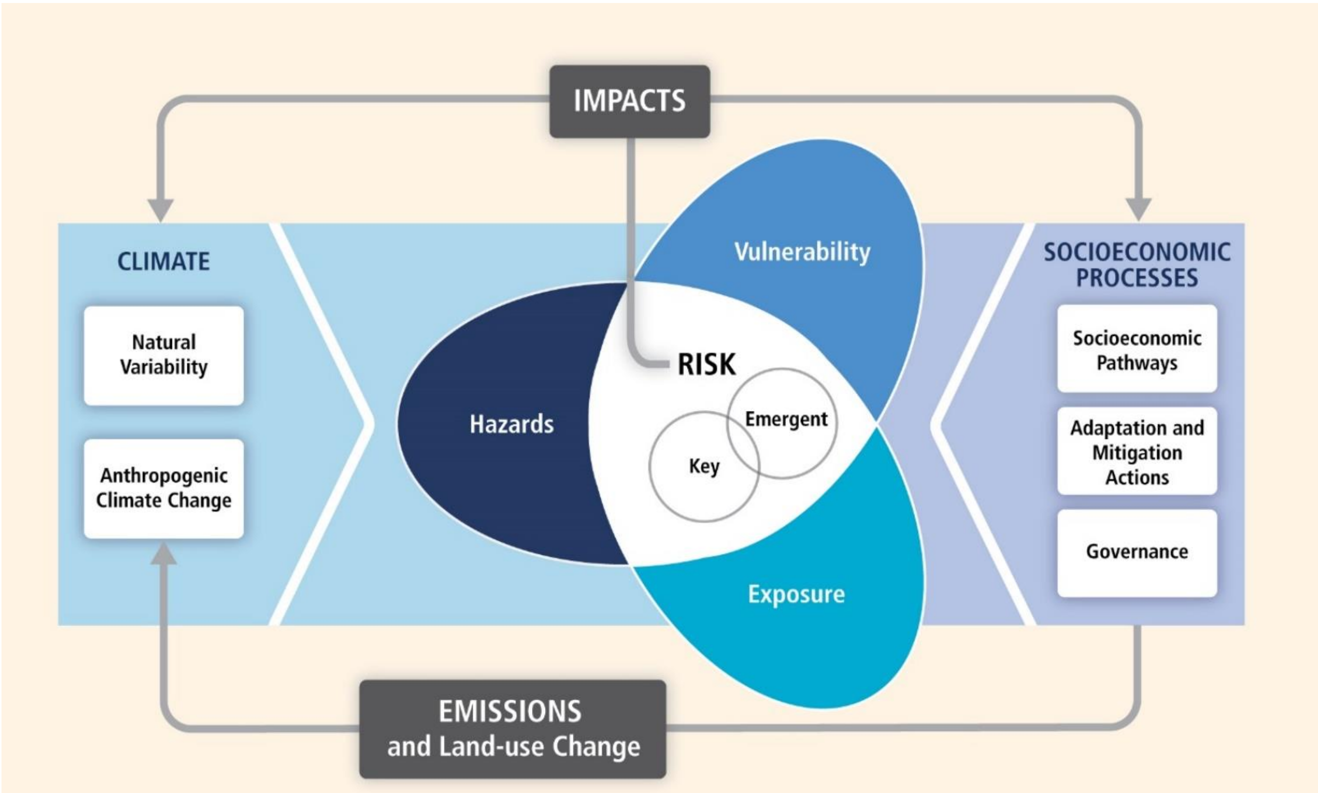
Risk refers to the “potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur.”

The IPCC has also defined risk as “the potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species” (SRCCL, 2019).

The following graphic from the IPCC's *Climate Change 2014* report depicts these concepts and the relationships among them:



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Building Resilience to Climate Change

Completing the climate risk assessment is an important step in building resilience in our communities. The IPCC defines resilience as "the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation" (Arctic Council, 2013).

The National Oceanic and Atmospheric Administration (NOAA) has defined five steps to resilience in the U.S. Climate Resilience Toolkit, shown in Figure 1. This report covers the first two steps: (1) Explore Hazards and (2) Assess Vulnerability and Risk. Future work will include identifying climate adaption and resilience strategies after the conclusions of this report have been considered.

Figure 1: NOAA Climate Resilience Toolkit

This report is being completed at the same time as the update to the Regional Hazard Mitigation Plan for the Thomas Jefferson Planning District. There is overlap between the two documents, and Figure 2 compares the hazard mitigation process with the climate change adaptation process. The major differences include the longer planning time horizon for climate adaptation, the types of hazards considered, and the additional environmental impacts from climate change.

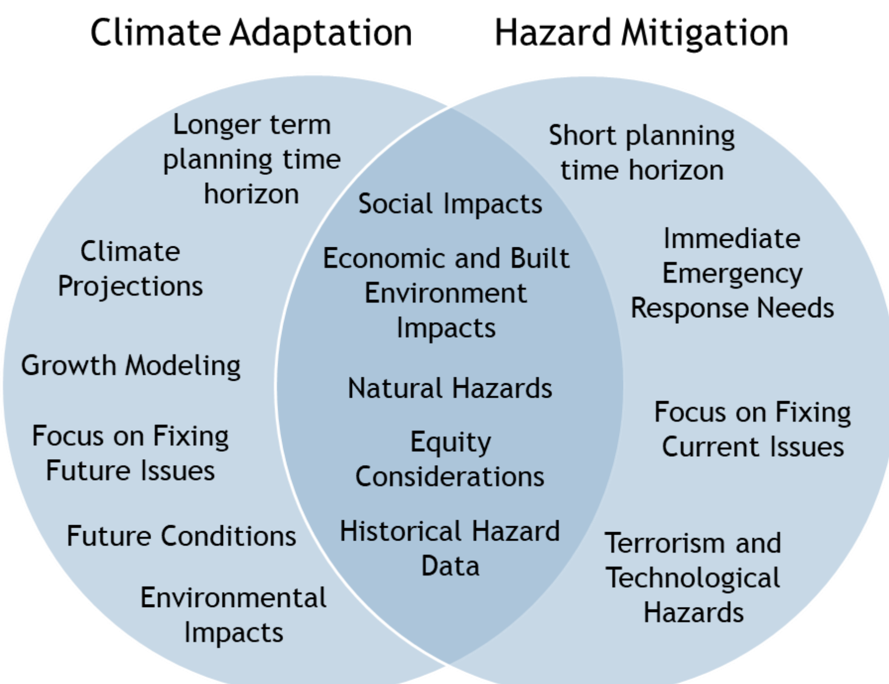


Figure 2: Climate Change Adaptation and Hazard Mitigation

In 2020, the County Board of Supervisors adopted a Climate Action Plan, which focuses on strategies to reduce greenhouse gas emissions and the severity of global climate change, known as climate change mitigation. This process also has overlaps with identifying climate adaptation strategies, which focus on preparing for the impacts of climate change on our local community. Figure 3 compares common climate adaptation strategies and climate mitigation strategies.

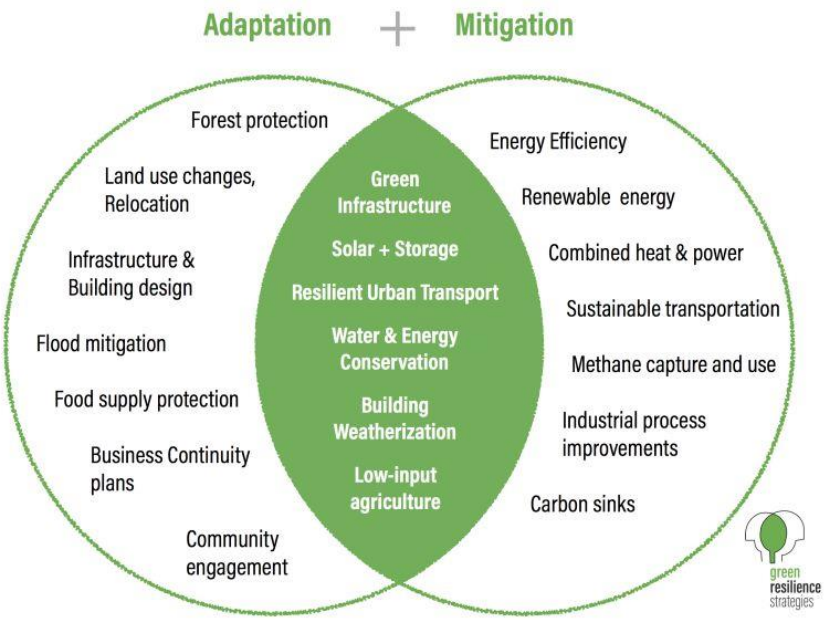


Figure 3: Climate Change Adaptation and Climate Change Mitigation (Green Resilience Strategies, 2017)

This report will help County elected officials and staff, local businesses, and community members identify current and future vulnerabilities and risks from climate change, focusing on five hazards—extreme heat, drought, wildfire, flooding, and diseases and pests. Other climate change impacts are considered, such as unseasonable weather, frost damage, fruit set loss (covered in extreme heat), and algal blooms (covered in drought). The report will help the County quantify the local impacts of climate change and build resilience.

Method

The basic approach of this assessment is to consider the interaction between what climate change will bring to our region and how that will affect the people, natural environment, built environment, and economy specific to Albemarle County. We do this by considering the intersection of climate-related hazards and specific conditions on the ground. Sometimes this literally takes the form of a layered map. For example, in Figure 73 we depict the areas of the county most likely to experience extreme heat superimposed on a countywide geographic distribution of buildings in poor condition or without central cooling in order to identify areas that will be more affected by the hotter heat waves anticipated in the future.

Using the formal concepts introduced above, the method involves considering climate-related *hazards*, *exposure* to those hazards, and *vulnerability* to the hazards' effects in conjunction with one another. We identify likely hazards based on what several climate models in aggregate predict for our region in the coming decades—extreme heat, drought, wildfire, flooding, and pests and disease. We identify exposure and vulnerability to these hazards based on a review of numerous socioeconomic indicators for Albemarle County. Putting these together, we quantify predicted impacts for the years 2050 and 2075 and under two future climate change scenarios—*low* emissions and *high* emissions.

Although we model each of the five hazards—extreme heat, drought, wildfire, flooding, and pests and disease—in separate chapters, it is important to understand that these hazards are interconnected. For example, droughts and extreme heat create the conditions for wildfire and for flooding when rain occurs. Additionally, socioeconomic factors such as population change or intentional changes in land use can exacerbate the conditions for these hazards.

When we display this information in tables, charts, and maps, we highlight key observations for the reader to consider. Each chapter contains a detailed description of the data used and how we present it. We retrieved all the data for this report from publicly accessible databases, County datasets, or partner organizations.

How to Read the Report

Most of the chapters of this report follow a similar structure. Understanding that structure will help readers navigate the information and locate sections of interest.

The **Introduction** presents the purpose of this report, outlines the topics covered within it, and defines key terminology. It largely mirrors the Executive Summary.

Chapter 1: Albemarle County provides information and data about the county's (1) population, (2) natural environment, (3) built environment, and (4) economy. These four categories form the basis of information about conditions in the county that may contribute to exposure and vulnerability to hazards exacerbated by climate change. Subsequent chapters on specific hazards will reference these four categories when discussing exposure and vulnerability. Chapter 1 could be understood as corresponding to the *socioeconomic processes* depicted at right in the IPCC 2014 graphic shown above.

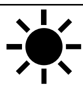
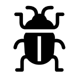
Chapter 2: Climate Change presents predictions over time for changing temperature and precipitation patterns in Albemarle County, based on multiple climate change models. Chapter 2 corresponds to the *climate* system depicted at left in the IPCC 2014 graphic shown above. These broad shifts in regional climate patterns set the stage for specific hazards discussed in subsequent chapters.

Chapters 3-7 cover the following climate-related hazards in order: extreme heat, drought, wildfire, flooding, and pests and diseases. These chapters follow a similar structure to one another, outlined below:

- ***Background:*** This section provides contextual information about the hazard in question and related concepts.
- ***Current and Future Conditions:*** This section discusses the specific predictions for the hazard in question, based on the broader climate models presented in Chapter 2. The material in this section corresponds to the likely *hazards*, one of the direct factors for risk in the IPCC 2014 graphic.
- ***Exposure:*** This section provides a brief overview of how the county's population, natural features, built environment, and economy may be exposed to the hazard. Only those categories that are explicitly exposed to the hazard are discussed in this section, which represents one of the direct factors for risk in the IPCC 2014 graphic.
- ***Vulnerability:*** This section examines potential vulnerabilities to the climate-related hazard that may worsen the impacts for some groups or parts of the community, addressing each of the four categories introduced in Chapter 1: (1) population, (2) natural environment, (3) built environment, and (4) economy. The section represents one of the direct factors for risk in the IPCC 2014 graphic.
- ***Potential Impacts:*** This section combines the previous information of each chapter and describes the impacts that will likely occur in the event of a given hazard. We categorize impacts by the same four

categories introduced in Chapter 1 and discussed in the section on vulnerability: (1) population, (2) natural environment, (3) built environment, and (4) economy. The section corresponds to the central risk item in the IPCC 2014 graphic.

Throughout the report, we use several visual icons to help the reader identify the hazards and aspects of the community that will be impacted.

Hazards				
Extreme Heat	Drought	Wildfire	Flooding	Pests & Disease
				

Community Category			
People	Natural Environment	Built Environment	Economy
			

Chapter 1: Albemarle County

Albemarle County is located in the Piedmont region of Virginia, approximately 110 miles southwest of Washington, D.C. and 70 miles northwest of Richmond. It is bordered by the counties of Augusta, Buckingham, Fluvanna, Greene, Louisa, Nelson, Orange, and Rockingham, and it surrounds the independent City of Charlottesville. The county has an area of approximately 726 square miles.

The region of Virginia to become Albemarle County was originally inhabited by Siouan-speaking Native American tribes: the Monacan, Occaneechi, Saponi, and Tutelo (Swanton, 1952). The county was originally annexed from the western part of Goochland County in 1744 and was named in honor of Willem Anne van Keppel, the Second Earl of Albemarle and then governor of the colony. The 1744 county boundary was altered later to create Amherst, Buckingham, Fluvanna, and Nelson counties, as well as to help create Appomattox and Campbell Counties. The current county boundaries were formed in 1777.

The County consists of the Town of Scottsville in the south; the Village of Rivanna in the east; the communities of Crozet in the west, Hollymead in the north, and Piney Mountain in the north; seven neighborhoods including Pantops in the east; and four rural areas. Figure 4 shows these different communities across the county.

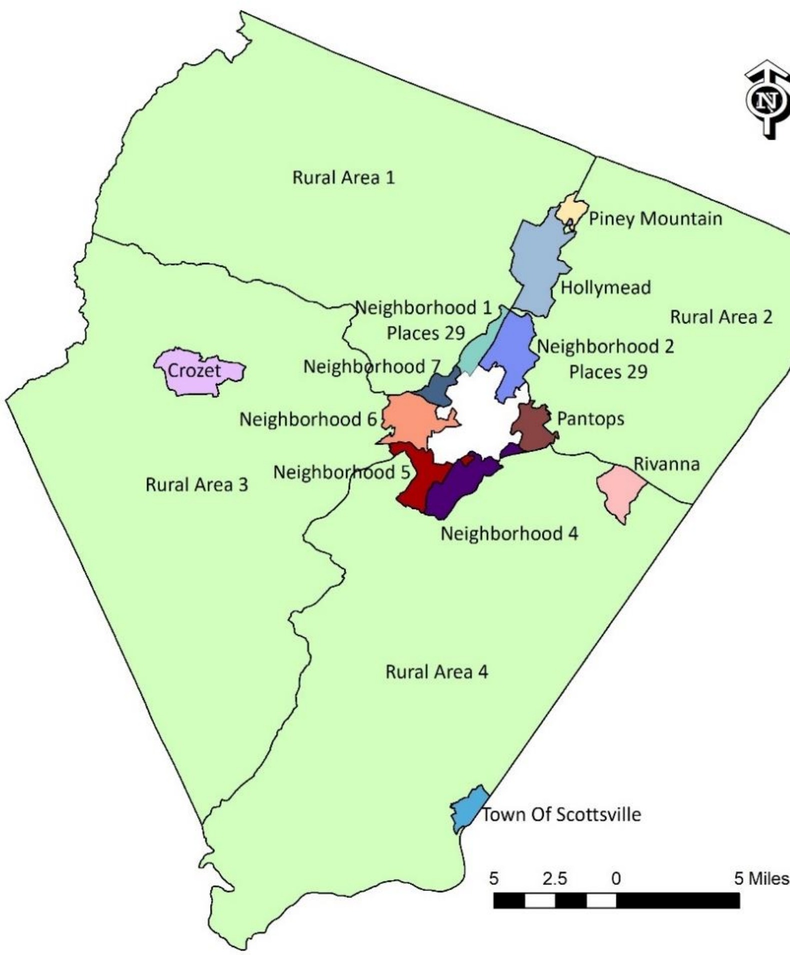


Figure 4 : Albemarle County Communities

Population

To determine how the population will be impacted by climate change, we need to identify characteristics that may make a household vulnerable. According to the U.S. Census Bureau, Albemarle County's population in 2020 was 112,395. The demographic estimates are provided in Table 1.

Table 1: Racial Groups in Albemarle County (U.S. Census Bureau)

Race	Population	Percent
White	81,866	72.84%
Black	9,953	8.86%
Asian	8,222	7.32%
American Indian or Alaskan Native	286	0.25%
Native Hawaiian or Pacific Islander	50	0.04%
Other Race	4,101	3.65%
Two or More Races	7,917	7.04%

The population also includes 8,453 Hispanic or Latino residents, which make up 7.5% of the population. The total population has been steadily growing since the 1940s. Table 2 shows the population and percent change by decade for the county.

Table 2: Population Growth (U.S. Census Bureau)

Year	Population	% Change
2020	112,395	13.6%
2010	98,970	24.9%
2000	79,236	16.5%
1990	68,040	22.0%
1980	55,783	47.7%
1970	37,780	22.0%
1960	30,969	16.2%
1950	26,662	8.2%
1940	24,652	-8.6%
1930	26,981	3.8%
1920	26,005	-12.90%

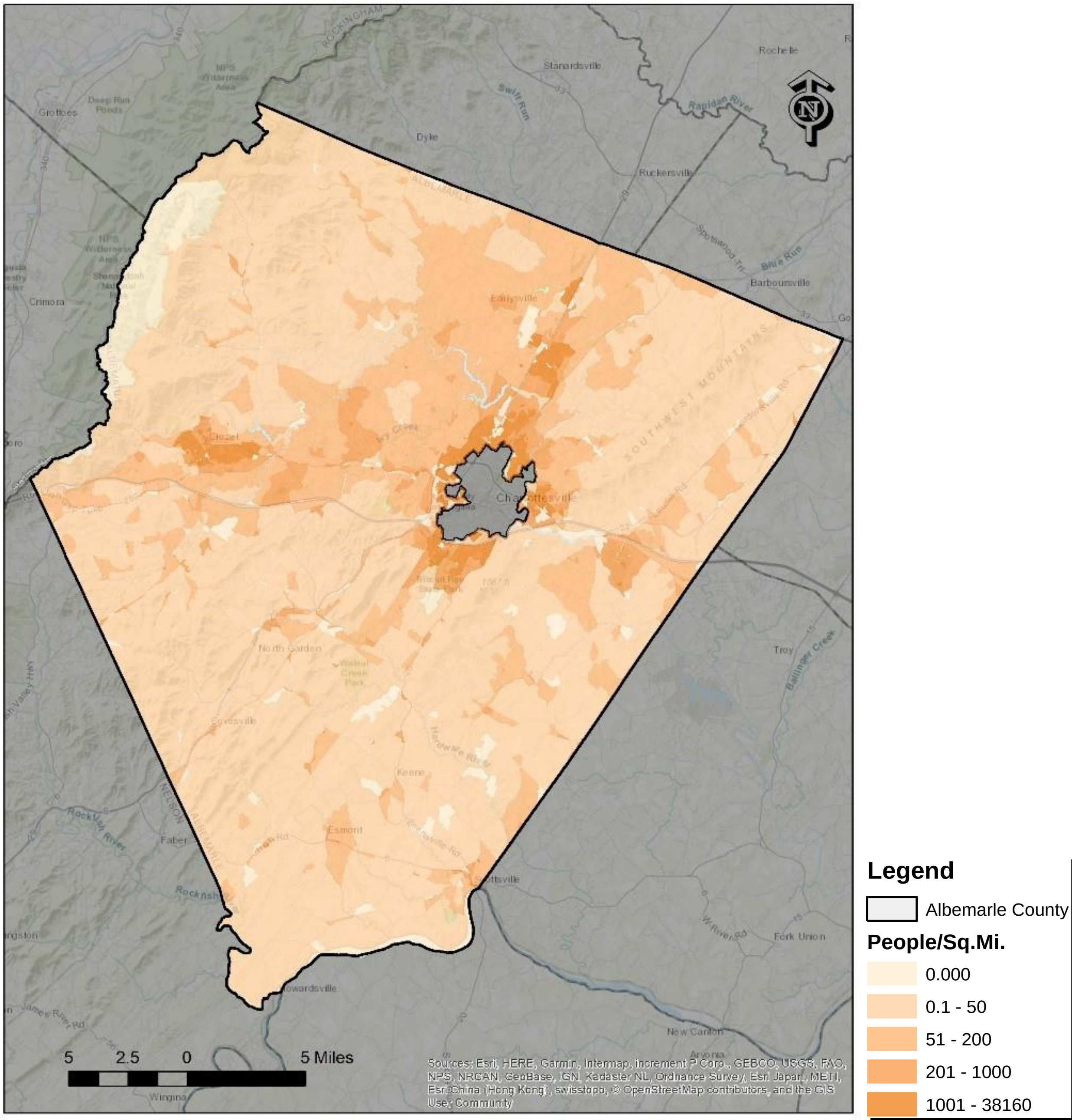


Figure 5: Population Density (U.S. Census, 2020)

We used local and national data to create vulnerability indicators for the county, which we categorized into several groups of related indicators: household, poverty, health, technology, and institutional housing. These indicators show characteristics of populations that have historically been either more susceptible or have more difficulty adapting to systemic shocks.

Table 3 shows the household indicators for vulnerable populations. These indicators were collected from the 2019 release of the American Community Survey (ACS). The ACS data table name is provided in the column labeled

"Source". In general, Albemarle County has an older population compared with the State and national numbers. The population of those who are 65 years of age or older, 65 years of age or older *and* living alone, and grandparents responsible for the grandchildren are higher than average.

Table 3: Potential Vulnerability - Household Indicators

Household Indicators	Albemarle	Virginia	United States	Source
65 years or older	18.01%	15.90%	16.50%	2015-2019 ACS, S0101
65+ Years Old and Living Alone	16.19%	10.35%	10.98%	2015-2019 ACS, DP02
Grandparent Responsible for Grandchild Under 18	2.28%	2.11%	2.04%	2015-2019 ACS, DP02
Under 18 years	19.70%	21.80%	22.20%	2015-2019 ACS, S0101
Single Parent Household	4.18%	6.25%	6.35%	2015-2019 ACS, DP02
No High School Diploma	7.94%	9.92%	11.47%	2015-2019 ACS, S1501
Limited English	1.56%	2.80%	4.30%	2015-2019 ACS, S1602

Table 4 shows the poverty indicators for the vulnerable population. These indicators also were collected from the 2019 ACS data release. In general, fewer people are below the poverty level, unemployed, and without vehicle access than the State and national averages. The median annual household income is also above the national average. This doesn't mean that there aren't parts of Albemarle with high levels of poverty; this simply indicates that the county averages are smaller than the national or state averages. Areas of poverty and other vulnerability indicators will be identified later in this report.

Table 4: Potential Vulnerability - Poverty Indicators

Poverty Indicators	Albemarle	Virginia	United States	Source
Median Annual Household Income	$79,880	$74,222	$62,843	2015-2019 ACS, S1901
Below Poverty Level	6.2%	9.94%	12.30%	2015-2019 ACS, S1701
SNAP/Food Stamps	4.83%	7.80%	10.70%	2015-2019 ACS, S2201
Received Public Assistance Income	4.75%	5.74%	6.61%	2015-2019 ACS, B17015
Housing Costs 30% or More of Income	17.93%	19.55%	21.10%	2015-2019 ACS, B25101
Crowding (More People Than Rooms)	3.33%	4.69%	4.90%	2015-2019 ACS, B25014G
Unemployed	2.60%	4.00%	4.50%	2015-2019 ACS, DP03
No Vehicle Access	4.73%	6.10%	8.60%	2015-2019 ACS, S2504

Table 5 shows the health indicators for the vulnerable population. These indicators were collected from the 2019 ACS data release and from the Center for Disease Control (CDC) Behavioral Risk Factor Surveillance System (BRFSS) data from 2018. In general, there are smaller percentages of health issues with the population in Albemarle when compared to State and national averages.

Table 5: Potential Vulnerability - Health Indicators

Health Indicators	Albemarle	Virginia	United States	Source
Disabled	8.75%	12.20%	12.70%	2015-2019 ACS, S1810
Obesity	27.45%	31.90%	31.74%	2018 BRFSS
Adult Asthma	8.60%	8.60%	9.50%	2018 BRFSS
Chronic Obstructive Pulmonary Disease (COPD)	5.50%	5.90%	6.60%	2018 BRFSS

High Blood Pressure	28.00%	33.60%	32.30%	2018 BRFSS
Kidney Disease	2.40%	3.00%	2.90%	2018 BRFSS
Diabetes	8.30%	9.50%	10.90%	2018 BRFSS
Poor Mental Health (Self Assessed)	13.16%	13.24%	14.10%	2018 BRFSS
Poor Physical Health (Self Assessed)	10.57%	11.75%	13.10%	2018 BRFSS
No Health Insurance	6.70%	7.90%	9.20%	2015-2019 ACS, S2701

Table 6 shows indicators for home conditions that may increase vulnerability. These indicators were collected from the 2019 ACS data release and the Albemarle County Parcel Data from 2021. In general, the Albemarle County numbers are similar to the State and national numbers. We did not collect State and national data for central air conditioning (AC) or house condition.

Table 6: Potential Vulnerability - Home Conditions

Home Conditions	Albemarle	Virginia	United States	Source
Multi-Unit Structures (10 or More)	12.60%	14.11%	14.19%	2015-2019 ACS, K202504
Mobile Homes	4.11%	4.92%	6.16%	2015-2019 ACS, K202504
Renters	34.04%	33.87%	35.89%	2015-2019 ACS, B25003
No Central AC	15.46%	Unknown	Unknown	2021, County Parcel Data
Poor House Condition	1.35%	Unknown	Unknown	2021, County Parcel Data
Very Poor House Condition	0.70%	Unknown	Unknown	2021, County Parcel Data

Table 7 shows technology indicators that may increase vulnerability. These indicators were collected from the 2019 ACS data release. In general, the number of households without a computer was higher than the State and national averages. The number of households without broadband internet was comparable to the State and national numbers.

Table 7: Potential Vulnerability - Technology Indicators

Technology Indicators	Albemarle	Virginia	United States	Source
Household Without Computer	8.50%	7.00%	7.10%	2015-2019 ACS, DP02
Household Without Broadband Internet	13.00%	13.30%	13.60%	2015-2019 ACS, DP02

Table 8 shows institutional housing indicators that may increase vulnerability (source: 2020 Decennial Census). In general, Albemarle County has a smaller population in correctional facilities compared to the State and national averages. In contrast, more people live in higher education housing and nursing facilities than the State average. There are no military barracks in the county.

Table 8: Potential Vulnerability - Institutional Housing Indicators

Institutional Housing Indicators	Albemarle	Virginia	United States	Source
Population in Correctional Facilities	0.30%	0.68%	6.16%	2020, DEC, P5
Population in Higher Education Housing	5.08%	1.07%	8.32%	2020, DEC, P5
Population in Nursing Facilities	1.07%	0.42%	4.88%	2020, DEC, P5

To help determine the future impact on the county population, we needed to determine what the population will likely be in the future. We combined U.S. Census Data with the University of Virginia Weldon Cooper Center's population projection data to produce Figure 6. A trend line based on the Weldon Cooper projections predicts populations for 2050 (151,651) and 2075 (184,763).

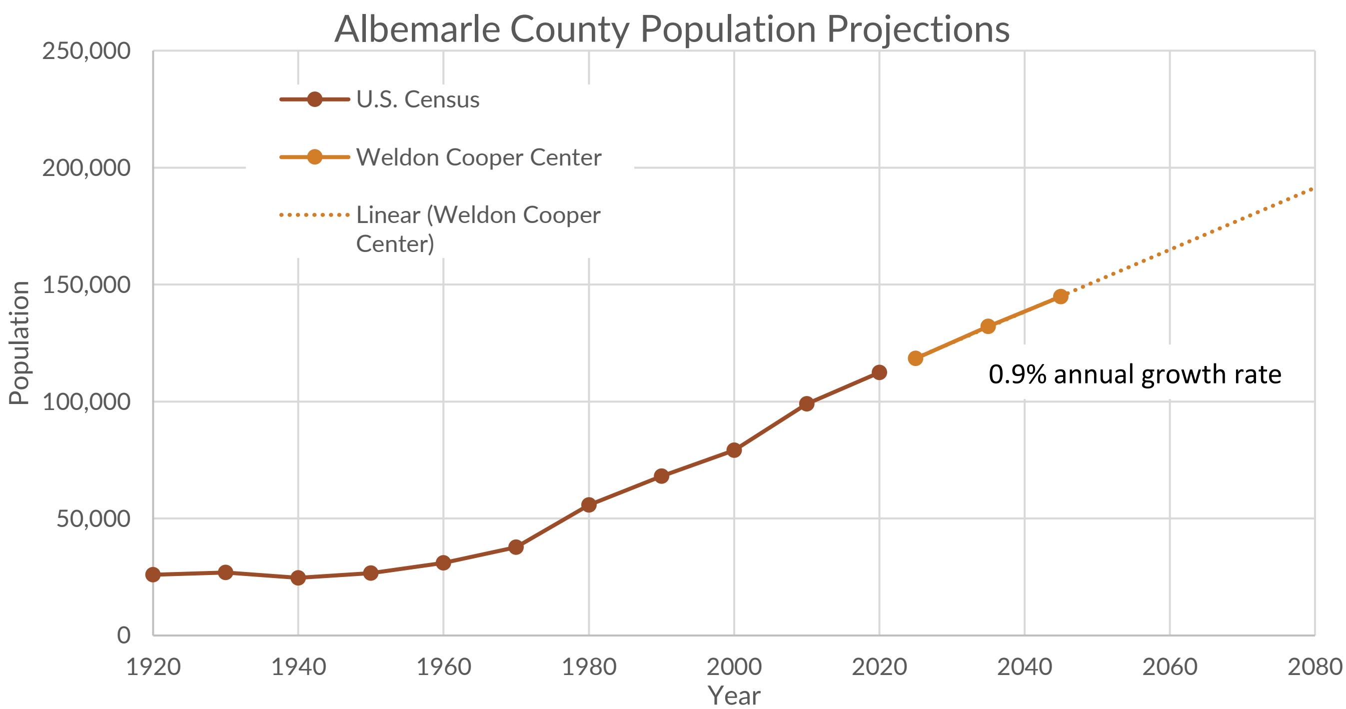


Figure 6: Albemarle County Population Projections (U.S. Census, 2020; University of Virginia Weldon Cooper Center, 2019).

Natural Features

Natural features are an important community asset that have more than just an economic value. They provide health and environmental benefits that are difficult to quantify, and they also help reduce the impacts of climate change.

Albemarle County's natural features include livestock, agriculture, forests, parcels in land conservation, and parks.

Livestock

There are more than 900 farms in Albemarle County (USDA NASS, 2017). Most of the livestock farms raise cattle, although several also raise horses and poultry. Figure 7 shows the number of livestock-raising farms by livestock type; Figure 8 shows the number of animals raised in the county. County livestock farmers sell $10.785 million of livestock per year.

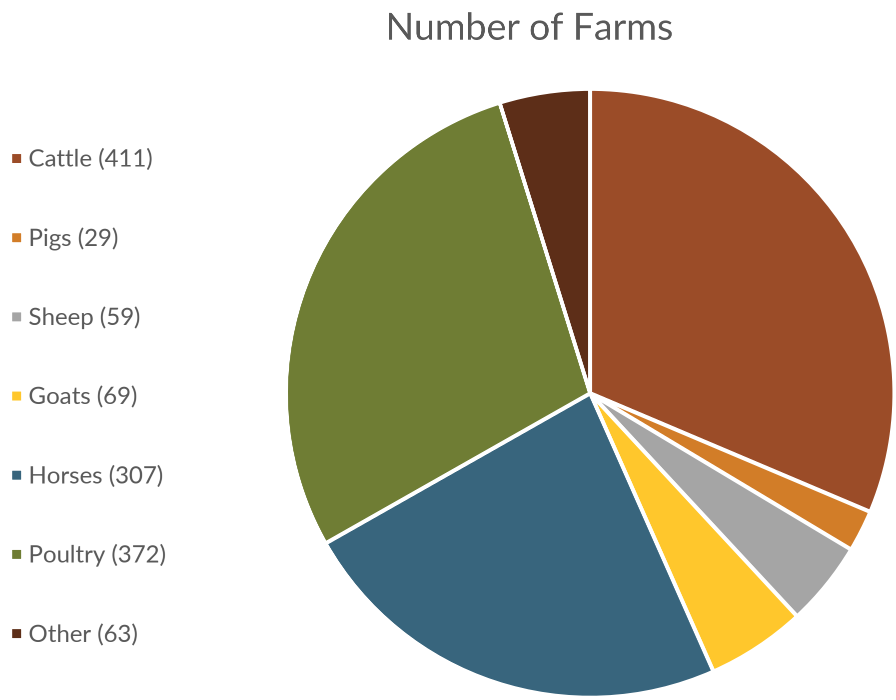


Figure 7: Number of Livestock Raising Farms (USDA NASS, 2017)

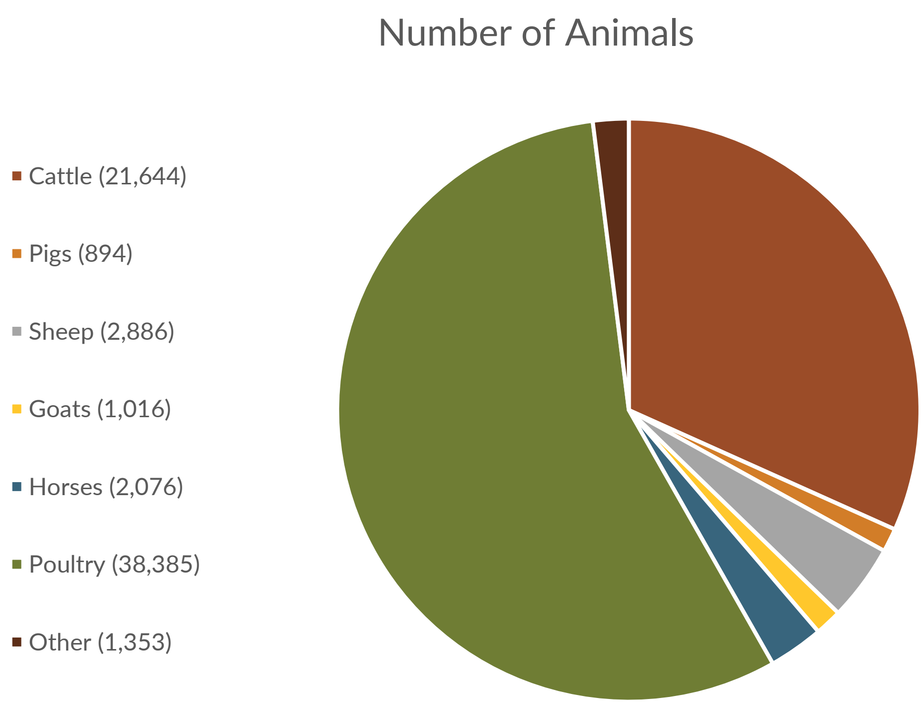


Figure 8: Number of Animals Raised on Farms (USDA NASS, 2017).

Agriculture

Cultivated crops, hay, orchards, vineyards, and pastureland can be found throughout the county. In 2019, there were approximately 90,432 acres of hay and pastureland and 4,523 acres of cultivated crops. Figure 9 shows the location of the cropland. Hay is the primary field and pasture crop grown in the county at nearly 80% of the overall cropland. Apples and vineyards are also prevalent in the amount of acreage, as well as economic value to the region.

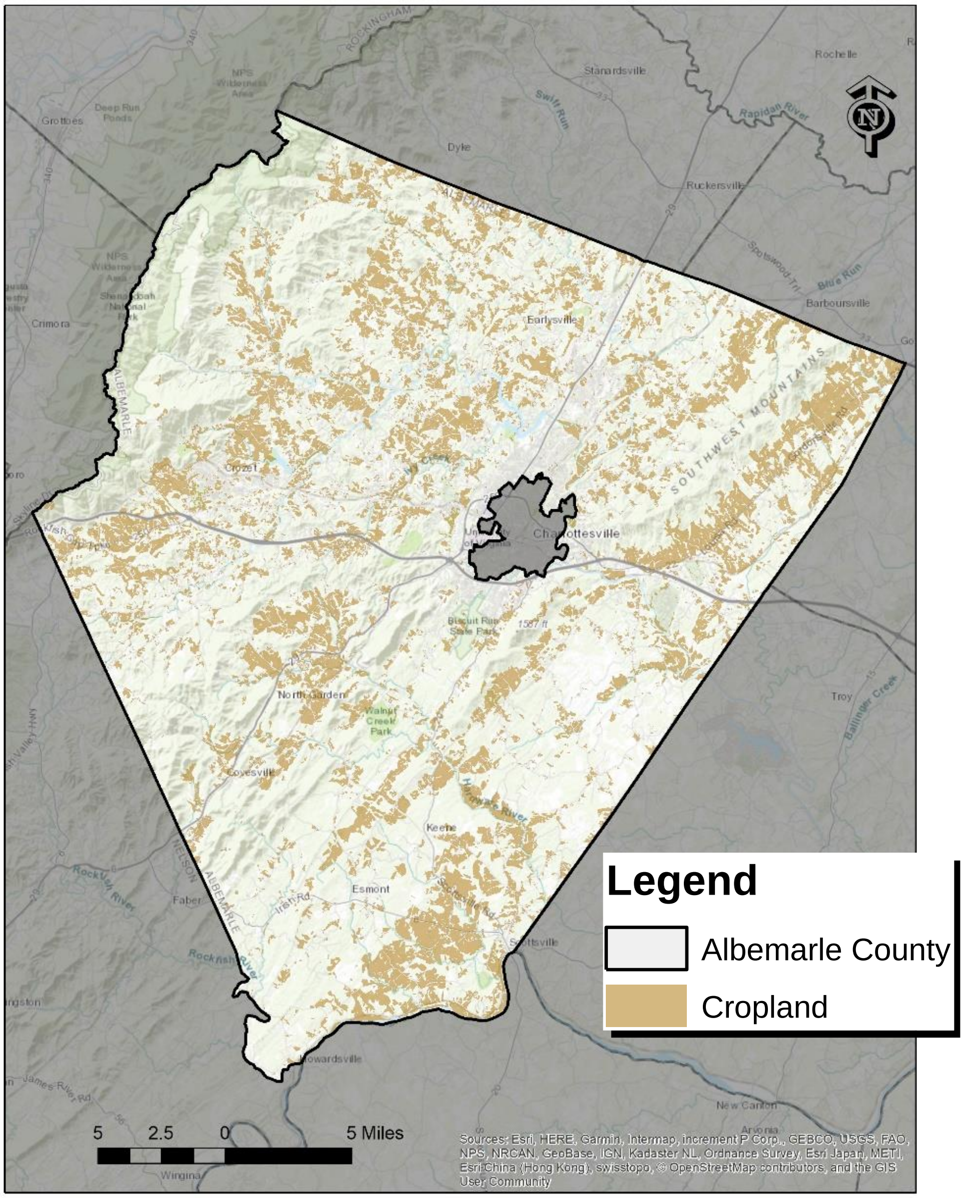


Figure 9: Cropland

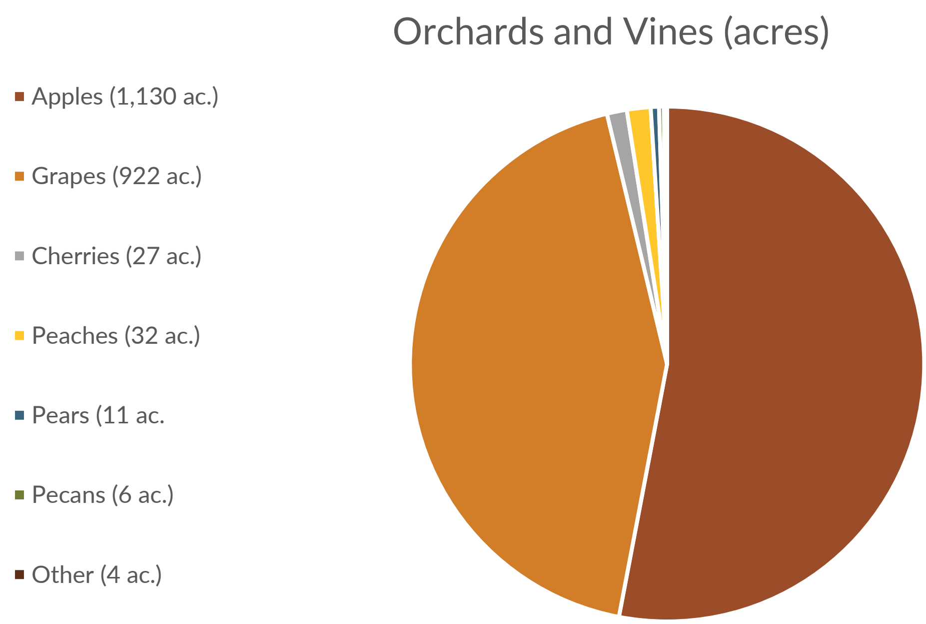


Figure 10: Orchards and Vines by Type (USDA NASS, 2017).

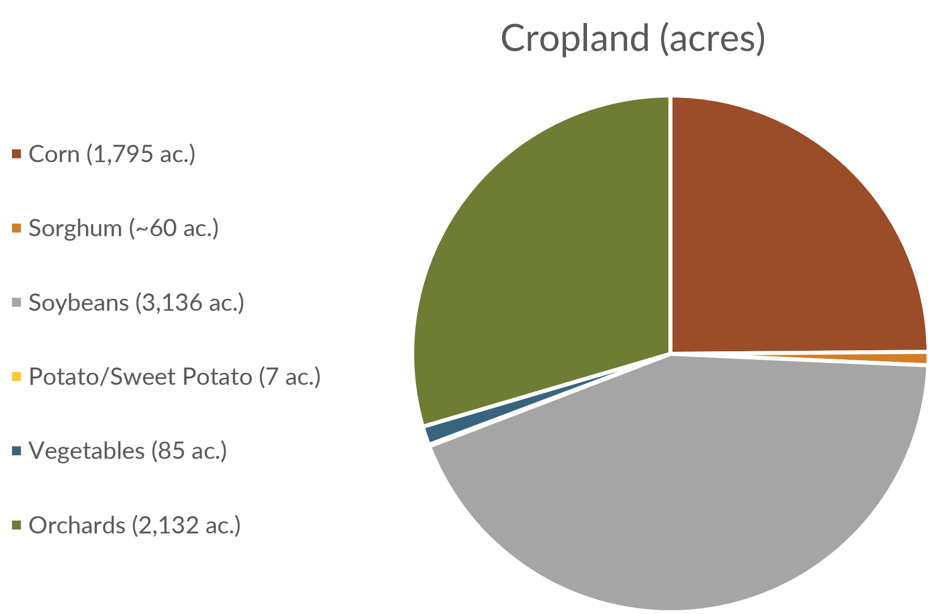


Figure 11: Cropland by Type (USDA NASS, 2017)

Figure 10 shows the acreage of orchards and vines by type, and Figure 11 shows the acreage of crops by type. Some agriculture is more susceptible to climate change than others.

Forests

Forest land is a natural asset that provides health benefits, recreation, and economic value, and will help lessen the impacts of climate change. Forested areas reduce the heat island effect of urban areas and reduce the magnitude and impacts of flood events. In 2019, the forested areas of the county consisted of approximately 213,327 acres of deciduous forest, 20,847 acres of evergreen forest, and 70,637 acres of mixed forest. Figure 12 shows the location of the different forested parts of the county.

Tree species that populate many forested areas include Virginia Pine, Loblolly Pine, Red Maple, Eastern Redcedar, Dogwood, Eastern Redbud, White Ash, Black Gum, Yellow Poplar, and White Oak. Over 8 million cubic feet of harvest removals from timberland are conducted annually (USFS EVALIDator, 2021).

To understand how the natural environment has changed over the years, we analyzed land use data from Global Forest Watch, established by the World Resources Institute (WRI) to provide data and tools for monitoring forests. Their tool depicts how land cover has changed over time (Figure 13). From 2001 to 2016, 3.8% of all land cover in Albemarle County changed from forest to grassland (Global Forest Watch, 2016).

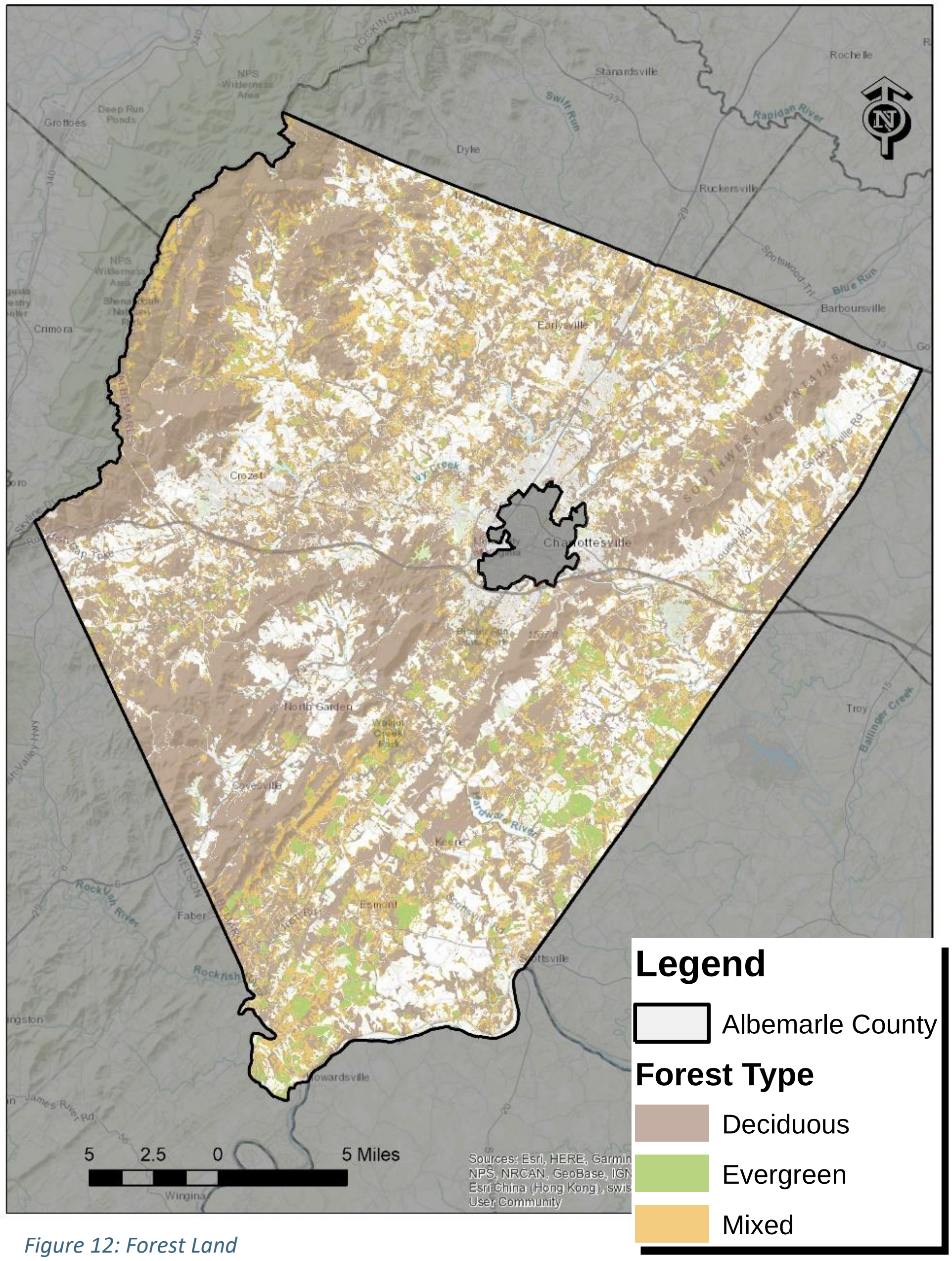


Figure 12: Forest Land

Additionally, Global Forest Watch collects data on tree cover loss and gain. From 2013 to 2020, 93% of tree cover loss in Albemarle County occurred within the natural forest (Global Forest Watch, 2020). Figure 14 shows gross tree cover loss in Albemarle County from 2001 to 2020, not including tree cover gain. From 2001 to 2012, Albemarle County experienced a gross tree cover gain of 13,467 acres and a gross tree cover loss of 17,703 acres, resulting in a net loss of 4,236 acres of trees.

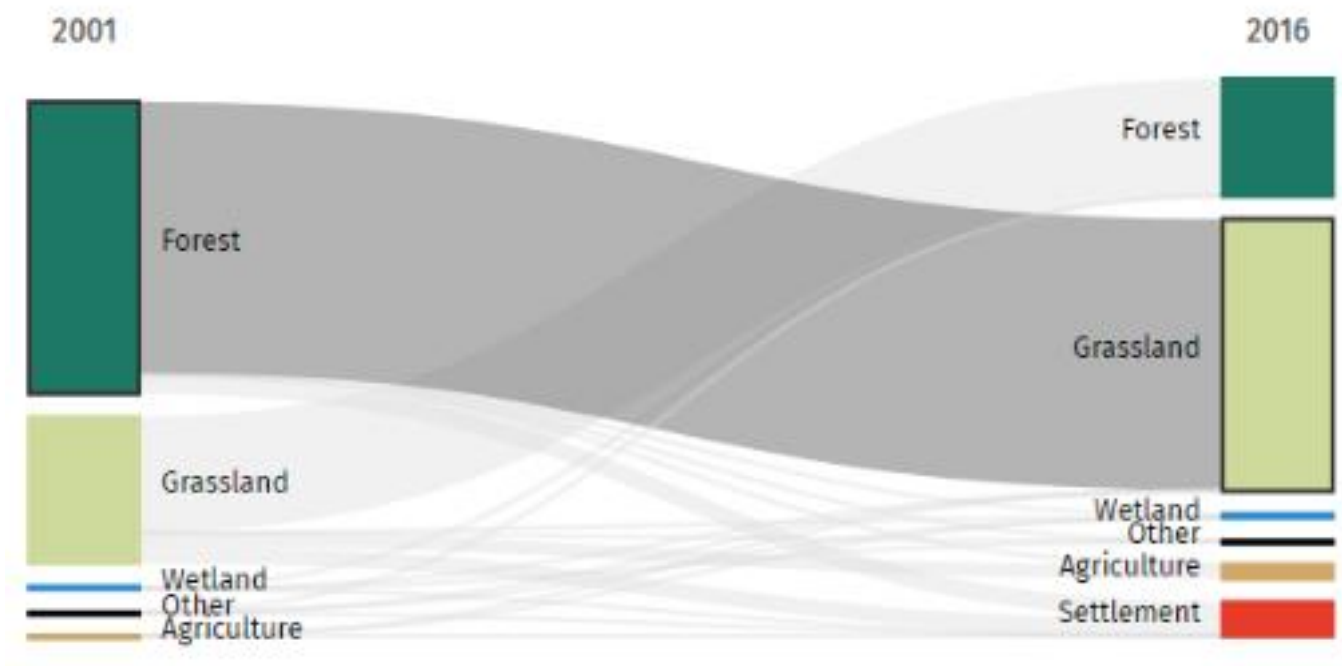


Figure 13: Albemarle County Land Cover Change (2001-2016) (Global Forest Watch, 2016)

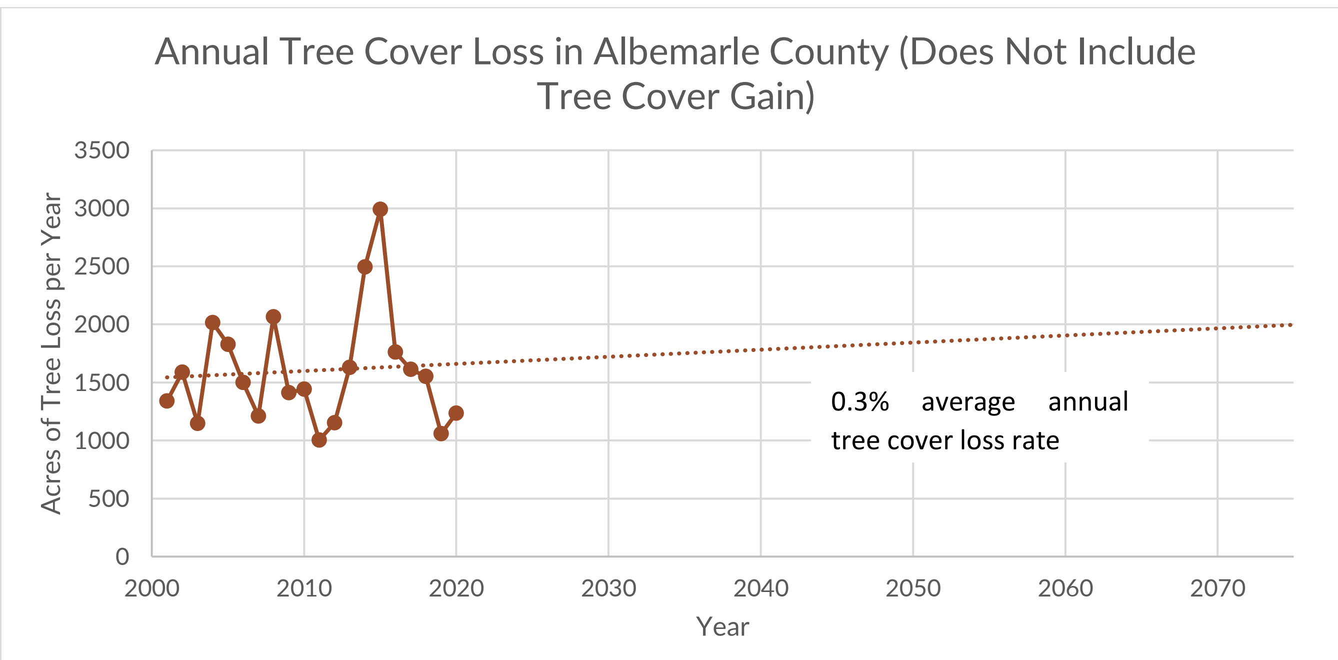


Figure 14: Annual Tree Cover Loss in Albemarle County

Land Conservation

Land in a land conservation program should be considered a natural asset since it protects natural and ecological resources, including drinking water. Land conservation will also help lessen the impacts of climate change. Undeveloped natural areas reduce the heat island effect of urban areas and the magnitude and impacts of flood events.

There are three programs that help protect and preserve natural and ecological resources in the county by restricting development. Figure 15 identifies the location of these land conservation programs. These approximations are likely high since a parcel of land may be completely or partially in a program, and the approximations include the total area of every participating parcel.

1) Agricultural/Forestal Districts: There are approximately 64,217 acres in this program, in which landowners are expected to limit development on their parcel for up to ten years.
2) Conservation Easements: There are approximately 109,285 acres in conservation easements, which protect land from development in perpetuity.
3) Open Space Use Agreements (OSUA): There are approximately 2,579 acres in open space use agreements, which limit construction and development activity on the property owner's land from four to ten years.

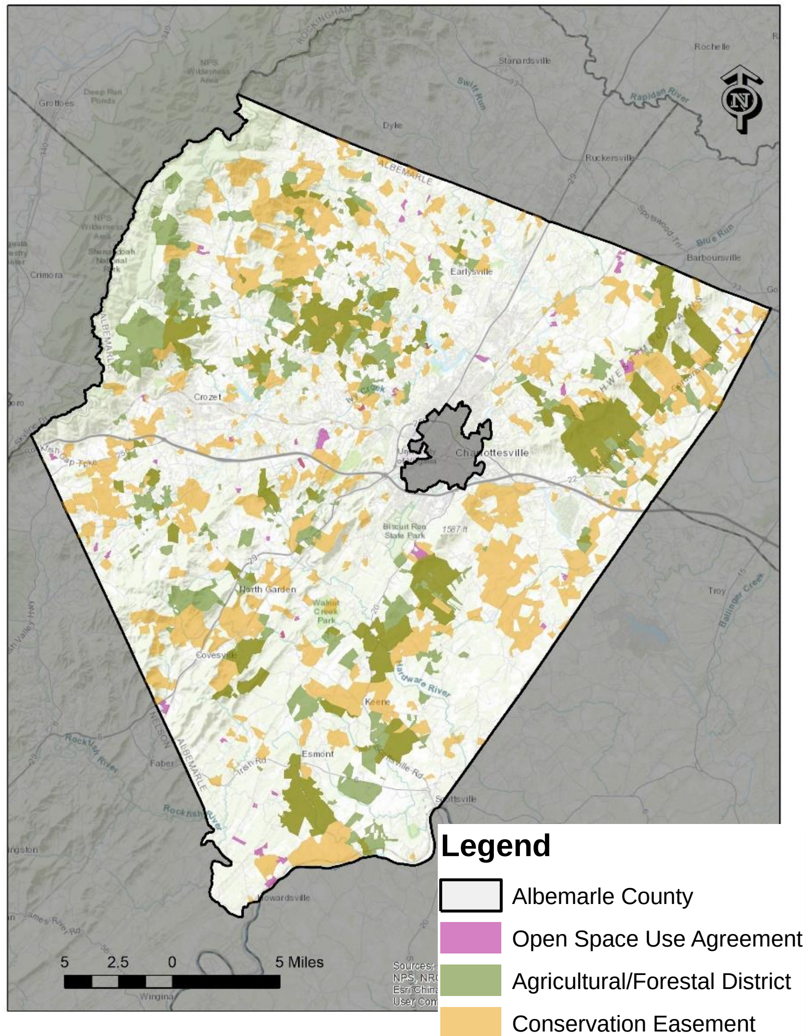


Figure 15: Land Conservation Areas

Parks

Albemarle County is home to thirteen public parks encompassing 3,093 acres. It also contains 14,131 acres of the Shenandoah National Park in the northwest. Figure 16 shows the location of these parks. Park land is a natural asset used for recreation, environmental education, positive health impacts, and social events. It will also help lessen the impacts of climate change by reducing the heat island effect of urban areas and reducing the magnitude of flood events. The parks in Albemarle County include:

- Beaver Creek Park (212 acres)
- Charlotte Y. Humphris Park (28 acres)
- Chris Greene Lake Park (237 acres)
- Darden Towe Park (115 acres)
- Dorrier Park (4 acres)
- Mint Springs Valley Park (508 acres)

- Patricia Ann Byrom Forest Preserve Park (587 acres)
- Preddy Creek Trail Park (452 acres)
- Simpson Park (14 acres)
- Totier Creek Park (205 acres)
- Walnut Creek Park (558 acres)
- Crozet Park (23 acres)
- Heyward Community Forest (150 acres)

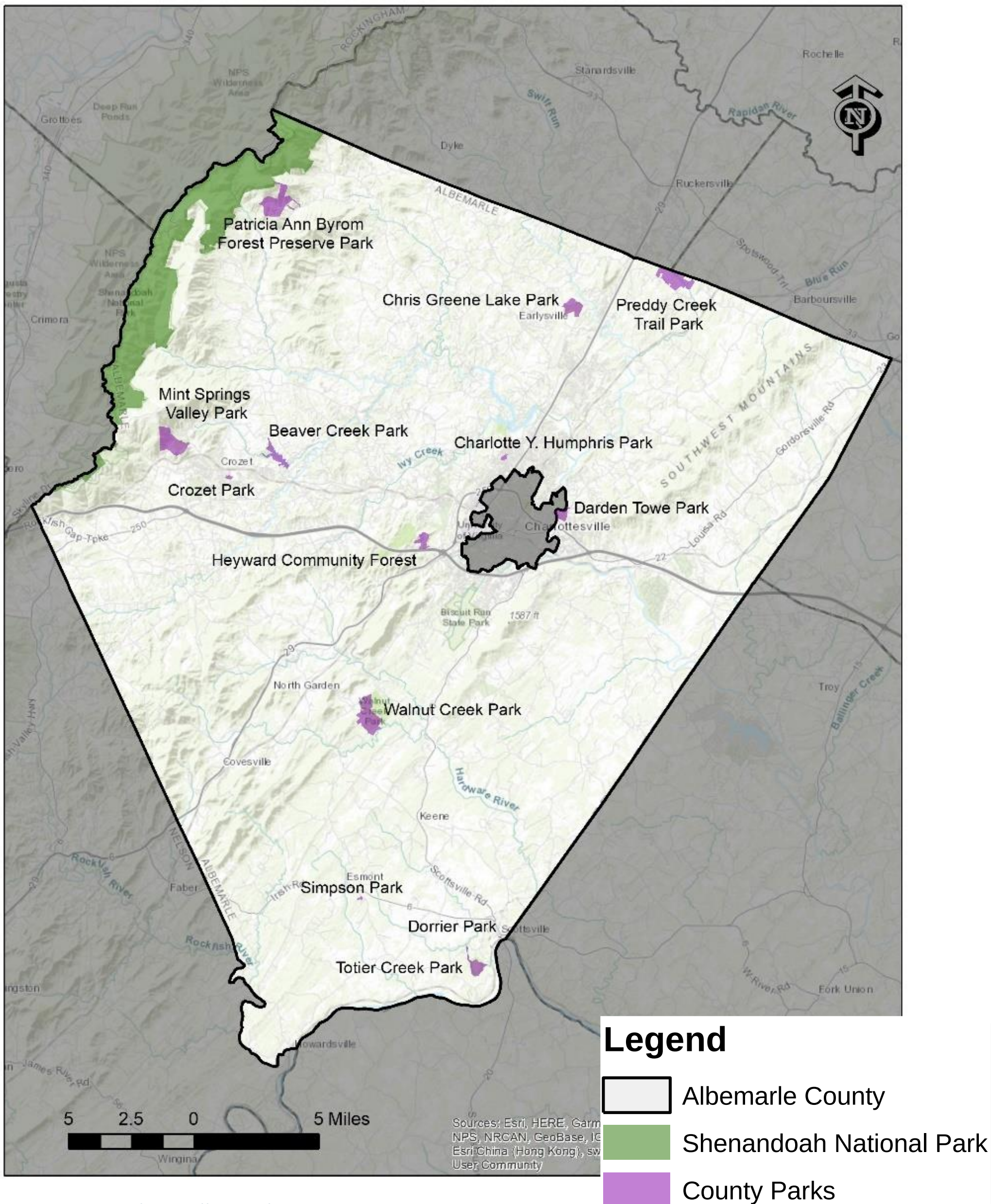


Figure 16: Parks in Albemarle County

Climate Mitigation

Several conservation practices also have atmospheric and climate benefits, through carbon sequestration and/or reduction of greenhouse gas (GHG) emissions. The USDA Natural Resources Conservation Service (NRCS) and Colorado State University have developed a carbon and greenhouse gas evaluation within their conservation practice planning tool, called COMET Planner, to help identify the quantitative benefits of conservation practices for climate mitigation (COMET Planner).

Table 9 shows the conservation practices in Albemarle County with climate benefits implemented in 2019, the number of practices implemented, the soil carbon benefit in metric tons, and the greenhouse gas reduction in metric tons of carbon dioxide equivalent.

Table 9: Climate Mitigation Assets (2019)

Conservation Practices with Climate Benefits Implemented in Albemarle County	Number Implemented	Soil Carbon (Metric Tons)	Greenhouse Gases (Metric Ton CO_2 Equivalent)
Cover Crop Traditional Rye Early Other	8	75.728	64.523
Cover Crop Traditional Wheat Early Aerial	8	2.909	2.479
Cover Crop Traditional Wheat Late Other	8	19.003	16.191
Cover Crop Traditional Wheat Normal Other	8	179.840	153.231
Forest Buffer	15	40.832	745.200
Grass Buffer	12	95.511	117.659
Grass Buffer – Narrow with Exclusion Fencing	1	6.176	7.608
Grass Buffer – Streamside with Exclusion Fencing	1	572.975	705.844
Grass Buffer – Narrow	12	13.827	17.033
Land Retirement to Ag Open Space	8	631.644	631.644
Precision Intensive Rotational/Prescribed Grazing	1	160.599	240.229
Tillage Management-Conservation	8	100.125	104.987
Tillage Management-Continuous High Residue	8	1,165.958	1,222.583
Tree Planting	14	73.771	4,448.561
Tree Planting – Canopy	3	0.060	3.621
Wetland Restoration - Floodplain	14	1.579	95.199

***Cover Crops* (top right) include grasses, legumes, and forbs planted for seasonal vegetative cover. *Grass Buffers* are strips of permanent vegetation at the edge or perimeter of a field (bottom right).**

By limiting soil-disturbing activities like *tillage*, carbon emissions are minimized and retained in the soil.

Establishing vegetation such as woodland, forests, and wetlands through *tree planting* and *wetland restoration* increases biomass carbon stocks.

Photos from USDA NRCS

Built Environment

Most development in Albemarle County occurs within designated growth areas. According to the County's parcel data, about 75% of new construction has occurred in the designated growth areas over the last ten years. Commercial properties are primarily located around Charlottesville (including Pantops); along Route 29 (north of Charlottesville); along I-64; and in the community of Crozet, village of Rivanna, and Town of Scottsville. Industrial properties are located along the Route 29 and I-64 corridors, near Crozet and Scottsville, and around Charlottesville. Educational and governmental facilities are spread out across the county to serve population centers.

The total structures in the county have a replacement value of approximately $23.4 billion. Figure 17 shows the value of the structures by occupancy as a percentage. Residential structures comprise a large majority of the building stock's value. Figure 18 shows the geographic distribution of structures by occupancy type.

Additionally, we used the County's parcel data to graph the number and types of buildings built each decade in the county. We added a trend line based on the past two decades to estimate the number of single-family homes in 2050 and 2075. Figure 19 depicts the number of single-family homes in the county from 1900 until 2020 with a trend line to 2075. Figure 20 depicts the number of *all other* residential buildings by decade built along with a trend line for building type. There was a large increase in mobile homes from 1980 until 2000 and a moderate increase from 2000 to the present. The number of duplexes and townhomes has increased since the 1960s while the number of apartments has increased since the 1990s. In the most recent decade, there has also been an increase in hotels, dormitory

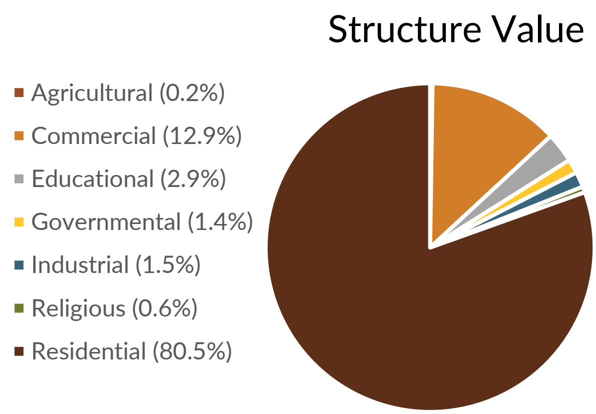


Figure 17: Value of Structures by Occupancy

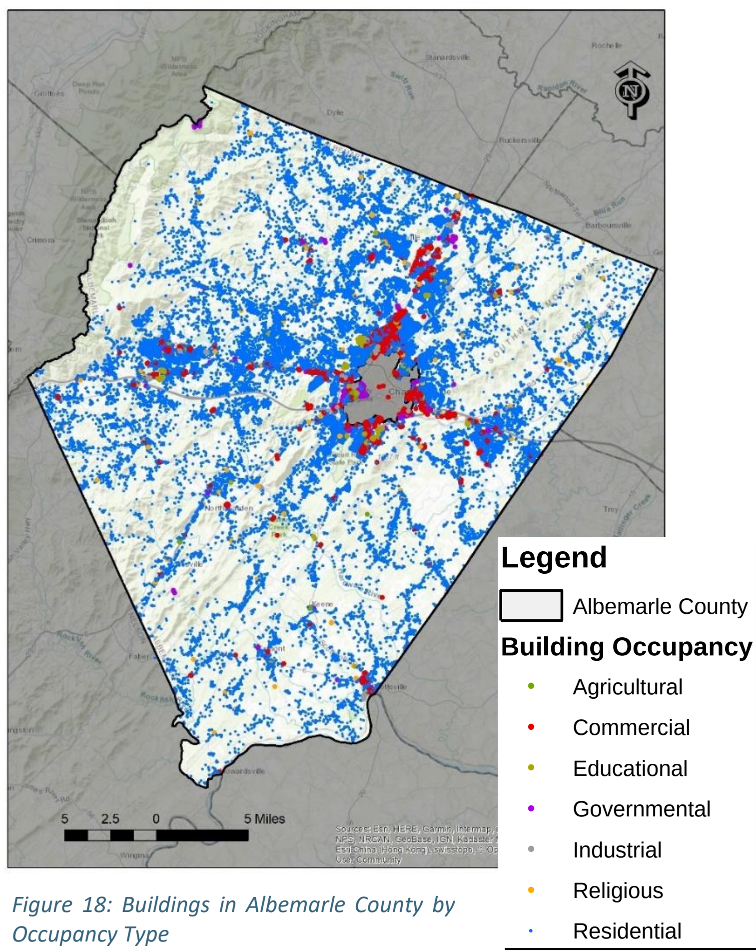


Figure 18: Buildings in Albemarle County by Occupancy Type

housing, and nursing homes. (We depict single-family homes separately because they number an order of magnitude greater than all other building types; in the same chart, the values for all other building types would be nearly indistinguishable.

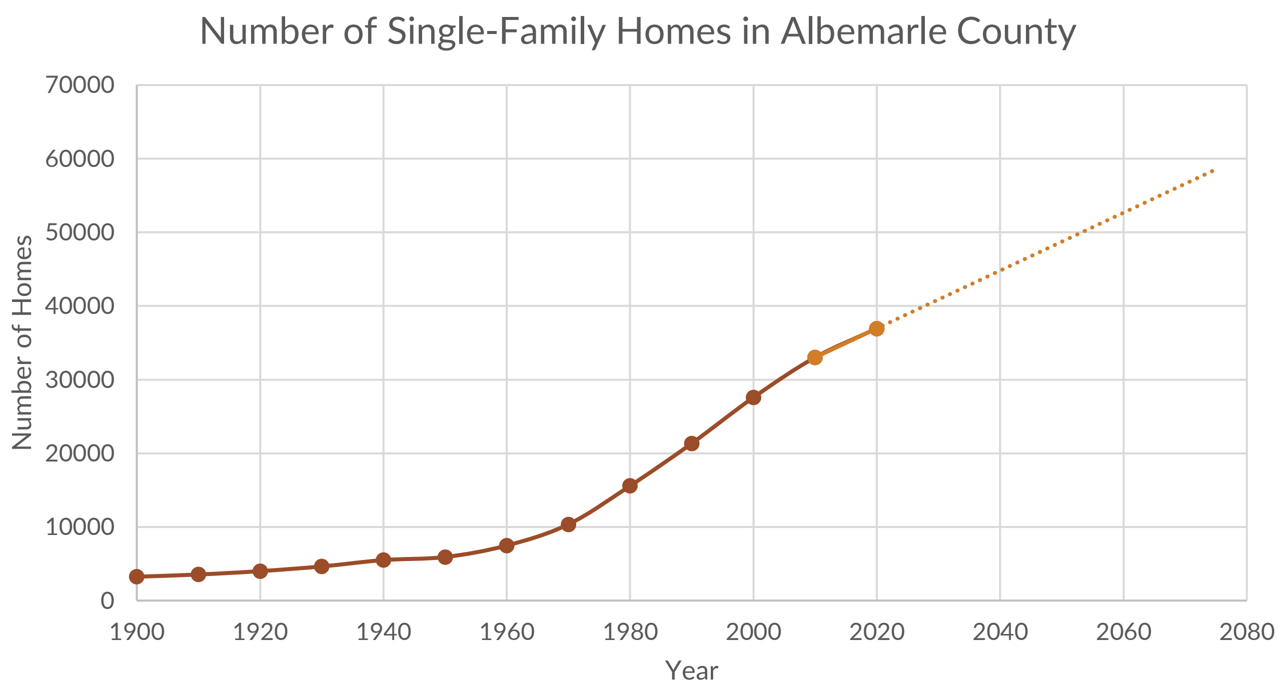


Figure 19: Single Family Homes Shown by Decade Built in Albemarle County. We depict all other residential building types in a separate chart below to allow for greater visual detail.

