July 2022—DRAFT

Northern Virginia

Hazard Mitigation Plan

Executive Summary

> **Successful mitigation leads to a more resilient community in the face of future disasters. Resilient communities proactively protect themselves against hazards, build self-sufficiency, and become more sustainable. Resilience…is fostered not only by government, but also by individual, organization, and business actions.**
>
> **—National Response Framework, United States Department of Homeland Security**

Mitigation is commonly defined as sustained actions taken to reduce long-term risks to people and property from hazards and their effects. Hazard mitigation focuses attention and resources on community policies and actions that produce successive benefits over time. A mitigation plan states the community's aspirations and the specific courses of action it intends to follow to reduce vulnerability and exposure to future hazard events. These plans are formulated through a systematic process centered on the participation of individuals, businesses, public officials, and other community stakeholders. Traditionally, mitigation plans address natural hazards. However, this plan discusses natural and non-natural hazards, their impacts, and strategies to reduce their risk. The National Institute of Building Sciences has found that natural hazard mitigation saves, on average, $6 for every $1 spent on federal mitigation grants.[1]

Disasters can happen anytime and anywhere. They can cause loss of life, damage buildings and infrastructure, and have devastating consequences for a community's economic, social, and environmental well-being. Nationwide, taxpayers pay billions of dollars annually to help communities, organizations, businesses, and individuals recover from disasters. These monies do not reflect the actual cost of disasters, as tax dollars do not cover additional costs incurred by insurance companies and private entities. Many natural disasters are predictable. Much of the damage and expenses caused by these events can be reduced or even avoided. By integrating mitigation into all aspects of disaster planning, communities can build resilience and reduce the risk of future hazard events.

The **2022 Northern Virginia Hazard Mitigation Plan (NOVA HMP)**[2] brings together hazard risk and disaster resilience efforts through its planning process and related activities with the aim of reducing long-term vulnerability for all jurisdictions in the region.

The hazard mitigation planning process benefits Northern Virginia and its jurisdictions in many ways:

- Hazard identification and risk assessment establish the foundation for all hazards and all phases of disaster and emergency management programs—mitigation, preparedness, prevention/ protection, response, and recovery.
- The inclusive planning process builds partnerships by involving agencies, organizations, individuals, and businesses.
- The planning process increases education and awareness of threats and hazards, as well as their impacts, consequences, and risks.

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[1] Multi-Hazard Mitigation Council (2019). Natural Hazard Mitigation Saves: 2019 Report. Principal Investigator Porter, K.; Co-Principal Investigators Dash, N., Huyck, C., Santos, J., Scawthorn, C.; Investigators: Eguchi, M., Eguchi, R., Ghosh., S., Isteita, M., Mickey, K., Rashed, T., Reeder, A.; Schneider, P.; and Yuan, J., Directors, MMC. Investigator Intern: Cohen-Porter, A. National Institute of Building Sciences. Washington, DC. http://2021.nibs.org/files/pdfs/NIBS_MMC_MitigationSaves_2019.pdf

[2] The *2022 Northern Virginia HMP* update project was funded by the Federal Emergency Management Agency through the Virginia Department of Emergency Management, Grant Agreement Number PDMC-PL-03-VA-2018-003 and administered by the Prince William County Office of Emergency Management.

- The Plan communicates needs and priorities to federal officials, and it positions local jurisdictions for financial and technical assistance.
- The Plan provides for the most efficient and effective use of resources to reduce risk.
- The process provides opportunities to align hazard risk reduction with other state and local objectives.

Effective mitigation begins by identifying threats and hazards that a community faces and determining the associated risks, consequences, and vulnerabilities. Comprehensive assessment requires risk information based on credible science, technology, and intelligence validated by experience. No single threat or hazard exists in isolation. For example, a severe thunderstorm can lead to flooding, dam failures, and hazardous material spills.

Understanding risks makes it possible to develop strategies and plans to manage or avoid them. Avoiding and reducing risks are ways to reduce a community's long-term vulnerability and build individual and community resilience.[3]

Risk, not the occurrence of incidents, drives this Plan. By fostering comprehensive risk considerations, this plan encourages behaviors and activities that will reduce future exposure and vulnerability for individuals and communities.

The planning area of the 2022 *HMP* includes 21 jurisdictions in the Northern Virginia region.

Table 1: 2022 Planning Area Jurisdictions

Counties	Towns	Cities
Arlington	Clifton	Alexandria
Fairfax	Dumfries	Fairfax
Loudoun	Haymarket	Falls Church
Prince William	Herndon	Manassas
	Leesburg	Manassas Park
	Lovettsville	
	Middleburg	
	Occoquan	
	Purcellville	
	Quantico	
	Round Hill	
	Vienna	

This Plan, which has two volumes, is designed to be a user-friendly source for all hazard information for participating jurisdictions. **Volume I** includes the **Base Plan, Appendices, and Jurisdiction Annexes**.[4] The Base Plan provides the regional context for the identification and risk assessment of natural hazards, the resulting mitigation strategy, and action plans for implementation. The appendices document the steps taken in updating the Plan and its specific components. The jurisdiction annexes present hazard risk and vulnerability information that is specific to that jurisdiction. They provide a foundation for developing effective and feasible mitigation actions that result in the successful reduction of hazard

[3] United States Department of Homeland Security. (2019). *National Response Framework*, Fourth Edition. https://www.fema.gov/sites/default/files/2020-04/NRF_FINALApproved_2011028.pdf
[4] The appendices and jurisdiction annexes are part of the overall plan but are separate from this document.

vulnerability. The jurisdiction annexes are self-contained documents that augment the regional context presented in the Base Plan.

Volume II is a new addition to this Plan. It presents the regional hazard and risk assessment and mitigation strategies that address **non-natural hazards**.

The 2022 NOVA HMP will be a useful tool for all communities and their stakeholders by increasing public awareness about local hazards and risks while providing information about the options and resources available to reduce those risks. Informing the public about potential hazards will help each of the region's jurisdictions protect itself against the effects of hazards, and it will enable informed decision-making on where to live, purchase property, or locate businesses.

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Volume I: Natural Hazard Base Plan

1. Introduction

What is hazard mitigation?

Mitigation is commonly defined as sustained actions taken to reduce long-term risks to people and property from hazards and their effects. Hazard mitigation focuses attention and resources on community policies and actions that produce successive benefits over time. A mitigation plan states the community's aspirations and the specific courses of action it intends to follow to reduce vulnerability and exposure to future hazard events. These hazard mitigation plans are formulated through a systematic process centered on the participation of individuals, businesses, public officials, and other community stakeholders.

A local hazard mitigation plan is the physical representation of a jurisdiction's commitment to reduce risks from natural hazards. Local officials can refer to the plan in their day-to-day activities and in making decisions about regulations and ordinances, granting permits, funding capital improvements, and undertaking other community initiatives. Local plans also serve as the basis for states to prioritize future grant funding as it becomes available.

The *2022 Northern Virginia Hazard Mitigation Plan* will be a useful tool for all communities and their stakeholders by increasing public awareness of local hazards and risks while providing information about the options and resources available to reduce those risks. Teaching the public about potential hazards will help each jurisdiction in the area protect itself against the effects of hazards, and it will enable informed decision-making on where to live, purchase property, or locate businesses.

To reduce the nation's mounting losses from natural disasters, the United States Congress passed the Disaster Mitigation Act of 2000 (DMA 2000) to amend the Robert T. Stafford Disaster Relief and Emergency Assistance Act. Section 322 of DMA 2000 emphasizes the need for state and local government entities to closely coordinate mitigation planning activities, and it makes the development of a hazard mitigation plan a specific eligibility requirement for any local government applying for federal mitigation grant funds. These funds include the Hazard Mitigation Grant Program (HMGP) and the Building Resilient Infrastructure and Communities (BRIC) program (formerly known as the Pre-Disaster Mitigation Program), administered by the Federal Emergency Management Agency (FEMA) under the Department of Homeland Security. Communities with an adopted and federally approved hazard mitigation plan thereby become pre-positioned and more apt to receive available mitigation funds before and after the next disaster strikes.

The *2022 Northern Virginia Hazard Mitigation Plan* (NOVA HMP) has been prepared in coordination with the offices of FEMA Region 3 and the Virginia Department of Emergency Management (VDEM) to ensure that it meets all applicable DMA 2000 and commonwealth requirements. The Local Mitigation Plan Crosswalk in **Appendix A** provides a summary of federal minimum planning standards, and it notes the location in this Plan where each requirement is met.

1.1. Plan Overview

Local hazard mitigation planning is the process of organizing community resources, identifying and assessing hazard risks, and determining how to best minimize or manage those risks. This process results in a hazard mitigation plan that identifies specific mitigation actions, each designed to achieve both short-term planning objectives and long-term risk reduction. To ensure the functionality of each mitigation action, responsibility is assigned to a specific individual, department, or agency, along with a schedule for its implementation. Plan maintenance procedures are established for the routine monitoring of implementation progress, as well as for evaluating and enhancing the mitigation plan itself. These plan maintenance procedures ensure that the plan remains current, dynamic, and effective over time.

Mitigation planning offers many benefits, including the following:

- Saving lives and property,
- Saving money,
- Faster recovery following disasters,
- Reducing future vulnerability through wise development and post-disaster recovery and reconstruction,
- Expediting the receipt of pre-disaster and post-disaster grant funding, and
- Demonstrating a firm commitment to improving community health, safety, and resiliency.

Typically, mitigation planning has the potential to produce long-term and recurring benefits by breaking the cycle of repetitive disaster loss. A core assumption of hazard mitigation is that pre-disaster investments significantly reduce the demand for post-disaster assistance by lessening the need for emergency response, repair, recovery, and reconstruction. Furthermore, mitigation practices enable individuals, businesses, and industries to reestablish themselves in the wake of a disaster, getting the community economy back on track sooner and with less interruption.

The benefits of mitigation planning go beyond solely reducing hazard vulnerability. Measures such as the acquisition or regulation of land in known hazard areas can help achieve multiple community goals, such as preserving open space, maintaining environmental health, and enhancing recreational opportunities. Thus, it is vitally important that any local mitigation planning process be integrated with other local planning efforts, and that any proposed mitigation strategies must consider other existing community goals or initiatives that will help complement or hinder their future implementation.

1.1.1. Background

Natural hazards are a part of the world around us. Their occurrence is inevitable, and while there is little, we can do to control their force and intensity, many actions can be taken to lessen their potential impacts on our communities. The effective reduction of a hazard’s impact can decrease the likelihood that such events will result in a disaster. The concept and practice of reducing risks to people and property from known hazards is generally referred to as hazard mitigation.

Hazard mitigation techniques include structural measures, such as strengthening or protecting buildings and infrastructure from the destructive forces of potential hazards, and nonstructural measures, such as adopting sound land-use policies or creating public awareness programs. Some of the most effective mitigation measures are implemented at the local government level, where decisions on the regulation and control of development are made.

A comprehensive mitigation strategy addresses hazard vulnerabilities that exist today and in the foreseeable future. Therefore, it is essential that projected patterns of development are evaluated and considered in terms of how that growth will increase or decrease a community’s overall hazard vulnerability. Land use is a particularly important topic in the Northern Virginia region, where many communities are facing rapid growth and redevelopment. Now is the time to effectively guide development away from identified hazard areas and environmentally sensitive locations before unsound development patterns emerge that place people and property in harm's way.

The Northern Virginia region is vulnerable to a wide range of natural hazards, including flooding, severe storms, hurricanes, and winter weather. These hazards threaten the safety of residents, and they have the potential to damage or destroy both public and private property, disrupt the local economy, and impact the overall quality of life of individuals who live, work, and play in the Northern Virginia region.

One of the most effective tools a community can use to reduce hazard vulnerability is a local hazard mitigation plan that is developed, adopted, and updated as needed. Such a plan establishes a broad community vision and guiding principles for addressing hazard risk, including the development of specific mitigation actions designed to reduce identified vulnerabilities. The *2022 NOVA HMP* (or "the Plan") is a logical first step toward incorporating hazard mitigation principles and practices into routine activities and functions of local government in the region.

The mitigation actions in the Plan go beyond recommending structural solutions to reduce existing vulnerability. Local policies addressing community growth, incentives to protect natural resources, and public awareness and outreach campaigns are examples of other measures that can help reduce the future hazard vulnerability of the region. The Plan has been designed to be a living document, with implementation and evaluation procedures included to help achieve meaningful objectives and successful outcomes.

1.1.2. Purpose

The purpose of the Plan is to:

- Protect life, safety, and property by reducing the potential for future damages and economic losses that result from all hazards,
- Make communities safer places to live, work, and play,
- Qualify for grant funding in both the pre-disaster and post-disaster environments,
- Speed recovery and redevelopment following future disaster events,
- Demonstrate a firm local commitment to hazard mitigation principles, and
- Comply with commonwealth and federal requirements for local multi-jurisdictional hazard mitigation plans.

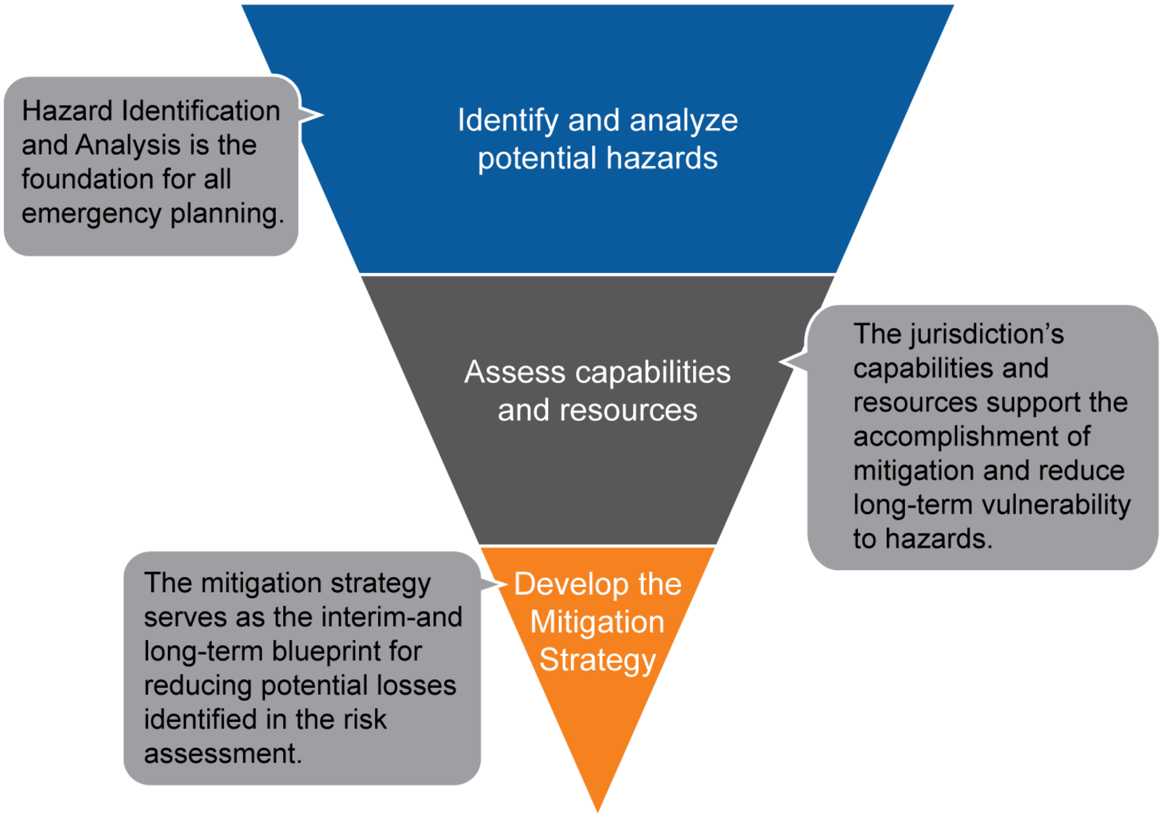

Figure 1: Purpose of the Northern Virginia Hazard Mitigation Plan

1.1.3. Applicability and Scope

The Plan is applicable to the geographic areas within the political boundaries of the participating jurisdictions of the Northern Virginia region. It involves the participation of multiple departments, agencies, and organizations in these jurisdictions, as well as key local, regional, commonwealth, and federal stakeholders that provide services and resources to or support NOVA jurisdictions. In addition, the Plan complements and is consistent with the *2017 Commonwealth of Virginia Hazard Mitigation Plan*.

The Plan is an update of the *2017 Northern Virginia Hazard Mitigation Plan*. It is a dynamic document that can serve as a guide for all-hazard planning, addressing natural and non-natural human-caused hazards in relation to prevention, preparedness, response, recovery, mitigation, and long-term redevelopment.

1.1.4. Authority and Guidance

The Plan was prepared in compliance with Section 322 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988 (Stafford Act), 42 U.S.C. 5165, as amended by Section 104 of the Disaster Mitigation Act of 2000 (DMA 2000). Local mitigation planning requirements are codified in the Code of Federal Regulations (CFR) Title 44, Section 201.6 (44 CFR §201.6). DMA 2000 specifies requirements for local governments to undertake a risk-based approach to reducing the impacts and consequences of natural hazards through mitigation planning. In addition, DMA 2000 requires that local plans be updated every five years, with each planning cycle requiring a complete review, revision, and approval of the mitigation plan by the Commonwealth and FEMA.

The Plan shall be routinely monitored, evaluated, and revised to maintain compliance with the following provisions, rules, and legislation:

- Section 322, Mitigation Planning, of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as enacted by Section 104 of the Disaster Mitigation Act of 2000 (P.L. 106-390), and
- FEMA's Interim Final Rule published in the Federal Register on February 26, 2002, 44 CFR Part 201.

The method and schedule for plan maintenance are provided in additional detail in **Section 3** of the Plan.

1.1.5. Plan Adoption

The Plan, developed in accordance with current commonwealth and federal rules and regulations governing local hazard mitigation plans, will be adopted by the 4 counties, 5 cities, and 12 participating municipalities in accordance with the authority and police powers granted to counties, cities, and municipalities under §15.2-2223 through §15.2-2231 of the Virginia State Code.

Following its designation as Approvable Pending Adoption (APA) by both VDEM and FEMA, the Plan will be brought forth to each participating jurisdiction for formal adoption by its governing body. Copies of local adoption resolutions are in **Appendix C**.

Additional information related to the adoption of the Plan is provided in **Section 3** of this Plan.

1.1.6. Plan Format and Content

The *2022 NOVA HMP* is presented in two volumes:

- **Volume I:** Natural Hazard Base Plan, Supporting Appendices, and Jurisdictional Annexes
- **Volume II:** Non-Natural Hazard Supplement

Table 2: 2022 Northern Virginia, Volume I: Hazard Mitigation Plan Organization

Part 1: The Plan	Content
Section 1: Introduction	• Provides the justification and approach to hazard mitigation • Defines the legal authority for hazard mitigation planning • Describes how the Plan is organized • Presents the regional profile to establish context for the Plan
Section 2: Planning Process	• Describes the process used to review, revise, and update the 2017 NOVA HMP • Describes changes in priorities and processes since the 2017 NOVA HMP • Defines the planning organization, participation, timeline, and public engagement aspects of the planning process • Lists existing plans, studies, reports, and technical information reviewed and integrated into the 2022 update

Part 1: The Plan	Content
Section 3: Plan Maintenance and Adoption	• Describes the method and schedule for monitoring, evaluating, and updating the Plan over the five-year planning cycle • Describes how the Plan and its strategy will be implemented and maintained by incorporating it into existing planning mechanisms • Provides maintenance procedures, forms, and checklists to help keep the Plan current • Describes how the Plan will be adopted by the governing bodies of participating counties, cities, and towns

Part 2: Natural Hazard Analysis	
Section 4: Hazard Identification and Risk Assessment Methodology	• Defines the hazard identification and risk assessment process • Identifies hazards considered for the 2022 Plan • Identifies hazards eliminated from consideration in the Plan • Presents a regional hazard profile, including federal disaster declarations and regional summaries of FEMA community lifelines and assets
Section 5: Hazard Profiles, Risks, and Vulnerability	• Defines the hazard identification and risk assessment process • Identifies hazards considered for the 2022 Plan • Identifies hazards eliminated from consideration in the Plan • Presents a regional hazard profile, including federal disaster declarations and regional summaries of FEMA community lifelines and assets
Section 6: Impacts of Climate Change	• Presents hazard profiles, including types, locations, extent, previous occurrences, and probability for future occurrences • Presents risk assessments related to the impacts and consequences of hazards and vulnerability analysis for 11 natural hazards included in the 2022 Plan

Part 3: Mitigation Strategy	
Section 7: Capability Assessment	• Provides a regional summary of the planning and regulatory, administrative and technical, safe growth, financial, and education and outreach capabilities of Plan participants • Describes how capabilities that support hazard mitigation may be improved • Presents the National Flood Insurance Program assessment and describes how jurisdiction will maintain compliance

Part 3: Mitigation Strategy	
Section 8: Mitigation Strategy	• Explains the process used to review and update the goals and objectives for the 2022 Plan • Presents a status summary of mitigation actions included in the 2017 plan • Presents a summary of new mitigation actions and previous actions moved forward in the 2022 Plan • Describes the criteria for prioritizing mitigation actions • Presents a summary of the jurisdictions' action plans for implementation • Describes federal, commonwealth, local, and other mitigation funding sources

Appendices	
Appendix A: The Plan	• Supporting Documentation for Part 1
Appendix B: Natural Hazard Analysis	• Supporting Documentation for Part 2
Appendix C: Adoption Resolutions	• Supporting Documentation for Part 3

Jurisdictional Annexes	
Jurisdictional Annexes	• Provide detailed jurisdiction-specific information on hazard risks and vulnerability, capabilities, mitigation actions, and action plans for implementation that augment information in the Base Plan

Table 3: 2022 Northern Virginia, Volume II: Non-Natural Hazards Supplement

Volume II	Non-Natural Hazards Supplement
Section 1: Introduction, Planning Process, and Plan Maintenance	• Describes the purpose for including non-natural hazards • Describes how the Plan is organized • Presents the regional profile to establish the context of the plan
Section 2: Hazard Profiles	• Presents hazard profiles, including types, locations, extent, previous occurrences, and probability for future occurrences • Presents risk assessments related to the impacts and consequences of hazards and vulnerability analysis for seven non-natural hazards included in the 2022 Plan
Section 3: Mitigation Actions and Implementation	• Describes the method and schedule for monitoring, evaluating, and updating the Plan over the five-year planning cycle • Describes how the Plan and its strategies will be implemented and maintained by incorporating them into existing planning mechanisms • Provides maintenance procedures, forms, and checklists to help keep the Plan current

The structure of the Plan is designed to be as reader-friendly and functional as possible. While significant background information is included in the Plan itself related to the processes used and studies completed (e.g., the risk and capability assessments), some information is separated from the more meaningful planning outcomes or actions (e.g., mitigation strategies and mitigation action plans) and provided as appendices.

1.1.7. The Planning Area

The jurisdictions covered by the Plan include the following 4 counties, 5 cities, and 12 towns. Hereinafter, they are referred to as the Northern Virginia Region, the Region, or the planning area (see Table 4 and Figure 2).

Table 4: 2022 Planning Area Jurisdictions

Counties	Towns	Cities
Arlington	Clifton	Alexandria
Fairfax	Dumfries	Fairfax
Loudoun	Haymarket	Falls Church
Prince William	Herndon	Manassas
	Leesburg	Manassas Park
	Lovettsville	
	Middleburg	
	Occoquan	
	Purcellville	
	Quantico	
	Round Hill	
	Vienna	

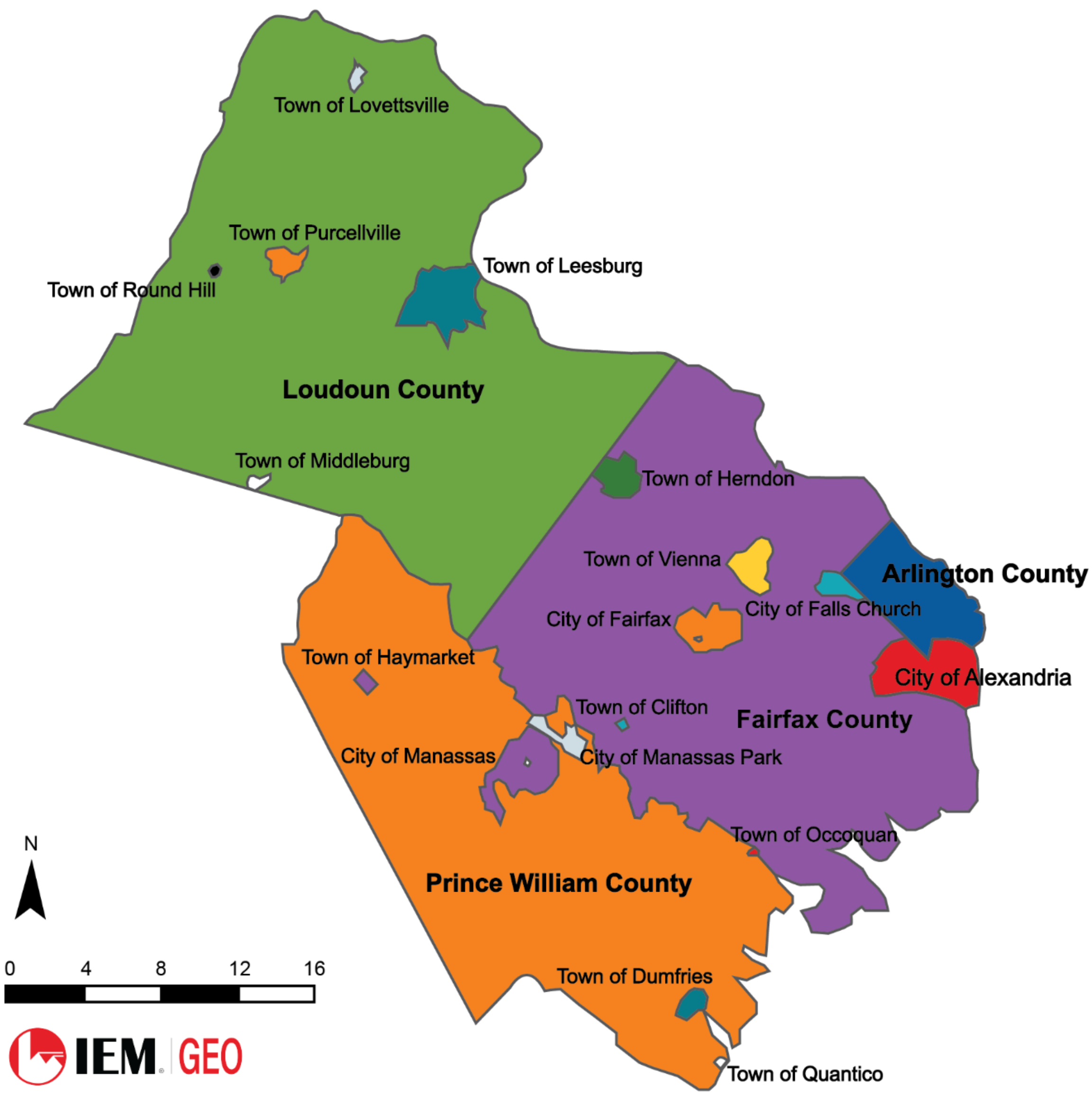

Figure 2: The Planning Area

1.2. Regional Profile

1.2.1. Physical Environment

1.2.1.1. Geography

The Northern Virginia planning area is in the northeast corner of the Commonwealth of Virginia, across the Potomac River from the Nation's Capital, Washington, D.C. It is part of the Washington, D.C.–Maryland–Virginia–West Virginia Primary Metropolitan Statistical Area, as defined by the U.S. Census.

Northern Virginia is home to numerous federal government facilities, such as the Pentagon, Central Intelligence Agency, and the United States Geological Survey. Historic and cultural resources include

George Washington's historic home on the Potomac, Mount Vernon; Arlington National Cemetery; and the Udvar–Hazy Center of the Smithsonian Institution's National Air and Space Museum at Dulles International Airport.

1.2.1.2. Hydrology

The planning area is part of three of the five physiographic provinces of Virginia: The Coastal Plain, the northern Piedmont, and the Blue Ridge. The coastal plain lies roughly east of Interstate 95/395, and it includes the eastern portions of the city of Alexandria, and Fairfax and Prince William Counties. The northern piedmont province lies roughly between Interstate 95 and United States Highway 15 in central Loudoun and western Prince William Counties. It is bounded by the Blue Ridge Mountains on the west, with ridges, foothills, and hollows rolling down to the Potomac River to the east. Elevations range from more than 1,950 feet above sea level in the Blue Ridge Mountains in western Loudoun County to sea level in eastern Prince William County on the Potomac River. The total planning area is 1,304 square miles.

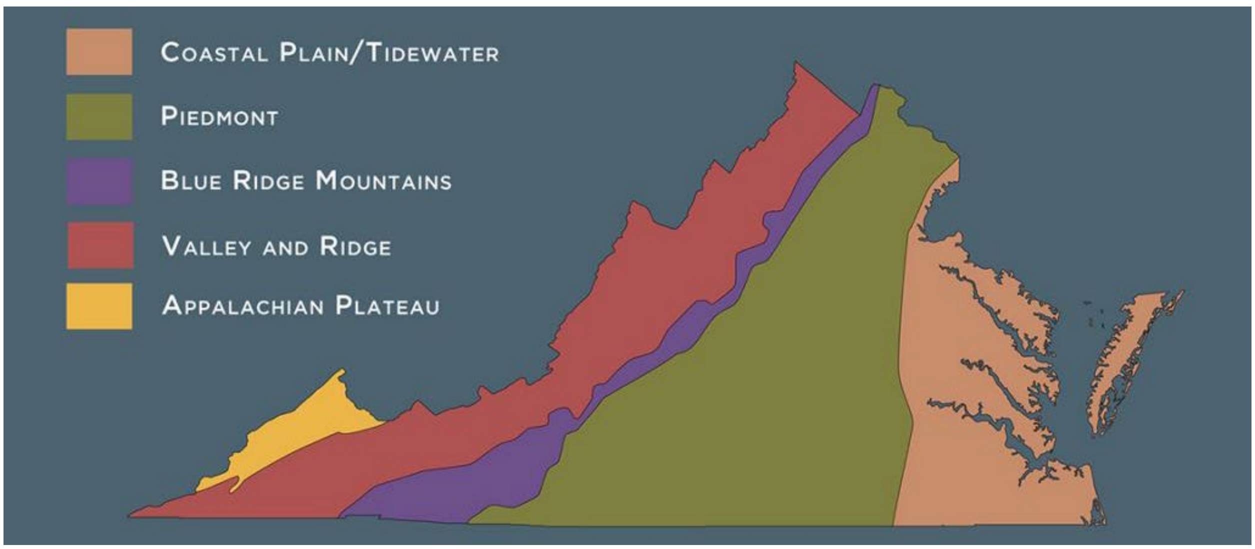

Figure 3: The Five Physical Regions of Virginia[5]

Northern Virginia lies entirely within the Potomac River watershed. After passing Harper's Ferry, West Virginia, the river forms the border between Maryland and Virginia, flowing in a southeasterly direction. The watershed, also known as the Potomac basin, contains a variety of land types, including forests. The basin also includes developed land, agriculture, water, and wetlands.[6]

The basin's major industries include agriculture and forestry throughout the basin, coal mining and pulp and paper production along the North Branch Potomac River; chemical production and agriculture in the Shenandoah Valley; high-tech, service, and light industry, as well as military and government installations in the Washington metropolitan area; and fishing in the lower Potomac estuary.[7]

Public water treatment plants treat approximately 83% of the basin's wastewater. Another 16% is treated by private septic systems. An average of approximately 486 million gallons of water is withdrawn daily in the Northern Virginia/Washington area for water supply. Approximately 100 million gallons per day of

[5] Virginia Museum of History and Culture. (n.d.). *The Regions of Virginia* https://virginiahistory.org/learn/regions-virginia
[6] Interstate Commission on the Potomac River Basin. (n.d.). *Potomac Basin Facts* https://www.potomacriver.org/potomac-basin-facts/
[7] Ibid.

groundwater are used in rural areas. Almost 86% of the basin's population receives its drinking water from public water suppliers, while 13% uses well water.[8]

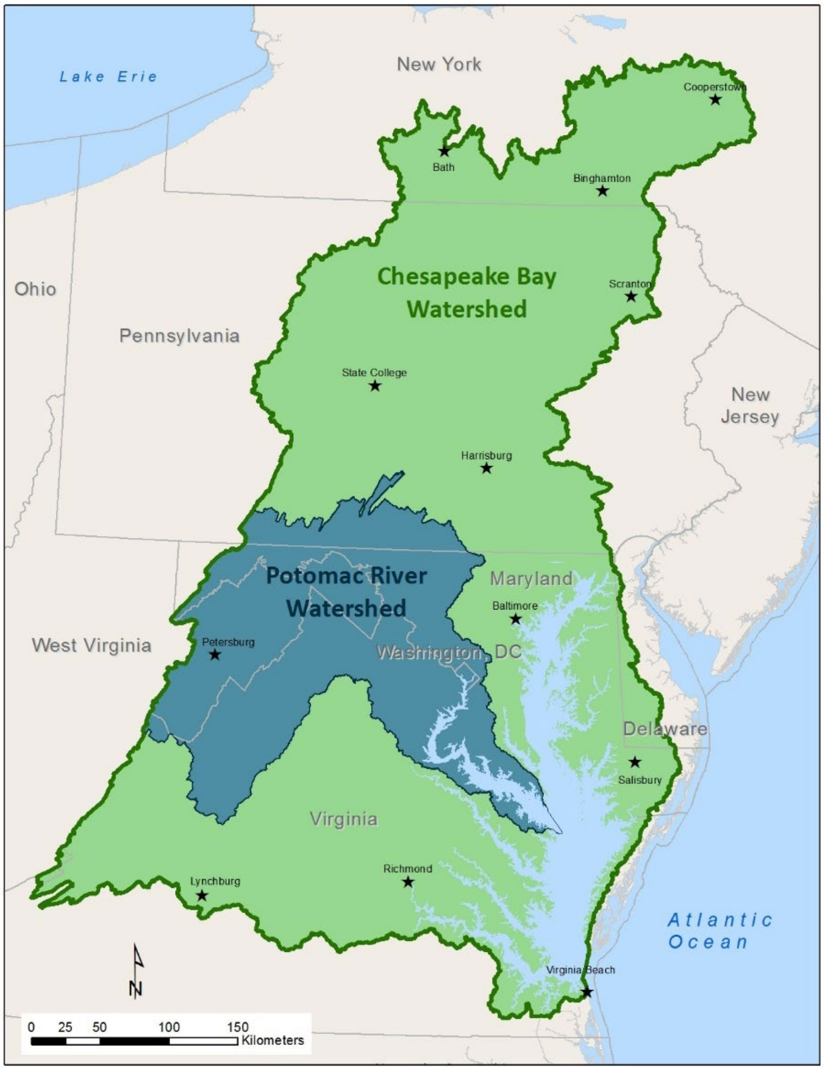

Figure 4: The Potomac River Watershed[9]

1.2.1.3. Climate

The area has a moderate climate. Average temperatures range from 26 degrees Fahrenheit (°F) to 87°F throughout the year, and the area experiences all four seasons. Winter (December–February) can be quite cold, and it often includes snow and ice; average temperatures range from 30–50 °F. January is typically the coldest month of the year. Spring (March–May) temperatures range between approximately 40°F–75°F. The summer months are June through August, and average temperatures then range from about 65°F to 95°F with high humidity. July is usually the hottest month. The fall (September–November) brings cooler temperatures and lower humidity. Average temperatures range from 40–80°F.[10] Annual

[8] Ibid.
[9] Potomac River Basin Atlas. (n.d.). *Sub-Watersheds*. https://www.potomacriver.org/Atlas-Maps/Subwatersheds/
[10]Virginia Tech Northern Virginia Center. (n.d.) *Climate and Weather* https://www.nvc.vt.edu/international/intlstudents/climate.html

rainfall averages above 40 inches, and the average snowfall ranges from approximately 15 inches at Reagan National Airport to 22 inches at Dulles International Airport.

Climate change amplifies existing weather patterns, and it can significantly alter them, increasing the extent and intensity of hazards. Extreme weather events have become more frequent over the past 40–50 years, and this trend is projected to continue. Rising sea level, coupled with potentially higher hurricane wind speeds, rainfall intensity, and storm surges, are expected to have a significant impact on coastal communities, including those in NOVA. More intense heat waves may mean more heat-related illnesses, droughts, and wildfires. The full extent of climate change on weather in NOVA is still emerging, and jurisdictions in the planning area should remain vigilant of the changing trends for planning and mitigation purposes.

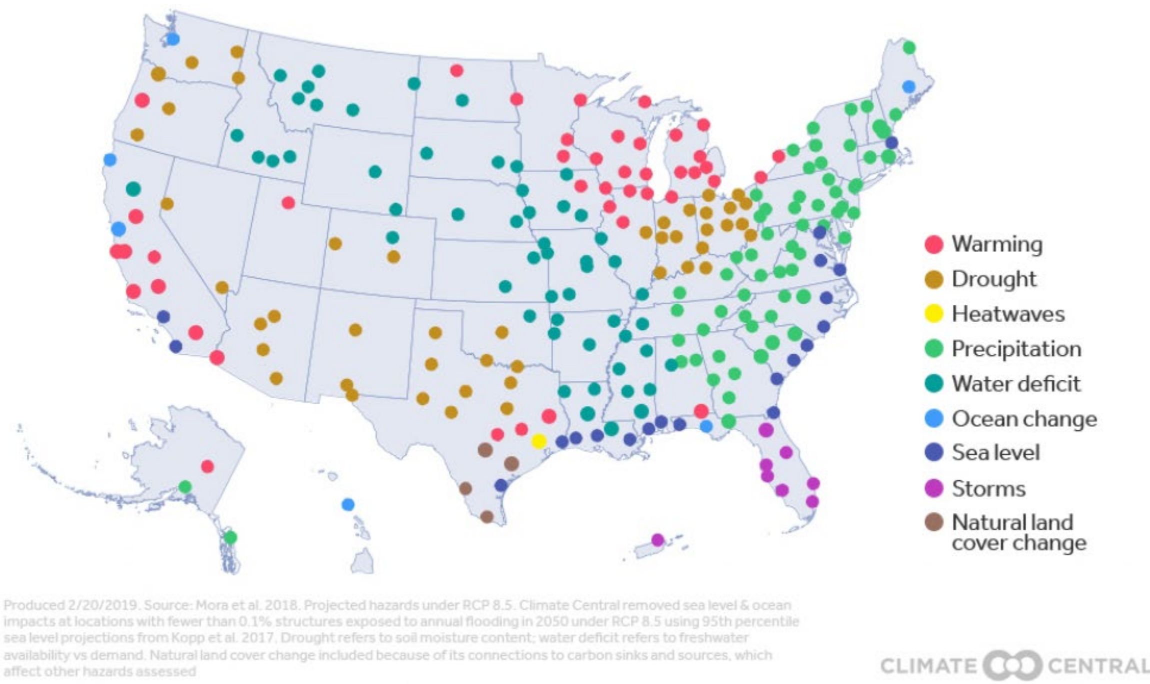

Figure 5: Most Intensified Hazards Due to Climate Change,[11] Social Environment

1.2.1.4. Brief History of the NOVA Region

People lived in Virginia for approximately 17,000 years before European contact. The Piedmont area, which includes the planning area, was home to two Siouan confederacies: the Monacan and the Manahoac.[12] The Northern Virginia region was colonized by the English in 1649, and it has a prominent place in American history. The region was the center of many conflicts during the Civil War because of its location between the Union capital of Washington, D.C., and the Confederate capital of Richmond, Virginia. Because of this history, the NOVA region is home to many historical and cultural sites and battlefields, including Manassas Battlefield Park. All of this presents unique planning considerations, especially for mitigation purposes.

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[11] Land Trust Alliance. (2019, February 20). *Climate Plie Up: Global Warming's Compounding Dangers* https://climatechange.lta.org/climate-pile-up-global-warmings-compounding-dangers/

[12] Virginia Department of Education. (n.d.). *Language* https://www.doe.virginia.gov/instruction/history/virginias-first-people/culture/language/index.shtml

1.2.1.5. County Government[13]

Counties in the Commonwealth have two distinct governmental capacities. As units of local government, they adopt and enforce local ordinances and provide services for their residents. As political subdivisions of the Commonwealth, they assist in the local implementation of commonwealth laws and programs. Counties are governed by boards of supervisors, constitutional officers, and appointed officials.

The Board of Supervisors constitutes the governing body of each Virginia County. In this capacity, the elected members of the board are responsible for establishing local public policy, raising local resources to support public programs, and acting through the county's appointed administrative officials to oversee the conduct of county affairs. Constitutional officers are responsible for overseeing statutory responsibilities, and they include positions such as county treasurer and sheriff.

Several appointed officials, boards, commissions, and advisory agencies serve each county, including a Planning Commission and a Board of Zoning Appeals.

The Commonwealth is responsible for maintaining local county roads, which is important for infrastructure mitigation planning purposes.

Virginia cities are distinct from cities in other states in that they are independent governmental entities. No county authority or taxing power extends into the boundaries of a Virginia city. Because of this, cities in the region are also required to serve (like counties) as administrative subdivisions of the Commonwealth for implementing commonwealth programs and policies.

Besides being an independent governmental entity, the City of Alexandria is a separate geographic entity, so it is not geographically located within any county.

1.2.1.6. City and Town Government[14]

Virginia towns are governmentally part of the county in which they are located. Thus, towns exist primarily to provide urban services to their residents. In general, they do not have responsibility for the administration of commonwealth programs. Forms of city and town governments throughout the NOVA region include the Council–Manager Form and the Mayor–Council Form.

1.2.1.7. Population and Demographics

Based on the 2020 United States Census, over 2.2 million people live in the planning area. This represents a 13.9% increase in population since the 2010 census.[15] Although cities in Virginia are separate entities from counties, for the purpose of census data collection, information about the cities and towns is reported in conjunction with the counties, except for the City of Alexandria.

[13] The Virginia General Assembly. (n.d.). *Virginia Government in Brief 2018-2022* https://publications.virginiageneralassembly.gov/download_publication/119
[14] Ibid.
[15] University of Virginia Weldon Cooper Center for Public Service Demographics Research Group. (n.d.). *Census 2020 Overview* https://demographics.coopercenter.org/census2020-differential-privacy

Table 5: 2010 and 2020 Decennial Census Counts by Population for NOVA Jurisdictions

Jurisdiction(s)	2010 Census Population	2020 Census Population	Numeric Increase	Percent Increase
City of Alexandria	139,993	159,467	19,474	13.9%
City of Fairfax	22,565	24,146	1,581	7%
City of Falls Church	12,332	14,658	2,326	19%
City of Manassas	37,821	42,772	4,951	13%
City of Manassas Park	14,273	17,219	2,946	21%
Arlington County	207,627	238,643	31,016	14.9%
Fairfax County Including the towns of Clifton, Herndon, and Vienna	1,081,699	1,150,309	68,610	6.6%
Loudoun County Including the towns of Leesburg, Lovettsville, Middleburg, Purcellville, and Round Hill	312,311	420,959	108,648	34.8%
Prince William County Including the towns of Dumfries, Haymarket, and Occoquan	402,002	482,204	80,202	20%
Totals	**2,230,623**	**2,550,377**	**319,754**	**14%**

The population density in the planning area is high. As measured by the 2020 Census,[16] Loudoun County had the lowest population density, and the City of Alexandria had the highest.

- City of Alexandria: 10,677.4 people per square mile
- Arlington County: 9,179.6 people per square mile
- Fairfax County: 2,941.8 people per square mile

[16] United States Census Bureau. (2021, August 25). Virginia Adds More Than 600,000 People Since 2010 https://www.census.gov/library/stories/state-by-state/virginia-population-change-between-census-decade.html

- Loudoun County: 816.2 people per square mile
- Prince William County: 1,438.3 people per square mile

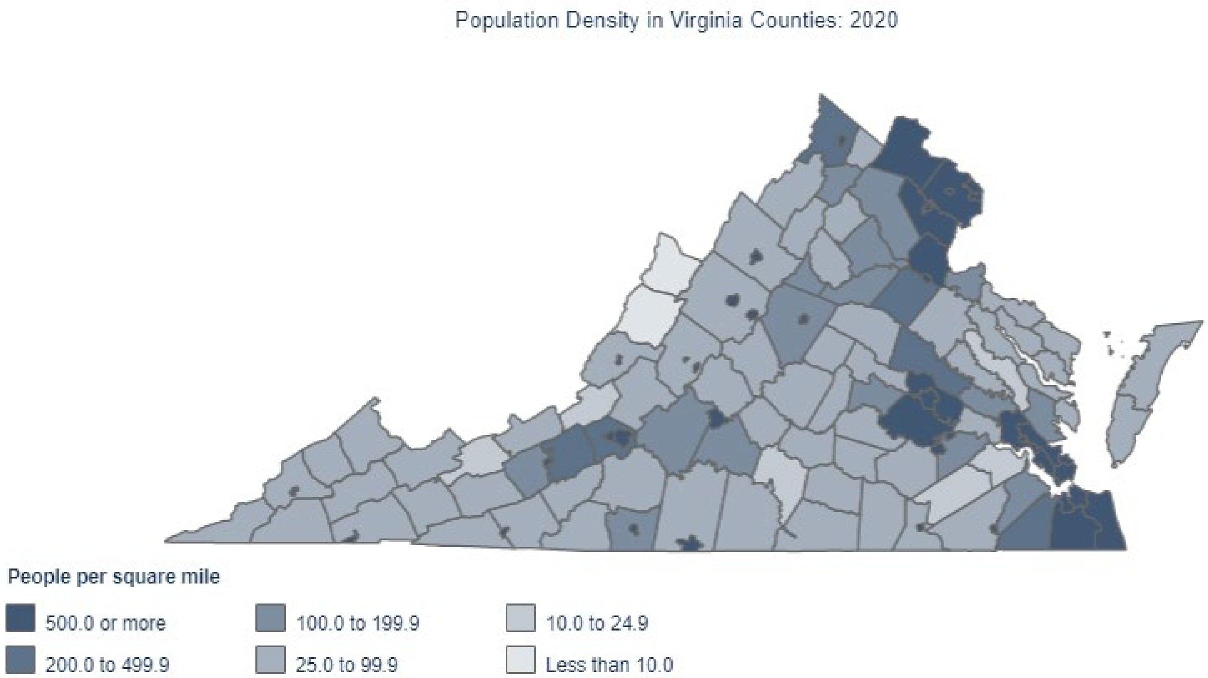

Figure 6: Population Density by County[17]

Continued population growth in NOVA is creating the need to expand capacity through new development, redevelopment, and infrastructure expansion. The Metropolitan Washington Council of Governments (MWCOG) population forecasts estimate a 17.3% increase in the NOVA region by 2045, resulting in a total population of 3,194,000.[18] This growth and the resulting increase in new or redeveloped built environment provide mitigation opportunities and challenges for the entire planning area.

Table 6: MWCOG Intermediate Population Forecasts for NOVA Jurisdictions (in Thousands)

Jurisdiction	Forecast for 2025	Forecast for 2030	Forecast for 2035	Forecast for 2030	Forecast for 2045	2025–2045 Numeric Increase	2025–2045 Percent Increase
City of Alexandria	185.5	197.7	207.4	217.3	231.8	46.3	25%
Arlington County	249.2	261.6	273.9	287.2	299.5	50.3	20.2%

[17] 2020 U.S. Census https://www.census.gov/library/stories/state-by-state/virginia-population-change-between-census-decade.html
[18] Metropolitan Washington Council of Governments. (2021, December 2). *Cooperative Forecasts: Employment, Population, and Household Forecasts by Transportation Analysis Zone* https://www.mwcog.org/documents/2021/12/02/cooperative-forecasts-employment-population-and-household-forecasts-by-transportation-analysis-zone-cooperative-forecast-demographics-housing-population/

Jurisdiction	Forecast for 2025	Forecast for 2030	Forecast for 2035	Forecast for 2030	Forecast for 2045	2025–2045 Numeric Increase	2025–2045 Percent Increase
City of Fairfax	29.2	31.6	32.7	33.9	35.2	6.0	20.3%
Fairfax County Including the towns of Clifton, Herndon, and Vienna	1,207.8	1,255.7	1,312.0	1,363.8	1,405.9	198.1	16.4%
City of Falls Church	18.4	20.8	22.3	23.4	24.5	6.1	33.2%
Loudoun County Including the towns of Leesburg, Lovettsville, Middleburg, Purcellville, and Round Hill	466.9	508.4	526.5	539.2	548.2	81.3	17.4%
City of Manassas	45.3	46.7	48.1	49.2	50.3	5.0	11.1%
City of Manassas Park	15.9	15.9	15.9	15.9	15.9	0	0%
Prince William County Including the towns of Dumfries, Haymarket, Occoquan, and Quantico	504.2	530.3	551.6	569.2	582.7	78.5	15.6%
Totals	**2,722.3**	**2,868.7**	**2,990.4**	**3,099.1**	**3,194.0**	**471.6**	**17.3%**

Table 7: 2020 Decennial Census Information by Race for NOVA Jurisdictions[19]

Jurisdiction	Asian Number (Percent)	Black Number (Percent)	Pacific Islander Number (Percent)	Native American	Other Race Number (Percent)	White Number (Percent)
City of Alexandria	15,230	35,436	417	3,225	25,956	97,735
Arlington County	34,246	24,900	539	4,317	32,948	169,402
City of Fairfax	5,144	1,440	53	447	3,947	16,147
Fairfax County Including the towns of Clifton, Herndon, and Vienna	269,522	130.292	2,974	20,054	176,774	689,040
City of Falls Church	2,099	815	39	241	1,443	11,887
Loudoun County Including the towns of Leesburg, Lovettsville, Middleburg, Purcellville, and Round Hill	102,090	38,065	1,009	6,867	53,147	267,606
City of Manassas	3,320	6,084	81	1,301	16,156	21,869
City of Manassas Park	2,062	2,551	45	414	6,947	7,586
Prince William County Including the towns of Dumfries, Haymarket, Occoquan, and Quantico	62,755	111,909	1,675	12,010	3,145	257,341

Note: Data is from those who self-identified as a race alone or in combinations with other races or ethnicities.

[19] University of Virginia Weldon Cooper Center for Public Service Demographics Research Group. (n.d.). *Census 2020 Overview.* https://demographics.coopercenter.org/census2020-differential-privacy

Table 8: 2020 Decennial Census Information About Hispanic or Latino* Population for NOVA Jurisdictions[20]

Jurisdiction	Population Count
City of Alexandria	29,372
Arlington County	37,362
City of Fairfax	4,278
Fairfax County Including the towns of Clifton, Herndon, and Vienna	199,234
City of Falls Church	1,529
Loudoun County Including the towns of Leesburg, Lovettsville, Middleburg, Purcellville, and Round Hill	59,744
City of Manassas	18,345
City of Manassas Park	7,799
Prince William County Including the towns of Dumfries, Haymarket, Occoquan, and Quantico	121,524

***Note*: *Hispanics or Latino** refers to a person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin regardless of race. https://demographics.coopercenter.org/census2020-differential-privacy.[21]

A Note about Using 2020 Census Data

The 2020 Census was different from previous censuses in several significant ways, and caution should be used when using the data, especially for comparisons with previous census data.[22]

- Every data element (population, race, Hispanic origin, age, vacant housing units, etc.), except the total population for the state and housing unit counts, is injected with "noise" by the Census Bureau, using a new privacy protection method called "differential privacy." This method, while not changing large populations very much, significantly distorted the population counts of small geographies (such as neighborhoods) and racial/ethnic groups, particularly when they account for a small share of the population. Numbers were artificially inflated or deflated to blur the community "portrait."
- Published racial data has been significantly altered not only by noise injection, but also by how the Census Bureau coded and processed the responses. The alteration is more significant than the changes in people's racial identification about themselves since the last census. As a result, the 2020 census data on race are not comparable to previous censuses.
- In addition, the pandemic impacted census taking and census results. College towns, for example, may still miss counting some students, especially those who live off campus.

[20] Ibid.
[21] U.S. Census Bureau, Population Estimates Program (PEP). (n.d). *Hispanic or Latino Origin*. https://www.census.gov/quickfacts/fact/note/US/RHI725219#:~:text=Hispanics%20or%20Latino%20refers%20to,or%20origin%20regardless%20of%20race.
[22] University of Virginia Weldon Cooper Center for Public Service Demographics Research Group. (n.d.). *Census 2020 Overview.* https://demographics.coopercenter.org/census2020-differential-privacy

1.2.1.8. Economics

Northern Virginia is a strong subregional component of the larger Washington economy, as are suburban Maryland and the District of Columbia. Most of the employment is in the profession and business services sector. The fifty largest employers in the planning area include federal, county, and city governments and services, education, and private companies. Northern Virginia represents 37% of all jobs in the Commonwealth.[23] As of January 2022, the economy showed signs of growth, employment rose, the unemployment rate fell, and housing market indicators were positive. Figure 7 shows the employment composition by sector, and Figure 8 lists the 50 largest employers in NOVA.

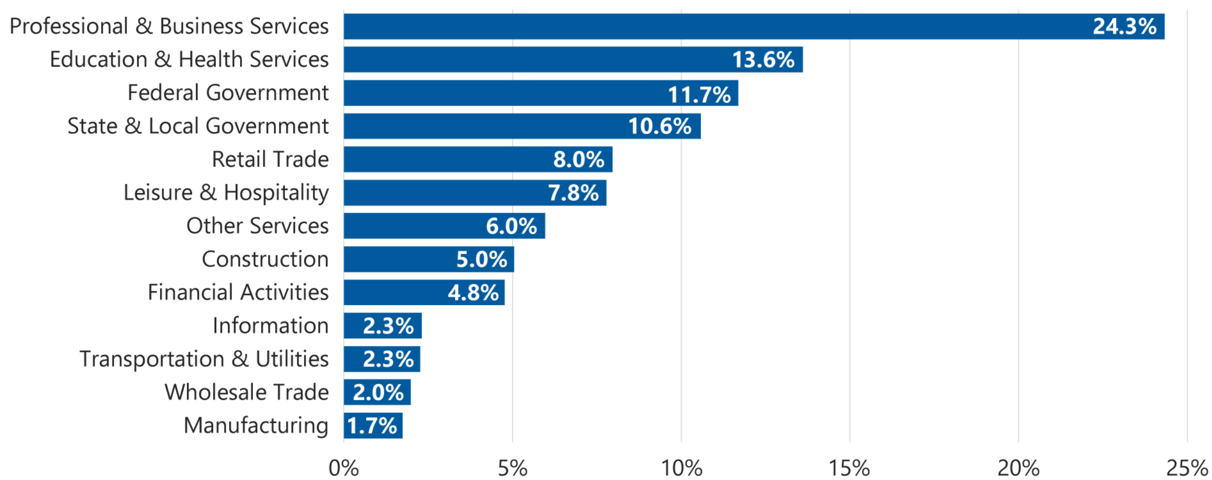

Figure 7: Employment Composition in Northern Virginia, by Sector[24]

[23] Virginia Department of Planning and Budget. (n.d.). Economic Forecast. https://dpb.virginia.gov/budget/buddoc20/parta/EconomicForecast.pdf

[24] George Mason University Schar School of Policy and Government Center for Regional Analysis. (2021, July 20). *Washington Area Economy: Performance and Outlook*. https://cra.gmu.edu/wp-content/uploads/2021/07/2021.7.20-Indicator-Slides.pdf

1 U.S. Department of Defense
2 Fairfax County Public Schools
3 Inova Health System
4 County of Fairfax
5 Loudoun County Schools
6 Prince William County School Board
7 U.S. Department of Homeland Defense
8 Booz, Allen and Hamilton
9 U.S. Department of Commerce
10 Capital One Bank
11 George Mason University
12 Federal Home Loan Mortgage
13 Arlington County School Board
14 Accenture National Securities
15 Wal Mart
16 United Airlines Inc
17 County of Prince William
18 Postal Service
19 County of Loudoun
20 Anteon Corporation
21 Navy Federal Credit Union
22 Northrop Grumman Corporation
23 Giant Food
24 Administaff
25 Science Applications International Corporation
26 Deloitte Consulting LLP
27 The Mitre Corporation
28 Amazon Web Services LLc
29 County of Arlington
30 Target Corp
31 SAIC Gemini, Inc.
32 The Home Depot
33\. Amazon Fulfillment Services Inc.
34 Virginia Hospital Center
35 Catholic Diocese of Arlington
36 Wegmans Store #07
37 Equifax Workforce Solutions
38 Security Forces, Inc.
39 City of Alexandria
40 Ernst & Young
41 Northern Virginia Community College
42 Harris Teeter Supermarket
43 Alexandria City Public Schools
44 Costco
45 United States Department of Justice
46 Fannie Mae
47 HCA Virginia Health System
48 Washington Metro Area Transit Authority
49 U.P.S.
50 Prime Now LLC

Figure 8: Fifty Largest Employers in Northern Virginia[25]

1.2.2. Built Environment

1.2.2.1. Land Use and Changes in Development Patterns

According to the 2019 Multi-Resolution Land Characteristics Consortium National Land Cover Database (NLCD), 90% of the types of land cover in the planning region has not changed since the 2016 NLCD land cover survey (see Figure 9). The biggest change is a .70% increase in urban land cover, much of which is in southeastern Loudoun County and northwestern Prince William County near the town of Haymarket.

[25] Virginia Employment Commission Labor Market Information. (2022, January 6). Community Profile Northern Virginia RC. https://virginiaworks.com/_docs/Local-Area-Profiles/5109000308.pdf

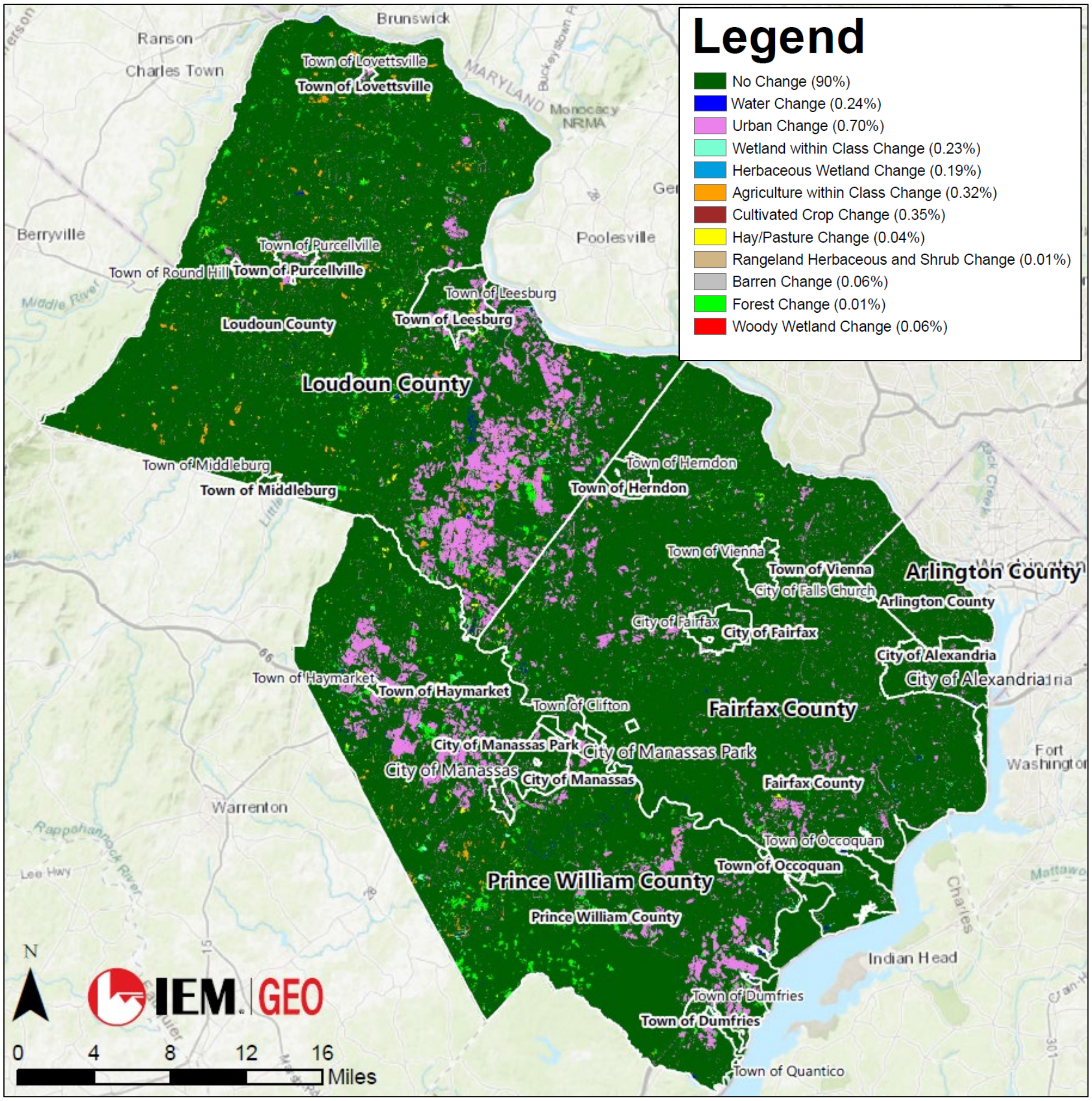

Figure 9: Land Cover Change Since 2016[26]

[26] Multi-Resolution Land Characteristics Consortium. (2019). *National Land Cover Database Land Cover Change Index*. https://www.mrlc.gov/data/nlcd-land-cover-change-index-conus

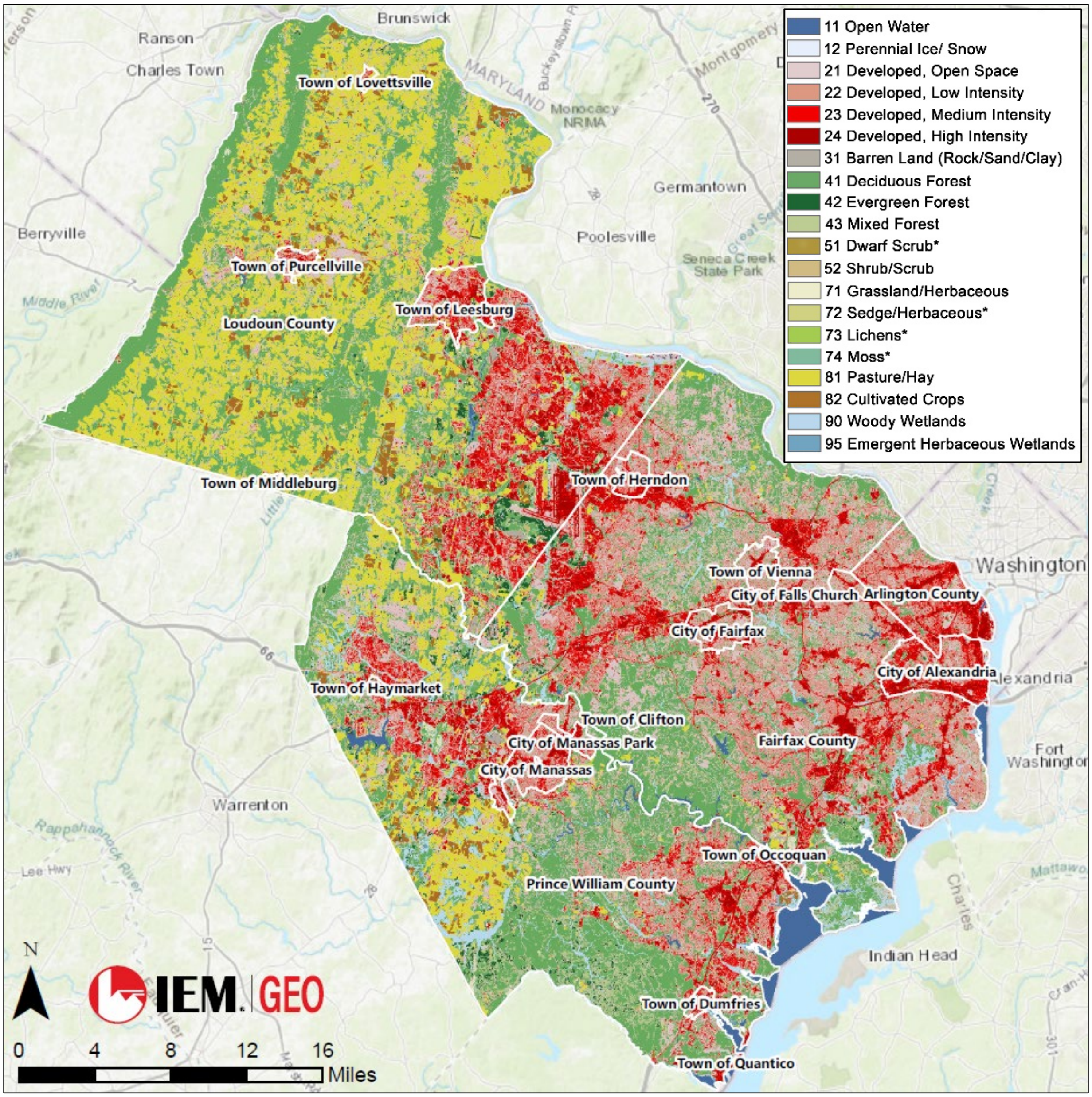

Figure 10: Land Cover in the NOVA Region, 2019[27]

As urban development grows to meet population demands, it is important for planning participants to continue to enforce existing land-use planning efforts, ordinances, and codes and update and expand them as necessary to meet evolving circumstances. Most planning participants have strong land-use capabilities and meet or exceed the American Planning Association's Safe Growth guidance. Additional information about these abilities is in the jurisdiction annexes.

27 Ibid.

1.2.2.2. Housing

There is a constant demand for affordable housing in the Northern Virginia planning area because of low vacancy rates, population growth, and economic expansion. Many households spend an excessive fraction of their income on housing, putting pressure on family budgets and forcing many to trade short commutes for more affordable housing options. In 2018, the MWCOG wrote a memo about meeting the region's current and future housing needs.[28] In this memo, MWCOG stated that the region would have, by 2045, more than 100,000 additional households than are currently projected. Based on the "jobs-to-housing" metric used in the study, to close this gap, the region would need to add 235,000 housing units by 2025 rather than the 170,000 currently anticipated. Similarly, the region would need to add 365,000 new units by 2030 rather than the 290,000 currently projected, and 690,000 units by 2045 compared to the 575,000 currently assumed. To meet short- and long-term housing needs, the region would need a sustained housing production of at least 25,600 units per year.

As of May 2021, the average sales price of a home in NOVA was $679,976.[29] This is more than the average in December 2014 of $408,000 referenced in the 2017 HMP. Incomes have not kept pace with rising home and rent prices, increasing the share of households that pay a large share of their income for housing. In the American Community Survey area that includes Arlington, Fairfax, and Loudoun counties and the cities of Alexandria, Fairfax, and Falls Church, almost half of the renters and a quarter of homeowners pay 30% or more of their income on housing. The US Department of Housing and Urban Development considers such a share unaffordable. Moreover, 23% of renters and 10% of homeowners are severely cost-burdened, meaning housing eats up at least half their income.[30]

An analysis using HAZUS-MH® software found an estimated 663,000 buildings in the NOVA region, with approximately 92% of the buildings associated with residential housing.

1.2.2.3. Transportation Systems

Roads

Northern Virginia has a substantial transportation network consisting of interstate, US, state, and county highways, rail systems, and airports. There are 12 interstate highways and 42 other highways in the region. Major highways include Virginia Route 7, 28, and 29; Interstates 66, 95, and 395; U.S. Highways 50 and 1; and U.S. Route 211 (Langston Boulevard). The Capital Beltway (Interstates 495 and 95) encircles Washington, D.C., and passes through the City of Alexandria and Fairfax County. The Fairfax, Loudoun, and Prince William Parkways also are significant thoroughfares in the region. The Point of Rocks bridge on U.S. Highway 15 north of Leesburg is the only bridge across the Potomac River between there and the Capital Beltway.

Trains and Buses

The Washington Metropolitan Area Transit Authority (WMATA) was created by an interstate compact in 1967 to plan, develop, build, finance, and operate a balanced regional transportation system in the region. Today, Metrorail serves 91 stations and has 117 miles of track with 1,500 buses. The Washington Area Metro Rail System (Metro) services the planning area with four rail lines. These lines take riders into Washington D.C., and they provide service to Ronald Reagan Washington National Airport. The expansion of the Silver Line to Dulles International Airport and into Loudoun County is mostly completed and could begin carrying passengers in 2022.

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[28] Metropolitan Washington Council of Governments. (2018, September 5). Memorandum: Meeting the Region's Current and Future Housing Needs. https://www.mwcog.org/documents/2018/09/12/regional-housing-memo-to-cog-board-cog-board-affordable-housing-housing/

[29] George Mason University Schar School of Policy and Government Center for Regional Analysis. (2021, July 20). *Washington Area Economy: Performance and Outlook*. https://cra.gmu.edu/wp-content/uploads/2021/07/2021.7.20-Indicator-Slides.pdf

[30] Urban Institute Greater DC (2018, October 2018). *What HQ2 Could Mean for the Washington Region's Housing Market, in 7 Charts*. https://apps.urban.org/features/amazon-hq2-washington-housing-charts/

The Virginia Railway Express (VRE) commuter rail system has two lines with stops in the cities of Alexandria, Manassas Park, and Manassas, the town of Quantico as well as Fairfax and Prince William Counties. Amtrak trains also operate in the planning area, with stops in the cities of Alexandria and Manassas and the Town of Quantico. Several bus systems also provide service throughout the region.

Airports

Ronald Reagan Washington National Airport and Washington Dulles International Airport provide commercial airline service to the area. From November 2020 to November 2021, 12.59 million passengers used Reagan National Airport, and 14.07 million passengers used Dulles International Airport.[31] In addition, Manassas Regional Airport in the City of Manassas is the largest general aviation airport in the Commonwealth.

Although the region has multiple transportation options, vehicular travel accounts for the majority of transportation. Transportation systems are vital to providing effective and efficient emergency responses and evacuations. High levels of traffic congestion are a regular occurrence in the region, and they will likely increase as the population grows, the demand for delivery services increases, and weather occurrences like heavy rain and snow that impact travel increase.

Planning participants are working to alleviate the burden on the region's transportation systems by creating and updating regional transportation plans, working with transit systems to expand service, and increasing the number of high occupancy toll lanes in the area.

1.2.2.4. Emergency Services and Hospital and Healthcare Facilities

There are 11 hospitals, not including Ft. Belvoir in the region, with a total bed capacity of 2,890 beds. Trauma centers include, Inova FFX – Level 1, Reston – Level 2, VHC Health – Level 2, Sentara – Level 3, Inova Loudoun – Level 3[32]. There are 110 fire stations, 46 police stations, and 14 emergency operations centers (EOCs)[33]. These facilities are located throughout the region. In Figure 11, medical care facilities are designated with a blue H, fire stations with a red diamond, police stations with a blue P, and EOCs with a green E. More details about these facilities are in the jurisdiction annexes.

[31] Metropolitan Washington Airports Authority. (2022, January 14). *Air Traffic Statistics, November 2021*. https://www.mwaa.com/sites/mwaa.com/files/2022-01/11-21%20ATS%20%281.14.22%29.pdf
[32] NVHA
[33] These numbers come from Hazus, a FEMA modeling software, local jurisdiction data may differ.

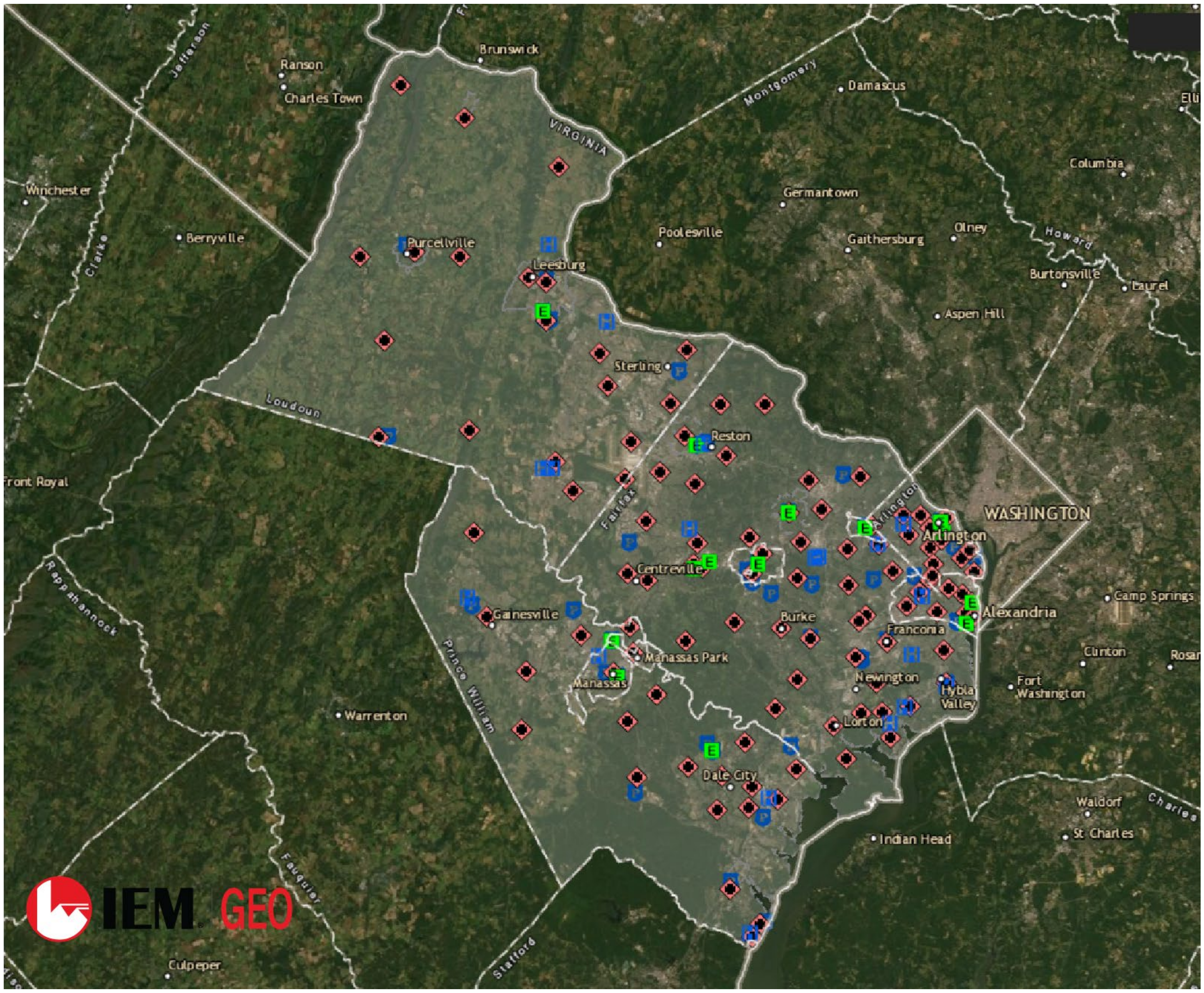

Figure 11: Emergency Services and Medical Care Facilities in Northern Virginia

1.2.2.5. Cultural and Historical Facilities

The NOVA region is home to many historical and cultural sites and Civil War era battlefields, including Manassas Battlefield Park, George Washington's historic home on the Potomac, Mount Vernon; Arlington National Cemetery; and the Udvar-Hazy Center of the Smithsonian Institution's National Air and Space Museum at Washington-Dulles International Airport.

In addition, many areas in the region are historic districts. The entire town of Haymarket is designated as a historic district, and Arlington County alone has 32 historic districts.

A significant number of churches, schools, community buildings, houses, monuments, cemeteries, parks, and farms are identified as historic buildings and structures, either locally or at the commonwealth or federal levels.

A Hazus map of historic buildings, districts, objects, and sites shows that they are throughout the planning area, with concentrations in Arlington County and the City of Alexandria.

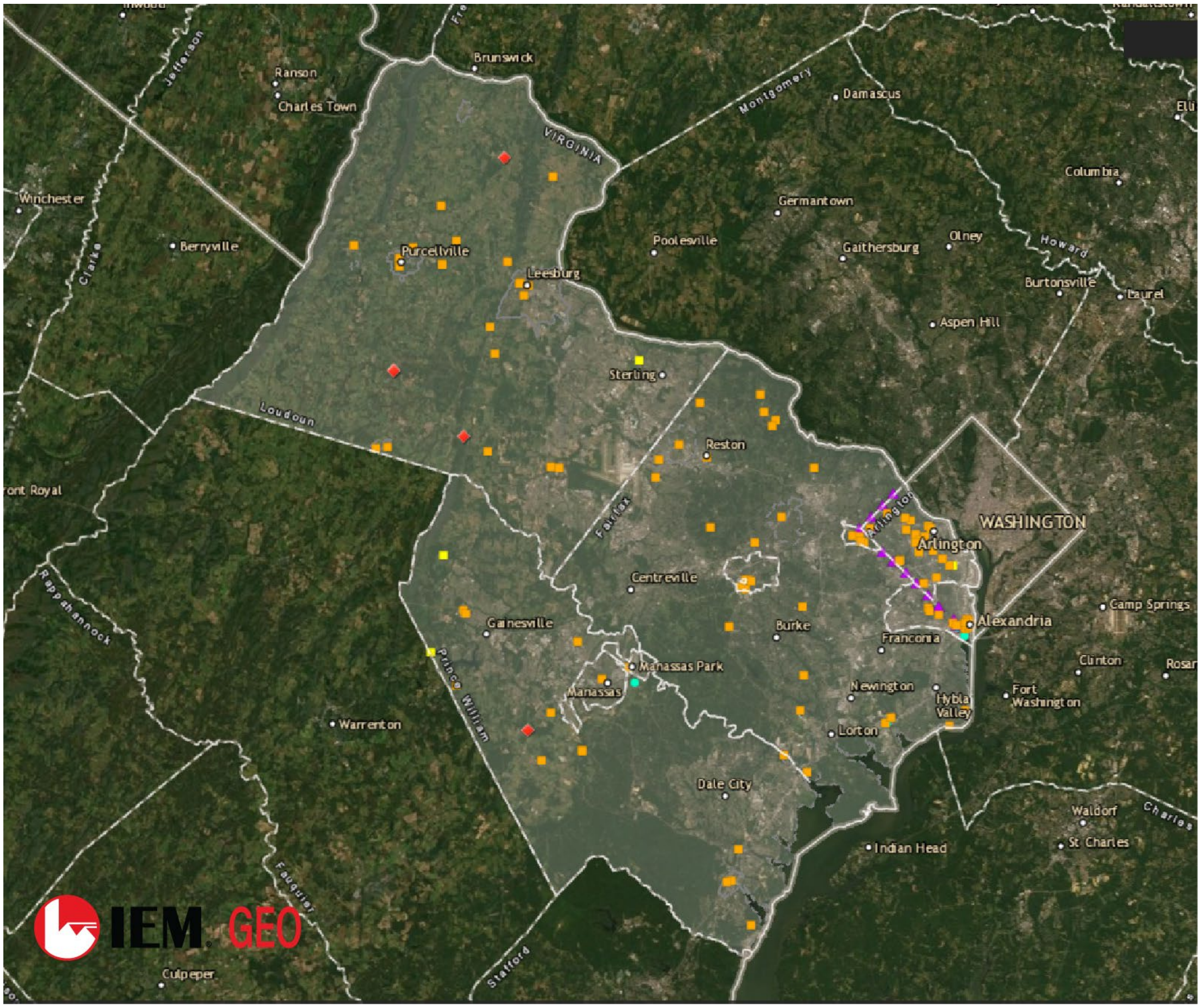

Figure 12: Historic Points in Northern Virginia

1.2.2.6. Future Conditions

It is anticipated that as the population continues to expand and additional businesses move into the NOVA region, more housing, buildings, and infrastructure will be built to accommodate growth. Plan participants have strong, detailed, and enforced building codes and zoning laws. There is an emphasis on regulating or prohibiting new construction in floodplains and flood zones. This is because the region has seen an increase in flooding occurrences, and previously unflooded areas have become inundated during high rain events.

Climate change is also anticipated to increase risks and vulnerabilities for future populations and infrastructure. Climate change increases the frequency, duration and intensity of natural hazards. These increases create new risks to local governments and challenge pre-existing mitigation plans. They also pose a unique threat to the most at-risk populations by exacerbating the impacts of disasters on underserved and socially vulnerable populations who already experience the greatest losses from natural hazards.

Aging infrastructure is a global challenge amplified by the intensifying natural disasters and aging workforce. These issues continue to highlight the adverse effects of climate change on our infrastructural systems and call for significant investment in improving the resilience of the world's built environment. Aging infrastructure will also be a concern as the demand to meet the needs of the increasing population will be a challenge to keep up with.

1.2.2.7. Federal Government and Military Presence

The NOVA region has buildings that house federal and high-level government operations. There is also a strong military presence in the area. The United States Marine Corps base in Quantico includes a Federal Bureau of Investigation training academy. The Joint Base Myer-Henderson Hall, near Arlington Cemetery, comprises Fort Myer, Fort McNair, Fort Belvoir, and Henderson Hall. It is commanded by the United States Army, but it has resident commands of the Army, Navy, and Marines.

2. Planning Process

Requirements

- **§201.6(c)(2)(1):** [The] plan documents the planning process, including how it was prepared and who was involved in the process for each jurisdiction.
- **§201.6(b)(2):** [The] plan documents an opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, agencies that have the authority to regulate development as well as other interests to be involved in the planning process.
- **§201.6(b)(1):** [The] plan documents how the public was involved in the planning process during the drafting stage.
- **§201.6(b)(3):** [The] plan describes the review and incorporation of existing plans, studies, reports, and technical information.
- **§201.6(b)(4)(iii):** The plan describes how the communities will continue public participation in the plan maintenance process.
- **§201.6(b)(4)(I):** The plan describes the method and schedule for keeping the plan current (monitoring, evaluating, and updating the mitigation plan within a 5-year cycle).

2022 HMP Update

- This section was reorganized and updated for consistency with the review criteria.
- Participant and engagement information was updated to reflect the 2021–2022 planning process and adaptation of engagement methodology to accommodate social distancing measures during the Coronavirus (COVID-19) pandemic.

The jurisdictions of Northern Virginia are committed to creating comprehensive and functional emergency management programs, which include mitigation, preparedness, prevention/protection, response, and recovery.

The mitigation planning process used for this 2022 Plan update followed multiple steps that built on previous planning efforts. It ensured that the 2022 Plan is compliant with Federal Emergency Management Agency (FEMA) regulations, consistent with the standards of the Emergency Management Accreditation Program (EMAP), and appropriate for all 21 participating jurisdictions in the Northern Virginia planning area to use.

2.1. Overview

The 2022 NOVA HMP update project was funded by FEMA through the Virginia Department of Emergency Management (VDEM) Grant Agreement Number PDMC-PL-03-VA-2018-003 and administered by the Prince William County Office of Emergency Management. A contract was executed with IEM to facilitate the Plan update process in coordination with Prince William County.

As part of the Plan update process, the contractor was tasked with researching national best practices in hazard mitigation planning and coordinating a jurisdiction needs analysis to identify specific community needs in relation to hazard vulnerabilities and mitigation planning. The results of these two tasks helped inform how the data and information in this update are presented in a more functional way.

In conjunction with the best practices and needs analysis, the contractor prepared multiple options for reorganizing the components of the Plan that would improve the ease of locating specific data and information, and, more specifically, merge data and information related to each jurisdiction into separate components of the Plan.

The *2017 Northern Virginia Hazard Mitigation Plan* underwent a comprehensive review and revision of this 2022 update. The update process was based on the accepted planning principles and guidance used in 2017, the planning criteria contained in 44 Code of Federal Regulations (CFR), Part 201.6, and the FEMA *Local Multi-Hazard Mitigation Planning Handbook (LHMP Handbook)* of March 2013. In addition, the document review included the standards of the Emergency Management Accreditation Program (EMAP) of 2019. The aim was to ensure consistency with the relevant standards for jurisdictions desiring to pursue accreditation. The EMAP standard is nationally recognized as a mark of excellence that provides a measure of accountability for a jurisdiction's emergency management program.

2.2. Summary of Changes

The 2022 revision is a comprehensive review and update of the *2017 Northern Virginia Hazard Mitigation Plan*. Changes to the Plan's format and contents involved a multistep process that included best practices research and an assessment of jurisdiction planning needs.

Table 9: Summary of Changes in the 2022 HMP

Section	Changes
All	• Comprehensive review and update of hazard risk and vulnerability data and information • Plan format reorganized to highlight the Plan support sections, hazard analysis, and mitigation strategy • Reformatted to be consistent with FEMA planning guidance • Jurisdiction Annexes developed to consolidate jurisdiction-specific data and information • Reviewed for consistency with the *2017 Virginia Hazard Mitigation Plan* • Non-natural hazards were added and addressed in a separate volume • Jurisdictional-specific annexes were added

Part 1: The Plan	Volume I: Base Plan
Section 1: Introduction	• Streamlined to highlight key information locations in the plan • Updated to reflect content location changes • Brief profile provided for Plan context
Section 2: Planning Process	• Participant and engagement information updated to reflect the 2021–2022 planning process and adaptation of engagement methodology to accommodate social distancing measures during the Coronavirus (COVID-19) pandemic
Section 3: Plan Maintenance and Adoption	• Reformatted to include procedural guidance to include the method and schedule for monitoring, evaluating, and updating the Plan • Expanded detail on Plan monitoring, evaluating, and updating to include roles and responsibilities, description of specific method and schedule, and data forms • Developed Plan maintenance worksheets (see Appendix A)

Part 2: Natural Hazard Analysis	Volume I: Base Plan
Section 4: Hazard Identification and Risk Assessment Methodology	• Hazard analysis methodology consolidated into a separate section • Updated description of the methodology
Section 5: Hazard Profiles, Risks, and Vulnerability	• Latest hazard impact and disaster declaration data added • Hazard profiles revised to reflect the latest impacts and consequences • Added new hazard profiles for human infectious diseases • Incorporated stakeholder input into hazard profiles • Detailed summary of 2019 flooding impacts and discussion of changes in level of risk and vulnerability added to Section 5.5, Flood/Flash Flood • High Hazard Potential Dam Grant Program (HHPD) requirements were considered and referenced in Section 5.1, Dam Failure
Section 6: Impacts of Climate Change	• New section incorporates discussion of climate change impacts to all natural hazards

Part 3: Mitigation Strategy	Volume I: Base Plan
Section 7: Capability Assessment	• Updated capabilities assessments conducted for all jurisdictions
Section 8: Goals and Objectives	• Goals and objectives from the 2017 NOVA HMP were reviewed and revised to a streamlined goal statement to ensure consistency with FEMA mitigation requirements
Section 9: Mitigation Actions	• Adapted from the 2017 NOVA HMP to include additional analysis of progress in mitigation • Updated funding descriptions and requirements were added per the latest FEMA guidance documents and the 2018 Virginia Hazard Mitigation Plan

Appendices	Volume I: Base Plan
Appendices to the Base Plan	• Documentation of the planning process, the data sources, and the mitigation strategy
Jurisdictional Annexes	• Detailed data and information incorporated into individual annexes for each jurisdiction

Section	Volume II: Non-Natural Hazards
Plan Sections	• Hazard Profiles (including risk assessment and vulnerability analysis) were developed for participation jurisdictions • Mitigation Strategies were developed for participating jurisdictions

2.3. Planning Organization

Planning organization roles and responsibilities were defined as an initial step in the planning process. Roles were described as follows:

- Project Team: Point of Contact, Deputy Emergency Management Coordinator for Prince William County Office of Emergency Management, and Contractor
- Planning Team:
  - Northern Virginia (NOVA) Emergency Managers (“Emergency Managers Group”)
  - NOVA Emergency Management Planners (“Planning Group”)
  - Subject matter experts/technical specialists

The NOVA Emergency Managers Group was tasked with oversight of the 2022 Plan update process. Some members of this group were involved with the 2017 Plan update, so they were familiar with the scope of hazards, risks, and mitigation opportunities and projects in the region. The NOVA Emergency Managers Group tasked all projected responsibilities to the NOVA Planning Group.

Table 10: Planning Entities, Participants, and Responsibilities

Project Team	Participants	Responsibilities
NOVA	Project Coordinator (Deputy Emergency Management Coordinator, Prince William County Office of Emergency Management)	• Point of contact for Northern Virginia Hazard Mitigation planning grant • Coordinate planning activities • Monitor project deliverables and schedules
IEM	Consultant Team	• Coordinate hazard mitigation planning process with Project Coordinator • Develop all Plan components, with updated data, analysis, and graphics • Coordinate community and public outreach activities with the Planning Group • Conduct Plan review and writing with contractor staff, update formats and information to meet compliance requirements • Prepare and submit deliverables • Prepare and submit weekly progress reports • Provide technical assistance to the Project Coordinator during the planning, writing, review, approval, and adoption processes

Planning Team	Participants	Responsibilities
Planning Group	Local Jurisdictions	• Represent their jurisdiction in the planning process • Participate in planning meetings through attendance and assistance in identifying, locating, collecting, compiling, and/or analyzing relevant information and data • Make planning recommendations as needed to the Emergency Managers Group • Participate in developing the risk assessment and mitigation strategy • Review the Plan and provide feedback and recommendations for improvement • Validate specific data and topics related to the area of authority and/or responsibility • Identify potential resources from agencies, departments, disciplines, and organizations that could support the mitigation strategy, including specific mitigation actions and potential funding sources
Stakeholders	Subject matter experts/technical specialists from other governments, nonprofits, and the private sector	• Assist in identifying, locating, collecting, compiling, and/or analyzing information and data relevant to expertise • Assist in developing the risk assessment and mitigation strategy • Validate specific data and topics related to the area of authority and/or responsibility • Review the Plan and provide feedback relevant to the area of expertise • Identify potential resources from agencies, departments, disciplines, and organizations that could support the mitigation strategy, including specific mitigation actions and potential funding sources

Since the 2017 update, the Emergency Managers Group has maintained its responsibilities as the oversight group for monitoring, evaluating, and revising the plan, and it will continue this function in overseeing and implementing the 2022 Plan.

A key focus of the 2021–2022 planning effort was the importance of working as a team to ensure regionwide involvement in the development of all components of the Plan. Representatives from participating jurisdictions, key stakeholders, and partner agencies and organizations gathered data and critical information throughout the planning process, and this was then analyzed and validated by the Planning Team. This process helped the Planning Team identify the greatest opportunities for loss reduction by addressing the most frequent hazards, building support and ownership of the mitigation strategy and its identified activities, and ensuring that the resulting strategy would lead to comprehensive progress in reducing risk.

2.4. Planning Process

The planning process followed the step-by-step framework described in FEMA's *LHMP Handbook.*[34] The following four steps describe the general methodology for mitigation planning:

- Identification and analysis of natural and non-natural hazards and their associated risks that could impact the community.
- Assessment of the community's vulnerability to natural and non-natural hazards.
- Assessment of the community's capabilities, including current policies, ordinances, and resources, to implement mitigation initiatives that reduce or avoid the impacts of disasters.
- Development of hazard mitigation strategies that can be implemented to reduce future vulnerability.

The process for moving each planning step forward involved presenting planning concepts, data, and plan elements to the Planning Group at scheduled meetings. The group then made recommendations to the Emergency Managers Group, who made decisions such as identifying hazards to include in the Plan; determining the plan format; reviewing, providing input, and approving plan components, and making the decisions necessary to move the plan update process forward.

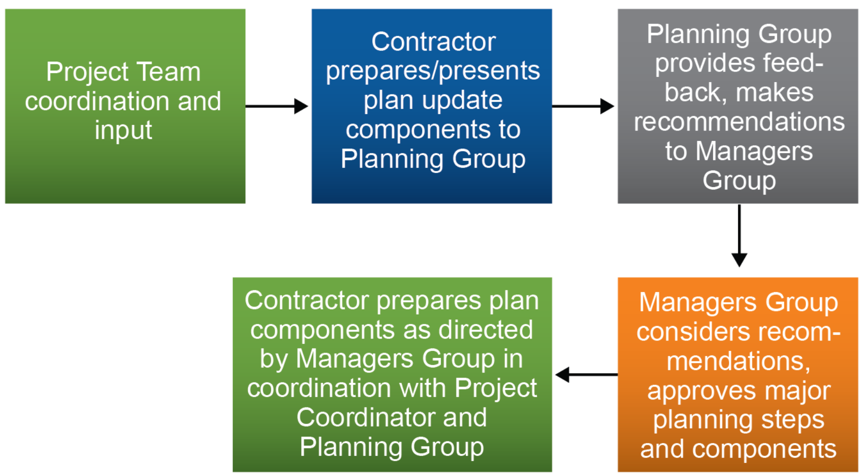

Figure 13: Planning Process

The planning process was initiated by the Prince William County Office of Emergency Management in 2020, with the development of a scope of work and a request for proposals from consultants to facilitate the plan update process. With the selection of a vendor and contract approval, the Project Team was formed, and work began in late February 2021. On March 9, 2021, the Project Team met virtually via Microsoft Teams to formally initiate the project by establishing a project management plan and schedule that addressed project coordination, stakeholder engagement, group meetings, one-on-one stakeholder meetings, public outreach and input, data review and updates, other community engagement opportunities, and briefings to key officials. Consideration was given to the following issues and needs at the outset of the process:

- What are the key hazard concerns of the jurisdictions?
- What partnerships should be forged to understand these concerns?

[34] Federal Emergency Management Agency. (2013, March). Local Mitigation Planning Handbook. https://www.fema.gov/sites/default/files/2020-06/fema-local-mitigation-planning-handbook_03-2013.pdf

- How can the whole community and emergency management support each other?
- How can the hazard mitigation plan be improved to make it more useable?
- What key issues need to be addressed to achieve a successful plan update?

A Virtual Engagement Plan outlining the methods and schedule for conducting public outreach in a COVID-19 environment was presented by the contractor at the March 2021 meeting and approved by the Planning Group.

2.5. Planning Meetings

The planning process was carried out through various methods, including project team coordination meetings, Planning Group and Emergency Managers Group meetings, email, virtual data collection, validation meetings, one-on-one virtual jurisdiction planning meetings, weekly progress reports to the Project Coordinator, public engagement opportunities, and phone and email communication to facilitate workflow and validate data and information. Meetings were conducted virtually throughout the planning period because of ongoing limitations for in-person meetings related to COVID-19 restrictions.