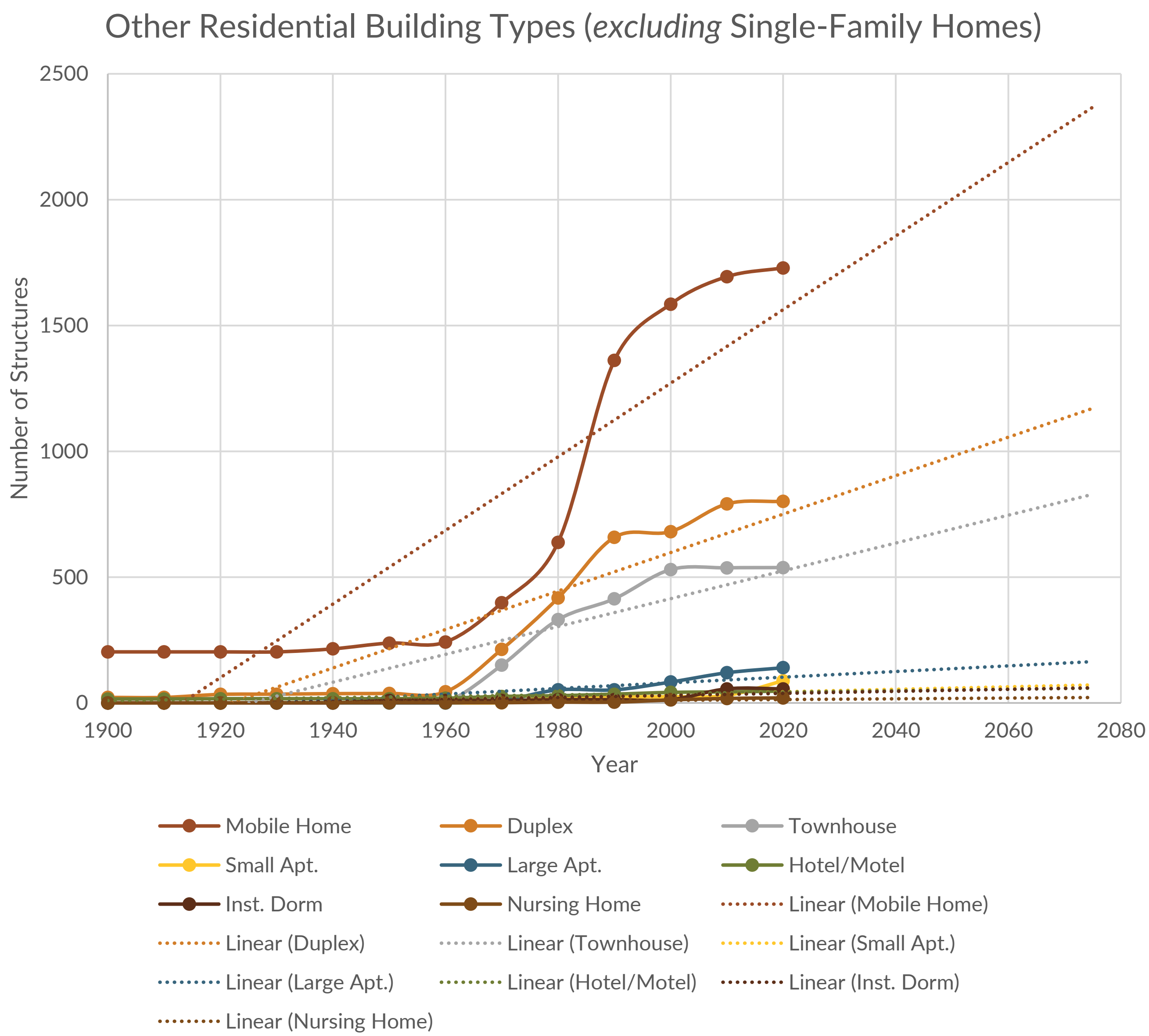


Figure 20: Other Residential Buildings Shown by Decade Built in Albemarle County. Linear trend lines depict a rough estimate of future growth. We depict single-family homes in a separate chart to allow for greater visual detail.

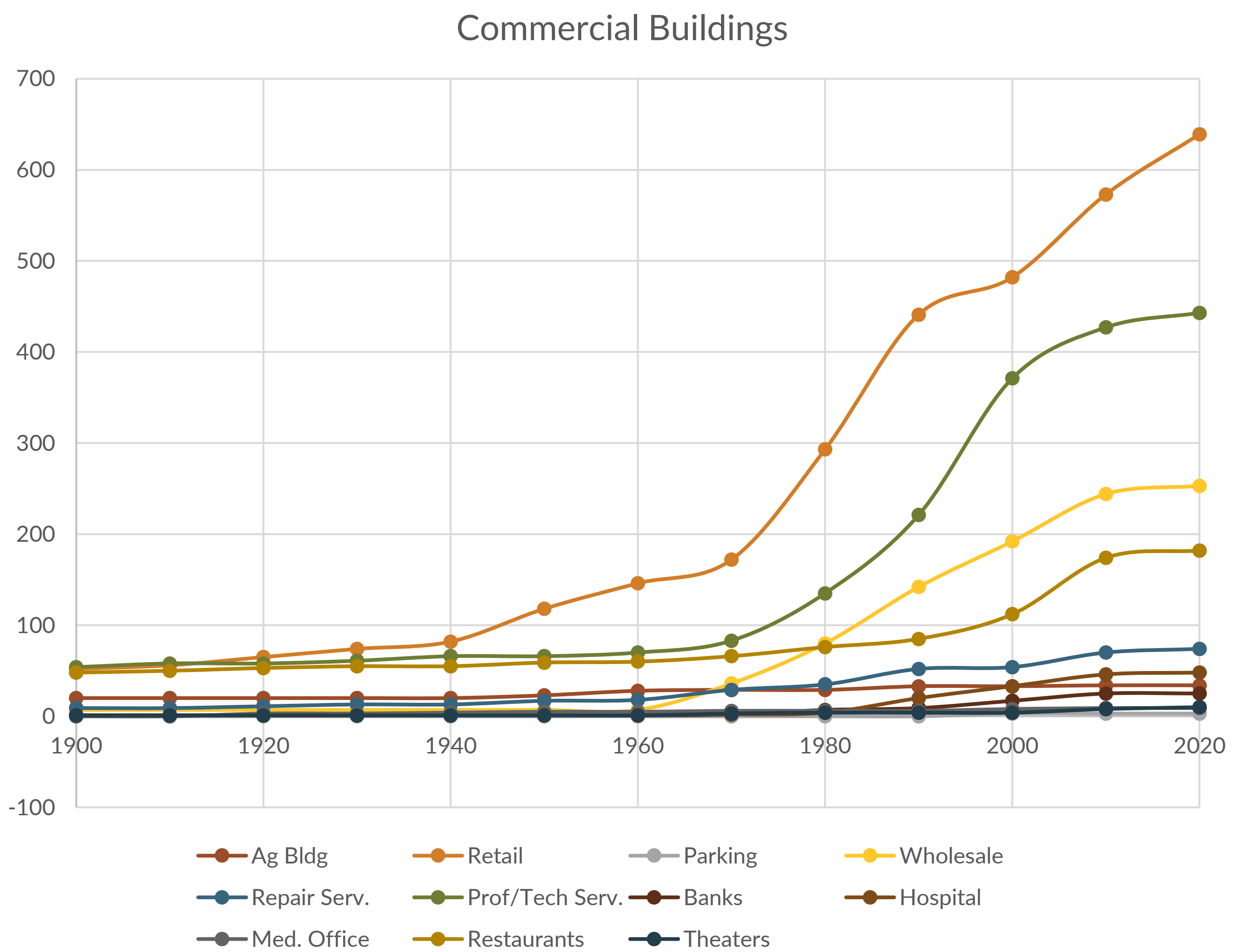


Figure 21: Commercial Buildings Shown by Decade Built in Albemarle County

We also used the county parcel data to show how commercial buildings have increased over time, depicted in Figure 21. Retail, professional, and technical services, wholesale, and restaurants have increased rapidly over the last forty years. Other commercial types have increased more slowly over time.

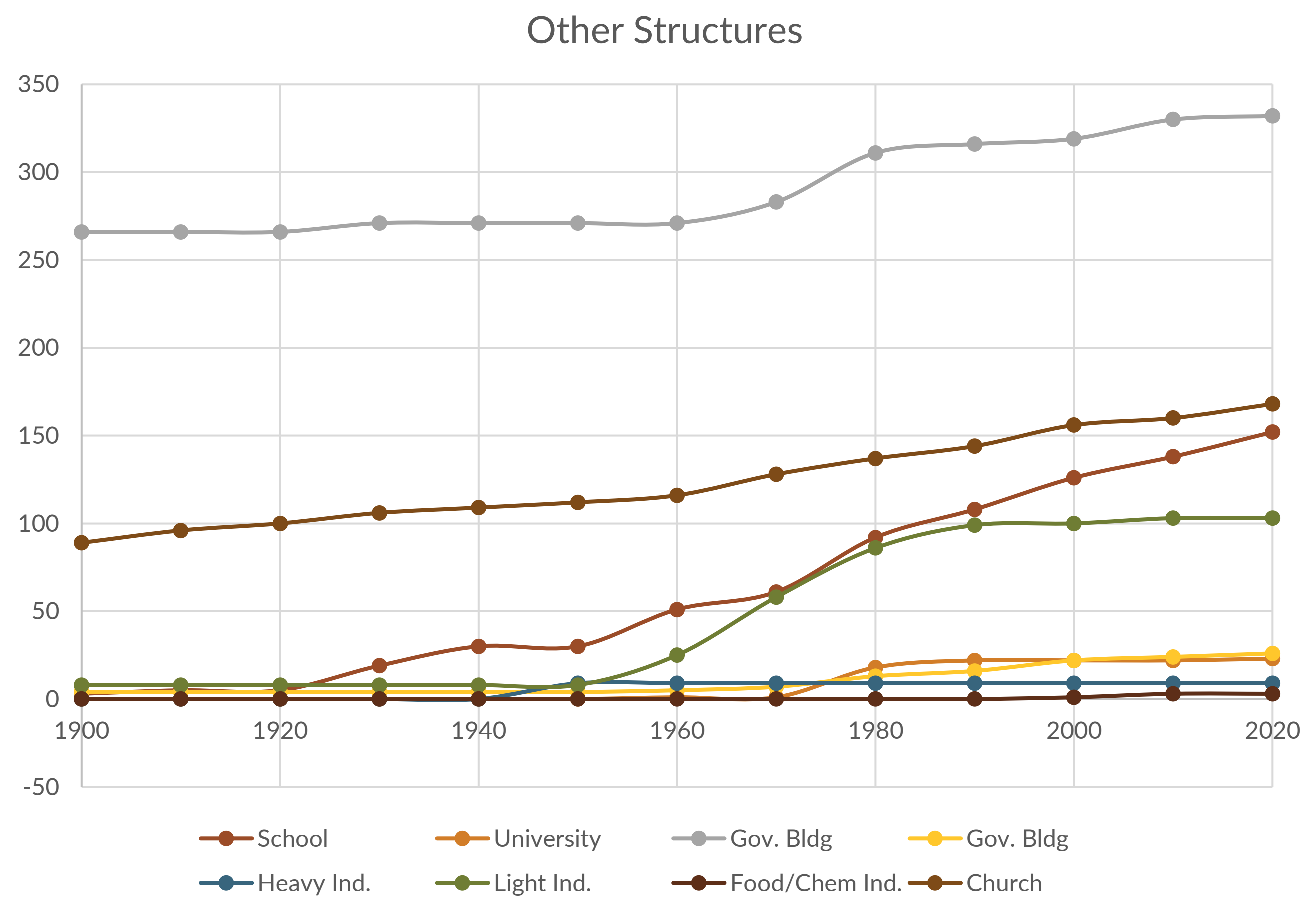


Figure 22: Other Structures Shown by Decade Built in Albemarle County

Figure 22 depicts how the number of non-residential and non-commercial buildings has changed over time, based on county parcel data. Schools, government buildings, and light industrial buildings have increased rapidly since the 1970s. Churches have increased steadily over time and other building types have increased more slowly over time.

The following sections provide additional details on the county's critical facilities, historic districts, housing, transportation, and utilities.

Critical Facilities

Facilities involved with emergency response (e.g., fire stations, rescue squads, police stations, emergency operations centers, and hospitals), as well as nursing homes and schools, are considered critical facilities. It is important to understand how the structure or function of critical facilities maybe be impacted by hazards exacerbated by climate change.

The following critical facilities were identified and mapped in Figure 23:

- Three police stations
- Eleven fire stations
- Eight rescue squads
- Two emergency operations centers
- Two hospitals
- Sixteen nursing homes
- Twenty-three public schools
- Twelve private schools

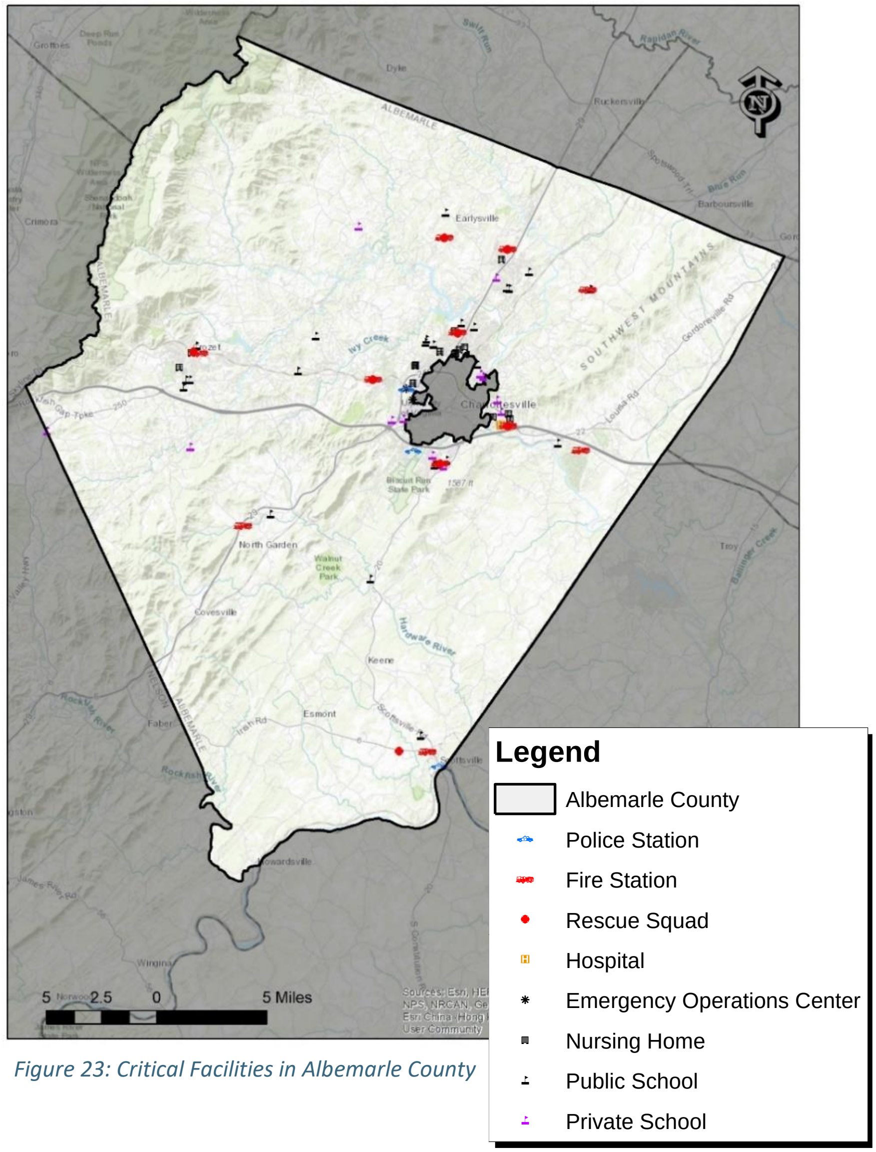


Figure 23: Critical Facilities in Albemarle County

Historic Districts

Albemarle County is home to several historic districts and properties, and the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Site of Monticello and the University of Virginia's Academical Village. The county's history helps create a robust tourism industry. Historic Districts in the county are:

- Advance Mills (Fray's Mill) Historic District – Advance Mills is one of Albemarle County's most recognizable milling communities and contains resources dating back to the early 1800s.
- Batesville Historic District – A small community in the southwestern part of Albemarle County at the intersection of Plank Road and Craig's Store Road that includes two country stores and a post office.
- Covesville Historic District – Located southeast of Charlottesville, Covesville was added to the National Register of Historic Places in June of 2005. It developed in response to religious settlement, transportation routes, and a successful apple-growing climate.
- Crozet Historic District – Crozet Historic District began in 1876 as a railroad stop that gave rise to a crossroads village along Three Notch'd Road. A prosperous fruit and orchard industry in the area transformed the village into a thriving community at the turn of the twentieth century.
- Proffit Historic District – Proffit dates to around 1870 when former slaves John Coles and Benjamin Brown purchased land from W. G. Carr. Plans were made to lay out a village, which became home to a community of freed African Americans.

- Skyline Drive Historic District – Constructed in the 1930's, several hundred Shenandoah National Park structures are listed in the National Register of Historic Places, including buildings (e.g., Big Meadows Lodge), bridges, stone-lined ditches, culverts, and retaining walls.
- Southern Albemarle Rural Historic District – 85,000-acre historic district in southeastern Albemarle County, which was added to the Virginia Landmarks Register and the National Register of Historic Places in 2006. The district includes many historic properties, such as Monticello, Ash Lawn-Highland, Tallwood, Pine Knot, and Jefferson Mill.
- Southwest Mountain Rural Historic District – District extends from the Orange County line south towards Charlottesville, encompassing state scenic roads Route 20 and Route 231. Protected by over 15,000 acres of conservation easements, the district is home to several historically significant dwellings, such as Castle Hill, Clover Fields, and Cobham Park. In addition to many historic agricultural structures, the district contains several African American settlements.

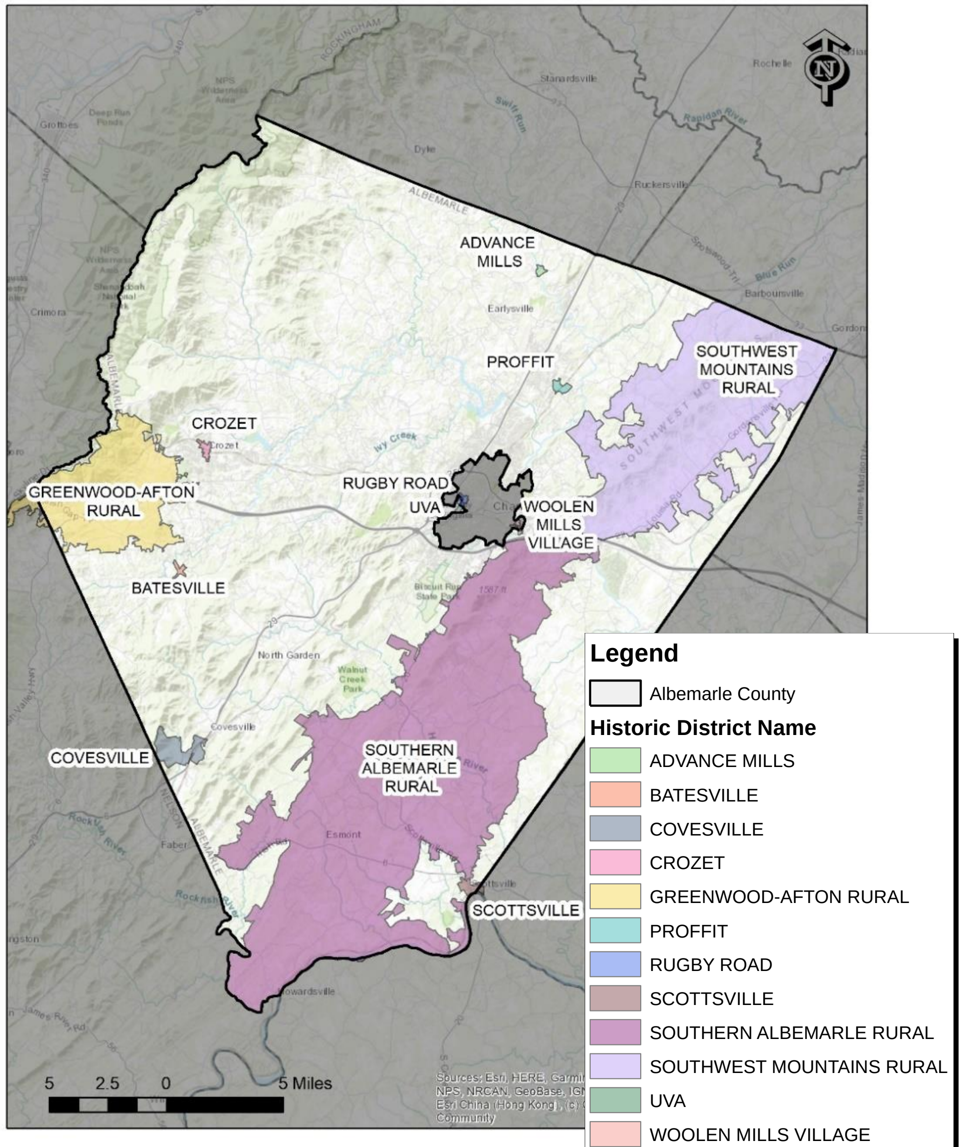


Figure 24:Historic Districts in Albemarle County

- UVA Area Historic District (Albemarle County and Charlottesville) – Located in Western Charlottesville and part of Albemarle, this district includes many original buildings and grounds designed by Thomas Jefferson.
- Greenwood-Afton Historic District (Albemarle, Augusta, and Nelson Counties) – Located on 16,200 acres in northwestern Albemarle County, consists of several historic villages, including Yancey Mills, Afton, Greenwood, and the historically African American enclaves of Newtown and Freetown.
- Scottsville Historic District (Albemarle and Fluvanna Counties) – Includes the town of Scottsville in southern Albemarle County along the James River.

A map of these historic districts is provided in **Error! Reference source not found.**.

Housing

According to the 2020 U.S. Census, there were 47,291 households in Albemarle County. This number includes single-family homes, multi-family homes, mobile homes, nursing homes, and institutional housing. The number does not include people staying in hotels and motels. Based on county parcel and building footprint data (2021), **Error! Reference source not found.** shows the percentage of the number of housing structures in the county. The vast majority are single-family homes. Multi-family structures and nursing homes are located in the urban areas outside of Charlottesville, on the Route 29 corridor, and in Rivanna, Scottsville, and Crozet. Mobile homes are located throughout the county. Residents in mobile homes, nursing homes, and institutional housing may be more susceptible to climate impacts.

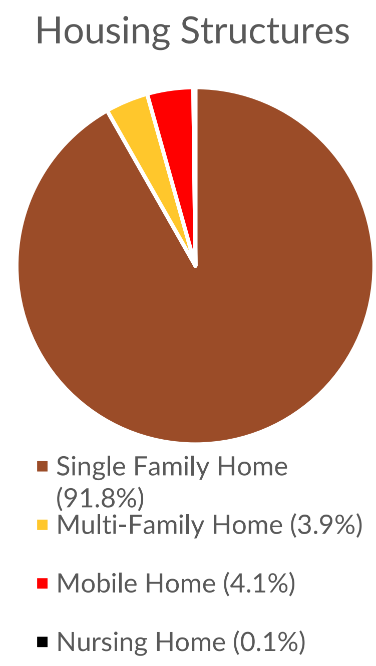


Figure 25: Percentage of Housing Structures by Type

Figure 26 provides a map showing the housing types in the county.

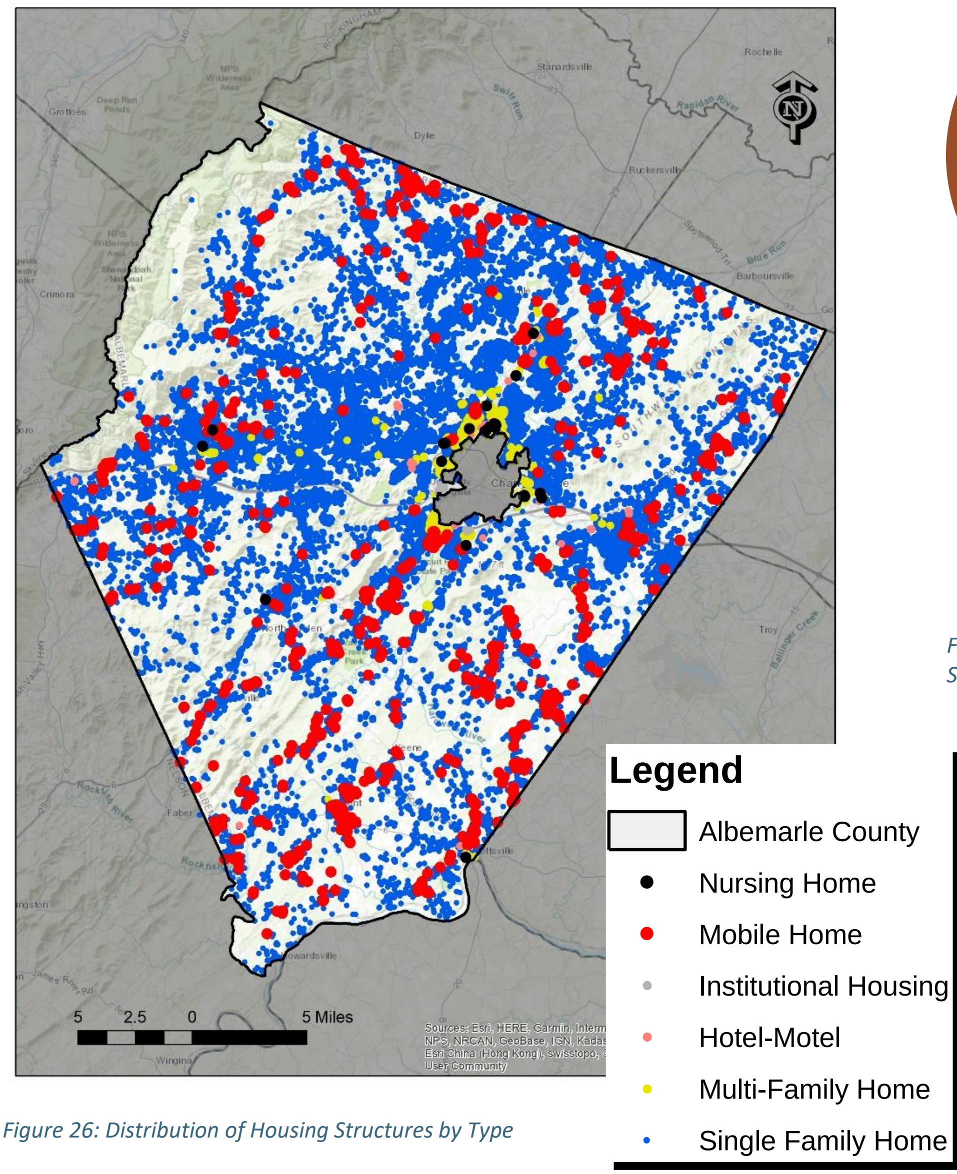


Figure 26: Distribution of Housing Structures by Type

The parcel data from the county provides information on the home's condition. Only 1.4% of residential structures are in poor condition, and 0.8% are in very poor condition. Homes in poor and very poor conditions are found throughout the county. Such structures could be more susceptible to climate change impacts. Figure 27 depicts the percentage distribution of housing conditions, and Figure 28 shows the geographic distribution of these conditions across the county.

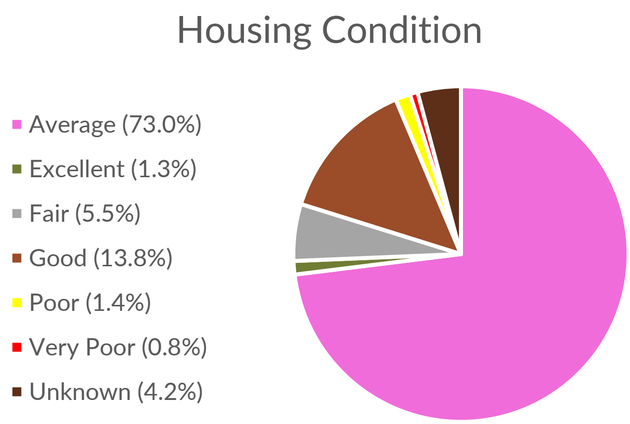


Figure 27: Housing Conditions Chart

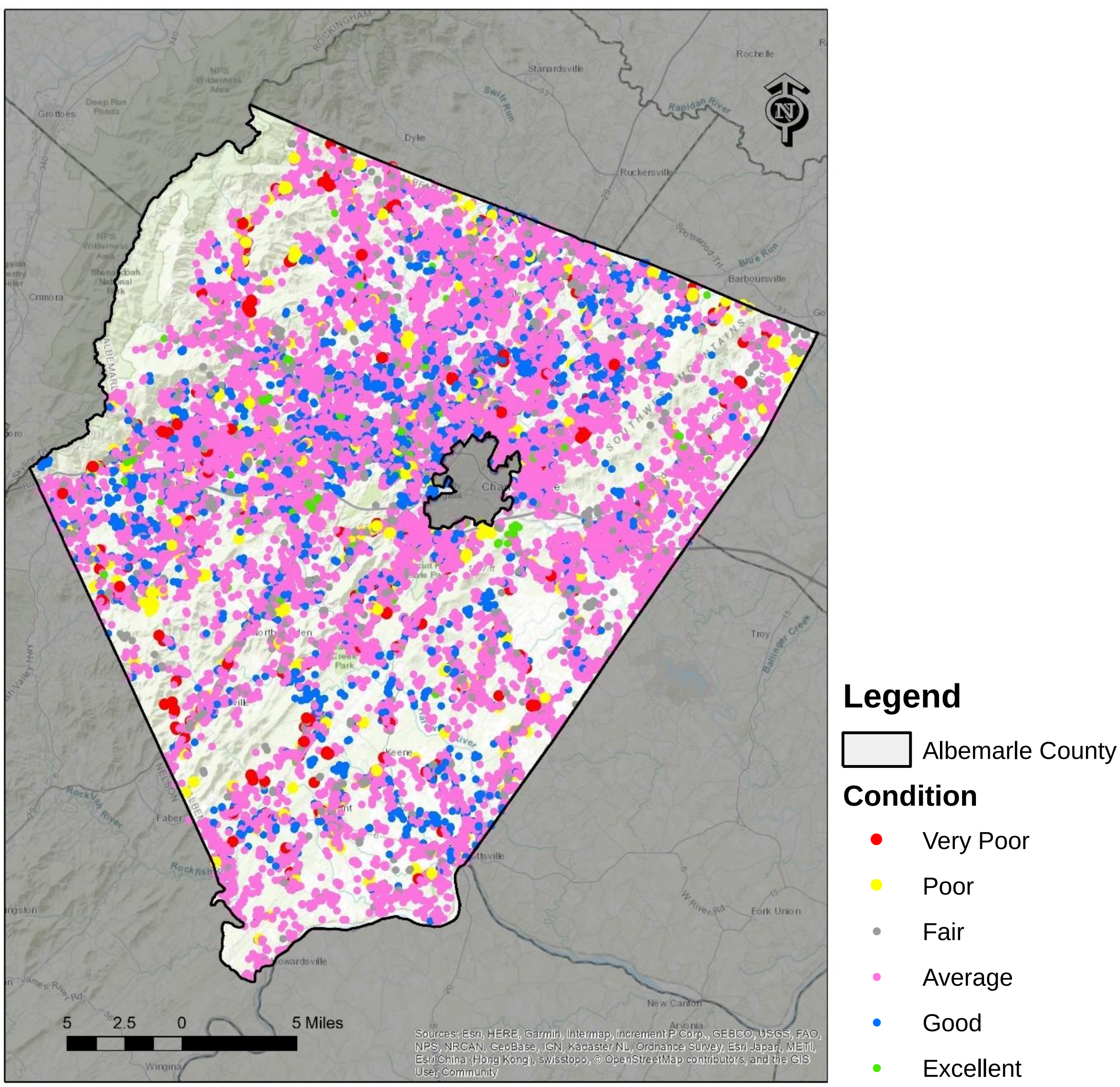


Figure 28: Housing Condition

County parcel data also identifies when homes were built, shown in Figure 29. Older homes are found throughout the county and may be more susceptible to climate change impacts. Although most homes were built after 1960, more than ten percent were built before 1900. There are several historical homes in the county. Figure 30 shows residential structures by year of construction. The red and orange dots indicate homes built prior to 1931, most of which are located outside the development areas.

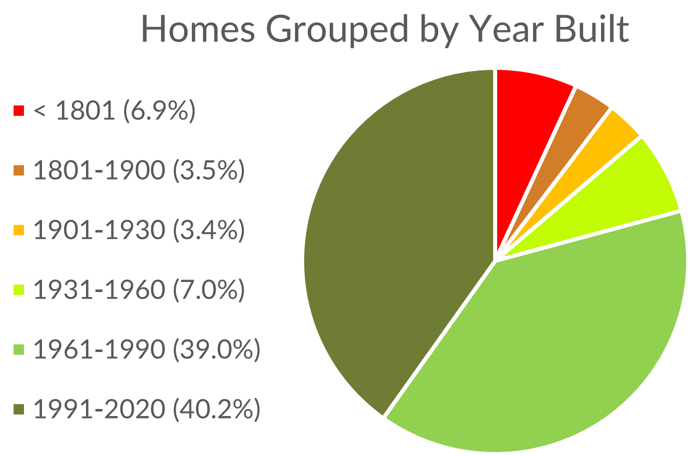


Figure 29: Percentage of homes built in 30-year increments between 1901 and 2020, in a 100-year increment between 1801 and 1900, and prior to 1801.

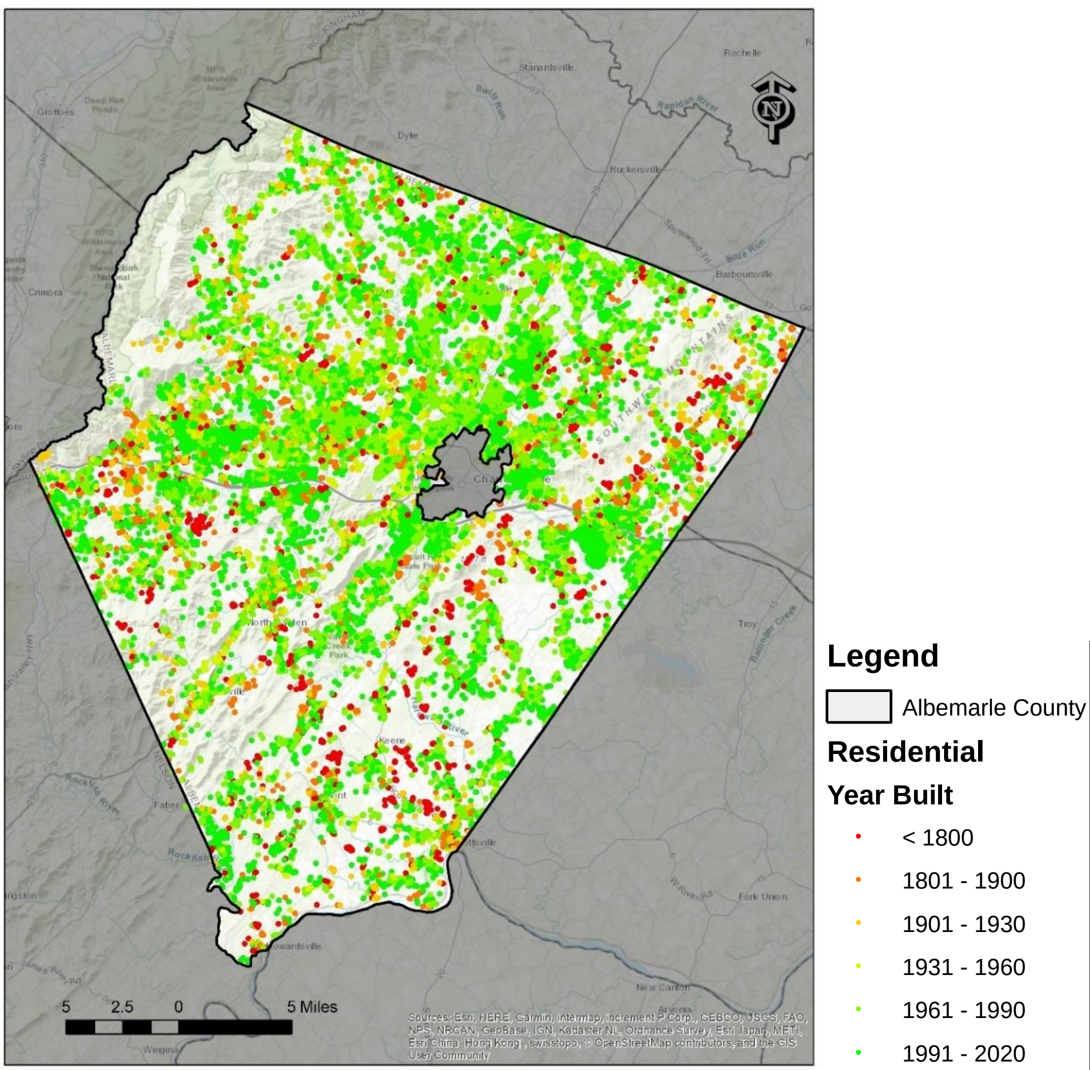


Figure 30: Residential Home Year Built Map

Transportation

Three major transportation corridors run through Albemarle County: Interstate 64, U.S. Route 250, and U.S. Route 29. Much of the county's growth has occurred along these routes. Many of the secondary roads are narrow and hilly, and some have restrictions for larger trucks. There is a regional RideShare program that matches commuters who wish to carpool.

Both freight and passenger service trains run north-south and east-west. Amtrak operates a station in Charlottesville with a north-south route going to Culpeper (north) and Lynchburg (south), and a west route going to Staunton. There is an additional freight service which goes east from Charlottesville through the county.

The Charlottesville Area Transit (CAT) provides bus transportation in Charlottesville and the surrounding developed areas, including the Route 29 corridor and Pantops. All CAT buses are accessible to people with disabilities and are equipped with wheelchair lifts. Prior to 2020, area youth (under 18) were allowed to ride free, as were University of Virginia employees and City of Charlottesville employees. Reduced fares were available for seniors 65 or older, people with qualifying disabilities, Albemarle County employees, and those with a Medicare Card. Since 2020, CAT has eliminated ridership fares until further notice.

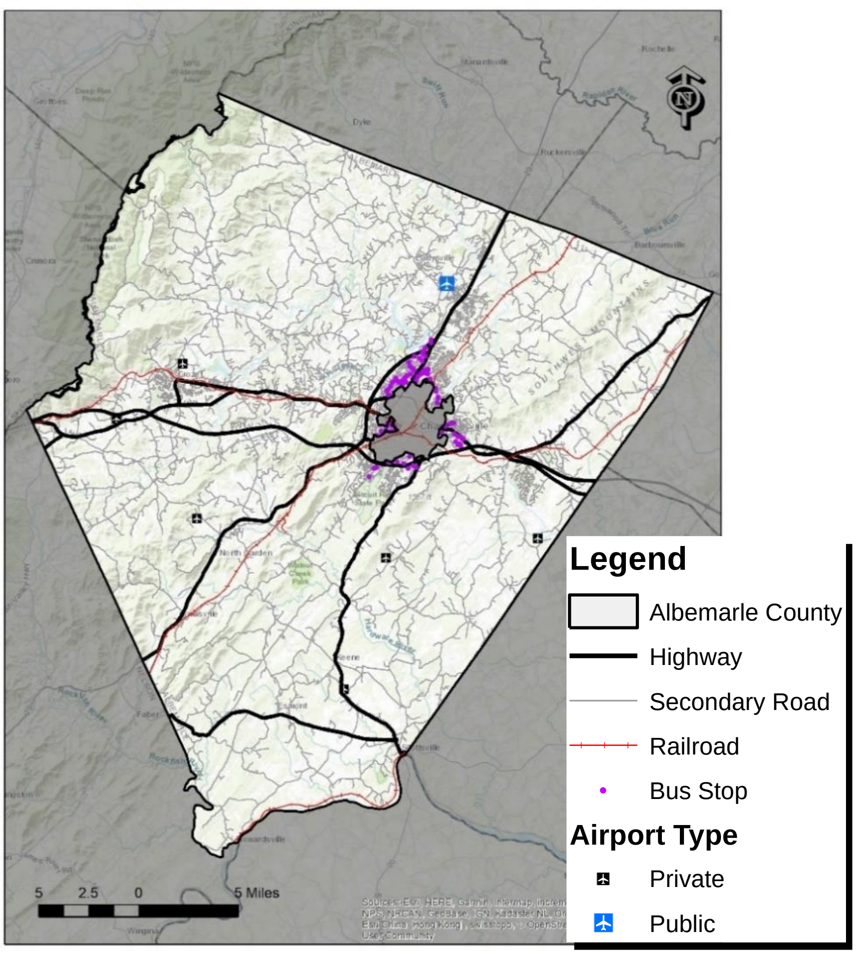


Figure 31: Albemarle County Transportation

JAUNT, Inc. is a regional public transportation system that provides service to Albemarle County as well as the surrounding counties and Charlottesville. JAUNT operates in both rural and urban areas, and residents can use it to commute to work, recreation, shopping, and other destinations. It is provided at low or no cost to the general public, seniors, and students. Transportation is also provided to those with disabilities.

The Charlottesville-Albemarle Airport is located in the northern part of the county, about eight miles north of Charlottesville. American Airlines, Delta Airlines, and United Airlines operate routes to Atlanta, Charlotte, Chicago, New York, Philadelphia, and Washington, D.C. There are five additional private runways in the county. Figure 31 shows the roadways, rail, airports, and bus stops in Albemarle County.

Utilities

Utilities can help the population adapt to climate change, by providing electricity to help cool and heat buildings and water during periods of drought. Losing utilities due to impacts from a climate-exacerbated hazard can cause major social and economic impacts to the community.

The Albemarle County Service Authority (ACSA) provides safe water, wastewater, and fire protection infrastructure to 20,252 customers in Albemarle County. The Rivanna Authorities provide clean water to ACSA and Charlottesville through five drinking water reservoirs: (1) Ragged Mountain Reservoir, (2) Sugar Hollow Reservoir, (3) South Fork Reservoir, (4) Beaver Creek, and (5) Totier Creek. Combined, these reservoirs contain 3.4 billion gallons in water storage. Rivanna Authorities also manage six water treatment plants with a combined nominal capacity of 19 million gallons per day. Figure 32 shows the areas of the county to which ACSA provides water and sewer service. Water and sewer pump stations, water and sewer treatment plants, and water tanks are shown on the map.

There are four power suppliers that service Albemarle County: Appalachian Power Company, Central Virginia Electric Cooperative, Dominion Virginia Power, and Rappahannock Electric Cooperative. Figure 32 also shows the locations of electric substations. There are three major natural gas lines in and adjacent to the county including the Columbia Gas line in the northeast corner of the county, the Columbia Gas line on the western part of the county, and the Transcontinental Gas line that runs along the eastern border just outside the county. Figure 32 shows the location of these three gas lines.

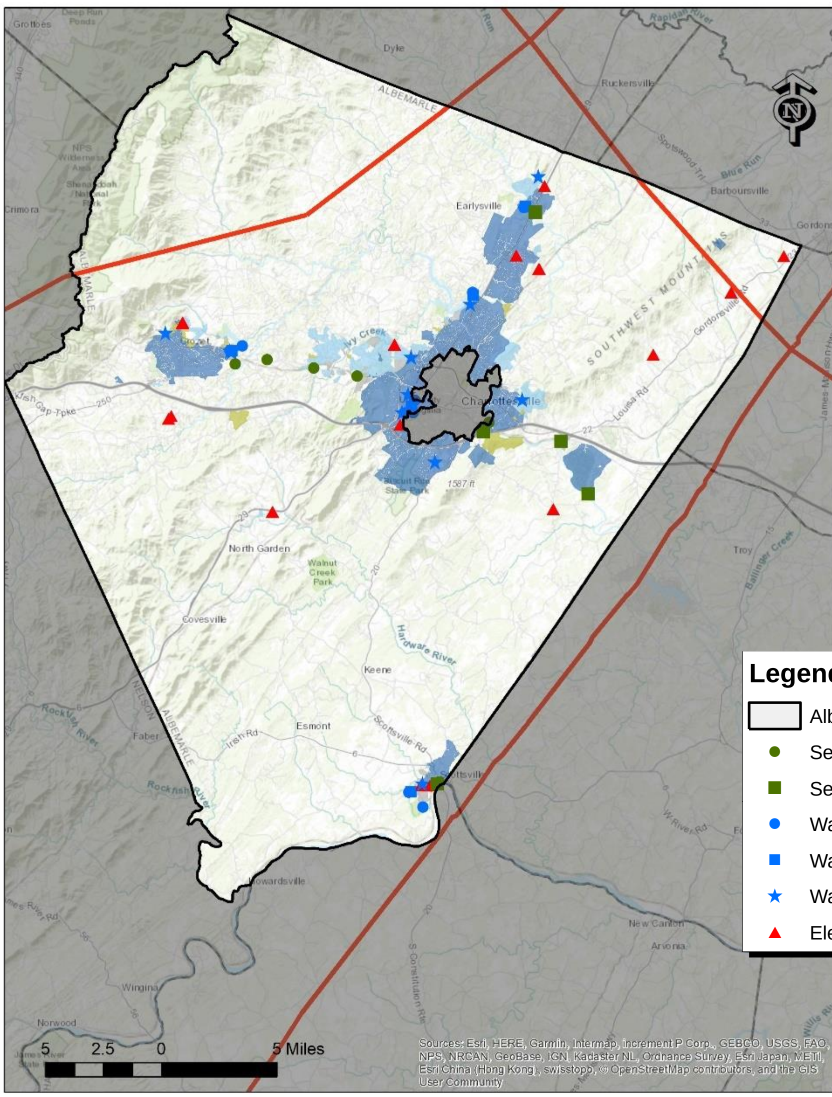


Figure 32: Utilities

Economic Growth and Development

The economy in Albemarle County is diversified with agriculture, education, government, health care, manufacturing, recreation, and tourism. The county has maintained a steady growth rate and healthy economy due, in part, to its proximity to major transportation routes and the City of Charlottesville, to being part of a major wine-producing region, and to tourism at several significant, historic sites. In 2020, there were 57,733 employees working in the county, with 65% in the private sector and 35% in the public sector. The real gross domestic product (real GDP) for the Charlottesville-Albemarle Metropolitan Statistical Area (MSA) was $12.343 Billion in 2020 (Albemarle County Economic Outlook, 2021).

Table 10 provides the number of employees working in the county by industry and year. The 2021 and 2022 numbers were forecasts.

Table 10: Number of Employees in Albemarle County. An asterisk (*) indicates forecasted data.

Industry	Employees (2017)	Employees (2018)	Employees (2019)	Employees (2020)	Employees (2021)*	Employees (2022)*
Accommodation and Food Services	4,087	4,395	4,398	4,398	3,439	3,598
Administrative and Waste Services	2,094	2,148	2,098	2,098	2,018	2,037
Ag., Forestry, Fishing, and Hunting	594	607	686	686	666	722
Arts, Entertainment, and Recreation	1,738	1,795	1,730	1,730	1,687	1,698
Construction	2,356	2,390	2,267	2,267	2,309	2,285
Educational Services	888	880	879	879	874	876
Finance and Insurance	925	961	980	980	1,019	1,058
Health Care and Social Assistance	6,316	6,303	6,486	6,486	7,066	7,219
Information	723	769	796	796	766	810
Management of Companies	1,374	1,336	1,332	1,332	1,329	1,319
Manufacturing	2,121	2,119	2,147	2,147	2,182	2,213
Mining, Quarrying, Oil and Gas Extraction	57	54	46	46	48	44
Other Services	1,962	1,990	2,046	2,046	1,972	2,029
Professional and Technical Services	3,682	3,713	3,714	3,714	3,875	3,922
Public Administration	1,604	1,627	1,671	1,671	1,681	1,729
Real Estate and Rental/Leasing	868	880	957	957	970	1,027
Retail Trade	6,149	6,240	6,175	6,175	5,740	5,799
Transportation & Warehousing	710	741	829	829	922	1,004
Unclassified	102	117	96	96	99	98
Utilities	42	30	30	30	29	25
Wholesale Trade	641	701	732	732	687	739

From 2001 to 2021, the combined GDP of Albemarle and Charlottesville has grown steadily with the population. Figure 33 shows the growth in GDP from 2001 to 2021 (U.S. Bureau of Economic Analysis). We added a trend line to depict a possible growth projection in the coming decades. However, many factors can change a community's

GDP from one year to the next, and this trend line should not be seen as an economic forecast. Figure 34 (next page) shows how each sector contributed to the overall GDP of Albemarle County and Charlottesville.

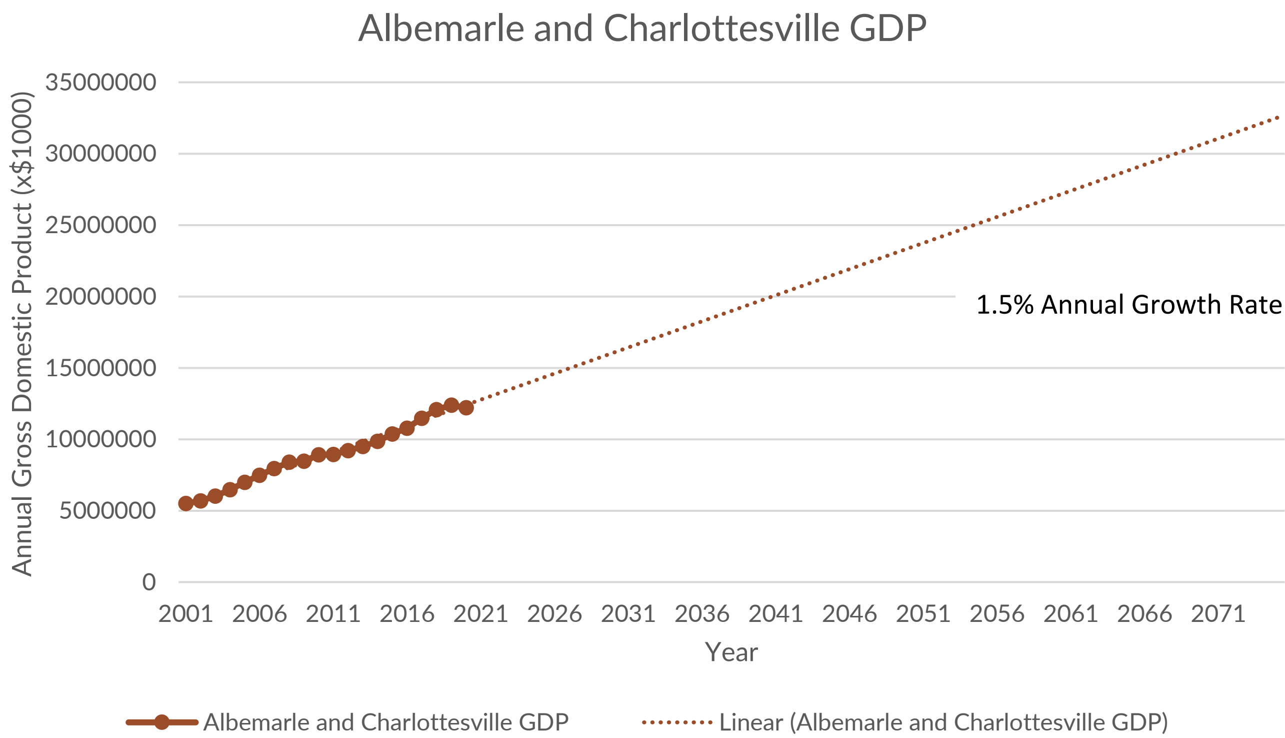


Figure 33: Albemarle County and Charlottesville gross domestic product (GDP) by year (U.S. Bureau of Economic Analysis, 2021)

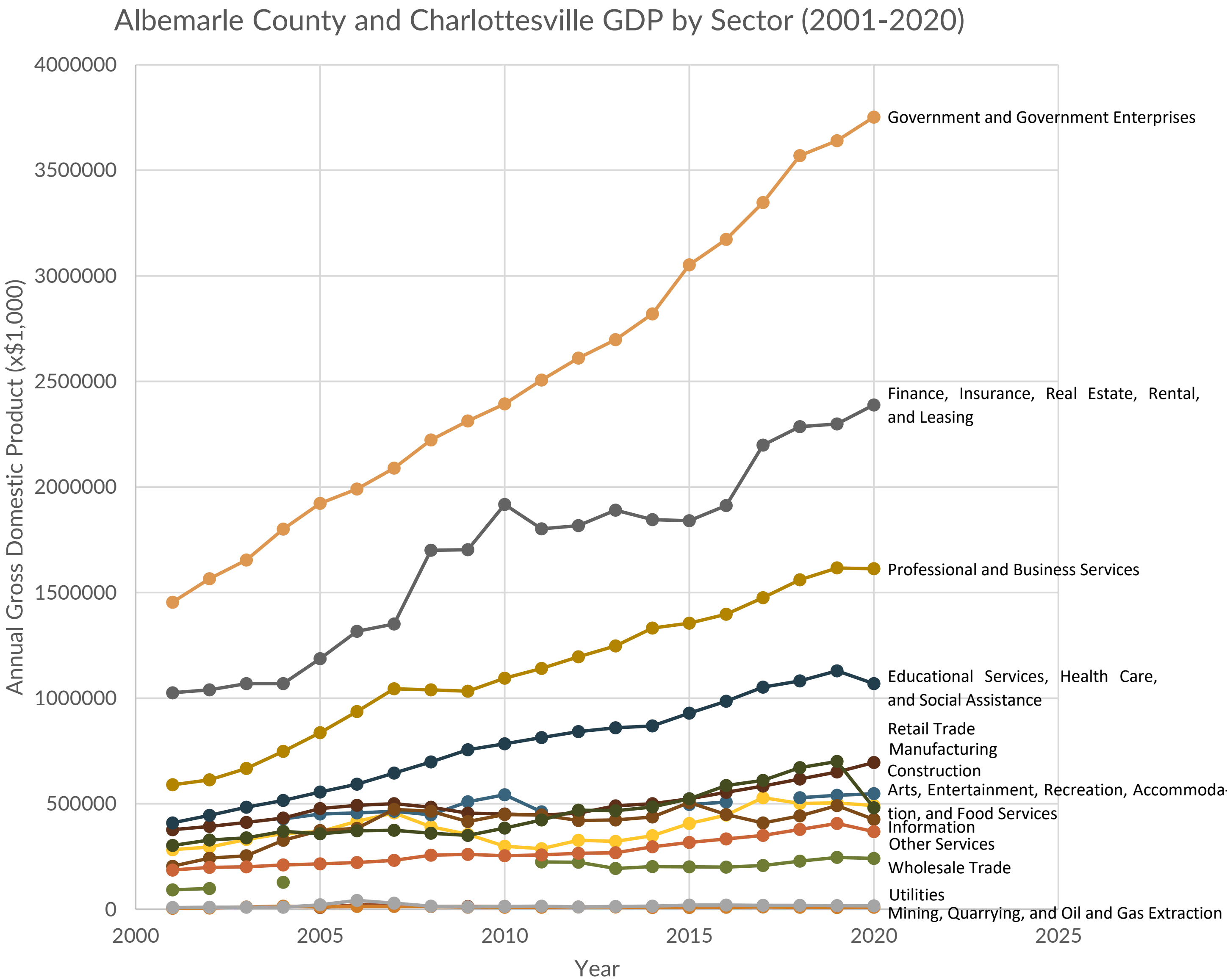


Figure 34: Annual sector Contributions to the gross domestic product (GDP) (2001-2020) (U.S. Bureau of Economic Analysis, 2021)

Chapter 2: Climate Change

In this report, we focused on identifying hazards that are exacerbated by climate change and modeling the impacts of those hazards. To better comprehend the hazard impacts, we must first understand the future climate. We explore the following hazards in this report:

Extreme Heat includes temperatures that are much hotter and/or more humid than average, as well as unseasonable weather. In the summer, this can cause heat-related illness, and in the late winter and early spring, this can cause damage to orchards and other agriculture.

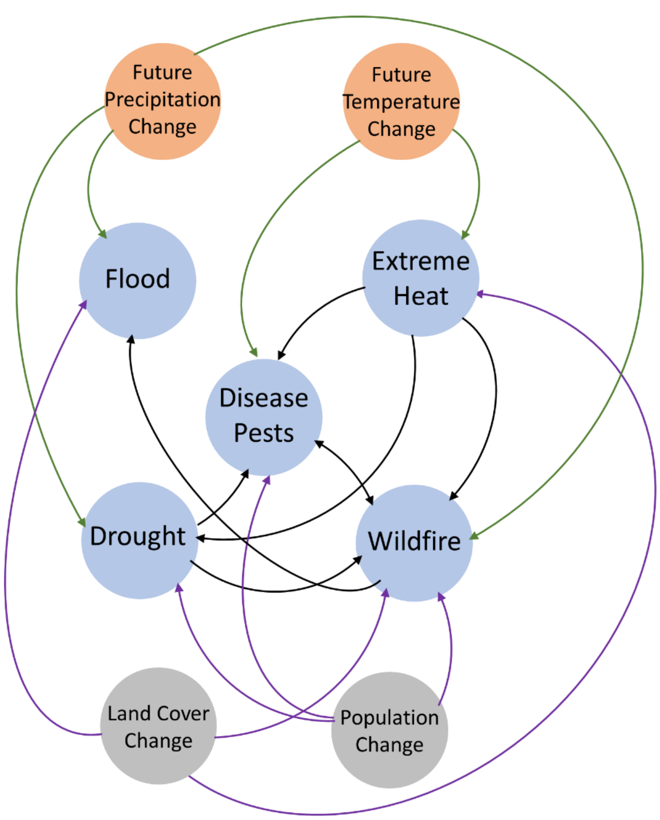
Drought includes a prolonged period of abnormally low rainfall, which can lead to lower surface and ground water levels.

Wildfire includes a destructive fire that can quickly spread over brush and forested land.

Flooding includes fluvial (or riverine) flooding caused by excessive or intense precipitation.

Disease and Pestilence includes pests and diseases that harm people, woodland, and agriculture.

Figure 35: Connecting Climate Change, Hazards, and Other Community Changes



Although we model these hazards separately, it is important to understand that they are interconnected. For example, droughts and extreme heat create wildfire conditions. Other factors such as land cover and population change can exacerbate conditions for hazards such as flooding and wildfire.

Figure 35 depicts how climate change, associated hazards, and other community changes are interconnected.

Current Climate

The current climate of the county is similar to other, mid-Atlantic communities. Historically, the average January temperature is 36°F while the average July temperature is 77°F. The typical growing season lasts 210 days, with the last freeze usually occurring in early April and the first freeze usually occurring in early November. The precipitation varies from an average low of 2.9 inches in February to an average high of 3.5 inches in

May. The wetter season lasts 4.6 months from April 11th to August 31st.

Temperature and precipitation observations have been recorded at Monticello in Albemarle County since 1950 and at the Charlottesville-Albemarle Airport since 1961. Graphs showing observations in this report were created using the observed temperature and precipitation data collected at Monticello by the NOAA Global Historical Climatology Network (GHCN). The current climate graphs have been placed adjacent to the future predictions to allow for easier comparison.

Climate Change Projections

To predict how the climate in Albemarle County will change, we use climate models to simulate future conditions. These models consist of a series of equations based on the laws of physics, fluid motion, and chemistry. Atmospheric models calculate winds, heat transfer, radiation, relative humidity, and surface hydrology while oceanic models calculate the physical and thermodynamical processes of the oceans. Atmospheric and oceanic models can be integrated to form an atmosphere-ocean coupled general circulation model with submodels for sea ice and evapotranspiration over land. There are multiple climate models from around the world, of which thirty-two will be used for this report. The climate models selected have publicly available results and were used to inform the IPCC Fifth Assessment Report. The climate models have gridded the entire world for the calculations including the interactions with neighboring grids.

These grids are very course and require statistical downscaling do be more relevant to a county. Statistical downscaling applies relationships to transform these large-scale projection grids to smaller grids at the local level. The process develops statistical relationships by comparing fine spatial scale observed conditions to climate model simulations of the same time period. These statistical relationships are then applied to the entire time period of the climate model simulation to produce finer geographic resolution for analysis. Downscaling is important for vulnerability and risk assessments where climate projections may be affected by localized conditions such as topography elements that are too fine to be captured by the global climate models.

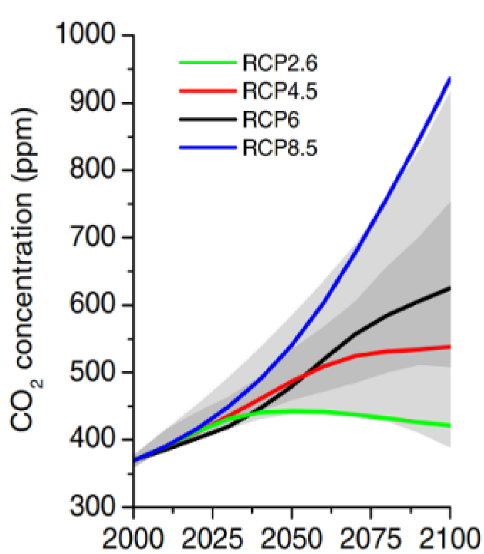


Figure 36: IPCC RCPs (van Vuuren et.al, 2011)

Climate risk and vulnerability assessments also require predicting what the international community will do to curb greenhouse gas emissions. To help show this uncertainty, four emissions scenarios were developed to reflect different paths forward. These emissions scenarios are called Representative Concentration Pathways (RCPs). Two emissions scenarios were selected for this report: RCP8.5, which represents significant increases in emissions through the end of the century and aligns with the current trajectory, and RCP4.5, which represents an increase in emissions until 2040, followed by a decline and stabilization by the end of the century. (The lowest emissions scenario, RCP2.6, requires a decline in emissions starting in 2020. Since this is no longer possible, RCP4.5 represents our best-case scenario. In this report, we refer to RCP4.5 as the low emissions scenario and RCP8.5 as the high emissions scenario. Figure 36 shows the atmospheric concentration of carbon dioxide (parts per million) under the four RCPs. The value after RCP (e.g., 4.5 or 8.5) refers to the cumulative measure of human emissions of greenhouse gases from all sources expressed in watts per square meter (IPCC AR5, 2014). Additional information on RCPs may be found at the IPCC Data Distribution Centre.

We used two different statistical downscaling methodologies for this report: the Localized Constructed Analogues (LOCA) technique (Pierce, D.W., et al., 2014), downloaded here: https://esgf-node.llnl.gov/projects/esgf-llnl/ and the Multivariate Adaptive Constructed Analogs (MACA) technique (MACA, Abatzoglou and Brown, 2012) downloaded here: https://climate.northwestknowledge.net/MACA/. We selected these two methodologies based on data reliability and availability. Most of the analysis conducted in this report used LOCA Coupled Model Intercomparison Project Phase 5 (CMIP5) data, except for the heat index analysis, which used the downscaled specific humidity and temperature data from MACA.

The LOCA data includes 32 climate models that provide daily maximum temperature, daily minimum temperature, and daily precipitation at a 1/16th degree spatial resolution covering 1950 through 2100. Each grid cell has a spatial area of approximately 3.4 miles by 3.4 miles. This daily observed and projected data was used in the hazard sections to help determine future probabilities or likelihood of an event occurring. The 2050 time horizon uses daily projected data from 2035 to 2065; the 2075 time horizon uses projected data from 2060 through 2090. This provided 31 years of modeled data at each time horizon to help determine probabilities.

The MACA data includes 20 climate models covering 2006 through 2100, providing daily and monthly data for maximum temperature, minimum temperature, precipitation accumulation, and maximum and minimum relative humidity at a 1/16th degree spatial resolution (approximately 3.4 miles by 3.4 miles). The modeled data begins in 2006 so it can be compared to the observed data for the region. Although the climate modeling data won't be an exact match with the recorded observations, the statistical probabilities should correspond reasonably well.

Climate Indicators

There are several ways we can assess the climate hazards identified as a concern to the County. Climate change indicators provide a means to project chronic and acute changes that may be representative of the climate hazards. These indicators were identified based on an initial review of sensitivities across the four categories of people, natural environment, built environment, and economy to ensure the indicators were most applicable to the vulnerability analysis, as well as a review of similar efforts undertaken in other communities. Table 11 provides a list of the climate change indicators and their associated hazards. Some of the climate change indicators may not be well known and have been defined below.

Table 11: Climate Change Indicators and the Hazards They Exacerbate

Climate Change Indicator	Excessive Heat	Drought	Wildfire	Flood	Disease/ Pestilence
Cooling Degree Days	✓				
Heating Degree Days	✓				
Growing Degree Days					✓
Days with Maximum Temperature > 87°F	✓	✓	✓		✓
Days with Maximum Temperature > 95°F	✓	✓	✓		✓
Days with Minimum Temperature < 32°F	✓				✓
Days with Maximum Temperature < 32°F	✓				✓
Days with Minimum Temperature > 80°F	✓		✓		
Average Daily Maximum Temperature	✓		✓		✓

Climate Change Indicator	Excessive Heat	Drought	Wildfire	Flood	Disease/ Pestilence
Average Daily Minimum Temperature	✓		✓		✓
Heat Index > 100°F	✓				
Total Annual Precipitation		✓	✓	✓	✓
Total Monthly Precipitation		✓	✓	✓	✓
Days with >1" Precipitation				✓	
Days with >2” Precipitation				✓	
Number of Dry Days (< 0.01” Precipitation)		✓			

A *cooling degree day* is calculated when the average temperature in a day is above 65°F. Values are calculated by subtracting 65°F from the mean daily temperature and summing those values over the period of interest. Studies have shown that when the outside temperature reaches this level, people consider cooling their building. It is a measurement to help quantify the demand for energy needed to cool buildings.

A *heating degree day* is a measure that reflects the amount of energy it takes to heat the indoor environment when the daily average temperature is below 65°F. Values are calculated by subtracting the mean daily temperature from 65°F and summing those daily values over the period of interest. The lower a location's number of heating degree days, the lower the demand for energy for heating.

A *growing degree day* is calculated when the temperature conditions are right for plants and animals to grow or develop. As development can only occur when temperature exceeds a species' base temperature (50°F for our calculations), values are calculated by subtracting 50°F from the mean daily temperature and summing the positive results over the period of interest.

In the remainder of this chapter, we display two charts for each of the climate change indicators: the first shows the observed data that has been recorded in the County, and the second shows the modeled data for the low and high emissions scenarios. A trend line has been added to the observed data for the last 25 years. Trend lines have also been added to the two emissions scenarios. Key observations accompany each chart. Subsequent chapters contain additional temperature and precipitation analysis for each hazard.

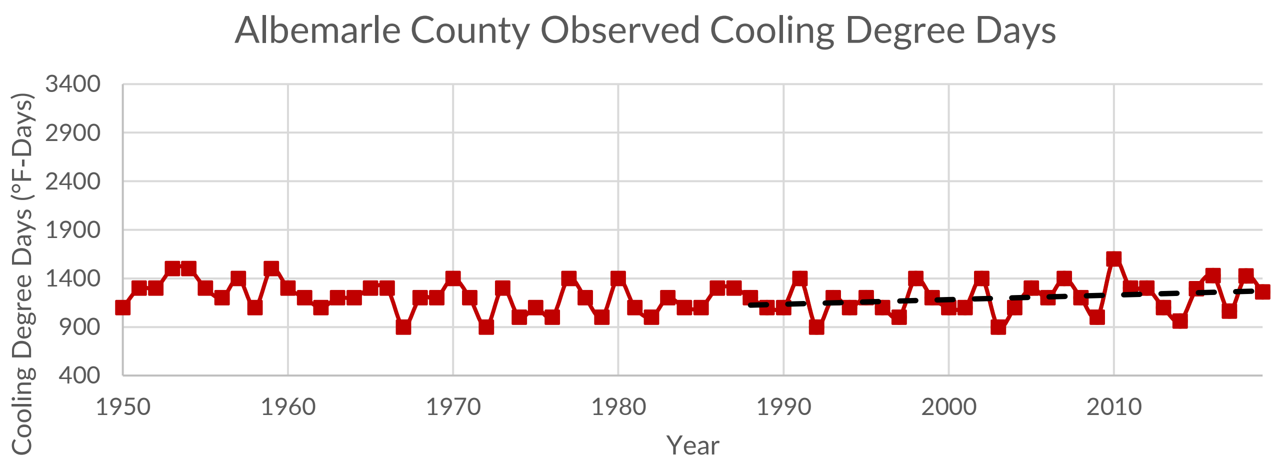


Figure 37: Observed Cooling Degree Days (Monticello Station, GHCN, 2019)

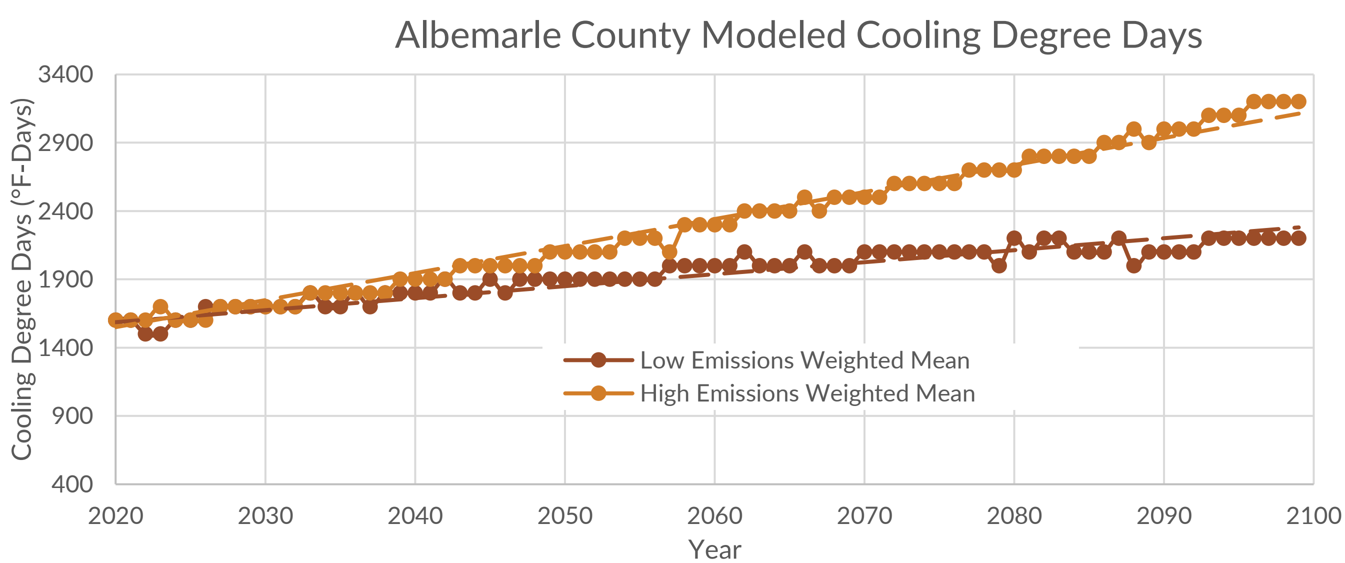


Figure 38: Modeled Cooling Degree Days (LOCA; Pierce et al. 2014)

Observations

Over the last 30 years, there has been an upward trend in cooling degree days.

In the coming decades, the number of days people will choose to cool their homes and work areas will increase. By the end of the century, the number of cooling degree days per year will more than double according to the high emissions scenario.

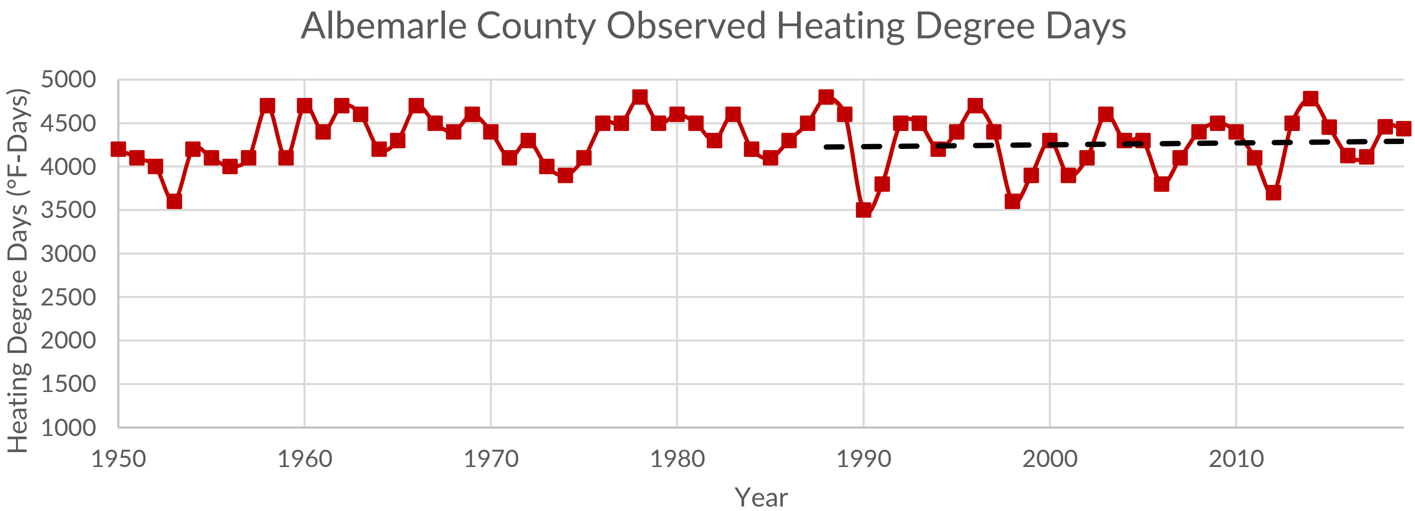


Figure 39: Observed Heating Degree Days (Monticello Station, GHCN, 2019)

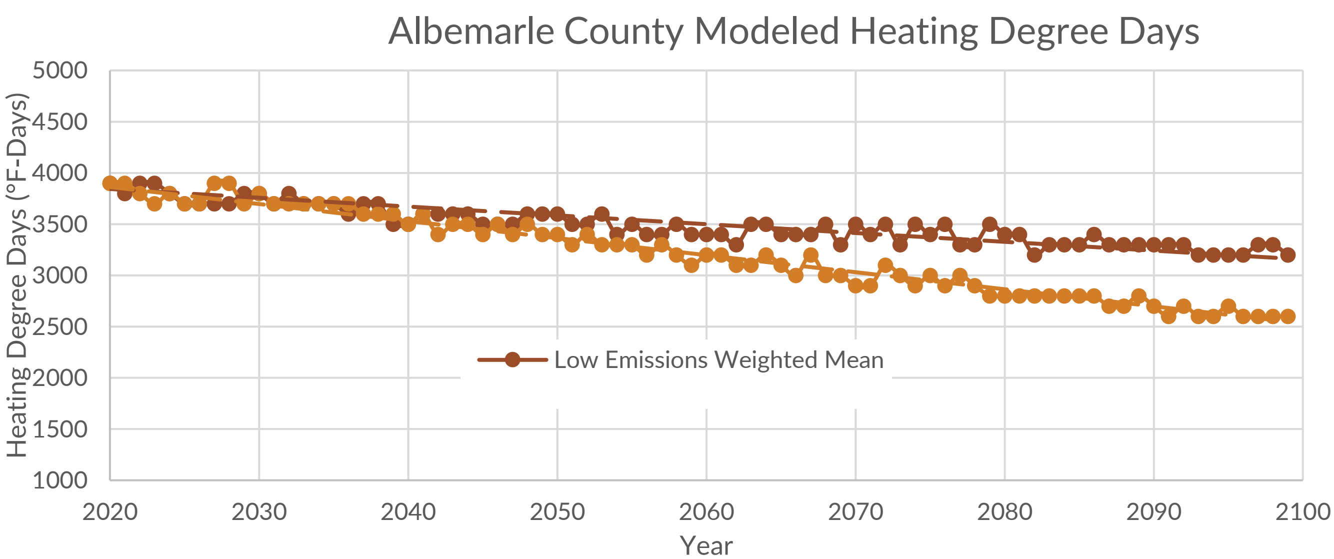


Figure 40: Modeled Heating Degree Days (LOCA; Pierce et al. 2014)

Observations

The number of days people will choose to heat their homes and work areas will decrease. By the end of the century, the number of heating degree days per year will be reduced by 38% according to the high emissions scenario.

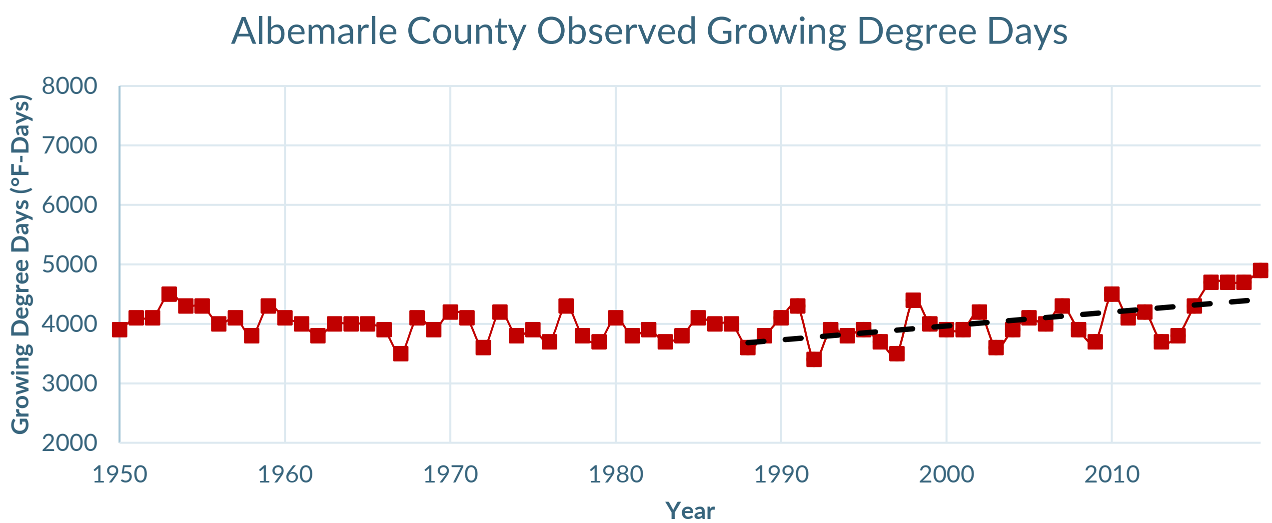


Figure 41: Observed Growing Degree Days (Monticello Station, GHCN, 2019)

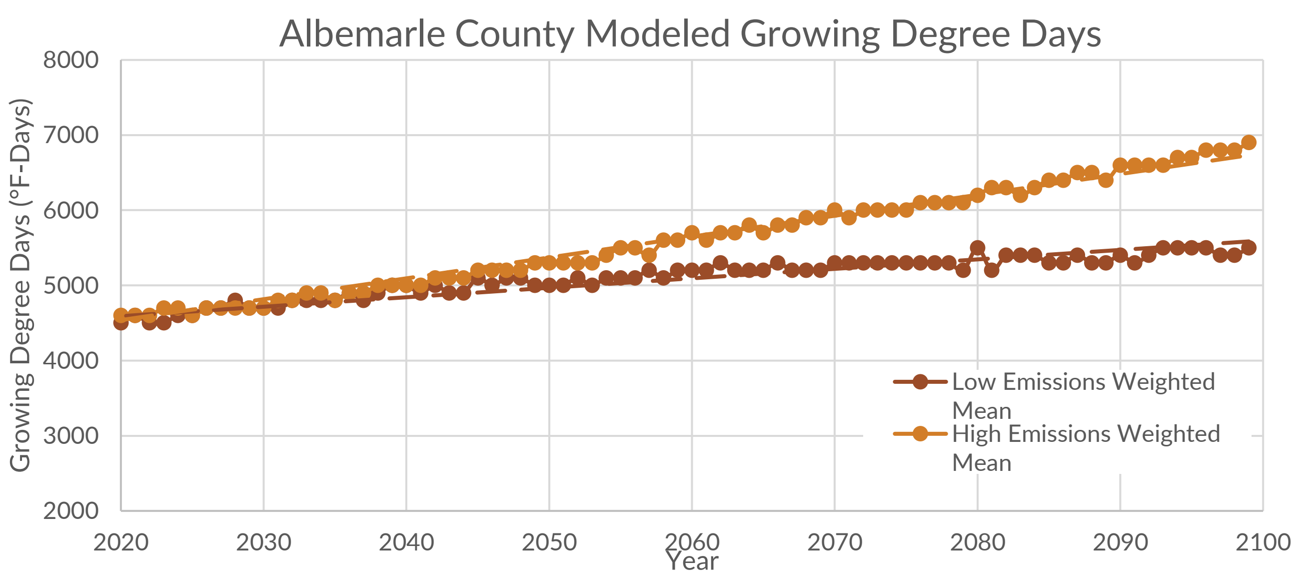


Figure 42: Modeled Growing Degree Days (LOCA; Pierce et al. 2014)

<u>Observations</u>

Over the last 30 years, there has been an upward trend in growing degree days.

Looking ahead, the number of days in which animals and plants (including invasive species, ticks, and mosquitoes) can grow and develop will continue to increase. By the end of the century, the number of days per year will increase more than 50% according to the high emissions scenario.

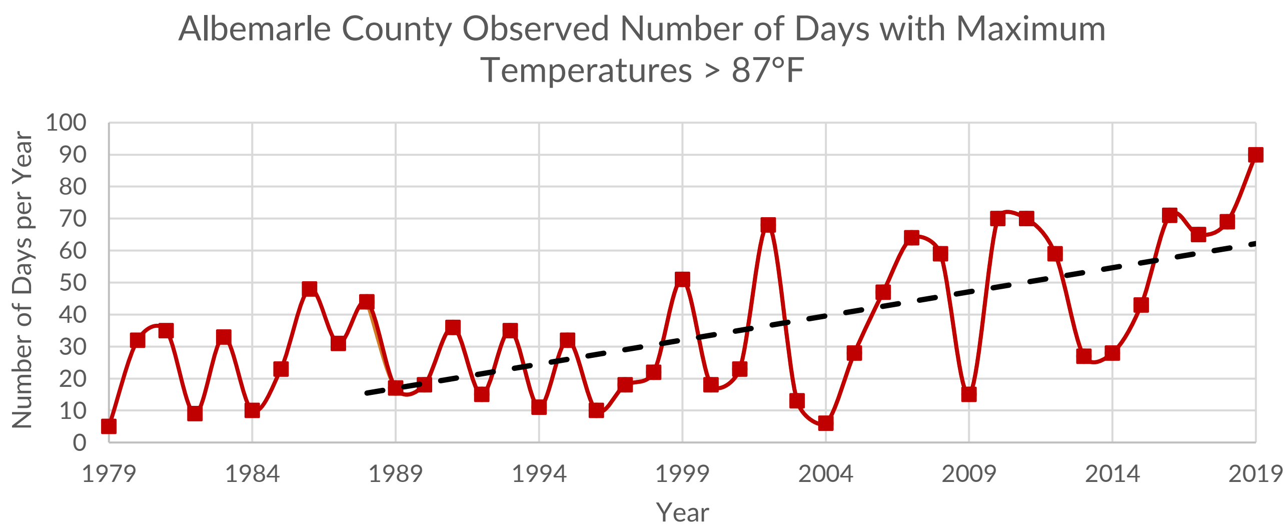


Figure 43: Observed Number of Days with Temperatures >87°F (NLDAS 1979-2019)

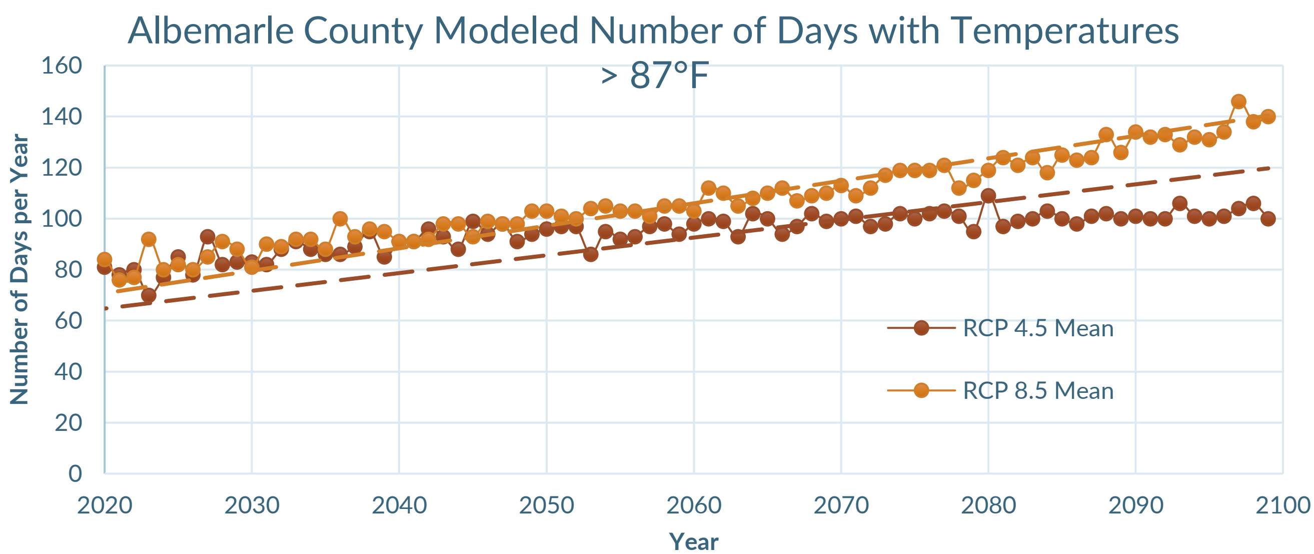


Figure 44: Modeled Number of Days with Temperatures >87°F (LOCA; Pierce et al. 2014)

<u>Observations</u>

Although the number of days per year with temperatures greater than 87°F is not a typical climate indicator, we included it after reviewing the temperatures when emergency services were needed for heat-related illness.

Over the last 30 years, there has been an upward trend.

By the end of the century, the number of days per year will double according to the high emissions scenario.

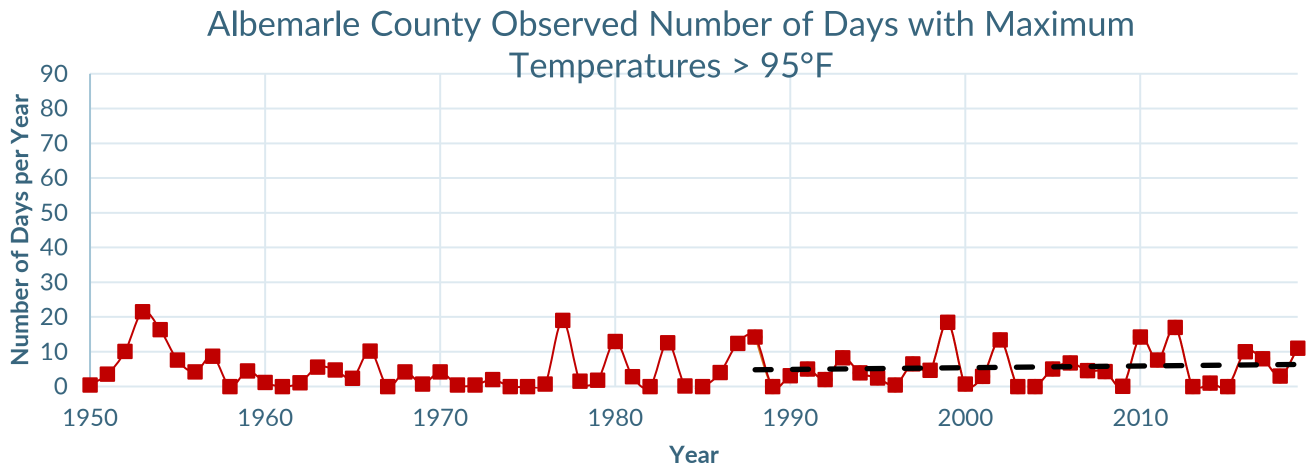


Figure 45: Observed Maximum Temperatures >95°F (Monticello Station, GHCN, 2019)

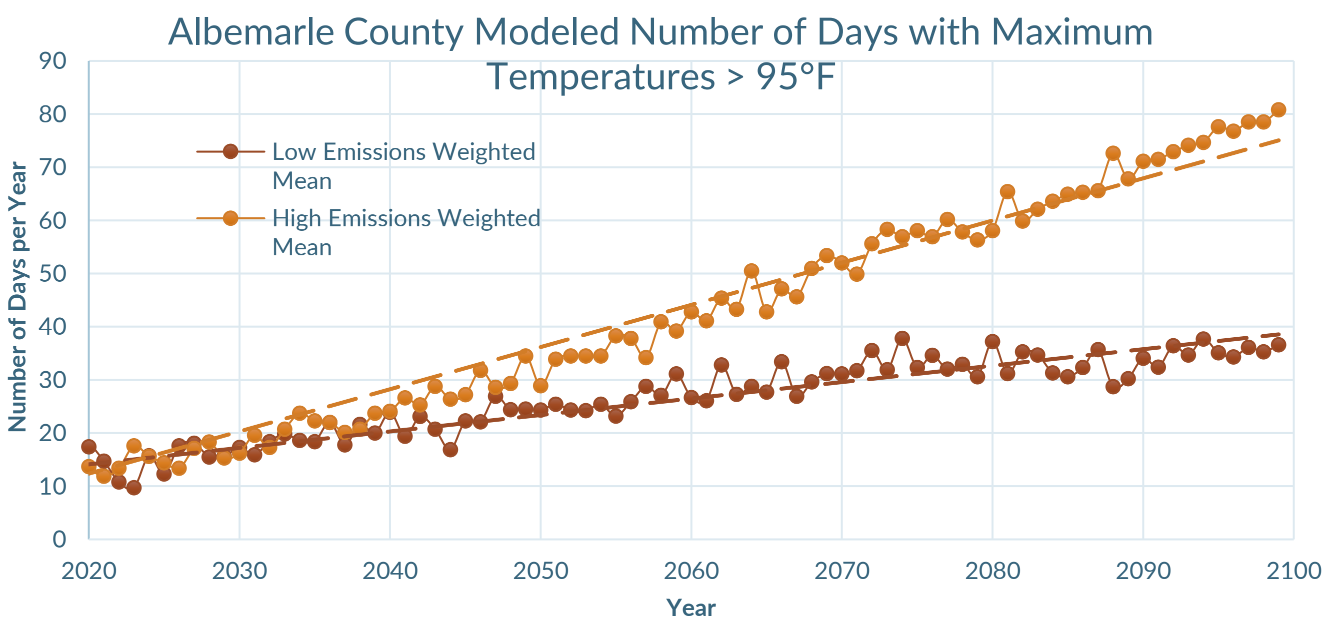


Figure 46: Modeled Maximum Temperatures >95°F (LOCA; Pierce et al. 2014)

Observations

The number of days with temperatures greater than 95°F shows the amount of extreme heat our community will be faced with in the future. By the end of the century, the number of days per year will quadruple according to the high emissions scenario.

Over the last 30 years, there has been a slight upward trend.

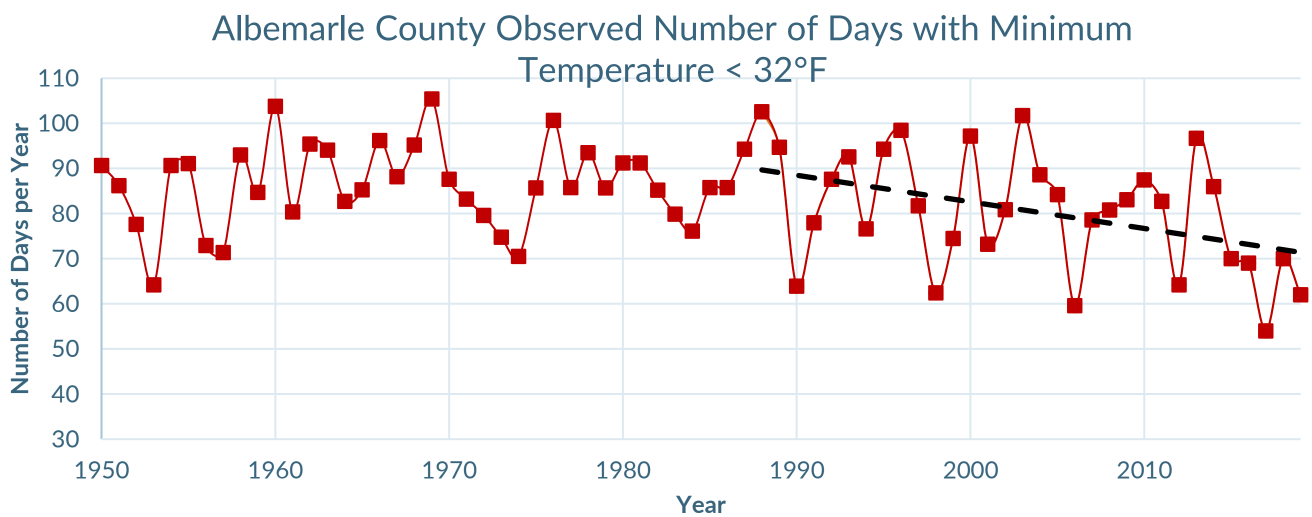


Figure 47: Observed Number of Days with Minimum Temperature < 32°F (Monticello Station, GHCN, 2019)

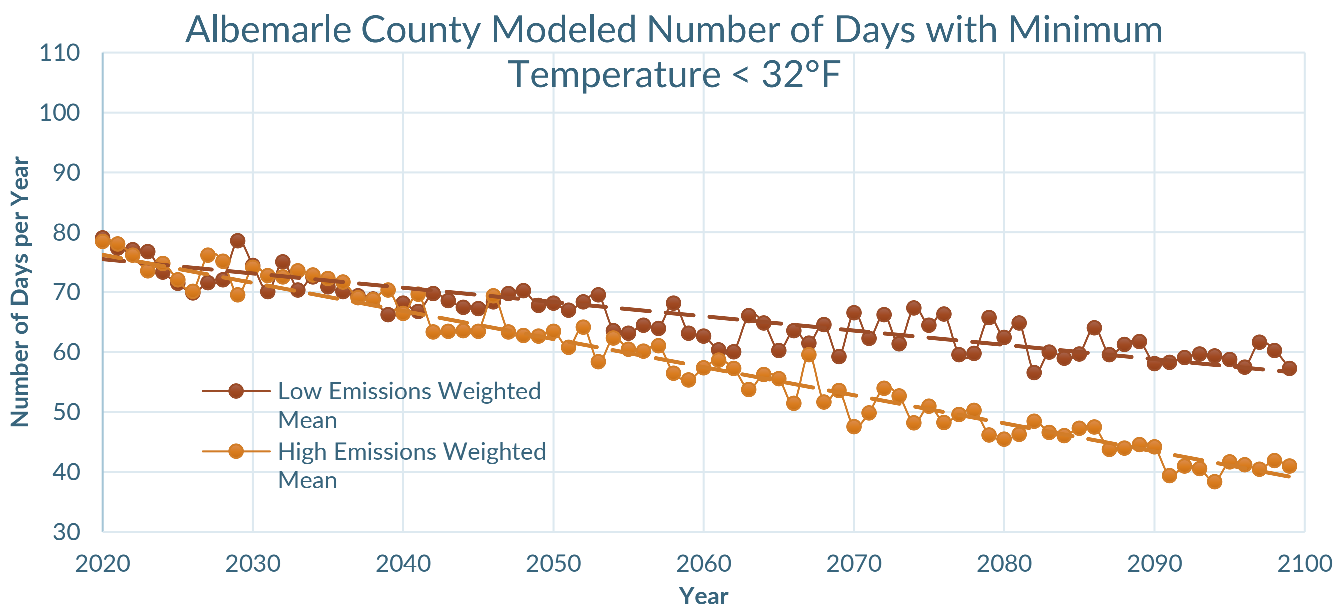


Figure 48: Modeled Number of Days with Minimum Temperature <32°F (LOCA; Pierce et al. 2014)

Observations

The number of days with temperatures less than 32°F shows that the conditions for pests and some invasive species will increase and the number of chill hours required for many fruits will decrease. By the end of the century, the number of days per year with freezing temperatures will be nearly halved.

Over the last 30 years, there has already been a downward trend.

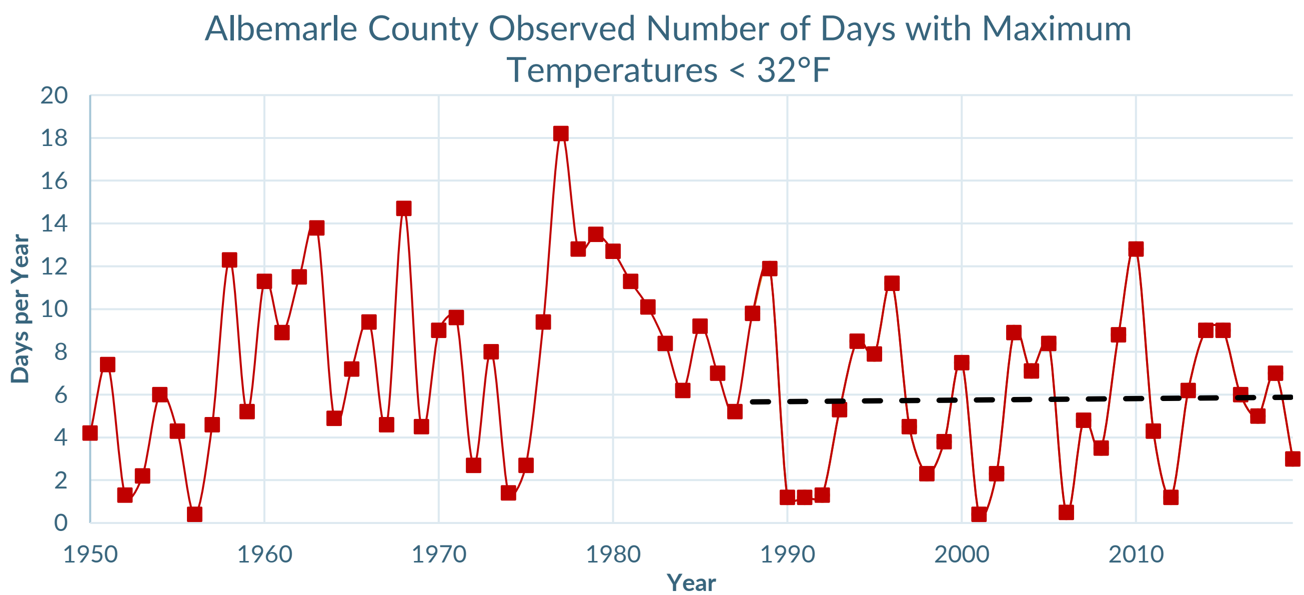


Figure 49: Observed Number of Days per Year with Maximum Temperatures < 32°F (Monticello Station, GHCN, 2019)

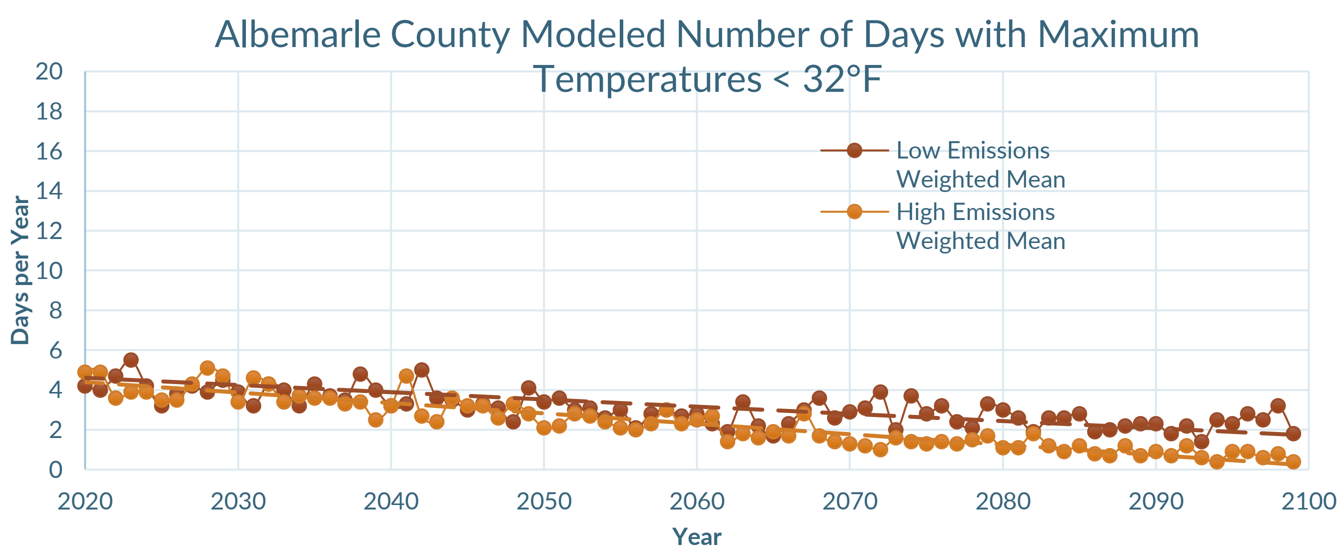


Figure 50: Modeled Number of Days per Year with Maximum Temperatures < 32°F (LOCA; Pierce et al. 2014)

Observations

The number of days with maximum temperatures less than 32°F shows that the conditions for pests and some invasive species will increase and the number of chill hours required for many fruits will decrease. By the end of the century, the average number of days per year with freezing maximum temperatures will be close to zero.

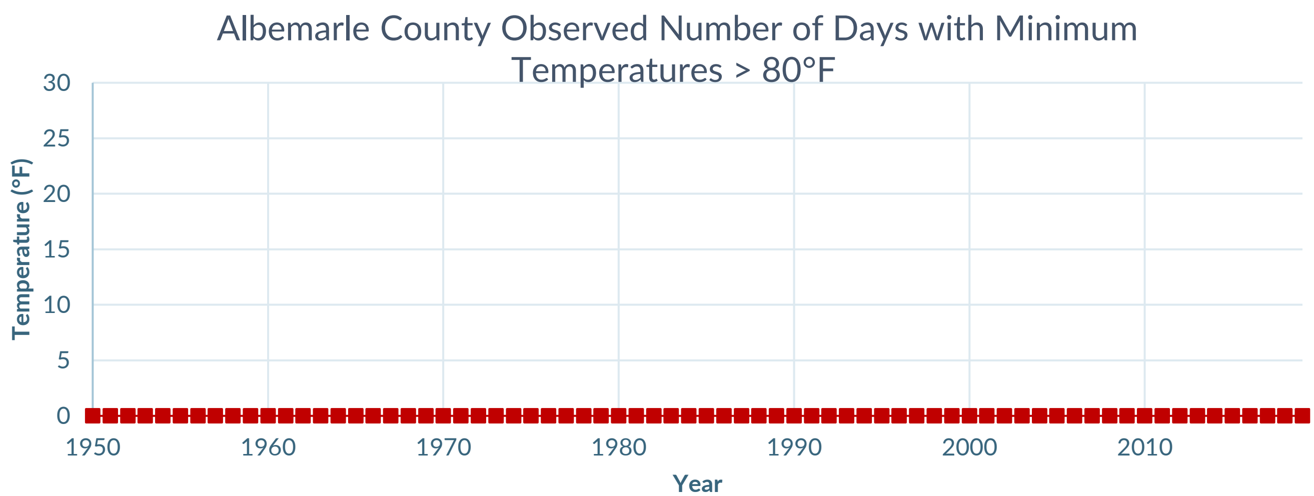


Figure 51: Observed Number of Days with Minimum Temperatures >80°F (Monticello Station, GHCN, 2019)

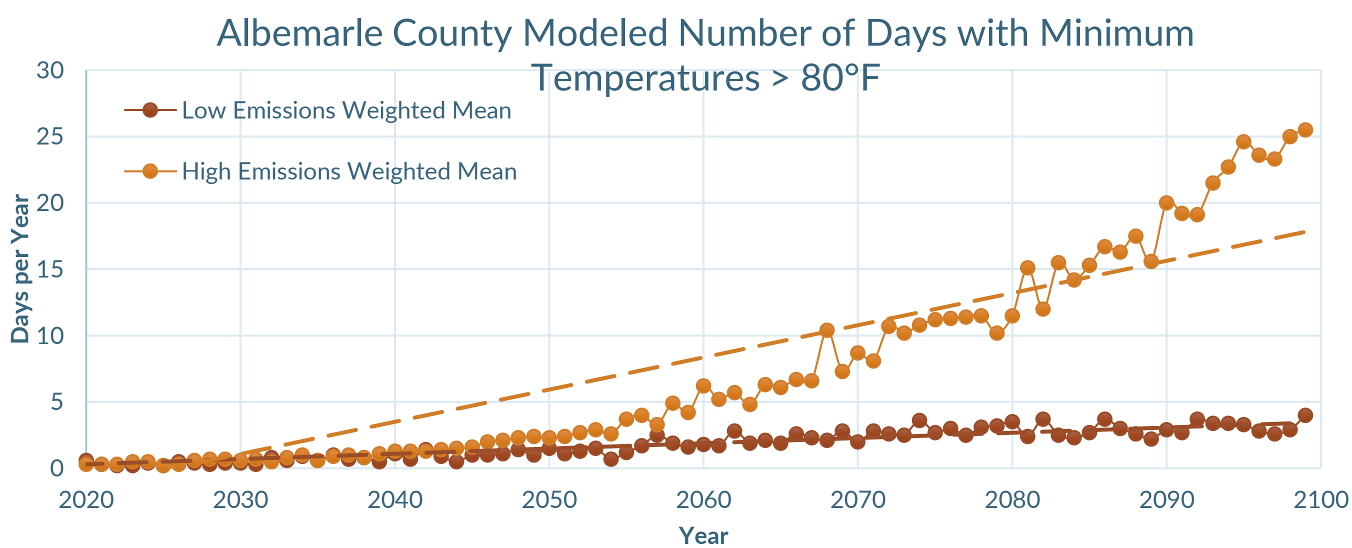


Figure 52: Modeled Number of Days with Minimum Temperatures >80°F

Observations

The number of days with minimum temperatures greater than 80°F indicates uncomfortably warm temperatures at night, which can be harmful to human health. By the end of the century, the average number of days per year with minimum temperatures above 80°F will increase by 26 days.

Over the last 30 years, there have been no observed minimum temperatures above 80°F.

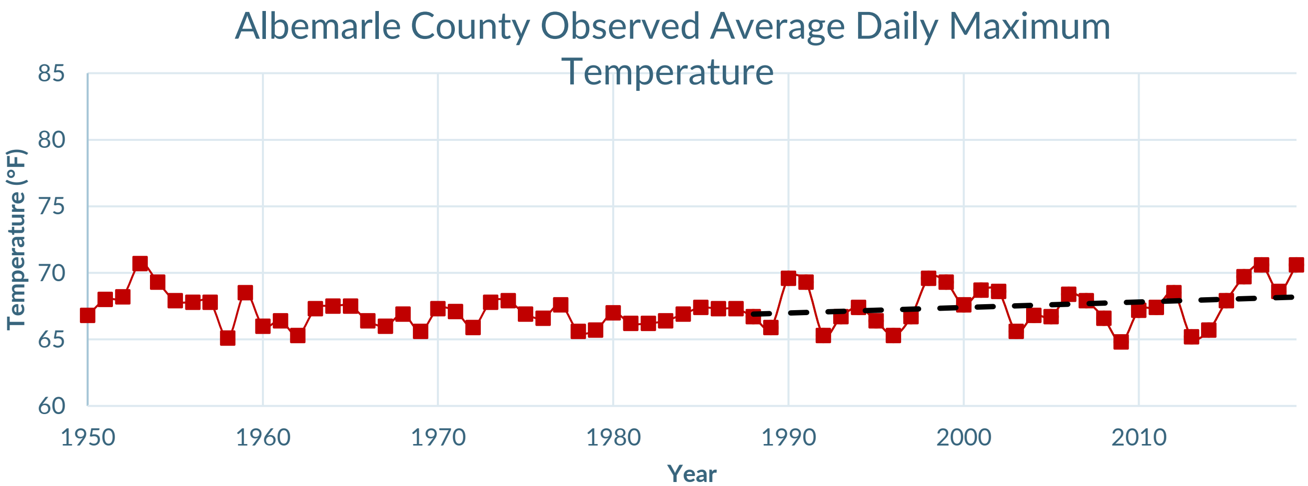


Figure 53: Observed Average Daily Maximum Temperature (Monticello Station, GHCN, 2019)

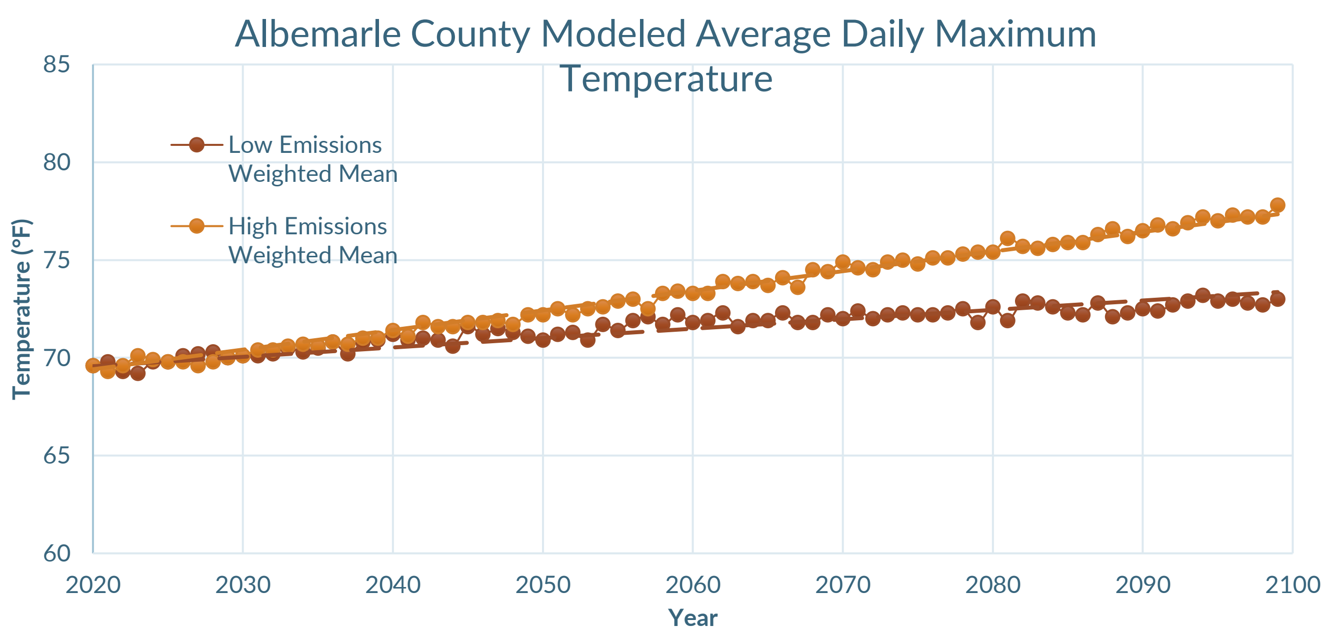


Figure 54: Modeled Average Daily Maximum Temperature (LOCA; Pierce et al. 2014)

Observations

Over the last 30 years, there has been an upward trend in average daily maximum temperature.

Future projections of the average daily maximum temperature show us how the local climate is going to shift over the next century. By the end of the century, the average temperature will have increased by nearly 8°F according to the high emissions scenario.

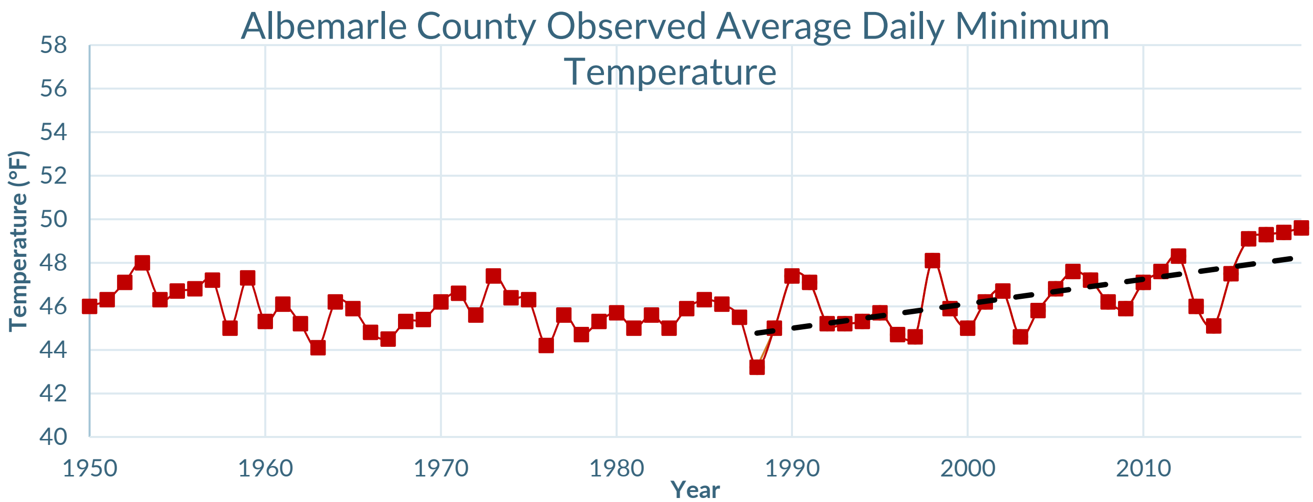


Figure 55: Observed Average Daily Minimum Temperature (°F) (Monticello Station, GHCN, 2019)

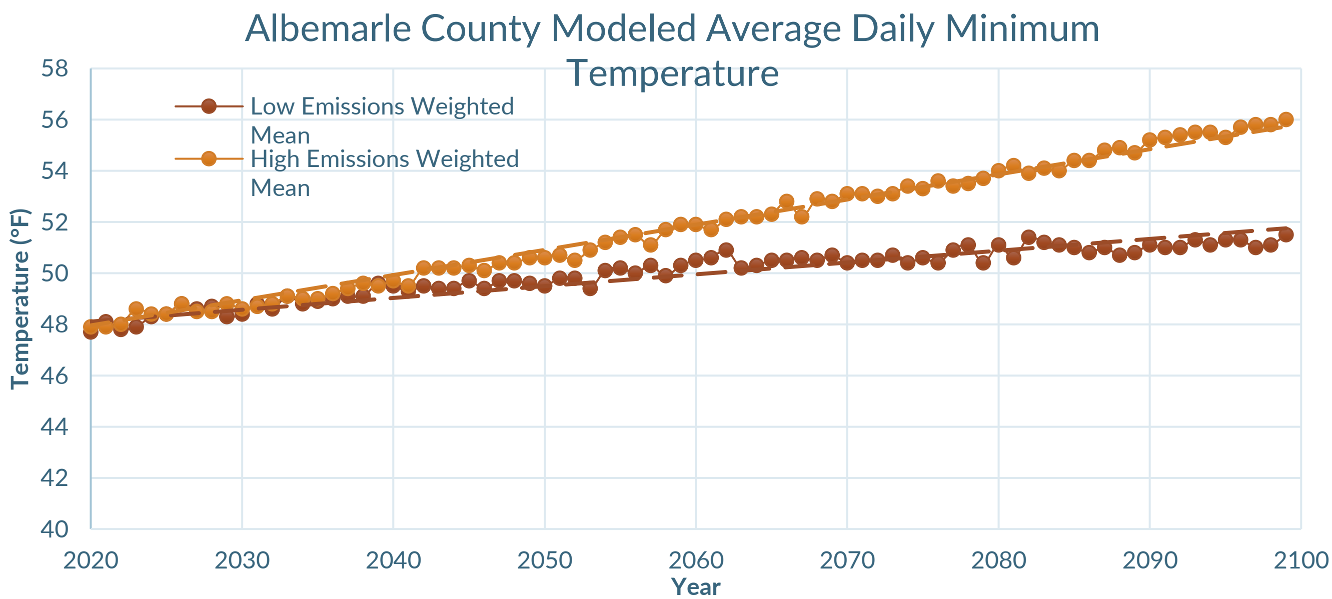


Figure 56: Modeled Average Daily Minimum Temperature (°F) (LOCA; Pierce et al. 2014)

Observations

Over the last 30 years, there has been an upward trend in average daily minimum temperature.

Future projections of the average daily minimum temperature also show us how the local climate will shift over the next century. By the end of the century, the average minimum temperature will have increased by nearly 8°F according to the high emissions scenario.

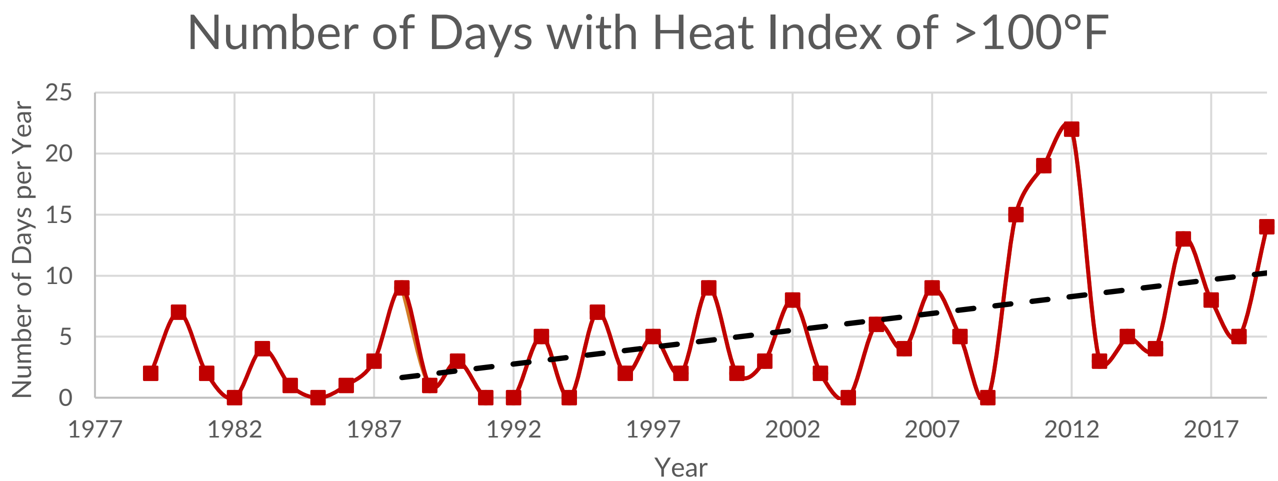


Figure 57: Number of Days with Heat Index Greater Than 100°F (NLDAS 1979-2019)

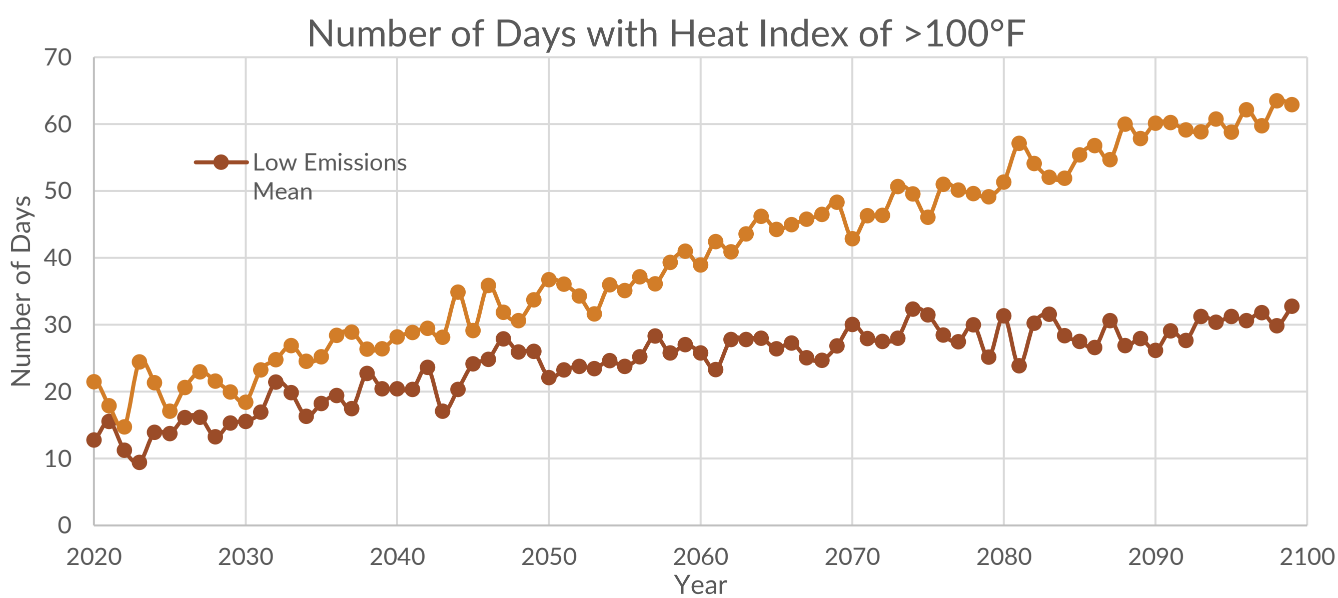


Figure 58: Number of Days with Heat Index Greater Than 100°F (MACA, Abatzoglou and Brown, 2012)

Observations

Because the summer can get very hot and humid in Albemarle County, we modeled heat index of greater than 100°F to show how many extreme heat days we can expect. By the end of the century, the number of extreme heat index days per year will triple according to the high emissions scenario.

Over the last 30 years, there has been an upward trend.

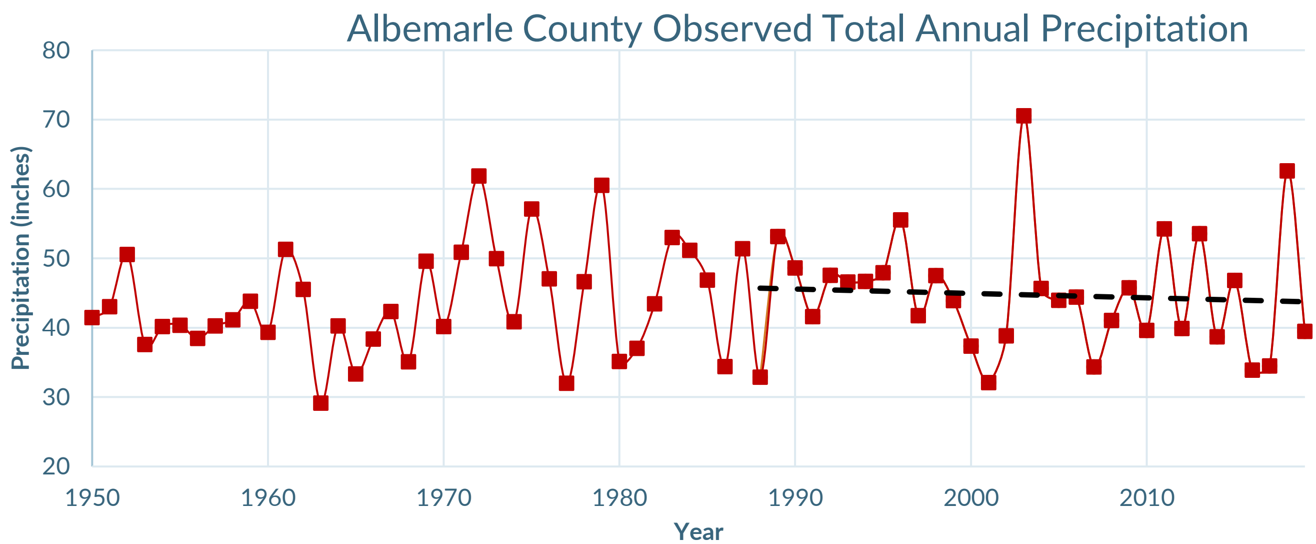


Figure 59: Observed Total Annual Precipitation (inches) (Monticello Station, GHCN, 2019)

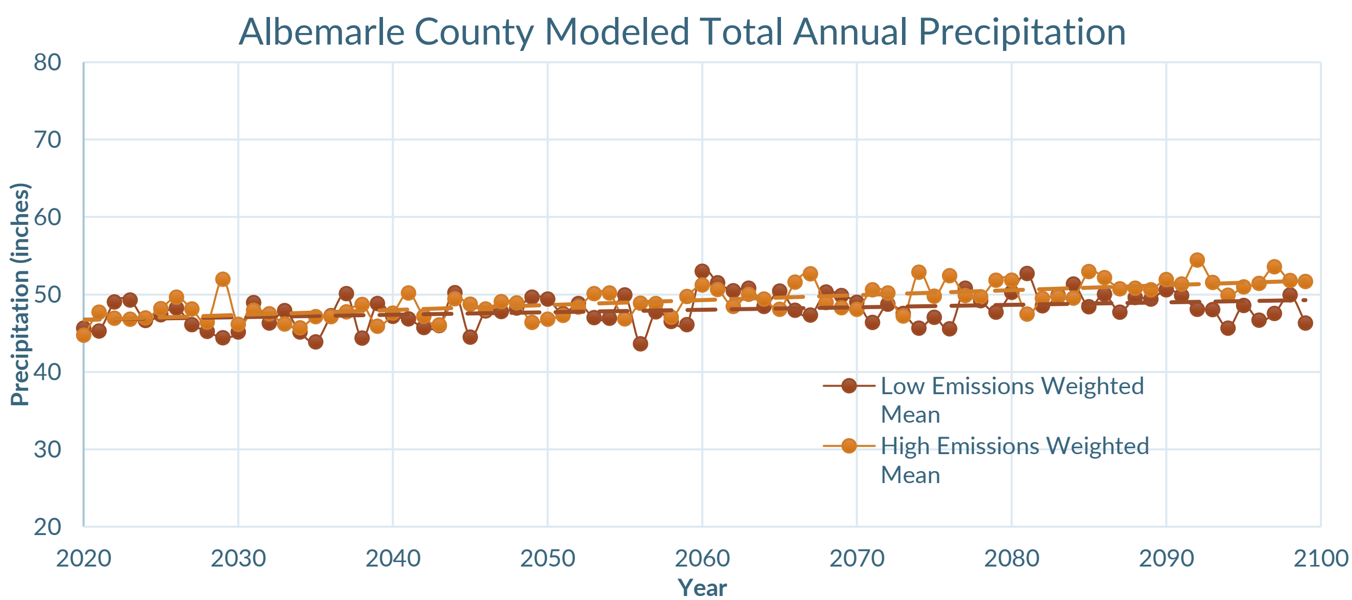


Figure 60: Modeled Total Annual Precipitation (LOCA; Pierce et al. 2014)

Observations

Although all climate models predict a warming trend in the county, some climate models predict more precipitation while others show less. When combining the data into a mean value, these tend to cancel each other out. On average, the models predict a slight increase in precipitation over the next century.

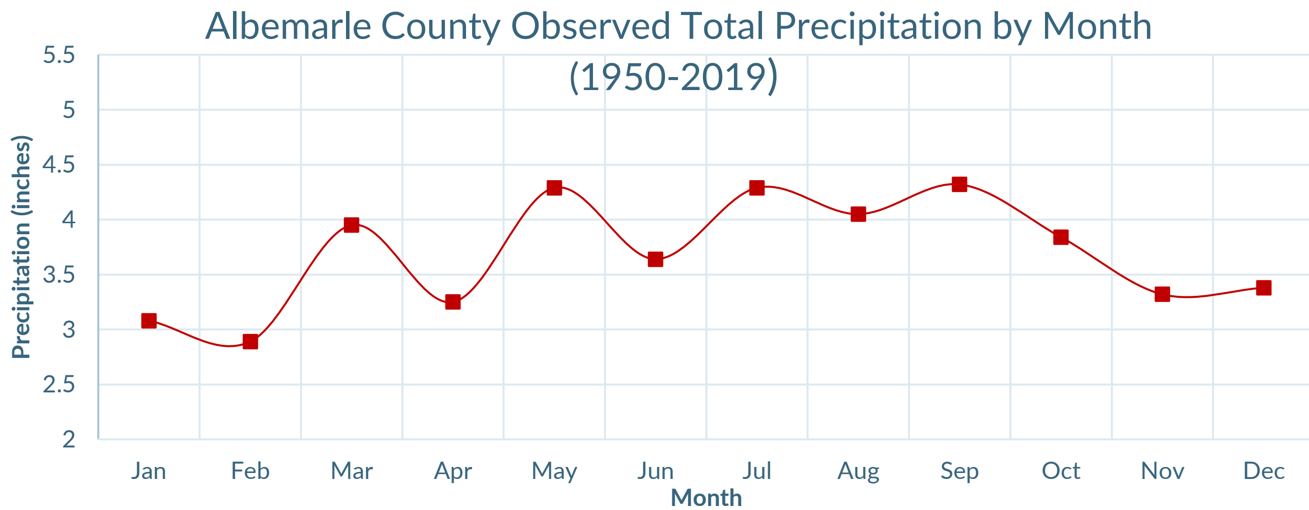


Figure 61: Observed Total Precipitation by Month (inches) (Monticello Station, GHCN, 2019)

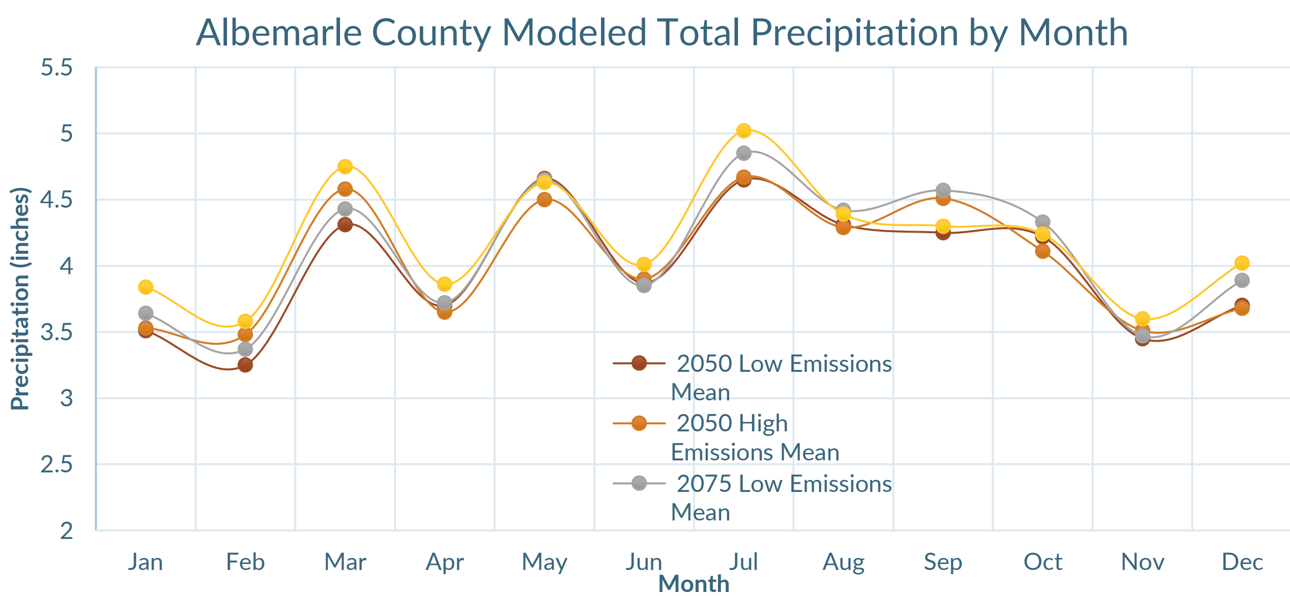


Figure 62: Modeled Total Precipitation by Month (inches) (LOCA; Pierce et al. 2014)

Observations

Another way to predict precipitation is to analyze when it will occur throughout the year. The amount of precipitation is expected to increase for all months, although there are higher peaks in some months (e.g., March), showing a larger differential than the observed data.

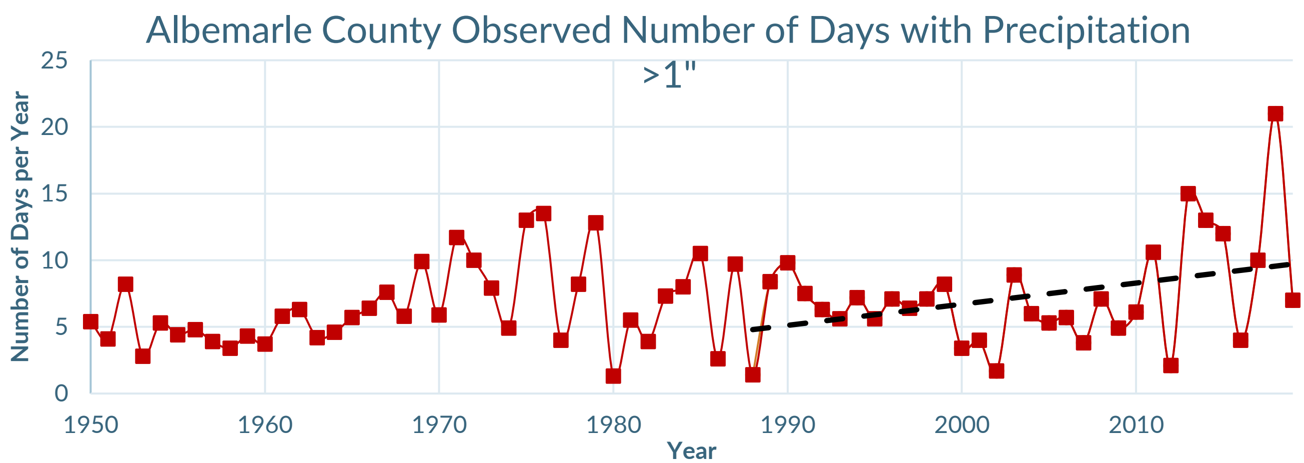


Figure 63: Observed Number of Days with Precipitation >1" (Monticello Station, GHCN, 2019)

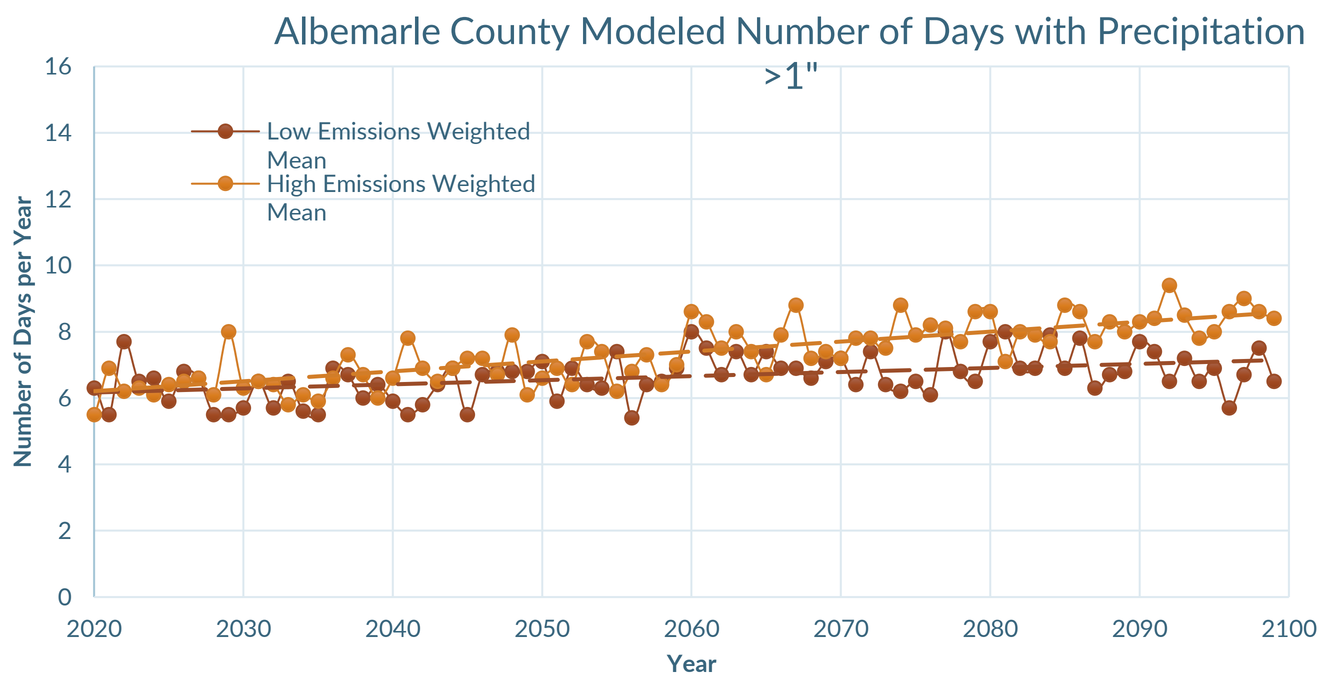


Figure 64: Modeled Number of Days with Precipitation >1" (LOCA; Pierce et al. 2014)

Observations

Although the mean value of the climate models shows a slight increase in annual precipitation over time, it is also important to understand if that precipitation will fall as an extreme event. The number of days when more than 1” of precipitation falls is expected to increase by 50% according to the high emissions scenario.

Over the last 30 years, there has been an upward trend.

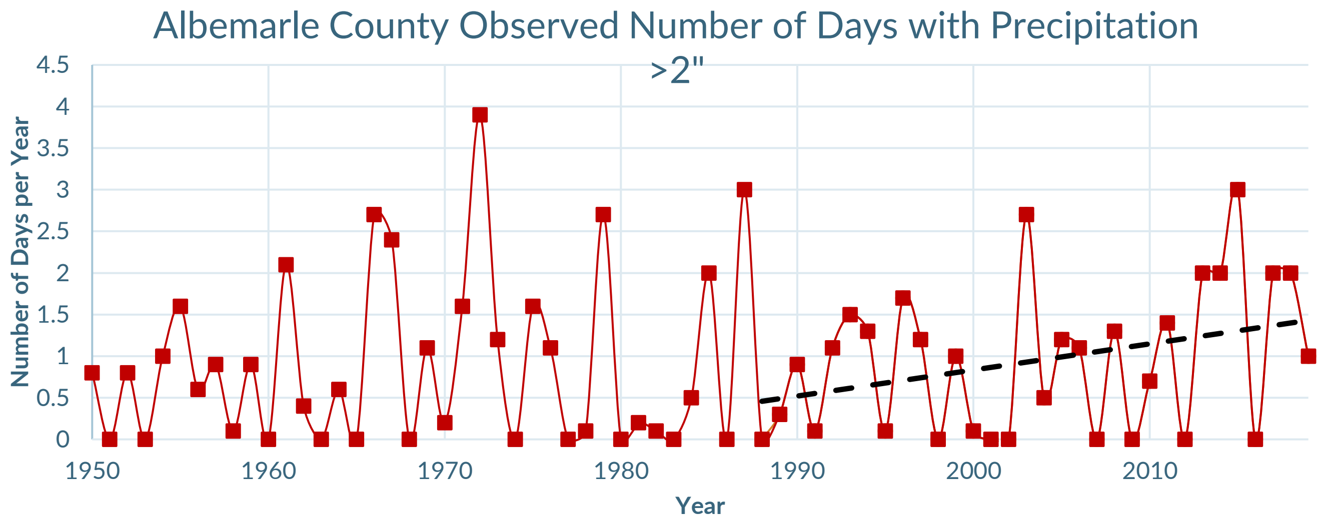


Figure 65: Observed Number of Days with Precipitation >2" (Monticello Station, GHCN, 2019)

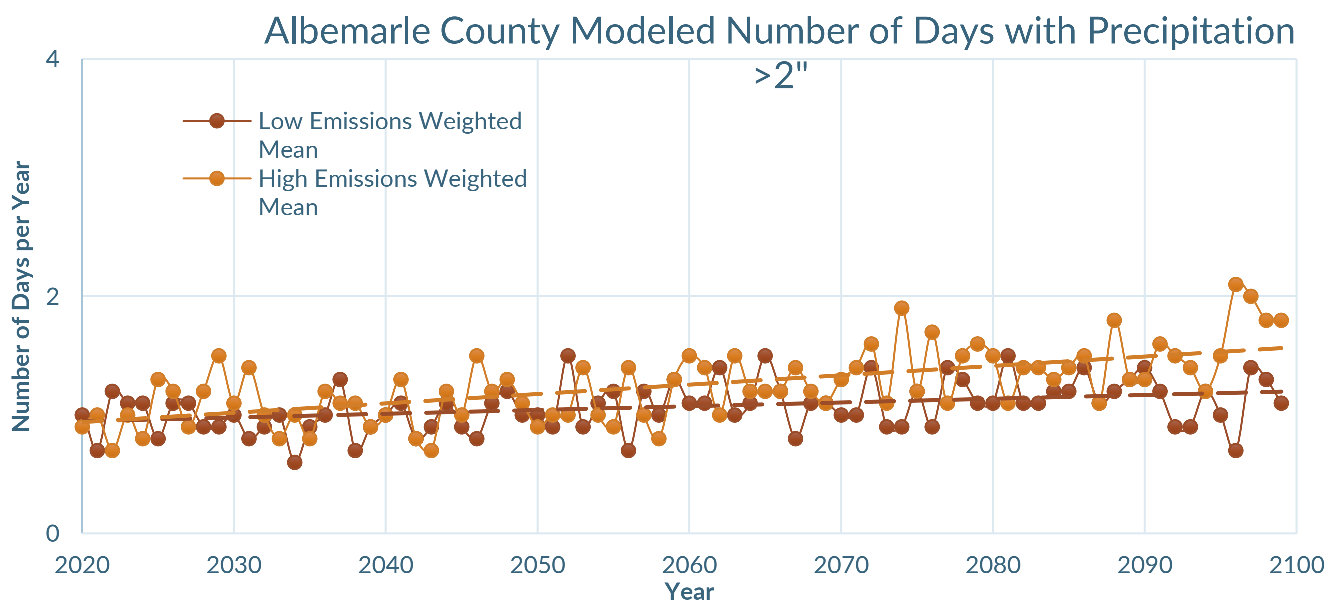


Figure 66: Modeled Number of Days with Precipitation >2" (LOCA; Pierce et al. 2014)

Observations

This climate indicator is similar to the previous one (Days with Precipitation > 1”), but it represents more extreme rainfall. The number of days when more than 2” of precipitation falls is expected to double according to the high emissions scenario.

Over the last 30 years, there has been an upward trend.

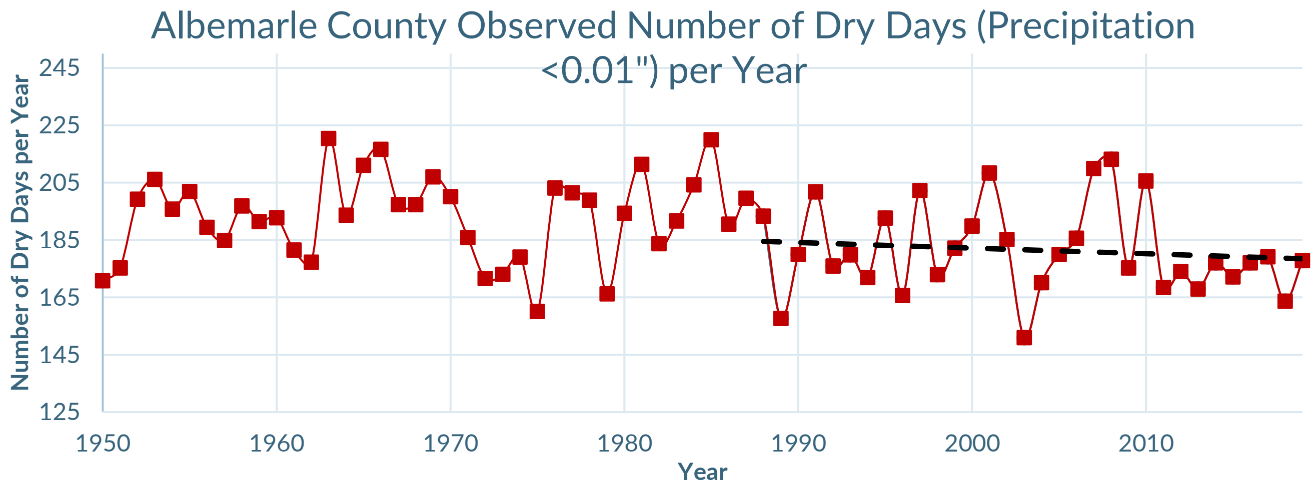


Figure 67: Observed Number of Dry Days (Precipitation <0.01") per Year (Monticello Station, GHCN, 2019)

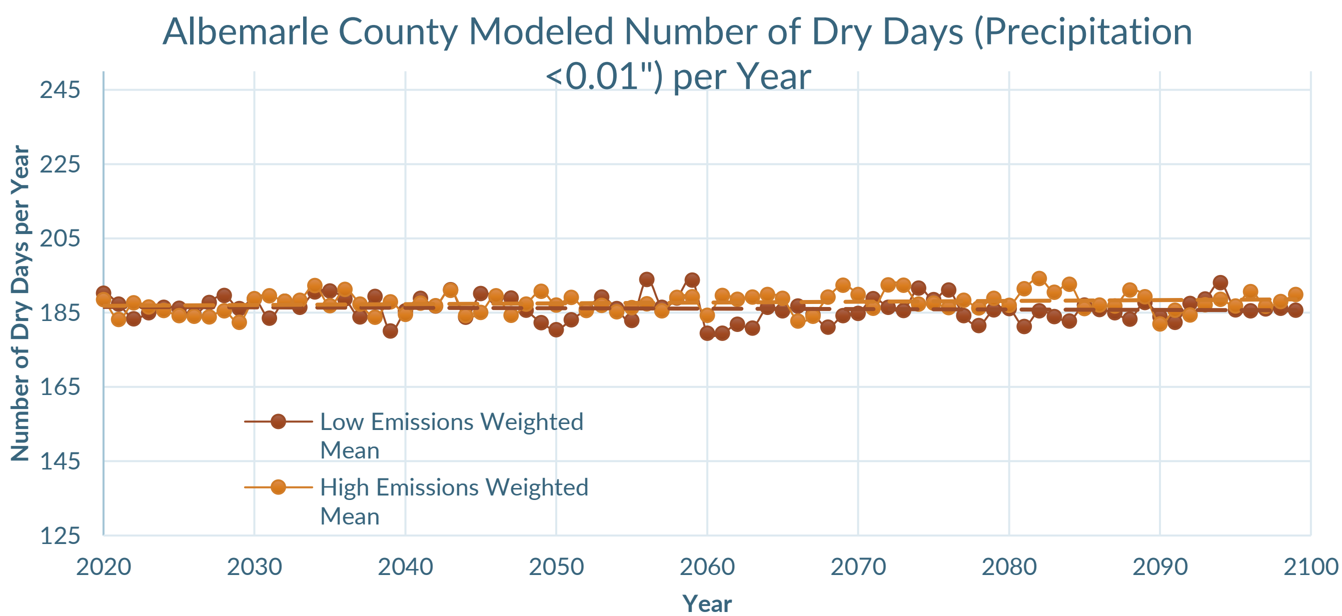


Figure 68: Observed Number of Dry Days (Precipitation <0.01") per Year (LOCA; Pierce et al. 2014)

Observations

This climate indicator helps to identify the likelihood of drought conditions. Since some precipitation models show more precipitation and some show less, the mean values show a flat trend.

Chapter 3: Extreme Heat

What We Can Expect

2050	+20-100% increase in heat advisories +5.5 to 9 times increase in evenings temperatures will be > 75°F +37,653 additional people exposed to heat island effect	+4-7 times increase in days temperatures will be stressful for cows and horses -7-10% decrease in probability of reaching orchard winter chill requirements +140-160% average number of days temperatures reach 60°F in Jan-Feb	49-55% increase in number of days AC is preferred 8-11 number of days per year electrical grid experiences strain 28-38 number of days per year roads, bridges and rail are stressed	9-18% decrease in employee productivity in manufacturing 12-21% decrease in employee productivity in construction 27-38 days outside workers exposed to unhealthy working conditions
2075	+60-360% increase in heat advisories +8.5 to 21 times increase in evenings temperatures will be > 75°F +64,368 additional people exposed to heat island effect	+7-12 times increase in days temperatures will be stressful for cows and horses -10-22% decrease in probability of reaching orchard winter chill requirements +160-240% average number of days temperatures reach 60°F in Jan-Feb	49-55% increase in number of days AC is preferred 8-11 number of days per year electrical grid experiences strain 28-38 number of days per year roads, bridges and rail are stressed	16-27% decrease in employee productivity in manufacturing 16-32% decrease in employee productivity in construction 33-60 days outside workers exposed to unhealthy working conditions
Identifying Vulnerabilities				
	• Elderly and children • Below poverty line • No air conditioning • Poor health • No vehicle access • Emergency responders • Pets	• High chill requirement orchards • Heat intolerant plant varieties • Long-haired livestock • Livestock without access to shade	• Buildings in poor or very poor condition • Uninsulated buildings • Non-heat-tolerant rail, bridges, and roads	• Agriculture, forestry, fishing, and hunting • Construction • Manufacturing • Quarrying, oil and gas extraction • Recreation

Background

Extreme heat and humidity results in many fatalities every year and is one of the deadliest weather-related events for the country. The National Weather Service (NWS) issues heat advisories when the daytime heat index values are between 100°F to 104°F. Additionally, if the heat index is between 95°F to 99°F for four consecutive days, a heat advisory is released. An excessive heat warning is issued when the daytime heat index is forecasted to be 105°F or higher or 75°F or higher at night for a 48-hour period.

The Heat Index is a measure of how hot it feels when relative humidity is factored in with the air temperature. Figure 69 shows a chart with both relative humidity and air temperature, which together create the heat index value that is used for heat advisories and warnings. The colors on the chart indicate potential levels of danger, with the red areas on the bottom right indicating extreme danger.