Along with the meetings outlined below, updates of the planning process were provided every month at both the NOVA Planner's Meeting and NOVA EM Meetings.

Table 11: Planning Meeting Schedule, Topics, Participants, and Format

Date	Topic	Participants
March 9, 2021	Project Team Initial Meeting	Project Coordinator, IEM Contractor
April 19, 2021	Kick-Off Meeting	Planning Group, IEM Contractor
May 25, 2021	Best Practices Research, Jurisdiction Needs Assessment, Plan Format	Planning Group, IEM Contractor
June 1, 2021	HIRA Overview, Hazard Risk Ranking Methodology	Planning Group, IEM Contractor
June 4, 2021	Plan Format, Risk Ranking Methodology, Non-natural Hazard decision	Managers Group, IEM Contractor
June 22, 2021	Hazard Data updates, Capabilities Assessment	Planning Group, IEM Contractor
July 6, 2021	Mitigation Strategy 1: Goals and Objectives, Hazard Problem Statements	Planning Group, IEM Contractor
July 20, 2021	Mitigation Strategy 2: Mitigation Actions and Priorities	Planning Group, IEM Contractor
August 3, 2021	Mitigation Strategy 3: Projects Workshop	Planning Group, IEM Contractor
September 14, 2021	Planning Wrap Up	Planning Group, IEM Contractor
February 1, 2022	Draft Plan Review Workshop	Planning Group, IEM Contractor

In addition to the scheduled planning meetings, separate meetings were held with multiple jurisdictions throughout the planning process to assess planning needs, collect and verify data and information, and provide technical assistance to the jurisdiction planning committees. A total of 44 meetings were held with jurisdictions.

Meeting agendas and formats varied based on whether it was a large group meeting or a one-on-one jurisdiction meeting. These interactions provided a step-by-step approach to accomplishing each planning objective.

Documentation of the planning and jurisdiction meetings, including schedules, agendas, minutes, handouts, and presentations, is provided in **Appendix A**.

2.6. Participation

Members of the NOVA Emergency Managers Group and Planning Group were determined by jurisdiction, with representation from each of the four counties, five independent cities, and many of the participating towns. County members also represented and assisted the towns through the planning process, providing data sources and technical assistance.

Stakeholders from VDEM, the Northern Virginia Emergency Response System, Metropolitan Washington Airports Authority, and the Northern Virginia Planning Commission participated in the NOVA Planning Group.

Over planning period from March 2021 to September 2022, stakeholders participated in the planning process, which included meetings, technical assistance, and plan review and input. The list of all participants in the Plan update process is provided in **Appendix A, Record of Participation**.

The participation of agencies and stakeholders was determined through input from the NOVA Emergency Managers and Planning groups. Coordination between state agencies, regional agencies and organizations, and local jurisdictions was accomplished with one-on-one virtual meetings and emails sent during the planning process, along with periodic phone meetings between the Planning Team members and the contractor. The stakeholder meetings were conducted virtually and by phone, and they were in addition to the regular meetings of the Planning Group.

During the planning meetings, stakeholders were asked to provide insight into how their agencies/ organizations engaged in mitigation and planning efforts, along with input and information on the hazards facing the jurisdictions and the NOVA region. Stakeholders were contacted by email to participate in stakeholder workshops, given progress reports and an opportunity to participate in public surveying, and provided hazard data sources and action items. They reviewed the draft of the Plan to provide input. Those who did not participate in the planning meetings or individual meetings provided input through technical review and assistance, and by providing data.

Throughout the planning process, between meetings and final submission, stakeholders were provided the opportunity to review drafts of the base plan which includes hazard profiles and provide feedback along with data such as damage histories, frequency of current and future events, and resources. The Planning Group, Emergency Managers Group, and stakeholder and public review comments were combined with final planning reviews to complete the final submission of the draft plan to the Commonwealth on September 27, 2022.

2.7. Timeline of Key Activities

Each step in the planning process was built on the foundation of activities conducted by the Planning Group and at other meetings, providing a high level of assurance that the mitigation actions proposed by the participants and the priorities for implementation are valid.

Planning milestones measured the successful outcome of each step in the planning process.

Table 12: Milestones in the Planning Process

Event or Product	Milestone	Method of Completion
Best Practices Research	• Identified methods and practices that informed the plan update, including plan format, content, and presentation	Contractor research and approval of the summary report by the Emergency Managers Group
Jurisdiction Needs Analysis	• Provided multiple opportunities for specific input from each jurisdiction related to methods to improve and enhance the plan	Jurisdiction Needs Questionnaire and follow-up jurisdiction meetings
General Planning Group Meetings	• Developed hazard mitigation planning network • Built components of the plan • Provided frequent opportunities for input and technical assistance • Marked progress in the plan update process	Meetings with this group occurred throughout the update process
Capabilities Assessment	• Analysis of planning and regulatory, administrative and technical, education and outreach, smart growth, funding, and National Flood Insurance Program capabilities	Capabilities Assessment Worksheets completed by jurisdiction representatives
Hazard Profiles and Risk Assessment	• Description of methodology: scope, steps, data sources, and validation • Identification of a comprehensive list of hazards to be addressed in the plan • Qualitative and quantitative examination of the vulnerability of critical community facilities, systems, and neighborhoods to the impacts of future disasters utilizing maps and geographic information system modeling and looking at specific vulnerabilities	Contractor research and Hazus analyses provided initial updated data and information that was reviewed and expanded by jurisdictions completing hazard identification and risk worksheets and reviewing and updating critical assets inventories
Outreach and Education	• Virtual Engagement Plan • Hazard survey for stakeholders • Draft Plan posted for public review and input	Jurisdictions posted Hazard Mitigation Fact Sheet, Hazard Survey, and draft Plan with public information releases
Mitigation Strategy and Implementation Plan	• Goals, objectives, and development of the mitigation strategy	Proposed revision of 2017 goals and objectives were presented to and approved by Planning Group and Emergency Managers Group Contractor worked directly with jurisdictions to review progress on previous actions and develop new actions,

Event or Product	Milestone	Method of Completion
		along with the Action Plan for Implementation
Plan Maintenance Procedures and Schedule	• Indicators to measure progress in next planning cycle: ▪ Monitoring ▪ Evaluation ▪ Updating	Procedural guidance was expanded with forms to utilize for monitoring and evaluating the plan
Public Input	• Hazard Survey • Comment period for review and input of draft plan	Information was posted by jurisdictions periodically throughout the planning process to solicit public input
Plan Approval	• Plan reviewed by VDEM; FEMA Approvable Pending Adoption (“APA”)	[PENDING]
Plan Adoption	• Plan adopted by all Jurisdictions	[PENDING]
Final Plan Approval	• FEMA letter documenting final approval	[PENDING]

2.8. Public Participation and Input

Public awareness of the Plan and input in the update process is a recognized benefit to jurisdictions in the NOVA region. The planning concept in Figure 14 represents the relationships between the Emergency Managers Group, the Planning Group, stakeholders, and the public.

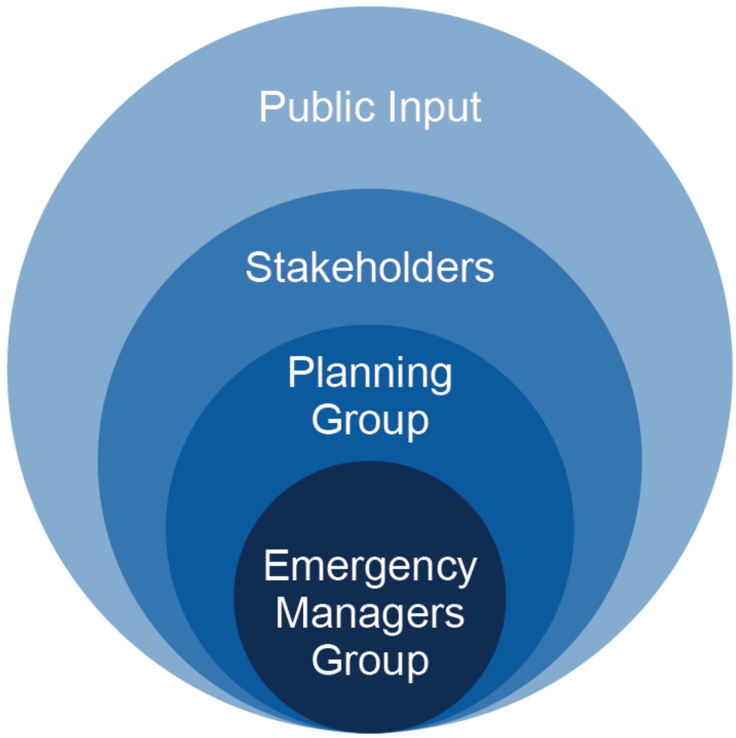

Figure 14: Planning Relationships

2.8.1. Public Engagement

The participants of the Northern Virginia All Hazards Mitigation Plan Update provided a survey link to the general public using public outreach on social media, county or city websites, and other means of outreach to their citizen for their comments and concerns about the natural and non-natural hazards that affect their area. The survey was open from August 8, 2021, to November 3, 2021.

The survey and survey results can be found in **Appendix A, Public Engagement**.

From the 1,000+ survey responses, climate change and pandemic were the most concerning hazards for residents in the Northern Virginia Area.

2.9. Review and Incorporation of Existing Plans, Studies, Reports, and Technical Information

Table 13: Review and Integration with Other Plans, Programs, and Initiatives

Document	How Information Was Used for the 2022 HMP Update

Arlington County, FEMA Risk MAP Community Coordination & Outreach Meeting, November 2020	• Reference document for jurisdiction annex
	  ▪ Schedule for the adoption of preliminary maps issued 9/18/2020
	• Reference document for flood sections
	  ▪ Image of risk zones on flood maps (Slide 8)

Arlington County, Comprehensive Emergency Management Program, April 2017	• Includes mitigation plan as a component plan (p. 4) • Identifies primary hazards as: natural (flood, wind damage, tornado, severe winter weather, drought, hurricane, and infectious disease) and non-natural (hazardous materials release, transportation accidents, gas pipeline incident, power failure, resource shortage, water contamination/shortage, and "intentional" [human-caused] civil/criminal disturbance, terrorism) (pp. 12–13) • References Threat and Hazard Identification and Risk Assessment (THIRA) as the foundation for vulnerability assessment (p. 12)
Arlington County Community Energy Plan, an element of Arlington County's Comprehensive Plan, September 2019	Reviewed climate action framework for consistency with the NOVA HMP goals and objectives. One goal is linked to the NOVA HMP goals: • Harden key facilities and community resources against power outages and resulting reduction or interruption of vital community services (p. 8)
Climate Resilience Dashboard, Northern Virginia Regional Commission. Website	Reviewed for climate change context in the Northern Virginia region
Fairfax County Emergency Operations Plan (EOP), June 2019	• Reviewed Hazard Mitigation Section X for consistency with the NOVA HMP goals and objectives. The mitigation goal in the EOP is to "reduce loss of life and property by lessening the impact of disasters" (p. 81) • HMGP project eligibility criteria outlined in EOP integrated into Fairfax County Jurisdiction Annex (p. 82)
Fairfax County Pre-Disaster Recovery Plan (PDRP), April 2020	• Relevant information integrated into the Fairfax County Jurisdiction Annex • The NOVA HMP included by reference in the PDRP • 2017 NOVA HMP hazard risk ranking included as a reference in the PDRP (p. 2-2) • Catastrophic Hazard Identification and Risk Assessment (Table 2.2, p. 2-2) integrated into the Jurisdiction Annex
Flood Risk Management Planning Resources for Washington, DC, January 2018.	References included in the flood hazard section • Includes information on flood risk management resources, mapping current flood risk, and riverine, interior, and coastal flooding

Document	How Information Was Used for the 2022 HMP Update
Loudoun County Emergency Operations Plan, July 2019	Reference document for jurisdiction profile • Reviewed THIRA for consistency with 2022 NOVA HMP hazards (pp. 1-12, 1-13)
Loudoun County General Plan, Interim Final Version, December 2020	Reference document for jurisdiction profile • Includes information on the county's growth management land practices for four types of policy areas—urban, suburban, transition, and rural—and joint land management areas and rural historic villages (Chapters 1–3) • Includes maps that address land use, natural and heritage resources, fiscal management, and public infrastructure • The county's comprehensive plan includes the general plan, general plan maps, and a countywide transportation plan
National Capital Planning Commission, 2018–2022 Strategic Plan, September 2017	Reference document for regional goals and consistency with the core responsibilities of the planning commission, including plan and project reviews, comprehensive planning, and federal capital improvements program projects in the NOVA planning region
National Capital Region Climate Change Report, Metropolitan Washington County of Governments, November 12, 2008	Reference document for climate change section • Includes information on the potential impacts of climate change on the Metropolitan Washington Region, which includes the planning area • Includes setting targets for reducing regional emissions and actions to meet these targets
Northern Virginia Emergency Response System, Casebook Scenarios, October 2020	Reference document for high wind/severe storm, cyberattack, acts of violence, terrorism, pandemic, and DC walkout evacuation hazard sections
"Northern Virginia Evacuation Plan" (PowerPoint Presentation), undated	Reference document for Capability Assessments • Includes evacuation concept of operations, enhancements to evacuation operations, key evacuation concepts, and evacuation plan scope (Slides 4–15) • Evacuation plan covers entire planning area
Region Forward, A Comprehensive Guide for Regional Planning and Measuring Progress in the 21st Century, Greater Washington 2050 Coalition, January 2010	Reference document for consistency with regional goals • "Coalition members found broad agreement on common goals that create a comprehensive vision for the region. The goal categories include land use, transportation, environmental, climate and energy, economic, housing, education, health and human services, and public safety" (p. 1).
Resilient ALX Charter, Alexandria Citizens Corps Council, 2020	Reference document for jurisdiction annex • This project "will take a comprehensive approach to understand areas of risk and develop a sound strategy to prepare for and mitigate against those risks" (City of Alexandria, Virginia Memorandum).
Terrorism Response, A Checklist and Guide for Fire Chiefs and Community Preparedness Leaders, 4th Edition, International Association of Fire Chiefs	Guidance for assessing threats and capabilities based on FEMA's National Preparedness Goal Core Capabilities • Reviewed for the Terrorism section in relation to target hazards, critical infrastructure protection, and response capabilities (p. 15)

Document	How Information Was Used for the 2022 HMP Update
	• References included in the Terrorism section of HMP
Prince William County Emergency Operations Plan 2020	Reviewed for Hazard Mitigation for consistency and incorporation.
Prince William County Comprehensive Plan 2019	The Comprehensive Plan is the blueprint for projected growth and development in the county. Was used to identify growth and future conditions.
Prince William County Strategic Plan July 2021	Reviewed for future conditions and possible

2.10. Future Planning and Mitigation Efforts

The jurisdictions in the Northern Virginia Planning Area remain committed to supporting and expanding the engagement of schools, nonprofits, private businesses, and other partners in mitigation planning and activities. This is achieved by encouraging partnerships during and after the local hazard mitigation planning process and by encouraging active engagement between local emergency management, public and private entities, organizations, and the public.

3. Plan Maintenance and Adoption

Requirements

- **§201.6(c)(4)(i):** [There is a] description of the method and schedule for keeping the plan current (monitoring, evaluating, and updating the mitigation plan within a 5-year cycle).
- **§201.6(c)(4)(iii):** [The plan discusses] how the community will continue public participation in the plan maintenance process.

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- Reformatted to include procedural guidance on the method and schedule for monitoring, evaluating, and updating the Plan.
- Expanded to include details on plan monitoring, evaluating, and updating in terms of roles and responsibilities, description of specific methods and schedule, and data forms.
- Developed plan maintenance worksheets and included in Appendix A.

3.1. Overview

The 2022 NOVA HMP is a living document that will guide mitigation actions over time. As conditions and circumstances change, new information may become available, and actions may progress over the life of the Plan. The actions and plan contents may be adjusted as necessary to maintain their relevance and effectiveness.

Periodic revisions and updates of the Plan are required to ensure the goals of the Plan remain current while considering potential changes in hazard vulnerability and mitigation priorities. In addition, revisions may be necessary to ensure the Plan is in full compliance with applicable federal and commonwealth regulations. Periodic evaluation of the Plan will also ensure specific mitigation actions are being reviewed and carried out according to each participating jurisdiction's individual Mitigation Action Plan for Implementation and Integration.

Implementation and maintenance of the Plan work in parallel to ensure the success of the mitigation strategy. This section outlines the process jurisdictions will follow to implement the Plan and integrate the information from the 2022 NOVA HMP into other planning mechanisms. This section provides the overall strategy for plan maintenance and outlines the method and schedule for monitoring, evaluating, and updating the Plan. The implementation and maintenance processes will serve to periodically assess project status, identify benchmarks, make appropriate adjustments as needed, and ensure the planning process is ongoing and progress in risk reduction is being made. The scope of this section includes the following plan maintenance steps:

- Monitoring the Plan,
- Evaluating the Plan,
- Updating the Plan,
- Integration and continued public participation.

This section includes procedures to implement each phase of the Plan maintenance process by assigning responsibility, identifying the method and schedule, and providing the sequenced format for collecting, analyzing, and reporting information that will keep the Plan up to date.

Plan maintenance activities take place at two levels. This section describes how the 2022 NOVA HMP Planning Group will carry out the Plan maintenance functions related to the **Base Plan** and its supporting appendices and attachments. Concurrently, each jurisdiction has the authority and responsibility to maintain its **Jurisdiction Annex** to the Plan and may choose to establish an internal schedule consistent with the regional planning area's schedule. For example, a jurisdiction may determine a semi-annual review of its mitigation actions is appropriate to monitor progress, particularly if several short-term actions are being implemented and completed simultaneously.

Maintenance of Volume II: Non-Natural Hazards, of this Plan, may take place in concert with the maintenance activities of the **Base Plan** and **Jurisdiction Annexes**, or the NOVA Planning Group may determine an alternative method and schedule for maintenance of the separate volume.

If a jurisdiction no longer wishes to actively participate in the development and maintenance of the plan, it must notify the NOVA HMP Coordinator and the Virginia Department of Emergency Management (VDEM) in writing.

3.1.1. Plan Maintenance Concept

The Plan maintenance process provides regional and community officials an opportunity to evaluate actions that have been successful and to execute documentation of potential losses avoided due to the implementation of specific mitigation measures. This process also provides the opportunity to address mitigation actions that may not have been successfully implemented as assigned. The Northern Virginia Emergency Managers will be responsible for reconvening the Planning Group and conducting reviews of the Plan in coordination with VDEM, as described in the method and schedule in this section.

3.1.2. Plan Review and Reporting Schedule

At a minimum, the NOVA HMP will be reviewed annually and following a disaster declaration for any of the planning area jurisdictions. Details of the review meetings may include the following:

- Meetings will be held, at a minimum, once a year.
- Meetings will be held within three months after a federal disaster declaration or significant hazard event for Plan review, revisions, and/or project prioritization.
- Meetings will be held when required or needed due to changes in federal or Commonwealth legislation and/or regulations that impact hazard mitigation in the planning area.

The NOVA HMP will be reviewed annually to assess the effectiveness of the Plan and to identify any required or recommended changes or amendments. A report will be prepared to document the results of the monitoring and evaluation steps, including the status of proposed mitigation actions and funding opportunities that have occurred since the previous plan review. In addition, the report will identify any obstacles or reasons for delays in the completion of mitigation actions, along with recommended strategies to overcome them.

Following a disaster declaration, the NOVA HMP Planning Group will reconvene, and the Plan will be revised as necessary to reflect lessons learned and to address specific circumstances arising from the event. It is the responsibility of the Northern Virginia Emergency Managers to reconvene the Planning Group and to ensure the appropriate stakeholders are invited to participate in the Plan revision and update process following the declaration of the disaster event.

Any necessary revisions to the NOVA HMP **Base Plan** elements shall follow the plan amendment process outlined in state and Federal Emergency Management Agency (FEMA) guidance. For changes and updates to jurisdictional Action Plans for Implementation and Integration, appropriate local designees will assign responsibility for the completion of the task.

Administrative changes, as defined in the Foreword of the Plan, may be made at any time by the Administrative Agency's NOVA HMP Coordinator, or his/her designee and documented in the Record of Changes.

Mitigation Actions may be changed, updated, removed, or added by a jurisdiction at any time, as long as the change or addition is approved by the local Jurisdiction Planning Committee.

3.1.3. Plan Amendment Process

Participating jurisdictions have the authority to approve and adopt changes to their own Action Plan for Implementation and Integration without approval from the NOVA HMP Planning Group; however, the Planning Group should be advised of all changes as a courtesy and for consideration of changes or modifications to the regional **Base Plan**. The Planning Group will be responsible for verifying that the proposed change will not impact the jurisdiction's compliance with current Commonwealth and Federal mitigation planning requirements. Changes to either the regional **Base Plan** or local Action Plan for Implementation and Integration, other than administrative changes—e.g., agency name changes or corrections that do not change the hazard risks, vulnerabilities, or intent of the mitigation strategy—will necessitate the adoption of these changes by the appropriate governing body. The changes will also be submitted to VDEM and FEMA for approval and record keeping.

The Planning Group and its participating jurisdictions will forward information on any proposed change(s) to all interested parties including, but not limited to, all impacted county and municipal departments, individuals, and businesses. When a proposed amendment or amendments may directly impact specific private individuals or properties, each jurisdiction will:

- Follow existing local, state, or federal notification requirements, which may include published public notices as well as direct mailings.
- Forward information on any proposed plan amendments to VDEM and FEMA for approval.
- Disseminate the information to seek input on the proposed amendment(s) for no less than a 45-day review and comment period.
- At the end of the 45-day review and comment period, forward the proposed amendment(s) and all comments to the Planning Group for final consideration.

The Planning Group will review the proposed amendment(s) along with the comments received, and if appropriate, will submit a recommendation for the approval and adoption of the change(s) to the Plan to each participating governing body within 60 days. In determining whether to recommend approval or denial of a plan amendment request, the following factors will be considered by the Planning Group:

- There are errors, inaccuracies, or omissions made in the identification of issues or needs in the Plan.
- New issues or needs have been identified that are not adequately addressed in the Plan.
- There has been a change in information, data, or assumptions from those on which the Plan is based.
- There has been a change in local capabilities to implement proposed hazard mitigation activities.

Upon receiving the recommendation from the NOVA HMP Planning Group and prior to the adoption of the amended Plan the governing body will review the recommendation from the group, including the factors listed above, and any oral or written comments received at the public comment period. Following that review, the governing body will make one of the following recommendations for action to the NOVA Emergency Managers:

- Adopt the proposed amendment(s) as presented.
- Adopt the proposed amendment(s) with modifications.
- Refer the amendment(s) request back to the Planning Group for further revision.
- Defer the amendment(s) request back to the Planning Group for further consideration and/or additional hearings.

To establish a more clearly defined system of plan maintenance that will continue in future planning cycles, the roles and responsibilities and the monitoring procedure and schedule, including the step-by-step actions and specific tasks associated with each action to maintain the plan, are defined.

3.2. Method and Schedule for Monitoring the Plan

This plan monitoring step tracks the implementation of the Plan over time.

Table 14: NOVA HMP Monitoring Roles and Responsibilities

Stakeholder	Roles and Responsibilities
NOVA HMP Coordinator/Designee	• Coordinate and facilitate the monitoring process. • Initiate and maintain a schedule of monitoring activities. • Collect data and disseminate reports. • Maintain records and documentation of all monitoring activities.
NOVA HMP Planning Group/Jurisdiction Representatives	• Participate in the monitoring process as requested by the NOVA HMP Coordinator. • Assist in collecting and analyzing data. • Assist in disseminating reports to stakeholders and the public. • Maintain records and documentation of all jurisdictional monitoring activities. • Promote the mitigation planning process with the public and solicit public input.

The following steps describe how the NOVA HMP planning area and its jurisdictions will monitor the progress of mitigation plan implementation annually and/or following a Federally Declared Disaster or significant event.

3.2.1. Hazard Mitigation Plan Monitoring Procedure and Schedule

Step 1: NOVA HMP Coordinator/Designee – Initiate monitoring process

- Notify the NOVA HMP Planning Group's jurisdiction representatives to facilitate an annual or post-disaster review.
  - Disseminate the Mitigation Action Monitoring Form* for mitigation action updates to Planning Group/jurisdiction representatives, along with the current list of mitigation actions in the Plan.
  - Disseminate the Mitigation Action Worksheet Form to representatives of stakeholder agencies with potential new mitigation actions.

- Notify NOVA HMP Planning Group's jurisdiction representatives to facilitate an annual or post-disaster review.
  - Disseminate the Mitigation Action Monitoring Form* for mitigation action updates to Planning Group/jurisdiction representatives, along with the current list of mitigation actions in the Plan.
  - Disseminate the Mitigation Action Worksheet Form to representatives of stakeholder agencies with potential new mitigation actions.

Step 2: NOVA HMP Coordinator/Designee and Planning Group/Jurisdiction Representatives – Collect and assess the status of current actions and identify new actions

- Assess progress for current actions, including implemented and funded actions and any new opportunities for mitigation actions.
  - Have any mitigation actions been completed?
  - Are different or additional resources now available?
  - Are mitigation actions being implemented and monitored?

Step 3: NOVA HMP Coordinator/Designee and Planning Group/Jurisdiction Representatives – Assess new opportunities for mitigation

- Has a major disaster occurred that presents opportunities for mitigation?
- Is there a new initiative, agency priority, existing planning mechanism, or information that is not represented in current actions?

Step 4: NOVA HMP Coordinator/Designee – Prepare and disseminate the status report to all planning area jurisdictions and stakeholders, including elected officials

- The status report may include:
  - Status of current and implemented actions.
  - Proposed new actions.[35]
  - Potential funding sources.
  - New opportunities for mitigation, including actions in development, new programs, etc.

Each jurisdiction participating in the Plan has identified an individual (by position or title and agency) who is responsible for monitoring the jurisdiction's actions and opportunities during the planning cycle. Jurisdiction Annexes provide the primary and alternate contacts for mitigation planning.

[35] The Mitigation Action Monitoring Form is provided in **Attachment A**. Jurisdictions may, annually or following a major disaster, update existing actions and/or add new mitigation actions to their current list of prioritized actions by using the Action Worksheets and Ranking System for Prioritizing Actions. This step does not require amendment to the Base Plan or Jurisdiction Annex.

3.3. Method and Schedule for Evaluating the 2022 Plan

This plan evaluation step assesses the plan's effectiveness in achieving its stated purpose and goals.

Table 15: NOVA HMP Evaluation Roles and Responsibilities

Stakeholder	Roles and Responsibilities
NOVA HMP Coordinator/Designee	• Coordinate and facilitate the evaluation process. • Maintain a schedule of evaluation activities. • Collect data and disseminate reports. • Maintain records and documentation of all evaluation activities.
NOVA HMP Planning Group/Jurisdiction Representatives	• Participate in the evaluation process. • Assist in collecting and analyzing information. • Assist in disseminating reports to stakeholders and the public. • Maintain records and documentation of all jurisdictional evaluation activities. • Promote the mitigation planning process with the public and solicit public input.

The following process describes the steps that NOVA HMP planning jurisdictions will take annually and/or following a Federally Declared Disaster or significant event to evaluate the effectiveness of the Plan.

Table 16: NOVA HMP Evaluation Procedure and Schedule

Action	Responsible Party	Tasks	Deliverable or Outcome
Initiate Annual Review	NOVA HMP Coordinator (or designee)	Notify lead agency/individual in each jurisdiction to facilitate annual review.	Work plan, schedule, and assigned resources to implement the plan review process.
Invite Planning Group and Key Stakeholders	NOVA HMP Coordinator (or designee)	Invite Planning Group members, key stakeholders, and others to participate in the plan evaluation process.	Invitation to participate, list of invited jurisdictions, existing and new stakeholders, and other key planning partners and public notice of annual evaluation.
Review Policies, Regulations, and Studies	NOVA HMP Coordinator (or designee) and Planning Group	Research new or updated laws, policies, regulations, initiatives, and studies that contribute to the hazard risk assessment or identified mitigation actions.	Status update for existing and new policies, regulations, initiatives, and/or studies.
Review Funding Programs and Planning Mechanisms	NOVA HMP Coordinator (or designee) and Planning Group	Assess changes in local, state, and federal agencies and their funding procedures, new grant programs or areas of focus and their potential integration into existing planning mechanisms.	Status update on existing and new funding procedures, grant programs, new areas of focus, and progress on integration into planning mechanisms.

Action	Responsible Party	Tasks	Deliverable or Outcome
Hazard Information	NOVA HMP Coordinator (or designee) and Planning Group	Research new or updated data and information that can contribute to risk assessments, loss estimates, or vulnerabilities in assets for participating jurisdictions.	Status update on recent disasters, hazard impacts and losses, lessons learned, and status of jurisdictional facilities and infrastructure. Annual update of NOVA HMP to reflect new risk assessment and capability data gathered from review of hazard events and impacts.
Mitigation Actions	NOVA HMP Coordinator (or designee) and Planning Group	Assess progress in previously implemented actions that reduce vulnerability and losses and any new opportunities for mitigation actions.	Status update on completed actions, pending actions, and implementation status of actions collected through monitoring procedure.
Outcomes	NOVA HMP Coordinator (or designee)	Maintain and complete documentation of the NOVA HMP review process, including any needed Plan updates, and prepare summary report.	Summary report of Mitigation Strategy Annual Update, including results of annual monitoring and evaluation process and Appendix A - *Plan Evaluation Checklist.*

Each jurisdiction participating in the Plan has identified an individual by position or title and agency who is responsible for evaluating the effectiveness of the jurisdiction's plan at achieving its purpose and goals during the planning cycle. Jurisdiction Annexes provide the primary and alternate contacts for mitigation planning.

3.4. Method and Schedule for Updating the 2022 Plan

This plan maintenance step reviews and revises the Plan on an established schedule to reflect changes in hazard risk, priorities, and development, as well as progress in local mitigation efforts.

The Plan review and revision process are ongoing throughout the five-year life cycle of the Plan. The monitoring and evaluation activities that are conducted, at a minimum, annually and following a major disaster, will assist in maintaining the currency of multiple components of the plan, such as the hazard identification and risk assessment and mitigation actions and priorities.

The end date for the completion of the Plan update will be five years from the date the FEMA "approvable pending adoption" Plan is adopted by the first jurisdiction, as confirmed by FEMA by letter. It is anticipated that the first adoption will occur in 2022, which would set a tentative date for Plan expiration in 2027.

Table 17: NOVA HMP Update Roles and Responsibilities

Stakeholder	Roles and Responsibilities
NOVA HMP Coordinator/Designee	• Coordinate and facilitate the Plan review, revision, and update process. • Maintain schedule of all Plan update activities. • Collect data and disseminate reports. • Maintain records and documentation of all monitoring, evaluation, and update activities. • Identify and implement opportunities for public participation and input in the planning process, including review of the revised draft plan.
NOVA HMP Planning Group/Jurisdiction Representatives	• Represent the jurisdiction and participate in the planning cycle, including Plan review, revision, and update process. • Collect and report data to the NOVA HMP Coordinator. • Maintain records and documentation of all jurisdictional Plan review and revision activities. • Promote the mitigation planning process with stakeholders and the public and solicit public input.

Following the five-year review, any necessary revisions will be implemented according to the reporting procedures and Plan amendment process outlined by state and FEMA guidance. Upon completion of the review and update/amendment process, the *Northern Virginia Hazard Mitigation Plan* will be submitted to the State Hazard Mitigation Officer for review and forwarded by VDEM to FEMA for approval.

The Plan update process and schedule are designed to focus on various components of the Plan throughout the five-year cycle. Based on the schedule described, all parts of the Plan will have been reviewed at the end of the five-year cycle, potentially reducing the time and resource burden in the final planning year.

Table 18: NOVA HMP Plan Five-Year Update Process and Schedule

Schedule	Plan Update Processes and Actions
Monitoring and Evaluation Activities – Ongoing throughout the five-year planning cycle	• Monitoring and evaluation results, meeting documentation, and other pertinent documents will be collected throughout the five-year life cycle of the Plan and used in the next NOVA HMP update. • Multiple meetings with elected officials, the NOVA HMP Planning Group, local jurisdictions, state and federal agencies, and interested parties will be conducted. • Activities, meetings, and interactions will be tracked and documented throughout the planning cycle. • The initial review of the NOVA HMP to kick-off the Plan update process will be conducted using the most recent version of the NOVA HMP that has incorporated annual and periodic revisions as its basis. • Complete the *Planning Considerations Worksheet* (**Attachment A**) to identify significant changes in planning capabilities or resources that have occurred since the previous update.

Schedule	Plan Update Processes and Actions
Updating the Risk Assessment – Conducted in the 1st quarter of the fifth year of the planning cycle	• NOVA HMP Coordinator and Planning Group/jurisdiction representatives will identify key stakeholders to invite to participate and contribute to the updated risk assessment. • Monitoring and evaluation results will be incorporated. • Changes since the previous Plan approval will be identified. • Each hazard will be assessed and updated to include new data since the date of plan approval and adoption and subsequent updates. • New hazard occurrences and potential changes in low-ranked hazards will be identified and assessed. • Any significant changes in jurisdictional risk assessments will be noted during Plan review and integrated into the updated NOVA HMP Base Plan.
Reviewing and Updating the Goals and Objectives – Conducted in the 2nd quarter of the fifth year of the planning cycle	• NOVA HMP Coordinator will coordinate with Planning Group/jurisdiction representatives and key partners to assess the status of current mitigation goals and objectives for potential revision. • Status of integration of mitigation goals and objectives with existing planning mechanisms will be assessed. • Any significant changes in mitigation goals, especially those that are inconsistent with the current Plan goals, will be assessed and incorporated as appropriate in the updated HMP. • Monitoring and evaluation results will be utilized to modify the goals and objectives and describe achievements.
Reviewing and Updating Mitigation Actions – Conducted in the 3rd quarter of the fifth year of the planning cycle	• NOVA HMP Coordinator will coordinate with Planning Group/jurisdiction representatives and key partners to obtain an update on the status of actions. • Monitoring and evaluation results will be utilized to assess the status and effectiveness of mitigation actions in meeting the goals and reducing risks. • Plan maintenance data from the implemented activities will be used to describe progress in the previous five years.
Compiling and Reviewing Information – Conducted in the 3rd quarter of the fifth year of the planning cycle	• NOVA HMP Coordinator and Planning Group/jurisdiction representatives will compile data and develop the updated HMP. • Draft will be made available for stakeholder review and input. • Draft will be made available for public review and comment. • All comments and suggestions will be incorporated, and the final draft completed.
FEMA Review – Conducted in the 4th quarter of the fifth year of the planning cycle	• FEMA review of draft HMP update.
Plan Adoption –	• Updated HMP will be adopted.

Adherence to the monitoring, evaluation, and update process schedule will ensure the Plan is kept current throughout its five-year cycle.

3.4.1. Integrating Mitigation into Existing Plans and Procedures

An ongoing responsibility of NOVA HMP Planning Group members and jurisdictional representatives is to identify additional stakeholders and existing planning mechanisms that can assist in integrating mitigation planning into short- and long-term community development and resiliency planning. This involves establishing hazard mitigation as a community planning priority that can be supported through the same community capabilities defined in **Section 7, Capabilities Assessment**:

- Planning and regulatory,
- Administrative and technical,
- Safe growth,
- Fiscal and resources, and
- Education and outreach.

Each step in the planning cycle includes ongoing opportunities to identify existing planning processes that will provide a platform for the integration of hazard mitigation planning.

Specific planning initiatives that provide the opportunity to integrate hazard mitigation are described in the jurisdiction *annexes.*

3.4.2. Continued Public Involvement

A critical part of plan maintenance is continuing to identify and provide opportunities for stakeholder and public involvement throughout the planning process and during the implementation of the Plan. Significant changes or amendments to the Plan may require a public hearing prior to implementing adoption procedures.

Additional efforts to involve the public in the maintenance, evaluation, and revision process will be made as necessary. These efforts may include:

- Advertising proposed changes to the NOVA HMP to the public.
- Utilizing the Planning Group and participant websites to advertise any maintenance and periodic review activities taking place.
- Keeping copies of the Plan accessible via websites accessible to the public.

References to opportunities for stakeholder and public involvement are addressed in Plan maintenance steps described in the monitoring, evaluating, and update method and schedule, as previously defined in this section.

3.4.3. Implementation of the Plan

The systems and procedures described in this section support the implementation of this Plan through the following measures:

- Annual review method and schedule that monitors and evaluates all elements of the Plan and tracks the implementation of the Plan over time.
- Incorporation of the Plan into existing planning mechanisms that support long-term resiliency planning.
- Documentation of progress in risk reduction through prioritizing and implementing local mitigation actions.

To assist with the Plan maintenance process, the following worksheets are provided as attachments in **Appendix A** as tools to monitor, evaluate, and update the plan:

- **Attachment A: Mitigation Action Monitoring Worksheet**
- **Attachment B: Plan Evaluation Checklist**
- **Attachment C: Planning Considerations Worksheet**

4. Hazard Identification and Risk Assessment Methodology

Requirements

§201.6(c)(2)(i): [The risk assessment shall include a] description of the type, location, and extent of all-natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and the probability of future hazard events.

§201.6(c)(2)(ii): [The risk assessment shall include a] description of the jurisdiction's vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description shall include an overall summary of each hazard and its impact on the community. All plans approved after October 1, 2008 must also address NFIP insured structures that have been repetitively damaged by floods. The plan should describe vulnerability in terms of the following:

- **§201.6(c)(2)(ii)(A):** (A) The types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard areas;
- **§201.6(c)(2)(ii)(B):** (B) An estimate of the potential dollar losses to vulnerable structures identified in…this section and a description of the methodology used to prepare the estimate.
- **§201.6(c)(2)(ii)(C):** (C) A general description of land uses and development trends within the community so that mitigation options can be considered in future land-use decisions.

§201.6(c)(2)(iii): For multi-jurisdictional plans, the risk assessment section must assess each jurisdiction's risks where they vary from the risks identified for the entire planning area.

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- Consolidated hazard analysis methodology into a separate section.
- Updated description of the methodology.

4.1. Overview

The foundation of the *2022 Northern Virginia Hazard Mitigation Plan* (HMP) is the hazard risk assessment. This assessment was built off the analysis of previous regional and commonwealth hazard mitigation plans, historical and statistical data, and other local plans that impact hazard risk, then updated to include recent data and shifts in hazard risk and vulnerability. To define effective mitigation actions to make the planning area more resilient to the impacts of future disasters, it is necessary to understand the particular hazards that threaten Northern Virginia and how they disrupt communities. It is also necessary to understand how the communities are vulnerable to the impacts of the identified hazards and the scope or extent of that vulnerability.

The purpose of this section is to provide, on a planning area-wide basis, an understanding of the risks posed by the hazards that threaten the Northern Virginia region. This section of the Plan presents the hazard identification and risk assessment methods, which include detailed descriptions of natural hazards that are known or are considered to be a threat to the people, property, infrastructure, environment, economy, or disaster operations of the participating jurisdictions. Non-natural hazard identification and risk assessment information is covered in Volume II of the HMP.

The following plans, studies, and documents provided essential hazard information described in this Plan update:

- Review of the 2018 Virginia State Hazard Mitigation Plan.
- Review of the 2017 Northern Virginia Hazard Mitigation Plan.
- Review of historical data of events that have occurred since the 2017 HMP was adopted, including input from subject matter experts and lessons learned from previous years.
- Assessment of current data archives provided by the NOAA National Centers for Environmental Information Storm Events Database.
- Analysis of specific hazard risk and vulnerabilities based on Hazus, Version 4.2, Level 1 model scenarios for earthquakes, floods, and high winds.
- Review of vulnerability and risk analyses contained in local plans for each jurisdiction, as applicable.
- Hazard identification surveys and risk ranking questionnaires completed by participants.
- Results and feedback from a hazard mitigation survey that was distributed to the public in all participating jurisdictions.
- Review of climate change studies and publications from various local, commonwealth, national, and international sources.
- Review of past Federal Disaster Declarations.
- Research on historical records, predictive models, and other verified data collected from a broad range of sources.

The hazard risk and vulnerability data presented in this Plan should also be used in the development and update of other local and commonwealth plans to provide a consistent foundation for all policies, plans, and programs that address hazards and the potential for reduction of the risk, impacts, consequences, and costs of disasters.

This section presents the hazards of highest concern, identified through a comprehensive risk assessment and consequence analysis. Hazards are described in terms of their characteristics, location and extent, history/previous events, probability of future occurrence, impacts and consequences, repetitive losses associated with the hazard (when applicable), and an overall analysis of vulnerability. Hazards that are considered to have a minimal potential for occurrence or minimal impacts/consequences were excluded from the hazard profile and did not receive further consideration in relation to vulnerability or mitigation actions.

For the 2022 HMP update, the risk assessment methodology was based on a quantitative analysis of risk developed to meet hazard mitigation planning criteria for FEMA's natural hazard planning requirements under Title 44 C.F.R., Part 201.6.

In addition to guiding mitigation planning, the detailed analysis of specific impacts and consequences factors provides guidance for all prevention, preparedness, response, and recovery plans; actions; and resources when a hazard occurs. For this hazard and risk assessment exercise to be truly successful, the results must dually inform and be informed by other jurisdictional planning efforts such as land use, transportation, capital projects, and comprehensive plans. A synergistic focus among planning initiatives will facilitate key decision-making and increase the efficiency and effectiveness of risk reduction efforts.

4.1.1. Definitions

- **Risk:** Potential for damage, loss, or other impacts created by the interaction of hazards with community assets.
- **Vulnerability:** Characteristics of community assets that make them susceptible to damage from a given hazard or threat.
- **Exposure:** People and property within the area the potential hazard could affect.
- **Risk assessment:** A product or process that collects information and assigns values to risks for the purpose of informing priorities, developing or comparing courses of action, and informing decision-making.
- **Extent:** The strength or magnitude of the hazard, which can be described in a combination of ways, depending on the hazard:
  - The value of an established scientific scale or measurement system.
  - Other measures of magnitude, such as water depth and wind speed.
  - The speed of onset, including the amount of warning time that allows for preparation.
  - The duration of the hazard event; for most hazards, the longer the duration, the greater the extent.
- **Probability:** The likelihood of the hazard occurring in the future, as described by historical frequencies, statistical probabilities, or general descriptions based on defined qualitative rankings.
- **Impacts:** How a hazard affects a particular area. What is at risk?
- **Consequences:** The vulnerabilities that follow from the set of conditions resulting from the hazard impacts.

4.2. Hazard Identification and Risk Assessment Process Methodology

The Planning Group is tasked with identifying natural hazards that impact the Northern Virginia region. In presenting these hazard profiles, it is important to describe how the decision to include these hazards was made. Non-natural hazard information is covered in Volume II of the Plan.

4.2.1. Step 1: Hazards for Initial Consideration

The initial step in identifying hazards for the 2022 NOVA HMP update began with reviewing the hazards included in the 2017 NOVA HMP, the 2018 Virginia COV-SHMP, and current FEMA hazard mitigation planning guidance. The following hazards were initially considered:

4.2.1.1. Natural Hazards

- Avalanche
- Dam Failure
- Drought
- Earthquake
- Extreme Temperatures

- Flood/Flash Flood
- Hail
- High Wind/Severe Storm (includes Hurricane and Tropical Storm)
- Landslide
- Lightning
- Non-Rotational Wind
- Sea Level Rise
- Sinkholes/Karst/Land Subsidence/Geological
- Solar Storm
- Storm Surge
- Tornado
- Tsunami
- Volcano
- Wildfire
- Winter Storm

4.2.2. *Step 2: Hazard Elimination*

The second step taken by the planning team was to identify which hazards are not likely to occur or significantly impact the planning area. Given Northern Virginia's location and geographical makeup, several hazards were precluded from occurring. There is no documentation or physical evidence to support that the following hazards have or will occur to a significant scale within the bounds of the planning area.

- Avalanche
- Tsunamis
- Volcanoes

Hail, lightning, non-rotational wind, and storm surge are addressed under high wind/severe storm since these hazards often occur simultaneously. Planning for these hazards in combination with one another allows for a more comprehensive mitigation strategy.

Sea level rise does not impact all jurisdictions in the planning area as most plan participants are located inland. Therefore, impacts from this hazard are addressed in the climate change section.

The planning group chose not to include solar storm in this update; however, including this hazard is a planning consideration for the next update as the impacts from this hazard become more well researched and documented.

4.2.3. Step 3: Hazards Included in the 2022 HMP

The Planning Group determined that all 11 hazards profiled in the 2017 HMP should be retained and the same methodology for assessing and ranking natural hazards in terms of probability of occurrence and potential impacts should be employed. A few planning participants opted not to include select hazards that were determined to not impact their jurisdiction. These exclusions are noted in the individual jurisdiction annexes, as appropriate.

It was determined by the Emergency Managers Group and the Planning Group that non-natural hazards should be included in a separate volume of the HMP. This decision was made so jurisdictions participating in the Emergency Management Accreditation Program (EMAP) could meet program requirements relating to hazard mitigation plans. Volume II of the HMP contains hazard profiles, mitigation strategies, and plan maintenance procedures for non-natural hazards identified as impacting the NOVA region. This volume of the HMP will be distributed on a limited, need-to-know basis, as determined by planning participants.

Table 19: Summary of Hazards Profiled in the 2022 HMP

Hazard	Justification for Inclusion	Information in the 2022 HMP
Dam Failure	• Numerous dams throughout the region. • Dam maintenance issues and extreme weather events could cause failures. • Numerous Federal Disaster Declarations for flooding.	• Full profile/risk assessment and vulnerability analysis.
Drought	• History of previous occurrences. • Potential for environmental impacts. • Potential to increase in severity due to climate change.	• Full profile/risk assessment and vulnerability analysis.
Earthquake	• History of damage experienced due to events in nearby locations.	• Full profile/risk assessment and vulnerability analysis.
Extreme Temperatures	• History of previous occurrences. • Potential for impacts on populations. • Potential to increase in severity due to climate change.	• Full profile/risk assessment and vulnerability analysis.
Flood/Flash Flood	• Losses from previous floods. • History of damaging floods and flash floods. • Numerous dams throughout the region. • Dam maintenance issues and extreme weather events could cause failures. • Numerous Federal Disaster Declarations for flooding. • Potential significant impact to critical infrastructure, property, populations, and the environment. • Potential to increase in severity due to climate change.	• Full profile/risk assessment and vulnerability analysis.
High Wind/ Severe Storm (including Hurricane and Tropical Storm)	• History of frequent occurrences. • Previous disaster declarations. • Potential for loss of life, environmental impacts, and property and critical infrastructure impacts.	• Full profile/risk assessment and vulnerability analysis.

Hazard	Justification for Inclusion	Information in the 2022 HMP
Karst/Sinkhole/Land Subsidence	• History of previous occurrences. • Previous impact on infrastructure. • Potential for loss of life and impact on critical infrastructure and property. • Potential to increase in severity due to increases in rain and flooding events.	• Minimal profile/risk assessment.
Landslide	• Potential for loss of life and impact on critical infrastructure. • Potential to increase in severity due to increases in rain and flooding events.	• Minimal profile/risk assessment.
Tornado	• History of previous occurrences. • Potential for loss of life, environmental impacts, and property and critical infrastructure impacts.	• Full profile/risk assessment and vulnerability analysis.
Wildfire	• Potential for loss of life, environmental impacts, and property and critical infrastructure impacts	• Full profile/risk assessment and vulnerability analysis.
Winter Weather	• History of previous occurrences. • Potential for loss of life and damage to infrastructure. • Previous disaster declarations. • Potential to increase in severity due to climate change.	• Full profile/risk assessment and vulnerability analysis.

4.2.4. Hazard Risk Ranking Methodology

The risk each jurisdiction faces for each hazard was quantified for ease of hazard ranking and risk comparison as well as for planning purposes.

A three-step process was utilized to quantify hazard risks, impacts, and consequences, which resulted in an overall risk score for each hazard. Based on the overall risk score, hazards were ranked as low, medium, or high.

Detailed hazard rankings are provided in the jurisdiction annexes.

4.2.4.1. Step 1: Total Probability Score

The total probability score had three components. Participants assigned numbers 1–4 to the three categories below using the following criteria for each hazard. The total number for all categories combined was then divided by three to find the average, i.e., the total probability score.

- Population vulnerability: If this hazard were to occur in the jurisdiction, what percentage of the population could be impacted?
  - 1: less than 25% of the total population of the jurisdiction.
  - 2: 25%–49% of the total population of the jurisdiction.
  - 3: 50%–74% of the total population of the jurisdiction.

    - 4: 75% or more of the total population of the jurisdiction.
- Geographic extent: If this hazard were to occur in the jurisdiction, how large of a geographic area could be impacted?
    - 1: negligible, less than 1% of the jurisdiction could be impacted.
    - 2: limited, between 1% and 10% of the jurisdiction could be impacted.
    - 3: significant, between 10% and 50% of the jurisdiction could be impacted.
    - 4: extensive, between 50% and 100% of the jurisdiction could be impacted.
- Probability of occurrence: What is the probability this hazard will occur in the future?
    - 1: unlikely, less than 1 event per year.
    - 2: low, 1–3 events per year.
    - 3: medium, 3–5 events per year.
    - 4: high, more than 5 events per year.

4.2.4.2. Step 2: Total Consequence Score

The total consequence score was calculated by assigning numbers 1–5 to the identified impact and consequences categories below using the following criteria for each hazard.

The total number for all five impact categories combined was divided by five to find the average, and the total number for all consequence categories was divided by seven to find the average. Then the average impact score and the average consequence score were added together to create the total consequence score.

Impact and Consequence Criteria

If this hazard were to occur in the jurisdiction, what would the impacts and consequences be?

Table 20: Impact and Consequence Criteria

Impact - People	
Risk of deaths and injuries from the hazard:	
1	Deaths very unlikely, injuries are unlikely.
2	Deaths unlikely, injuries are minimal.
3	Deaths unlikely, injuries may be substantial.
4	Deaths possible, injuries may be substantial.
5	Deaths probable, injuries will likely be substantial.

Impact - Residential Property	
Amount of residential property damage from the hazard:	
1	Less than $1,000 in damages.
2	$1,000–$50,000 in damages.
3	$51,000–$500,000 in damages
4	$501,000–$2,000,000 in damages.

5	More than $2,000,001 in damages.

Impact - Commercial Property	
Amount of business property damage from the hazard:	
1	Less than $5,000 in damages.
2	$5,001 to $100,000 in damages.
3	$100,001 to 5,000,000 in damages.
4	$5,000,001 to $10,000,000 in damages.
5	More than $10,000,001 in damages.

Impact - Environment	
Amount of environmental impacts from the hazard:	
1	Impact to limited area with no immediate environmental harm or long-term effects.
2	Impact to wider area with limited environmental harm but no long-term effects.
3	Impact to major area; some immediate environmental harm noted; expected long-term effects.
4	Impact to major area; immediate environmental harm noted with long term effects.
5	Major impact with potential for significant harm to the environment and long-term effects.

Impact - Program Operations/Resources	
Ability to continue critical program operations and maintain resource availability needed to respond to the hazard:	
1	No impact to operations/resources.
2	Reduction or loss of operations/resources for less than 24 hours.
3	Reduction or loss of operations/resources for between 24 and 48 hours.
4	Reduction or loss of operations/resources for up to one week.
5	Reduction or loss of operations/resources for more than one week.

Consequences - Population	
How the hazard impacts basic needs and social services for the population:	
1	No impact to needs and services for the population.
2	Temporary need for shelter, food, and water for less than 24 hours.
3	Temporary need for shelter, food, and water for between 24 and 48 hours.
4	Short-term shelter, food, water, transportation, and social services for up to one week.
5	Long-term emergency housing, food, water, and other needs and services for more than one week.

Consequences - Responders	
Types of consequences for community's first responders, considering operational, physical, or psychological factors:	
1	No potential consequences anticipated.
2	Consequences are somewhat probable based on previous occurrences, losses, or hazard/threat assessment.

3	Consequences are moderately probable based on previous occurrences, losses, or hazard/threat assessment.
4	Consequences are likely based on previous occurrences, losses, or hazard/threat assessment.
5	Consequences are highly likely based on previous occurrences, losses, or hazard/threat assessment.

Consequences - Continuity of Operations/Delivery of Services	
Ability to continue essential program functions and services needed to respond to the hazard:	
1	No impact on essential functions/services.
2	Reduction or loss of essential functions/services for less than 24 hours.
3	Reduction or loss of essential functions/services for between 24 and 48 hours.
4	Reduction or loss of essential functions/services for up to one week.
5	Reduction or loss of essential functions/services for more than one week.

Consequences - Property, Facilities, and Infrastructure	
Types of consequences to community's property, facilities, and infrastructure, considering operational or physical factors:	
1	No consequences anticipated.
2	Consequences are somewhat probable based on previous occurrences, losses, or hazard/threat assessment.
3	Consequences are moderately probable based on previous occurrences, losses, or hazard/threat assessment.
4	Consequences are likely based on previous occurrences, losses, or hazard/threat assessment.
5	Consequences are highly likely based on previous occurrences, losses, or hazard/threat assessment.

Consequences - Environment	
Types of consequences to the natural environment including land, water, air, and mineral assets:	
1	No potential consequences anticipated.
2	Consequences are somewhat probable based on previous occurrences, losses, or hazard/threat assessment.
3	Consequences are moderately probable based on previous occurrences, losses, or hazard/threat assessment.
4	Consequences are likely based on previous occurrences, losses, or hazard/threat assessment.
5	Consequences are highly likely based on previous occurrences, losses, or hazard/threat assessment.

Consequences - Economic Condition/Loss (Direct and Indirect)	
Amount of loss to community's economic conditions through business or industry closures or loss of workforce:	
1	No impact to community's economy.
2	Temporary business or industry closures, with minimal impact of less than 10% of the economy affected.
3	Short-term business/industry closures of less than 24 hours, with more than 10% but less than 25% of the economy impacted.

4	Long-term or permanent business/industry closures, with more than 25% but less than 50% of the community's economy impacted.
5	More than 50% of the community's economy impacted.

Consequences - Public Confidence in Governance	
Types of consequences related to level of public confidence in governance:	
1	Public highly confident in governance and will heed warnings and messages. No consequences anticipated.
2	Public significantly confident and likely to heed warnings and messages. Some consequences may occur.
3	Public somewhat confident and will probably heed warnings and messages. Consequences may be expected.
4	Public confidence is questionable. It is unknown how public will respond to official information and warnings.
5	Public confidence is known to be low. Lives may be at risk if timely, accurate, and clear information and warnings are not issued.

4.2.4.3. Step 3: Total Overall Risk Score

To quantify the total overall risk a hazard posed to each jurisdiction, the total probability score and the total consequence score were combined to create the total overall risk score. This score determined whether the hazard risk was ranked low, medium, or high.

Members of the Planning Group consulted event history, a variety of data sources, and internal stakeholders to determine the numbers that should be assigned to each category for each hazard for each jurisdiction.

The three highest ranked natural hazards in the planning area were winter storm, flood, and high wind/severe storm. Although there were some slight variations among jurisdictions as to where in the top three these hazards ranked, these were the top three hazards for all participants

The quantified hazard risk ranking was one tool used when determining the overall risk from each hazard. In addition to the risk ranking, Hazus data was used to determine risk, impact, and consequences from earthquake, flood, and high wind/hurricane. Other valuable local data sources were used in conjunction with the risk ranking to conduct a holistic risk assessment for each hazard and each jurisdiction.

The Planning Group opted to use data from the 2011 5.8 magnitude earthquake event that impacted the region to quantify the risk. This earthquake, with an epicenter near the town of Mineral in Louisa County—approximately 61 miles from the southernmost boundary of the planning area—was one of the highest magnitude earthquakes to occur east of the Rocky Mountains. It is representative of a realistic event that could impact the planning area in the future. The population vulnerability, geographic extent, probability of future occurrence, impacts, and consequences experienced by the NOVA region as a result of the earthquake informed the numbers chosen for each jurisdiction's hazard risk ranking. Therefore, earthquake is ranked as a medium risk hazard for all jurisdictions with the exception of Arlington County, which chose to rank earthquake as a low risk hazard.

If a jurisdiction does not experience a hazard, zeros were used in the risk ranking to represent the lack of risk. These hazards are shown as "N/A" in Table 21.

Table 21: Hazard Risk Ranking Summary

Jurisdiction	Hazard										
	Dam Failure	Drought	Earthquake	Extreme Temperatures	Flood	High Wind/Severe Storm	Karst/Sinkhole/ Land Subsidence	Landslide	Tornado	Wildfire	Winter Weather
Arlington County	N/A	Medium	Low	Medium	High	High	Low	N/A	Medium	Low	High
City of Alexandria	Medium	Medium	High-Medium	Medium	High	High	Low	Low	Medium	Low	High
City of Fairfax	Medium	Medium	Medium	Medium	High	High	Low	Low	Medium	Low	High
City of Falls Church	Medium	Medium	Medium	Medium	High	High	Low	Low	Medium	Low	High
City of Manassas	Medium	Medium	Medium	Medium	High	High	Low	Low	High	Low	High
City of Manassas Park	Low	Medium	Medium	Medium	High	High	Medium	Low	Medium	Low	High
Fairfax County	Medium	Medium	Medium	Medium	High	High	Low	Low	Medium	Low	High
Town of Clifton	High	Medium	Medium	Medium	High	High	Low	Low	Medium	Low	High
Town of Herndon	High	Medium	Medium	Medium	High	High	Low	Low	Medium	Low	High
Town of Vienna	High	Medium	Medium	Medium	High	High	Low	Low	Medium	Low	High

Jurisdiction	Hazard										
	Dam Failure	Drought	Earthquake	Extreme Temperatures	Flood	High Wind/Severe Storm	Karst/Sinkhole /Land Subsidence	Landslide	Tornado	Wildfire	Winter Weather
Loudoun County	Medium	Medium	Medium	Medium	High	High	Low	Low	High	Low	High
Town of Leesburg	Medium	Medium	Medium	Medium	High	High	Low	Low	High	Low	High
Town of Lovettsville	Medium	Medium	Medium	Medium	High	High	Low	Low	High	Low	High
Town of Middleburg	Medium	Medium	Medium	Medium	High	High	Low	Low	High	Low	High
Town of Purcellville	Medium	Medium	Medium	Medium	High	High	Low	Low	High	Low	High
Town of Round Hill	Medium	Medium	Medium	Medium	High	High	Low	Low	High	Low	High
Prince William County	High	Medium	Medium	Medium	High	High	Low	Low	Medium	Low	High
Town of Dumfries	Medium	Medium	Medium	Medium	High	High	Low	Low	Medium	Low	High
Town of Haymarket	Medium	Medium	Medium	Medium	High	High	Low	Low	Medium	Low	High
Town of Occoquan	High	Medium	Medium	Medium	High	High	Medium	Low	High	Low	Medium

4.2.4.4. Step 4: Hazard Profiles

Individual profiles of each hazard addressed in this Plan are presented in **Sections 5.1** through **5.11**.

Table 22: Hazard Profile Elements

Hazard Profile Element	Description
Hazard Definition and Characteristics	The hazard is defined or described in relation to its general characteristics, including specific types, as applicable.
Location	In general, the entire planning area is susceptible to most natural hazards profiled in the plan, such as winter storm, flood, and severe storm. Impacts of other types of hazards, such as dam failure, karst/sinkhole/land subsidence, landslide, and wildfire, occur in more localized areas in the region. Potential impact areas for each hazard profiled in this Plan are described in the jurisdiction annexes.
Extent and Previous Occurrences	Information on historical occurrences, including federally declared disasters and the extent of the loss of life, injuries, and damages are described in this sub-section. Extent also considers other measures of magnitude, such as water depth, speed of onset, or duration of the event. For most hazards, the longer the duration, the greater the extent of the impact.
Probability of Future Events	Discussion of the likelihood of the hazard occurring in the future and changes in hazard trends and patterns. Challenges exist in using statistics to document past natural hazard events due to the difference in hazard definitions, how incidents are reported, and the type of database that produces an analysis of these events. For the purpose of this plan, the National Center for Environmental Information (NCEI), Storm Events Database (NOAA) serves as the primary data source for documenting previous weather occurrences and calculating future probabilities. ***Frequency Analysis:*** Where quantitative data was available, it was used to estimate the probability of the occurrence of a given event. The recurrence interval or return period is based on the probability that a given event will be equaled or exceeded in any given year. This was calculated by dividing the number of years on record by the number of events. Ten or more years of data are typically required to perform a valid frequency analysis for the determination of recurrence intervals. More confidence can be placed in the results of a frequency analysis based on, for example, 30 years of record than on an analysis based on ten years or less. Data from previous occurrences assisted in the Hazus analysis for earthquake, flood, and high wind/hurricane.
Risk Assessment	An assessment of risks associated with hazards is presented. Hazard risks to the population, built environment, community lifelines, natural environments, and the economy are evaluated. Additionally, a summary table of how each jurisdiction ranked the hazard—low, medium, or high—is shown for easy risk comparison throughout the region.

Hazard Profile Element	Description
Vulnerability Analysis	An analysis of vulnerability, including impacts and consequences, was completed. This includes the types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard areas and a description of potential dollar losses from damage to vulnerable structures. The FEMA Hazus program was used to model 2,500-year return event scenarios for flood, earthquake, and high wind/hurricane. This analysis delivers in-depth information about estimated direct economic losses and dollar exposure, anticipated sheltering needs and debris generation, and risk to existing buildings and infrastructure, community lifelines, and critical facilities. Potential impacts from climate change are also briefly discussed. An in-depth profile of climate change is presented in Section 6.
Future Population and Development Trends	Discussion on the impact of development in hazard-prone areas throughout the planning area related to each hazard.
Factors for Consideration in the Next Planning Cycle	Describes specific points to consider in relation to each hazard when conducting plan maintenance for monitoring, evaluating, and updating the Plan.
Data Sources	Data sources for each hazard section are provided in the footnotes.

4.3. General Hazard Information

This section of the Plan provides general information that may be applicable to all hazards having the potential to impact jurisdictions in the planning area. Individual characteristics of specific hazards are further described in the individual hazard sections.

4.3.1. Declarations

4.3.1.1. FEMA Declarations

As of December 2021, the planning area has been subject to 24 major disaster declarations since 1972.[36] Twenty-one of these declarations have been for natural hazards and three have been for non-natural hazards: one for the September 11, 2001 terrorist attacks and two for the coronavirus (COVID-19) pandemic. Both COVID-19 declarations, DR-4512-VA and EM-3448-VA, have an incident period start date of January 20, 2020 and were deemed to be ongoing at the conclusion of the HMP planning process in 2022.

[36] FEMA. (n.d.). *Virginia*. https://www.fema.gov/locations/virginia

Table 23: Major Disaster Declarations Including Northern Virginia by Type, 1972–December 2021[37]

Date	Disaster Number	Disaster Type	Declared Jurisdiction(s)*
June 29, 1972	DR-339-VA	Tropical Storm Agnes	Arlington, Fairfax, Loudoun, and Prince William Counties, Cities of Fairfax and Falls Church
October 7, 1972	DR-358-VA	Severe Storms and Flooding	City of Alexandria
October 10, 1972	DR-359-VA	Severe Storms and Flooding	City of Alexandria
November 10, 1985	DR-755-VA	Severe Storms and Flooding	City of Alexandria
February 2, 1996	DR-1086-VA	Blizzard of 1996 (Severe Snowstorm)	All jurisdictions
October 23, 1996	DR-1133-VA	Hurricane Fran and Severe Storm Conditions	Prince William County
October 12, 1999	DR-1923-VA	Hurricane Floyd	Fairfax County, City of Fairfax
February 28, 2000	DR-1318-VA	Severe Winter Storm	Arlington, Fairfax, Loudoun, and Prince William Counties, Cities of Fairfax and Manassas
September 11, 2001	DR-1392-VA	Terrorist Attack	Arlington County
March 27, 2003	DR-1458-VA	Severe Winter Storm, Snowfall, Heavy Rain, Flooding, and Mudslides	All jurisdictions
September 18, 2003	DR-1491-VA	Hurricane Isabel	All jurisdictions
September 12, 2005	EM-3420-VA	Hurricane Katrina Evacuation	All jurisdictions
July 13, 2006	DR-4027-VA	Severe Storms, Tornadoes, and Flooding	Arlington and Fairfax Counties, City of Alexandria
February 16, 2010	DR-1905-VA	Severe Winter Storms and Snowstorms	All jurisdictions
April 27, 2010	DR-1874-VA	Severe Winter Storms and Snowstorms	Arlington, Fairfax, and Prince William Counties, Cities of Fairfax, Falls Church, Manassas, and Manassas Park

[37] FEMA. (n.d.). *Virginia*. https://www.fema.gov/locations/virginia

Date	Disaster Number	Disaster Type	Declared Jurisdiction(s)*
September 3, 2011	DR-4024-DR	Hurricane Irene	City of Alexandria
November 17, 2011	DR-1874-VA	Remnants of Tropical Storm Lee	Fairfax and Prince William Counties, Cites of Alexandria and Falls Church
July 27, 2012	DR-4072-VA	Severe Storms and Straight-line Winds	Arlington and Fairfax Counties, Cites of Fairfax and Falls Church
October 20, 2012	EM-3359-VA	Hurricane Sandy	Arlington, Fairfax, Loudoun, and Prince William Counties, Cities of Alexandria, Falls Church, and Manassas Park
November 26, 2012	DR-4092-VA	Hurricane Sandy	Arlington, Loudoun, and Prince William Counties, Cities of Fairfax, Falls Church, and Manassas
April 19, 2016	DR-4262-VA	Severe Winter Storm and Snowstorm	All jurisdictions
September 11, 2018	EM-3403-VA	Hurricane Florence	All jurisdictions
March 12, 2020	EM-3448-VA	COVID-19 Pandemic	All jurisdictions
April 2, 2020	DR-4512-VA	COVID-19 Pandemic	All jurisdictions

*Towns are included in county declarations.

4.4. Population Vulnerability

4.4.1. Social Vulnerability Index

Residents of Northern Virginia may be at risk of certain localized hazards, such as dam failure and flooding, depending on their proximity to hazard-prone areas. In addition, hazards that can impact the entire planning area, e.g., extreme temperatures, high wind/severe storm, and winter weather, may put residents at risk. Although residents may potentially experience hazard risk, not all residents are equally vulnerable to the impacts of these risks. A number of factors, including poverty, lack of access to transportation, and crowded housing, may weaken a community's ability to prevent human suffering and financial loss in the case of a disaster.

Information about specific at-risk populations is addressed in each hazard section; however, this section provides insight into what factors create higher hazard vulnerability for populations.

There are multiple methodologies and tools available to identify and measure the extent of population vulnerability in relation to hazards. For the purpose of this plan, the Centers for Disease Control and Prevention's (CDC) Social Vulnerability Index (SVI) is presented as one tool that provides a quantifiable ranking to indicate potential levels of vulnerability when hazards impact jurisdictions.

The most recent SVI information comes from 2018. Social and economic factors can change rapidly and jurisdictions in the planning area should remain aware of the potentially shifting vulnerabilities in their communities. This is especially important in light of the social and economic upheaval caused by the COVID-19 pandemic, which has caused dramatic short-term impacts on many populations, for which the long-term impacts are not yet clear.

CDC Social Vulnerability Index[38]

What is social vulnerability?

Every community must prepare for and respond to hazardous events. The degree to which a community exhibits certain social conditions, including poverty, a low percentage of vehicle access, or crowded households, may affect that community's ability to prevent human suffering and financial loss in the event of a disaster. These factors describe a community's social vulnerability.

What is the CDC Social Vulnerability Index?

The CDC Agency for Toxic Substances and Disease Registry's Geospatial Research, Analysis & Services Program (GRASP) created the CDC Social Vulnerability Index to help public health officials and emergency response planners identify and map the communities that will most likely need support before, during, and after a hazardous event. SVI indicates the relative vulnerability of every United States Census tract. Census tracts are subdivisions of counties for which the Census collects statistical data. SVI ranks the tracts on 15 social factors, including unemployment, minority status, and disability, and further groups them into four related domains:

- Socio-economic status
- Household composition and disability
- Minority status and language
- Housing and transportation

[38] Centers for Disease Control and Prevention. (2020, January 31). CDC SVI 2018 Documentation. https://svi.cdc.gov/Documents/Data/2018_SVI_Data/SVI2018Documentation.pdf

How can SVI help communities be better prepared for hazardous events?

SVI provides specific socially and spatially relevant information to help officials and local planners better prepare communities to respond to emergency events such as severe weather. SVI can be used to:

- Allocate emergency preparedness funding according to community need.
- Estimate the amount and type of needed supplies such as food, water, medicine, and bedding.
- Decide how many emergency personnel are required to assist people.
- Identify areas in need of emergency shelters.
- Create an evacuation plan that accounts for those who have special needs, such as those without vehicles, older adults, or people who have a primary language other than English.
- Identify communities that will need continued support to recover following an emergency or natural disaster.
- Identify appropriate mitigation actions to lower hazard risk for vulnerable populations.

The SVI is composed of 15 factors, as depicted in Figure 15.

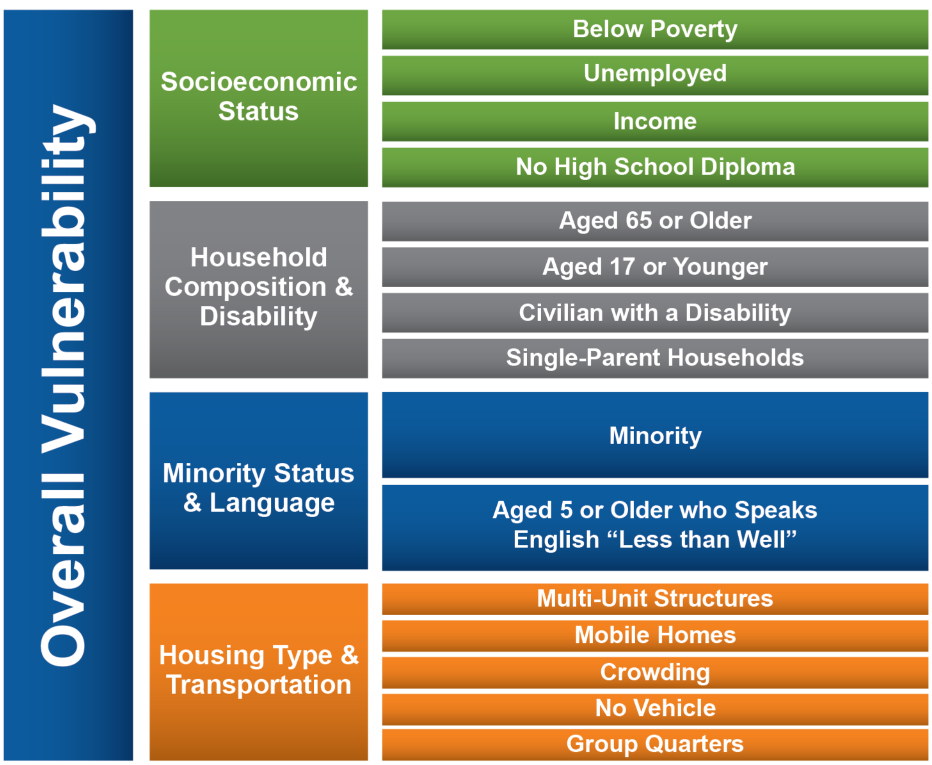

Figure 15: CDC Social Vulnerability Index Variables (2018)[39]

[39] Centers for Disease Control and Prevention. (2020, January 31). *CDC SVI 2018 Documentation*. https://svi.cdc.gov/Documents/Data/2018_SVI_Data/SVI2018Documentation.pdf

Table 24: CDC Social Vulnerability Index, by Jurisdiction (2018)[40]

Jurisdiction*	Overall SVI Score	Social Vulnerability Level
Arlington County	0.1401	Low
City of Alexandria	0.2003	Low
City of Fairfax	0.2411	Low
City of Falls Church	0.1389	Low
City of Manassas	0.4446	Low to Moderate
City of Manassas Park	0.528	Moderate to High
Fairfax County	0.1876	Low
Loudoun County	0.0904	Low
Prince William County	0.3022	Low to Moderate

*Towns are included in county SVI information.

SVI data was utilized at the lowest available level of detail, which is the Census tract. Figure 16 shows the SVI index, a percentile calculation that takes each of the 15 factors into account.

[40] Agency for Toxic Substances and Disease Registry. (2018, October 9). *CDC's Social Vulnerability Index (SVI)*. https://svi.cdc.gov/map.html

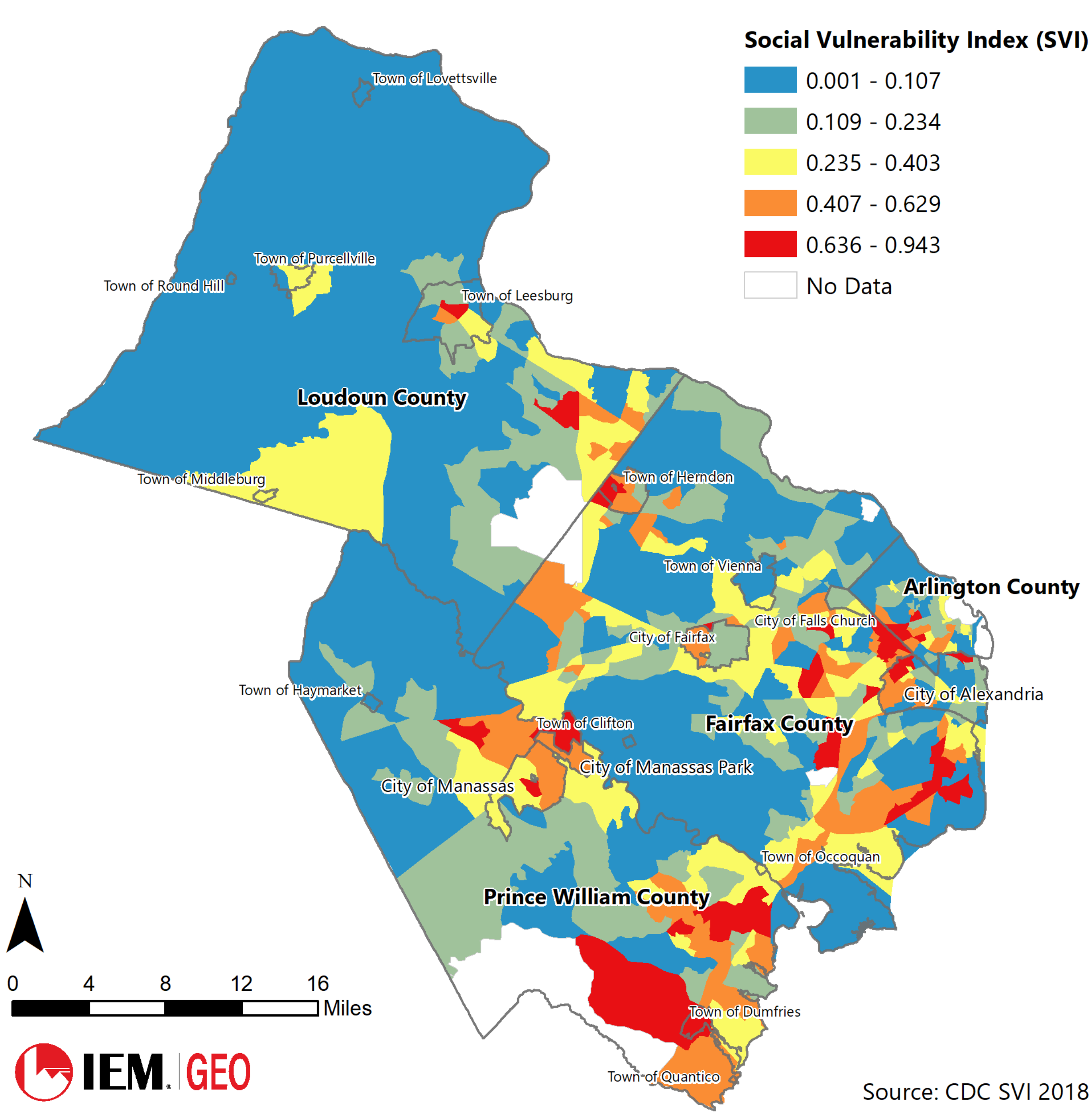

Figure 16: CDC Social Vulnerability Index Variables by Census Tract

Based on the CDC SVI scores, Prince William County, the City of Manassas, and and the City of Manassas Park, have the highest level of vulnerability.

4.4.2. Community Resilience Estimates

Community resilience is the capacity of individuals and households within a community to absorb the external stresses of a disaster.[41] The 2019 Community Resilience Estimates (CRE) are produced using the information on individuals and households from the 2019 American Community Survey (ACS) and the

[41] United States Census Bureau. (2021, August 10). *2019 Community Resilience Estimates Quick Guide*. https://www2.census.gov/programs-surveys/demo/technical-documentation/community-resilience/cre_quickguide_2019.pdf

Census Bureau's Population Estimates Program (PEP). According to the United States Census Bureau, the CRE estimates community resilience to disasters by using small area estimation (SAE) techniques to combine data from several sources and produce high-quality estimates:[42]

- American Community Survey (ACS) microdata
  - Analysis is performed on the individual and household level restricted ACS microdata to determine the number of individual risk factors.
- Population Estimates Program
  - This program utilizes age, sex, and race and ethnicity data from the Census Bureau's Population Estimates Program.

The CRE was mapped at the lowest available detail, which is the Census tract. The CRE encompasses the following risk factors:

- Income-to-poverty ratio
- Households with broadband Internet
- Households without a vehicle
- Single or no caregiver
- Unit level crowding
- Age greater than 65
- Communication barriers
- No health insurance
- Disability
- No one in household employed full time

Figure 17 shows the percentage of the population that contains three or more risk factors. This population represents the highest risk group.

[42] United States Census Bureau. (2021, October 8). *Methodology*. https://www.census.gov/programs-surveys/community-resilience-estimates/technical-documentation/methodology.html

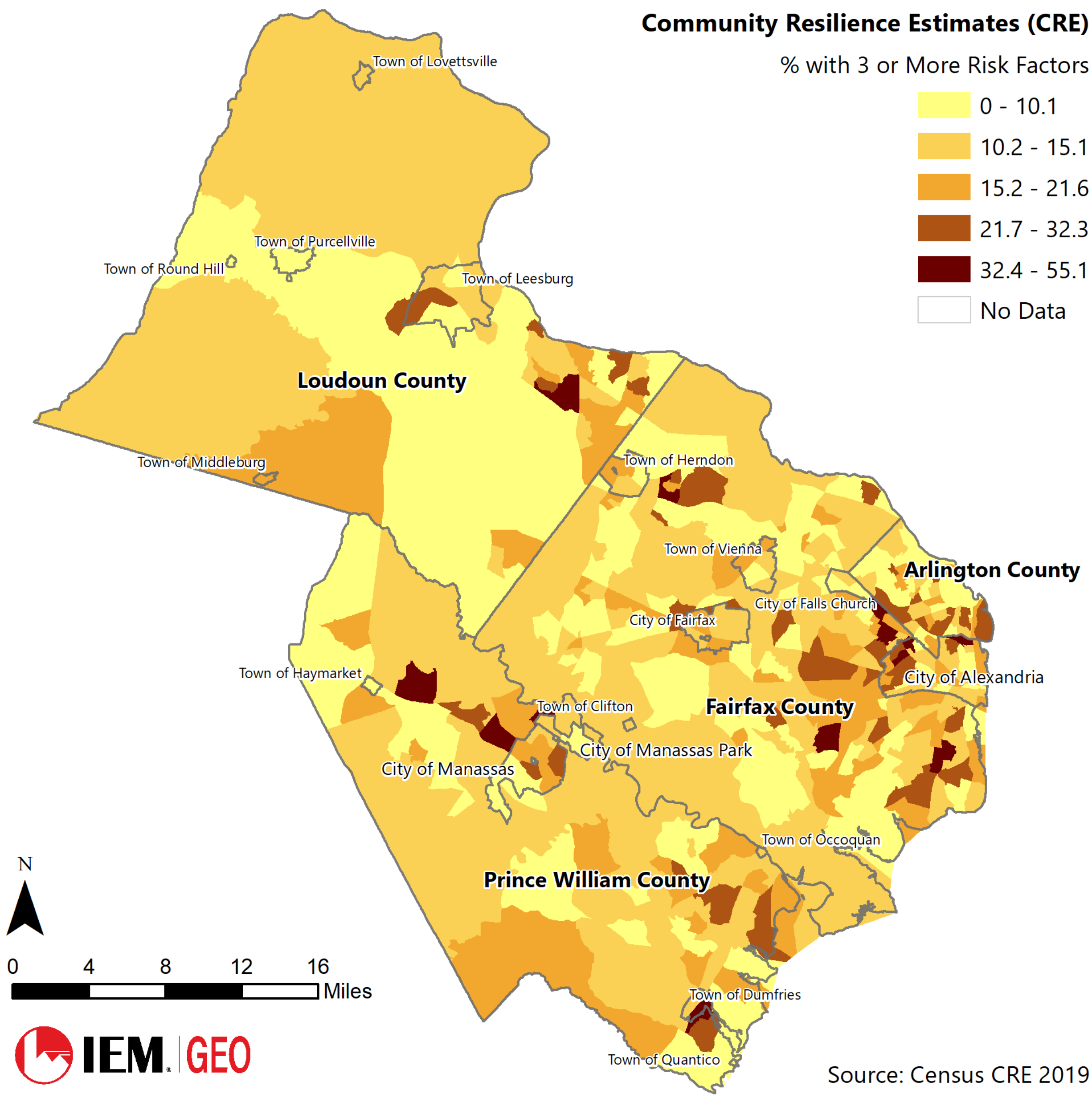

Figure 17: Community Resilience Estimates

4.5. FEMA Community Lifelines

FEMA developed the community lifelines construct to increase effectiveness in disaster operations and better position the jurisdictions to respond to incidents. Lifelines are the most fundamental services in a community that, when stabilized, enable all other aspects of society. A lifeline enables the continuous operation of critical business and government functions and is essential to human health and safety or economic security. There are seven FEMA-identified lifeline categories, each of which has its own components: safety and security; food, water, and shelter; health and medical; energy (power and fuel); communications; transportation; and hazardous materials.[43]

The goals and objectives of FEMA's Strategic Plan promote using mitigation to reduce the risk to community lifelines before a disaster and to quickly stabilize a community after a disaster by preventing cascading impacts.[44] FEMA's Building Resilient Infrastructure and Communities grant program focuses on projects and initiatives that reduce the likelihood that community lifelines will fail as a result of an incident.

During the HMP planning process, the vulnerability of these lifelines were analyzed in relation to each hazard to determine any gaps and opportunities for mitigation that may exist and be identified in the jurisdictional annexes. Vulnerability analyses for earthquake, flood, and high wind/hurricane were based on Hazus data; therefore, data from additional sources were added to complete the analysis of lifeline categories.

Community Lifelines Outlined

- **Safety and Security:** Law Enforcement/Security, Fire Service, Search and Rescue, Government Service, Community Safety
- **Food, Water, Shelter:** Food, Water, Shelter, Agriculture
- **Health and Medical:** Medical Care, Public Health, Patient Movement, Medical Supply Chain, Fatality Management
- **Energy:** Power Grid, Fuel
- **Communications:** Infrastructure, Responder Communications, Alerts Warnings and Messages, Finance, 911 and Dispatch
- **Transportation:** Highway/Roadway/Motor Vehicle, Mass Transit, Railway, Aviation, Maritime
- **Hazardous Materials:** Facilities, HAZMAT, Pollutants, Contaminants

[43] United States Department of Homeland Security. (2019, November). *Community Lifelines Fact Sheet*. https://www.fema.gov/sites/default/files/2020-05/LifelinesFactSheetandPosterv2.pdf
[44] FEMA. (2020, July 22). *Building Resilient Infrastructure and Communities (BRIC) and Community Lifelines*. https://www.fema.gov/sites/default/files/2020-07/fema_bric_session-4_community-lifelines.pdf

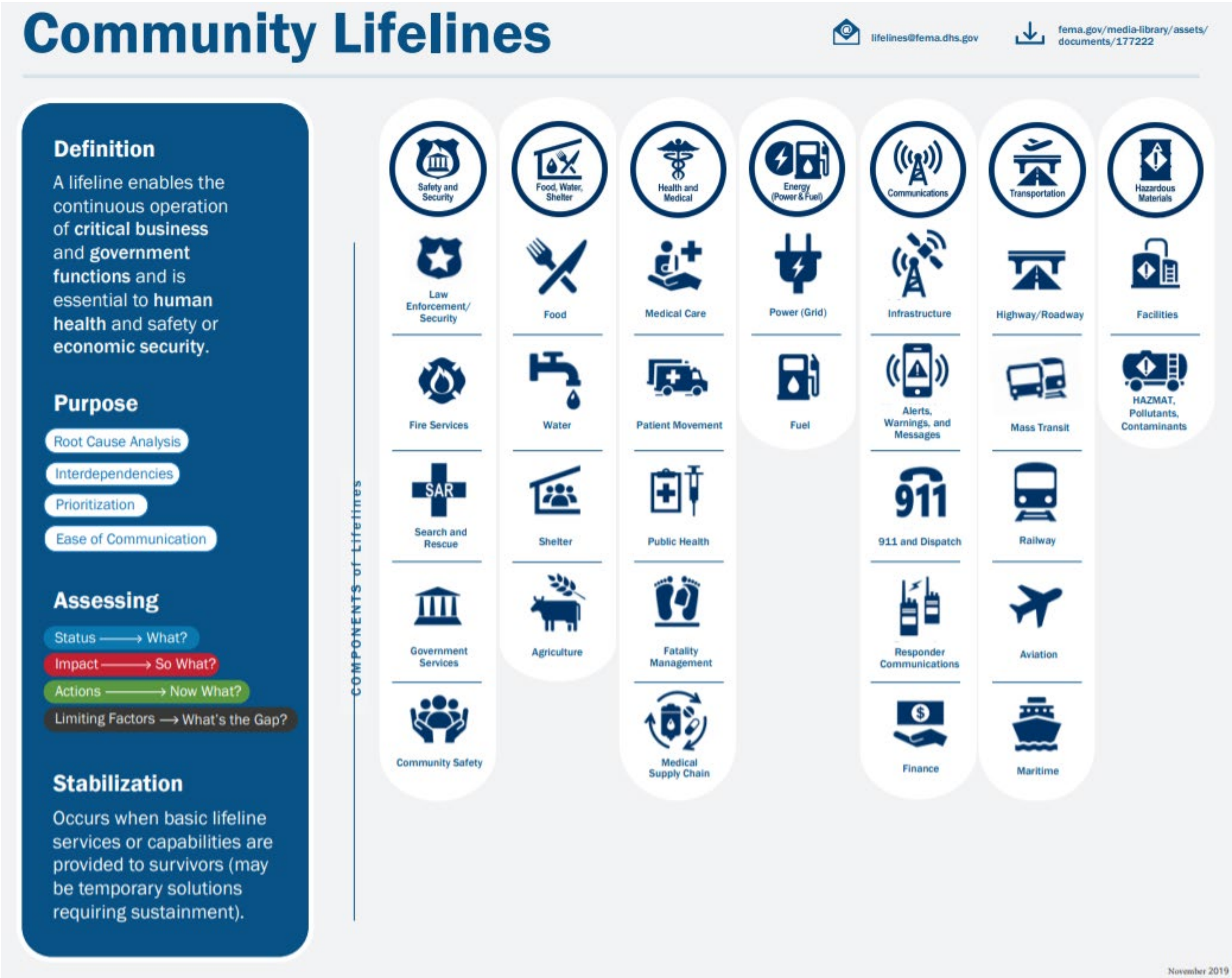

Figure 18: FEMA Community Lifelines[45]

[45] United States Department of Homeland Security. (2019, November). *Community Lifelines Fact Sheet*. https://www.fema.gov/sites/default/files/2020-05/LifelinesFactSheetandPosterv2.pdf

5. Hazard Profiles, Risks, and Vulnerability

5.1. Dam Failure

2022 HMP Update

The dam failure hazard was reviewed, and a new analysis was performed that included but was not limited to the following:

- Enhancing and reformatting the Dam Failure profile to include consideration of requirements for the High Hazard Potential Dam (HHPD) Grant Program
- Enhancing hazard characteristics
- Confirming the number of dams in the planning area and their level of concern as being classified as high, significant, or low hazard dams, based on the Virginia Department of Conservation and Recreation (DCR) Dam Safety Inventory System (DSIS)
- Updating hazard incident occurrence throughout the planning area
- Updating data sources
- Adding factors for consideration in the next planning cycle

Table 25: Dam Failure Profile

<table>
<tr><th colspan="5">Dam Failure</th><th>Overall Vulnerability</th></tr>
<tr><th colspan="5">Definition, Key Terms, and Overview</th><td rowspan="6">Medium</td></tr>
<tr><td colspan="5">Dam: A barrier constructed across flowing water to obstruct, direct, or slow down the flow, typically creating a lake or reservoir.

Dam failure: A catastrophic type of failure characterized by the sudden, rapid, uncontrolled release of impounded water or the likelihood of such an uncontrolled release. A systematic failure of the dam structure results in an uncontrolled release of water, which can cause flooding that exceeds the 100-year floodplain boundaries.</td></tr>
<tr><th rowspan="2">Frequency</th><th rowspan="2">Probability</th><th colspan="3">Potential Magnitude</th></tr>
<tr><th>Injuries/Deaths</th><th>Infrastructure</th><th>Environment</th></tr>
<tr><td>Low</td><td>Low</td><td>Moderate</td><td>Moderate</td><td>Moderate</td></tr>
</table>

5.1.1. Hazard Profile

Worldwide interest in dam and levee safety has risen significantly in recent years. Aging infrastructure, new hydrologic information, and population growth in floodplain areas downstream from dams and near levees have resulted in an increased emphasis on safety, operation, and maintenance. The distinction between dams and levees is their purpose: dams are constructed to impound water behind them, and levees are constructed to keep water out of the land behind them. This section does not address levee failure, as there are no major levees located in the Northern Virginia region.

There are about 91,000 dams in the United States today,[46] and the majority of them are privately owned. Public owners include the commonwealth, local authorities, and federal agencies. Benefits provided by dams include water supplies for drinking, irrigation, and industrial uses, as well as flood control, hydroelectric power, recreation, and navigation.

A primary cause of dam failure is overtopping, which occurs in approximately 34% of all dam failures in the United States. Overtopping occurs when water spills over the top of the dam, frequently because of inadequate spillway design, debris blocking spillways, foundation failure, piping (water escaping through narrow channels under the dam), or insufficient maintenance. Other conditions that lead to dam failure include the following:

- Prolonged periods of rainfall and flooding, which cause most failures
- Inadequate spillway capacity, resulting in excess overtopping of the embankment
- Internal erosion caused by embankment or foundation leakage, also called piping
- Improper maintenance, including failure to remove trees, repair internal seepage problems, or maintain gates, valves, and other operational components
- Improper design or use of improper construction materials
- Failure of upstream dams in the same drainage basin
- Landslides into reservoirs, which cause surges that result in overtopping
- High winds, which can cause significant wave action and result in substantial erosion
- Destructive acts of terrorists

Dam failure may also be triggered by an earthquake that occurs within or outside the planning area. An earthquake can cause longitudinal cracks at the tops of embankments, leading to structural failure. While several dams in the region received damage from the earthquake in 2011, there was no dam failure.

When a dam fails, the energy of the water stored behind the dam can cause rapid and unexpected flooding downstream, resulting in loss of life and major property damage. There can also be devastating effects on water supply and power generation if the water behind the dam serves one of those purposes. The terrorist attacks of September 11, 2001, generated increased focus on protecting the country's water infrastructure, including ensuring the safety of dams.

Dams are classified according to their potential impact on the population or property. The NID and the VA DCR use the same classification to categorize the hazard potential of dams—high, significant, or low. This classification may change over time, as it is tied to how the failure of the dam may lead to loss of life and property downstream. The classifications are described by the DCR as follows:[47]

- **High:** Dams that, upon failure, would cause probable loss of life or serious economic damage
- **Significant:** Dams that, upon failure, might cause loss of life or appreciable economic damage.
- **Low:** Dams that, upon failure, would lead to no expected loss of life or significant economic damage.

[46] United States Army Corps of Engineers. (n.d.). *National Inventory of Dams*. https://nid.sec.usace.army.mil/#/

[47] Virginia Department of Conservation and Recreation. (2021, February 26). *Dam Safety Program*. https://www.dcr.virginia.gov/dam-safety-and-floodplains/dam-safety-index

There is a classification called special criteria, which apply to dams that, upon failure, would cause damage only to the property of the dam owner.

These hazard classifications are not related to the physical condition or structural integrity of the dam or the probability of its failure, but strictly to the potential for adverse downstream effects from failure or incorrect operation of the dam or its facilities. There are no dam failure inundation maps available for the NOVA region that can be included in this Plan.

Because dams represent a risk to public safety, they require ongoing maintenance, monitoring, safety inspections, and sometimes rehabilitation to continue safe service. Unless specifically excluded, all dams in Virginia are regulated. More than 2,900 dams are regulated in the Commonwealth.

Table 26: Hazard Profile Summary

<table>
<tr><td rowspan="8">Dam Failure
Assessment: Medium Risk Hazard</td><td>Location</td><td>Specific local locations</td><td>Potential Cascading Effects</td></tr>
<tr><td>Extent</td><td>Low to Moderate</td><td rowspan="7">• Rapid unexpected flooding downstream, resulting in loss of life and property damage
• Devastating effects on water supply and power generation
• Damage to homes, businesses, environmental assets, and people living in the flood inundation zone</td></tr>
<tr><td>Duration</td><td>Several minutes to several days</td></tr>
<tr><td>Probability</td><td>Low</td></tr>
<tr><td>Seasonal Pattern</td><td>No seasonal pattern</td></tr>
<tr><td>Speed of Onset</td><td>There may be a sudden failure, or one may occur slowly, if there is infrastructure deterioration that goes unnoticed if regular assessments are not conducted</td></tr>
<tr><td>Warning Time</td><td>Minutes or hours</td></tr>
<tr><td>Repetitive Loss</td><td>Potentially, if there are previously damaged structures in the inundation area</td></tr>
</table>

5.1.1.1. Location

The Commonwealth's regulatory agency for dams is the DCR. Through its Dam Safety and Floodplain Management Program, DCR maintains the Dam Safety Inventory System (DSIS), which presents information about all the dams in Virginia that DCR tracks. In addition to high hazard dams, the DCR observes and regulates numerous smaller dams (e.g., farm pond impoundments) that present less severe hazard threats. The DCR maintains data on all commonwealth-regulated dams in the NOVA region, including information on the potential impacts of failure. Based on the DSIS, there are 310 dams within the planning area. Of those, 57 are identified as high hazard dams: 28 in Fairfax County, 14 in Loudoun County, and 15 in Prince William County.