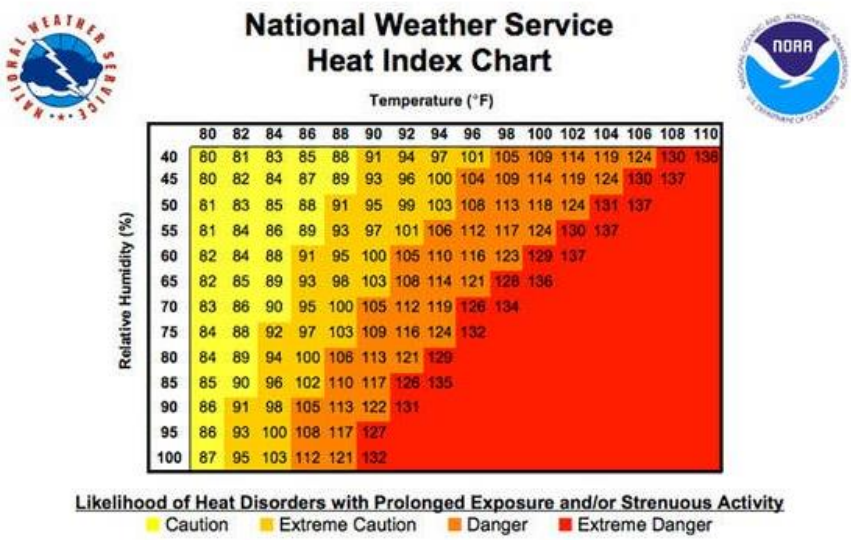


Figure 69: Heat Index (NWS)

In this chapter, we also examine the effect that unseasonable weather more generally can have on agriculture, from trees not fruiting due to a lack of chill hours to blossoms arriving too early before a hard freeze.

Current and Future Conditions

The climate in Albemarle County is typical of mid-Atlantic states with the average high annual temperature of 65°F. On average, January is the coldest month with an average high temperature of 42°F, while July is the hottest month with an average high temperature of 86°F. On average, there are two nights per year when nighttime temperatures remain above 75°F (Monticello Station, GHCN, 2013). Table 12 shows the current and future average temperatures for the county. The average temperatures increase several degrees while the number of extreme events (e.g., number of nights when temperatures are above 75°F) increase rapidly.

Table 12: Current and Future Average Temperatures (LOCA; Pierce et al. 2014).

Average Temperatures	Current (Avg. Ann.)	2050		2075	
		Low Emissions	High Emissions	Low Emissions	High Emissions
Avg. High Annual Temp.	65°F	71°F	73°F	73°F	76°F
January Avg. High Temp.	42°F	49°F	50°F	49°F	52°F
July Avg. High Temp.	86°F	93°F	94°F	94°F	98°F
Avg. Number of Nights when Temps. are above 75°F	2	13	20	19	44

Our typical growing season averages 210 days, with the last frost usually occurring in early April and the first usually in early November. Certain fruits, such as apples, require a minimum number of chill hours (temperatures between 32°F to 45°F) in order to bear fruit. The number of chill hours differs between varieties but ranges from

200 to 1000+ hours per year. There are, on average, 160 days per year that contribute to the total number of chill hours (Monticello Station, GHCN, 2013). Table 13 shows the current and future average number of such days for the county. The likelihood of reaching the number of chill hours required to fruit will decrease while the chance of plants blooming early due to high temperatures will increase. A hard frost is still a probability in future climate scenarios, which could result in damaged blooms.

Table 13: Growing Considerations (LOCA; Pierce et al. 2014).

Average Temperatures	Current (Avg. Ann.)	2050		2075	
		Low Emissions	High Emissions	Low Emissions	High Emissions
Avg. Number of Days that Contribute to Chill Hours	160	150	145	146	131
Avg. Number of Days to Expect a Hard Frost (<28°F)	44	40	37	37	27
Avg. Number of Days in Jan. and Feb. when Temps > 60°F	5	12	13	13	17

On average, there are presently five heat advisories and one heat warning every year. Table 14 shows the current and future extreme conditions based on the heat index. These days will have adverse impacts on people outdoors, pets, livestock, and wildlife. The future extreme events will increase significantly.

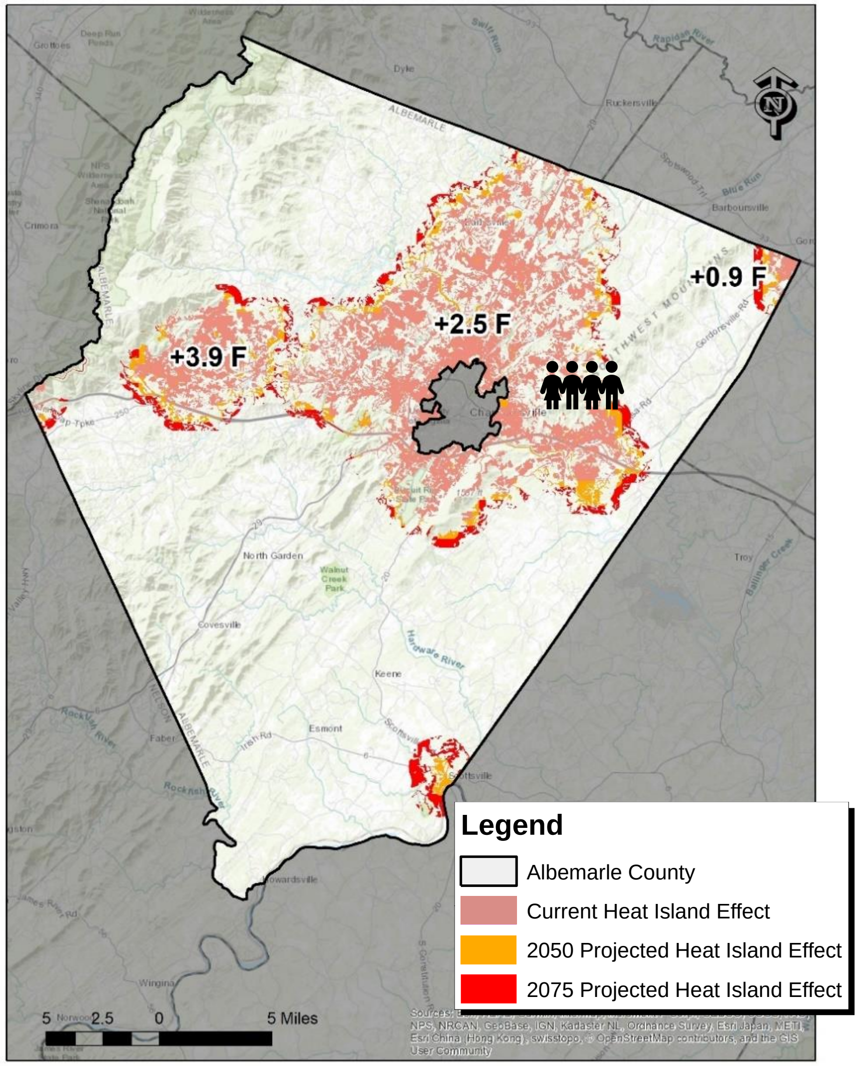
Table 14: Health Considerations

Average Temperatures	Current (Avg. Ann.)	2050		2075	
		Low Emissions	High Emissions	Low Emissions	High Emissions
Avg. Annual Number of Heat Advisories	5	24	35	33	50
Avg. Annual Number of Heat Warnings	1	10	18	16	32

Areas in the county that are more developed experience what is known as a heat island effect. Buildings, roads, parking lots, and other built-up areas absorb and re-emit the sun's heat more than the natural environment, which results in areas or islands with a higher temperature. Daytime temperatures in urban areas are about 1-7°F higher than temperatures in outlying areas. Nighttime temperatures are about 2-5°F higher. In 2016, the Center for International Earth Science Information Network (CIESIN) at Columbia University used NASA satellite data from 2013 to create the Global Urban Heat Island (UHI) data set. We took that data and removed the natural areas (parks and forests) to create a local version of the data. This new heat island effect data is shown in Figure 70. There is a current heat island effect around Charlottesville that creates a 2.5°F daytime temperature difference, a 3.9°F daytime temperature heat island around Crozet, and a 0.9°F daytime temperature heat island around Gordonsville.

Assuming Albemarle grows according to the Comprehensive Plan and development trends over the last 15 years (75% of construction in development areas), and using the population estimates in Chapter 1, we have modeled the future projected heat island effect areas, also shown in Figure 70.

Figure 70: Urban Heat Island Effect Areas



Exposure

The entire county will be exposed to the extreme heat hazard, but the parts of the county in the heat island effect will be exposed to greater extremes. The following community assets will be exposed to the heat island effect currently, in 2050, and in 2075.

People

Since the heat island effect is created by developed areas, it makes sense that the population centers will be exposed to this effect, resulting in a large population in the heat island effect areas. Using the population models identified earlier, the total population for the years 2050 and 2075 have been added to Table 15. We combined the 2020 Census data with the current heat island effect data to determine the population exposed to the heat island effect. Reviewing the development trends over the previous 30 years, 76.7% of new growth occurred within the areas identified as growth areas in the Comprehensive Plan. These areas experience the heat island effect. In 2050, we expect the Town of Scottsville to experience the heat island effect as a growing population center, which explains the sudden jump in the percent of the overall population exposed for this year.

Table 15: Population Exposed to Heat Island Effect

Year	Population	Population Exposed to Heat Island Effect	Population Exposed to Heat Island Effect (%)
2020	112,395	92,139	82.0%
2050	151,651	128,903	85.0%
2075	184,763	154,277	83.5%

Using the 2020 Decennial Census Block Data, we identified the demographic characteristics of the population exposed to the heat island effect. Black, Asian, and Latino residents are currently impacted at a higher percentage than the county average. The County's Asian population had the largest percentage living within the heat island effect areas, at with 97%. Table 16 shows the demographic breakdown exposed to the heat island compared to the county as a whole.

Table 16: Population Demographics Exposed to Heat Island Effect

Demographics	Exposed to Heat Island Effect (%)	Albemarle County Average (%)
White	70.6%	72.8%
Black	9.2%	8.9%
Asian	8.7%	7.3%
American Indian	0.2%	0.3%
Other Race	4.1%	3.7%
Two or More Races	7.2%	7.0%
Hispanic or Latino	8.1%	7.5%

Built Environment

All of the built environment will be exposed to extreme heat. Buildings, utilities, transportation, and critical facilities are found in the highly developed areas. The following community assets are located in the heat island effect areas:

- Hospital (2)
- Police Station (2)
- Fire Station (7)
- Rescue Squad (6)
- Emergency Ops Center (2)
- Public School (19)
- Private School (9)
- Nursing Home (16)
- Electric Substation (11)
- Water Treatment Plant (2)
- Water Pump Station (4)
- Water Tank (9)
- Sewer Treatment Plant (3)
- Sewer Pump Station (4)
- Airport (1)
- Bus Stop (101)

Vulnerability

The vulnerability assessment helps identify sensitivities in our community so that actions may be taken to reduce harmful impacts. This is different from a risk assessment, which incorporates the likelihood of an event occurring. We know that at least some amount of extreme heat is going to occur in the future, and this section focuses on what makes our community vulnerable.

People

The social vulnerability assessment includes identifying different conditions of the population that increase some groups' sensitivity or decrease their ability to adapt. This component of the vulnerability assessment includes household indicators (Table 17) and poverty indicators (Table 18). The other social vulnerability indicators discussed in Chapter 1: Albemarle County were based on data associated with geographic areas (Census Tracts) too broad to use in the vulnerability analysis. Each component of the social vulnerability indicator was weighted equally.

In addition to humans, pets are also susceptible to extreme heat.

Table 17: Social Vulnerability - Household Indicators

Household Indicators
65 years or older
65+ Years Old and Living Alone
Grandparent Responsible for Grandchild Under 18
Under 18 years
Single Parent Household
No High School Diploma
Limited English

Observations

The red areas north of Charlottesville score highly for household vulnerability due to larger numbers of residents 65 years or older, grandparents caring for grandchildren, and residents with no high school diploma.

The red areas in the southern part of the county score highly for household vulnerability due to larger numbers of residents 65 years or older, single parents, and residents with no high school diploma.

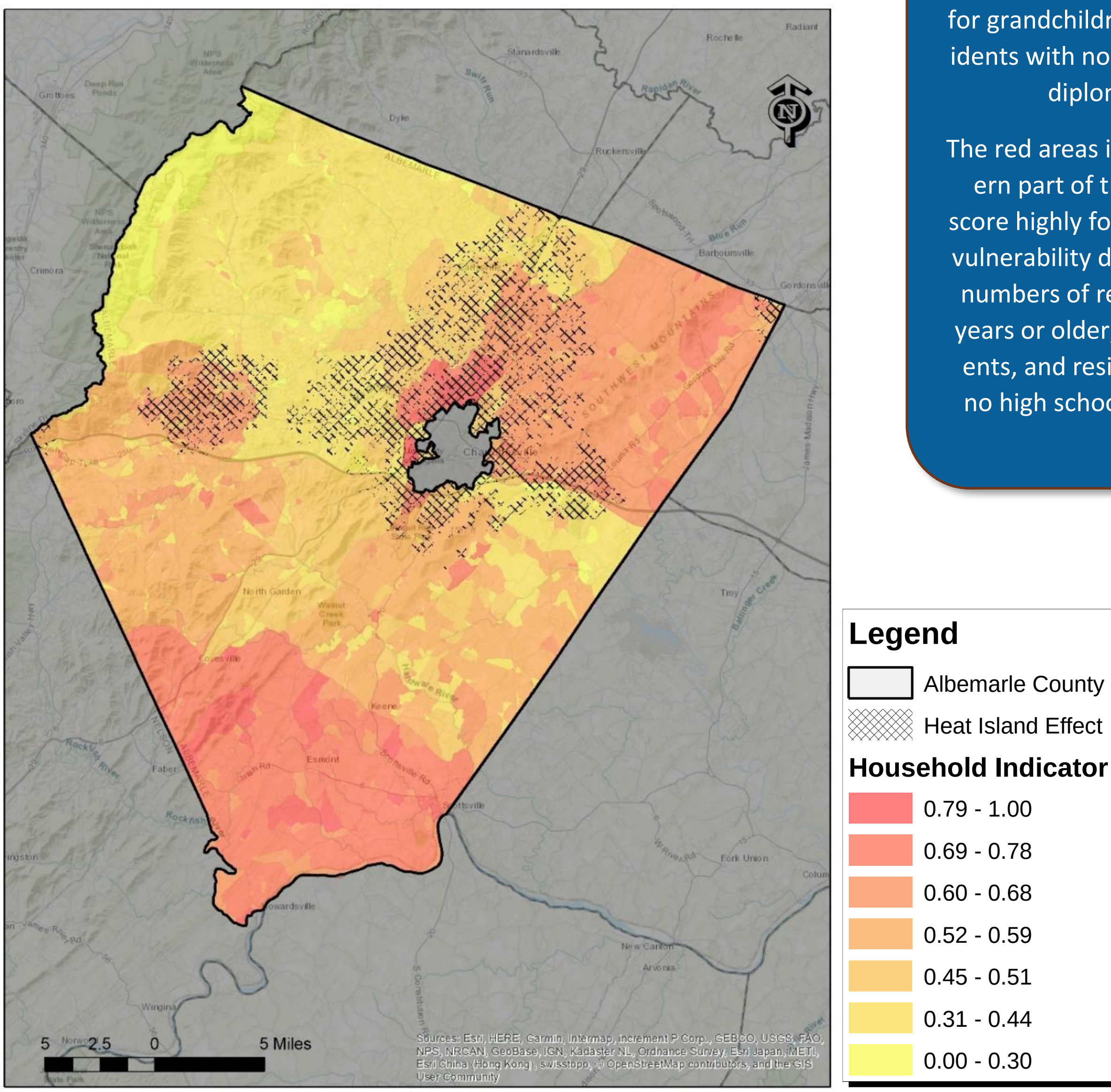


Figure 71: Social Vulnerability - Household Indicators

Table 18: Social Vulnerability - Poverty Indicators

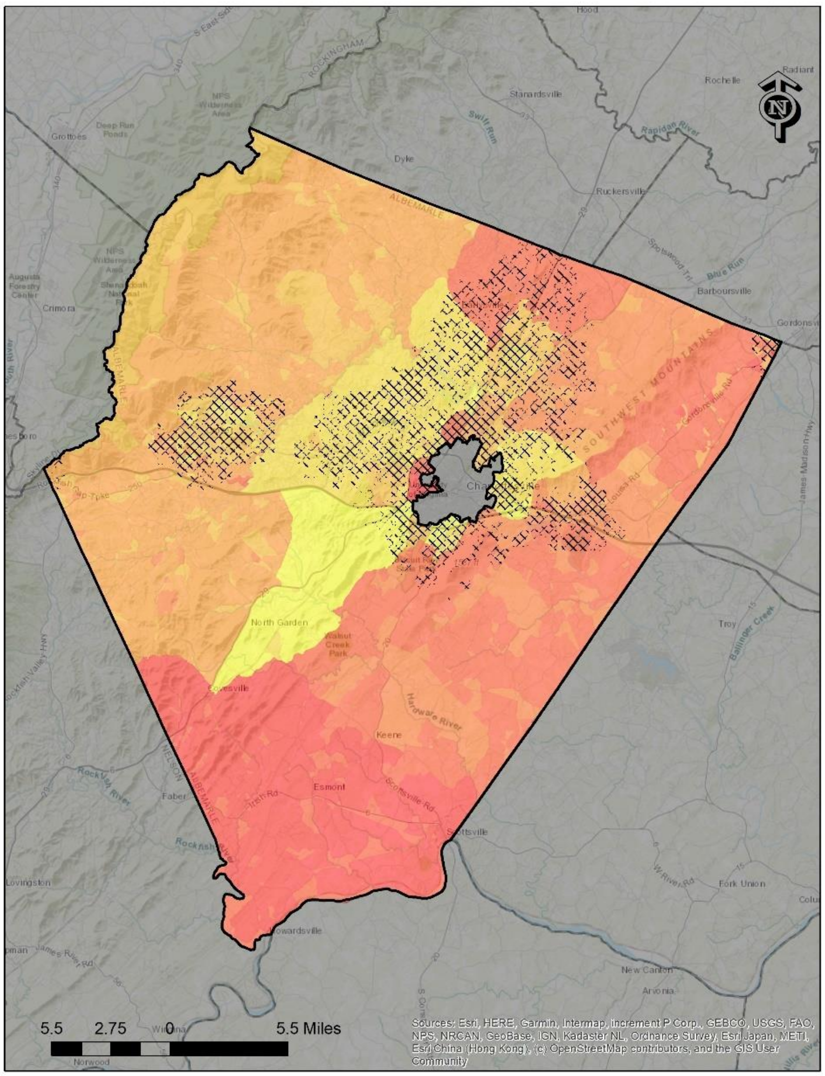
Poverty Indicators
Median Annual Household Income
Below Poverty Level
SNAP/Food Stamps
Received Public Assistance Income
Housing Costs 30% or More of Income
Crowding (More People Than Rooms)
Unemployed
No Vehicle Access

Observations

The red areas north of Charlottesville along the Greene and Orange County borders have a high poverty indicator due to higher home costs relative to income and a larger number of people on public assistance.

The red areas in the southern part of the county have a high poverty indicator due to the median income, home costs relative to income, and unemployment.

The red areas directly west of Charlottesville have a high poverty indicator due to the number of people living below the poverty line, the median income, and a higher level of unemployment.



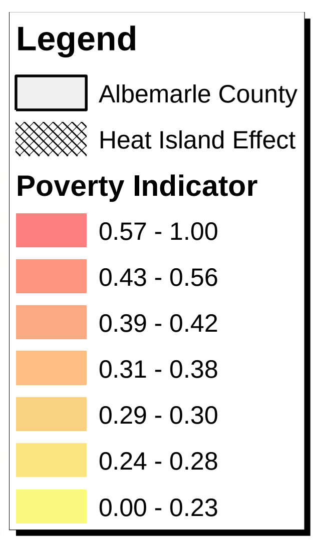


Figure 72: Social Vulnerability - Poverty Indicators

Natural Features

The agriculture found in Albemarle County is discussed in Chapter 1: Albemarle County; some of what is grown here may be more susceptible to extreme heat. It is important to understand that although the temperatures will be higher in the winter, there is still a chance of hard frosts (<28°F), including unseasonably late. If plants start blooming early due to warmer wintertime temperatures, it only takes one day of frost to damage crops.

Although vegetables make up little of the total acreage farmed (not counting corn or soybeans), there are several farms which provide vegetables to local customers. Several vegetables have cool weather varieties which will fail under extreme heat. Some traditional cool weather vegetables now have heat tolerant varieties available.

For example, when evening temperatures don't drop below 80°F, alfalfa, clovers, bromegrass, orchardgrass, fescues, needlegrasses, and wheatgrasses struggle to grow at all, while millet, sudangrass, sorghums, bluestems, gramas, switchgrass, and other warm-season grasses thrive (UNL Extension, 2019). Additionally, hay that has been stored with a moisture content of 15% or more can contain heat-resistant fungi that become active at 113°F. These fungi breakdown complex carbohydrates, further heating the hay until their deaths at 175°F, which in turn creates a chemical reaction that further heats the hay until it combusts (UMO Extension, 1993).

Since apple orchards and grape vines make up such a large part of the acreage and economy for the County, we focus on their susceptibilities in the following charts. Apple trees require a minimum number of chill hours to fruit; that number varies by the apple variety. Table 19 provides examples of low, medium, and high chill apple varieties (Chaney, 2021). As winter temperatures increase, it will be increasingly difficult to successfully grow a high chill variety apple in the County.

Table 19: Apple Varieties and Chill Hours (Chaney, 2021)

Apple Type	Chill Hours	Varieties
Low Chill	200-300	Anna, Dorsett Golden, Beverly Hills, Pettingill, Sundowner
Medium Chill	400-700	Fuji, Granny Smith, Golden Delicious, Gordon, Pink Lady, Winter Banana, Gala
High Chill	1,000+	Honeycrisp, McIntosh, Red Delicious

Many grape varieties do well under heat stress and produce a more consistent harvest. However, there are some varieties that don't perform as well. Table 20 provides examples of common wine grape varieties that are heat tolerant and heat intolerant (Denig, 2019).

Table 20: Common Wine Grape Varieties (Denig, 2019)

Heat Tolerance	Grape Varieties
Intolerant	Chardonnay, Gewürztraminer, Pinot Gris, Pinot Noir, Riesling, Sauvignon Blanc,
Tolerant	Syrah, Grenache, Zinfandel, Shiraz

Livestock can also be susceptible to extreme heat. Long-haired breeds, unshorn sheep, dairy cattle, and animals left without shade are particularly susceptible.

Built Environment

There are several components of the built environment that can be more susceptible to extreme heat. Buildings and infrastructure can be built to withstand extreme heat, but much of the built environment was constructed in a time when very high temperatures were not considered. This section covers infrastructure and buildings that may be more susceptible to extreme heat.

Buildings can be more susceptible to extreme heat if they are in poor or very poor condition, don't have air conditioning, or are mobile homes. These indicators are provided in Table 21. We took the County's site level parcel data and joined it to the Census Blocks to identify areas that may be more susceptible to extreme heat, shown in Figure 73.

Table 21: Built Environment Vulnerability – Building Indicators

Building Indicators
Condition – Poor or Very Poor
No Central Air Conditioning
Mobile Homes

Observations

The red areas southeast of Charlottesville have a high percentage of poor condition and lack of central air conditioning.

The red areas in the northwest and southwest are due to higher numbers of mobile homes, homes in poor condition, and lack of air conditioning.

The red areas west of Charlottesville are due to high numbers of homes with no central air conditioning and some mobile homes.

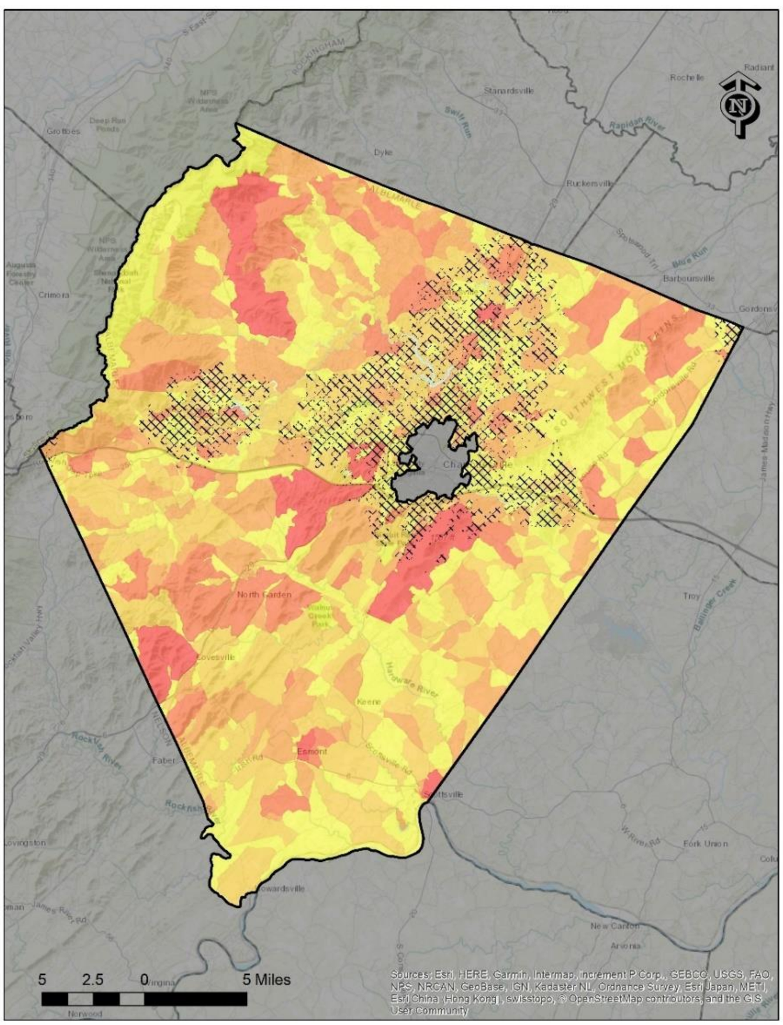


Figure 73: Built Environment Vulnerability

Roadways can also fail if they are not built to withstand high temperatures. After several days of temperatures in the upper nineties in Henrico County, stretches of I-295 failed and caused damage to vehicles (ABC News, 2017). Railway steel expands at high temperatures, which can result in fracturing. In the U.S., railways have a maximum safe temperature of 110°F (GSA, 2010). Rail in the sun and in use can see temperatures over 110°F when the air temperature is in the nineties (Wired, 2019).

Airplanes have a maximum temperature at which they can operate since warmer air is less dense and prevents sufficient lift generation. The maximum temperatures are usually between 118°F and 126°F, depending on the type of airplane.

The electrical grid is also vulnerable to extreme temperatures. The sustained demand from the population using air conditioners does not allow transformers time to cool down properly overnight, causing them to overheat and become damaged. Electrical users may experience blackouts when circuit breakers shut off the flow of power to prevent equipment damage. In parts of the U.S. where communities experience temperatures greater than 110°F, the strain on the electrical grid is a major issue. Losing power when temperatures are so high can lead to heat illness and death.

Economy

There are certain economic sectors that are more susceptible to extreme heat. Businesses that require work outside such as agriculture, recreation, and construction can see a drop in productivity, more absenteeism, and work stoppages due to extreme conditions. Other jobs such as manufacturing and warehousing may not have an air-conditioned space for employees doing manual labor. Table 22 provides information on those industries that may be more susceptible to extreme heat. Information concerning the number of employees, wages, and number of businesses along with a percentage of the industry compared to the others in the County is provided.

Table 22: Industries Susceptible to Extreme Heat (BEA, 2021)

Albemarle County Industry	Employees	Employees (% of Total)	Wages (x$1000)	Wages (%)	Businesses (Number)	Businesses (%)
Agriculture, Forestry, Fishing, and Hunting	686	1.7	20,129	1.0	86	2.3
Arts, Entertainment, and Recreation	1,730	4.3	50,691	2.5	66	1.7
Construction	2,267	5.7	123,168	6.0	301	8.0
Manufacturing	2,147	5.4	142,015	6.9	114	3.0
Mining, Quarrying, Oil and Gas Extraction	46	0.1	2,768	0.1	5	0.1
Transportation & Warehousing	829	2.1	39,493	1.9	60	1.6

Potential Impacts

In this section of the report, we discuss what potential impacts the County may face in the future. This involves reviewing historical impacts, the thresholds at which those impacts occurred, and then assessing the probabilities of reaching those thresholds in the future.

People

One major impact is heat-related illness so severe it requires ambulance services. Between January 2016 and June 2021, data has been collected on how often an ambulance is dispatched and emergency medical service is provided to people suffering from a heat-related illness. Figure 74 shows the number of heat-related emergencies at a range of temperatures from 2016 to 2021. Figure 75 shows the probability of a specific temperature occurring.

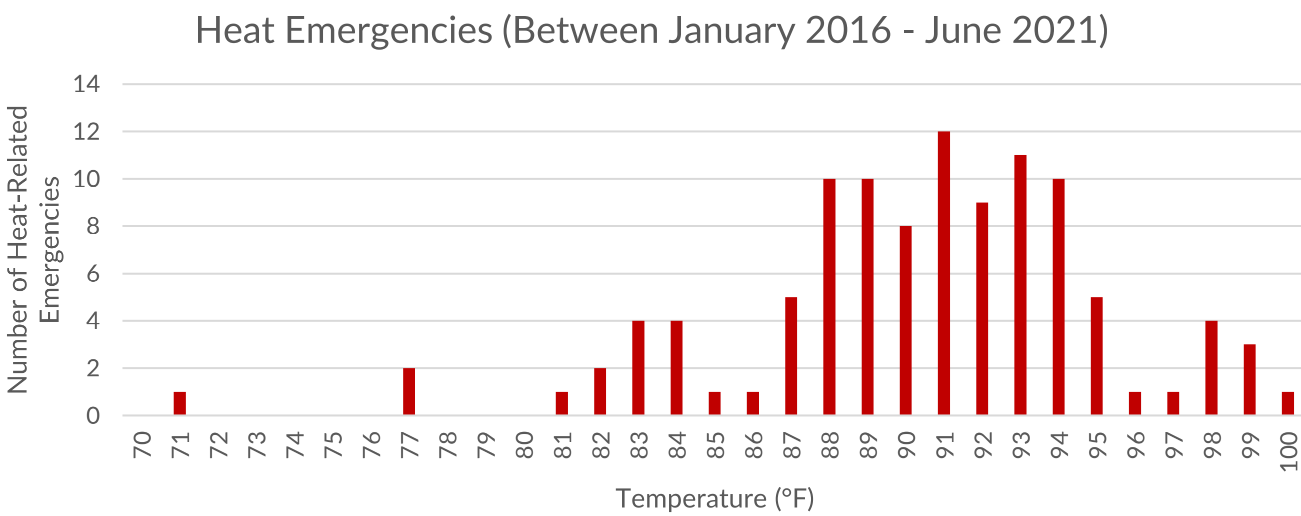


Figure 74: Heat Emergencies Requiring Ambulatory Care (2016-2021)

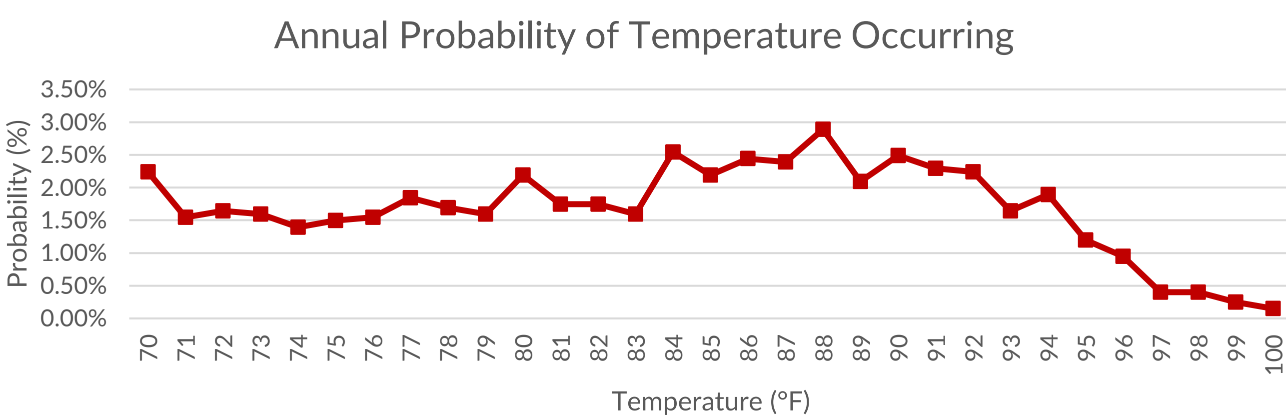


Figure 75: Annual Probability of Temperature Occurring Between 2016 and 2021

We used the data shown in the previous two figures to develop the probability of a heat emergency occurring based on a given high temperature, shown in Figure 76. When temperatures are 98°F or higher, the probability of a heat emergency requiring an ambulance is over 35%.

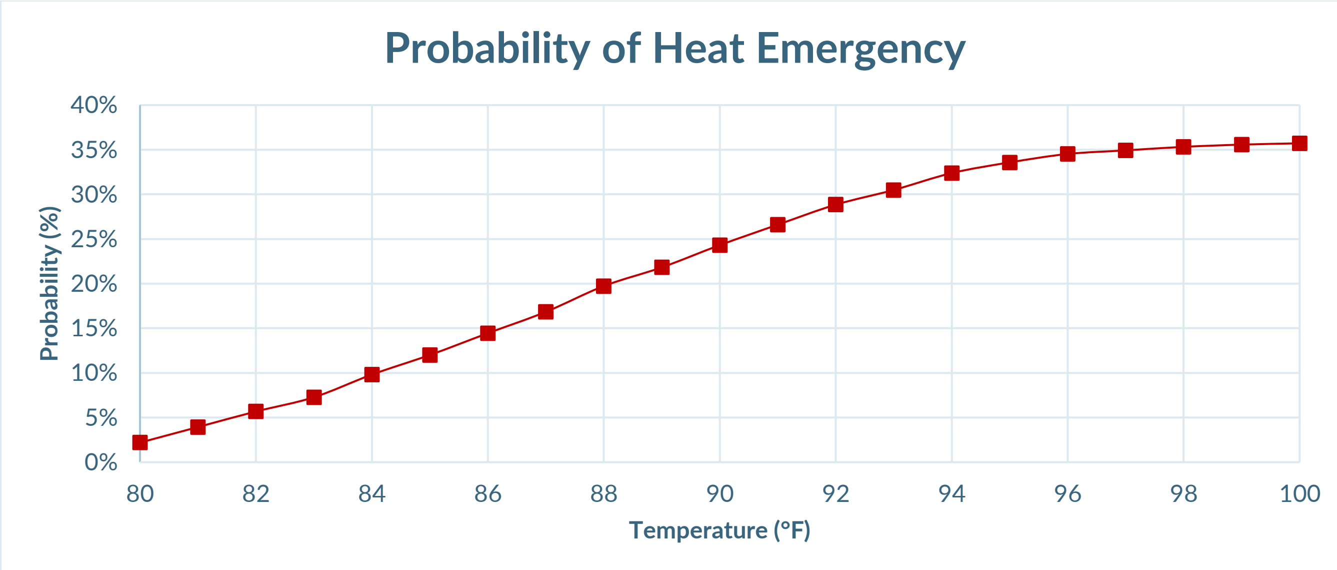


Figure 76: Probability of a Heat Emergency Requiring an Ambulance

Using these probabilities, the future high temperatures in 2050 and 2075, and the population increase, future heat emergencies can be modeled. Figure 77 shows the projected ambulatory care for heat emergencies for the 2050 and 2075 time horizons and the two emissions scenarios. By 2075, the number of heat-related ambulatory care cases will nearly triple. These values do not include a scenario where the electrical grid fails during a major heat event, which could lead to much more widespread heat illness.

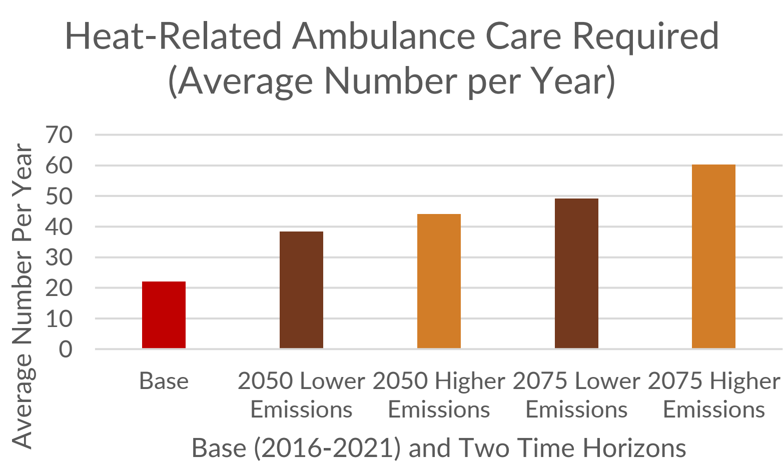


Figure 77: Projected Heat-Related Ambulatory Care for Future Time Horizons

Natural Features

For livestock, extreme heat impacts include: (1) decreased performance (e.g., feed intake, growth, milk, eggs), (2) increased mortality, and (3) decreased reproduction. Livestock loss data was not available for the county, so we modeled future livestock losses using the methodology described in Economic Losses from Heat Stress by U.S. Livestock Industries (St-Pierre, N.R., et al., 2003). The methodology uses a temperature-humidity index to calculate the probability of mortality, the dry matter intake (DMI) loss, production loss, the days open (DO) loss, which is the loss from the average number of days open from heat stress, and how long the livestock is heat stressed per year. Table 23 provides the variables used to calculate the economic loss due to heat based on this methodology. The livestock inventory is from the USDA NASS data (2017). The THI threshold indicates when the livestock becomes uncomfortable in heat and humidity; death is the value of the livestock; livestock that produce milk, eggs, or fiber have an output loss value equal to the price of one unit of output; DO loss is the price for one day open for that animal class; and DMI loss is the unit price of DMI for that animal class.

Table 23: Livestock Heat Loss Methodology Constants

Livestock	Inventory	THI Threshold	Death ($/unit)	Output Loss ($/unit)	DO Loss ($/day)	DMI Loss ($/kg)
Cattle	21,644	75	1,200	0	1.8	0
Pigs	894	72	250	0	1.5	0
Sheep	2,886	72	250	2.2	1.5	0
Goats	1,016	72	100	2.2	1.5	0
Poultry	38,385	70	2	1.2	0	0.13

The methodology identified above was used to calculate the livestock losses for the high emissions scenarios for 2050 and 2075. Table 24 shows the loss results for livestock, which includes livestock death, production loss, and open days loss for the 2050 high emissions scenario. Table 25 shows the 2075 high emissions scenario livestock loss. These losses are the average annual loss for livestock at the two time horizons. Climate variability means that the losses may be much more or less.

Table 24: 2050 High Emissions Scenario Annual Livestock Losses

Livestock	Inventory	Heat Stress Deaths (per 1,000)	Production Loss (kg/head)	Increase in Days Open	DMI Reduction	Heat Stress (h/yr)	Average Total Loss ($) per Year
Cattle	21,644	1.1	0	0.6	0.0 kg/head	1,330	51,946
Pigs	894	1.4	0	9.7	7.7 kg/head	1,537	13,321
Sheep	2,886	1.4	0	9.7	7.7 kg/head	1,537	43,001
Goats	1,016	1.4	0	9.7	7.7 kg/head	1,537	15,138
Poultry	38,385	3.9	1,012 doz/1,000	0	681 kg/1,000	803	1,055
						Total	**124,461**

Table 25: 2075 High Emissions Scenario Annual Livestock Losses

Livestock	Inventory	Heat Stress Deaths (per 1,000)	Production Loss (kg/head)	Increase in Days Open	DMI Reduction	Heat Stress (h/yr)	Average Total Loss ($) per Year
Cattle	21,644	2.7	0	1.6	56.6 kg/head	1,991	132,461
Pigs	894	3.3	0	18.8	13.6 kg/head	2,200	25,948
Sheep	2,886	3.3	1.1	18.8	13.6 kg/head	2,200	90,750
Goats	1,016	3.3	1.1	18.8	13.6	2,200	31,948

Livestock	Inventory	Heat Stress Deaths (per 1,000)	Production Loss (kg/head)	Increase in Days Open	DMI Reduction	Heat Stress (h/yr)	Average Total Loss ($) per Year
					kg/head		
Poultry	38,385	8.0	1,640 doz/1,000	0	1,108 kg/1,000	3,186	1,370
						Total	**282,477**

There are several agricultural loss types including losses due to (1) extreme heat, (2) hard frost after warm temperatures, and (3) fruit set failure. Agricultural data collected by the USDA was identified and used for this analysis. Many losses were not collected based on a host of reasons, so this data should be considered a subset of the whole. Loss due to extreme heat was collected for 2006 through 2018 and is plotted in Figure 78 along with the number of days when temperatures were greater than 95°F. Years when there was extreme heat typically produced losses. The total loss collected by USDA due to extreme heat for Albemarle County from 2006 to 2018 was $4,647,605, which results in a calculated average annual loss of $357,508.

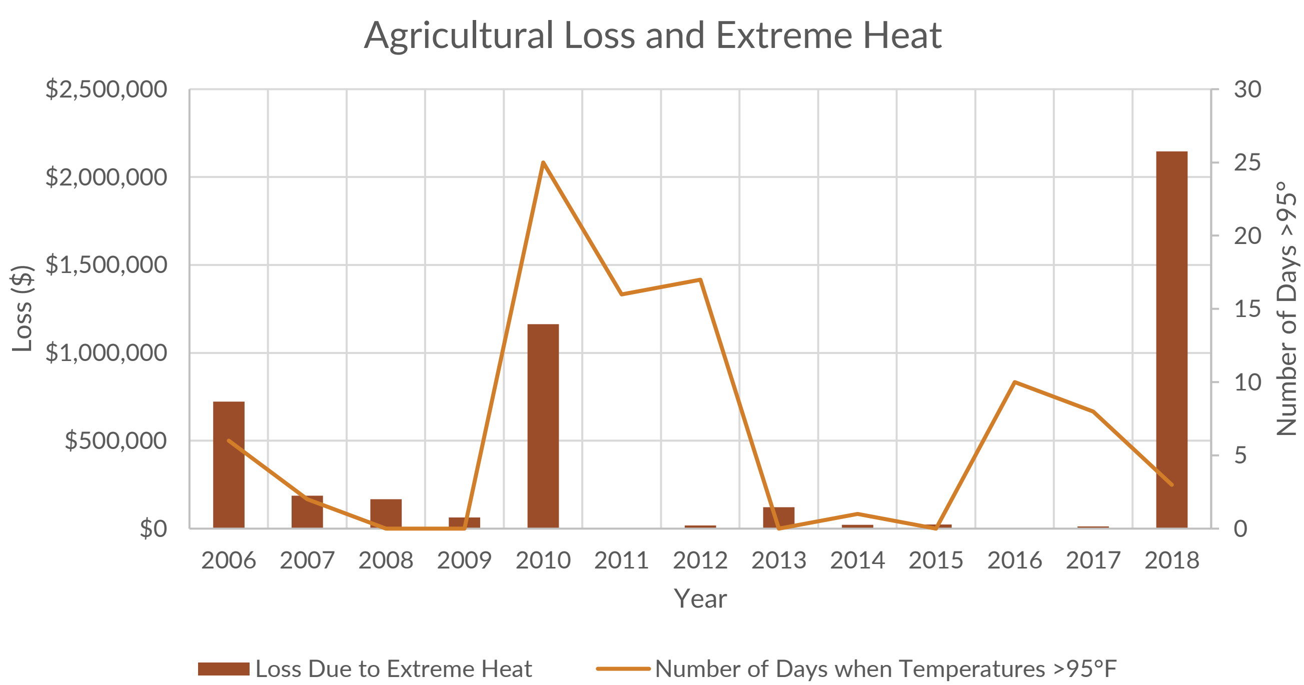


Figure 78: Agricultural Loss due to Extreme Heat

We compared the monthly average temperature to the agricultural loss in which the month occurred. A probability graph was created with the data and is shown in Figure 79. Climate change will alter these probabilities, creating these losses more frequently.

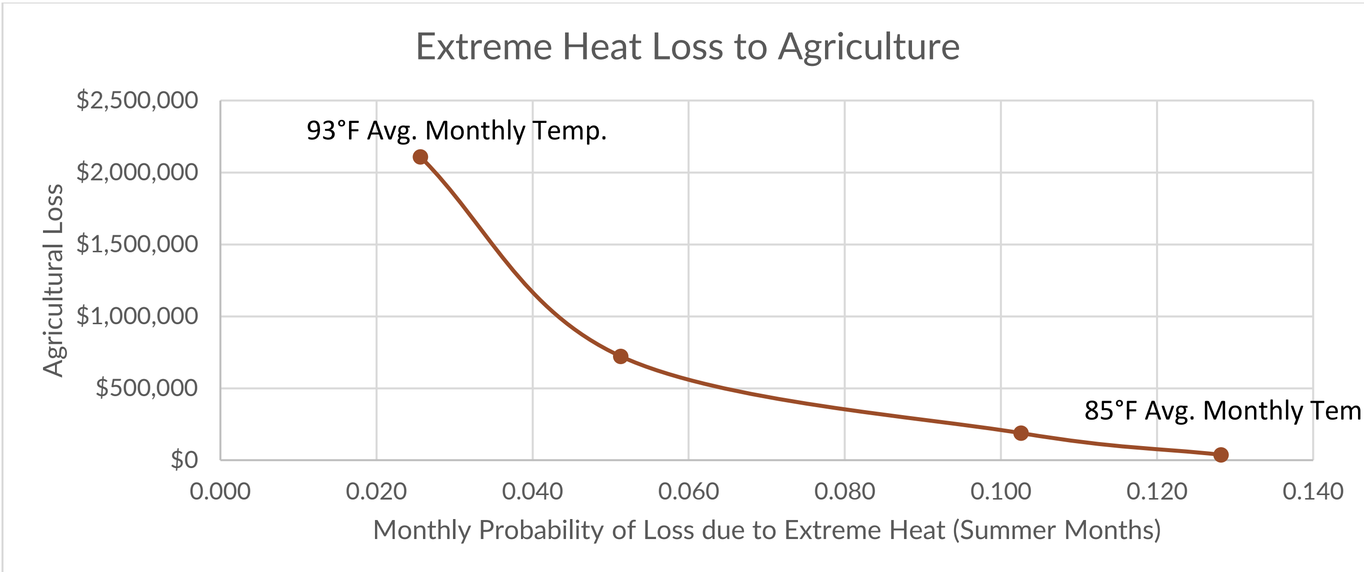


Figure 79: Extreme Heat Loss Probabilities

Next, we looked at losses due to a hard frost in the spring. Data from 2000 to 2019 was identified and analyzed to determine the conditions required for the loss. The total loss from these 20 years is $11,631,788, with an average annual loss of $581,589. In each of the high loss springs, higher temperatures were followed by a hard frost. The likelihood of attaining 80-degree weather in spring months has increased, although the chance of getting a hard frost in late spring has decreased. Figure 80 shows the losses by year with the number of hard frosts and days with temperatures over 80 degrees in the spring.

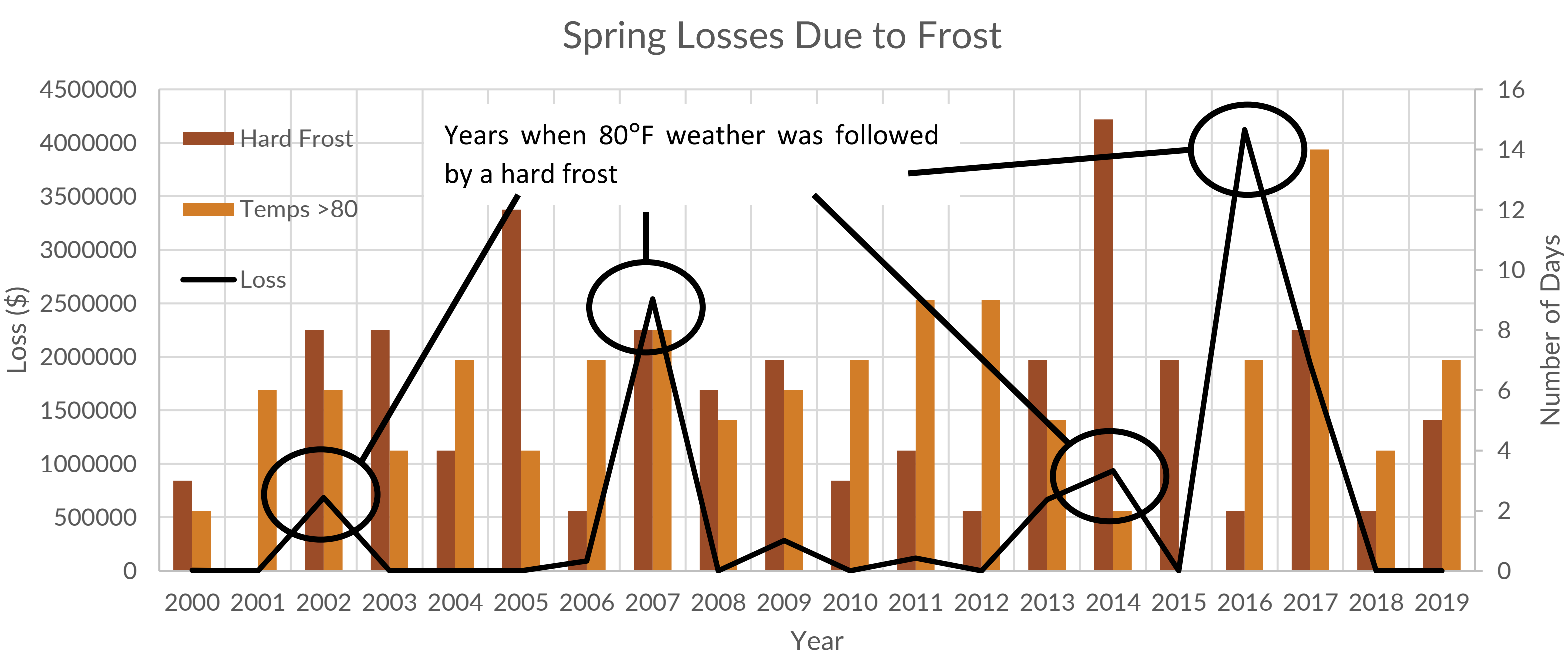


Figure 80: Agricultural Losses due to Spring Hard Frost

The last type of agricultural loss is that due to fruit set failure. From 1992 until 2018, there have been six years where there was fruit set failure loss resulting in a total of $575,546 of damage which is an average annual loss of

$21,317. This is similar to the frost loss and will occur more often in the future. Table 26 provides the loss information.

Table 26: Fruit Set Failure Loss

Fruit Set Failure	Loss ($)
1992	5,302
1994	87,328
1995	350,546
1996	112,182
1998	16,743
2000	3,445
Total	**575,546**

Table 27: Current and Future Agricultural Losses

Agricultural Loss	Current (Avg. Ann.)	2050		2075	
		Low Emissions	High Emissions	Low Emissions	High Emissions
Probability of Significant Heat Loss (%)	4.1	19.7	28.8	27.1	41.1
Extreme Heat Loss ($)	$357,508	$414,289	$605,661	$569,910	$864,328
Probability of Significant Frost Loss (%)	14.2	14.2	18.5	20.0	20.0
Frost Loss ($)	$581,589	$756,066	$820,512	$820,512	$1,029,628
Probability of Significant Fruit Set Failure Loss (%)	6.3	12.6	15.7	15.1	24.4
Fruit Set Failure ($)	$21,317	$42,465	$53,039	$50,924	$82,646
Total	**$406,345**	**$1,212,819**	**$1,479,211**	**$1,441,346**	**$1,976,602**

Additionally, extreme heat can impact tree functions, resulting in a decrease in photosynthesis and growth, and a shift in biomass allocation (Teskey et al. 2014). Extreme heat and drought together produce positive feedbacks that intensify their effects, with impacts that vary across species. The European heatwave in the summer of 2003 (with average temperatures 10°F above average) resulted in a 30% reduction in ecosystem primary function (Ciais et al. 2005) while the 2010 heat wave in Russia (with high temperatures of 111.2°F) resulted in an estimated 50% reduction in ecosystem primary function (Allen et al. 2010).

Built Environment

One major additional cost will be running air conditioners longer during the year. To determine how much we spend on an annual basis to run air conditioning, we identified the average price Virginians pay using data provided by the U.S. Energy Information Administration for residential and other buildings. Then we used the county's property data to determine how many residences and other air-conditioned buildings reside in the county. The household projections identified earlier in this report were used to show how that cost will increase for the two time horizons due to population growth. The last step was to use the cooling degree days to show how much more money would be spent on air conditioning for the future time horizons.

Table 28shows these values for residential structures, and Table 29 shows these values for other buildings.

Table 28: Current and Future Air Conditioning Costs for Residences

Average Temperatures	Current (Avg. Ann.)	2050		2075	
		Low Emissions	High Emissions	Low Emissions	High Emissions
Cooling Degree Days	1,203	1,894	2,090	2,081	2,632
Population	112,395	151,651		184,763	
Households	41,496	55,989		68,214	
Air Conditioning Costs per Year	$189	$298	$328	$327	$414
Total Air Conditioning Costs per Year	**$7,842,744**	**$16,660,218**	**$18,384,295**	**$22,301,933**	**$28,206,962**

Table 29: Current and Future Air Conditioning Costs for Other Buildings

Average Temperatures	Current (Avg. Ann.)	2050		2075	
		Low Emissions	High Emissions	Low Emissions	High Emissions
Cooling Degree Days	1,203	1,894	2,090	2,081	2,632
Number of Other Buildings	2,553	3,445		4,197	
Air Conditioning Costs per Year	$707	$1,113.29	$1,228.50	$1,223.21	$1,547.08
Total Air Conditioning Costs per Year	**$1,805,278**	**$3,834,922.73**	**$4,231,778.51**	**$5,133,557.73**	**$6,492,803.43**

The next impact we investigated was the impact to the Charlottesville-Albemarle Airport operations. When an extreme heat event occurs, the airport may have to suspend operations. According to the Charlottesville-Albemarle Airport Authority's Comprehensive Annual Financial Report, the airport generates approximately $8,819,889/year in revenue (CAAA, 2019). Although much of the travel occurs during holidays and the summer, to simplify the analysis we will take the total value and divide by the number of days per year for an average daily revenue of $24,164. Loss was determined by the average number of extreme events (>110°F) that would occur during the two future time horizons.

Table 30: Airport Loss due to Extreme Heat

Albemarle County Built Environment	2050				2075			
	Low Emissions		High Emissions		Low Emissions		High Emissions	
	Days of Concern per Year	Avg. Annual Loss ($)	Days of Concern per Year	Avg. Annual Loss ($)	Days of Concern per Year	Avg. Annual Loss ($)	Days of Concern per Year	Avg. Annual Loss ($)
Airport Operations	0	0	1	24,164	1	24,164	6	144,984

Economy

Between 1980 and 2016, there was already a 20% reduction in labor productivity in Virginia due to extreme heat (Yang and Shindell, 2021). Most of the labor productivity losses are in the construction and manufacturing industries, although other industries were impacted too. We decided to look at those industries where workers are outside or in no or poorly air-conditioned spaces. These industries are identified in Table 31. To understand the heat exposure threshold limits, we used the OSHA guidance on permissible heat exposure threshold limit values, shown in Table 32. Unfortunately, the BEA combines the industry information for Charlottesville and Albemarle, so this analysis will include both jurisdictions. The industries considered to have a light work load include arts, entertainment, and recreation. Moderate work includes manufacturing; mining, quarrying, oil and gas extraction;

and transportation and warehousing. Heavy work includes agriculture, forestry, fishing, and hunting; and construction.

Table 31: Albemarle County and Charlottesville Industries (BEA, 2021)

Albemarle County and Charlottesville Industry	Employees	Wages (x$1000)	Businesses (Number)	GDP ($)
Agriculture, Forestry, Fishing, and Hunting	686	20,129	86	57,725,291
Arts, Entertainment, and Recreation	1,730	50,691	66	145,370,000
Construction	2,267	123,168	301	491,514,000
Manufacturing	2,147	142,015	114	547,342,000
Mining, Quarrying, Oil and Gas Extraction	46	2,768	5	10,070,000
Transportation & Warehousing	829	39,493	60	152,210,524

Table 32: Permissible Heat Exposure Threshold Limit Value (OSHA, 2008)

Work/Rest Regimen	Light Work Load	Moderate Work Load	Heavy Work Load
Continuous Work	86°F	80°F	77°F
75% Work, 25% Rest	87°F	82°F	78°F
50% Work, 50% Rest	89°F	85°F	82°F
25% Work, 75% Rest	90°F	88°F	86°F

The daily maximum temperature data was used to create current values for productivity for the different work types. To model how the temperature fluctuates during the day, the maximum temperature was assumed to be a perfect sine function with a period of 24 hours. This was required since the climate data is provided by day and not hourly, while we need to calculate how many hours are at a certain temperature. The OSHA threshold values were used to develop productivity loss curves based on maximum temperature. These curves are shown in Figure 81 for the three work types.

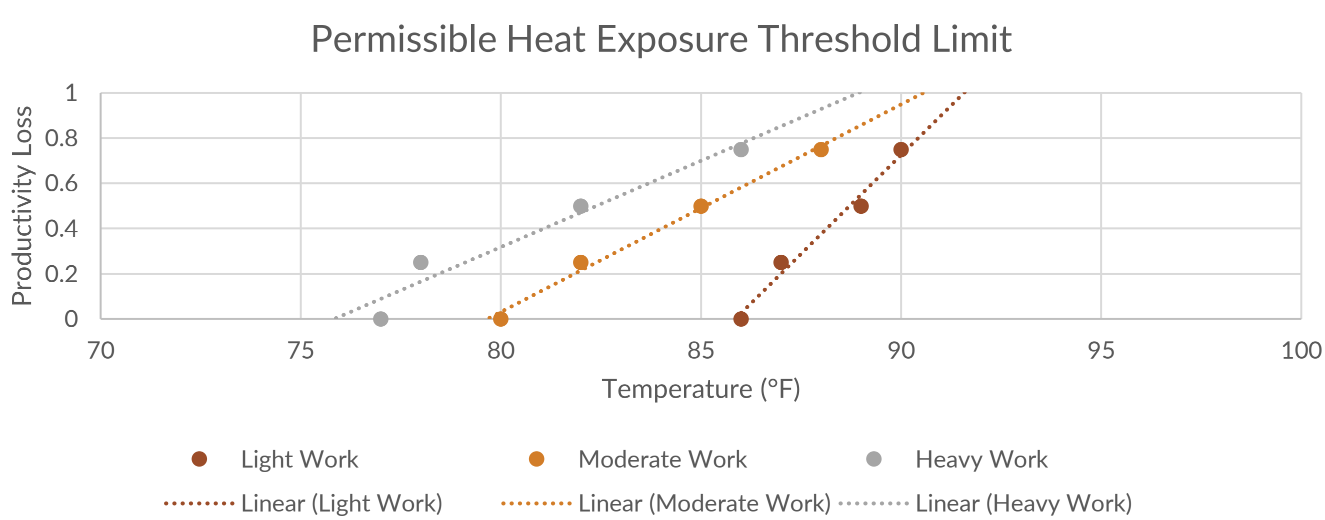


Figure 81: Productivity Loss as a Function of Temperature

The number of days each threshold is reached for the three types of work and two time horizons is identified using the climate data and provided in Table 33. Some of the work at the 75% productivity level is simliar to the current conditions since those temperatures are only in the seventies. The major change occurs at the 25% or 0%

productivity level. If workers are not provided air conditioned spaces, there will be several hours a day when no work can occur.

Table 33: Number of Days Productivity Decline is Reached

Productivity		2050		2075	
	Current	Low Emissions	High Emissions	Low Emissions	High Emissions
75% (Light Work)	14	17	16	16	14
50% (Light Work)	5	9	8	8	8
25% (Light Work)	8	18	17	17	15
0% (Light Work)	12	50	62	59	87
75% (Moderate Work)	5	22	21	21	19
50% (Moderate Work)	8	24	23	23	21
25% (Moderate Work)	12	26	25	25	22
0% (Moderate Work)	14	59	70	68	95
75% (Heavy Work)	25	27	26	26	24
50% (Heavy Work)	30	29	28	28	26
25% (Heavy Work)	8	16	15	16	14
0% (Heavy Work)	26	85	95	93	118

Finally, we converted days to hours at each threshold to determine the change in productivity from the current values. The overall GDP for each industry was used to determine productivity loss for the Charlottesville/Albemarle area. Table 34 shows these values. Please note that some of the values are negative in the 75% and 50% productivity loss categories since those days will become 25% and 0% productivity days compared to the current climate.

Table 34: GDP Loss due to Change in Productivity (Albemarle County and Charlottesville)

Productivity Loss	2050		2075	
	Low Emissions	High Emissions	Low Emissions	High Emissions
75% (Light Work)	$149,353	$99,568	$99,568	$0
50% (Light Work)	$398,274	$298,705	$298,705	$298,705
25% (Light Work)	$1,493,527	$1,344,175	$1,344,175	$1,045,469
0% (Light Work)	$7,567,205	$9,956,849	$9,359,438	$14,935,274
75% (Moderate Work)	$486,043	$243,021	$243,021	-$243,021
50% (Moderate Work)	$3,402,300	$2,916,257	$2,916,257	$1,944,171
25% (Moderate Work)	$11,665,028	$10,935,964	$10,935,964	$8,748,771
0% (Moderate Work)	$45,688,026	$56,380,968	$54,436,796	$80,683,109
75% (Heavy Work)	$376,191	$188,096	$188,096	-$188,096
50% (Heavy Work)	-$376,191	-$752,383	-$752,383	-$1,504,765
25% (Heavy Work)	$4,514,296	$3,950,009	$4,514,296	$3,385,722
0% (Heavy Work)	$44,390,573	$51,914,399	$50,409,634	$69,219,198
Total	**$119,754,624**	**$137,475,628**	**$133,993,567**	**$178,324,537**

Chapter 4: Drought

What We Can Expect

2050	Up to 149 consecutive dry days per year Up to 6.2 times increase in probability of a major drought occurring Up to 12.9% probability of water restrictions per year	206 average number of dry days per year Up to an average of 17 algal bloom outbreaks per year Increase of more than 2 times the average annual agricultural loss	+35% Water demand +10% Planned water supply +$500K annual water costs due to drought	Up to 7.1% of county businesses very susceptible to water restrictions Up to 10.6% of employees work for businesses susceptible to water restrictions +$360K in annual business loss
2075	Up to 160 consecutive dry days per year Up to 12 times increase in probability of a major drought occurring Up to 22.6% probability of water restrictions per year	216 average number of dry days per year Up to an average of 22 algal bloom outbreaks per year Increase of more than 3 times the average annual agricultural loss	+64% Water demand -5% Planned water supply +$800K annual water costs due to drought	Up to 7.1% of county businesses very susceptible to water restrictions Up to 10.6% of employees work for businesses susceptible to water restrictions +$450K in annual business loss
Identifying Vulnerabilities				
	• Elderly and children • Below poverty line • Poor health • No vehicle access • Those with shallow wells	• Younger trees • Drought intolerant plant varieties • Sandy soils and soils without clay • Farms not using rotational grazing	• Businesses requiring large amounts of water • Businesses with a supply chain dependent on water • Water utilities	• Agriculture • Manufacturing • Mining, Quarrying, oil and gas extraction • Recreation

The National Weather Service defines drought as a period of unusually persistent dry weather that persists long enough to cause serious problems such as crop damage and/or water supply shortages. The severity of the drought depends on the degree of moisture deficiency, the duration, and the size of the affected area.

After a major drought in 2001-2002, the State of Virginia developed the Virginia Drought Assessment and Response Plan, which describes how the Virginia Department of Environmental Quality (DEQ) monitors and evaluates the drought conditions in the Commonwealth and when it issues warnings. Shortly after the State developed their plan, a Rivanna Regional Drought Response Committee was formed with representatives from the Rivanna Water & Sewer Authority (RWSA), Albemarle County Service Authority (ACSA), City of Charlottesville, and Albemarle County. This committee created the Drought Response and Contingency Plan, which provides additional information on local water sources, operating procedures, emergency water sources, drought condition monitoring, and notifications. This plan was later updated in 2015.

Background – State Response

The Virginia DEQ monitors the drought conditions of the State using four indicators: (1) precipitation, (2) groundwater levels, (3) streamflow, and (4) reservoir levels. The drought monitoring website is updated daily and uses a regional map of the State and four quadrant grids to display the current drought conditions. When at least two indicators exceed the threshold for state determination, a recommendation is made by the Virginia Drought Coordinator for the region. Figure 82 shows an example of the State's drought indicator map.

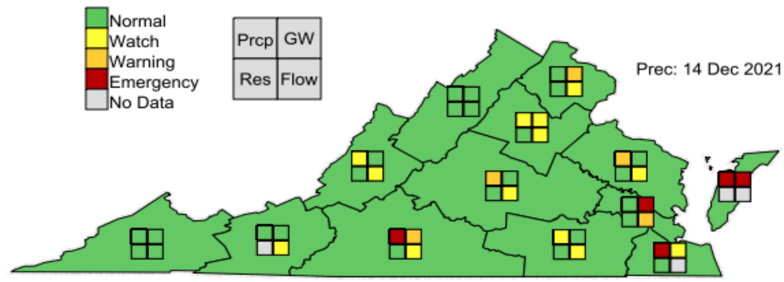


Figure 82: Virginia Drought Indicator Map

For the precipitation indicator, DEQ uses the Parameter-elevation Regressions on Independent Slopes Model (PRISM) precipitation data created by Oregon State and supported by the USDA. DEQ compares the PRISM data to the long-term normal for that part of the year. The water year is October 1 through September 30 and is the time of year when the ground and surface water get recharged before the weather warms and evaporation and plant transpiration exceed precipitation. Table 35 provides information on how the normal, watch, warning, and emergency precipitation values are categorized.

Table 35: Precipitation Indicator

Months Analyzed	Normal (% of normal)	Watch (% of normal)	Warning (% of normal)	Emergency (% of normal)
October - December	>75.0	<75.0	<65.0	<55.0
October - January	>80.0	<80.0	<70.0	<60.0
October - February	>80.0	<80.0	<70.0	<60.0
October - March	>80.0	<80.0	<70.0	<60.0
October - April	>81.5	<81.5	<71.5	<61.5
October - May	>82.5	<82.5	<72.5	<62.5
October - June	>83.5	<83.5	<73.5	<63.5
October - July	>85.0	<85.0	<75.0	<65.0
October - August	>85.0	<85.0	<75.0	<65.0
October - September (and previous 12 months)*	>85.0	<85.0	<75.0	<65.0

** Values are carried into October if a deficit exists at the beginning of the water year.*

For the groundwater and surface water indicators, DEQ compares the groundwater levels and streamflow records to long-term records for each month. Daily records are used for the groundwater comparison and weekly averages are used for the surface water comparison. Table 36 provides the threshold that defines each drought state category. For the drought region covering Albemarle County, the groundwater monitoring wells in Buckingham County and Colonial Heights are used while the streamflow gaging station in Farmville along the Appomattox River is used.

Table 36: Groundwater and Surface Water Indicators

Drought State	Threshold
Normal	25th percentile
Watch	Between 10th and 25th percentile
Warning	Between 5th and 10th percentile
Emergency	<5th percentile

For the reservoir level indicator, DEQ reviews the number of days of usable storage remaining. For the drought region covering Albemarle County, the reservoir levels at Lake Moomaw and the Charlottesville Water Supply Reservoir System are used. Table 37 provides the threshold that defines each drought category.

Table 37: Reservoir Level Indicator

Drought State	Threshold
Normal	>120 days of usable storage
Watch	Between 90 and 120 days of usable storage
Warning	Between 60 and 90 days of usable storage
Emergency	< 60 days of remaining usable storage

For the drought warnings and watches, State and local government work together to educate the public on water conservation, to help large water users (>10,000 gallons per day) decrease their withdrawals, and, in some case, to require that local public waterworks impose use restrictions. Once a drought emergency is declared by the Governor, the following non-essential water uses are prohibited: (1) unrestricted irrigation of lawns; (2) unrestricted irrigation of golf courses; (3) unrestricted irrigation of athletic fields; (4) washing paved surfaces; (5) washing mobile equipment such as cars; (6) using water for ornamental fountains, waterfalls, misting machines, and reflecting pools; (7) use of water to fill and top off outdoor swimming pools, and (8) water served at restaurants only at customer's request. In extreme cases, water rationing conducted locally may be required when the public's health and safety is at risk.

Background – Local Response

The RWSA provides drinking water supply and treatment for ACSA and the City of Charlottesville in three systems: (1) Urban Water System containing the City and urban area in Albemarle County surrounding the City, (2) Crozet Water System which serves the ACSA for the Crozet community, and (3) the Scottsville Water System which serves the ACSA for the Town of Scottsville. The water sources of these three systems are identified in Figure 83. Approximately one mile of a new pipeline from South Rivanna Reservoir to Ragged Mountain Reservoir has been constructed, with the rest planned for 2027-2035.

There are also emergency water sources that could be used in a severe drought. The Beaver Creek Reservoir, a current source for the Crozet Water System, could be used to meet the needs of the Urban Water System using Mechums River. Chris Greene Lake, currently used for recreation, could be used as a supplemental source, although the safe yield of the system is only 0.5 million gallons per day (mgd) by drawing down the lake by five feet. Chris Greene Lake is located on Jacob's Run, which flows to the North Fork Rivanna River upstream of the North Fork Rivanna Water Treatment Plant (WTP). Lake Albemarle, currently used for recreation, could be used as a supplemental water source with a safe yield of 0.7 mgd by drawing down the lake to 15 vertical feet. However, the lake has no outlet structure to allow release, so a method of delivering water to the stream would be required. There are also water quality concerns. RWSA uses information from State and federal data sources to help determine drought potential. It also has contracted with a private water resources management consulting firm to use the OASIS® model to monitor drought probabilities and help define the stages of drought that correspond to the State's watch, warning, and emergency states. The modeled hydrologic conditions using OASIS® help determine the drought state. Table 38 identifies the local thresholds for drought watches, warnings, and emergencies.

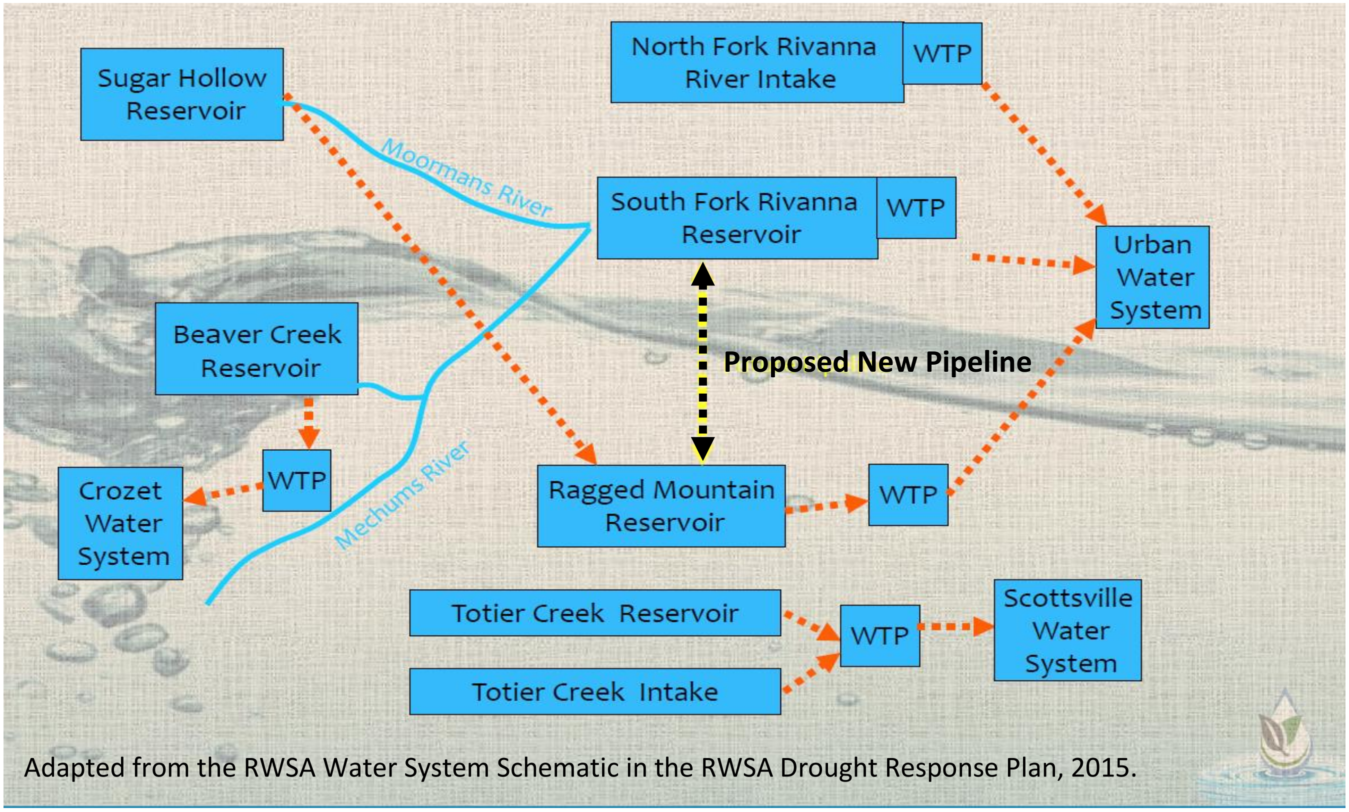


Figure 83: RWSA Water System Schematic

Table 38: Local Drought Hydrologic Conditions

Drought State	Threshold	Reservoir Storage Equivalency
Watch	20% of greater probability that total useable reservoir storage will be less than 75% within 12 weeks	75% total useable reservoir storage is equivalent to 78% of total reservoir storage
Warning	10% of greater probability that total useable reservoir storage will be less than 60% within 10 weeks	60% total useable reservoir storage is equivalent to 74% of total reservoir storage
Emergency	5% of greater probability that total useable reservoir storage will be less than 50% within 8 weeks	50% total useable reservoir storage is equivalent to 70% of total reservoir storage

When water rationing is required, the procedure provided in the Drought and Water Emergency Public Notification Plan in accordance with the ACSA Rules and Regulations is followed. The procedure begins with voluntary water restrictions (drought/water emergency watch stage), then mandatory water restrictions for businesses outlined in the Drought and Emergency Public Notification Plan (drought/water emergency warning stage), and finally water rationing is implemented (drought/water emergency stage restrictions). Penalties of $500 (first offense) and $1,000 (each additional offense) are imposed on any person violating the water restriction rules.

This final phase has never been implemented. The final phase results in the implementation of emergency rates shown in Table 39. Rationing will be based on a customer's water use 12 months before the emergency state and leaks must be repaired in 3 days. All businesses, institutions, and government entities are to develop and implement a written plan to reduce their water use by 20%. A customer may request an exemption, in writing, to the ACSA Executive Director if they find that compliance with the restriction would create an unjust hardship.

Table 39: Emergency Water Rates

Home	Rate Increase
Single-Family Level 1 (0-3,000 gallons per month)	Normal Rate x 1.25
Single-Family Level 2 (3,001-6,000 gallons per month)	Normal Rate x 1.50
Single-Family Level 3 (6,001-9,000 gallons per month)	Normal Rate x 2.00
Single-Family Level 4 (>9,000 gallons per month)	Normal Rate x 2.00
Multi-Family	Normal Rate x 1.50

Current and Future Conditions

There have been several years when the county has experienced different levels of drought conditions. Observed data from 1970 through 2020 was compared to the years the county experienced drought impacts to determine the current frequency and understand the threshold of some of the major drought events. The 2001-2002 drought included three years of very low precipitation (2000 at 82% of average, 2001 at 71% of average, and 2002 at 87% of average). The average annual precipitation for the period of 1950 to 2020 is 45.0 inches. Figure 84 shows the annual precipitation and identifies which years experienced drought conditions.

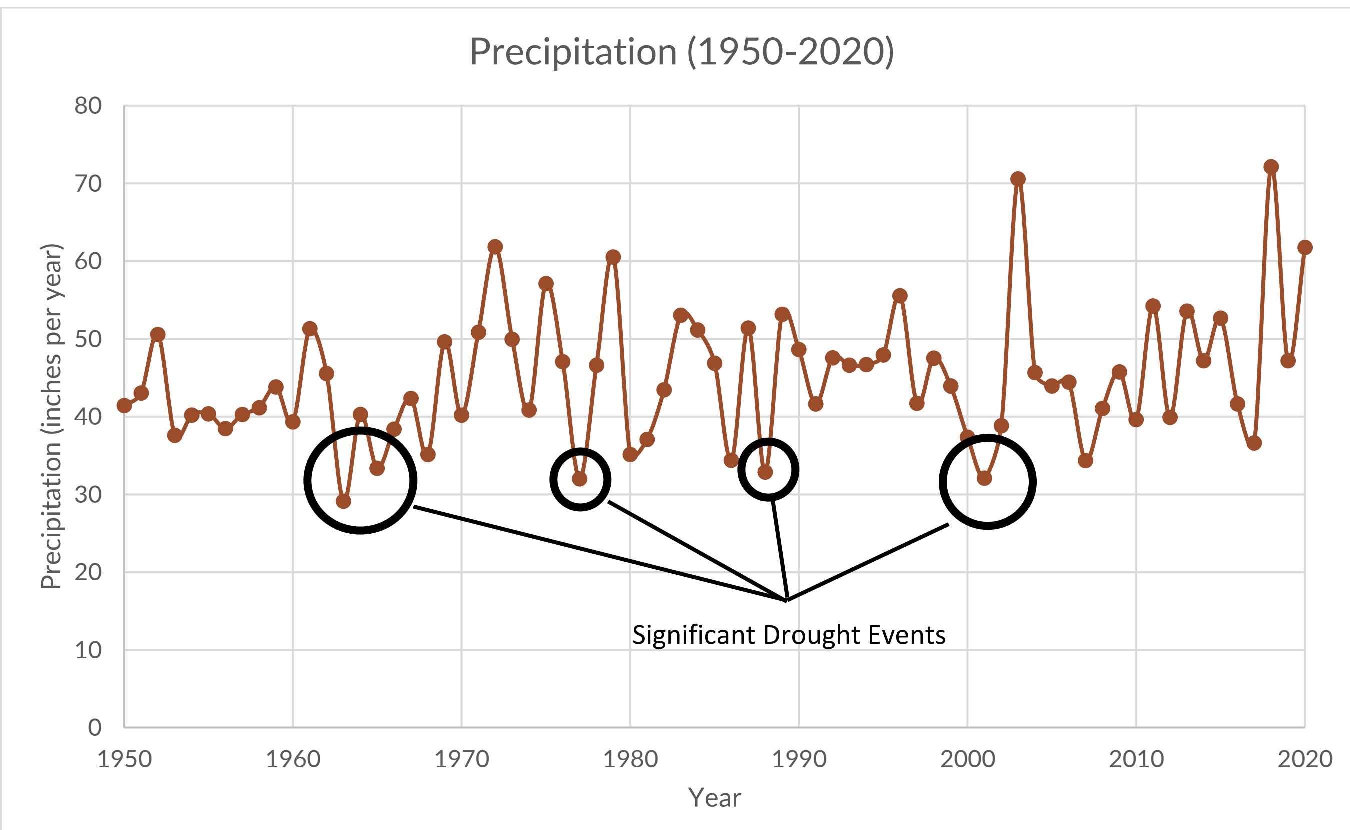


Figure 84: Annual Precipitation (Monticello Station, 1950-2020)

The three other drought indicators used by the State were data collected by stream gages, groundwater wells, and reservoir operators. Figure 85 shows the discharge flow data from the USGS gage on the James River in Scottsville, which has been collecting data since 1980. Figure 86 shows the reservoir levels from RWSA from 2015 through 2020. In each of the figures, we can see the years where major and minor drought events occurred.

Figure 87 shows the data from the USGS groundwater monitoring well, which has been collecting data in Albemarle County since 1965.

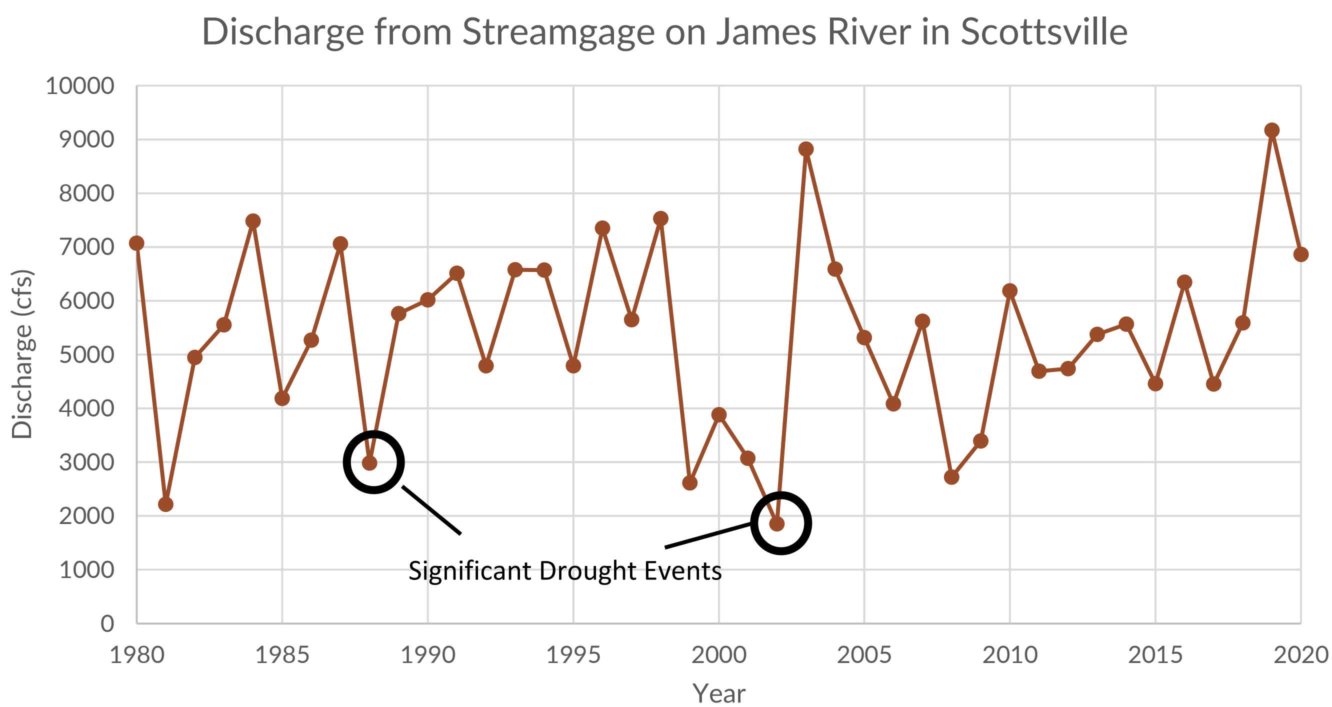


Figure 85: Stream Gage Discharge Data (USGS)

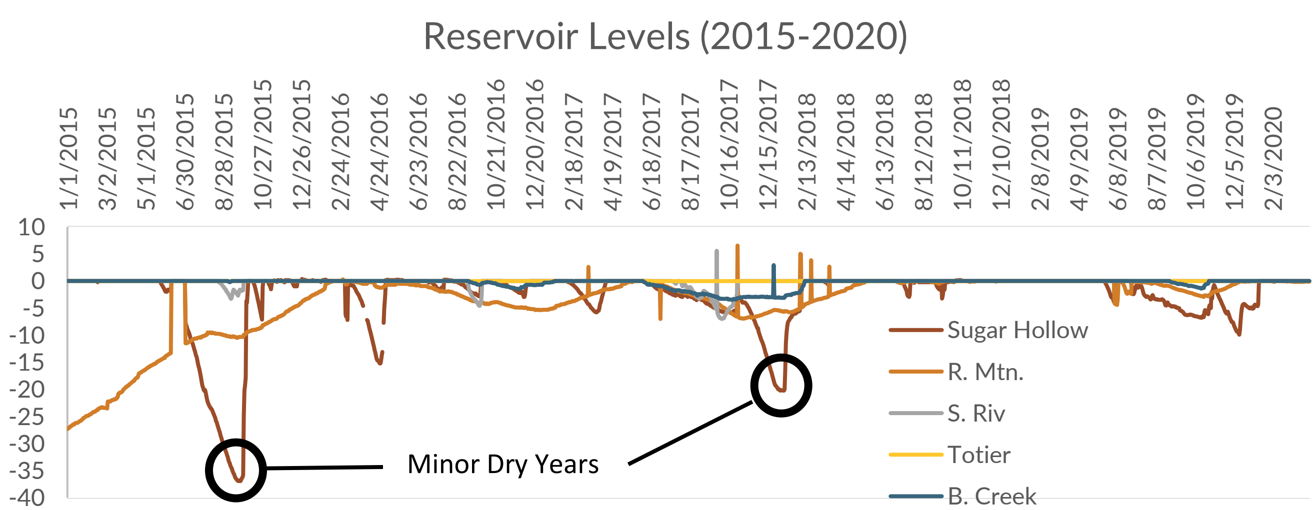


Figure 86: Reservoir Levels (2015-2020) (RWSA)

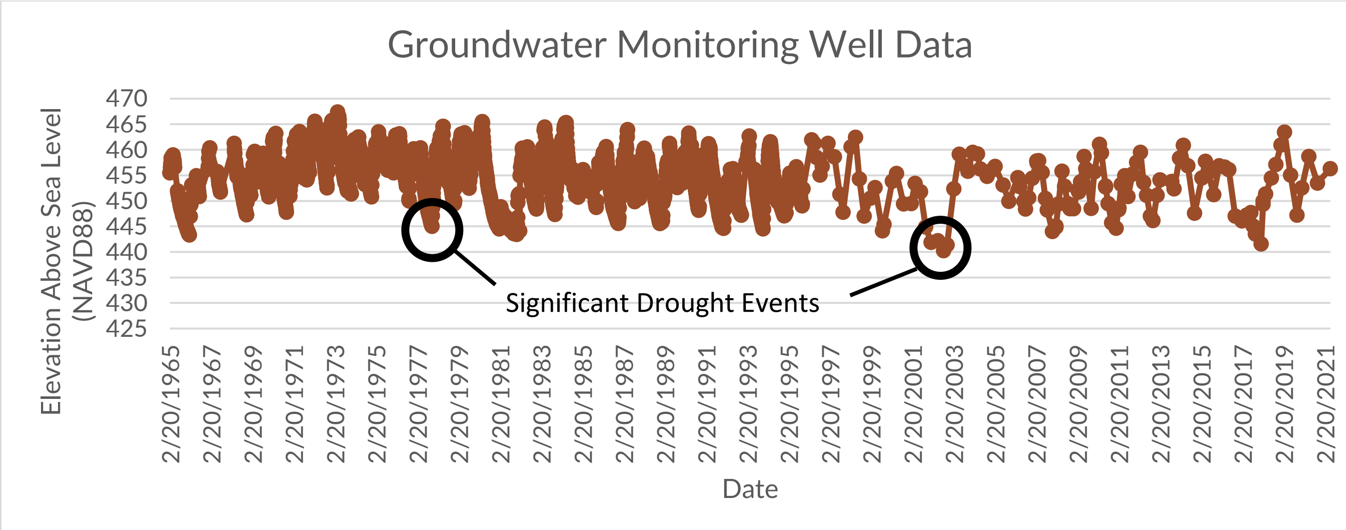


Figure 87: Groundwater Monitoring Well (USGS)

There are other ways to measure a drought, including the Keech-Byrum Drought Index and the Palmer Drought Severity Index. The latter uses precipitation, temperature, and soil moisture to calculate the Index. Figure 88 came from a Washington Post article on September 2002 by the Virginia State Climatologist, Patrick Michaels, and it shows the Palmer Drought Severity Index for Maryland. The 1930 event shown in Figure 88 was calculated to be more extreme than the 2001-2002 event. Reviewing even older records from Fort Monroe, Virginia show that the period from 1851 to 1855 received only 60% of its rainfall per year (Washington Post, 2002). This event would be catastrophic with today's population.

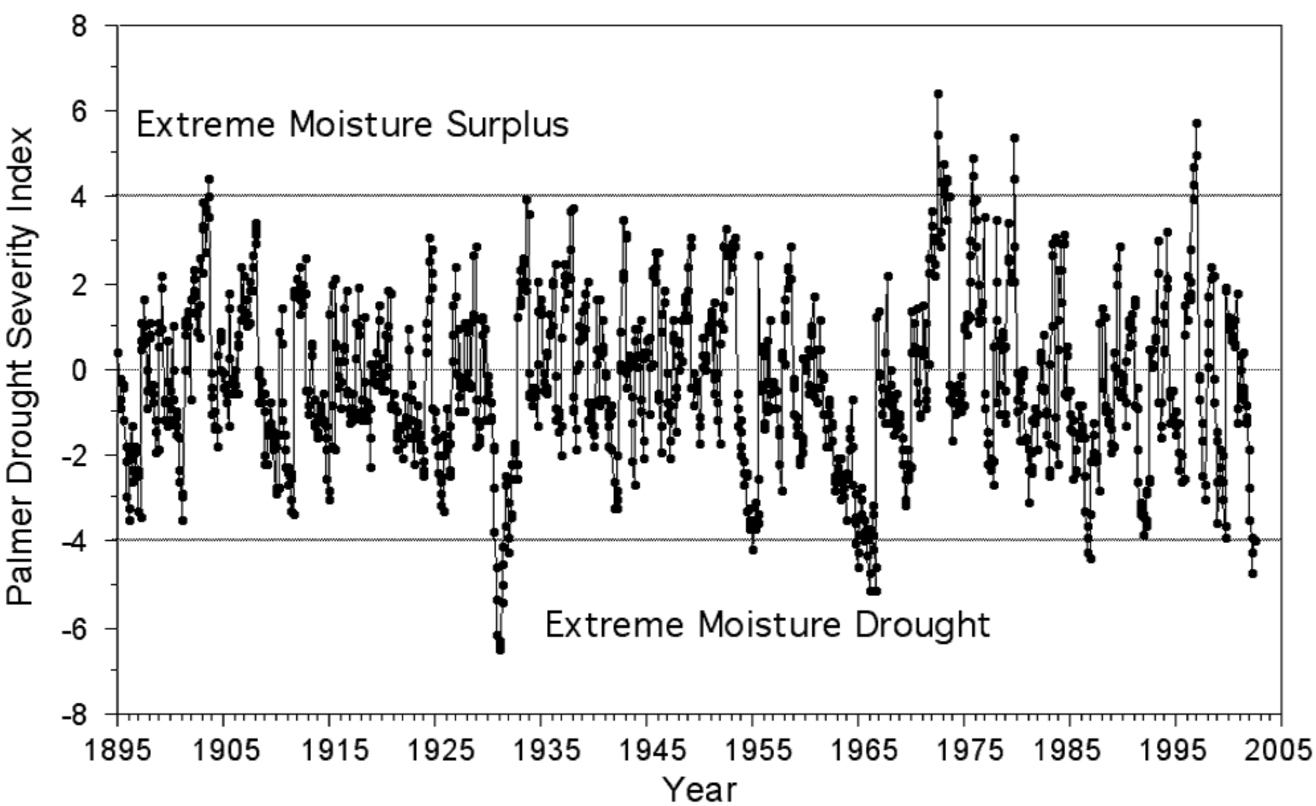


Figure 88: Palmer Drought Severity Index (1895-2002)

To determine the current probability of a significant drought impacting the county, we took the number of significant droughts and divided by the number of years precipitation data is available. We'll define a drought as a year in which the annual precipitation is 34 inches or less, based on the data in Figure 84. Using this value results in droughts over five different years. The current probability of drought is 5 years of events divided by 71 years of data which is .07 or a 7.0% annual probability of experiencing a drought.

Climate data was analyzed for low and high emissions scenarios for a time horizon of 2050 and 2075. For the 2050 time horizon, data from 2035 to 2065 was used while the 2075 time horizon used data from 2060 to 2090. Some of the climate models predict a wetter future while others predict a drier future. Figure 89 shows the annual drought probability distribution for the downscaled climate models that show a drier future. Some models show a lower drought probability while others show a much higher probability. The modeled drought probability is based only on annual precipitation, which is a limitation. A drought index with multiple variables such as temperature and soil moisture would be a more comprehensive assessment, although future data may be difficult to model for soil moisture. Temperatures are expected to increase across all models, which will increase the magnitude of future droughts.

The probabilities shown in Figure 89 are for droughts similar to that experienced in 2002. A catastrophic drought where the annual precipitation is 60% or less than average has occurred once in the last 250 years, giving it an annual probability of 0.5%. Using the climate models, the probability of a catastrophic drought increases with time shown in Figure 90. The annual probability of a major drought in the 2075 high emissions scenario is nearly that of the minor drought today.

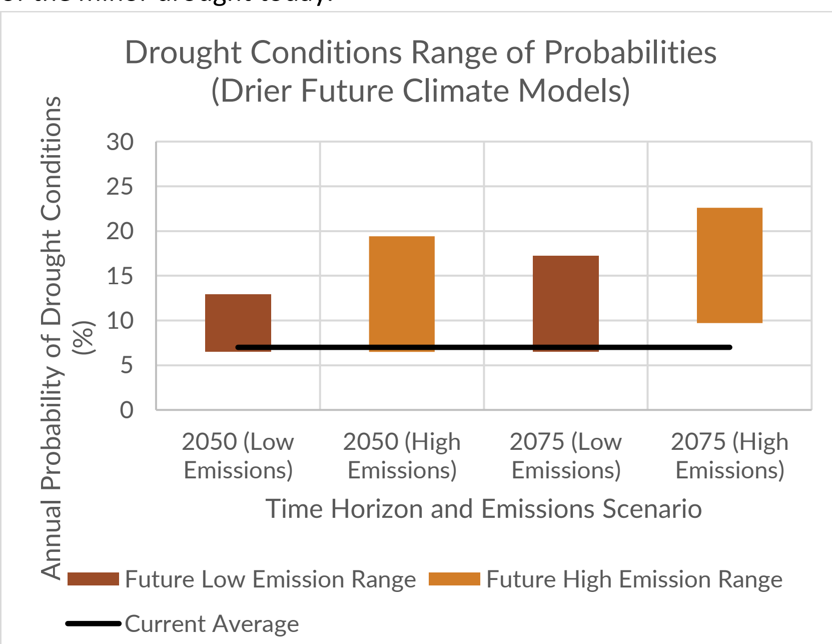


Figure 89: Probability of Drought Conditions for 2050 and 2075

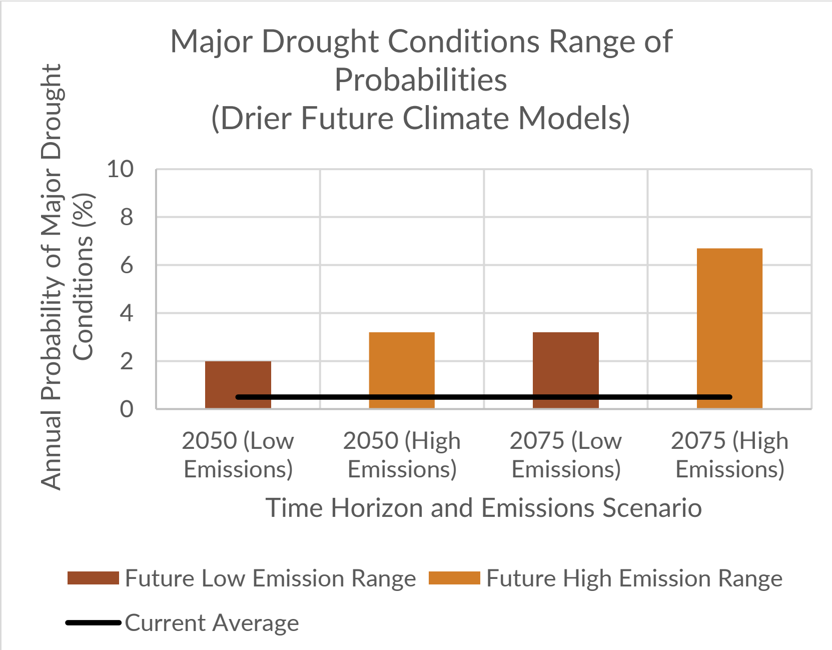


Figure 90: Probability of Major Drought Conditions for 2050 and 2075

Other drought indicators include number of dry days per year and number of consecutive dry days per year. The average number of dry days per year from 1950 through 2020 is 186. Figure 91 shows the climate model distribution of the average number of dry days per year for the two time horizons and two emissions scenarios. Figure 92 shows the climate model distribution of the average consecutive number of dry days per year for the two time horizons and two emissions scenarios. The average number of consecutive dry days per year from 1950 through 2020 is 119.

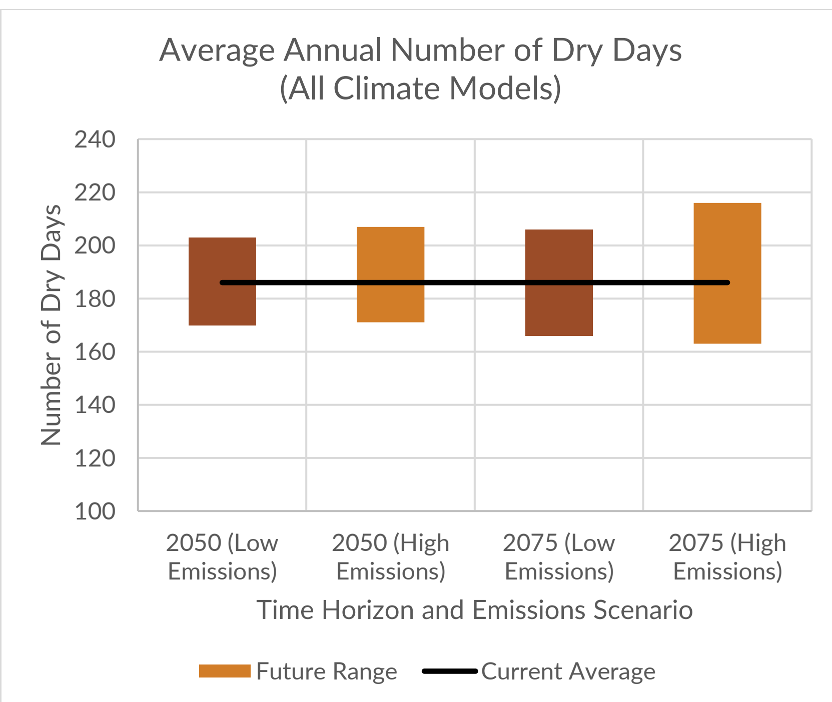


Figure 91: Average Number of Dry Days per Year

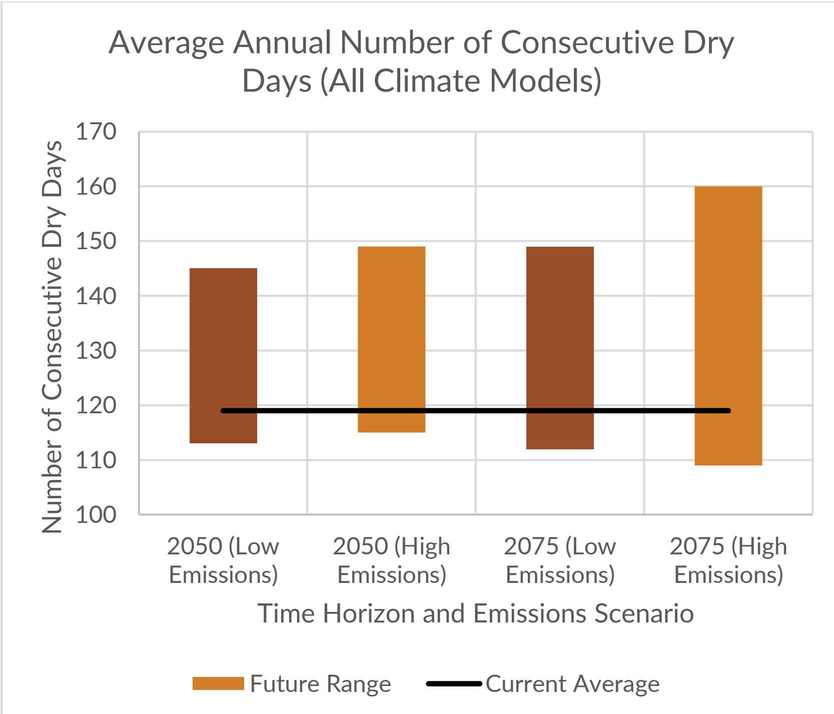


Figure 92: Average Number of Consecutive Dry Days per Year

Harmful algae are treated in county lakes used for drinking water and recreation. The algae come about during specific environmental conditions based on precipitation, temperatures, and nutrient concentrations. Drought, or extended periods of low rainfall, reduces the degree to which water in lakes is replaced with fresh water—leading to more stagnation and the buildup of algae. The County and RWSA contract with a lake management company to monitor and treat the four lakes at three parks for harmful algae. Currently, the cost to do this is approximately $100,000 per year, which includes monitoring between May and September roughly 11 chemical applications. Using the methodologies described in Climate Change Impacts on Harmful Algal Blooms in U.S. Freshwaters: A Screening-Level Assessment, the number of days when the algae concentration is 20,000 cells per mL is calculated. This threshold was identified as a concentration which could cause impacts to human health. The increased number of applications for the two time horizons and emissions scenarios is provided in Table 40.

Table 40: Algae Applications

Water Use and Costs During Drought	Current	2050		2075	
		Low Emissions	High Emissions	Low Emissions	High Emissions
Number of Algae Applications	11	14	17	16	22

Exposure

Due to the nature of a drought, the entire county will be exposed. This includes the people, natural and built environments, and economic sectors.

Vulnerability

The vulnerability assessment helps identify sensitivities in our community so that actions may be taken to reduce potential impacts. This is different from a risk assessment, which includes probability. We anticipate drought occurring at some point in the future, and this section focuses on what makes our community vulnerable.

People

The social vulnerability assessment includes identifying different conditions of the population that increase some groups' sensitivity or decrease their ability to adapt. This component of the vulnerability assessment includes household indicators (Table 41) and poverty indicators (Table 42). The other social vulnerability indicators discussed in Chapter 1: Albemarle County were based on data associated with geographic areas (Census Tracts) too broad to use in the vulnerability analysis. Each component of the social vulnerability indicator is weighted equally. Figure 93 shows the household indicators while Figure 94 shows the poverty indicators.

Table 41: Social Vulnerability - Household Indicators

Household Indicators
65 years or older
65+ Years Old and Living Alone
Grandparent Responsible for Grandchild Under 18
Under 18 years
Single Parent Household
No High School Diploma
Limited English

Observations

The red areas north of Charlottesville score highly for household vulnerability due to larger numbers of residents who are 65 years or older, who care for grandchildren, and who lack a high school diploma.

The red areas in the southern part of the county score highly for household vulnerability due to a larger number of residents who are 65 years or older, are single parents, and lack a high school diploma.

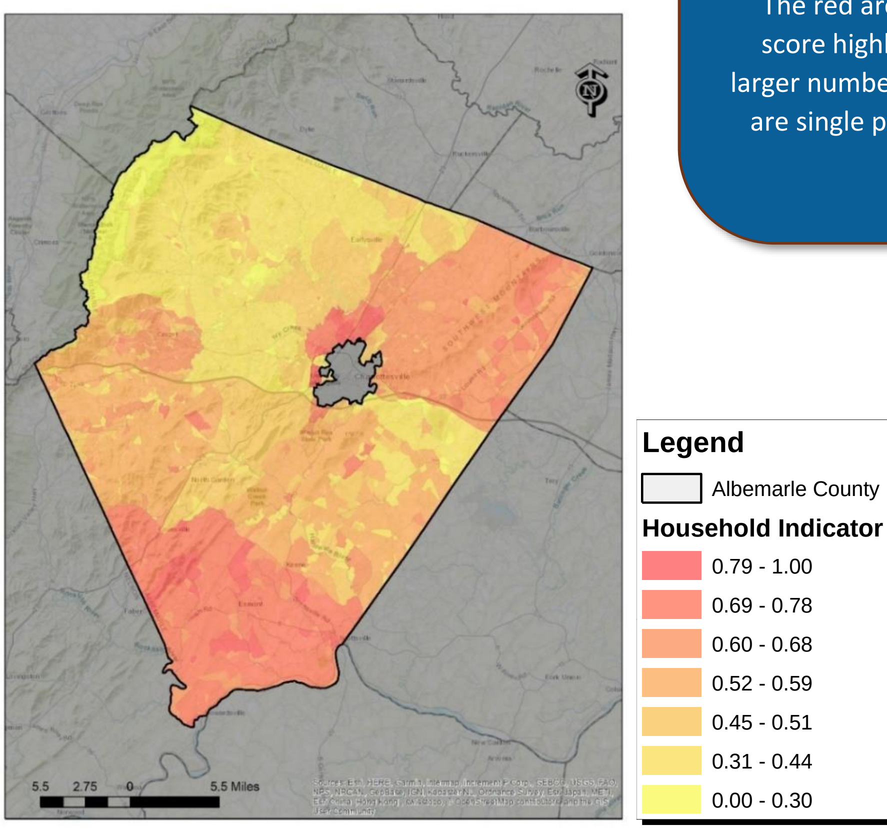


Figure 93: Social Vulnerability - Household Indicators

Table 42: Social Vulnerability - Poverty Indicators

Poverty Indicators
Median Annual Household Income
Below Poverty Level
SNAP/Food Stamps
Received Public Assistance Income
Housing Costs 30% or More of Income
Crowding (More People Than Rooms)
Unemployed
No Vehicle Access

Observations

The red areas north of Charlottesville along the Greene and Orange County borders have a high poverty indicator due to home costs relative to income and a larger number of people on public assistance.

The red areas in the southern part of the county have a high poverty indicator due to the median income, home costs relative to income, and unemployment.

The red areas directly west of Charlottesville have a high poverty indicator due to the number of people living below the poverty line, the median income, and the high level of unemployment.

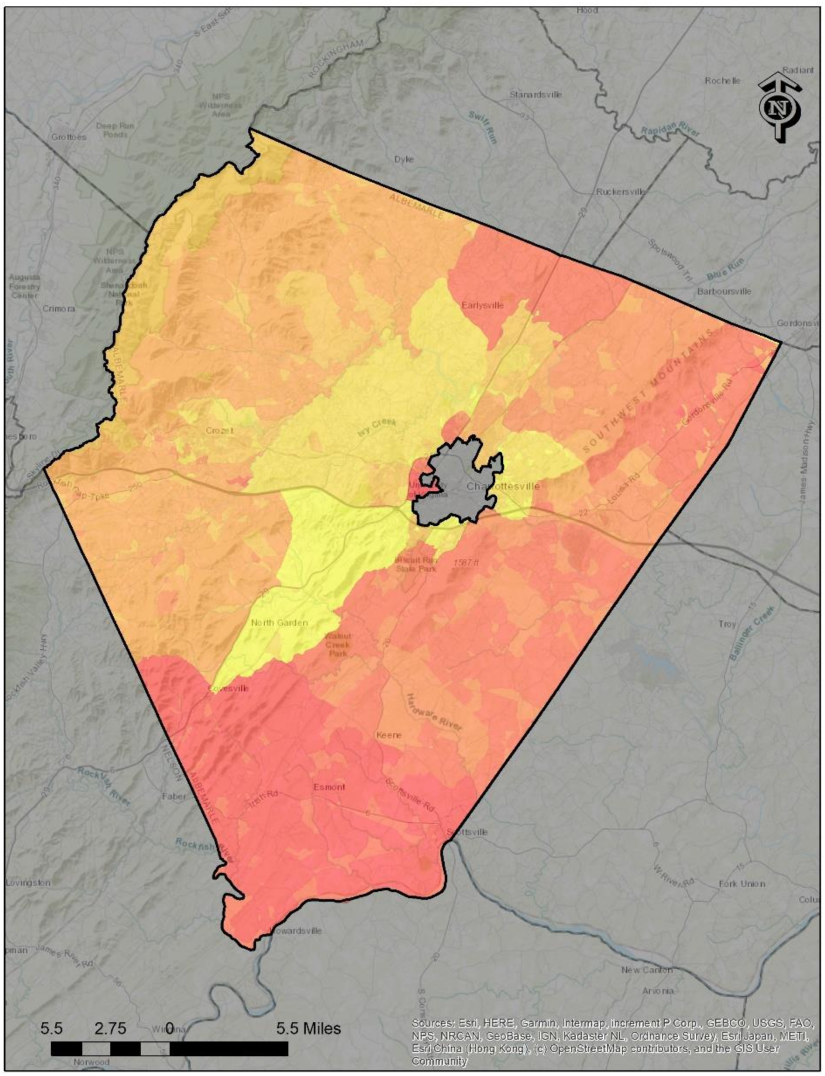


Figure 94: Social Vulnerability - Poverty Indicators

Since vulnerable populations may have trouble paying the emergency water rates during a drought, we show the poverty indicator for just the ACSA-services areas of the county in Figure 95.

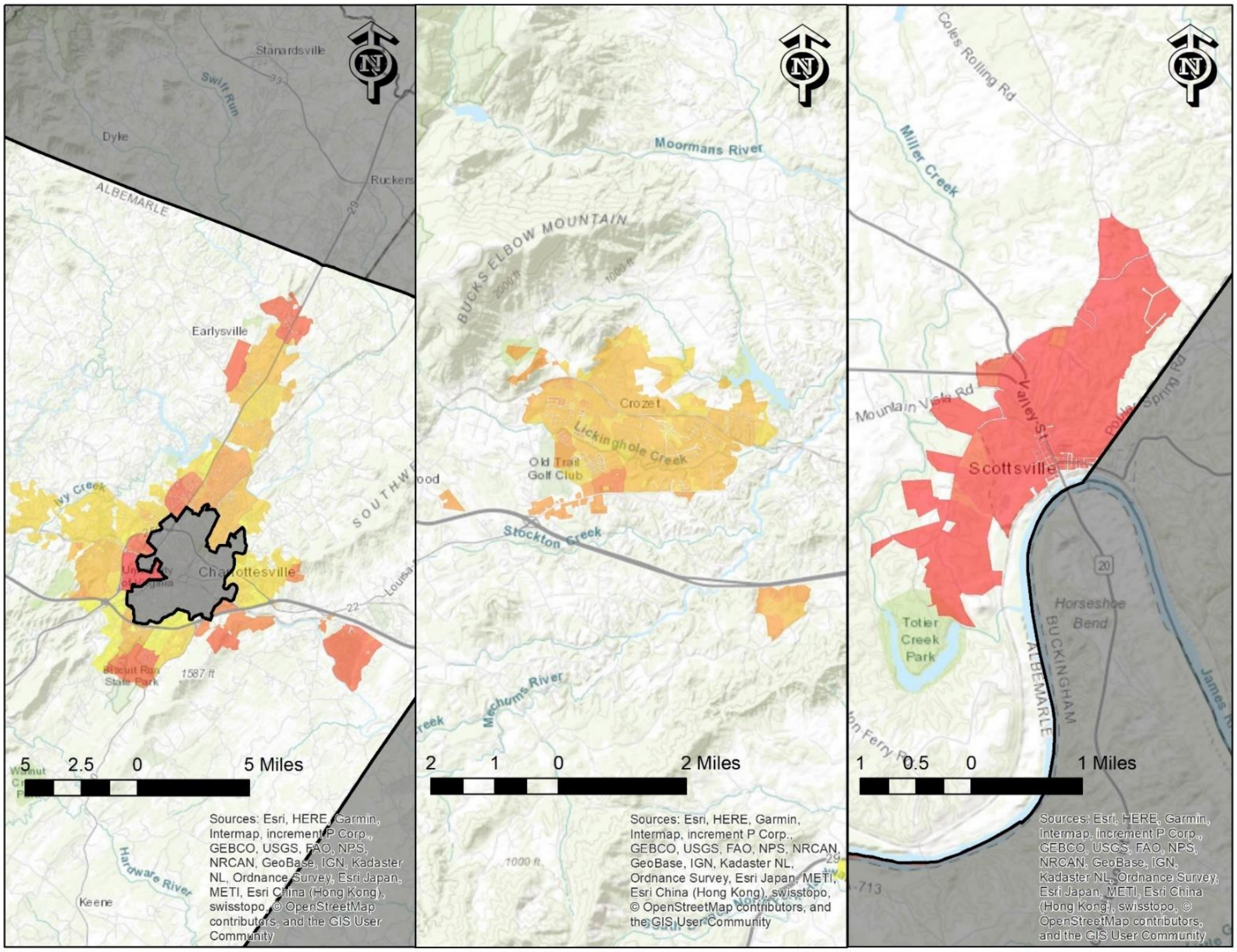
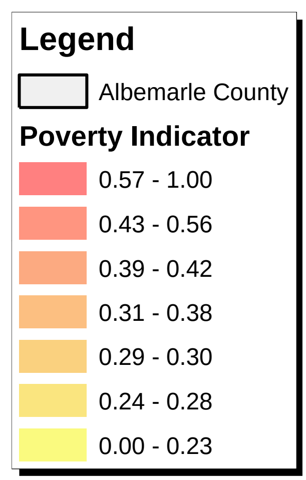


Figure 95: Poverty Indicator for ACSA Service Areas



Natural Features

The agriculture found in Albemarle County is discussed in Chapter 1: Albemarle County; some of what is grown here may be more susceptible to drought.

The USDA has identified several strategies to help mitigate the impacts of drought on agricultural fields. These include rotational grazing, incorporating deep-rooted legumes into pastures, incorporating warm-season perennial and annual grasses into grazing systems, and utilizing commodities (brewer's grain, corn gluten, and soybean hulls) to extend pastures and stock for drought. There are varieties of hay that are heat tolerant and some that are not. Table 43 provides some examples.

Table 43: Common Pasture and Hay Coverage

Drought Tolerance	Pasture Varieties
Intolerant	Ryegrass, Red Clover
Tolerant	Alfalfa, Sericea, Tall Fescue, Orchardgrass

(Source: OSU Extension Service, 2021)

Since apple orchards and grape vines make up such a large part of the acreage and economy for the County, we decided to focus on their susceptibilities. Dwarf and semi-dwarf fruit tree varieties are more drought sensitive than standard-sized trees. The major sensitivity to drought concerns the root stock, however. Table 44 provides information on which root stock are more drought tolerant.

Table 44: Apple Variety Root Stock

Drought Tolerance	Root Stock
Intolerant	Mark, M26, CG5087, G11, CG4814, M9
Tolerant	M7, G935, G202, G214

(Source: Atkinson, 1999)

Many grape varieties do well under drought stress and produce a consistent harvest. However, there are some varieties that don't perform as well. Table 45 provides examples of common wine grape varieties that are drought tolerant.

Table 45: Common Wine Grape Varieties

Drought Tolerance	Grape Varieties
Intolerant	Varieties with a small, shallow root
Tolerant	Barbera, Cardinal, Emerald Riesling, Flame Seedless, Merlot, Muscat of Alexandria, Pinot Chardonnay, Red Malaga, Sauvignon Blanc, Zinfandel, Ramsey, and other varieties with a large root system

(Source: University of British Columbia, 2020)

Farmers who raise livestock may find that the cost to feed animals increases as grazable land and the amount of harvested grass is limited. Rotational grazing and ensuring the animals have an appropriate amount of land in which to graze can help mitigate this issue. Otherwise, farmers may be forced to make decisions on processing or selling parts of herds.

Trees are also impacted by drought conditions, and their growth can be slowed by half in major drought (Teskey et al. 2014). Several conservation practices can also be impacted by climate change, including non-drought resistant cover crops and tree planting.

To help identify which areas are more and less susceptible to drought, the USDA's soil survey data was downloaded and categorized. Those soil types containing some clay help retain moisture longer than sandier and loose soils. Also, land that is steeply sloped has a hard time retaining any precipitation that may fall. Figure 96 shows a map of the soil types categorized as good, moderate, and poor based on clay content and slope. Figure 97 shows a map of the county's cropland categorized by water retention potential.

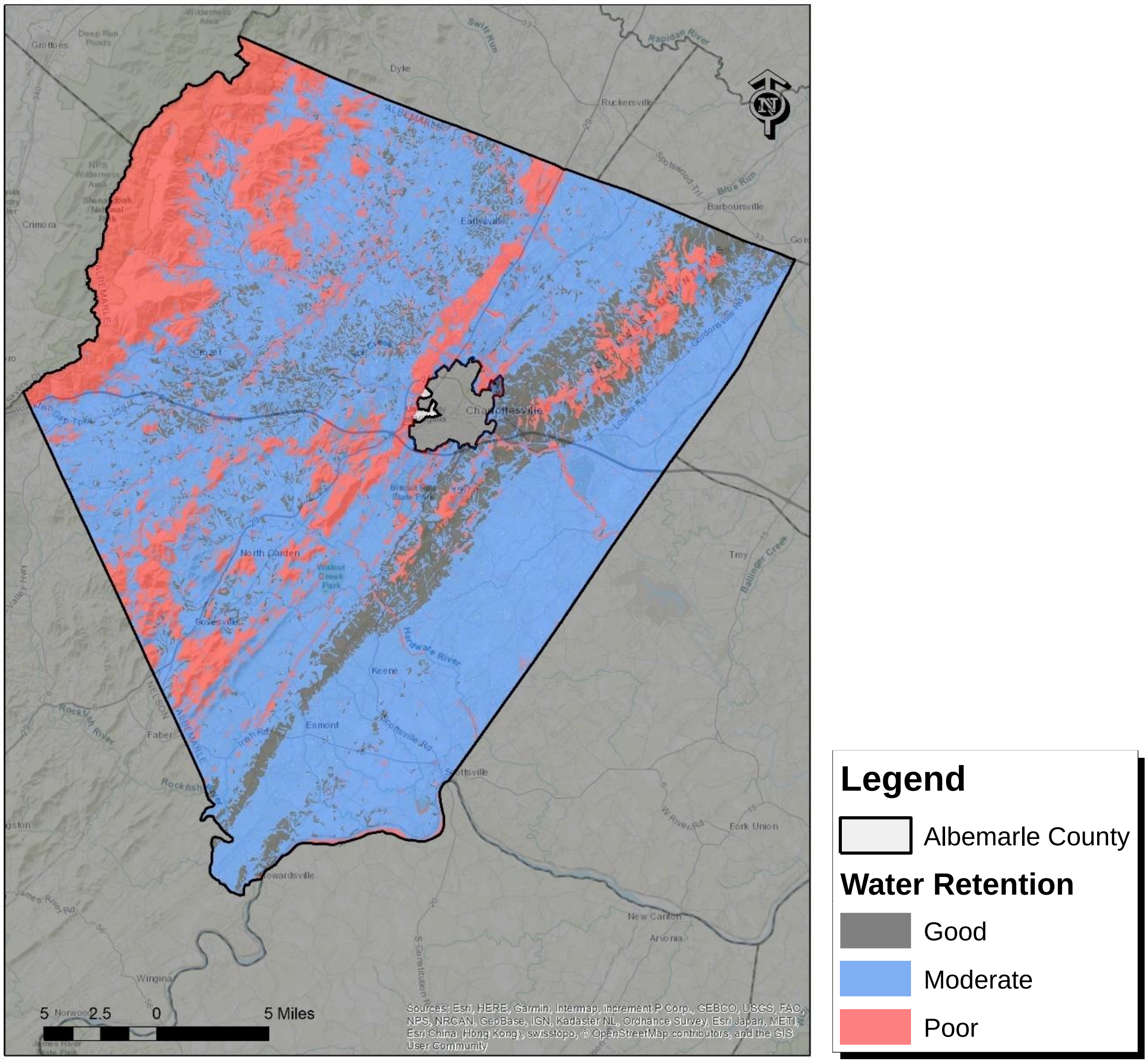


Figure 96: Soil Water Retention

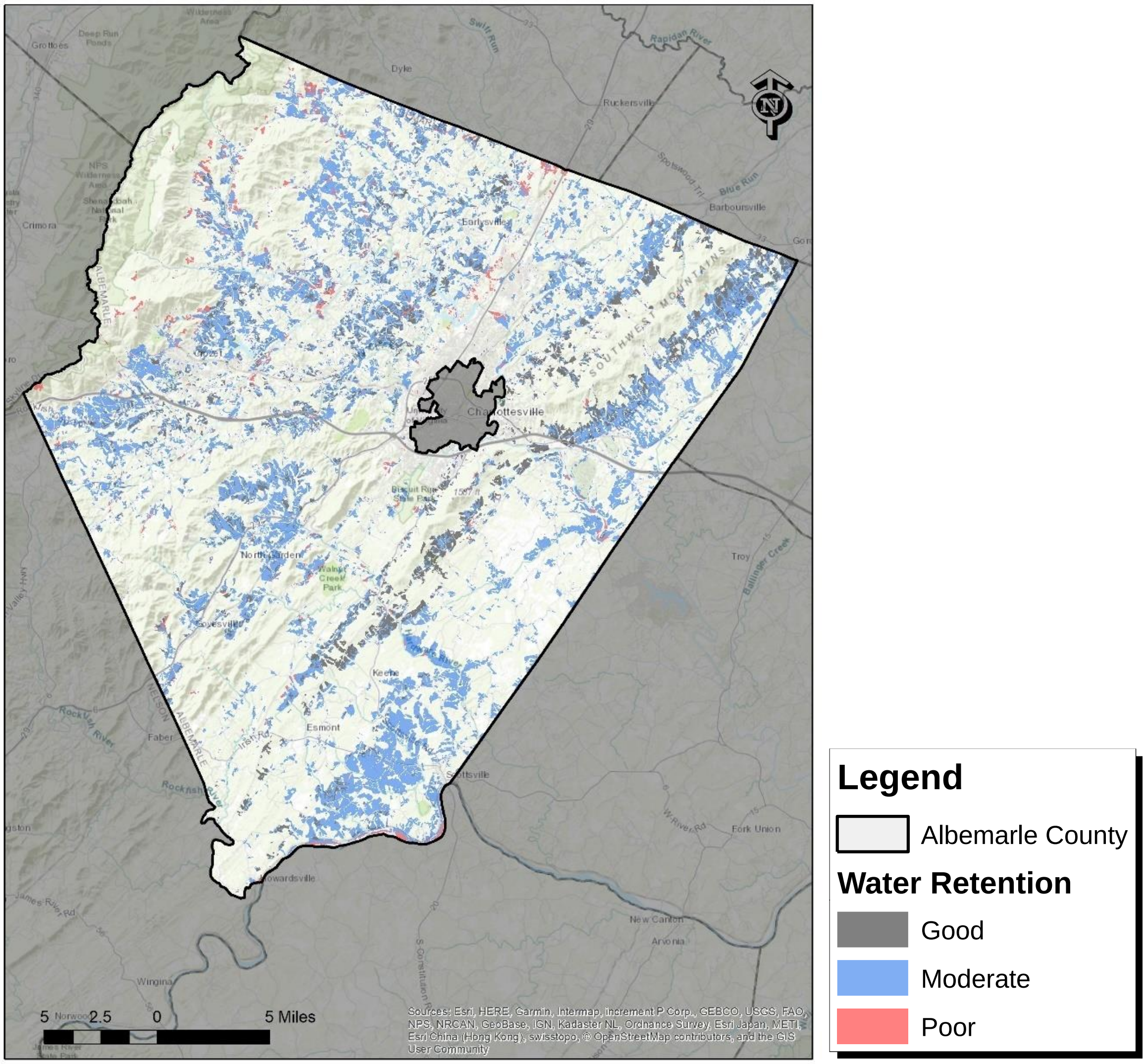


Figure 97: Soil Water Retention for Cropland

Built Environment

Major water users are more susceptible to drought, and these include water utilities, golf courses, farmers using irrigated agriculture, mining operations, and some commercial users. Figure 98 shows the major surface water and groundwater users in the county. The symbol's size is based on the amount of water used in a year in millions of gallons.

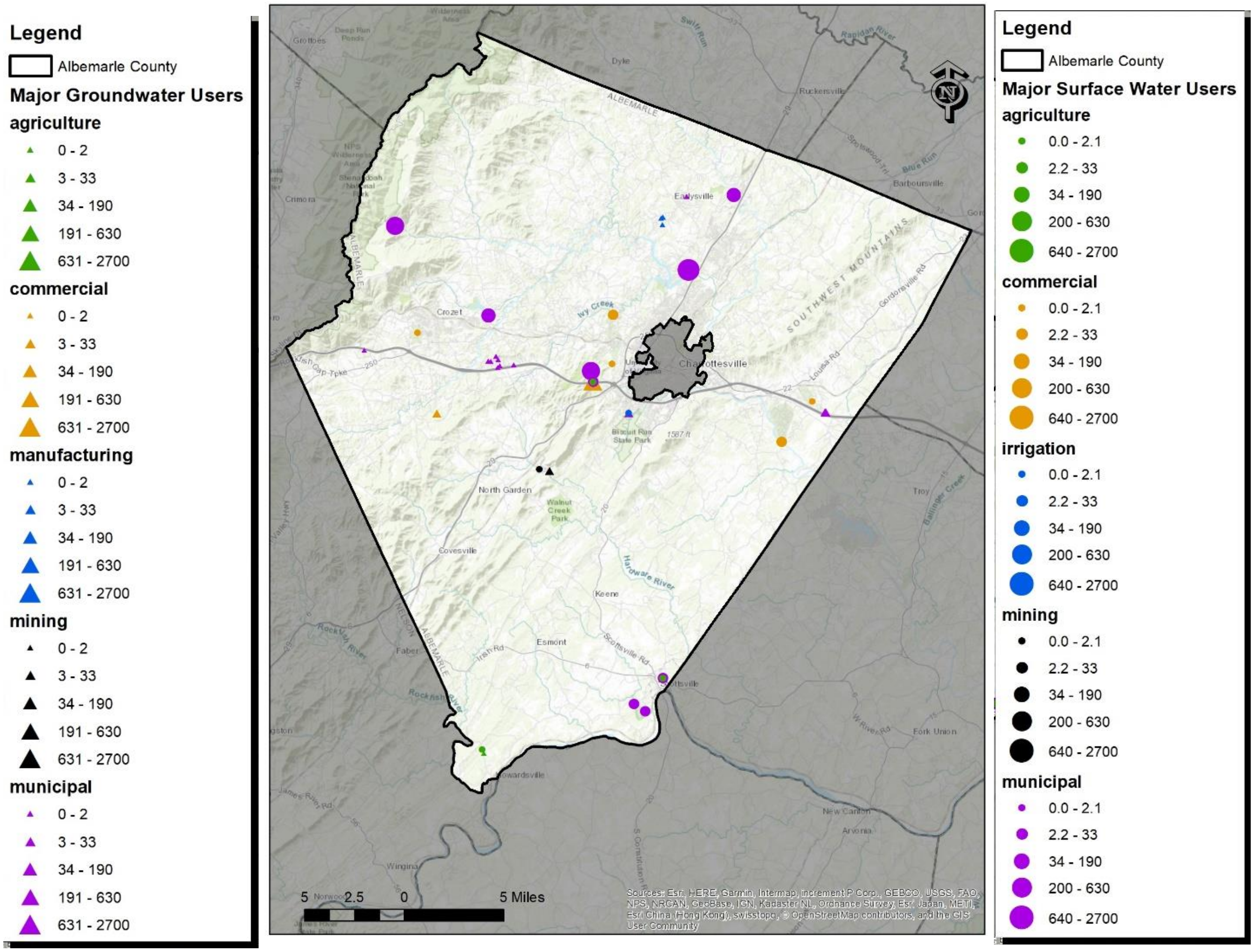


Figure 98: Major Water Users

The ACSA publishes an annual report that includes the number and type of customers. Using this information for the last twenty years, we show the trend in water demand and number of customers (Figure 99), as well as the trend in demand by user type (Figure 100). The line in Figure 99 represents the total number customers. Although this number rises over the twenty years, the water demand stays relatively constant due to the use of water-saving technology (e.g., low-flow devices).

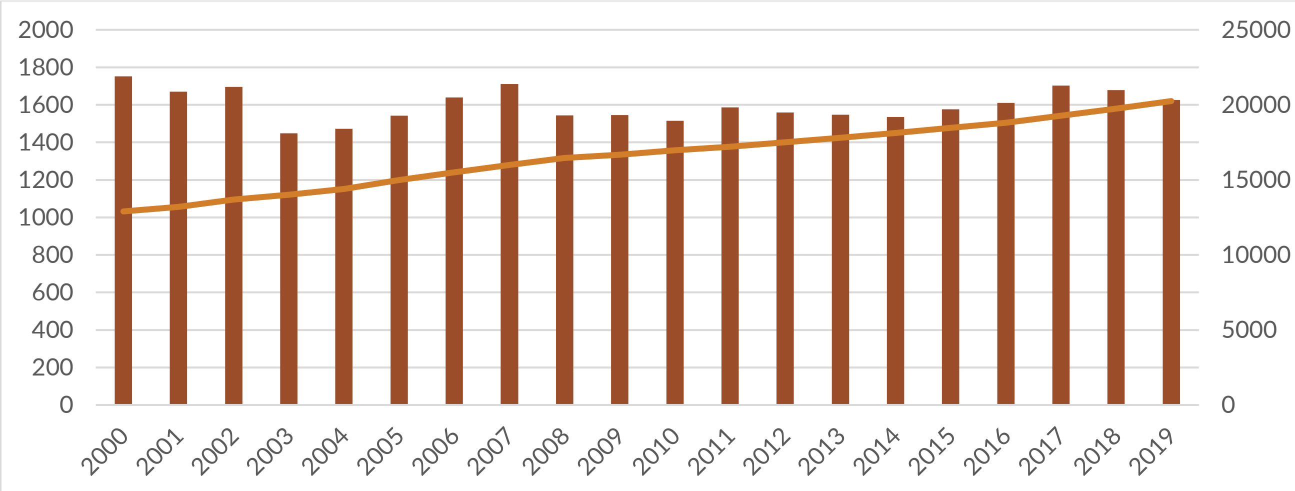


Figure 99: Water Demand and Number of Customers

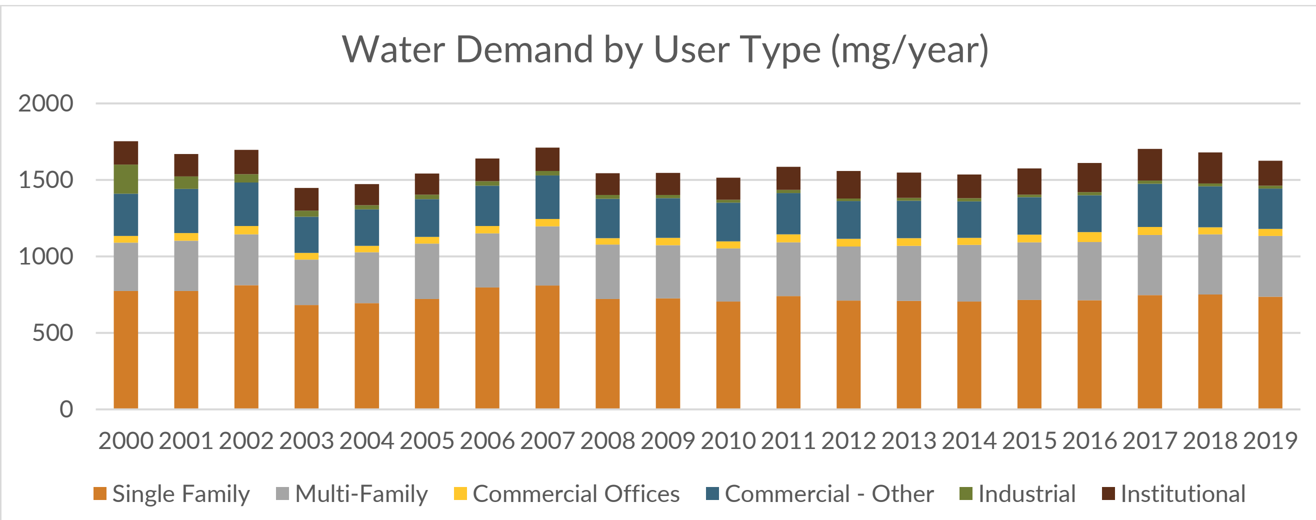


Figure 100: Water Demand by User Type

Because the ACSA data only includes water users served by public utility, users on well water are not included in the previous charts. Since drought also impacts well-water users, we used property data maintained by the county to determine total number of users. We identified all properties outside the water utility service areas as ground-water users, and we assigned them a water usage type that matched the same type of user on ACSA water. Figure 101 shows the total water demand for the county. Those users with shallow wells will also be more susceptible to major drought conditions.

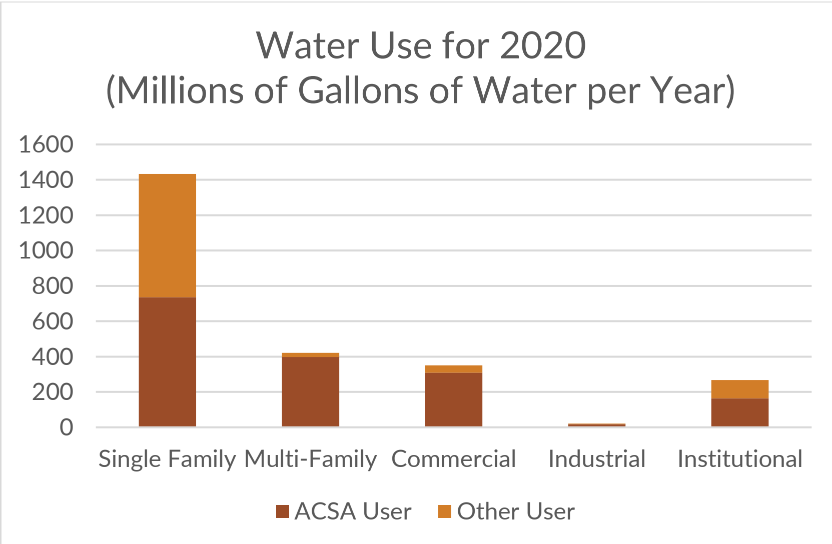


Figure 101: Total Albemarle County Water Use (2020)

In 2020, RWSA hired Hazen and Sawyer to develop a RWSA Safe Yield and Reliability Analysis Update Report. This report assessed the current and future capacity of the RWSA water sources and the projected population and water demand to 2070. It used information from the 2001-2002 drought to help with planning, along with the DEQ requirement that the system must have at least 60 days of water in storage during drought scenarios. The report modeled the loss of useable storage due to sedimentation and the operational yield. Figure 102 provides one of the results of the report, showing that the projected operational yield meets demand through 2060 but falls short by 2070. The report also provides several buildout scenarios to help the system meet demand beyond 2060. RWSA has moved forward with increasing the Ragged Mountain Reservoir by 12 feet and building the new pipeline from South Rivanna Reservoir to Ragged Mountain Reservoir.

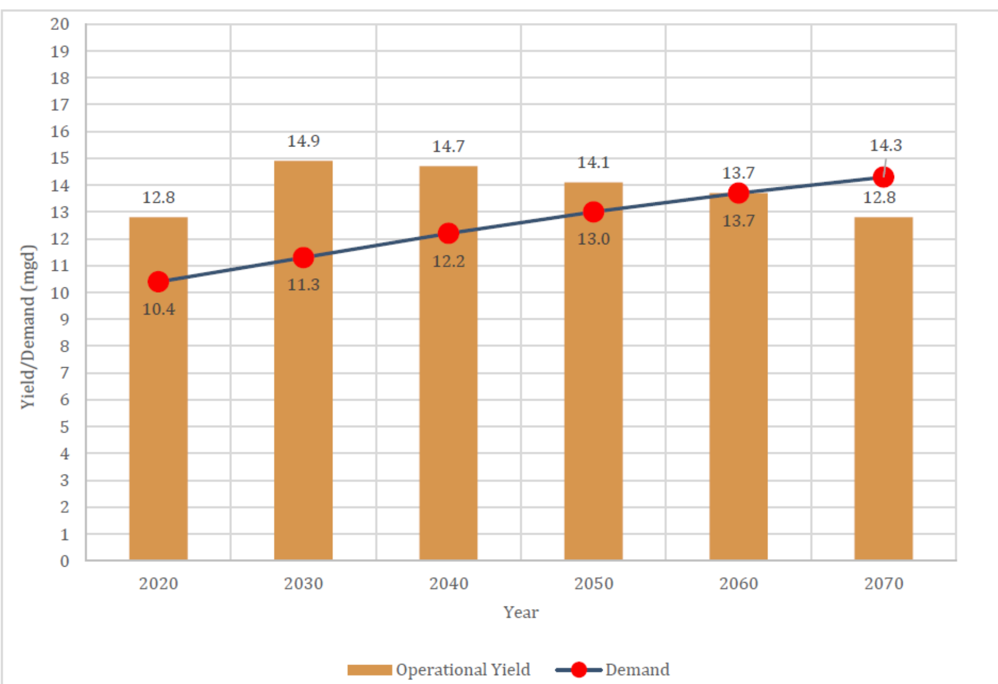


Figure 102: Operational Yield Over the Planning Horizon (Hazen and Sawyer, 2020)

Economy

Certain economic sectors are more susceptible to drought. Businesses that require water such as agriculture, recreation, and mining may have to reduce or suspend work due to water restrictions or may have agricultural loss.

Table 46 provides information on industries that may be more susceptible to drought. Information concerning the number of employees, wages, and number of businesses along with a percentage of the industry compared to the others in the County is provided.

Table 46: Industries Susceptible to Extreme Heat

Albemarle County Industry	Employees	Employees (% of Total)	Wages (x$1000)	Wages (%)	Businesses (Number)	Businesses (%)
Agriculture, Forestry, Fishing, and Hunting	686	1.7	20,129	1.0	86	2.3
Arts, Entertainment, and Recreation	1,730	4.3	50,691	2.5	66	1.7
Manufacturing	2,147	5.4	142,015	6.9	114	3.0
Mining, Quarrying, Oil and Gas Extraction	46	0.1	2,768	0.1	5	0.1

Potential Impacts

In this section of the report, we discuss potential impacts the County may face in the future. This involves assessing historical impacts, the thresholds at which those impacts occurred, and the probabilities of reaching those thresholds in the future.

People

Although droughts don't harm people as immediately as the other hazards covered in this report, not having access to clean drinking water in a severe drought can cause major illness and death. If the drought is so extreme as to cause the water authority to implement emergency rates, it will be difficult for more vulnerable members of the community to have access to water. In 2021, the COVID pandemic caused many people to lose their jobs and more than 550 ACSA customers were in arrears. Actions were taken to alleviate this hardship through government relief.

Natural Features

Figure 103 shows drought loss data collected by the USDA for 1993 through 2021. For that 28-year timespan, there were $8,100,889 in recorded losses—approximately $289,317 in annual losses.

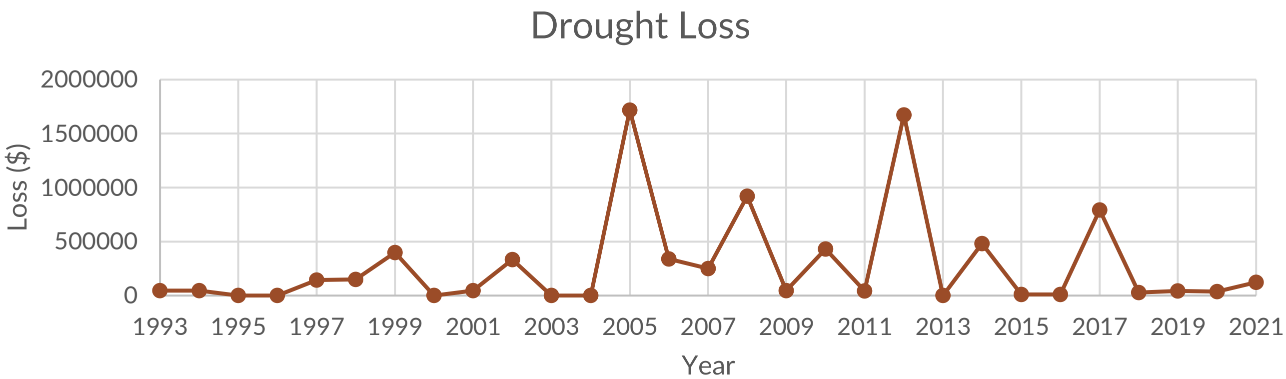


Figure 103: Drought Loss (USDA, 2021)

The drought probability calculated earlier in this chapter for current conditions (7%) was used with the average annual loss to calculate a significant agricultural loss of $4.13 million. Next, we calculated the probability of that drought event occurring for the two time horizons and two emissions scenarios. The annualized loss is then calculated for those time horizons and emissions scenarios based on the new probability. Finally, we calculated the new 7% annual chance event for each time horizon and emissions scenario to show how that event will become more likely. Table 47 shows these values. Additionally, a major drought event could impact the vineyards and orchards in the county, potentially resulting in loss of tourism.

There are some climate mitigation practices that may be impacted by climate change too. Cover crops (non-drought resistant) and tree plantings intended to sequester carbon may fail in significant droughts.

Table 47: Agricultural Loss due to Drought

Loss	Current (Avg. Ann.)	2050		2075	
		Low Emissions	High Emissions	Low Emissions	High Emissions
Drought Probability	7%	12.9%	19.4%	17.2%	22.6%
Significant Drought Loss	$4,133,100	$4,133,100	$4,133,100	$4,133,100	$4,133,100
Annualized Loss	$289,317	$533,170	$801,821	$710,893	$934,081
7% Annual Probability Loss	$4,133,100	$7,616,713	$11,454,591	$10,155,617	$13,344,009

There will be additional costs to monitor and treat Chris Greene Lake, Mint Springs Upper Lake, Mint Springs Lower Lake, and Walnut Creek Lake. Additional monitoring time will be needed since algal growth could occur earlier and later in the year for the future time horizons. The number of treatments will also increase using the projections identified in the current and future conditions section. Table 48 provides the estimated costs associated with monitoring and treating the lakes. This doesn't include other lakes that may need to be treated in the future.

Table 48: Algae Monitoring and Application Costs

Water Use and Costs During Drought	Current (Avg. Ann.)	2050		2075	
		Low Emissions	High Emissions	Low Emissions	High Emissions
Costs of Algae Monitoring	$53.6K	$71.6K	$71.6K	$89.4K	$89.4K
Costs of Algae Treatments	$49.5K	$63.0K	$76.5K	$72.0K	$99.0K
Total Costs	**$103.1K**	**$134.6K**	**$148.1K**	**$161.4K**	**$188.4K**

Built Environment

During a major drought event when water restrictions have been placed on residents and businesses, above-average emergency rates can be activated. To help quantify the impact of those rate changes, we identified the current rates charged to customers and the emergency rates that would be charged to customers during major droughts. We reviewed the ACSA annual report (2021) to determine how much water was used by different customers and multiplied the use by the rate to calculate total water costs per year. Table 49 shows water use and cost for residential users and other users. We used the household and other structure projections to determine the water use and cost for 2050 and 2075.

Table 49: Current and Future Water Use

Water Use (Approximate)	Current (Avg. Ann.)	2050	2075
Household Use (ACSA-Provided)	1,135 (mg/yr)	1,531 (mg/yr)	1,865 (mg/yr)
Residential Water Costs per Year	$10.31M	$13.92M	$16.95M
Other Use (ACSA-Provided)	491.6 (mg/yr)	663.3 (mg/yr)	734.6 (mg/yr)
Other User Water Costs per Year	$4.47M	$6.03M	$7.35M

We assumed that water use would decrease by 20% since that is required by ACSA during major drought events. The additional water costs due to drought were calculated and then the drought probability for the current and future time horizons was used to predict an annualized loss.

Table 50: Water Costs

Water Use and Costs During Drought	Current (Avg. Ann.)	2050		2075	
		Low Emissions	High Emissions	Low Emissions	High Emissions
Normal Total Water Costs ($)	$14.78M	$19.95M		$24.30M	
Water Use Change due to Drought	-20%	-20%		-20%	
Drought Water Costs ($)	$17.73M	$23.93M		$29.16M	
Additional Drought Costs ($)	$2.96M	$3.99M		$4.86M	
Probability of Drought	7%	12.9%	19.4%	17.2%	22.6%
Annualized Loss ($)	**$206,953**	**$514,588**	**$773,876**	**$835,928**	**$1,098,371**

Economy

Some industries will be impacted more than others if mandatory water restrictions are put into place. Businesses that are identified in drought warnings and by the State as major water consumers (e.g., car washes, pressure washing businesses, golf courses, manufacturing, mining/quarrying, and agriculture) may sustain losses. We reviewed the large water consumers in the county and found one quarry and one manufacturing facility listed. Reviewing the County parcel data and conducting a business search identified 12 car washes and 9 pressure washing companies in the county. Impacts to these business types are provided in the table below (Agricultural losses, already analyzed in the natural features section of this chapter, are excluded from the following table.) For the impact analysis, we assumed a 6-month drought (based on previous drought durations) with a current occurrence probability of 7% (based on the probabilities in the current and future conditions section). Table 51 shows the drought-susceptible businesses and calculated loss.

Table 51: Albemarle County Drought Susceptible Businesses

Albemarle County Industry	Number of Businesses	Number of Employees	Annual Revenue ($)	Drought Loss ($)
Car Wash	12	<20	1,668,000	834,000
Pressure Wash	9	<20	900,000	450,000
Mining and Quarrying	1	<20	2,000,000	1,000,000
Manufacturing	1	20-30	1,246,000	623,000

The drought loss was fixed for each scenario and current condition while the probability of attaining that condition was calculated for each time horizon and emissions scenario. Table 52 shows these annualized losses and drought probabilities. This estimate doesn't include new businesses created in 2050 and 2075.

Table 52: Drought Annualized Losses for Businesses

		2050		2075	
Industry Losses	Current (Avg. Ann.)	Low Emissions	High Emissions	Low Emissions	High Emissions
Car Wash Losses ($)			834,000		
Pressure Washing Losses ($)			450,000		
Mining and Quarrying Losses ($)			1,000,000		
Manufacturing ($)			623,000		
Drought Probability (%)	7	12.9	19.4	17.2	22.6
Annualized Loss ($)	203,490	375,003	563,958	500,004	656,982

Chapter 5: Wildfire

What We Can Expect

	People	Natural resources	Buildings	Economy
2050	+1,393 additional people in current 0.1% wildfire occurrence area Up to 200 people seeking public shelter during significant event (4'-6' flame) Up to 2.5x Increase in probability of significant wildfire occurring (4'-6' flame)	Chris Greene Lake Park, Mint Springs Valley Park, and Patricia Ann Byrom Forest Preserve Park in 0.1% occurrence area +$12K average annual agricultural losses	+$250K average annual property losses +$4.5K average annual utility losses	+$300K average annual business loss (professional services) +$7K average annual business loss (retail services) +$21K average annual business loss (medical clinic services)
2075	+1,919 additional people in current 0.1% wildfire occurrence area Up to 330 people seeking public shelter during significant event (4'-6' flame) Up to 3x Increase in probability of significant wildfire occurring (4'-6' flame)	Chris Greene Lake Park, Mint Springs Valley Park, Patricia Ann Byrom Forest Preserve Park, Preddy Creek Trail Park, Walnut Creek Park, Heyward Community Forest in 0.1% occurrence area +$15K average annual agricultural losses	+$300K average annual property losses +$5.5K average annual utility losses	+$400K average annual business loss (professional services) +$9K average annual business loss (retail services) +$26K average annual business loss (medical clinic services)
Identifying Vulnerabilities				
	• Elderly and children • Below poverty line • Poor health • No vehicle access • Those living and working in secluded areas (limited roads in and out)	• Farms without adequate water supply • Farms with fuel storage adjacent to equipment, buildings, and livestock • Orchards and vineyards without fire breaks	• Buildings and infrastructure located in wildland-urban interface (WUI) • Businesses and homes without defensible zones	• Forestry • Hunting • Recreation • Businesses located in wildfire high hazard area

According to the National Wildfire Coordinating Group Glossary, a wildfire is "an unplanned ignition caused by lightning, volcanoes, unauthorized and accidental human-caused actions, and escaped prescribed fires" (NWCG 2010). The Virginia Department of Forestry (VDOF) indicates that there are three principal factors that can lead to the formation of wildfire hazards: topography, fuel, and weather. Virginia traditionally has had two wildfire seasons: spring and fall. The environmental conditions that exist during these seasons exacerbate the hazard. When relative humidity is low and high winds are coupled with a dry forest floor (brush, grass, leaf litter), wildfires may easily ignite.

However, fire does play a vital role in the maintenance of the health of many ecosystems (Hutto 2008, Pollet and Omi 2002), in part by promoting vegetation and by stimulating the establishment and growth of particular trees and other plants (Brown 2000).