There is some discrepancy between national and local records for the number of dams and their classification in the planning area. National Inventory of Dams (NID) records show there are 213 dams located in the NOVA region, with 58 classified as high hazard potential dams.[48] Of those 58, 30 are in Fairfax County, 14 are in Loudoun County and 14 are in Prince William County. Two are located in the City of Manassas. One of those is considered a high hazard potential dam and is included in the Prince William County count. The hazard risk assessment in this section is based on DSIS data.

Besides federal and commonwealth dam inventories, some jurisdictions in the planning area maintain their own inventories. These do not necessarily align with the other inventories, because they may include small privately owned dams that are beneath the volume threshold for being documented in the other inventories. For example, the Fairfax County Department of Emergency Management and Security maintains a local inventory of 45 dams in the jurisdiction, of which 26 are classified as high hazard.

5.1.1.2. Extent

While dams offer many benefits, they can also pose a risk to communities if they are not designed, operated, and maintained properly. In the event of a dam failure, the energy of the water stored behind even a small dam can cause loss of life and significant damage to property downstream of the dam. Such properties may be quickly submerged in floodwaters, and residents may become trapped by rapidly rising water. The failure of a dam can put large numbers of people and significant amounts of property in harm's way.

5.1.1.3. Previous Occurrences

Dam failures in the region have not been common, and none has been reported since the 2017 HMP. However, there have been some notable recent events throughout Virginia. Most failures occur because of poor maintenance of the dam combined with major rainfall, such as that which occurs during hurricanes and thunderstorms. In 1995, torrential rains burst the Timberlake Dam in Campbell County, killing two people downstream in the flooding. Following Hurricane Floyd in 1999, 13 dam failures were reported across the eastern portion of the Commonwealth, causing significant damage.

The Barcroft dam in Fairfax County failed during heavy rains associated with Hurricane Agnes in June 1972. Although it caused no loss of life, that dam failure damaged the Holmes Run area, most notably the destruction of an overpass at Van Dorn Street and Holmes Run. This event caused $300,000 in damage and cost an additional $200,000 to clear 29 acres of trees and debris from the stream. The dam, which was built in 1913, also suffered major damage and had to be rebuilt to restore Lake Barcroft, a recreational area for community residents.

5.1.1.4. Probability of Future Occurrence

From the first documented incident in 1848 through 2017, dam failures have occurred in the United States at an average of nearly 10 each year, mostly linked to small dams that result in limited flooding and downstream impact.[49] Since 1980 when dam safety became a national priority, the average number of dam failures has increased to 24 per year. Nevertheless, in 96% of dam failure events, the resulting flooding does not result in deaths or significant property damage.[50]

Predicting the probability of flooding from dam failure requires a detailed, site-specific engineering analysis for each dam. This is because failure may result from hydrologic and hydraulic design limitations, or from geotechnical or operational factors.

[48] Stanford University. (2018 September). *National Performance of Dams Program, Dept. of Civil & Environmental Engineering (NPDP-01 V1)*. http://npdp.stanford.edu/sites/default/files/reports/npdp_dam_failure_summary_compilation_v1_2018.pdf
[49] Ibid.
[50] Ibid.

Dam failure is considered unlikely in the NOVA region, given the number of safety measures in place and rigorous programs of inspection and dam oversight. DCR requires specific operation and maintenance procedures for dams that present the greatest risk or require structural repair. It also requires routine inspections of dams and regularly updated emergency action plans (EAPs) for each of the major and commonwealth-regulated dams in the NOVA region. As such, future damage from dam failure and associated dollar losses are expected to be negligible, though the danger remains real and will continue to receive critical attention through DCR's Dam Safety and Floodplain Management Program.

Dam failure remains an unlikely occurrence for all major and non-regulated dams in the NOVA region.

5.1.2. Risk Assessment

Because of the lack of specific data on the probability of dam failure and inundation zones, the potential risk to critical facilities and existing buildings and infrastructure was not estimated for this revision of the Plan. Virginia's new Impounding Structure Regulations require dam break inundation zone mapping, and additional information is available from the DCR Dam Safety Program. However, a few observations about the impact of dam failure are discussed.

5.1.2.1. People

Persons living in a dam inundation area may be affected by dam failure if there is little to no advance warning to allow them to evacuate in a timely fashion. Because many dams are used for recreational purposes and are located adjacent to parks and other open spaces where visitors may gather, dam failure may affect those who do not live nearby but who enjoy visiting the recreational amenities.

5.1.2.2. Economy

The failure of dams may result in catastrophic localized damage. Vulnerability to dam failure is contingent on dam operations planning and the nature of downstream development. Depending on the elevation and storage volume of the impoundment, the amount of water released could impact businesses located in the inundation area. Nearby commercial establishments, including those of persons who manage a home-based business, may be affected.

5.1.2.3. Built Environment, Community Lifelines, and Assets

Many types of structures in the built environment may be affected by dam failure. These include roads, bridges, culverts, homes, farms, parks, and greenspace. The built environment may also include communities and their assets, such as utility systems and infrastructure. Any or all of these may be damaged when a dam fails.

5.1.2.4. Natural Environment

The natural environment includes open spaces and other resources that may also include the built environment, such as parks that encompass trees or waterways. The natural environment could be affected by dam failure if trees are damaged or there is soil erosion from heavy water flow. Agricultural lands, while developed, may include shrubbery, water sources, crops, and livestock. Agricultural lands could suffer from soil erosion, drowned crops, or fields that cannot be planted or harvested.

5.1.3. Vulnerability Analysis

5.1.3.1. Historical

Because of the lack of specific data related to previous dam failure events in the planning area, it is difficult to identify the exact exposure of the population, property, economy, or environment related to this hazard. Enhanced coordination between emergency managers, dam owners and operators, USACE, and DCR will increase the availability of critical data and information necessary for appropriate mitigation actions.

5.1.3.2. Scenario

When data on the probability of dam failure and inundation zones do not exist or are unavailable, the vulnerability of critical facilities, existing buildings, and infrastructure could not be estimated for this revision of the Plan. Virginia's new Impounding Structure Regulations[51] require dam break inundation zone mapping and additional information to be available from the DCR Dam Safety Program.

5.1.3.3. Hazard Analysis Summary

The hazard ranking process included consideration of probability and consequences in determining an overall risk score and ranking. Information presented in this section and the hazard risk ranking process present the quantitative and qualitative summaries for dam failure. The Hazard Identification and Risk Assessment methodology is described in **Section 4, Base Plan**.

Table 27: Hazard Risk Rankings for Dam Failure, by Jurisdiction

Jurisdiction	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
Arlington County	0	0	0	**N/A**
City of Alexandria	1.0	4.4	5.5	**Medium**
City of Fairfax	1.0	4.5	5.5	**Medium**
City of Falls Church	1.0	4.5	5.5	**Medium**
City of Manassas	1.0	4.1	5.1	**Medium**
City of Manassas Park	1.0	3.1	4.1	**Low**
Fairfax County	1.0	4.5	5.5	**Medium**
Town of Clifton	**0**	**0**	**0**	**High**
Town of Herndon	1.0	4.5	5.5	**High**
Town of Vienna	1.0	4.5	5.5	**High**
Loudoun County	1.0	4.4	5.5	**Medium**
Town of Leesburg	1.0	4.4	5.5	**Medium**
Town of Lovettsville	1.0	4.4	5.5	**Medium**
Town of Middleburg	1.0	4.4	5.5	**Medium**
Town of Purcellville	1.0	4.4	5.5	**Medium**
Town of Round Hill	1.0	4.4	5.5	**Medium**

[51] https://www.dcr.virginia.gov/laws-and-regulations/document/damsafetyregulations.pdf

Jurisdiction	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
Prince William County	1.3	5.2	6.5	High
Town of Dumfries	1.0	4.1	5.1	Medium
Town of Haymarket	1.0	4.1	5.1	Medium
Town of Occoquan	4.0	7.9	11.9	High
Town of Quantico	1.0	4.1	5.1	Medium

5.1.3.4. Future Population and Development Trends

Because the potential consequence of dam failure is flooding, the flood zones identified in the current Flood Insurance Rate Maps (FIRMs) serve as guidance for appropriate development near dams. In addition, federal, and state regulations restrict significant development in these areas. Current land-use codes incorporate standards that address and mitigate dam failure.

The potential for impacts of future growth and development on dam failure will be monitored and evaluated in the next planning cycle to consider whether the level of risk has changed and whether there are opportunities for mitigation related to development that could reduce hazard impacts in the future.

5.1.3.5. Opportunities for Mitigation

In recent years, the Federal Emergency Management Agency (FEMA) has recognized the need to address the high level of vulnerability of dams in recognition of the overall deterioration of the nation's infrastructure. Concern about the safety of dams and potentially affected communities led to the development of the National Dam Safety Program/High Hazard Potential Dam Grant Program (NDS/HHPD), which that may be used for eligible mitigation projects. The Planning Committee or individual jurisdictions may wish to consider this potential funding source for improving the security of dams deemed to be at high or significant risk. The callout box below describes this program in detail.

Coronavirus (COVID-19) relief funds were distributed by the United States Congress to federal, state, and local government agencies, nonprofit organizations, and individuals in 2020 and 2021. The main funding programs were the Coronavirus Aid, Relief, and Economic Security (CARES) Act (2020), the Coronavirus Response and Consolidated Appropriations Act (2021), and the American Rescue Plan Act (ARPA) (2021).[52] These funds have a broad range of allowable expenses, including supporting public health, replacing lost public sector revenue, and investing in water, sewer, broadband, and cybersecurity infrastructure. Within these overall categories, recipients have broad flexibility to decide how best to use this funding to meet the needs of their communities.[53] As of December 2021, $350 billion was allocated to states, counties, cities, tribal governments, territories, and non-entitlement units of local government.[54]

Virginia Department of Conservation and Recreation (DCR) funds and controls the Dam Safety and Floodplain Management Grants. The fund was established to provide grants to public and private dam owners whose dams are under state regulations and to help local governments improve methods for flood prevention and protection. Another recent influx in federal funds that can be used for mitigation actions comes from the Infrastructure Investment and Jobs Act, which was passed by Congress on November 6,

[52] USA Spending. (2021, September 20). *The Federal Response to COVID-19*. https://www.usaspending.gov/disaster/covid-19?publicLaw=all
[53] United States Department of the Treasury. (n.d.). *Coronavirus State and Local Fiscal Recovery Funds*. https://home.treasury.gov/policy-issues/coronavirus/assistance-for-state-local-and-tribal-governments/state-and-local-fiscal-recovery-funds
[54] USA Spending. (2021, September 20). *The Federal Response to COVID-19*. https://www.usaspending.gov/disaster/covid-19?publicLaw=all

2021. This investment in infrastructure includes legislation that addresses repairing and rebuilding roads and bridges with a focus on climate change, mitigation, and resilience, and making the nation's infrastructure resilient against the impacts of climate change, cyberattacks, and extreme weather events. The ways in which this legislation will be administered was still being determined at the time this Plan was written.

National Dam Safety Program/High Hazard Potential Dam Grant Program (NDS/HHPD)[55]

The Virginia Department of Conservation and Recreation (DCR) serves as the commonwealth's dam safety agency, working in partnership with federal agencies and other stakeholders under the National Dam Safety Program to encourage and promote the establishment and maintenance of effective federal and state dam safety programs to reduce the risk to life, property, and the environment.

For the purposes of the HHPD program, all dam risk includes incremental risk, non-breach risk, and residual risk associated with each eligible high hazard potential dam, as well as the reason(s) a state has determined the dam is an eligible high hazard potential dam. To be eligible for an HHPD grant, the high hazard dam must have an emergency action plan approved by DCR, and it must fail to meet minimum dam safety standards of the commonwealth and pose an unacceptable risk to the public.

High hazard potential is a classification standard for any dam whose failure or incorrect operation would cause loss of human life and significant property destruction. There are 58 dams ranked as high hazard in the NOVA planning area.

Funding from the HHPD program provides technical, planning, design, and construction assistance for eligible rehabilitation activities that reduce dam risk and increase community preparedness.

Objectives of the program include:

1. Provide financial assistance for repair, removal, or rehabilitation of eligible high hazard potential dams
2. Protect the federal investment by requiring operation and maintenance of the project for 50 years following completion of rehabilitation
3. Encourage state, local, and territorial governments to consider all dam risks in state and local mitigation planning
4. Promote community preparedness by requiring recipients to develop and implement floodplain management plans that address potential measures, practices, and policies to reduce loss of life, injuries, damage to property and facilities, public expenditures, and other adverse effects of flooding in the area impacted by the project; plans for flood fighting and evacuation; and public education and awareness of flood risks
5. Reduce the potential consequences to life and property of high hazard potential dam incidents
6. Incentivize states to incorporate risk-informed analysis and decision-making into their dam safety practice
7. Reduce the overall number of high hazard potential dams that pose an unacceptable risk to the public

[55] Federal Emergency Management Agency. (2021, October 20). *Rehabilitation of High Hazard Potential Dam (HHPD) Grant Program*. https://www.fema.gov/emergency-managers/risk-management/dam-safety/rehabilitation-high-hazard-potential-dams

8. Promote a program of emergency action plan implementation, compliance, and exercise for high hazard potential dams
9. Reduce costs associated with dam rehabilitation through the deployment of innovative solutions and technologies

Eligible activities include the repair, removal, or rehabilitation of eligible high hazard potential dams. For the purposes of the HHPD program, rehabilitation means the repair, replacement, reconstruction, or removal of a dam that is carried out to meet applicable state dam safety and security standards.

The HHPD grant **period of performance** is 36 months from the date of the award.

Specific criteria for the HHPD grant program are in FEMA Policy 104-008-7.

5.1.3.6. Factors for Consideration in the Next Planning Cycle

Future monitoring, evaluating, and updating of this Plan should consider the following factors related to dam failure, as well as other information from updates of Virginia's COV-SHMP:

- Have dam failure events occurred in the planning area since the adoption of 2022 HMP?
- Did dam failure events take place in areas adjacent to the planning area that impacted the planning area by virtue of their being located upstream of the planning area?
- Has any new scientific research or methodology changed the ability to predict dam failure events or assess risk and vulnerability?
- Have there been significant changes in the population, built environment, natural environment, or economy that could affect the risk or vulnerability to dam failure?
- Is there new evidence related to the impacts of climate change that could affect the level of risk or vulnerability to dam failure?
- Has any new funding source for dam failure research or the repair, removal, or rehabilitation of dams become available?

5.2. Drought

2022 HMP Update

The drought hazard was reexamined, and a new analysis was performed that included but was not limited to the following:

- Reformatting the hazard section to improve flow and clarity.
- Refreshing the hazard profile with updated data, maps, and imagery, where available.
- Updating the assessment of risk and vulnerability by jurisdiction based on new data.
- Ranking the hazard by jurisdiction using the methodology described in Section 4.

Though drought and extreme heat are often interrelated hazards, they can and do occur independently of each other. The 2012 plan update consolidated the analysis of each into one section; however, the 2017 plan update separated them into different sections, a practice which is continued in this 2022 update.

Table 28: Drought Profile

<table>
<tr><th colspan="5">Drought</th><th>Overall Vulnerability</th></tr>
<tr><th colspan="5">Definition, Key Terms, and Overview</th><td rowspan="6">Medium</td></tr>
<tr><td colspan="5">A prolonged period with no rain, particularly during the planting and growing seasons in agricultural areas. Drought can also result from limited winter precipitation followed by moderately long periods without rain during the spring and summer months.</td></tr>
<tr><th>Frequency</th><th>Probability</th><th colspan="3">Potential Magnitude</th></tr>
<tr><td rowspan="2">Low</td><td rowspan="2">Moderate</td><th>Injuries/Deaths</th><th>Infrastructure</th><th>Environment</th></tr>
<tr><td>Low</td><td>Moderate</td><td>High</td></tr>
</table>

5.2.1. Hazard Profile

Drought is a period without substantial rainfall that persists from one year to the next. It is a normal part of virtually all climatic regions, including areas with high and low average rainfall. Drought is one of the most complex of all natural hazards because it is difficult to determine precisely when it begins and ends. In addition, droughts can result from other hazards, such as extreme heat. The impact of drought on wildlife and area farming is enormous, often killing crops, grazing land, edible plants, and, in severe cases, even trees. A secondary hazard of drought is wildfire, because dying vegetation serves as a prime ignition source. Therefore, a heat wave combined with a drought is a very dangerous condition.

Drought is a normal, recurrent feature of climate, although at times it is considered a random event. Its characteristics vary significantly from one region to another. Drought is a temporary condition; it differs from aridity, which is a permanent climate feature in regions with low rainfall.

Drought can have a widespread impact on the environment and the economy, depending upon its severity. Unlike other natural disasters, it typically does not directly result in loss of life or damage to property. However, drought can have indirect impacts on livelihoods and well-being that can lead, over the long term, to loss of life.

Drought, as a persistent moisture deficiency, can lead to adverse impacts on vegetation, people, and animals. High temperatures, high winds, and low humidity can worsen drought conditions and leave areas more susceptible to wildfire. Human demands and actions can also hasten drought-related impacts. Drought may be classified as meteorological, hydrologic, agricultural, or socioeconomic.

Table 29: Definitions of Drought Types[56]

Term	Definition
Meteorological Drought	The degree of dryness or departure of actual precipitation from an expected average or normal amount based on monthly, seasonal, or annual time scales. This type of drought usually takes at least three months to develop and can last for years.
Hydrological Drought	The effects of precipitation shortfalls on stream flows and reservoir, lake, and groundwater levels. The frequency and severity of hydrological drought is often defined on a watershed or river basin scale. Although all droughts originate from a precipitation shortfall, hydrologists are more concerned with how this deficiency plays out through the hydrologic system. Hydrological droughts are usually out of phase with, or follow the occurrence of, meteorological and agricultural droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system such as soil moisture, stream flow, and groundwater and reservoir levels.
Agricultural Drought	Agricultural drought links various characteristics of meteorological or hydrological drought to agricultural impacts, focusing on precipitation shortfalls, differences between actual and potential evapotranspiration (evaporation combined with transpiration), soil water deficits, and reduced groundwater or reservoir levels. Crop water demand depends on prevailing weather conditions, biological characteristics of the specific crops, their stage of growth, and the physical and biological properties of the soil.
Socioeconomic Drought	The effect of demands for water that exceed the supply because of a weather-related supply shortfall, occurring when physical water shortage begins to affect the population, individually and collectively. Most socioeconomic definitions of drought associate it with supply, demand, and economic good.

There is a link between the various types of droughts. Meteorological droughts are typically defined by the level of dryness when compared to an average, or normal, amount of precipitation over a given period. Hydrological drought is directly related to the effect of precipitation shortfalls on surface and groundwater supplies. Agricultural droughts relate common characteristics of drought to their specific agricultural-related impacts, emphasizing factors like soil water deficits, water reservoir levels, and differing water needs based on stages of crop development. Human factors, particularly changes in land use, can alter the hydrologic characteristics of a basin. Socioeconomic drought results from water shortages that limit the ability to supply water-dependent products in the marketplace, including food supplies.

[56] National Drought Mitigation Center. (n.d.). *Types of Drought*. https://drought.unl.edu/Education/DroughtIn-depth/TypesofDrought.aspx

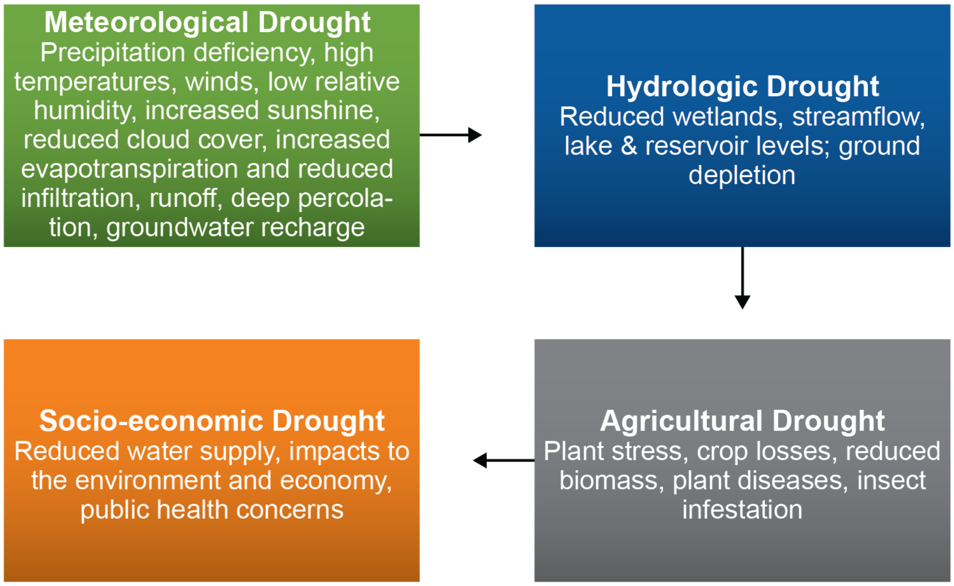

Figure 19: Interrelationship and Related Impacts of the Hydrological Cycle[57]

Drought should be considered relative to some long-term average conditions of balance between precipitation and evapotranspiration in a particular area, a condition often perceived as "normal." It is also related to the timing (i.e., principal season of occurrence, delays in the start of the rainy season, occurrence of rains in relation to principal crop growth stages) and the effectiveness (i.e., rainfall intensity, number of rainfall events, antecedent moisture conditions, etc.) of the rains. Other climatic factors such as high temperature, high wind, and low relative humidity are often associated with drought in many regions of the world and can significantly affect its severity.

Table 30: Hazard Profile Summary

<table>
<tr><td rowspan="8">Drought

Assessment: Medium Risk Hazard</td><td>Location</td><td>Jurisdiction-wide</td><td>Potential Cascading Effects</td></tr>
<tr><td>Extent</td><td>Moderate to significant</td><td rowspan="7">• Water supply shortage
• Decrease in agricultural production
• Livestock loss
• Loss of natural resources
• Food supply shortage
• Increased fire hazard
• Economic loss</td></tr>
<tr><td>Duration</td><td>Several weeks to several years</td></tr>
<tr><td>Probability</td><td>Moderately low</td></tr>
<tr><td>Seasonal Pattern</td><td>No distinct seasonal pattern but may be exacerbated by excessive heat in the summer</td></tr>
<tr><td>Speed of Onset</td><td>Slow</td></tr>
<tr><td>Warning Time</td><td>Days to weeks</td></tr>
<tr><td>Repetitive Loss</td><td>N/A</td></tr>
</table>

[57] National Drought Mitigation Center, University of Nebraska–Lincoln, Types of Drought. Retrieved at: https://www.drought.unl.edu/Education/DroughtIn-depth/TypesofDrought.aspx

5.2.1.1. Location

All jurisdictions in the Northern Virginia region are susceptible to drought conditions, although these are typically not as severe as those in other parts of the Commonwealth or in other regions of the country. According to historical Palmer Drought Severity Index (PDSI) records,[58] for the years 1895 to 2010, the Northern Virginia region was in severe to extreme drought conditions for only 5 to 10% of the time, compared to areas in the western portion of the United States that experienced severe to extreme drought conditions for more than 20% of the time.

According to the United States Department of Commerce, Bureau of Economic Analysis,[59] less than 1% of the Northern Virginia region's civilian workforce is involved in the farm or agriculture sector. According to the United States Department of Agriculture's 2017 Census of Agriculture, Loudoun County is the agricultural leader in the Northern Virginia region with more than 1,259 active farms on 142,452 acres of farmland, with an average farm size of approximately 100 acres. Cropland accounts for 49% of the land on farms, with pastureland for cattle accounting for 27%.

The number of farms and acres of farmland have declined by 10% from the previous statistical update in 2012. As continued development impacts previously undeveloped agricultural lands, agricultural production in the region is becoming potentially less vulnerable to drought.

5.2.1.2. Extent

Scientists and meteorologists use several tools to indicate the occurrence and severity of drought. The PDSI uses mathematical equations that incorporate precipitation and temperature data to estimate evaporation, runoff, and soil moisture recharge; it measures the extent or magnitude of drought by evaluating the duration and intensity of long-term drought-inducing circulation patterns. Long-term drought is cumulative, with the intensity of drought during a month dependent upon that month's weather patterns plus the cumulative patterns of previous months. The hydrological impacts of drought take longer to develop. The fixed mathematical formulas can be applied retroactively to historical data, and the National Center for Environmental Information (NCEI) maintains a database of monthly PDSI dating to 1895. The PDSI drought classifications are based on observed drought conditions.

Table 31: Palmer Drought Severity Index (PDSI) Classifications[60]

Drought Index	Drought Condition Classifications						
	Extreme	Severe	Moderate	Normal	Moderately Moist	Very Moist	Extremely Moist
Z Index	-2.75 and below	-2.00 to -2.74	-1.25 to -1.99	-1.24 to +.99	+1.00 to +2.49	+2.50 to +3.49	N/A
Meteorological	-4.00 and below	-3.00 to -3.99	-2.00 to -2.99	-1.99 to +1.99	+2.00 to +2.99	+3.00 to +3.99	+4.00 and above

58 Dai PDSI data provided by the NOAA/OAR/ESRL PSL, Boulder, Colorado, USA, from their Web site at: https://psl.noaa.gov/data/gridded/data.pdsi.html
59 United States Department of Agriculture. (2017). *2017 Census of Agriculture, County Profile for Loudoun County, Virginia.* http://www.nass.usda.gov/AgCensus
60 National Drought Mitigation Center. (n.d.). *Measuring Drought*. https://drought.unl.edu/ranchplan/DroughtBasics/WeatherandDrought/MeasuringDrought.aspx

Drought Index	Drought Condition Classifications						
	Extreme	Severe	Moderate	Normal	Moderately Moist	Very Moist	Extremely Moist
Hydrological	-4.00 and below	-3.00 to -3.99	-2.00 to -2.99	-1.99 to +1.99	+2.00 to +2.99	+3.00 to +3.99	+4.00 and above

The planning area is highlighted in green on the PDSI summary map for the United States from 1895 to 1995. As can be seen, the Eastern United States has not experienced as many significant long-term droughts as the Central and Western regions of the country. The PDSI can also be used to develop maps showing the percentage of time an area is considered to be in extreme or severe drought conditions.

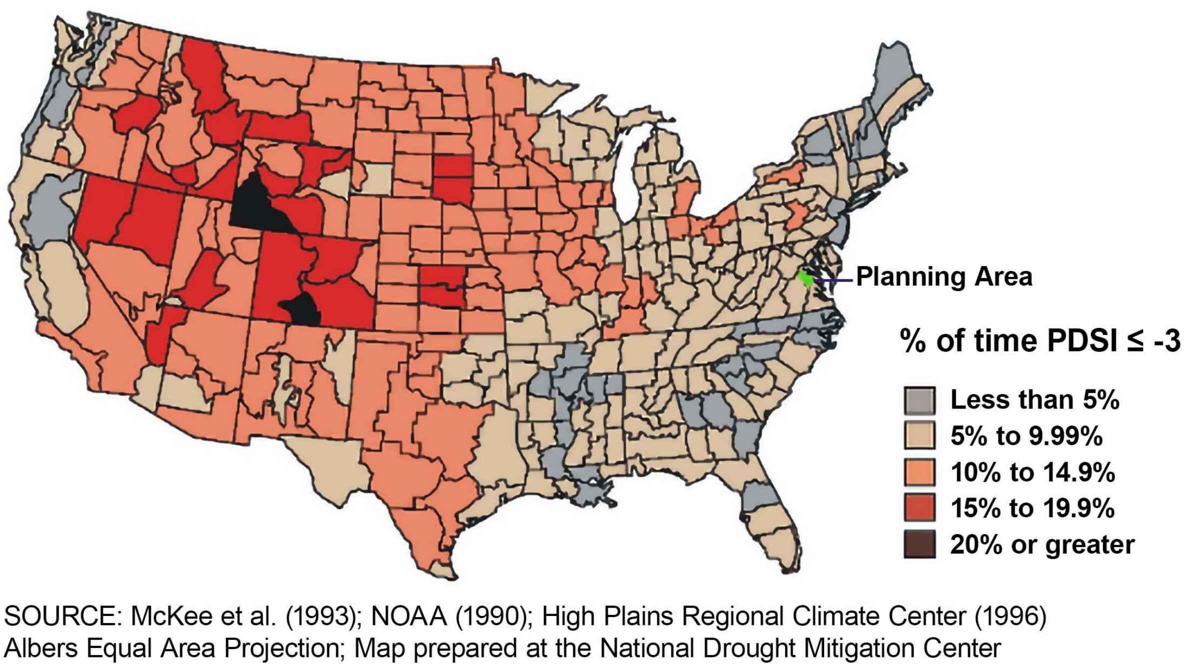

Figure 20: Historic Palmer Drought Severity Index (1895-1995), Percent of Time in Severe and Extreme Drought[61]

In addition to the PDSI, the United States Drought Monitor produces maps based on a drought classification system that summarizes conditions and impacts in a format that is easy for the general public to understand. Drought intensity is classified from D0 (abnormally dry) to D4 (exceptional drought. The classifications identify the level of intensity using the associated descriptor and define possible impacts at the various stages of drought. In addition, the classifications integrate other drought monitoring tools within each drought category.

[61] National Drought Mitigation Center. (2021). *Historic Palmer Drought Severity Index*. https://www.drought.unl.edu/monitoring/HistoricPDSI.aspx

Table 32: United States Drought Monitor Intensity Scale[62]

Category	Description	Possible Impacts	Ranges				
			Palmer Drought Severity Index (PDSI)	CPC Soil Moisture Model (Percentiles)	USGS Weekly Streamflow (Percentiles)	Standardized Precipitation Index (SPI)	Objective Drought Indicator Blends (Percentiles)
D0	Abnormally Dry	Going into drought: • Short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: • Some lingering water deficits. • Pastures and crops not fully recovered.	-1.0 to -1.9	21-30	21-30	-0.5 to -0.7	21-30
D1	Moderate Drought	• Some damage to crops, pastures. • Streams, reservoirs, and wells low; some water shortages developing or imminent. • Voluntary water-use restrictions requested.	-2.0 to -2.9	11 to 20	11 to 20	-0.8 to -1.2	11 to 20
D2	Severe Drought	• Crop or pasture losses likely. • Water shortages common. • Water restrictions imposed.	-3.0 to -3.9	6 to 10	6 to 10	-1.3 to -1.5	6 to 10
D3	Extreme Drought	• Major crop/pasture losses. • Widespread water shortages or restrictions.	-4.0 to -4.9	3 to 5	3 to 5	-1.6 to -1.9	3 to 5
D4	Exceptional Drought	• Exceptional and widespread crop/pasture losses. • Shortages of water in reservoirs, streams, and wells, creating water emergencies.	-5.0 or less	0 to 2	0 to 2	-2.0 or less	0 to 2

[62] National Drought Mitigation Center. (2021). *United States Drought Monitor, Drought Classification*. https://droughtmonitor.unl.edu/About/AbouttheData/DroughtClassification.aspx

When geographic areas are classified as D0, they are considered "drought watch" areas because they are in one of the following conditions: drying out and possibly heading for drought; recovering from drought but not yet back to normal; or suffering long-term impacts of drought such as low reservoir levels. The short-term drought indicator focuses on one- to three-month precipitation predictions; the long-term indicator focuses on six- to sixty-month predictions.

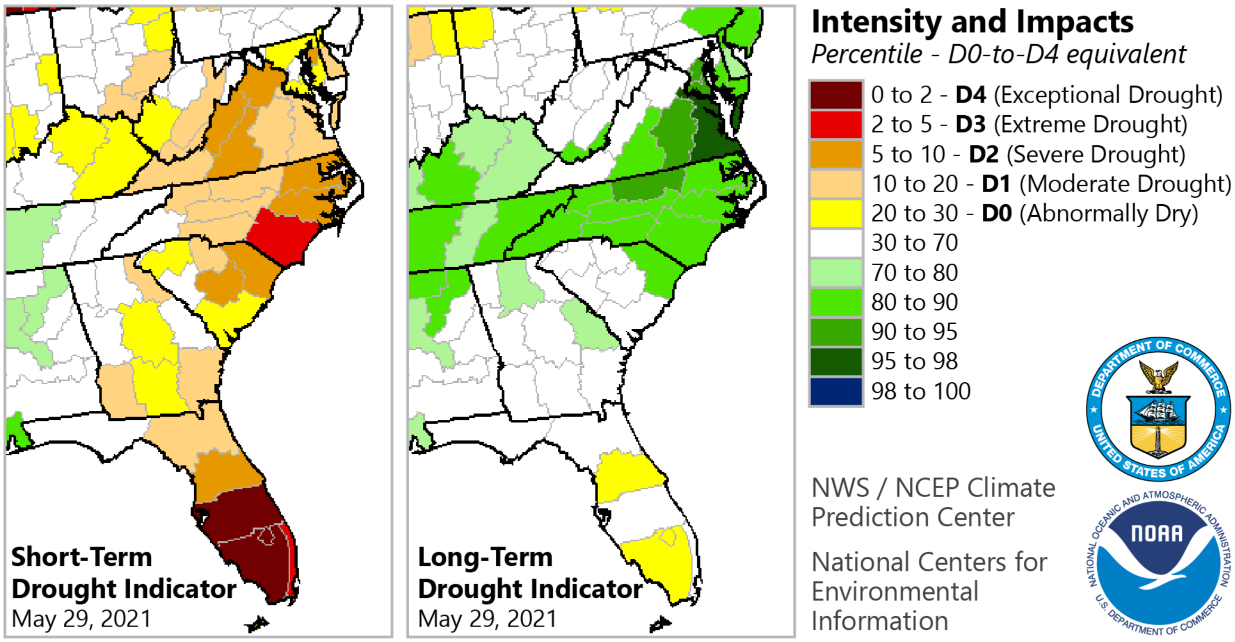

Figure 21: Examples of Short-Term and Long-Term Drought Prediction Maps, May 29, 2021[63]

5.2.1.3. Previous Occurrences

Because of the widespread geographic nature of the hazard, droughts typically affect large land areas, such as the entire Northern Virginia region. Descriptions of previous occurrences of drought in Northern Virginia have been consolidated to cover the entire planning area.

Table 33: Previous Drought Events, All Northern Virginia Jurisdictions, 1950–June 2021[64]

Jurisdiction	Drought Events 1950 to 2021
Arlington County	9
City of Alexandria	9
City of Fairfax	10
City of Falls Church	10
City of Manassas	12
City of Manassas Park	12
Fairfax County	10

[63] National Drought Mitigation Center. (2021). *United States Drought Monitor*. https://droughtmonitor.unl.edu/

[64] National Oceanic and Atmospheric Administration (2021). *National Center for Environmental Information Storm Events Database*, 1950-June 30, 2021 [Data set]. https://www.ncdc.noaa.gov/stormevents/

Jurisdiction	Drought Events 1950 to 2021
Town of Clifton	10
Town of Herndon	10
Town of Vienna	10
Loudoun County	12
Town of Leesburg	12
Town of Lovettsville	12
Town of Middleburg	12
Town of Purcellville	12
Town of Round Hill	12
Prince William County	12
Town of Dumfries	12
Town of Haymarket	12
Town of Occoquan	12
Town of Quantico	12

Based on NCEI data records, significant drought years in Northern Virginia occurred in 1987, 1998, 1999 and 2007. There have been no additional drought events reported since the 2017 Plan.

Table 34: Previous Drought Event Periods in Northern Virginia, 1997–2007[65]

Jurisdictions Affected (By NWS Zone)	Begin Date	End Date	Drought Period
Prince William County	7/1/1997	7/31/1997	4 weeks
Prince William County, City of Manassas	8/1/1998	8/31/1998	4 weeks
Prince William County	11/1/1998	11/30/1998	4 weeks
Arlington, Fairfax, and Prince William Counties	12/1/1998	12/31/1998	4 weeks
Arlington, Fairfax, and Prince William Counties	5/1/1999	5/31/1999	4 weeks
Arlington, Fairfax, and Prince William Counties	6/1/1999	6/30/1999	4 weeks
Arlington, Fairfax, and Prince William Counties, Cities of Alexandria and Falls Church	7/1/1999	7/31/1999	4 weeks
Arlington, Fairfax, and Prince William Counties	8/1/1999	8/31/1999	4 weeks
Arlington, Fairfax, and Prince William Counties	9/1/1999	9/17/1999	3 weeks
Arlington, Fairfax, and Prince William Counties	7/24/2007	7/31/2007	4 weeks

[65] Ibid.

Jurisdictions Affected (By NWS Zone)	Begin Date	End Date	Drought Period
Arlington, Fairfax, and Prince William Counties	8/1/2007	8/21/2007	3 weeks
Fairfax and Prince William Counties	10/1/2007	10/30/2007	4 weeks

Because droughts do not exhibit distinct beginning and end dates, it can be difficult to determine the period of a drought; multiple instances may be recorded for the same long-term drought. More detailed information on historical drought events can be obtained through the NCEI Storm Events Database.

Although 31 drought events since 1950 are documented in separate zones in the NCEI database, the events are spread over multiple jurisdictions, often with similar beginning and ending dates. Therefore, National Weather Service (NWS) zones listed within the same time period have been grouped as one incident. Each event is depicted as affecting multiple jurisdictions and possibly additional communities adjacent to the planning area. Because of the widespread nature of drought, towns located within each county are included in the county-level data.

Table 35: Drought Impacts for Northern Virginia Jurisdictions, 1950–June 2021[66]

Number of County and/or Zone Areas Affected	5
Number of Days with a Drought Event	12
Number of Days with a Drought Event and Death	0
Number of Days with a Drought Event and Death or Injury	0
Number of Days with a Drought Event and Property Damage	0
Number of Days with a Drought Event and Crop Damage	0
Number of Drought Event Types Reported	1

[66] National Oceanic and Atmospheric Administration (2021). *National Center for Environmental Information Storm Events Database,* 1950-June 30, 2021 [Data set]. https://www.ncdc.noaa.gov/stormevents/

Significant Previous Occurrences

Table 36: Summary of Previous Significant Drought Events[67]

Date(s)	Impacts
July 1997	• Dry weather reduced crop yields, including corn, hay, alfalfa, and soybeans. • Counties reported crop damage in the millions. • Temporary water restriction in some counties.
August 1998	• Only 0.45 inches of rain fell at Dulles International Airport, significantly less than the normal rainfall of 3.94 inches. • Reduced crop yields by estimated 20%–40% across the region, affecting corn, hay, and soybeans. • Winter feed reserves used to sustain livestock. • Increasingly dry timber and brush; five fires broke out in National Forests. • Reservoirs continued to dry out; water emergency declared in one county.
November–December 1998	• Fifth and sixth months with drought conditions across the region. • During November, only 0.91 inches of rain fell at Reagan National Airport in Arlington County, 2.19 inches below normal. • The five-month rain total at the airport was 5.78 inches, 11.38 inches below normal. • Total of 11.15 inches of rain from July through November. • Fairfax County had only 57% of its normal rainfall from July to November; Loudoun County had only 6.22 inches of rain. • Water supply reservoirs at record lows, with only backup reserve water, forcing mandatory water restrictions. • Second worst agricultural drought in 100 years; 89% of topsoil moisture was rated short or very short, and 76% of pastureland was rated poor or very poor. Hardest hit were barley, corn, hay, soybeans, tobacco, and wheat. • First time the Farm Service Agency made direct payments for grazing losses. • Loudoun County reported one-third of winter hay already fed to livestock by end of November, necessitating use of feed reserves. • Unprecedented number of forest and brush fires—65 reported statewide during November.

[67] Ibid.

Date(s)	Impacts
May–July 1999	• Climatological drought continuing since summer of 1998. • May was seventh month of below-normal precipitation and eighth driest month on record. • During May, only 2.22 inches of rain fell at Dulles International Airport, 1.80 inches below normal. • Fairfax and Loudoun counties each registered 2.0 inches of rain during June. • Potomac River water levels fell to average daily flow of 18% of the long-term average. • With low water tables, some voluntary water restrictions were issued. • Impacts on agriculture, with crop losses and trees prematurely shedding leaves in orchards. • Irrigation sources drying up, forcing reduction of herd sizes. • Dry forest conditions led to sizable brush fires. • Second warmest July on record, with average temperature of 82.9 degrees; record highs of over 90 degrees for 22 days in June. • PDSI indicated Extreme Drought. • Between August 1998 and July 1999, precipitation was 10–16 inches below average. Measurable rain fell on only eight days during July. • Low water tables forced additional voluntary and mandatory water restrictions. • Increasing number of wildlife entering populated areas searching for food and water.
August–September 1999	• Wells and springs remained short of water. • High temperatures were at or above 90 degrees through 19 August, then cooled into the 70s and 80s for the remainder of the month. • From September 1998 through August 1999, precipitation was 8–14 inches below average. • The KBDI measure of fire danger listed Northern Virginia at 650 prior to 26 August and 500 by month's end, indicating a slight decline in severity due to some rainfall. • The lack of rainfall continued to affect water levels along the Potomac River. The flow of water past Washington, D.C., was below average for the twelfth consecutive month. During August, the average daily flow of the river was only 11% of average. • Water was released from reservoirs to boost water levels, and some waterways ran dry. Beaverdam Reservoir in Loudoun County was 13 feet below capacity. • Many communities continued voluntary and mandatory water restrictions. • Loudoun and several other counties were declared federal drought disaster areas. Several crops never reached maturity, and agricultural losses in multiple counties reached in the millions. Hay production in Prince William County was cut by 65%. Loudoun County lost 50% of its corn crops. • Forests and rural vegetation were dangerously dry. A record fire season was reported for January through August, with 1,444 fires burning 9,373 acres. Some counties instituted mandatory burn bans during the month. • Loudoun County estimated $15 to $20 million in agricultural losses.

Date(s)	Impacts
August–October 2007	• Severe agricultural drought conditions were experienced in multiple Mid-Atlantic areas, including the Washington, D.C. metro area. • Some locations averaged rainfall totals 6 inches below normal, leading to some water restrictions. • In early October, rainfall deficits totaled nearly 10 inches. • All counties and independent cities in the Commonwealth were designated primary disaster areas except for Arlington County and the independent cities of Alexandria and Falls Church, which were designated contiguous disaster areas. • Many counties and cities posted both voluntary and mandatory water restrictions throughout the month. Just before rainfall towards the end of the month, the National Drought Monitor listed much of Northern Virginia and the Northern Piedmont under extreme drought conditions.

5.2.1.4. Probability of Future Occurrence

Although the entire Northern Virginia region is vulnerable to drought and historically suffers drought conditions between 5%–10% of the time, it is difficult to calculate the probability of future occurrences because the incidence of drought is highly unpredictable and may be localized. No sources of information on long-term historic frequency of drought or future probability were identified for inclusion in this Plan. This may be a result of multiple different definitions leading to inconsistent reporting over time. Based on past events, it remains possible over the long-term that the Northern Virginia region will experience recurring drought conditions, the severity of which cannot be fully quantified.

The United States Drought Monitor is one tool that can be utilized by plan participants to monitor the development of short- and long-term drought conditions. This resource presents drought estimations for a given point in time and can be used for planning, mitigation, and preparation.

5.2.2. Risk Assessment

Impacts from drought in the planning area are primarily related to cascading effects on water supply and agriculture and the resulting increase in wildfires. Lack of rainfall during drought conditions affects water levels along the Potomac River, the main water source for the upper Northern Virginia region. Many of the major reservoirs serving the Northern Virginia region, including the Occoquan in Fairfax County and the Beaverdam in Loudoun County, have experienced dangerously low levels in the past due to ongoing periods of drought. During these periods, many locations are forced to impose water restrictions, which could lead to economic impacts for the region. The most vulnerable residents are those in the more rural areas, many of whom draw their water supply from wells.

Short-term droughts can impact agricultural productivity, while longer-term droughts are more likely to impact not only agriculture but also water supply. Jurisdictions that have invested in water supply and distribution infrastructure are generally less vulnerable to drought. Short- and long-term drought may lead to an increase in the incidence of wildfires, which might in turn lead to increased potential for landslides or mudflows once rain does fall.

5.2.2.1. Population and Property

There is low risk of human injury and/or death due to drought in Northern Virginia; however, water shortages may impact vulnerable populations who are unable to plan for shortages or access alternate water sources. Extreme long-term drought may also impact food supplies.

5.2.2.2. Built Environment, Community Lifelines, and Assets

Vulnerability associated with drought has not been quantified in terms of geographic extent for this revision; as a result, specific vulnerabilities of the built environment, Community Lifelines, and assets have not been calculated. Most drought-related damages do not impact buildings or infrastructure.

Since 1950, the region has been severely impacted by numerous instances of a long-term drought with agricultural damages totaling approximately $25 million, most of which are attributable to agricultural losses in Loudoun and Prince William counties. Prior to this period, very little historical data exists on drought events.

5.2.2.3. Natural Environment and Economy

Crop damages resulting from drought are difficult to predict, as agricultural productivity often varies with growing conditions from year to year. Past events have demonstrated, however, that drought can lead to crop failure, loss of trees and native species, and impacts on watersheds and waterways. These impacts have economic consequences, including agricultural losses related to crops and livestock, disruption to business operations, and loss of revenues from recreation and tourism.

5.2.2.4. Hazard Risk Ranking Summary

The hazard ranking process considered probability and consequences in determining an overall risk score and ranking. Information in this section and the hazard risk ranking process present the quantitative and qualitative summary for drought. The Hazard Identification and Risk Assessment methodology is described in **Section 4, Base Plan**.

Table 37: Hazard Risk Rankings for Drought, by Jurisdiction

Jurisdiction	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
Arlington County	1.7	3.2	4.8	**Medium**
City of Alexandria	2.3	3.3.	5.6	**Medium**
City of Fairfax	2.0	3.2	5.2	**Medium**
City of Falls Church	2.0	3.2	5.2	**Medium**
City of Manassas	2.3	3.2	5.5	**Medium**
City of Manassas Park	2.3	3.2	5.5	**Medium**
Fairfax County	2.0	3.2	5.2	**Medium**
Town of Clifton	2.0	3.2	5.2	**Medium**
Town of Herndon	2.0	3.2	5.2	**Medium**
Town of Vienna	2.0	3.2	5.2	**Medium**
Loudoun County	2.0	3.2	5.2	**Medium**
Town of Leesburg	2.0	3.2	5.2	**Medium**
Town of Lovettsville	2.0	3.2	5.2	**Medium**
Town of Middleburg	2.0	3.2	5.2	**Medium**
Town of Purcellville	2.0	3.2	5.2	**Medium**
Town of Round Hill	2.0	3.2	5.2	**Medium**
Prince William County	2.3	3.4	5.7	**Medium**

Jurisdiction	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
Town of Dumfries	2.3	3.2	5.5	**Medium**
Town of Haymarket	2.3	3.2	5.5	**Medium**
Town of Occoquan	2.0	2.0	4.0	**Medium**
Town of Quantico	2.3	3.2	5.5	**Medium**

5.2.3. Vulnerability Analysis

There is no single standardized methodology for estimating vulnerability to the hazard of drought; however, annualized crop losses of $463,000 can be calculated based on NCEI data for previous events. Future updates to this Plan should consider methods for quantifying annual drought losses in sectors outside of agriculture. This might include defining losses related to maintaining water supply, hydropower, tourism, and recreation and would require data sources outside of NCEI storm events data, including detailed local reports of occurrences and associated damages. Because drought does not pose a direct threat to life and property, its impact is primarily measured by its potential and actual economic effects on the agricultural sector as well as municipal and industrial water supplies. This economic effect can also be expected to affect related sectors, such as wholesale and retail trade.

Table 38: Annualized Property and Crop Loss Due to Drought, 1950-2021 [68]

Jurisdiction	Annual Total Property and Crop Damage (151 Total Drought Events)
Arlington County	$22,315
City of Alexandria	$22,315
City of Fairfax	$0
City of Falls Church	$22,315
City of Manassas	$28,160
City of Manassas Park	$0
Fairfax County	$22,315
Town of Clifton	Included in Fairfax County estimate
Town of Herndon	Included in Fairfax County estimate
Town of Vienna	Included in Fairfax County estimate
Loudoun County	$317,304
Town of Leesburg	Included in Loudoun County estimate
Town of Lovettsville	Included in Loudoun County estimate
Town of Middleburg	Included in Loudoun County estimate
Town of Purcellville	Included in Loudoun County estimate
Town of Round Hill	Included in Loudoun County estimate

[68] National Oceanic and Atmospheric Administration (2021). *National Center for Environmental Information Storm Events Database,* 1950-June 30, 2021 [Data set]. https://www.ncdc.noaa.gov/stormevents/

Jurisdiction	Annual Total Property and Crop Damage (151 Total Drought Events)
Prince William County	$28,160
Town of Dumfries	Included in Prince William County estimate
Town of Haymarket	Included in Prince William County estimate
Town of Occoquan	Included in Prince William County estimate
Town of Quantico	Included in Prince William County estimate
Total Annualized Property and Crop Loss Due to Drought	**$462,886**

5.2.3.1. Future Population and Development Trends

Future development and the resulting population increase have the potential to elevate drought vulnerability in the future; the degree of vulnerability depends on climate change variables and how well jurisdictions manage growth relevant to the water supply needs of the population and the agricultural and industrial sectors. The impacts and consequences of the 1998-99 drought can serve as a guide for future planning and regulatory actions based on appropriate development in the region's jurisdictions.

5.2.3.2. Factors for Consideration in the Next Planning Cycle

Future monitoring, evaluating, and updating of this Plan should consider the following factors related to drought, as well as other information from the Virginia COV-SHMP:

- Have drought events occurred within the planning area since adoption of 2022 HMP?
- Did drought events take place in areas adjacent to the planning area that impacted the planning area by virtue of proximity?
- Has new scientific research or methodology changed the ability to predict drought events or assess risk and vulnerability?
- Has there been significant change in the population, built environment, natural environment, or economy that could affect the level of risk or vulnerability to drought, including land use for agricultural purposes and water infrastructure?
- Is there new evidence related to the impacts of drought that could affect the level of risk or vulnerability to drought?

5.3. Earthquake

2022 HMP Update

The earthquake hazard was reviewed, and a new analysis was performed that included but was not limited to the following:

- Reformatting the hazard section to improve flow and clarity.
- Refreshing the hazard profile
- Updating number of previous occurrences and associated losses by jurisdiction
- Updating data sources and imagery, where available.
- Updating risk assessment and vulnerability analysis, by jurisdiction.
- Reviewing and re-evaluating hazard ranking using methodology described in Section 4, Base Plan

Table 39: Earthquake Profile

<table>
<tr><th colspan="5">Earthquake</th><th rowspan="2">Overall Vulnerability</th></tr>
<tr><th colspan="5">Definition, Key Terms, and Overview</th></tr>
<tr><td colspan="5">An earthquake is the motion or trembling of the ground produced by sudden displacement of rock in the earth's crust. Earthquakes result from crustal strain, volcanism, landslides, or the collapse of caverns. Earthquakes can affect hundreds of thousands of square miles, cause damage to property measured in the tens of billions of dollars, result in loss of life and injury to hundreds or thousands, and disrupt the social and economic functioning of the affected area. Earthquakes are naturally occurring and are caused by earth movement.
Fault: A fracture or zone of fractures between two blocks of rock that allows blocks to move relative to each other. Rapidly occurring movement results in an earthquake incident.[69]
Magnitude: Earthquake intensity measured on logarithmic scale that describes the energy release of an earthquake through a measure of shock wave amplitude.
Seismic: Of or relating to earthquakes or other vibrations of the earth and its crust.
Tectonic plates: The earth’s outermost layer is broken into large rocky plates that lie on top of a partially molten layer of rock. These tectonic plates move relative to each other at different rates, from two to 15 centimeters (or one to six inches) per year. This movement is responsible for many phenomena, including earthquakes, volcanoes, and the development of mountain ranges.[70]</td><td rowspan="5">Medium</td></tr>
<tr><th>Frequency</th><th>Probability</th><th colspan="3">Potential Magnitude</th></tr>
<tr><td rowspan="2">Low</td><td rowspan="2">Moderate</td><th>Injuries/Deaths</th><th>Infrastructure</th><th>Environment</th></tr>
<tr><td>Low</td><td>Moderate</td><td>Moderate</td></tr>
</table>

[69] United States Geological Survey. (n.d.). *What is the relationship between faults and earthquakes? What happens to a fault when an earthquake occurs?* https://www.usgs.gov/faqs/what-relationship-between-faults-and-earthquakes-what-happens-a-fault-when-earthquake-occurs?qt-news_science_products=0#qt-news_science_products
[70] National Geographic Society. (n.d.). *Plate Tectonics*, https://www.nationalgeographic.org/encyclopedia/plate-tectonics

5.3.1. Hazard Profile

Earthquakes are primarily caused by the release of stresses accumulated as a result of the rupture of rocks along opposing fault planes in the earth's outer crust. These fault planes are typically found along borders of the earth's ten tectonic plates. These borders generally follow the outlines of the continents, with the North American plate following the continental border with the Pacific Ocean in the west and the mid-Atlantic trench in the east. Earthquakes occurring in the mid-Atlantic trench usually pose little danger to humans. Although the greatest earthquake threat to North America lies along the Pacific Coast, there is some threat to the eastern United States from the Caribbean Plate.

The areas of greatest tectonic instability lie at the perimeters of the slowly moving plates. These locations are subject to strains from plates traveling in opposite directions and at different speeds. Deformation along plate boundaries causes strain in the rock and leads to a buildup of stored energy. When built-up stress exceeds the strength of the rocks, a rupture occurs. Rock on both sides of the fracture is snapped, releasing the stored energy and producing seismic waves that generate an earthquake.

Ground shaking can lead to the collapse of buildings and bridges and disrupt gas lines, electricity, and phone service. Death, injuries, and extensive infrastructure and property damage are possible with this hazard. Some secondary threats caused by earthquakes may include fire, hazardous material release, landslides, flash flooding, and dam failure.

Most property damage and earthquake-related deaths are caused by the failure and collapse of structures due to ground shaking. The level of damage depends upon the amplitude and duration of the shaking, features that are directly related to the earthquake's size, distance from the fault, location, and regional geology. Other damaging earthquake effects include landslides (the down-slope movement of soil and rock in mountain regions and along hillsides) and liquefaction, in which ground soil loses shear strength and thus the ability to support foundation loads. In the case of liquefaction, anything relying on the substrata for support can shift, tilt, rupture, or collapse.

Table 40: Hazard Profile Summary

<table>
<tr><td rowspan="8">Earthquake
Assessment: Medium Risk Hazard</td><td>Location</td><td>Jurisdiction-wide</td><td>Potential Cascading Effects</td></tr>
<tr><td>Extent</td><td>Minimal to moderate</td><td rowspan="7">• Property damage to homes and businesses
• Infrastructure damage and disruption of services
• Water supply shortage.
• Increased fire hazard from gas line ruptures
• Economic harm from business loss or temporary closures
• Death and injury
• Damage to the environment and habitats</td></tr>
<tr><td>Duration</td><td>Minutes</td></tr>
<tr><td>Probability</td><td>Low</td></tr>
<tr><td>Seasonal Pattern</td><td>No seasonal pattern</td></tr>
<tr><td>Speed of Onset</td><td>Slow</td></tr>
<tr><td>Warning Time</td><td>Minor ground shaking may precede a stronger event</td></tr>
<tr><td>Repetitive Loss</td><td>N/A</td></tr>
</table>

5.3.1.1. Location

The potential for earthquakes exists across all of Virginia; however, based on scientific and historical data, the Northern Virginia region is in an area that has a slightly lower risk of earthquakes than other areas of the Commonwealth, such as the southwest portion.

Virginia has three main seismic zones that relate to most earthquakes, none of which are in the Northern Virginia planning area. These zones are believed to be the sources of most magnitude 6 or greater earthquakes during the past 1.6 million years around Virginia, though there has never been an earthquake event of that magnitude recorded in Virginia in modern times.

Because of the geophysical nature of the hazard, the entire planning area is susceptible to impacts from a major earthquake.

5.3.1.2. Extent

Earthquakes are measured in terms of their magnitude and intensity. Magnitude is measured using the Richter Scale, an open-ended logarithmic scale that describes the energy release of an earthquake through a measure of shock wave amplitude. Each unit increase in magnitude on the Richter Scale corresponds to a ten-fold increase in wave amplitude, or a thirty-two-fold increase in energy.

Intensity is commonly measured using the Modified Mercalli Intensity (MMI) Scale based on direct and indirect measurements of seismic effects. The scale levels are typically described using Roman numerals ranging from I, which corresponds to instrumental or imperceptible events, to XII, which represents catastrophic effects. Both the Richter and MMI scales are used by the National Weather Service (NWS) as measures of impact.

Table 41: Modified Mercalli Intensity (MMI) and Peak Ground Acceleration (PGA)[71]

MMI	PGA (%)	Perceived Shaking	Potential Damage
I	<0.17	Not Felt	None
II	0.17 - 1.4	Weak	None
III	0.17 - 1.4	Weak	None
IV	1.4 -3.9	Light	None
V	3.9 -9.2	Moderate	Very Light
VI	9.2 -18	Strong	Light
VII	18 -34	Very Strong	Moderate
VIII	34 - 65	Severe	Moderate to Heavy
IX	65 - 124	Violent	Heavy
X	> 124	Extreme	Very Heavy
XI	> 124	Extreme	Very Heavy
XII	> 124	Extreme	Very Heavy

[71] Wu, Y., Teng, T., Shin, T., & Hsiao, N.C. (2003). Relationship between Peak Ground Acceleration, Peak Ground Velocity, and Intensity in Taiwan. *Bulletin of the Seismological Society of America*. 93. 386-396. 10.1785/0120020097

Category	Effects	Richter Scale (approximate)
I. Instrumental	Not felt	1-2
II. Just perceptible	Felt by only a few people, especially on upper floors of tall buildings	3
III. Slight	Felt by people lying down, seated on a hard surface, or in the upper stories of tall buildings	3.5
IV. Perceptible	Felt indoors by many, by few outside; dishes and windows rattle	4
V. Rather Strong	Generally felt by everyone; sleeping people may be awakened	4.5
VI. Strong	Trees sway, chandeliers swing, bells ring, some damage from falling objects	5
VII. Very Strong	General alarm; walls and plaster crack	5.5
VIII. Destructive	Felt in moving vehicles; chimneys collapse; poorly constructed buildings seriously damaged	6
IX. Ruinous	Some houses collapse; pipes break	6.5
X. Disastrous	Obvious ground cracks; railroad tracks bent; some landslides on steep hillsides	7
XI. Very disastrous	Few buildings survive; bridges damaged or destroyed; all services interrupted (electrical, water, sewage, railroad); severe landslides	7.5
XII. Catastrophic	Total destruction; objects thrown into the air; river courses and topography altered	8

Figure 22: Comparison of the Modified Mercalli Intensity Scale and the Richter Magnitude Scale[72]

Most earthquake events in the planning area register at a magnitude lower than 3.0 and are not felt by people.

5.3.1.3. Previous Occurrences

The first recorded earthquake in Virginia occurred in 1774. Since 1900, there have been more than 541 earthquakes documented in the Commonwealth,[73] 18 at a magnitude of 4.5 or higher on the Richter Scale. The largest event before 2011 occurred in Giles County in 1897, with a magnitude of 5.8; however, the most recent major earthquake, on August 23, 2011, with an epicenter 11 kilometers south-southwest of Mineral, Virginia, was also measured at a magnitude of 5.8.

Most epicenter locations are clustered northwest of Richmond or in the southwestern region of the Commonwealth. Epicenters of seven earthquakes are noted to have occurred in or within proximity of the planning area:

- March 23, 1974: 2.5 magnitude, exact location not identified
- September 29, 1997: 2.5 magnitude, 3.7 miles south-southwest of the City of Manassas, Virginia
- May 6, 2008: 2.0 magnitude, Ravensworth, Virginia
- July 16, 2010: 3.6 magnitude, 3.1 miles north-northwest of Barnesville, Maryland

[72] Global Weather & Climate Center. (2020, March 25). *Geoscience Topics: Salt Lake Quake!* https://www.globalweatherclimatecenter.com/geoscience-topics/salt-lake-quake
[73] United States Geological Survey. (2019, June 26). *Information by Region-Virginia*. https://www.usgs.gov/programs/earthquake-hazards/science/information-region-virginia#overview

- August 23, 2011: 5.8 magnitude, near Mineral, Virginia
- June 13, 2013: 2.0 magnitude, 4.3 miles west-northwest of Calverton, Virginia
- January 17, 2016: 3.0 magnitude, 1.9 miles northeast of Ranson, West Virginia
- August 17, 2018: 1.3 magnitude, 1.2 miles east-northeast of Belmont, Virginia

None of the earthquakes documented with epicenters near the planning area have been major earthquakes.

Most earthquakes have resulted in very little property damage, if any, and there are no historical records of earthquake-related damages in the Northern Virginia region. Northern Virginia has not been included in any federal disaster declarations for earthquake, and only one earthquake event has been recorded by the NWS.

The United States Geological Survey (USGS) has also documented 62 significant earthquake events as having occurred within 300 miles of the Northern Virginia region, including some centered outside of Virginia. There are no reported casualties or significant property damages for the Northern Virginia region as a result of these events.

It is assumed that these events were experienced across the planning region, though it is possible that there were no specific reports of damages in localized geographic areas. The historic occurrences discussed here were initially included in the 2013 and 2018 Commonwealth of Virginia State Hazard Mitigation Plans and are retained here to maintain current awareness of the hazard history.

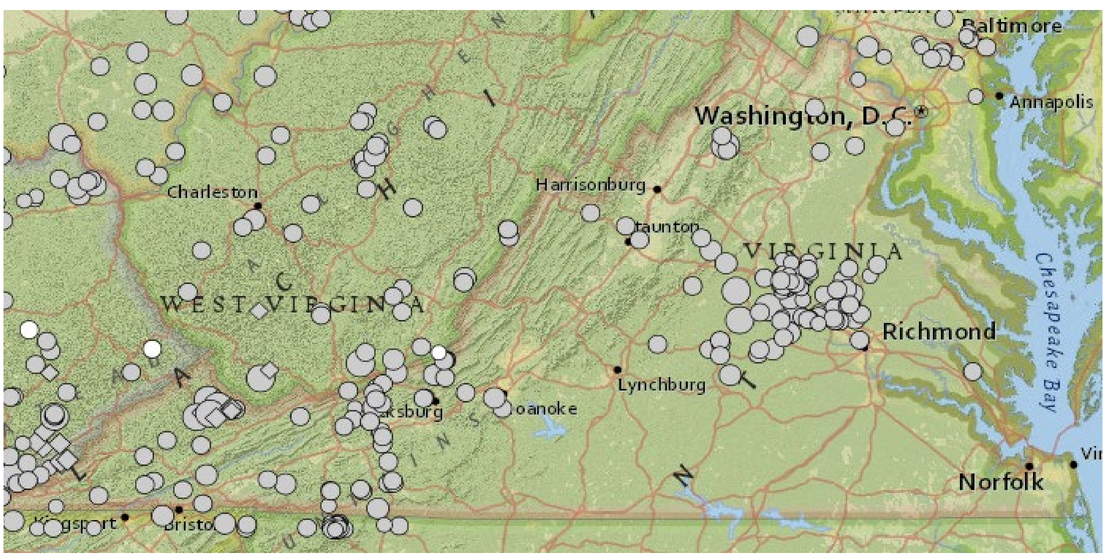

Figure 23: Epicenter Locations of Documented Earthquakes in Virginia, 1774–2016[74]

Significant Earthquake Events

May 6, 2008

A minor earthquake of 2.0 magnitude occurred near Annandale, a census-designated place in Fairfax County. Felt reports were primarily received from people in Fairfax County, Washington, D.C., and Montgomery County, Maryland.

[74] United States Geological Survey. (2021). *Earthquake Hazards.* https://www.usgs.gov/programs/earthquake-hazards/earthquakes

August 23, 2011

The most significant major earthquake causing any impact the planning area in recent years is the 5.8 magnitude event on August 23, 2011, which caused significant damage and was felt over thousands of square miles. The event was followed by major aftershocks for two days. The earthquake struck the Piedmont region of Virginia with an epicenter near the Town of Mineral in Louisa County, approximately 61 miles from the southern boundary of the planning area. The earthquake was felt in approximately 12 states and into Canada. No fatalities from the event were recorded, though some injuries were reported. Damage was widespread and estimated at hundreds of millions of dollars, much of which was uninsured. The earthquake caused the automatic shutdown of the North Anna Nuclear Power Station in Louisa County. It was one of the highest magnitude earthquakes to occur east of the Rocky Mountains and resulted in a multi-county federal disaster declaration, DR-4042-VA. No jurisdictions within the planning area were included in this declaration.

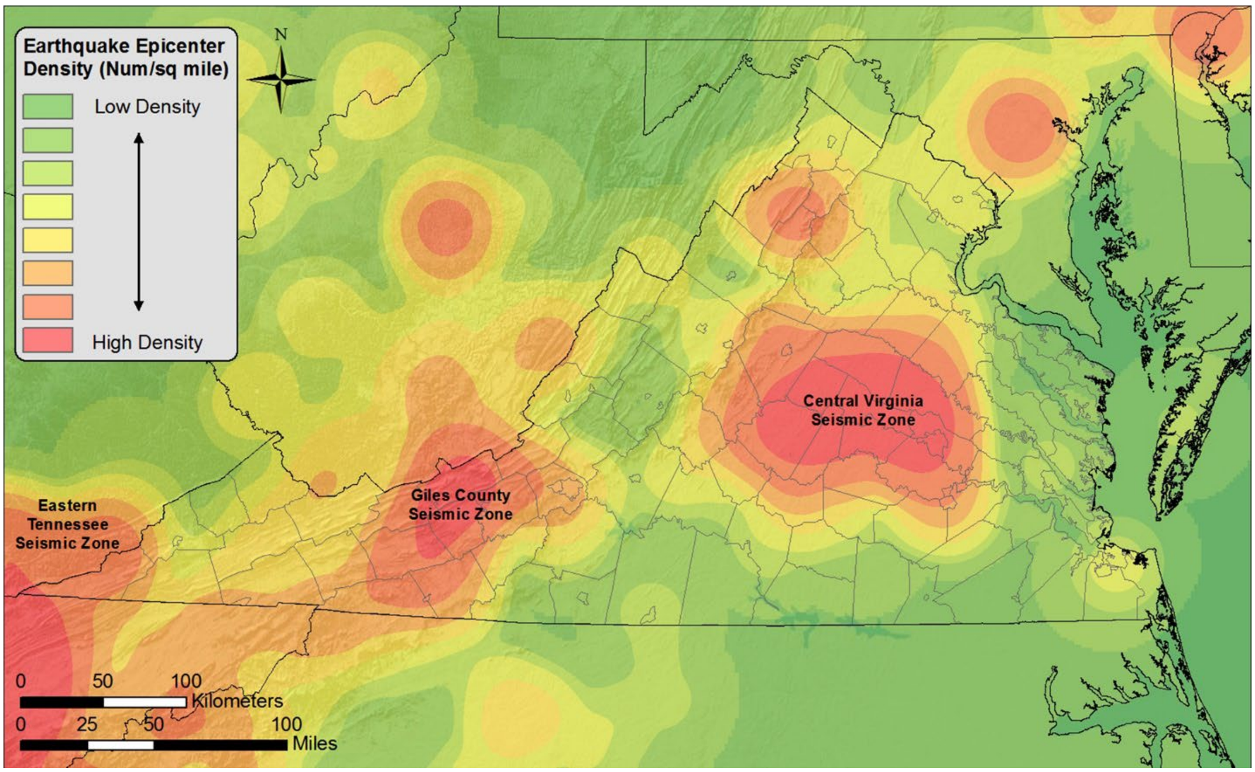

Figure 24: 2011 Virginia Earthquake Epicenter Density[75]

During the event, a pipe ruptured in the Pentagon in Arlington County, resulting in the flooding of at least two corridors. Damage was also reported at an Arlington County theater and several additional structures in Arlington County. The City of Manassas reported slight damage to city hall and the fire and rescue headquarters. In Prince William County, the earthquake caused damage to a dam and slight damage to several county facilities.

[75] UVAToday. (2015, July 1). *An Earthquake History: Finding Faults in Virginia*. https://news.virginia.edu/content/earthquake-history-finding-faults-virginia

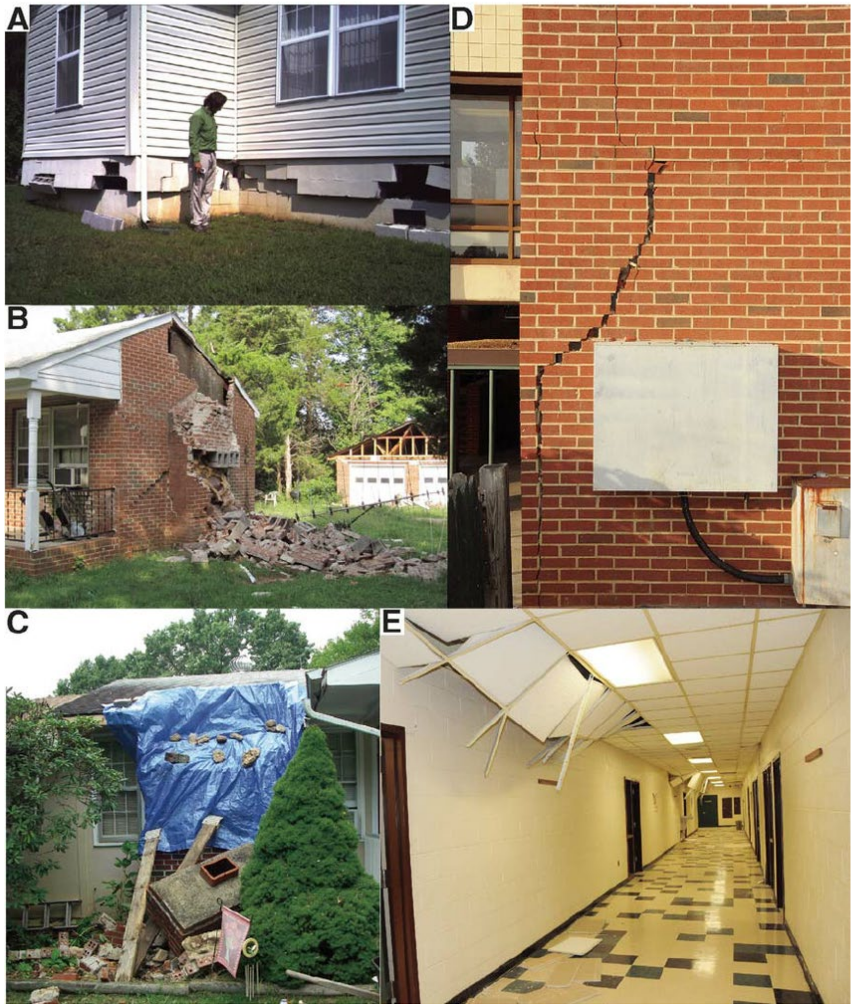

Figure 25: Examples of Structure Damage in Louisa County, Virginia After the 2011 Earthquake[76]

A familiar image from the August 2011 earthquake is damage to the Washington National Cathedral in Washington, D.C. The ground movement caused displacement of segments of the structure's stone spires. The Washington Monument was also damaged and closed for three years for repairs.

[76] Horton, J., Chapman, M. & Green, R. (2015). The 2011 Mineral, Virginia, earthquake, and its significance for seismic hazards in eastern North America—Overview and synthesis. 10.1130/2015.2509(01)

Figure 26: Earthquake Damage to Washington National Cathedral in Washington, D.C. After the 2011 Earthquake[77]

Table 42: August 23, 2011 Louisa County, Virginia Earthquake Report[78]

Date	August 23, 2011
Time	17:51
Location	Virginia (Louisa County), Maryland, Washington, D.C.
Latitude	37.936
Longitude	-77.933
Magnitude	5.8
Modified Mercalli Intensity (MMI)	7
Deaths	0
Injuries	0
Missing Persons	0
Damage	$200 Million
Damage Description Level	4

[77] United States Geological Survey. (2019, August 5). *M5.8 August 23, 2011, Mineral, Virginia*. https://www.usgs.gov/programs/earthquake-hazards/science/m58-august-23-2011-mineral-virginia#overview
[78] National Oceanic and Atmospheric Administration National Centers for Environmental Information. (2021, August 30). *Significant Earthquake Information*. https://www.ngdc.noaa.gov/hazel/view/hazards/earthquake/event-more-info/9861

Total Houses Destroyed	0
Total Houses Damaged	600
Total Houses Damaged Description Level	3

Incident Description:

- Moderately heavy damage (MMI VIII) occurred in rural Louisa County, southwest of Mineral. Widespread light to moderate damage occurred from central Virginia to southern Maryland including the District of Columbia area. Minor damage reported in parts of Delaware, southeastern Pennsylvania, and southern New Jersey. Very strongly felt (MMI VII) in the Virginia communities of Boston, Bumpass, Kents Store, Louisa, Mineral, Rhoadsville, and Sumerduck. Felt strongly in much of central Virginia and southern Maryland. Felt throughout the eastern United States from central Georgia to central Maine and west to Detroit, Michigan and Chicago, Illinois. Felt in many parts of southeastern Canada from Montreal to Windsor.

Tectonic Summary:

- This event occurred as reverse faulting on a north or northeast-striking plane within a previously recognized seismic zone, the Central Virginia Seismic Zone. The Central Virginia Seismic Zone has produced small and moderate earthquakes since at least the 18th century. The previous largest historical shock from the Central Virginia Seismic Zone occurred in 1875; effective seismographs had not yet been invented, but the felt area of the shock suggests that it had a magnitude of about 4.8. The 1875 earthquake shook bricks from chimneys, broke plaster and windows, and overturned furniture at several locations. A magnitude 4.5 earthquake on December 9, 2003, also produced minor damage.
- Although less frequent than in the western United States, earthquakes in the central and eastern United States are typically felt over a much broader region (see Figure 27). East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 earthquake in the eastern United States can typically be felt as far as 62 miles from its source, and it infrequently causes damage near its source. A magnitude 5.5 earthquake in the eastern United States usually can be felt as far as 311 miles from its source and may cause damage as far away as 25 miles
- Estimated total economic losses from the 2011 earthquake were from $200 to $300 million, including major damage to the National Cathedral, Armed Forces Retirement Home, Washington Monument, and 600 houses. The shaking was felt by approximately one-third of the United States population and caused minor damage as far away as Charleston, South Carolina, 373 miles from the epicenter. The shaking caused the first ever shutdown of a United States commercial nuclear power plant at the North Anna nuclear power facility located about 14 miles northeast of the epicenter.
- Louisa County residential property damage was estimated at $18.3 million, and the total estimate of private property damage in the epicentral region was $21.4 million. [...] Damage to businesses, churches, and nonprofits in Louisa County was estimated at $1.5 million as of September 2011, and damage to public structures was estimated at $66.2 million, including $63.8 million to replace two schools.

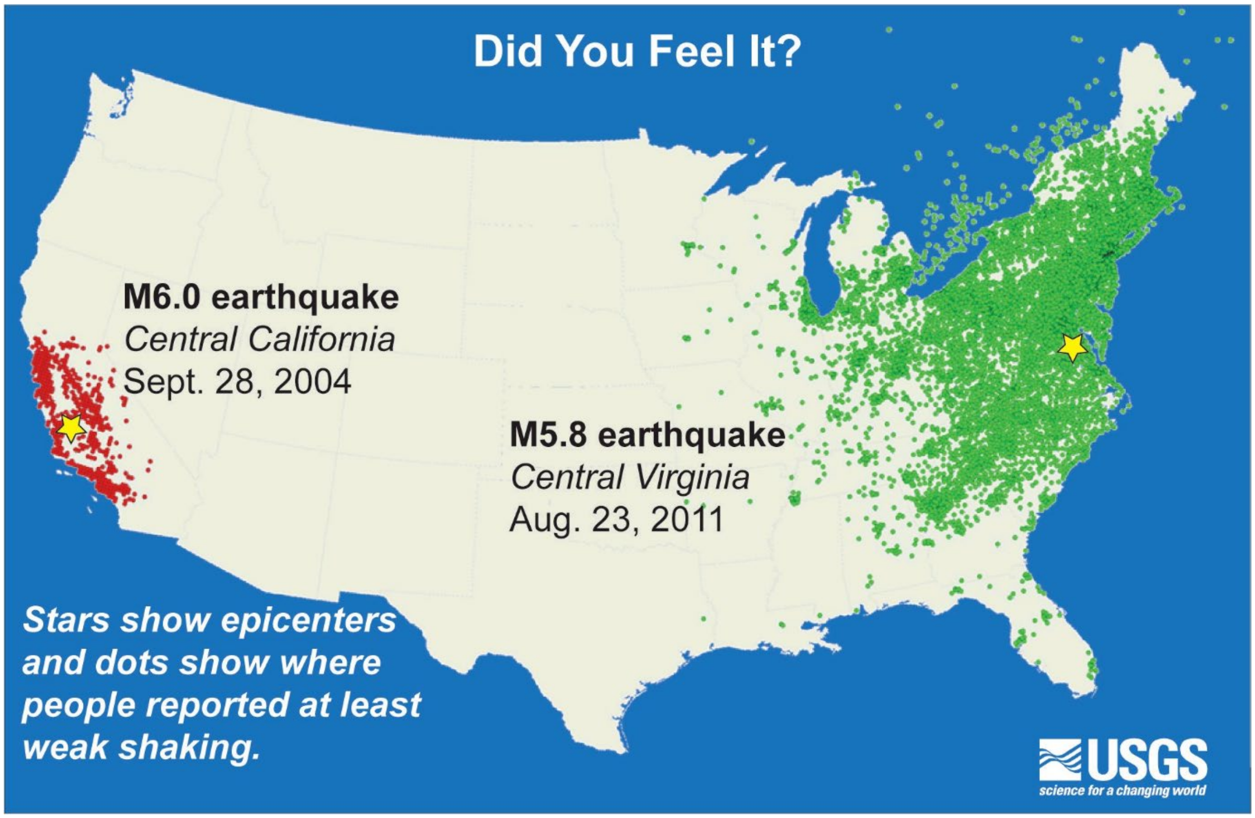

Figure 27: Comparison of Site Reports for West Coast and East Coast Earthquakes[79]

Due to the terrain, earthquakes east of the Rocky Mountains have a far wider geographic range in which people report feeling the shaking. A report released by the USGS on August 4, 2021, about this event included significant observations by Thomas Pratt, a USGS research geophysicist and expert on eastern earthquakes:

> *One of the fascinating things we discovered was heightened ground shaking in Washington, D.C., resulting in damage to buildings in the city at distances that would not ordinarily be expected.*
>
> *USGS scientists found that the strength of ground shaking from the Mineral earthquake was substantially greater to the northeast than in other directions. This direction is nearly parallel to the orientation of the Appalachian Mountains and the eastern edge of the continent, which shows the influence of large-scale features like mountain ranges on ground shaking.*
>
> *Subsequent research identified that the underlying sediment is what led to amplified shaking. We were familiar with that phenomenon on the West Coast of the United States and internationally, but the Mineral earthquake showed the significance of this effect in the eastern U.S. The areas on sediment received significantly stronger shaking than nearby locations on firmer rock.*

[79] United States Geological Survey reported in the Advancing Earth and Space Science Blogosphere. (2012, August 23). *The Rare 5.8 Virginia Earthquake: One Year Later*. https://blogs.agu.org/geospace/2012/08/23/the-rare-5-8-virginia-earthquake-one-year-later/

> *Knowing the amplification caused by these sediments and the direction of shaking will help emergency managers identify communities that may be more vulnerable to shaking. This knowledge will help the USGS refine its seismic hazard maps, which estimate the strength of ground shaking that can be expected during earthquakes in each area of the country.*
>
> *These insights can also be used by emergency managers when planning for and responding to disasters; state and local governments as they refine building codes; and architects and engineers as they design and renovate buildings to mitigate the effects of future earthquakes. In addition, the science helps inform planning for major infrastructure investments such as dams and reservoirs.*[80]

5.3.1.4. Probability of Future Occurrences

Given Northern Virginia's proximity to the Central Virginia Seismic Zone, it is highly likely that the planning area will experience earthquakes in the future. Based on past historic data that documented 541 events between 1900 and 2021, there is a recurrence interval of 0.235% in any given year. However, historic records also indicate the likely magnitude for most earthquakes is minor (less than 3.0 on the Richter Scale).

Probabilistic ground motion maps are typically used to assess the magnitude and frequency of seismic events. These maps measure the probability of exceeding a certain ground motion, expressed as percent peak ground acceleration (%PGA), over a specified period of years. The severity of earthquakes is site-specific and is influenced by soil type and proximity to the earthquake epicenter, among other factors. The 2,500-year return period, or 0.04%-annual chance of occurrence, is much more varied than the 100-year return period.

Southwest and Central Virginia have an increased likelihood of experiencing a significant earthquake. The PGA zones for the 2,500-year return period were used as the geographic extent parameter for ranking earthquakes. Potential earthquake ground motion that will reach a certain level during an event can be evaluated by examining peak ground acceleration studies. The data show peak horizontal ground acceleration, defined as the fastest measured change in speed, for a particle at ground level that is moving horizontally due to an earthquake, with a 10% and 2% probability, respectively, of exceedance in 50 years.

[80] United States Geological Survey. (2021, August 4).*10-Year Anniversary of US's Most Widely Felt Earthquake*. https://www.usgs.gov/news/10-year-anniversary-us-s-most-widely-felt-earthquake?qt-news_science_products=7#qt-news_science_products.

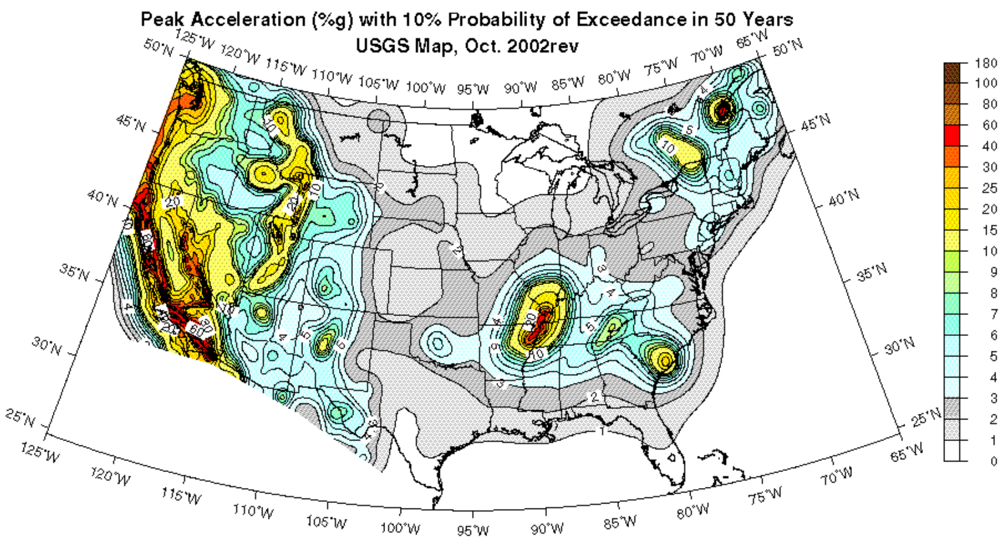

Figure 28: Peak Acceleration with 10% Probability of Exceedance in 50 Years[81]

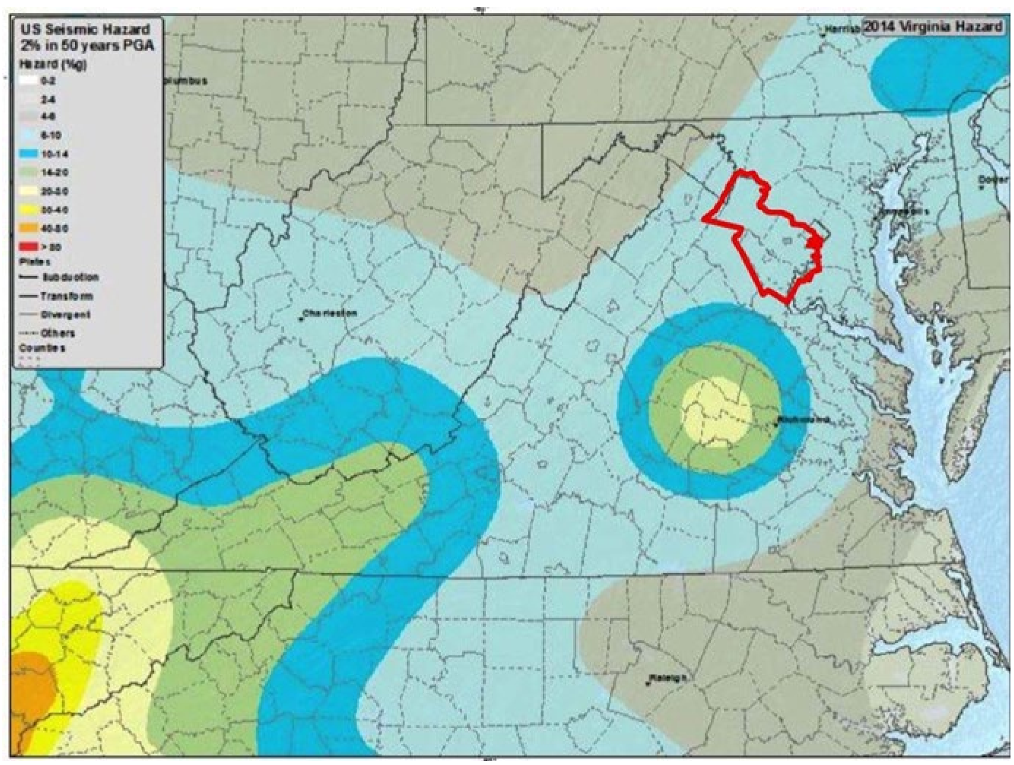

Figure 29: Peak Acceleration with 2% Probability of Exceedance in 50 Years[82]

[81] Matheu, E., Yule, D. & Kala, R. (2005). Determination of Standard Response Spectra and Effective Peak Ground Accelerations for Seismic Design and Evaluation

[82] United States Geological Survey. (2019, December 23). *2014 United States (Lower 48) Seismic Hazard Long-Term Model*. https://www.usgs.gov/programs/earthquake-hazards/science/2014-united-states-lower-48-seismic-hazard-long-term-model#multimedia

5.3.2. Risk Assessment

Like other states on the eastern seaboard, the Commonwealth of Virginia is designated by the USGS as a moderate risk state for earthquake occurrence. Earthquake events can and occasionally do occur, though they are much less intense than those that occur along the west coast of the United States. The greatest seismic risk in Virginia is in the Eastern Tennessee Seismic Zone, located in the southwestern portions of the Commonwealth and far from the Northern Virginia region.

Earthquakes are low-probability, high-consequence events. While they may occur only once in the lifetime of an asset, they may have devastating impacts. A moderate earthquake can seriously damage unreinforced buildings, building contents, and non-structural systems and seriously disrupt building operations. Moderate and even very large earthquakes may occur, however infrequently, in areas of normally low seismic activity. Consequently, local construction is seldom designed to standards required to mitigate potential earthquake impacts. As such, buildings and infrastructure in the Northern Virginia region are particularly vulnerable to higher magnitude earthquakes.

5.3.2.1. Population

Although people residing or working in sub-standard structures may be more at risk than others in an earthquake, the random nature of the location and timing of these events makes it difficult to identify specific vulnerable populations. In general, preparedness messages highlighting appropriate life-safety measures in an earthquake are the most effective method of saving lives.

5.3.2.2. Built Environment and Community Lifelines

Earthquake impacts are mostly felt in the built environment, putting homes, businesses, and Community Lifeline infrastructure at the greatest risk. As the earth shakes, structures not built to withstand specific earth movement can “fracture” and, in extreme events, collapse. As the 5.8 earthquake in August 2011 demonstrated, even masonry structures such as the National Cathedral and Washington Monument were vulnerable to shifting motions. Enhanced building codes can require construction methods and materials to help withstand major earthquakes; however, in areas with a lower probability of this level of event it is considered to be too costly to require building to these standards.

5.3.2.3. Natural Environment

Although major earthquakes can shift the ground and cause changes in topography, it is unlikely that this would occur in Northern Virginia, based on historical information. Minor earthquakes could lead to minor fissures that disrupt the flow of rivers, creeks, or streams; however, this type of occurrence would be extremely rare.

5.3.2.4. Economy

The risk to the Northern Virginia economy from a major earthquake could be high if structures of major employers and government agencies are damaged. This could result in short- or long-term business and office closures, loss of wages, and loss of employment.

5.3.2.5. Hazard Risk Ranking Summary

The hazard ranking process considered probability and consequences in determining an overall risk score and ranking. Information presented within this section and the hazard risk ranking process present the quantitative and qualitative summary for earthquakes. The Hazard Identification and Risk Assessment methodology is described in **Section 4, Base Plan**.

Table 43: Hazard Risk Rankings for Earthquake, by Jurisdiction

Hazard	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
Arlington County	1.3	2.8	4.1	**Low**
City of Alexandria	1.7	3.2	4.9	**High-Medium**
City of Fairfax	1.7	3.2	4.9	**Medium**
City of Falls Church	1.7	3.2	4.9	**Medium**
City of Manassas	2.3	3.2	5.5	**Medium**
City of Manassas Park	2.3	3.2	5.5	**Medium**
Fairfax County	1.7	3.2	4.9	**Medium**
Town of Clifton	1.7	3.2	4.9	**Medium**
Town of Herndon	1.7	3.2	4.9	**Medium**
Town of Vienna	1.7	3.2	4.9	**Medium**
Loudoun County	1.7	3.2	4.9	**Medium**
Town of Leesburg	1.7	3.2	4.9	**Medium**
Town of Lovettsville	1.7	3.2	4.9	**Medium**
Town of Middleburg	1.7	3.2	4.9	**Medium**
Town of Purcellville	1.7	3.2	4.9	**Medium**
Town of Round Hill	1.7	3.2	4.9	**Medium**
Prince William County	2.3	3.7	6.1	**Medium**
Town of Dumfries	2.3	3.2	5.5	**Medium**
Town of Haymarket	2.3	3.2	5.5	**Medium**
Town of Occoquan	2.0	4.7	6.7	**Medium**
Town of Quantico	2.3	3.2	5.5	**Medium**

5.3.3. Vulnerability Analysis

Although the recurrence interval for significant earthquake events in the Northern Virginia region is low, the potential impact of a major seismic event along the Eastern Tennessee or Central Virginia seismic zone could be moderately destructive. The Federal Emergency Management Agency's Hazus Program was used to determine potential impacts on the planning area from an earthquake.

5.3.3.1. Hazus Analysis

The FEMA Hazus Program was utilized to model a 2,500-year return event earthquake scenario for the planning area based on an event in Goochland County, Virginia, approximately 95 miles from the southern boundary of the planning area. This model evaluated the vulnerability related to damage to buildings and infrastructure according to ground shaking data from the USGS ShakeMap website.

Due to the region's overall low seismic risk, most infrastructure and buildings have not been designed to withstand major ground shaking events. Although these incidents may be few and far between, when they do occur, they may generate substantial losses. Hazus was used to update damage and loss estimates for the probabilistic ground motions associated with each of three return periods (scenarios for 100, 500, and 2,500 years). Building damage estimates were used as the basis for computing direct economic losses. Losses include building repair costs, contents and business inventory losses, costs of relocation, capital- and wage-related costs, and rental losses.

All Hazus reports, GIS-maps, and other information generated by the models are included in **Appendix B**.

Hazus-Generated Earthquake Model Reports in Appendix B

- Earthquake 100-year Global Summary Report
- Earthquake 500-year Global Summary Report
- Earthquake 1,000-year Global Summary Report
- Earthquake 2,500-year Global Summary Report
- Earthquake 2,500-year Advanced Engineering Building Model (ABEM) Report
- Earthquake 2,500-year Building Stock Exposure by General Occupancy
- Earthquake 2,500-year Direct Economic Losses for Buildings
- Earthquake 2,500-year Direct Economic Losses for Transportation
- Earthquake 2,500-year Direct Economic Losses for Utilities
- Earthquake 2,500-year Quick Assessment Report: 2:00 a.m.
- Earthquake 2,500-year Quick Assessment Report: 2:00 p.m.
- Earthquake 2,500-year Quick Assessment Report: 5:00 p.m.
- Earthquake 2,500-year Transportation System Dollar Exposure
- Earthquake 2,500-year Utility System Dollar Exposure

Hazus may be used to evaluate a variety of hazards and associated risks to support hazard mitigation. The current scenarios utilized a Level 1 analysis for the earthquake module, meaning the scenarios are based on hazard and inventory data included with the program and do not include additional, locally collected data. This is an acceptable level of information for mitigation planning. A future version of this Plan could be enhanced with Level 2 or 3 analyses, which would include local data and detailed engineering data, respectively.

The estimates of social and economic impacts contained in this report were produced using Hazus loss-estimation methodology software based on current scientific and engineering information. There are uncertainties inherent in any loss-estimation technique. As such, there may be differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. Results may be improved by adding community-based information about local assets to enhance the program inventory, dataset inventory, geotechnical information, and observed ground motion data.

Building stock data includes structural and nonstructural damage to buildings, contents, inventory, and business interruption costs. Utility infrastructure includes damages to facilities and pipelines. Transportation infrastructure accounts for road segments, bridges, tunnels, and facilities.

Data from the Hazus region-wide 2,500-year probabilistic scenario shows the Northern Virginia planning area can expect over $4.1 billion in damage to buildings, transportation, and utility systems from such an event. The scenario modeled a 6.5 magnitude earthquake centered near the same location as the actual 2011 Louisa County earthquake at a depth of approximately 33 feet; this is the same scenario used in the 2017 Plan. This scenario was maintained for assessment continuity.