Years of drought, and tree diseases and pestilence can lead to environmental conditions that promote wildfires. Accidental or intentional setting of fires by humans is the largest contributor to wildfires. Residential areas or "woodland communities" that expand into wild land areas also increase the risk of wildfire threats.

In the U.S., wildfires occur and have occurred more frequently in recent years in the western part of the country (National Interagency Fire Center 2021). As many as 90% of wildland fires in the U.S. are caused by people, according to the U.S. Department of Interior.

Virginia has a fairly low wildfire risk compared with the rest of the country. Ranking the states by number of fires in 2021, Virginia is ranked number 30 and ranking the states by acres burned, Virginia is ranked number 34 with California ranked number 1 in both categories. Figure 104 shows wildfire likelihood across the U.S. Each year in Virginia, 60 homes and other structures are damaged or destroyed by wildland fire with suppression efforts credited with protecting more than 460 homes and 280 other structures (VDOF 2021).

Background – Wildland-Urban Interface (WUI)

The wildland-urban interface (WUI) is the area where the built environment, usually homes, and wildland vegetation meet or intermingle. This is the area where wildfires pose the greatest risk to people, due to the proximity of flammable vegetation. The WUI is where people often start wildfires with the vast majority of fires caused by people. In Virginia, the leading cause of wildfires is escaped burning debris. Federal wildfire management policy prioritizes fuel treatments and the promotion of fire-adapted communities in the WUI, Virginia has passed a law banning burning before 4pm during the spring, and some local jurisdictions use a variety of land use planning tools to limit the environmental impacts of housing growth in the WUI (Radeloff, et al. 2018).

Woodland Home Communities (WHC) are the clusters of homes located along forested areas at the WUI that are particularly susceptible to a nearby wildfire incident. The characteristics of WHC areas include: (1) located close to wildland fuels (primarily forested areas); (2) contain greater than 10 addressable structures; and (3) are isolated. WHCs pose two problems related to wildfires. First, there will be more wildfires-prone due to human ignitions. Second, wildfires that occur will pose a greater risk to lives and homes, they will be harder to fight, and letting natural fires burn becomes impossible.

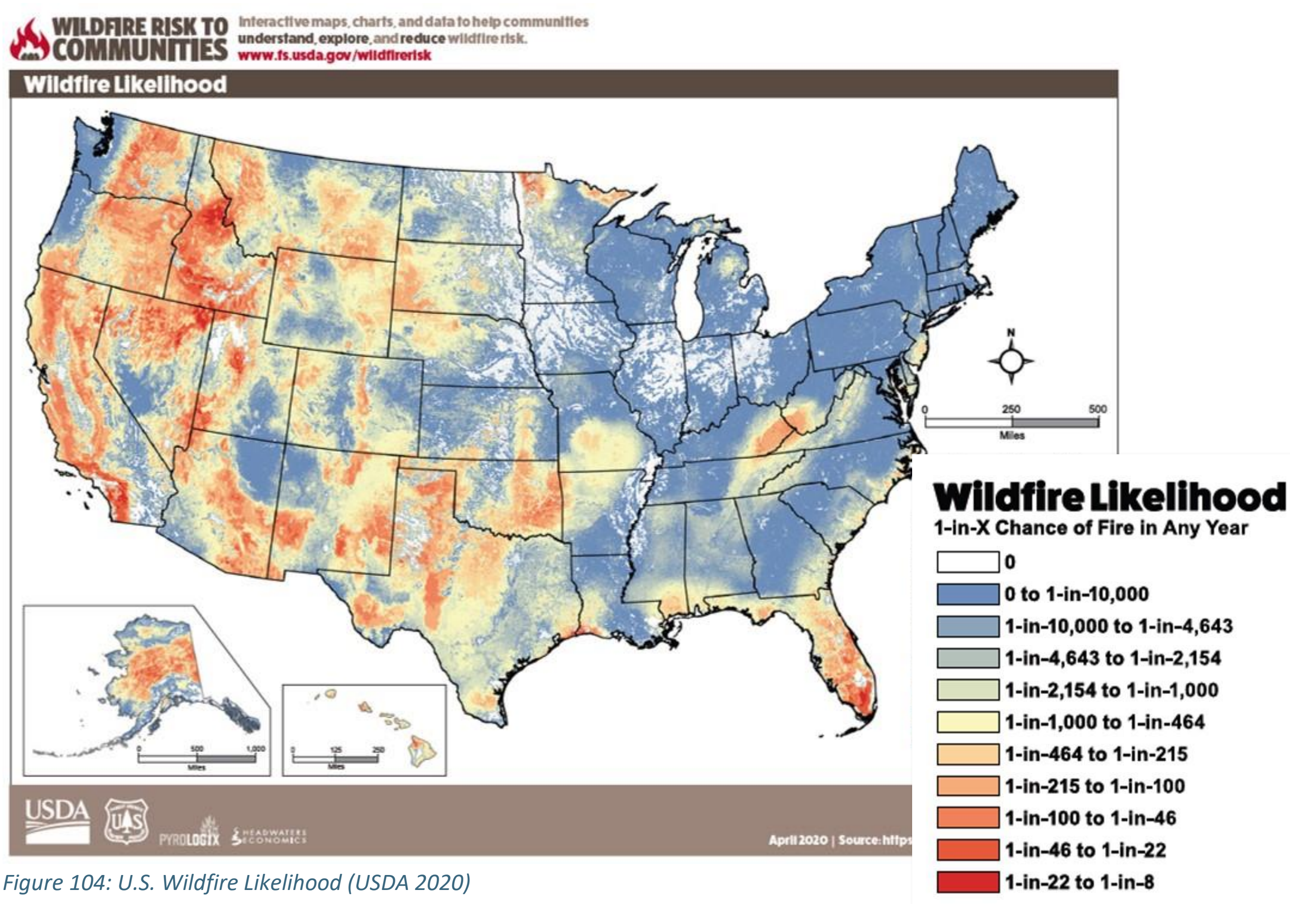


Figure 104: U.S. Wildfire Likelihood (USDA 2020)

Current and Future Conditions

From 2016 through 2021, Albemarle County Fire has responded to 1,063 wildfire incidents in and around the county resulting in approximately $364,500 in loss and 1,100 acres burned. The incidents include fires of all sizes with the largest resulting in 300 acres of damage. Figure 105 shows the causes of these incidents. The 300-acre fire was categorized as misuse of fire.

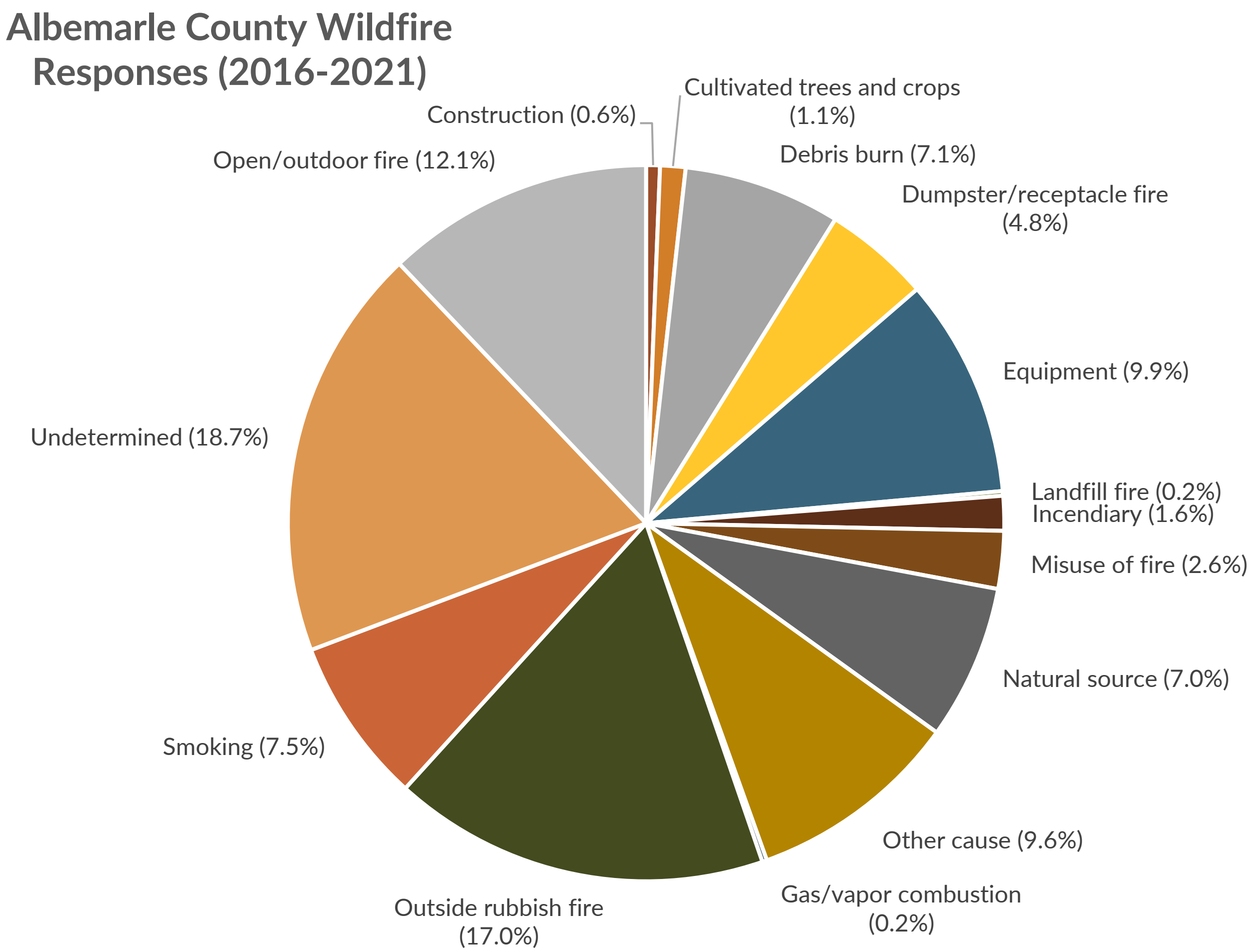


Figure 105: Albemarle County Wildfire Responses (Albemarle County 2016-2021)

Next, we looked at the State wildfire incidents by collecting data on number of fires from the Insurance Information Institute by year. This data was available from 2010 to 2020 with 2012 missing information. Figure 106 shows the number of wildfires in Virginia (resulting in insured loss) by year compared to the total precipitation from that year. The only year during this period where voluntary drought restrictions were implemented was 2017, which was the same year the largest number of wildfires occurred (1,522 events). The average number of wildfires during non-drought years was 683 events, statewide. Comparing the two numbers, wildfire occurred 2.2 times more often in a drought year than an average non-drought year.

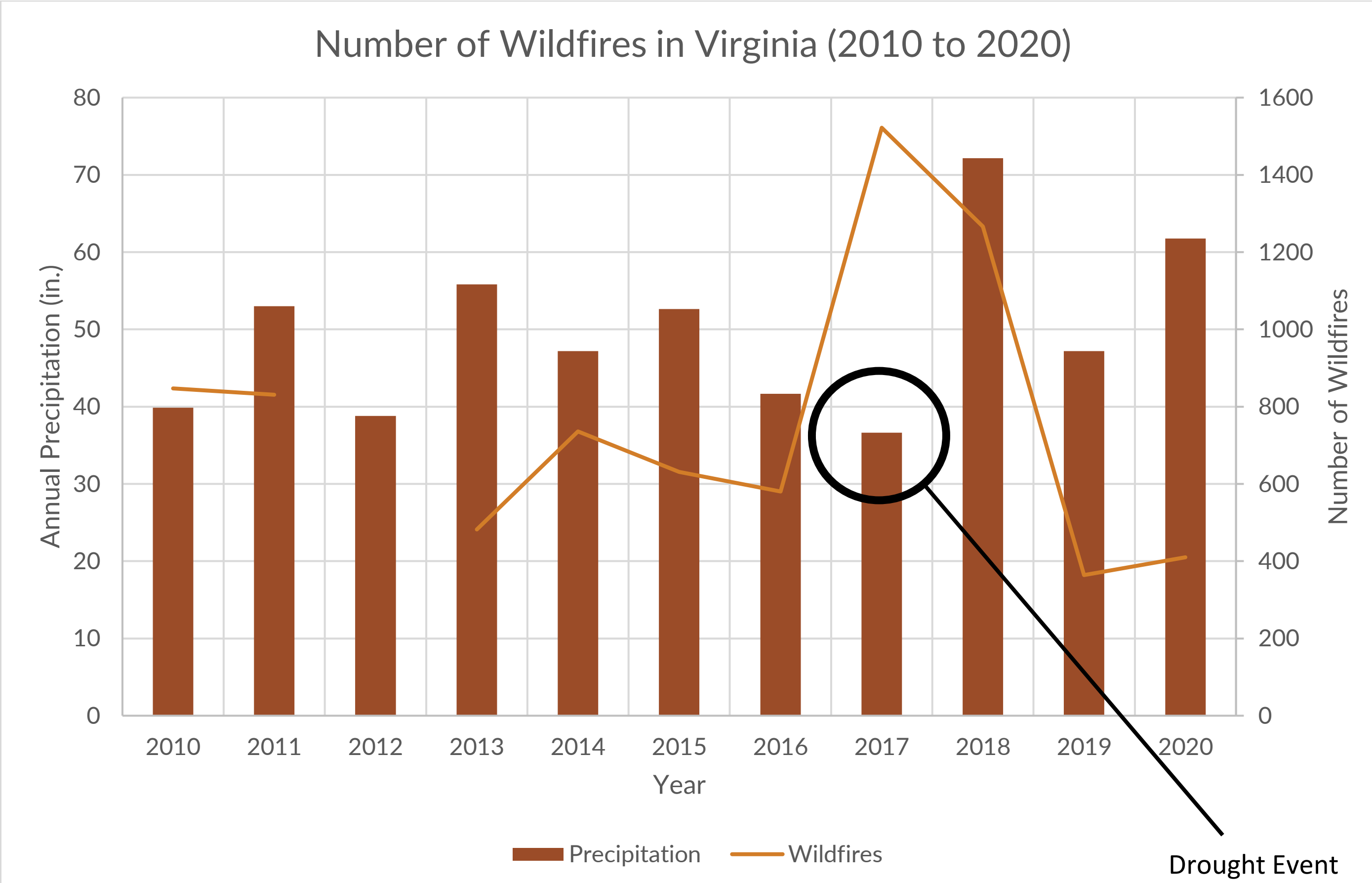


Figure 106: Number of Wildfires in Virginia and Annual Precipitation (Insurance Information Institute, 2021)

Since the likelihood of wildfire can be tied to the likelihood of drought events, we can use the analysis conducted in the drought chapter for wildfire. The current annual probability of a significant drought is 7.0%. Climate data was analyzed for low and high emissions scenarios for a time horizon of 2050 and 2075. For the 2050 time horizon, data from 2035 to 2065 was used while the 2075 time horizon used data from 2060 to 2090. Some climate models show a lower drought probability while others show a much higher probability. This drought probability is based only on annual precipitation which is a limitation. Figure 107 shows the current and future drought probabilities.

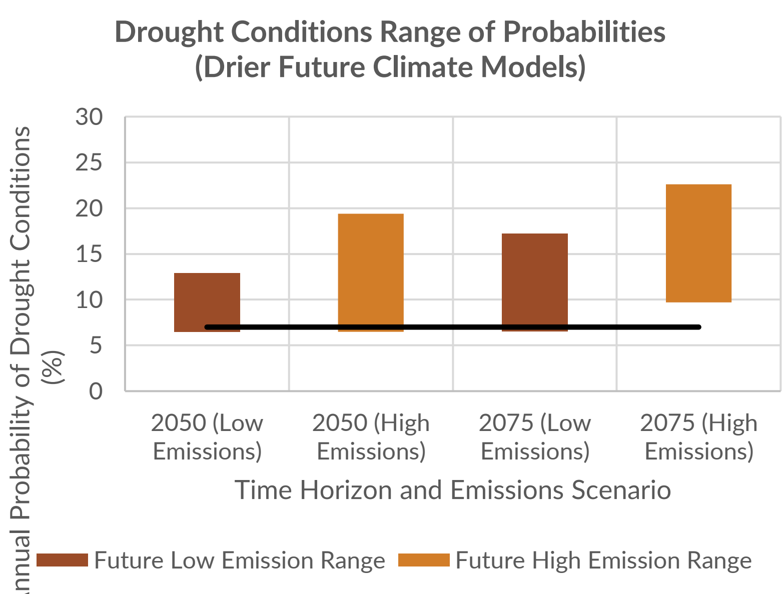


Figure 107: Drought Probabilities for Future Time Horizons

For wildfires, there is currently a 0.1% probability of having a significant wildfire with that average changing for the 2050 and 2075 time horizons. The 2050 low emissions climate models predicting a drier future show that probability increasing up to nearly twice the current probability while the high emissions climate models show an increase of up to two and a half times the current probability. The 2075 low and high emissions climate models predicting a drier future show that probability increasing by up to three times the current probability. Figure 108 shows the current and future wildfire probabilities.

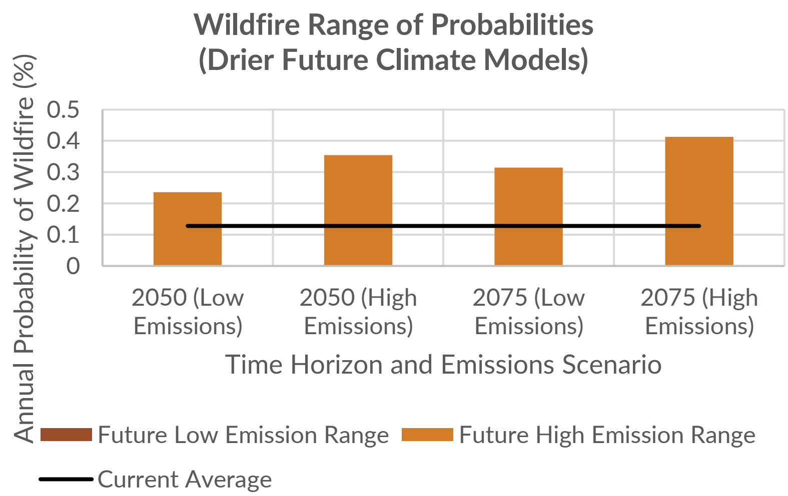


Figure 108:Wildfire Probabilities for Future Time Horizons

Exposure

There are some areas in the county that have a higher risk of experiencing a wildfire than others. To help determine which areas were more at risk, the U.S. Forest Service's Wildfire Risk to Communities spatial data was downloaded and overlaid with population, natural environment, and built environment data. This data was developed in 2020 using the vegetation and wildland fuels from the LANDFIRE 2014 model with the burn probability coming from the Forest Service Fire Simulation System (FSim). To create a product with a finer resolution, the data was upsampled to the native 30m resolution of the LANDFIRE fuel and vegetation data spreading the values of the modeled burn probability into developed areas represented in LANDFIRE fuels as non-burnable. Additional information on the modeling is found here.

Figure 109 shows the areas and their annual burn probability. The maximum current probability is 0.128% which equates to a 781-year event. As the county becomes hotter and potentially drier, this probability will become more likely. Although this figure helps identify the wildfire probability it does not identify the flame height.

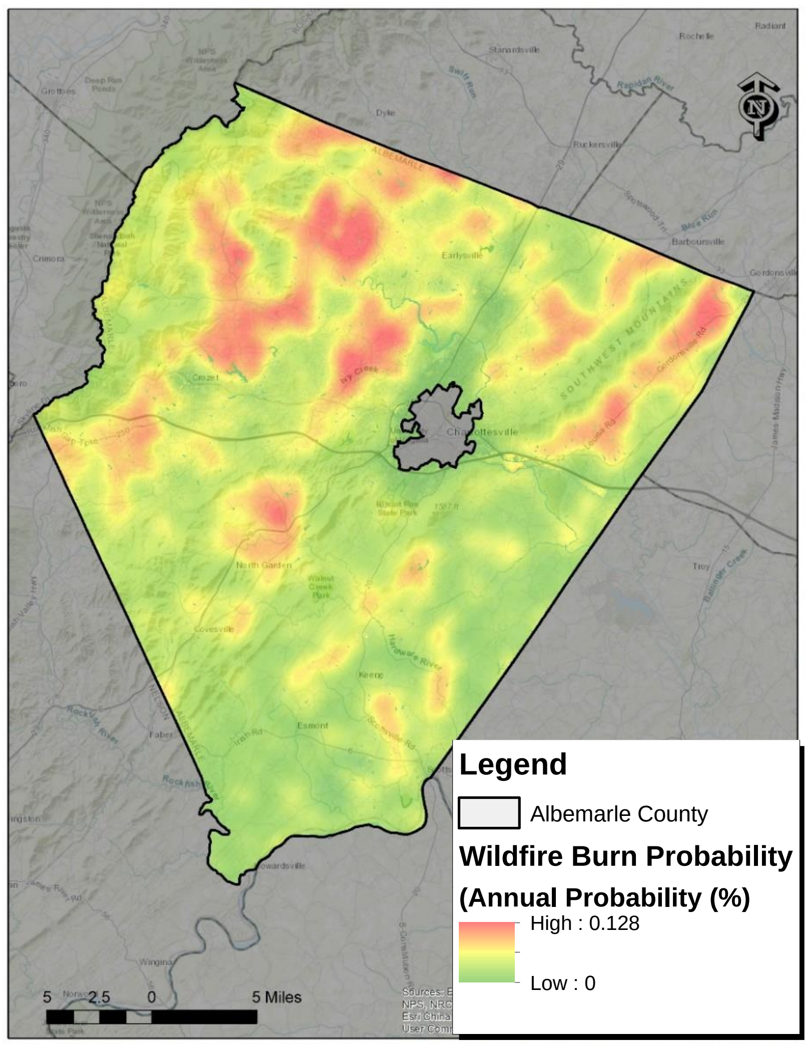


Figure 109: Wildfire Burn Probability (USFS LANDFIRE, 2014)

Figure 110 provides the flame length that is associated with the probability in Figure 109. The flame length ranges from 0 to 6 feet in the county.

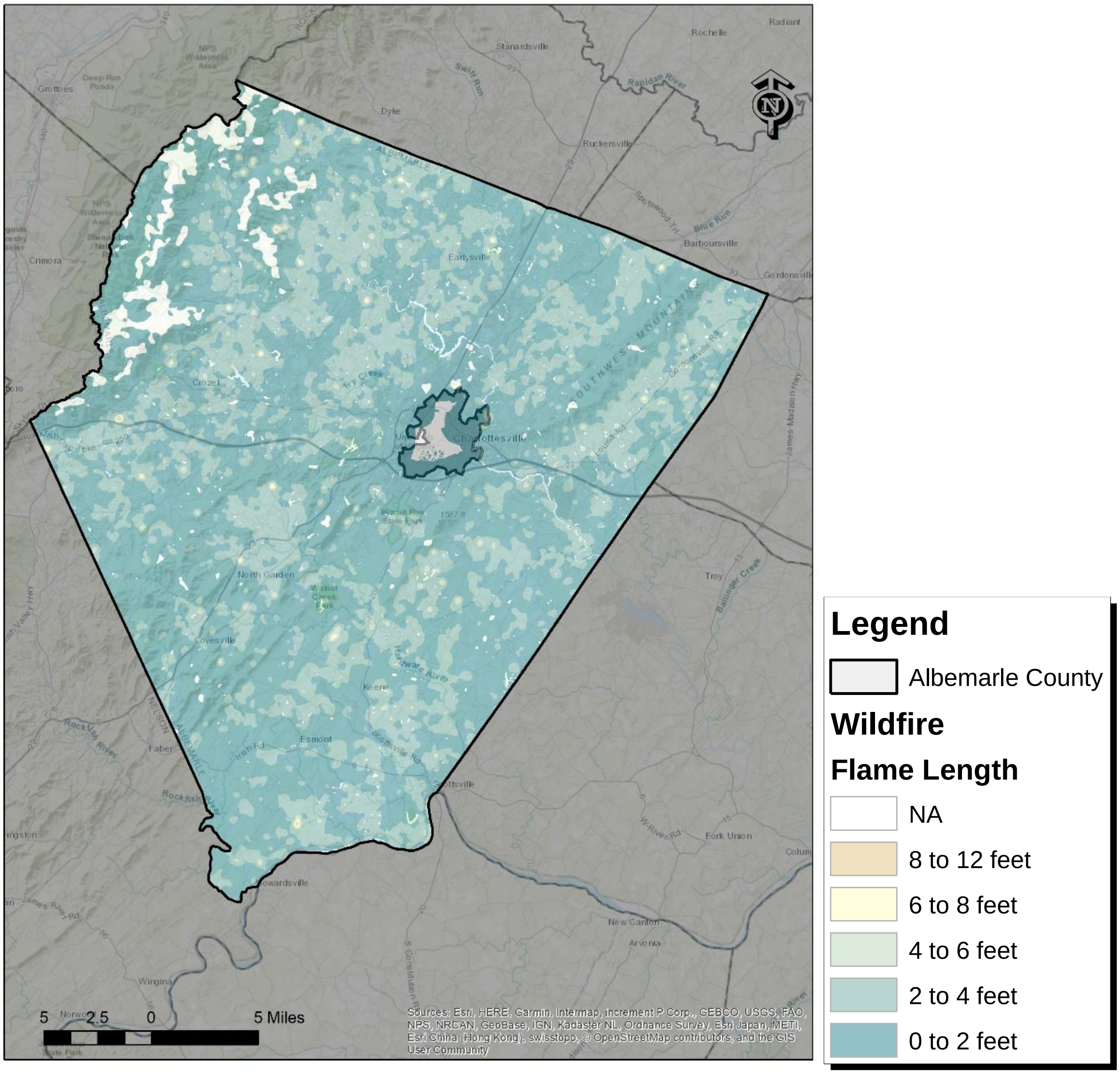


Figure 110: Wildfire Flame Length

People

We used the individual residential building county data and the number of people per household to help model the 2020 population located in the 1000-year or likelier wildfire probability areas (called 1000-year hazard areas in this report). This population is approximately 1,236. Most people in the wildfire 1000-year risk areas are white. Table 53 shows the demographic breakdown of the people in the wildfire 1000-year risk areas while Figure 112 shows the location of the population.

The data used to identify the population in the current 1000-year wildfire areas was then projected for the 2050 and 2075 time horizons to come up with 2,629 and 3,155 as shown in Figure 111.

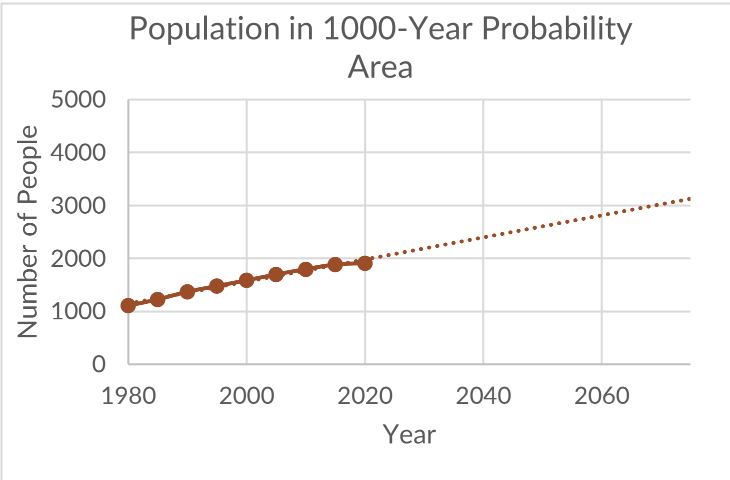


Figure 111: Population Projections for Wildfire Exposure

Table 53: Population Demographics Exposed to Wildfire

Demographics	Exposed to Wildfire Risk Areas (%)	Albemarle County Average (%)
White	90.5%	72.8%
Black	1.2%	8.9%
Asian	2.0%	7.3%
American Indian	0.1%	0.3%
Other Race	1.3%	3.7%
Two or More Races	4.9%	7.0%
Hispanic or Latino	3.6%	7.5%

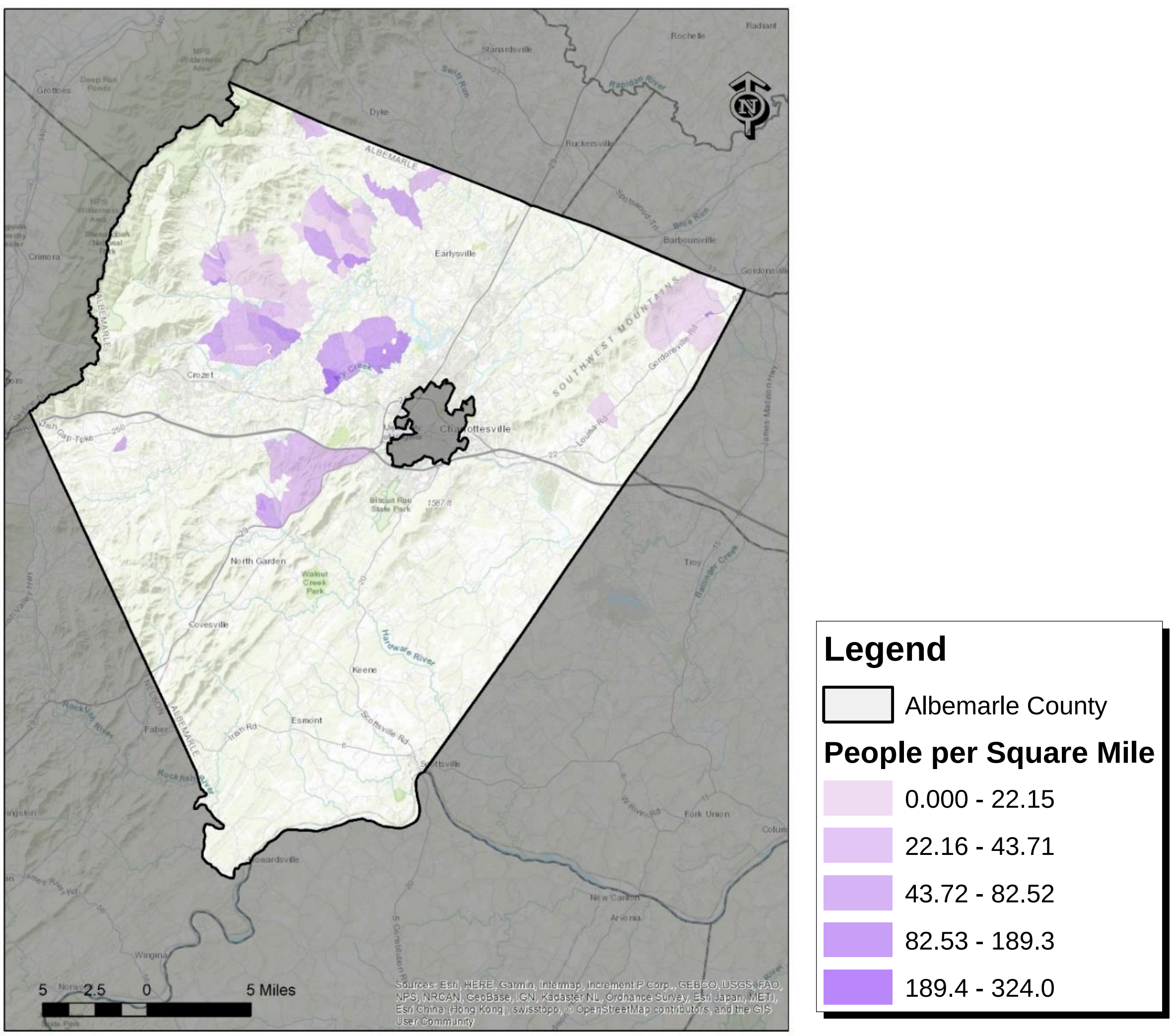


Figure 112: Population in Wildfire Area

Natural Features

The natural features exposed to the wildfire hazard include forestland, cropland, and parks. It can be assumed that some of the climate mitigation would be exposed to the 1000-year wildfire areas too.

Of the park land, Beaver Creek Park is partially exposed to the 1000-year hazard area. Additionally, there are 8,167 acres of hay/pasture land, 40 acres of cultivated crops, and 5,358 acres of forestland in the wildfire 1000-year hazard area. Figure 113 shows the natural features in the wildfire 1000-year hazard areas.

In 2050 and 2075, the 1000-year hazard area will increase in size. For the 2050 time horizon, Chris Greene Lake Park, Mint Springs Valley Park, and Patricia Ann Byrom Forest Preserve Park will be in the 1000-year or likelier area. For the 2075 time horizon, Chris Greene Lake Park, Mint Springs Valley Park, Patricia Ann Byrom Forest Preserve Park, Preddy Creek Trail Park, Walnut Creek Park, and Heyward Community Forest will be in the 1000-year or likelier area.

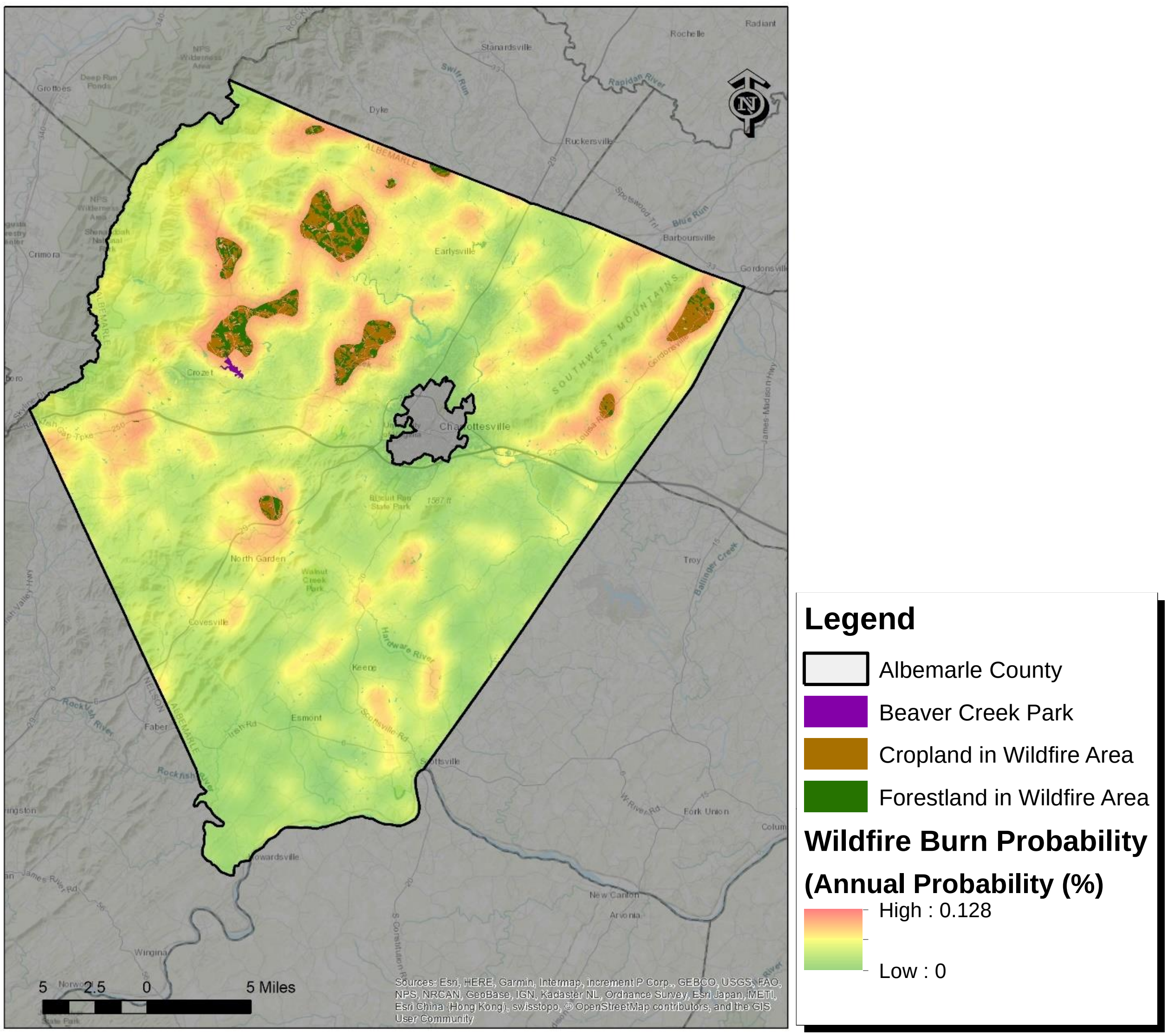


Figure 113: Natural Areas in Wildfire Hazard

Built Environment

In 2020, there were 752 buildings in the wildfire 1000-year hazard area with 748 residential structures (including 11 mobile homes, 4 townhomes, and a hotel), two schools, two post offices, two churches, one medical clinic, one retail store, and four office buildings. Additionally, there is an electric substation and two gas pipelines exposed to the 1000-year hazard areas. Although the exposure analysis identifies these areas, the impact analysis includes all buildings and probabilities. Figure 115 shows the number of buildings exposed to the current 1000-year wildfire hazard area from 1980 through 2020. Figure 114 shows the areas that have a high number of buildings exposed to the wildfire 1000-year hazard areas.

Figure 114: Built Environment in Wildfire Areas

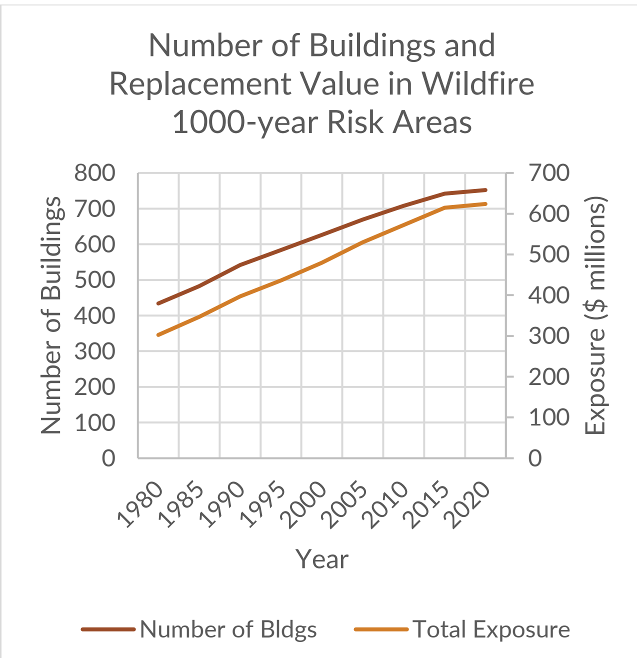
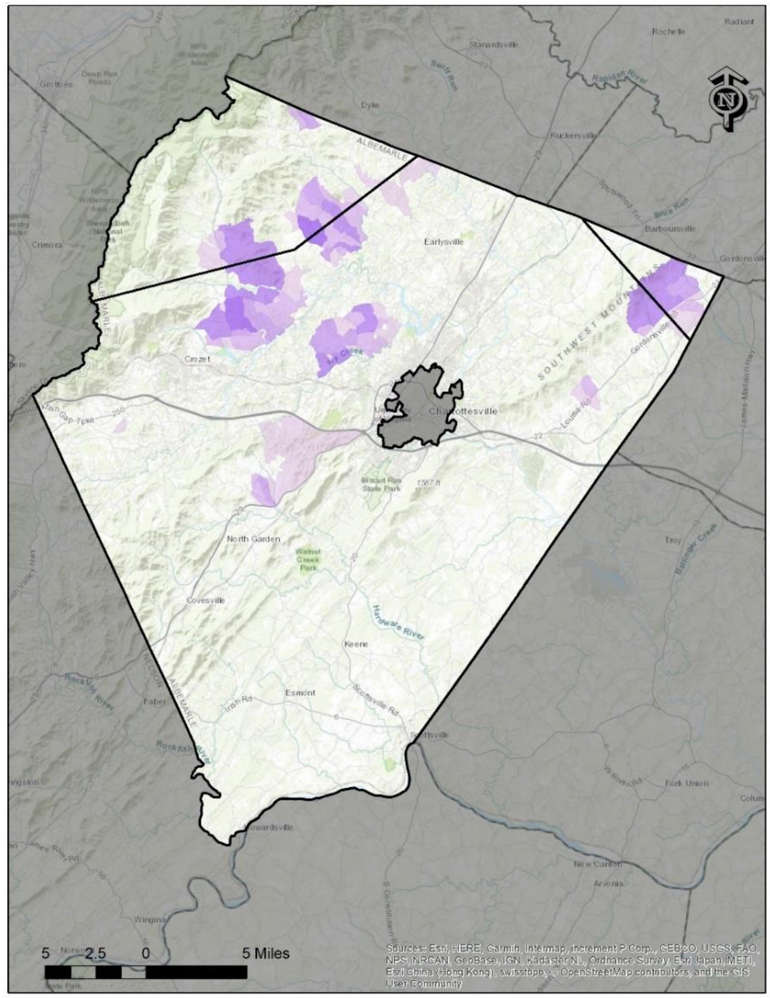


Figure 115: Buildings Exposed to Wildfire Hazard Area



Vulnerability

The vulnerability assessment helps identify susceptibilities in our community so that actions may be taken to reduce potential impacts. This is different from a risk assessment which includes a likelihood component. We anticipate wildfire occurring in the future, and this section focuses on what makes our community vulnerable.

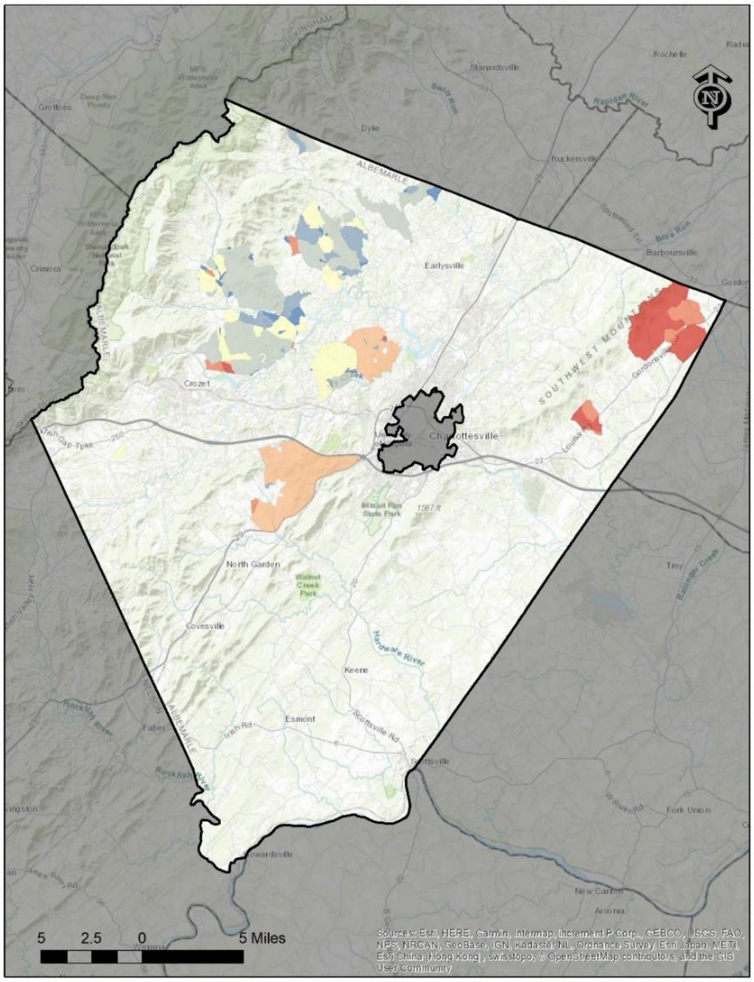
People

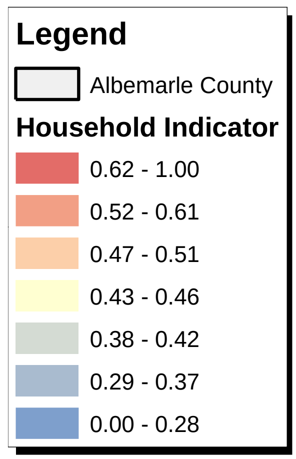
The social vulnerability assessment includes identifying different characteristics of the population which increase your susceptibility or decrease your ability to adapt. This component of the vulnerability assessment includes household indicators (Table 54) and poverty indicators (Table 55). The other social vulnerability indicators identified in the Albemarle County section were assigned to very broad geographic areas (Census Tracts) and thus were not used in the vulnerability analysis. Each component of the social vulnerability indicator will be weighted the same.

Figure 116 shows the household indicator for the wildfire 1000-year hazard areas.

Table 54: Social Vulnerability - Household Indicators

Household Indicators
65 years or older
65+ Years Old and Living Alone
Grandparent Responsible for Grandchild Under 18
Under 18 years
Single Parent Household
No High School Diploma
Limited English





Observations

The red areas in the east have a high household indicator due to a larger number of elderly and single parent households.

Figure 116: Social Vulnerability - Household Indicators

Figure 117 shows the poverty indicators in the wildfire 1000-year risk areas.

Table 55: Social Vulnerability - Poverty Indicators

Poverty Indicators
Median Annual Household Income
Below Poverty Level
SNAP/Food Stamps
Received Public Assistance Income
Housing Costs 30% or More of Income
Crowding (More People Than Rooms)
Unemployed
No Vehicle Access

Observations

The red areas to the east are due to the high percentage of those living below the poverty level, average median income, and rate of unemployment.

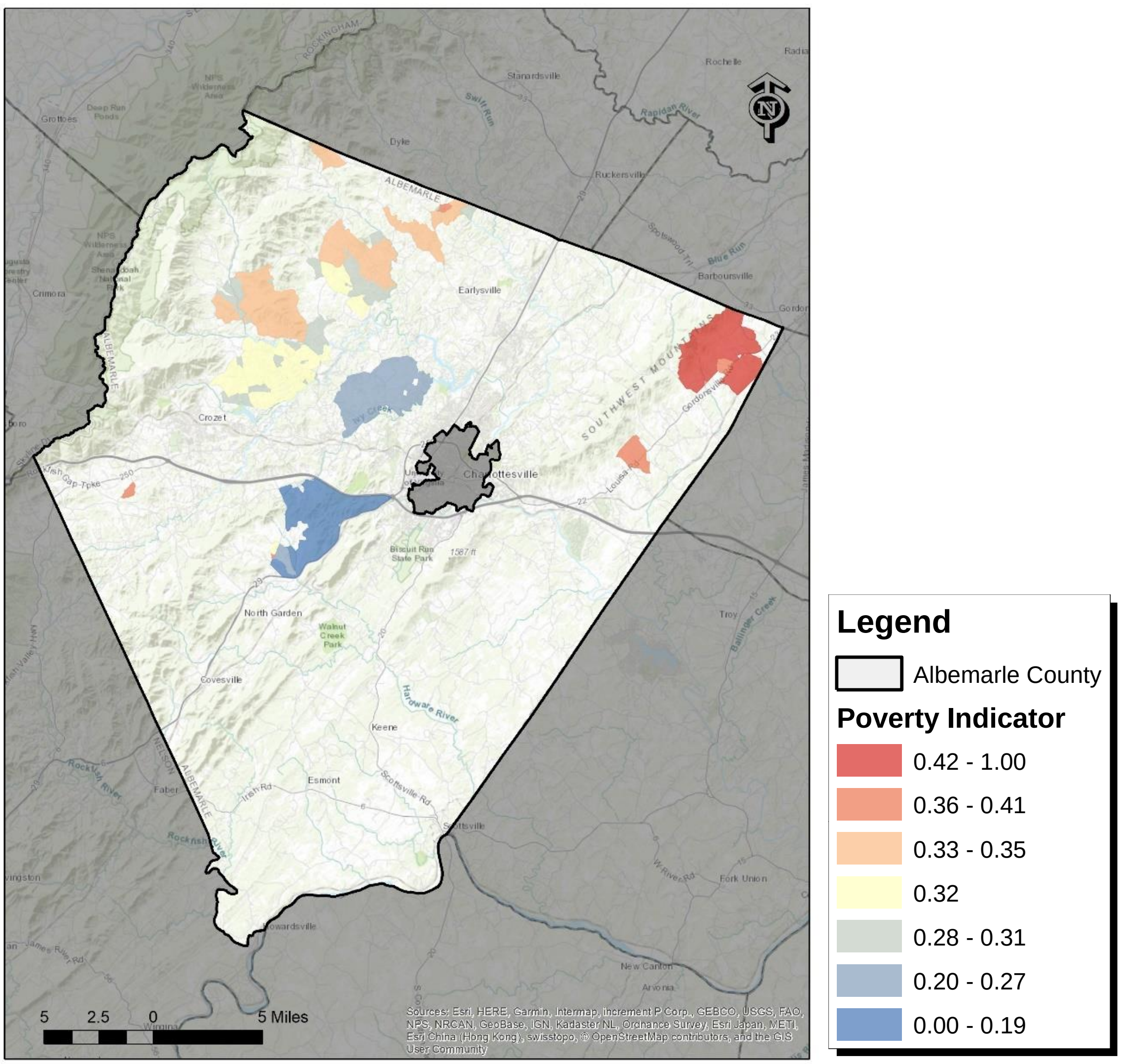


Figure 117: Social Vulnerability - Poverty Indicators

Natural Features

Most of the natural features in Albemarle County are susceptible to wildfire including the trees and orchards, agriculture, livestock, and parks. Agriculture not directly burned by the fire can suffer from smoke taint. Farms can trim back vegetation and create fire breaks around their orchards and vineyards to reduce susceptibility. Drip irrigation can also cause additional loss when the hose burns and melts against the vines. Grazing livestock is one way to reduce susceptibility along with ensuring fuel storage is well away from buildings, equipment, and livestock; and farms have an adequate water supply.

Built Environment

Buildings and smaller neighborhoods which are only accessible through one road are more susceptible to wildfire than neighborhoods with multiple access roads. Also, buildings with gas tanks outside the residence may be more susceptible to loss. Firewise communities are less susceptible to wildfire due to the wildfire mitigation they've undertaken.

Firewise Communities have taken mitigative measures to reduce wildfire damage and be more resilient. This voluntary organization, created by the National Fire Protection Association, provides members with resources such as checklists and toolkits to support homeowners who want to lower their wildfire risk.

Most of the buildings exposed to the higher hazard wildfire areas are residential and there are several ways to reduce your vulnerability to wildfire. In the late 1990s, the USDA Fire Service developed the Home Ignition Zone which is divided into three zones shown in Figure 118. The following information comes from the National Fire Protection Association.

Immediate Zone (the home and 0-5' from home)

- Clean roofs and gutters of dead leaves, debris and pine needles that could catch embers.
- Replace or repair any loose or missing shingles or roof tiles to prevent ember penetration.
- Reduce embers that could pass through vents in the eaves by installing 1/8 inch metal mesh screening.
- Clean debris from exterior attic vents and install 1/8 inch metal mesh screening to reduce embers.
- Repair or replace damaged or loose window screens and any broken windows Screen or box-in areas below patios and decks with wire mesh to prevent debris and combustible materials from accumulating.
- Move any flammable material away from wall exteriors—mulch, flammable plants, leaves and needles, firewood piles—anything that can burn. Remove anything stored underneath decks or porches.

Intermediate Zone (5-30' from home)

- Clear vegetation from under large stationary propane tanks.
- Create fuel breaks with driveways, walkways/paths, patios, and decks.
- Keep lawns and native grasses mowed to a height of four inches.
- Remove ladder fuels (vegetation under trees) so a surface fire cannot reach the crowns. Prune trees up to six to ten feet from the ground; for shorter trees do not exceed 1/3 of the overall tree height.

- Space trees to have a minimum of eighteen feet between crowns with the distance increasing with the percentage of slope.
- Tree placement should be planned to ensure the mature canopy is no closer than ten feet to the edge of the structure.
- Tree and shrubs in this zone should be limited to small clusters of a few each to break up the continuity of the vegetation across the landscape.

Extended Zone (5-30' from home)

- Dispose of heavy accumulations of ground litter/debris.
- Remove dead plant and tree material.
- Remove small conifers growing between mature trees.
- Remove vegetation adjacent to storage sheds or other outbuildings within this area.
- Trees 30 to 60 feet from the home should have at least 12 feet between canopy tops.
- Trees 60 to 100 feet from the home should have at least 6 feet between the canopy tops.

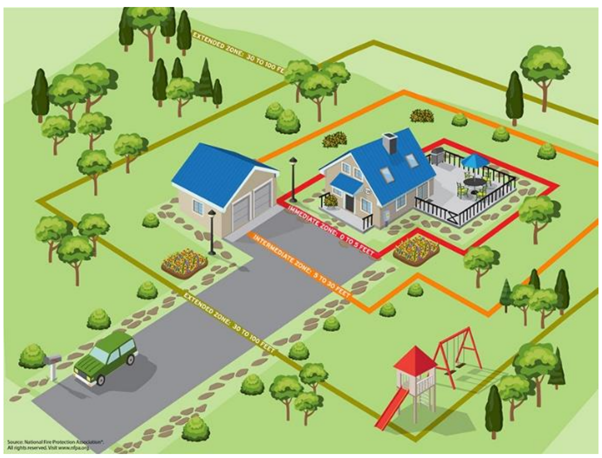


Figure 118: Home Ignition Zones (USDA Forest Service)

Economy

There are certain economic sectors which are more susceptible to wildfire. Businesses which are directly exposed to the wildfire hazard will suffer losses while businesses which require access to the forests and natural areas could also suffer business interruption or property losses. Table 56 provides information on those industries which may be more susceptible to wildfire. Information concerning the number of employees, wages, and number of businesses along with a percentage of the industry compared to the others in the County is provided.

Table 56: Industries Susceptible to Wildfire

Albemarle County Industry	Employees	Employees (% of Total)	Wages (x$1000)	Wages (%)	Businesses (Number)	Businesses (%)
Agriculture, Forestry, Fishing, and Hunting	686	1.7	20,129	1.0	86	2.3
Arts, Entertainment, and Recreation	1,730	4.3	50,691	2.5	66	1.7

Potential Impacts

In this section of the report, we discuss what potential impacts the County may face in the future. This involves reviewing historical impacts, the thresholds at which those impacts occurred, and then looking at the probabilities of reaching those thresholds in the future.

People

To determine the population that would need to be evacuated due to wildfire and potential damage to the homes, we used the wildfire potential consequence dataset along with the county's building and parcel data. The number of people in the wildfire potential consequence areas was then projected for the 2050 and 2075 time horizons based on the new impacts. We then used the public shelter methodology in Hazus, FEMA's risk assessment software, to determine how many people would need public shelter which is based on the household income levels. Table 57 shows the displaced population and shelter requirements for a 0.1% annual chance event and for the two time horizons and emissions scenarios.

Table 57: Wildfire Social Impacts (0.1% Annual Chance Event)

Loss	Current (Avg. Ann.)	2050		2075	
		Low Emissions	High Emissions	Low Emissions	High Emissions
Displaced Population (0.1% event)	360	1,525	2,353	1,978	3,917
Public Shelter Requirements (0.1% event)	31	131	202	170	336
Displaced Population (Annual)	.36	1.5	2.4	2.0	3.9
Public Shelter Requirements (Annual)	.03	0.1	0.2	0.2	0.3

Natural Features

According to the County's dispatch log, there were seven cultivated crop fires and four cultivated tree fires resulting in a total of $34,000 in damage which results in an annualized loss of $6,800 per year between 2017 and 2021. Using the future wildfire probabilities, annual agriculture losses can be projected and are shown in Table 58.

Table 58: Wildfire Agricultural Losses

Loss	Current (Avg. Ann.)	2050		2075	
		Low Emissions	High Emissions	Low Emissions	High Emissions
Annualized Agricultural Loss	$6,800	$12,538	$18,859	$16,734	21,941

Built Environment

According to the County's dispatch log, there were 1,050 other incidents involving property loss due to wildfire or brush fire resulting in a total of $330,488 in damage and an annualized loss of $66,098 per year between 2017 and 2021. Due to the short time span in which data has been collected, we decided to model potential losses using the USFS wildfire risk data. The probability and flame length data were presented in the vulnerability section. The other dataset collected for the impact analysis was the potential consequences to buildings data which uses the flame length probabilities to determine the consequences of the buildings that reside in each area. Figure 119 shows a map of this data for Albemarle County. This was used with the building structure locations and replacement value to determine the potential average annual loss of every structure which had a wildfire probability assigned to it. Figure 120 shows a map of every structure in the county and the average annual loss of the structure.

Adding up all the losses at the building level resulted in a total wildfire average annual loss in the county of $137,726. This loss primarily consisted of residential home loss, mostly single-family home loss of nearly 94% of the total loss. Figure 121 shows the loss break down by building occupancy.

Buildings and infrastructure in the higher county average potential consequences areas include: two schools, two post offices, two churches, one medical clinic, one retail store, four office buildings, an electric substation and transmission lines, and two gas pipelines.

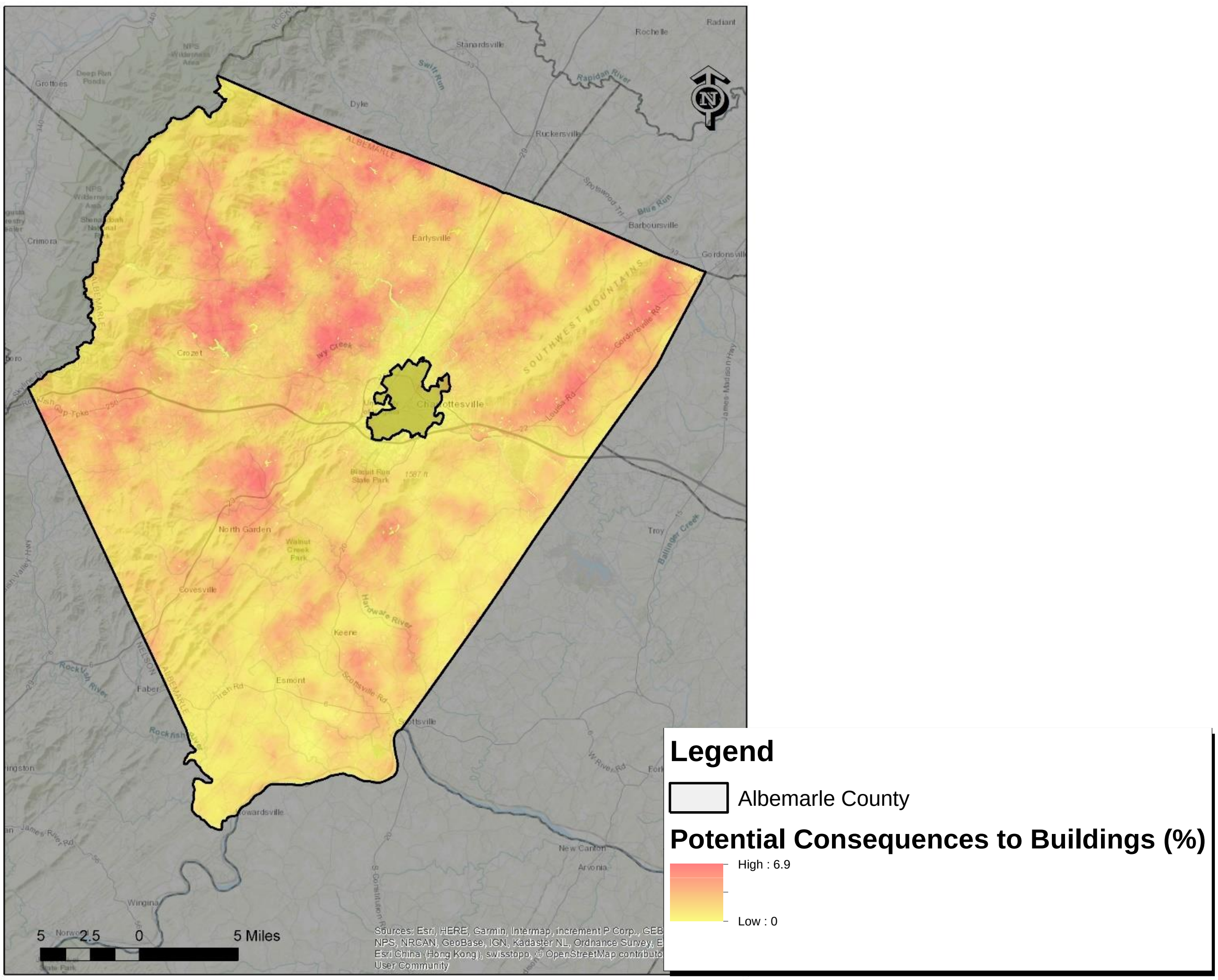


Figure 119: Potential Consequences to Buildings due to Wildfire (USFS 2000)

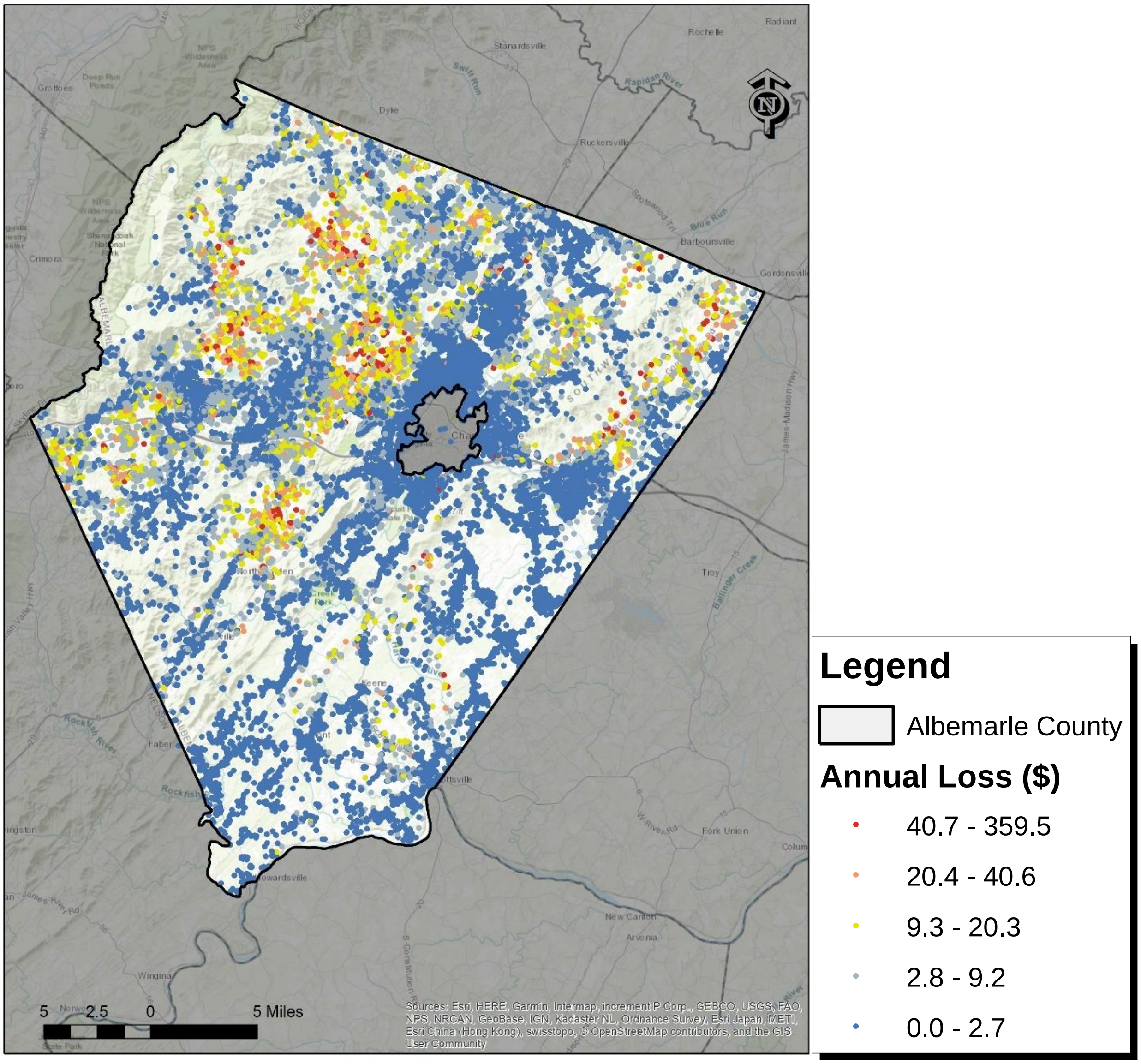


Figure 120: Wildfire Average Annual Loss

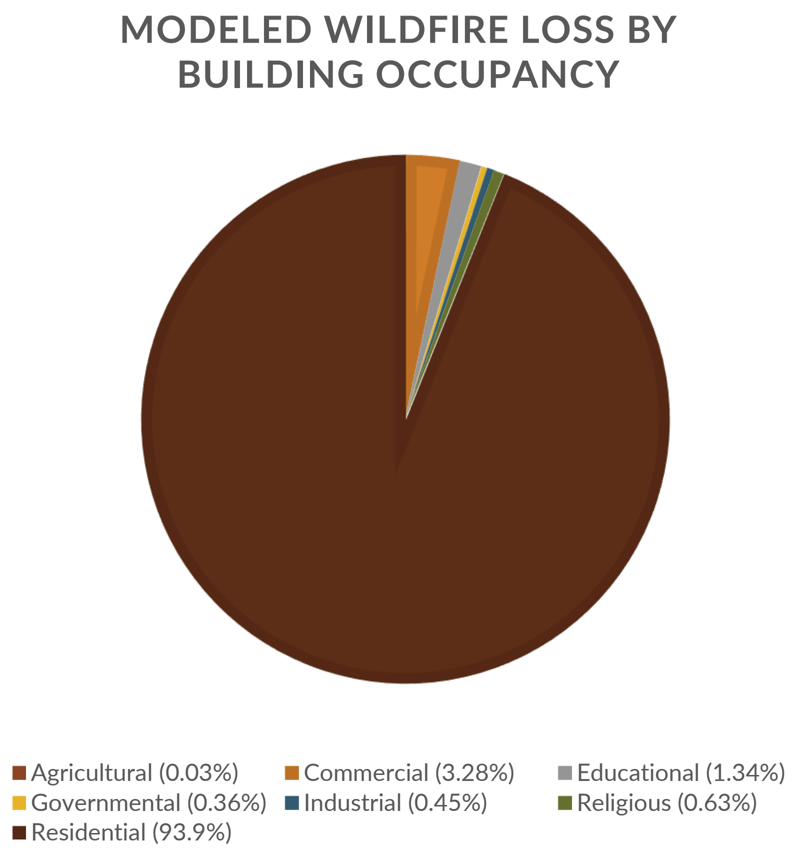


Figure 121: Wildfire Loss by Building Occupancy

The USFS datasets were also used to calculate the annual loss for the utilities. Then we took the new wildfire probabilities calculated in the current and future conditions section to determine how the annual losses would change for the 2050 and 2075 time horizons and two emissions scenarios. Table 59 shows these losses for the different time horizons and scenarios. The 2050 and 2075 losses do *not* include losses due to future building development. It is difficult to determine where future development will occur outside the development areas so these future buildings were not included in the analysis.

Table 59: Wildfire Annual Losses

Loss	Current (Avg. Ann.)	2050		2075	
		Low Emissions	High Emissions	Low Emissions	High Emissions
Wildfire Probability	0-0.128%	0-0.236%	0-0.355%	0-0.315%	0-0.413%
Building Annualized Loss	$137,726	$253,932	$381,974	$338,935	$444,382
Utility Annualized Loss	$2,500	$4,609	$6,934	$6,152	$8,066
Total Annualized Loss	$140,226	$258,542	$388,908	$345,087	$452,448

Economy

There are seven businesses in the wildfire potential consequence area with enough damage to shut down operations temporarily. The businesses include two convenience stores, four professional office buildings, and a medical office. There is a section adjacent to U.S. Route 64 and U.S. Route 29 just west of Charlotteville which could cause the roadway to shutdown which would impact trucking and other transportation. Also, the rail line southwest of Charlottesville could be shut down which would impact rail transport (goods and people).

Agricultural losses are covered in the natural features section while impacts to the other businesses are provided below. For the impact analysis, we assumed the business would endure business interruption losses over the course of a week. Regional business interruption parameters were identified in FEMA's Hazus software and used to calculate annual revenue based on square footage and business type. Table 60 shows the potentially impacted businesses and calculated loss.

Table 60: Albemarle County Wildfire Businesses Impacts (0.1% Annual Chance Scenario)

Albemarle County Industry	Number of Businesses	Number of Employees	Square Footage	Annual Revenue ($)	Wildfire Loss ($)
Convenience Store	2	<20	2,388	198,108	3,800
Professional Services Office	4	40-60	20,336	9,333,817	179,000
Medical Office	1	<20	4,400	640,728	12,000

The annual wildfire loss was calculated for the current conditions and the future probabilities were used to determine the future annual losses. Again, future development was not taken into consideration for the future losses. Table 61 shows these annualized losses and wildfire probabilities. More businesses will potentially be more severely damaged in the future scenarios.

Table 61: Wildfire Annualized Losses for Businesses

		2050		2075	
Industry Losses	Current (Avg. Ann.)	Low Emissions	High Emissions	Low Emissions	High Emissions
Convenience Store (.1% Loss)	$3,800	$7,006	$10,539	$9,352	$12,261
Professional Services Office (0.1% Loss)	$179,000	$330,031	$496,446	$440,508	$577,554
Medical Office (0.1% Loss)	$12,000	$22,125	$33,281	$29,531	$38,719
Significant Wildfire Probability (%)	0-0.128%	0-0.236%	0-0.355%	0-0.315%	0-0.413%
Annualized Loss ($)	**$249**	**$848**	**$1,918**	**$1,510**	**$2,596**

Chapter 6: Flooding

What We Can Expect

2020	• 518 people in 100-year floodplain • 5 mobile homes, 10 duplexes, and 1 retirement community exposed to 100-year event • 82 people requiring public shelter for 100-year event	• 7,695 acres of pastureland in 100-year floodplain • 698 acres of cropland in 100-year floodplain • +1 hazmat facility 200' uphill from 100-year floodplain	• 281 buildings exposed to current 100-year floodplain • $258M property exposure • 1 sewer treatment station, 3 sewer pump stations, and 3 water pump stations potentially exposed	• Up to 75 county businesses exposed and susceptible to 100-year flood • $800K in average annual losses due to business interruption
2075	+612 additional people in 100-year floodplain +6 duplexes, +1 townhouse, +2 apartment buildings, +1 hotel +106 people requiring public shelter for 100-year event	+1,219 acres of pastureland in 100-year floodplain +32 acres of cropland in 100-year floodplain +Freight trains exposed to 100-year floodplain	+267 buildings exposed to 100-year floodplain +$245M property exposure + 1 fire station, +1 police station, +2 water pump stations, +1 electrical substation	+55 county businesses exposed and susceptible to 100-year flood +$1.4m in average annual losses due to business interruption
Identifying Vulnerabilities				
	• Elderly and children • Below poverty line • Poor health • No vehicle access • Those required to travel for work	• Grazing land in floodplain • Barns and storage buildings in floodplain • Agriculture susceptible to long duration floods	• Mobile homes and buildings with short foundations such as slab on grade. • Buildings and infrastructure exposed to flooding without flood-proofing	• Businesses requiring employees or customers to travel through flooded roadways • Businesses directly exposed to flooding

Areas that are at risk of flooding within Albemarle County will change over time due to changing rainfall patterns driven by climate change.

The National Flood Insurance Program (NFIP), managed by the Federal Emergency Management Agency (FEMA), defines a *flood* as "a general and temporary condition of partial or complete inundation of two or more acres of normally dry land area or of two or more properties", typically from either overflow of inland or tidal waters or an unusual and rapid accumulation or runoff of surface waters from any source. A floodplain is an area adjacent to a stream that is subject to flooding.

The definition of a flood is important to those seeking an insurance payout. If the water damage does not fit FEMA's definition, the claim may be denied.

To understand how the floodplain may change in the future, it is important to consider how rainfall generates runoff in watersheds (hydrological modeling) and how this runoff then flows through channel and streams on its way to the floodplain (hydraulic modeling). Although simplified models were run for this county-wide analysis, it is important to understand that FEMA generates and maintains the regulatory (official) floodplain maps and data. The analysis provided in this report is meant for planning purposes only and should not be used for building and infrastructure design.

Background – Watershed

A watershed is a land area where the runoff from rainfall is generated and ultimately flows into a conveyance, such as a channel or stream. Watershed boundaries follow the highest elevations, from the tops of hills and along ridges, and terminates at an outfall. The outfall could be as small as a drainage channel or as large as a major river, such as the James River. The watersheds in Albemarle County generally have their highest elevations in the west and north and discharge to the east and south (as indicated in Figure 122)—and ultimately to the Chesapeake Bay.

Changes in the land around Albemarle County can alter how water flows through the watershed and into the streams, potentially creating a larger floodplain.

A computer model is used to predict how the watershed features (land cover, soils, etc.), atmospheric exchanges (precipitation, evapotranspiration, etc.), human uses (agriculture, conservation, development, etc.), flow processes (overland, interflow, channel flow, etc.), transport processes (sediments, nutrients, pathogens, etc.), and events (low and high flow conditions) influence the water flow through the environment.

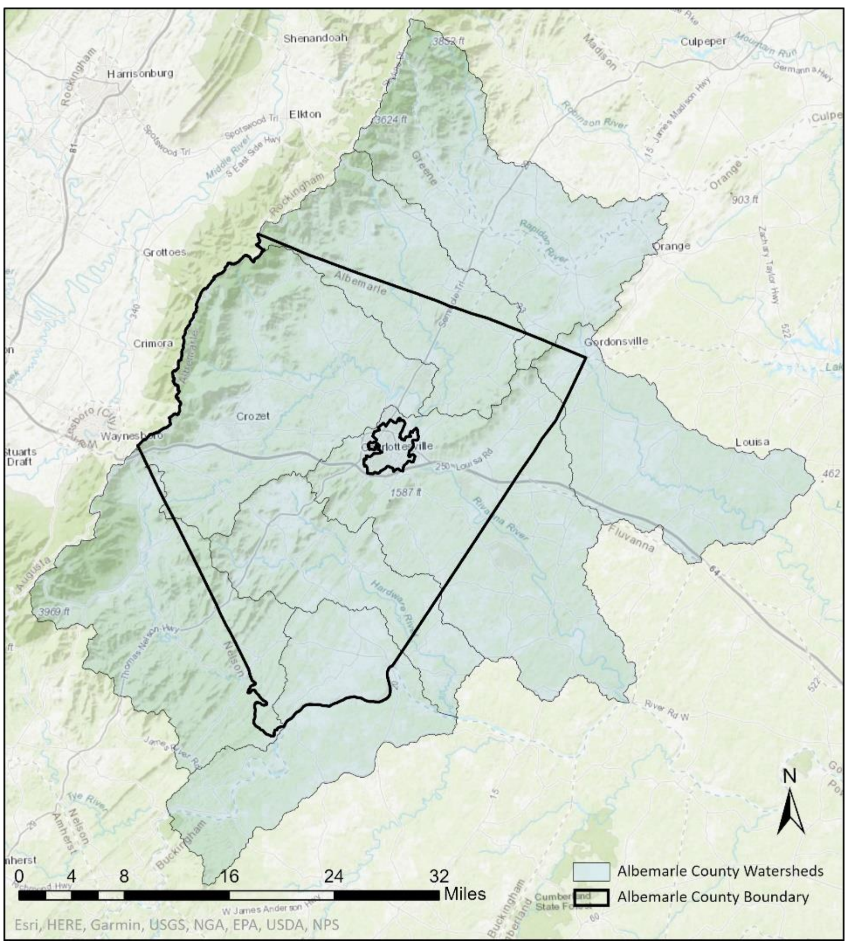


Figure 122: Albemarle County Watershed

The flow in a river or stream is based on the watershed elements described above including the rainfall, rainfall distribution, and physical and climatic characteristics (Mutreja, 1986). Since the amount and rate of the rainfall are the greatest drivers for modeled flow generation, these variables were studied in detail to evaluate the changes in the flows across the two time horizons and two emissions scenarios. Additionally, the climate models predicting a wet future were used for this project to determine future flows. The result of the watershed modeling is a series of flows corresponding to specific likelihoods. One common likelihood metric is the 1% annual chance event, also known as the 100-year event or base flood event. This is the scenario we used for this project.

Historical flow data is collected by river gages and may be found on the [USGS Water Data website.](#) The rivers and gages in and just outside Albemarle County are shown in Figure 123.

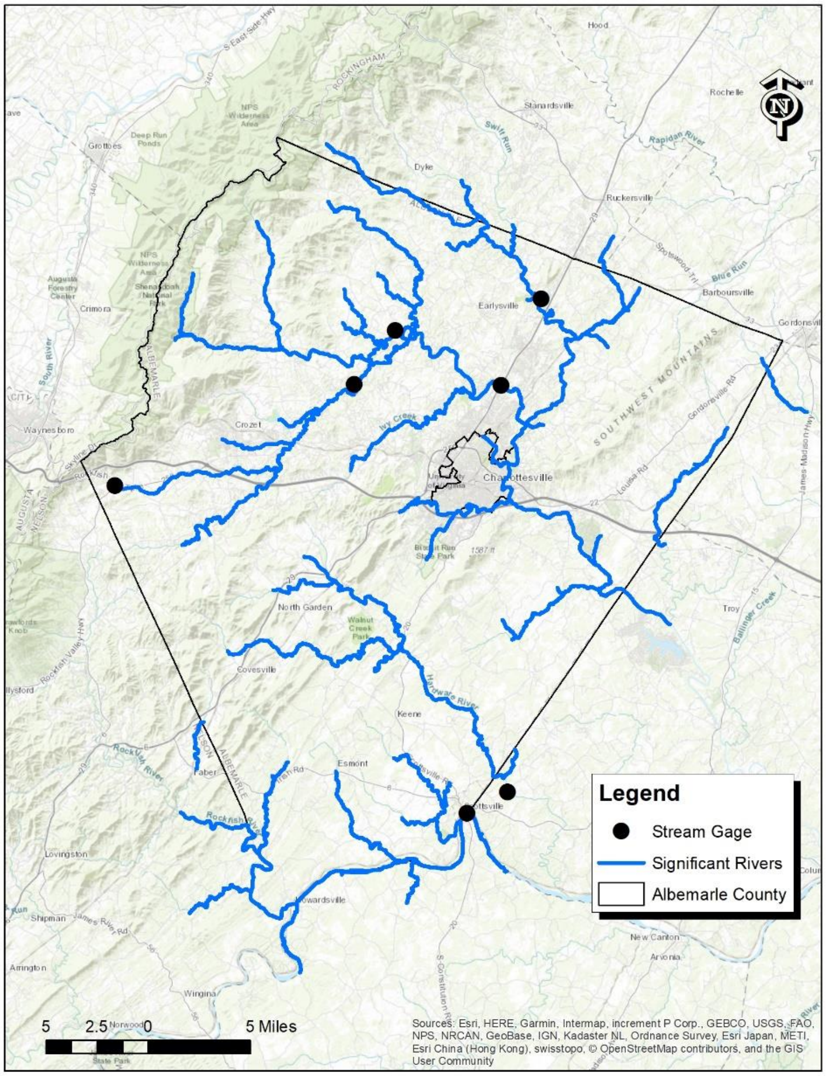


Figure 123: Significant Rivers and Stream Gages

Background – Floodplains

After the hydrologic model is used to identify flow values from watersheds into streams, a hydraulic computer model is used to determine how the water moves through the streams and drainage infrastructure—including how high the water rises and the extent to which the land around the streams and rivers are flooded. The result of this analysis is the mapped extent and depth of the flood waters for the flow scenario. This modeling requires detailed elevation data, structure data such as that for bridges, and land cover data. We used an elevation model created for the region from a Light Detection and Ranging (LiDAR) process, which involves using eye-safe lasers to create a 3D representation of the environment. Although this elevation model may change in the future due to major earthmoving projects, it was left unaltered for the 2050 and 2075 time horizons since those projects are unknown. However, the land cover information was updated using the County's Comprehensive Plan future development zones. The land cover areas are used to determine how much surface friction the floodwaters are subject to during a storm event. The less friction, the faster the flow and the greater the impacts downstream.

Areas which undergo development, especially the development of natural areas, can exacerbate the flood hazard. Figure 124 shows the development areas in the county along with the elevation model.

The current floodplain maps for Albemarle County are maintained by FEMA at the [Map Service Center](). You can use their website interface to enter your address and identify your current flood risk. Just remember that the current FEMA floodplain map for Albemarle County uses historical data to predict flood likelihoods and does not consider future changes to precipitation that may be drive by climate change. Also, flooded areas may extend beyond those areas defined by the FEMA 100-year floodplain in the future, depending on the amount and intensity of rainfall.

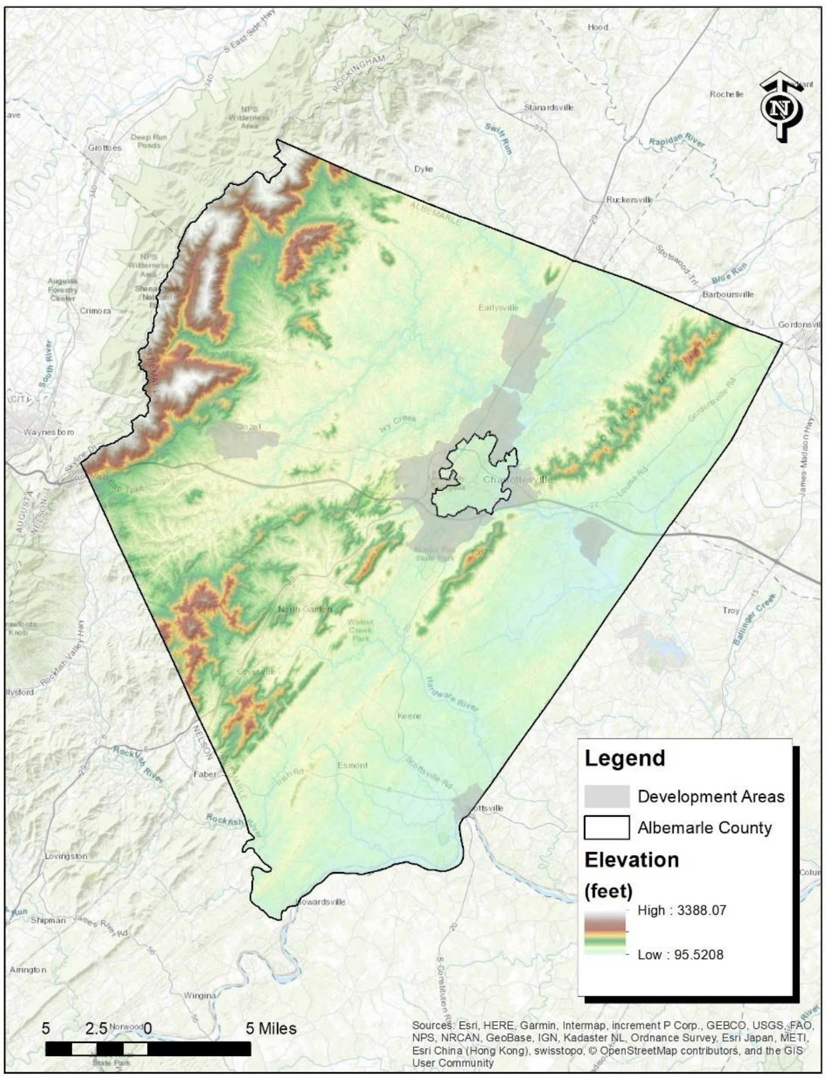


Figure 124: Albemarle County Development Future Development Areas and Elevations

Current and Future Conditions

According to NOAA's National Centers for Environmental Information (NCEI), Albemarle County has experienced 170 flood and flash events from 1950 through 2021. This includes two events which resulted in injuries and eight events which resulted in property damage. From 1970 through 2000, the average annual rainfall was 45.6 inches.

Figure 125 shows the average annual precipitation values used to determine the 2050 statistical values. Figure 126 shows the average annual precipitation values used to determine the 2075 statistical values. The trends indicate an increase in precipitation over time with a leveling off towards the end of the century.

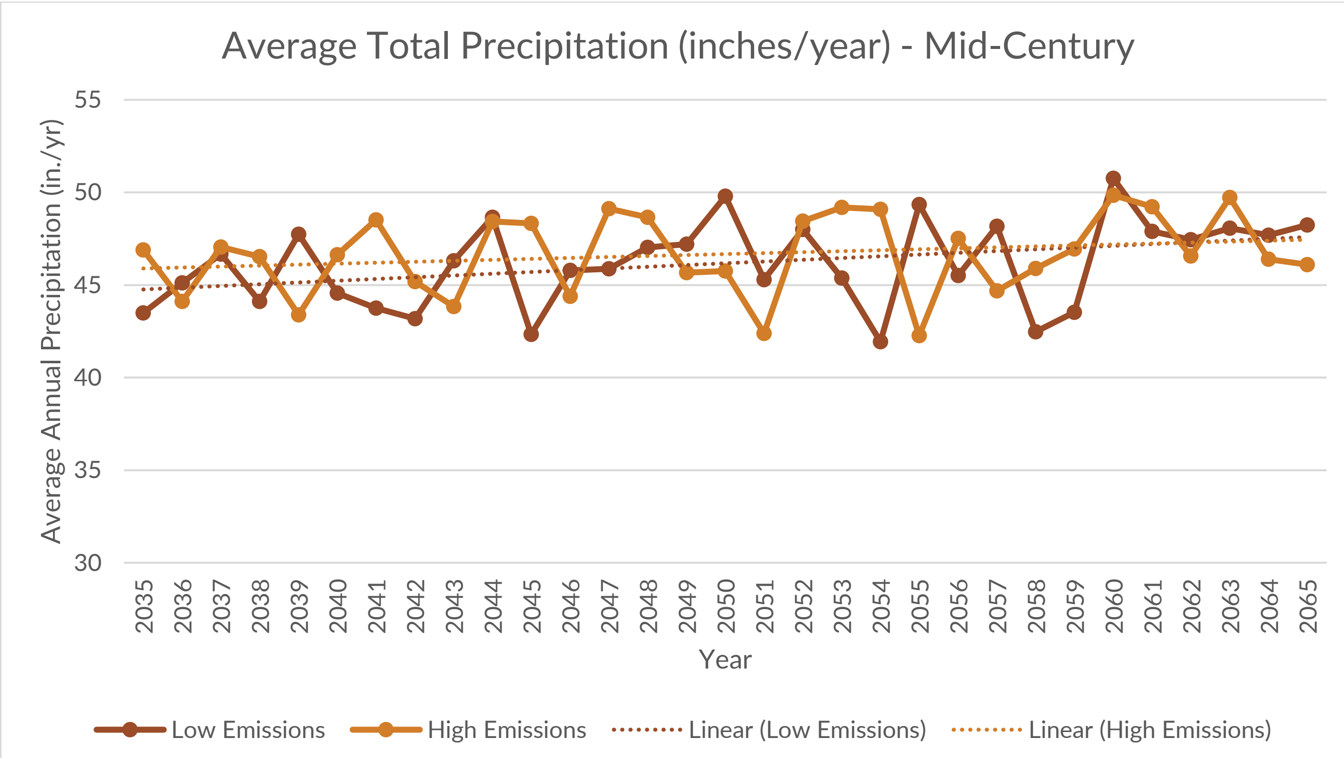


Figure 125: Average Annual Precipitation Used for 2050 Time Horizon

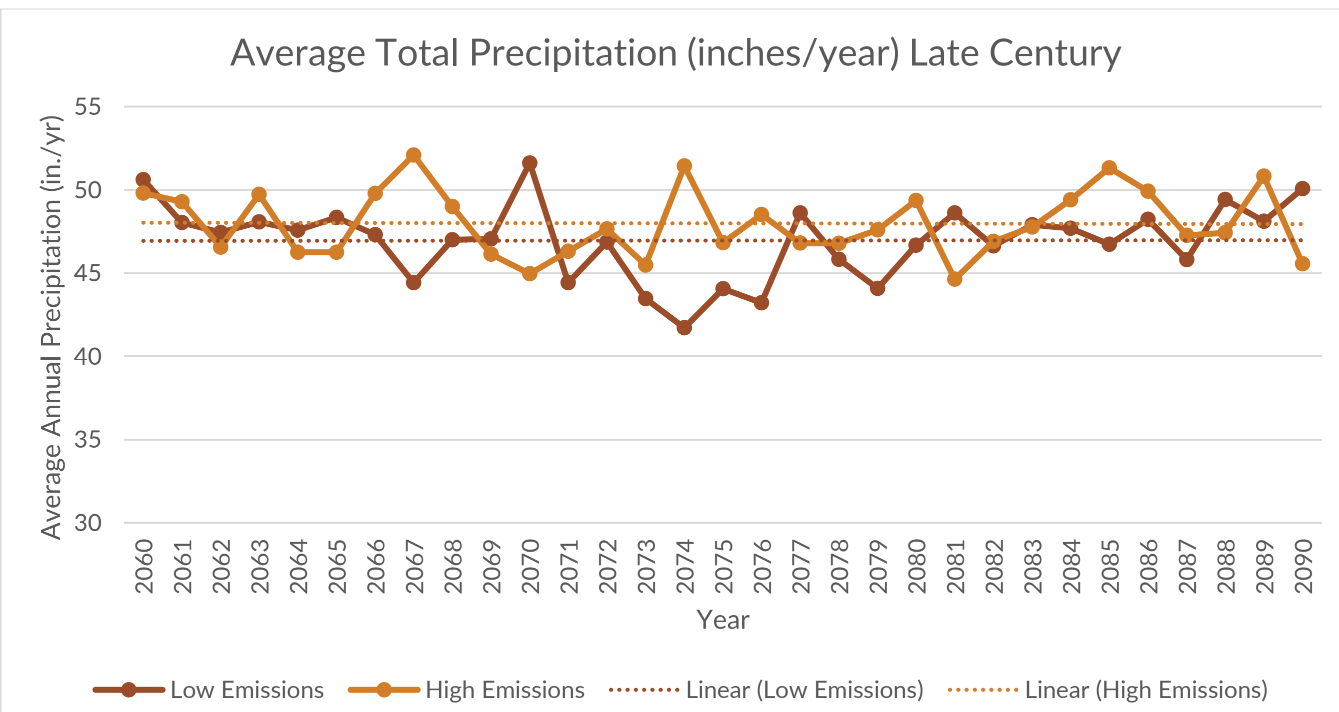


Figure 126: Average Annual Precipitation Used for 2075 Time Horizon

Intensity-Duration-Frequency (IDF) Curves

The Mid-Atlantic Regional Integrated Sciences and Assessments Program (MARISA) was established in 2016 with a five-year grant from NOAA with an initial focus on the Chesapeake Bay Watershed and later included the entire State of Virginia (https://midatlantic-idf.rcc-acis.org/). One of the products created from the MARISA program was the development of projected Intensity-Duration-Frequency (IDF) Curves for two future time horizons for all the counties in Virginia. IDF curves are graphical representations of the probability that a given average rainfall intensity will occur within a given period of time (Dupont and Allen, 2000). Design storms created from IDF curves are used for designing urban drainage systems, evaluating hydraulic structures, and assessing flood vulnerabilities. Figure 127 shows the IDF curves for several current return period events along with the projected median 100-year IDF curve for the 2075 time horizon for both emissions scenarios. To simplify this project, the worst-case scenario was identified (2075 high emissions scenario) and new floodplains were modeled. The precipitation amount associated with a 100-year return period under the 2075 high emissions scenario equates to the current 250-year return period precipitation scenario. In other words, a storm expected, on average, only once every 250 years given today's climate should be expected every 100 years in the year 2075. The results also indicate that the amount of rainfall associated with a 100-year, 24-hour storm will increase from 10.4 inches to approximately 12 inches in the year 2075.

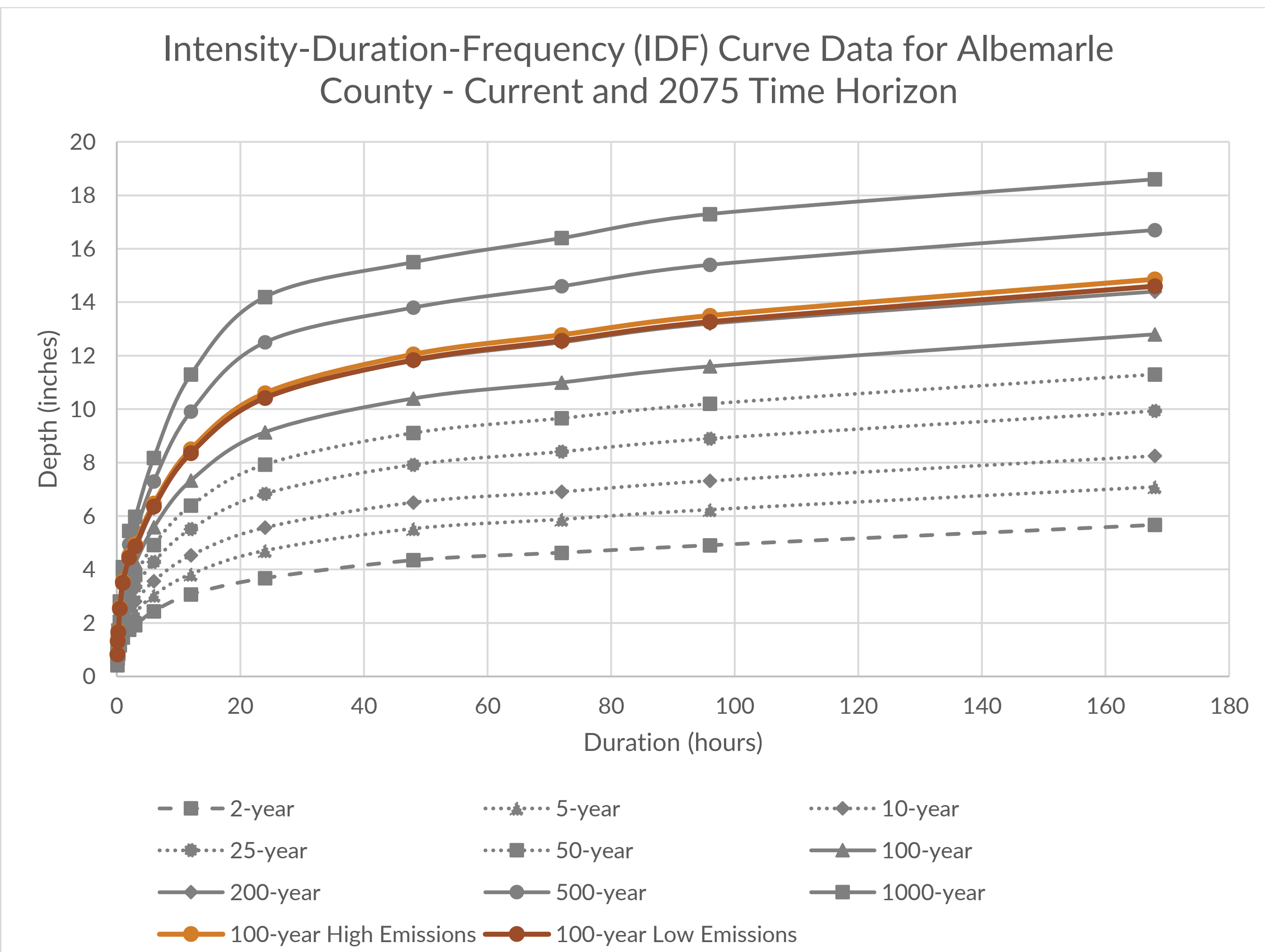


Figure 127: Intensity-Duration-Frequency (IDF) Curves – Current Values and 2075 Time Horizon

Floodplain Modeling

To predict future floodplains, several different models and data were used. FEMA's Hazus software was used as the main model to complete the risk assessment. Figure 128 shows how the different models and data were used to generate future floodplains and determine losses.

Hazus was used to identify the streams within the county using a 1-meter Digital Elevation Model (DEM) from 2015 (USGS, 2015). A smaller drainage unit was used (0.25 square miles) to identify more upstream areas which may have been missed by the FEMA Flood Insurance Study (FIS), but still cause flooding. The additional areas can be found in the exposure section and in the future floodplain mapping.

The hydrology was conducted outside of Hazus using the MARISA IDF curves described in the previous section and the hydrology used to create the FIS report. The future IDF curves were compared to the current IDF curves to determine the future 100-year return period event in terms of current probabilities. The future 100-year return period event was identified as very close to the current 250-year event so the 250-year flow values for the different reaches were identified using the FIS and integrated into the Hazus hydrology model.

Then the Hazus hydraulic model was used with the 1-meter DEM, the hydrology outputs, and the future landcover data. The future landcover data was used to determine the friction imposed on flows in the floodplain. Developed areas have less friction—creating more flood velocity and impacting the extent of the floodplain. Areas in the floodplain and identified as being developed in the future had the Manning's n coefficient (a friction factor) reduced to represent a developed area.

Hazus used the output of the hydraulic analysis (a floodplain) with the county property data to determine a loss based on the depth of flooding, type of building, building replacement value, building elevation, and building foundation type.

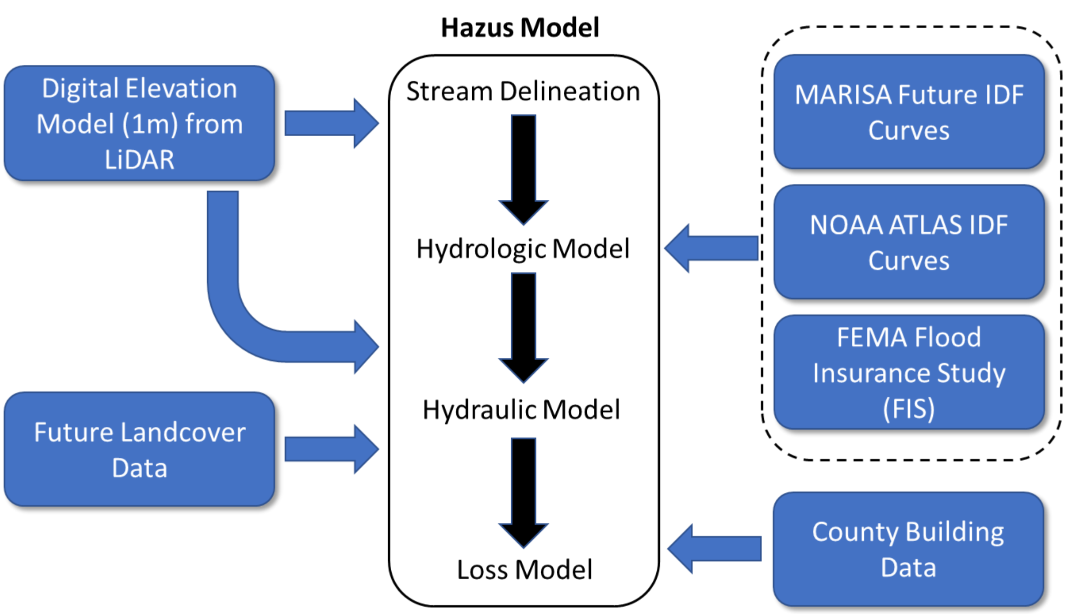


Figure 128: Flood Risk Modeling

Exposure

As we mentioned in the previous section, to simplify this project, one future floodplain was modeled using the worst-case 100-year scenario, which was the 2075 high emissions scenario. In the next sections, the current and future floodplain will be referenced. The current floodplain represents the conditions from 2016 when the floodplain was last updated by FEMA. The depths of flooding were modeled for the current floodplain and potential future floodplain. This allows for a more detailed analysis since some buildings and infrastructure may sit above the flood elevations. Figure 129, Figure 130, Figure 131, and Figure 132 show the current and future floodplains.

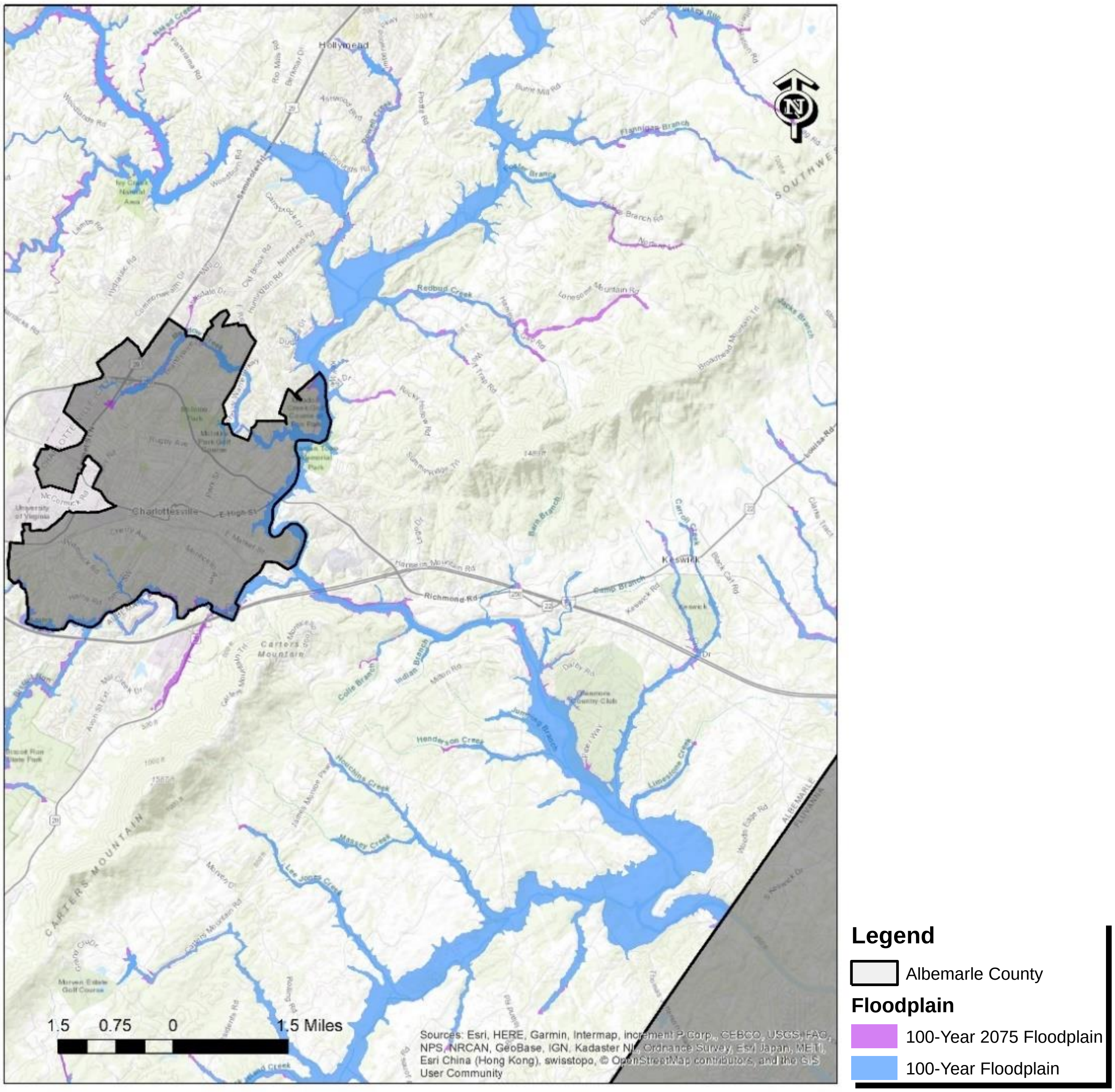


Figure 129: Current and Potential Future Floodplain (Keswick, Hollymead & Rivanna)

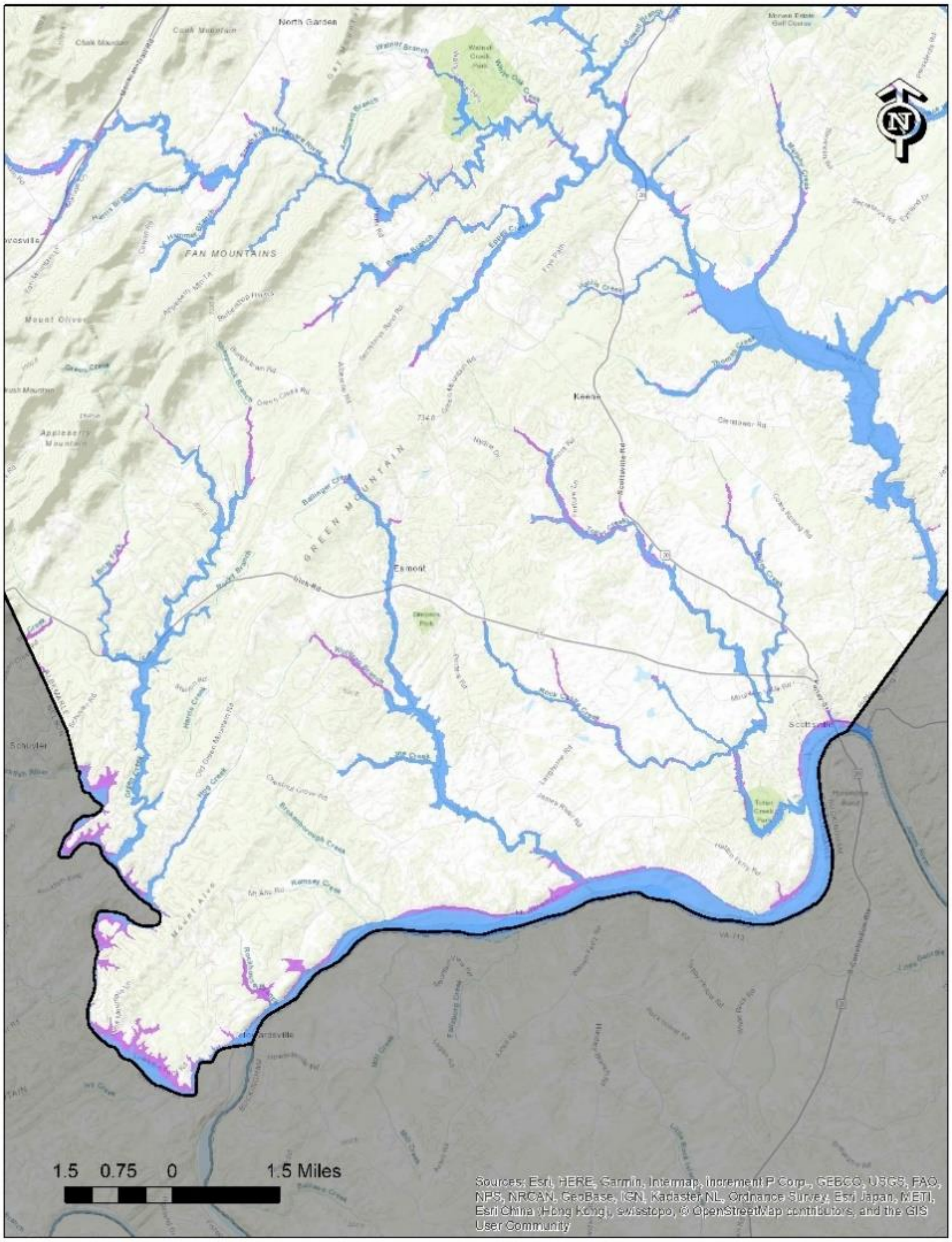
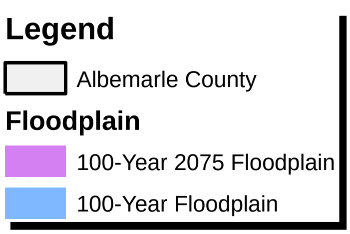


Figure 130: Current and Potential Future Floodplain (Esmont & Scottsville)



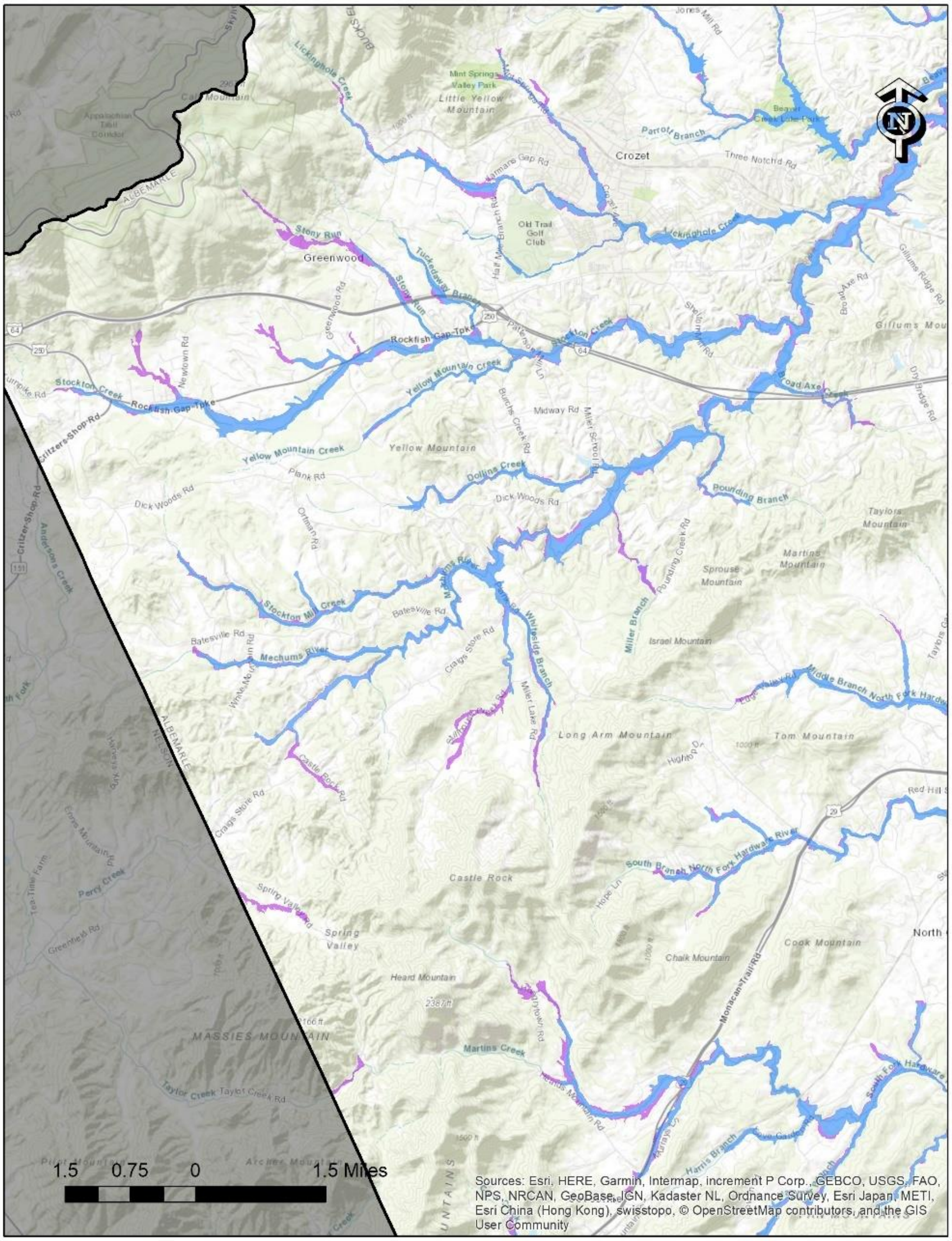


Figure 131: Current and Potential Future Floodplain (Covesville & North Garden)

Legend

Albemarle County

Floodplain

100-Year 2075 Floodplain

100-Year Floodplain

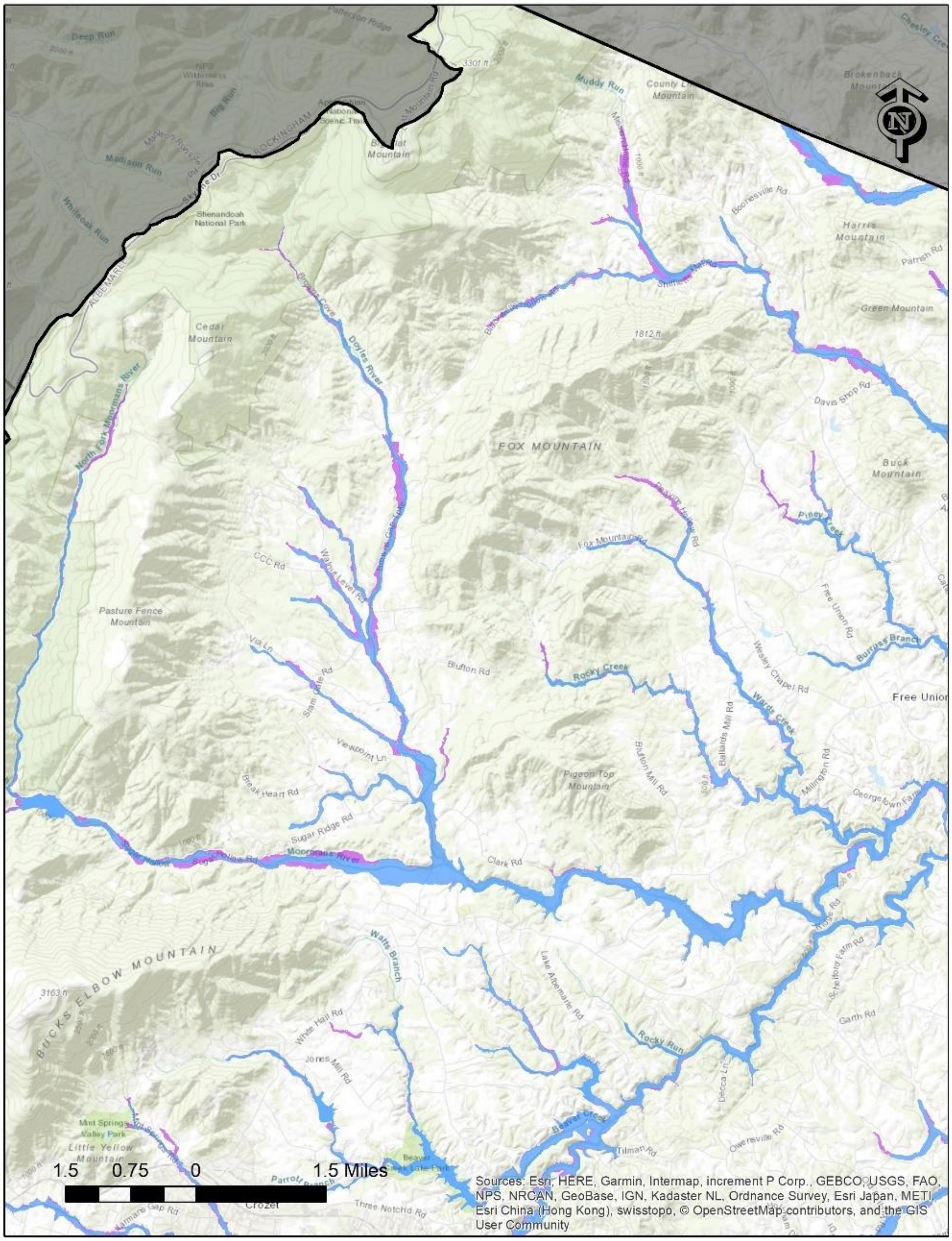


Figure 132: Current and Potential Future Floodplain (Crozet & Whitehall)

Legend

Albemarle County

Floodplain

100-Year 2075 Floodplain

100-Year Floodplain

People

We used the individual residential building data provided by the county and the number of people per household to model the population residing in the floodplain. The 2020 population located in the current 100-year floodplain is approximately 518. Table 62 shows the demographic breakdown of the people in the flood risk areas.

Table 62: Population Demographics Exposed to Flooding (U.S. Census 2020)

Demographics	Exposed to Flood Risk Areas (%)	Albemarle County Average (%)
White	79.2%	72.8%
Black	7.2%	8.9%
Asian	5.8%	7.3%
American Indian	0.2%	0.3%
Other Race	1.9%	3.7%
Two or More Races	5.7%	7.0%
Hispanic or Latino	4.5%	7.5%

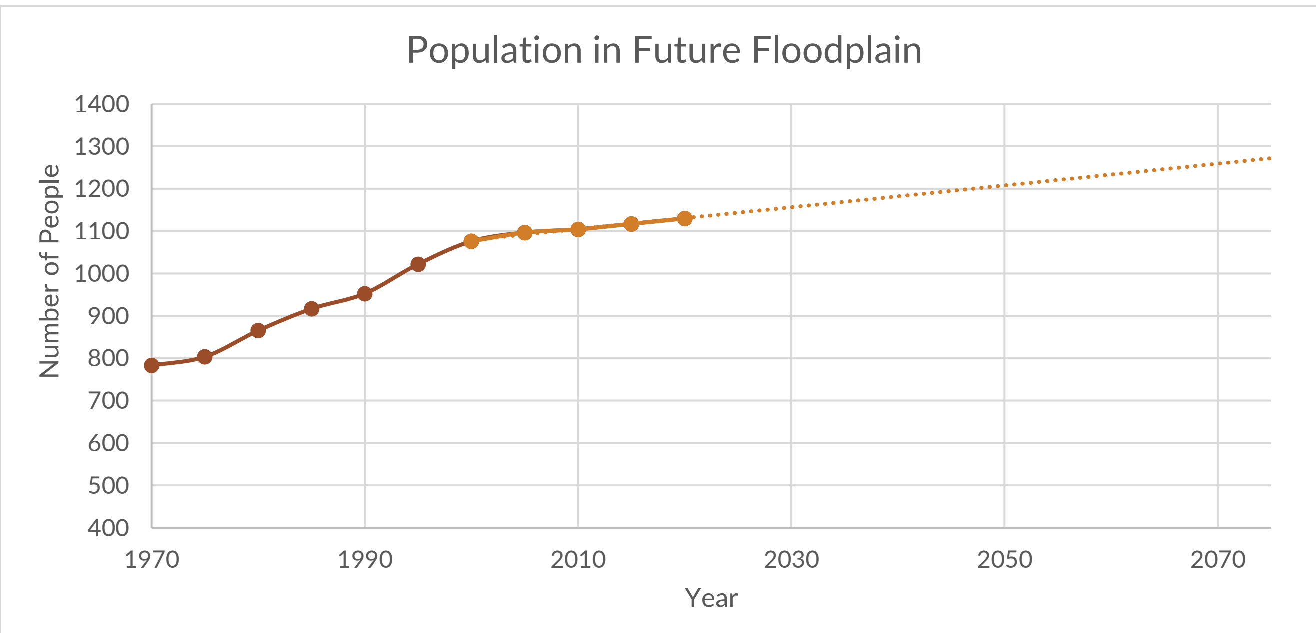


Figure 133: Population Projections for Flood Exposure

The data used to identify the population in the flood areas was then projected for the 2050 and 2075 time horizons. In the last twenty years there has been a slower population increase within the future floodplain and in the last 14 years there has been no new development in the current floodplain due to regulations. However, those homes located just above the current base flood elevation could be inundated if the base flood increases in extent. At the more recent rate of growth, we predict around 1208 people will reside in the future floodplain in 2050 and 1272 people in the future floodplain in 2075. Figure 133 shows population growth in the future floodplain since 1970 and the projected growth to 2075. Figure 134 shows the population density of the Census Blocks with residential buildings in the floodplain.

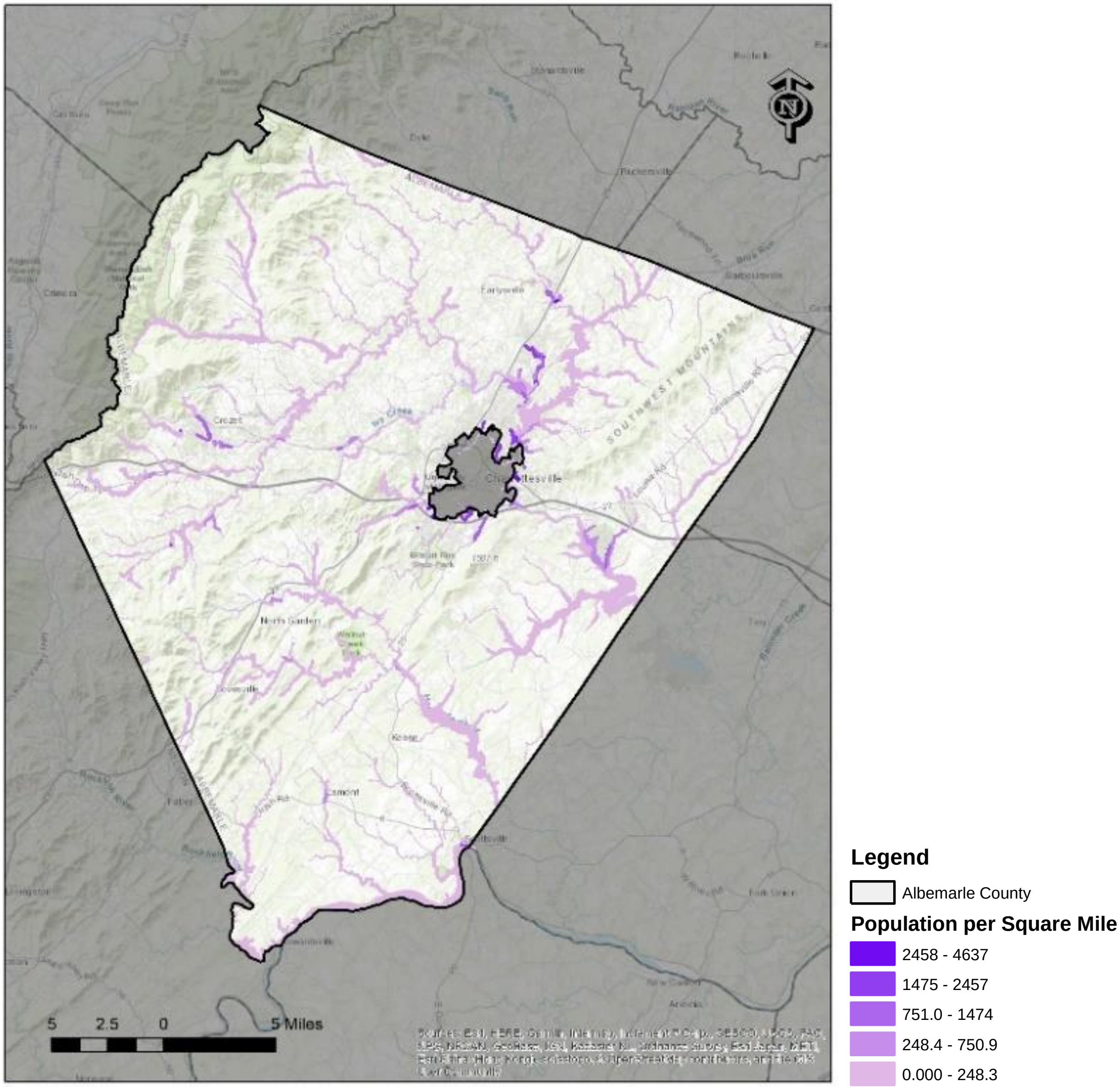


Figure 134: Population in Floodplain (U.S. Census 2020)

Natural Features

The natural features exposed to the flood hazard include forestland and cropland. Within the current base floodplain, there are 7,692 acres of hay/pastureland, 697 acres of cultivated crops, and 16,227 acres of forestland. Within the future floodplain, we predict there will be 8,951 acres of hay/pastureland, 730 acres of cultivated crops, and 19,271 acres of forestland. Figure 135 shows the natural features in the future floodplain.

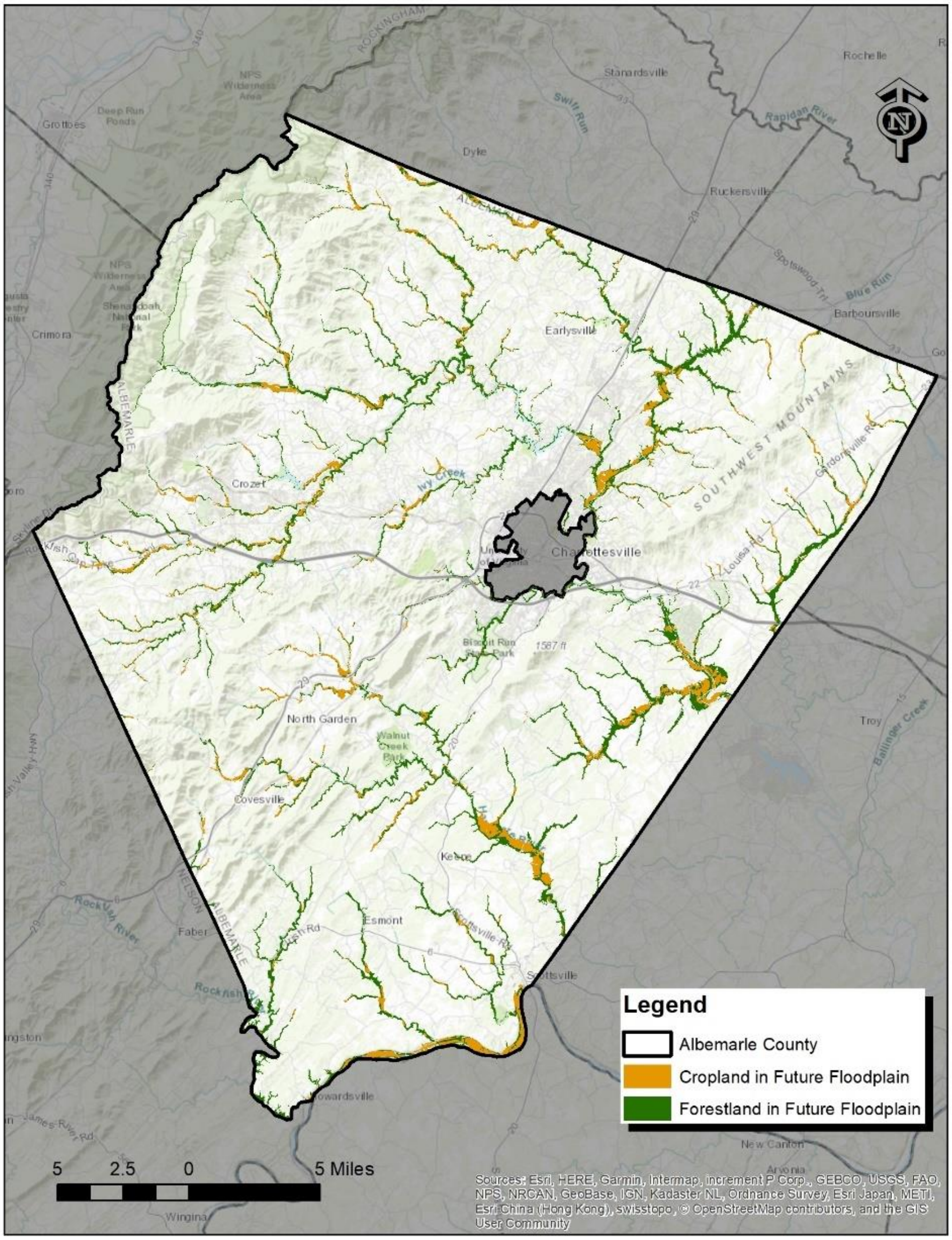


Figure 135: Natural Areas in Flood Hazard

Built Environment

In 2020, there were 280 buildings in the base floodplain—not including 196 sheds and other outbuildings. The buildings consisted of 187 residential structures (including 5 mobile homes, 10 townhomes, and a retirement community), 62 commercial structures, nine government buildings, four churches, and nine agricultural buildings. Additionally, there are three sewer pump stations, three water pump stations, and one sewer treatment plant exposed to the current base floodplain. Across the river in Charlottesville, there is one facility containing hazardous materials adjacent to the floodplain and a mobile home park in the floodplain. Approximately $258 million of property is exposed to the current floodplain. Figure 136 shows a breakdown of the property exposed. Figure 137 shows the locations of the buildings exposed to the current and future floodplains.

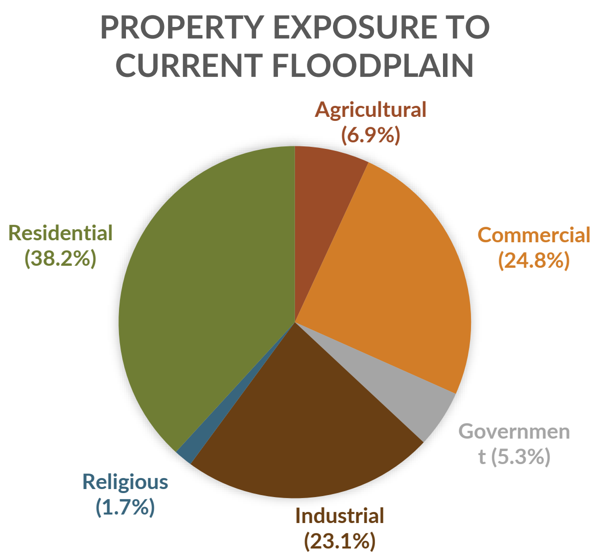


Figure 136: Value of Property Exposed to Current Floodplain

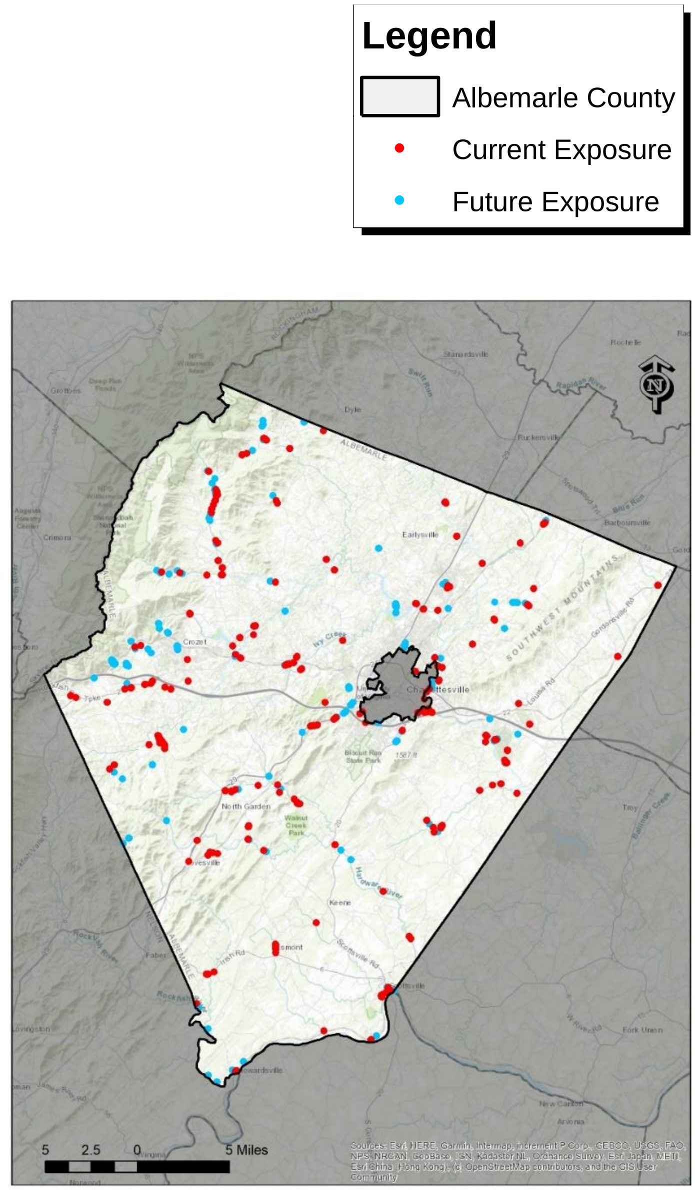


Figure 137: Built Property in Flood Areas

Vulnerability

The vulnerability assessment helps identify susceptibilities in our community so that actions may be taken to reduce potential impacts. This is different from a risk assessment which includes a likelihood component. We know flood is going to occur in the future and this section focuses on what makes our community vulnerable.

People

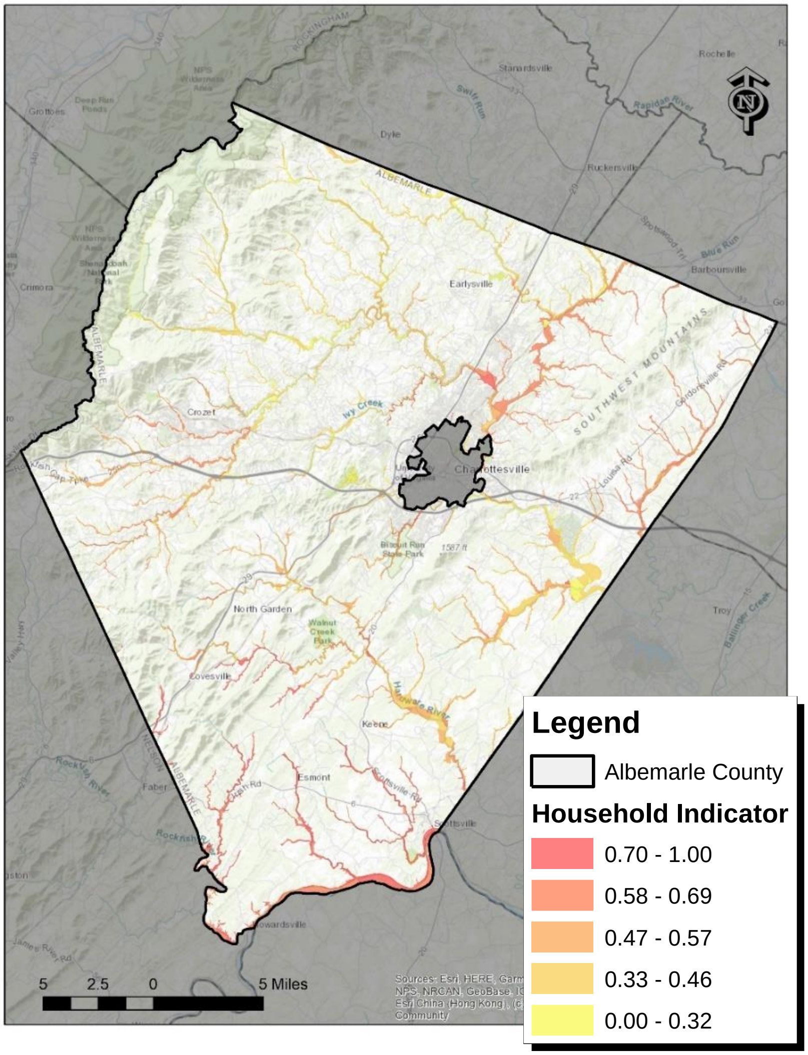


Figure 138: Social Vulnerability - Household Indicators

The social vulnerability assessment includes identifying different characteristics of the population which increase the population's susceptibility or decrease its ability to adapt. This component of the vulnerability assessment includes household indicators (Table 63) and poverty indicators (Table 64). Each set of indicators is used to create and map a vulnerability score which is then combined to create an overall social vulnerability score. Each component of the social vulnerability indicator will be weighted the same. Figure 138 shows the household indicator in the flood hazard areas.

Table 63: Social Vulnerability - Household Indicators

Household Indicators
65 years or older
65+ Years Old and Living Alone
Grandparent Responsible for Grandchild Under 18
Under 18 years
Single Parent Household
No High School Diploma
Limited English

Observations

The high vulnerability areas north of Charlottesville and in Scottsville are due to the higher percentage of single parent households, lower education level, and larger numbers of children.

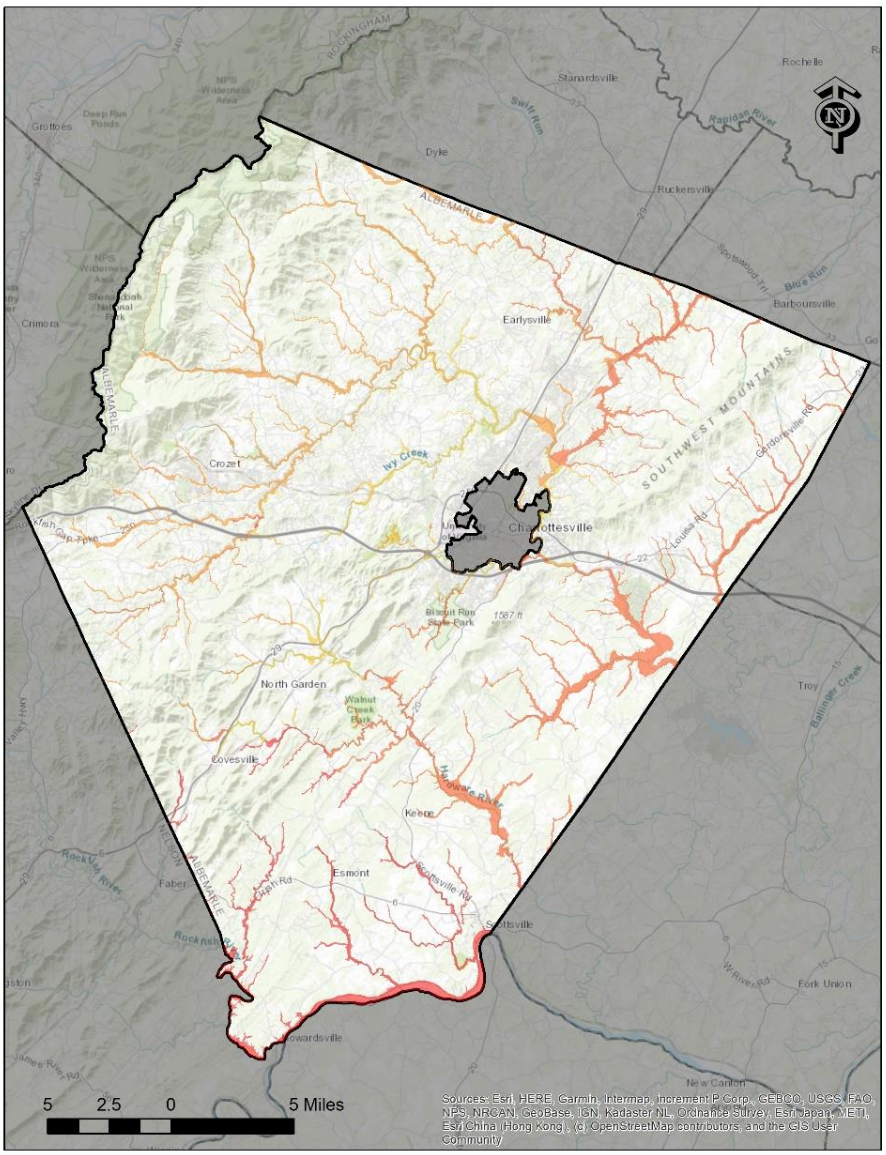
Figure 139 shows the poverty indicators in the flood hazard area.

Table 64: Social Vulnerability - Poverty Indicators

Poverty Indicators
Median Annual Household Income
Below Poverty Level
SNAP/Food Stamps
Received Public Assistance Income
Housing Costs 30% or More of Income
Crowding (More People Than Rooms)
Unemployed
No Vehicle Access

Observations

The high vulnerability areas in the eastern part of the county are due to the higher percentage of those living below the poverty level, lower average median income, and higher rate of unemployment. The high values to the south are due to lower average median income and higher housing costs.



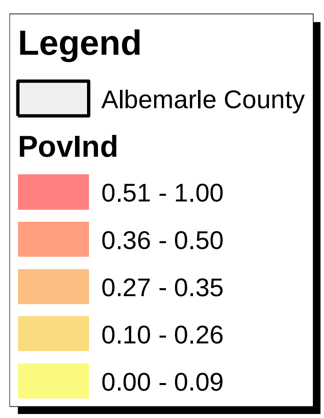


Figure 139: Social Vulnerability - Poverty Indicators

Natural Features

Livestock can be very susceptible to flooding and should have their exposure reduced during an event. Agricultural sheds and barns containing livestock which are in a floodplain or low-lying area should not be locked and should allow livestock to leave if necessary. Agriculture is particularly susceptible to flooding when that flooding lingers for several days—so length of time is important to consider. It also depends on when the flooding occurs. For instance, a flooded field of crops ready to be harvested is more susceptible to damage and losses than a field between growing seasons.

According to the U.S. Army Corps of Engineers Agricultural Flood Damage Analysis (AGDAM) database, hay sustains substantial damage after three or more days of flooding—with the most damage occurring during the summer growing season. AGDAM shows substantial damage to vineyards if the vines are exposed to water for more than seven days. Since vineyards are established year-round, they are susceptible to flooding year-round. Many vineyards are built on hills which allows for good drainage and minimal damage. Fruit trees sustain major damage after being exposed to flood water for 14 days or more. Trees are more resilient to flooding than other types of agriculture.

Built Environment

Buildings and smaller neighborhoods which are only accessible through a single road crossing the floodplain are more susceptible to flooding. Buildings that have an elevated first floor and have electrical and mechanical components elevated are less susceptible to flooding. Other dry and wet flood-proofing also makes a building less susceptible to flooding. Buildings in poor condition and older buildings can be more susceptible to flood damage. Mobile homes are also more susceptible to flood damage. Figure 140 shows a breakdown of buildings in the current floodplain by the year built. Figure 141 shows a breakdown of the building condition for the buildings in the current floodplain.

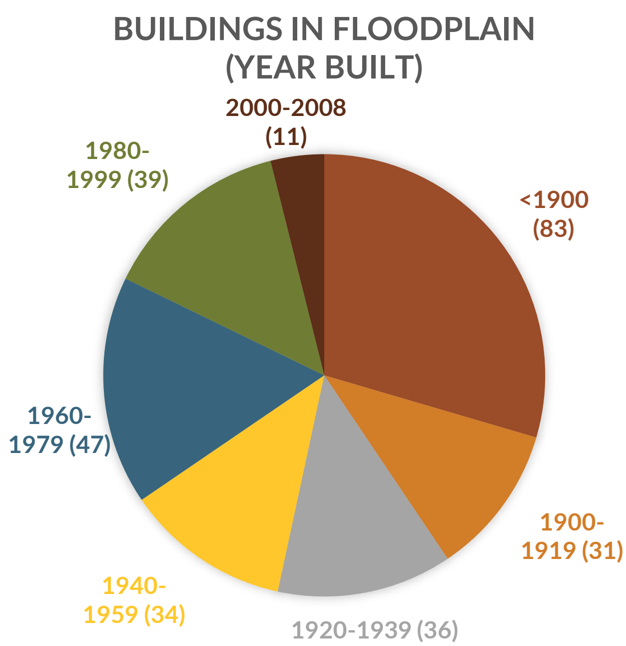


Figure 140: Buildings in Floodplain (Year Built)

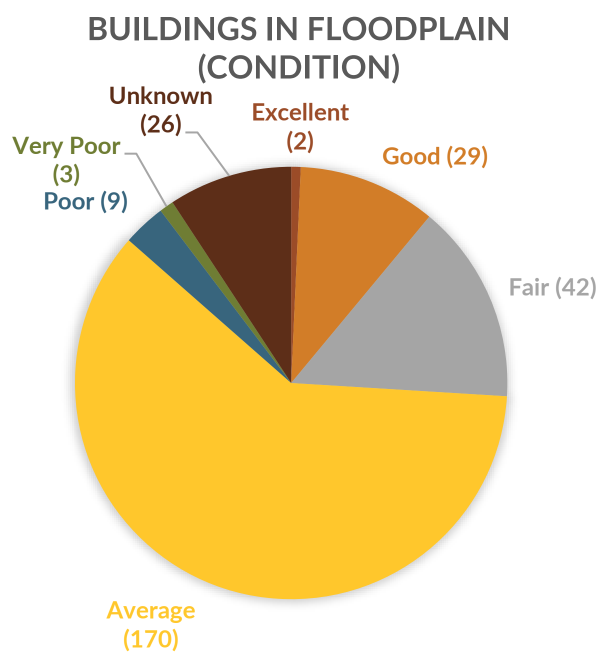


Figure 141: Buildings in Floodplain (Condition)

Economy

There are certain economic sectors which are more susceptible to flooding. Businesses which are directly exposed to flooding will obviously suffer losses. In addition, businesses which are difficult to access—by employees or customers—are also more susceptible to loss in flood conditions. Businesses which rely on shipping by truck or freight train that travel routes passing through a floodplain may experience losses, too.

Potential Impacts

In this section of the report, we discuss what potential impacts the County may face in the future. This involves using FEMA's Hazus software to develop loss estimates and social impacts.

People

During a 100-year flood event, some households are going to be displaced and some part of that population is going to seek public shelter. Others may be injured or killed if they become trapped in their homes or vehicles. Every family in a home that was impacted by the 100-year flood scenario will be assumed to be displaced. Hazus was used to determine how many people in these households would seek public shelter, based on their average annual household income. Table 65 shows the displaced households and shelter requirements for the current 100-year floodplain and 2075 high emissions scenario 100-year floodplain.

Table 65: Displaced Households and Shelter Requirements

Flood	Displaced Households	Shelter Requirements (People)
Current 100-year Floodplain	196	82
Future 100-year Floodplain	441	188

Natural Features

Figure 142 shows the loss data due to floods and precipitation from USDA for the years 1992 through 2020. For that 29-year timespan, there was $3,437,244 in recorded losses or losses of approximately $118,526 per year. Table 58 shows the current and future annualized losses for agriculture due to flooding and precipitation.

Table 66: Flood Agricultural Losses due to flood and precipitation

Loss	Current (Avg. Ann.)	2075 High Emissions
Annualized Agricultural Loss	$118,526	$296,315

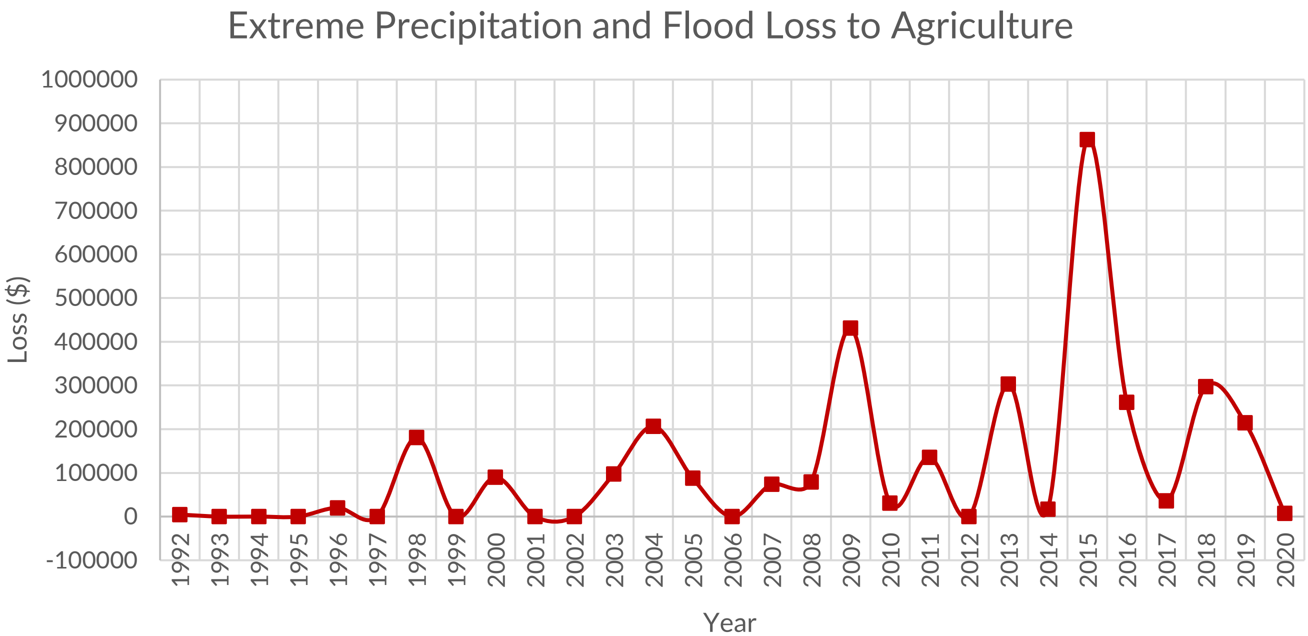


Figure 142: Agricultural Loss due to Flood and Precipitation, 1992-2020 (USDA, 2020)

Built Environment

To determine the current and future building losses for the county, we integrated the floodplains and building inventory into the Hazus software. The building footprint and parcel data were used to create a site-specific dataset for the County—which included the building's replacement value, content value, use, and first floor height based on elevation certificates when they were available. Hazus used the flood depth at the site's location with the building characteristics to determine the structure, content, and inventory losses. Table 67 shows the losses for the current and future 100-year floodplain. The future loss assumes that no additional buildings would be built in the future floodplain. Currently, building in the current 100-year FEMA regulatory floodplain is prohibited by the County but there is no prohibition on building in the future floodplain. Figure 143 shows the building loss for the current 100-year scenario by building occupancy while Figure 144 shows the building loss for the future 100-year scenario.