Table 44: Estimated Direct Economic Losses from Probabilistic 2,500-Year Earthquake Return Interval[83]

Jurisdiction*	Building Losses	Transportation Infrastructure	Utility Infrastructure	Total
Arlington County	$359,916,000	$15,331,000	$5,748,000	$347,551,000
City of Alexandria	$284,828,000	$6,294,000	$5,377,000	$281,238,000
City of Fairfax	$67,670,000	$127,000	$88,000	$63,745,000
City of Falls Church	$28,828,000	$1,000	$35,000	$274,243,000
City of Manassas	$76,980,000	$353,000	$4,332,000	$80,787,000
City of Manassas Park	$20,833,000	$139,000	$28,000	$20,592,000
Fairfax County	$1,929,731,000	$27,003,000	$25,228,000	$1,828,219,000
Loudoun County	$441,720,000	$4,977,000	$30,872,000	$440,526,000
Prince William County	$724,815,000	$10,717,000	$36,923,000	$699,632,000
Totals	**$3,935,168,000**	**$64,941,000**	**$108,632,000**	**$3,935,167,000**

*Town information is included in county totals.

Table 45: Estimated Dollar Exposure of Transportation and Utility Assets from Probabilistic 2,500-Year Return Interval Earthquake[84]

Jurisdiction*	Transportation Exposure	Utilities Exposure	Total
Arlington County	$1,908,225,000	$802,793,000	$3,092,013,000
City of Alexandria	$1,583,341,000	$685,247,000	$2,565,087,000
City of Fairfax	$189,675,000	$9,317,000	$266,877,000
City of Falls Church	$39,809,000	$3,935,000	$72,454,000
City of Manassas	$227,906,000	$319,296,000	$628,867,000
City of Manassas Park	$16,590,000	$319,296,000	$356,886,000
Fairfax County	$8,293,279,000	$2,325,526,000	$12,600,767,000
Loudoun County	$2,411,988,000	$5,018,429,000	$7,907,986,000
Prince William County	$288,081,000	$2,145,060,000	$3,205,596,000
Totals	**$14,958,894,000**	**$11,628,899,000**	**$30,696,533,000**

*Town information is included in county totals.

[83] Hazus, Earthquake 2500-year Direct Economic Losses for Buildings, Transportation and Utilities, August 17, 2021
[84] Hazus Earthquake 2500-year Transportation System Dollar Exposure and Utility System Dollar Exposure, August 3, 2021.

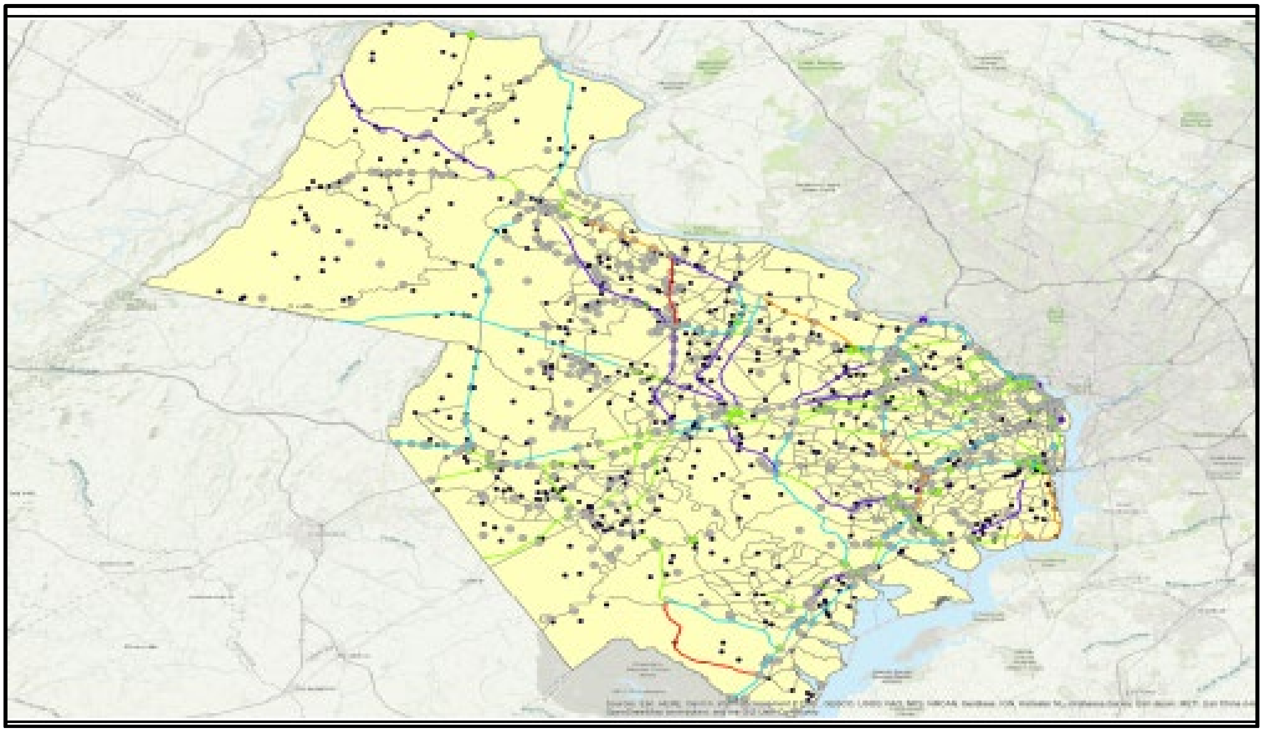

Figure 30: Potential Transportation Lifeline Damage Locations[85]

5.3.3.2. Community Lifelines and Critical Facility Risk

There are 11 hospitals, not including Ft. Belvoir in the region, with a total bed capacity of 2,890 beds. Based on the 2,500-year scenario, 24% would be unavailable, while 76% would be undamaged on the day of the earthquake. These beds would be available for use by both patients already hospitalized and for those injured during the earthquake. After one week, 89% of the beds would be back in service. Thirty days after the event, 98% of beds would be operational.

The Hazus scenario estimates that most essential facilities would maintain functionality of greater than 50% on the day of the earthquake.

[85] Federal Emergency Management Agency (2021, August 3). *Hazus Earthquake 2,500-year Global Risk Report, Earthquake Scenario: NOVA 2,500 Year 6.5 Magnitude*

Table 46: Damages to Essential Facilities from Probabilistic Earthquake Scenario, 2,500-Year Return Interval[86]

Type of Facility	Total	Number of Facilities		
		At Least Moderate Damage (> 50%)	Complete Damage (> 50%)	With Functionality (> 50% on day 1)
Hospitals	19	0	0	19
Schools	846	0	0	846
Emergency Operations Centers	14	0	0	14
Police Stations	46	0	0	46
Fire Stations	110	0	0	110

5.3.3.3. Sheltering Needs

The Hazus earthquake model estimates 2,436 households to be displaced in this scenario. Of a total planning area population of 2,230,623 people, 1,283 people would seek temporary shelter.

5.3.3.4. Debris Generation

For the 2,500-year scenario, Hazus estimates the region would need to pick up a total of 1.21 million tons of brick, wood, concrete, and steel debris after the event. Of that amount, 84% would be brick and wood debris, with the remainder composed of reinforced concrete and steel. Assuming that debris is hauled from disaster sites in trucks with an estimated capacity of 25 tons each, debris cleanup will require 48,520 truckloads to remove the debris generated.

5.3.3.5. Existing Buildings and Infrastructure Risk

There are an estimated 663,000 buildings in the region with an aggregate total building replacement value, excluding contents, of $341.5 billion. Most buildings in the region are used for residential housing. Wood frame construction makes up 70% of the building inventory.[87]

Based on the Hazus scenario, roughly 22,807 buildings would experience moderate damage. Approximately 554 buildings would be damaged beyond repair.

[86] Ibid.
[87] Federal Emergency Management Agency (2021, August 3). *Hazus Earthquake 2,500-year Global Risk Report, Earthquake Scenario: NOVA 2,500 Year 6.5 Magnitude*

Table 47: Expected Building Damage by Occupancy, 2,500-Year Earthquake Scenario, None to Moderate, with Totals[88]

Occupancy Type	None		Slight		Moderate	
	Count	%	Count	%	Count	%
Agriculture	1,311.38	0.23	218.96	0.34	99.32	0.44
Commercial	26,687.93	4.67	4,501.83	6.97	2,523	11.06
Education	1,458.55	0.26	236.71	0.37	134.07	0.59
Government	918.41	0.16	154.48	0.24	93.31	0.41
Industrial	6,280.76	1.1	1,072.40	1.66	663.08	2.91
Other Residential	21,475.78	3.76	2,923.84	4.53	1,481.63	6.50
Religious	2,921.86	0.51	395.14	0.61	202.87	0.89
Single Family	510,550.99	89.32	55,059.17	85.28	17,609.54	77.21
Subtotals	**571,604.00**	**-**	**64,562.53**	**-**	**22,807.00**	**-**

Table 48: Expected Building Damage by Occupancy, 2,500-Year Earthquake Scenario, Extensive to Complete, with Totals[89]

Occupancy Type	Extensive		Complete		Totals
	Count	%	Count	%	Count
Agriculture	18.76	0.45	1.58	0.29	1,650
Commercial	463.93	11.16	50.89	9.19	34,229
Education	21.74	0.52	2.94	0.53	1,854
Government	14.98	0.36	1.82	0.33	1,182
Industrial	116.29	2.8	12.47	2.25	8,144
Other Residential	200.54	4.82	18.21	3.29	26,100
Religious	40.99	0.99	5.14	0.93	3,564
Single Family	3,280.70	78.90	460.6	83.19	586,961
Subtotals	**4,158.00**	**-**	**554**	**-**	**-**

[88] Federal Emergency Management Agency (2021, August 3). *Hazus Earthquake 2,500-year Global Risk Report, Earthquake Scenario: NOVA 2,500 Year 6.5 Magnitude*
[89] Ibid.

Table 49: Building Loss for 2,500-Year Earthquake Scenario, Type of Loss by Jurisdiction[90]

Jurisdiction	Structural	Non-structural	Contents	Inventory	Relocation	Income	Wage	Rental	Total
Arlington County	$62,754,000	$169,182,000	$44,190,000	$356,000	$35,324,000	$12,406,000	$20,934,000	$3,823,000	**$359,916,000**
City of Alexandria	$47,783,000	$130,317,000	$36,433,000	$338,000	$30,639,000	$10,563,000	$13,006,000	$15,750,000	**$284,828,000**
City of Fairfax	$11,447,000	$27,132,000	$8,353,000	$164,000	$6,946,000	$4,360,000	$5,345,000	$3,922,000	**$67,670,000**
City of Falls Church	$5,086,000	$12,268,000	$3,504,000	$52,000	$2,983,000	$1,457,000	$1,779,000	$1,547,000	**$28,674,000**
City of Manassas	$13.203,000	$33,433,000	$10,680,000	$254,000	$8,353,000	$3,018,000	$4,330,000	$3,709,000	**$76,990,000**
City of Manassas Park	$3,859,000	$9,735,000	$2,813,000	$78,000	$2,206,000	$566,000	$674,000	$902,000	**$20,833,000**
Fairfax County *Town of Clifton* *Town of Herndon* *Town of Vienna*	$464,386,000	$911,319,000	$244,752,000	$2,696,000	$190,822,000	$58,883,000	$67,801,000	$89,073.000	**$1,929,731,000**
Loudoun County *Town of Leesburg* *Town of Lovettsville* *Town of Middleburg* *Town of Purcellville* *Town of Round Hill*	$88,082,000	$210,687,000	$53,764,000	$814,000	$46,074,000	$10,578,000	$12,637,000	$19,084,000	**$441,720,000**
Prince William County *Town of Dumfries* *Town of Haymarket* *Town of Occoquan* *Town of Quantico*	$135,663,000	$354,828,000	$100,005,000	$1,164,000	$69,771,000	$16,023.000	$18,932,000	$28,427,000	**$724,815,000**
Totals	**$732,263,000**	**$1,858,900,000**	**$504,494,000**	**$5,916,000**	**$393,119,000**	**$117,853,000**	**$139,274,000**	**$183,349,000**	**$3,935,168,000**

[90] Federal Emergency Management Agency (2021, August 3). *Hazus Earthquake 2,500-year Global Risk Report, Earthquake Scenario: NOVA 2,500 Year 6.5 Magnitude*

The National Oceanic and Atmospheric Administration National Centers for Environmental Information does not monitor earthquake hazard events, so information from this source is not available to calculate annualized loss estimates.

In addition, a qualitative assessment was performed by planning participants. Given the widespread nature of the hazard it was determined that all counties, cities, and towns have the same qualitative risk associated with the hazard.

The geographic extent ranking category used the PGA values for the 2,500-return period. This return period represents a 0.04% annual chance of occurrence in any given year. The Northern Virginia planning region was ranked as being of "moderate" risk of the earthquake hazard. Parameters that did not have recorded events in the NCDC database were given the lowest default score.

5.3.3.6. Potential Impacts of Climate Change

Scientific and governmental organizations continue to research climate change to learn how it can potentially affect the frequency and intensity of natural hazards. To date, USGS has identified only one correlation between the weather and earthquake induction:

> *Large changes in atmospheric pressure caused by major storms like hurricanes have been shown to occasionally trigger what are known as "slow earthquakes," which release energy over comparatively long periods of time and do not result in ground shaking like traditional earthquakes do. While such large low-pressure changes could potentially be a contributor to triggering a damaging earthquake, the numbers are small and are not statistically significant.*[91]

5.3.3.7. Opportunities for Mitigation

Data Collection and Incorporation

In its 2018 Hazard Mitigation Plan, the Commonwealth of Virginia included an action item to develop a more complete database of critical facilities, an enhanced Commonwealth facility database, and an energy-gathering pipeline facility database. The Virginia Department of Emergency Management (VDEM) also discussed the possibility of standardizing the definition of a critical facility for local plan revisions and advising communities on essential assets to be collected for this project, providing a template for future local plans to follow. Such data would enable Hazus users to incorporate more local data into the risk modeling process and more accurately pinpoint structures likely to be affected with an extent identified by a given return period. At present, Hazus runs are conducted using a fixed database that may not include all buildings and critical facilities, especially for fast-growing areas such as Northern Virginia.

Updating Building Codes

Emergency managers and seismologists agree there is no more important factor in reducing a community's risk from an earthquake than the adoption and enforcement of up-to-date building codes. Evaluating older buildings and retrofitting structural and nonstructural components are also critical steps. To survive and remain resilient, communities could also strengthen core infrastructure and critical facilities so that they can withstand an earthquake or other disaster and continue to provide essential services.

[91] Buis, A. (2019, October 29). *Can Climate Affect Earthquakes, Or Are the Connections Shaky?* National Aeronautics and Space Agency Global Climate Change. https://climate.nasa.gov/news/2926/can-climate-affect-earthquakes-or-are-the-connections-shaky/

Professionals in the disaster response and recovery field have been known to say, "earthquakes don't kill people, buildings do."[92] They are referring to the fact that while it is not possible to control seismic occurrences, communities have the ability to adopt and enforce the latest building codes maintained by the International Code Council (ICC), whose codes include the following:

- **International Building Code (IBC), which** applies to almost all types of new buildings.
- **International Residential Code (IRC), which a**pplies to new one- and two-family dwellings and townhouses of not more than three stories in height.
- **International Existing Building Code (IEBC), which a**pplies to the alteration, repair, addition, or change in occupancy of existing structures.

The ICC publishes new editions of the International Codes every three years, and many states and localities have adopted them since the first editions were issued in 2000.

Some provisions within the IBC, IRC, and IEBC are intended to ensure that structures can resist seismic forces during earthquakes. These seismic provisions represent the best available guidance on how structures should be designed and constructed to limit seismic risk. Changes or additions to seismic provisions come from an array of sources, including new research results and documentation of performance in past earthquakes.

Stronger building codes may also lessen the impact of other hazards, such as severe storms, tornadoes, and floods.

National Earthquake Hazards Reduction Program

The National Earthquake Hazards Reduction Program (NEHRP) spearheads federal efforts to reduce the fatalities, injuries, and property losses caused by earthquakes. It was established by Congress in 1977 and directs four federal agencies to coordinate their complementary activities to implement and maintain the program: FEMA, the National Institute of Standards and Technology (NIST); the National Science Foundation (NSF); and the USGS. NEHRP also partners with state and local governments, universities, research centers, professional societies, trade associations, and businesses to mitigate earthquake risks.[93]

NEHRP funding is available to support the seismic mitigation planning components of the local hazard mitigation process. Funding may also be used to promote education and community awareness about seismic hazards, including education about earthquake insurance for high-risk areas.

5.3.3.8. Factors for Consideration in the Next Planning Cycle

Future monitoring, evaluating, and updating of this Plan should consider the following factors related to earthquakes, as well as other information from the Virginia COV-SHMP:

- Since the adoption of the 2022 NOVA HMP, has the region experienced an earthquake or small tremors? Were these centered in the planning region or close enough to be felt within the planning area?
- Has any new scientific research or methodology changed the ability to predict earthquake events or assess risk and vulnerability?
- Has there been any significant change in the population, built environment, natural environment, or economy that could affect the risk or vulnerability to earthquakes?

[92] Federal Emergency Management Agency. (2021, July 1). *Seismic Codes*. https://www.fema.gov/emergency-managers/risk-management/earthquake/seismic-building-codes
[93] National Earthquake Hazards Reduction Program. (2021, January 21). *Background and History*. https://www.nehrp.gov/index.htm

- Is there any new evidence related to the impacts of climate change that could affect the level of risk or vulnerability to earthquakes?
- Has the Virginia Tech Seismological Laboratory, the Commonwealth's center of earthquake science, released new findings or updates about earthquakes within Virginia boundaries or in adjacent states?

5.4. Extreme Temperatures

2022 HMP Update

The extreme temperature hazard was reexamined, and a new analysis was performed that included but was not limited to the following:

- Reformatting the hazard section to improve flow and clarity
- Refreshing the hazard profile with updated data, maps, and imagery where available
- Updating the assessment of risk and vulnerability by jurisdiction based on new data
- Ranking the hazard by jurisdiction using the methodology described in detail in Section 4

Extreme heat and drought are often interrelated hazards; however, they can and do occur independently of each other. The 2010 Plan update consolidated their analysis into one section; however, the 2017 Plan update treated them as separate hazards, an approach that is continued in this 2022 update. Extreme Cold and Winter Weather are also often interrelated hazards but can occur independently and are addressed as separate hazards in this update.

Table 50: Extreme Temperatures Profile

<table>
<tr><th colspan="5">Extreme Temperatures</th><th>Overall Vulnerability</th></tr>
<tr><th colspan="5">Definition, Key Terms, and Overview</th><td rowspan="6">Medium</td></tr>
<tr><td colspan="5">Extreme heat: Temperatures that hover 10 degrees Fahrenheit (°F) or more above the average high temperature for the region and last for several weeks.

Extreme cold: The definition of extreme cold varies in different parts of the country; however, temperatures at or below 0°F for an extended period are usually defined as extreme cold in the Northern Virginia region. Extreme cold events are usually part of winter storms but can occur at any time of the year.</td></tr>
<tr><th>Frequency</th><th>Probability</th><th colspan="3">Potential Magnitude</th></tr>
<tr><td rowspan="2">Low</td><td rowspan="2">Moderate</td><th>Injuries/Deaths</th><th>Infrastructure</th><th>Environment</th></tr>
<tr><td>Low</td><td>Low</td><td>Low</td></tr>
</table>

5.4.1. Hazard Profile

Temperature extremes can result from heat waves, unseasonably cold weather, and winter storms. Other natural hazards such as floods and severe storms occur more frequently in the Northern Virginia region and serve to overshadow extreme temperature when considering hazard mitigation planning; however, the effects of extreme temperatures, especially on the population, can be devastating.

5.4.1.1. Extreme Heat

Atmospheric variables can affect the impacts of extreme heat. Humid conditions exacerbate human discomfort with high temperatures and can increase the adverse effects of prolonged exposure to extreme heat. Heat-related illnesses like heat exhaustion or heat stroke happen when the body is not able to cool itself. While the body normally cools itself by sweating, during extreme heat, this might be insufficient. In these cases, a person's body temperature rises faster than it can cool itself, which can cause damage to the brain and other vital organs.

Additionally, extended periods of hot weather in combination with lack of rainfall and dry conditions can lead to drought and resulting impacts to crops and livestock, and indirectly, to the economy.

Heat is one of the leading weather-related killers in the United States, despite the ability to prevent or reduce the risk of heat exhaustion and heat stroke through outreach and intervention.[94]

The relationship between heat and humidity is best explained through the Heat Index chart, developed by the National Weather Service (NWS) as a means of portraying how the combined threat of heat and humidity impacts people. Humid conditions can make it seem hotter than it actually is.[95]

5.4.1.2. Extreme Cold

What is considered an excessively cold temperature varies according to the normal climate for the region. Whenever temperatures drop decidedly below normal and wind speed increases, heat leaves the human body more rapidly, increasing the possibility of negative effects of these extreme cold temperatures.

Wind chill can multiply the impacts of extremely cold temperatures, especially to people. Wind chill describes the rate of heat loss on the human body resulting from the combined effect of low temperature and wind. As winds increase, heat is carried away from the body at a faster rate, driving down the skin temperature and eventually the internal body temperature.

Every winter, extremely cold arctic air joining together with brisk winds leads to dangerously cold wind-chill values. People exposed to extreme cold are susceptible to frostbite in a matter of minutes. Areas most prone to frostbite are uncovered skin and the extremities, such as hands and feet. Hypothermia is another threat during extreme cold, occurring when the body loses heat faster than it can generate heat. Cold weather can also affect crops, especially in late spring or early fall, when cold air outbreaks can damage or kill produce, as well as residential plants and flowers. A freeze occurs when the temperature drops below 32°F. Freezes and their effects are significant during the growing season, as plant species have different tolerances to cold temperatures.

Table 51: Hazard Profile Summary

Extreme Temperature **Assessment: Medium Risk Hazard**	**Location**	Jurisdiction-wide	**Potential Cascading Effects**
	Extent	Low to moderate	• Public health impacts, especially to medically vulnerable populations • Crop loss • Economic loss
	Duration	Hours to days	
	Probability	Moderately low	

[94] United States Environmental Protection Agency. (March 2016). *Excessive Heat Events Guidebook*. https://www.epa.gov/heatislands/excessive-heat-events-guidebook
[95] National Weather Service. (n.d.) *What is the Heat Index?* https://www.weather.gov/ama/heatindex

	Seasonal Pattern	Related to seasonal weather patterns Extreme heat may coincide with drought periods and extreme cold may be exacerbated by wind.	
	Speed of Onset	Moderate to fast	
	Warning Time	Hours to days	
	Repetitive Loss	N/A	

5.4.1.3. Location

Extreme temperature is not a hazard with a defined geographic boundary. All jurisdictions within the Northern Virginia planning area are susceptible to the effects of extreme heat and extreme cold. Higher elevations away from coastal areas tend to be a few degrees cooler, on average, than lower elevations.

5.4.1.4. Extent

One of the highest temperatures on record in the planning area was 105°F, recorded on August 17, 1997, at Ronald Reagan Washington National Airport in Arlington County. On average, the warmest temperatures in the region occur in July and the coldest occur in January.

Extreme Heat

The NWS issues a range of watches and warnings associated with extreme heat:[96]

- **Excessive Heat Outlook–Be Aware!** The potential exists for an excessive heat event in the next three to seven days. An outlook is used to provide information to those who need considerable lead time to prepare for the event, such as public utilities, emergency management, and public health officials.
- **Excessive Heat Watch–Be Prepared!** Conditions are favorable for an excessive heat event in the next 24 to 72 hours. A watch is used when the risk of a heat wave has increased, but its occurrence and timing is still uncertain. It is intended to provide enough lead time so those who need to set preparation plans in motion can do so, such as established local excessive heat event plans.
- **Excessive Heat Warning–Take Action!** Issued within 12 hours of the onset of extremely dangerous heat conditions. The warning is used when the maximum heat index temperature is expected to be 105°F or higher for at least two days and nighttime air temperatures will not drop below 75°F; however, the criteria vary across the country, especially for areas not used to extreme heat conditions that could lead to serious illness or death.
- **Heat Advisory–Take Action!** Issued within 12 hours of the onset of extremely dangerous heat conditions when the maximum heat index temperature is expected to be 100°F or higher for at least two days and nighttime air temperatures will not drop below 75°F; however, the criteria vary across the country, especially for areas that are not used to dangerous heat conditions that could lead to serious illness or death.

[96] National Weather Service. (n.d.). Heat Watch vs. Warning. https://www.weather.gov/safety/heat-ww

Extreme heat can be measured with the Heat Index (HI) chart, developed by the NWS. The HI is sometimes referred to as the "apparent temperature." The HI, given in degrees Fahrenheit, is a measure of how hot it truly feels when relative humidity (RH) is added to the actual air temperature.

To find the HI, the NWS calculates the apparent temperature. For example, if the air temperature is 96°F and the RH is 65%, the HI—or how hot it actually feels—is 121°F. Since HI values were devised for shady, light wind conditions, exposure to full sunshine can increase HI values by up to 15°F. Also, strong winds, particularly with very hot, dry air, can be extremely hazardous. This corresponds to a level of HI that may cause increasingly severe heat disorders with continued exposure and/or physical activity.

Relative Humidity (%)

Air Temperature

°F	40	45	50	55	60	65	70	75	80	85	90	95	100
110	136												
108	130	137											
106	124	130	137										
104	119	124	131	137									
102	114	119	124	130	137								
100	109	114	118	124	129	136							
98	105	109	113	117	123	128	134						
96	101	104	108	112	116	121	126	132					
94	97	100	103	106	110	114	119	124	129	135			
92	94	96	99	101	105	108	112	116	121	126	131		
90	91	93	95	97	100	103	106	109	113	117	122	127	132
88	88	89	91	93	95	98	100	103	106	110	113	117	121
86	85	87	88	89	91	93	95	97	100	102	105	108	112
84	83	84	85	86	88	89	90	92	94	96	98	100	103
82	81	82	83	84	84	85	86	88	89	90	91	93	95
80	80	80	81	81	82	82	83	84	84	85	86	86	87

With Prolonged Exposure and/or Physical Activity

With Prolonged Exposure and/or Physical Activity
Extreme Danger
Heat stroke or sunstroke highly likely
Danger
Sunstroke, muscle cramps, and/or heat exhaustion likely
Extreme Caution
Sunstroke, muscle cramps, and/or heat exhaustion possible
Caution
Fatigue possible

Figure 31: Heat Index and Relative Humidity, Effects on People[97]

Extreme Cold

Extremes of cold temperature have reached below 0°F F. Combined with wind chill, the temperature has reached as low as -10°F in higher elevations of the planning area.

The NWS issues a range of watches and warnings associated with extreme cold, including notices about wind chill, freezes, and frost:[98]

- **Wind Chill Warning–Take Action!** Issued when dangerously cold wind chill values are expected or occurring. Those in an area with a wind chill warning should avoid going outside during the coldest parts of the day. If those in the area do have to go outside, they should dress in layers, cover exposed skin, and make sure at least one other person knows their whereabouts.

[97] National Weather Service. (n.d.). *National Weather Service New York, NY Excessive Heat Page*. https://www.weather.gov/okx/excessiveheat

[98] National Weather Service. (n.d.). Wind Chill Warning vs. Watch. https://www.weather.gov/safety/cold-wind-chill-warning

- **Wind Chill Watch–Be Prepared!** Issued when dangerously cold wind chill values are possible. As with a wind chill warning, those in the area should adjust their plans to avoid being outside during the coldest parts of the day. Those travelling in the watch area should make sure their cars have at least a half a tank of gas and an updated winter survival kit.
- **Wind Chill Advisory–Be Aware!** Issued when seasonably cold wind chill values, but not extremely cold values, are expected or occurring. Those in an area under this type of advisory should dress appropriately and cover exposed skin when venturing outdoors.

- **Hard Freeze Warning–Take Action!** Issued when temperatures are expected to drop below 28°F for an extended period, killing most types of commercial crops and residential plants.
- **Freeze Warning–Take Action!** Issued when temperatures are expected to go below 32°F for a long period of time. This temperature threshold kills some types of commercial crops and residential plants.
- **Freeze Watch–Be Prepared!** Issued when there is a potential for significant, widespread freezing temperatures within the next 24-36 hours. A freeze watch is issued in the autumn until the end of the growing season and in the spring at the start of the growing season.
- **Frost Advisory– Be Aware!** Issued when areas of frost are expected or occurring, posing a threat to sensitive vegetation.

Extreme cold can be measured using the Wind Chill Temperature (WCT) index chart, developed by the NWS. The WCT calculates the dangers from winter winds and freezing temperatures. The index does the following:

- Calculates wind speed at an average height of 5 feet, the typical height of an adult human face, based on readings from the national standard height of 33 feet, which is the typical height of an anemometer.
- Is based on a human face model.
- Incorporates heat transfer theory based on heat loss from the body to its surroundings during cold and breezy or windy days.
- Lowers the calm wind threshold to 3 miles per hour (MPH).
- Uses a consistent standard for skin tissue resistance.
- Assumes no impact from the sun, i.e., clear night sky.

Based on the WCT, at a temperature of 0°F, even a light wind of 5 MPH can create a wind chill of -11°F and cause frostbite within 30 minutes.

Wind Chill Chart

Temperature (°F)

Wind (mph) / Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T=Air Temperature (°F) V=Wind Speed (mph)

Effective 11/01/01

Figure 32: Wind Chill Chart[99]

5.4.1.5. Previous Occurrences

The NOAA, National Centers for Environmental Information (NCEI) Storm Events Database tracks reports of "excessive heat," "cold/wind chill," and "extreme cold/wind chill." Based on the records from January 1950 through June 2021, a total of 33 excessive heat events were reported for the planning area, affecting six county zones with a reported total of 13 days of excessive heat events. There was one heat-related death in the City of Alexandria and no injuries reported. No property or crop damages were associated with these events.

[99] National Weather Service. (n.d.). *Wind Chill Chart*. https://www.weather.gov/safety/cold-wind-chill-chart

Table 52: Excessive Heat Events and Impacts, 1950-2021[100]

Date	Impacts
May 18, 1996	• Four-day heat wave • 100 cases of schoolchildren with heat exhaustion during an air show in Manassas Regional Airport in the City of Manassas • Three cases of heat exhaustion in the City of Alexandria • Many schools were closed • Forced power “brownout” to cut energy consumption
July 13, 1997	• Seven days of temperatures in the middle or upper 90°F • Intense media coverage may have saved lives, as there were no direct heat-related deaths in Virginia
August 16, 1997 Record Highs: Summer Months	• Record high temperatures over 100°F with heat index values from 105 to 110°F for two days • No heat-related deaths
January 6, 1998 Record Highs: Winter Months	• An unencumbered flow of tropical air from the Caribbean impacted the state for 2.5 days • New record highs, with temperatures remaining above 60°F • Mean temperatures between 15°F and 20°F above normal

During the same period, a total of 39 cold or extreme cold events were reported, affecting all county zones, including the independent cities, with a total of 13 days of cold or extreme cold. There was one hypothermia-related death in the City of Fairfax and one injury reported. Minimal crop and no property damage were associated with these events.

[100] National Oceanic and Atmospheric Administration (2021). *National Center for Environmental Information Storm Events Database,* 1950-June 30, 2021 [Data set]. https://www.ncdc.noaa.gov/stormevents/

Table 53: Excessive Cold/Wind Chill Events and Impacts, 1950-2021[101]

Date(s)	Impacts
March 11–13, 1998	• The second arctic air mass of the winter of 1997/1998 caused an estimated $25,000 damage to fruit crops in northern Virginia due to accelerated bud growth brought on by the previously mild and moist conditions earlier in the winter. These conditions may have also decreased the resistance of fruit trees to the hard freeze. • The coldest morning, March 13, produced several record low temperatures, including at Washington Dulles International Airport, which had a low of 16°F, breaking a previous record of 18 set in 1984.
January 22, 2000	• The morning of January 22, temperatures dropped into the single digits above and below zero. Lows included 7°F at Dulles International Airport located in Fairfax and Loudoun counties. Reagan National Airport in Arlington County dropped only to 14°F because its metropolitan location tends maintain higher temperatures.
January 5, 2018	• Arctic air and gusty winds caused wind chills to drop between -5°F and -15°F.
January 21, 2019	• The combination of cold temperatures and strong winds produced wind chills as low as -10°F.

5.4.1.6. Probability of Future Events

Based on historical data from the NCEI Storm Events Database, the return interval for extreme heat events is 0.46% in any given year. Using the same formula, the return interval for extreme cold events is 0.55% in any given year, indicating that extreme cold is slightly more likely to occur than extreme heat.

5.4.2. Risk Assessment

The greatest danger from extreme temperatures is to people, as prolonged exposure can impact both healthy individuals and those with pre-existing medical conditions.

Health-related illnesses include heat stroke, heat exhaustion, heat cramps, sunburn, and heat rash. Although all these illnesses can cause problems, the two most deadly are heat stroke and heat exhaustion.

Older adults, the very young, and people with mental illness and chronic diseases are at highest risk from extreme heat. High heat indexes can exacerbate pre-existing health and medical conditions, and some medications may make the body more susceptible to impacts from extreme heat.

However, even young, healthy people can be affected if they participate in strenuous physical activities during hot weather. Summertime activity, whether on the playing field or the construction site, must be balanced with actions that help the body cool itself to prevent heat-related illness such as heat exhaustion and heat stroke.

[101] Ibid.

Extreme heat conditions can increase the incidence of mortality and morbidity in affected populations. People can suffer heat-related illnesses when the body is unable to compensate for the extreme heat and properly cool itself. Very high body temperatures can cause damage to the brain and other vital organs.

Extreme cold can cause frostbite or hypothermia and quickly become life threatening. People who have poor blood circulation, drink alcohol or use illicit drugs, remain outdoors for long periods of time, or are not properly dressed for extreme cold temperatures may have a greater chance of developing frostbite or hypothermia.

Body temperatures that are too low affect the brain, making it difficult to think clearly or move well. This makes hypothermia particularly dangerous to those with the condition, as they may not understand what is happening or know what to do about it.

Additionally, when extreme cold occurs simultaneously with precipitation events such as a snow or ice storms, accidents that can cause injury or death may occur, such as slip and fall accidents, overexertion accidents related to shoveling snow or clearing ice, and motor vehicle accidents.

5.4.2.1. Who Is Most at Risk?

Heat and cold stress are environmental hazards. Because of their unique physiology, children are more susceptible to temperature extremes and their health effects. Children are less able to regulate their body temperature compared with adults. As a result, children are more likely to develop significant health effects when they are exposed to environmental temperature extremes.

5.4.2.2. Built Environment, Community Lifelines, and Assets

Since 1950, the region has experienced multiple events of extreme temperature; however, no property damage related to this hazard has been documented. Based on the lack of previous impacts, risk and vulnerability associated with this hazard have not been quantified for this Plan update.

5.4.2.3. Natural Environment and Economy

Since 1950, the region has experienced multiple events of extreme temperature; however, only minimal impacts to the economy and the natural environment, including an estimated $25,000 damage to fruit trees, have been documented. Based on the lack of previous impacts, risk and vulnerability associated with this hazard have not been quantified for this Plan update.

5.4.2.4. Hazard Risk Ranking Summary

The hazard ranking process considered probability and consequences in determining an overall risk score and ranking. Information presented within this section and the hazard risk ranking process present the quantitative and qualitative summary for extreme temperatures. The hazard identification and risk assessment methodology are described in **Section 4, Base Plan**.

Table 54: Hazard Risk Rankings for Extreme Temperature, by Jurisdiction

Hazard	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
Arlington County	2.3	2.9	5.2	**Medium**
City of Alexandria	2.7	2.5	5.2	**Medium**
City of Fairfax	2.7	2.5	5.2	**Medium**

Hazard	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
City of Falls Church	2.7	2.5	5.2	**Medium**
City of Manassas	3.0	2.5	5.5	**Medium**
City of Manassas Park	3.0	2.5	5.5	**Medium**
Fairfax County	2.7	2.5	5.2	**Medium**
Town of Clifton	2.7	2.5	5.2	**Medium**
Town of Herndon	2.7	2.5	5.2	**Medium**
Town of Vienna	2.7	2.5	5.2	**Medium**
Loudoun County	2.3	2.7	5.0	**Medium**
Town of Leesburg	2.3	2.7	5.0	**Medium**
Town of Lovettsville	2.3	2.7	5.0	**Medium**
Town of Middleburg	2.3	2.7	5.0	**Medium**
Town of Purcellville	2.3	2.7	5.0	**Medium**
Town of Round Hill	2.3	2.7	5.0	**Medium**
Prince William County	3.0	2.5	5.5	**Medium**
Town of Dumfries	3.0	2.5	5.5	**Medium**
Town of Haymarket	3.0	2.5	5.5	**Medium**
Town of Occoquan	4.0	2.4	6.4	**Medium**
Town of Quantico	3.0	2.5	5.5	**Medium**

Based on previous occurrences and minimal impacts, this hazard is ranked as a low risk and provides justification for a minimal hazard profile. Consequently, **a vulnerability assessment will not be conducted**.

5.4.2.5. Future Population and Development Trends

Future development and the resulting population increase has a minimal potential to elevate vulnerabilities to extreme temperature; however, depending on climate change variables, an increase in vulnerability related to public health and safety is possible.

5.4.2.6. Factors for Consideration in the Next Planning Cycle

Future monitoring, evaluating, and updating of this Plan should consider the following factors related to extreme temperature, as well as other information from the next Virginia COV-SHMP:

- Have extreme temperature events occurred within the planning area since adoption of the 2022 HMP?
- Did extreme temperature events take place in areas adjacent to the planning area that impacted the planning area by virtue of being in proximity?
- Has new scientific research or methodology, potentially related to climate change, improved the ability to predict extreme temperature events or assess risk and vulnerability?
- Has there been significant change in the population, built environment, natural environment, or economy that could affect the risk or vulnerability to extreme temperature, including land use for agricultural purposes?

5.5. Flood/Flash Flood (Including Erosion)

2022 HMP Update

The Flood/Flash Flood hazard was reexamined, and a new analysis was performed, which included, but was not limited to the following:

- Reformatted the hazard section to improve clarity and flow
- Refreshed the hazard profile with updated data, maps, and imagery, where available
- Updated the assessment of risk and vulnerability by jurisdiction based on new data
- Reviewed and re-evaluated of the hazard ranking by jurisdiction using the methodology described in detail in Section 4, Base Plan

Table 55: Flood/Flash Flood Profile

<table>
<tr><th colspan="5">Flood/Flash Flood</th><th>Overall Vulnerability</th></tr>
<tr><th colspan="5">Definition, Key Terms, and Overview</th><td rowspan="6">High</td></tr>
<tr><td colspan="5">Flood: an overflow of water onto normally dry land; the inundation of a normally dry area caused by rising water in an existing waterway (e.g., a river, stream, or drainage ditch); ponding of water at or near the point where the rain fell. Flooding may last days or weeks and is a longer-term event than flash flooding.

Flash Flood: A flood caused by heavy or excessive rainfall in a short period of time, generally less than six hours. Events are usually characterized by raging torrents after heavy rains that run through riverbeds, urban streets, or mountain canyons sweeping up everything before them. They can occur within minutes or hours of excessive rainfall, or even in cases of zero rainfall, such as after a levee or dam has failed, or after a sudden release of water by a debris or ice jam.</td></tr>
<tr><th>Frequency</th><th>Probability</th><th colspan="3">Potential Magnitude</th></tr>
<tr><td rowspan="2">Moderate</td><td rowspan="2">High</td><th>Injuries/Deaths</th><th>Infrastructure</th><th>Environment</th></tr>
<tr><td>Minimal</td><td>High</td><td>Moderate</td></tr>
</table>

5.5.1. Hazard Profile

Flooding is the most common and costly natural hazard in the United States; a hazard that impacted 99 percent of the counties in the United States in 1996, causing thousands of fatalities.[102] Nearly 90% of presidential disaster declarations result from natural events where flooding was a major contributor. As of November 2021, the National Weather Service Report, *Preliminary U.S. Flood Fatality Statistics*, shows that there have been 144 fatalities to date in 2021, with one occurring in Virginia.[103]

[102] Federal Emergency Management Agency (FEMA), Historical Flood Risk and Costs. Retrieved at: https://www.fema.gov/data-visualization/historical-flood-risk-and-costs
[103] National Weather Service, Preliminary US Fatality Statistics, https://www.weather.gov/arx/usflood. Accessed on: November 12, 2021.

Within the region of Northern Virginia, there have been more than 976 flood or flood-related events since 1950 that included five deaths, 27 people injured, and more than $59 million in property damage. Floods also caused more than $300,000 in crop damage.[104]

Regardless of the circumstances leading to a flood or flash flood event, occurrences resulting from excessive precipitation may be classified into one of two types:

- **General floods:** precipitation over a given river basin for a long period of time. A flood event may last for several days. The primary types of flooding include riverine, coastal, and urban. Riverine flooding is a function of excessive precipitation levels and water runoff volumes within the watershed of a stream or river. Coastal flooding is typically a result of storm surge, wind-driven waves, and heavy rainfall produced by hurricanes, tropical storms, nor'easters, and other large coastal storms. Urban flooding occurs where man-made development has obstructed the natural flow of water and decreased the ability of natural groundcover to absorb and retain surface water runoff.
- **Flash flood:** the product of heavy, localized precipitation in a short period of time across a given location. Most flash flooding is caused by slow-moving thunderstorms in a local area or by heavy rains associated with hurricanes and tropical storms. Flash flood events may also occur from a dam or levee failure within minutes or hours after heavy amounts of rainfall affect the region, or from a sudden release of water held by an ice jam. Although flash flooding occurs often along mountain streams, it also occurs frequently in urbanized areas where much of the ground is covered by impervious surfaces. Flash flood waters move at very high speeds– "walls" of water can reach heights up to 10 to 20 feet. Flash flood waters and the accompanying debris can uproot trees, roll boulders, and damage or destroy buildings, bridges, and roads.

The severity of a flooding event is determined by the following:

- A combination of stream and river basin topography and physiography
- Precipitation and weather patterns
- Recent soil moisture conditions
- The degree of vegetative clearing

5.5.1.1. Erosion

Erosion is the gradual breakdown and movement of land due to both physical and chemical processes of water, wind, and general meteorological conditions. Natural (geologic) erosion has occurred since the Earth's formation and continues at a slow and uniform rate each year.

The two general causes of soil erosion—wind and water—can both cause significant soil loss. Winds blowing across sparsely vegetated or disturbed land can pick up soil particles and transport them to other locations. Water flowing over land also transports soil particles to other locations. Wind erosion generally impacts wider and lesser-defined areas than water erosion, but water erosion can transport larger particles than wind. Major storms, such as hurricanes, may cause significant erosion by combining the impacts of high winds and high velocity water flow over large flood areas, including storm surges that significantly impact the shoreline.

Wind erosion is not a significant hazard in the planning area and will not be further addressed in this section.

The main causes of water erosion are stream or overland flow and wave action. **Stream or overland flow erosion** results from mechanical or chemical removal, and transportation of soil particles to a new location. Mechanical erosion is caused by hydrodynamic forces pushing particles down-gradient,

[104] NOAA, National Centers for Environmental Information, Storm Events Database, January 1, 1950–June 30, 2021.

hydraulic drag forces pulling particles down-gradient, and/or hydraulic uplift. Susceptibility of an area to stream or overland flow erosion is a function of soil characteristics, vegetative cover, water quality, topography, and climate. Soils weathered from calcareous carbonate rock (i.e., limestone and dolomite), are more susceptible to chemical erosion by dissolution than other soils. Vegetative cover can be very helpful in controlling erosion by shielding the soil surface from direct water contact and reinforcing the soil, with the foliage serving as an energy dissipater and the root mat reinforcing the near surface soils.

Wave action occurs within waterways that are navigable or wide enough in area to allow wind-driven waves to impact a shoreline. Within the Northern Virginia region, the Potomac River is the primary body of water that could enable wave action to cause erosion.

Water quality impacts both chemical and mechanical erosion; water with a relatively high concentration of carbon dioxide, oxygen, and organic acids accelerates dissolving minerals from calcareous carbonate soils. Sand and gravel that are transported during periods of high velocity flow increase mechanical erosion through abrasion of the flow bed.

Topography of the area, including size, shape, and slope, is a key variable in determining water flow velocity, which in turn is a key variable in the magnitude of the hydraulic forces producing erosion. The greater the slope length and gradient, the more potential an area has for erosion. Climate can also affect the amount of runoff, especially the frequency, intensity, and duration of rainfall and storms. When rainstorms are frequent, intense, or are long in duration, erosion risks are high. Seasonal changes in temperature and rainfall amounts define the period of highest erosion risk for the year.

During the mid to late 1960s, the importance of erosion control garnered increased public interest in the United States. Implementation of erosion control measures consistent with sound agricultural and construction operations was needed to minimize the adverse effects associated with increasing settling of soil particles due to water or wind. The increase in governmental regulatory programs and public concern has resulted in a wide range of erosion control products, techniques, and analytical methodologies in the United States. The preferred method of erosion control in recent years has been the restoration of vegetation. These measures are addressed in the Northern Virginia region through local sedimentation and erosion control programs.

Table 56: Hazard Profile Summary

<table>
<tr><td rowspan="8">Flood/Flash Flood

Assessment: High Risk Hazard</td><td>Location</td><td>Jurisdiction-wide</td><td>Potential Cascading Effects</td></tr>
<tr><td>Extent</td><td>Moderate to significant</td><td rowspan="7">• Traffic/roadway damage/closures
• Resident/visitor/responder safety
• Loss of deliverable services
• Major redirect of response operations/equipment
• Loss of revenue
• Property and infrastructure damage</td></tr>
<tr><td>Duration</td><td>Several hours to weeks or days</td></tr>
<tr><td>Probability</td><td>Moderate</td></tr>
<tr><td>Seasonal Pattern</td><td>More likely in late spring with snow melt, or summer with excessive rainfall events</td></tr>
<tr><td>Speed of Onset</td><td>Slow to Rapid</td></tr>
<tr><td>Warning Time</td><td>Minutes to hours</td></tr>
<tr><td>Repetitive Loss</td><td>Moderate</td></tr>
</table>

5.5.1.2. Location

There are numerous rivers and streams flowing through the Northern Virginia region. When heavy or prolonged rainfall events occur, these rivers and streams are, to some degree, susceptible to flooding. The most notable of these bodies of water is the Potomac River, which, in the past, has been the source of significant storm surge and tidal flooding–particularly in waterfront communities such as Arlington and Alexandria.

The entire Northern Virginia region falls within the Potomac River Basin, which serves as the border between Maryland and Virginia and flows in a southeasterly direction into the Chesapeake Bay. The topography of the upper region of the basin is characterized by gently sloping hills and valleys.

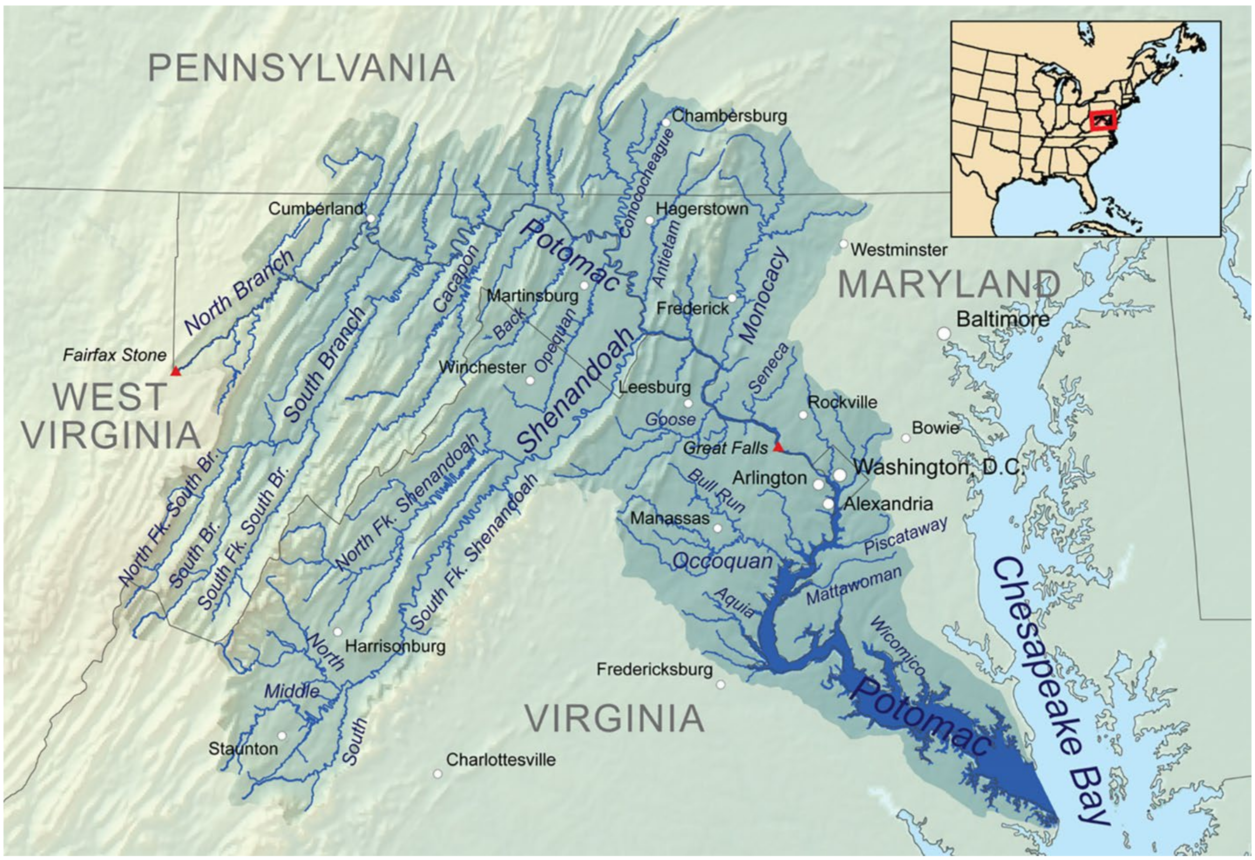

Figure 33. The Potomac River Watershed[105]

In Great Falls, Maryland, the Potomac River begins a more rapid descent to sea level by dropping 76 feet in less than one mile through a deep gorge. Eastward of Great Falls, the Potomac flows between Washington, DC; Arlington; and Alexandria. Here, the river broadens and is flanked by low marshes in many places along the eastern side of Prince William County, where tides further influence the river. The Potomac then flows through the coastal plain and eventually expands to more than 11 miles wide as it reaches the Chesapeake Bay.

While some of the most dramatic flooding events in Northern Virginia are associated with the tidal flooding of the Potomac River during hurricanes or tropical storms, other more frequent inland flood hazards exist throughout the region. Too much rainfall or snowmelt in too little time causes serious flooding problems along even the smallest of tributaries or storm drainage systems. The low-lying areas most prone to this type of flooding are known as floodplains or Special Flood Hazard Areas (SFHAs).

[105] American Rivers. Retrieved at: https://www.americanrivers.org/

These locations, which are more commonly referred to as the “100-year floodplain” (areas with a 1%-annual-chance of flooding), are routinely surveyed and mapped by FEMA as part of a Flood Insurance Study (FIS) sponsored by the National Flood Insurance Program (NFIP). These studies and associated maps are then provided to local communities in order to regulate the development of land within these hazard areas. Jurisdiction-specific flood maps that show the FEMA floodplain relative to regional boundaries and assets are included in the jurisdiction annexes.

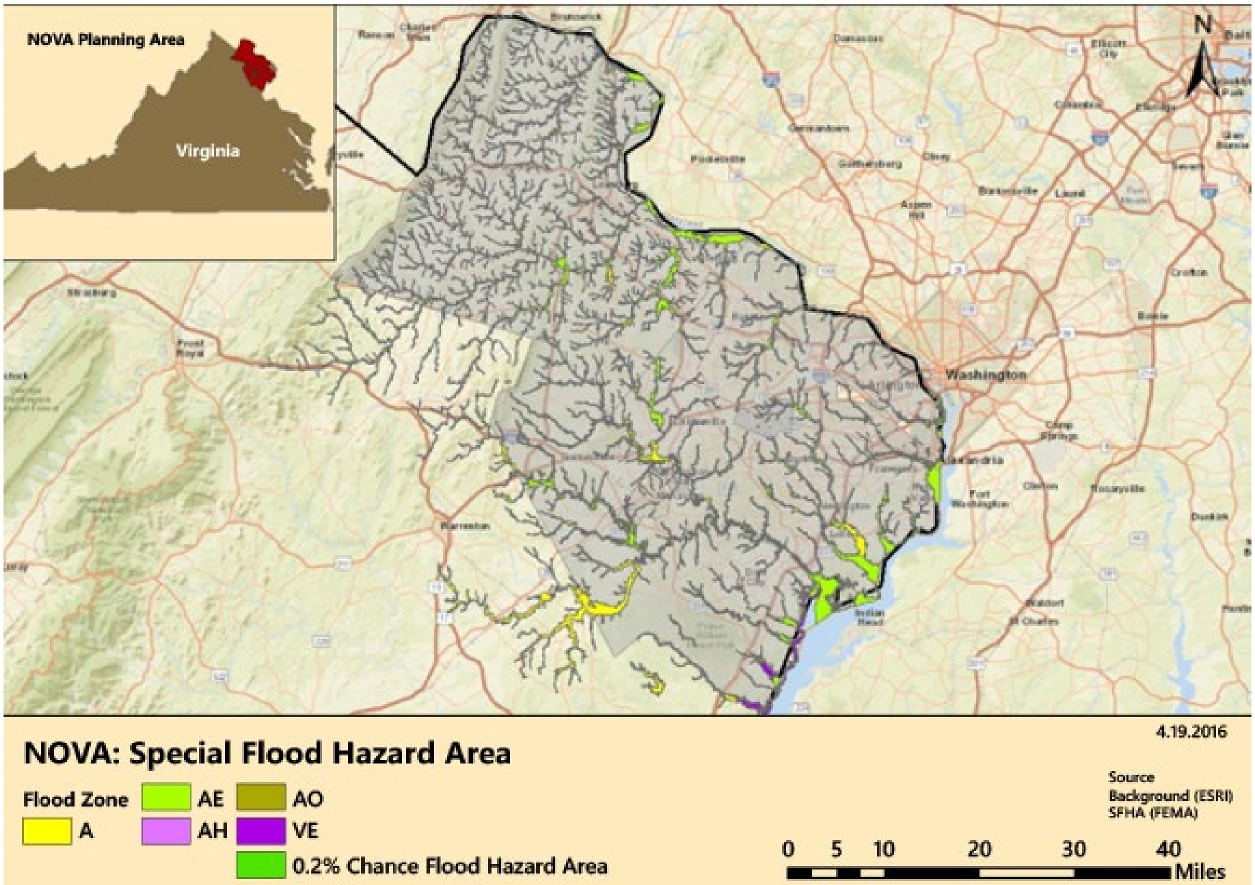

Figure 34: FEMA Special Flood Hazard Area (SFHA) Map of the Northern Virginia Region[106]

Flash flooding can occur quickly outside of identified flood-hazard areas and is frequently related to stormwater systems blocked with debris, or excessive rainfall events that exceed the capacity of these systems. Back-up from these systems can close and damage infrastructure such as roads and culverts, as well as personal property. Sloped streets and other areas that act as drainage channels during heavy rainfall are highly susceptible to flash flooding. In these locations, stormwater run-off may exceed the design capacity of the drainage systems, leading to increased water depth and velocity. Overland flow erodes ravines, accelerates head-cutting, and steepens side slopes. Steep hillsides that have been cut to accommodate roads are especially susceptible to these conditions and may lead to extensive erosion.

While local erosion hazard areas are not identified, the areas of greatest concern are typically those areas consisting of steep slopes and fast-running stream channels, as well as large construction sites involved in the excavation and disturbance of their natural state. Erosion events are often extremely localized in nature and often go unreported unless they damage infrastructure, or the resulting topography presents a new hazard.

[106] National Flood Hazard Layer data. Retrieved at: https://www.fema.gov/flood-maps/national-flood-hazard-layer

Arlington, Fairfax, Loudoun, and Prince William Counties, City of Alexandria, Towns of Occoquan, Dumfries, Quantico, and Leesburg all have tidal shorelines along the Potomac River and its associated embayment's and tributaries. The accretion and erosion of these shorelines are influenced by wind-induced waves, littoral currents, tidal currents, sea-level rise, boat wake, and storm water runoff. Other contributing factors include the physical characteristics of the shoreline (e.g., topography and soil), as well as human activities (e.g., land use, dredging, and shoreline stabilization).

The Northern Virginia Regional Council (NVRC) study, "Tidal Shoreline Erosion in Northern Virginia" (September 1992), discussed the erosion situation for various segments of the shoreline in the Northern Virginia region, as well as locations of "priority" erosion concern. The report served as a valuable resource document for the Commonwealth and local officials to assist in planning for shoreline and erosion control throughout Northern Virginia. In addition, the report augments a computer data file also created by NVRC that contains the names, mailing addresses, and tax parcel numbers of tidal Potomac shoreline property owners. This data is distributed to the Shoreline Erosion Advisory Service and Northern Virginia local governments. Combined with the set of approximately 360 low altitude aerial photographs, these work products serve as a historical record of current planning efforts and future research. Specific areas of Northern Virginia noted in the study for shoreline stabilization efforts include:

- Twenty (20) percent of the Northern Virginia shoreline has been artificially stabilized with 32 miles of hard structures.
- Arlington County has 13.3 miles of tidal shoreline, with 4.9 miles of hardened shoreline (37 percent). This information has not been updated since the 2006 Plan creation and remains the best available data for the 2021 update to this Plan.
- The City of Alexandria has the shortest shoreline length (8.8 miles), with the largest percent stabilized (58 percent, or 5.1 miles).
- Fairfax has the most tidal shoreline in Northern Virginia (87 miles), and the most artificial stabilization (13.3 miles), but the smallest percent of stabilized shoreline (15 percent).
- Prince William County has approximately 48 miles of shoreline with 8.7 miles of artificial shoreline stabilization structures.

Local areas susceptible to flood and flash flood are further identified in the jurisdiction annexes.

5.5.1.3. Extent

The strength or magnitude of flooding varies depending on multiple meteorological, environmental, and geological features such as latitude, altitude, topography, and atmospheric conditions. In addition, there is seasonal variation in severe weather events that influences a storm's characteristics, warning time, speed of onset, and duration. Flash Flooding is most common in NOVA and may not always have warning. Flash flooding can be caused by 3 inches of rain from a thunderstorm passing through., and duration can last from minutes to hours, or even to multiple days in extreme events.

The term "stage" refers to the height of a river, or any other body of water, above a locally defined elevation. As with most rivers in the United States, the Potomac River has gauging stations where measurements of the river's stage and discharge are continually taken. These are plotted on a hydrograph, which shows the stage or discharge of the river as measured at the gauging station versus time. The Middle Atlantic River Forecast Center maintains and monitors the status of all rivers within the planning area. The Center currently indicates eight gauges on waterways that impact Northern Virginia, including seven on the Potomac River and one on Goose Creek in Loudoun County.

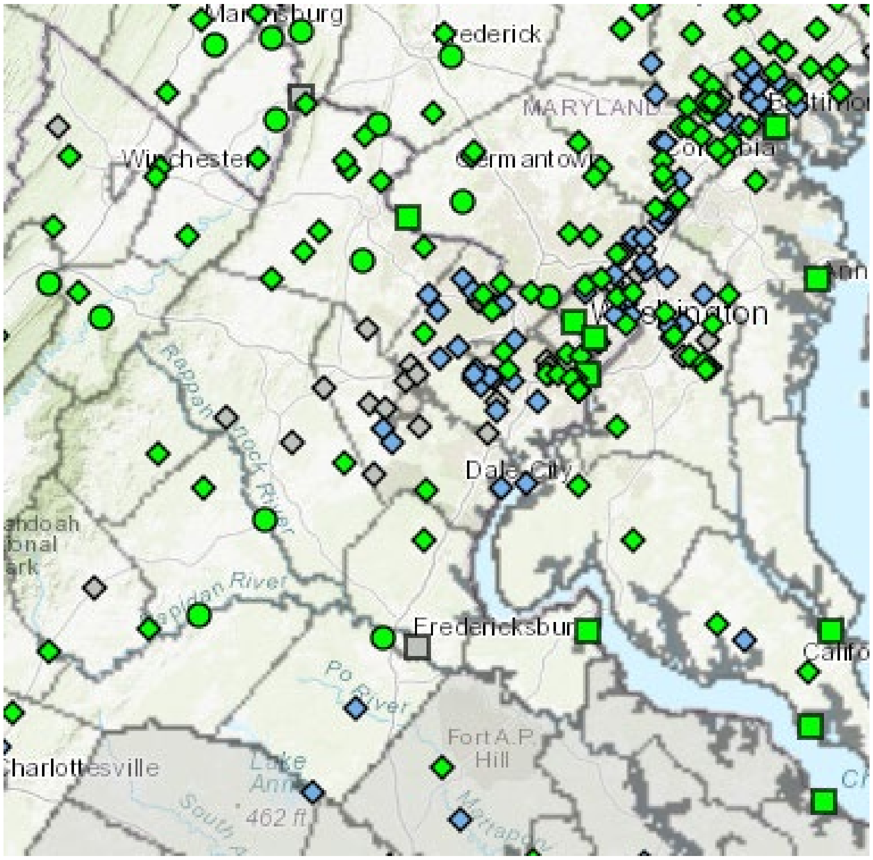

Figure 35: River Gauges in Northern Virginia[107]

The Forecast Center maintains multiple flood-planning resources, including hydrographic models at specific gauge sites, and interactive inundation maps which illustrate potential water depth values for specific locations. The hydrographic models provide multiple-day forecasts of river depth compared to flood stage. As an example, the Potomac River at Alexandria hydrograph for the period from January 5 to January 13, 2021 indicates a fluctuating river stage that briefly denotes a level over the flood action stage of 2.6 feet, with a slight increase to minor flood stage of 3.3 feet between January 5 and 6. The river stage then quickly receded below the action stage level for the succeeding days.

[107] National Weather Service Advanced Hydrologic Prediction Services https://water.weather.gov/ahps2/index.php?wfo=lwx

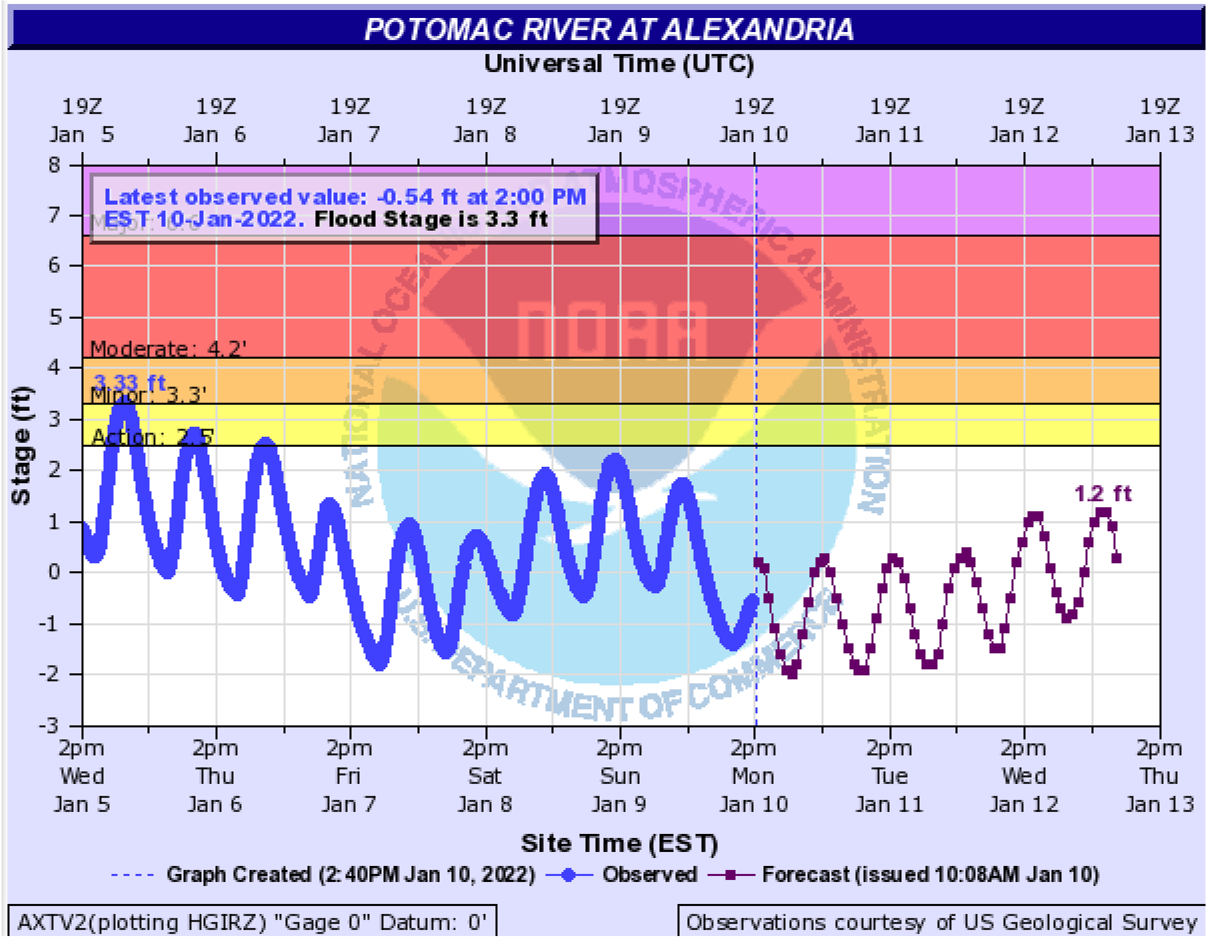

Figure 36: Hydrograph of Potomac River Gauge at Alexandria, January 2021[108]

The Forecast Center's inundation maps provide information related to potential water depth at specific locations. The example provided in Figure 37 illustrates a potential depth of 0 to 1.61 feet at a specific address within the City of Alexandria and shows the current stage (bottom left corner) that is below flood stage.

108 Mid-Atlantic River Forecast Center, Advanced Hydrologic Prediction Service. Retrieved at: https://water.weather.gov/ahps2/hydrograph.php?wfo=lwx&gage=axtv2

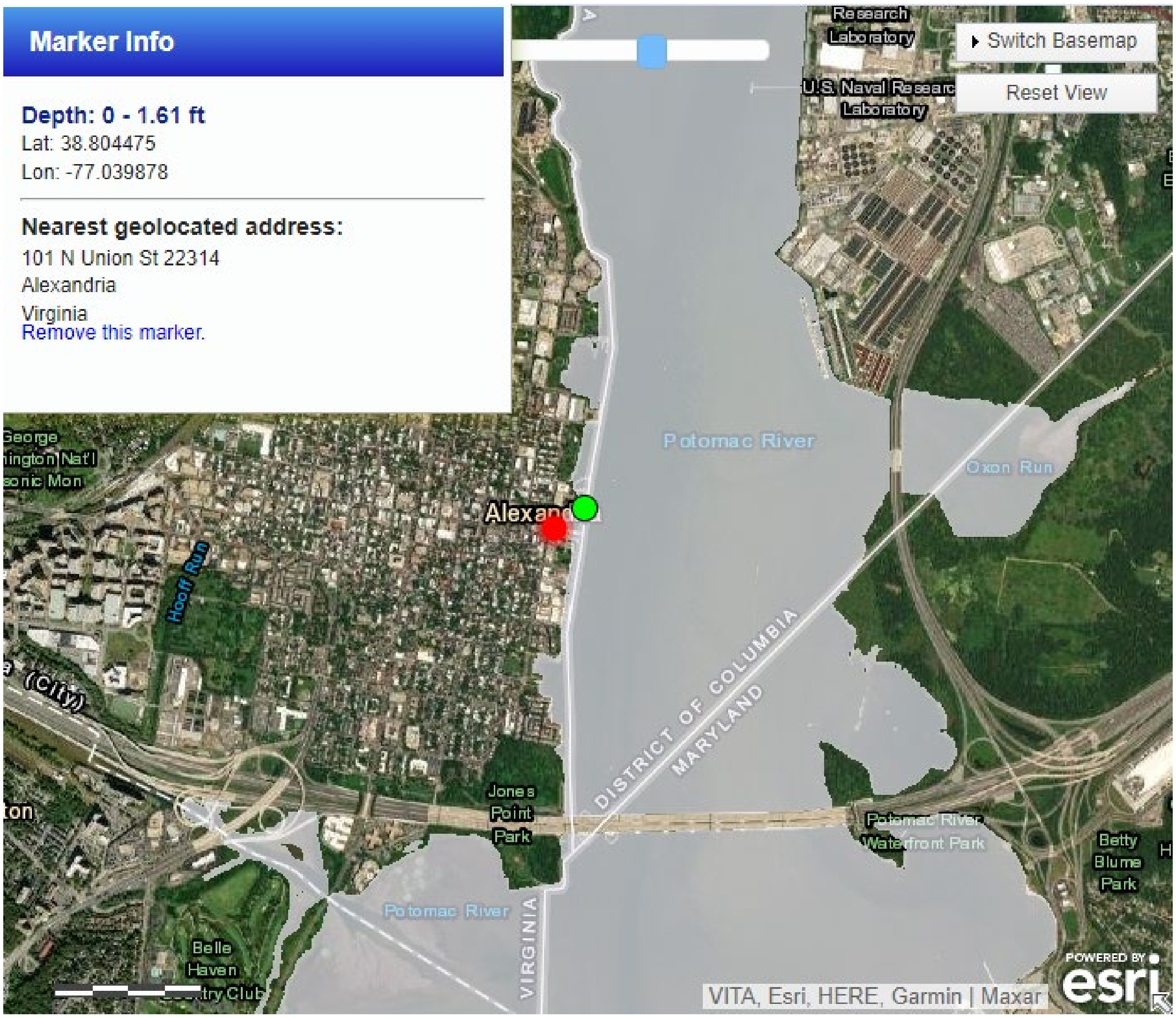

Figure 37: Sample Inundation Map, Potomac River at Alexandria[109]

The National Weather Service issues flood advisories, watches, and warnings to assist emergency management preparations, as well as to warn the public.[110]

- **Flood Advisory: Be Aware:** A Flood Advisory is issued when a specific weather event that is forecast to occur may become a nuisance. A Flood Advisory is issued when flooding is not expected to be bad enough to issue a warning. However, it may cause significant inconvenience, and if caution is not exercised, it could lead to situations that may threaten life and/or property.
- **Flood Watch: Be Prepared:** A Flood Watch is issued when conditions are favorable for a specific hazardous weather event to occur. A Flood Watch is issued when conditions are favorable for flooding. It does not mean flooding will occur, but it is possible.
- **Flood Warning: Take Action!** A Flood Warning is issued when the hazardous weather event is imminent or already happening. A Flood Warning is issued when flooding is imminent or occurring.

[109] Mid-Atlantic River Forecast Center, Inundation Map for Potomac River at Alexandria. Retrieved at: https://water.weather.gov/ahps2/inundation/index.php?gage=axtv2
[110] https://www.weather.gov/safety/flood-watch-warning

- **Flash Flood Warning: Take Action!** A Flash Flood Warning is issues when a flash flood is imminent or occurring. If you are in a flood prone area move immediately to high ground. A flash flood is a sudden violent flood that can take from minutes to hours to develop. It is even possible to experience a flash flood in areas not immediately receiving rain.
- **Flash Flood Emergency:** Issued for exceedingly rare situations when a severe threat to human life and catastrophic damage from a flash flood is happening or will happen soon.
- **Urban and Small Stream Advisory:** These advisory alerts the public to flooding, which is generally only an inconvenience (not life-threatening) to those living in the affected area and is issued when heavy rain will cause flooding of streets and low-lying places in urban areas. It is also used if small rural or urban streams are expected to reach or exceed bank full. Some damage to homes or roads may occur.
- **Coastal Flood Advisory:** Minor flooding is possible (i.e., over, and above normal high tide levels.
- **Coastal Flood Watch:** Flooding with significant impacts is possible.
- **Coastal Flooding Warning**: Flooding that will pose a serious threat to life and property is occurring, imminent or highly likely.

5.5.1.4. Previous Occurrences

Records of previous flood events are available through the Storm Events Database, maintained by the NOAA, National Centers for Environmental Information (NCEI). The database currently documents weather hazards between 1950 and September of 2021.[111] Flood incidents are reported by date, type and impacts to life safety, property, and agricultural crops. Flooding, as an event type, was first tracked in 1996.

Nearly 1,000 flood events have occurred throughout the planning area since 1950, and the occurrences range widely in terms of location, magnitude, and impact. The most frequent flooding events are localized in nature, resulting from heavy rainfall in areas that are unable to adequately handle storm water runoff. These events typically do not threaten lives or property and will not result in emergency or disaster declarations, therefore more detailed historical data is difficult to obtain.

Table 57: Flood Events in Northern Virginia, 1950–2021[112]

Jurisdiction	Number Events	Fatalities	Injuries	Property Damage	Crop Damage	Total Property and Crop Damage
Arlington County	67	1	27	$8,978,000	$0	$8,978,000
City of Alexandria	44	0	0	$98,000	$0	$98,000
City of Fairfax	10	1	0	$0	$0	$0
City of Falls Church	16	0	0	$600,000	$0	$600,000
City of Manassas	16	0	0	$0	$0	$0

[111] Data maintained through September 30, 2021, as of January 2022. For the purpose of this update, data collection was cut off at June 30, 2021.
[112] NOAA, NCEI Storm Events Database, 1950 to June 30, 2021. The search encompassed a cross-section of NCEI flood-related categories: flood; coastal flood; flash flood; heavy rain; thunderstorm wind; heavy rain; storm surge/tide; and tropical storm. County reported events include impacts in towns, where applicable.

Jurisdiction	Number Events	Fatalities	Injuries	Property Damage	Crop Damage	Total Property and Crop Damage
City of Manassas Park	8	0	0	$0	$0	$0
Fairfax County	406	3	0	$32,418,000	$35,000	$32,453,000
Loudoun County	153	0	0	$2,008,000	$170,000	$2,178,000
Prince William County	242	0	0	$15,591,000	$100,000	$15,691,000
TOTAL	962	5	27	$59,093,000	$305,000	$59,398,000

Table 58: Types of Flood Events Occurring in Northern Virginia, 1950–2021[113]

Jurisdiction	Coastal Flood	Flash Flood	Flood	Heavy Rain	Storm Surge/Tide	Tropical Storm	Total
Arlington County	15	19	13	12	3	5	67
City of Alexandria	2	24	8	9	2	0	44
City of Fairfax	0	5	5	0	0	0	10
City of Falls Church	0	6	0	10	0	0	16
City of Manassas	0	7	3	6	0	0	16
City of Manassas Park	0	2	1	5	0	0	8
Fairfax County	1	174	202	23	2	4	406
Loudoun County	0	59	70	15	0	0	153
Prince William County	0	69	150	17	2	4	242
TOTAL	**18**	**365**	**452**	**97**	**9**	**13**	**962**

Based on the historical record of 962 flood events occurring in the northern region of Virginia since 1950, the return interval for flooding would be 0.07 percent in any given year.[114]
Discussion of significant flood events for each participating jurisdiction is included in its jurisdictional annex.

Erosion

There is no known database of historic erosion events in the Northern Virginia region.

5.5.1.5. Probability of Future Occurrence

Periodic flooding of lands adjacent to rivers, streams, and shorelines (known as floodplains) is a natural occurrence that can be expected to take place based upon established recurrence intervals. The recurrence interval of a flood is defined as the average time interval, in years, expected between a flood event of a particular magnitude and an equal or larger flood.

[113] NOAA, NCEI Storm Events Database, 1950 to June 30, 2021.
[114] Return interval calculated on the number of years of record (70.5 years) divided by the number of flood events (962) identified within the NOAA, National Centers for Environmental Information, Storm Events Database, as of June 30, 2021.

A 100-year flood is not a flood that occurs every 100 years. In fact, the 100-year flood has a 26 percent chance of occurring during a 30-year period, or the typical length of many mortgages. The 100-year flood is a regulatory standard used by federal agencies, states, and NFIP-participating communities to administer and enforce floodplain management programs. The 100-year flood is also used by the NFIP as the basis for insurance requirements nationwide.

Table 59: Annual Probability Based on Flood Recurrence Intervals[115]

Flood Recurrence Interval	Annual Chance of Occurrence
10-year	10.0%
50-year	2.0%
100-year	1.0%
500-year	0.2%

Flooding remains highly likely throughout the identified flood hazard areas of the Northern Virginia region. Smaller floods caused by heavy rains and inadequate drainage capacity in urbanized areas will be more common, but not as costly as the large-scale floods that may occur at much less frequent intervals.

Erosion

At this time, there is no comprehensive database related to erosion incidents in Northern Virginia jurisdictions on which to calculate the probability of future occurrences based on historical events. However, future occurrences of erosion of both shorelines and inland areas of natural run-off remain probable in localized areas throughout the Northern Virginia region. According to projects researching the changing climate, including sea-level rise and increased storm events, erosion is expected to increase.

The Virginia Department of Conservation and Recreation (DCR) is the state-level agency responsible for monitoring erosion and sediment control through the Shoreline Erosion Advisory Service (SEAS). The SEAS website notes that “some Virginia shorelines have historic erosion rates of up to 30 feet per year,” but does not specifically identify the referenced locations.[116]

5.5.1.6. Future Occurrences Linked to Climate Change

Based on multiple scientific projections related to global warming and climate change, more excessive rainfall events leading to flood and flash flood could impact the Northern Virginia region in the future. Flooding linked to these events might result in riverine, coastal, or flash floods. An additional consideration for future flood events is sea-level rise, for which some jurisdictions within the Northern Virginia planning area are susceptible.

Since 2008, the NVRC has been engaged in a series of projects, studies, and efforts related to helping the region adapt to more frequent flooding, rising sea levels, and other projected impacts of climate change. These efforts have been funded in part by the National Oceanic and Atmospheric Administration (NOAA) through the Virginia Coastal Zone Management Program (VCZMP), which resulted in three Sustainable Shorelines and Community Management reports that document the projected impacts of sea level rise on tidal shorelines in the Northern Virginia region, as well as analyze potential adaptation strategies that could be implemented to reduce the regions’ vulnerability to future sea-level rise. These reports have laid the foundation for NVRC to continue working to provide technical assistance to local governments striving to build coastal resiliency.

[115] FEMA, National Flood Insurance Program
[116] Virginia Department of Conservation and Recreation, Shoreline Erosion Advisory Service website; Retrieved on December 22, 2021 at: https://www.dcr.virginia.gov/soil-and-water/seas

Additional data related to the impact of climate change on the extent of future flooding is described in **Section 6, Impacts of Climate Change**.

5.5.1.7. National Flood Insurance Program (NFIP)

The Flood Insurance and Mitigation Administration, a component of FEMA, manages the NFIP. The three components of the NFIP are:

- Flood Insurance
- Floodplain Management
- Flood Hazard Mapping

Nearly 20,000 communities across the United States and its territories participate in the NFIP by adopting and enforcing floodplain management ordinances to reduce future flood damage. In exchange, the NFIP makes federally-backed flood insurance available to homeowners, renters, and business owners in these communities. Community participation in the NFIP is voluntary.

Flood insurance is designed to provide an alternative to disaster assistance to reduce the escalating costs of repairing damage to buildings and their contents caused by floods. Flood damage is reduced by nearly $1 billion a year through communities implementing sound floodplain management requirements and property owners purchasing flood insurance. Additionally, buildings constructed in compliance with NFIP building standards are exposed to approximately 80 percent less damage annually than those not built-in compliance with current codes.

In addition to providing flood insurance and reducing flood damages through floodplain management regulations, the NFIP identifies and maps the nation's floodplains. Mapping flood hazards creates broad-based awareness and provides the data needed for floodplain management programs to actuarially rate new construction for flood insurance.

Community Rating System

The Community Rating System (CRS) is a voluntary initiative for those communities participating in the NFIP that recognizes and encourages community floodplain management activities that exceed the minimum NFIP standards. Depending on the level of participation, individual flood insurance premium rates for policyholders can be reduced from 5 percent to 45 percent in Special Flood Hazard Areas. CRS activities also enhance public safety, reduce damages to property and public infrastructure, minimize economic disruption and losses, and protect the environment. Implementation of some CRS activities can help projects qualify for other federal assistance programs as well.

Table 60: Legend for Community Status Book Labels and Definitions

Legend: Community Status Book Labels and Definitions	
Community Name	Jurisdiction participating in the National Flood Insurance Program
County	County in which the jurisdiction is located
Initial FHBM Identified	Date the Flood Hazard Boundary Map (FHBM) was developed
Initial FIRM Identified	Date of the first Flood Insurance Rate Map (FIRM)
Current Eff Map Date	Date the most recent jurisdictional Flood Insurance Rate Map (FIRM) was developed
Reg-Emer Date	Date the jurisdiction joined NFIP as either a regular participant or on an emergency basis

Legend: Community Status Book Labels and Definitions	
CRS Entry Date	Date the jurisdiction joined the Community Rating System (CRS)
Current Eff Date	Effective date as of the most current CRS review.
CRS Class	CRS Class rating on a scale of 1 to 10, with 1 being the highest rating
% Disc SFHA	For CRS members, percentage of discount on flood insurance premium for structures located in a Special Flood Hazard Area
% Disc Non SFHA	For CRS members, percentage of discount on flood insurance premium for structures not located in a Special Flood Hazard Area

Table 61: Participating Communities in the National Flood Insurance Program, Northern Virginia Region[117]

Community Name	County	Initial FHBM Identified	Initial FIRM Identified	Current Eff Map Date	Reg-Emer Date	CRS Entry Date	Current Eff Date	CRS Class	% Disc SFHA	% Disc Non SFHA
Arlington County	Arlington		10/1/1969	8/19/2013	12/31/1976	10/1/1992	10/1/2008	8	10%	5%
Alexandria, City of	-	8/22/1969	8/22/1969	6/16/2011	5/8/1970	10/1/1992	10/1/2013	6	20%	10%
Fairfax, City of	-	5/5/1970	12/23/1971	6/2/2006	12/17/1971	-	-	-	-	-
Falls Church, City of	-	9/6/1974	2/3/1982	7/16/2004	2/3/1982	5/1/2007	10/1/2016	6	20%	10%
Manassas, City of	-	5/31/1974	1/3/1979	1/5/1995	1/3/1979	-	-	-	-	-
Manassas Park, City of	-	3/11/1977	9/29/1978	1/5/1995	9/29/1978	-	-	-	-	-
Fairfax County	Fairfax	5/5/1970	3/5/1990	9/17/2010	1/7/1972	10/1/1993	10/1/2014	6	20%	10%
Clifton, Town of	Fairfax	3/28/1975	5/2/1977	9/17/2010	5/2/1977	-	-	-	-	-
Herndon, Town of	Fairfax	6/14/1974	8/1/1979	9/17/2010	8/1/1979	-	-	-	-	-
Vienna, Town of	Fairfax	8/2/1974	2/3/1982	9/17/2010	8/1/1979			8	10%	5%
Loudoun County	Loudoun	4/25/1975	1/5/1978	2/17/2017	1/5/1978	10/1/1992	5/1/2003	10		0%
Leesburg, Town of	Loudoun	8/30/1974	9/30/1982	2/17/2017	9/30/1982	-	-	-	-	-
Lovettsville, Town of	Loudoun	4/15/1977	7/5/2001	2/17/2017	10/22/2013	-	-	-	-	-
Middleburg, Town of	Loudoun		7/5/2001	2/17/2017	7/31/2001	-	-	-	-	-
Purcellville, Town of	Loudoun	7/11/1975	11/15/1989	2/17/2017	11/15/1989	-	-	-	-	-
Round Hill, Town of	Loudoun		7/5/2001	2/17/2017	1/10/2006	-	-	-	-	-

[117] FEMA, National Flood Insurance Program, Community Status Report. Accessed September 9, 2021

Community Name	County	Initial FHBM Identified	Initial FIRM Identified	Current Eff Map Date	Reg-Emer Date	CRS Entry Date	Current Eff Date	CRS Class	% Disc SFHA	% Disc Non SFHA
Prince William County	Prince William	1/10/1975	12/1/1981	8/3/2015	12/1/1981	10/1/1996	10/1/2019	7	15%	5%
Dumfries, Town of	Prince William	6/18/1976	5/15/1980	8/3/2015	5/15/1980	-	-	-	-	-
Haymarket, Town of	Prince William	8/9/1974	1/17/1990	1/5/1995	1/31/1990	-	-	-	-	-
Quantico, Town of	Prince William	11/1/1974	8/15/1978	8/3/2015	8/15/1978	-	-	-	-	-
Occoquan, Town of	Prince William	7/19/1974	9/1/1978	1/5/1995	9/1/1978	-	-	-	-	-

As of August 17, 2022, there were a total of 7,030 flood active insurance policies in the Northern Virginia region. These policies amounted for more than $6.1 million in flood insurance premiums paid in the region. Approximately 2,712 claims have been filed, accounting for nearly $32.7 million in payments.

Floodplain management regulations are the cornerstone of NFIP participation. Communities that participate in the NFIP are expected to adopt and enforce floodplain management regulations that apply to all types of floodplain development and ensure that development activities will not cause an increase in future flood damages. Buildings in floodplains are required to be elevated at or above the Base Flood Elevation (BFE), as established by the local regulations.

Repetitive Loss Properties and Severe Repetitive Loss Properties

A Repetitive Loss Property (RL) is a property that is insured under the NFIP that has filed any NFIP-insured property that, since 1978 and regardless of any change(s) of ownership during that period, has experienced: a) four or more paid flood losses; b) two paid flood losses within a 10-year period that equal or exceed the current value of the insured property; or c) three or more paid losses that equal or exceed the current value of the insured property. Nationwide, RL properties constitute 2 percent of all NFIP insured properties but are responsible for 40 percent of all NFIP claims. Mitigation for RL properties are a high priority for FEMA, and the areas in which these properties are located typically represent the most flood-prone areas of a community.

A second category of RL properties has been identified for those properties that have sustained the highest levels of damages and claims, which are known as Severe Repetitive Loss (SRL) properties. The SRL properties are defined as buildings that are covered under a Standard Flood Insurance Policy (SFIP) and have sustained flood damage for which: (a) four or more separate claim payments have been made under a SFIP, with the amount of each claim exceeding $5,000, and with the cumulative amount of such claims exceeding $20,000; or (b) at least two separate claim payments have been main under an SFIP, with the cumulative amount of those payments exceeding the fair market value of the insured structure as of the day before the loss.

The identification of RL properties is an important element to conduct a local flood risk assessment, as the inherent characteristics of properties with multiple flood losses strongly suggest that they will be threatened by continual losses. The RL properties are also important to the NFIP as structures that floods frequently put a strain on for the National Flood Insurance Fund.

A primary goal of FEMA is to reduce the number of structures that meet these criteria, whether through elevation, acquisition, relocation, or a flood-control project that lessens the potential for continual losses.

According to FEMA, there are currently 195 Repetitive Loss properties and 20 Severe Repetitive Loss properties within the Northern Virginia region. The specific addresses of the properties are maintained by FEMA, VDEM, and local jurisdictions, but are deliberately not included in this Plan as required by Law. Of these 215 properties, fourteen (14) are unmitigated, and 112 of them are also uninsured. The insured properties have been paid more than $7.8 million from 247 payable claims.

5.5.2. Risk Assessment

Flooding impacts a community as it affects the lives of its citizens and overall community functions. As such, the most high-risk areas of a community will be those most affected by floodwaters in terms of potential loss of life, damage to homes and businesses, and disruption of community services and utilities. For example, an area with a floodplain near densely populated areas and a great deal of the built environment is more vulnerable to the impacts of flooding than a rural or undeveloped floodplain, where potential floodwaters would have little or no community impact.

The severity of flooding may be magnified to the degree that floodwaters affect vulnerable populations, or those that may require special assistance during a flood event or may not be able to protect themselves prior to an event or may not be able to understand potential risks. Populations such as non-English speaking persons, the elderly, the disabled, and those in lower socioeconomic groups may be at higher risk. Tourists and visitors to the area have also increased vulnerability, as they are less familiar with local geography and means by which residents are warned about potentially dangerous conditions.

5.5.2.1. Built Environment and Community Lifelines and Assets

The impacts of floodwaters on Community Lifelines, such as police and fire stations, hospitals, and water or wastewater treatment facilities can increase the overall impacts of a flood event on a community. In general, relatively few of these facilities in the Northern Virginia region are in areas with a high flood risk.

The built environment, especially along the shorelines of the Potomac River, is especially at risk to sea-level rise that is projected to occur as part of climate change. Climate change may include the region possibly experiencing more intense precipitation events that exacerbate flood impacts, creating higher levels of storm water run-off and damaging property and critical infrastructure.

5.5.2.2. Natural Environment and Economy

Many areas previously impacted by flood have been converted to open space or returned to their natural environment via jurisdictions. Recognition that filling in or paving over previously natural run-off areas along the region's rivers and creeks during earlier development has led to jurisdictions taking actions in recent years that return a waterway to its previous capacity to provide an alternate method for increasing water flow and storm-water run-off during rainfall events. Jurisdictions within the region are closely monitoring the increased incidence of flash flood specifically to identify localized trouble spots that may develop in the future.

The importance of recognizing each flood-related hazard is discussed in the publication Flood Risk Management Planning for Washington, DC,[118] which discusses flooding beyond the boundaries of the District of Columbia while assessing the risk from the Potomac River Watershed. The watershed encompasses the entire planning area and extends northward into Pennsylvania and westward to the Virginia/West Virginia state-line. In addition to addressing overall flood risk, the report describes riverine, interior, and coastal flooding, highlighting the need to identify and prepare for each flood hazard separately.

Additional resources are available to floodplain managers and other responsible departments and agencies to address flood risk.

Table 62: Flood Risk Management Resources[119]

		Flood Type			Tool Type		
Resource Name	Agency	Riverine	Interior	Coastal	Projection	Map	Report
Flood Insurance Rate Maps	FEMA	✓	✓	✓		✓	✓
Flood Inundation Mapping Tool	USACE	✓		✓		✓	
Storm Surge Inundation Maps	USACE			✓		✓	
Sea Level Rise Viewer	NOAA			✓		✓	

[118] National Capital Planning Commission and The Silver Jackets, supported by United States Army Corps of Engineers (USACE), Flood Risk Management Planning for Washington, D.C.
[119] National Capital Planning Commission and The Silver Jackets, supported by United States Army Corps of Engineers (USACE), Flood Risk Management Planning for Washington, D.C.

		Flood Type			Tool Type		
Resource Name	**Agency**	**Riverine**	**Interior**	**Coastal**	**Projection**	**Map**	**Report**
Surging Seas Risk Finder	Climate Central			✓	✓	✓	✓
Sea Level Change Curve Calculator	USACE			✓	✓		
Precipitation Modeling	DOEE		✓		✓		
CMIP Climate Data Processing Tool	DOT		✓	✓			

Publicly available flood risk data for each county in the planning area may be found online at the sites listed below, which indicate the degree to which each area takes flooding seriously and recognizes the need to disseminate hazard-related information to the public.

Table 63: Flood Preparedness and Risk Information Available from Northern Virginia Jurisdictions

Arlington County	Stormwater Management, Floodplains and Flood Insurance Maps https://www.arlingtonva.us/Government/Programs/Sustainability-and-Environment/Stormwater/Flood-Insurance-Rate-Maps
Fairfax County	Department of Emergency Management and Security https://www.fairfaxcounty.gov/emergency/readyfairfax/flooding
Loudoun County	Non-Regulatory Flood Risk Resources https://www.loudoun.gov/3944/Non-Regulatory-Flood-Risk-Products
Prince William County	Office of Emergency Management - Flooding https://www.pwcva.gov/flooding

As a resource for all communities located in the planning area, the Virginia Department of Conservation and Recreation provides information for each community to ascertain its flood risk,[120] and the National Weather Service website includes a page dedicated to Flooding in Virginia.[121]

5.5.2.3. Hazard Risk Ranking Summary

The hazard ranking process included consideration of probability and consequences in determining an overall risk score and ranking. Information presented within this section and the hazard risk ranking process present the quantitative and qualitative summary for flood/flash flood. The Hazard Identification and Risk Assessment methodology is described in **Section 4, Base Plan**.

[120] Commonwealth of Virginia, Department of Conservation and Recreation, Virginia Flood Risk, and Information, https://www.dcr.virginia.gov/dam-safety-and-floodplains/fpvfris, accessed November 12, 2021
[121] NOAA, National Weather Service, Flooding in Virginia, https://www.weather.gov/safety/flood-states-va, accessed November 12, 2021

Table 64: Hazard Risk Rankings for Flood, by Jurisdiction

Jurisdiction	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
Arlington County	2.7	4.1	6.8	High
City of Alexandria	2.0	4.2	6.2	High
City of Fairfax	1.7	4.2	5.9	High
City of Falls Church	1.7	4.2	5.9	High
City of Manassas	1.7	4.2	5.9	High
City of Manassas Park	1.7	4.2	5.9	High
Fairfax County	2.7	4.2	6.9	High
Town of Clifton	1.7	4.2	5.9	High
Town of Herndon	1.7	4.2	5.9	High
Town of Vienna	1.7	4.2	5.9	High
Loudoun County	1.7	4.1	5.8	High
Town of Leesburg	1.7	4.1	5.8	High
Town of Lovettsville	1.7	4.1	5.8	High
Town of Middleburg	1.7	4.1	5.8	High
Town of Purcellville	1.7	4.1	5.8	High
Town of Round Hill	1.7	4.1	5.8	High
Prince William County	2.3	5.7	8.1	High
Town of Dumfries	1.7	4.2	5.9	High
Town of Haymarket	1.7	4.2	5.9	High
Town of Occoquan	4.0	6.9	10.9	High
Town of Quantico	1.7	4.2	5.9	High

5.5.3. Vulnerability Analysis

Multiple factors contribute to the relative vulnerabilities of certain areas in the floodplain. Development, or the presence of people and property in the hazardous areas, is a critical factor in determining vulnerability to flooding. Additional factors that contribute to flood vulnerability range from specific characteristics of the floodplain to characteristics of the structures located within the floodplain. Some of these factors, and how they may relate to the Northern Virginia planning region, include:

- **Flood depth:** The greater the depth of flooding, the higher the potential for significant damages.
- **Flood duration:** The longer duration of time that floodwaters are in contact with building components, such as structural members, interior finishes, and mechanical equipment, the greater the potential for damage.
- **Velocity:** Flowing water exerts forces on the structural members of a building, increasing the likelihood of significant damage.
- **Elevation:** The lowest possible point where floodwaters may enter a structure is the most significant factor contributing to its vulnerability to damage due to flooding.