Table 67: Hazus Losses for Current and Future Flooding

Flood Source	Structure Loss ($)	Content Loss ($)	Bus. Inventory Loss ($)	Total Loss ($)	Annualized Loss ($)
Current 100-year Floodplain	22,264,520	26,950,912	1,097,677	50,313,109	503,131
Future 100-year Floodplain	86,275,731	107,720,546	7,601,657	201,597,934	2,015,979

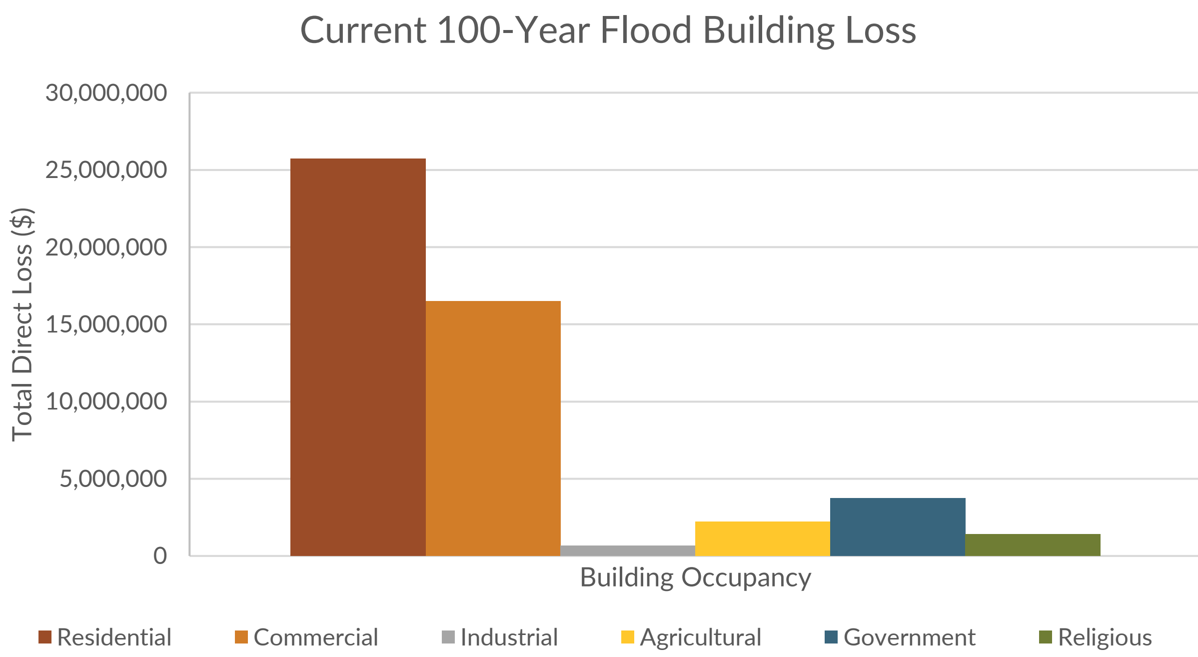


Figure 143: Current 100-Year Flood Building Loss

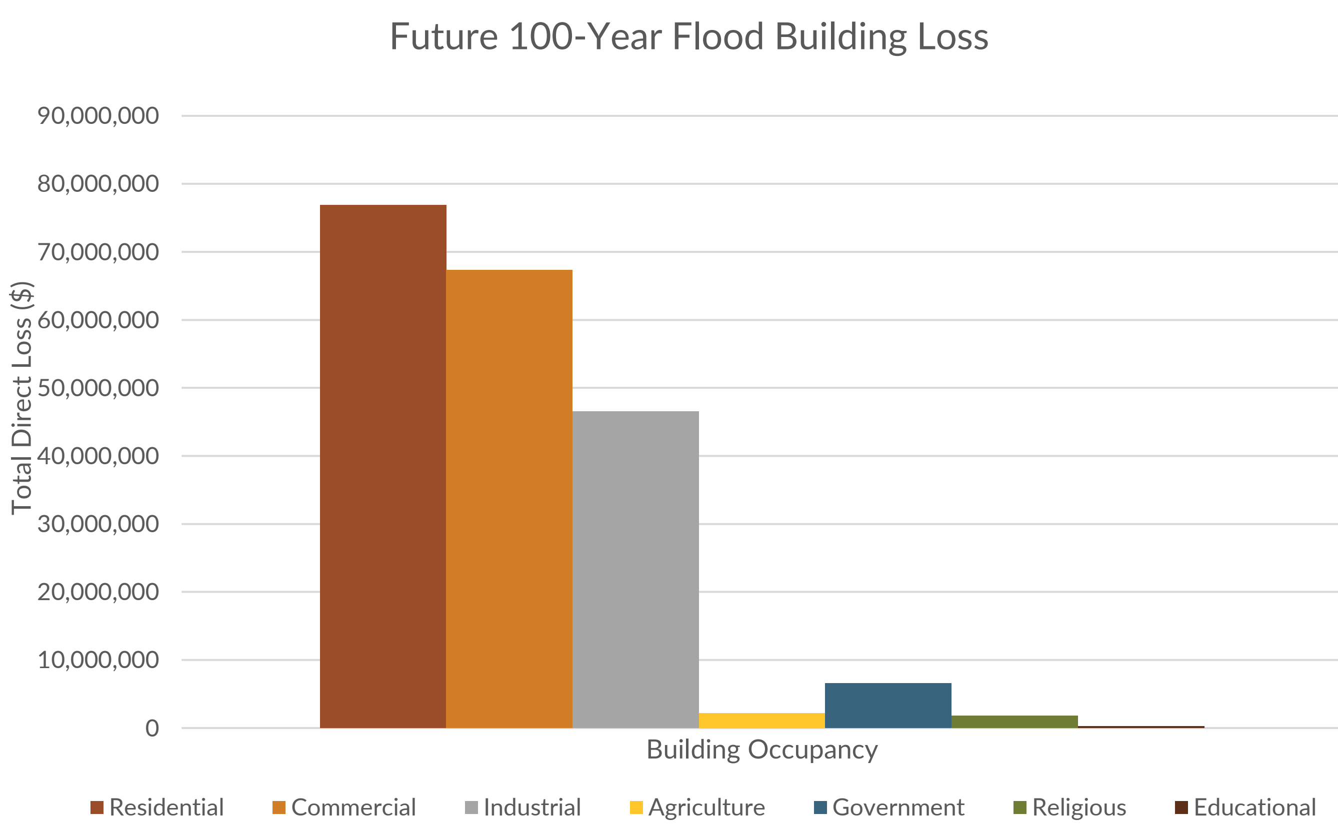


Figure 144: Future 100-Year Flood Building Loss

Economy

We also used Hazus to model the economic losses to the businesses and industry of Albemarle County. Hazus calculates the business interruption losses due to business relocation, rental income loss, capital related loss, and income loss. Business square footage and regional business parameters were used to model these losses.

Table 68 shows the business interruption losses for the current and future 100-year scenarios.

Table 68: Business Interruption Losses

Flood Source	Relocation Loss ($)	Rental Income Loss ($)	Capital Related Loss ($)	Income Loss ($)	Total ($)	Annualized Loss ($)
Current 100-year Floodplain	165,600	22,602,608	7,888,940	49,295,549	79,952,697	799,527
Future 100-year Floodplain	302,539	38,254,786	25,808,411	161,268,788	225,634,524	2,256,345

We used the County's parcel data and Hazus to determine which types of businesses were impacted by the current and future 100-year flood. Figure 145 shows the number of businesses impacted by the current 100-year flood scenario while Figure 146 shows the number of businesses impacted by the future 100-year flood scenario.

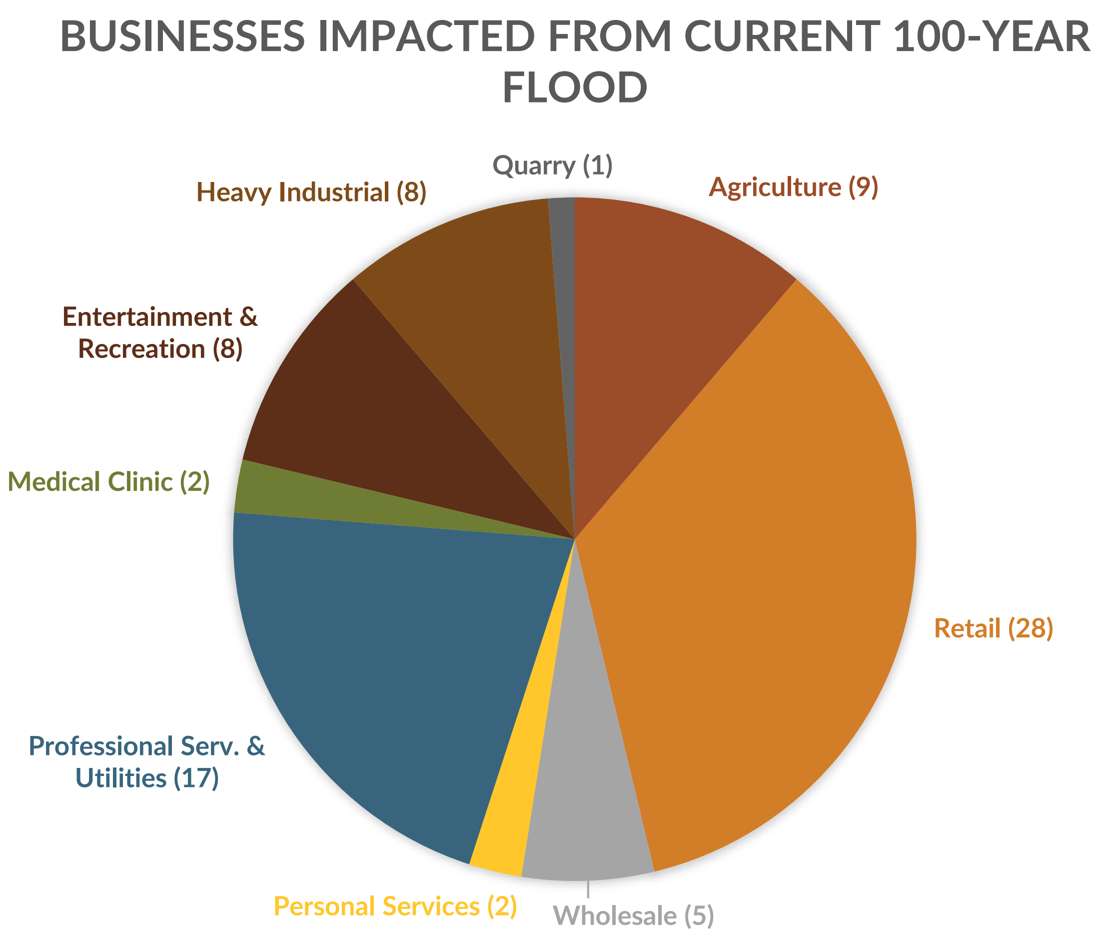


Figure 145: Businesses Impacted by Current 100-Year Flood

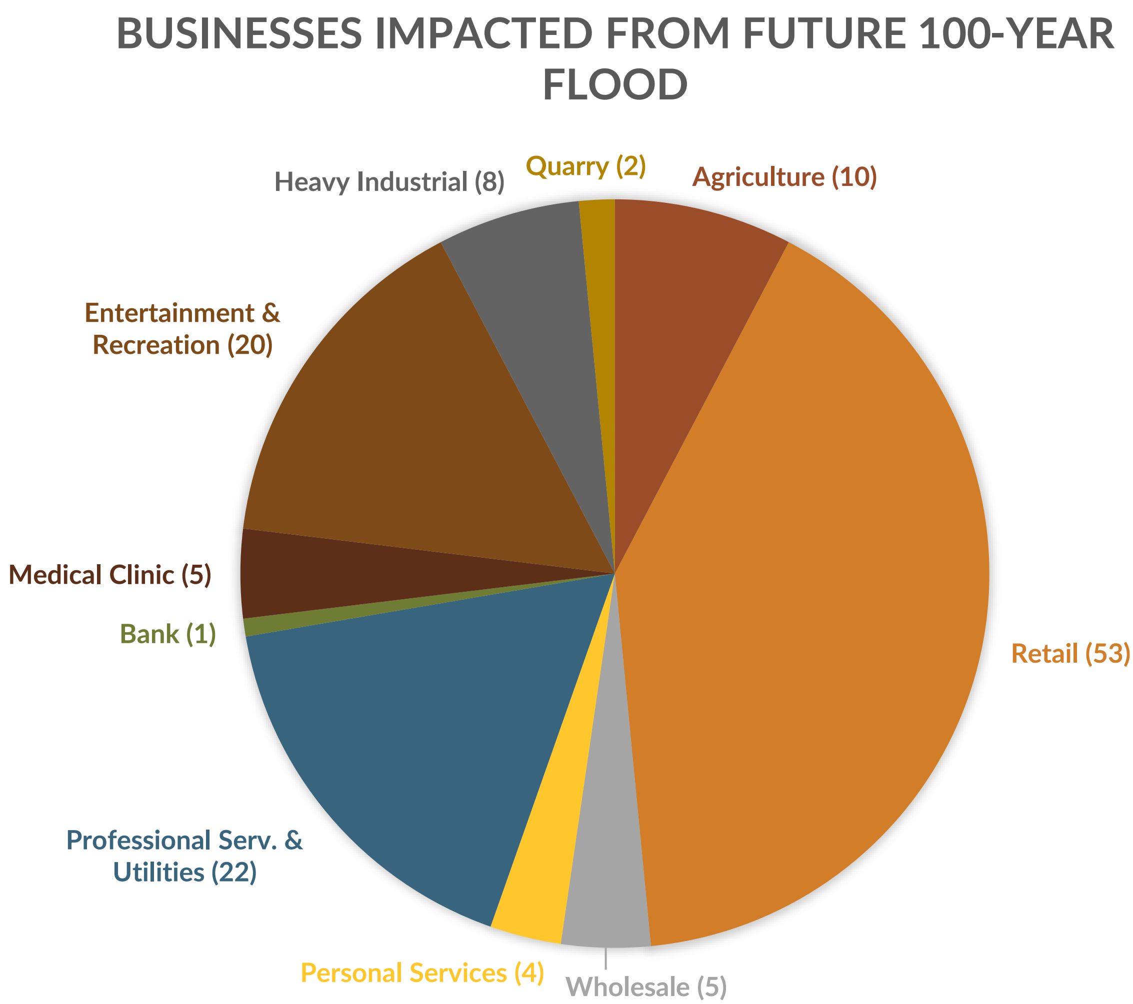


Figure 146: Businesses Impacted by Future 100-Year Flood

Chapter 7: Pests and Diseases

What We Can Expect

2050	+25-30 additional days per year of mosquito activity +19-23 additional days per year of tick activity +39,256 additional people exposed to tick-borne disease area of concern	Increased chance of Fusiform Rust and Brown Spot Needle Disease Increased chance of Southern Pine Beetle and Pine Reproduction Weevils	Increased medical capacity to treat +80 additional Lyme Disease cases per year Increased pest control around buildings	86 agricultural, forestry, fishing, and hunting businesses potentially impacted 686 employees potentially impacted $57.7M of GDP potentially impacted
2075	+30-43 additional days per year of mosquito activity +24-34 additional days per year of tick activity +72,368 additional people exposed to tick-borne disease area of concern	Increased chance of Fusiform Rust and Brown Spot Needle Disease Increased chance of Southern Pine Beetle and Pine Reproduction Weevils	Increased medical capacity to treat +150 additional Lyme Disease cases per year Increased pest control around buildings	86 agricultural, forestry, fishing, and hunting businesses potentially impacted 686 employees potentially impacted $57.7M of GDP potentially impacted
Identifying Vulnerabilities				
	• Elderly and children • Below poverty line • Pre-existing health conditions • People working outdoors • Pet exposure	• Trees stressed due to drought conditions • Damaged trees from animal browsing, wind, lightning, flooding, wildfire	• Grass and brush height around buildings • Dryer landscaping without standing water	• Agriculture, forestry, fishing, and hunting • Recreation

This vulnerability and risk assessment focuses on existing pests and diseases impacting Albemarle County and those that may move into the county by 2050 or 2075. There is always the possibility that a pest or disease not currently found in the U.S. may by introduced from other parts of the world. Instead of listing all the worldwide pests and diseases, we decided to focus on those which have an easier, more direct path of migration. Pests and diseases which impact people, livestock, trees, and agriculture are considered in this document.

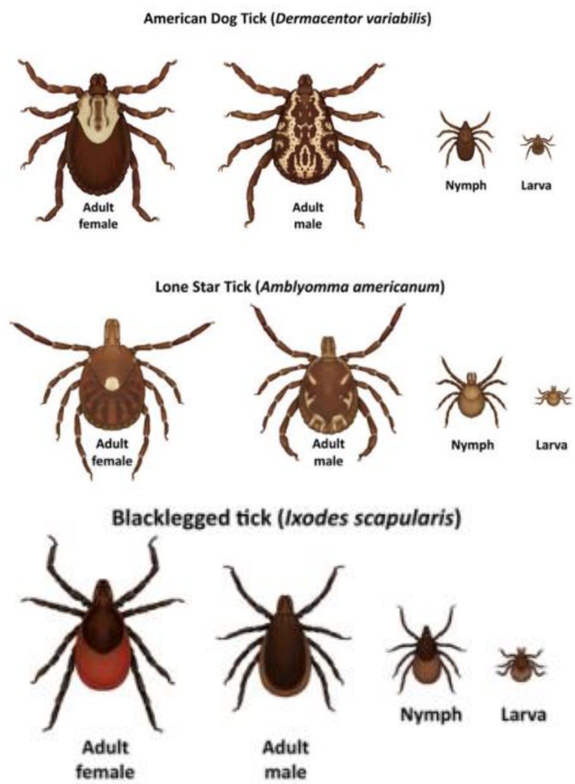
Background

Crop Biosecurity and Emergency Management

The USDA Animal and Plant Health Inspection Service (APHIS) manages the Plant Protection and Quarantine (PPQ) Program which safeguards U.S. agriculture and natural resources from the introduction, establishment, and spread of plant pests and noxious weeds. PPQ is the lead federal agency for plant health emergencies and works closely with federal, state, and local agencies; universities; industries; and private entities in developing and implementing science-based framework designed to protect against invasive pests and diseases. PPQ works within the National Plant Health Emergency Management Framework described here to provide preparedness, response, recovery, and pest exclusion.

Human Disease Emergency Management

The Center for Disease Control (CDC) works to protect the U.S. from diseases starting domestically and abroad. As the nation's health protection agency, CDC conducts critical science and provides health information that protects the U.S. against expensive and dangerous health threats and responds when they arise. The CDC funds several projects focusing on the spread of disease from ticks and mosquitoes.



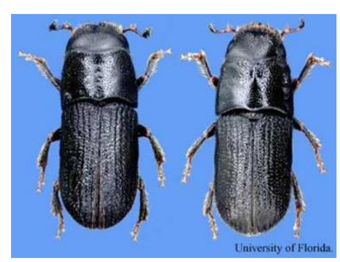
Human and Animal Pests

Ticks (native and non-native pest) are external parasitic arachnids that feed off mammals, birds, and sometimes reptiles and amphibians. In Virginia, there are three common ticks: (1) American Dog Tick, (2) Lone Star Tick, and (3) Deer Tick. The American Dog Tick is dark brown with wavy lines on its back and grow to be about 5mm long. It passes the diseases Rocky Mountain Spotted Fever and Tularemia. The Lone Star Tick is light reddish brown with a central white spot on its back and get about 5 mm long. It passes the diseases Alpha Gal, Ehrlichiosis, and Tularemia. The Deer Tick, also known as the Blacklegged Tick, is off-white or reddish and has black legs. It is a smaller tick usually 2-3mm in length. It passes the diseases Anaplasmosis, Babesiosis, and Lyme Disease. (Virginia Tech, 2014).

Mosquitoes (native and non-native pest) are small flying insects which suck the blood from humans and animals. In 2021, there have been 58 species of mosquito found in Virginia. One of the most aggressive mosquitoes is the Asian Tiger mosquito which is quicker than most mosquitoes, lives in a variety of environments and conditions, bites during the daytime, and can be skittish biting multiple times. In Virginia, mosquitoes can spread Eastern Equine Encephalitis, Jamestown Canyon Virus, La Crosse Virus, St. Louis Encephalitis, and West Nile Virus.

Tree and Vegetative Pests

Southern Pine Beetle (native pest) is a very destructive invasive insect native to the southeastern U.S. To reproduce, the southern pine beetle (SPB) must kill its host pine. Large populations of SPB can destroy forests and urban forests, recreational areas, and habitats for endangered species.



Other Bark Beetles (native pest) include more than 600 species of beetles which serve in important ecological roles in small numbers where they live in dead, weakened, and dying host conifer trees.

Pine Reproduction Weevils (native pest, right) is a very dark, elongate, oval insect up to 1/2 inch long with indistinct to distinct gray or pale orange spots of scales on the wings and thorax. They feed at night on the conifer seedlings or near the tips of branches of larger plants. Females lay their eggs on the roots of these trees. The weevils breed in all species of pines, hemlocks, junipers, spruces, firs, and cedars.

Nantucket Pine Tip Moth (native pest, right) is a moth with heads, bodies, and appendages covered with gray scales with mottled rusty-red markings. Larvae causes damage to young trees (up to five years old) by feeding inside growing shoots, buds, and conelets. The preferred host is the loblolly pine.

Forest Tent Caterpillar (native pest, right) has the biggest footprint of any indigenous tent caterpillar in North America (Furniss and Carolin 1977) and is a major defoliator of a variety of deciduous hardwood trees. The caterpillars spin silken mats on the trunks and large branches of trees where they molt and feed. Forest Tent Caterpillars can reach outbreak proportions causing massive defoliation of host trees and becoming a nuisance to people.

Hardwood Borers (native pest) usually attack hardwoods experiencing some kind of stress, although the clear-wing moths (right) attack healthy trees. These insects attack the tree year after year and may eventually weaken it enough that it is prone to wind breakage. Some borers develop in the root system, damaging young trees. Emerald Ash Bores have also destroyed much of the Ash population in Virginia.

Figure 4. Adult clear-wing moth. *Photo: James Solomon, USDA Forest Service, Bugwood.org.*

Hemlock Wooly and Balsam Wooly Adelgid (non-native pest, right) is a very small, invasive, aphid-like insect that attacks North American hemlocks (Hemlock Wooly) and firs (Balsam Wooly). They can be identified by the white woolly masses that form on the underside of branches at the base of the tree's needles. They stay at this location for the rest of their lives. Their feeding disrupts the flow of nutrients to the tree twigs and needles leading to a decline in tree health and mortality in 4 to 10 years.

Gypsy Moth (non-native pest, left) is an insect which feeds on a large variety of tree leaves from oak, maple, apple, crabapple, hickory, basswood, aspen, willow, birch, pine, spruce, hemlock, and others. It does prefer oak tree leaves, however. Periodically, large populations can cause defoliation damaging and killing trees they are feeding on.

Spotted Lanternfly (non-native pest, below) is an invasive insect first detected in the U.S. in 2014. It feeds on a variety of fruit, ornamental, and wood trees and could seriously impact the grape, orchard, and logging industries. Below appear different stages of development: first instar nymph (left), fourth instar nymph (middle), egg mass (right, left tree trunk), and mature adults (right, right tree trunk) (USDA Animal and Plant Health Inspection Service).

Human and Animal Diseases

Lyme disease is the most common vector-borne disease in the United States and is transmitted to humans through the bite of infected blacklegged ticks. Typical symptoms include fever, headache, fatigue, and a characteristic skin rash (red center surrounded by a clear ring with a red circle around it). If left untreated, infection can spread to joints, the heart, and the nervous system. Lyme disease is diagnosed based on symptoms, physical findings (e.g., rash), and the possibility of exposure to infected ticks. Most cases of Lyme disease can be treated successfully with a few weeks of antibiotics.

Eastern Equine Encephalitis (EEE) is a very uncommon (only a few cases in U.S. per year) virus spread to people by the bite of an infected mosquito. Most cases occur in eastern or Gulf Coast states. Although rare, EEE is very serious with an approximate mortality rate of 30%. Many survivors have ongoing neurologic problems.

Jamestown Canyon Virus is spread to people by infected mosquitoes. The virus is found throughout much of the United States, but most cases are reported from the upper Midwest. Cases occur from late spring through mid-fall. Fever, headache, and fatigue are common symptoms with Jamestown Canyon virus disease. Jamestown Canyon virus can cause severe disease, including encephalitis (inflammation of the brain).

La Crosse Virus is spread to people by the bite of an infected mosquito. Most people infected with the virus do not have symptoms. Some people may develop severe disease, including encephalitis (inflammation of the brain). Severe disease occurs most often in children under 16 years of age. Most cases occur in the upper Midwestern, mid-Atlantic, and southeastern states.

St. Louis Encephalitis is a virus spread to people by the bite of an infected mosquito. Most people infected with SLE virus do not have symptoms. Those people who do become ill may experience fever, headache, nausea, vomiting, and tiredness. Some people may develop encephalitis (inflammation of the brain) or meningitis (inflammation of the membranes that surround the brain and spinal cord). In rare cases, long-term disability or death can occur.

West Nile Virus (WNV) is the leading cause of mosquito-borne disease in the continental United States. It is most commonly spread to people by the bite of an infected mosquito. Cases of WNV occur during mosquito season, which starts in the summer and continues through fall. Most people infected with WNV do not feel sick while about 1 in 5 people who are infected develop a fever and other symptoms. About 1 out of 150 infected people develop a serious, sometimes fatal, illness.

Babesiosis is caused by microscopic parasites that infect red blood cells and are spread by blacklegged ticks. Many people who are infected feel fine and do not have any symptoms. Some people develop flu-like symptoms, such as fever, chills, sweats, headache, body aches, loss of appetite, nausea, or fatigue. Because Babesia parasites infect red blood cells, babesiosis can cause hemolytic anemia.

Plague is a disease that affects humans and other mammals caused by the bacterium, Yersinia pestis. Humans usually get plague after being bitten by a rodent flea that is carrying the plague bacterium or by handling an animal infected with plague. In the U.S., the numbers of rats increase in years when winter temperatures are higher which allow rats to have more litters (Andreassen 2021).

Avian Influenza (also known as H5N1 and bird flu) are strains of the influenza virus that primarily infect birds. These viruses occur naturally among wild aquatic birds worldwide and can infect domestic poultry and other bird and animal species. It does not normally infect humans. Signs and symptoms of bird flu infections in people can include: fever or feeling feverish, cough, sore throat, runny or stuffy nose, muscle or body aches, fatigue, headaches, eye redness (or conjunctivitis), and difficulty breathing. Other possible symptoms are diarrhea, nausea, and vomiting (CDC 2022).

Harmful algal blooms are the rapid growth of algae or cyanobacteria that can cause harm to people, animals (including pets and livestock), and the local ecology. It can look like foam, scum, paint, or mats on the surface of water and can be different colors. These blooms can produce toxins that make people and animals sick. Blooms occur in fresh water, such as lakes and rivers, and salt water, such as oceans or bays.

Tree Diseases

Fusiform Rust is a widespread and damaging disease of loblolly pine and slash pine in the southeast U.S. that is caused by a fungus. The disease leads to rust galls or cankers on the main stem and/or branches of trees. Rust galls effect wood quality and yield by causing deformed and broken stems in young trees.

Brown Spot Needle Disease impacts Longleaf Pine seedlings, which are heavily infected while in the grass stage and often die after repeated defoliations. Nursery grown longleaf pine seedlings are particularly susceptible. The most common symptom is dead needles of seedlings and small saplings. The seedling appears dead, but close examination will usually reveal a green and healthy bud. Infected needles develop gray-green spots, which later turn brown. Eventually, a yellow band develops on the needle.

Oak Wilt is a vascular disease caused by a fungus that spreads locally from infected trees to nearby healthy trees. Primarily transmitted through root grafts, it causes sudden wilting (especially in the red oak group), early leaf drop, discolored leaves, and sometimes, vascular streaking in the sapwood. Some oaks develop brown veins in their leaves, although green tissue remains. Early symptoms are wilting, bronzing, and shedding of leaves at the ends of branches. Bronzing begins on the tips and outer margins of leaves and spreads to the midribs and base.

Oak Decline is a slow-acting disease complex that involves the interaction of predisposing factors such as climate, site quality and advancing tree age. No single cause is responsible for the decline. Trees that are greater than 70 years of age and that occur on drier sites such as shallow, rocky soils on ridgetops and south- to west-facing upper slopes are most affected. Mortality of rootlets in the upper 12 inches of the soil initiates dieback in severe droughts. The first indication of oak decline is the progressive dieback of one-third to one-half of the upper crown leaves from the tips of the branches.

Littleleaf Disease (right) is the most serious disease of shortleaf pine in the southern U.S. It is a disease caused by a combination of different factors including a fungus, low soil nitrogen, and poor internal soil drainage. Littleleaf disease rarely occurs in younger trees less than 20 years old and becomes increasingly severe in older stands. Annual losses to Littleleaf disease are $15 million.

Dogwood Anthracnose (left) is a fungal disease impacting dogwood trees with leaf blight and canker. Symptoms of infection include angular-shaped leaf spots and blotches, marginal leaf scorch, and a complete blight of infected foliage. Leaf spots are round to blotchy and have tan centers with reddish-purple margins. Additionally, succulent shoots and small stems can be killed and perennial cankers can develop on larger branches. Stem and branch cankers disrupt water and mineral transport, leading to a progressively worsening canopy dieback.

Beech Bark Disease (right) is caused by a pathogen that does not attack trees until they have been extensively infested with a non-native scale insect. The scale has mouthparts that pierce and suck, causing wounds through which the fungus can enter the tree. Larger trees are usually attacked first rather than juvenile trees.

The butternut tree (left) is being killed throughout its range by the Butternut Canker caused by the fungus described as a new species in 1979. Although there are no reports of this fungus causing disease outside of North America, it is thought to be an exotic pathogen.

Current and Future Conditions

Although some climate change effects can be beneficial, evidence suggests that, overall, pest problems are likely to become more unpredictable and larger in magnitude (Gregory et al. 2009). This is due in part to how the seasons will change in the future. The traditional winter season will become shorter with spring-like temperatures beginning earlier, fall-like temperatures ending later, and more summer-like temperatures lasting longer. These changes in seasons will alter the occurrence of pests and diseases creating a more hospitable environment longer during the year. However, predicting the effects of climate change on pests is not easy due to the complicated interacting influences of increasing atmospheric CO_2 concentration, changing climatic regimes, and altered frequency and intensity of extreme weather events (Bebber et al. 2013; Gregory et al. 2009). Projections are further challenged by the fact that climate change can also exert its effects on pests indirectly, such as the differing responses of host crops and natural enemies of pests. Other indirect pest responses result from changes in the efficacy of pest control strategies (e.g., biological control, synthetic pesticides, etc.) (Barzman et al. 2015; Lamichhane et al. 2015), as well as changes in land use and crop management practices, which can often have a greater effect on pest pressure than the direct effects of climate change alone (Hoffmann et al. 2008; Cock et al. 2013).

According to the CDC, there were 400 confirmed cases of Lyme disease in Albemarle County from 2000 to 2019 (averaging 20 cases per year). However, the CDC's data only represents confirmed cases and the actual number of cases is estimated to be 4,000 over the same period of time (CDC Surveillance Data). During 2019, Virginia had 302 cases of Rocky Mountain Spotted Fever, and 1 non-congenital Zika Virus confirmation.

Disease spread by mosquitos and ticks will increase in 2050 and 2075 since the temperatures required for these insects to be active will increase. Using the downscaled data for Albemarle County, average temperatures were compared with the temperatures at which these insects are active. Mosquitoes reach peak activity at 80°F and become inactive once the temperatures reach 50°F (NIH, 2017). Ticks go dormant once the temperatures reach 45°F. Table 69 shows the number of additional days in 2050 and 2075 that will have mosquito activity based on the change in average temperatures while Table 70 shows the number of additional days in 2050 and 2075 that will have tick activity. Figure 147, Figure 148, and Figure 149 show the months when mosquitoes will be active for the current conditions, 2050, and 2075. Figure 150, Figure 151, and Figure 152 show the months when ticks will be active for the current conditions, 2050, and 2075.

Table 69: Additional Days of Mosquito Activity

Year	Emissions Scenario	Additional Days of Mosquito Activity
2050	Low	24.5
2050	High	29.5
2075	Low	30.1
2075	High	42.9

Table 70: Additional Days of Tick Activity

Year	Emissions Scenario	Additional Days of Tick Activity
2050	Low	19.4
2050	High	23.3
2075	Low	23.9
2075	High	33.6

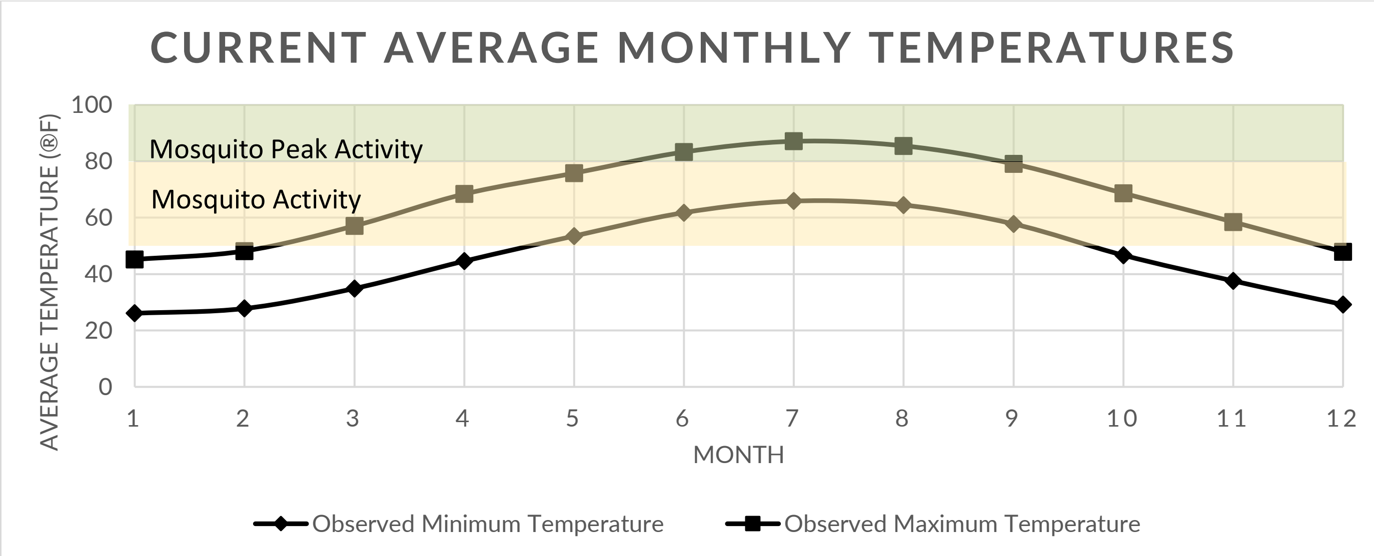


Figure 147: Current Mosquito Activity

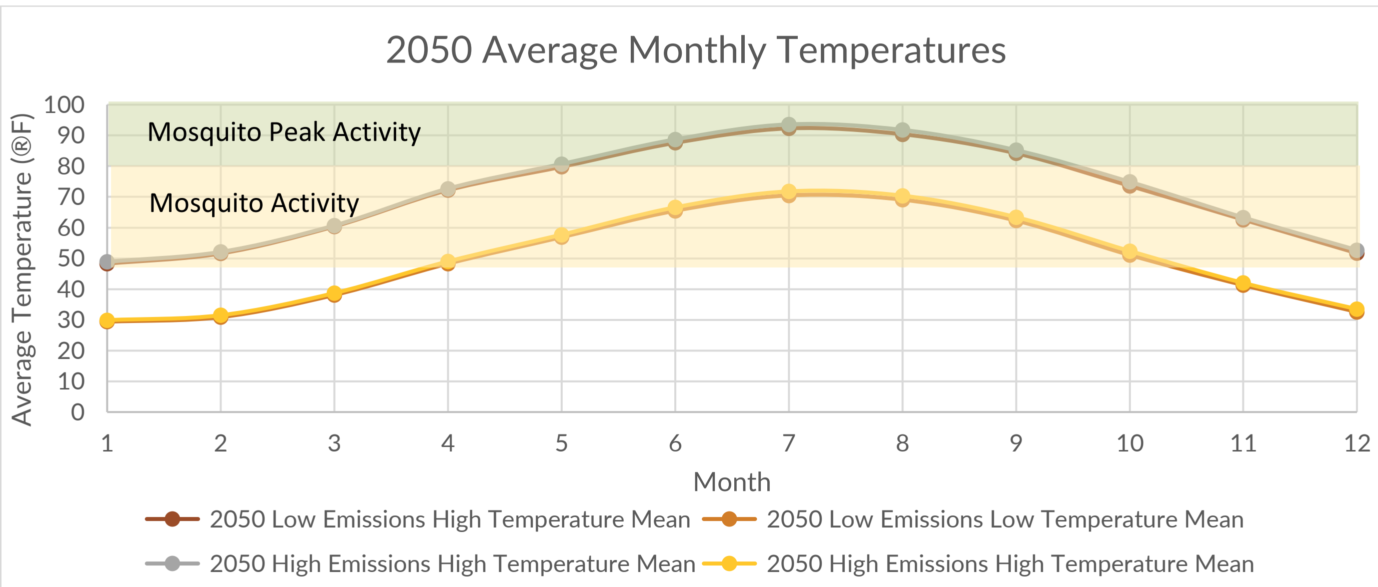


Figure 148: 2050 Mosquito Activity

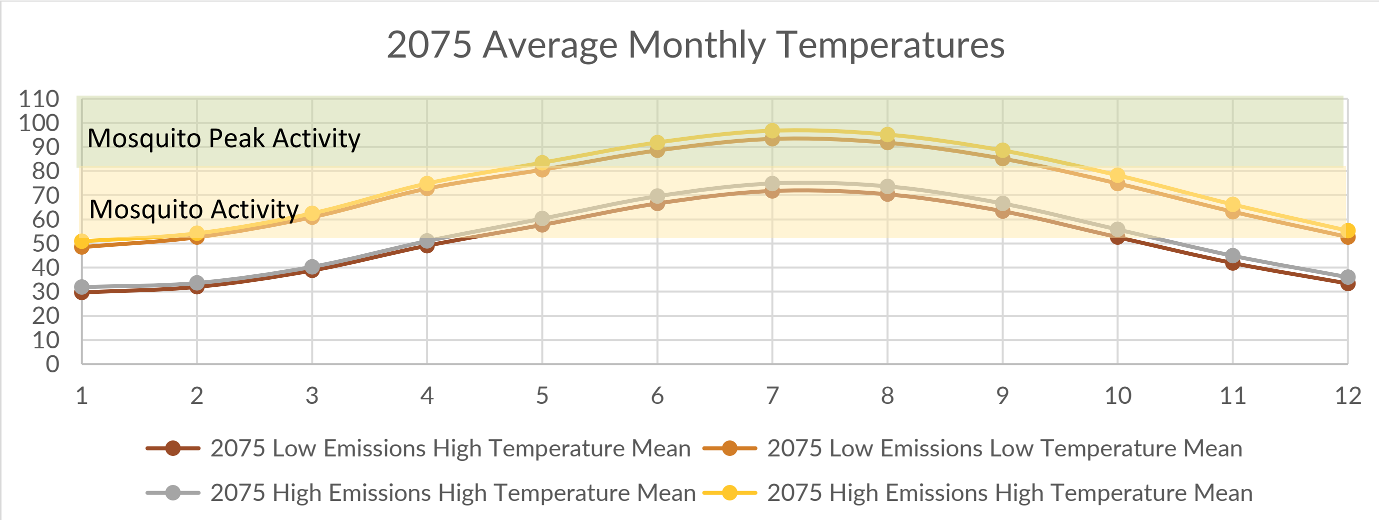


Figure 149: 2075 Mosquito Activity

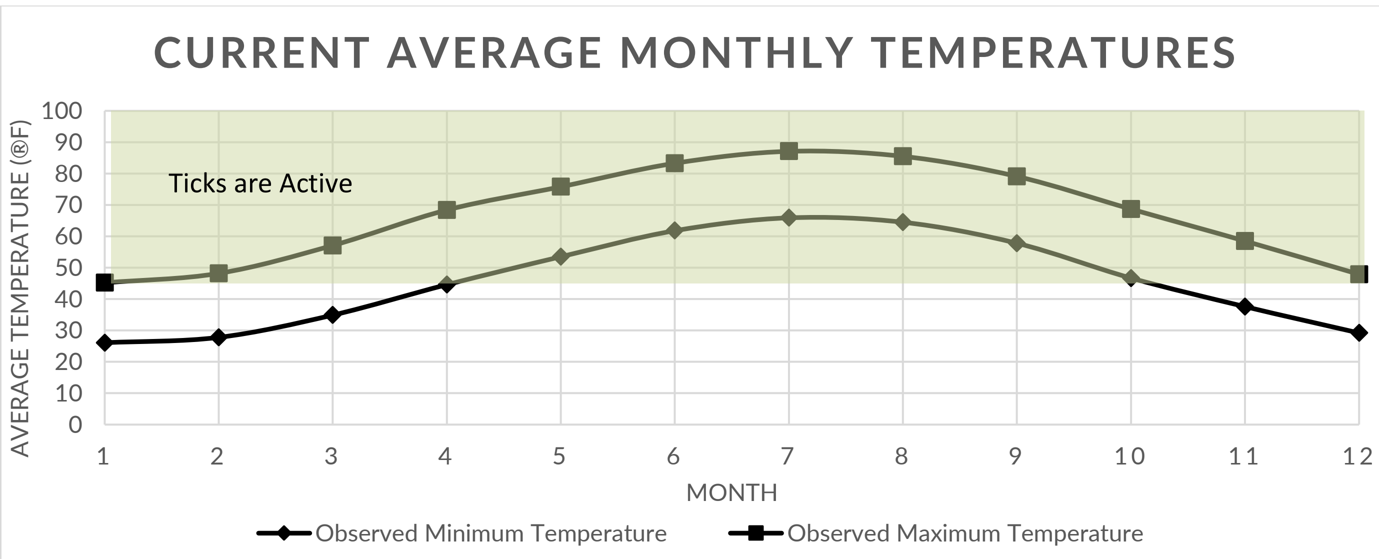


Figure 150: Current Tick Activity

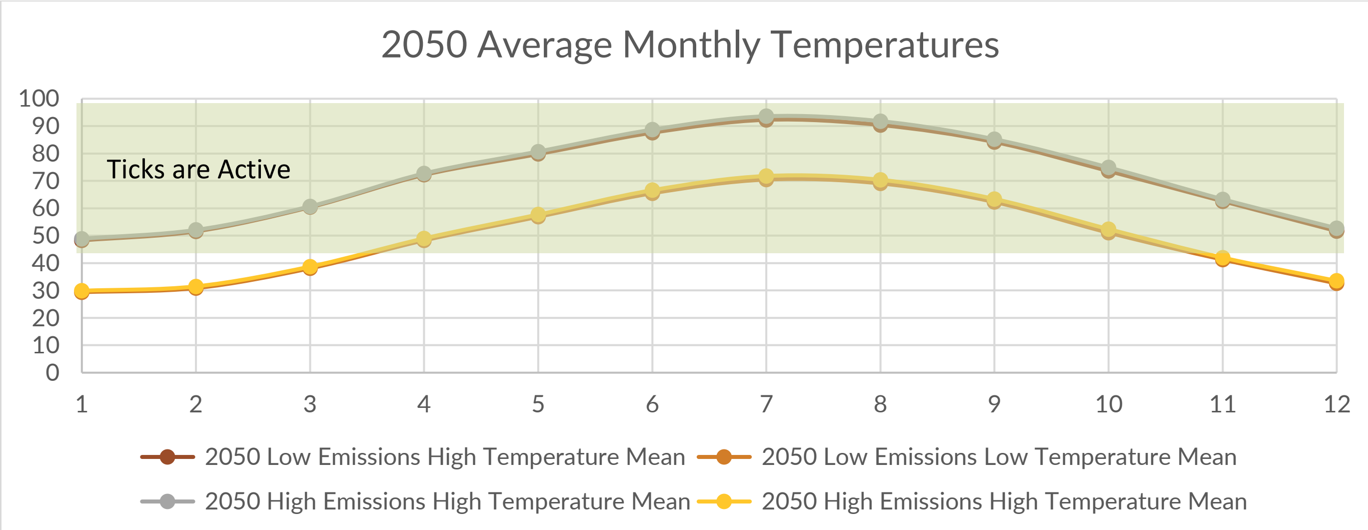


Figure 151: 2050 Tick Activity

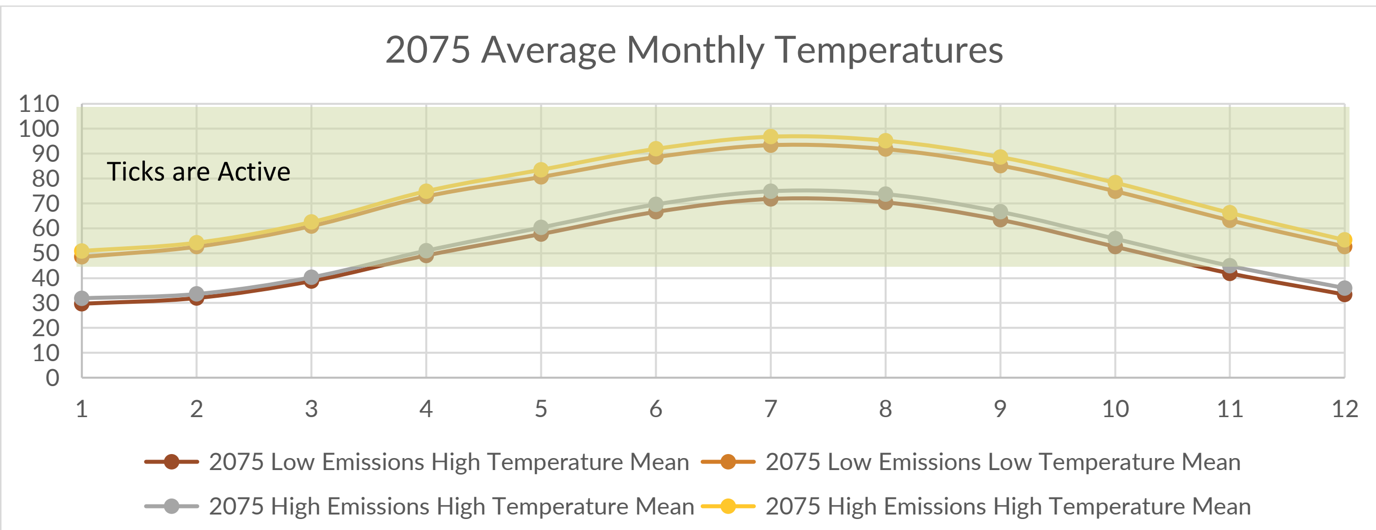


Figure 152: 2075 Tick Activity

Exposure

Most of the county will be exposed to mosquito- and tick-borne disease, but there are some areas which will be more likely to have these pests. Mosquitoes will be more likely to appear in areas with standing water but not permanent natural water features (e.g. ponds and lakes) where predators will eat mosquitoes and their larvae. The presence of ticks is highly likely at the edge of tree lines where there is a transition to cropland and pastureland (Virginia Tech, 2020).

The U.S. Forest Service has collected surveys for tree disease and pests from 1999 to 2018. Figure 153 shows the areas of concern identified by the USFS and what impacted those areas (disease name and pest name).

The additional number of days when mosquitoes and ticks are active is going to increase exposure to the community. From Table 69 and Table 70, the average number of additional days in which mosquitoes will be active is 25-30 (year 2050) and 30-43 (year 2075) while the average number of additional days in which ticks will be active is 19-23 (year 2050) and 24-34 (year 2075).

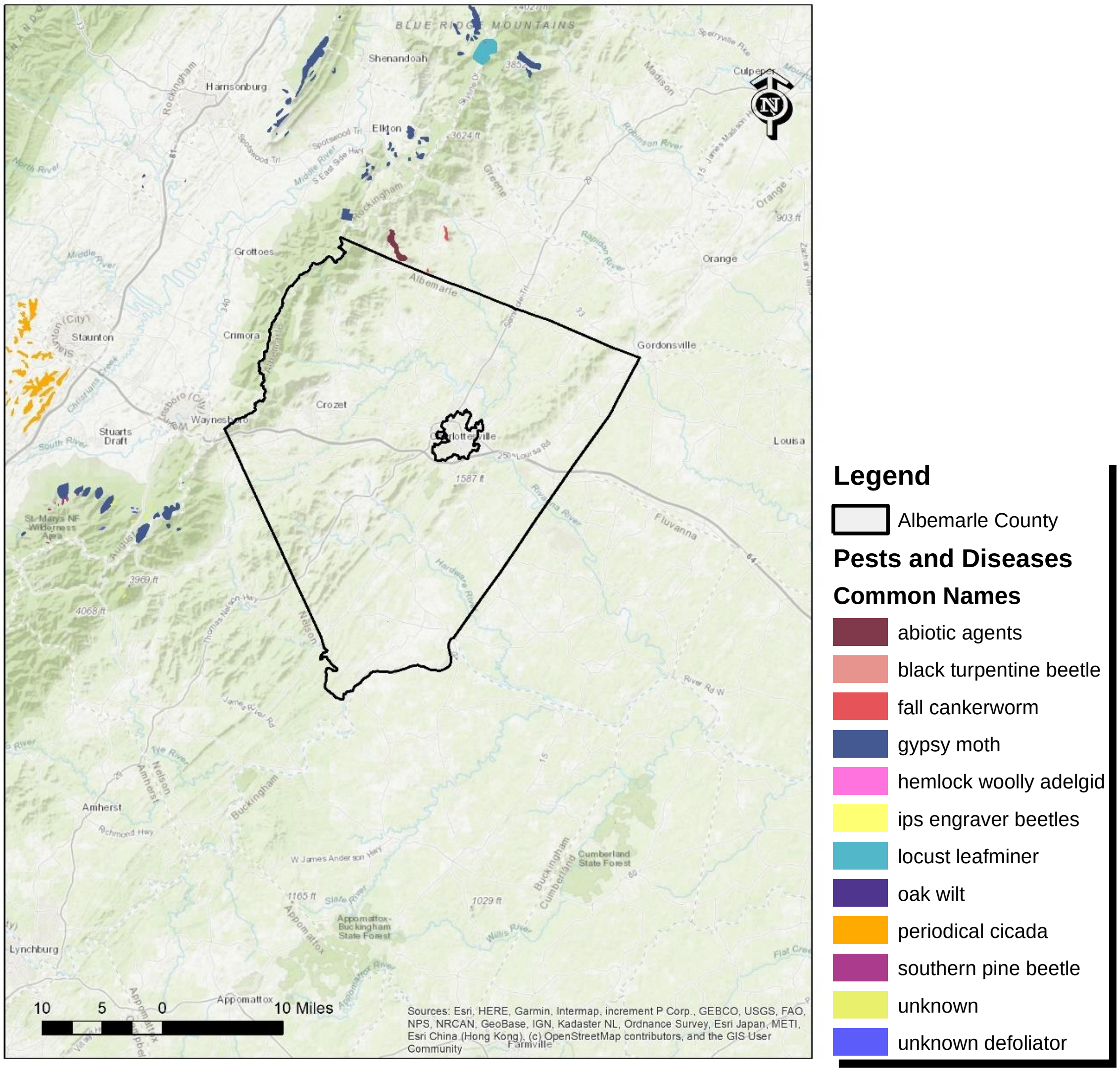


Figure 153: Pests and Diseases Monitored by USFS (2021)

Vulnerability

The vulnerability assessment helps identify susceptibilities in our community so that actions may be taken to reduce potential impacts. This is different from a risk assessment which includes a likelihood component. We know diseases and pests are going to occur in the future and this section focuses on what makes our community vulnerable.

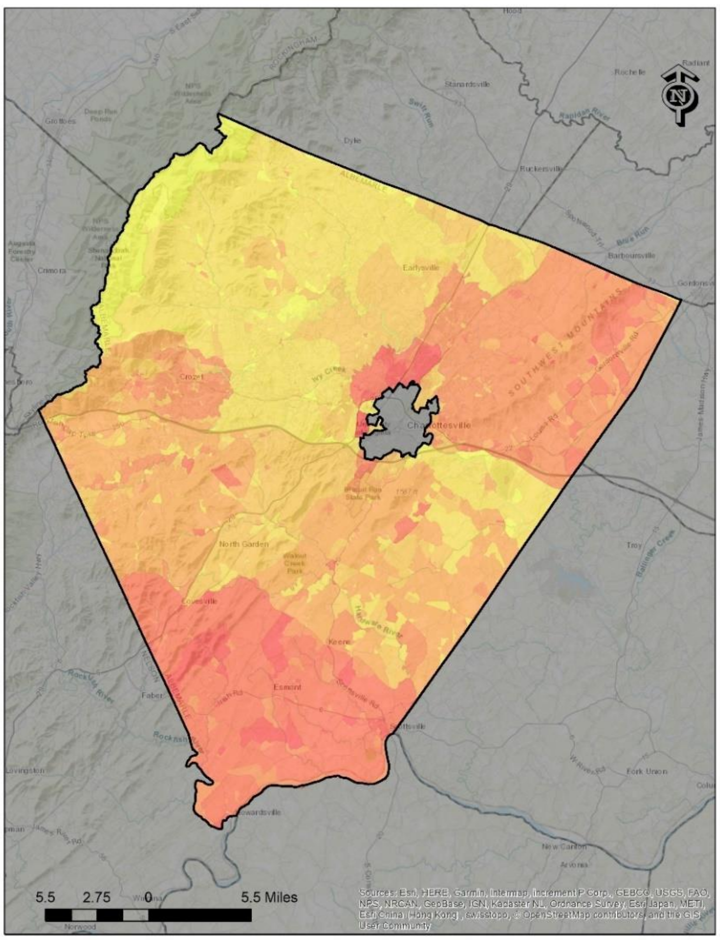
People

The social vulnerability assessment includes identifying different characteristics of the population which increase your susceptibility or decrease your ability to adapt. This component of the vulnerability assessment includes household indicators (Table 71) and poverty indicators (Table 72). Each set of indicators will be used to create and map a vulnerability score which will be combined in the end to create an overall social vulnerability score. Each component of the social vulnerability indicator will be weighted the same. Figure 154 is a map which shows the household indicator for the county.

Additionally, pets should be checked for ticks every time they are let outdoors. Your veterinarian may have some pest control recommendations.

Table 71: Social Vulnerability - Household Indicators

Household Indicators
65 years or older
65+ Years Old and Living Alone
Grandparent Responsible for Grandchild Under 18
Under 18 years
Single Parent Household
No High School Diploma
Limited English



Observations

The high value areas outside of Charlottesville are due to the high percentage of elderly, children, education, and single parent households.

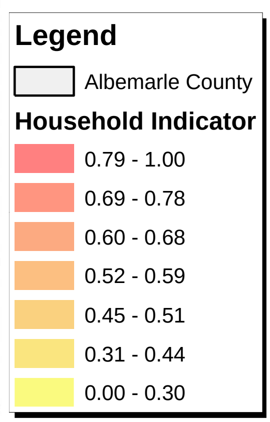


Figure 154: Social Vulnerability - Household Indicators

Figure 155 is a map which shows the poverty indicators in the pest and disease hazard area.

Table 72: Social Vulnerability - Poverty Indicators

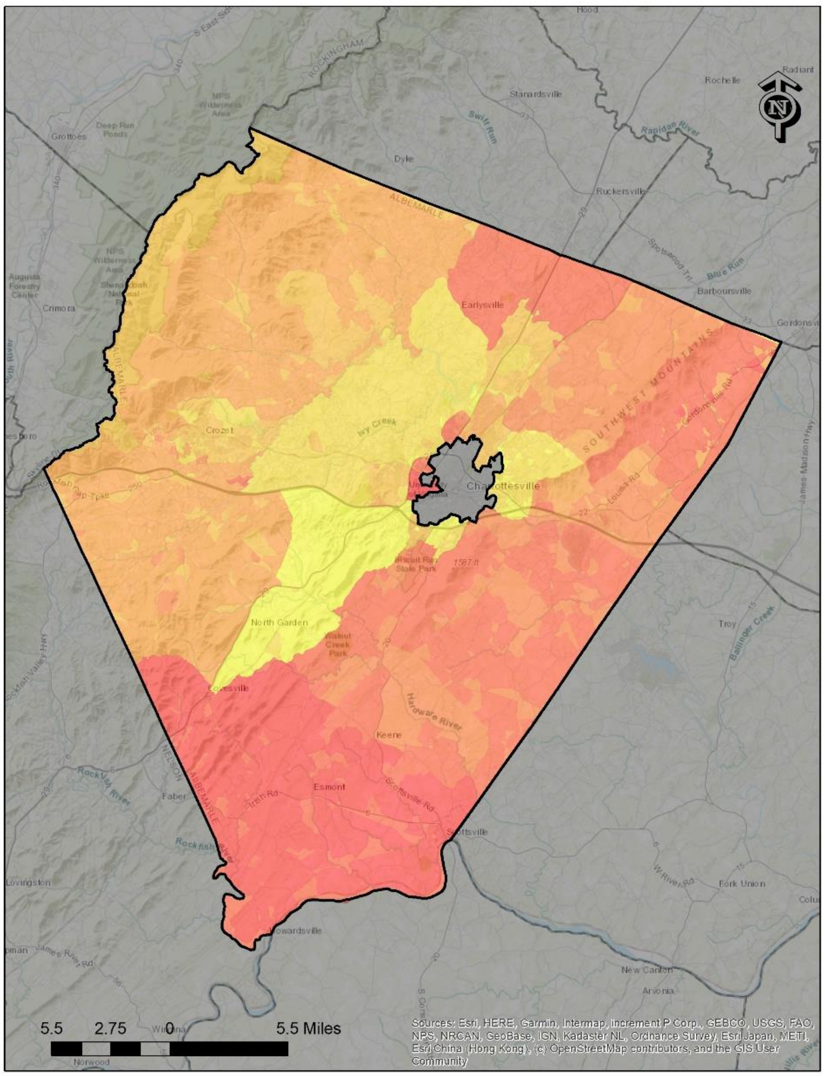
Poverty Indicators
Median Annual Household Income
Below Poverty Level
SNAP/Food Stamps
Received Public Assistance Income
Housing Costs 30% or More of Income
Crowding (More People Than Rooms)
Unemployed
No Vehicle Access

Observations

The red areas north of Charlottesville along the Greene and Orange County borders have a high poverty indicator due to home costs relative to income and large number of people on public assistance.

The red areas in the southern part of the county have a high poverty indicator due to the median income, home costs relative to income, and unemployment.

The red areas directly west of Charlottesville have a high poverty indicator due to the number of people living below the poverty line, the median income, and the high level of unemployment.



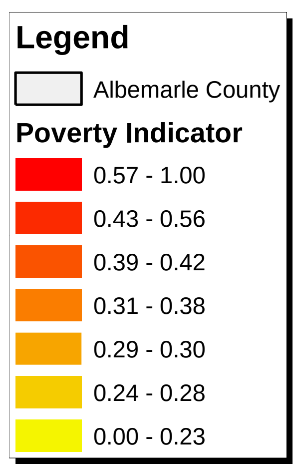


Figure 155: Social Vulnerability - Poverty Indicators

Natural Features

Most of the natural features in Albemarle County have some susceptible to diseases and pests including the trees and orchards, forested areas, agriculture, livestock, and parks. Trees that have been damaged by other events such as fire, wind, flooding, and animal browsing are more susceptible to diseases and pests. Certain species of trees are more susceptible based on the need of the damaging organism. This information is provided in the background section of this chapter.

Livestock, such as horses and cows are susceptible to disease-carrying pests and farmers should ensure standing water is not available for mosquitoes and deer are kept out of the fields. Other types of livestock, such as chickens and other domestic fowl, are not susceptible to these pests and can be used as pest control.

The increasing frequency of heat stress, drought, and flooding events could translate into the increased spread of existing vector-borne diseases and macro-parasites, along with the emergence of new diseases and transmission models (IFAD, 2002). Livestock management practices such as controlling which animals enter and leave an area; quarantining sick animals; implementing appropriate antibiotics, vaccines, and diagnostic tools; practicing good hygiene; controlling disease vectors; and adopting other biosecurity measures can make livestock less vulnerable.

In their climate vulnerability publication, *Survival by Degrees: 389 Bird Species on the Brink,* the National Audubon Society lists the following numbers of vulnerable bird species in Central Virginia: 17 with high vulnerability, 26 with moderate vulnerability, and 21 with low vulnerability. Specific bird species are found on their website: (https://www.audubon.org/climate/survivalbydegrees).

Built Environment

Although there aren't direct risks to the built environment, the built environment can lower the vulnerability of people and natural features. Buildings and infrastructure which create standing water for mosquito larvae are more susceptible to mosquito-borne disease. Dry landscaping which and integrating predators (e.g. fish) into ponds helps create a less susceptible area for mosquito-borne disease.

To reduce susceptibility to ticks, tick-free areas can be established around buildings. Figure 156 shows examples of reducing tick activity. Examples of reducing tick populations near buildings include:

- Keep grass mowed.
- Remove leaf litter, brush and weeds at the edge of the lawn.
- Restrict the use of groundcover, such as pachysandra in areas frequented by family and roaming pets.
- Remove brush and leaves around stonewalls and wood piles.
- Discourage rodent activity. Clean up and seal stonewalls and small openings around the home.
- Move firewood piles and bird feeders away from the house.
- Use plantings that do not attract deer (contact your local Cooperative Extension or garden center for suggestions) or exclude deer through various types of fencing.
- Move children's swing sets and sand boxes away from the woodland edge and place them on a wood chip or mulch type foundation.
- Trim tree branches and shrubs around the lawn edge to let in more sunlight.
- Adopt dryer or less water-demanding landscaping techniques with gravel pathways and mulches. Create a 3-foot or wider wood chip, mulch, or gravel border between lawn and woods or stonewalls.

- Consider areas with decking, tile, gravel and border or container plantings in areas by the house or frequently traveled.
- Widen woodland trails.
- If you consider a pesticide application as a targeted treatment, do not use any pesticide near streams or any body of water, as it may kill aquatic life or pollute the water itself.

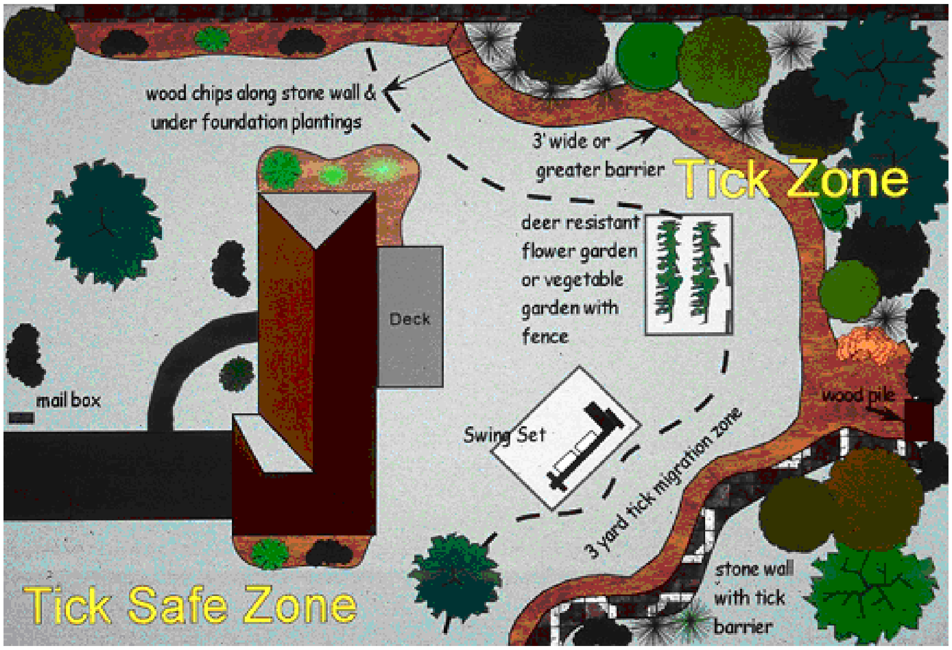


Figure 156: Tick Safe Zones Around Buildings (New York Department of Health)

Economy

There are certain economic sectors which are more susceptible to diseases and ticks. Businesses which require staff or customers to be outdoors exposed to pests will suffer losses as will industries which harvest agriculture and trees. Table 73 provides information on those industries which may be more susceptible to disease and pests. Information concerning the number of employees, wages, and number of businesses along with a percentage of the industry compared to the others in the County is provided.

Table 73: Industries Susceptible to Extreme Heat

Albemarle County Industry	Employees	Employees (% of Total)	Wages (x$1000)	Wages (%)	Businesses (Number)	Businesses (%)
Agriculture, Forestry, Fishing, and Hunting	686	1.7	20,129	1.0	86	2.3
Arts, Entertainment, and Recreation	1,730	4.3	50,691	2.5	66	1.7

Potential Impacts

In this section of the report, we discuss what potential impacts the County may face in the future. This involves reviewing historical impacts, the thresholds at which those impacts occurred, and then looking at the probabilities of reaching those thresholds in the future.

People

The social impacts related to disease and pestilence include additional human disease cases due to the increase in tick and mosquito activity. Additionally, the increased population in 2050 and 2075 will result in more people exposed to and impacted by the ticks and mosquitoes. Table 74 shows the current number of Lyme disease cases for Albemarle County residents based on the CDC data in the Current and Future Conditions section. Reviewing the number of other human illnesses spread by mosquitoes and ticks provided by CDC, Lyme disease makes up 75% of all cases. Assuming the Albemarle County average is similar to the national average, the current other human disease numbers were calculated. Using the populations estimates and the increased insect activity described in the current and future section, the 2050 and 2075 disease cases were modeled.

Table 74: Human Disease Cases Current and Future

Loss	Current (Avg. Ann.)	2050		2075	
		Low Emissions	High Emissions	Low Emissions	High Emissions
Annual Human Lyme Disease Cases	200	284	287	350	359
Annual Other Tick/Mosquito-Spread Human Lyme Disease Cases	13	18	19	23	23

Natural Features

The pestilence and disease loss data collected by the USDA for 2010 through 2020 was graphed and is provided in Figure 157. For that 11-year timespan, there were $769,212 in recorded losses or approximately $69,928 in annual losses. Table 75 shows the current and future annualized loss for agriculture due to pests and disease. With the increased average temperatures, insects will be active longer increasing the average annual loss to agriculture. Much of the impacts due to insects and diseases may be in conjunction with drought and extreme heat.

Table 75: Pest and Disease Agricultural Losses

Loss	Current (Avg. Ann.)	2050		2075	
		Low Emissions	High Emissions	Low Emissions	High Emissions
Annualized Agricultural Loss	$69,928	$73,645	$74,392	$74,507	$76,365

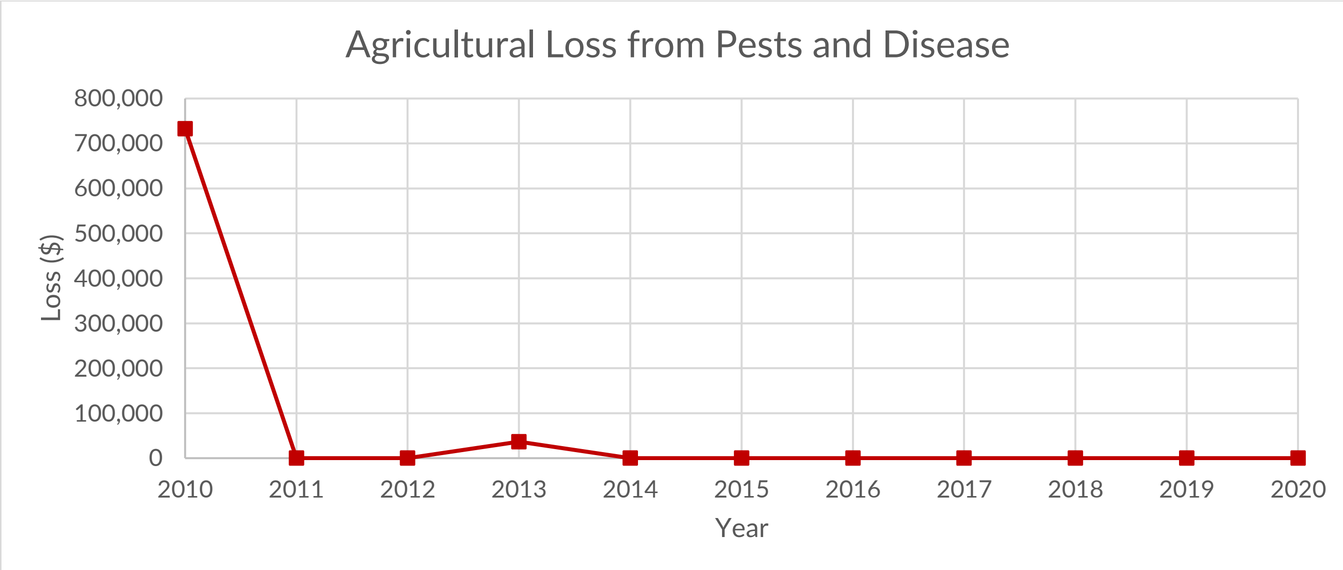


Figure 157: Agricultural Loss from Pests and Disease (USDA 2020)

Built Environment

Pests and diseases will have minimal impacts on the built environment.

Economy

The major economic sectors impacted by pests and diseases include the agricultural and forestry industries. It is difficult to model losses associated with these sectors, but there will be $57.7M in economic exposure.

Table 76: Albemarle County and Charlottesville Industries (BEA, 2021)

Albemarle County and Charlottesville Industry	Employees	Wages (x$1000)	Businesses (Number)	GDP ($)
Agriculture, Forestry, Fishing, and Hunting	686	20,129	86	57,725,291

Glossary

Built Environment: The human-made surroundings that provide the setting for human activity, ranging in scale from buildings and parks or green space to neighborhoods and cities that can often include their supporting infrastructure, such as water supply or energy networks

Carbon Sequestration: The process of capturing, securing and storing carbon dioxide from the atmosphere (UC Davis)

Climate Action Plan: Comprehensive roadmap that outlines the specific activities that an agency will undertake to reduce greenhouse gas emissions. Climate action plans build upon the information gathered by greenhouse gas inventories and generally focus on those activities that can achieve the relatively greatest emission reductions in the most cost-effective manner

Climate Change: A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC)

Climate Change Adaptation: The process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate (IPCC)

Climate Change Mitigation: A human intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC)

Climate Indicator: An aggregate measure used to measure the climate change on complex environmental phenomena in terms of trends and variability

Climate Modeling: Tools for improving our understanding and predictability of climate behavior on seasonal, annual, decadal, and centennial time scales. Models investigate the degree to which observed climate changes may be due to natural variability, human activity, or a combination of both.

Community Assets: The collective resources which individuals and communities have at their disposal

Conservation Easement: A private legal agreement between a landowner and a land trust that protects land and its conservation values permanently

Conservation Practices: A facility or practice that is designed to prevent or reduce soil erosion, prevent or reduce non-point source water pollution, or achieve or maintain compliance with soil and water conservation standards

Cooling Degree Day: When the average temperature in a day is above 65°F. Studies have shown that when the outside temperature reaches this level, people consider cooling their building so this can be used as a measurement to help quantify the demand for energy needed to cool buildings

Cover Crops: Grasses, legumes, and forbs plants for seasonal vegetative cover

Critical Facility: A facility for which even a slight chance of flooding might be too great. Critical facilities include, but are not limited to schools, nursing homes, hospitals, police, fire and emergency response installations, installations which produce, use or store hazardous materials or hazardous waste

Drought: a prolonged period of abnormally low rainfall which can lead to lower surface and groundwater levels

Drought Response and Contingency Plan: Plan developed by the Rivanna Regional Drought Response Committee that provides additional information on local water sources, operating procedures, emergency water sources, drought condition monitoring, and notifications

Ecological Resources: Natural resources that provide certain necessary but overlooked system maintenance functions within ecosystems

Ecosystem Services: Any positive benefit that wildlife or ecosystems provide to people. The benefits can be direct or indirect—small or large

Extreme Heat: Temperatures which are much hotter and/or more humid than average

Floodplain: An area of low-lying ground adjacent to a river, formed mainly of river sediments and subject to flooding

Grass Buffers: Strips of permanent vegetation at the edge or perimeter of a field.

Greenhouse Gasses: Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, which absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, by the atmosphere itself, and by clouds (IPCC)

Growing Degree Day: When the temperature conditions are right for plants and animals to grow or develop

Hazard: The potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources (IPCC)

Hazard Mitigation Plan: A plan that assesses hazard vulnerabilities and identifies mitigation actions that jurisdictions will pursue in order to reduce the level of injury, property damage, and community disruption that might otherwise result from such events

Heat Advisory: Issued when the daytime heat index values are between 100°F to 104°F or if the heat index is between 95°F to 99°F for four consecutive days

Heat Index: The measure of how hot it feels when relative humidity is factored in with the air temperature

Heat Islands: Urbanized areas that experience higher temperatures than outlying areas (EPA)

Heat Warning: Issued when the daytime heat index is forecasted to be 105°F or higher or 75°F or higher at night for a 48-hour period

Infrastructure: The basic physical and organizational structures and facilities (e.g. buildings, roads, power supplies) needed for the operation of a society or enterprise

Native Plant/Pest/Disease: Plant/Pest/Disease that is a part of the balance of nature that has developed over hundreds or thousands of years in a particular region or ecosystem

Natural Asset: An asset of the natural environment. These consist of biological assets (produced or wild), land and water areas with their ecosystems, subsoil assets and air

Non-Native Plant/Pest/Disease: A plant/pest/disease introduced with human help (intentionally or accidentally) to a new place or new type of habitat where it was not previously found

Open Space Use Agreements (OSUA): Agreements that limit construction and development activity on the property owner's land and lasts from four to ten years

Resilience: The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation

Risk: The potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems

Virginia Drought Assessment and Response Plan: Plan developed by the state of Virginia that describes how the Virginia Department of Environmental Quality (DEQ) monitors and evaluates the drought conditions in the Commonwealth and when it issues warnings

Vulnerable Population: Groups and communities at a higher risk for poor health as a result of the barriers they experience to social, economic, political and environmental resources, as well as limitations due to illness or disability

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt

Watershed: An area where the runoff from rainfall is collected and drained into a larger body of water, such as a river

Wildfire: A destructive fire which can quickly spread over brush and forested land

Wildland-Urban Interface: The area where the built environment, usually homes, and wildland vegetation meet or intermingle

Woodland Home Communities: Clusters of homes located along forested areas at the wildland-urban interface that are particularly susceptible to a nearby wildfire incident

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