- **Construction Type:** Certain types of construction are more resistant to the effects of floodwaters than others. Typically, masonry buildings, constructed of brick or concrete blocks, are the most resistant to damages simply because masonry materials can come into contact with limited depths of flooding without sustaining significant damage. Wood frame structures are more susceptible to damage because the construction materials used are easily damaged when inundated with water.

5.5.3.1. Exposure

Estimations of potential exposure and loss in this section are based on data from both historical and scenario analysis.

Erosion vulnerability for the region is difficult to determine because there are no historical records for previous occurrences of erosion events. The Northern Virginia region's vulnerability to erosion is limited to those immediate areas along rivers, creeks, and streams, and to areas of loose soils with steep slopes such as valleys and road-cuts. In most cases where erosion poses an imminent threat to property, erosion control techniques are typically applied before damages occur. Therefore, future structural damages caused by long-term erosion and associated dollar losses are expected to be negligible.

As discussed previously in this section, the NVRC prepared a study that identified the erosion situation for various segments of the shoreline in the Northern Virginia region, as well as the locations of "priority" erosion concern. Future updates will re-assess progress in addressing shoreline erosion through the current and succeeding studies.

Estimation of Flood Losses

Hazus is a regional loss estimation model developed by FEMA and the National Institute of Building Sciences to provide both a methodology and software application for use in developing multi-hazard losses on a regional scale. Loss estimates are used primarily by local, state, and regional officials to plan and foster efforts to reduce risk from multi-hazards, and to help communities better develop their emergency response and recovery programs.

The 2022 Hazus for the Flood hazard analysis was completed using a 100-year scenario, or a scenario of flood extent determined as an event that includes a 1 percent annual chance of flooding in any given year. This section highlights points from the Hazus flood module summary report. Full reports on Hazus data generated for all three hazards are included in **Appendix B**.

The Hazus flood scenario extent (geographic breadth) that identifies exposed essential facilities and total exposure for a 100-year flood scenario was run for each county and city within the planning area. County-level reports and data include towns.

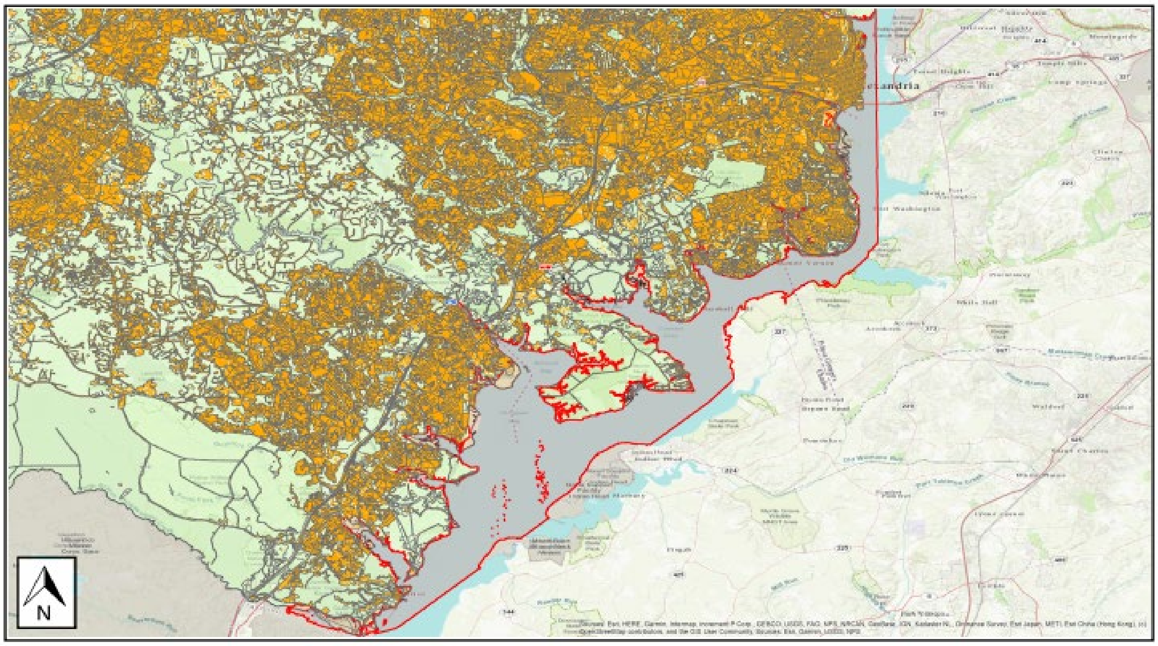

Figure 38: Area Included in the HAZUS Flood Model Run for a 100-Year Flood Scenario[122]

The Flood Hazus report includes summaries of physical damage to residential and commercial buildings, schools, essential facilities, and infrastructure, as well as economic loss including lost jobs, business interruptions, repair, and reconstruction costs.

Flood Hazard Elements Discussed in the 2022 Hazus Flood Model Report

- Flood Vehicle Dollar Exposure (Night)
- Flood Transportation System Dollar Exposure
- Flood Utility System Dollar Exposure
- Flood Building Stock Exposure by General Occupancy
- Flood Building Stock Exposure by Building Type
- Flood Building Damage by Building Type
- Flood Vehicle Damage Exposure (Day)
- Flood Building Damage Count by General Building Type
- Flood Building Damage by General Occupancy (Pre-Firm)
- Flood Building Damage by General Occupancy (Post-Firm)
- Flood Building Damage by General Occupancy
- Flood Building Damage Count by General Occupancy Pre-Firm
- Flood Building Damage Count by General Occupancy Pre-Firm
- Flood Building Damage by General Occupancy
- Flood Fire Station Facilities Damage and Functionality

[122] Hazus Flood Global Summary Report – Study Region Overview Map.

- Flood Emergency Operation Center Damage and Functionality
- Flood School Damage and Functionality
- Flood Police Station Facilities Damage and Functionality
- Flood Care Facilities Damage and Functionality
- Flood Potable Water System Facility Damage
- Flood Light Rail Bridge Damage and Functionality
- Flood Highway Bridge Damage and Functionality
- Flood Global Summary Report
- Flood Combined Wind and Flood Direct Economic Losses for Buildings
- Flood Debris Summary Report
- Flood Quick Assessment Report
- Flood Waste Water Facility Damage
- Flood Direct Economic Loss for Transportation
- Flood Depreciated Direct Economic Loss for Buildings
- Flood Direct Economic Annualized Losses for Buildings

A community's vulnerability to the flood hazard is calculated by relating potential flooding depth to the annual chance of inundation for that depth. An analysis of the 100-year return interval event was performed to assess risk to essential facilities.

Depth, duration, and velocity of water in the floodplain are the primary factors contributing to flood losses. Associated hazards that contribute to flood losses include channel erosion and migration, sediment deposition, bridge scouring, and the impact of flood-born truck. The Hazus Flood Model allows users to estimate flood losses due to flood velocity to the general building stock. The flood model does not currently estimate losses due to high velocity flash floods.

The Hazus flood assessment included streams and coastal reaches located in the planning region with a drainage area of ten square miles or more. The flood depth grid was developed for the 100-year return period. The flood model incorporates NFIP entry dates to distinguish pre-FIRM and post-FIRM census blocks. A 10-mile threshold was used to delineate stream reaches in the event of overflow. Loss estimation for this Hazus module is based on specific input data (i.e., square footage of buildings for specified types or populations) and local economic data for use in estimating the economic impact of flood hazards. Data for this analysis was provided at the census block level.

Table 65: Hazus Direct Economic Loss Categories and Descriptions[123]

Name	Data Input for HAZUS Model	HAZUS Output
Building	Cost per sq. ft. to repair damage by structural type and occupancy for each level of damage	Cost of building repair or replacement of damaged and destroyed buildings
Contents	Replacement value by occupancy	Cost of damage to building contents
Inventory	Annual gross sales in $ per sq. ft.	Loss of building inventory as contents related to business activities

[123] Hazus Global Reports, August 3, 2021.

Name	Data Input for HAZUS Model	HAZUS Output
Relocation	Rental costs per month per sq. ft. by occupancy	Relocation expenses (for businesses and institutions)
Income	Income in $ per sq. ft. per month by occupancy	Capital-related incomes losses as a measure of the loss of productivity, services,
Rental	Rental costs per month per sq. ft. by occupancy	Loss of rental income to building owners
Wage	Wages in $ per sq. ft. per month by occupancy	Employee wage loss as described in income loss

The Hazus flood analysis predicts that the direct economic losses to buildings and their contents due to a major 100-year flood event in Northern Virginia region is $1,616,891,000. This was calculated for Capital Stock and Income Losses and was broken down into respective subcategories: Capital Stock Losses include losses for building, contents, and inventory; Income Losses include relocation, capital-related, wages, and rental income losses. Some jurisdictions in the study region did not have any building losses in this scenario.

Table 66: Direct Economic Losses for Buildings and Building Economic Losses for 100-Year Flood Scenario[124]

Jurisdiction	Capital Stock Losses				Income Losses				
	Building Loss	Contents Loss	Inventory Loss	Building Loss Ratio %	Relocation Loss	Capital Related Loss	Wages Losses	Rental Income Loss	Total Loss
Arlington County	561,000	506,000	5,000	0.3	58,000	174,000	159,000	30,000	$1,493,000
Alexandria, City of	39,906,000	42,504,000	670,000	1.3	16,353,000	26,828,000	25,850,000	10,291,000	$162,402,000
Loudoun County *Including the Towns of Leesburg, Lovettsville, Purcellville, Middleburg, and Round Hill*	178,368,000	132,180,000	1,207,000	3.2	31,066,000	23,202,000	55,983,000	12,719,000	$434,725,000
Fairfax County *Including the Towns of Clifton, Herndon, and Vienna*	178,167,000	130,489,000	2,270,000	1.4	30,419,000	27,261,000	50,150,000	12,835,000	$431,591,000

[124] Hazus Report Flood Direct Economic Losses for Buildings, August 3, 2021

Jurisdiction	Capital Stock Losses				Income Losses				
	Building Loss	Contents Loss	Inventory Loss	Building Loss Ratio %	Relocation Loss	Capital Related Loss	Wages Losses	Rental Income Loss	Total Loss
Prince William County *Including the Towns of Dumfries, Haymarket, and Occoquan, and Quantico*	240,638,000	175,751,000	3,039,000	2.4	41,114,000	41,151,000	54,676,000	18,434,000	$574,803,000
Manassas, City of	2,054,000	3,352,000	11,000	11.4	825,000	3,409,000	1,591,000	635,000	$11,877,000
Total	**$639,694,000**	**$484,782,000**	**$7,202,000**	**20.00%**	**$119,835,000**	**$122,025,000**	**$188,409,000**	**$54,944,000**	**$1,616,891,000**

For the flood scenario model, the built-in default inventory of assets included in the standard Comprehensive Data Management System (CDMS) was used, with no inventory adjustments accounting for locally reported critical assets (e.g., Level 1 analysis). As such, discrepancies may appear between self-reported critical asset data and Hazus-generated data included in this section. **Appendix B** includes a description of the methodology used for the flood scenarios described in this section, and the grouping of counties, cities, and towns in each model.

Essential Facilities at Risk

The vulnerability of the region's building stock was assessed using GIS analysis to identify an asset's location within the extent of known hazard areas that can be spatially defined. Determinations were made by using the most recent available data for critical facility locations and delineable hazard areas. The actual level of risk for each facility may only be determined by additional on-site assessment.

Table 67: Number of Critical Facilities Potentially at Risk to Flood[125]

Jurisdiction	Fire Stations	Hospitals	Police Stations	Schools	EOCs	Total
Arlington County	0	0	0	0	0	0
Fairfax County	1	0	0	0	0	1
Town of Clifton	0	0	0	0	0	0
Town of Herndon	0	0	0	0	0	0
Town of Vienna	0	0	0	0	0	0
Loudoun County	1	0	0	0	0	1
Town of Leesburg	0	0	0	0	0	0
Town of Lovettsville	0	0	0	0	0	0
Town of Purcellville	0	0	0	0	0	0
Town of Middleburg	0	0	0	0	0	0
Town of Round Hill	0	0	0	0	0	0
Prince William County	0	0	1	0	0	1
Town of Dumfries	0	0	0	0	0	0
Town of Haymarket	0	0	0	0	0	0
Town of Occoquan	0	0	0	0	0	0
Town of Quantico	0	0	0	0	0	0
City of Alexandria	0	0	0	1	0	1
City of Fairfax	0	0	0	0	0	0
City of Falls Church	0	0	0	0	0	0
City of Manassas	0	0	0	0	0	0
City of Manassas Park	0	0	0	0	0	0
TOTAL	**2**	**0**	**1**	**1**	**0**	**4**

[125] Hazus Flood Reports: Fire Station Facilities Damage and Functionality; Care Facilities (Hospital) Damage and Functionality; Police Station Facilities Damage and Functionality; School Damage and Functionality; and Emergency Operation Center Damage and Functionality. Dated August 3, 2021.

Table 68: Estimated Shelter Requirements[126]

Jurisdiction	Number of Displaced People	Number of People Needing Short-Term Sheltering
Arlington County	14	13
Fairfax County	5,039	2,858
Town of Clifton	0	0
Town of Herndon	0	0
Town of Vienna	0	0
Loudoun County	3,088	1,396
Town of Leesburg	0	0
Town of Lovettsville	0	0
Town of Purcellville	0	0
Town of Middleburg	0	0
Town of Round Hill	0	0
Prince William County	4,806	2,192
Town of Dumfries	0	0
Town of Occoquan	0	0
City of Alexandria	2,465	1,011
City of Fairfax	0	0
City of Falls Church	0	0
City of Manassas	0	0
City of Manassas Park	0	0
TOTAL	**15,412**	**7,470**

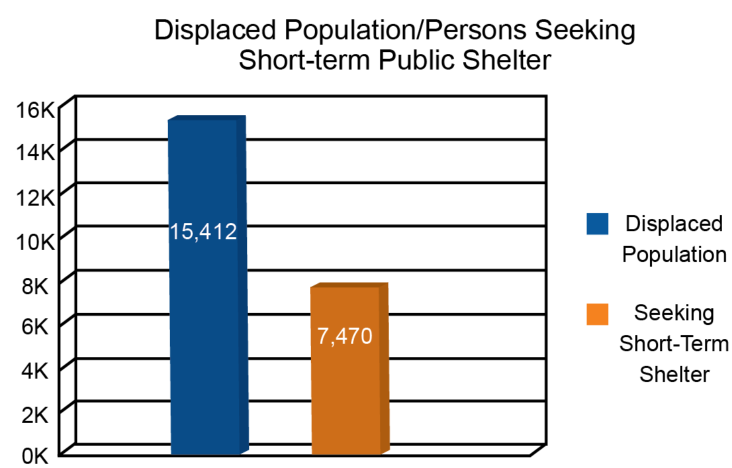

Figure 39: Comparison of Displaced Population/Persons Seeking Short-term Public Shelter in Northern Virginia Region[127]

[126] Hazus Flood Shelter Summary Report, August 3, 2021
[127] HAZUS Flood Shelter Summary Report, August 3, 2021

Northern Virginia properties most vulnerable to flooding are in SFHAs identified by FEMA, which were produced after Flood Insurance Studies (FIS) for each area were completed. The Digital FIRMs for each jurisdiction illustrate the location of SFHAs based on the most recently available floodplain data provided by the FEMA Map Service Center. Digital data was available for all localities within the Northern Virginia planning region.

Overall Loss Estimates and Ranking

The loss estimates and ranking results for the flood hazard in the Northern Virginia region is primarily based on the results of the detailed GIS and Hazus analysis, NCEI Storm Events Database, the hazard analysis included in the 2018 Commonwealth of Virginia Hazard Mitigation Plan, and each jurisdiction's qualitative ranking.

A number of flooding events throughout the region have been documented by NCEI. Events range widely in terms of location, magnitude, and impact. The most frequent flooding events are localized and result from heavy rains in a short period of time over urbanized areas that are not able to appropriately handle storm water runoff. These events typically do not threaten lives or property and will not result in emergency or disaster declarations, thus historical data of this type of flooding is not readily available.

The Commonwealth of Virginia's 2018 Hazard Mitigation Plan ranking of the flood hazard was based on the NCEI database. This update to the NOVA HMP used this same framework to establish a common system for evaluating and ranking hazards. The geographic extent score for each jurisdiction is based on the percent of the jurisdiction that falls within the SFHA, as defined by FEMA.

5.5.3.2. Potential Impacts of Climate Change

The impacts of climate change related to future floods and flash floods, which includes related erosion, is discussed in **Section 6, Impacts of Global Warming**.

5.5.3.3. Future Population and Development Trends

Future development and the resulting population increase have the potential to elevate vulnerabilities to flood and flash flood in the future, depending on climate change variables and the capabilities of jurisdictions to balance development pressures in relation to appropriate use of floodplains. Continued focus on enhancing floodplain and stormwater management regulations and practices will be key to reducing the risk from future development.

5.5.3.4. Factors for Consideration in the Next Planning Cycle

Future monitoring, evaluating, and updating of this Plan should consider the following factors related to flood/flash flood as well as other information from the Virginia COV-SHMP:

- Have any flood/flash flood events occurred since adoption of this plan?
- Has any new scientific research or methodology changed the ability to predict flood/flash flood events or to assess risk and vulnerability?
- Has there been any significant change in the population, built environment, natural environment or economy that could affect the risk or vulnerability to flood/flash flood?
- Is there any new evidence related to the impacts of climate change that could affect the level of risk or vulnerability to flood/flash flood?

5.6. High Winds/Severe Storms (Including Thunderstorms, Hurricanes, and Tropical Storms)

2022 HMP Update

For the 2022 updated HMP, Hurricanes and Tropical Storms are included with High Winds and Severe Storms.

The 2022 Plan update continued to incorporate formatting changes and analyses implemented in the 2017 Plan. These changes include but were not limited to the following:

- Re-examining High Winds, Severe Storms, Thunderstorms, Hurricanes, and Tropical Storms.
- Refreshing the hazard profiles for each hazard included in this section
- Updating the previous occurrences
- Updating the assessment of risk by jurisdiction based on new data
- Ranking of the hazards by jurisdiction using the methodology described in Section 4
- Reformatting the section to improve clarity and, as available and appropriate, incorporate new maps and imagery

Table 69: High Winds/Severe Storms Profile

<table>
<tr><th colspan="5">High Winds/Severe Storms[128]</th><th>Overall Vulnerability</th></tr>
<tr><th colspan="5">Definitions, Key Terms, and Overview</th><td rowspan="6">High</td></tr>
<tr><td colspan="5">High Winds: Winds not associated with a specific thunderstorm or hurricane that are 40 mph or greater, or wind gusts of 58 mph or greater.
Severe Storms/Thunderstorms: A thunderstorm that produces hail of one inch in diameter or larger and/or winds equal or exceeding 58 mph
Tropical Storm: A tropical cyclone that has maximum sustained surface winds of between 39 mph (34 knots) and 74 mph (64 knots).[129]
Hurricane: A tropical cyclone that has maximum sustained surface winds of 74 mph or greater (74 knots or greater).[130]</td></tr>
<tr><th>Frequency</th><th>Probability</th><th colspan="3">Potential Magnitude</th></tr>
<tr><td rowspan="2">High</td><td rowspan="2">High</td><th>Injuries/Deaths</th><th>Infrastructure</th><th>Environment</th></tr>
<tr><td>Low</td><td>High</td><td>Moderate</td></tr>
</table>

[128] NOAA National Weather Service, Hazard Weather Definitions. Retrieved at: https://www.weather.gov/unr/hwd
[129] National Hurricane Center, Tropical Cyclone Wind Speed Probabilities Products. Retrieved at: https://www.nhc.noaa.gov/aboutnhcprobs2.shtml
[130] National Hurricane Center, Tropical Cyclone Wind Speed Probabilities Products. Retrieved at: https://www.nhc.noaa.gov/aboutnhcprobs2.shtml

5.6.1. Hazard Profile: High Winds/Severe Storms

Wind is the motion of air past a given point caused by a difference in pressure between one location and another. Wind poses a threat to Northern Virginia in many forms, including wind produced by severe thunderstorms and tropical weather systems. The effects can include blowing debris and interruptions in elevated electrical power and communications utilities; wind can also intensify the effects of severe storms that occur in combination with winter weather. The hazard may harm people and animals and damage property and infrastructure.

More than 100,000 thunderstorms occur each year in the United States, though only about 10% of these storms are classified as *severe*. A thunderstorm with wind gusts in excess of 58 mph (50 knots) and/or hail with a diameter of 1 inch or more is classified as a severe thunderstorm. Although thunderstorms affect a small area, they are dangerous because they can generate tornadoes, hail, strong winds, flash flooding, and lightning. While thunderstorms can occur in all regions of the United States, they are most common in the central and southern states, because atmospheric conditions in those areas are ideal for generating and feeding these powerful storms.[131]

Thunderstorms occur when air masses of varying temperatures and moisture content collide. Rapidly rising warm, moist air is the driving force behind the creation of thunderstorms. These events may occur singularly, in lines, or in clusters. They can move through an area quickly or linger for hours. Straight-line winds, which in extreme cases may result in wind gusts that exceed 100 mph, are responsible for most thunderstorm-related wind damage. One type of straight-line wind, the downburst, can cause damage equivalent to that of a strong tornado and can be extremely dangerous to the aviation industry.

Lightning, which may accompany high winds, is a discharge of electrical energy resulting from the buildup of positive and negative charges within a thunderstorm, creating a bolt when the buildup of charges becomes strong enough. This flash of light usually occurs within the clouds or between the clouds and the ground. A bolt of lightning can reach temperatures approaching 50,000 degrees Fahrenheit. As it flashes, lightning rapidly heats the surrounding air, which cools following the bolt. This rapid heating and cooling of the air causes thunder. On average, 89 people are killed each year by lightning strikes in the United States.

Some storms produce a particular type of high wind called a derecho. Derechos are widespread, long-lived, straight-line windstorms associated with severe thunderstorms. They can cause hurricane-force winds, tornadoes, heavy rains, and flooding. Derechos travel quickly, with sustained winds that often exceed the threshold for hurricane-force winds. They typically occur in the summer months, though they can occur any time of year and at any time of the day or night.

Hailstorms are another potentially destructive outgrowth of severe thunderstorms. Early in the development of a hailstorm, ice crystals form within a low-pressure front due to the rapid rising of warm air into the upper atmosphere and the subsequent cooling of the air mass. Frozen droplets gradually accumulate on the ice crystals until, having developed sufficient weight, they fall as precipitation—as balls or irregularly shaped masses of ice greater than 0.75 inches (1.91 cm) in diameter. The size of hailstones is a direct function of the size and severity of the storm. High velocity updraft winds are required to keep hail in suspension in thunderclouds. The strength of the updraft is a function of the intensity of heating at the Earth’s surface. Higher temperature gradients relative to elevation above the surface result in increased suspension time and hailstone size.

Derechos are another type of severe storm. Though these strike more frequently in the Mississippi River Valley, derechos occur in the eastern United States often enough for the NWS to map their frequency of occurrence. In addition to high winds and hail associated with these events, severe storms can also be

[131] National Weather Service

accompanied by lightning, which may cause fires, property damage, and death, or serious injury to humans.

This section includes NOAA, National Centers for Environmental Information (NCEI) data listed for the period January 1, 1950 through May 31, 2021 and the following hazards in the search criteria: High Wind, Hurricane (Typhoon), Marine High Wind, Marine Strong Wind, Marine Thunderstorm Wind, Strong Wind, Thunderstorm Wind, Tropical Depression, and Tropical Storm.

Table 70: Hazard Profile Summary

<table>
<tr><td rowspan="8">High Wind/ Severe Storm, Including Thunderstorms and Hurricanes
Assessment: High Risk Hazard</td><td>Location</td><td>Jurisdiction-wide</td><td>Potential Cascading Effects</td></tr>
<tr><td>Extent</td><td>Moderate to significant</td><td rowspan="7">• Power/utility outages
• Traffic/roadway damage or closures
• Visitor/staff safety
• Need for increased security
• Loss of deliverable services
• Redirect industry/government assets (people/equipment)
• Loss of revenue</td></tr>
<tr><td>Duration</td><td>Several minutes to several hours</td></tr>
<tr><td>Probability</td><td>High</td></tr>
<tr><td>Seasonal Pattern</td><td>Year-round, but more intense in summer and hurricane season from June 1 to November 30</td></tr>
<tr><td>Speed of Onset</td><td>Slow</td></tr>
<tr><td>Warning Time</td><td>Minutes to hours and days</td></tr>
<tr><td>Repetitive Loss</td><td>N/A</td></tr>
</table>

5.6.1.1. Location

Although most frequent in the Southeast and parts of the Midwest, thunderstorms are relatively common across Northern Virginia and have been known to occur in all calendar months. No one portion of Northern Virginia is more likely than another to experience thunderstorms.

5.6.1.2. Extent

The extent of the High Winds Hazard depends on the assets affected when an event strikes the planning area, as well as the strength of the storm precipitating the high winds. Wind events can cause damage as slight as toppled patio chairs and as severe as uprooted large trees and destroyed structural roofing.

Several tools provide measurement of the magnitude and severity of high winds/severe storm events.

Beaufort Wind Scale

Force levels six through 12 on the Beaufort Wind Scale describe the impact high winds can have on the natural and built environment.

Table 71: Beaufort Wind Scale

Force	Wind (Knots)	WMO Classification	Appearance of Wind Effects
0	< 1	Calm	Calm; smoke rises vertically
1	1-3	Light Air	Smoke drift indicates wind direction; wind vanes still
2	4-7	Light Breeze	Wind felt on face; leaves rustle, vanes begin to move
3	8-12	Gentle Breeze	Leaves and small twigs constantly moving; light flags extended
4	13-18	Moderate Breeze	Dust, leaves, and loose paper lifted; small tree branches move
5	19-24	Fresh Breeze	Small trees begin to sway
6	25-31	Strong Breeze	Larger tree branches moving; whistling in wires
7	32-38	Near Gale	Whole trees moving; resistance felt walking against wind
8	39-46	Gale	Whole trees in motion; resistance felt walking against wind
9	47-54	Strong Gale	Slight structural damage occurs; slate blows off roofs
10	55-63	Storm	Seldom experienced on land; trees broken or uprooted, "considerable structural damage"
11	64-72	Violent Storm	If experienced on land, widespread damage
12	73+	Hurricane	Violence and destruction

Wind Zone Map

FEMA's wind zone map (see Figure 40) shows how extreme windstorms vary in frequency and strength across the United States. The map is based on 40 years of tornado history and over 100 years of hurricane history. Zone IV, the darkest area on the map, has experienced both the greatest number and the strongest tornadoes. Wind speeds in Zone IV can be as high as 250 mph. The planning area in the map is highlighted in green and falls within Zone II, a hurricane-susceptible region where winds can be as high as 160 mph.

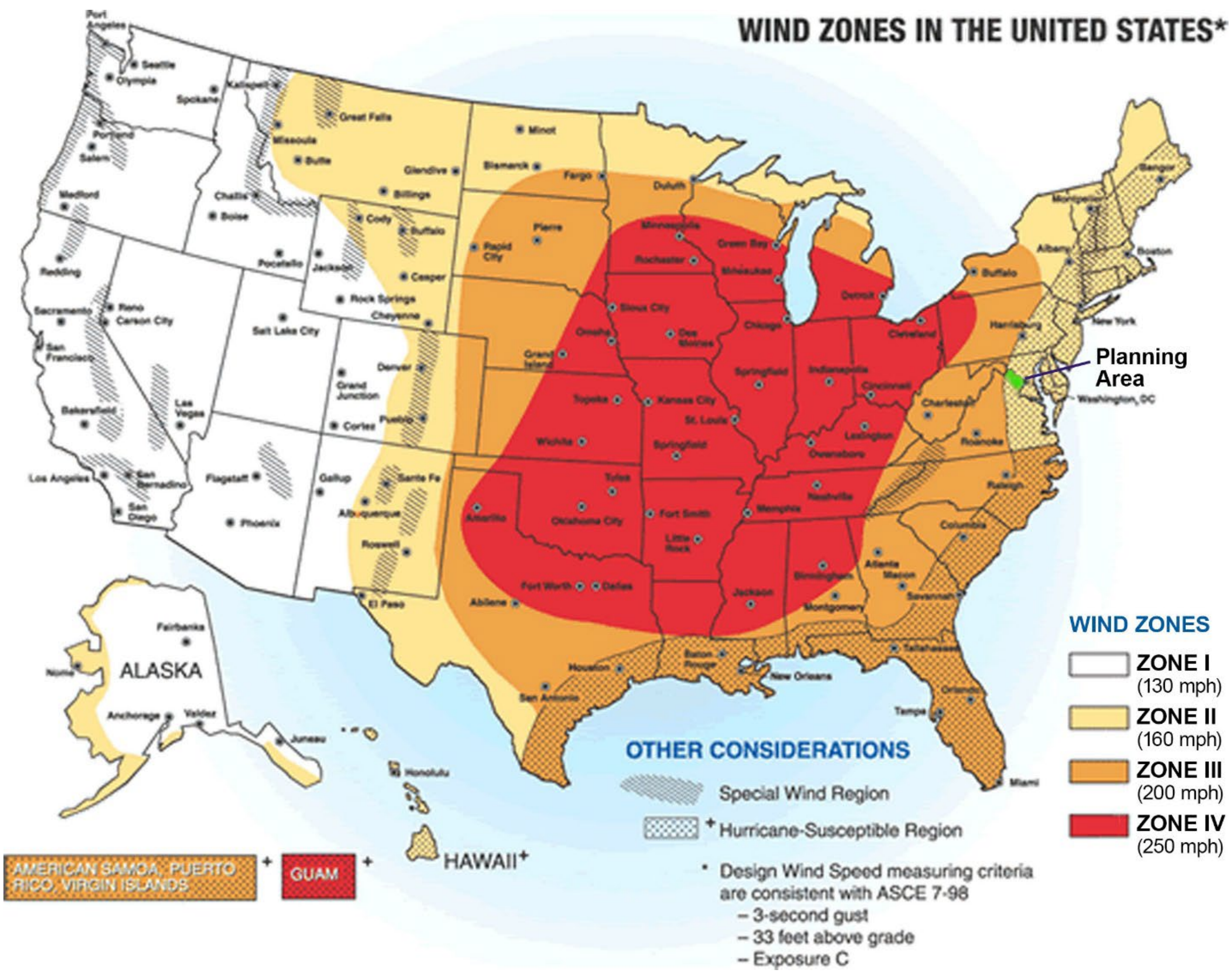

Figure 40: Wind Zones in the United States

5.6.1.3. Previous Occurrences

Numerous severe storm and high wind events have been identified and recorded as reported to NCEI. They have occurred throughout the planning region but have varied widely in terms of location, magnitude, and impact. Where possible, NCEI tracks reports of these events separately by impacted jurisdiction, although it is not always possible to identify damages below a county or city level. In most cases, therefore, damages that were reported for counties and cities include damages that occurred within towns. Damage reports for townships are included in county reports. This report includes over 1,800 separately recorded events that caused approximately $61,543,400 in combined property and crop damage and resulted in 54 reported injuries and six fatalities in the region.

Table 72: High Wind and Severe Storm Events in Northern Virginia, 1950-2021[132]

Jurisdiction	Number of High Wind/ Severe Storm Events	Direct Deaths	Direct Injuries	Property Damage	Crop Damage	Total Property and Crop Damage
Arlington County	182	0	29	$10,350,100	$5,750	$10,355,850
City of Alexandria	65	0	0	$450,000	0	$450,000
City of Fairfax	24	1	0	$87,000	0	$87,500
City of Falls Church	58	0	0	$5,091,000	0	$5,091,000
City of Manassas	33	0	0	$761,500	$2,000	$763,500
City of Manassas Park	1	0	0	$10,000	0	$10,000
Fairfax County *Including Town of Clifton Town of Herndon Town of Vienna*	595	4	17	$29,389,850	$62,250	$29,452,100
Loudoun County *Including Town of Leesburg Town of Lovettsville Town of Middleburg Town of Purcellville Town of Round Hill*	532	1	6	$2,224,650	$219,600	$2,444,250
Prince William County *Including Town of Dumfries Town of Haymarket Town of Occoquan Town of Quantico*	301	0	2	$17,503,450	$81,750	$17,585,200
TOTAL	**1,820**	**6**	**54**	**$65867550**	**$371,350**	**$66238900**

[132] NOAA, National Centers for Environmental Information, High Wind and Severe Storm Events, as of May 31, 2021.

Significant Wind Events

On **May 26, 2021**, fourteen jurisdictions throughout the planning area reported thunderstorm wind occurrences with wind speeds of between 50 and 72 mph. A pre-frontal trough and approaching cold front ignited multiple rounds of severe thunderstorms during the afternoon and evening hours. Some thunderstorms produced significant microbursts. Communities reported a collective damage total of $477,000.

On **July 22, 2020**, reports of damage totaling $136,000 were recorded by NCEI. An upper-level trough interacted with a stalled surface front draped over the Mid-Atlantic, resulting in numerous scattered showers and thunderstorms developing as early as midday in the lee of the Appalachian Mountains. The storms coalesced into a bow echo and moved eastward across central Maryland and Northern Virginia (including the Washington, D.C. metro region) during the midafternoon and exited the area by nightfall.

On **June 23, 2015**, 13 communities in all four Northern Virginia counties, plus the City of Alexandria, were affected by a front that moved south through the region. Southerly flow ahead of the front led to an unstable air mass, which combined with steepening mid-level lapse rates and increased shear leading to numerous severe thunderstorms being triggered ahead of the front. The collective damages reported by all communities equaled $19,000, but all jurisdictions were affected by downed trees and wind gusts of 50 mph and higher.

During the afternoon and evening of Friday **June 29, 2012**, an intense, long-lived line of thunderstorms raced eastward at nearly 60 mph from the Midwest to the Mid-Atlantic coast. In their wake, these storms left behind a swath of destruction that killed at least 20 people, caused millions in property damage, and caused massive power outages in major urban areas along the storm's path. Meteorologists use the term "derecho" to describe this special type of violent and long-lived windstorm.

In addition, with this derecho, communications were disrupted across large areas, including the national Capital/DC region. In northern Virginia, loss of power to a key communications facility knocked out the 911 service for a period of time. Other communications issues were loss of telephone landlines, disruptions to cellular network calling, and scattered outages to internet service among private, government, and commercial sectors.

On **August 5, 2010**, a hot and humid air mass hung over Virginia. A series of upper-level disturbances in a zonal flow passed through the Mid-Atlantic during this time. Showers and thunderstorms developed during the afternoon and evening hours. There was enough instability from the hot and humid air mass to produce thunderstorms accompanied by damaging winds and large hail. Nineteen reports from across the Northern Virginia region indicated a minimum of $125,000 in damage across the region.

On **June 4, 2008**, 41 jurisdictions across the planning region reported damage from thunderstorm winds ranging from 50 to 65 mph. A stalled front residing across the Mid-Atlantic during the afternoon and evening allowed moisture and instability to pool along the boundary. Combined with several strong upper-level disturbances, this resulted in numerous thunderstorms, many becoming severe. While penny-sized hail was reported in spots, damaging winds from the thunderstorms were widespread, and the event spawned several EF-1 tornadoes elsewhere in the state. NCEI-recorded damage to the planning area totaled $288,000, with one reported death.

On **July 2, 2006**, $5,164,000 in damage was reported by nine communities throughout Northern Virginia. A frontal boundary, combined with very strong daytime heating and instability, contributed to scattered severe thunderstorm activity. Much of north-central Virginia, including the Washington, D.C. metro region, experienced damages from the severe thunderstorms. The worst damages occurred in the Annandale area of Fairfax County. An NWS survey team concluded that damages were caused from a wet microburst. Winds associated with the microburst were around 70 mph. Extensive property damage occurred during these storms, including numerous downed trees and powerlines. Local power companies reported more than 100,000 power outages in the Washington, D.C. metro region from this bout of severe weather.

On **March 2, 2018**, a Nor'easter impacted Northern Virginia with sustained winds of 35 mph and gusts up to 70 mph. High wind warnings led to school closures in Prince William and Fairfax counties. Southbound lanes of I-95 were closed due to a large sign that was bent near travel lanes. Air and rail travel were also disrupted, and power outages also affected the region.

On **August 7, 2000**, scattered thunderstorms developed across northeast Virginia during the hot, humid afternoon and evening. These storms produced winds in excess of 55 MPH, large hail, frequent lightning, and heavy rainfall, causing downed power lines that led to widespread loss of electricity. Reported damage from nine communities totaled $933,000.

On **June 24, 1998**, thunderstorm wind damage reported in six locations totaled $1,710,000. Hundreds of trees and power lines were knocked down, and numerous structures incurred minor damage as downburst winds associated with a heavy precipitation supercell (and embedded tornado) raced through the area. The damaging winds were associated with the rear-flank downdraft portion of the storm.

5.6.1.4. Probability of Future Occurrence

Since severe storms are difficult to predict, it is extremely challenging to determine the probability of future occurrences with any degree of accuracy. However, it can be projected that Northern Virginia will continue to experience severe thunderstorms with high frequency. Based on analysis of previous events in the NCEI database, it appears that those events causing injury, death or damage have occurred on a seemingly random basis with no specific portion of Northern Virginia more likely to experience them than any other.

A total of 1,820 high wind events were recorded between 1950 and the first five months of 2021, or roughly 70.5 years. This averages out to 26 hazard events annually, which indicates a high likelihood of future occurrence.

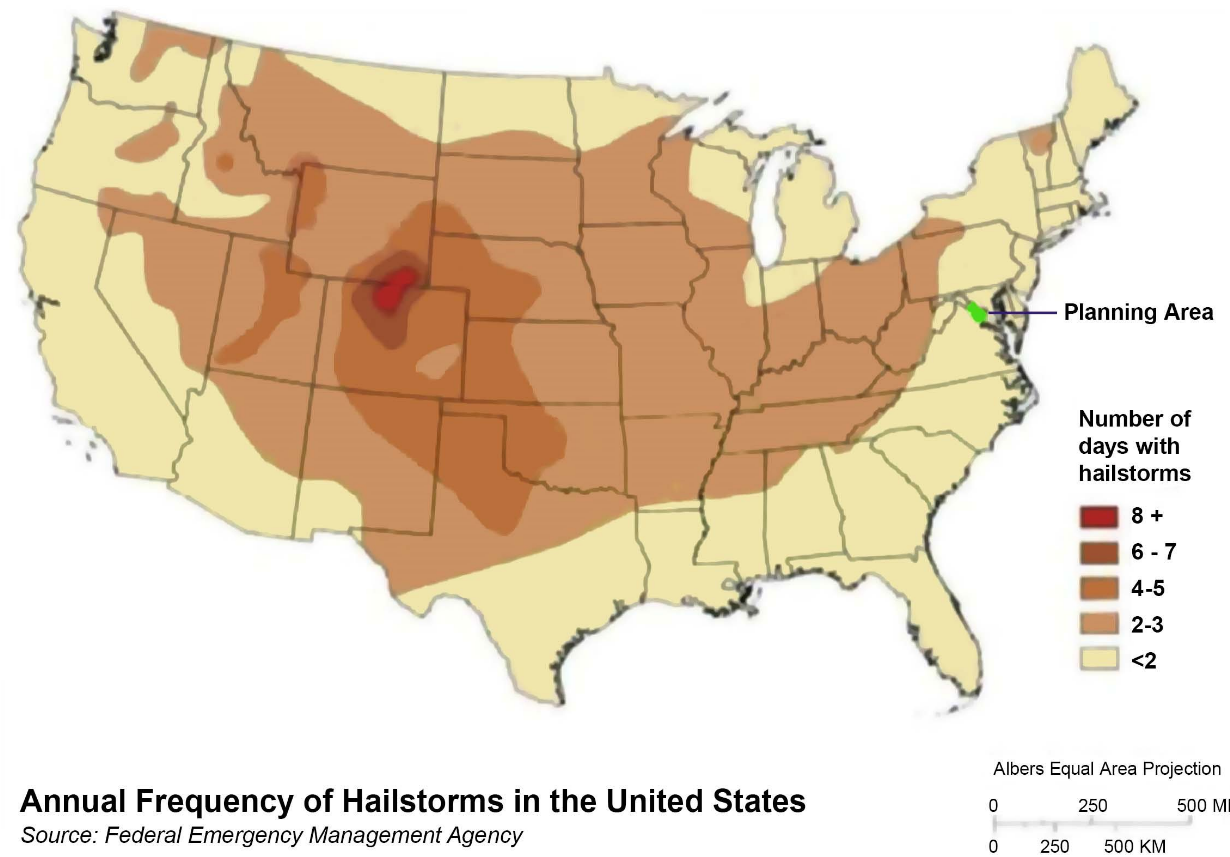

Figure 41: Annual Frequency of Hailstorms in the United States[133]

[133] Federal Emergency Management Agency

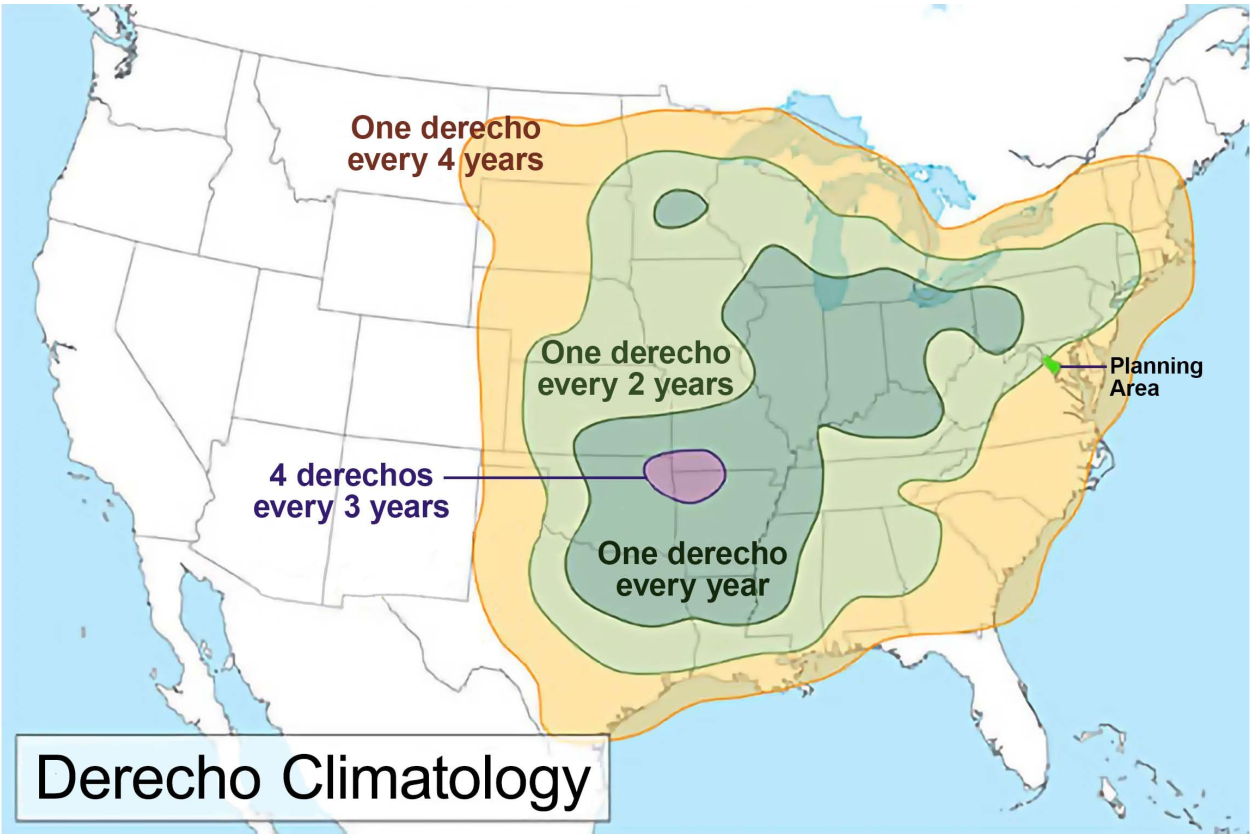

Figure 42: Derecho Climatology in the United States[134]

Based on derecho data from the National Weather Service, the planning area could expect to experience at least one derecho strike every 2-4 years, on average.

Climate Change

Climate change is projected to increase the frequency and intensity of extreme weather events, including severe thunderstorms. Using global climate models and a high-resolution regional climate model, one study that investigated the link between severe thunderstorms and global warming found a net increase in the number of days with environmental conditions that foster the development of severe thunderstorms. This was true for much of the United States, including Northern Virginia.[135]

5.6.2. Risk Assessment: High Winds/Severe Storms

Risk cannot be fully estimated for damaging thunderstorm wind, hail, and lightning events due to the lack of intensity-damage models for these hazards. Instead, financial impacts of damaging thunderstorm events are illustrated using data included from the NCEI Storm Events Database. While multiple communities often submit reports for the same incident, each report describes how the event affected their jurisdiction. During the cited period, there were six deaths and 54 injuries directly related to severe storm events, so the population across the Northern Virginia is at risk. Given the regionwide reported property and crop damages total of $61,543,400, figures show that structures and agricultural assets are at risk of high wind/severe storms.

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[134] National Weather Service Forecast Office, Cleveland, Ohio.
[135] IPCC Changes in Climate Extremems and their Impacts on the Natural Physical Environment https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap3_FINAL-1.pdf

5.6.2.1. People

There are 2,230,623 residents in the planning area, according to the 2010 U.S. Census Bureau figures, the most recently available official data. High winds and severe thunderstorms may affect the entire population, but those living in communities along the Potomac River are particularly at risk from winds and storms approaching from over the waterway. More vulnerable communities include the City of Alexandria, the City of Arlington, and much of Fairfax and Loudoun Counties. In the planning area, the Towns of Lovettsville and Middleburg (Loudoun County) are among the communities that are the farthest from the lower Potomac River (over 30 miles), but they are also situated just a few miles from Occoquan Creek, a Potomac Tributary; thus, inland communities may also be impacted by a hazard event.

Lightning presents a significant threat to human safety and has historically caused injuries and death in the Northern Virginia region. According to the Virginia State Climatology Office, most lightning-related deaths and injuries in Virginia have involved males between the ages of 20 and 40 years old who were caught outdoors on golf courses, ball fields, near open water, or under trees.

5.6.2.2. Built Environment and Community Lifelines

While not a major threat to human safety, hail can be extremely destructive to crops and personal property (particularly vehicles, as well as roofs, siding, and windows of buildings). Most hail damage recorded for the Northern Virginia region has been in Fairfax and Loudoun counties, though all areas are equally at risk.

Quantitative assessment of Community Lifelines for thunderstorm wind risk was not feasible for this update because such events are not geographically specific and are likely to affect the entire planning area. What is known is that age of construction plays a role in vulnerability of facilities to thunderstorm winds. In general, concrete, brick, and steel-framed structures tend to fare better in thunderstorm wind events than older, wood-framed structures. It is important to note that not all critical facilities have redundant power sources, and structures may not be wired to allow the addition of an emergency backup generator for residential or commercial use. Future updates should consider including a more comprehensive examination of critical facility vulnerability to thunderstorm winds; upgrading generator capacity at essential facilities is determined to be a high mitigation priority and is included in the mitigation strategy actions.

Maintaining continuity of operations of transportation, infrastructure, utilities, and government assets is critical to minimizing economic damage that may result from businesses being unable to move equipment or product. Government and private employers must be able to maintain continuity of operations, especially in the Capital region, where thousands of employees perform work that affects national security and other nationwide priorities, as well as for staff in all sectors to carry out mission- and business-critical operations.

Community recreation areas with existing structures are also vulnerable to high wind events. Streetlights, power poles, and shelters set up in the area's federal, state, and local parks are at risk of high winds. The region is a tourist destination for special events held outdoors, so high winds and severe storms may cause damage to temporary tents and stages erected to accommodate such festivities.

Power outages are caused by falling limbs, trees, and poles, by power lines slapping together, and by flying debris, all of which affects property, the population, and the economy.

5.6.2.3. Natural Environment

Communities within the planning area include natural assets vulnerable to high wind. High winds may topple trees, blocking roads, natural wetlands, and run-off areas. Lightning strikes have the potential to ignite wildland fires, causing loss of forested areas as well as structures.

5.6.2.4. Economy

As part of the Capital region, the planning area's economy is driven, in part, by its proximity to Washington, D.C. The already dense commuter traffic could be exacerbated by a high wind or severe storm event, as might area bus and rail transportation systems. Many people living in the suburban counties of the planning area travel to jobs outside the city. Tourist destinations may be affected by a reduced number of visitors and may lose the ability to maintain economic continuity of operations. If these and other attractions and business assets are impacted, they would realize fewer dollars coming from those sources. These include renowned assets such as Old Town Alexandria, Arlington National Memorial Cemetery, and an important Town of Quantico economic asset, the U.S. Marine Corps Base, which is also listed in the National Register of Historic Places.

5.6.3. Vulnerability Analysis: High Winds/Severe Storms

The Northern Virginia region faces uniform susceptibility to the effects of severe thunderstorms, including high winds, lightning, and hail. The buildings most at risk of thunderstorm winds are assumed to include manufactured homes and older residential structures. Another great concern for the Northern Virginia region in relation to high winds is damage to electric power lines; power outages for residents and businesses across the area can disrupt the availability of emergency services, including 911. During past events, storm winds have downed trees across power lines, snapped utility poles, and even blown down transformers, resulting in widespread outages. Downed power lines create a dangerous threat to public safety; although difficult to quantify, long-term power outages can result in significant hardship for residents and major economic impacts for local businesses.

5.6.3.1. Exposure

Because severe storms are not geo-specific, the entire planning area population is exposed to such hazard events.

Building exposures were calculated by the Hazus Hurricane Wind scenario, which identifies the exposure of structures in the planning region that are also at risk of severe storms.

Table 73: Total Building Exposure by General Occupancy, Northern Virginia Region[136]

Occupancy	Exposure ($1000)	Percent of Total
Residential	$287,641,972,000	84.23%
Commercial	$39,194,388,000	11.48%
Industrial	$5,227,982,000	1.53%
Agricultural	$688,752,000	0.20%
Religious	$4,026,943,000	1.18%
Government	$1,401,09,0003	0.41%
Education	$3,334,545,000	0.98%
TOTAL	**$341,515,675,000**	**100.00%**

[136] Hazus Report, Building Stock Exposure by General Occupancy. August 3, 2021.

5.6.4. Hazard Profile: Hurricanes and Tropical Storms

Hurricanes and tropical storms, as well as nor'easters and typhoons, are classified as cyclones and defined as a closed circulation developing around a low-pressure center in which the winds rotate counterclockwise in the Northern Hemisphere (and clockwise in the Southern Hemisphere) and whose eye diameter typically averages 10 to 30 miles across. A tropical cyclone refers to any such circulation that develops over tropical waters. Tropical cyclones act as a safety valve, limiting the continued buildup of heat and energy in tropical regions by maintaining the atmospheric heat and moisture balance between the tropics and the pole-ward latitudes. The primary damaging forces associated with these storms are high-level sustained winds, heavy precipitation, and tornadoes. Coastal areas are also vulnerable to the additional forces of storm surge, wind-driven waves, and tidal flooding, which can be more destructive than cyclone wind.

The key energy source for a tropical cyclone is the release of latent heat from the condensation of warm water. Tropical cyclone formation requires a low-pressure disturbance, warm sea surface temperature, rotational force created by the earth's rotation, and the absence of significant wind shear in the lowest 50,000 feet of the atmosphere. Most hurricanes and tropical storms form in the Atlantic Ocean, Caribbean Sea, or Gulf of Mexico during the official Atlantic hurricane season, which encompasses the months of June through November. The peak of the Atlantic hurricane season is in early to mid-September.

Such events can be dangerous and costly for affected communities, as was learned during Hurricane Isabel in 2003 when the region suffered approximately $32 million in damages (nearly $2 billion statewide). In 2011, the remnants of Tropical Storm Lee impacted Fairfax and Prince William Counties and the City of Alexandria. The storm dropped between five and seven inches of rain over the Northern Virginia area. In Fairfax County, the Virginia Department of Transportation estimated the storm caused approximately $10 million in damages to roads and bridges throughout the county. In late October 2012, Hurricane Sandy blanketed the region with heavy rain and high winds, resulting in downed trees, debris issues, and transportation interruptions.

5.6.4.1. Location

Although the Northern Virginia region rarely experiences the direct impact of a landfalling hurricane, all jurisdictions within the planning area are susceptible to the remnants of such storms, including hurricane- and tropical storm-force winds, heavy rains, and significant storm surge and tidal flooding. Coastal jurisdictions along the Potomac River can also experience storm surge or tidal flooding.

5.6.4.2. Extent

Hurricanes develop when barometric pressure (measured in millibars or inches) at the center of a tropical disturbance falls and winds increase. If the atmospheric and oceanic conditions are favorable, this disturbance can intensify into a tropical depression. When maximum sustained winds reach or exceed 39 mph, the system is designated a tropical storm, given a name, and closely monitored by the National Hurricane Center in Miami, Florida. When sustained winds reach or exceed 74 mph, the storm is deemed a hurricane. Hurricane intensity is further classified by the Saffir-Simpson Scale currently used by NOAA's National Hurricane Center, which rates hurricane intensity on a scale of 1 to 5, with 5 being the most intense (see Table 74).

Saffir-Simpson Hurricane Wind Scale

The Saffir-Simpson scale provides examples of the type of damage and impacts in the United States associated with winds of the indicated intensity. Categories 3, 4, and 5 are classified as "major" hurricanes, and while hurricanes within this range comprise only 20% of total tropical cyclone landfalls, they cause 70% of the damage in the United States.

In general, the extent of damage rises by an estimated factor of four for every category increase.[137] It should be noted that the descriptions of wind-caused damage linked to the scale depend on local building codes and how well they are enforced. The scale does not address other hurricane-related impacts, such as storm surge, rainfall-induced floods, and tornadoes.

Table 74: Saffir-Simpson Hurricane Wind Scale[138]

Category	Sustained Winds	Types of Damage Due to Hurricane Winds
1	74–95 mph 64–82 kt 119–153 km/h	Very dangerous winds will produce some damage. Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap, and shallowly rooted trees may be toppled. Extensive damage to power lines and poles will likely result in power outages that could last several days.
2	96–110 mph 83–95 kt 154–177 km/h	Extremely dangerous winds will cause extensive damage. Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block roads. Near-total power loss is expected with outages that could last from several days to weeks.
3 (major)	111–129 mph 96–112 kt 178–208 km/h	Devastating damage will occur. Well-built frame homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4 (major)	130–156 mph 113–136 kt 209–251 km/h	Catastrophic damage will occur. Well-built frame homes may sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted, and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5 (major)	157+ mph 137+ kt 252+ km/h	Catastrophic damage will occur. A high percentage of frame homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks to months.

A storm surge is a large dome of water often 50 to 100 miles wide and rising anywhere from four to five feet in a Category 1 hurricane to 20 feet or more in a Category 5 storm; it is dependent on the topography of the land being impacted and other storm variables. The storm surge arrives ahead of landfall of the storm's eye, and, in general, the more intense the hurricane is, the higher the surge level. Water rise can be very rapid, posing a serious threat to those who have not yet evacuated flood-prone areas. A storm surge is a wave that has outrun its generating source and become a long period swell. The surge is highest in the right-front quadrant of the direction in which the hurricane is moving. As the storm approaches shore, the greatest storm surge will be to the north of the hurricane eye. Such a surge and associated breaking waves can be devastating to coastal regions, causing severe beach erosion and property damage along the immediate coast.

Hurricanes may also spawn damaging tornadoes and cause inland flooding associated with heavy rainfall that usually accompanies these storms. For example, Hurricane Floyd was at one time a Category 4

[137] National Hurricane Center, The Saffir-Simpson Hurricane Wind Scale, May 2021. Retrieved at: https://www.nhc.noaa.gov/aboutsshws.php
[138] Ibid.

hurricane racing towards the North Carolina coast. As far inland as Raleigh, more than 100 miles from the coast, communities were preparing for extremely damaging winds exceeding 100 mph. However, Floyd made landfall as a Category 2 hurricane and will be remembered for causing the worst inland flooding disaster in North Carolina's history. In Virginia, Floyd dropped 10-20 inches of rain over the southeastern part of the Commonwealth, causing the closure of more than 300 roads from flooding and downed trees. A total of 64 jurisdictions were affected by the more than $255 million in storm damages.[139]

Like hurricanes, nor'easters are ocean storms capable of causing substantial damage to coastal areas in the eastern United States due to their associated strong winds and heavy surf. Nor'easters are named for the winds that blow in from the northeast. These storms track up the East Coast along the Gulf Stream, a band of warm water that lies off the Atlantic coast. They are caused by the interaction of the jet stream with horizontal temperature gradients and generally occur during the fall and winter months when moisture and cold air are plentiful.

Nor'easters are known for dumping heavy amounts of rain and snow, producing hurricane-force winds, and creating high surf that causes severe beach erosion and coastal flooding. There are two main components to a nor'easter: (1) a Gulf Stream low-pressure system (counterclockwise winds) generated off the southeastern coast, gathering warm air and moisture from the Atlantic and pulled up the East Coast while generating strong northeasterly winds along the western forward quadrant of the storm; and (2) an Arctic high-pressure system (clockwise winds) which meets the low-pressure system with cold, air blowing down from Canada. When the two systems collide, the moisture and cold air produce a mix of precipitation and have the potential for creating dangerously high winds and heavy seas. As the low-pressure system deepens, the intensity of the winds and waves will increase and cause serious damage to coastal areas as the storm moves northeast.

Table 75: Dolan-Davis Nor'easter Intensity Scale, with Levels of Coastal Degradation[140]

Storm Class	Beach Erosion	Dune Erosion	Overwash	Property Damage
1 (Weak)	Minor changes	None	No	No
2 (Moderate)	Modest, mostly to lower beach	Minor	No	Modest
3 (Significant)	Erosion extends across beach	May be significant	No	Loss of many structures at local level
4 (Severe)	Severe beach erosion	Severe dune erosion	On low beaches	Loss of structures at community level
5 (Extreme)	Extreme beach erosion	Dunes destroyed over extensive areas	Massive, in sheets and channels	Extensive at regional level; millions of dollars

5.6.4.3. Previous Occurrences

Most hurricanes and tropical storms that affect Virginia originate in the Atlantic Ocean. Since 1851, a total of 32 storms came within 75 miles of the Northern Virginia region. Since 1972, one or more jurisdictions were affected by hurricanes or tropical storms that led to a FEMA Presidential Declaration. These were also awarded for events outside the planning area that caused people to evacuate, temporarily or permanently, to the planning area.

[139] National Weather Service, Wilmington, NC Weather Forecast Office. Hurricane Floyd: September 16, 1999. Retrieved at: https://www.weather.gov/ilm/Floyd
[140] North Carolina Division of Emergency Management

Table 76: Federal Disaster Declarations for Hurricanes and Tropical Storms, Northern Virginia Planning Area[141]

Date of Declaration	Event	Jurisdictions Included in Declaration								
		Arlington County	Fairfax County	Loudoun County	Prince William County	Alexandria, City of	Fairfax, City of	Falls Church, City of	Manassas, City of	Manassas Park, City of
10/15/2018	Hurricane Florence * (EM-3403-VA)	✓	✓	✓	✓	✓	✓	✓	✓	✓
11/26/2012	Hurricane Sandy (DR-4092-VA)	✓		✓	✓	✓		✓	✓	
10/29/2012	Hurricane Sandy (EM-3359-VA)	✓		✓	✓	✓		✓	✓	
11/17/2011	Remnants of Tropical Storm Lee (DR-4045-VA)		✓		✓	✓				
9/3/2011	Hurricane Irene (DR-4024-VA)				✓	✓				
9/12/2005	Hurricane Katrina Evacuation (EM-3240-VA)	✓	✓	✓	✓	✓	✓	✓	✓	✓
9/18/2003	Hurricane Isabel (DR-1491-VA)	✓	✓	✓	✓	✓	✓	✓	✓	✓
10/12/1999	Hurricane Floyd (DR-1293-VA)		✓				✓			
10/23/1996	Hurricane Fran/Severe Storm Conditions (DR-1135-VA)				✓					
6/29/1972	Tropical Storm Agnes (DR-339-VA)	✓	✓	✓	✓	✓	✓	✓		

The planning region may have felt residual or indirect impacts from 36 hurricanes and tropical storms between 1872 and 2020. Hurricane impacts may be felt up to 200 miles away from the center of circulation. Six of these storms were classified as hurricanes (including Isabel in 2003 and Irene in 2011) and 25 as tropical storms as they impacted the region.

[141] FEMA Disaster Declarations for Hurricanes and Tropical Storms, Virginia, 1972 – 2021.

Table 77: Historical Hurricane and Tropical Storms in the Northern Virginia Region, 1851-2021 [142]

Year	Month	Name	Wind Speed (mph)	Intensity
1872	October	Not named	45	Tropical Storm
1874	September	Not named	60	Tropical Storm
1876	September	Not named	80	Category 1
1878	October	"Gale of '78"	105	Category 2
1882	September	Not named	45	Tropical Storm
1883	September	Not named	45	Tropical Storm
1888	September	Not named	50	Tropical Storm
1888	September	Not named	40	Tropical Storm
1893	August	Not named	70	Tropical Storm
1893	October	Not named	90	Category 1
1893	October	Not named	50	Tropical Storm
1896	September	Not named	80	Category 1
1899	October	Unnamed	65	Tropical Storm
1904	September	Unnamed	65	Tropical Storm
1928	September	Unnamed	45	Tropical Storm
1933	August	Unnamed	60	Tropical Storm
1943	October	Unnamed	40	Tropical Storm
1944	August	Unnamed	50	Tropical Storm
1945	September	Unnamed	40	Tropical Storm
1949	August	Unnamed	45	Tropical Storm
1952	September	Able	45	Tropical Storm
1954	October	Hazel	78	Tropical Storm
1955	August	Connie	60	Tropical Storm
1955	August	Diane	65	Tropical Storm
1979	September	David	45	Tropical Storm
1983	September	Dean	45	Tropical Storm
1992	September	Danielle	45	Tropical Storm
1996	July	Bertha	70	Tropical Storm
1999	September	Floyd	45	Tropical Storm
2003	September	Isabel	75	Category 1
2008	September	Hanna	40	Tropical Storm
2011	September	Irene	120	Category 1
2011	September	Lee (remnants)	60	Tropical Storm
2012	October	Sandy	80	Category 1
2018	September	Florence	65	Category 1
2020	August	Isaias	72	Category 1

[142] 2017 Northern Virginia Hazard Mitigation Plan, and National Centers for Environmental Information.

Eight of the historic storms made direct tracks through the region. This includes the “Gale of ’78,” a Category 2 hurricane which is further described under Previous Occurrences. An additional 25 storm tracks for tropical depressions and extratropical systems came within 75 miles of the region. Although some narrative information has been gathered on the impacts of these events, data on estimated property damages could only be accessed through the NCEI since the mid-1990s. These events have amounted to more than $38 million in property and crop damages, most of which is attributable to the effects of storm surge and tidal flooding resulting from the storms.

5.6.4.4. Significant Historic Hurricane Events

Tropical storm and hurricane events discussed in this section affected the planning area overall. Those affecting one or more jurisdictions are included in the jurisdictional annexes.

On **August 4, 2020**, Tropical Storm Isaias moved up the East Coast, creating heavy rainfall and tropical storm-force winds and spawning tornadoes. The storm affected the I-95 corridor, as well as communities further inland. Arlington, Fairfax, and Prince William Counties collectively reported $24,000 in damage, including downed trees and numerous instances of flooding and flash flooding.

On **September 11, 2018**, all jurisdictions in the state of Virginia were included in Federal Emergency Declaration EM-3403-VA for the Public Assistance program in advance of anticipated impact from Hurricane Florence. Tropical storm watches and warnings were issued at various times after 2100 UTC 11 September for the Virginia coast from the North Carolina-Virginia border northward to the mouth of the Chesapeake Bay. Heavy rainfall caused multiple incidents of flash flooding and minor to moderate flooding across the state, although NWS has not recorded dollar amounts of damage in the Storm Events Database.

On **October 29, 2012**, Hurricane Sandy passed Northern Virginia on the way up the Atlantic Coast, before turning northwest and making landfall northeast of Maryland. On the way, Sandy brought high winds and heavy rains to Northern Virginia, resulting in tropical storm-force winds throughout the area, downed trees and power lines, river flooding, and some isolated flash flooding. Some structures were damaged throughout the area, mostly due to falling trees, which displaced some residents.

On **September 4, 2011**, Tropical Storm Lee made landfall in southern Louisiana. Several days later, the remnants of Lee arrived in Northern Virginia. Record rainfall, coming on the heels of Hurricane Irene a few days before, resulted in flooding of most of the creeks and waterways throughout Northern Virginia, leading to an estimated four fatalities, all from drowning. In Manassas Park, one home was displaced in a dry creek bed on the west side of the city.

On **August 27–28, 2011**, Hurricane Irene impacted the entire Northern Virginia area. Widespread power outages impacted utility production and distribution throughout the area, resulting in several utility service providers being offline and leaving tens of thousands of residents and businesses without electrical service. Trees were also downed throughout the area, and some minor flooding was reported, including basement flooding.

On **September 6–7, 2008**, Tropical Storm Hanna made landfall between North and South Carolina on September 6, 2008, with maximum sustained winds of near 70 mph. The storm tracked north and then northeast through eastern Virginia, traveling just to the east of Northern Virginia through the Chesapeake Bay, before moving into the Northeast and New England. As the storm slowly weakened, maximum sustained winds were between 40 and 50 mph at the time of the center’s closest proximity to Northern Virginia. Peak winds across Northern Virginia gusted to between 35 and 45 mph, and the storm produced three to eight inches of rain across the area. Weak or decaying trees were downed, and flooding of low-lying areas was reported.

On **September 18–19, 2003**, Hurricane Isabel made landfall on the North Carolina coast. Its huge wind field was already piling water up into the southern Chesapeake Bay. By the time Isabel moved into central Virginia, it had weakened and was downgraded to a tropical storm. Isabel's eye tracked well west of the bay, but the storm's 40 to 60 mph sustained winds pushed a bulge of water northward up the bay and its tributaries, producing a record storm surge. The Virginia western shore counties of the Chesapeake Bay and the tidal tributaries of the Potomac, Rappahannock, and other smaller rivers experienced a storm surge which reached five to nine feet above normal tides.

On **September 16, 1999**, Hurricane Floyd made landfall just east of Cape Fear, NC and moved across the state of Virginia up through Maryland; the eye of the hurricane passed east of Chesapeake Bay and created wind gusts and heavy rainfall, including 4.57 inches recorded at Washington National Airport (Arlington County). A total of $150,000 in damage was reported by Arlington, Fairfax, and Prince William Counties.

5.6.5. Risk Assessment: Hurricanes and Tropical Storms

5.6.5.1. Probability of Future Occurrences

While Northern Virginia is unlikely to experience a direct hit from a Category 4 or Category 5 hurricane, the region remains susceptible to the effects of such storms making landfall elsewhere along the Atlantic Coast. Hazus-MH models show that the region can expect to see hurricane-force winds (with peak gust wind speeds of up to 59.1 mph) at least once every 50 years. The probabilistic hurricane model for the 1,000-year return period shows peak gusts of 92.2 mph.

Hazard Risk Ranking Summary: High Winds/Severe Storms, Including Hurricanes and Tropical Storms

The hazard ranking process included consideration of probability and consequences in determining an overall risk score and ranking. Information presented within this section and the hazard risk ranking process presents the quantitative and qualitative summary for high winds/severe storms, including hurricanes and tropical storms. The Hazard Identification and Risk Assessment methodology is described in **Section 4, Base Plan.**

Table 78: Hazard Risk Rankings for High Wind/Severe Storms, by Jurisdiction

Hazard	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
Arlington County	2.7	3.0	5.7	High
City of Alexandria	2.7	3.3	6.0	High
City of Fairfax	2.7	3.2	5.9	High
City of Falls Church	2.7	3.2	5.9	High
City of Manassas	2.7	3.2	5.9	High
City of Manassas Park	2.7	3.2	5.9	High
Fairfax County	2.7	3.2	5.9	High
Town of Clifton	2.7	3.2	5.9	High
Town of Herndon	2.7	3.2	5.9	High
Town of Vienna	2.7	3.2	5.9	High
Loudoun County	2.7	3.4	6.1	High

Hazard	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
Town of Leesburg	2.7	3.4	6.1	High
Town of Lovettsville	2.7	3.4	6.1	High
Town of Middleburg	2.7	3.4	6.1	High
Town of Purcellville	2.7	3.4	6.1	High
Town of Round Hill	2.7	3.4	6.1	High
Prince William County	3.3	5.4	8.7	High
Town of Dumfries	2.7	3.2	5.9	High
Town of Haymarket	2.7	3.2	5.9	High
Town of Occoquan	4.0	5.4	9.4	High
Town of Quantico	2.7	3.2	5.9	High

5.6.6. Vulnerability Analysis: Hurricanes and Tropical Storms

Historical data shows that the Northern Virginia region is vulnerable to damaging hurricane and tropical storms. For purposes of this assessment, vulnerability is quantified for hurricane and tropical storm-force winds. For the most part, the Northern Virginia region faces a uniform susceptibility to hurricanes and tropical storm winds. Though historical data and computer models indicate that Fairfax County may on average face higher wind speeds than other areas, the difference in peak gusts is not deemed significant (less than 20 mph). However, based on the higher amount of residential and commercial exposure, Fairfax and Arlington counties are slightly more vulnerable to these winds.

5.6.6.1. Hazus Scenario

The vulnerability analysis for hurricane was completed using the Hazus hurricane wind model, which uses state of-the-art wind field models and calibrated and validated hurricane data. Wind speed has been calculated as a function of central pressure, translation speed, and surface roughness. This assessment is based on a Level 1 analysis using Hazus-provided data with no local data adjustments. This is an acceptable level of information for mitigation planning. Future updates may be enhanced by using Level 2 and 3 analyses, which include additional local data inputs. Dollar values shown in this report provide the cost of an aggregation of building types. In some instances, detailed, building-specific loss estimations were not accessible for smaller communities and their values are included in county-level data. To include them would have required significant local data that was unavailable for this update. Note that storm surge and waves have not been implemented in the present version of the Hurricane Model.

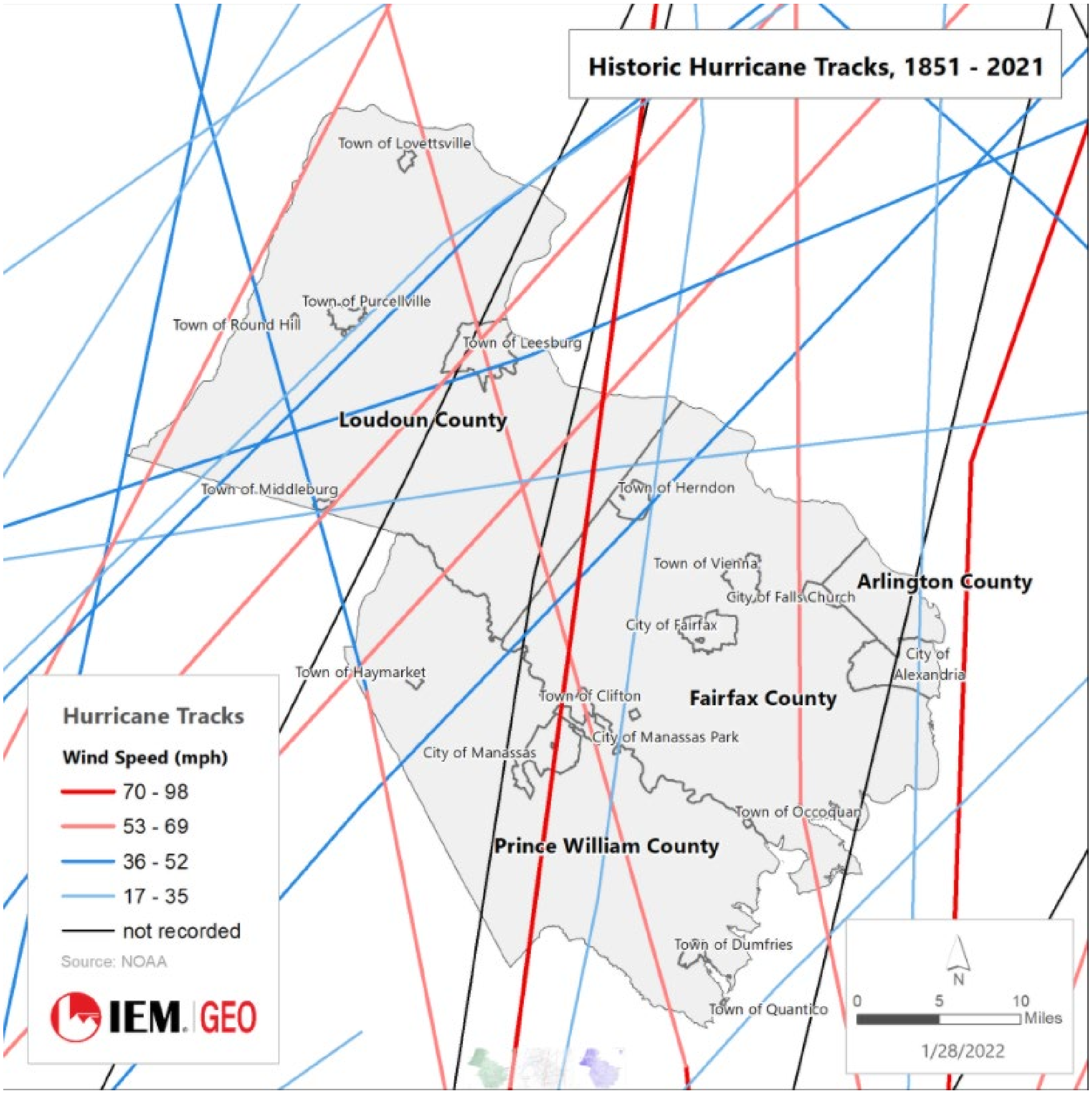

Figure 43: Historic Hurricane Tracks with Critical Facilities, 1851–2021[143]

Loss estimation for this Hazus module is based on specific input data: square footage of buildings for specified types or population, and information about the local economy, used in estimating losses. Additional data and reports generated by Hazus for the planning may be found in **Appendix B**.

143 NOAA, National Hurricane Center, Historic Hurricane Tracks.

Table 79: Hazus Direct Economic Loss Categories and Descriptions[144]

Category Name	Description of Data Input into Model	Hazus Output
Building	Cost per sq. ft. to repair damage by structural type and occupancy for each level of damage	Cost of building repair or replacement of damaged and destroyed buildings
Contents	Replacement value by occupancy	Cost of damage to building contents
Inventory	Annual gross sales in $ per sq. ft.	Loss of building inventory as contents related to business activities
Relocation	Rental costs per month per sq. ft. by occupancy	Relocation expenses (for businesses and institutions)
Income	Income in $ per sq. ft. per month by occupancy	Capital-related incomes losses as a measure of the loss of productivity, services, or sales
Rental	Rental costs per month per sq. ft. by occupancy	Loss of rental income to building owners
Wage	Wages in $ per sq. ft. per month by occupancy	Employee wage loss as described in income loss

The hurricane wind scenario models were run using the Hazus built-in default inventory of assets from the Comprehensive Data Management System (CDMS). No additional, locally reported critical assets were added to the inventory. Therefore, discrepancies may appear if comparing locally generated reports to Hazus reports when considering and listing specific planning elements, such as critical assets and historic occurrences. **Appendix B** includes a description of the methodology used to create the model for the hurricane wind scenarios and the grouping of counties, cities, and towns included in each model.

Additionally, Hazus reports including population data are based on U.S. Census reports utilizing 2010 data, the most recently available official information available from that resource.

Annualized loss is defined as the expected value of loss in any one year. It is developed by aggregating the losses and exceedance probabilities for the 10-, 20-, 50-, 100-, 200-, 500-, and 1000-year return periods. Hazus estimates direct and indirect economic losses due to hurricane wind speeds that include the following:

- Damage to buildings and contents
- Economic loss (business interruptions)
- Social impacts

[144] Hazus Scenario for Hurricane Wind. August 3, 2021.

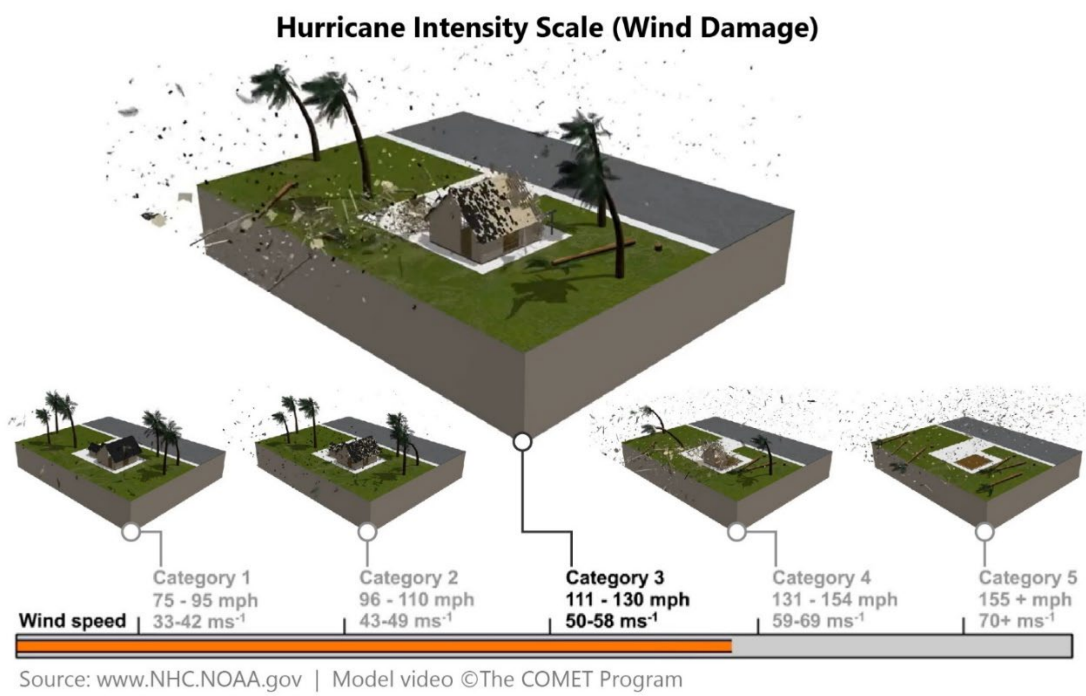

Figure 44: Potential Wind Damage to Building in Major Category 3 Hurricane[145]

Hazus reports included in **Appendix B** illustrate the 3-second peak wind gust speeds for the 100- and 1000-year return periods. Wind speeds are based on estimated 3-second gusts in open terrain at 10 meters above ground at the centroid of each census track. It is mandated that buildings in categories shown in this section must be designed as structurally resilient for a 100-year mean recurrence interval wind event. Among these designated as essential facilities, or facilities with a high degree of exposure, are those that:

- Serve as a congregate area for more than 300 people
- Are used as emergency shelter during a hurricane or other hazard
- House a day care center with capacity greater than 150 occupants
- Are designed for use during emergency preparedness, communication, or emergency operation center or response
- House critical national defense functions
- Contain sufficient quantities of hazardous materials

For Northern Virginia, Hazus wind gust data for the 1000-year and 100-year return period events indicate that the southeastern portions of Northern Virginia are generally more likely to experience the highest wind gusts in both scenarios. This corresponds to the strongest winds associated with hurricanes typically occurring in the storm's right front quadrant (relative to the direction of the storm's movement). For a 1000-year event, southeastern sections of Arlington, Fairfax, and Prince William counties can expect to see gusts topping 90 mph. Although the scenario projects slightly lower wind gusts in western Loudoun County and far western Prince William County, gusts may still exceed 80 mph in both locations. For a 100-year event, wind gusts of nearly 70 mph may affect portions of Fairfax and Prince William counties, with gusts of between 55 and 65 mph expected elsewhere in Northern Virginia.

[145] National Hurricane Center, Saffir-Simpson Hurricane Wind Scale. Retrieved at: https://www.nhc.noaa.gov/aboutsshws.php

Table 80: Direct Economic Annualized Hurricane Building Losses[146]

Jurisdictions	Capital Stock Losses				Income Losses				
	Building Damage	Contents Damage	Inventory Loss	Loss Ratio %	Relocation Loss	Capital Related Loss	Wages Losses	Rental Income Loss	Total Loss
Arlington County, City of Arlington	15,425,000	3,893,000	0	0.05	692,000	2,000	3,000	112,000	20,128,000
Fairfax County	95,769,000	23,052,000	1,000	0.06	4,17,000	5,000	6.000	564,000	123,575,000
Loudoun County	23,570,000	5,396,000	0	0.05	1,18,000	1,000	1,000	174,000	30,325,000
Prince William County	35,903,000	8,722,000	0	0.07	1,729,000	1.000	2,000	247,000	46,603,000
Alexandria, City	11,570,000	2,976,000	0	0.05	528,000	2,000	3,000	88,000	15,168,000
Fairfax, City	2,012, 000	470,000	0	0.04	89,000	0	0	12,000	2,584,000
Falls Church, City	1,343,000	340,000	0	0.06	62,000	0	0	10,000	1,755,000
Manassas, City	2,503,000	601,000	0	0.05	141,000	0	0	21,000	3,266,000
Manassas Park, City	940,000	223,000	0	0.06	56,000	0	0	8,000	1,228,000
TOTAL	**$189,035,000**	**$445,674,000**	**$2,000**	**0.06**	**$8,657,000**	**$13,000**	**$15,000**	**$1,236,000**	**$244,632,000**

[146] Hazus Report: Hurricane Direct Economic Losses for Buildings. July 26, 2021.

5.6.6.2. Community Lifelines Exposure

The Hazus scenario estimates that damage to community lifelines/critical facilities may be negligible during storms of lesser impact, but analyses for the longer return periods show they may be severely damaged.

- The expected loss of use for both healthcare facilities and Emergency Operation Centers following a 100-year event is less than one day for the planning area as a whole. The Hazus hurricane model return periods showed 100% functionality in all jurisdictions following a 10-year, 20-year, 50-year, 100-year, and 1,000-year events.
- The 2021 Hazus model showed that hospitals across the planning area are expected to retain full functionality even during a 1000-year hurricane.

Fire stations, police stations, and schools throughout the planning area may expect to retain a high degree of functionality even during a 1000-year hurricane event and would experience loss of function for less than one day.

The Hazus model also estimates the number of households expected to be displaced from their homes during the hurricane, as well as the number of displaced people who will require accommodations in temporary public shelters. A comparison of shelter needs in each jurisdiction for each event extent included in the Hazus model shows a progressive number of persons displaced and needing shelter for each event category.

Table 81: Displaced Households by Event Extent[147]

Jurisdiction	10-Year	20-Year	50-Year	100-Year	200-Year	500-Year	1000-Year
Alexandria, City	0	0	0	49	383	536	346
Arlington County	0	0	0	63	434	947	652
Fairfax County	0	0	1	466	2,501	9,458	13,578
Fairfax, City	0	0	0	10	40	231	301
Falls Church, City	0	0	0	7	34	103	87
Loudoun County	0	0	5	105	20	2,771	10,380
Manassas, City	0	0	0	6	50	435	1,370
Manassas Park, City	0	0	0	4	21	184	497
Prince William County	0	0	1	118	1,286	4,197	12,102
TOTAL	**0**	**0**	**7**	**828**	**4,769**	**18,862**	**39,313**

[147] Hazus: Hurricane Shelter Summary Report. July 26, 2021.

Table 82: Shelter Needs by Event Extent[148]

Jurisdiction	10-Year	20-Year	50-Year	100-Year	200-Year	500-Year	1000-Year
Alexandria, City	0	0	0	21	172	243	155
Arlington County	0	0	0	28	206	455	317
Fairfax County	0	0	1	275	1,418	5,266	7,565
Fairfax, City	0	0	0	6	22	123	161
Falls Church, City	0	0	0	3	16	51	42
Loudoun County	0	0	5	65	16	1,593	5,924
Manassas, City	0	0	0	6	35	302	953
Manassas Park, City	0	0	0	3	15	132	359
Prince William County	0	0	1	80	833	2,667	7,521
TOTAL	**0**	**0**	**7**	**487**	**2,733**	**10,832**	**22,997**

Debris Generation

Debris estimates for the various Hazus return models indicate that the tonnage of debris generated for a 10- or 20-year event would be negligible, while that generated by a 1,000-year is estimated at 536,264 tons. A 100-year event is expected to generate 63,991 tons of debris. If building debris tonnage is converted to an estimated number of truckloads, it will require 1,284 truckloads (25 tons per truck) to remove the building debris generated by the hurricane. The number of Eligible Tree Debris truckloads will depend on how the 15,668 tons of *Eligible Tree Debris* are collected and processed. The volume of tree debris generally ranges from about 4 cubic yards per ton for chipped or compacted tree debris to about 10 cubic yards per ton for bulkier, uncompacted debris.[149]

5.6.6.3. Existing Buildings and Infrastructure Risk

It is generally assumed that the buildings most at risk from high wind events include manufactured homes and residential buildings constructed in earlier decades and designed to meet less stringent building codes. There may have been a lower degree of code enforcement at the time of construction. If not well-maintained, such buildings may have deteriorated over the years.

Table 83: Building Exposure by Type of Occupancy[150]

Occupancy	Exposure	Percent of Total
Residential	$287,641,972,000	84.23%
Commercial	$39,194,388,000	11.48%
Industrial	$5,227,982,000	1.53%
Agricultural	$688,752,000	0.20%
Religious	$4,026,943,000	1.18%
Government	$1,401,09,0003	0.41%
Education	$3,334,545,000	0.98%
TOTAL	**$341,515,675,000**	**100.00%**

148 Ibid.
149 Hazus: Hurricane Debris Generated Report, July 26, 2021. Reported by event return period.
150 Hazus: Building Stock Exposure by General Occupancy Report. July 26, 2021.

Residential buildings are estimated to receive a majority of the damages from hurricane winds. The more frequent return periods result in fewer damages that fall within the moderate to destruction classifications. The 500- and 1000-year return periods result in severe damage and destruction to buildings in the Northern Virginia region.

Table 84: Number of Residential Buildings/Total Buildings Damaged, by Return Period[151]

Return Period	Damage Level									
	Minor		Moderate		Severe		Destruction		Total	
	Residential	Total	Residential	Total	Residential	Total	Residential	Total	Residential	Total
10	0	0	0		0	0	0	0	0	0
20	0	0	0		0	0	0	0	0	0
50	219	326	5,454	5,454	0	0	0	0	5,673	5,780
100	448	591	32,857	32,857	1	1	0	0	33,306	33,448
200	2,326	2,591	121,667	121,671	1,095	1,095	0	0	125,088	125,358
500	9,623	10,237	354,623	354,654	11,603	11,604	0	0	375,849	376,496
1000	26,619	27,624	481,896	481,981	40,381	40,389	307	307	548,897	550,301

In the case of a 100-year hurricane event, total building losses for Northern Virginia are estimated to run in excess of $4 billion according to the Hazus report *Direct Economic Losses for buildings – 100-year Event*. The same report indicates estimated losses for a 1000-year hurricane event, for which the model estimates regional building loss for the region at over $41 billion. Details for some participating jurisdictions are incorporated into county results reported by the model and could not be reliably separated out in this Level 1 assessment.

[151] Hazus: Hurricane Quick Assessment Report. July 26, 2021.

Table 85: Annualized Building Losses, by Type and Jurisdiction[152]

Jurisdiction	Building Loss	Content Loss	Inventory Loss	Relocation Loss	Income Loss	Rental Loss	Wage Loss	Total Loss
Arlington County	$15,425,000	$3,903,000	0	$692,000	$2,000	$112,000	$3,000	**$20,128,000**
Fairfax County *Including* *Town of Clifton* *Town of Herndon* *Town of Vienna*	$95,769,000	$23,052,000	$1,000	$4,178,000	$5,000	$564,000	$6,000	**$123,575,000**
Loudoun County *Including* *Town of Leesburg* *Town of Lovettsville* *Town of Middleburg* *Town of Purcellville* *Town of Round Hill*	$23,570,000	$5,396,000	0	1,182,000	$1,000	$174,000	$1,000	**$30,325,000**
Prince William County *Including* *Town of Dumfries* *Town of Occoquan*	$35.903,000	$8,722,000	0	1,729,000	$1,000	$247,000	$2,000	**$46,603,000**
City of Alexandria	$11,570,000	$2.976,000	0	$528,000	$2,000	$88,000	$3,000	**$15,168,000**
City of Fairfax	$2,012,000	$470,000	0	89,0000	0	12,000	0	**2,584,000**
City of Falls Church	$1.343,000	$340,000	0	$62,000	0	$10,000	0	**$1,755.000**
City of Manassas	$2,503,000	$601,000	0	$141.000	0	$21,000	0	**$3,266,000**
City of Manassas Park	$940,000	$223,000	0	$56,000	0	$8,000	$0	**$1,228,000**
TOTAL	**$189,035.000**	**$45,674,000**	**$1,000**	**$8,657,000**	**$13,000**	**$123,600**	**$15,000**	**$244,632,000**

[152] Hazus: Direct Economic Losses for Buildings, Annualized Losses Report. July 26, 2021.

Table 86: 100-Year Hurricane Building Losses, by Type and Jurisdiction[153]

Jurisdiction	Building	Contents	Inventory	Relocation	Capital	Wages	Rental	Total
Arlington County	$15,425,000.00	$3,893,000.00	0	$692,000.00	$2,000	$3,000	$112,000	$20,128,000
Fairfax County *Including Town of Clifton Town of Herndon Town of Vienna*	$95,769,000.00	$23,052,000.00	$1,000.00	$4,178,000.00	$5,000	$6,000	$564,000	$123,575,000
Loudoun County *Including Town of Leesburg Town of Lovettsville Town of Middleburg Town of Purcellville Town of Round Hill*	$23,570,000	$5,396,000	0	$1,182,000	$1,000	$1,000	$174,000	$30,325,000
Prince William County *Including Town of Dumfries Town of Occoquan*	$35,903,000	$8,722,000	0	$1,729,000	$1,000	$2,000	$247,000	$46,603,000
City of Alexandria	$11,570,000	$2,976,000	0	$528,000	$2,000	$3,000	$88,000	$15,168,000
City of Fairfax	$2,012,000	$470,000	0	$89,000	0	0	$12,000	$2,584,000
City of Falls Church	$1,343,000	$340,000	0	$62,000	0	0	$10,000	$1,755,000
City of Manassas	$2,503,000	$601,000	0	$141,000	0	0	$21,000	$3,266,000
City of Manassas Park	$940,000	$223,000	0	$56,000	0	0	$8,000	$1,228,000
TOTAL	**$189,035,000**	**$45,674,000**	**$1,000**	**$8,657,000**	**$11,000**	**$15,000**	**$1,236,000**	**$244,632,000**

[153] Hazus: Direct Economic Losses for Buildings, 100-Year Event Report. July 26, 2021.

Table 87: 1000-Year Hurricane Building Losses, by Type and Jurisdiction [154]

Jurisdiction	Building	Contents	Inventory	Relocation	Income	Rental	Wage	Total
Arlington County	$1,050,560,000	$202,349,000	0	$49,194,000	0	$3,823,000	0	**$1,305,927,000**
Fairfax County *Town of Clifton* *Town of Herndon* *Town of Vienna*	$12,881,507,000	$3,504,069,000	$31,000	$695,584,000	$38,000	$67,354,000	$13,000	**$17,148,596,000**
Loudoun County *Town of Leesburg* *Town of Lovettsville* *Town of Middleburg* *Town of Purcellville* *Town of Round Hill*	$6,571,365,000	$2,179,669,000	$72,000	$412,575,000	$463,000	$52,166,000	$171,000	**$9,216,481,000**
Prince William County *Town of Dumfries* *Town of Occoquan*	$7,643,975,000	$2,560,577,000	$55,000	$462,850,000	$227,000	$57,614,000	$135,000	**$10,725,433,000**
City of Alexandria	$642,248,000	$115,292,000	0	$28,885,000	0	$2,148,000	0	**$788,572,000**
City of Fairfax	$296,715,000	$79,210,000	$2,000	$16,627,000	0	$1,583,000	0	**$394,137,000**
City of Falls Church	$121,529,000	$26,177,000	0	$6,144,000	0	$505,000	0	**$154,356,000**
City of Manassas	$690,045,000	$242,493,000	$18,000	$49,686,000	$107,000	$6,801,000	$39,000	**$989,190,000**
City of Manassas Park	$233,893,000	$79,303,000	$6,000	$17,610,000	$13,000	$2,324,000	$5,000	**$333,153,000**
TOTAL	**$30,131,839,000**	**$8,989,139,000**	**$183,000**	**$1,739,155,000**	**$847,000**	**$194,319,000**	**$363,000**	**$41,055,846,000**

[154] Hazus: Direct Economic Losses for Buildings, 1000-Year Event Report. July 26, 2021.

5.6.6.4. Overall Loss Estimates and Ranking

Based on the Hazus models run to cover the planning area, the annualized losses due to hurricanes in Northern Virginia total approximately $245 million. To compute loss, the models used the Hazus probabilistic hurricane scenario, which considers the expected value of loss in any one year and is developed by aggregating the losses and exceedance probabilities for the 10-, 20-, 50-, 100-, 200-, 500-, and 1000-year return periods.

Another method of calculating potential losses from hurricanes and tropical storms is to annualize the NCEI data that documents estimated property and crop losses in Northern Virginia due to severe storm and high wind events, including tropical storms and hurricanes. This method results in annualized losses of approximately $1.5 million. This figure is very low compared to the data produced by the Hazus scenario; however, this can be explained by the fact that the annualized losses take into consideration worst case storms like the 500-year and 1,000-year, which have likely not occurred in the region in the past 70 years. In addition, NCEI data is mostly collected through initial damage reports, which do not account for more detailed follow-up damage assessment data.

Based on this analysis and available data, the high wind/severe storm hazard is ranked as being a hazard of “High” concern for all jurisdictions in Northern Virginia. The high wind/severe storm hazard incorporates thunderstorm winds and hurricane/tropical storm winds along with non-thunderstorm-related wind damage.

Given the widespread nature of the hazard, all counties, cities, and towns were determined to have the same risk of the hazard.

Future Population and Development Trends

Future development and the resulting population increase has the potential to elevate vulnerabilities to high winds/severe storms in the future, depending on climate change variables and jurisdictional ability to manage appropriate growth. An increase in structures and population has the potential to result in a higher threat to the population and higher levels of property damage in future events. The impacts and consequences from previous storm events can serve as a guide for future planning and regulatory actions based on appropriate development in the region’s jurisdictions.

5.6.6.5. Factors for Consideration in the Next Planning Cycle

Future monitoring, evaluating, and updating of this Plan should consider the following questions related to High Winds/Severe Storms, including Hurricanes and Tropical Storms:

- Has more recent data about these hazards been discussed in the Commonwealth COV-SHMP expected to be updated in 2023?
- Have high wind, severe storm, thunderstorm, hurricane, or tropical events been recorded by professional weather experts in the NCEI database or other resources familiar with these hazards?
- Has new scientific research or methodology changed the ability to predict such hazard events?
- Has there been a significant change in the population, built environment, natural environment or economy that could affect the risk or vulnerability to wind-related hazard events?
- Is there new evidence related to the impacts of climate change that could affect the level of risk or vulnerability to wind-related events?
- Review the updated Commonwealth 2023 COV-SHMP update for discussion of new or updated information included in the plan’s section on wind-related events.

5.7. Landslide

2022 HMP Update

The landslide hazard was reviewed, and a new analysis was performed that included but was not limited to the following:

- Reformatting the hazard section to improve flow and clarity.
- Refreshing the hazard profile with updated data, maps, and imagery, where available.
- Updating the assessment of risk and vulnerability by jurisdiction based on new data.
- Ranking the hazard by jurisdiction using the methodology described in Section 4.

Due to the determination of low overall vulnerability, this hazard is minimally profiled, and a comprehensive vulnerability analysis was not justified for this Plan update. Potential changes in risk and vulnerability will be monitored during the next planning cycle.

Table 88: Landslide Profile

<table>
<tr><th colspan="5">Landslide</th><th>Overall Vulnerability</th></tr>
<tr><th colspan="5">Definition, Key Terms, and Overview</th><td rowspan="6">Low</td></tr>
<tr><td colspan="5">Landslide/slope failure is the movement of rock, dirt, and debris down a slope. Landslides are occasionally referred to by other terms, such as creep, debris flow, rock fall, and others.</td></tr>
<tr><th>Frequency</th><th>Probability</th><th colspan="3">Potential Magnitude</th></tr>
<tr><td rowspan="2">Low</td><td rowspan="2">Low</td><th>Injuries/Deaths</th><th>Infrastructure</th><th>Environment</th></tr>
<tr><td>Low</td><td>Low</td><td>Low</td></tr>
</table>

5.7.1. Hazard Profile

The United States Geological Survey (USGS) indicates that landslides occur in every state in the United States and kill between 25 and 50 people every year nationwide. They cause more than $1 billion in damage, making them one of the more costly natural hazards.[155]

Types of movement include rotational, translational, block, fall, topple, avalanche, earth flow, creep, and lateral spreading. Landslide materials in motion generally consist of fractured or weathered rock, loose or unconsolidated soils, and vegetative debris. Landslides may be triggered by both natural and human-caused changes in the environment, including heavy rain, rapid snow melt, steepening of slopes due to construction or erosion, earthquakes, volcanic eruptions, and changes in groundwater levels.

Inadequate storm drainage or leaking water distribution systems may also have the same cumulative effects as extreme storm events in contributing to landslides. The blockage of stream flow may have significant impact on flood potential in topographic settings that constrict the flow of floodwaters during

[155] United States Geological Survey (USGS). https://landslides.usgs.gov/learn/ls101.php

high flow events. Landslides/slope failures affect access and traffic safety during these storm events in addition to causing fatalities and major damage to infrastructure. Landslides/slope failures in developed areas can cause significant damage to buildings and property.

Table 89: Landslide Terms and Definitions[156]

Term	Definition
Block Slide	A block of rockslides as a unit along a slip plane down a slope.
Creep	Slow-moving landslide often noticed only due to crooked trees and disturbed structures.
Debris Landslide	Predominately gravel, cobble, boulder sediments and trees move quickly down slope.
Debris Flow	Coarse sediments flow downhill and spread out over relatively flat areas.
Earth Flow	Fine-grained sediments flow downhill and typically form a fan structure.
Rock Fall	Blocks of rock fall away from a bedrock unit *without* a rotational component.
Rock Topple	Blocks of rock fall away from a bedrock unit *with* a rotational component.
Rotational Slump	Blocks of fine-grained sediment rotate and move down slope.
Slip Plane	A **plane surface** through a crystal, along which **slip** can take place under some conditions without apparently disrupting the crystal.
Transitional Slide	Sediments move along a flat surface without a rotational component.

Mudflows, sometimes referred to as mudslides, lahars, or debris avalanches, are fast-moving rivers of rock, earth, and other debris saturated with water. They develop when water rapidly accumulates in the ground, such as during heavy rainfall or rapid snowmelt, changing the soil into a flowing river of mud or "slurry." Slurry can flow rapidly down slopes or through channels and can strike with little or no warning at avalanche speeds. Slurry can travel several miles from its source, growing in volume as it picks up trees, cars, and other materials along the way. As the flows reach flatter ground, the mudflow spreads over a broad area where it can accumulate in thick deposits.

Among the most destructive types of debris flows are those that accompany volcanic eruptions. A spectacular example in the United States was a massive debris flow resulting from the 1980 eruptions of Mount St. Helens in the State of Washington. Areas near the bases of many volcanoes in the Cascade Mountain Range of California, Oregon, and Washington are at risk from the same types of flows during future volcanic eruptions.

Nationally, landslides are considered a hazard of such concern that a recent federal policy was enacted to broaden the USGS's current activities and enhance coordination with other federal agencies. The *National Landslide Preparedness Act (P.L. 116-323*) was signed into law on January 5, 2021, authorizing a national landslide hazards reduction program. Section 3 of the Act authorizes landslide-related grant programs for research, mapping, assessment, and data collection.

[156] United States Geological Survey (USGS), Landslides Glossary. Retrieved on January 3, 2021, at: https://www.usgs.gov/programs/landslide-hazards/landslides-glossary

Table 90: Hazard Profile Summary

Landslide **Assessment: Low-Risk Hazard**	**Location**	Localized, site-specific	**Potential Cascading Effects (All Site-Specific)**
	Extent	Minimal	• Property damage • Loss of life • Infrastructure damage • Road closures • Environmental impact • Public safety threat
	Duration	Minutes to hours	
	Probability	Low	
	Seasonal Pattern	No seasonal pattern, but may be exacerbated by snow melt in late spring or excessive rainfall events in summer	
	Speed of Onset	Slow to rapid	
	Warning Time	Minutes to hours	
	Repetitive Loss	N/A	

Table 91: Landslide Hazard Ranking Parameters for Northern Virginia Jurisdictions[157]

Jurisdiction	Population Vulnerability	Population Density	Injuries and Fatalities	Property Damage	Crop Damage	Events	Geographic Extent	Total Risk Ranking
Arlington	High	High	Low	Low	Low	Low	Low	Medium-Low
Alexandria, City of	Medium-High	High	Low	Low	Low	Low	Medium-High	Medium
Fairfax, City of	Medium	High	Low	Low	Low	Low	Low	Medium-Low
Falls Church, City of	Low	High	Low	Low	Low	Low	Low	Low
Manassas, City of	Medium	High	Low	Low	Low	Low	Low	Medium-Low
Manassas Park, City of	Low	High	Low	Low	Low	Low	Low	Low
Fairfax County (including towns)	High	High	Low	Low	Low	Low	Low	Medium-Low
Loudoun County (including towns)	High	Medium-High	Low	Low	Low	Low	Medium-High	Medium-Low
Prince William County (including towns)	High	Medium-High	Low	Low	Low	Low	Low	Medium-Low

[157] 2018 Commonwealth of Virginia State Hazard Mitigation Plan, Table 3.13-4.

The potential impacts of landslides depend on the type of landslide that occurs (specific site, slope, gradual, or sudden) and the location where the subsidence occurs. The impacts of landslides occurring in nonurban areas are likely to be less damaging than those that occur in heavily populated locations. The amount of structural damage depends on the type of construction, the structure location and orientation with respect to the landslide location, and the characteristics of the event.

Potential impacts from landslides include damage to residential, commercial, and industrial structures; damage to underground and above-ground utilities; damage to transportation infrastructure, including roads, bridges, and railroad tracks; and damaged or lost crops. The extent and value of the potential damage cannot be assessed because the nature of the damage is site- and event-specific.

5.7.1.1. Hazard Risk Ranking Summary

The hazard ranking process included consideration of probability and consequences of a landslide in determining an overall risk score and ranking. Information within this section and the hazard risk ranking process presents the quantitative and qualitative summary for landslides. The Hazard Identification and Risk Assessment methodology is described in **Section 4, Base Plan.**

Table 92: Hazard Risk Rankings for Landslide, by Jurisdiction

Hazard	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
Arlington County	0	0	0	**NA**
City of Alexandria	1.0	2.5	3.5	**Low**
City of Fairfax	1.0	2.5	3.5	**Low**
City of Falls Church	1.0	2.5	3.5	**Low**
City of Manassas	0	0	0	**Low**
City of Manassas Park	1.0	2.7	3.7	**Low**
Fairfax County	1.0	2.5	3.5	**Low**
Town of Clifton	1.0	2.5	3.5	**Low**
Town of Herndon	1.0	2.5	3.5	**Low**
Town of Vienna	1.0	2.5	3.5	**Low**
Loudoun County	1.3	2.5	3.8	**Low**
Town of Leesburg	0	0	0	**Low**
Town of Lovettsville	1.3	2.5	3.8	**Low**
Town of Middleburg	1.3	2.5	3.8	**Low**
Town of Purcellville	1.3	2.5	3.8	**Low**
Town of Round Hill	1.3	2.5	3.8	**Low**
Prince William County	1.0	2.7	3.7	**Low**
Town of Dumfries	1.0	2.7	3.7	**Low**
Town of Haymarket	1.0	2.7	3.7	**Low**
Town of Occoquan	2.0	2.0	4.0	**Low**
Town of Quantico	1.0	2.7	3.7	**Low**

5.7.1.2. Location

Although mountainous areas in Virginia are the most susceptible to landslide events, they do occur elsewhere in the state, including the Northern Virginia region; however, these events are quite rare and limited in terms of their impact on people and property. Minor landslide events are possible in localized, steep-sloped areas of the Northern Virginia region during extremely wet conditions. These areas are primarily located in western Loudoun County, as well as some areas of moderate risk in extreme eastern areas of Fairfax and Prince William counties.

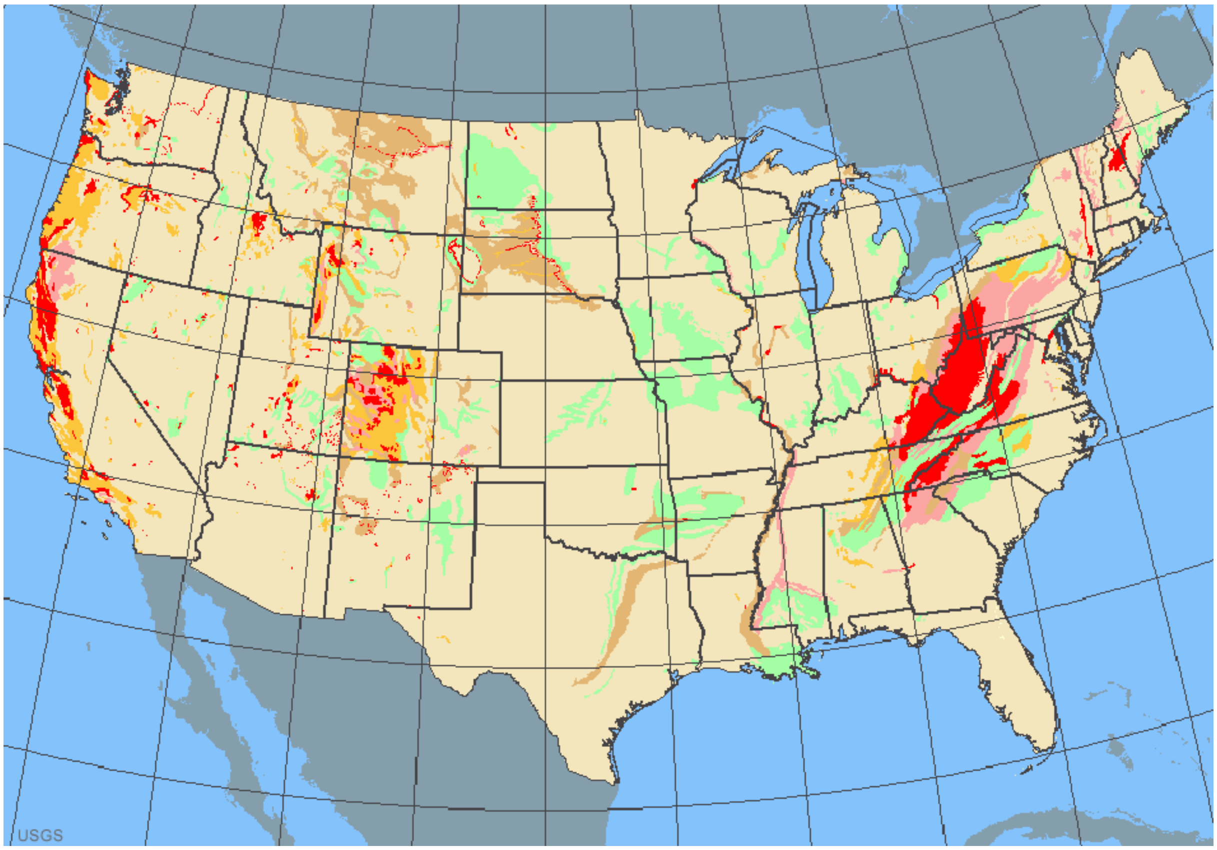

Figure 45: Relative Landslide Incidence and Susceptibility in the Conterminous United States[158]

Figure 45 provides a general indication of where landslide events are most likely to occur in Virginia based on landslide incidence and susceptibility data provided by the USGS and mapped by the Virginia Department of Emergency Management. (Red and pink areas have the highest incidence and susceptibility.)

Localized sites where slopes have been cut through (e.g., to accommodate roads, rail lines, utility lines, or other infrastructure) are susceptible to landslides. In addition, areas that have been previously filled for development may also be susceptible to slope failure, especially when accompanied by heavy rainwater run-off, earthquake, or other ground disturbance caused by human activity.

The U.S. Landslide Inventory provides an interactive map that indicates the level of confidence related to landslide incidents. As indicated on the map, there is one site in the planning area, near Dale City in Prince William County, that has been mapped in the Inventory with a noted level of confidence of "confident consequential landslide at this location."

[158] United States Geological Survey (USGS).

5.7.1.3. Extent

The USGS divides landslide risk into six categories, which are grouped into three broader categories to be used for risk analysis and ranking; geographic extent is based on these groupings. These categories are as follows:

High Risk

- High susceptibility to landslides, and moderate incidence.
- High susceptibility to landslides, and low incidence.
- High landslide incidence (more than 15% of the area is involved in landslide).

Moderate Risk

- Moderate susceptibility to landslide, and low incidence.
- Moderate landslide incidence (1.5%–15% of the area is involved in landslide).

Low Risk

- Low landslide incidence (less than 1.5% of the area is involved in landslide).

Although landslides frequently occur without notice, there are warning signs of potential landslide development, including:

- Slumping or leaning fence posts, utility poles, trees, etc.
- Tension crack visible in the ground surface
- New cracks in building walls
- Newly sagging floors or pavements

5.7.1.4. Historical Occurrences

Although other areas of the state have documented incidents of landslide, the National Centers for Environmental Information (NCEI) indicates no incidents of “debris flow” in the Northern Virginia planning area between 1950 and June 30, 2021. In addition, the *2018 Commonwealth of Virginia Hazard Mitigation Plan (COV-SHMP)* records no incidents within the Northern Virginia jurisdictions through 2015.

5.7.1.5. Probability of Future Events

Landslide probability is highly site-specific and can be only somewhat accurately characterized on a localized basis. Relative risk ranking is intended only for general comparison to the other hazards that impact Virginia.

The probability of occurrence for landslide is dependent on the amount of water present to mobilize the slide, the total size of the slide, and the amount of development in the area that could potentially be impacted. Landslides are more common in areas with steeper slopes (generally greater than 22 degrees) and in poorly drained soils. Some areas that are generally prone to landslides include old landslide sites, base of slopes, base of minor drainage hollows, base or top of old fill slope, base or top of a steep cut slope, and developed hillsides where leach field septic systems are used.

Landslide susceptibility or landslide risk maps can go beyond inventory maps and depict areas that have the potential for landslides. These areas are determined by correlating some of the principal factors that contribute to landslides—such as steep slopes, weak geologic units that lose strength when saturated, and poorly drained rock or soil—with the past distribution of landslides; however, none of these maps are available for the planning area.

5.7.2. Risk Assessment

Landslides can cause serious damage to highways, buildings, homes, and other structures that support a wide range of economies and activities. Landslides commonly coincide with other natural disasters. Expansion of urban development contributes to greater risk of damage by landslides.

5.7.2.1. Built Environment and Community Lifelines

For the purposes of this risk assessment, buildings potentially at risk for landslides were not considered because landslide incidence data is highly generalized owing to the small scale and the scarcity of precise landslide information for much of the country, and is therefore unsuitable for local planning or actual site selection.

5.7.2.2. Natural Environment and Economy

Because some slope stability problems are associated with marine clay in Fairfax County (marine clay becomes loose as moisture content increases, and is subject to slope creep if the natural slope is steepened during site development), the county has identified areas of marine clay and has established regulations requiring special engineering investigations and design procedures in these areas.

Without well-established occurrence probabilities as well as reliable historical data related to impacts, true risk and annualized dollar losses cannot be accurately estimated.

The 2018 COV-SHMP provides a relative risk table for multiple jurisdictions in relation to landslides. The Northern Virginia jurisdictions identified as high- or medium-high risk jurisdictions include the City of Alexandria and Loudoun County.

5.7.2.3. Future Population and Development Trends

Future development and the resulting population increase has the potential to increase landslide vulnerability in the future, depending on site-specific characteristics and interaction with other natural hazards, including variables related to climate change and jurisdictions' capabilities to manage appropriate growth.

With future growth, various non-structural mitigation methods, such as zoning and grading ordinances, as well as structural methods, should be analyzed in terms of cost-effective actions. One such non-structural method to reduce the likely consequences of debris flows would be zoning and grading ordinances to avoid building in areas of potential hazard or to regulate construction to minimize the potential for landslides. Loudoun County has adopted zoning ordinances preventing the development of building sites with steep slopes along the Blue Ridge (defined in the ordinance as exceeding a 15% grade, equivalent to an 8-degree slope), which substantially reduces the hazards of landslides and debris flows within that area.

5.7.2.4. Factors for Consideration in the Next Planning Cycle

Future monitoring, evaluating, and updating of this Plan should consider the following factors related to landslides, as well as other information from the Virginia COV-SHMP:

- Have landslide events occurred within the planning area since the adoption of 2022 HMP?

- Did landslide events occur in areas adjacent to the planning area that impacted the planning area by virtue of their proximity?
- Have new scientific studies, research, or methodology changed the ability to predict landslide events or assess risk and vulnerability?
- Has there been significant change in the population, built environment, natural environment, or economy that could affect the risk or vulnerability to landslides, including expansion of critical infrastructure in landslide-susceptible areas?
- Is there new evidence related to the impacts of landslides that could affect the level of risk or vulnerability?

If risk factors related to landslide increase in the next planning cycle, the *National Landslide Hazards Mitigation Strategy – A Framework for Loss Reduction* (Circular 1244), published by the United States Department of the Interior, United States Geological Survey,[159] provides a comprehensive strategy to identify landslide mitigation options that consider appropriate actions within regulatory, research, detailed engineering studies, public awareness and education, and resiliency through emergency preparedness, response and recovery alternatives.

[159] Spiker, Elliott C., & Gori, Paula L (2003). National Landslide Hazards Mitigation Strategy – A Framework for Loss Reduction (Circular 1244), United States Department of the Interior, United States Geological Survey. https://pubs.usgs.gov/circ/c1244/c1244.pdf

5.8. Sinkhole/Karst

2022 HMP Update

The sinkhole/karst hazard was reviewed, and a new analysis was performed that included but was not limited to the following:

- Reformatting the hazard section to improve flow and clarity.
- Refreshing the hazard profile with updated data, maps, and imagery, where available.
- Updating the assessment of risk and vulnerability by jurisdiction based on new data.
- Ranking the hazard by jurisdiction using the methodology described in Section 4.

Due to the determination of low overall vulnerability, this hazard is minimally profiled, and a comprehensive vulnerability analysis was not justified for this Plan update. Potential changes in risk and vulnerability will be monitored during the next planning cycle.

Table 93: Sinkhole/Karst Summary

Sinkhole/Karst					Overall Vulnerability
Definition, Key Terms, and Overview					Low
Karst: A landscape made up of water-soluble soft rocks such as limestone, dolomite, and gypsum. Rainwater seeping into the rock can result in karst landscapes being worn away from the top or dissolved from weak points inside the rock. Karst landscapes feature caves, sinking or underground streams, and closed depressions on the surface. In the broadest sense, karst encompasses many surface and subsurface conditions that give rise to problems in engineering geology. **Sinkhole:** A natural depression or hole in the land surface formed when underlying rock dissolves and collapses. Sinkholes generally occur in limestone regions and are connected to subterranean passages. Sinkholes are often caused by groundwater enlarging cavities in an underlying bedrock of highly soluble limestone.					
Frequency	Probability	Potential Magnitude			
		Injuries/Deaths	Infrastructure	Environment	
Low	Low	Low	Low	Low	

5.8.1. Hazard Profile

Sinkholes are a frequent occurrence in karst areas underlain by calcareous carbonate formations, especially limestone and dolomite. Groundwater flows through cracks, fissures, joints, and other discontinuities in the rock mass, dissolving the carbonate minerals and creating small voids. Over time, continued water seepage and dissolution of minerals enlarges the void to form caves and caverns in the rock. As the void increases in size, so does the load supported by the void roof. If the strength of the roof layer becomes less than the weight of the material above it, the roof fails, and the overburden materials collapse into the void. When the collapse manifests itself at the surface, the resulting depression is referred to as a "sinkhole." Other calcareous carbonate materials include partially to well-cemented shell formations found in coastal areas of the southeastern United States.

The process of sinkhole formation depends on a complex set of variables including geologic structure, geochemistry, hydrologic conditions, and development activity. If the roof above the void is sound rock and the water level falls below the roof level, future growth of the void may not reduce the roof thickness and collapse may not occur. However, if the roof rock is fractured or otherwise cracked, shallow groundwater from above can flow into the void, bringing with it eroded overburden soil. The erosion of overburden soil into the rock void creates a corresponding soil void that can migrate to the surface, resulting in a collapse of the soil roof even though the underlying rock has not collapsed.

Changes in hydrologic conditions, whether natural or man-made, can increase the occurrence of sinkholes. An increase in the volume and/or velocity of flow through the rock brings more fresh water to dissolve soluble minerals and more energy to erode solid particles, expanding existing voids or creating new ones. Water supply and open-pit mining are common reasons for pumping large volumes of water through soluble calcareous formations.

Sinkholes vary in size, ranging from a few feet to a mile or more in diameter, and can reach several hundred feet below the surface. Areas of abundant sinkholes are referred to as "karst topography." Karst areas have few surface streams because drainage is primarily through underground solution channels.

Sinkholes can also occur in most geologic environments—including those not underlain by calcareous carbonate rocks—due to the impacts of constructed facilities. Undetected leaks in underground utility lines can result in subsurface erosion of soil from around the pipe. Left undetected, the erosion creates a void that expands upward until the soil roof cannot support the overburden load and the roof collapses.

Major natural hazards such as extreme storm events, flooding, seismic events, and wildfire can trigger an incident. Inadequate storm drainage or leaking water distribution systems may have the same cumulative effect as extreme storm events. The blockage of stream flow may have a significant impact on flood potential in topographic settings that constrict the flow of floodwaters during high-flow events. In addition to fatalities and the costs of repair to infrastructure, sinkholes also compromise access and traffic safety during these same storm events. Sinkholes in developed areas can cause significant damage to buildings and property.

Table 94: Hazard Profile Summary

<table>
<tr><td rowspan="8">Sinkhole/Karst Assessment: Low-Risk Hazard</td><td>Location</td><td>Localized, site-specific</td><td>Potential Cascading Effects (all site-specific)</td></tr>
<tr><td>Extent</td><td>Minimal</td><td rowspan="7">• Property damage
• Infrastructure damage
• Road closures
• Environmental impact
• Public safety threat</td></tr>
<tr><td>Duration</td><td>Minutes to hours</td></tr>
<tr><td>Probability</td><td>Low</td></tr>
<tr><td>Seasonal Pattern</td><td>No seasonal pattern, but may be exacerbated by snow melt in late spring or excessive rainfall events in summer</td></tr>
<tr><td>Speed of Onset</td><td>Slow to rapid</td></tr>
<tr><td>Warning Time</td><td>Minutes to hours</td></tr>
<tr><td>Repetitive Loss</td><td>N/A</td></tr>
</table>

5.8.1.1. Hazard Risk Ranking Summary

The hazard ranking process included consideration of probability and consequences of sinkholes/karst in determining an overall risk score and ranking. Information within this section and the hazard risk ranking process present the quantitative and qualitative summary for sinkhole-karst. The Hazard Identification and Risk Assessment methodology is described in **Section 4, Base Plan.**

Table 95: Hazard Risk Rankings for Sinkhole/Karst, by Jurisdiction

Hazard	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
Arlington County	1.3	2.7	4.1	Low
City of Alexandria	1.0	2.5	3.5	Low
City of Fairfax	1.0	2.5	3.5	Low
City of Falls Church	1.0	2.5	3.5	Low
City of Manassas	1.0	2.5	3.5	Low
City of Manassas Park	1.0	2.5	3.5	Medium
Fairfax County	1.0	2.5	3.5	Low
Town of Clifton	1.0	2.5	3.5	Low
Town of Herndon	1.0	2.5	3.5	Low
Town of Vienna	1.0	2.5	3.5	Low
Loudoun County	1.0	2.5	3.5	Low
Town of Leesburg	1.0	2.5	3.5	Low
Town of Lovettsville	1.0	2.5	3.5	Low
Town of Middleburg	1.0	2.5	3.5	Low
Town of Purcellville	1.0	2.5	3.5	Low
Town of Round Hill	1.0	2.5	3.5	Low
Prince William County	1.0	2.5	3.5	Low
Town of Dumfries	1.0	2.7	3.7	Low
Town of Haymarket	1.0	2.7	3.7	Low
Town of Occoquan	2.0	3.2	5.2	Medium
Town of Quantico	1.0	2.7	3.7	Low

5.8.1.2. Location

Sinkholes are prevalent in the Great Valley region of central Virginia, including karst terrains in the Shenandoah Valley, where voids are formed by the natural dissolution of soluble rock such as limestone and dolomite.

According to the Virginia Department of Mines, Minerals and Energy, sinkholes are very rare in the Northern Virginia region and do not pose a significant risk. However, a band of metamorphosed limestone, dolostone, and marble is located in eastern Loudoun County and the Town of Leesburg, which has a history of sinkhole activity. The karst regions in Northern Virginia are classified as “short karst,” which includes fissures, tubes, and caves generally less than 1,000 feet long and 50 feet or less in vertical extent.

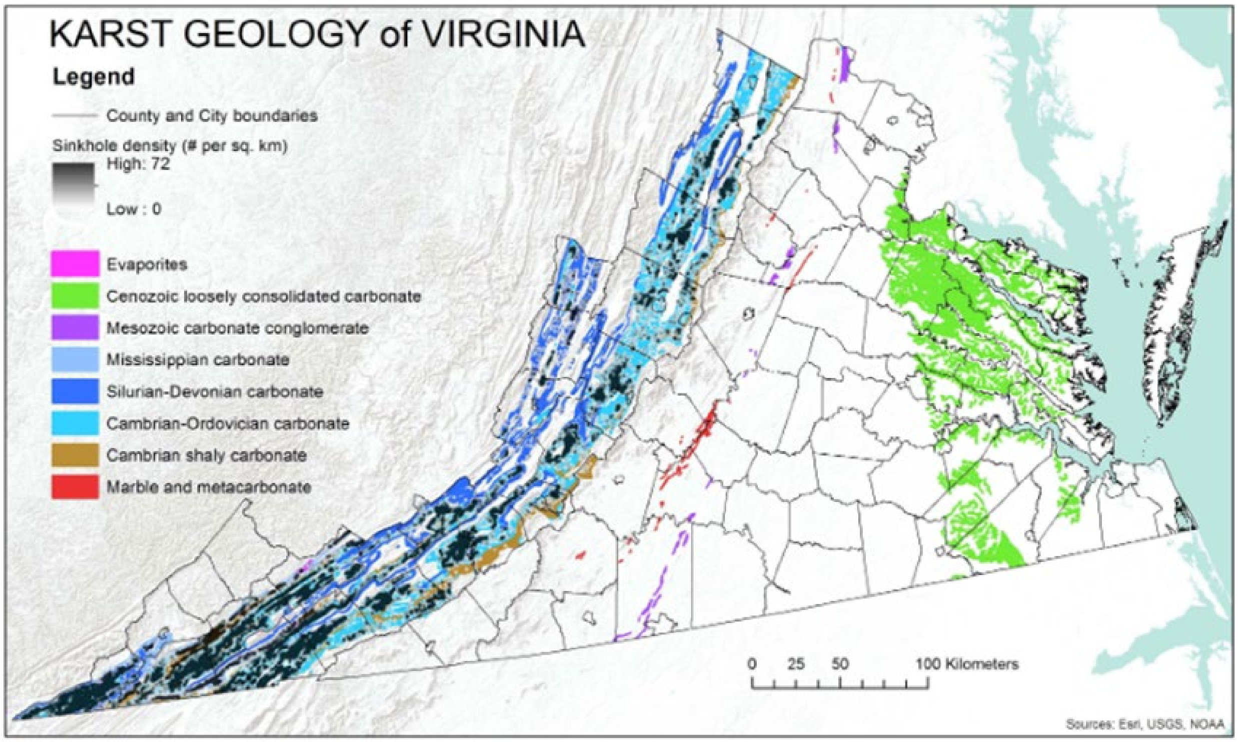

Figure 46: Karst Regions and Historical Subsidence in Virginia[160]

Loudoun County has a region of karst geology located in an area roughly one mile on either side of State Route 15 from just south of Leesburg, north to the Potomac River Bridge. The region is bounded sharply to the west by the Bull Run Fault, which runs at the base of Catoctin Mountain through Loudoun County. The area is primarily composed of the following geologic formations:

- Frederick Limestone
- Tomstown Dolomite
- Catharpin Creek Formation
- Catharpin Creek Formation Goose Creek Member
- Balls Bluff Siltstone Leesburg Member

160 [A Resident's Guide to Sinkholes (virginia.gov)]

Figure 47: Loudoun County Limestone District[161]

5.8.1.3. Extent

Although sinkholes frequently occur without notice, there are warning signs of potential sinkhole development, including the following:

- Slumping or leaning fence posts, utility poles, trees, etc.
- Discolored vegetation

[161] 2017 Northern Virginia Hazard Mitigation Plan

- Visible tension cracks in the ground surface
- Discolored well water
- New cracks in building walls
- Newly sagging floors or pavements

Sinkhole formation is aggravated and accelerated by urbanization, which increases water usage, alters drainage pathways, overloads the ground surface, and redistributes soil. According to FEMA, the number of human-induced sinkholes has doubled since 1930, costing nearly $100 million. However, the apparent increase in sinkhole frequency may be attributable to reporting biases. Changes in ground water levels increase the overburden stress on the void roof, increasing the potential for roof collapse; thus, using that period as indicating a larger trend may not be appropriate, especially given the context of the initial data. Furthermore, naturally occurring sinkholes under expensively developed real estate result in higher insurance payouts and increase premiums, or loss of coverage for property owners.

5.8.1.4. Previous Occurrences

Sinkholes may occur in localized areas of the Northern Virginia region; however, most are shallow and tend to be caused by soil washed away under the ground surface due to flash flooding or broken utility lines, rather than karst conditions. To date, there have been no Federal Declared Disasters in Virginia for sinkholes/karst.

Since 2017, three sinkholes in the planning area have been reported by local media sources:

- On **August 8, 2021**, a sinkhole was discovered outside of Leesburg on Route 15. The road was temporarily closed for repairs by the Virginia Department of Transportation.[162]
- On **August 12, 2020**, a large sinkhole, caused by flash flooding from a heavy rainfall, was reported in Manassas Park. It was estimated at 50 feet by 100 feet and washed a parked car into a nearby creek. The sinkhole temporarily blocked access to a community of about 400 residents.[163]
- In **April 2015**, a sinkhole opened in the Exeter Community of Loudoun County. The hole, which measured approximately 30 by 40 feet, formed in the parking lot of a townhouse community, and caused some damages, including the sinking of the roadway and disruption of water service to approximately 65 structures in the area. Reports indicate this was the second sinkhole in this same area in the previous two decades.

Other known events, although not comprehensive, were documented in the 2017 NOVA HMP. These include the following:

- In **June 2014**, heavy rain caused the collapse of a major thoroughfare in Loudoun County. The collapse occurred on Dry Mill Road and exposed a 48-inch water main, resulting in a five-mile detour for motorists.
- In **2008**, a sinkhole 20 feet deep and 25 feet wide closed Dale Boulevard west of Mapledale Avenue, about four miles from Interstate 95 in Prince William County.
- On **August 11, 2001**, heavy rainfall washed out a culvert and created a sinkhole in Arlington County; no damages were reported.

No karst events in Northern Virginia are identified in the 2018 COV-SHMP.

[162] Loudounnow.com. July 8, 2021. https://loudounnow.com/2021/07/08/rt-15-business-to-close-due-to-sinkhole/
[163] Hedgpeth, Dana. The Washington Post. Large sinkhole forms in Northern Virginia as flash flooding prompts water rescues. August 12, 2020. https://www.washingtonpost.com/dc-md-va/2020/08/12/sinkhole-manassas-virginia-flooding/

5.8.1.5. Probability of Future Events

It is impossible to predict incidents of land subsidence with precision; they can occur suddenly and without warning or over an extended period of several years. However, some factors associated with a decrease in roof strength are wet conditions, vibrations, and increased surface loading. Land subsidence resulting from a drawdown of the groundwater table is likely to occur over a number of years. Procedures for predicting the occurrence of land subsidence have not yet been developed.

To include karst in the risk assessment, some general assumptions were made. Geographical Extent, using USGS Karst Topography maps, was the primary basis for establishing risk and was calculated as a percent of the jurisdictional area. In lieu of probability of future occurrence, areas with more karsts were assumed to be at greater risk.

5.8.2. Risk Assessment

As discussed previously, sinkholes are relatively uncommon events in the Northern Virginia region. The existing soil types are not conducive to creating natural sinkholes, and those sinkholes that do occur are related to soil piping or the dissolution of sparse carbonate rock and typically cause very little damage. There are no known sources of sinkhole probability data for the region and no record of historical incidences causing property damages.

5.8.2.1. Built Environment and Community Lifelines

The vulnerability of each identified critical facility was assessed for the 2017 NOVA HMP update using GIS analysis by comparing their physical location with the extent of known hazard areas that can be spatially defined through GIS technology. Of those critical facilities identified in the region, some were determined to be in known hazard areas upon further GIS analysis and thereby determined to be "potentially at risk." This assessment was not updated for 2022 because there have been no significant changes in the physical locations of the facilities.

Loudoun County maintains a karst feature database (developers in the County are responsible for mapping karst features to determine whether all requirements or ordinances and provisions have been met). For applications within the LOD, all documentation and studies are outlined in Section 4-1900 of the zoning ordinance. This organization allows Loudoun County to significantly reduce sinkhole risk to facilities, property, and people.

Using the Limestone Layer available through Loudoun County's website, mapped critical assets in Loudoun County were viewed via the County's GIS portal. Of the mapped critical assets—which include schools, fire stations, police stations, other public safety assets, and emergency medical assets—at least one fire station was found to be located within the known limestone area of Loudoun County.

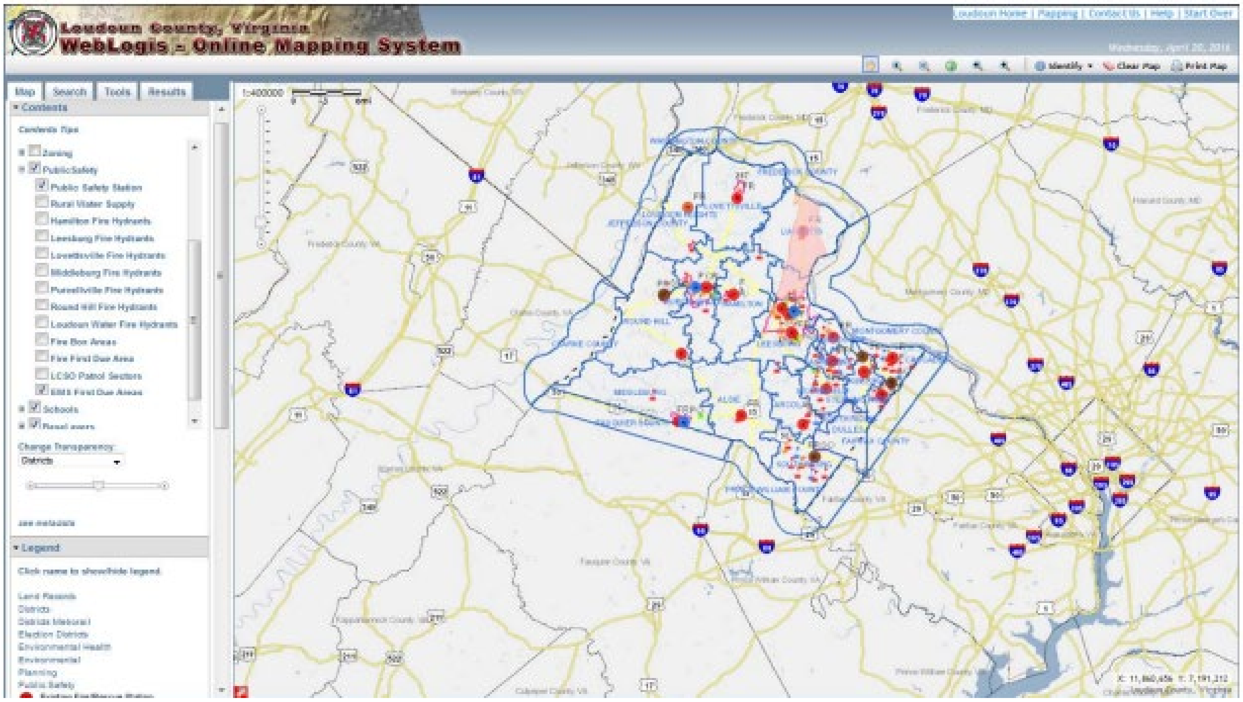

Figure 48: Loudoun County Limestone Overlay District and Critical Assets Map[164]

Loss estimates could not be calculated for sinkhole/karst events due to a lack of detailed and accurate information regarding structures and assets located in the previously determined hazard areas. In addition, due to the extremely localized and site-specific nature of typical karst events, any inventory of potential at risk structures may grossly over-estimate potential losses.

The *2018 COV-SHMP* provides a relative risk table for multiple jurisdictions in relation to sinkholes/karst. All jurisdictions in the planning area were determined to be medium-low or low risk for sinkholes/karst.

5.8.2.2. Future Population and Development Trends

Future development and resulting population increase have the potential to elevate vulnerabilities to sinkholes/karst in the future, depending on site-specific characteristics and interaction with other natural hazards, including variables related to climate change and jurisdictions' capabilities to manage appropriate growth.

With future growth, various non-structural mitigation actions—such as zoning and grading ordinances as well as structural methods—should be analyzed in terms of cost-effective mitigation alternatives. One non-structural method to reduce the likely consequences of debris flows would be zoning and grading ordinances to avoid building in areas of potential hazard or to regulate construction to minimize the potential for sinkholes/karst.

Loudoun County has adopted an LOD in its zoning ordinance that seeks to preserve and protect the unique geologic characteristics and the quality of the groundwater in its limestone area. The ordinance is intended to regulate land use and development in areas underlain by limestone and in areas with karst features and karst terrain in such a manner as to:

- Protect the health, safety, and welfare of the public;

[164] 2017 Northern Virginia Hazard Mitigation Plan, Figure 4.48.

- Protect groundwater and surface water resources from contamination; and
- Reduce potential for property damage resulting from subsidence or other earth movement.

5.8.2.3. Factors for Consideration in the Next Planning Cycle

Future monitoring, evaluating, and updating of this Plan should consider the following factors related to sinkholes/karst, as well as other information from the Virginia COV-SHMP:

- Have sinkhole/karst events occurred within the planning area since the adoption of 2022 HMP?
- Did sinkhole/karst events occur in areas adjacent to the planning area that impacted the planning area by virtue of their being in proximity?
- Have new scientific studies, research, or methodology changed the ability to predict sinkhole/karst events or assess risk and vulnerability?
- Has there been significant change in the population, built environment, natural environment, or economy that could affect the risk or vulnerability to sinkholes/karst, including expansion of critical infrastructure in landslide-susceptible areas?
- Is there new evidence related to the impacts of sinkholes/karst that could affect the level of risk or vulnerability?

5.9. Tornado

2022 HMP Update

The 2022 Plan updated continued to incorporate formatting changes and analyses implemented in the 2017 Plan. These changes include, but were not limited to the following:

- Refreshing the hazard profile
- Updating the previous occurrences
- Determining the number of hazard events and losses by jurisdiction using NCEI and other data sources (where available)
- Updating the assessment of risk by jurisdiction based on new data
- Ranking of the hazard by jurisdiction using the methodology described in Section 4
- Reformatting sections to improve clarity and, as available and appropriate, incorporate new maps and imagery

Table 96: Tornado Profile

<table>
<tr><th colspan="5">Tornado</th><th>Overall Vulnerability</th></tr>
<tr><th colspan="5">Definition, Key Terms, and Overview</th><td rowspan="6">Medium</td></tr>
<tr><td colspan="5">Tornado: A violent windstorm characterized by a twisting, funnel-shaped cloud extending to the ground. Tornadoes are most often generated by thunderstorm activity (but sometimes result from hurricanes and other tropical storms) when cool, dry air intersects and overrides a layer of warm, moist air, forcing the warm air to rise rapidly.

Funnel Cloud: A rotating column of air like that of a tornado; however, the column does not touch the ground.

Waterspout: A tornado that forms over warm water and may move inland.</td></tr>
<tr><th rowspan="2">Frequency</th><th rowspan="2">Probability</th><th colspan="3">Potential Magnitude</th></tr>
<tr><th>Injuries/Deaths</th><th>Infrastructure</th><th>Environment</th></tr>
<tr><td rowspan="1">Low</td><td>Moderate</td><td>Low</td><td>Moderate</td><td>Low</td></tr>
</table>

5.9.1. Hazard Profile

A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud extending to the ground. Tornadoes are most often generated by thunderstorm activity (but sometimes result from hurricanes and other tropical storms) when cool, dry air intersects and overrides a layer of warm, moist air, forcing the warm air to rise rapidly. The damage caused by a tornado is a result of the high wind velocity and wind-blown debris, also accompanied by lightning or large hail. According to the National Weather Service (NWS), tornado wind speeds normally range from 40 to more than 300 miles per hour.

The most violent tornadoes have rotating winds of 250 miles per hour or more and can cause extreme destruction, turning ordinary objects into deadly missiles.

On average, more than 800 tornadoes are reported each year in the U.S., according to the National Oceanic and Atmospheric Agency (NOAA), resulting in an average of 80 deaths and 1,500 injuries annually. Tornadoes are more likely to occur during the spring and early summer months of March through June, but they can also develop in other months. They are also more likely to form in the late afternoon and early evening but can occur at any time of day. Most tornadoes are a few dozen yards wide and touch down only briefly; however, even small, short-lived tornadoes can inflict tremendous damage. Highly destructive tornadoes can carve out a path of devastation more than a mile wide and several miles long.

Tornado Warning vs. Watch[165]

- **Tornado Watch:** Be Prepared! Tornadoes are possible in and near the watch area.
- **Tornado Warning:** Take Action! A tornado has been sighted or indicated by weather radar. There is imminent danger to life and property.

Waterspouts are weak tornadoes that form over warm water; they are most common along the Gulf Coast and southeastern states where the water is warmer. Waterspouts occasionally move inland, becoming tornadoes that cause damage and injury. However, most waterspouts dissipate over the open water, causing threats only to marine and boating interests. Typically, a waterspout is weak and short-lived, and because they are so common, most go unreported unless they cause damage.

The destruction caused by tornadoes ranges from light to devastating, depending on the intensity, size, and duration of the storm. Typically, tornadoes cause the greatest damage to structures of light construction such as residential homes (particularly mobile homes) and tend to remain localized in impact. The Fujita–Pierson Scale for Tornadoes (F Scale) was developed in 1971 to rate tornado intensity based on associated damages. The Enhanced Fujita Scale (EF Scale) was developed and implemented operationally in 2007.

Table 97: Hazard Profile Summary

<table>
<tr><td rowspan="8">Tornado

Assessment: Medium-Risk Hazard</td><td>Location</td><td>Jurisdiction-wide</td><td>Potential Cascading Effects</td></tr>
<tr><td>Extent</td><td>Minor to significant</td><td rowspan="7">• Impact on infrastructure, including roads and bridges
• Impact on critical facilities, such as bridges, major roadways, water, and wastewater treatment plans
• Loss of natural resources
• Economic losses if businesses must close because employers or employees are unable to reach the workplace</td></tr>
<tr><td>Duration</td><td>Several minutes</td></tr>
<tr><td>Probability</td><td>Moderate</td></tr>
<tr><td>Seasonal Pattern</td><td>Typically, March through November</td></tr>
<tr><td>Speed of Onset</td><td>Slow to rapid, depending on conditions</td></tr>
<tr><td>Warning Time</td><td>None, or a few minutes</td></tr>
<tr><td>Repetitive Loss</td><td>N/A</td></tr>
</table>

165 Understand Tornado Alerts (weather.gov)

5.9.1.1. Location

Tornadoes are a non-spatial hazard, meaning they can occur anywhere in the planning area and may affect all or part of the region. According to the NOAA Storm Prediction Center (SPC), historically, the highest concentration of tornadoes in the United States has been in Oklahoma, Texas, Kansas, and Florida. Although the Great Plains region of the central United States does favor the development of the largest and most dangerous tornadoes (earning the designation of “tornado alley”), the trend in frequency and location of tornadoes in recent years has shifted to southeastern states, especially Alabama, Mississippi, and Tennessee. Although the planning area is located outside of “tornado alley” and does not experience as many tornadoes as other regions, there are nonetheless many examples of tornadoes tracking through Northern Virginia.

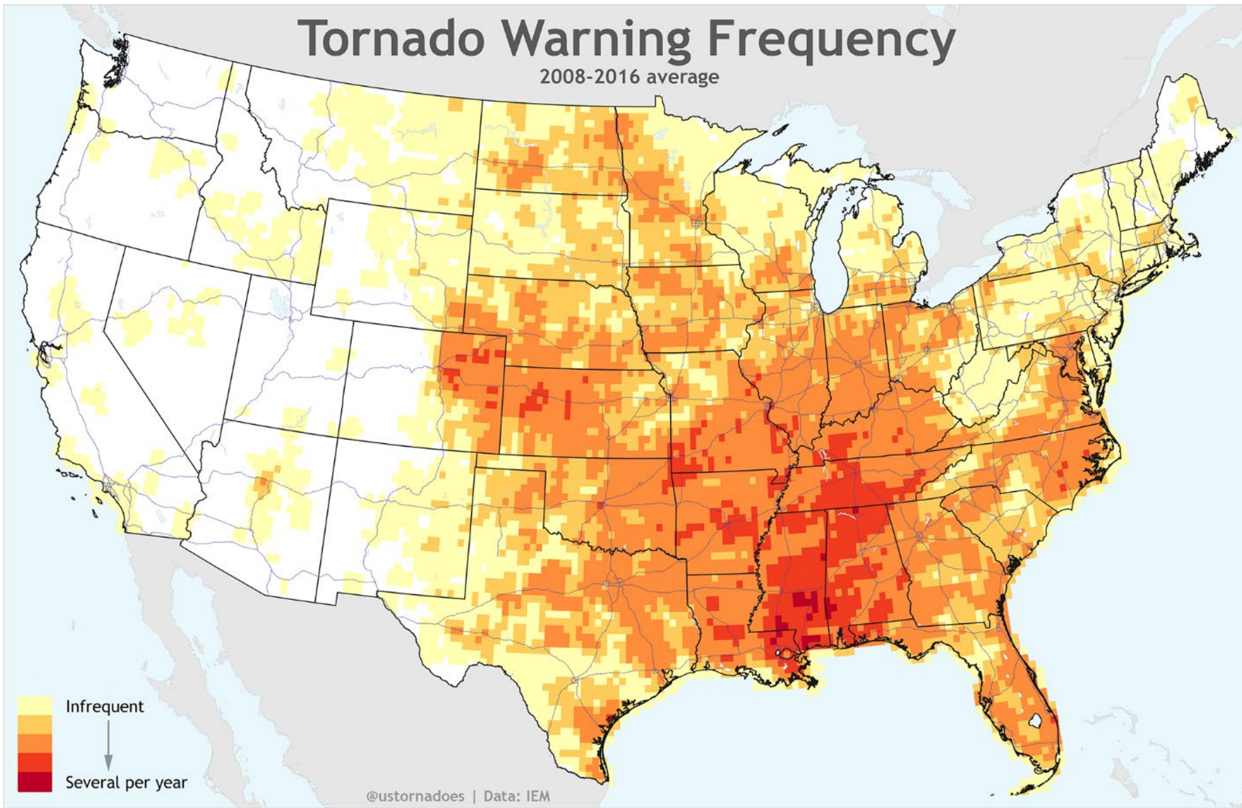

Figure 49: Annual Average Tornado Warning Frequency, 2008–2016[166]

Tornadoes most often occur in the United States east of the Rocky Mountains, but they are not limited to those regions; all jurisdictions within the planning area are susceptible to tornadoes. National Centers for Environmental Information (NCEI) data indicates that tornadoes most frequently occur between the months of May and November. However, tornadoes associated with tropical cyclones that may affect coastal areas are most common in September and October when the incidence of tropical storm systems is highest. This type of tornado usually occurs around the perimeter of the storm, most often in the northeast quadrant and ahead of the storm path or the storm center as it comes ashore. These tornadoes commonly occur as part of large outbreaks and generally move in an easterly direction.

[166] U.S. Tornadoes, 2020.

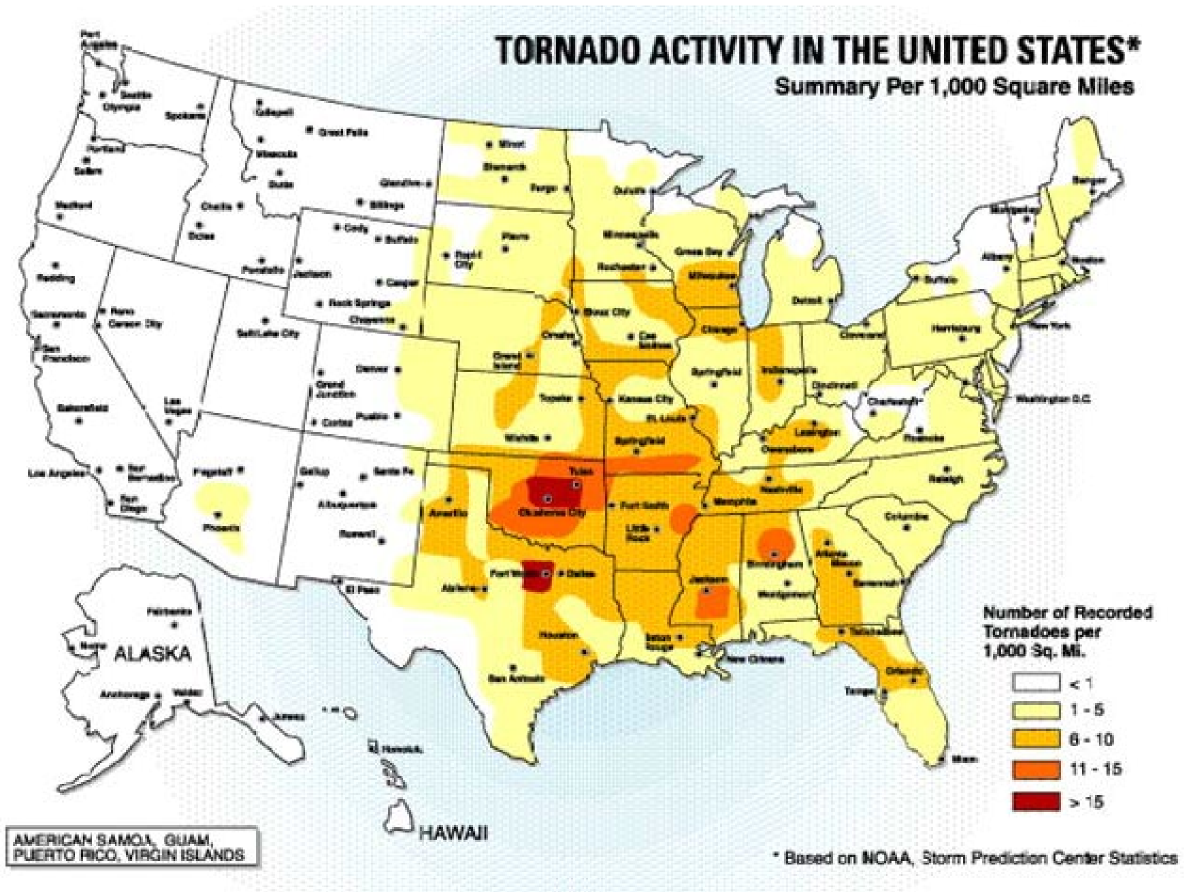

Figure 50: Tornado Activity in the United States[167]

5.9.1.2. Extent

The magnitude or severity of a tornado is measured by the Enhanced Fujita scale.

The magnitude of tornadoes was first measured by intensity on the Fujita-Pearson Tornado Scale, or simply the Fujita Scale, or F-Scale. The Fujita Scale, however, did not measure tornadoes by their size or width, but rather the amount of damage to human-built structures and trees. The scale ranged from F0 for the weakest, to F6 for the most powerful, although an F6 has never been recorded. The Fujita Scale was updated in 2007 to the Enhanced F-Scale. The enhanced scale classifies EF0-EF5 damage as developed by engineers and meteorologists across 28 different types of damage indicators (DI) and degrees of damage (DoD). To establish a rating, the National Weather Service will examine the damage to different structures and use their formulated chart to assign an EF-number to the tornado.

Most tornadoes that occur in Virginia are less intense (EF0 through EF2 on the EF-Scale) than those that occur elsewhere in the country, but occasionally they are of sufficient magnitude to inflict major damage and destruction.

[167] American Society of Civil Engineers

Table 98: Comparison Between the Fujita Scale (F-Scale) and Enhanced Fujita (EF) Scale, Including Potential Damage Descriptions[168]

Fujita Scale Developed in 1971 and Used Until 2007			Enhanced Fujita Scale (EF) Used as Measure of Magnitude in the U.S. Since 2007		
F Category	**Wind Speed (mph)**	**Potential Damage**	**EF Category**	**Wind Speed (mph)**	**Potential Damage**
F0	< 73	Light damage. Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.	EF0	65–85	Light damage. Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-
F1	73–112	Moderate damage. Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.	EF1	86–110	Moderate damage. Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows/other glass broken.
F2	113–157	Considerable damage. Roofs torn from frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.	EF2	111–135	Considerable damage. Roofs torn off well-constructed houses; foundations of frame homes shifted; mobile homes completely destroyed; large trees snapped or uprooted; light-object missiles generated; cars lifted off
F3	158–206	Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.	EF3	136–165	Severe damage. Entire stories of well-constructed homes destroyed; severe damage to large buildings, (e.g., shopping malls); trains overturned; trees debarked; heavy cars lifted off the ground and thrown; structures with weak
F4	207–260	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown, and large missiles generated.	EF4	166–200	Devastating damage. Well-constructed houses and whole frame houses completely leveled; cars thrown, and small missiles generated.

168 National Weather Service, The Enhanced Fujita Scale (EF Scale). Retrieved at: https://www.weather.gov/oun/efscale

Fujita Scale Developed in 1971 and Used Until 2007			Enhanced Fujita Scale (EF) Used as Measure of Magnitude in the U.S. Since 2007		
F Category	Wind Speed (mph)	Potential Damage	EF Category	Wind Speed (mph)	Potential Damage
F5	261–318	Incredible damage. Well-constructed houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 m (109 yd); trees debarked; incredible phenomena will occur.	EF5	> 200	Incredible damage. Well-constructed houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 m (109 yd.); high-rise buildings have significant structural deformation; incredible phenomena will occur.

Most tornadoes that occur in Virginia are less intense (EF0 through EF2 on the EF-Scale) than those that occur elsewhere in the country, but occasionally they are of sufficient magnitude to inflict major damage and destruction.

5.9.1.3. Previous Occurrences

From 1950 through the June 2021, 944 tornadoes were documented in Virginia—an average of 13.4 tornadoes per year. However, the average number of tornadoes in Virginia within the past twenty years (2000- 2020) was 28.6, indicating either an increase in the frequency of these events, more accurate reporting, or both. Nationwide statistics have suggested that prior to 1990, only one third of all tornadoes were recorded. Many occurred in unpopulated areas or caused little property damage and therefore were not reported to the NWS, while others may have been recorded separately as high wind events instead of tornadoes. Thus, the actual average number of tornadoes that Virginia experiences, in a given year, is likely higher than historical NOAA records indicate. Tornado fatality records began in 1916.

During the period 2000 to June 30, 2021, 48 tornado events were reported in the Northern Virginia jurisdictions—an average of 2.34 tornado events per year.

According to NCDC records, the Northern Virginia region experienced approximately 79 funnel cloud and tornado events from 1950 through June 30, 2021. Most of these events were recorded as either F0/EF0 or F1/EF1 events, although there have been some stronger events recorded as F2 and F3.

In total, these tornado events are reported to have caused at least two fatalities, 59 injuries and approximately $52.8 million in property and crop damages. More detailed information on each of these historical tornado events can be obtained through the NCEI Storm Events Database.

Table 99: Tornado Events in the Northern Virginia Region (1950–2021), by Jurisdiction[169]

	Annualized Property and Crop Damage	Total Property and Crop Damage	Injuries	Fatalities	Number of Events
Arlington County	$15,603	$1,100,000	0	2	3
City of Alexandria	$0	$7,500	0	0	2
City of Fairfax*	$0	$0	0	0	0
City of Falls Church	$35,461	$2,500,000	0	0	1
City of Manassas	$0	$0	0	0	2
City of Manassas Park	$0	$0	0	0	1
Fairfax County *Including Town of Clifton, Town of Herndon, Town of Vienna*	$487,957	$34,401,000	45	1	26
Loudoun County *Including Town of Leesburg, Town of Lovettsville, Town of Purcellville, Town of Middleburg, Town of Round Hill*	$154,085	$10,863,000	2	0	27

169 NOAA, National Centers for Environmental Information, Storm Events Database, 1950 to June 30, 2021.

	Annualized Property and Crop Damage	Total Property and Crop Damage	Injuries	Fatalities	Number of Events
Prince William County *Including Town of Dumfries, Town of Haymarket, Town of Occoquan, Town of Quantico*	$55,489	$3,912,000	0	1	17
TOTAL	**$748,595**	**$52,783,500**	**59**	**2**	**79**

*NCEI does not provide a detailed breakdown of tornado events in all towns within each county. Consequently, town events are included with the county data.

On **July 24, 2018**, an EF0 tornado struck Thomas Jefferson High School and tracked north towards Little River Turnpike. The tornado touched down briefly just south of the softball field, damaging fences, two sheds, light poles and several trees. Damage was minimal and proximal to the high school grounds. A shipping container was lofted over 100 yards as the tornado crossed the softball field moving northeast over an adjacent athletic field. Damages were approximately $10,000.

On **June 20, 2015**, an EF-0 tornado produced a 2.1-mile path of damage that was approximately 100 yards wide. The bulk of the damage occurred at the Broad Run Golf Training center in Prince William County, where about a half-dozen softwood trees between 12 and 18 inches in diameter were snapped approximately 4 feet above the ground. The damage at the baseball fields at the intersection of Route 28 and Godwin Road included a scoreboard secured by 4x4s being snapped, along with baseball dugout roofs lifted and blown away. Damage was sporadic along the 2.1-mile path.

On **October 15, 2014**, severe thunderstorms produced a confirmed EF-0 tornado near Belle Haven in Eastern Fairfax County. The tornado created a path of vegetative damage approximately 1.5 miles long. The tornado continued north across the Belle Haven Country Club, where larger tree limbs were snapped. The tornado then briefly moved into the City of Alexandria, likely lifting across Interstate 495 at the intersection of George Washington Parkway, where large tree branches were also downed. Several large tree branches were snapped in the adjacent neighborhood to the north before the radar signature weakened. Estimated maximum winds were 55–65 mph.

On **May 16, 2014**, a tornado touched down near Sunny Bank Lane in Loudoun County. A large tree was uprooted, and other trees and large branches were found uprooted and collapsed in different directions, along with branches snapped or twisted at various points along Light Horse Court.

On **April 27, 2011**, an EF-1 tornado snapped numerous trees along Carriage Ford Road, Aden Road and Garman Drive in Prince William County. Siding and shingles were removed from several homes in the area. Horse run-ins and sheds were also damaged. The doors of a detached garage were blown in. A fence was also damaged along with some signs and small trees in the parking lot of a shopping center. A few trees were snapped along Linton Hall Road before the tornado lifted.

On **October 13, 2011**, thunderstorms developing behind a front that contained strong aloft winds produced damaging wind gusts. Rapidly changing winds in both direction and speed caused some of the stronger thunderstorms to produce tornadoes near the warm front. Trees were sporadically uprooted and snapped along a path some three miles long, starting near Clifton and ending just west of Fairfax City.

On **July 23, 2008**, a weak tornado touched down in Prince William County in an industrial park near Wellington. The tornado produced siding and roof damage to homes and toppled trees. It also damaged the roof of a retail home center in Sudley Towne Plaza before lifting after crossing Sudley Road near Route 234.

On **June 4, 2008**, strong upper-level thunderstorms developed over the area, resulting in several severe thunderstorms. An EF-1 tornado crossed into south-central Loudoun County, producing a damage path near the town of Aldie.

On **July 4, 2007**, a funnel cloud was spotted near Pickett Road in Fairfax by the Department of Public Works and Environmental Services. Severe weather in the area caused the need for sheltering those attending Fourth of July celebrations. No reports of damage or injuries were received as a result of this funnel cloud; however, a man was killed in Annandale when a tree fell onto his car during storms earlier in the afternoon.

On **September 17, 2004**, a tornadic thunderstorm entered western Fairfax County from Prince William County. The storm had a path approximately seven miles in length. Beginning on Old Centerville Road, the storm produced scattered tree damage and minor roof damage in the Loudoun Town area. A line of damage was carved from Lee Highway northward into the Centerville and Chantilly areas. The tornado destroyed one home, damaged approximately 50 other structures, and was responsible for downed trees and powerlines. The parent thunderstorm produced another tornado on the east side of the City of Manassas that caused structural and tree damage before continuing into Manassas Park, where several dwellings were damaged in the Yorkshire subdivision. At its strongest, this tornado produced F2 damage estimated at $1 million.

On **September 24, 2001**, five tornadoes touched down in Northern Virginia during the afternoon and early evening. One tornado, which remained on the ground for 15 miles, passed through densely populated areas of eastern Fairfax County, the western portion of the City of Alexandria, and Arlington County, causing minor injuries and significant damage to trees, residences, and businesses. Its strength varied between F0 and F1 as it crossed the interstates three times during rush-hour traffic. Cars were hit with flying debris and some windows were blown out. Hundreds of homes and numerous parked vehicles were also damaged. Most of the damage was minor and limited to the exteriors and roofs of homes. A few homes suffered more significant damage, mainly in the Shirlington area of Arlington County. Total damages were estimated at $1 million. Only two people are known to have been injured. Before the tornado moved into Washington, DC, it passed right by the Pentagon City Mall and the Pentagon itself. Numerous recovery workers at the Pentagon in the aftermath of the 9-11 attack had to take cover from the tornado in underground tunnels. One of the tornadoes touched down in Prince William County, where it downed some trees in the Prince William Forest Park area. The tornado moved north into the Lake Montclair community, where it took down a few trees, broke branches, and bent siding on homes. The weak tornado lifted shortly thereafter.

On **May 25, 1997**, a small, short-lived tornado with winds up to 70 miles per hour, knocked down between 75 and 100 trees and limbs, some of which fell onto residences, vehicles, and other property in South Arlington. Scattered structural damage included aluminum siding, gutters, shingles, and plastic fascia.

On **June 24, 1996**, a tornado associated with the mesocyclone of a heavy-precipitation super cell touched down in extreme southeastern Loudoun County near Bull Run Creek, then proceeded east-southeast for 20 miles, knocking down more than 1,000 trees and causing substantial property damage, especially in western Fairfax County, before lifting along the Capital Beltway at the Braddock Road interchange less than two miles west of Annandale. The most significant damage occurred along Tree Line Drive, where 11 of 17 homes incurred moderate to major damage. The combined effort of several agencies produced property damage estimates along the track (not including flora) totaling $2.9 million. Included in that total are 323 homes that sustained minor damage. An estimated 80,000 homes lost power along the track of the tornado in Fairfax County; for some homes, power was not restored until several days after the event.

On **April 16, 1993**, a tornado touched down approximately half a mile southwest of Saint Louis in the southern part of Loudoun County and moved east-northeast for about 1.7 miles. The storm knocked down and damaged hundreds of trees. The roofs of two barns were blown off, windows were blown out, and fences were ripped up.

On **September 5, 1979**, Hurricane David spawned six tornadoes across Virginia. A strong F3 tornado struck Fairfax County and the City of Fairfax, tracking 18 miles, killing one person and injuring six. It struck the same school hit by a tornado on April 1, 1973, this time causing $150,000 in damage. Numerous cars were demolished, 90 homes were damaged, and trees and debris blocked roads. Damages in Fairfax County reached $2.5 million dollars.

On **April 1, 1973**, a strong F3 tornado struck a populated area of Northern Virginia. It touched down in Prince William County and traveled 15 miles northeast through Fairfax and into Falls Church. Extensive damage occurred along a six-mile stretch in Fairfax. A high school, two shopping centers, an apartment complex, and 226 homes were damaged. Thirty-seven people were injured. It could have been much worse, but it was Sunday, and "Blue Laws" were still in effect—the normally busy shopping center, which had extensive damage, was closed and school was not in session. Damage totaled an estimated $14 million.

On **May 2, 1929**, on a day known as "Virginia's Deadliest Tornado Outbreak," the town of Hamilton in Loudoun County (six miles northwest of Leesburg) experienced one of the five tornadoes that caused widespread destruction across the state. The tornado's path was reportedly 200 yards in breadth and two miles long, and it destroyed a house, barn, as well as some smaller buildings at one farm. It caused several injuries but no deaths. Other nearby farms were damaged, as well as a brick church.

On **November 17, 1927**, a tornado touched down in a rural part of Fairfax County and moved northeast across the western part of Alexandria, across the Potomac River and Washington, DC, and into Maryland. More than 100 people were injured in Alexandria and more than 200 homes were unroofed and torn apart.

Although tornado events have occurred in the planning area, none were of a damage level that would warrant a Presidential Disaster Declaration.

5.9.1.4. Probability of Future Occurrence

The NOAA, NCEI data for the 1950–2021 period shows a dramatic upward trend in annual average number of tornadoes. This may be partly explained by more accurate and timely record-keeping or reporting but may also be linked to increasingly severe weather events resulting from climate change.

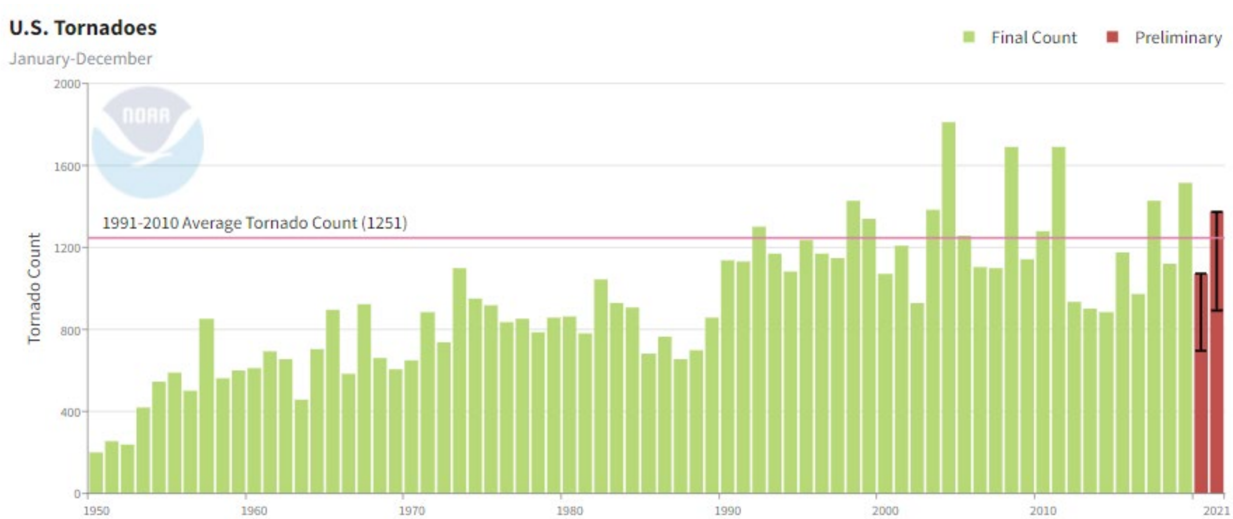

Figure 51: Average Number of Tornadoes, by Year (1950–2021)

The probability of future tornado events was examined through analysis of the NCEI historical data and in consideration of data presented in the *2018 Commonwealth of Virginia State Hazard Mitigation Plan (COV-SHMP)*, dated March 2018. For the Commonwealth's plan, an extensive frequency analysis was performed on the historical tornado records between 1950 and 2016 (including touchdown points and tornado tracks) using GIS techniques. The results of this analysis pinpointed areas that have experienced slightly higher frequency of tornadoes. It should be noted that what is considered to be "High" is relative to tornado frequency in the entire Commonwealth of Virginia. The "High" designation is still low in comparison with frequencies experienced in "tornado alley" and throughout the southern states. Based on this analysis, Fairfax County and Loudoun County have the highest annual frequency of tornadoes within a range of .289 to .409. Prince William County is indicated as having a "Medium-High" annual frequency with .198 to .288. The *COV-SHMP* identified multiple jurisdictions within the planning area that were considered to be at higher risk for tornadoes:

- Arlington County
- City of Alexandria
- City of Fairfax
- City of Manassas
- Fairfax County
- Loudoun County
- Prince William County

Comparison of the NCEI data from the period 1950 to June 2021 is consistent with this frequency analysis, showing that Loudoun County has experienced 27 tornado events, while Fairfax County has experienced 26 since 1950—more than any other jurisdictions in Northern Virginia. Prince William County comes in third, having recorded 17 such events during that same period.

Based on this analysis, it is likely that the Northern Virginia region will continue to experience weak to moderately intense tornadoes. It is unlikely that very strong tornadoes (F4 or F5) will strike the area, although it remains a possibility. Climate change is projected to increase the frequency and intensity of extreme weather events, including severe thunderstorms. At this time, it remains uncertain whether this may also translate into an increased frequency of tornadoes.

5.9.2. Risk Assessment

Tornadoes are a high-impact, low-probability hazard. A tornado's impact is dependent on its intensity and the vulnerability of development in its path.

Risk cannot be fully estimated for tornadoes due to the lack of intensity–damage models for this particular hazard. Instead, estimates of the financial impacts of tornadoes can be developed based on historical data contained within the NCEI storm events data. Examination of data shows that there were 79 tornado events in Northern Virginia between 1950 and June 2021, causing approximately $53 million in property and crop damages. Loudoun County has recorded more tornado damage than any other Northern Virginia jurisdiction. NCEI data shows that the county has suffered more than $14.5 million in property and crop damages since 2000.

5.9.2.1. People

There is no completely safe place during a tornado, but there are some that are safer than others. Those who are unable to reach a storm shelter in a timely manner are at risk for injury or death during a tornado event. Given the large number of "superhighways" in the Capital Region, it is conceivable that the people tied up in traffic during rush hour would need to shelter in their cars; however, tornadoes could lift vehicles to become flying debris. Those who live in areas not served by a warning siren or other notification system would be at risk if they do not see the impending event advancing or receive some type of warning. Many jurisdictions now use automated warning systems as a means of notification, although access to mobile phones, computers, or other digital equipment is necessary to receive the warning.

If the building you are in or close to does not have a shelter, go to the basement or an inside room without windows on the lower floor. If there is no basement, go to the center of the building and avoid mobile homes.

5.9.2.2. Economy

Even a tornado that is fast-moving or of short duration can severely impact the economy. Commercial and government structures, if not built to high construction standards, may be damaged or destroyed by a tornado. Those affected by a tornado event may not be able to reach their workplace because they themselves are busy recovering from the event, sorting through debris from a damaged house, or inspecting their property. The Capital Region includes a high concentration of government structures, museums, high-rise buildings, major employers, and small businesses that are at risk for economic loss as a result of a tornado impact.

5.9.2.3. Built Environment and Community Lifelines

The destruction of buildings and critical infrastructure by tornadoes ranges from light to devastating depending on the intensity, size, and duration of the tornado. Typically, tornadoes cause the greatest damage to structures of light construction such as residential homes (particularly mobile homes) and tend to remain localized in impact.

Northern Virginia includes a significant number of assets that are an extension of services provided by the federal government and based in the District of Columbia. The disruption of utilities and transportation systems, as well as lost hours of government and commercial operations (as well as decreased productivity) are the consequences of tornado events. Vulnerability to these damages varies in large part due to specific factors, including proactive measures such as regular tree maintenance and placing utility systems underground, which can minimize property vulnerability. Localities that have experienced tornado events are likely to be more prepared to deal with them and are less vulnerable than localities that have not experienced tornadoes.

5.9.2.4. Natural Environment and Cultural and Historic Assets

Northern Virginia is fortunate with many open spaces, forests, and other natural environments indigenous to the region. It is conceivable that a formidable tornadic event might also affect national assets, including Arlington National Cemetery with its many monuments and headstones.

5.9.2.5. Hazard Risk Ranking Summary

The hazard ranking process included consideration of probability and consequences in determining an overall risk score and ranking. Information presented within this section and the hazard risk ranking process present the quantitative and qualitative summary for tornadoes. The Hazard Identification and Risk Assessment methodology is described in **Section 4, Base Plan.**

Table 100: Hazard Risk Rankings for Tornadoes, by Jurisdiction

Hazard	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
Arlington County	1.3	4.2	5.5	Medium
City of Alexandria	1.3	4.5	5.8	Medium
City of Fairfax	1.3	4.2	5.5	Medium
City of Falls Church	1.3	4.2	5.5	Medium
City of Manassas	1.3	4.3	5.6	High
City of Manassas Park	1.3	4.3	5.6	Medium
Fairfax County	1.3	4.2	5.5	Medium
Town of Clifton	1.3	4.2	5.5	Medium
Town of Herndon	1.3	4.2	5.5	Medium
Town of Vienna	1.0	4.2	5.2	Medium
Loudoun County	1.7	4.1	5.8	High
Town of Leesburg	1.7	4.1	5.8	High
Town of Lovettsville	1.7	4.1	5.8	High
Town of Middleburg	1.7	4.1	5.8	High
Town of Purcellville	1.7	4.1	5.8	High
Town of Round Hill	1.7	4.1	5.8	High
Prince William County	1.3	4.8	6.1	Medium
Town of Dumfries	1.3	4.3	5.6	Medium
Town of Haymarket	1.3	4.3	5.6	Medium
Town of Occoquan	4.0	6.0	10.0	Medium
Town of Quantico	1.3	4.3	5.6	Medium

5.9.3. Vulnerability Assessment

Tornado vulnerability is based on construction codes and standards for buildings and infrastructure, the availability of shelters or safe rooms, and advanced warning capabilities.

A quantitative analysis of tornado impact was performed for the *2017 NOVA HMP* and was retained for the 2022 update. For the purposes of this assessment, no assumption was made as to the level of damage that the asset would sustain; therefore, the values displayed represent the entire value of the asset and its contents.

Table 101: Scenario Vulnerability Assessment for Tornadoes, by Jurisdiction[170]

Jurisdiction	Number of Assets Damaged	Value of Assets	Value of Contents	Total
Arlington County	83	$488,255,187	$27,000,723	$515,255,910
City of Alexandria	6	$55,873,350	$50,000,000	$105,873,350
City of Fairfax	0	$0	$0	$0
City of Falls Church	3	$18,662,700	$0	$18,662,700
City of Manassas	7	$10,191,160	$796,050	$10,987,210
City of Manassas Park	6	$40,408,100	$0	$40,408,100
Fairfax County	61	$511,768,862	$78,281,693	$590,050,555
Town of Clifton	-	-	-	-
Town of Herndon	8	$18,762,385	$2,514,029	$21,276,414
Town of Vienna	6	$13,250,000	$700,000	$13,950,000
Loudoun County	22	$245,335,780	$245,335,780	$490,671,560
Town of Leesburg	14	$26,397,517	$1,517,642	$27,915,159
Town of Lovettsville	$0	$0	$0	$0
Town of Middleburg	4	$297,620	$297,620	$595,240
Town of Purcellville	2	$28,030	$28,030	$56,060
Town of Round Hill	0	$0	$0	$0
Prince William County	0	$0	$0	$0
Town of Dumfries	0	$0	$0	$0
Town of Haymarket	6	$3,187,813	$205,877	$3,393,690
Town of Quantico	0	$0	$0	$0

The type and age of construction plays a role in facilities' vulnerability to tornadoes. In general, concrete, brick, and steel-framed structures tend to fare better in tornadoes compared to older, wood-framed structures or manufactured homes. However, even well-constructed buildings are vulnerable to the effects of a stronger (generally EF2 or higher) tornado. Finally, not all critical facilities have redundant power sources, and some may not even be wired to accept a generator. Plan updates should consider closer examination of critical facilities' risk by looking at those facilities' construction type in jurisdictions considered to be at higher risk of tornadoes.

5.9.3.1. Future Population and Development Trends

Future development and the resulting population increase has the potential to increase tornado vulnerability in the future, depending on climate change variables and jurisdictions' capabilities to manage growth appropriate to zoning ordinances, building codes, and population distribution. The impacts and consequences from previous tornado events can serve as a guide for future planning and regulatory actions based on appropriate development in the region's jurisdictions.

[170] 2017 Northern Virginia Hazard Mitigation Plan

5.9.3.2. Factors for Consideration in the Next Planning Cycle

Future monitoring, evaluating, and updating of this Plan should consider the following factors related to tornadoes as well as other information from the *COV-SHMP*:

- Have any tornadic events occurred since this Plan was adopted, or did events occur in adjacent jurisdictions that impacted people or property in the planning area?
- Have any of the communities installed warning sirens or other systems that would enable the population to take cover in the event of an expected tornado?
- Have the results of new scientific research or methodology changed the ability to predict tornado events or assess risk and vulnerability?
- Has the community developed—or is it planning to develop—additional storm shelters?
- Have there been significant changes in the demographics, built environment, natural environment, or economy that could affect the risk or vulnerability to tornado events?
- Is there any new evidence related to the impacts of climate change that could affect the level of risk or vulnerability to tornado events?
- Has there been a significant increase in the number of persons who fall into one or more of the vulnerable population categories, thereby increasing the number and types of persons or groups at higher risk from tornado events?
- Closely examine critical facilities at risk by determining their construction type in all or some areas of the planning area.

5.10. Wildfire

2022 HMP Update

The Wildfire hazard was reexamined, and a new analysis was performed. This new analysis included but was not limited to the following:

- Reformatting the hazard section to improve flow and clarity
- Refreshing the hazard profile with updated data, maps, and imagery, where available
- Updating the assessment of risk and vulnerability by jurisdiction based on new data
- Ranking the hazard by jurisdiction using the methodology described in Section 4

Table 102: Wildfire Profile

<table>
<tr><th colspan="5">Wildfire</th><th>Overall Vulnerability</th></tr>
<tr><th colspan="5">Definition, Key Terms, and Overview</th><td rowspan="5">Low</td></tr>
<tr><td colspan="5">Any fire occurring in a wildland area (i.e., grassland, forest, brush land), except for prescribed burns. (Prescribed, or “controlled,” burning is the practice of igniting fires under specific conditions and in accordance with strict parameters by land management agencies).</td></tr>
<tr><th rowspan="2">Frequency</th><th rowspan="2">Probability</th><th colspan="3">Potential Magnitude</th></tr>
<tr><th>Injuries/Deaths</th><th>Infrastructure</th><th>Environment</th></tr>
<tr><td>Low</td><td>Low</td><td>Low</td><td>Low</td><td>Moderate</td></tr>
</table>

5.10.1. Hazard Profile

Wildfires are part of the natural management of the Earth’s ecosystems but may also be caused by natural or human factors. Nearly 85% of wildland fires in the United States are started by negligent or intentional human behavior, such as smoking in wooded areas or improperly extinguishing campfires. The second most common cause of wildfire is lightning.[171] Wildland fires are usually signaled by dense smoke that fills the area for miles around.

States are responsible for responding to fires on nonfederal (state-owned, local, and private) lands, except for land that is protected by federal agencies under cooperative agreements. Although a small percentage of fires account for most acres burned, most wildland fires cannot be classified as catastrophic. Only about 1% of fires become conflagrations—raging, destructive fires—and predicting which ones will turn into conflagrations depends on multiple factors, including geography and weather conditions.

State and local governments can impose fire safety regulations on home sites and developments to help curb wildfire. Land treatment measures such as fire access roads, water storage, helipads, safety zones,

[171] United States National Park Service, Wildfire Causes and Evaluations, based on 2000-2017 Wildland Fire Management Information and U.S. Forest Service Research Data Archive. Retrieved at: https://www.nps.gov/articles/wildfire-causes-and-evaluation.htm

buffers, firebreaks, fuel breaks, and fuel management can be designed as part of an overall fire defense system to aid in fire control. Fuel management, prescribed burning, and cooperative land management planning can also be encouraged to reduce fire hazards.

Fire probability depends on local weather conditions, outdoor activities (such as camping, debris burning, and construction), and the degree of public cooperation with fire prevention measures. Drought conditions and other natural disasters (tornadoes, hurricanes, etc.) may increase the probability of wildfires by producing fuel in both urban and rural settings. Forest damage from hurricanes and tornadoes may block interior access roads and fire breaks, pull down overhead power lines, and damage pavement and underground utilities.

Table 103: Definitions of Wildfire Types

Term	Definition
Surface Fire	A surface fire, the most common type of wildfire, burns along the floor of a forest, moving slowly and killing or damaging trees.
Ground Fire	A ground fire (muck fire) is usually started by lightning or human carelessness and burns on or below the forest floor.
Crown Fire	A crown fire spreads rapidly by wind and moves by jumping along the tops of trees.

Human activities are the leading cause of wildfire incidents in Virginia. The cause of the greatest number of fires during the period from 1995 to 2016 was debris burning and the intentional setting of fires.[172] Lacking a distinct beginning and end period, a wildfire's duration varies based on location, weather, fuel source, and available firefighting resources.

Virginia's wildfire season normally occurs in the spring (March and April) and fall (October and November). During these times, the relative humidity is usually lower, winds tend to be higher, and the fuels are cured to the point where they readily ignite. Also, during these times, hardwood leaves are on the ground, providing more fuel and allowing sunlight to reach the forest floor, which warms and dries the surface fuels.

Fire activity varies from month to month and year to year based on precipitation amounts. During years of adequate rain and snow, wildfire occurrence is typically low. Lack of moisture during other years means extended periods of warm, dry, windy days and therefore increased fire activity. The damage caused by Hurricane Isabel in 2003 increased the threat of wildfires in Virginia and created a major threat to lives and homes in the eastern half of Virginia for several years to come. The dead and downed timber caused by the storm had time to cure and produce large wildfires that were difficult to suppress.

[172] 2018 Commonwealth of Virginia Hazard Mitigation Plan, March 2018.

Table 104: Hazard Profile Summary

<table>
<tr><td rowspan="8">Wildfire

Assessment: Low Risk Hazard</td><td>Location</td><td>Rural, forested areas</td><td>Potential Cascading Effects</td></tr>
<tr><td>Extent</td><td>Low</td><td rowspan="7">• Water supply shortage
• Loss of natural resources
• Low of wildlife
• Loss of natural resources
• Economic loss</td></tr>
<tr><td>Duration</td><td>Hours to days</td></tr>
<tr><td>Probability</td><td>Low</td></tr>
<tr><td>Seasonal Pattern</td><td>No seasonal pattern, but may be more likely during winter and, in summer, exacerbated by severe storms with lightning</td></tr>
<tr><td>Speed of Onset</td><td>Slow to rapid</td></tr>
<tr><td>Warning Time</td><td>Minutes to hours</td></tr>
<tr><td>Repetitive Loss</td><td>N/A</td></tr>
</table>

5.10.1.1. Location

Wildfires commonly begin unnoticed and spread quickly through vegetative fuels. As discussed in the ranking methodology section, the Virginia Department of Forestry (VDOF) risk assessment presented in the *2017 Northern Virginia Hazard Mitigation Plan (NOVA HMP)* represents the geographic extent and locations throughout the Commonwealth that have a higher risk for wildfire. The geographic extent score for a given jurisdiction is based on the percent of the jurisdiction that falls within the "high" risk area as defined by VDOF. Fairfax and Prince William Counties have the highest percent of land area within the high-risk classifications, compared to the other jurisdictions in the planning region. Several areas in Northern Virginia are conducive to wildfires—among them, the Conway-Robinson State Forest and Prince William Forest Park in Prince William County.

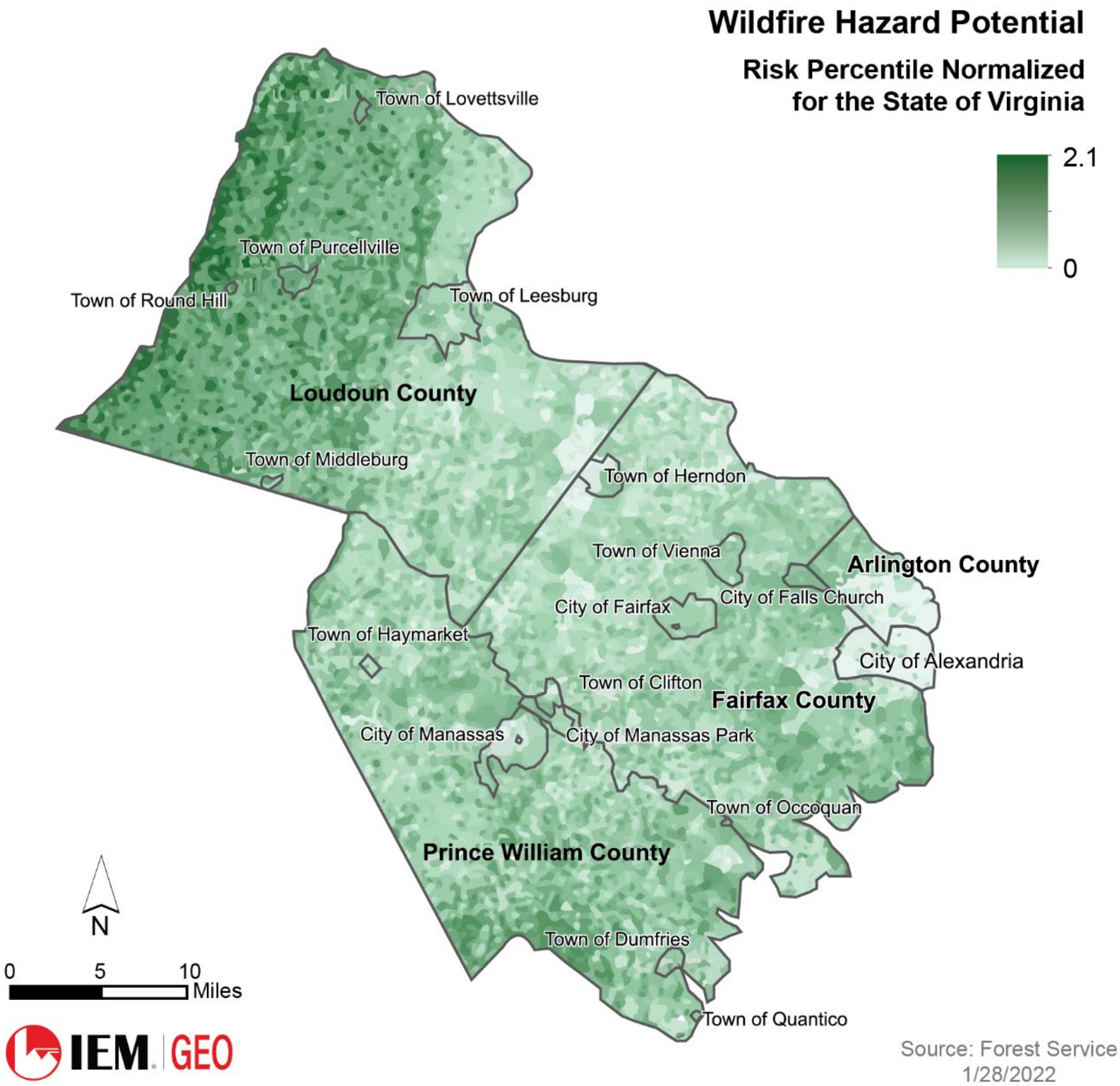

Figure 52: Wildfire Risk Assessment of Northern Virginia[173]

Individual homes and cabins, resorts, recreational areas, camps, subdivisions, businesses, and industries are sometimes located within high fire-hazard areas. The increasing demand for outdoor recreation puts more people in wildlands during holidays, weekends, and vacation periods. Unfortunately, wildland residents and visitors are rarely educated or prepared for the inferno that can sweep through brush and timber and destroy property in minutes. The Northern Virginia region is not considered as at risk of wildfire as other areas of the state, but wildfires do occur.

5.10.1.2. Extent

In the planning area, fires are typically small, burning an average of approximately 16 acres before being suppressed. Of the 141 recorded historical incidents during this period, six fires burned an area greater than 10 acres (all in Loudoun or Prince William County). This is a significant increase in the last few years, as ten of these fires occurred between 2009 and 2013.

[173] United States Forest Service, January 28, 2022.

5.10.1.3. Previous Occurrences

There are an average of 700 fires a year in Virginia which burn just under 9,500 acres (10-year average). More than 60 homes and other structures are damaged or destroyed by wildland fire throughout the Commonwealth.

Although the National Centers for Environmental Information (NCEI), Storm Events Database documents wildfire events, it does not show any events reported for the planning area between 1950 and June 30, 2021. Limited data is available through the Virginia Department of Forestry, primarily due to the lack of reporting for small fires.

Table 105: Wildfire Events in Northern Virginia (1995-2020) by Jurisdiction[174]

Jurisdiction	Number of Fires	Total Acres
Fairfax County	2	3
Loudoun County	100	379
Town of Leesburg	2	2
Prince William County	36	615
Town of Dumfries	1	6
TOTAL	**120**	**368**

The available data illustrates that majority of the wildfire occurrences in the Northern Virginia region were caused by debris burning and other human activities.

Based on the number of historical occurrences, wildfires are somewhat prevalent in the Northern Virginia region. These events, however, are usually contained to very small areas and have caused minimal damages to property due to strong fire response and suppression capabilities and resources.

Local records of wildfire occurrences do exist, though the recorded detail varies significantly from jurisdiction to jurisdiction. Thus, it is difficult to determine the incidence and impacts of wildfire for comparison purposes. Most wildfires that do occur are contained before they grow large and are handled by local fire resources, which means that most data regarding previous occurrences is stored, in some form, at the local level. For this update, no jurisdictions reported wildfire events.

Given the amount of wildland/urban interface acreage within the planning area, it is expected that there are numerous wildfire events to which local responders are called, sometimes multiple times in a single day. For example, on February 19, 2011, Fairfax County responded to a 20-acre wildfire, a 2-acre wildfire, a 5-acre wildfire, and numerous other incidents.

5.10.1.4. Probability of Future Occurrence

Future wildfire incidents are difficult to predict, as the factors influencing wildfire generation vary greatly with changing weather conditions and human activities.

While the VDOF Wildfire Risk Assessment does indicate the relative propensity for wildfires in the planning area, this assessment does not assign probabilities of occurrence or return intervals as is common with some of the other hazards. Based on past events, it remains possible over the long-term that the Northern Virginia region will experience recurring wildfire conditions, the severity of which cannot be fully quantified.

[174] Virginia Department of Forestry,

Although the entire Northern Virginia region is vulnerable to wildfire and events have occurred in the planning area, it is difficult to calculate the probability of future occurrences due to human interaction and the unpredictable and localized nature of the hazard. In addition, the link between drought conditions and wildfire presents an additional challenge to calculating a specific return interval for probability.

Based on U.S. Forest Service data, the annual wildfire burn probability risk for the planning area ranges from 0% to 2.17%. All jurisdictions are at low or very low risk for potential wildfires.

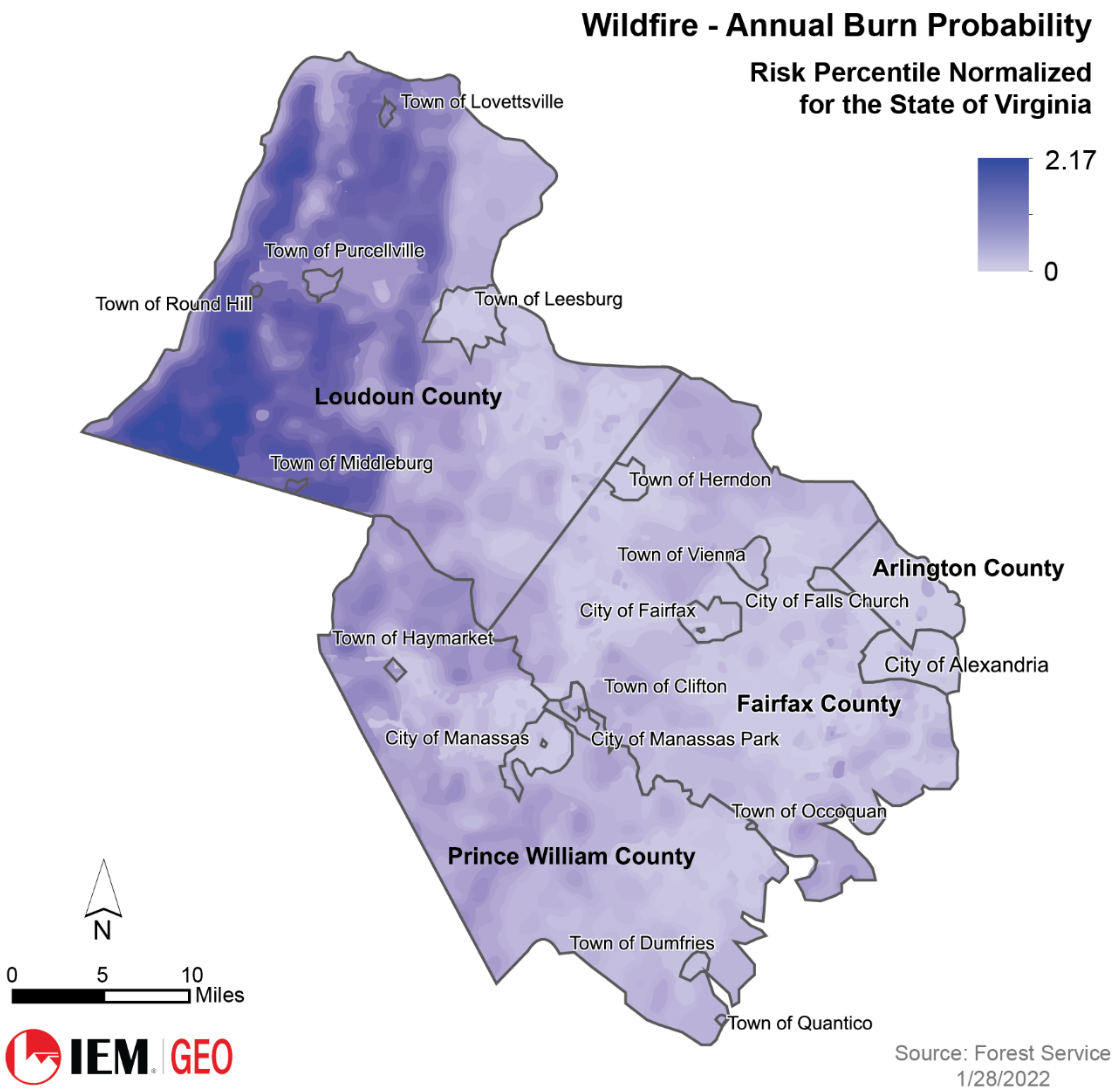

Figure 53: Wildfire Hazard Potential, VDEM Region 7[175]

One tool utilized for monitoring the development of conditions that may impact wildfire activity is the Keetch-Byram Drought Index (KBDI). The KBDI assesses the risk of fire by indicating the net effect of evapotranspiration and precipitation in producing cumulative moisture deficiency in deep duff (accumulated layers on the forest floor) and upper soil layers. The KBDI utilizes a scale from 0 to 800, with the higher number indicating a higher probability of fire activity and a higher likelihood of extreme fire

175 United States Forest Service, January 28, 2022.

behavior. The KBDI is most often used by fire response agencies as a guide to ensure that adequate resources, such as personnel, equipment, and water supplies, are on hand to respond to more frequent or severe wildfires.

The KBDI image presented in this section indicates that most of the Mid-Atlantic states, including Virginia and the planning area, are at low risk for wildfire on the date indicated.

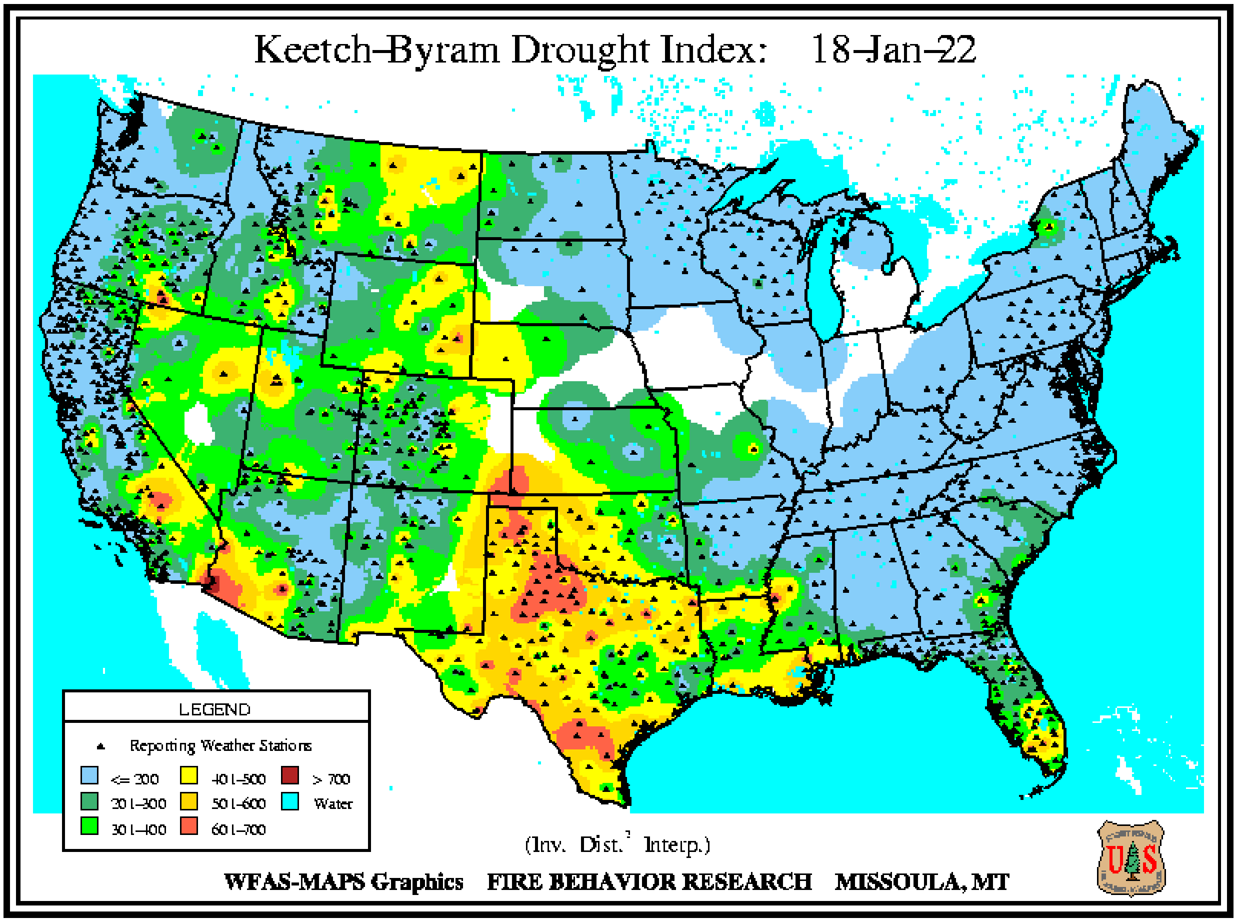

Figure 54: Keetch-Byram Drought Index, January 18, 2022[176]

5.10.2. Risk Assessment

The risk associated with wildfire in the planning area has not been formally quantified, due to the lack of precise information on probability and impact. A VDOF wildfire risk assessment conducted in 2002 and 2003[177] identified specific factors that could influence the occurrence and advancement of wildfires, including the following:

- Density of historical wildfires
- Land cover (fuel)
- Percent slope

[176] National Drought Monitoring Center, University of Nebraska, Lincoln. Accessed January 18, 2022 at: https://droughtmonitor.unl.edu/data/png/current/current_usdm.png (Note: This map is updated frequently.)
[177] 2018 Commonwealth of Virginia Hazard Mitigation Plan, March 2018.

- Slope orientation/aspect
- Population density
- Distance to roads
- Railroad buffer
- Road density and developed areas

For this update, risk of wildfire is focused on damages to infrastructure and population, rather than a discussion of the risk of fires starting or spreading.

5.10.2.1. Population and Property

There is low risk of human injury or death due to wildfire in Northern Virginia; however, people residing in areas of the wildland/urban interface are at greater risk. In addition, visitors to forested recreational areas are also at higher risk.

5.10.2.2. Built Environment, Community Lifelines, and Assets

A number of jurisdictions in the planning area included a review by the Insurance Services Office (ISO), an outside auditing group noted as a source of information about risk with its Building Code Effectiveness Grading Schedule (BCEGS). ISO performs a periodic review to assess a community's building codes and the degree to which the codes are enforced. The program emphasizes mitigation of loss from natural hazards. A community with safer buildings is likely to experience lower fire-related damages and losses, ultimately lowering insurance costs.

The agency has developed advisory rating credits that apply to BCEGS classifications ranging 1–3, 4–7, 8–9, and 10, and other scores that may be applied to different types of residential or commercial structures.

Table 106: BCEGS Ratings for Participation Northern Virginia Jurisdictions

Jurisdiction	Year of Evaluation	BCEGS Rating(s)
Arlington County		Awaiting response from ISO
City of Alexandria	1998	Class 3
City of Fairfax	2016	Class 3
City of Falls Church	2014	3- Residential 2- Commercial
City of Manassas	2018	3- 1 and 2 Family Residential 2- Commercial and industrial
City of Manassas Park	2000	Class 3
Fairfax County	2018	2- Residential 1- Commercial Class 2
Town of Clifton	Falls under county's score	
Town of Herndon	Falls under county's score	
Town of Vienna	Falls under county's score	
Loudoun County	2020	Class 3

Jurisdiction	Year of Evaluation	BCEGS Rating(s)
Town of Leesburg	Falls under county's score	
Town of Lovettsville	Falls under county's score	
Town of Middleburg	Falls under county's score	
Town of Purcellville	Falls under county's score	
Town of Round Hill	Falls under county's score	
Prince William County	2018	Class 2
Town of Dumfries	Falls under county's score	
Town of Haymarket	Falls under county's score	
Town of Occoquan	Falls under county's score	
Town of Quantico	Falls under county's score	

One area of concern related to wildfires is the potential for extreme heat and flames to damage gas pipelines and other above-ground facilities associated with their operation. Damage to this infrastructure could result in temporary or long-term shutdown.

5.10.2.3. Natural Environment and Economy

Environmental damages due to wildfire are uncertain because locations vary, and magnitude is unknown. However, as evidenced by past events, the natural environment, including forested land, is at a moderate risk of impacts from wildfire. These impacts may lead to economic consequences for timber and agricultural losses, business disruption or loss, and loss of revenues from recreation and tourism.

5.10.2.4. Hazard Risk Ranking Summary

The hazard ranking process considered probability and consequences in determining an overall risk score and ranking. Information presented within this section and the hazard risk ranking process present the quantitative and qualitative summary for wildfire. The Hazard Identification and Risk Assessment methodology is described in **Section 4, Base Plan**.

Table 107: Hazard Risk Rankings for Wildfire, by Jurisdiction

Hazard	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
Arlington County	1.0	3.0	4.0	**Low**
City of Alexandria	1.0	3.0	4.0	**Low**
City of Fairfax	1.0	3.0	4.0	**Low**
City of Falls Church	1.0	3.0	4.0	**Low**
City of Manassas	0	0	0	**Low**
City of Manassas Park	1.0	3.0	4.0	**Low**
Fairfax County	1.0	3.0	4.0	**Low**
Town of Clifton	1.0	3.0	4.0	**Low**
Town of Herndon	1.0	3.0	4.0	**Low**
Town of Vienna	1.0	3.0	4.0	**Low**

Hazard	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
Loudoun County	1.0	2.8	3.8	Low
Town of Leesburg	1.0	2.8	3.8	Low
Town of Lovettsville	1.0	2.8	3.8	Low
Town of Middleburg	1.0	2.8	3.8	Low
Town of Purcellville	1.0	2.8	3.8	Low
Town of Round Hill	1.0	2.8	3.8	Low
Prince William County	1.0	3.0	4.0	Low
Town of Dumfries	1.0	3.0	4.0	Low
Town of Haymarket	1.0	3.0	4.0	Low
Town of Occoquan	2.0	2.0	4.0	Low
Town of Quantico	1.0	3.0	4.0	Low

5.10.3. Vulnerability Analysis

Vulnerability to wildfire is influenced by many factors, such as land cover, weather, and the effectiveness of land management techniques. Although highly urbanized areas may be less vulnerable to wildfire, suburban neighborhoods located at the urban/wildland interface are vulnerable. The primary impacts of most wildfires are timber loss and environmental damage, although the threat to nearby buildings is always present. Secondary impacts may also include landslides and mudslides caused by the loss of groundcover which stabilizes the soil.

There is no single standardized methodology for estimating vulnerability to the wildfire hazard; however, the Virginia Department of Forestry's *Wildfire Risk Assessment* model identified the level of risk based on the areas where conditions are more conducive to wildfire occurrence and advancement. This assessment also identified areas that required further investigation at larger scales and highlighted the spatial relationships between areas of relatively high risk and other geographic features of concern, such as woodland home communities, fire stations, and fire hydrants.[178] The data presented in the assessment was determined to be valid for this update.

Table 108: Wildfire Risk by Jurisdiction[179]

Jurisdiction	Low (acres)	Low % Area	Medium (acres)	Medium % Area	High (acres)	High % Area	Total Acres
Arlington County	16,064	96.30%	435	2.61%	183	1.10%	16,682
Fairfax County	143,682	57.22%	77,244	30.76%	30,174	12.02%	251,100
Town of Clifton	43	26.06%	95	57.58%	27	16.36%	165
Town of Herndon	2,734	99.93%	1	0.04%	0	0.00%	2,736

[178] Virginia Department of Forestry, Wildfire Risk Assessment, 2003. Data presented in the 2017 Northern Virginia Hazard Mitigation Plan, Table 4.104.
[179] Ibid.

Jurisdiction	Low (acres)	Low % Area	Medium (acres)	Medium % Area	High (acres)	High % Area	Total Acres
Town of Vienna	2,795	99.25%	21	0.75%	0	0.00%	2,816
Loudoun County	136,046	42.16%	166,511	51.60%	20,114	6.23%	322,672
Town of Leesburg	4,670	58.46%	2,635	32.98%	684	8.56%	7,989
Town of Purcellville	278	13.69%	1,738	85.62%	14	0.69%	2,030
Town of Middleburg	219	33.08%	389	58.76%	55	8.31%	662
Town of Round Hill	0	0.00%	165	69.62%	71	29.96%	237
Prince William County	87,118	39.77%	98,129	44.79%	33,828	15.44%	219,076
Town of Dumfries	745	73.40%	255	25.12%	14	1.38%	1,015
Town of Haymarket	240	78.43%	66	21.57%	0	0.00%	306
Town of Occoquan	83	74.77%	27	24.32%	0	0.00%	111
Town of Quantico	44	93.62%	3	6.38%	0	0.00%	47
City of Alexandria	9,644	98.83%	114	1.17%	0	0.00%	9,758
City of Fairfax	3,801	94.65%	215	5.35%	0	0.00%	4,016
City of Falls Church	1,275	100.00%	0	0.00%	0	0.00%	1,275
City of Manassas	6,130	95.50%	287	4.47%	2	0.03%	6,419
City of Manassas Park	741	65.29%	265	23.35%	129	11.37%	1,135
TOTAL	**416,352**	**48.97%**	**348,595**	**41.00%**	**85,295**	**10.03%**	**850,247**

Based on the Wildfire Risk Assessment, Prince William County has over 15% of its acreage in the high-risk category, with the Town of Round Hill having almost one-third of its acreage at high risk. Fairfax County has approximately 12% of its acreage in the high-risk category, with over 16% of the Town of Clifton's area in high risk. The Northern Virginia region is mostly low (48.97%) and medium (41%) risk, with a tenth of the region in the high-risk category.

5.10.3.1. Built Environment, Community Lifelines, and Assets

Historically, wildfires have been larger and caused more damages in areas of Loudoun and Prince William counties, not only because of increased vegetative fuel loads, but also because the areas are more sparsely settled and have lower rapid fire-response capabilities. The most at-risk properties within these areas are structures located along the wildland-urban interface, defined by the National Wildfire Coordinating Group as the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels. Structures with combustible roofs and less than 30 feet of cleared defensible space are particularly at risk.

Fuels reduction projects are conducted by federal and state agencies responsible for fire response in the wildland/urban interface with a focus on high-risk communities and adjacent natural resources that are inherently important to social and/or economic stability. These projects focus on increasing public and firefighter safety, reducing risk of unwanted fire, protecting recreational opportunities on public lands, strengthening rural economies, and increasing public understanding of fire management.

The data available in the Hazus scenario model conducted for this update was utilized as the basis for determining critical and historical facilities in wildfire risk areas to determine which facilities were at an increased risk for wildfire or are located in the urban/wildland interface. Most of the region falls within areas currently classified as having low or very low potential for wildfire, with other areas classified as non-burnable.

The lack of wildfire probabilities and detailed infrastructure data led to the inability to calculate potential losses due to wildfire.

Future updates to this Plan should consider methods for quantifying annual wildfire losses, which might include defining life/safety, property, environment, and economic losses related to hydropower, tourism, and recreation, based on detailed local reports of occurrences and associated damages.

5.10.3.2. Future Population and Development Trends

Future development and the resulting population increase has the potential to elevate vulnerabilities to wildfire in the future, depending on climate change variables and jurisdictions' capabilities to manage growth appropriate to minimize fire impacts and ensure an adequate water supply. As suburban residential development continues to expand, it is reasonable to expect an increase in human/wildland interactions, resulting in more wildfires.

As climate warning progresses, precipitation is more likely to increase in the winter but decline during the summer, leading to increased drying of soils. This process, combined with less rain in the summer, could lead to more frequent, severe, and longer-lasting droughts that could result in more dry forest fuel. Increased heat waves may also increase the risk of wildfires.

5.10.3.3. Factors for Consideration in the Next Planning Cycle

Future monitoring, evaluating, and updating of this Plan should consider the following factors related to wildfire as well as other information from the COV-SHMP:

- Have wildfire events occurred within the planning area since adoption of 2022 HMP?
- Did wildfire events take place in areas adjacent to the planning area that impacted the planning area?
- Has new scientific research or methodology changed the ability to predict wildfire events or assess risk and vulnerability?
- Has there been significant change in the population, built environment, natural environment, or economy that could affect the risk or vulnerability to wildfire, including changes in land use?
- Is there new evidence related to the impacts of wildfire that could affect the level of risk or vulnerability to wildfire?

5.11. Winter Weather

2022 HMP Update

The Winter Weather hazard was reexamined, and a new analysis performed. This new analysis included, but was not limited to:

- Reformatting the hazard section to improve flow and clarity
- Refreshing the hazard profile with updated data, maps, and imagery, where available
- Updating the assessment of risk and vulnerability by jurisdiction based on new data
- Ranking the hazard by jurisdiction using the methodology described in detail in Section 4
- Extreme Cold was separated from the Winter Weather section for the 2016 Plan update and continues to be included in the Extreme Temperatures section for the 2022 update

Based on the 2022 hazard analysis, the hazard name was changed to Severe Winter Weather to emphasize the difference between winter weather that is within the day-to-day capabilities and resources of the jurisdictions, and those that require additional mitigation to reduce the level of risk.

Table 109: Winter Weather Profile

<table>
<tr><th colspan="5">Winter Weather</th><th>Overall Vulnerability</th></tr>
<tr><th colspan="5">Definition, Key Terms, and Overview[180]</th><td rowspan="6">High</td></tr>
<tr><td colspan="5">Winter Weather: An event in which the main types of precipitation are snow, sleet or freezing rain.
Severe Winter Weather: A life-threatening winter storm for which a jurisdiction requires additional capabilities, resources, or actions.
Blizzard: A winter storm with winds of 35 miles per hour or greater, and significant snow or blowing snow with visibility of less than one-quarter mile.
Ice Storm: Ice accumulation that could cause extremely dangerous conditions and significant property or crop damage.</td></tr>
<tr><th>Frequency</th><th>Probability</th><th colspan="3">Potential Magnitude</th></tr>
<tr><td rowspan="2">Moderate</td><td rowspan="2">High</td><th>Injuries/Deaths</th><th>Infrastructure</th><th>Environment</th></tr>
<tr><td>Moderate</td><td>High</td><td>Moderate</td></tr>
</table>

5.11.1. Hazard Profile

Winter weather may range from a moderate snow over a period of a few hours to blizzard conditions with blinding wind-driven snow that lasts for several days. Some winter storms impact multi-state regions. Winter storms may be accompanied by low temperatures, ice, and heavy and/or blowing snow, which can severely impair visibility.

Winter weather may include snow, sleet, freezing rain, or a mix of these wintry forms of precipitation.

[180] National Weather Service, Hazardous Weather Definitions

- **Sleet:** Raindrops that freeze into ice pellets before reaching the ground, usually bounce when hitting a surface, and do not stick to objects; however, sleet can accumulate like snow and cause a hazard to motorists.
- **Freezing rain:** Rain that falls onto a surface with a temperature below freezing, forming a glaze of ice. Even small accumulations of ice can cause a significant hazard, especially on power lines and trees.
- **Ice storm:** Occurs when freezing rain falls and freezes immediately upon impact. Communications and power can be disrupted for days, and even small accumulations of ice may cause extreme hazards to motorists and pedestrians.
- **Freeze:** Characterized by low temperatures, especially when they fall below the freezing point (zero degrees Celsius or 32 degrees Fahrenheit). House fires and carbon monoxide poisoning may occur when households use supplemental heating devices (wood, kerosene, etc.) and fuel-burning lanterns or candles for emergency heating or lighting.

Table 110: National Weather Service Winter Weather Warnings, Watches, and Advisories[181]

Term	Definition
Blizzard Warning	Issued for frequent gusts greater than or equal to 35 mph and accompanied by falling and/or blowing snow, frequently reducing visibility to less than ¼ mile for three hours or more.
Winter Storm Warning	Significant winter weather event including snow, ice, sleet, blowing snow, or a combination of these.
Wind Chill Warning	Chill values of -35°F or colder that can cause frostbite within as short a period as 10–15 minutes of exposure.
Freeze Warning	Temperatures of 32°F or colder for a significant period that could kill outdoor plants at the beginning or end of the growing season.
Winter Storm Watch	Issued when conditions are favorable for a significant winter storm event (heavy sleet, heavy snow, ice storm, heavy snow, blowing snow, or a combination of events).
Wind Chill Watch	Issued when there is the potential for a combination of extremely cold air and strong winds to create dangerously low wind chill values.
Winter Weather Advisory	A combination of winter weather conditions, such as 3 to 6 inches of snow expected within a 24-hour period; 5 to 8 inches of snow within a 24-hour period; light freezing precipitation; and/or blowing snow.
Wind Chill Advisory	Wind chill values between -25°F and -35°F that can cause frostbite within as short a period as 20–25 minutes of exposure.
Freeze Advisory	Temperatures in the mid-30s (°F) accompanied by clear skies, light winds, and high humidity near the ground that could kill outdoor plants at the beginning or end of the growing season.

[181] National Weather Service, Winter Weather Warnings, Watches, and Advisories. Retrieved at: https://www.weather.gov/safety/winter-ww

Table 111: Hazard Profile Summary

<table>
<tr><td rowspan="8">Severe Winter Weather

Assessment: High-Risk Hazard</td><td>Location</td><td>Jurisdiction-wide</td><td>Potential Cascading Effects</td></tr>
<tr><td>Extent</td><td>Moderate to Significant</td><td rowspan="7">• Impact on critical infrastructure, including roads, bridges, utility lines, water facilities
• Loss of natural resources
• Economic losses if businesses must close because employers or employees are unable to reach the workplace
• Long-term power outages
• Significant impacts to travel on major roadways</td></tr>
<tr><td>Duration</td><td>Less than one week</td></tr>
<tr><td>Probability</td><td>High</td></tr>
<tr><td>Seasonal Pattern</td><td>September through April</td></tr>
<tr><td>Speed of Onset</td><td>Slow to rapid, depending on conditions</td></tr>
<tr><td>Warning Time</td><td>6 to 12 hours</td></tr>
<tr><td>Repetitive Loss</td><td>N/A</td></tr>
</table>

5.11.1.1. Location

The Northern Virginia region is in a part of the country that experiences hazardous winter weather conditions, including severe winter storms that bring heavy accumulations of snow, sleet, and freezing rain. On average, the region receives approximately 15 to 21 inches of snow annually. The region's biggest winter storms are typically associated with Nor'easters.

All jurisdictions within the planning area are susceptible to severe winter weather. During these events, winds around the storm's center can become intense, building waves that erode the Potomac shoreline and sometimes pile water inland causing extensive coastal flooding and severe erosion. These systems may also produce blinding snowfall that may accumulate to a foot or more of mixed precipitation that may leave a coating of ice. Other types of winter weather systems are more of a nuisance and generally do not cause major damage. Weather systems such as the "Alberta Clipper" (a fast-moving storm from the Alberta, Canada region), or a cold front sweeping through from the west, generally do not bring more than a few inches of snow in a narrow 50- to 60-mile-wide band.

The hazard ranking process included consideration of probability and consequences in determining an overall risk score and ranking. Information presented within this section and the hazard risk ranking process present the quantitative and qualitative summary for severe winter weather. The Hazard Identification and Risk Assessment methodology is described in **Section 4, Base Plan**.

Table 112: Hazard Risk Rankings for Severe Winter Weather, by Jurisdiction

Hazard	Total Probability Score	Total Consequence Score	Overall Risk Score	Ranking
Arlington County	3.3	3.8	7.1	High
City of Alexandria	3.3	3.5	6.8	High
City of Fairfax	3.7	3.5	7.2	High
City of Falls Church	3.7	3.5	7.2	High
City of Manassas	3.7	3.5	7.2	High
City of Manassas Park	3.7	3.5	7.2	High
Fairfax County	3.7	3.5	7.2	High
Town of Clifton	3.7	3.5	7.2	High
Town of Herndon	3.7	3.5	7.2	High
Town of Vienna	3.7	3.5	7.2	High
Loudoun County	3.3	3.5	6.8	High
Town of Leesburg	3.3	3.5	6.8	High
Town of Lovettsville	3.3	3.5	6.8	High
Town of Middleburg	3.3	3.5	6.8	High
Town of Purcellville	3.3	3.5	6.8	High
Town of Round Hill	3.3	3.5	6.8	High
Prince William County	3.7	4.8	8.5	High
Town of Dumfries	3.7	3.5	7.2	High
Town of Haymarket	3.7	3.5	7.2	High
Town of Occoquan	3.7	3.5	7.2	High
Town of Quantico	3.7	3.5	7.2	High

5.11.1.2. Extent

The Regional Snowfall Index (RSI), an evolution of the Northeast Snowfall Impact Scale (NESIS)[182] seeks to rank snowstorms regionally throughout the United States based on the impacts these systems have on society. The scale is broken into five event categories ranging from 1, ("Notable") to 5 ("Extreme"). The amount of snowfall for a particular storm and the population impacted are the factors used in assigning NESIS values. This scale differs from other meteorological indices in that it uses population information in addition to meteorological measurements. Virginia is included in the Southeast region. Researchers have calculated the scores for high-impact storms dating back to the 1900s.

[182] The Northeast Snowfall Impact Scale (NESIS) was developed by Paul Kocin and Louis Uccelline, National Weather Service, 2005.

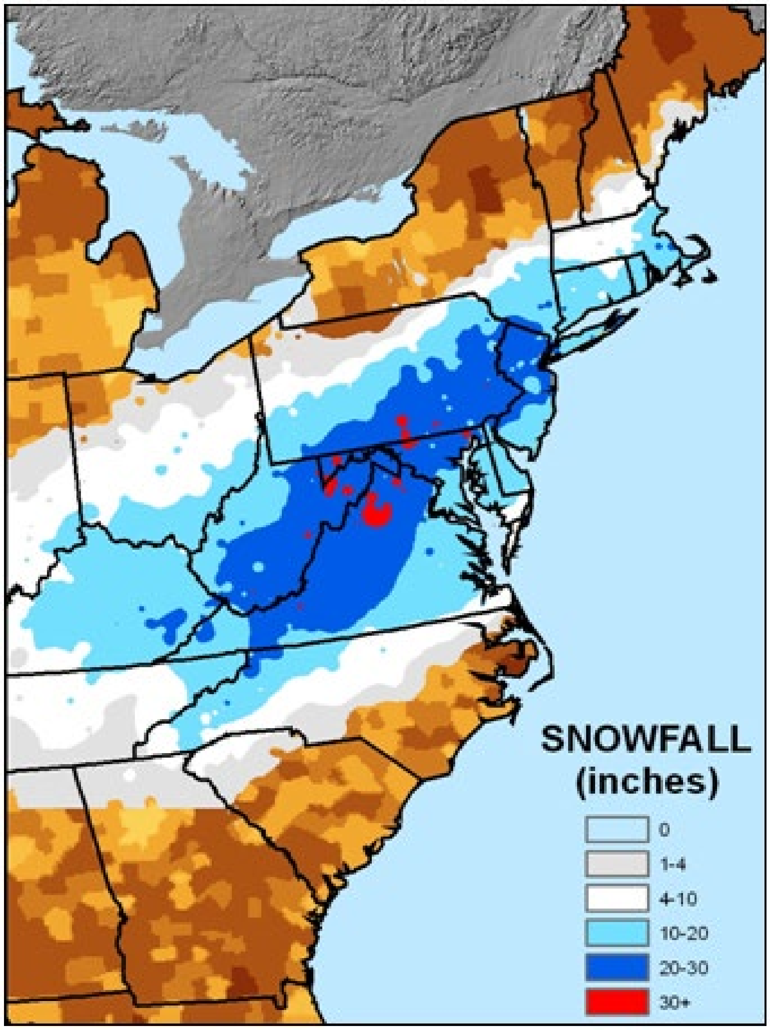

Figure 55: Example of Regional Snowfall Index (previously the Northeast Snowfall Impact Scale) with Snowfall, in Inches[183]

The NESIS image illustrates the planning area in dark blue, which relates to an event of 20 to 30 inches of snow, or a Category 4 ("Crippling").

5.11.1.3. Previous Occurrences

The National Centers for Environmental Information's Storm Events Database documents severe winter weather events (including blizzard, heavy snow, ice storm, winter storm, and winter weather) between 1996 and 2021. Within that period, there have been 503 winter storm event reports, causing an estimated $1.025 million in property damage.[184] There were five deaths and four injuries within the Northern Virginia region as a result of these events. The NCEI records winter storm events at a geographic county level;

[183] NOAA, Northeast Snowfall Impact Scale. Retrieved at: https://www.ncdc.noaa.gov/snow-and-ice/rsi/nesis
[184] NOAA, National Centers for Environmental Information, Storm Events Database, 1950 to June 30, 2021. Most storm damages are attributable to traffic accidents and roof or other structural collapses, which are frequently insured and not reported to the National Weather Service. It is important to note that the considerable costs associated with lost wages and business opportunities, lowered productivity, and snow and ice removal are not factored into NCEI loss estimates and are therefore not accounted for here.

thus, all towns and cities within the same geographic area are included in the storm and damage estimates for that area because of the typically widespread spatial nature of winter storms.

Table 113: Winter Storm Events in Northern Virginia (1996 – 2021), by Jurisdiction[185]

Jurisdiction	Number of Winter Storm Events	Deaths	Injuries	Property and Crop Damage
Arlington County, the City of Alexandria, and the City of Falls Church	120	1	0	$440,000
Fairfax County, the City of Fairfax, & the Towns of Clifton, Herndon, and Vienna	148	3	4	$315,000
Loudoun County and the Towns of Leesburg, Lovettsville, Middleburg, Purcellville, and Round Hill	101	1	0	$235,000
Prince William County, the City of Manassas, the City of Manassas Park, & the Towns of Dumfries, Haymarket, Occoquan, and Quantico	134	0	0	$35,000
TOTAL	**503**	**5**	**4**	**$1,025,000**

[185] NOAA, National Centers for Environmental Information, Storm Events Database, 1996–June 30, 2021.

Table 114: Federal Disaster Declarations for Winter Weather, all Jurisdictions[186]

Date of Declaration	Disaster Number	Hazard Event	Arlington County	Fairfax County	Loudoun County	Prince William County	City of Alexandria	City of Fairfax	City of Falls Church	City of Manassas	City of Manassas Park
4/19/2016	DR-4262-VA	Severe Winter Storm and Snowstorm	X	X	X	X	X	X	X	X	X
4/27/2010	DR-1905-VA	Severe Winter Storms and Snowstorms	X	X	X	X	X	X	X	X	X
2/16/2010	DR-1874-VA	Severe Winter Storms and Snowstorm	X	X		X	X	X	X	X	X
3/27/2003	DR-1458-VA	Severe Winter Storm, Snowfall, Heavy Rain, Flooding, and Mudslides	X	X	X	X	X	X	X	X	X
2/28/2000	DR-1318-VA	Severe Winter Storm	X	X	X	X	X	X		X	
2/2/1996	DR-1086-VA	Blizzard of 1996 (Severe Snowstorm)	X	X	X	X	X	X	X	X	X

[186] FEMA, Disaster Declarations. Retrieved at: https://www.fema.gov/disaster/declarations

Significant Previous Occurrences

While there have been numerous instances of winter storm events occurring in the planning area, numerous jurisdictions in the region have been included in federal disaster declarations. In all but two instances, all jurisdictions in the planning area were included in the declaration. This point also shows the degree to which winter storm is a non-spatial hazard.

January 2016 – A coastal low-pressure system rapidly intensified in the Mid-Atlantic coast area and tapped into moisture from the Gulf of Mexico and Atlantic Ocean, producing heavy precipitation that resulted in snowfall due to cold air in the region. Gusty winds also accompanied the storm, creating low visibility and blizzard conditions across portions of the state. Snowfall reports between 30 and 36 inches were received across western Loudoun County, with a total of 36.3 inches near Round Hill. The storm is the fourth on the list of historic storms ranked on the NESIS scale and resulted in a federal disaster declaration (FEMA DR-4262). The storm was rated 7.66 on the southeast region RSI scale, or “Crippling.”

Winter of 2014 – In January 2014, four separate storms moved through the area, each dumping ice or snow in the area. The January 21 event was particularly harsh, with most of the planning area receiving more than 5 inches of snow. The City of Manassas reported 6 to 10 inches of snow and partially activated their Emergency Operations Center for the event. February 12–13 saw the next round of snow, with more than 8 inches falling. March 3 saw yet another round of significant snowfall throughout the area, with more than 5 inches recorded; some areas, such as the City of Manassas, reported accumulations of 6 to 10 inches.

February 2010 – All of NOVA was included in DR-1905, which occurred February 5–11, 2010. This event was declared as a result of severe winter storms and snow. Record-breaking snowfall fell over Northern Virginia and much of the Mid-Atlantic area. A storm system moving through the Midwest phased with another system moving across the South, then tracked northeast and east along the Mid-Atlantic coast before heading out to sea. Snow began during the afternoon of February 5 and continued into the early evening of February 6. As much as 32.4 inches fell over the two-day period at the National Weather Service (NWS) Forecast Office in Sterling, Virginia near Dulles International Airport, with 17.8 inches at Ronald Reagan Washington National Airport. Travel by air, rail or roadway became nearly impossible, as winds gusting over 35 mph whipped snow into drifts of up to 4 feet deep. This storm was the second paralyzing snowstorm of the season for what would turn out to be (according to NWS data) Northern Virginia’s snowiest winter on record. The storm was nicknamed “Snowpocalypse” and “Snowmageddon” by local media and others. The snow forced the shutdown of the federal government for four and a half consecutive days.

A dry, powdery snow accompanied by wind gusts of 40 to 50 mph caused white-out conditions across a considerable portion of Northern Virginia, particularly on the morning of February 10. Snow drifts up to four feet high leftover from the storm of February 5–6 and up to a foot of additional accumulation from this storm brought travel in the area to a standstill once again. Conditions were so fierce that at 7:00 a.m., the Virginia Department of Transportation ceased snowplow operations, citing visibility of less than 100 feet at times. Total accumulations from this storm were greatest over the eastern and northern sections of the region, where accumulations of 10 to 14 inches were common near the borders with the District of Columbia and Maryland. Lighter amounts of generally 5 to 9 inches fell over the rest of the region. The storm was rated as an 8.103 on the southeast region RSI scale, or “Major.”

December 2009 – Arlington County, Fairfax County, Prince William County, the City of Alexandria, the City of Fairfax, the City of Falls Church, the City of Manassas, and the City of Manassas Park were also included in DR-1874, which occurred December 18–20, 2009. A storm system that formed over the Gulf of Mexico gathered strength as it tracked to a position off the Carolina coast and then along the Eastern Seaboard. Snow began falling over Northern Virginia during the evening of December 18 and continued into much of the following day, bringing travel to a halt as roads, railways, and runways became snow-covered and, in some cases, impassable.

The initial heavy, wet nature of the snow, combined with winds that gusted to over 35 mph at times, left thousands in the Mid-Atlantic without power. Ronald Reagan Washington National Airport recorded 15 inches of snow on December 19, for a two-day storm total of 16.4 inches. Slightly higher amounts fell just to the west and south with Dulles International Airport, totaling 19.3 inches. This event was rated a 12.776 on the southeast region RSI scale, or "Crippling."

5.11.1.4. Probability of Future Occurrences

The probability of future winter weather events is usually determined based on an examination of the historical frequency of occurrence of such events. The NCEI Storm Events database contains winter weather events and damages dating back to 1996, but it does not systematically document the magnitude or intensity of each event. The NCEI database also records these events at a geographic county level, with individual accounts from municipalities or unincorporated areas of the county included in the reports. Long-term weather station observation data provides more detailed information on event magnitude (as measured by snowfall depth, precipitation types, and temperature), but does not provide detailed information regarding historical impacts.

Using the number of winter storm events documented in the NCEI database, divided by the number of years of record (24.5), a return interval of 0.216 can be determined for the region in any given year. The amount of snowfall varies slightly throughout the planning area and from month to month throughout the winter season. The western areas of Loudoun County typically receive higher levels, but these amounts are variable based on any given year and the factors related to each storm event.

Table 115: Average Monthly Snowfall (in Inches) 1991-2020[187]

October	November	December	January	February	March	April
0	0.3	2.8	6.9	7	3.9	0.1

Based on this analysis and the historical record, winter storms will remain a highly likely occurrence for the entire Northern Virginia region. If history continues to hold true, western sections of Loudoun County can expect a slightly higher likelihood of experiencing accumulating snowfall relative to the remainder of Northern Virginia.

Long-range climate modeling suggests that as the planet warms, a trend of more winter precipitation taking the form of liquid precipitation (rather than snowfall) would result. Future hazard mitigation plan updates will factor the latest climate science as part of the updated hazard analysis method for determining the probability of future occurrence of winter weather.

5.11.2. Risk Assessment

The risks related to winter storms can be assessed in relation to people, property, the environment, and the economy.

5.11.2.1. People

Everyone who lives, works, and travels in the planning area are potentially at risk for impacts of severe winter storms. The hazards created by winter weather, including blizzards and ice storms create especially significant danger to life, travel, and employment conditions.

In addition, impacts to transportation may cause motorists to be stranded on area roadways for extended periods of time. Due to the transient nature of the area, there are a significant amount of people in this

[187] Weather Service: https://www.weather.gov/media/lwx/climate/iadsnow.pdf

region who are not prepared for winter weather and know what to do which increases risk. The possibility of loss of life is significant if these jurisdictions are affected by a severe winter storm, especially if more than one weather element is present (such as heavy snowfall and ice at the same time). Storm effects can lead to accidents on icy roads, heart attacks while shoveling snow, and hypothermia due to prolonged exposure to the cold. In addition, the safety of emergency responders may be at risk during outside operations that require prolonged exposure or when icy conditions are present.

Vulnerable populations identified by the jurisdiction include people who speak limited English, the elderly, those of lower socioeconomic status, the disabled (physical and mental) and people who lack access to traditional methods of communication in order to receive preparedness messages and warnings (e.g., no TV, radio, or internet; or are vision or hearing impaired).

5.11.2.2. Built Environment and Community Lifelines and Assets

Property damage due to winter storms includes damage done by (and to) trees, water pipe breakage, structural failure due to snow loads, and injury to livestock and other animals.

Northern Virginia jurisdictions are a mix of residential, commercial, industrial, and governmental buildings and facilities. There are also numerous bridges, communication facilities, and utility (electricity, water, and sewer) infrastructures located in the urban as well as suburban and rural areas. The communication systems throughout the region (such as voice, internet and emergency services) are an issue if damaged. Winter weather hitting any area of the region would likely cause damage to property, especially if there is a great deal of snow.

Roof and building collapse can result from snow buildup that exceeds the load capacity of the roof. Collapse due to overloading can usually be prevented by removing excess snow as it accumulates. If damaged buildings are left unprotected, later storms can cause additional damage. Prolonged ice and snow buildup on roofs can cause ice dams, which will allow moisture to penetrate the building and damage both interior materials and structural members.

The consequences of winter storm events are the disruption of utilities and transportation systems, as well as lost hours of government and commercial business operations and decreased productivity. Vulnerability to these damages varies due in large part to specific factors, including proactive measures such as regular tree maintenance and utility system winterization, which can minimize property vulnerability. Localities accustomed to winter weather events are typically more prepared to deal with them and therefore less vulnerable than localities that rarely experience winter weather.

The frequency of structural fires tends to increase during winter weather, primarily due to utility interruptions and improper use of alternative heating sources (e.g., fireplaces, gas, or propane heaters). Fires during these events also present a greater danger because water supplies may freeze and impede firefighting efforts.

5.11.2.3. Natural Environment

The environmental vulnerabilities due to winter weather include water contamination/pollution, soil damage from chemical spills, and natural gas leaks, which can occur due to heavy snow and snow melt in the spring.

Northern Virginia has a large amount of majestic old trees, forests, and acres of open space included in federal, state, and local recreational areas. Even assets such as Arlington National Cemetery (although it is not considered a recreational site) include broad acreage and many trees. Wildlife flourishes throughout the planning area and is at risk during a severe winter storm.

5.11.2.4. Economy

The impacts of winter storms are primarily quantified in terms of the financial cost associated with preparing for, responding to, and recovering from them. The primary source of data providing some measurement of winter storm impacts is the NCEI Storm Events Database. The database includes winter event data back to 1996 but is not necessarily complete or consistent from event to event. Although a more comprehensive, labor-intensive analysis utilizing other data sources could produce a potential intensity–damage relationship between winter weather occurrences and resultant damages, such an analysis was not performed for this update. The branches of government most often affected by winter storms include the Virginia Department of Transportation and local public works and transportation departments. Roadway treatment operations often begin in advance of a winter storm and continue for as long as necessary.

The cost of snow removal, repairing damages, and loss of business could have a significant economic impact on the planning area. The effects of a winter weather would be felt on infrastructure such as communication, transportation, and other utility interruptions which, in turn, are costly to repair and restore. In addition, the loss of services—even temporarily—could lead to indirect economic loss, based on business closures if employees are unable to reach their workplace.

Due to the significant number of federal office buildings in the region, federal government operations could be heavily impacted by a significant winter storm. In addition to government offices, a number of global businesses and industries are headquartered in the region. Significant winter weather could create severe disruption of government and commercial activity, resulting in short- to long-term economic losses (both direct and indirect) in the jurisdictions.

5.11.3. Vulnerability Assessment

Although the annual probability of winter weather conditions can be estimated, data on the total financial impact of these events is incomplete. The primary impacts of winter storms can be determined in terms of the financial cost related to preparing for, responding to, and recovering from these events; however, additional costs related to these events include traffic accidents, roof damage to homes and business, and other impacts that may be insured. For this reason, the actual economic impact is difficult to quantify. Instead, estimates of the financial impacts of severe winter storms can be developed based on NCEI winter weather event data that runs from January 1996 to June 2021. Examination of NCEI data shows that there were at least 503 winter weather events in the database, producing an estimated annualized loss of $41,837, based on total estimated losses of more than $1 million for the 24.5-year period of record.

The winter weather frequency data from the Commonwealth shows a strong trend toward more winter weather occurring in areas at higher latitudes and at higher elevations. The mountainous western portion of the state and the northern portions of the state, including Northern Virginia, experience winter weather more often and with greater severity than other portions of Virginia. Although the magnitude of damages from winter storms is perhaps not typically as great as experienced in association with extreme flooding or a severe earthquake, winter storms occur much more frequently and usually over broader areas. In addition, storm events with relatively low intensity can nevertheless cause significant impacts, especially in areas unaccustomed to such events.

Losses associated with winter storms are typically related to snow removal and business interruption, although power failure is also a significant secondary hazard commonly associated with winter storms, and particularly ice events. In addition to the impacts on transportation, power transmission, and communications, severe winter storms in the Northern Virginia region have at times caused severe property damage due to roof collapses. According to FEMA, most injuries and fatalities related to winter storms are caused by vehicle accidents and hypothermia. The entire Northern Virginia region is generally equally susceptible to winter storms and has experienced similar numbers of events and levels of damage.

5.11.3.1. Vulnerability of Community Lifelines

Quantitative assessment of community lifelines for winter storm risk was not feasible for this update. Even so, it is apparent that transportation structures are at greater risk from winter storms. In addition, building construction types—particularly roof span and construction method—are factors that determine the ability of a building to perform under severe stress weights from snow. Finally, not all critical facilities have redundant power sources, and some may not even be wired to accept a generator for auxiliary heat. Future updates should consider including a more comprehensive examination of critical facility vulnerability to winter storms.

Severe winter storms may impact critical pipelines through ground motion due to frost heave putting pressure on brittle pipelines, resulting in breakage. In addition, snow and ice may accumulate and damage control mechanisms that support pipeline operations. Regional power or telecommunication systems necessary for routine pipeline operations are also at risk for damage or loss.

5.11.3.2. Future Population and Development Trends

Because severe winter storms are not limited to geographic boundaries or population groups, it is difficult to identify development and population trends that impact this hazard. Current land use and building codes incorporate standards that address and mitigate snow accumulation.

The potential for impacts of future growth and development on severe winter storms will be monitored and evaluated in the next planning cycle to consider whether the level of risk has changed, and whether there are mitigation opportunities related to development that may reduce hazard impacts in the future.

5.11.3.3. Factors for Consideration in the Next Planning Cycle

Future monitoring, evaluation, and updating of this Plan should consider the following factors related to severe winter storms as well as other information from the *COV-HMP* updates:

- Have any severe winter storm events occurred since this Plan was adopted?
- Has any new scientific research or methodology changed the ability to predict severe winter storm events or assess risk and vulnerability?
- Has there been any significant change in the population, built environment, natural environment, or economy that could affect the risk or vulnerability to severe winter storm events?
- Is there any new evidence related to the impacts of climate change that could affect the level of risk or vulnerability to severe winter storm events?

6. Climate Change

§201.6(c)(2)(i): [The] risk assessment shall include a] description of the type, location, and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.

2022 HMP Update

The 2017 Northern Virginia (NOVA) Hazard Mitigation Plan (HMP) had *global warming* as a discussion point in relation to climate change in Section 3(B)(3) and other specific hazard sections, such as Section 4(VI) Flood. For this update, the topic is addressed as "climate change" to help convey that there are other changes besides rising temperatures. Elements of climate change are treated separately from individual hazards to emphasize the potential impacts on multiple sectors by various hazards. In addition, this section includes information on climate change mitigation and adaptation strategies in development by the Commonwealth of Virginia and HMP participants.

To profile climate change for the 2022 NOVA HMP update, the hazards impacted by this trend and/or its consequences are addressed in this section.

This section is not intended to provide a comprehensive review of current scientific evidence and data on climate change on either a global or jurisdictional scale. Nor does it propose or advocate for specific policy-making or regulatory initiatives related to climate change. It is intended to serve as a guide for identifying potential mitigation initiatives and actions for HMP participants and to link these activities to the strategies, goals, and objectives aimed at mitigating the potential impacts and consequences of climate change.

While this Plan carefully outlines all hazards that threaten the region, it is recommended that elected officials, planners, and the emergency management community recognize the potential for the changing nature of the climate and its future impacts.

Since the 2017 Plan, there has been increasing confidence that certain changes in multiple atmospheric and meteorological conditions may be attributed to climate change. New climate information and data are included in this update discuss in the following areas:

- Characteristics
- Impacts and consequences
- Vulnerabilities
- Changes in development in hazard prone areas
- Climate change initiatives

Specific data sources and key documents are provided as footnotes in this section.

Climate Change: Definition and Key Terms

- A sustained increase in the average temperature of the Earth that is sufficient to cause climate change.
- A change in the usual weather found in a place, such as the amount of rain a place receives in a year, the usual temperature for a month or a season, or a change in the location and amount of snowfall.

Climate change is both a present threat and a slow-onset disaster because it amplifies existing hazards. Extreme weather events have become more frequent over the past 40 to 50 years, and this trend is projected to continue. Rising sea levels, coupled with potentially higher hurricane wind speeds, rainfall intensity, and storm surge, are expected to have a significant impact on coastal communities, including those in Northern Virginia. More intense heat waves may mean more heat-related illnesses, droughts, and wildfires. As climate science evolves and improves, future updates to this Plan might consider including climate change as a parameter in the ranking or scoring of natural hazards.[188]

6.1. Characteristics

Climate change is a worldwide concern because of its potential to significantly impact people, natural resources, property, and economic conditions. While the magnitude of these changes is difficult to predict, there is broad agreement in the scientific community that they will continue to occur and will dramatically affect many aspects of peoples' daily lives.

Climate change, in and of itself, is not an individual hazard, and it is not required to be addressed by federal mitigation planning criteria. However, analyzing the conditions brought on by climate change can provide a better understanding of its risk and how the population, the environment, property, and the economy may be affected by it. In addition, changing climatic conditions may exacerbate the impacts of other hazards currently affecting the Northern Virginia region.

The effects of climate change are already impacting the communities in the planning area, and they are projected to increase in coming years. At the same time, this presents the opportunity to identify, through research and its application, appropriate mitigative and adaptive strategies and activities that can lessen the effects of climate change on the environment and future populations.

6.1.1. What Might Happen to the Earth's Climate?[189]

Scientists think the Earth's temperature will keep increasing for the next 100 years, causing:

- More snow and ice to melt
- Ocean levels to rise
- Some places to become hotter; other places to experience colder winters with more snow
- Some places to receive more rain; other places to receive less rain
- Some places to be exposed to stronger hurricanes

[188] *2017 Northern Virginia Hazard Mitigation Plan*. (2017). http://arlington.granicus.com/MetaViewer.php?view_id=2&event_id=1101&meta_id=163110
[189] National Aeronautics and Space Administration (NASA). (2017, May 14). *What is Climate Change?* https://www.nasa.gov/audience/forstudents/k-4/stories/nasa-knows/what-is-climate-change-k4.html

- Changes in the usual weather found in a given place, such as the annual amount of rain, the usual temperature for a month or a season, or a change in the locations and amounts of snowfall.

The Fourth Assessment Report[190] from the Intergovernmental Panel on Climate Change (IPCC) is a global reference point on the science of climate change. It states that between 1880 and 2012 there was an increase in global average temperature of approximately 1.5 °F. In addition, between 1901 and 2010, there was an increase in the global average sea level of about 7.5 to 8.3 inches. The report predicted that under current climate models, the global mean warming at the end of the twenty-first century will range from 0.5 °F to 8.6 °F, and sea levels could rise between 10.2 and 32.3 inches relative to the 1986–2005 average.

Scientists from George Mason University and the Center for Ocean-Land-Atmosphere Studies in Maryland have examined the original data for the moderate scenario presented in the Fourth Assessment Report, and they have calculated that the average warming for Virginia and the adjoining areas from 2000 to 2099 will be 5.6 °F, and that precipitation will increase by 11 percent.

The Fifth Assessment Report from the IPCC[191] notes that changes in extreme events have been observed since about 1950. It notes that "some of these changes have been linked to human influences, including a decrease in low temperature extremes, an increase in high temperature extremes, an increase in extreme high sea levels and an increase in the number of heavy precipitation events in a number of regions."[192]

Climate change is impacting the United States in the following ways:

- Rising air and water temperatures and changes in precipitation are intensifying droughts, increasing heavy downpours, reducing snowpack, and causing declines in surface water quality, with varying impacts across regions.
- Sea level rise threatens coastal areas with flooding and saltwater contamination, impacting sensitive coastal ecosystems and public and private property and potentially impacting power plants and energy availability.

6.1.2. Climate Change and Rising Temperatures

The average surface temperatures of the world's oceans have risen 2 °F since the pre-industrial era of 1880 to 1900.[193] This increase may seem minimal, but it has a significant impact on the heat capacity of the world's oceans. The extra accumulated heat drives regional and seasonal temperature extremes, reduces snow cover and sea ice, intensifies heavy rainfall, and changes habitat ranges for plants and animals.

Figure 56 tracks the trend in average annual global temperatures since 1880 compared to the long-term average from 1901 to 2000. The "zero" line represents the long-term average temperature for the entire planet; blue and red bars show the difference above and below average for each year. The overall trend since 1980 has been a steady rise in the average annual temperature of ocean surface waters. The 10 warmest years on record have all occurred since 2005, with seven of the 10 occurring since 2014. In perspective, as each new year is added to the historical record, it has become one of the 10 warmest on record at that time, but it is ultimately replaced as the "top ten" window shifts forward in time.

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[190] Intergovernmental Panel on Climate Change. (2012). *Climate Change 2012: Synthesis Report. A*s noted in the 2017 Northern Virginia Hazard Mitigation Plan.
[191] Intergovernmental Panel on Climate Change. (2014). *Climate Change 2014: Synthesis Report.* https://www.ipcc.ch/report/ar5/syr/
[192] Ibid., page 7.
[193] Dahlman, L. & Lindsey, R. (2021). *Climate Change: Global Temperature*. National Oceanic and Atmospheric Association. National Oceanic and Atmospheric Administration. https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

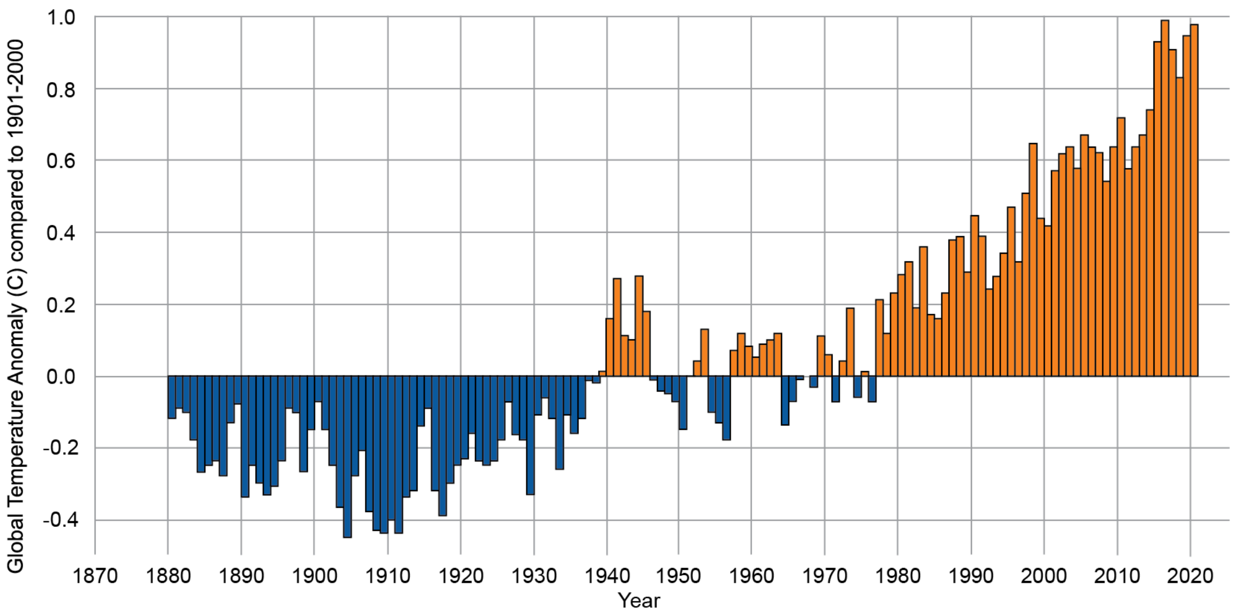

Figure 56: History of Global Ocean Surface Temperature Since 1880[194]

6.1.3. The Significance of Global Average Temperatures for Northern Virginia

While the Northern Virginia region is not seeing the highest increase in average temperatures compared to other parts of the world, it is experiencing some of the effects of this phenomenon in different ways. Most importantly, increases in extreme heat events bring an increased risk to public health and the environment. In addition, some areas might experience longer periods of drought or more frequent excessive rainfall events as a result of higher levels of moisture absorbed into the atmosphere.

The Commonwealth's diverse geographic elements, including the Appalachian and Blue Ridge Mountains in the west and the Atlantic coastal region in the east, highly influence the temperature and precipitation patterns in Northern Virginia, with the west and north being cooler and drier than the eastern coastal region. Since the beginning of the twentieth century, temperatures have risen approximately 1.5 °F in the region, with the average annual temperatures since 2000 exceeding previous highs in the 1930s. The below-average number of very cold nights since 1990 indicates a warming trend in winters, and average summer temperatures between 2005 and 2014 exceeded those in the early 1930s.

[194] Dahlman, L. & Lindsey, R. (2021). *Climate Change: Global Temperature*. National Oceanic and Atmospheric Association. National Oceanic and Atmospheric Administration. https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

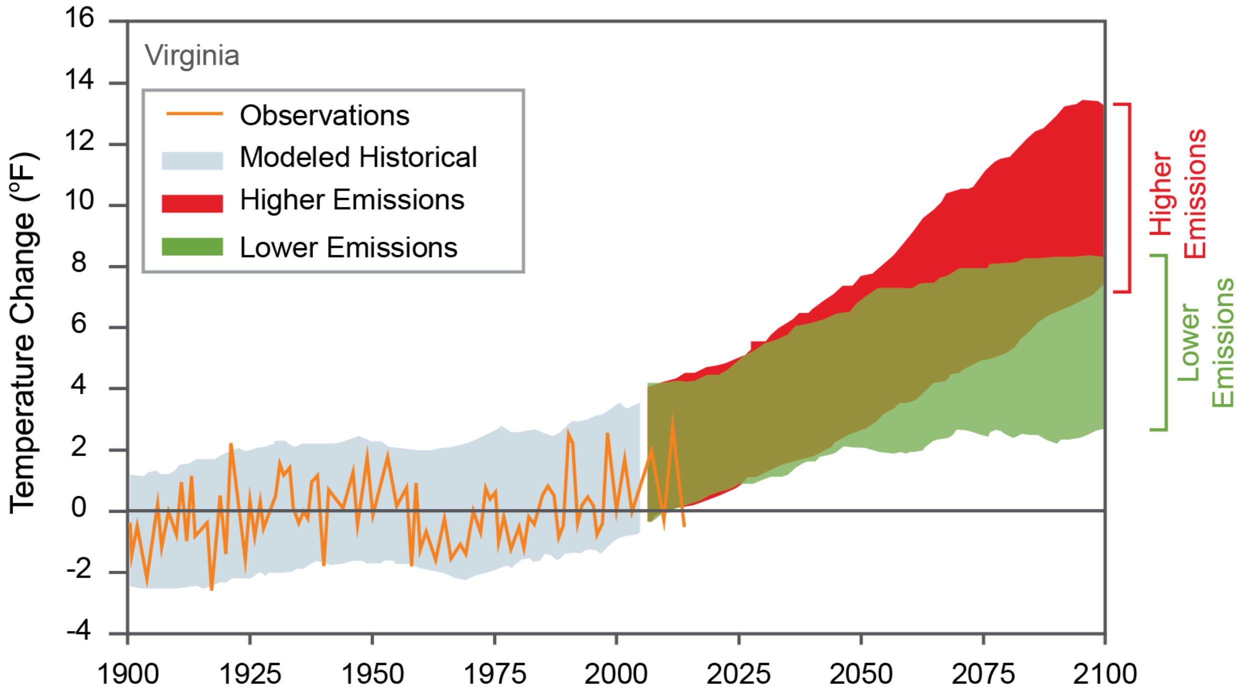

Figure 57: Observed and Projected Temperature Change in Virginia, 1900–2100 [195]

6.1.4. Climate Extremes Index

A relatively new index developed by the National Oceanic and Atmospheric Association (NOAA) provides an assessment of climate extremes based on previous events distributed through a long-term record. Figure 58 shows the annual index for 2018, indicating that the entire southeast United States, including Virginia, was ranked in the top tenth percentile, with a Climate Extremes Index of 44.60 percent.

6.1.5. Precipitation

Over the previous two decades, annual precipitation has generally been above the long-term average, and there has been an upward trend in the annual number of extreme precipitation events. The average annual summer precipitation has been below or near the long-term average in the most recent decade.

[195] Runkle, J., K. Kunkel, L. Stevens, S. Champion, B. Stewart, R. Frankson, and W. Sweet. (2017). *State Climate Summary – Virginia, 2017*. National Oceanic and Atmospheric Association (NOAA) National Center for Environmental Information (NCEI). https://statesummaries.ncics.org/chapter/va/

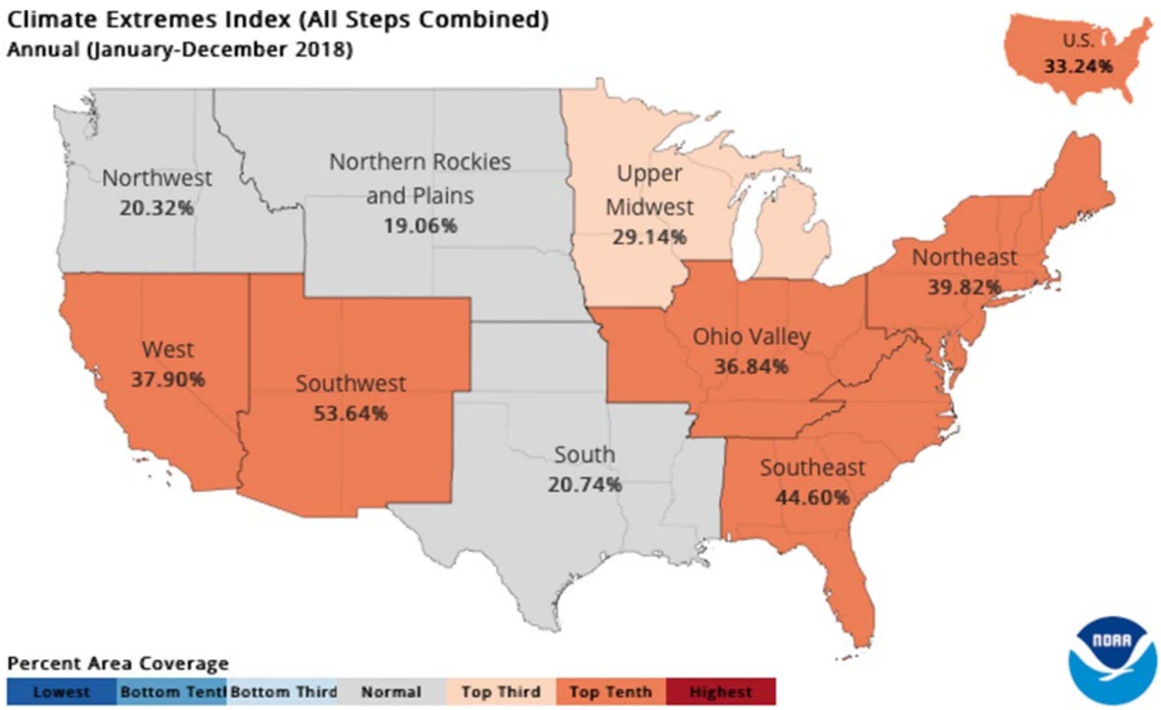

Figure 58: Example of Climate Extremes Index, 2018 [196]

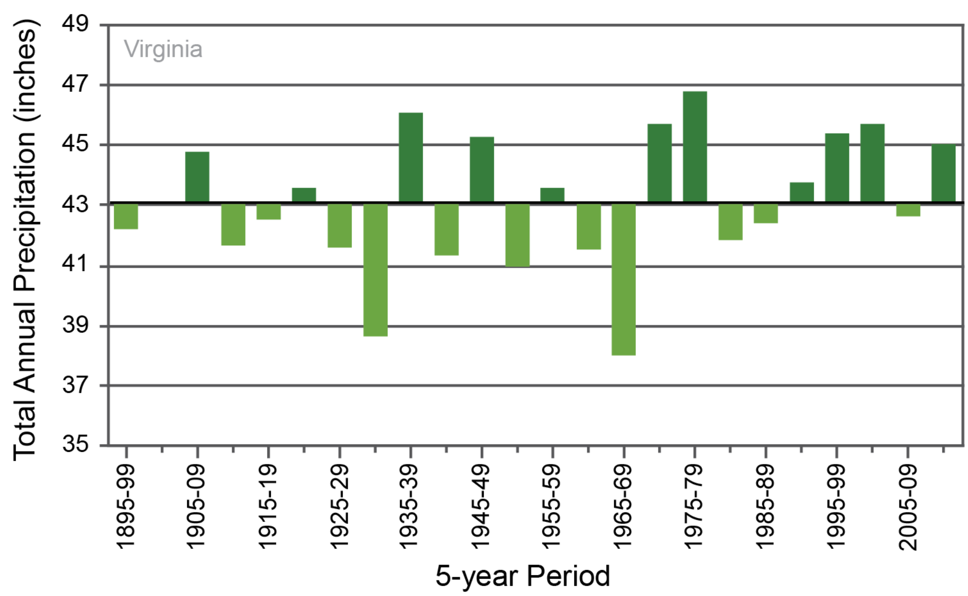

Figure 59: Extreme Precipitation Events in Virginia in Five-Year Periods, 1895–2009 [197]

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[196] Gleason, K. & National Center for Atmospheric Research Staff (Eds). (2019, December 12). *The Climate Data Guide: U.S. Climate Extremes Index (CEI).* https://climatedataguide.ucar.edu/climate-data/us-climate-extremes-index-cei

[197] Runkle, J., K. Kunkel, L. Stevens, S. Champion, B. Stewart, R. Frankson, and W. Sweet. (2017). *State Climate Summary – Virginia, 2017*. National Oceanic and Atmospheric Association (NOAA) National Center for Environmental Information (NCEI). https://statesummaries.ncics.org/chapter/va/

6.1.6. Climate Change and Increasing Flood Risk

The general description of current flood characteristics, risks, and vulnerabilities is provided in **Section 5.5, Flood**, with specific local impacts described in the Jurisdiction Annexes.

Future flood risk—coastal, riverine, and flash—due to climate change has been studied at great length by the scientific community with several key messages relevant to hazard mitigation planning:

- The climate change trend will change ocean levels.
- These changes will vary by location and magnitude.
- Meteorological factors that drive the development of weather patterns contribute to higher precipitation events.

The Fourth National Climate Assessment[198] notes that global sea level is very likely to rise by 0.3–0.6 feet by 2030, 0.5–1.2 feet by 2050, and 1.0–4.3 feet by 2100 under a range of emission scenarios from very low to high. This would increase both the depth and frequency of coastal flooding. Under higher emissions scenarios, the sea level around the Southeast United States could rise over eight feet by 2100. By 2050, several Southeast United States cities are projected to experience more than 30 days of high tide flooding regardless of scenario, and more extreme coastal flood events are projected to increase in frequency and duration. For example, water levels that currently have a one percent chance of occurring each year—known as a 100-year event—will be more frequent with sea level rise. This increase in flood frequency suggests the need to consider revising flood study techniques and standards that are currently used to design and build coastal and urban infrastructure.

Specific conclusions regarding flooding are highlighted in the assessment:[199]

- Higher sea levels will cause storm surges from tropical storms to travel farther inland than in the past, impacting more coastal properties. The combined impacts of sea level rise and storm surge in the Southeast United States have the potential to cost up to $56–60 billion (in 2015 dollars) each year up to 2050 and up to $79–99 billion up to 2090 under low to higher scenarios.
- Extreme rainfall events have already increased in frequency and intensity in the Southeast, and there is high confidence they will continue to increase. The region has experienced increases in the number of days with more than three inches of precipitation and a 16 percent increase in observed five-year maximum daily precipitation. This is defined as the amount falling in an event expected to occur only once every five years. The frequency and severity of extreme precipitation events are projected to continue to increase in the region under both lower and higher emissions scenarios.
- By the end of the century, under a higher emissions scenario, projections indicate approximately twice as many heavy rainfall events, defined as two-day precipitation events with a five-year return period, and a 21 percent increase in the amount of rain falling on the heaviest precipitation days, defined as days with a 20-year return period. These projected increases would directly affect the vulnerability of the Southeast's coastal and low-lying areas.
- Natural resources, industry, the local economy, and the population of the Southeast United States are at increasing risk of these extreme events.
- Existing flood map boundaries do not account for future flood risk due to the increasing frequency and intensity of precipitation events, as well as new development that would reduce the floodplain's ability to manage stormwater. As building and rebuilding in flood-prone areas continue, the risk of higher losses will continue to grow.

[198] Carter, L., Terando, A., Dow, K., Hiers, K., Kunkel, K.E., Lascurain, A., Marcy, D., Osland, M., & Schramm, P. (2018). *Fourth National Climate Assessment, Chapter 19: Southeast*. United States Global Change Research Program. https://nca2018.globalchange.gov/chapter/19/
[199] Ibid.

- Increases in the number of extreme rainfall events stress deteriorating infrastructure, such as transportation and stormwater systems that have not been designed to withstand these extreme events.

The message is clear: The combined effects of rising numbers of high tide flooding and extreme rainfall events, along with deteriorating storm water infrastructure, are increasing the frequency and magnitude of coastal and lowland flood events.

6.1.7. Sea Level Rise

An additional consideration for future flood events is sea level rise, for which jurisdictions bordering the Potomac River and other tidal-influenced waterways are susceptible.

Sea level rise is expected to continue and possibly accelerate as the Earth warms. The global mean sea level has risen approximately eight to nine inches since 1880, with most of that rise occurring in the past 25 years. The global mean sea level in 2019 was 3.4 inches higher than the 1993 average, the highest annual average in the satellite record during that time. In one year, 2018–2019, the global sea level rose 0.24 inches. In the United States, the mid-Atlantic region is experiencing the second fastest rate of sea level rise after the Gulf of Mexico.[200]

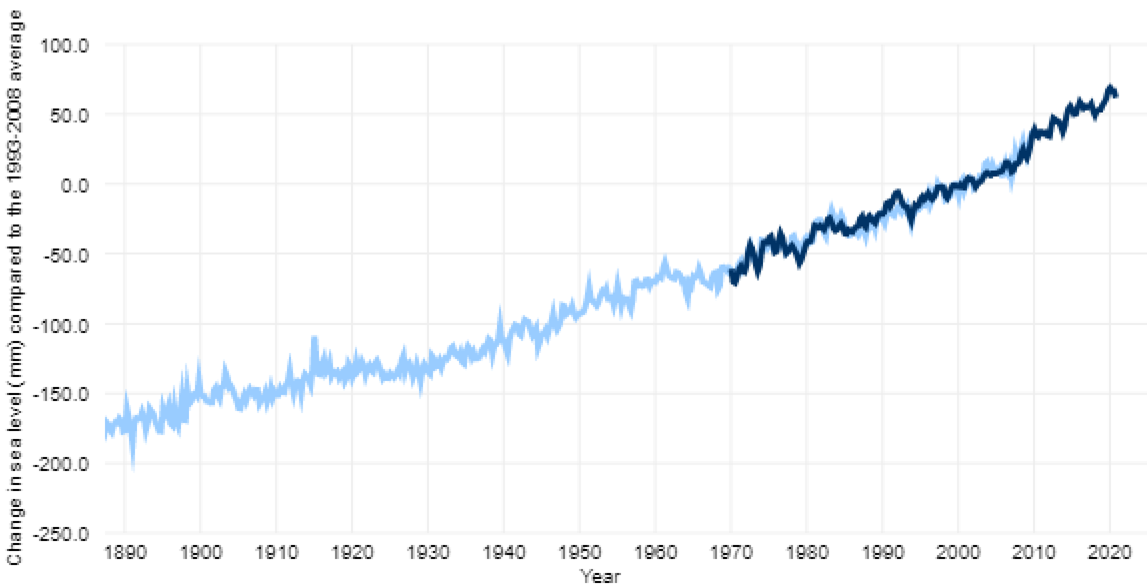

Figure 60: Global Changes to Sea Level, 1880–2020[201]

Based on multiple computer models, the lower possible scenario of global mean sea level rise by 2100 is at least 12 inches above the 2000 levels. With higher rates of emissions, sea level rise could reach 8.2 feet above 2000 levels by 2100. Neither scenario calculates changes in the melting of ice sheets, which contributes to sea level rise. Some scientists suggest that should the Greenland and West Antarctic ice sheets collapse, the sea level rise will be several feet higher than the high scenario indicates.[202]

[200] Dahlman, L. & Lindsey, R. (2021). *Climate Change: Global Temperature.* National Oceanic and Atmospheric Association (NOAA). https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature
[201] Dahlman, L. & Lindsey, R. (2021). *Climate Change: Global Temperature.* National Oceanic and Atmospheric Association (NOAA). https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature
[202] Ibid.

6.1.7.1. Specific Areas at Risk from Sea Level Rise

The Northern Virginia Regional Commission (NVRC), in a study of sustainable shorelines and community management,[203] found that Northern Virginia will not experience wide-scale inundation from sea level rise. However, there are four area "hot spots" that will see impacts to their social, economic, and environmental assets. They are as follows:

Arlington County

- Ronald Reagan Washington National Airport
- Four Mile Run corridor

City of Alexandria

- Four Mile Run Corridor
- Daingerfield Island
- Old Town
- Jones Point

Fairfax County

- Huntington
- Belle Haven/New Alexandria
- Dyke Marsh
- Tidal embayment's
- Hallowing Point

Prince William County

- Occoquan River
- Occoquan National Wildlife Refuge
- Tidal embayment's
- Town of Quantico

Looking more closely at one of the "hot spots"—the Ronald Reagan Washington National Airport – illustrates the potential impacts. The airport is situated along the banks of the Potomac River, in an area that had been mostly underwater and was built up by sand and gravel fill. Approximately 200 acres of the airport are in the 100-year floodplain, which is 11.4 feet above mean sea level. Under the high-emissions scenario, permanent inundation of portions of taxiways and access roadways is possible.

In addition to mapping high-resolution sea level rise and storm surge inundation for Northern Virginia, the NVRC study also quantified specific elements threatening to both the built and natural environments, and it developed strategies to protect, adapt, or retreat communities located in areas at risk. It emphasized that protection strategies should be considered for critical infrastructure and areas of erosion along the Potomac River. Detailed studies in several areas were conducted as part of the report to identify specific vulnerabilities under the following five scenarios:

[203] Sustainable Shorelines and Community Management in Northern Virginia Phase III, September 30, 2013, Northern Virginia Regional Commission. (2013). *Sustainable Shorelines and Community Management in Northern Virginia Phase III*. https://www.novaregion.org/DocumentCenter/View/10838/FY10-Phase-III-Report-Sustainable-Shorelines-Community-Management?bidId=

- Mean High Water (MHW): the area that inundates currently at an average high tide
- Mean High Water (MHHW): the area that inundates at the average of the highest tides each tidal day, as observed over a 19-year period
- Steady State: MHHW + 1-foot projected sea level rise
- Average Accelerated: MHHW + 3 feet projected sea level rise
- Worst Case: MHHW + 5 feet projected sea level rise

Figure 61: Projected Mean High-Water Scenario, Sea Level Rise for Ronald Reagan Washington National Airport, 2100[204]

6.1.8. Case Study – City of Alexandria Climate Adaption Planning

The City of Alexandria's vulnerability to sea level rise is highlighted in the NVRC report. Although it is not expected that the planning area will experience extensive sea level inundation, some of the areas in the city are vulnerable to flooding from sea level rise and storm surge on a small scale. They are the Four Mile Run corridor (Figure 62), Old Town (Figure **63**), and Jones Point (Figure **64**).

[204] Sustainable Shorelines and Community Management in Northern Virginia Phase III.

In addition, the city has undertaken a variety of climate initiatives to address its vulnerability to sea level rise, including the following:

- Strategic policy initiatives, such as Eco-City Alexandria, a Climate Emergency Declaration, and a Green Building Policy
- Climate planning partnerships
- Emissions inventory updates to track reduction
- Energy and Climate Change Action Plan 2012
- Environmental Action Plan 2040

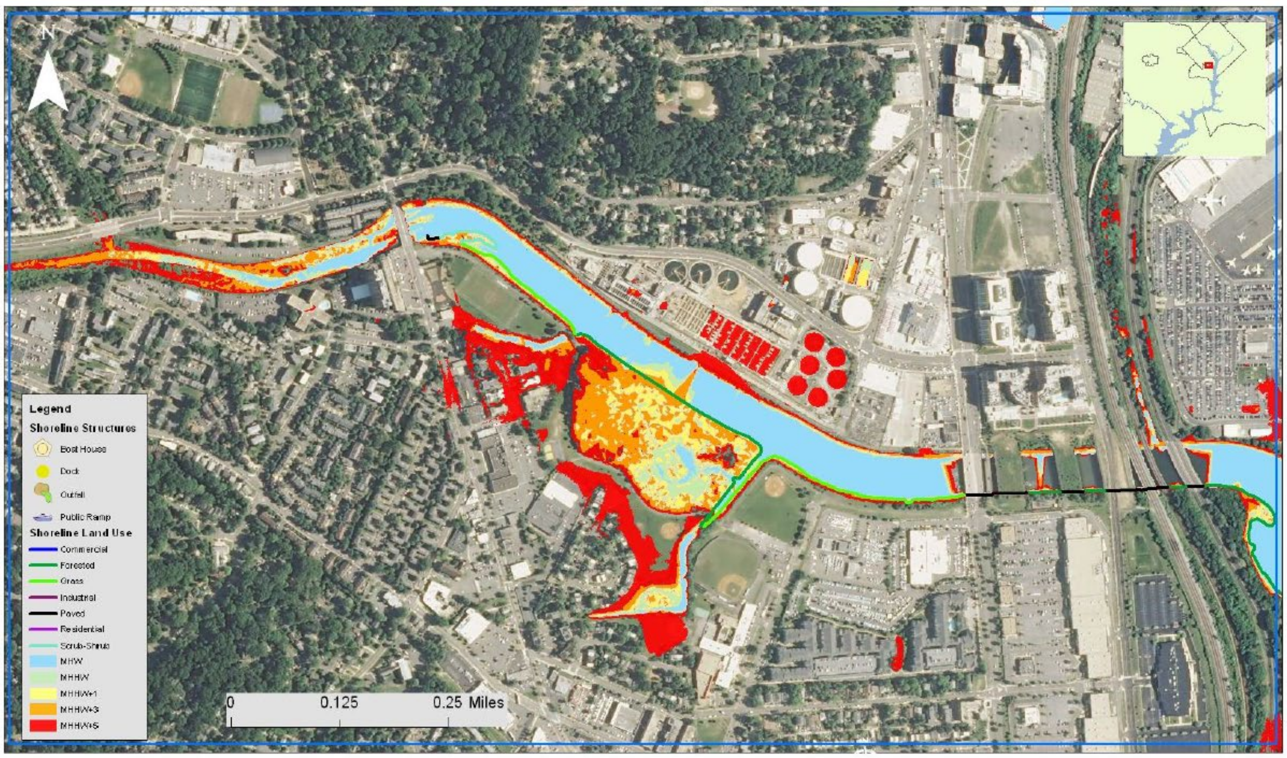

Figure 62: Four Mile Run Corridor Shoreline Land Use and Shoreline Structures, City of Alexandria Side Only[205]

[205] Sustainable Shorelines and Community Management in Northern Virginia Phase III.

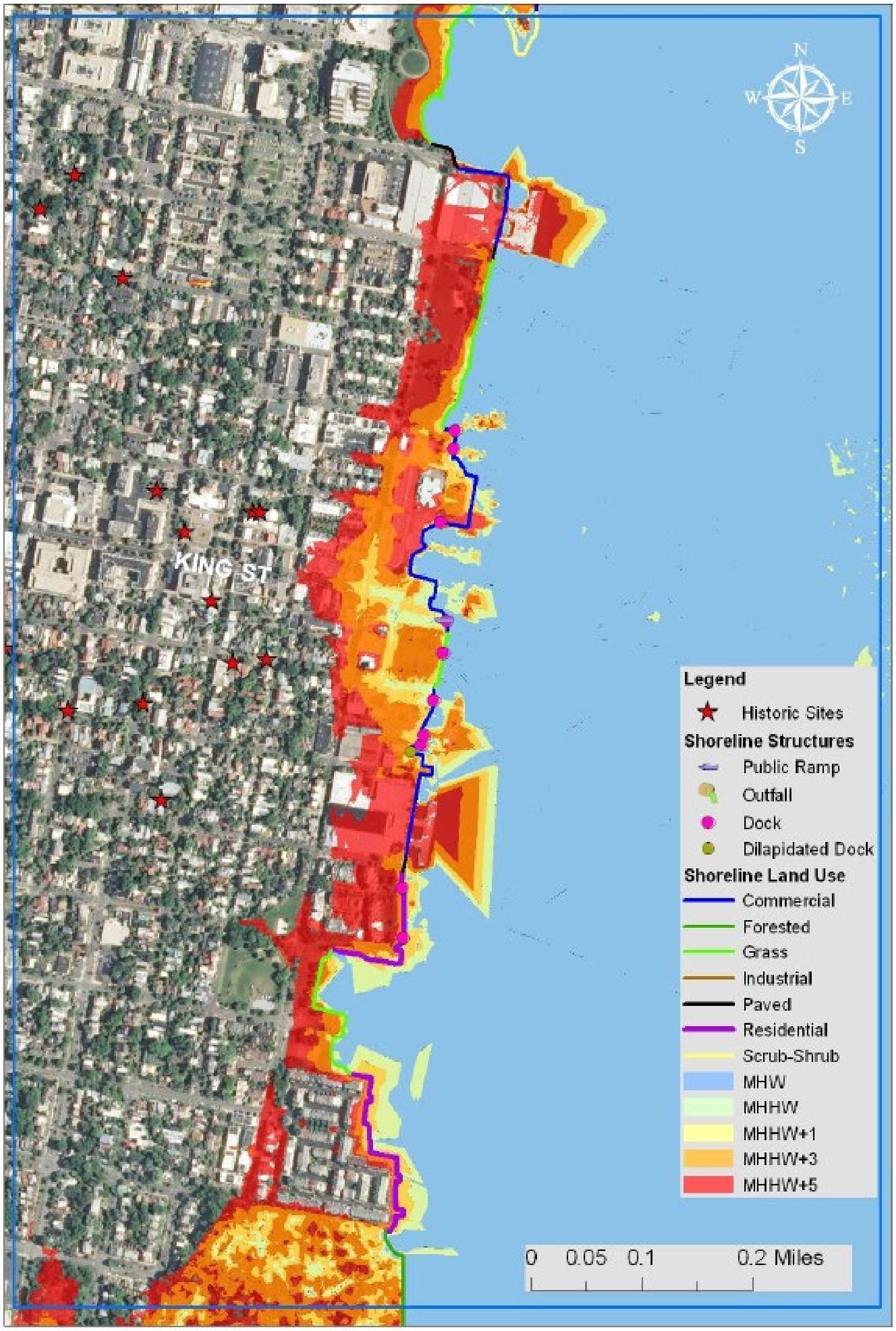

Figure 63: Old Town Shoreline Land Use – City of Alexandria[206]

[206] Sustainable Shorelines and Community Management in Northern Virginia Phase III.

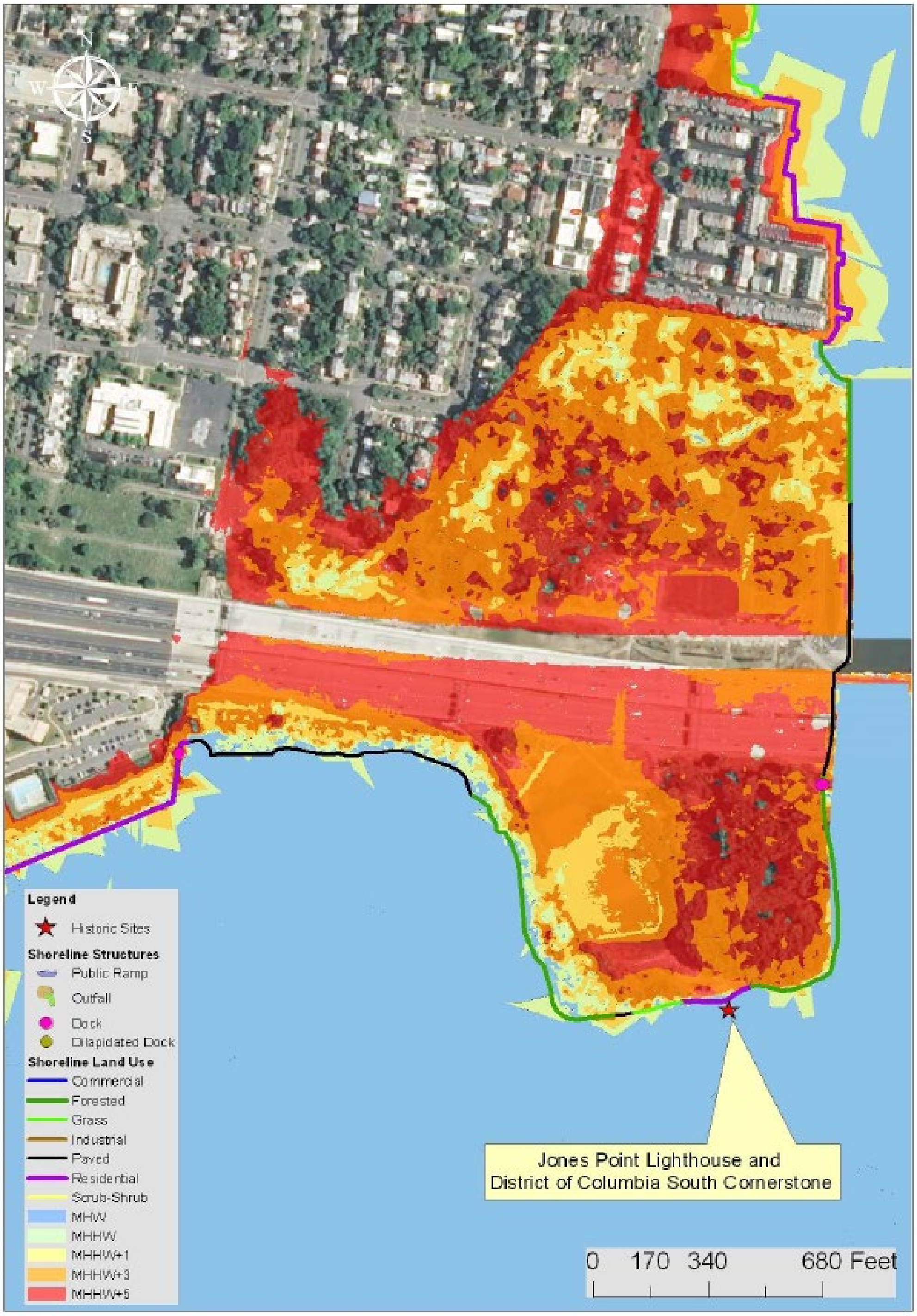

Figure 64: Jones Point Shoreline Land Use – City of Alexandria[207]

[207] Sustainable Shorelines and Community Management in Northern Virginia Phase III.

6.1.9. Summary of Climate Change Projections for the Twenty-First Century

Projections for changes in climate generally follow scenarios based on higher or lower emissions. The high emissions scenario projects the current “worst case” picture that should be considered for mitigation planning purposes:

- Unprecedented warming with more intense heat waves posing health risks to people, animals, environments, and infrastructure
- Less intense cold waves
- Increasing annual precipitation rates
- Increasing number of heavy precipitation events
- Periodic droughts become more intense because higher temperatures increase the rate at which the soil loses moisture during dry spells
- Sea level rise in coastal areas because of increasing ocean surface temperatures

6.2. Impacts and Consequences of Climate Change

The United States Climate Resilience Toolkit classifies the potential impacts and consequences of climate change in the Southeast United States, including Virginia, by population circumstances (urban or rural) and environment (coastal or ecosystem) (see. The impacts and consequences described potentially affect the population, built environment, natural environment, and economy.

Table 116: Potential Impacts from Climate Change in the Southeast United States, Including Virginia[208]

Impact Category	Description
Urban	• Increase in the number of days when nighttime temperatures stay above 75 °F • Greater increases in timing, frequency, intensity, and duration of heat waves—defined as prolonged periods of temperature and humidity—than the national average • Elevated utility costs to cool homes and businesses • Increased heat-related illnesses • Decline in labor productivity • Rapid population shifts • Socioeconomic inequalities leading to disproportionate impacts on vulnerable populations in relation to health risks • Increased days of lower air quality because of carbon dioxide, allergens, dust-raising activities, and particulate matter in the air • Increased vector-borne disease from standing water that breeds mosquitoes
Rural	• Food production impacts: ▪ Changes in agricultural crops, seasons, and quality ▪ Impacts from decreased water availability for livestock • Unreliable energy production if dependent on water availability, such as for natural gas and nuclear power plants • Increased ocean and freshwater temperatures that impact fishing • Decline in labor productivity • Health risk to workers with outdoor jobs • Increased vulnerability because of demographics, occupations, earnings, literacy, poverty incidence, and lack of access to healthcare and community services • Limited government capacity and resources to respond to events
Coastal	• Significant critical infrastructure vulnerable to rising sea level and coastal flooding • More frequent high tide flooding, perhaps occurring daily by 2100 • Increased saltwater intrusion, affecting surface and groundwater supplies, habitats, agricultural lands, and water management infrastructure • Decline in coastal economies dependent on tourism • Rapidly growing population • Increased economic investment in coastal areas • Transportation infrastructure and connection points vulnerable to high water levels: ▪ Impacts on supply chains (imports and exports) • Threats to vital coastal ecosystems
Ecosystems	• Rising sea levels, fresh water being invaded with saltwater, and the death of deciduous trees • Redistribution of species • Changes in species' ranges and behavior • Transformation of temperate ecosystems by poleward-moving tropical organisms, plants, and crops in response to rising temperatures

[208] U.S. Climate Resilience Toolkit. (2018). *Ecosystem Impacts: Natural Ecosystems are Responding to Climate Change.* https://toolkit.climate.gov/regions/southeast/ecosystems-impacts

Impact Category	Description
	• Spread of disease-carrying vectors, such as mosquitoes • Warmer winters that allow northward expansion of tropical and subtropical species • Less southern migration of bird species, reducing plant pollination and the control of certain pests • Increased northern migration of fish populations • Increased tree mortality, which allows new species to intrude • Increased dieback of critical plant species from prolonged rainfall inundation • Changing patterns of wildfire, such as frequency, intensity, size, pattern, season, and severity

6.3. Vulnerabilities

6.3.1. People

Hazards linked to climate change can instigate both direct and indirect vulnerabilities that affect the health and well-being of the population, including the following:

- Contaminated water
- Decreased water quantity
- Failure of sanitation systems
- Outbreaks of Infectious disease
- Loss of health and medical services, including mental health care
- Separation from social and/or community cultural systems
- Job loss
- Economic decline

Additional indirect impacts could result in long-term consequences that prohibit or delay the onset of conditions leading to public health issues. Extreme weather events encourage outbreaks of disease and infestation, flooding leads to an increase in fungal growth and nematodes, while drought leads to increases in locust and white fly populations. Changes in ecosystems, agriculture, and water supplies can have extreme impacts on human health.

In addition to more intense heat, the related deterioration of air quality could increase the occurrence of many health problems, especially cardiovascular and respiratory problems.

Other populations that may be considered vulnerable in relation to health and medical systems and services include:

- Those with physical and/or mental disabilities
- Those with visual impairments
- Those who are dependent on electricity, such as those on oxygen, ventilators, and other medical equipment required for life-support
- Older adults

- Those experiencing socioeconomic disadvantages
- Those without housing
- Those without sufficient access to healthcare

Projections for warmer winters and hotter summers also increase the frequency of outbreaks of vector-borne diseases, such as West Nile virus and Lyme disease from mosquitos and ticks, respectively. Seasonal pollen production also will accelerate, extending the allergy season and increasing risks for asthma.

Emergency responders may also be affected by climate change, such as increased service demands and stress-related and other personal vulnerabilities.

6.3.2. Built Environment and Critical Infrastructure

Projected changes in climate-related hazards will impact the built environment in a variety of ways. Severe weather events that produce high winds, such as hurricanes and tropical storms, will be more likely to damage or destroy residences, businesses, and Community Lifeline infrastructure.

Coastal areas and properties will be especially vulnerable to sea level rise. Much of the critical infrastructure in coastal areas, such as electric, water, sanitary, communications, and transportation systems, could be negatively impacted by multiple hazard effects. For example, although power failures occur periodically from a variety of causes, the probability of failure of the energy system increases as the intensity of extreme events increases. This type of cascading incident, depending on severity, could pose significant health and safety risks, and it would normally require the involvement of local emergency management organizations to coordinate provisions for food, shelter, water, heating and cooling, and other support services.

Hazard-specific consequences for critical infrastructure are related to specific hazard impacts.

Temperature-related impacts may include:

- Increased strain on building and industrial materials
- Increased peak electricity loads in summer and reduced or increased heating requirements in winter

Precipitation-related impacts may include:

- Increased street, basement, and sewer flooding
- Reduction of water quality

Sea level rise-related impacts may include:

- Inundation of low-lying areas and wetlands
- Increased structural damage and impaired operations of Community Lifelines such as power, water, sewer, drainage, transportation, communication, and health and medical

The impacts of climate change have the potential to affect military installations in low-lying areas susceptible to sea level rise and storm surge, also creating a threat to national security. Coordination between federal agencies, the military, and local jurisdictions in the planning area is critical to addressing these risks.

The NVRC uses NOAA data and local parcel information on its Climate Resilience Dashboard to show the impact sea level rise could have on jurisdictions in Northern Virginia. Based on these technical data, the following could be impacted:[209]

- Parcels impacted: 1,015
- Acres impacted: 2,135
- Property value impacted: $262,127,733

Depending on the approach and conditions of the sites being addressed for sea level rise, there could be unintended consequences of shoreline protection, such as armoring, which ignores the surge-reducing benefits of areas such as wetlands. Protecting one area could increase flood impacts in another. Other options include a mix of approaches that might have additional benefits. The NVRC's Sustainable Shorelines and Community Management in Northern Virginia report notes, "living shorelines combined with zoning measures and in some cases structural measures, can be combined to provide an integrated, redundant, and flexible approach to planning a climate change adaptation strategy on a site-specific basis."[210] Generally, the three broadly defined categories of shoreline adaptation strategies are retreat, accommodate, and protect. Adaptation strategies should be appropriately tailored to the unique circumstances of a specific area. Descriptions of specific actions that could address sea level rise are presented in the NVRC report.

Virginia Code now requires that living shoreline approaches be used unless it is proven that they are unfeasible for a specific site. Please refer to the Virginia Law website for more details.

Although numerous studies and plans have been or are being developed, there is no conclusive optimal approach to reducing coastal threats to property.

Table 117: Approaches and Benefits of Shoreline Protection to Address Sea Level Rise[211]

Approach	Potential Benefits
Armor the shore with seawalls, dikes, revetments, bulkheads, and other structures.	Preserves existing land uses, but wetlands and beaches are squeezed between development and the rising sea.
Elevate the land, and possibly wetlands and beaches, as well.	Preserves the natural shores and existing land uses, but often costs more than shoreline armoring and may encourage coastal development.
Retreat by allowing the wetlands and beaches to take over land that is dry today.	Preserves natural shores, but existing land uses are lost.

Detailed estimates of potential exposure of property and critical infrastructure is presented in relation to flood in **Section 5.5**.

[209] Northern Virginia Regional Commission. (2019). Climate Resilience Dashboard: Sea Level Rise Impact on Northern Virginia [GIS map]. Retrieved December 10, 2021, from https://www.arcgis.com/apps/opsdashboard/index.html#/43b6ba6a06994711b8da848f31eb18d1

[210] Northern Virginia Sustainable Shoreline Community Management Project. (2013). *Sustainable Shorelines and Community Management in Northern Virginia, Phase III*. p. 11 https://www.novaregion.org/DocumentCenter/View/10838/FY10-Phase-III-Report-Sustainable-Shorelines-Community-Management?bidId=

[211] U.S. Climate Change Science Program (2009). *Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region*, *Synthesis and Assessment Product 4.1*. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100483V.PDF?Dockey=P100483V.PDF

6.3.3. Natural Environment

Environmental impacts from various climate change conditions, such as extreme heat, drought, and sea level rise, increase vulnerability of ecosystems, crops, livestock, and, ultimately, food supplies.

Especially vulnerable to environmental impacts are the jurisdictions through which the Potomac River flows, including the City of Alexandria and the counties of Northern Virginia. A 2018 study conducted by the National Academy of Sciences found that 37 percent of the waterways in the United States, including the Potomac River, have become saltier over time, impacting water treatment systems and quality. Salt intrusion into the water supply occurs from rising sea water and run-off from road salt in the winter.

Water supplies and quality will also be impacted by extreme heat and drought. Rising sea levels and intense flooding will affect sensitive natural protective barriers along shorelines and inland waterways. Ultimately, changes in the natural environment will lead to a higher incidence of public health issues.

As climate and weather patterns shift, the resulting environmental issues may be leveraged as a tool for terror and political violence. This emerging threat is not related to “eco-terrorism.” Rather, it is related to a growing potential for vulnerable ecosystems to be exploited or destroyed as a means to “intimidate or provoke a state of terror in the general public for a political, ideological, or philosophical agenda.[212]

Although incidents of terrorism related to climate change have not been felt in the United States, the potential for incidents of this type does exist, and they have occurred in other countries. One study theorizes that “detrimental climate change implications that particularly affect natural resources, such as floods and droughts, create civil unrest and eventually a vacuum for terrorist events to occur. This would most likely occur in conjunction with poor governance and/or political terror, which would result in a poor distribution of resources for the population.”[213] This specific study found a relationship between climate trends and agriculture in Nigeria as a threat multiplier for conflict. For example, severe drought from climatic weather shifts raises the vulnerability of water systems, restricting water supplies. In this situation, extremist groups have stepped up attacks as a strategic tactic of coercion to manipulate the water supply, especially in countries under extreme, long-term drought conditions.

By focusing on sound scientific data, delivered with consistent messaging across multiple government agencies, the potential for violent and/or criminal acts related to climate change appropriate to prevent or mitigate actions could be identified.

6.3.4. Economy

The economic costs of climate change can be extraordinary. Impacts from conditions linked to climate change can affect the region’s economy in relation to jobs, the prices of goods and services, and costs of development and construction.

The Northern Virginia jurisdictions, as part of the National Capital Region, have a significant portion of their economies focused on government facilities and workers and major commercial and industrial employers. Threats to Community Lifelines in the region could bring catastrophic losses to the economy.

Highly commercialized areas of Northern Virginia line the Potomac River, which has some tidal influence from the Chesapeake Bay and the Atlantic Ocean. Many of these areas are the sites of federal agency headquarters, large employers, and multifamily residences. Increasing tidal action combined with flooding from more frequent excessive rainfall events and sea level rise can cause direct and indirect economic losses through building damage, business closures, and loss of infrastructure in the coming decades.

[212] Somers, S. (2019, September 9). *How Terrorists Leverage Climate Change.* New Security Beat. https://www.newsecuritybeat.org/2019/09/terrorists-leverage-climate-change/

[213] Lytle, N. *Climate Change as a Contributor to Terrorism: A Case Study in Nigeria and Pakistan*. (2017). Senior Theses. 207. https://scholarcommons.sc.edu/senior_theses/207

6.3.5. Continuity of Services and Program Operations

Government services and emergency operations can be disrupted by the impacts and consequences of hazards related to climate change. Extreme temperatures may increase the demand for emergency medical calls and heating and cooling centers for a larger population. Issues related to addressing sea level rise appropriately may lead to controversial approaches and disagreements among elected leadership. Flooding and severe storms may impact government facilities and limited resources. In addition, the consequences of events that impact a greater population will strain the capabilities and capacity of multiple sectors of government operations and services.

6.3.6. The Interconnectivity of Critical Systems

The impacts of climate change exacerbate the risks to interconnected systems, many of which span regional and national boundaries. They are already exposed to a range of stressors, such as aging and deteriorating infrastructure, changes in land use, and population growth. As the IPCC noted in its Fourth National Climate Assessment, "Extreme weather and climate-related impacts on one system can result in increased risks or failure in other critical systems, including water resources; food production and distribution; energy and transportation; public health; international trade; and national security." [214]

One example of economic impact caused by the interconnectivity of critical systems that occurred in May of 2021 was a ransomware attack on the Colonial Pipeline system. The system feeds refined gasoline, diesel, and jet fuel supplies from Texas throughout the southeastern United States and mid-Atlantic region, including major airports and New York. This system is the primary fuel source for many Virginia fuel retailers, and it delivers approximately 45 percent of the fuel consumed on the East Coast.[215] The entire system was shut down for five days to contain the threat. Fuel resources for suppliers and users came dangerously close to being unavailable before the crisis was averted. Had the event continued beyond this time, user's systems would have experienced shutdowns, impacting power companies and major government services and businesses. Even though catastrophic impacts were avoided, the short-term shutdown led to limited fuel availability and a rise in gas prices throughout the supply area within four days. Virginia Governor Ralph Northam declared a state of emergency, Executive Order 78, to address gasoline supply disruptions throughout the Commonwealth.[216]

Although the cause of this incident was attributed to a cyberattack rather than climate change, it demonstrates the interconnectivity of lifeline systems and how impacts at one critical location can affect the entire Northern Virginia region and other parts of the United States simultaneously. Future incidents related to climate change have the potential to create similar, if not wider-scale, impacts. Much of the country's oil and gas resources are linked to seaports that could be vulnerable to sea level rise, impacting their operations.

The interconnectivity of critical systems is acutely obvious in the use of fuels and in efforts at federal, state, and local levels to reduce emissions by reducing the levels of greenhouse gases (GHGs). States have policy authority to enact laws for the good of the public, the economy, and the environment. Local governments have authority for land use, decisions on zoning and development, maintenance and operation of local infrastructure and vehicle fleets, and the enforcement of building codes. Mechanisms that control GHG emissions will be most effective if they are coordinated across multiple levels of government.

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[214] Carter, L., Terando, A., Dow, K., Hiers, K., Kunkel, K.E., Lascurain, A., Marcy, D., Osland, M., & Schramm, P. (2018). *Fourth National Climate Assessment, Chapter 19: Southeast. United States*. Global Change Research Program, p 26. https://nca2018.globalchange.gov/chapter/19/

[215] Dempsey, T., & Franklin, J. (2021, May 11). *Northman: Virginia Under State-of-Emergency After Colonial Pipeline Ransomware Cyberattack*. WUSA9. https://www.wusa9.com/article/news/local/virginia/virginia-state-of-emergency-colonial-pipeline-ransomware-cyberattack/65-bd86b798-d278-4da2-9c19-94d887c0d965

[216] Ibid.

6.3.7. Sector Vulnerability

Vulnerabilities related to the multiple hazard characteristics of climate change can be classified in specific sectors.

Table 118: Climate Change Vulnerabilities, by Sector

Sector	Vulnerabilities
Water Climate changes that affect the quality and quantity of water available for use by people and ecosystems increase risks and costs to agriculture, energy production, industry, recreation, and the environment through:	• Groundwater depletion • Sea level rise that results in flooding and saltwater contamination of water systems • Aging and deteriorating water infrastructure • Reduced reliability of hydropower production
Health and Safety Impacts from increasingly extreme weather events can result in:	• Poorer air quality and health risks from wildfire and ground-level ozone pollution • Food and water contamination • Increases in vector-borne diseases and heat-related deaths • Increase in frequency and severity of allergic illnesses, including asthma and hay fever • Long-term mental health consequences • Increase in impacts on vulnerable populations such as the elderly, children, those with low income, and communities of color
Economy Changing temperatures, sea level rise, and more frequent extreme events are expected to increasingly disrupt and damage critical infrastructure and property and reduce labor productivity and community vitality; including:	• Regional economies that depend on natural resources and favorable climate conditions, such as agriculture, tourism, and fisheries • Reduced efficiency of power generation, which, combined with increasing demand, leads to higher costs • Global impacts that affect trade and economy, including import and export prices and United States businesses with overseas operations and supply chains
Natural Environment, Ecosystems, and Services Changing temperatures, sea level rise, and more frequent extreme events are expected to increasingly disrupt and damage critical ecosystems that protect the environment, health, and property, including:	• Increasing wildfire frequency Although NOVA does not have a high risk of wildfire, the number of events in the region could increase, as could wildfire incidents outside the region. The region could experience impacts from these out-of-area fires, such as smoke and smog, which can negatively impact natural environments and ecosystems. • Changes in insect outbreaks • Migration of native species • Degradation of regional heritage and quality of life tied to ecosystems and outdoor recreation

Sector	Vulnerabilities
Agriculture* and Food Changing temperatures, extreme heat, drought, wildfire, and heavy downpours can increasingly disrupt agricultural productivity, and impact: **Although the NOVA region does not have a significant agricultural base, it could be impacted by food shortages caused by impacts on agriculture.*	• Poorer livestock health • Declines in crop yields and quality • Threats to rural livelihoods • Threats to sustainable food security • Threats to price stability
Infrastructure Rising sea levels and excessive rainfall events can increasingly disrupt or inundate Community Lifelines, including:	• Impact on entrances to bridges, tunnels, and highway segments • Increased salinity of water and wastewater plants and sewer outfall systems • Coastal lifeline systems permanently under water • Utility system disruption or failure • Increased wear and tear on equipment not designed for saltwater exposure • More frequent delays and service interruptions on transportation systems • Economic impact related to the failure of systems • Potential loss of life

6.4. Changes in Development in Hazard-Prone Areas

It is expected that coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution during the twenty-first century. Population growth and the rising value of infrastructure in coastal areas increases the vulnerability to climate variability, with losses projected to rise even more if the intensity of tropical systems, severe storms, and related conditions increases.

As noted earlier in this section, current flood map boundaries do not account for future flood risk from increasing frequency and intensity of precipitation events, as well as new development that would reduce the floodplain's ability to manage stormwater. As building and rebuilding in flood-prone areas continue, the risk of higher losses will continue to grow.

6.4.1. Future Development in Hazard-Prone Areas

Currently, there is no consistent quantitative method to assess the impact of future development in relation to climate change. This is primarily because of the multiple complex hazard characteristics and conditions, multiple infrastructure systems, and limits to local government authority. Readiness for increased exposure will be low unless measures for adaptation are implemented. Mapping storm surge and flood zones is one tool to assess potential vulnerabilities in development-prone coastal and waterfront areas. Modeling, such as that conducted for the city of Alexandria, can help guide future development and adaptive approaches for existing infrastructure. In addition, policy changes that limit the siting of new development or infrastructure, including transportation corridors, in high-risk areas may reduce future vulnerability. Land use restrictions, such as setbacks and design elevations and modifications to building codes for structural elements and corrosion-resistant equipment may also help to lower the risk of multiple hazards.

6.5. Climate Change Initiatives

The impacts and consequences of hazard conditions related to climate change are at the forefront of government policy and planning. Several jurisdictions in the planning area have already adopted policies, initiated and completed plans, and undertaken various initiatives and actions to address the effects of climate change. Others are in the initial phases of developing policies and plans, with a focus on reducing emissions of GHGs.

6.5.1. Mitigation versus Adaptation

Climate change is inevitable, and some degree of change will affect the population and environment regardless of future mitigation. Climate change mitigation is avoiding and reducing emissions of heat-trapping greenhouse gases into the atmosphere to reduce warming and further climate change.

Climate change adaptation is altering human behavior, systems, and, if possible, ways of life to reduce the impacts of climate change. Some actions should be taken to minimize climate-induced risks to the environment, human health, society, and economics. These actions are classified as "adaptation," defined as "adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities."[217]

6.5.2. Efforts to Address Climate Change

In recent years, jurisdictions in the Northern Virginia region have implemented multiple initiatives intended to address climate change through policy, research, and adaptive measures.

Table 119: Climate Change Initiatives in the Commonwealth of Virginia and Northern Virginia Jurisdictions

Type of Initiative	Measure	Date Implemented/ Updated
Commonwealth of Virginia		
Executive Order 24	Issued to increase Virginia's resilience to recurrent flooding, sea level rise, and other natural hazards applied equally to all individuals	2018
Executive Order 29	Established the Virginia Council on Environmental Justice for the protection of natural resources	2019
Executive Order 59	Established the Governor's Commission on Climate Change to create a Climate Change Action Plan to evaluate expected impacts on the Commonwealth's natural resources, public health, and economy; identify what Virginia needs to do to prepare for the likely consequences of climate change; and identify approaches being pursued by other states, regions, and the federal government. The Final Report: A Climate Change Action	2007

[217] Intergovernmental Panel on Climate Change. (2014). *Climate Change 2014: Synthesis Report.* https://www.ipcc.ch/report/ar5/syr/

Type of Initiative	Measure	Date Implemented/ Updated
	Plan, dated December 15, 2008, was the product of this effort.	
Virginia Carbon Rule	Allowed the Commonwealth to join the Regional Greenhouse Gas Initiative. Funds generated from legislation go toward community flood preparedness, coastal resilience, climate planning efforts, and energy efficiency programs	June 2020
Virginia Coastal Resilience Master Planning Framework	Identified core principles of the Commonwealth's approach to coastal protection and adaptation to serve as a blueprint for implementing the first project-driven Coastal Resilience Master Plan by the end of 2021	October 2021
Living shorelines; development of general permit; guidance	"Living shoreline" means a shoreline management practice that provides erosion control and water quality benefits; protects, restores, or enhances natural shoreline habitat; and maintains coastal processes through the strategic placement of plants, stone, sand fill, and other structural and organic materials. When practicable, a living shoreline may enhance coastal resilience and attenuation of wave energy and storm surge.[218]	May 2022
Metropolitan Washington Council of Governments (COG)		
National Capital Region Climate Change Report	Multiple jurisdictions in Northern Virginia have adopted the COG's climate goals on climate change established in Resolution R31-07, which created a regional climate change initiative. The report highlights actions to address energy consumption, transportation, and land use and promote green economic development.	November 2008
Arlington County		
Climate Action Resolution	Confirmed commitment to climate action by implementing the Community Energy Plan	2017
Community Energy Plan, Comprehensive Plan	Long-term vision for transforming how the county generates, uses, and distributes energy, with a goal of becoming a carbon neutral community by 2050	2019
Climate Change, Energy and Environment Commission	Advisory commission to the County Board created to focus on climate change-related and sustainability actions. One objective is to liaise with various commissions in related areas, including emergency preparedness.	December 2020
City of Alexandria		
Energy and Climate Change Action Plan (2012–2020)	The Plan builds on the Environmental Action Plan 2030 and further defines the city's path to significant reduction of greenhouse gas (GHG) emissions. It describes the potential local impacts (as of 2011), lists the steps the city had already taken, and presents steps to mitigate and adapt to future climate change. Chapter 5 addresses potential impacts and risks and related adaptation and preparedness measures.	March 2011

[218] https://law.lis.virginia.gov/vacode/title28.2/chapter1/section28.2-104.1/

Type of Initiative	Measure	Date Implemented/ Updated
Environmental Action Plan 2040	Established a citywide environmental plan to address climate change as indicated by changing conditions in the atmosphere, extreme weather events, rising coastal water, and record-breaking rainfall and high temperatures	July 2019
Climate Initiatives	Partnerships and supporting pledges through the COG to develop a region wide GHG emissions inventory and support the 2015 Paris Agreement; supported of the United States Conference of Mayors' Climate Protection Agreement (2005)	Various dates
City of Falls Church		
Environmental Sustainability Council	Addressed a wide range of environmental and sustainability issues related to the quality of life in the community, including stormwater, streams and natural springs, urban forest, and climate, air, and energy.	Est. 1989
City of Fairfax		
Climate Change Planning	The city is working to plan for and mitigate the impacts of climate change in the community.	September 2021
Climate Change Initiatives	Participating in the COG GHG inventories	2005-2018
Environmental Sustainability Committee	Created to guide the city to become an environmentally sustainable "green city" by recommending programs and policies and undertaking actions to engage residents and businesses.	2016
Fairfax County		
Community-Wide Energy and Climate Action Plan – Final Report	The county's first GHG reduction plan toward carbon neutrality by 2050. Develops strategies and actions for buildings and energy efficiency, energy supply, transportation, waste, and natural resources.	September 14, 2021
Resilient Fairfax – Climate Adaptation and Resilience Plan	Resilient Fairfax, led by the Office of Environmental and Energy Coordination (OEEC), is a program to strengthen the county's resilience to changing climate conditions. The first Resilient Fairfax Climate Adaptation and Resilience Plan is scheduled for completion in fall 2022. The Plan includes detailed analyses and strategies to help the county better prepare for changing climatic conditions and hazards, such as increasing temperatures, severe storms, and flooding.[219]	2022
Loudoun County		
Loudoun County Energy Strategy	Developed to support the county's economic competitiveness and respond to the impact of the county's energy use on the environment	December 2009; amended 2010
Loudoun Climate Project	Advocacy group formed to increase understanding of climate change and how it influences personal choices and public policy	2021

[219] https://www.fairfaxcounty.gov/environment-energy-coordination/resilient-fairfax

Type of Initiative	Measure	Date Implemented/ Updated
Resolution of the Loudoun County School Board	Resolution committing the school board to the support of climate change initiatives and opportunities to reduce carbon consumption by facilities and transportation	June 2020
Prince William County		
Climate Resolution	Commits the county to a 100% renewable energy grid by 2035 and 100 percent carbon neutrality by 2050; incorporates equity principles and environmental justice into the Community Energy Master Plan	November 2020
Community Energy and Sustainability Master Plan	PWC's Office of Environmental & Energy Sustainability is leading the development of the first event Community Energy and Sustainability Master Plan and is scheduled for completion in 2023.	2023
Sustainability Commission	On November 17, 2020, the PWC Board of Supervisors authorized the creation of a Sustainability Commission, a public advisory board charged with advising on potential enhancements to the CESMP and other related program areas.	November 2020

6.5.3. Actions to Reduce Risks and Increase Resilience

Climate change scientists agree that the reduction of future risks from climate change depends primarily on decisions made now. Since we are already committed to some level of climate change, responding to climate change involves a two-pronged approach: 1) emissions reduction (also referred to as "climate mitigation") seeks to reduce greenhouse gas (GHG) emissions to slow down climate change itself, and 2) "climate resilience/adaptation," which is also necessary to ensure communities are prepared for and adapting to hazards such as severe storms, flooding, and extreme temperatures.

Table 120: Suggested Actions to Reduce Risk and Build Resilience Against Climate Change[220]

Hazard	Suggested Actions
Extreme Heat	• Increase urban tree cover. • Install cool roofs to reduce the negative health impacts of heat. • Implement urban designs that facilitate air movement and alleviate heat. • Increase standards for insulation of buildings and homes. • Increase preparedness education about heat-related health issues for healthcare providers and the public.
Increased Precipitation and Flood	• Increase capacities of stormwater systems. • Identify infrastructure that should be elevated or relocated to avoid future inundation. • Continue acquisition, elevation, and relocation projects for property owners.

[220] Liao, K. J. (2011, January 26). Impacts of Climate Change on the Environment: Mitigation and Adaptation [PowerPoint slides]. Department of Environmental Engineering, Texas A&M University-Kingsville. https://www.tamuk.edu/engineering/_docs_CoE/research/interdisciplinary-seminar-series/impacts-of-climate-change-on-the-environment.pdf

Hazard	Suggested Actions
	• "Flood-proof" mechanical systems and/or components of industrial and commercial structures. • Update flood hazard mapping.
Drought	• Develop water usage and/or restriction plans for governments, homes, and businesses. • Identify alternate water sources. • Develop new drought- and heat-resistant varieties of crops. • Develop new or improve existing irrigation systems to reduce water leakage. • Conserve soil moisture through mulching. • Implement drought-resistant landscaping. • Educate the public on water-saving measures.
Sea Level Rise	• Preserve estuaries and wetlands to accommodate rising levels of saltwater. • Develop long-term plans to address sea level rise for at-risk public and private property. • Conduct feasibility studies to determine potential shoreline protection measures against erosion and flood. • Change land use in high-risk areas.
Increased Severe Storms	• Enhance emergency preparedness messaging. • Expand or enhance early warning systems. • Update or increase resilience of infrastructure, including roads, power grids, and stormwater systems. • Identify options for effective post-event emergency relief.

6.5.4. Cost Effectiveness of Climate Change Mitigation

The *Governor's Commission on Climate Change, Final Report* notes the difficulty of quantifying actual steps to mitigate climate change regarding costs and benefits, but it provides guidance related to the cost effectiveness of specific GHG measures. Figure 65 illustrates strategies to reduce GHGs reduction strategies for nine sets of actions and the savings attributable to each of these actions. The Final Report also provides estimates of the savings in relation to metric tons of emissions attributable to each set of actions.

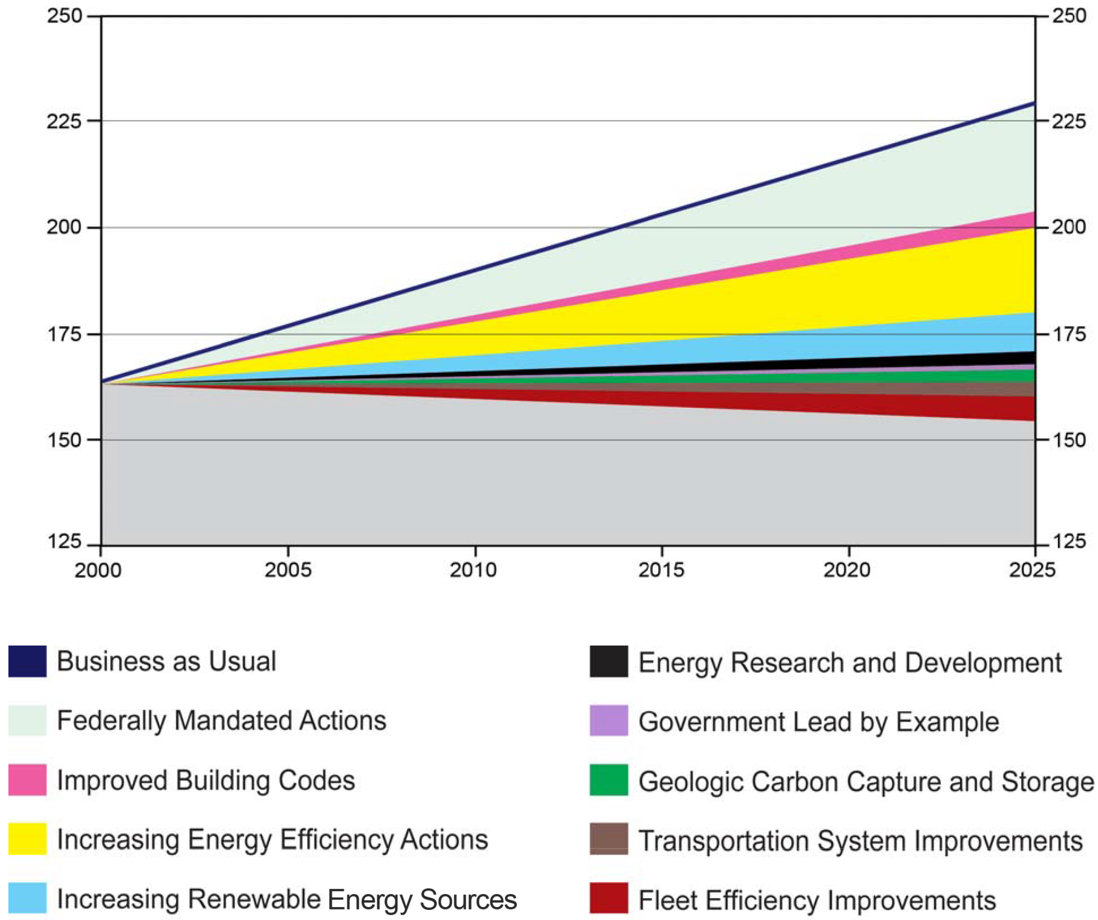

Figure 65: Strategies to Reduce the Emissions of Greenhouse Gasses (MMt CO_2e)[221]

Various methods have been developed for conducting benefit cost analysis applied to climate change, based on metrics structured on the total GHGs reduced during a project's lifetime. However, not all projects can be calculated or are applicable to this method.

6.5.5. Summary

Early in 2021, the governor released a plan to address climate change in Virginia. It aligned with current federal climate and infrastructure policies and focused on future clean energy goals. While efforts to reduce GHGs are targeted at an identified cause of climate change, there is no commonwealth-level institutional infrastructure to monitor the widespread impacts of the various conditions resulting from climate change or to coordinate climate change analysis and initiatives with local jurisdictions. Additional data and progress in documenting the impacts of climate change will be monitored and addressed in the next Plan update.

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[221] MMt: Methylcyclopentadienyl manganese tricarbonyl, an additive used in leaded gasoline to increase octane rating. CO_2e: Carbon dioxide equivalent. CO_2 measures only carbon dioxide, whereas CO_2e includes all greenhouse gases.

Governor's Commission on Climate Change. (2008). *Final Report: A Climate Change Action Plan.* https://www.naturalresources.virginia.gov/media/governorvirginiagov/secretary-of-natural-resources/pdf/ccc_final_report-final_12152008.pdf

7. Capability Assessment

Requirements

- **§201.6(c)(3)** – [The plan shall include the following:] A *mitigation strategy* that improves these existing tools. policies, programs, and resources, and its ability to expand on and identified in the risk assessment, based on existing authorities, provides the jurisdiction's blueprint for reducing the potential losses.

2022 HMP Update

- Updated capability assessments were conducted for all jurisdictions.

7.1. Overview

The mitigation strategy serves as the long-term blueprint for reducing the potential losses identified in the risk assessment. The Stafford Act directs hazard mitigation plans to describe hazard mitigation actions and establish a strategy to implement those actions. Therefore, all other requirements for a hazard mitigation plan lead to and support the mitigation strategy.

Hazard mitigation is any sustained action taken to reduce or eliminate the long-term risk to life and property from hazard events. It is an ongoing process that occurs before, during, and after disasters and serves to break the cycle of damage and societal impacts in hazardous areas. An aim of the mitigation planning process is to incorporate mitigation into a community's existing authorities, policies, procedures, and programs to reduce or avoid long-term vulnerabilities to the identified hazards.

This section provides an analysis of the current mitigation capabilities, including an assessment of National Flood Insurance Program participation and compliance. Strong mitigation capabilities are highlighted and areas for improvement are identified. A ranking summary table displays the capabilities of jurisdictions, providing a comprehensive view of the region's capabilities.

7.2. Capability Assessment Summary

Assessing mitigation capabilities is an integral part of the mitigation planning process in which jurisdictions identify, review, and analyze the resources currently available to them that can be used for reducing the impact of hazards on their communities.[222] This assessment of capabilities identifies the framework that is in place, or should be in place, for the implementation of mitigation actions[1].
During the planning process, jurisdictions examined planning and regulatory, administrative and technical, safe growth for future development, financial, education and outreach, and National Flood Insurance Program capabilities. The capability assessment incorporated any new capabilities that have emerged in the past five years. This section provides a summary of the capabilities of NOVA planning participants. Detailed jurisdiction-specific assessments are provided in the Jurisdiction Annexes.

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[222] Federal Emergency Management Agency. (2016, September) *State Hazard Mitigation Planning Key Topics Bulletins: Mitigation Capabilities*. https://www.fema.gov/sites/default/files/2020-06/fema-state-mitigation-capabilities-planning-bulletin_09-26-2016.pdf#:~:text=An%20assessment%20of%20state%20mitigation%20capabilities%20is%20essential,efforts%20targeted%20for%20state-level%20and%20%20local%20planning.

7.2.1. Capabilities Assessment Summary Ranking and Gap Analysis

7.2.1.1. Mitigation Capabilities and Capacity Building

Capacity building: increasing resilience by assessing and growing mitigation capabilities

Resilience is the capacity of communities to survive, adapt, grow, and even transform – when conditions require it – in the face of stresses and shocks. Building resilience is about making communities better prepared to withstand hazard events and better able to bounce back quickly and emerge stronger from these events. The assessment of mitigation capabilities is an essential step toward resilience. Building resilience cannot effectively occur unless there has been an honest assessment of a jurisdiction's capabilities to plan, manage, and assign resources to facilitate long-term hazard risk reduction (FEMA). Mitigation capacity building is becoming more prominent and realistically achieved with the implementation of FEMA's Building Resilient Infrastructure and Communities (BRIC) program, which began in fiscal year 2020. This program, which replaced the Pre-Disaster Mitigation (PDM) program, supports communities through capability and capacity building, encouraging and enabling innovation, promoting partnerships, enabling large projects, maintaining flexibility, and providing consistency.

Mitigation Capabilities

To complete the assessment, jurisdictions reviewed legislative and departmental capabilities to identify resources, strengths, and gaps for implementing hazard mitigation efforts. Using a Capabilities Assessment Worksheet, the jurisdictions documented existing institutions, plans, policies, ordinances, programs, and resources that could be brought to bear on implementing the mitigation strategy.

The capabilities in relation to hazard mitigation were assessed in the following categories:

- Planning and regulatory
  - Planning and regulatory capabilities are based on the implementation of plans, ordinances, and programs that demonstrate a jurisdiction's commitment to guiding and managing growth, development, and redevelopment in a responsible manner while maintaining the general welfare of the community. Although some conflicts can arise, these planning initiatives generally present significant opportunities to integrate hazard mitigation principles and practices into the local decision-making process.
- Administrative and technical
  - Administrative capabilities encompass the ability of a jurisdiction to develop and implement mitigation projects, policies, and programs and are directly tied to its ability to direct staff time and resources for that purpose.
  - These capabilities can be evaluated by determining how mitigation-related activities are assigned to local departments and if there are adequate personnel resources to complete these activities in a jurisdiction. The degree of coordination among departments will also affect administrative capability for the implementation and success of proposed mitigation activities.
  - Technical capabilities can generally be assessed by looking at the level of knowledge and technical expertise of jurisdictional employees, such as personnel skilled in using Geographic Information Systems (GIS) to analyze and assess community hazard vulnerability.
- Safe Growth Assessment
  - Using the American Planning Association's Basic Safe Growth Audit Questions, jurisdictions evaluate the extent to which hazard mitigation principles or practices are successfully integrated into existing actions that influence the long-term risk to people and property from hazards and promotes internal consistency. This process also identifies gaps or conflicts regarding community development and future hazard vulnerability, provides an important

connection between community development, public safety, and risk management, and identifies opportunities for further integration.

- Financial
  - This capability was assessed by reviewing a jurisdiction's access to or eligibility to utilize routine government funding resources such as capital improvement funding, taxes, fees, and Commonwealth and federal funding sources to fund past and future mitigation actions.
- Education and outreach
  - This capability was assessed by analyzing the education and outreach programs and methods already in place in a jurisdiction that could be used to implement mitigation activities and communicate hazard-related information.

After the assessment was completed, each capability category was ranked on a qualitative basis as demonstrated by the jurisdiction's authorities, programs, plans, and/or resources:

- **Limited:** the jurisdiction has limited capabilities within this category and is generally unable to implement most mitigation actions.
- **Low:** the jurisdiction has some capabilities within this category and can implement a few mitigation actions.
- **Moderate:** the jurisdiction has some capabilities within this category, but improvement is needed in order to implement some mitigation actions.
- **High:** the jurisdiction has significant capabilities within this category as demonstrated by its authorities, programs, plans and/or resources, and can implement most mitigation actions.

A summary of the NOVA region's mitigation capability rankings is presented in Table 3.1. Thorough assessments of each jurisdiction's capabilities and gap analyses showing areas of improvement are provided in the Jurisdiction Annexes. Highlights of NOVA's mitigation capabilities include:

- High planning and regulatory capabilities across participants. The participating towns that have moderate capabilities in this category have strong relationships with their county partners and can collaborate and share resources to fill any gaps that may exist.
- Almost all participants had high to moderate administrative and technical capabilities. Again, because of the overall strength of these capabilities in the planning area, those with moderate or low capabilities can share resources to fill any gaps that may be present.

No matter the strength of mitigation capabilities, there is always room for improvement due to constantly changing factors such as population, staffing, finances, and different types and magnitudes of hazards. During the assessment, a gap analysis was performed to identify ways in which capabilities could be expanded and improved to reduce risk. Key areas for improvement include:

- Increases in financial capabilities are necessary to complete a broad range of mitigation actions that will protect life, property, and the environment.
- An increase in public education about natural and human-caused hazards is necessary to better prepare the population—especially vulnerable populations—about hazards, including the increasing severity and frequency of hazards such as flooding.
- Many participants had low or moderate safe growth capabilities, making this an area that can be expanded and improved to reduce risk. Integrating mitigation into safe growth focuses such as land use, environmental management, ordinances and regulations, and local programs and policies can increase a community's safety as it grows.

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Table 121: Mitigation Capability Assessment Ranking Summary

Jurisdiction	Capability				
	Planning and Regulatory	Administrative and Technical	Safe Growth	Financial	Education and Outreach
Arlington County	High	High	High	Moderate	High
City of Alexandria	High	High	Moderate	Moderate	Moderate
City of Fairfax	High	High	High	Moderate	Moderate
City of Falls Church	High	High	Moderate	Moderate	Moderate
City of Manassas	High	High	Moderate	Moderate	Moderate
City of Manassas Park	High	Moderate	High	Moderate	Moderate
Fairfax County	High	High	High	Moderate	Moderate
Town of Clifton	Moderate	Low	Low	Low	Moderate
Town of Herndon	High	Moderate	High	Moderate	Moderate
Town of Vienna	Moderate	Moderate	Moderate	Moderate	Moderate
Loudoun County	High	High	High	Moderate	Moderate
Town of Leesburg	High	High	Low	Moderate	Low
Town of Lovettsville	High	High	High	Moderate	Low
Town of Middleburg	Moderate	Moderate	Moderate	Moderate	Moderate
Town of Purcellville	Moderate	High	Moderate	Moderate	Low
Town of Round Hill	High	High	High	Moderate	Moderate
Prince William County	Moderate	Moderate	Moderate	Moderate	Moderate
Town of Dumfries	Low	Moderate	Moderate	Moderate	Low
Town of Haymarket	Moderate	Moderate	Moderate	Moderate	Moderate
Town of Occoquan	Moderate	Moderate	Moderate	Low	Moderate

NFIP Assessment and Continued Compliance

The administration of the National Flood Insurance Program (NFIP) is a key component of jurisdictional hazard management capabilities.[223]

The United States Congress established the NFIP with the passage of the National Flood Insurance Act of 1968. Some planning participants partake in the Community Rating System (CRS), which is a part of the NFIP. The CRS is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. This is done by providing flood insurance premium discounts to property owners in communities participating in the CRS program. Credit points are earned for a wide range of local floodplain management activities; the total number of points determines the amount of flood insurance premium discounts provided to policyholders.[224]

A summary of participant NFIP information is presented in Table 122. All jurisdictions included in the planning process participate in the NFIP. The table also provides the date of the Flood Insurance Rate Map (FIRM) in effect in each community.

These maps were developed by FEMA or its predecessor and show the boundaries of the 100-year and 500-year floods. Nine of the maps are over 15 years old. Some plan participants have experienced dramatic growth since the effective date of their most recent FIRM and this change is not reflected in the FIRM. This difference may mean that the actual floodplain varies from that depicted on the map.

Fairfax County, the towns of Clifton, Herndon, Vienna, the City of Alexandria, the City of Fairfax, and the City of Falls Church are currently working with FEMA to update FIRMs for their communities. Additionally, Prince William County is currently undergoing a CRS recertification process which includes evaluating the county's flood preparedness, flood damage reduction efforts, mapping and regulations, and public information activities.

Repetitive and Severe Repetitive Loss Strategy

Plan participants employ a number of strategies to reduce the number of repetitive loss and severe repetitive loss properties in their jurisdictions, including regulatory requirements such as building code enforcement and floodplain and zoning ordinances, comprehensive planning activities including land use planning, and environmental management activities such as open space and natural environment preservation.

These strategies serve to make local jurisdictions eligible for increased federal cost share for FEMA Flood Mitigation Assistance (FMA) grants. The strategy adheres to the requirements from 44 C.F.R. $201.4 (c)(3)(v).

Definitions

For properties to be eligible for an increased federal cost share in FMA grants, the definitions below must apply, as stipulated in the Biggert-Waters Flood Insurance Reform Act of 2012:

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[223] Federal Emergency Management Agency. (2013, March 1). *Integrating Hazard Mitigation into Local Planning: Case Studies and Tools for Community Officials*. https://www.fema.gov/sites/default/files/2020-10/fema_integrating-hazard-mitigation_case-studies_tools-community-officials.pdf

[224] Federal Emergency Management Agency. (2016, September) *State Hazard Mitigation Planning Key Topics Bulletins: Mitigation Capabilities*. https://www.fema.gov/sites/default/files/2020-06/fema-state-mitigation-capabilities-planning-bulletin_09-26-2016.pdf#:~:text=An%20assessment%20of%20state%20mitigation%20capabilities%20is%20essential,efforts%20targeted%20for%20state-level%20and%20%20local%20planning.

A **repetitive loss** property is a structure covered by a contract for flood insurance made available under the NFIP that:

1. Has incurred flood-related damage on two occasions, in which the cost of the repair, on average, equaled or exceeded 25 percent of the market value of the structure at the time of each such flood event; and
2. At the time of the second incidence of flood-related damage, was covered under a contract for flood insurance which contained an increased cost of compliance coverage.

A **severe repetitive loss property** is a structure that:

1. Is covered under a contract for flood insurance made available under the NFIP; and,
2. Has incurred flood-related damage:
    a. For which four or more separate claims payments have been made under flood insurance coverage with the amount of each such claim exceeding $5,000 and with the cumulative amount of such claim payments exceeding $20,000; or
    b. For which at least two separate claims payments have been made under such coverage, with the cumulative amount of such claims exceeding the market value of the insured structure.

The NFIP's Flood Insurance Manual provides the following definitions for NFIP and CRS purposes:

A repetitive loss structure is an NFIP-insured structure that has had at least two paid flood losses of more than $1,000 each in any 10-year period since 1978.

The severe repetitive loss group consists of any NFIP-insured property that has met at least one of the following paid flood loss criteria since 1978, regardless of ownership, with two of the claim payments occurring within ten years of each other:

1. Four or more separate claim payments of more than $5,000 each (including building and content payments); or
2. Two or more separate claim payments (building payments only) where the total of the payments exceeds the current value of the property.

Specific information about NFIP compliance, CRS participation, and NFIP-insured structures that have been categorized as repetitive loss (RL) and severe repetitive loss (SRL) properties are included in the jurisdiction annexes.

Table 122: NFIP Participation Summary[225]

Jurisdiction and Community Identification Number (CID)	Initial Flood Hazard Boundary Map (FHBM) Identified	Initial Flood Insurance Rate Map (FIRM) Identified	Current Effective Map Date	Regular-Emergency Date	Digital Flood Insurance Rate Map (DFIRM)/ (Q3)
Arlington County 515520#	-	10/1/1969	8/19/2013	12/31/1976	DFIRM
City of Alexandria 515519#	8/22/1969	8/22/1969	6/16/2011	5/8/1970	DFIRM
City of Fairfax 515524#	5/5/1970	12/23/1971	6/2/2006	12/17/1971	DFIRM
City of Falls Church 510054#	9/6/1974	2/3/1982	7/16/2004	2/3/1982	DFIRM
City of Manassas 510122#	5/31/1974	1/3/1979	1/5/1995	1/3/1979	DFIRM
City of Manassas Park 510123#	3/11/1977	9/29/1978	1/5/1995	9/29/1978	DFIRM
Fairfax County 515525#	5/5/1970	3/5/1990	9/17/2010	1/7/1972	DFIRM
Town of Clifton 510186#	3/28/1975	5/2/1977	9/17/2010	5/2/1977	DFIRM
Town of Herndon 510052#	6/14/1974	8/1/1979	9/17/2010	8/1/1979	DFIRM
Town of Vienna 510053#	8/2/1974	2/3/1982	9/17/2010	2/3/1982	DFIRM
Loudoun County 510090A	4/25/1975	1/5/1978	7/5/2001	1/5/1978	DFIRM

[225] Federal Emergency Management Agency. (n.d.). *Community Status Book Report Virginia: Community Participating in the National Flood Program.* https://www.fema.gov/cis/VA.pdf

Jurisdiction and Community Identification Number (CID)	Initial Flood Hazard Boundary Map (FHBM) Identified	Initial Flood Insurance Rate Map (FIRM) Identified	Current Effective Map Date	Regular-Emergency Date	Digital Flood Insurance Rate Map (DFIRM)/ (Q3)
Town of Leesburg 510091A	8/30/1974	9/30/1982	7/5/2001	9/30/1982	DFIRM
Town of Lovettsville 510259A	4/15/1977	7/5/2001	2/17/2017	10/22/2013	DFIRM
Town of Middleburg 51036DA	-	7/5/2001	7/5/2001	7/31/2001	DFIRM
Town of Purcellville 510231A	7/11/1975	11/15/1989	7/5/2001	11/15/1989	DFIRM
Town of Round Hill 510279A	5/13/1977	7/5/2001	7/5/2001	1/10/2006	DFIRM
Prince William County 510119A	1/10/1975	12/1/1981	8/3/2015	12/1/1981	DFIRM
Town of Dumfries 510120A	6/18/1976	5/15/1980	8/3/2015	5/15/1980	DFIRM
Town of Haymarket 510121#	8/9/1974	1/17/1990	1/5/1995	1/31/1990	DFIRM
Town of Occoquan 510124#	11/1/1974	8/15/1978	8/3/2015	8/15/1978	DFIRM
Town of Quantico 510232A	11/1/1974	8/15/1978	8/3/2015	8/15/1978	DFIRM

Table 123: CRS Participation Summary[226]

Jurisdiction	CRS Entry Date	Current Effective Date	Current Class	Percent Discount SFHA	Percent Discount Non-SFHA
Arlington County	10/1/1992	10/1/2008	8	10	5
City of Alexandria	10/1/1992	10/1/2013	6	20	10
City of Falls Church	5/1/2007	10/1/2016	6	20	10
Fairfax County	10/1/93	10/1/2014	6	20	10
Town of Vienna	10/1/1996	10/1/2011	8	10	5
Loudoun County	10/1/1992	5/1/2003	10	0	0
Prince William County	10/1/1996	10/1/2019	7	15	5

[226] Federal Emergency Management Agency. (n.d.). *Community Status Book Report Virginia: Community Participating in the National Flood Program.* https://www.fema.gov/cis/VA.pdf

8. Mitigation Strategy

Requirements

- **§201.6(c)(3)(i)** – [The hazard mitigation strategy shall include a] description of mitigation goals to reduce or avoid long-term vulnerabilities to the identified hazards.
- **§201.6(c)(3)(ii)** – [The hazard mitigation strategy shall include a] section that identifies and analyzes a comprehensive range of specific mitigation actions and projects being considered to reduce the effects of each hazard, with particular emphasis on new and existing buildings and infrastructure. All plans approved by FEMA after October 1, 2008, must also address the jurisdiction's participation in the NFIP, and continued compliance with NFIP requirements, as appropriate.
- **§201.6(c)(3)(iii)** – [The hazard mitigation strategy shall include an] action plan, describing how the action identified in paragraph (c)(3)(ii) of this section will be prioritized, implemented, and administered by the local jurisdiction. Prioritization shall include a special emphasis on the extent to which benefits are maximized according to a cost-benefit review of the proposed projects and their associated costs.
- **§201.6(c)(3)(iv)** – For multi-jurisdictional plans, there must be identifiable action items specific to the jurisdiction requesting FEMA approval or credit of the plan.
- **§201.6(c)(4)(ii)** – [The plan shall include a] process by which local governments incorporate the requirements of the mitigation plan into other planning mechanisms such as comprehensive or capital improvements, when appropriate.

2022 HMP Update

- Goals and objectives from the 2017 NOVA HMP 2017 were reviewed and revised into a streamlined goal statement to ensure consistency with FEMA mitigation requirements.
- Mitigation actions were adapted from the 2017 NOVA HMP to include additional analysis of progress in mitigation.
- Updated funding descriptions and requirements were added per the latest FEMA guidance documents and the 2018 Virginia State Hazard Mitigation Plan.

8.1. Overview

The mitigation strategy serves as the long-term blueprint for reducing the potential losses identified in the risk assessment. The Stafford Act directs hazard mitigation plans to describe hazard mitigation actions and establish a strategy to implement those actions. Therefore, all other requirements for a hazard mitigation plan lead to and support the mitigation strategy.

This Plan update is an opportunity for NOVA jurisdictions to assess previous goals and adjust them to address current realities.[227] Updated and streamlined mitigation goals and objectives are presented in this section. The mitigation strategy is designed to support these goals and objectives.

[227] Federal Emergency Management Agency. (2011, October 1). *Local Mitigation Plan Review Guide*. https://www.fema.gov/sites/default/files/2020-06/fema-local-mitigation-plan-review-guide_09_30_2011.pdf

The status of mitigation actions included in the 2017 HMP is discussed, as are new action items and how these action items were prioritized. All actions support the goals and objectives and promote an inclusive mitigation strategy. A summary of the types of actions identified by participants is presented to display the wide range of projects chosen, which represents a broad and inclusive approach to mitigation in the region.

A description of how participants will incorporate and integrate the mitigation risk assessment and goals into existing jurisdictional plans and procedures is described, and a list of potential federal, nonprofit, and Commonwealth funding sources is provided as a resource for participants to utilize when exploring financial support options for mitigation projects.

8.2. Review and Update Process

The 2017 NOVA HMP included six regional mitigation goals with the purpose of reducing or eliminating long-term risk for communities in the planning area. The NOVA Planning Group reviewed these goals during a mitigation strategy planning workshop and chose to condense and streamline them without changing their nature and intent.

8.3. 2022 Goals and Objectives

The NOVA Planning Group reviewed the mitigation goals included in the 2017 HMP and unanimously agreed to forego them and adopt the following hazard mitigation goals:

> ***“Our goals are to protect life and reduce bodily harm from the natural and non-natural hazards identified in this Plan, and to lessen the impacts of these hazards on property, the environment, and the community.”***

These streamlined goals provide a long-term policy statement and vision that supports the mitigation strategy and will be achieved through the completion of the hazard mitigation actions and action plans identified in each jurisdiction’s annex. These actions and action plans state a specific strategy for achieving these mitigation goals over the next five years. The mitigation actions detail the specific actions the jurisdictions will take, and the action plans describe how the actions will be prioritized and implemented to reduce the risk of hazards identified in the HMP. These goals are the basis of this Plan and summarize what the NOVA Hazard Mitigation Planning Group will accomplish by implementing it.

8.4. Status of 2017 Mitigation Actions

A thorough review of mitigation actions identified in the 2017 HMP was conducted to determine the effectiveness of each action and the progress made to date. Each participating jurisdiction was asked to review and update the status of each action to determine whether: the action was completed; the strategy is no longer applicable; or if the action should be moved forward and included in the 2022 Plan update. The updated status of previous mitigation actions is provided in the individual jurisdiction annexes.

8.5. New Mitigation Actions

Each participating jurisdiction updated its list of mitigation actions based on the review of its risk assessment, its existing capabilities, and the status of its action items in the 2017 HMP. The lists of actions include community-specific details from a comprehensive range of action item categories and are included in each jurisdiction annex.

Additionally, jurisdictions were urged to complete a New Action Information Page for each new action item included in the HMP. This optional page gave participants the tools to critically think through action items, and the information included serves as a strong starting point for hazard mitigation grant applications. Details covered on this page include a detailed description of the action, a cost-benefit analysis, a plan for implementation, and three alternative actions considered. These pages are included in the annexes of the jurisdictions that completed them.

FEMA identifies four primary types of mitigation actions to reduce long-term vulnerabilities: local plans and regulations; structure and infrastructure; natural systems protection; and public education and awareness. Additional details about these types of actions are shown in Table 124. These actions are also traditionally eligible for hazard mitigation and other types of funding.

Table 124: Primary Types of Action Items[228]

Local Plans and Regulations	
Definition	**Examples**
These actions include government authorities, policies, or codes that encourage risk reduction.	• Comprehensive plans • Land use ordinances • Subdivision regulations • Development review • Building codes and enforcement • NFIP Community Rating System (CRS) participation • Capital improvement programs • Open space preservation • Stormwater management regulations and master plans • Community wildfire protection plans, fuels management, and fire breaks
Structure and Infrastructure Projects	
Definition	**Examples**
These actions involve modifying existing structures and infrastructure to protect them from a hazard or remove them from a hazard area. These actions also include constructing new structures to reduce the impact of hazards. This could apply to public or private structures as well as critical facilities and infrastructure.	• Acquisitions and elevations of structures in flood-prone areas • Utility undergrounding • Structural retrofits (e.g., shelters) • Floodwalls and retaining walls • Detention and retention structures • Culverts • Safe rooms

[228] Federal Emergency Management Agency. (2016, October). *State Mitigation Planning Key Topics Bulletins: Mitigation Strategy*. https://www.fema.gov/sites/default/files/2020-06/fema-state-mitigation-strategy-planning-bulletin_10-26-2016_0.pdf

Natural Systems Protection	
Definition	**Examples**
These are actions that minimize damage and losses while preserving or restoring the function of natural systems.	• Sediment and erosion control • Stream corridor restoration • Forest management • Conservation easements • Wetland restoration and preservation

Public Education and Awareness Programs	
Definition	**Examples**
These are long-term, sustained programs to inform and educate the public and stakeholders about hazards and mitigation options. This can also include training.	• Radio or television spots • Websites with maps and information • Social media • Real estate disclosure • Presentations to school groups or neighborhood organizations • Mailings to at-risk populations and residents in hazard-prone areas • StormReady certification • Participation in the FireWise USA program

A strong mitigation strategy includes an analysis of actions and projects that are based on a jurisdiction's risk, vulnerabilities, and community priorities. These actions should represent a comprehensive range of mitigation alternatives that address the vulnerabilities to the hazards that the jurisdictions determine are most important.[229]

Table 125 shows the number of each type of FEMA-identified primary action item types. This range of projects demonstrates how planning participants are dedicated to taking a multifaceted approach to risk reduction.

Table 125: Number of Types of Action Items Selected by Participants

Local Plans and Regulations	Structure and Infrastructure Projects	Natural Systems Protection	Public Education and Awareness Programs	Training	Preparedness
108	171	24	53	24	6

8.6. Prioritization of Mitigation Actions

The Planning Group reviewed the action items prioritization process from the 2017 HMP and agreed to adopt the same process as part of the 2021 update. Through discussion and self-analysis, each jurisdiction used the STAPLE/E criteria when considering and prioritizing mitigation actions. Only actions

[229] Federal Emergency Management Agency. (2011, October 1). *Local Mitigation Plan Review Guide* https://www.fema.gov/sites/default/files/2020-06/fema-local-mitigation-plan-review-guide_09_30_2011.pdf

that satisfied the STAPLE/E criteria to the satisfaction of the jurisdiction and had the potential to reduce vulnerability to hazards were included in the Plan.

The STAPLE/E evaluation method uses seven criteria for evaluating a mitigation action: social, technical, administrative, political, legal, economic, and environmental. Within each of these criteria are additional considerations that may call upon the hazard risk assessment and other sources of information for evaluation. Table 126 describes each category and its considerations.

Table 126: STAPLE/E Evaluation Criteria for Mitigation Actions

(S) Social	
Definition	**Considerations**
The public must support the overall mitigation implementation strategy and specific mitigation actions. The mitigation action is evaluated in terms of community acceptance and impact on the population.	• **Community acceptance:** will the action disrupt housing or cause the relocation of people? Is the action compatible with present and future community values? • **Impact on population:** will the proposed action adversely affect one segment of the population?
(T) Technical	
Definition	**Considerations**
It is important to determine if the proposed action is technically feasible, will help to reduce losses in the long term, and has minimal secondary impacts. This category evaluates whether the action is a whole or partial solution, or not a solution at all.	• **Technical feasibility:** how effective is the action in avoiding or reducing future losses? • **Long-term solution:** does the action solve the problem or only a symptom? • **Secondary impacts:** will the action create more problems than it solves?
Administrative	
Definition	**Considerations**
This category examines the anticipated staffing, funding, time, and maintenance requirements for the mitigation action to determine if the jurisdiction has the personnel and administrative capabilities to implement the action or whether outside help will be necessary.	• **Staffing:** does the jurisdiction have the capability (staff, technical experts, and training) to implement the action? • **Funding allocated:** does the jurisdiction have the funding to implement the action or can it readily be obtained? • **Time:** can the action be accomplished in a timely manner? • **Maintenance/Operations:** can the community provide the necessary maintenance? It is important to remember that most federal grants will not provide funding for maintenance.

(P) Political	
Definition	**Considerations**
This category considers the level of political support for the mitigation action.	• **Political support:** is there political support to implement and maintain this action? Have political leaders participated in the planning process so far? • **Local champion or proponent:** is there a respected community member willing to help see the action to completion? • **Public and stakeholder support:** is there enough public support to ensure the success of the action? Have all stakeholders been offered an opportunity to participate in the planning process?
(L) Legal	
Definition	**Considerations**
Whether the jurisdiction has the legal authority to implement the action or whether the jurisdiction must pass new laws or regulations is important in determining how the mitigation action can be best carried out.	• **Commonwealth authority:** does the Commonwealth have authority to implement the action? • **Existing local authority:** are proper laws, ordinances, and resolutions in place to implement the action? • **Potential legal challenge:** is there a technical, scientific, or legal basis for the mitigation action (i.e., does the mitigation action "fit" the hazard setting)? Are there any potential legal consequences? Is the action likely to be challenged by stakeholders who may be negatively affected?
(E) Economic	
Definition	**Considerations**
Economic considerations must include evaluation of the present economic base and projected growth. Cost-effective mitigation actions that can be funded in current or upcoming budget cycles are more likely to be implemented than actions requiring general obligation bonds or other instruments that would incur long-term debt to a community.	• **Benefits of action:** what financial benefits will the action provide? • **Cost of action:** does the cost seem reasonable for the size of the problem and the likely benefits? What burden will be placed on the tax base or local economy to implement this action? • **Contribution to economic goals:** does the action contribute to community economic goals, such as capital improvements or economic development? • **Outside funding required:** are there currently sources of funding that can be used to implement the action? Should the action be considered "tabled" for implementation until outside sources of funding are available?

(E) Environmental	
Definition	**Considerations**
The impact on the environment is an important consideration due to public desire for sustainable and environmentally healthy communities. Statutory considerations, such as the National Environmental Policy Act (NEPA), also need to be kept in mind when using federal funds.	• **Impact on land/water bodies:** how will this action impact land/water? • **Impact on endangered species:** how will this action impact endangered species? • **Impact on hazardous materials and waste sites:** how will this action impact hazardous materials and waste sites? • **Consistency with community environmental goals:** is this action consistent with community environmental goals? • **Consistency with federal laws:** is the action consistent with federal laws, such as NEPA?

After considering the STAPLE/E criteria, each jurisdiction assigned a prioritization category of low, medium, or high to each action item being created or retained. The categories were defined as:

- **Low:** The action has the potential to reduce vulnerability to hazards, is based on one to two STAPLE/E criteria and is feasible and important for the jurisdiction. The action should be implemented as funding becomes available. The projected timeline for completion is 5 or more years.
- **Medium:** The action has the potential to reduce vulnerability to hazards and based on three to four STAPLE/E criteria, is feasible and important for the jurisdiction. Its implementation is not as urgent as a high-priority action item, and it can be implemented in the long term. The projected timeline for completion is 3 to 5 years.
- **High:** The action has the potential to reduce vulnerability to hazards, is based on five or more STAPLE/E criteria and is feasible and important for the jurisdiction. It is especially important for the jurisdiction to implement it in the short term and as quickly as possible. The projected timeline for completion is 1 to 2 years.

8.7. Funding Priorities

As necessary, jurisdictions will seek outside funding sources to implement mitigation projects in both pre-disaster and post-disaster environments. When applicable, potential funding sources have been identified for proposed actions listed in the mitigation strategies.

Funding priority will go toward action items with a high positive impact on community resilience as measured by the action’s scope and cost-benefit analysis.

8.8. Integrating Mitigation into Existing Plans and Procedures

Through effective communication of the hazard mitigation opportunities and benefits that exist in communities, local leaders and elected officials can achieve agreement on efforts to integrate hazard mitigation into local planning. Educating jurisdictional leadership, staff, and community members about the benefits of mitigation actions is the best way to ensure seamless integration between mitigation planning and other local planning efforts.

The jurisdictions in NOVA continue to work on developing strategies and opportunities to better incorporate mitigation actions from the previous Plan into ongoing local planning activities. Additionally, jurisdictions have identified approaches to promote the integration of action items included in the 2022 HMP into local planning mechanisms.

The primary means for integrating mitigation strategies into other local planning mechanisms will be the revision, updating, and implementation of each jurisdiction's individual plans that require specific planning and administrative tasks (for example, Plan amendments, ordinance revisions, and capital improvement projects).

The members of the Planning Group will remain charged with ensuring that the goals and strategies of new and updated local planning documents for their jurisdictions are consistent with the goals and actions of the HMP and will not contribute to increased hazard vulnerability in the planning area or its participating jurisdictions.

Best practice while updating other community plans, such as a comprehensive plan, capital improvement plan, or emergency management plan, is for jurisdictions to provide a copy of the NOVA HMP to the appropriate parties. This will ensure that plans are integrated and all goals and strategies of new and updated local planning documents are consistent with and support the goals of the Plan and will not contribute to increased hazards in the jurisdiction or planning area.

It is recommended that the Plan be publicly posted on county, city, and town websites for review by the public and stakeholders to support community mitigation efforts. The following steps are suggestions for implementing this HMP into local plans:

1. Change is proposed by an elected official or other interested party.
2. The proposal is placed on the local agenda of the governing body.
3. The agenda is published at least 10 days in advance of the meeting at which it will be discussed, so members of the public have an opportunity to attend the discussion meeting. Publication may be made by posting the agenda on the city's website, in the city newsletter, or on a public bulletin board.
4. The proposal is discussed at the public meeting, including any comments by members of the public in attendance.
5. The proposal is voted on by the governing body.
6. If the proposal is passed, the change is implemented by the appropriate local authority.

8.9. Action Plan for Implementation and Integration

Several notable challenges and missed opportunities to incorporate hazard mitigation into local planning efforts have been identified by FEMA,[230] including the following:

- Hazard mitigation plans are often developed or updated without the active participation or leadership of local planning and community development staff.
- Local land use planners are less willing to embrace hazard mitigation planning as falling within their professional purview.
- Hazard mitigation plans often include mitigation strategies or actions that are focused on a disconnected series of emergency services, structure or infrastructure protection projects, and

[230] Federal Emergency Management Agency. (2013, March 1). *Integrating Hazard Mitigation into Local Planning: Case Studies and Tools for Community Officials*. https://www.fema.gov/sites/default/files/2020-10/fema_integrating-hazard-mitigation_case-studies_tools-community-officials.pdf

public outreach initiatives, with less emphasis on non-structural measures available through local land use planning or policy alternatives.

- Hazard mitigation plans are typically completed as stand-alone documents that cover multiple jurisdictions, and it is relatively uncommon for them to be directly linked or integrated with other community-specific planning tools such as comprehensive land use plans and development regulations.

To combat these challenges, increase accountability, and more clearly identify how jurisdictions will incorporate the hazard mitigation risk assessment and goals into existing plans and procedures, participants completed an Action Plan for Hazard Mitigation Implementation and Integration assessment during the planning process. Participants identified which existing plans and procedures they would work to incorporate mitigation into and provided a brief action plan for how this will be achieved. Jurisdiction-specific Action Plans are provided in the annexes.

8.10. Implementation Resources and Funding Opportunities

Determining current and/or potential implementation resources and funding opportunities for each identified action item is a vital part of the mitigation strategy planning process. By exploring, identifying, and designating funding sources now, jurisdictions are poised to complete identified action items as implementation and funding opportunities arise.

Under 44 CFR §201.6, local governments must have a FEMA-approved local mitigation plan in order to apply for and/or receive hazard mitigation project grant funds for the following federal Hazard Mitigation Assistance (HMA) programs:

- Hazard Mitigation Grant Program (HMGP)
- Building Resilient Infrastructure and Communities (BRIC)
- Flood Mitigation Assistance (FMA)
- Repetitive Flood Claims (RFC)
- Severe Repetitive Loss (SRL)

FEMA funding programs for cost-effective hazard mitigation for facilities damaged by natural disasters which are eligible under the Stafford Act, HMA and National Flood Insurance Act of 1968 are illustrated in Figure 66.

Stafford Act Section 406	Stafford Act Section 404	National Flood Insurance Act of 1968 NFIA	Stafford Action Section 203
PA Programs	**HMA Programs**		
Disaster-related programs **PA**: Mitigation of incident-caused damage  Funding: Available for disaster-damaged facilities only*	***Disaster-related programs*** **HMGP:** Multi-hazard statewide mitigation  Funding: Available for damaged and non-damaged facilities based on a percentage of dollars obligated to the PA and IA programs	***Non-disaster-related programs*** **FMA:** Flood mitigation for insured properties 	***Non-disaster-related programs*** **BRIC:** Planning, Large-scale infrastructure projects 
NOTE: **PA** = Public Assistance **HMA** = Hazard Mitigation Assistance **HMGP** = Hazard Mitigation Grant Program		**FMA = Flood Mitigation Assistance** **BRIC** = Building Resilient Infrastructure and Communities **IA** = Individual Assistance	
* *Exception for Alternative Procedures Projects (See Guide)*			

Figure 66: Federal Policies That Provide Funding for Local Hazard Mitigation

Mitigation activities can and should be implemented through a variety of funding streams. FEMA funding sources, including the Hazard Mitigation Grant Program (HMGP), the Building Resilient Infrastructure and Communities (BRIC) program, the Flood Mitigation Assistance (FMA) program, and Sections 404 and 406 of Hazard Mitigation Funding tend to be relied on heavily for mitigation action completion. However, it is important to research and leverage other available funding opportunities and not to limit funding sources to FEMA assistance programs. Funding opportunities may include other federal agencies, Commonwealth, local and tribal programs, as applicable, or private funding. In addition to funding, mitigation implementation resources such as regulatory and technical assistance are available to assist jurisdictions in completing action items and integrating mitigation into planning and resilience efforts.

In addition to the sources identified above and in Table 3.8, Coronavirus (COVID-19) relief funds were distributed by the United States Congress to federal, state, and local government agencies, nonprofit organizations, and individuals in 2020 and 2021. The main funding programs were the Coronavirus Aid, Relief, and Economic Security (CARES) Act (2020), the Coronavirus Response and Consolidated Appropriations Act (2021), and the American Rescue Plan Act (ARPA) (2021).[231] These funds have a broad range of allowable expenses, including supporting public health expenditures, replacing lost public sector revenue, and investing in water, sewer, broadband, and cybersecurity infrastructure. Within these overall categories, recipients have broad flexibility to decide how best to use this funding to meet the

[231] USA Spending. (2021, September 20). *The Federal Response to COVID-19* https://www.usaspending.gov/disaster/covid-19?publicLaw=all

needs of their communities[232]. As of December 2021, $350 billion has been allocated to states, counties, cities, tribal governments, territories, and non-entitlement units of local government[233].

Another recent influx in federal funds that can be used for mitigation actions is the Infrastructure Investment and Jobs Act which was passed by Congress on November 6, 2021. This once-in-a-generation investment in infrastructure includes legislation that addresses repairing and rebuilding roads and bridges with a focus on climate change, mitigation, and resilience, and making the nation's infrastructure resilient against the impacts of climate change, cyberattacks, and extreme weather events[234]**. The methods by which this legislation will be implemented were still being determined at the time this Plan was written.**

8.10.1. Hazard Mitigation Grant Program (HMGP)

The **Hazard Mitigation Grant Program (HMGP)** is authorized under section 404 of the Robert T. Stafford Act and 44 C.F.R. part 206. The purpose of HMGP is to provide funds to states, territories, Indian tribal governments, and communities to significantly reduce or permanently eliminate future risks to lives and property from natural hazards. Entities pursuant of HMPG funding must have fully patriated in a FEMA-approved hazard migration plan.

- Because the Commonwealth has an enhanced hazard mitigation plan, HMGP funds are 20% of the federal share of a federally declared presidential disaster and are broken down into three categories:
  - 5% initiative projects
  - 7% plan development and revision
  - 88% regular projects
- The grant application period is open for 12 months after the declaration date. All applications are made through and reviewed by the Commonwealth and approved by FEMA.

The **Flood Mitigation Assistance Program (FMA)** is a competitive grant program that provides funding states, territories, Indian tribal governments. FMA funds can be used for projects that reduce or eliminate the risk of repetitive flood damage to buildings insured by the National Flood Insurance Program (NFIP).

- The Virginia Department of Emergency Management administers the Flood Mitigation Assistance program. Its purpose is to implement cost-effective measures that reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insured under the NFIP.
- The FMA funds planning activities that assess a community's flood risk and identify actions to reduce risk. Additionally, FMA funds property acquisitions, structure demolitions, and structure relocations, along with other flood mitigation activities.
- The repetitive and severe repetitive loss strategy outlined in this Plan serves to allow a cost share of 90% federal funds for repetitive and severe repetitive loss mitigation activities.

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[232] United States Department of the Treasury. (n.d.). *Coronavirus State and Local Fiscal Recovery Funds* https://home.treasury.gov/policy-issues/coronavirus/assistance-for-state-local-and-tribal-governments/state-and-local-fiscal-recovery-funds
[233] USA Spending. (2021, September 20). *The Federal Response to COVID-19* https://www.usaspending.gov/disaster/covid-19?publicLaw=all
[234] The White House. (2021, November 6). *Fact Sheet: The Bipartisan Infrastructure Deal* https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/06/fact-sheet-the-bipartisan-infrastructure-deal/

- **Building Resilient Infrastructure and Communities (BRIC)**
  - The newest FEMA pre-disaster hazard mitigation program replaced the Pre-Disaster Mitigation (PDM) program. FEMA opened the first application period for the FY2020 Notices of Funding Opportunities that included BRIC.
  - BRIC supports communities through capability- and capacity-building, encouraging and enabling innovation, promoting partnerships, enabling large projects, maintaining flexibility, and providing consistency.
  - Priorities are to incentivize public infrastructure projects and projects that mitigate risk to one or more community lifelines, incentivize projects that incorporate nature-based solutions, and increase funding to applicants that facilitate the adoption and enforcement of the latest published editions of building codes.

8.10.2. Sections 404 and 406 Hazard Mitigation Funding

The Stafford Act established 404 and 406 mitigation activities for facilities requiring repair, restoration, or replacement as a result of a presidentially declared disaster. Although Sections 404 and 406 are distinct programs with key differences in their scope, purpose, and funding, both support hazard mitigation goals.

- **Section 404- Hazard Mitigation Grant Program** funding is used to provide protection to undamaged parts of a facility or to prevent or reduce damages caused by future disasters.
- **Section 406- Public Assistance** funding provides discretionary authority to fund mitigation measures in conjunction with the repair of the disaster-damaged facilities, so is limited to declared counties and eligible damaged facilities.

Table 127: Eligible Activities by Hazard Mitigation Assistance Program

Eligible Activities	HMGP	FMA	BRIC
1. Mitigation Projects	√	√	√
▪ Property Acquisition and Structure Demolition	√	√	√
▪ Property Acquisition and Structure Relocation	√	√	√
▪ Structure Elevation	√	√	√
▪ Mitigation Reconstruction	√	√	√
▪ Dry Floodproofing of Historic Residential Structures	√	√	√
▪ Dry Floodproofing of Non-Residential Structures	√	√	√
▪ Generators	√		√
▪ Localized Flood Risk Reduction Projects	√	√	√
▪ Non-Localized Flood Risk Reduction Projects	√		√
▪ Structural Retrofitting of Existing Buildings	√	√	√
▪ Non-Structural Retrofitting of Existing Buildings and Facilities	√	√	√
▪ Safe Room Construction	√		√
▪ Wind Retrofit for One- and Two-Family Residences	√		√
▪ Infrastructure Retrofit	√	√	√
▪ Soil Stabilization	√	√	√
▪ Wildfire Mitigation	√		√
▪ Post-Disaster Code Enforcement***	√		√

Eligible Activities	HMGP	FMA	BRIC
▪ Advance Assistance	√		√
▪ 5 Percent Initiative Projects*	√		
▪ Aquifer and Storage Recovery**	√	√	√
▪ Flood Diversion and Storage**	√	√	√
▪ Floodplain and Stream Restoration**	√	√	√
▪ Green Infrastructure**	√	√	√
▪ Building Code Adoption and Enforcement***			√
▪ Partnership Expansion***			√
▪ Project Scoping***			√
▪ Miscellaneous/Other**	√	√	√
2. Hazard Mitigation Planning	√	√	√
3. Technical Assistance		√	√
4. Management Costs	√	√	√

*FEMA allows increasing the 5 percent initiative amount up to 10 percent for a Presidential Major Disaster Declaration under HMGP. The additional 5 percent initiative funding can be used for activities that promote disaster-resistant codes for all hazards. As a condition of the award, either a disaster-resident building code must be adopted, or an improved Building Code Effectiveness Grading Schedule is required.

**Indicates that any proposed action will be evaluated on its own merit against program requirements. Eligible projects will be approved provided funding is available.

***Activities are only eligible for funding under the BRIC State/Territory Allocation and BRIC Tribal Set Aside; they are not eligible for funding under the BRIC National Competition.

Sources: FEMA. (2015, February 27). *Hazard Mitigation Assistance Guidance.* https://www.fema.gov/sites/default/files/2020-04/HMA_Guidance_FY15.pdf and FEMA. (2021, November 12). *Building Resilient Infrastructure and Communities (BRIC).* https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities/before-apply

Table 128: Sources for Mitigation Funding and Assistance from Federal Agencies and Organizations

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type: Regulatory	Type: Technical	Type: Financial
Grants.gov	Searchable catalog of federal grant opportunities across agencies.	United States Department of Health and Human Services (DHHS)	http://www.grants.gov/web/grants/home.html	x	x	x
Federal Grant Programs for State and Local Governments	Website that lists types of FEMA grant programs, and includes policies, eligibility, agencies, and types of funding instrument.	Federal Emergency Management Agency (FEMA)	https://www.grants.gov/web/grants/search-grants.html?keywords=FEMA		x	x
National Earthquake Hazards Reduction Program	Provides research to advance understanding of the occurrence and impact of earthquakes.	National Institute of Standards and Technology (NIST), National Science Foundation (NSF), and United States Geological Survey (USGS)	http://www.nehrp.gov/index.htm		x	
Decision, Risk, and Management Science Program	Scientific research directed at increasing the understanding and effectiveness of decision-making by individuals, groups, organizations, and society.	National Science Foundation (NSF)	https://beta.nsf.gov/funding/opportunities		x	
Aquatic Ecosystem Restoration	This program helps to restore significant ecosystem functions, structure, and dynamic processes that have been degraded.	United States Army Corps of Engineers (USACE)	http://www.nae.usace.army.mil/Missions/Public-Services/Ecosystem-Restoration-Authorities/	x	x	x
Beneficial Uses of Dredged Materials	Direct assistance for projects that protect, restore, and create aquatic and ecological habitats, including connection with dredging in authorized federal wetlands as part of navigation projects.	United States Environmental Protection Agency (EPA)	https://www.epa.gov/cwa-404/beneficial-use-dredged-material	x	x	x

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type		
				Regulatory	Technical	Financial
Water Grants	A variety of grants related to water and wastewater infrastructure projects, including a catalog of federal funding for watershed protection projects.	EPA	https://www.epa.gov/nps/watershed-funding		x	x
Urban Waters Small Grants Program	Programs that protect and restore urban waters by improving water quality through activities that also support community revitalization and other local priorities.	EPA	https://www.epa.gov/urbanwaters/urban-waters-small-grants		x	x
Funding and Technical Assistance for Climate Adaptation	Multiple resources on technical and funding assistance for green infrastructure, Smart Growth, and creating resilient water utilities.	EPA	https://www.epa.gov/arc-x/federal-funding-and-technical-assistance-climate-adaptation		x	x
Community Development Block Grant (CDBG)	Grants to states and local governments to develop viable communities (e.g., housing, suitable living environments, expanded economic opportunities) and recover from federally declared disasters. Principally for low- and moderate-income areas.	United States Department of Housing and Urban Development (HUD)	https://www.hud.gov/program_offices/comm_planning/cdbg	x	x	x
Disaster Housing Assistance Program	Emergency assistance for housing, including minor repair of homes to establish livable conditions, and mortgage and rental assistance.	HUD	https://portal.hud.gov/hudportal/HUD?src=/program_offices/public_indian_housing/publications/dhap			x

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type		
				Regulatory	Technical	Financial
HOME Investment Partnerships Program	Grants to state and local governments and consortia for permanent and transitional housing, including financial support for property acquisition and rehabilitation for low-income persons.	HUD	https://www.hud.gov/program_offices/comm_planning/home			x
HUD Disaster Resources	Grants and a variety of disaster assistance related to housing, including mortgage assistance.	HUD	https://portal.hud.gov/hudportal/HUD?src=/info/disasterresources			x
CDBG Section 108 Loan Guarantee	Offers states and local governments financing for certain community development activities, such as housing rehabilitation, economic development, and large-scale physical development projects.	HUD	https://portal.hud.gov/hudportal/HUD?src=/hudprograms/section108			x
National Flood Insurance Program (NFIP)	Formula grants to states to assist communities in complying with NFIP floodplain management requirements; Community Assistance Program - State Support Services Element.	FEMA	https://www.fema.gov/national-flood-insurance-program	x		
High Hazard Potential Dam Grant Program	Provide technical, planning, design, and construction assistance in the form of grants for rehabilitation of eligible high hazard potential dams.	FEMA	https://www.fema.gov/emergency-managers/risk-management/dam-safety/rehabilitation-high-hazard-potential-dams	x	x	x

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type: Regulatory	Type: Technical	Type: Financial
Hazard Mitigation Assistance Grant Program (HMA)	Grants to provide funding for eligible mitigation activities that reduce disaster losses and protect life and property from damage by future disasters. Includes FMA, HMGP, HMGP Post Fire, and BRIC, which are detailed below.	FEMA	http://www.fema.gov/hazard-mitigation-assistance		x	x
Flood Mitigation Assistance Program (FMA)	Grants to states and communities for pre-disaster mitigation planning and projects to help reduce or eliminate the long-term risk of flood damage to structures insurable under the National Flood Insurance Program.	FEMA	http://www.fema.gov/flood-mitigation-assistance-program		x	x
Hazard Mitigation Grant Program (HMGP)	Grants to states and communities for planning and projects providing long-term hazard mitigation measures following the declaration of a major disaster.	FEMA	http://www.fema.gov/hazard-mitigation-grant-program		x	x
Hazard Mitigation Grant Program (HMGP) Post Fire	Grants available to help communities implement hazard mitigation measures after wildfire disasters.	FEMA	https://www.fema.gov/grants/mitigation/post-fire			x
Building Resilient Infrastructure and Communities Grant Program (BRIC)	Grants for mitigation activities that support priorities, including natural hazard risk reduction activities that mitigate risk to public infrastructure and community lifelines.	FEMA	https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities	x	x	x
Public Assistance: Hazard Mitigation Funding under Sections 404 and 406	Hazard mitigation discretionary funding available under Sections 404 and 406 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act following a federally declared disaster.	FEMA	https://www.fema.gov/95261-hazard-mitigation-funding-under-section-406-stafford-act			x

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type		
				Regulatory	Technical	Financial
Assistance to Firefighters Grant Program (AFG)	Assists in local funding for fire equipment, staffing, facility construction, and emergency response costs.	FEMA	https://www.fema.gov/welcome-assistance-firefighters-grant-program			x
Partners for Fish and Wildlife	Financial and technical assistance to private landowners interested in pursuing restoration projects affecting wetlands and riparian habitats.	United States Fish and Wildlife Service (USFWS)	https://www.fws.gov/partners/resourceBenefits.html		x	x
Historic Preservation Financial Assistance - General	Federal financial assistance specifically for historic preservation. Initiatives include sustainability and climate resilience, and community revitalization and economic benefits.	Advisory Council on Historic Preservation	https://www.achp.gov/initiatives		x	x
Federal Highway Administration Emergency Relief Program	Funding for the repair or reconstruction of federal aid highways that have suffered serious damage as a result of natural disasters or catastrophic failures resulting from an external cause.	United States Department of Transportation (USDOT)	http://www.fhwa.dot.gov/programadmin/erelief.cfm			x
Rebuilding American Infrastructure with Sustainability and Equity (RAISE)	Investing in surface transportation infrastructure for roads, bridges, transit, rail, ports, or intermodal transportation. Replaces previous TIGER and BUILD programs.	USDOT	https://www.transportation.gov/RAISEgrants/about		x	x
Emergency Farm Loans Program	USDA's Farm Service Agency (FSA) provides emergency loans to help producers recovery from production and physical losses due to drought, flooding, other natural disasters or quarantine.	United States Department of Agriculture (USDA)	https://www.fsa.usda.gov/programs-and-services/farm-loan-programs/emergency-farm-loans/			x

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type		
				Regulatory	Technical	Financial
Landscape Planning Programs	Planning and programs that help improve natural resource management. Includes the Emergency Watershed Protection Program, the Watershed and Flood Prevention Operations Program, and the Watershed Rehabilitation Program.	USDA National Resources Conservation Service (NRCS)	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/		x	x
Regional Conservation Partnership Program	Co-investment funding for partners to implement projects that address on-farm, watershed, and regional natural resource concerns.	NRCS	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/rcpp/	x	x	x
Environmental Quality Incentives Program	Provides financial and technical assistance for agricultural producers and non-industrial forest managers to address natural resource concerns and deliver environmental benefits such as improved water and air quality, conserved ground and surface water, increased soil health and reduced soil erosion and sedimentation, improved or created wildlife habitat, and mitigation against drought and increasing weather volatility.	NRCS	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/	x	x	x
Conservation Innovation Grants (CIG)	A competitive program that supports the development of new tools, approaches, practices, and technologies to further natural resource conservation on private agricultural lands. CIG works to address water quality, air quality, soil health, and wildlife habitat challenges.	NRCS	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cig/			x

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type		
				Regulatory	Technical	Financial
Conservation Technical Assistance Program	Provides farmers, ranchers, and forestland owners with the knowledge and tools they need to conserve, maintain, and restore the natural resources on their lands and improve the health of their operations for the future.	NRCS	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/technical/		x	
Financial Assistance	Financial assistance to help plan and implement conservation practices that address natural resource concerns or opportunities to help save energy, improve soil, water, plant, air, animal, and related resources on agricultural lands and non-industrial private forest land.	NRCS	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/		x	x
Easement Programs	Programs that provide financial and technical assistance to help landowners conserve agricultural lands and wetlands and their related benefits.	NRCS	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/		x	x
Healthy Forests Reserve Program	Helps landowners restore, enhance and protect forestland resources on private lands through easements and financial assistance.	NRCS	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/forests/		x	x
Land and Water Conservation Fund	Funding allows four federal agencies to acquire and develop private lands for public outdoor recreation areas and facilities, and congressional appropriation for matching funds for state and local government land acquisition projects.	United States Bureau of Land Management, United States Forestry Service, United States Fish and Wildlife Service (FWS), and National Park Service	http://www.lwcfcoalition.org/		x	x

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type		
				Regulatory	Technical	Financial
Missions and Appropriations	Federal budget and funding to support USACE missions including research, feasibility studies, construction, and disaster relief.	USACE	https://www.usace.army.mil/Missions/	x	x	x
Flood Risk Management Program	Fosters public understanding of the options for dealing with flood hazards and promotes the prudent use and management of the nation's flood plains. Types of assistance include general technical services and general planning guidance.	USACE	https://www.iwr.usace.army.mil/Missions/Flood-Risk-Management/Flood-Risk-Management-Program/		x	
United States Climate Resilience Toolkit Funding Opportunities	A range of government entities and private foundations offer financial and technical resources to advance local adaptation and mitigation efforts.	United States Global Change Research Program	https://toolkit.climate.gov/content/funding-opportunities			x
Small Business Administration (SBA) Disaster Loan Assistance	SBA provides low-interest, long-term loans to facilitate recovery from physical and economic damage caused by a declared disaster. These include home and personal property loans, business physical disaster loans, economic injury disaster loans, and military reservists' economic injury loans.	SBA	https://www.sba.gov/loans-grants/see-what-sba-offers/sba-loan-programs/disaster-loans			x
National Dam Safety Program/High Hazard Potential Dam Grant Program	The primary purpose of the National Dam Safety Program is to provide financial assistance to states to strengthen their dam safety programs.	FEMA	https://www.fema.gov/emergency-managers/risk-management/dam-safety/grants			x

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type: Regulatory	Type: Technical	Type: Financial
Community Emergency Response Team (CERT)	Nine-week citizen training program for disaster preparedness and basic disaster response skills for individuals, families, neighborhoods, community organizations, and businesses.	FEMA, state and local governments	https://community.fema.gov/PreparednessCommunity/s/welcome-to-cert		x	
Forest Legacy Program	Encourages the protection of privately-owned forest lands through conservation easements or land purchases.	United States Forest Service, USDA	https://www.fs.usda.gov/managing-land/private-land/forest-legacy			x
Historic Preservation Fund Disaster Recovery Grant Program	Provides financial assistance for the immediate needs of historic property owners after a disaster. The program is designed to foster partnerships between local, state, and federal community planners in order to ensure that important cultural resources are integrated with statewide hazard mitigation planning efforts.	National Park Service (NPS)	https://www.nps.gov/subjects/historicpreservationfund/disaster-recovery.htm		x	x
National Trust for Historic Preservation Grants	Offers grants that are primarily for planning preservation projects, though some special programs focus on preservation planning in particular fields or geographic regions or allow for the funding of physical preservation work.	National Trust for Historic Preservation	https://forum.savingplaces.org/build/funding/grant-seekers			x
National Coastal Wetlands Conservation Grant Program	Provides funding to protect, restore and enhance coastal wetland ecosystems and associated uplands.	FWS	https://www.fws.gov/coastal/coastalgrants/			x

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type: Regulatory	Type: Technical	Type: Financial
North American Wetlands Conservation Act	Offers grants to protect wetlands that provide valuable benefits such as flood control, reducing coastal erosion, improving water and air quality, and recharging groundwater.	FWS	https://www.fws.gov/birds/grants/north-american-wetland-conservation-act.php			x
Battlefield Land Acquisition Grant Program	Provides funding for the permanent protection of historic battlefield lands through fee simple acquisition or through the purchase of an interest in the land through a preservation covenant.	NPS	https://www.nps.gov/subjects/battlefields/battlefield-land-acquisition-grant-program.htm			x
The Coastal and Estuarine Land Conservation Program	Offers financial assistance to purchase threatened coastal and estuarine lands or obtain conservation easements.	National Oceanic and Atmospheric Administration Office of Coastal Management	https://coast.noaa.gov/czm/landconservation/?redirect=301ocm			x
Readiness and Environmental Protection Integration Program	Promotes conservation projects or natural resource restoration efforts around military bases.	United States Department of Defense (DOD)	https://repiprimers.org/	x	x	x
Army Compatible Use Buffer Program	This program is designed to minimize incompatible development and loss of habitat surrounding Army facilities by utilizing permanent conservation easements, fee-sales, or other interests in land from willing landowners.	DOD	https://www.repi.mil/Buffer-Projects/Service-Programs/			x
Homeland Security Grant Program	Supports efforts to build and sustain core capabilities across the five mission areas of Prevention, Protection, Mitigation, Response, and Recovery based on allowable costs.	United States Department of Homeland Security (DHS)	https://www.fema.gov/homeland-security-grant-program		x	x

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type		
				Regulatory	Technical	Financial
Emergency Management Performance Grant (EMPG) Program	Assists local, tribal, territorial, and state governments in enhancing and sustaining all-hazards emergency management capabilities.	DHS	https://www.fema.gov/emergency-management-performance-grant-program		x	x

Table 129: Sources for Mitigation Funding and Assistance from National Non-Profit Organizations

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type		
				Regulatory	Technical	Financial
American Red Cross	Shelter, food, support, supplies, and direct assistance to populations impacted by disaster.	American Red Cross, Virginia Region	https://www.redcross.org/local/virginia.html		x	x
The Nature Conservancy	Conservation organization partnering with communities, business, government, and other non-profits to protect ecologically important lands and waters for nature and people.	The Nature Conservancy	https://www.nature.org/en-us/		x	x
The Trust for Public Land	Assistance to state and local governments including land conservation transactions, conservation finance, and park design and development.	The Trust for Public Land	http://www.tpl.org/services/conservation-finance		x	x
Public Health Programs	Provides funding, expertise, information, leadership and/or connections to specific groups of people for projects addressing priority public health challenges.	CDC Foundation	http://www.cdcfoundation.org		x	x

Table 130: Sources for Mitigation Funding and Assistance from Commonwealth Agencies and Organizations

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type		
				Regulatory	Technical	Financial
Urban Area Security Initiative Program (UASI)	Supports efforts to build capabilities to prevent terrorism in high-density urban areas with high threat levels.	Virginia Department of Emergency Management	https://www.vaemergency.gov/divisions/finance/grants/preparedness-grant-programs/	x	x	x
State Homeland Security Program (SHSP)	Supports local government efforts in building capacity to prevent terrorism.	Virginia Department of Emergency Management	https://www.vaemergency.gov/divisions/finance/grants/preparedness-grant-programs/	x	x	x
Nonprofit Security Grant Program (NSGP)	Provides funding support for target hardening and other physical security enhancements and activities to nonprofit organizations that are at high risk of terrorist attack.	Virginia Department of Emergency Management	https://www.vaemergency.gov/divisions/finance/grants/preparedness-grant-programs/			x
Shelter Upgrade Fund	Provides matching funds to localities to install, maintain, or repair infrastructure related to backup energy generation for emergency shelters, including solar energy generators, and to improve the hazard-specific structural integrity (wind retrofit) of shelter facilities owned by the locality.	Virginia Department of Emergency Management	https://www.vaemergency.gov/divisions/finance/grants/			x
Dam Safety, Flood Prevention and Protection Assistance Fund	Commonwealth funded grants to help dam owners and Virginia localities enhance public safety and reduce the risk of dam failures and property damage from flooding.	Virginia Department of Conservation and Recreation	https://www.dcr.virginia.gov/dam-safety-and-floodplains/dsfpm-grants	x	x	x

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type		
				Regulatory	Technical	Financial
Virginia Community Flood Preparedness Fund	The fund was established to provide support for regions and localities across Virginia to reduce the impacts of flooding, including flooding driven by climate change. The fund will prioritize projects that are in concert with local, state and federal floodplain management standards, local resilience plans and the Virginia Coastal Resilience Master Plan.	Virginia Department of Conservation and Recreation	https://www.dcr.virginia.gov/dam-safety-and-floodplains/dsfpm-cfpf			x
Virginia Recreational Trails Program	A federal 80-20 matching reimbursement program for building and rehabilitating trails and trail-related facilities. Eligible project types include new recreation trails, restoration and/or rehabilitation of existing trails, water trail facilities, and land acquisition.	Virginia Department of Conservation and Recreation	https://www.dcr.virginia.gov/recreational-planning/trailfnd			x
Open Space Recreation and Conservation Fund	Funding for projects such as acquisition of land for recreational purposes and preservation of natural areas, and the development, maintenance, and improvement of state park sites and facilities.	Virginia Department of Conservation and Recreation	https://www.dcr.virginia.gov/checkoff			x
Virginia Land Conservation Foundation	Provides funds for permanent conservation easements and to purchase open spaces and parklands, lands of historic or cultural significance, farmlands and forests, and natural areas.	Virginia Department of Conservation and Recreation	https://www.dcr.virginia.gov/virginia-land-conservation-foundation/			x

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type		
				Regulatory	Technical	Financial
Clean Water Financing and Assistance Program	Protects and enhances water quality by providing flexible funding solutions and assistance to localities, organizations and citizens of the Commonwealth. The program administers three funding programs: Virginia Clean Water Revolving Loan Fund, Stormwater Local Assistance Fund, and Water Quality Improvement Fund. Eligible project types include land conservation, remediation of brownfield properties, and living shorelines.	Virginia Department of Environmental Quality	https://www.deq.virginia.gov/water/clean-water-financing			x
Virginia Coastal Zone Management Grant Program	Provides annual financial awards to promote coastal resource protection, coastal resource sustainable use, and coastal management coordination.	Virginia Department of Environmental Quality	https://www.deq.virginia.gov/coasts/coastal-zone-management			x
Conservation Reserve Enhancement Program	The program aims to improve Virginia's water quality and wildlife habitat by offering financial incentives, cost-share and rental payments to farmers who voluntarily restore riparian forest buffers, grass and shrub buffers, and wetlands using approved best management practices.	Virginia Department of Conservation and Recreation	https://www.dcr.virginia.gov/soil-and-water/crep			x
Open-Space Lands Preservation Trust Fund	Provides grants for acquisitions, easements, rights of way, and other methods of protecting open space for farming, forestry, recreation, wildlife, water quality, and more.	Virginia Outdoors Foundation	https://www.vof.org/protect/grants/			x

Program or Source	Description	Lead Agency or Agencies	Internet Resource	Type		
				Regulatory	Technical	Financial
Targeted Environmental Remediation and Restoration Accounts	Provides grants for conservation efforts, including natural area preserves and public education.	Virginia Outdoors Foundation	https://www.vof.org/protect/grants/			x
Get Outdoors	Provides grants for projects that increase equitable access to safe open space in Virginia's communities. Some examples of costs that can be covered include planning, capacity building, and infrastructure.	Virginia Outdoors Foundation	https://www.vof.org/protect/grants/			x
Virginia Department of Historic Resources Grants	These grants include funds for the preservation of historical graves and cemeteries, and archaeological sites threatened by erosion or impending development.	Virginia Department of Historic Resources	https://www.dhr.virginia.gov/grants/			x
Emergency Supplemental Historic Preservation Fund	Provides funding for projects that mitigate the threat of damage to historic properties from future natural disasters.	Virginia Department of Historic Resources	https://www.dhr.virginia.gov/grants/disaster-assistance/			x
Purchase of Development Rights Programs	This program is designed to compensate landowners who voluntarily place an agricultural conservation easement on their property for conservation purposes.	Virginia Department of Agriculture and Consumer Services	https://www.vdacs.virginia.gov/conservation-and-environmental-farmland-preservation-tools.shtml			x

9. Plan Maintenance

This volume of the Plan is a living document that will guide mitigation actions over time. As conditions and circumstances change, new information may become available, and actions may progress over the life of the Plan. The actions and Plan contents may adjust as necessary to maintain the relevance and effectiveness of the Plan.

Periodic revisions and updates of the volume should occur to ensure the goals of the Plan are kept current while considering potential changes in hazard vulnerability and mitigation priorities. In addition, periodic evaluation of the Plan will also ensure specific mitigation actions are being reviewed and carried out according to each participating jurisdiction's individual Mitigation Action Plan for Implementation and Integration.

Implementation and maintenance of the Plan work in parallel to ensure the success of the mitigation strategy. Maintenance of this volume may take place in concert with the maintenance activities of the Base Plan and jurisdiction annexes. Alternatively, the NOVA Planning Group may determine an alternative method and schedule for maintenance of the separate volume.